Enhancing Ecosystem Services

Private Profitability of Selected Measures

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Publication date:
2013

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
Callaway, J. M., Wieben, E., & Olhoff, A. (2013). *Enhancing Ecosystem Services: Private Profitability of Selected Measures*. UNEP Risø Centre, Technical University of Denmark.

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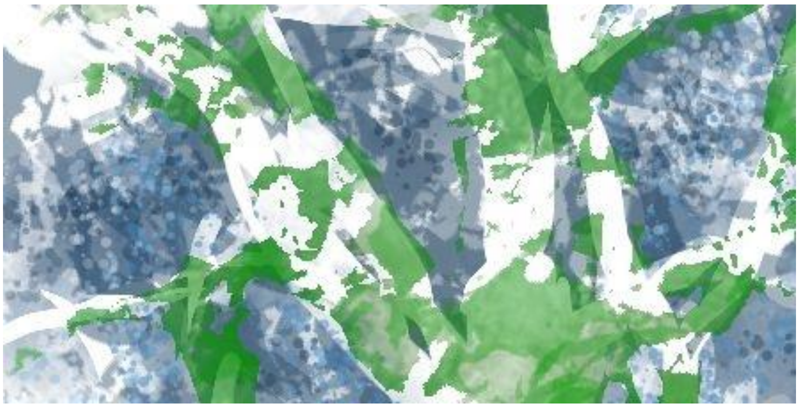

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2013

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Abbreviations

ac	alley cropping
ACC	Annualized capital cost
af	agroforestry
ai	agricultural intercropping
APV	Annualized present value
AR	Annualized revenue
AVCP	Annualized variable production cost
BAU	Business-as-usual
bp	balsa
BT	Bench terraces
CB	Contingent Behavior
CBA	Cost-benefit analysis
CBR	Cost- benefit ratio
cc	cash crops
CDN	Canadian dollars
cp	contour planting
CP	Chisel plow
CS	Consumer surplus
ct	complementary tree growing
CT	Costa Rican tourists
CV	Contingent Valuation
CVM	Contingent Valuation Method
ETB	Ethiopian Birr
ff	farm forestry
FJ	Fanya juu terraces
Frw	Rwandan franc
FT	Foreign tourists
ho	horticulture
KSh	Kenyan Shillings
MCWH	Micro-catchment water harvesting
MFI	Micro Finance Institutions
NGO	Non-Governmental Organization
NPV	Net Present Value
NT	No tillage
PA	Protected areas
PES	Payments for Environmental Services
pi	perennial intercropping
Ps	Phillippine peso
PVCC	Present value of capital cost
RMB	Chinese renminbi
ROLAC	UNEP Regional Office for Latin America & the Caribbean
Rs	Pakistani rupees
RWH	Rainwater harvesting
SB	Soil bunds
sc	sun coffee
STB	Stone bunds
T	Terraces
ta	Taungya
TCM	Travel Cost Model
Tk	Bangladeshi taka
TSh	Tanzanian Shillings
UNEP	United Nations Environment Programme
URC	UNEP Risø Centre
USD	United States dollar

wl	woodlot
WTP	Willingness to pay

Chapter 1: Introduction

Background

The work reflected in this project report is a part of a larger project, "Microfinance for Ecosystem-Based Adaptation" under the Regional Office for Latin America and the Caribbean (ROLAC) of the United Nations Environment Programme (UNEP) in collaboration with Frankfurt School - UNEP Collaborating Centre. The objectives of the project are to:

- Increase capacities in microfinance institutions (MFI) for financing ecosystem-based adaption.
- Strengthen awareness and capacity for microfinance clients to invest in adaptation actions.
- Influence national and international public policies to promote adaptation through microfinance.

The major focus of the project is to examine and build the capacity of MFIs to fund ecosystem-based approaches both for development purposes and to adapt to climate change in the Andean regions of Columbia and Peru. Specifically, micro-finance was targeted due to:

- Its focus on vulnerable populations,
- The fact that micro-finance has developed into a very concrete and innovative way of implementing small projects to help these populations,
- The potential and accomplishments of micro-financing instruments to improve local livelihoods,
- The transparency of MFI processes, and
- The high growth potential of the region in relative terms.

The project has already begun and will last until 2015. Initial project scoping covers the climate change impacts on ecosystem services and the impacts of a number of selected ecosystem–based activities and practices. The work presented in this report is one of the deliverables of a subcontract between ROLAC and the UNEP Risø Centre (URC), where the objective is to find information about the profitability of these activities, their impact on local livelihoods and what can be learned from existing cost benefit analyses of these projects that is potentially relevant to microfinance.

Objectives

Consequently, the objectives of this research were to: 1.) identify and review available information sources that have estimated the private market costs and benefits of ecosystem-based practices, taken from a list of ecosystem-based adaptation options developed by ROLAC, and 2.) use this literature to provide ROLAC with preliminary information about the costs and benefits of these practices and their impacts on local community income, with an eye toward identifying the factors affecting the financial feasibility of these practices and issues related to their financing.

Organization

This report consists of seven chapters. Following this introduction, chapter 2 contains a discussion of "economic fundamentals", which briefly explains the economic framework for the cost benefit analysis (CBA) conducted for each of the ecosystem-based adaptation options in this report. It also provides a definition of the terms used in CBA as applied in this report, as well the formulas used to calculate these metrics in the papers we reviewed. It also contains a discussion of issues of importance to lending institutions related to CBA. This includes a discussion of the concept of "payment for ecosystem services" (PES) which is an idea that has been implemented in connection with a number of ecosystem projects worldwide, to allow beneficiaries of such projects to contribute funds to ecosystem projects to make them profitable. Finally, it includes an example of a cost benefit analysis of a hypothetical agroforestry project to further understanding of the principles and application of CBA.

The main part of this report is contained in chapters three through six. These chapters deal with the following four types of ecosystem-based adaptation practices[1] for which we found literature that was helpful for quantifying the private market value of benefits and costs:

- Chapter 3: Construction and restoration of terraces
- Chapter 4: Agroforestry and silvopastoral systems
- Chapter 5: Rainwater harvesting
- Chapter 6: Ecotourism.

Each of these chapters contains a brief description of the environmental benefits, a description of the practice and its purpose, the barriers to the implementation of the practice and finally a discussion of the economic results, with reference to financing issues, as reported in the table of each of these chapters, including a table at the end of each chapter that summarizes the net benefits of the relevant CBA studies.

At the end of this report there is a Technical Appendix (Annex 1). It is devoted to presenting the private economic benefits and costs of these practices as found in specific references listed in the table, along with the impacts on community income (where it is quantified), and finally some brief comments about the findings in the references. Each table covers from 9 – 14 references. We did not consider the economic value of the climate change damages, adaptation benefits, real costs and net adaptation benefits of these practices. There were two reasons for this. First of all, the accounting used to estimate these practices is quite complex, especially for projects that produce both development and adaptation benefits and, secondly, because there are

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[1] *The original list included 10-11 practices. These four options were singled out partly because 1.) They were judged to be among the most important and likely to be targeted, 2.) The literature on some of the other options was often found to be combined under one of these headings, 3.) It was difficult to find sources that contained cost-benefit analyses of these practices from a private market standpoint, and 4.) the short-time horizon of this effort.*

very few studies that try to do this and in the cases initially identified, the accounting was done incorrectly or was not transparent, based on the current state of the art.[2]

In the main, these references are from scholarly journals. While we did undertake to find out about specific ecosystem programs undertaken with multi- and by bi-lateral, national government or NGO financing, it proved extremely difficult to track down the contacts within the relevant project organizations and publications from their projects. At the same time, we discovered that many of the publications we did find in scholarly journals were related to specific development projects, for which little information was readily available. Consequently, the search for project documents was dropped in favor of using papers published in the scholarly literature.

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[2] *However, some of the theoretical flavor of the differences between standard cost benefit analysis and the analysis of adaptation benefits and costs is shown in Chapter 2.*

Chapter 2: Economic Fundamentals

This chapter of the report has four basic objectives. The first is to briefly explain what ecosystem values are in an economic framework; how they can be valued generally; and how valuation is approached in chapters 3 through 6, covering the different ecosystem options. The second objective is to narrow in a bit and provide a rudimentary understanding of the concepts and terms used in cost benefit analysis of ecosystem services, as it is applied in the literature reviewed in chapters 3 through 6. This chapter will touch on some of the key issues that arise in the use of cost benefit analysis for ecosystem services and how various external factors can effect cost-benefit calculations. Finally, it contains an example of a hypothetical cost benefit analysis and explores a variety of issues covered earlier in the chapter that can affect the results.

Ecosystem Services: the Framework for Valuation

The Millennium Ecosystem Assessment defines ecosystem services as “the benefits people obtain from ecosystems” (MA, 2005). Fisher and Turner (2008) have broadened this definition. For them, “ecosystem services are the aspects of ecosystems utilized (actively or passively) to produce human well-being.” Both of these definitions focus on the effects of ecosystem service production and consumption on the welfare of human beings. This brings into focus the use of traditional economic analysis to quantify and value changes in the production and/or consumption ecosystem services.

Specific examples of ecosystem services include pollination of plants, climate regulation, insect pest control, maintenance of soil fertility and health, provision of shade and shelter and waste absorption. The list is virtually endless. Some of these services are tied directly, or fairly directly, to human activity, both on the production and consumption sides. For example, agricultural practices directly impact soil quality and health, and the goods and services from agricultural production are directly consumed by household members or sold in intermediate and final markets. In these cases, the linkages between ecosystems and economic activity make it easier to infer the value of changes in these ecosystem services than in other cases. For example, agricultural practices can also affect soil erosion rates from fields. Poor soil management can have a direct impact on agricultural production by reducing both the productivity and size of fields. But the impacts do not end there. The sediments are usually transported by overland flow into streams and then rivers where they can reduce water quality and make both water treatment and irrigation more costly to remote users. In the latter example, there are numerous intermediate, hydro- and bio-geochemical transformative stages which alter the physical characteristics of the ecosystem and there are also changes in the type of economic activities that are affected. Because of this complexity, these types of changes in ecosystem services are much harder to measure, not because the economic methods for valuation need to be changed, but rather because of the need for data and models to characterize all the physical transformation from points of origin to where the impacts on economic activities occur.

Similarities and differences in these two examples are instructive for this report for two reasons. First of all, both cases assume that all of the benefits and costs of the change in ecosystem services can be measured by the costs and benefits incurred by farmers through their production of agricultural commodities *on the land they farm*. However, the second case assumes that the actions of the farmer produce a technological externality that influences the benefits and costs of downstream water users. From an economic standpoint, the optimal policy action to regulate the impacts of upstream agricultural practices on downstream users would involve simultaneously accounting for the benefits and costs of both sets of users. However, the regulatory mechanisms to do this are rarely in place in developing countries and, while it can be shown that economic instruments can be used to arrive at an optimal solution for both groups, these instruments are rarely used even in developing countries. Nonetheless, fertilizer taxes are one example of such an instrument used to control nitrate and phosphate pollution in some developed countries.

For the purposes of this study, we take the approach that is used in the first example This means, first of all, that the options for improving ecosystem service values will be treated as if all of the benefits and costs of introducing these options can be measured by the financial flows on the farms where the practice is applied and not off-site. Second, it will be assumed that all of the on-site benefits and costs can be measured through the direct economic benefits and costs, as measured by the cash flows of the farmer. As such, the analysis does not include changes in the net benefits of consumers, due to changes in product prices. However, most of the cost benefit studies we have reviewed make the assumption that market prices are not affected by the adoption of an option. Those that do take into account the possible adoption of higher value crops also do not include the economic effects of changes in market prices on consumers.[3]

While the focus of this study is to estimate the costs and benefits of ecosystem enhancing projects as reflected in the cash flows of farmers and eco-tourism operators, it is also important to relate these benefits and costs to ecosystems and other landowners, who might be affected positively or negatively by the choice of the alternatives.

The interplay between ecosystems and private market economics is complicated. In Figure 2.1 we present a schematic diagram that shows, in a very basic way, how the operation of a farm that is "connected" to other farms by flows of water, above and below the surface, can have economic impacts on these other farms. At the top of this figure an "upstream household farm" is presented. The upstream household provides inputs, such as household labor, to the management of the annual or perennial crops (including trees) and livestock that contribute to the nutritional and economic wellbeing of household members. At the same time, the household can also purchase inputs, such as land, machinery and equipment and additional labor in local markets in return for cash expenditures and recurring payments on loans and other farming expenses. The output of the farm, harvested crops and household processed livestock products, can be consumed either within the household or in return for cash revenue or bartered goods

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[3] A widely used approximation to the welfare effects of product price changes on consumers is "consumer surplus". It measures the change in the maximum willingness of consumers to pay for a good, rather than doing without it, less the change in the cost of purchasing the good.

and services obtained from local markets. This revenue is used to buy goods and services, of all kinds, that the household does not produce internally, and to pay off farm loans and the expenses incurred from farming-related expenses, and some of this revenue can also be saved to meet future expenses.

In many cases, farming has a negative impact on the environment, which varies widely from practice to practice. Pollutants, such as nitrogen and phosphates, can be mixed in runoff or move downward into groundwater systems to eventually pollute streams and lakes, through accelerated eutrophication. Poor soil conservation practices can lead to changes in runoff patterns that not only act as a medium in which soil sediments flow into streams and lakes, but also to increased overland peak flows that increase damages from mudslides and from downstream flooding. The downward facing arrow, labeled "negative ecosystem impacts", represents these kinds of ecosystem effects on downstream land users. These impacts are called negative technological externalities, as there are no institutional mechanisms that will give upstream farmers an incentive to reduce the harm that their actions cause downstream.

The downstream household farm, or farm area, in Figure 2.1 has to cope with the economic damages caused by the upstream farm. The type of economic damage that occurs depends heavily on geophysical conditions in the downstream area, the nature of the ecosystem insult caused by the upstream land use, the agricultural commodities produced, and the management practices employed, by the downstream farm operator(s). Several different kinds of economic impacts are possible. First of all, capital and production costs can be increased, when the quantity and/or quality of ecosystem services impaired, sometimes forcing farmers to purchase some substitute inputs in local markets. Primary productivity, measured by the quantity and quality of crop yields and livestock products (including work), can fall, which will reduce the revenue received by downstream farmers. Either increased costs or reduced revenues have the effect of lower the net income of downstream land users and, potentially, eroding the nutritional wellbeing of household members if household consumption is reduced.

These effects can also spill over into local markets. Lower profitability hurts local incomes if farmers have less net income to purchase local goods. Reductions in farm output also can increase local prices of agricultural products purchased in markets and these price increases may accelerate if local food sellers are forced to import higher-priced food products from domestic production outside the region. If the upstream and downstream markets are connected through trade, as shown in the two-way arrow labeled "Flow of goods, resources and income", this can ameliorate the economic value of the downstream damage to some extent due to the benefits from trade. However, the same financial transmission mechanism that helps ease the economic damage on downstream households can also transfer some of these economic losses upstream, for example, by helping to reduce food price increases downstream, but increasing them slightly upstream. Ironically, if upstream users respond to this by intensively or extensively expanding their existing cultivation systems to earn more revenue due to higher food prices, damages downstream will also increase until the system reaches a private market financial equilibrium, but at the expense of ecosystems.

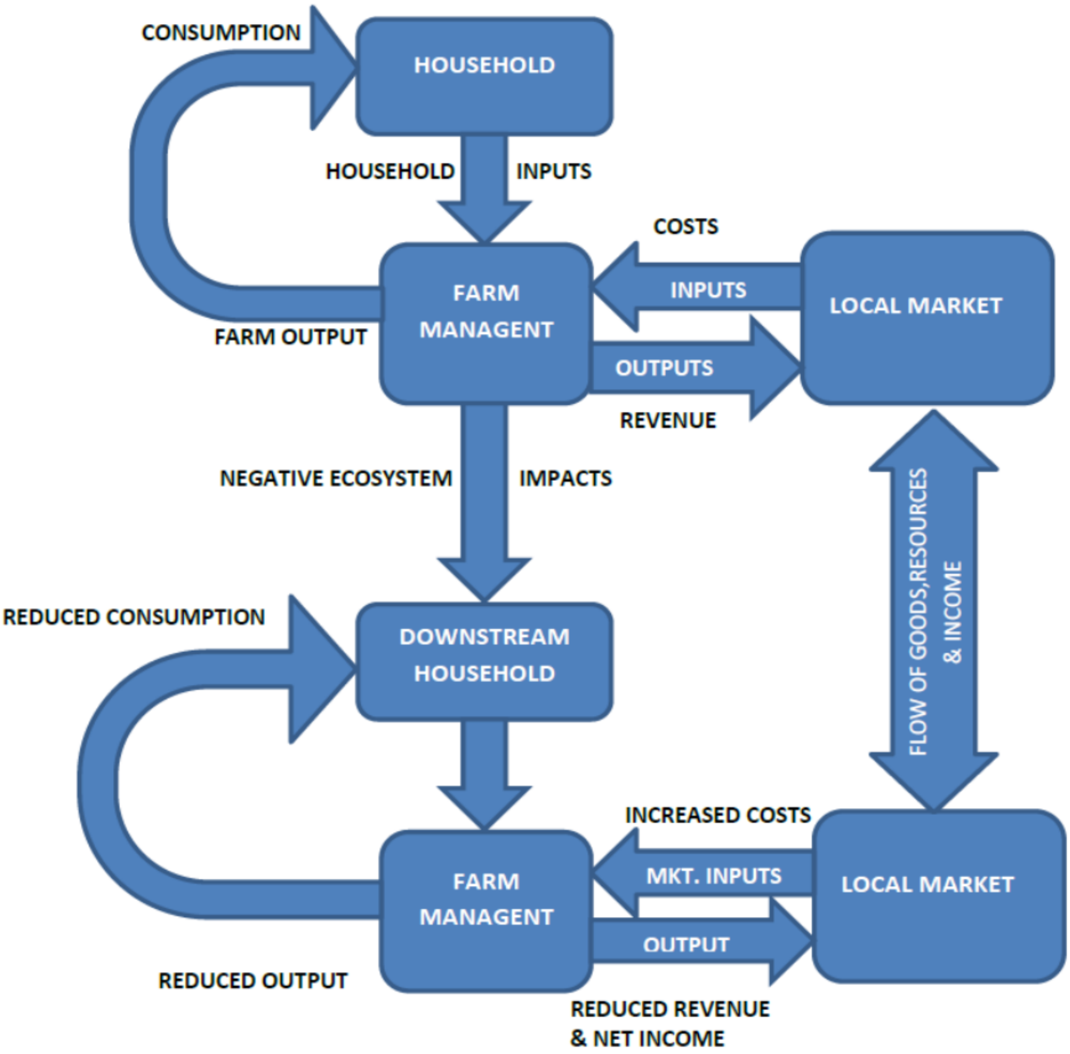

FIGURE 2.1. A Schematic Diagram of the Linkages between Two Farms, Linked both by Ecosystems and Markets

Economic Analysis of Options for Ecosystem-based Adaptation activities

Figure 2.2 illustrates conceptually the valuation approach taken in the options considered in chapters 3 through 5, for terracing, agroforestry and rainwater harvesting. Valuation in chapter 6 (ecotourism) has some qualitatively different aspects than the other options since valuing ecotourism raises the question of how much ecotourists are willing to pay to experience the ecosystem amenities in conservation reserves. This is treated, specifically, in the text of chapter 6. The approach used to value the on-site benefits and costs of ecotourism activities from a private market perspective does not change and is consistent with the principles shown in Figure 2.2.

Figure 2.2 is a static analysis that applies to a single time period and does not include the dynamics of capital accounting. To do this, we would need to show both the short-run and long-run supply curves for the commodity, but that will only complicate matters, as the short-run accounting is easy to adjust for different long-run capital costs (Just et al. 1982).

The horizontal axis in the figure measures the output of an agriculture commodity (in tons) from a farm, while the vertical axis measures the price (and the marginal cost) of the product (in US$/ton). The output of the farmer is assumed to be so small that it does not affect the market price of the product. This is illustrated by the dashed line at $60, labeled Demand (Price). The figure also contains two supply curves, each of which shows the minimum marginal cost (on the vertical axis) of producing increasing levels of output (on the horizontal axis). The supply curve of the farmer's existing agricultural practice is labeled, Supply (E_0). We assume that the ecosystem-based project activity (E_1) is profitable to the farmer. As a result of this assumption, the agricultural product supply curve shifts to the right and is labeled Supply (E_1), indicating that the marginal cost of production, after the adoption of E_1, is everywhere lower along that supply curve than the supply curve for E_0.

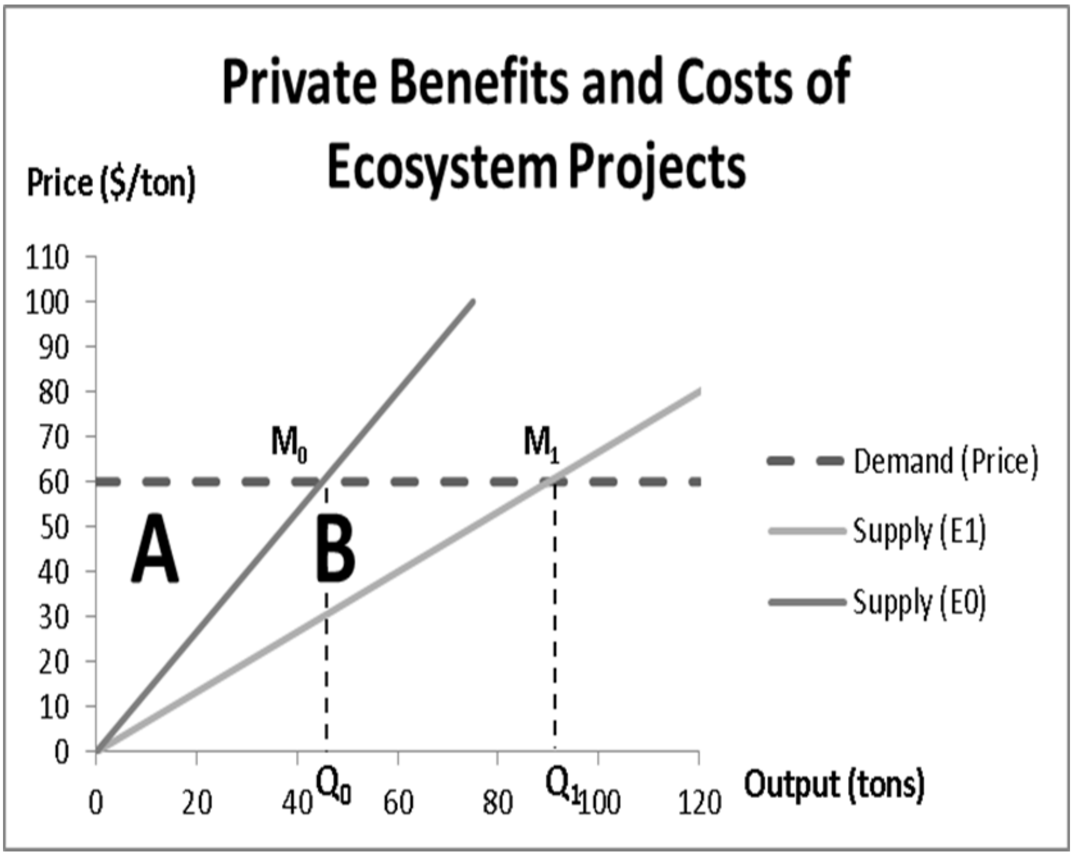

FIGURE 2.2. Conceptual Illustration of Valuation of Private Benefits and Costs of Activities that Enhance Ecosystem Services

In both cases, a profit maximizing farmer will produce the agricultural commodity until the marginal cost of the last unit produced equaled the market price. Thus, the privately optimal commodity output level associated with E_0 is Q_0, while the optimal commodity output level associated with E_1 is Q_1. The revenue received by the farmer under E_0 is equal to P x Q_0, as measured by the rectangular area $0\$60M_0Q_0$. The variable cost to the farmer of producing Q_0 is measured by the area under the supply curve for E_0, which is equivalent to the triangular area

$0M_0Q_0$. The *gross margin* to the farmer is equal to P x Q_0 – variable costs, and that amount is depicted by the triangular area 0\$60$M_0$0, labeled A. This is the net benefit of the farmer, considering only variable costs and not taking into account the farmer's capital cost (which is not shown in this diagram). If one applies the same concepts of profit maximization to the ecosystem-based option (E_1), the agricultural output level will increase to Q_1 at the constant market price of \$60/ton. Using the same cost benefit accounting methods applied to E_0 for E_1, it turns out that the gross margin for the agricultural practice E_1, the gross margin of this option is equal to the area 0\$60$M_1Q_1$0, which is labeled A + B. Thus the gross margin difference is measured by the area A + B – A = +B.

But what would happen if the ecosystem-based option were not profitable? In that case, the answer is simple, because all we would need to do is reverse the labeling of the supply curves, so that the adoption of the new option would result in the supply curve shifting to the left, instead of to the right. Consequently, the incremental loss in gross margins would be equal to the area, –B.

The full accounting for all private costs and benefits, including capital costs, for conducting a cost benefit analysis of different agricultural practice alternatives on a single farm or in a single farm area is shown in Table 2.1.1. The definitions of the terms in this table follow right after it in Table 2.1.2.The study includes all of the definitions of terms commonly associated with cost benefit analysis practice. It also shows the calculations to quantify these terms into economic metrics. These same definitions will be used in the example cost benefit analysis, contained later on in the chapter.

TABLE 2.1.1. Cost-Benefit Terms and Calculations

Economic Term	Time Periods (years)				Total, over time (N=4)
	0	1	2	3	
Undiscounted Values					
Capital Cost/year	CC_0	CC_1	CC_2	CC_3	$\Sigma_t\ CC_t$
Variable Cost/year		VC_1	VC_2	VC_3	$\Sigma_t\ VC_t$
Total Costs/year	CC_0	$CC_1 + VC_1$	$CC_2 + VC_2$	$CC_3 + VC_3$	$\Sigma_t\ [CC_t + VC_t]$
Total Revenue/year		R_1	R_2	R_3	$\Sigma_t\ R_t$
Gross Margin/year		$R_1 - VC_1$	$R_2 - VC_2$	$R_3 - VC_3$	$\Sigma_t\ (R_t - VC_t)$
Net Benefits/year	CC_0	$R_1 - VC_1 - CC_1$	$R_2 - VC_2 - CC_2$	$R_3 - VC_3 - CC_3$	$\Sigma_t\ (R_t - VC_t - CC_t)$

Table 2.1.1 Continued on next Page

TABLE 2.1.1 (Continued). Discounted Values = Present Values

Present Value of Capital Cost (PVCC)	$CC_0/(1+r)^0$	$CC_1/(1+r)^1$	$CC_2/(1+r)^2$	$CC_3/(1+r)^3$	$\Sigma_t [CC_t/(1+r)^t]$
Present Value of Variable Cost (PVVC)		$VC_1/(1+r)^1$	$VC_2/(1+r)^2$	$VC_3/(1+r)^3$	$\Sigma_t [VC_t/(1+r)^t]$
Present Value of Total Costs (PVTC)	$CC_0/(1+r)^0$	$(CC_1 + VC_1)/(1+r)^1$	$(CC_2 + VC_2)/(1+r)^2$	$(CC_3 + VC_3)/(1+r)^3$	$\Sigma_t [(CC_t + VC_t)/(1+r)^t]$
Present Value of Total Revenue (PVTR)		$R_1/(1+r)^1$	$R_2/(1+r)^2$	$R_3/(1+r)^3$	$\Sigma_t[R_t/(1+r)^t]$
NPV/year	CC_0	$(R_1 - VC_1 - CC_1)/(1+r)^1$	$(R_2 - VC_2 - CC_2)/(1+r)^2$	$(R_3 - VC_3 - CC_3)/(1+r)^3$	$\Sigma_t [(R_t - VC_t - CC_t)/(1+r)^t]$
Annualized Net NPV (APV)	$(NPV*r)/[1-(1+r)^{-N}]$				NA

TABLE 2.1.2. Definitions of Terms in Table 2.1.1

Capital Costs	Fixed, one-time expenses incurred on the purchase of land, buildings, construction, and equipment used in the production of goods or in the rendering of services.
Variable Costs	Expenses that vary with the output or the scale of production, as measured with reference to a fixed input. For example, in agriculture variable costs can be expressed in terms of the scale of production (cost per unit output) or they can vary with the land input (cost per hectare).
Total Revenue	The income a firm receives for the sale of all its goods and services, where $R_t = \Sigma_i (P_{i,t}*Q_{i,t})$; $P_{i,t}$ = The price of the i^{th} product in period t and $Q_{i,t}$ = the quantity of the i^{th} good sold in period t.
Gross Margin	Total revenue less variable costs. If the capital costs are annualized, then they are sometimes added to the variable costs. In that case gross margin is equal to total revenue less the sum of variable costs and the annualized capital costs
Net Revenue or Net Benefits	Total revenue minus the sum of capital plus variable costs
Present Value	The future amount of money that has been discounted to reflect its current value, as if it existed today. The present value is always less than or equal to the future value because money has interest-earning potential, a characteristic referred to as the time value of money. All costs and benefits can be discounted to reflect this.
Discount Rate (r)	The rate at which owners of firms (in our case) trade current for future income. So, if r=10%, this means that if a firm expects to incur an expense or receive earnings of \$X one year from now, the Present Value of either cash flow is $\$X/(1+r)^1$
Time Periods (t)	t=1,2,...,N, where N is the last time period
Net Present Value (NPV)	The sum of the discounted value of the annual net benefits of the firm. This is equal to NPV $= \Sigma_t [(R_t - VC_t - CC_t)/(1+r)^t] = [(R_t - VC_t - CC_t)/r]*[1-(1+r)^{-N}]$.
Annualized NPV (APV)	The annual net revenue of the firm expressed in each period as an even flow of undiscounted net revenues. It is the same in each period. It is calculated as APV $= (NPV*r)/[1-(1+r)^{-N}]$. It is possible to annualize all benefits and costs.
Payback Period	As used in this study, it is the length of time it takes for the discounted revenue of the firm to pay off the sum of the discounted costs of the firm.
Internal Rate of Return (IRR)	The rate of discount at which NPV of the firm equals 0. If the rate of discount is higher than the IRR, NPV < 0 and the project is not "economically feasible", meaning that costs outweigh the benefits.
Benefit/Cost Ratio (BCR)	The ratio of the sum of discounted annual benefits to the sum of discounted annual costs. The benefit cost ratio is sensitive to the scale of projects and can lead to inconsistent rankings compared to NPV. It is calculated as: [Σt Rt/(1+r)t]/ Σt [(VCt + CCt)/(1+r)t] .

Applying Cost Benefit Analysis to Climate Change Adaptation

The ultimate objective of ROLAC is to evaluate various ecosystem-based options as adaptation projects. To do so will involve estimating adaptation costs and benefits and net benefits. While cost-benefit principles underlie the calculation of these metrics, the task of estimating them is complicated by the need to include the effects of climate change. As Callaway (2003a and 2003b) has shown, the first task is to make an estimate of the economic impacts of climate change on a project's benefits and costs using only existing measures for adapting to climate variability. Assuming climate change reduces net benefits, the resulting *climate change damages* will be negative. This is sometimes referred to as the "cost of inaction". When options are specifically introduced to adapt to climate change, their *climate change benefits* can be estimated as the reduction in the economic value of climate change damages. The variable and capital costs associated with investing in and operating these adaptation measures, plus any indirect opportunity costs, then represent the *real costs of adaptation.* The net adaptation benefits are therefore calculated as the difference between the adaptation benefits and the real costs of adaptation. Consequently, incremental calculations can be made by comparing the net benefits of adaptation for two different adaptation projects.

To show how this can be done in a static framework, we refer to Figure 2.3. This figure is based entirely on the conceptual approach in Figure 2.2 as far as supply, demand and optimal output determination. The option E_1 represents existing practices, while E_0 is now a climate change + development option. E_1 is considered a development option, at least partially, because switching from E_0 to E_1 produces higher private net benefits than E_0. However, there are now four agricultural product supply curves, instead of two. The supply curves under the current climate are denoted by E_0, C_0 and E_1, $C_{0,}$ where C_0 refers to the current climate. These are the same supply curves shown in Figure 2.1. The effects of adverse climate change on these two supply curves are represented by the supply curves E_0, C_1 and E_1, C_1, both of which lie to the left of their supply curves under the existing climate, indicating that climate change increases the costs of both options.

The loss in private net benefits of the existing option, E_0, takes into account the fact that it is in short-run an adjustment to climate change. This loss, equal to the area A2, is a measure of *climate change damages*. The supply curve E_1, C_0 represents the adaptation option, under the changed climate. It lies to the right of the supply curve for E_0 under the existing climate, which means that adopting this option not only eliminates the climate change damages, A1, but also generates additional benefits equal to the area B1. Thus, the absolute net benefits of adaptation are greater than the absolute value of climate change damages, meaning that the net adaptations are equal to the sum of the areas A2 + B1. But what about the net economic loss incurred by the impact of climate change on E_1; how does one account for this? If E_1 is viewed both as a development and an adaptation option, then this loss as measured by B_2 is a loss in the development benefits of E_1, where B1 + B2 =B represent the net development benefits, without factoring in climate change, as discussed for Figure 2.1. Moreover, let's assume that this option is implemented, but the climate does not change. In that case, B_2 represents an addition to the development benefits from those measured under the climate change adaptation accounts. This effectively makes E_1 a no-regrets option which both reduces climate change damages if the climate does change and provides even greater net benefits over E_0 if the climate does not change.[4]

We purposely did not look for studies that estimated the adaptation benefits and costs of ecosystem-based projects, because of the rather data-intensive nature of the calculations required to estimate climate change damages, adaptation benefits and costs and the net benefits of adaptation. This is a challenge for the future, once it can be determined whether the private benefits of these projects can attract micro-financing.

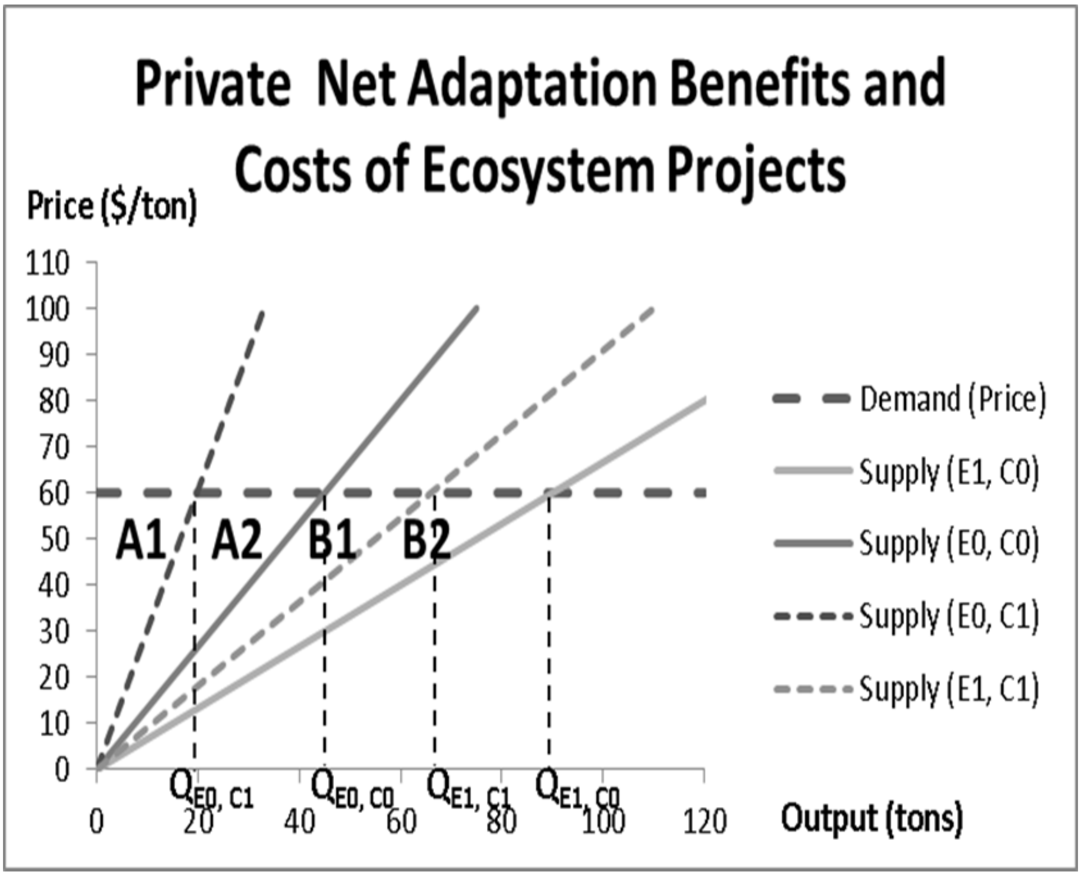

FIGURE 2.3. Conceptual Illustration of Valuation of Climate Change Damages and the Net Benefits of Adaptation for the Same Two Options as in Figure 2.2

Financing Issues

One of the most important issues in project finance is the relationship between discount rates and the time profiles of benefits and costs of projects. The opportunity cost of capital, as reflected in private lending rates is often quite high in developing countries. In many of the cost benefit analyses reviewed for this project, discount rates reflecting the local opportunity cost of capital were quite high, above 10% and as high as 30%. Interest rates used by multi-lateral finance institutions and regional banks are often much lower. And many groups and economists

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[4] *This does not take into account what happens if the climate change is different than C_1. In that case one needs to assess the robustness of the net adaptation benefits to a variety of climates.*

recommend discounting both mitigation and adaptation projects at much lower interests, reflecting rates of social time preference. On the other hand, several of the studies we reviewed indicated that the implicit discount rates of small farmers in developing countries are quite high, indicating that they place more value on current, as opposed to delayed income.

The effect of high discount rates is illustrated in Figure 2.4, using the hypothetical data in Table 2.2. The table is fairly self-explanatory. It is entirely hypothetical, but could look something like an agroforestry project that combines an annual crop with short-rotation wood supply, harvested at the end of the project.

TABLE 2.2. The Effects of Increasing Discount Rates on the Time Streams of Benefits and Costs and Net Present Value for a Hypothetical Development Project Over Time

Year	Capital Cost	Variable Cost	Annual Revenue	Net Benefit	Cumulative Net Present Value			
					5%	10%	20%	24.80%
0	100	20	30	-90	-90	-90	-90	-$90
1	10	10	45	25	-$66	-$67	-$69	-$70
2	10	10	45	25	-$44	-$47	-$52	-$54
3	10	10	45	25	-$22	-$28	-$37	-$41
4	10	10	45	25	-$1	-$11	-$25	-$31
5	10	10	45	25	$18	$5	-$15	-$22
6	10	10	45	25	$37	$19	-$7	-$16
7	10	10	45	25	$55	$32	$0	-$11
10	10	20	125	95	$113	$68	$15	$0

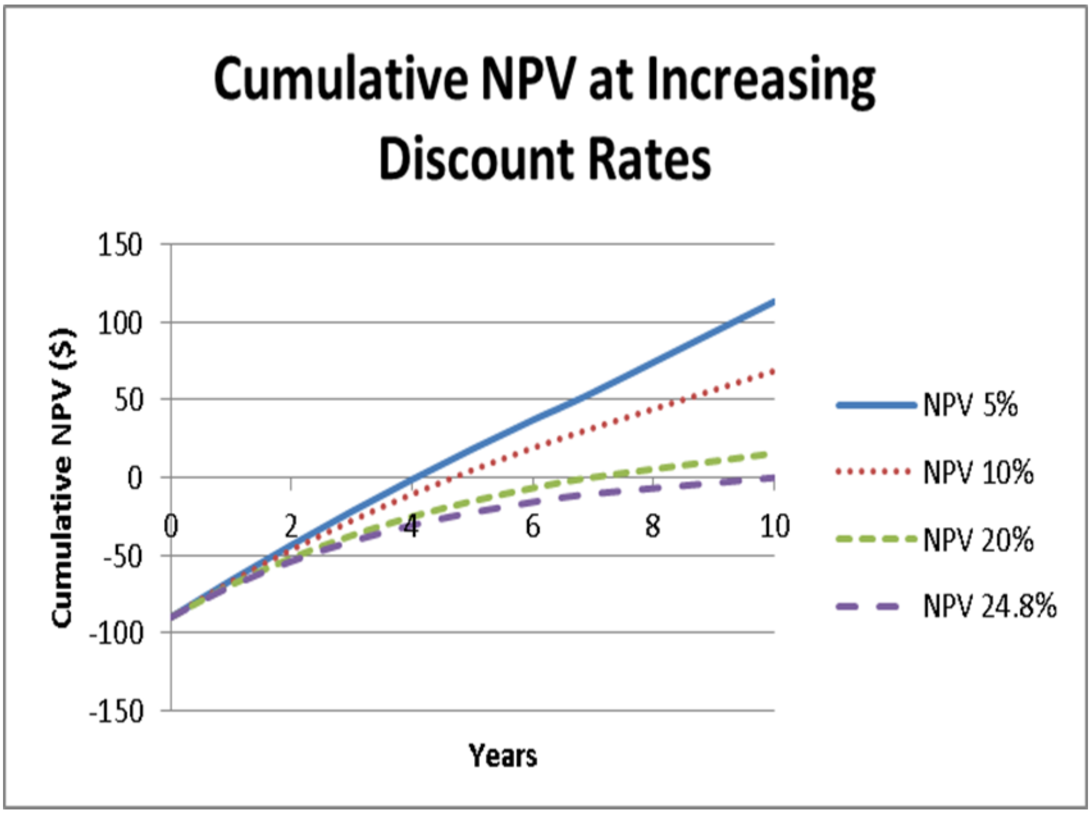

FIGURE 2.4. Illustration of the Effect of Increasing Discount Rates on Cumulative NPV.

The first three interest rates used in this simulation represented discount rates of 5%, 10% and 20%. The last discount rate is actually the internal rate of return (IRR), found by setting cumulative NPV in year 10 to solving for the IRR. Successively increasing discount rates has three effects:

- Lower Cumulative NPV in each period, creating large differences in the terminal NPV, which is the NPV for the project over the entire time period
- Increasing the length of the payback period, as measured by the point in time when the discounted stream of cumulative net benefits equal zero
- Making the project unprofitable at discount rates above the IRR value

The features of the data that leads to this type of result are: 1. high initial investment in period zero that is, effectively, not discounted; 2. a relatively strong even-flow of annual gross margins from year 1 to year 10, each of which is discounted more heavily as time progresses; and 3. a high gross margin value of the harvest at the end of the project, which is discounted at the heaviest weight. If loan rates are high, or if farmer preferences favor current over future net private returns, projects with the kind of cumulative NPV flows shown in Table 2.2 and Figure 2.3 may be rejected in favor of projects where the trajectory is flatter and less sensitive to discounting.

Related to the features described above is the fact that local lenders in developing countries are often not familiar with projects that present challenge time profiles of benefits and costs, even if the NPV is positive. Local capital constraints and lack of deposits to back up loans can have similar effects, pushing lenders to approve only short-term loans to projects that are profitable in the longer term. Added to these pressures on financing, is the fact revealed in several studies that local farmers often overestimate their yields at the same time when they are competing in markets where year-to-year product prices can be highly volatile for reasons beyond their control. This kind of bias and uncertainty pushes local lenders in the direction of conservatism.

A final set of issues revolves about the differences between the private and social benefits of ecosystem-based projects.[5] This study only considers private profitability from the sale of agricultural commodities, or in the case of ecotourism the revenues and costs related to conservation reserves and vendors in and around protected areas who provide lodging, meals and recreation packages. However, the social benefits and costs of conservation projects can be much wider and, in total, can include[6]:

- ***Private market benefits***: These benefits represent the beneficial effects which changes in ecosystem services have directly on firms and which can be captured through higher profits (due to improved revenues or reduced costs). These benefits are the focus of the review of the literature for different ecosystem-based adaptation options, presented in chapters 3 through 6. These benefits can apply both to farmers who adopt ecosystem-

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[5] *While the classification used here is distilled from a wide variety of sources, a good recent essay about the challenges of estimating these values, influencing them through policy and appropriating them is Fisher et al. (2009).*

[6] *Negative benefits in all these categories represent costs.*

based practices, owners of ecotourism sites and vendors who provide goods and services to ecotourists.

- ***Market user benefits***: These are the benefits which people receive from ecosystem services that are sold in markets. The most obvious examples from this study are the benefits received by consumers of non-timber forest products, such as fruits and berries, and medicinal herbs. Strictly speaking, the willingness to pay of ecotourists that is captured by entry fees also fits in this category, albeit these benefits are also counted as costs to the ecotourists (and, as stated above, revenue to ecotourism site owners). These benefits are registered in various cash accounts as out of pocket expenses, on one side of the equation, and as revenues on the other side.
- ***Private market externality benefits and costs***: These are the market benefits (or costs) which firms and individuals experience from the actions of other firms and individuals as a result of positive (or negative) technological externalities. An obvious example is the beneficial effect of upstream soil conservation practices by farmers on downstream farmers and water users (so long as these benefits to other users are registered on their financial sheets through increased revenues or reduced costs). While economic agents make adjustments to these externalities, they generally do not have to pay for their beneficial effects (or be compensated for their negative effects), even though these impacts do effect their cash flows.
- ***Non-market user benefits***: These are benefits which are not sold in markets, but improve the welfare of individuals, as evidenced by many forms of recreation behavior, such as visits to conservation reserves, hiking, bird watching, fishing, etc. Some, but not all, of these benefits are captured in user fees. Some forms of these behaviors are obtrusive (fishing and hunting), while others are relatively unobtrusive (bird watching). The ecosystem services associated with these benefits have no direct cost to users, but can be inferred from observed preferences of individuals through the purchase of complementary goods and services (such as travel and lodging, fishing licenses and bird watching paraphernalia, etc.) and/or through the opportunity cost of the time spent receiving these benefits. Alternatively, they can be estimated by various stated preference methods through which people are asked questions about their willingness to pay or the use of these services given changes in their availability or policies that affect their availability. As such, these benefits may be associated, indirectly, with observed or hypothetical cash flows. The user benefits that can be captured through payments in markets, directly, fall into the previous category. Those that cannot be directly captured through market transactions fall into this category. These benefits are approximated by consumer surplus (see fn. 2).
- ***Non-user, non-market benefits***: Individual welfare of people who do not use an ecosystem service can also be increased by the *knowledge* that the service is being improved. In addition, non-users may want to avail themselves of future use of an ecosystem service and be willing to pay for an option to preserve the service for their own use or the use of future generations. These values are partially reflected in charitable contributions. However, general practice involves asking non-users to state their preferences for changes in specific ecosystem services through changes in their willingness to pay for their existence, or for various future use options. These benefits are hard to appropriate through market transactions because the property rights associated with the externali-

ties are not well defined and the necessary transactions costs associated with measuring and verifying their physical impacts are extremely high (Coase, 1960). In cases where technological externalities of this kind are addressed, it is generally through indirect regulations (e.g. water quality regulations to control suspended solids and mineral content downstream) or taxes (e.g. on fertilizer use to reduce non-point source solids).

The main point of showing the different types of benefits associated with improvements in ecosystem services is that when a farmer or public agency, adopts practices that enhance flows of ecosystem services, there are potentially many forms (and demonstrably large) benefits that are not registered in the financial flows of the farmers or public agencies through market transactions. As a result, lenders have no incentive to consider them. One possible way of approaching this issue is through the use of Payments for Ecosystem Services (PES).[7]

Payments for Ecosystem Services (PES)[8]

The concept of PES is based on the general idea that when ecosystem conservation activities are implemented, direct private market benefits to the economic agents undertaking these activities may not fully cover their costs. This net loss in benefits represents an opportunity cost of this activity. Unless this opportunity cost can be overcome, the conservation activity will not be undertaken and existing, often harmful, environmental practices will continue. On the other hand, there may be substantial use and non-use values associated with these activities, which could be used to offset these losses. If these benefits (or some part of them) could be transferred back to the economic agent undertaking this activity in the form of PES to make the conservation activity profitable, it would be undertaken. The most obvious connection is through the transfer of private market externality benefits. The idea, here, is that the "upstream conservationist" faces an opportunity cost which defines his or her minimum willingness to accept compensation to switch agricultural practices. The downstream activity, in turn, receives net benefits from the externality, which define his or her maximum willingness to pay to accept these benefits. If the estimated total net benefits to both groups of the conservation activity are positive (taking into account the externality), PES could be used to duplicate a sole-owner solution (Baumol and Oates, 1979) to the mal-distribution of benefits between the two groups. Take the obvious example of water pollution. If the minimum willingness of the upstream conservationist to accept compensation (the opportunity cost) to undertake a new agricultural practice is less than or equal to the maximum willingness of the downstream user to pay for the externality benefits, then the general conditions for a private market-based transfer of the externality (cleaner water leading to increased yields) from the conservationist to the downstream user would be met. Subsequently, the groups would be at least as well off as they were under the existing, harmful cultivation practice.

However, the devil lies in the detail of designing programs and instruments that effectively satisfy the economic conditions for such trade to occur (Engel et al. 2008). Therefore, it is more

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[7] *Subsidies are another possibility. However, they are not addressed because of the well-known tendency for subsidies to attract "free riders" (Cornes and Sandler, 1986).*

[8] *The literature on PES is extensive. This brief discussion is a distillation of the ideas and concepts found in several works: Engle et al. (2008) Gómez-Baggethun et al. (2010), Landell Mills and Porras (2002), Muradian et al. (2010), Wunder (2005) and Wunder et al. (2008)*

often the case that PES programs rely to some (and even a greater extent) on payments from individuals and groups that experience non-market use and non-use benefits. Nevertheless, there is substantial recent evidence that PES programs in some countries have fared very well (Gómez-Baggethun et al. 2010). However, some experts believe that the "Commodification" of ecosystem services has set the stage for creating systems of property rights in poor developing countries that are not consistent with cultural norms, leading to the privatization of some traditional common property systems that work very well to protect the environment (Corbera et al. 2007).

The literature reviewed in chapters 3 through 6 does not cover PES, because we were not tasked to include these benefits in our initial review of the literature review of the private profitability of options for ecosystem-based adaptation activities. Nevertheless, it is important for lenders to become familiar with this approach to project financing and to be able to assess their economic efficiency. A great deal of the literature on PES is somewhat one-sided, and perhaps overly-optimistic about the success of PES, particularly in remote rural areas of developing countries. Redefining property rights in these countries through PES is easier in theory than in practice.

Example of Private Cost Benefit Analysis Based on the Financial Flows of the Firm

Many of the studies that are included in ANNEX 1 contain Cost Benefit analyses. However, because these types of analyses generally require a lot of data and calculations, the technical details of the analysis is usually not included in a paper in a scholarly journal and it is therefore almost impossible to duplicate the correct calculations as a result. Therefore, we include a hypothetical example to show how it is done and to illustrate many of the main points made earlier in this chapter.

The hypothetical example given here includes two projects, one embracing a practice that represents current practice, while the other is an agro-forestry project. The current practice involves raising annual crops for home consumption and market sale. The agroforestry project involves raising the same crop while at the same time establishing, managing, and harvesting fast-growing, short rotation, trees for fuelwood and timber supply that are spaced intermittently on crop land. The thinning of trees provides fuel wood and the harvesting for timber supply is done selectively to avoid erosion problems associated with clear-cutting and to reduce the loss of top-soil from open crop land. The benefits associated with these ecosystem values are not included in the analysis. The cost benefit analysis of both practices is based entirely on the private financial returns to the farmer.

The meat of the example is in Table 2.3, which is covered in depth below.

The cells in first three rows under the label *Inputs* in this part of the example show the fixed costs of capital and the variable costs of household labor, and market goods used to produce an annual crop. There are at least three ways to obtain information about the quantity of these goods and services: from surveys of local farmer practices and, in cases involving commercial crops, through farm budgets produced by the National agricultural service, or by farm practices observed by researchers in conjunction with information from vendors about per unit costs of the required inputs. For small farmers, the most important cost is generally household labor (row 2), which raises the question of how to price a unit of household labor. A common practice is to use the local hourly wage rate for purchased labor. This practice is supported by the idea that the local wage rate reflects the marginal opportunity cost of local field labor that the farmer would have to purchase in the local labor market if insufficient household labor was not available or if household members chose to work at paying jobs at this rate. As previously stated, the current practice involves the planting, managing and harvesting of annual crop. Thus, apart from capital costs, labor costs, as well as higher costs of inputs purchased in the market, such as fuel and fertilizer, all of the costs are the same in periods 3 through 10, once the land is cleared and the soil is properly prepared.

The cells in row 4 represent the sum of all the annual costs in each year 1-10. Row 5 contains the present value of the costs in Row 4, using the formula for the Present Value of Total Costs in each year as shown in Table 2.1: $(CC_t + VC_t)/(1+r)^t$, where CC_t and VC_t represent the annual capital and variable costs (HH labor and market goods and services) and r is the discount rate. The discount rate for all costs and benefits, shown in the Table is 4%. (In Table 2.4, we show how increasing the discount rate affects the private profitability of both alternatives to the farmer). The final column in all of these and the remaining rows show the sum of annual costs, benefits or net benefits. Notice that the present value of the total costs, by year, and the sum of these costs over all years is slightly less than the corresponding total cost entry, just above it. This reflects the impact of discounting future cash flows to adjust for the time value of money and no price inflation in any of the cost categories is included to make this clear[9].

TABLE 2.3. Cost-Benefit Example for Existing Practice and Agro-Forestry Options Discounted at 4% (US Dollars)

Existing Agricultural Practice (IRR = 23.23%)											
	Years										
Inputs	1	2	3	4	5	6	7	8	9	10	Total
Capital	1,150	0	0	0	0	0	0	0	0	0	1,150
HH Labor	200	100	50	50	50	50	50	50	50	50	700
Purchased inputs	50	10	10	10	10	10	10	10	10	10	140
Total Costs	1,400	110	60	60	60	60	60	60	60	60	1,990
PV of Total Costs	1,346	102	53	51	49	47	46	44	42	41	1,821
Outputs											
Total Revenue	200	400	400	400	400	400	400	400	400	400	3,800
PV Total Revenue	192	370	356	342	329	316	304	292	281	270	3,052
Net Cash Flows											
Gross Margin	-50	290	340	340	340	340	340	340	340	340	2,960
Net Revenue	-1,200	290	340	340	340	340	340	340	340	340	1,810
Net Present Value (NPV)	-1,154	268	302	291	279	269	258	248	239	230	1,231
Annualized NPV (APV)	152	152	152	152	152	152	152	152	152	152	---

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[9] *Inflation can be included in the calculation by discounting at the rate $[(1+a)/(1+r)]^t$, where a is the average annual rate of inflation.*

TABLE 2.3 (CONTINUED)

Agro-Forestry Practice (IRR=18.46%)

Inputs	1	2	3	4	5	6	7	8	9	10	Total
Capital	1,450	0	0	0	0	0	0	0	0	0	1,450
HH Labor	300	100	70	100	70	70	70	70	120	160	1,130
Purchased inputs	80	40	40	60	40	40	40	80	40	100	560
Total Costs	1,830	140	110	160	110	110	110	150	160	260	3,140
PV of Total Costs	1,760	129	98	137	90	87	84	110	112	176	2,782
Outputs											
Total Revenue	200	400	400	660	400	400	400	400	860	1,500	5,620
PV Total Revenue	192	370	356	564	329	316	304	292	604	1,013	4,341
Net Cash Flows											
Gross Margin	-180	260	290	500	290	290	290	250	700	1,240	3,930
Net Revenue	-1,630	260	290	500	290	290	290	250	700	1,240	2,480
Net Present Value (NPV)	-1,567	240	258	427	238	229	220	183	492	838	1,558
Annualized NPV (APV)	192	192	192	192	192	192	192	192	192	192	---

See Table 2.1.1 and Table 2.1.2 for definitions of economic terms and formulas for calculating them

The next two rows for which there are cell entries under the label *Outputs* (rows 6 and 7). The first of these rows contains the annual revenue received from the consumption and sale of the annual crops grown. Thus, if the farmer produces an amount of one annual crop (Q_t) and the market price of the crop is P_t, the annual revenue is equal to Q_t*P_t. If more than one crop is produced then the same procedure is followed for all crops and the resulting annual revenues are summed over all the crops. The use of the market price of the crop for home consumption is, again, defended on opportunity cost principles. The total amount of crop production per unit area (average annual yield) can be obtained through local farm surveys, farm crop budgets in some cases, from crop yield models and by observation/experimentation on the part of researchers, while the distribution of use can generally be obtained only by farm surveys. The price of the crops in local markets can be obtained through local market data. Some studies reduce the value of revenues lost through wastage according to the lost revenue (a cost), but that is not included here for the sake of exposition.

The cell entries in row 7 for the present value of total revenue represent the discounted values of the values of the total revenue (in the row entry above it). The values for present value of total annual revenue and total revenue are obtained from Table 2.1, in the same way used to discount the total costs. In this example, a common discount rate of 4% is used to discount all cash flows, both costs and revenues.

The next 5 rows under the label *Net Cash Flows* represent different ways to bring together the costs and benefits of this alternative in cash flow terms to measure the profitability of the alternative. All of the formulas for these terms can be found in Table 2.1. The gross margin in row 8 represents the difference between annual (and total) revenue and the annual (and total) variable costs (labor + inputs purchased from markets), while the net revenue in row 9 captures the difference between annual (and total) revenue and both capital and variable costs.

Gross margin is only higher than net revenue for year 1, the only year in which capital costs are incurred. This is simply because annual gross margin less capital costs equals net revenue. The remaining terms in rows 10 and 11 operate only on the net revenue terms in row 8, as follows (see Table 2.1 for the formulas used):

- **Net Present Value:** The discounted annual values of net revenue, which sum to the Net Present Value (Present Value of Net Revenue)
- **Annualized Net Present Value:** A single value in each period which represents an even flow of the net revenues of the firm, which when discounted, equals the NPV. This is the corollary to the average annual net revenue, taking the time value of money into account.

Thus, the bottom line for this option is that, given a present value of net revenue of $3052 and a present value of cost of $1821, the Net Present Value of the option, discounted at 4% over 10 years is $1231.

The second project is more complicated. It includes all of the cash flows associated with the annual crop in each of the ten years, plus the costs and revenues associated with agro-forestry. This includes higher capital costs and establishment costs in all years, plus still higher costs and revenues in year 4, the year of the first fuelwood thinning, in year 9, as a result of the second thinning, and in year 10 due to the final harvest of small dimension saw timber, used locally in home and fence construction. The data needed to construct these tables is not that much different than for annual crops, with two main exceptions. First of all, unless the agroforestry practice being employed is wide-spread locally, it may be difficult to find data on costs and yields. Second, the yield data for forestry practices need to include harvestable forest biomass in each period (to capture tree growth), as well as the biomass that is actually harvested in relevant periods (for firewood, timber supply and other end uses). This data is hard to find in developing countries, except for plantation species. Even if the same species are used in agroforestry practices as in plantations, the biomass increments by period are likely to smaller on household farms than on plantations, and the magnitude of these deviations are much in doubt unless there is specific research in the region to draw upon. Therefore, it is important to perform a sensitivity analysis of the annual biomass increments to determine how risky over-estimation can be in determining the net cash flows of agro-forestry practices on small, household farms.

The bottom line results for the agroforestry option are higher values for both the present value of revenues and costs, which are $4341 and $3140, respectively. The net present value equals $1558 and the corresponding annualized value is $192/year, which when discounted and summed over all years is also equal to the net present value of $1558.

Table 2.4 shows the impact of increases in the discount rate on the internal rate of return (which is equal to the discount rate at which an option's NPV equals zero over its lifetime), the Net Present Value, the benefit-cost ratio and the break even period when the NPV becomes positive for both options.

TABLE 2.4. Cost-Benefit Example: Aggregate Financial Indictors

Internal Rate of Return (Per cent)							
Current Agricultural Practice	23.23%						
Agro-Forestry Option	18.46%						
NPV at Different Discount rates (USD dollars)							
	4.00%	8.00%	10.00%	10.90%	12.00%	15.00%	20.00%
Current Practice	$1,231	$813	$648	$580	$506	$329	$107
Agro-forestry	$1,558	$920	$677	$580	$471	$222	-$80
Benefit-Cost Ratio at Different Discount rates(Benefits/Costs)							
Current Practice	1.67	1.48	1.40	1.36	1.32	1.22	1.08
Agro-forestry	1.56	1.37	1.28	1.25	1.21	1.10	0.96
Break Even at Different Discount Rates During (number of years from start)							
Current Practice	5 yrs.	6 yrs.	6 yrs.	6 yrs.	7 yrs.	7 yrs.	9 yrs[1].
Agro-forestry	6 yrs.	9 yrs.	9 yrs.	9 yrs.	9 yrs.	10 yrs.	Never

[1] The annual cropping practice breaks even in the 10th year.

The results of Table 2.4 are plotted graphically in Figures 2.5 and 2.6.

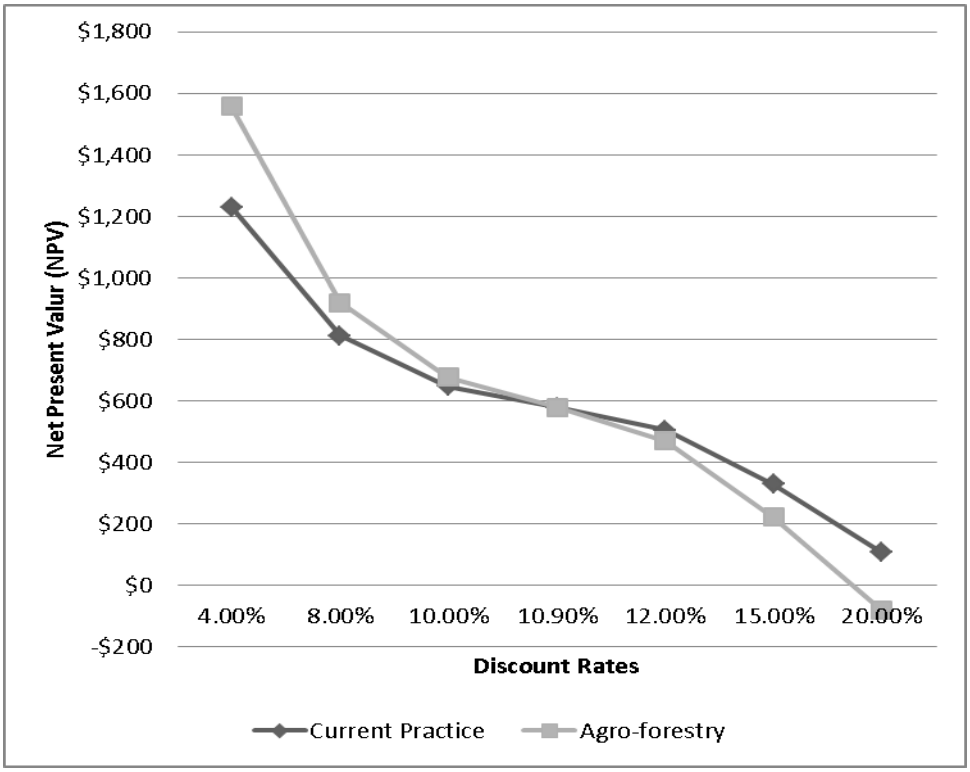

FIGURE 2.5. Net Present Value at Different Discount Rates in the Cost Benefit Example

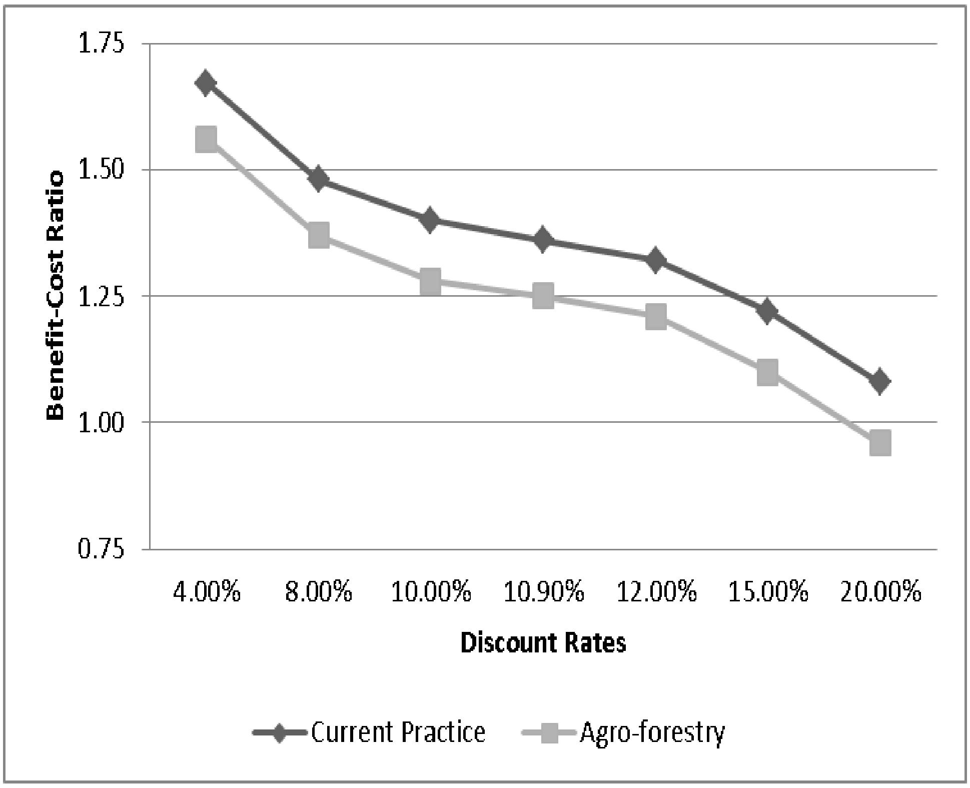

FIGURE 2.6. Benefit Cost Ratio at Different Discount Rates in the Cost Benefit Example

We have seen from Table 2.3 that, at a 4% discount rate, the agroforestry option has a higher Net Present value than the conventional agricultural option. However, Table 2.4 and Figure 2.5 tell a different story. While it is important to note that the NPV of both options falls as the discount rate is increased, these two sets of information show that the forestry practice is only "superior" to the annual cropping practice up to about a 10.9% rate of discount, where the net present value of the two practices cross each other in Figure 2.5 at a common NPV value of $580. At higher discount rates, the annual cropping practice dominates the agroforestry option, using the NPV criteria. This feature highlights the importance of the magnitude of the discount rate in project comparisons.

So, what is the proper rate of discount rate for these private financial flows? There is no single "right" answer. However, since the cash flows of both options are based on private costs and revenues and not social costs and benefits, the answer is that the appropriate rate of discount should be the discount rate that determines the opportunity cost of capital to the farmer, which is equal to the market interest rate (loan rate) to which the farmer has access in both these cases and for other opportunities. In developing countries, this is likely to be quite high, in many cases more than 11%, if 10 year loans are even available in the locality. We will return to this issue when we adjust the cost benefit analysis for private externalities, due to the farm practices in both options.

Interestingly, it can be seen from Table 2.4 and Figure 2.6 that the Benefit Cost Ratio (BCR) of the two projects is always higher for the annual cropping practice, even when the NPV of the agroforestry practice is higher than the NPV of the annual cropping practice. Why is this? The answer is that the Benefit Cost Ratio is a relative measure, while NPV is an absolute measure. This can be seen by considering the following two options for the same farm and land area:

- Project A:
    - Discounted Benefits (revenue): 80
    - Discounted Costs: 30
    - NPV = 50
    - BCR = 2.67
- Project B:
    - Discounted Benefits (revenue): 800
    - Discounted Costs: 400
    - NPV = 400
    - BCR = 2.00

Now ask yourself: which project would the farmer prefer, other things being equal, a net return of $50 (Project A) from his land with a BCR of 2.67 or a net return of $400 (Project B) with a lower BCR of 2.00? If we assume that the farmer has access to the resources to undertake both options, then the obvious answer is the $400 from Project B. If, due to local market conditions, the farmer only had access to resources that cost $40, then he would have no choice but to accept the return of $40 from Project A. So, the overall answer is qualified in very practical terms. When the resources of the farmer to undertake projects are limited, the use of BCA may be preferable, while if the farmer has access to the resources needed for both projects, NPV is preferable.

The final piece of information in Table 2.4 shows the period in which the two options will break even (Cumulative NPV=0) at varying discount rates. As expected, this increases for both projects as the discount rate increases. Both options will break even at their internal rate of return, in 10 years for both projects, but at different discount rate, 15% for the agroforestry option and 23% for the annual cropping practice. In between these maximum break even periods, the break even period for the annual cropping practice is slightly more sensitive more than the agroforestry option. But up to the internal rate of return for each option, it always takes longer for the forestry option to break even than for annual cropping practice option as the discount rate is increased. This difference has direct bearing on the ability of the farmer to pay back the initial loan on capital from these returns, especially at intermediate discount (loan) rates between 8% and 12%.

Adding in Downstream Impacts and Economic Values

Table 2.5 represents a final modification to Table 2.4 by adding in the costs or benefits of the private negative externality (costs) and the counter-acting private positive externality (benefits) of agroforestry option. To capture this, it is assumed that in every year, the agricultural cropping practice reduces the annual NPV of downstream farm owners by an undiscounted amount of $60/year, compared to what would be the case, if there were no upstream agricultural practice (a pristine state). This is due to the effect of increased peak runoff in summer storms and the faster land erosion downstream. This represents a negative technological externality: upstream farmers have no economic incentive to adjust their cropping patterns in ways that will reduce downstream economic losses. Now assume that the economic damage caused by upstream agroforestry reduces the annual NPV of downstream farmers by only $20/yr, undiscounted, compared to a pristine state. This means that, relative to the current states of the environment in both areas, agro-forestry actually adds $40/year, undiscounted, to the bottom line of downstream farmers. Relative to the current states of the environment, this additional $40 represents a positive technological externality, even though the agroforestry farmer does not benefit from his actions that improve the state of the environment.

TABLE 2.5. Accounting for Economic Damages on Other (Downstream) Users

NPV at Different Discount Rates, No Damage Values Included							
	4%	8%	10%	11%	12%	15%	20%
Current Practice	$1,231	$813	$648	$580	$506	$329	$107
Agro-forestry	$1,558	$920	$677	$580	$471	$222	-$80
Private Damages to Down-Stream Users Due to Option							
Current Practice	-$487	-$403	-$369	-$355	-$339	-$301	-$252
Agro-forestry	-$162	-$134	-$123	-$118	-$113	-$100	-$84
Reduced Damage by Agroforestry	$325	$269	$246	$237	$226	$201	$168
NPV at Different Discount Rates, With Downstream Damages Included							
Current Practice	$744	$410	$279	$225	$167	$28	-$145
Agro-forestry	$1,396	$786	$554	$462	$358	$122	-$164
Maximum Net Benefit to Agroforestry Including Compensation From Downstream Farmers							
Max NPV	$1,883	$1,189	$923	$817	$697	$423	$88

Table 2.5 gives a flavor of the indication of how these two upstream options play out in a social accounting framework. The first part of the table shows the NPV of the two upstream farm practice options, not taking into account downstream damages, at different discount rates. It is the same as the first part of Table 2.4. The first two rows of the second part of the table show the NPV of the downstream damages contributed by each upstream farm practice option. As can be seen, the downstream damage values are quite a bit higher for the annual cropping practice than agroforestry at all rates of discount. The last row in this part of the table shows the net benefits (reduced damages) created downstream as a result of choosing the agroforestry option, instead of the annual cropping practice option, by the upstream farmer. The reduced damages of agroforestry over annual cropping decrease as the discount rate increases, from $325 at 4% to $168 at 20%. The third part of the table adds the NPV of the downstream damages to the ex-

isting NPV for both options. This represents a collective accounting for both upstream and downstream users, based strictly on private returns

A PES type scheme only makes sense at discount rates above 11%, in which case the current practice has the higher NPV, but has a smaller negative economic impact on downstream farmers. If we look at the situation at a 12% rate of discount, it can be seen that if we do not include the private downstream damages in the calculations, the current practice has a higher NPV, \$506 vs. \$471 for the agroforestry option and is preferred by the upstream farmer. However, if we include the downstream private damages, then the agroforestry option has the higher NPV, \$358 vs. \$167 for the current practice, making agroforestry the preferred option. One way to make the agroforestry option attractive is for downstream farmers to compensate upstream farmers in a way that encourages upstream farmers to adopt the agroforestry option. Since the downstream farmers experience \$226 (\$339 - \$113) less damage as a result of the agroforestry practice compared to the current practice, this is more than enough to compensate upstream farmers for the \$35 (\$506 - \$471) difference needed to make agroforestry competitive with the current practice.

However, this approach assumes that upstream farmers also have a right to do some damage to downstream farmers, and downstream users will surely ask why they should not have the right to be compensated for damages arising from upstream, based on their right to a pristine state of nature. In that case, the downstream farmers would require a minimum amount of compensation to cover their losses, which are \$339 for the current practice and \$113 for the agroforestry practice. If the upstream farmers decide they want to go ahead with the current practice, they will earn a net benefit of \$167, after paying the \$339 in compensation (\$506 - \$339). If, instead, they choose the agroforestry option, they will earn a net benefit of \$358, after paying \$113 in compensation. In other words, they will be better off by \$191 (\$358 - \$167). This amount represents their maximum WTP compensation to compensate upstream farmers for their losses, while the downstream farmers would be willing to accept as little as \$113.

In both cases, there is room for bargaining, but the result in terms of the choice of practice, the agroforestry option, is the same in both cases, even though the assignment of property rights differs. But the assignment of property rights in this case, if it is even possible, still has one major problem. In the first case, the upstream farmers determine how much money they stand to lose from switching to from the current practice to the agroforestry option. This determines their willingness to accept compensation for downstream damages. In the second case, the downstream farmers determine the damages from the two options on which they base their willingness to accept compensation from upstream farmers. This is a contentious point because it allows both groups to overstate the amounts they are willing to accept. Now, it can be argued that this problem can be solved by giving a "disinterested" third party the responsibility for making these determinations. However, governance issues circumscribe the degree of disinterestedness that can be achieved on a country by country basis. Finally, the fact that the medium which often gives rise to the general problem of technological externalities, namely flows of surface and ground water, has its own problems. In particular, ownership of this "good" is generally vested in "the people", not individuals and allocating property rights to individuals is, in itself, contentious and regulation of flows is generally the responsibility of the public sector.

Summaries of Net Present Values and Economic Impacts of Ecosystem Services Enhancing Alternatives

The Technical Appendix at the end of this report contains four large tables which summarize the information from the studies we reviewed, covering Terracing (Table A3.1), Agroforestry (Table A4.1), Rainwater Harvesting (Table A5.1) and Ecotourism (Table A6.1). These tables summarize the Costs and Benefits of these different projects in quantitative terms and also the main qualitative results of each Table. The introduction to Annex 1 explains how to read and interpret the tables.

The quantitative information from the studies about costs and benefits found in these tables is not always consistent in economic terms within any single table or across the tables for different types of ecosystem services enhancing alternatives. This is basically because: 1. the methodologies that were used varied widely and the results were presented using different metrics (for example average annual gross margin, annualized net benefits, NPV over time , benefit cost ratios and internal rates of return) 2. different currencies in different years were used that did not compensate for exchange rate fluctuations across regions and years, and finally 3. many of the alternatives examined under the same type of option were often qualitatively different and it was difficult, if not impossible, to normalize the results to make consistent comparisons due to the fact that the appropriate units and metric for normalizing the benefits and costs were ambiguous or left out.

Nevertheless, an attempt was made to summarize the NPV/ha. and/or the economic impact of each alternative studied on the income of local residents. This was an arduous exercise, first of all, because of the sheer number of studies; secondly, because the values had to be expressed in US dollars for a common recent year and this involved a lot of searching to find the correct exchange rates and price inflators for different years for many developing countries compared to the US; and finally because of all the inconsistencies in the results we have already pointed to. The tables containing these summaries, along with short discussions of the results can be found at the end of chapters 3 through 6.

Chapter 3: Construction and restoration of Terraces

Definition:

A terrace is a leveled surface used in farming to cultivate sloping, hilly or mountainous terrain. The construction of terraces is a widespread soil conservation practice in the Andean region. This technology has been applied for many centuries where the Incas solved the problem of erosion and low productivity by building terraces and irrigation channels.

Benefits to environment and agricultural production:

Terracing provides an opportunity for improvements in soil, crop and water management though its main functions (Posthumus and de Graaff, 2004):

- Enhancement of natural conditions for agricultural production
- Improved water availability due to water conservation
- Decrease in the rate of erosion and therefore less soil nutrient loss
- Increase the water-holding capacity of the soil
- Generating environmental and ecological benefits

Development and purpose:

Slow-forming terraces are constructed from a combination of infiltration ditches, hedgerows and earth or stone walls. This technology decreases superficial water run-of, increasing water infiltration and intercepting the soil sediment. They usually take between three to five years, or as much as 10 years to fully develop.

Terracing facilitates climate change adaptation by optimizing water usage. This is particularly relevant in the Andean region, where there is dependence on the melting glaciers for water supply as well as uncertainty about future rainfall patterns.

Terraces allow for the development of larger areas of arable land in a rugged terrain and can facilitate modern cropping techniques such as mechanization, irrigation and transportation on sloping lands. They increase the moisture content of the soil through improved water retention. They capture water run-off which can be diverted through irrigation channels at a controlled speed to prevent soil erosion. They increase soil exposure to the sun and they replenish the soil and maintain its fertility as the sediments are deposited in each level, increasing the content of organic matter and preserving biodiversity. Terraces are also expected to increase crop yields in the region as a response to the soil's improved capacity to retain water. This can altogether provide opportunities for rural farmers to increase and diversify agricultural production to generate additional income.

Terraces can be developed and implemented at farm-level without specific institutional and organizational arrangements.

Barriers to implementation

The main obstacles for terrace implementation include the limited access to credit by farmers and the slow rate of return considering the time it takes for crop yield to increase, which can take up to ten years (Yanggen et al., 2003). Given the long time frame required for results, issues over access to land or land rights could prevent a farmer from adopting this technology over traditional practices. Farmers faced with land tenure insecurity tend to have shorter planning horizons and view permanent structures requiring long-term investments as riskier (Dvorak, 1996). Furthermore, those farmers also have little incentive to invest in soil conservation.

The reduction in available land area for cultivation due to the space taken by the ditch and banks, or vegetation strips can be a significant disincentive for farmers with very limited access to land.

Economic analyses of Benefits and Costs of Terracing

Table A3.1 (see Annex 1) presents information about the benefits and costs and net benefits of terracing systems on a world-wide basis. Most of the references come from scholarly publications, as there was insufficient time to do the networking required to locate local project documents. However, as stated at the end of chapter two and for reasons detailed in this chapter, it was very difficult to compare the detailed benefits and costs contained in each study that was reviewed. Nevertheless, we have summarized the main Net Present Value results, so far as is possible, for these studies at the end of this chapter.

The findings, as expected, are mixed. In some cases the net benefits of terracing are positive and quite substantial, but in some cases they are either small or negative. In all of the cases, the factors which lead to variations in the economic results are due to specific differences in terracing technologies, local economic and social conditions and institutions, and in local agronomic, climatic and geophysical conditions, about which more will be said. The approach we wanted to take was comparative: to compare the benefits and costs of terracing (and the other ecosystem project options) with the next-best practice to get measures of incremental benefits. But reality is far different: different researchers use different approaches and have different data and experimental designs to get their points across. We had also wanted to focus exclusively on the cash flows associated with financial benefits and costs of farmers and not the benefits and costs from a social perspective. But, again, in some studies these wider benefits and costs were included (and often not specified). Finally, we had wanted to focus on ecosystem-based adaptation options that would not only be more profitable from a private perspective, but would also reduce the economic value of the damages due to climate change, by more than, existing practices. But there are very few studies that do this for the options being investigated, although the number is increasing quite fast.

The first three studies of terracing in the Peruvian Andes by John Antle and his colleagues (Antle et al. 2006a, 2006b and 2007) and the MS thesis of one of his students (Valdivia 2002) are important for three reasons. First of all, published data for crop yields was missing from all these studies, which indicates a severe shortcoming. And indeed, the vast number of studies in this table did not rely on published data, but instead used farmers' reported estimates, observations by the researchers or experimental field data, some of which were reported to be unreliable. Having more reliable and homogenous data than is currently available in many developing countries is an important concern of lenders and their insurers. As a result, these studies were forced to rely on sensitivity analysis, showing the influence of various factors, such as land productivity, interest/discount rates, and payment periods had on the net present value of benefits. In these studies, private project net benefits were most sensitive to the time it took for slow forming terraces to reverse soil erosion and, after that, the time rate at which the private benefits of reduced soil erosion increased. The shorter the stabilization period and the faster the rate at which soil conditions improved, the lower the adverse impact of high discount (interest) rates on the net benefits of terracing. Thirdly, and perhaps most importantly of all, Antle et al. (2006a) found evidence in the Andes that, in many cases, there would exist a level of soil degradation from which it was physically feasible to recover the land to a productive state with slow forming terraces, but not economically feasible from a private perspective at existing crop prices, with existing interest rates, payback period requirements, and even with high-valued crops. This suggests that some kind of policy intervention is required to make terrace investment "reversible", whether by payment for environmental services (PES) practices, subsidies, or other type of market or mixed market-regulatory system.

The rest of the studies deal with different kinds of terracing systems that are less relevant to the Andean region, and are in locations where there are also vast differences in socio-economic conditions and institutions, climate and agronomic and geophysical conditions. However, a number of the conclusions reached in these studies are relevant to Andean conditions. One of these is the impact, not of capital costs, but labor costs on the private profitability of terracing systems. Two of the studies in Table A3.1 focused on this issue directly (Posthumus and de Graaff 2005 and Bizoza and de Graff 2012) and analyzed the private benefits and costs of bench terracing systems on steep slopes in Peru and Rwanda. Of interest to financing groups is that they found farmers' estimates of productivity and revenues were skewed in the direction of the higher profitability by as much as 100% compared to their own estimates, based on market data. They also found out that, when capital costs were correctly adjusted upward, private profitability was highly sensitive to labor costs, which are extensive due to high maintenance demands by these terraces on steep slopes. Reducing labor input costs by 50% had the effect of turning long-term losses into small, but sustainable benefits. The justification for this is that in both places – and throughout the Andes – small farmers had little access to wage labor markets and would be forced, in effect, to volunteer their labor inputs in order to sustain their livelihoods. This means that lenders need to look carefully at labor market conditions when they undertake their financial calculations to determine if their loans have acceptable rates of return.

At least two of the studies included soil erosion costs in their cost-benefit calculations (Zhou et al. 2009a and 2009b), whose results from an Iowa catchment in the United States were included in two columns of Table A3.1, and Tinge et al. (2005) whose study focused on catchments in the Highlands of Tanzania. The first two studies included calculations of the economic cost of on-site and off-site damages due to soil erosion, while the latter study included these costs, as well as the benefits of reducing these damages. Actually, the two measures would be the same as long as the benefits of the conservation methods were associated with higher net profits on- and off-site. But this was not completely clear from the information presented. As such, these studies underscore two additional items of interest to lenders. First, lenders need to think about whether off-site financial flows are important to their own analyses, especially if the costs and benefits do not appear on the borrowers- financial flows and, secondly, lenders need to have the technical capacity to evaluate the quality and consistency of the cost-benefit studies they use to help justify the loans.[10]

Finally, there is one cross-cutting issue that was not investigated in Table A3.1 or in any the comparable tables for other options. This is the extent to which private incentives can promote conservation, an issue which has direct bearing on farmer incentives to do additional "good things" for off-site farmers and townspeople for which the farmers are not rewarded in terms of financial flows[11] A key relationship that has been investigated in this context is the degree of correspondence based on the motivation of increasing tenure security in land and that of increasing land productivity. The argument goes like this: when land tenure is secure, the time horizons of projects can be increased. Being able to discount cost and benefit cash flows over longer periods of time increases the Net Present Value of a conservation option (Lee, 1980 and McConnell, 1983). However, Feininger and Jin (2006), among others, have also pointed out that, while reforming land tenure laws can enhance investments in terracing and conservation by making capital investments more secure (due to the longer time horizon), they can also promote other high productively investments that do not lead to terracing or land conservation (for example, intensive coffee plantations).

Public policy needs to be able to better balance the two motivations when they are in competition. However, creating market mechanisms to do this is difficult in countries that lack the institutional and technical capacity, data collection and monitoring systems to support them.

Summary of Net Present Value Results

Table 3.1, below, summarizes the main net present value results for the terracing studies that were reviewed as a part of this project. It is based on Table A3.1 in the Technical Appendix. Some studies have been dropped because we wanted to keep the focus on developing countries and/or a combination of the methodologies and data were not sufficient to normalize the NPV estimates for purposes of comparison. The comparison metric used in this table is NPV per hectare.

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[10] *One of the problems encountered during this research was that a number of studies "hid" intermediate estimates of financial flows needed to verify their calculations or used unconventional cost-benefit accounting practices that were also hard to verify.*

[11] *This is exactly the conundrum that has given rise to PES programs to help offset farmer's costs and improve livelihoods of off-site ecosystem users.*

TABLE 3.1. Summary of Net Present Value (NPV) Results for Terracing in Developing Countries

Information Source	Antle et al. (2007a), Antle et al (2007b), Valdivia (2002)	Posthumus and DeGraff (2005)	Bizoza and DeGraff (2012)	Tenge et al. (2005)	Teshome et al. (2013)	Adgo et al. (2013)
Location	La Encanada watershed, Cajamaraca, Peru	Pacucha watershed, Apurımac, Peru	Nyamagabe and Gicumbi Districts in N. Rwanda	West Usambara Highlands, Tanzania	Debre Mewi and Anjeni watersheds, Ethiopian Highlands	Anjenie watershed, Ethiopia
New Practice	Bench Terraces (BT) vs. Current Practice (NT)	Bench Terraces vs. Current Practice	Bench Terraces vs. Current Practice	Bench Terraces (BT) vs. Fanya ju (FJ)	Soil Bunds(SB) vs. Stone Bunds (STB) Vs. Fanya ju (FJ)	Fanya yu Terraces vs. Current Practice
Net Present Value NPV ($)/ha (2012 USD)						
Current Practice or alternative NPV	$2400/ha	Not given	$1915/ha	FJ: $5/ha to $16/ha	SB: - $9/ha to $105/ha	- $408/ha
New Practice NPV	$1400/ha to $3200/ha	-$2400/ha to $630/ha	$2606/ha	BT: $143 to $354/ha	STB: $1265/ha to $2217/ha FJ: $1345/ha to $2718/ha	$1355/ha to $1774/ha
Incremental NPV	- $1,000/ ha to $800/ha	Unknown	$691/ha	No current practice given	STB: $1732/ha FJ: $2022/ha	$1763/ha to $2182/ha

The table covers five pieces of information (in each row) for a given study (in each column). The information in the first three rows – the information source (See References), the location in which the study was conducted and the New (ecosystem) practice being investigated – were taken directly from Table A3.1 in the Technical Appendix. The last three rows give the economic values of the NPV/ha. in common, 2012 US dollars for the current agricultural practice, the terracing option and the incremental NPV, which is equal to the difference between the two, or the NPV/ha (terracing option) less the NPV/ha. (current practice). Finally, it should be noted that, to make the economic values comparable, additional calculations (which do not appear in Table A3.1) had to be made in some cases.

The two Latin American sets of studies arrived at somewhat different estimates of the profitability of bench terraces. Those by Antle and his associates and Valdivia shows that constructing and operating bench terrace systems are quite profitable, while the study by Posthumus and DeGraff indicate that the NPV/ha. of this practice is either highly negative or only slightly profitable. The problem is that the capital costs are too high to recover with the increased revenues created by bench terraces. They show that the projects can be made profitable by reducing the price of labor by one half to reflect the fact that household labor is often treated as a fixed cost by the household and returns to labor are more important to these farmers than returns to land. It was not possible to compare the NPV/ha. of both studies because Posthumus and DeGraff did not calculate the net benefits of the current practice option. However, if we compare the incremental net benefit range calculated in the papers by Antle and Valdivia with the net benefit range in the study by Posthumus and DeGraff, the estimates are quite close, which may be may be due to ambiguity about the methodologies in both papers. The two papers deserve deeper study, plus some communication with the authors, but it looks as if this option is profitable in the region and the main issue is the length of time it takes for the positive effects of bench terracing on the soil to improve yields and increase revenue and how the length of this delay in reaching profitability influences the ability to pay off the capital costs.

The study by Bizoza and DeGraff, comparing the benefits and costs of bench terraces in Rwanda, confirms the profitability of bench terraces, as the net benefits and incremental net benefits of this alternative fall within the ranges of the two previous studies. However, as stressed previously, there are often so many differences between geophysical and economic and social conditions between the various study areas, the closeness of the results may just as well be due to accident as to the robustness of the technology. However, neither conclusion can be rejected without further study. What all the areas share in common are high rates of soil erosion due to plentiful runoff, conditions that are among those that are ideal for implementing bench terraces

The remaining four studies are from Africa, covering soil bunds, stone bunds and Fanya yu terracing. These are all sloping types of terraces, designed mainly to capture runoff between terraces and, secondarily, to stabilize soil. They are appropriate mainly for arid and semi-arid regions where soil bunds are already common practice. These systems have lower capital costs, prevent less soil erosion, and begin to boost crop yields (but not reduce soil erosion) to their system maximum more quickly than bench terraces, which are not common practice in dry areas where soil moisture is limiting. As a result, in the three studies by Tenge, Teshome, Adgo and their co-authors, the net benefits and incremental net benefits of the more sophisticated types of terraces (stone bunds and Fanya yu) are positive and quite close. Therefore, the profitability of these two terracing systems could be worth investigating in the Andean region, where geophysical conditions are appropriate, but their incremental profitability will depend highly on the profitability of the existing practices, which are quite low in the African case studies. Moreover, the study by Tenge and his co-authors reveals that Fanya ju agriculture, as practiced in Tanzania is far less profitable than Bench terracing, where conditions make both of them viable.

Chapter 4: Agroforestry and Silvopastoral systems

Definition

The establishment of agroforestry and silvopastoral systems is an integrated approach that combines the production of trees, crops, pasture and livestock on the same land area. Agroforestry is especially suitable for hillside farming where agriculture may lead to rapid soil loss since the planting of trees improves soil retention, cleaner water, biodiversity, shade and reduced wind erosion.

Benefits to environment and agricultural production

Agroforestry presents an excellent opportunity to promote sustainable forest management while providing income generating opportunities at farm and community level. The semi-forested structure of agroforestry farms provides habitats for an increased number of species thereby improving biodiversity and ecosystem-functioning. Economic risks are reduced as systems produce multiple products and conservation and rehabilitation measures are prioritized, altogether stimulating sustainable rural development (Alavalapati et al., 2004). This activity can improve resilience of agricultural production to adapt to climate change through tree growing for intensification, diversification and buffering of farming systems. As trees are deep-rooted, they are less susceptible to inter-annual variability or extreme events such as drought or floods than annual crops. Tree-based systems improve soil quality and fertility by contributing to water retention, thereby reducing water stress.

Agroforestry systems support maximum use of the land and promote long-term production. They also provide construction materials as well as cheaper and more accessible fuel wood.

Certification schemes have also proven their ability to reduce the risk from fluctuating food prices and promote fair incomes to smallholder farmers for products harvested from agroforestry systems, such as coffee and cocoa (Millard, 2011).

Planning and Development

This activity requires substantial management and considerable understanding of the systems' properties and functions. Both selection of trees and crops requires knowledge of their uses, interaction and adaptation as well as market opportunities. Furthermore, land tenure issues should be properly addressed.

Economic challenges to implementation

World-wide multi- and bi-lateral donors and NGOs are pushing forward with agroforestry programs and projects, often promoting schemes that look good on paper, but ignore the objectives of farmers for whom they are intended. This is especially the case with planting rapidly growing, short-rotation trees, which involve fairly high levels of land preparation and intensive management. This leads to both higher capital and variable (operating) costs, as well as revenue profiles over time that do not address farmers needs for current income. Also, as in all developing countries, higher initial capital costs are harder to pay off over time since high discount rates penalize future returns.

Economic analyses of the benefits and costs of Agroforestry

Tables A4.1.1 and A4.1.2 (Annex 1) present information about the costs, benefits and net benefits of agroforestry systems on a world-wide basis. Two of the entries, Chang et al. (2011) and Sharma et al. (2011), cover the use of buffer strips – which can be planted with crops or trees – to reduce both erosion and water pollution and mulching with noxious plants and weeds to retain soil moisture. This is also a conservation practice that can be, and is, used in conjunction with agroforestry. The results of these two studies were left in the table for informational purposes and to illustrate that agroforestry can be composed of a number of conservation practices whose costs and benefits are often included in the analysis of agroforestry, but are not specifically spelled out.

The studies presented in these tables specifically focus in on, or draw attention to, a number of issues associated with quantifying the private (and social) costs and benefits of terracing practices. Those that have to do with quantification have already been touched upon in the section on terracing and include:

- Different quantifications methods and metrics that make it hard to compare the results of all of the studies in the table in a consistent manner;
- Lack of clarity in describing some aspects of the quantification methodology, hidden assumptions, and – for any number of reasons – quantitative results that are hard to duplicate from the estimates that are available in the text.

One of the most important aspects of this problem is studies that do not include control cases. Business-as-usual, or next-best alternative cases are used in cost benefit analysis to compare alternatives from an incremental point of view; that is: to quantify the additional net benefits (or net costs) associated with a proposed action. Studies like this included Dunn et al. (1990), Mir and Kahn (2008) and Kibria and Saha (2011), which did examine agroforestry alternatives, but did not compare them to a control case. However, the majority of the rest of the studies about agroforestry did use a control case of some kind that was either an existing or planned form of agriculture or forestry, widely practiced in the region.

Another interesting problem along the lines mentioned above is the selection of the financial metric used to compare options. Chapter 2 identified the net present value (NPV) and the discounted benefit-cost ratio (BCR) as two different ways of comparing, or ranking, projects. The study by Kibria and Saha (2011) compares banana and pineapple agroforestry in Madhupur sal forest of Tangail, Bangladesh to identify the suitable agroforestry practices of the area. An interesting finding of this study is that the NPV analysis shown in Table 4.1 indicated that banana agroforestry is financially more profitable than other two systems, while the BCR is higher in pineapple agroforestry, which we did not show. Results like this are not uncommon (Boardman et al. 2006) and are due to the fact that the NPV is sensitive to project scale (size), while the BCA is a relative measure and the capital costs of Banana agroforestry are quite large.

Another issue that pops up in many of the different studies reviewed, not just in agroforestry, but in all of the other areas is the long-term vs. short-term profitability of ecosystem-based activities in the agricultural sector. This issue is raised directly in the studies by Kibria and Saha (2011) and Lojka et al. (2008). In the former, the authors indicate that, while banana cultivation adversely affects soil nutrients and requires increasing inputs of chemical fertilizers, especially on thin and already degraded soil, the study was based on short-term observations and measurements. Thus, the authors conclude, longer term studies may draw different conclusions about the profitability of banana versus pineapple and lemon agroforestry. The latter study emphasizes the importance of taking into account long-term interactions between agronomic and geophysical factors and profitability of agroforestry systems. In their study, differences in soil nutrient dynamics affected the profitability of different systems over time. If it takes a longer period of time to reach a new equilibrium, such that nutrient cations and N, lost during cropping, are replaced by fallow systems at higher levels, this will push economic benefits farther into the future, where the impact of discounting is heavier. Under these circumstances, it will take even longer for the economic benefits to overcome the economic costs than is true of the physical soil benefits and costs. Thus, it is important to underpin long-term BCA studies with long-term findings about important physical processes, which is not always the case.

The long- vs. short-term nature of BCA studies of agroforestry has a direct bearing on the financing of these measures for the important reason that agroforestry and many other ecosystem-based options do have long payback periods. Lenders often attach payback criteria to their loans and in poor developing countries, payback periods tend to be shorter due to higher interest rates. If the profitability of agroforestry options, or terracing, and many other conservation options that have large upfront capital (establishment) costs and benefits, which increase over time, arbitrarily short payback periods required by lenders will limit financing. Use of lower discount rates for ecosystem-based projects to reflect social rates of time preference as opposed to market interest rates, as is often urged, will solve the problem to some extent, but will also require intervention by national, regional or international banking institutions to support these loans.

Two additional issues that are illustrated in the studies in Tables A4.1.1 and A4.1.2 are the use of social accounting supported by PES programs and the effect of socio economic conditions on the adoption of agroforestry practices. The two are related.

For this study, the main focus has been to estimate the private benefits of ecosystem options since lenders often base their decisions on financial flows and not benefits and costs that do not appear in financial accounts. Therefore, studies that focused specifically on PES to augment private benefits were generally not covered. However, in the case of agroforestry, there is an important exception, the study by Quntero et al. (2009), which showed that the agroforestry options in a two Andean watersheds in Ecuador and Peru were not financially competitive with business-as-usual practices. Moreover, the difference between the private net benefits of the agroforestry and business-as-usual practices could not be made up by an on-the-ground PES scheme. In other words, the socioeconomic evaluation revealed that continued deforestation under business-as-usual practices yields higher farming income than agroforestry and conservation with PES. However, many farmers still adopted agroforestry and conservation practices, even though it was not financially feasible!

The answers as to why this happens vary from place to place. In our literature review we found a number of studies that looked at the factors underlying adoption of conservation and ecosystem-based options, but we did not review them in any detail because they did not meet the criteria set down in the project objectives. However, several studies that were reviewed under agroforestry did touch on some of these factors. Quintero et al. (2009) found that a combination of factors that might have helped to motivate farmers to adopt conservation practices, included the following: a preference for the income stream offered by agroforestry over traditional forestry due to high interest rates; the certainty of PES payments as opposed to the riskiness of basing decisions on expected future timber prices and; the fact that the watershed was a protected area tended to weaken incentives to convert land to traditional logging practices.

The study by Hoch et al. (2012), which compares the profitability of short-rotation high yield timber systems and agroforestry promoted by local NGOs with low intensity complementary high value tree production, also finds differences in the adoption of these alternatives by small holders that contradicted NGO estimates. They used two case studies of smallholder farmers to show why this was happening. The differences revealed that with low intensity complementary high value tree production provided co-benefits that were "private" in nature and affected characteristics of their cash-flows that are not measured in traditional CBA. The problem for lenders is to find out whether to include these factors into their loan review and approval process and, if so, what weight should be given to them.

Finally, as in the case of terracing, the studies reviewed in Tables A4.1.1 and A4.1.2 all point to the importance of local social and economic conditions, institutions, agronomic and geophysical conditions, as well as national and local conservation polices on the CBA results. Moreover, as some studies reviewed here have shown, the results of CBA sometimes do not explain very well why financially less attractive agriculture and forestry practices are adopted by some groups of land owners over those with higher net benefits.

Summary of Net Present Value Results

Tables 4.1.1 and 4.1.2, below, collectively summarize the main net present value results for the agroforestry studies that were reviewed as a part of this project. They are based on Table A4.1.1and A4.1.2 in the Technical Appendix. Some studies have been dropped because we wanted to keep the focus on developing countries and/or a combination of the methodologies and data were not sufficient to normalize the NPV estimates for purposes of comparison. The comparison metric used in this table is NPV per hectare.

TABLE 4.1.1. Summary of Net Present Value Results for Agroforestry in Developing Countries

Information Source	Dunn et al. (1990)	Current and Scheer (1995)	Hoch et al. (2012)	Quintero et al. (2009)	de Souza et al. (2012)	Lojka et al. (2008)
Location	Southern Ecuador	Central American and Caribbean countries	Amazon regions of Brazil, Bolivia, Peru and Ecuador	Moyobamba (Peru) and Pimampiro (Ecuador) watersheds	Zona da Mata of Minas Gerais State, Brazil	Peruvian Amazon
Technology	Planting of Alder on field boundaries, in pastures and on crop land	Five land use systems: intercropping (AI), alley cropping (AC), contour planting (CP), perennial intercropping (PI), Taungya (TA) and woodlot (WL)	Balsa plantations (BP), agroforestry (AF), and plantations with complementary tree growing (CT)	Current practice (CP), mixed agroforestry options without PES (AF) and with PES (AFP)	Sun coffee (CP) vs. agroforestry (AF)	Imperata Fallow (CP) vs. tree fallow (AF)
Net Present Value NPV ($)/ha (2012 USD)						
Current Practice or alternative NPV	Not given	Not given	Not given	CP: $917/ha to $1810/ha	CP: $11,246/ha	CP: $593/ha to $1054/ha
New Practice NPV	Low: $394/ha Mean: $2,280/ha High: $6,536/ha	AI: $1300/ha to $2863/ha AC: $847/ha to $1335/ha CP: $761/ha to $1426/ha PI: $1405/ha to $2867/ha TA: $2868/ha to $6797/ha WL: -$33/ha to $764/ha	BP: -$639/ha to - $378/ha AF: -$745/ha to -$393/ha CT: - $100/ha to $360/ha	AF: $728/ha to $1318/ha AFP $764/ha to $1386/ha	AF: $17,570/ha	AF: $676/ha to $1,645/ha
Incremental NPV	Unknown	Unknown	Unknown	AF vs. CP: -$1,073/ha to $401/ha AFP vs. CP -$1,037/ha to $469/ha	AF vs. CP: $6,324/ha	AF vs. CP: $83/ha to $590/ha

The two tables are identical in format. Each one presents the same five pieces of information (in each row) for a given study (each column), as was the case with Tables A4.1 and 4.1.2. The information in the first three rows – the information source (See References), the location in which the study was conducted and the New (ecosystem) practice being investigated – were taken directly from Table A4.1 and A4.1.2 in the Technical Annex. The last three rows give the economic values of the NPV/ha. in common, 2012 US dollars for the current agricultural practice, the agroforestry option and the incremental NPV, which is equal to the difference between the two, or the NPV/ha (terracing option) less the NPV/ha. (current practice). Finally, it should be noted that, to make the economic values comparable, additional calculations (which do not appear in Tables A4.1.1 and A4.1.2) had to be made in some cases.

The results in Table 4.1.1 are based on studies that were conducted in Latin America, Central America and the Caribbean region and were grouped together in this study because they were in or in close proximity to the study region, compared to the rest of the agroforestry studies. However, comparisons of NPV and incremental NPV are made even more difficult than for terracing systems because, even though the agroforestry systems are differentiated to some degree, the exact options in each study differ by a larger or smaller degree. Moreover, it is not possible without much additional study to know the contributions of these differences to differences in the benefits and costs of each option in each place. The same can be said for the effects of differences in the geophysical conditions and socio-economic conditions. Furthermore, no reference existing practice exists for three out of the possible six cases.

Nevertheless, some tentative conclusions are possible. First of all, the net benefits reported in the studies by Dunn, Current and Scheer, Quintero, de Souza and Lojka and their various colleagues are all positive, with the exception of the woodlot case reported by Current and Scheer. Only the net benefit estimates from the study by Hoch et al. are overwhelmingly negative in value. Unfortunately, only three of the six studies present estimates of the incremental net benefits. In these cases, de Souza reports relatively low opportunity costs associated with the NPV of the current practice, sun coffee – almost $11,000/ha – compared to a substantially higher NPV for the agroforestry option – about $17,500/ha, resulting in an incremental net benefit of around $6,300/ha. This is somewhat encouraging prospect for regional ecosystems since export demand for sun coffee is extremely high and this crop is a growing source of revenue all over Latin and Central America, but is a source of concern from the perspective of ecosystem effects. In three of the five cases that were examined in this study, the production of, and revenue from both coffee and other agricultural crops increased, while reducing the level of adverse ecosystem effects. In the other two studies that report incremental benefits, these are negative to fairly low, around - $1,000/ha to around $450/ha, as reported by Quintero et al., to less than $600/ha as reported by Lojka et al. However, given the ecosystem benefits of many different agroforestry practices, revenues could be increased by the use of PES.

The results for the studies in other developing countries are summarized in Table 4.1.2. These results are different than those shown in the tables in the Technical Appendix, in that in several cases we made assumptions that all forestry or an all agriculture option was the current practice, making it possible to compute incremental net benefits. This is the case with the studies by Rasul, Sharma et al., Mir and Kahn, and Nissan et al. This assumption seemed relatively safe and made it possible to present incremental benefit estimates for all but two studies, Kibria and Saha and that by Chia-Ling Chang et al.

Looking first at the net benefits in all of the agroforestry options in this table, all of the NPV estimates are positive, except for those in the paper by Chia-Ling Chang et al., which contains misleading results because the NPV was normalized on the area of the buffer strips (planted with trees) and not farm area. Thus, the resulting estimates are likely to be too high or too low, depending on the relationship between farm area and buffer strip area. The net benefit estimates in Kibria and Saha and Mir and Kahn are in the range of $20,000/ha., quite large when compared to most of the net benefit estimates reported for Central and Latin America in the previous option. The higher estimates appear to be due to the higher prices for the specific agriculture and forestry products grown on commercial farms and to higher yields, since management is more intensive than on small farms. The net benefit estimates for the studies by Rasul, Sharma et al. and Nissen are smaller, in the same range as the studies in the previous table. This is consistent with the fact that these studies are for small farms. The net benefit estimates in Chia-Ling Chang et al. are problematic because the farm area used to normalize these estimates is unknown and differences in scale will affect the results substantially.

TABLE 4.1.2. Summary of Net Present Value Results for Agroforestry in Developing Countries

Information Source	Kibria and Saha (2011)	G. Rasul (2006)	A.R. Sharma, et al. (2011)	Mir and Kahn (2008)	Nissen at al. (2001)	Chia-Ling Chang et al. (2011)
Location	Madhupur Sal Forest, Tangail District, Bangladesh	Chittagong Hill Tracts, Bangladesh	Western Himalayan region, India	Shalimar, Pakistan	Mindanao, Philippines	Shihmen reservoir watershed, Taiwan
Technology	Pineapple (PA), lemon (LE) and banana (BA) agroforestry compared	Agroforestry (AF) and Horticulture (HO) vs. cash crops (CPC) and farm forestry (CPT)	Mulching rain fed crops Kudzu (KU), wild sage (WS) and subabul (SU) vs. current practice (CP)	Willow plantations (CPT) vs. willow + crops agroforestry (AF)	Intercropping (IC) vs. all trees (CPT) or all crops (CPC)	Riparian buffer strips, width: 10M, 50M, 100M
Net Present Value NPV ($)/ha (2012 USD)						
Current Practice or	Not given	CPT: $523/ha, CPC: $943/ha	CP: $678/ha	CPT: $17,433/ha	CPT: $2337/ha, CPC: $18,010/ha	Not given
New Practice NPV	PA: $22,847/ha LE: $21,139/ha PN: $18.920/ha	AF: $388/ha HO: $606/ha	KU: $1,355/ha WS: $1117/ha SU: $1284/ha	AF: $21,378/ha	IC: $7,245/ha	10M: $468,000/ha[1] 50M: $50.70/ha[1] 100M: -$4.200/ha[1]
Incremental NPV or	Unknown	AF vs. CPT: - $135/ha AF vs. CPC: - $555/ha HO vs. CPT: $83/ha HO vs. CPC: -$337/ha	KU: $667/ha WS: $439/ha SU: $606/ha	AF vs. CPT: $3,945/ha	IC vs. CPT: $4,908/ha, IC vs. CPC: -$10,765/ha	Unknown

[1] NPV results are given strip hectares, not in farm area; therefor, the larger the strip area the lower the net benefits. Since strip area in each class varied by an order of magnitude, the NPV/ha would be far lower, but no farm areas were given.

Interestingly, the estimates of incremental net benefits for the four studies where these values can be computed are just as mixed as they were for the Central and Latin American regions, reported in the previous table. The incremental net benefits for all of the agroforestry alternatives compared to the relevant current practice are negative. Those reported by Sharma et al. are positive, but small, in the range of $400/ha to $700/ha. In the study by Mir and Kahn, the incremental net benefits are higher by an order of magnitude, around $4,000/ha, while the results presented in Nissen et al. are mixed. Intercropping is a highly competitive substitute for tree planting, earning incremental net benefits of about $5,000/ha, but does not compete favorably with annual crops, showing an incremental loss in net benefits around -$11,000/ha.

While it is difficult to draw any exact conclusions from the last set of studies outside of Latin and Central America, the weight of the results from both tables suggests that the competitiveness of agroforestry options against existing practices, on average, is not necessarily (but can in some cases be) very large and is at least somewhat likely to be small or negative. Profitability could be potentially improved somewhat by grafting PES programs onto the agroforestry options that have strong environmental benefits. However, the profitability of specific projects will depend on a variety of geophysical and socio-economic factors that cannot be pinned down without project by project by project cost benefit evaluations. Also, more focus needs to be placed on investigations of agroforestry options that are competitive with small farmer practices in the Andean region, as in the study by Lojka et al.

Chapter 5: Rainwater harvesting and capture

Definition

Rainwater harvesting is a technique for inducing, storing and conserving local surface rainwater runoff for livestock and agricultural purposes in arid and semi-arid regions.

Benefits to environment and agricultural production

Collection and storage of rainwater can provide suitable and reliable water supply during seasonal dry periods and droughts. Additionally, widespread rainwater storage capacity can greatly reduce land erosion and flood inflow to major rivers as well as contribute to the stabilization of declining groundwater tables. Increasing the availability of irrigation water during dry season has been shown to yield considerable increases in agricultural production. Rainwater harvesting therefore constitute an important adaptation strategy in areas with high rainwater variability as a means to enhance crop and livestock production as well as maintaining ecosystem functioning by increasing soil moisture levels.

Development and purpose

Rainwater can be collected through the use of micro-catchments that aim to store water before it evaporates or enters watercourses. The harvesting infrastructure can be either natural or constructed and can take many forms. This include below ground tanks (pots, jagüeyes, cisterns) and excavations of small on-farm ponds and reservoirs into which rainwater is directed from the ground surface. Volumes of these are typically small (around few m^3) and are usually used by a single household or institution. Rainwater technologies are generally simple to install and operate and running costs are reasonably low. To mitigate the effects of water shortage and soil nutrient deficiency, developing country farmers in regions without irrigation are also turning to small scale water harvesting methods to improve yields. Two of these are mulching and zai which are widely used in sub-Saharan Africa. With mulching, a farmer spreads mulch over soil to help retain moisture for subsequent crop uptake. Mulch is typically derived from a basic ecosystem resource – local grasses, plant cuttings and even noxious weeds. Mulching is a relatively simple technique to implement and requires very little in terms of education and skill to implement[12]. A zai is a small hole dug in the ground. For a farmer to dig 10-12,000 zai per hectare is not uncommon. In each zai, the farmer places a mixture of soil and organic matter like manure, and then adds either the seed to be planted or an entire plant. Farmers add manure to attract termites. The termites dig tunnels in the soil, which in turn improves the water retention properties of the soil. They also bring nutrients from deep soil layers closer to the surface for uptake by the plant.

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[12] *This is not to be confused with mulching using black plastic in conjunction with irrigation, but the purpose is the same, to prevent soil moisture loss.*

Economic challenges to implementation

While larger rainwater harvesting systems can be quite profitable, large capital and associated labor costs of constructing these rainwater storage systems mean that payback periods are long. However, at the high interest rates experienced in many developing countries, increasing the length of time over which farmers can pay off their loans does not help a great deal. The combination of high early capital costs, followed over time by a stream of benefits due to higher yields and revenues is hard to balance when high discount rates "penalize" future returns.

Barriers to implementation

The main shortcoming of rainwater harvesting is the high cost of many of the systems. In places where precipitation records are poor there is an additional risk that these systems will not be properly-sized to be optimal for the existing climate variability. Climate change magnifies this problem enormously due to large uncertainties in global and regional climate models and lack of reliability of precipitation forecasts, in particular. Also where water harvesting systems are just being adopted, they may create new water conflicts with existing uses and additional legislation to regulate potential adverse impacts would be required.

Economic Analyses of Benefits and Costs of Rainwater Harvesting and Capture

The first five studies in Tables A5.1.1 and A5.1.2 (Annex 1) come from the report *Profit from Storage: Costs and Benefits of Water Storage* (Tuinhof et al. 2012) and are worth treating together as they touch on a number of major issues and findings about this practice. There are numerous case studies in the report, all by different authors, so the estimation of project costs and benefits is not consistent, a problem also identified in the two previous chapters.

The study from Kenya (Tuinhof et al. 2012) covers the sand storage dams in the Kitui valley. Sand storage dams are relatively small and built into the bed of a seasonal river. During the periods of peak velocity flows, sand builds up behind the dam and this creates a sandy layer in the riverbed. This grows over periods of years until it the sand level reaches the top of the dam. This layer serves as an aquifer of stored water that is recharged by water running through the river, making it available for use in the dry season. In addition to increasing available water supply, these dams also improve water quality through reduced sedimentation. In the Kitui valley, these dams were often developed as a cascading system that reduces total water leakages in the system and increases ground water recharge compared to non-cascading dams.

The examples given in the study suggest that the NPV of a typical dam in this system is about $6,000 after 15 years and $20,000 after 20 years. However, the rate of interest used to discount benefits and costs was only 5%. Private financers in Kenya would have demanded much higher interest rates and this would have made the dams economically infeasible in some cases. Governmental legislative and regulatory support is also required since flow patterns to individual communities and users are altered. While the dams can be made smaller, hydrologic considerations are paramount in dam design if rainy season runoff is very high energy, and the legal-regulatory issues may become more complex due to upstream farmer to downstream farmer conflicts.

Check dams are the subject of the study in Pasak Nagm, a small village of around 350 people in Thailand. Check dams are built to reduce the adverse effects of deforestation on runoff. Check dams can be built across small gullies and streams, usually upstream or at the boundaries of watershed areas. They reduce the rate of water flow, increase percolation into groundwater systems and constrain sediment flows. Simple check dams are constructed with the use of natural materials that are locally available such as rocks, logs, sticks and branches. Permanent dams are made of concrete. Generally speaking, check dams are very flexible and can be tailored to local geophysical conditions.

The check dams at Pasak Nagm are multiple-use, designed for community water supply, agricultural use and livestock water. The dams are small, 1 to 4 meters wide and 0.5 to 1 meter deep. Construction practices vary and most are built of locally available materials, although there are a few, larger concrete structures.

The costs of these structures were comparatively modest. Basic dams, constructed of locally available materials cost between $17 to $34. These costs increased to $34 to $167 if the materials had to be purchased from the outside. Permanent structures cost as much as $334, still relatively modest. No estimate of private economic benefits was calculated, but the qualitative benefits attributed to the project were numerous, including:

- Flow in streams and gullies has been increased and some ephemeral streams have year-round flows.
- Check dams contributed to conserve water for domestic use, tending water for cattle and agriculture.
- Reduced out-migration to cities due to increased agricultural income.
- Forest areas recovered and canopy cover is increasing; forest foods, medicinal plants, and natural materials have become more abundant, creating extra income for villagers.
- Soil humidity has increased.
- The occurrence and severity of forest fire has reduced significantly.
- Biodiversity of the area is improved.
- Rejuvenated ecosystems have led to the promotion of eco-tourism and study visits, as an additional source of income within their own village.

The projects were externally financed with village labor contributions. No mention in the study was made of legal-regulatory issues associated with changes in the patterns of flows. It is at least somewhat likely that water flows have increased everywhere along the treated streams. However, this may attract new settlement and water use that would likely be greater upstream than downstream.

The Next three studies we reviewed in the Tuinhof report (2012) followed the same general pattern as the Pasak Nagm study in several different ways:

- Ranges of capital costs were given for all of the projects, consistent with local conditions.

- Project benefits and net benefits were not estimated. However, high estimates of gross margins were reported in all cases, the question being whether or not these sums covered the capital costs of the project.
- All of the projects were reported to have improved the well-being of community members and, in most cases, farmers, although the use of surface water harvesting tanks by Ethiopian farmers was found to be barely profitable.
- The capital costs of all of the projects were externally financed or subsidized. In one case – installation of gulley plugs in Terai, India – community labor donations were also used to cover high labor construction costs. This leads to the general conclusion that these projects could not be supported by private market finance.

The chapter covering the building of four multiple-use dams and systems of reservoirs behind the dams at high elevations in Peru has many of the attributes of the three previous projects, but is of special interest since it covers the region of interest to ROLAC. The dams were built to rejuvenate high altitude ecosystems, provide recharge to groundwater systems in the area, and for stock watering at high elevation and irrigation at lower elevations. These are relatively large projects, co-financed through external and local-community sources, with relatively large capital costs and not an object of private finance. The capital costs are detailed, but there is no in-depth treatment of the project (ADAPTS) benefits or net benefits. However, a break-even analysis done for the project suggests that net annual return for large dams is about USD 845/ha at 10% and USD 1475/ha with a payback period of 15 years. The benefits to local communities were not investigated and probably depend on the impact of the project on downstream farm incomes. This is probably fairly small since each reservoir could only add about five additional hectares of irrigated land. No total is given.

The remaining seven studies share a common couple of traits: they all focus on-farm rainwater harvesting practices and they all purport to estimate the private NPV of rainwater harvesting practices, although the calculation methods and/or metrics are not consistent across studies and therefore comparisons are hard to make. However, the calculations of net present values (or annualized net present values) differ quite widely from study to study. At the high end, Niggi et al. (2005) estimate that construction of small farm ponds in Kenya would provide additional supplemental irrigation net benefits worth $200/yr. or about double current net benefits. While Senkondo et al. (2004) did not estimate the incremental NPV of excavated bunded basins in Tanzania, the incremental gross margin of this option for maize production was around 175,000 Tsh/ha/yr. and over 2,000,000 Tsh/ha/yr. for onions. These gross margins, which exclude capital costs, are on the order of 10^5 to 10^6 times gross margins under the business-as-usual scenario. At the low end, Goel et al. (2005) report that only 5/18 of the water storage systems that were reviewed had an incremental benefit-cost ratio greater than 1, due to very high relative construction costs of small and medium-size structures. Mushtaq et al. (2007) in their study of the construction of on-farm ponds in India also found that only larger ponds had positive NPV values at prevailing interest rates of around 12% and greater. The remaining studies by Juan et al. (2003), and Oron et al. (1983), and Panagrahi et al. (2007) showed mixed results, depending on assumptions about the price of family labor, interest rates, pond size and crops grown. Finally, all of the studies were explicitly or implicitly sensitive to assumptions about crop yields and revenues due to the uncertainty of expected future prices. The longer the payback period, the greater this uncertainty becomes, since many of the crops selected in all the studies are produced by small farmers who sell their products into local markets with volatile prices.

Thus, a general conclusion that can be drawn from these studies, as in the two previous chapters, is that the private profitability of even quite similar projects is highly dependent on local agronomic and geophysical conditions as well as socioeconomic conditions and institutions. This is compounded by the fact that the types and combinations of rainwater harvesting options are even more diverse than in agroforestry and it is hard to find comparisons of common options, although on farm ponds and small reservoirs look to be a promising option, although it may be necessary to find a firm empirical basis for reducing household labor costs in order to justify small ponds.

It is also noted that none of these studies looked at the motivation of small land owners to adopt rainwater harvesting practices to see if private profitability of these farmers was the most important factor affecting their decision to adopt a given practice. We also did not find any studies using the payment for ecosystem services (PES) principle to make up for the lack of profitability of rainwater harvesting practices. This principle is particularly relevant for rainwater harvesting practices that have off-site consequences, such as sand storage dams, check dams and other practices that influence surface water flows or groundwater storage.

As a result of these findings, it seems relatively clear that financing institutions need to require or conduct their own independent evaluations of the profitability of these measures on a case-by-case basis. In some cases, this will require building the technical capacity to conduct or review such analyses and the institutional capacity to tailor lending decisions to the results of these studies.

Summary of Net Present Value Results

Tables 5.1.1 and 5.1.2., below, collectively summarize the main net present value results for the rainwater harvesting studies that were reviewed as a part of this project. They are based on Table A5.1.1and A5.1.2 in the Technical Appendix. Some studies have been dropped because we wanted to keep the focus on developing countries and/or a combination of the methodologies and data were not sufficient to normalize the NPV estimates for purposes of comparison. The comparison metric used in this table is NPV per hectare.

The two tables are identical in format. Each one presents the same five pieces of information (in each row) for a given study (each column), as was the case with Tables A5.1.1 and A5.1.2. The information in the first three rows – the information source (See References), the location in which the study was conducted and the New (ecosystem) practice being investigated – were taken directly from Table A5.1.1 and A5.1.2 in the Technical Annex. The last three rows give the economic values of the NPV/ha. in common, 2012 US dollars for the current agricultural practice, the agroforestry option and the incremental NPV, which is equal to the difference between the two, or the NPV/ha (terracing option) less the NPV/ha. (current practice). In these tables, all of the net benefit estimates are considered to be incremental, although that was not made clear in all of the studies. Finally, it should be noted that, to make the economic values comparable, additional calculations (which do not appear in Tables A5.1.1 and A5.1.2) had to be made in some cases.

Table 5.1.1. Summary of Net Present Value Results for Rainwater Harvesting in Developing Countries

Information Source	Tuinhof et al (2012)	Sami et al. (2012) and Tuinhof et al (2012)	Tuinhof et al. (2012)	Hatibu et al. 2006	Nigigi et al. (2005)	Yuan et al. (2003)
Location	Kitui, Kenya	Terai India	Amhara, Ethiopia	Northern Tanzania	Laikipia district, Kenya	Gansu, China
Technology	Sand storage dam, maximum capacity 4000m3/yr	Gully Plugs and Bunds	Surface water harvesting tanks, maximum capacity 115 to 130 m2	Multiple rainwater harvesting options to expand catchment area and ponds	Farm ponds plus drip irrigation	Expanding collection areas and storing water in cellars, on farm
Net Present Value NPV ($)/ha (2012 USD)						
Current Practice or	CP not given[3]	CP not given[3]	CP not given[3]	CP not given[3]	CP not given[3]	CP not given[3]
New	Not given	Not given	Not given	Not given	Not given	Not given
Incremental NPV	$4,000 to $6,000[1]	$3,000/ha to $30,000/ha[2]	- $500/ha to $800/ha	$500/ha to $3,700/ha	$2,365/ha	< $120/ha to $1,700/ha

[1] Dam provides drinking water to 150 people and supplementary irrigation (no area given).

[2] An approximation based on estimated from available data in study.

[3] All benefits are incremental, based on increased yields and/or area due to additional water supply.

As the tables show, we found no studies of rainwater harvesting for the Andean region and those we did find came from a fairly broad range of countries and embraced a wide range of technologies, including sand storage dams, gulley plugs, ponds, storage cellars and tanks, expanding and modifying catchment area and structure. This problem is further complicated by the different scales of the technologies considered, for example, different sizes of catchment areas and small reservoirs (ponds and on-farm dams). As previously noted, the variety in the types and scales of technologies make it very difficult to compare the net benefits across the various studies, even though all of the results were normalized on a farm area basis.

TABLE 5.1.2. Summary of Net Present Value Results for Rainwater Harvesting in Developing Countries

Information Source	Senkondo et al. (2004)	Panagrahi et al. (2007)	Mushtaq et al. (2007)	Oron et al. (1983)	Goel et al. (2005)
Location	Semi-arid regions of Tanzania	Eastern India	Zhangi Irrigation System, China	Israel	Northwest Himalayas, India
Technology	Excavated bunded basins to capture water.	On-farm reservoirs to provide supplemental irrigation	Small, medium and large ponds for supplemental irrigation	Micro-catchment water harvesting with vertical infiltration pipes	Different size of water harvesting structures and crops irrigated
Net Present Value NPV ($)/ha (2012 USD)					
Current Practice or alternative NPV	CP not given[3]	CP not given[3]	CP not given[3]	CP not given[3]	CP not given[3]
New Practice NPV	Not given	Not given	Not given	Not given	Not given
Incremental NPV	-$390/ha to $2,650/ha	$200/ha to $1,500/ha	-$2,040/ha to $5,931/ha	-$300/ha to $1,200/ha	-$866/ha to $377/ha

[3] All benefits are incremental, based on increased yields and/or area due to additional water supply

Farm ponds and on-farm reservoirs are one area in which some useful comparisons can be made, although such comparisons are bedeviled by differences in storage capacity. These structures were considered in the studies by Nigigi et al., Panagrahi et al. and Mushtaq et al. With the exception of the study by Mushtaq et al., all of the net benefit values were positive and the upper range of the estimates in all of these studies was strongly positive, on the order of thousands of dollars. In the case of the study by Mushtaq et al, negative net benefits were, interestingly, not associated with high capital costs, but with high household labor costs, which had to be reduced in many cases to make the estimate of net benefits positive. It should be added, that the use of farm ponds and on-farm dams is a practice that is used widely and effectively, either to act as a buffer for normal irrigation water supplies from public authorities and also to capture water from ephemeral streams to provide supplementary irrigation to rainfed crops after the end of the rainy season. Unfortunately, these water supply sources are often very shallow and subject to high evaporation. The higher end net benefit values reflect the flexibility of the marginal benefits that this option can provide: a little more soil moisture at the right time can be far more valuable to small farmers then extensive or intensive irrigation from large dams, with the proviso that high household labor costs can be problem in the construction phase.

Chapter 6: Ecotourism

Definition

Ecotourism is a conservation activity that generally, but not always, involves tourist visits to "protected areas" for multiple purposes, such as enjoying the surroundings of natural ecosystems, wildlife viewing and many other high-value, low-impact forms of recreation. While ecotourism is intended to provide sustainable travel activities with minimal impact to natural areas, some production activities may be allowed, including the harvesting of non-timber forest products, such as berries and medicinal herbs, albeit under strict regulatory control. Ecotourism is not always associated with protected areas. Increasingly, conservation practices implemented by small farmers in many developing countries – often in remote, scenic regions – have helped to rejuvenate surrounding natural ecosystems and have been promoting ecotourism to these areas by developing nature trails and facilities for low impact recreation activities.

The International Ecotourism society has set forth principles to guide ecotourism activities, which help to better explain the overall purposes and practices of ecotourism:

- Minimize the impact of visiting the location (i.e. - the use of roads).
- Build respect and awareness for the environment and cultural practices.
- Ensure that the tourism provides positive experiences for both the visitors and the hosts.
- Provide direct financial aid for conservation.
- Provide financial aid, empowerment and other benefits for local peoples.
- Raise the traveler's awareness of the host country's political, environmental and social climate.

Benefits to environment and agricultural production

Ecotourism activities can be developed as part of a larger effort to promote alternatives, or activities that are complementary, to agriculture in rural communities. Income generation from ecotourism offers incentives for ecosystem restoration and conservation, while reducing dependence on agriculture as an income source. The development of ecotourism can facilitate biodiversity conservation in communities by creating local awareness of the economic and environmental benefits from conservation efforts. The overall economic impacts of ecotourism involve *international*, *national and local* income and job creation in tourism agencies, transportation, lodging facilities, guides and park staff, and the like. These direct impacts ripple through local and national and international economies via inter-industry transactions creating multiplier effects. Originally, ecotourism was largely promoted for its ability to improve local livelihoods and develop a broader income base for traditional agriculture to survive in rural areas. However, there is much recent evidence to show that the majority of income generated by ecotourism goes to firms outside the local and national domains.

Development and purpose

Ecotourism is developed to yield economic benefits and employment opportunities to local people, support conservation through long-term management of protected areas and minimize human impact of travel activities.

Economic challenges to implementation

There are basically, two primary economic challenges to ecotourism implementation. On the microeconomic side, the main challenge is how to make ecotourism activities profitable (sustainability is assumed). Thus, a great deal of attention is being paid to the issue of "optimal" entry fees, based on the willingness-to-pay of tourists and to other forms of support, primarily through "Payment for Economic Services" (PES). Analyses from studies suggest that the total cost of the conservation of ecosystem destinations may exceed the direct financial benefits. In that case, PES programs try to make up the "opportunity cost" of the associated conservation activities with payments from individuals and firms who benefit directly or indirectly from these conservation activities. Where applying the principle of the “user pays” (plus PES) may not meet all costs related to environmental protection, it is sometimes argued that the responsibility of the public authorities to cover the remaining costs.[13]

Barriers to implementation

Interestingly, much of the resistance against ecotourism activities comes from local residents, concerned about the inroads on their traditional way of life and about "exploitation" by private sector vendors and from some conservation activists who believe that ecotourism in some forms is degrading natural areas and is not sustainable. The issue of profitability, already touched upon, also represents an obstacle to the implementation of ecotourism and is not helped by declining expenditures at the donor and national government levels. Raising park entry fees is one solution that has been tried with good success in, for example, Costa Rica. On the other hand, PES programs have often not been sufficient to cover the opportunity costs of conservation activities and a great deal of PES income does not come from activities outside the ecotourism area whose private profits are improved by conservation activities within the natural area, but rather from NGOs and conservation groups. For PES to become effective as a market mechanism it must be linked to a regulatory framework that allows those who improve ecosystem services in one place to capture the benefits of the positive externality in other places (that currently is "free"), not unlike "cap and trade" programs associated with e.g. air pollution regulations.

Economic Analyses of Benefits and Costs of Ecotourism Activities

Ecotourism is conceptually a great deal different than the other ecosystem-based activities in the previous three chapters. There are a number of reasons for this:

- Ecotourism is not a farm activity, but can be organized at the community level on a small scale where there are areas that deserve protection from an ecosystem diversity standpoint.

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[13] *http://www.unep.fr/shared/publications/cdrom/WEBx0139xPA/statmnts/pdfs/vefraf.PDF*

- The profitability of ecotourism applies mainly to those who manage the park and vendors who are dependent on income from ecotourism for their firms to survive. The economic impacts of ecotourism, on the other hand, are not measured by benefits and costs, but rather by the impacts of park revenues and expenditures by tourists on local household cash incomes. However, much of the expenditures by tourists who visit ecotourism sites are not spent in the park or nearby small communities, but appear on foreign and national accounts.
- The accounts of many of these "actors" are not available and so private cost benefit studies are hard to find, except at the level of the public park owners, which are usually national or local governmental organizations.
- The demand-side issue of how much visitors to ecotourism reserves are willing to pay (WTP) for "experiencing" park ecosystem amenities is extremely important and not at all present in the previously covered activities.
- The issue of the impact of visitors on the local economy is covered much more extensively in the literature under ecosystem tourism than for other ecosystem-based activity.

For these reasons, Tables A6.1.1 and A6.1.2 (in the Technical Appendix) look a bit different than the previous tables, as they focus more on issues related to the willingness to pay of park visitors, both as a measure of the economic value that park users (and in some case, non-users) place on the ecosystem amenities they experience in the park and, if used correctly, to determine optimal entry fees. In addition, the effects on local income and livelihoods are treated more extensively.

The first eight studies reviewed in these tables focus on the willingness to pay (WTP) of park users for park ecosystem amenities. The first of these (and the oldest) by Tobias and Mendelsohn (1991) is a study of the WTP by tourists for trip visits to Monte Verde Cloud Forest in Costa Rica. It also uses a participation model, linked weakly to the WTP model to determine visitation. Combining the two gives estimates of the marginal WTP for one trip and total revenue per year. The value/trip was estimated at $35/trip/yr.; estimated annual visitation was in the range of $400,000 to $500,000. They also estimated the present value of consumer surplus (CS) of all park visitors in perpetuity at 4 per cent[14] to be in the range of $2.4 – $2.9 million. Higher discount rates give lower CS estimates, as shown in the table.

This study is noteworthy for its use of a "revealed preference" approach, the Travel Cost Model (TCM), which relies upon the notion that the demand for park amenities can be inferred in the payment for complementary goods (travel), as revealed in park visitation data. As such, the estimated welfare values in this study are based on what people actually do (through revealed preferences), rather than upon how much people say they are willing to pay (through stated preferences) to experience park amenities. Of the seven WTP studies, this is the only one to employ a revealed preference method. The remaining studies rely on a variety of stated prefer-

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[14] *Consumer Surplus (CS) is , a measure of the maximum WTP of a park visitor less the costs of making the visit, and came up with an annual estimate*

ence methods, including Contingent Valuation (CV)[15], Contingent Behavior (CB)[16] and Choice Experiments[17] and are all based on information obtained from surveys. CV studies directly elicit responses to questions about willingness-to-pay, while CB studies ask people how they would change their visitation, in response to changes in park characteristics and infer WTP from stated trip behavior. Choice experiments present survey respondents with a variety of different "bundles" of park characteristics, including the entrance cost, and then infer and value how much individuals are willing to pay more for one set of characteristics than another.

These methods have different strengths and weaknesses, and environmental economists are continually making "improvements" and modifications, as well as statistical tests to compare results. The important thing to remember about them is that, when compared in the same study, estimates can not only vary widely. For example, Ellingson and Seidel (2007) highlight the challenges in using non-market valuation techniques for policy formation in a developing country setting. Tourists to the Eduardo Avaroa Reserve in Bolivia were asked both their willingness to pay and changes in their visitation to the park due to an improvement in tourism services at the reserve. WTP for the CV approach yielded an estimate of $37/trip, while the corresponding estimate for the CB approach was more than twice that amount ($77/trip).

There are several other important issues associated with this group of WTP that require clarification. First of all, estimates of an "efficient" or "optimal" fee in several of these WTP studies are based on a relatively simple principle. Since the demand for park amenities (a bundle of flows of ecosystem services that visitors enjoy) is negatively related to marginal WTP, the higher the fee, the lower the measure of tourist visits becomes The optimal fee is one that maximizes revenue and that fee will depend on the curvature of the demand function insofar as demand is price-sensitive[18].

Related to this problem is the ability of park owners to capture the entire estimated consumer surplus associated with a given optimal entry fee. This is because the value of marginal WTP times total visitation, while it correctly captures park revenue, is generally different than total consumer surplus. Both the sign and magnitude of this difference depends both on the curvature of the estimated demand and the price of admission. In this regard, projected revenues are reliable indicators of park revenues from entrance fees and estimates of consumer surplus are a measure of the residual total WTP left over after the fee is paid. The lower the entry fee, the greater is the consumer surplus not captured. However, when the entry fee diverges from its optimum – whether it is higher or lower – revenues will decrease.

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[15] *CV was used in Chase et al. (1998), Wang and Jia (2012), Lee and Hahn (2002), Wilson and McLean (2010), Ellingson and Seidel (2010)*

[16] *CB was used in Ellingson and Siedel (2010),*

[17] *Choice experiments are limited to the study by Naido and Adamowicz (2005) and Hearne and Salinas (2002)*

[18] *The general rule is that if the elasticity of marginal willingness to pay (fee) with respect to visitation is less than -1 in absolute terms (inelastic), a small increase in fee will increase revenue, while if it is greater in absolute terms than -1 (elastic), a fee increase will reduce revenue.*

Another important issue is the question of what to do with WTP bids of zero, as raised in the study by Wang and Jia (2012) and Wilson and McLean (2010). In their CV study of WTP for entry to Dalai Lake Protected Area in China 26.4 per cent of the survey respondents were not willing to pay any amount of money for park access. Upon follow up, the most common explanation given for the unwillingness to pay was that it was the government's responsibility to protect biodiversity and the environment. They were excluded from the study as protest bids, thus the estimated marginal WTP for park entry as a result was somewhat higher. A more satisfactory approach would have been to split the sample of respondents, randomly, and changed the payment vehicle from a fee payment to a payment of additional taxes to determine if these were true protest votes or the result of "free-riding" on government obligations.

The paper by Hearne and Salinas (2002) raises an important question about possible correlations between the ecosystem services which a protected area is designed to provide (i.e., bird watching vs. better views of the landscape from trails) to different groups of tourists, based on personal demographic and socio-economic characteristics. This is a more general aspect of the issue of whether conservation reserves should be designed for rich, foreign tourists or the local and/or national population of park visitors. This issue has profound revenue issues, as we shall soon see, and some that are more of an "ethical" nature. It also underlies some of the disenchantment of rural people who live near the parks and view them as exploitative.

Finally, the conclusion that can be drawn from these studies is that tourists – particularly foreign tourists, who in aggregate make up the largest proportion of total visitation in many areas – are willing to pay a great deal more to enter and enjoy park amenities than they are currently being charged. Public developers and owners can benefit from undertaking these studies to revise existing park design and entry fees. Also, only one of these studies, by Wilson and McLean (2010) look at both the cost and benefit side of equation to determine if the protected national areas they investigated in Canada were profitable. They found that the net present value of the existing PNAs was positive for the majority of silvicultural budgets, discount rates, and benefit restrictions considered, which would be a fruitful area of further investigation.

The second group of seven studies in Table 6.1 focuses more generally on the economic impacts of ecotourism. The results are mixed. Gosling in his 1999 review of the literature of the economic impacts of ecotourism found evidence for substantial use and non-use values associated with ecotourism. Surveying the general scene at the time he concluded that while potential benefits were large, very little of the revenue that is generated ends up in local pockets and better means had to be found to increase revenues, internalize non-use values and even out the distribution of these revenues. The more recent studies we reviewed showed that while the importance of ecotourism is growing rapidly, the uneven distribution of income to local communities is still a problem.

Kremen et al. (2000) found that the NPV of local benefits of the Masoala National Park Integrated Conservation and Development Program (ICDP) in Madagascar ranged from $113,000 – $527,000, depending on project lifetime (10 or 30 years) and discount rates (3, 10 and 20 percent). Of this between $1,500 to around $19,000 was related to ecotourism. At the national level, the NPV of ICDP ranged from – $27,000 to around – $265,000, while national ecotourism benefits were in the range of $4,000 to $43,000, the largest of all included benefit categories. The global net benefits of ICDP ranged from about $70,000 to $645,000 for which carbon conservation values in protected areas were the largest value. Thus, it seems that ecotourism generally has greater economic impacts at the national level, and perhaps the international level if one includes the revenues to foreign tourist agencies and overseas travel. However, in all cases the net benefits from ecotourism exceeded the opportunity cost of commercial forestry. Kirby et al. (2011) only looked at the local net benefits of ecotourism in the Tambopata region of Peru and found, there too, that these were higher than all currently practiced alternatives, including unsustainable logging, ranching, and agriculture.

Looking just at the local situation, Bookbinder et al. (1998) found less reason to be optimistic. They interviewed 996 households in the vicinity of Royal Chitwan National Park, Nepal and found that, of the estimated 87,000 working-age people living near the park, less than 1100 were employed directly by the ecotourism industry. In addition, only 6% of the surveyed households earned income directly or indirectly from ecotourism; the average annual salary of these households from ecotourism was $600. On the basis of these findings, they concluded that ecotourism in Royal Chitwan National Park provided little employment potential; had a marginal effect on household income; and offered few benefits for local people. A study by Ohl-Shacher et al. (2008) of income generation and distribution from tourism revenues from Casa Matsiguenka Lodge Manu National Park, Peru told a somewhat similar story. The private rate of return on the lodge's investment was negative at even very low discount rates (over about 1.0 percent). The contribution of the lodge to per capita income was not particularly high, covering about 35% of estimated total individual per person cash needs and reaching over two-thirds of the households. However, very little income was distributed to the community apart from wages.

Finally, on a more optimistic note, Wunder (2000) concluded from his study of autonomous ecotourism vs. paternalistic ecotourism models in 5 places around the Cuyabeno Wildlife Reserve in Ecuador that local residents received significant benefits that out-competed other income sources, and that income differences between communities could be better explained by different degrees of tourism specialization than by a varying degree of autonomy from tourist agencies.

So, in general, these few studies show some progress since the turn of the millennium, but that much ecotourism revenue still leaves local areas or originates and stays in overseas points of visitor origin.

Summary of Net Present Value Results

Tables 6.1.1 and 6.1.2., below, collectively summarize the main net present value results for the ecotourism studies that were reviewed as a part of this project. They are based on Table A6.1.1and A6.1.2 in the Technical Appendix. Some studies have been dropped because we wanted to keep the focus on developing countries and/or a combination of the methodologies and data was not sufficient to normalize the NPV estimates for purposes of comparison. The comparison metric used in this table is NPV per hectare.

The first three columns of both tables are identical, providing the information source (See References), the location in which the study was conducted and the New (ecosystem) practice being investigated – were taken directly from Table A6.1.1 and A6.1.2 in the Technical Annex. However, the second part of Table 6.1.1 is slightly different than the previous tables in that it adds a single row to at the end of the cost benefit analysis to include the impact of the ecotourism option on local income. Unfortunately, there were not enough data in each study to provide a common metric of this impact in all of the studies. For those three papers in which this impact was assessed, two of them are expressed in terms of dollars/household/year.

TABLE 6.1.1. Summary of NPV Results for Ecotourism in Developing Countries

Information Source	Kirby et al. (2011)	Kremen et al. (2003)	Ohl-Shacher et al. (2008)	Gossling (1999)	Bookbinder et al. (1998)
Location	Tambopata region, Peruvian amazon	Masoala National Park Integrated Development Plan (IDCP) Madagascar	Casa Matsigenka Lodge Manu National Park, Peru	Global by country	Royal Chitwan National Park, Nepal
Technology	Multiple land uses, including ecotourism in rain forests	Multiple land uses, including ecotourism	Casa Matsigenka Lodge income, costs and profits	Costa Rican ecotourism profits	Local impacts of ecotourism
Net Present Value ($)/ha					
Current Practice (CP) or alternative	CP not given[1]	CP not given[1]	CP not given[1]	CP not given[1]	CP not given[1]
Incremental NPV	[2]$26.15/ha/yr	[3]$56.52/ha/yr	[4]$10,600/yr for lodge	$426/ha/yr	[5]$45/ha/yr to $65/ha/yr
Impact on Local Income	28% to 45% of revenues go to local staff salaries	Not calculated	$9.67/hh/yr	Not calculated	$50/hh/year

[1] All benefits are incremental, based new activity, eco-tourism

[2] Based on park area of approximately 275,000 ha

[3] Based on local park area of 2300 km2

[4] Total Park area was not given

[5] Based on local park area of 932 km2

All of the incremental NPV/ha estimates in Table 6.1.1 were considered to be incremental net benefits because the alternative(s) were so varied and difficult to pin down. However, in several of these studies estimates of the net benefits for aggregated ecotourism at the national and regional levels were presented and in many countries the net benefits of ecotourism were positive compared to farming and plantation forestry, although these estimates included avoided environmental damages. However, as in previous studies, only financial flows were included in the net benefit analysis in this table. Neither the economic value of the environmental damages avoided by ecotourism, nor the non-market benefits of ecotourism were included in the estimate of net benefits in this table.

The net benefits of ecotourism in the studies by Kirby et al, Kremen et al. and Bookbinder et al. are quite close, $26.15/ha/yr, $56.52/ha/yr and $55/ha/yr. The latter value is higher than the other two due largely to the well-developed ecotourism infrastructure and marketing in Costa Rica compared to Peru and Madagascar (which is also difficult to access). At a 10% discount rate for all future years, the corresponding NPV values would be $260/ha (Kirby et al.), $565/ha (Kremen et al.), $550/ha (Bookbinder et al.) and $4,260/ha (Gossling), which places them in the low to middle-range of the NPV estimates for the other options (except for Gossling). These estimates would be much higher if park owners were willing to try to capture some of the willingness to pay of park users and non-users, not reflected in entry fees, through PES programs.

The impact of the various ecotourism lodges and facilities varies greatly in these studies, but unfortunately it is hard to find a common metric that captures all of the issues involved. The range of $9.67/hh/yr given in Ohl-Shacher et al. is about one-fifth of the $50/hh/yr cited by Bookbinder et al. However, as Ohl-Shacher et al. point out, only 6% of the households in the adjoining villages receive any income at all from park vendors. The problems, as stated previously in this chapter, are that park wages per household are generally low, the per cent of the local population receiving income from park vendors is small and most of cash flows associated with ecotourism represents leakages from the park area into the national and international economy in the form of expenditures on international travel and transport from major national cities to the park, advertising and marketing expenses, etc.

Table 6.1.2 covers the various willingness-to-pay studies in which various valuation techniques were used to elicit information about how much money visitors to the park were willing to pay for access to the park and, in several cases, their total willingness to pay to enjoy all or some of the ecosystem benefits of the park. We only included estimates of the former and the resulting impact on park revenues. Estimates of total willingness-to-pay for ecosystem preservation were not included because the part of these values that did not include the park entry fee is not included in financial accounts. It is also difficult for park owners to capture these values except through entry fees. Moreover, as park entry fees are increased to capture more and more of total willingness-to-pay, park visitation declines. Depending on the shape of demand functions for ecosystem services preservation, raising entry fees will reduce park visitation and, at some point, result in decreased revenues. As a result, many studies focus on estimation of the maximum revenue that can be achieved, before it starts to decrease due to the fee increase. This is referred to as the "optimal" fee in most studies.

TABLE 6.1.2. Summary of Economic Impact Results for Ecotourism in Developing Countries

Information Source	Tobias and Mendelsohn (1991)	Chase et al. (1998)	Ellingson and Siedel (2003)	Wang and Jia (2012)	Naido and Adamowicz (2005)
Location	Monte Verde Cloud Forest, Costa Rica	Three national parks in Costa-Rica	Eduardo Avora Reserve, Bolivia	Dalai Lake Protected Area, China	National Forest Reserves, Uganda
Technology	Protected area tourism	Efficient pricing for access to protected areas	Efficient pricing for access to protected areas	Efficient pricing for access to protected areas	Optimal pricing to prevent bio-diversity loss
Annual Revenue from Park Fees and Impacts on Local Income (2012 USD)					
Annual Revenue from Operation	Average: at optimal fee of $35/trip: $450,000/yr	Ave. Existing fee ($10.75/trip): $343,260/yr Efficient fee $(1.98/trip): $2.56 million/yr	Existing fee ($4/trip):$ 1.86 million/yr. Optimal fee ($75/trip): million/yr to $ 1.89million/yr	Existing fee ($3.02/trip):$600,000/yr Optimal fee ($50/trip): $7.94 million/yr	Existing fee ($3.15/trip): $ 7,000/yr Optimal fee ($47.53/trip): $18,000 to $40,000/yr
Impact on Local Income	Not calculated	Not Calculated	Not Calculated	Not Calculated	Not Calculated

As can be seen from Table 6.1.2, existing fees generally bring in far less revenue than the optimal fee, based on willingness-to-pay, except for Chase et al. where a reduction in the average fee of the three parks from$10.75/trip to $1.98 resulted in increased revenues of about 2.2 million/year. In the studies by Ellingson and Siedel, Wang and Jia, and Naido and Adamowicz, on the other hand, fairly substantial fee increases resulted in higher revenues. However, the magnitude of the ration of the percentage change in revenue to the percentage change in the fee varied greatly. In the study by Ellingson and Seidel a large change in the fee (over 1000 per cent) resulted in only 1.6 per cent change in revenue. The paper by Wang and Jia, on the other hand showed somewhat comparable percentages in the percentage of the fee and the revenue increases. However, the fee increased at a large percentage rate than the revenue. The case of Naido and Adamowicz also showed a large percentage change in the fee, while the percentage revenue change was much smaller in relative terms, showing a very low relative sensitivity to the fee increase. In general, foreign tourists are willing to pay more to experience pristine states of nature that are much different than those they experience at home compared to local residents and foreign tourists generally have more money to spend than local residents, so it stands to reason that the composition of the origin of tourists will influence how large the entrance fee can be before visitation starts to drop off.

There are two lessons to learn from this. First, sites that can attract a lot of foreign tourists compared to local tourists will earn higher revenues than sites that can attract only local tourists (and the costs will also be higher because foreign tourists demand better accommodations). Second, optimal pricing dictates one fee for local tourists and another, usually much higher, fee for foreign tourists. However, this does not eliminate the problem of revenue leakages outside the local community, which are higher as a per cent of their total expenditures on the trips they take to ecotourism cites. Thus, a world-renown ecotourism site can have a highly positive financial balance, while contributing to very little to the local economy, but the opposite can also be true. This is why the private costs and returns to ecotourism ventures need to be predicted fair accurately to ensure they not only turn a profit in the long-run, but also provide significant benefits to the local community.

Chapter 7: Conclusions

This report reviewed a number of economic studies in the areas of terracing, agroforestry, rainwater harvesting and ecotourism to gather information about the private cost and benefits of these activities. We found that, in each category it is extremely difficult, not only to compare the results of individual studies but also to arrive at general conclusions about which measures are privately profitable (i.e., financially feasible to the land owner) or even socially profitable (i.e., factoring in financial benefits to other economic activities and non-market and non-use values).

Without further assessment it is also unlikely that the cost benefit analysis results from any single or group of studies can be transferred to a specific site with any degree of confidence[19]. As a matter of finance practice, It also seems unlikely that microfinance would be available for individual ecosystem-based adaptation projects that were not supported by a cost benefit analysis, or by a reliable and unbiased benefit transfer study, based on very similar projects in the same locality, where perhaps the differences between the projects can easily be accounted for, such as different scales.

In all of the cases we looked at, the factors which lead to differences in the private profitability of a specific measure in a specific location are related to differences in local climatic, agronomic and geophysical conditions as well as local economic conditions, institutions and even farmer objectives.

Sources of methodological variation in cost benefit study results

More specifically, we can point to a number of sources of variation in the methodologies of these studies that demonstrate how difficult it is to generalize the results from specific studies, except in various obvious ways, and to guide lenders in the practices they must institute to ensure that the projects that they are funding will be profitable. These include:

1. **Technology and practice variation:** There is no such thing as a generic terracing, agroforestry, rainwater harvesting or ecotourism technology/option and not only can the

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[19] Four excellent sources that discuss the practice and reliability of various benefit transfer methodologies are available on line: Boyle et al. (2010): https://economics.byu.edu/Documents/Jaren%20Pope/BKPP10.pdf; King and Mazotta (2000): http://www.ecosystemvaluation.org/benefit_transfer.htm; Lindjem and Navrud (2007): http://mpra.ub.uni-muenchen.de/11484/1/MPRA_pap-er_11484.pdf; and Nelson and Kennedy (2009): http://www.econ.psu.edu/papers/The%20Use%20of%20Meta-Analysis_re113008.pdf.

agricultural practices vary widely within any one these broad categories, but practices within one or more of these categories is often combined with practices from another category.

2. **Treatment of a control option:** The relevant comparison of costs and benefits in a CBA for a conservation option is with the existing land use practice. This requires collecting information of the costs and benefits of both land use practice and comparing the net benefits in relevant ways. This was not done in many of the studies we reviewed and it is problematic because, unless the incremental financial net benefits of the proposed land use practice are positive compared to the existing land use, a private market incentive to adopt the project is lacking. However, in many cases we were able to develop estimates of NPV and incremental NPV for some of the studies related to terracing, agroforestry and rainwater harvesting, which appear in tables at the end of the chapters dedicated to these practices.
3. **Data sources:** Data such as crop yields (land productivity), product and input market prices, as well as input requirements and costs are the basic data which underlie CBA calculations in the agricultural sector. These data can come from a variety of different sources, and, as seen in several studies, some of them can be systematically biased or unreliable.
4. **Short vs. long term effects:** Terracing and agroforestry, in particular, as well as any land use practices devoted to perennial crops, are long term options not only in physical, but also in economic terms. The financial feasibility of these measures can be highly sensitive to the rate at which output productivity increases over time and, in the case of some terracing systems on steep slopes, the calculations involved are not trivial. In all of these cases, the reliability of, and possible bias in data sources has to be eliminated, or at least factored into the analysis.
5. **Treatment of input costs:** Several studies we reviewed were not financially feasible unless the opportunity cost of labor was significantly reduced. The justification was that local employment opportunities for farm households were limited and, thus, market wages did not reflect the opportunities they faced. These justifications need to be considered carefully in each and every case to ensure the test of financial feasibility is met. More damaging is the practice sometimes observed (in other studies) of not including the opportunity cost of land when accounting for the opportunity cost of land used to sequester carbon[20].
6. **Local markets and "economic conditions":** In a number of studies, thin markets for locally produced agricultural products and volatile agricultural commodity prices were cited as a source of uncertainty about the effects of commodity prices on financial feasibility. Questions were also raised about the compatibility of the economic (and non-economic) objectives that underlie small farmer decisions in remote areas with the narrow economic objectives that underlie cost benefit analysis, namely: short-run maximization of profits in product market and the net present value of returns to land in asset markets for long-term crops (mainly trees).

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[20] *This would be equal to the net benefit of the current land use for the converted area. Measuring incremental net benefits for the option of a whole would effectively take care of this problem.*

The bigger valuation picture

For this study, we reported mainly on studies that focused on financial flows of costs and benefits accrued to land owners (or operators) undertaking a specific ecosystem-based agricultural practice.[21] However, as noted in chapter 2, the measures that were reviewed in this study can also yield some economic values that are not reflected in these cash flows. Methods for measuring and capturing these flows were also discussed in chapter 2. The fact that some of these values may be difficult to measure or transfer to land owners in monetary terms is not so much of a problem as the more practical issue of whether the MFI has the financial backing (from whatever institutional source) or can find a means to recover the necessary funds to make the project "sufficiently feasible" to induce economic agents to undertake the desired activity. Payments for ecosystem service (PES) programs represent one means to recover net benefits associated with positive technological externalities that improve the bottom lines of off-site activities.

Local economic impacts

Except for a group of studies that concentrated directly on this issue with reference to the ecotourism, we did not find many cost-benefit studies that looked at local income impacts. The ecotourism studies we did investigate generally concluded that of all the income generated by ecotourism, the majority of it was received by national and overseas sources. On the other hand, some studies showed that in some regions, ecotourism generated more income than any other commercial activity, including large-scale intensive agriculture and commercial logging. Whether this income was well-distributed within the local community is, however, another issue and, there too, the results were different depending on the regional and site-specific focus of the study.

In his study (Wunder 2000) tests the two hypotheses that 1) autonomous (locally controlled and market driven) tourism produces more income than "paternalistic" models dependent on international and national tour operators and 2) local tourism provides strong incentives for conservation. In the case of the Cuyabeno Wildlife Reserve in Ecuador, he finds mixed evidence of the former, with notable inequities in the distribution of income, but stronger support for the latter hypothesis. He does not offer any solutions to the problem of the unequal distribution of income, and we have not followed up on his study. However, it would seem that one of the challenges of microfinancing is to try to do something about this by building equality of income distribution into one of the project financing criteria and developing mechanisms to raise the funds to support this objective if it in any way reduces project net benefits.

Conclusions from Summaries of Benefits and Costs

At the end of Chapters 3 through 6, an effort was made to compare the net benefits for the studies within each type of ecosystem enhancing land practice, using a common metric, Net Present Value (in USD) per ha. Using a common metric did not erase the variability of the estimates due to factors already discussed, but it did make possible a few weak conclusions:

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[21] *This is the case for most of the studies of terracing, agroforestry and rainwater harvesting. In the case of ecotourism, there was a somewhat broader consideration of willingness to pay for ecotourism by park visitors, which included non-market use and non-use values.*

- **Terracing:** Bench terracing, the prevailing structure used in the Andean region, is marginally profitable. The profitability of this practice depends highly on the opportunity cost of household labor, since the construction of bench terraces is very labor intensive. There is also the problem that it takes several years for these terraces to take hold and function optimally. Farmers who depend on steep and degraded fields for their food production and income and who have a low personal opportunity cost of labor will generally view this investment as one which improves their livelihood. Farmers with access to fertile fields for agricultural production, and/or can also rely on off-farm sources of income, will find these investments less financially attractive.
- **Agroforestry:** There are many different specific types of agroforestry options that can be practiced in the Andean region and the studies that were reviewed from Central and Latin America and the Caribbean region were quite diverse, complicating comparisons. However, it appears that agroforestry cannot only be marginally profitable on small farms, but probably can compete with high value commercial crops, such as coffee by increasing yields of, and revenue from, both coffee and the other crops. The major impediments to agroforestry profitability are higher capital and labor associated with establishment costs and, when tree planting is involved, the relatively long time delays in receiving the benefits of thinning and final harvests, due to the effect of discounting over time.
- **Rainwater Harvesting:** This is another area in which there are many different types of water collection, storage and distribution technologies, and the cost benefit estimates in the studies we examined were accordingly difficult to compare. However, one practice that appeared to be economically feasible in the region from a cost benefit perspective was small ponds and farm dams, constructed to provide supplemental irrigation water for the dry season. The only real barrier to the profitability of these kinds of projects is high construction costs, which on small farms means high labor costs. However, ponds can have negative consequences off-site, by reducing overland runoff or stream flow available to downstream water users and needs to be institutionally supervised to prevent this.
- **Ecotourism:** The studies we reviewed generally showed that ecotourism sites and facilities are generally profitable, but the studies we reviewed are biased toward larger ecotourism facilities that are located at, and developed as, international tourist destinations. For example, we did not find any studies that explored the private benefits and costs of adding walking trails through native forests adjacent to small villages. But there is reason to believe that, at best, they can only be marginally profitable due to poor access and local facilities. The studies we reviewed also suggested that, while large and prestigious ecotourism sites could generate a great deal of revenue, the impact on the economy of local communities was generally small and that largest share of expenditures by visitors never reached the local community because they were being spent on long-distance air travel and transportation between regional or national capitals and the site.

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ANNEX 1 – Technical Appendix

Introduction

The purpose of this introduction is to explain how to read the tables in the Technical Appendix.

There are eight tables, in all, in the Technical Appendix.. Each of the tables presents an overview of the important information on Terracing (Chapter 3), Agroforestry (Chapter 4), Rainwater Harvesting (Chapter 5) and Ecotourism (Chapter 6). The corresponding tables are:

TABLE	CHAPTER
A3.1.1 & A3.1.2	3
A4.1.1 & A4.1.2	4
A5.1.1 & A5.1.2	5
A6.1.1 & A6.1.2	6

The results of the studies reviewed in Chapters 4 through 6 are summarized by two tables, since the number of studies covered in these chapters contained too much information to fit into one table.

The Tables for Chapters three though six are identical in format. The two tables for Chapter 6 are different because ecotourism involves a somewhat different set of issues than in the previous studies. These differences will be covered in two examples. The results of Example 1 follow, below.

Example 1: Agroforestry from TABLE A.4.1.2

Row 1	Information Source	de Souza et al. (2012)
Row 2	Location	Zona da Mata of Minas Gerais State, Brazil
Row 3	Methodology	CBA based on financial data and interviews
Row 4	Technology/ Activity	Comparison private benefits and costs of mixed agroforestry (AF) and sun coffee (SC) plots
Row 5	Present value of capital cost/ha (PVCC) or Annualized capital cost/ha/yr. (ACC)	ACC: $\Sigma_t[\text{Capital Cost}_t/(1+r)^t]*r/[1-(1+r)^{-N}]$ AF: $285/ha/yr SC: $243/ha/yr
Row 6	Annualized variable production cost (AVPC)	AVPC: $\Sigma_t[\text{Variable Cost}_t/(1+r)^t]*r/[1-(1+r)^{-N}]$ AF: $2,826/ha/yr SC: $2,063/ha/yr
Row 7	Annualized revenue (AR), or gross Revenue, or Gross Margin (GM)	AR: $\Sigma_t[\text{Total Revenue}_t/(1+r)^t]*r/[1-(1+r)^{-N}]$ AF: $5463/ha/yr SC: $3811/ha/yr
Row 8	Net Present Value (NPV) per ha. (currency) or Annualized Present Value (APV) per ha/yr or Internal rate of return (IRR)	APV: $[NPV*r]/[1-(1+r)^{-N}]$ AF: $2352/ha/yr SC: $1506/ha/yr NPV (12%, 15 yrs) : $\Sigma_t[\text{Total Revenue}_t - \text{Capital Cost}_t - \text{Variable Cost}_t]/(1+r)^t = [APV/r]*[1-(1+r)^{-N}]$ AF: $17,570/ha SC: $11,246/ha
Row 9	Effect on Rural Income	not covered
Row 10	Comments	Land productivity and Total Revenue were about 43%

		higher for agroforestry than sun coffee, while costs for agroforestry were only35% higher than for sun coffee. Agroforestry provides considerable, additional ecosystem benefits that were not valued.

The example shown above is copied directly from Table 4.1.2 Row 1 gives the information source, the precise reference for which can be found in the references. Row 2 contains the location of the study. Row 3 explains the type of study, while Row 4 describes the comparison between agroforestry and sun coffee, which is much in demand in export markets.

Rows 5 through 10 cover the economic analysis, as follows:

- Row 5 summarizes capital costs in one of two ways, either by the present value of the capital costs over a specific time period (PVCC) or by the equivalent annualized value of NPV (ACC). The calculation of present values and annualized values are covered in Table 2.1.1 and 2.1.2. NPV is equal to the sum of the discounted net benefits (total revenue – capital costs – variable costs) of an option. ACC converts NPV into single annual equivalent measure of net benefits that, when discounted and summed over time, equal the NPV.
- Row 6 summarizes the annualized variable production costs (AVPC), which is an annualized measure of the variable cost, as defined in Table 2.1.1 and 2.1.2. In some cases, the present value of variable cost (PVVC) is given, instead.
- Row 7 summarizes the annualized revenue (AR), which is the annualized measure of the total revenue generated by the option, as defined in Table 2.1.1 and 2.1.2. In some cases, the present value of variable cost (PVVC) is calculated, instead.
- Row 8 conceptually represents the net project benefits: Revenue – Capital Cost – Variable Cost = Net Benefits. These can be expressed in annualized terms (APV) or over the entire time period (NPV). However, a number of studies did not report all of the metrics required to arrive at this net benefit, or if they did the calculations and results for each component was not shown. So, the case here represents an "ideal" study in which all of the cost benefit components were included in the study. In some cases, the gross margin (GM) was stated, instead of NPV or APV. GM is equal to revenue minus variable cost and does not include capital costs (although it can be included by annualizing the capital cost and, thereby treating it as a variable cost over time). Sometimes, neither of these measures was given in a study and the internal rate of return (IRR) was substituted, instead. As defined in Tables 2.1.1 and 2.1.2, the IRR of an option is the discount rate at which discounted (or annualized) net benefits equals the sum of discounted (or annualized) capital plus variable costs.
- Row 9 covers economic impact of the option local communities. Except for ecotourism, most of the studies in the other categories did not include any assessment of these impacts.
- Row 10 shows general comments including those which amplify the quantitative results or reveal important limitations.

The second example refers to the economic analysis of ecotourism. Studies in this area have a different focus than in terracing, agroforestry and rainwater harvesting. There were only a few studies in the literature that even looked at the costs and benefits of ecotourism facilities and these did not contain thorough analyses, as was sometimes the case for the studies in the three other land use categories[22]. Rather these studies tended to focus on the willingness-to-pay (WTP) of visitors to "experience" the ecosystem (and tourism amenity) services inside protected areas and on the impact of park revenues and visitor expenditures on local economies. The

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[22] *Nevertheless, some partial estimates of the benefits and costs of these facilities were constructed from study data and the results appear in the economic summary table at the end of Chapter 6, Table 6.1.1.*

focus on WTP had two important aspects. The first was to determine how operators of protected areas could price entry fees so as to maximize revenues. The second was to determine how much "consumer surplus"[23] was left over after park visitors paid the revenue maximizing fee. This is a measure of the net benefits of the park ecosystem services to the tourist. Values of WTP and consumer surplus were obtained in the studies either through surveys of park visitors (users) by asking them how much they would be willing to pay for the ecosystem services of the park, or by using observed behavior to infer their WTP. The first approach uses a variety of survey formats and methods to uncover WTP through "stated" preferences of individuals as compared to the second approach which uses observed behavior (data) to uncover the "revealed" preferences of park visitors.

To capture these differences, a different table format was used for Tables A6.1.1 and A6.1.2. This format is shown below in Example 2.

Example 1: Agroforestry from TABLE A.6.1.1

Row 1	Information Source	Chase et al. (1998)
Row 2	Location	Three national parks in Costa- Rica
Row 3	Methodology	Ex-ante analysis of effects of differential fee pricing at different national parks to increase revenues
Row 4	Technology/ Activity	Efficient pricing for access to ecotourism activities
Row 5	Annual WTP/trip and/or park entry fee	Annual WTP/trip: $ 21.60 - $24.90. Existing entry fee: $ 9.56 - $12.28. Optimal multi-tier fees: $ 6.48 - $7.37
Row 6	Annual revenue from users (or social value) =Annual Expenditures by visitors	Total Annual Revenue from fees: Existing entry fee: $ 343,260/yr Optimal multi-tier fees : $ 2,566,475/yr
Row 7	Total NPV or PV of Consumer Surplus (PVCS) from users (or total social value)	No net welfare or cash flow calculations were made, as the purpose of the study was to show how efficient pricing could increase revenues.
Row 8	Impact on local economy	Not discussed. However, at efficient prices, projected visitation fell, lowering demand for local ecotourism services and the number of bed-nights
Row 9	Comments	Higher revenues and profits could be dedicated to enhance conservation, but might also be expropriated as rents by public sector owners for non-ecosystem and welfare improvement purposes outside the region

Unlike the cost benefit studies there are no real calculations to make in this particular study used in this example. Also, this study focused only efficient pricing to park access, while others focused primarily on impacts on local communities. A handful of studies included cost analyses and these are summarized from a net benefit perspective, for comparative purposes in Table 6.1.1.

The first four rows are the same as included in the first example. This was an ex-ante study to estimate efficient pricing in three national parks in Costa Rica and its impact on visitation and revenues from park visitors Rows 5 through 8 contain the following information:

- Row 5 summarizes the range of the average WTP of a visitor to the three parks. It also shows the corresponding range of the average WTP of a visitor under both the existing fee structure and the optimal fees, which were based on the age and origin of the tourist

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[23] *Consumer surplus is the amount a tourist would be willing to pay to experience ecosystem services rather than do without this experience. It is equal to the total WTP of a tourist for park ecosystem services less the amount paid in entry fees.*

and reflected different degrees of visitation responsiveness to changes in fees among these groups.

- Row 6 shows the corresponding revenue associated with the existing fees and the optimal fees. Note that while the existing fees in Row 5 are higher than the optimal fees, the revenue from the optimal fees is much higher than the revenue from the existing fees. This is due to differences among the age and origin groups in how their visitation behavior (more or fewer trips) responds to fee changes.
- Row 7, which covers the total WTP and the consumer surpluses of visitors, was not calculated due to the narrow focus of the study. It was covered in other studies.
- Row 8, which covers the effect of the impact of the increased revenues on communities around the park and was not calculated due to the narrow focus of the study. However, fewer visitors as a result of higher entry fees means fewer bed-nights and that is likely to hurt the local economy.
- Row 9 contains amplifying comments. In this case, the fact that revenues increase as a result of the efficient fee structure raises the question of where the impacts of higher revenues will be felt the most. It is suggested that the parks' owners, the national government, might not necessarily use the added revenues to enhance ecosystems or benefit local communities.

Table A3.1.1: Summary of Results for Terracing Options

Information Source	Antle et al. (2007a), Antle et al (2007b), Valdivia (2002)	Posthumus and DeGraff (2005)	Zhou et al. (2009a and 2009b)	Zhou et al. (2009a and 2009b) Same studies with different comparisons	Onduru et al. (2011)PPT	Bizoza and DeGraff (2012)	Tenge et al. (2005)
Location	La Encanada watershed, Cajamaraca, Peru	Pacucha watershed, Apurımac, Peru	Four Mile Creek, Iowa	Four Mile Creek, Iowa	Upper Tana Catchment, Kenya	Nyamagabe and Gicumbi Districts in N. Rwanda	West Usambara Highlands, Tanzania
Methodology	Sensitivity analysis with agro-economic optimization model	Cost-benefit analysis (CBA) including damage costs of soil erosion	Water Erosion Prediction Project Model and CBA	Water Erosion Prediction Project Model and CBA	CBA	CBA	CBA, including damage costs of soil erosion and benefits of reductions
Technology/ Activity	Bench Terracing (BT) and planting trees and shrubs on top of terrace walls. Current practice (NT)	Bench terraces (BT) vs. Current Practice (NT)	Chisel Plow + Terraces (CP+T) compared to chisel plow (CP)	No tillage and terracing (NT+T) compared to no tillage and no terraces (NT)	Bench terraces (BT)	Bench terraces (BT) vs. Current practice (NT)	Bench terraces (BT) Fanya juu (FT)
Present value of capital cost/ha. (PVCC). or Annualized capital cost/ha/yr. (ACC)	Not given	PVCC: BT: $1366-2088/ha. CP: $0.00/ha	ACC: CP: $0.00/ha/yr. CP+T ACC: $126/ha/yr.	ACC: NT: $0.0/ha/yr. NT+T: $126/ha/yr.	Not given	PVCC: BT: Frw 800,000/ha NT: Frw 0.0/ha	PVCC: BT: $250/ha FJ: $165/ha
Annualized variable production cost (AVPC)	Not given	Not given	AVPC: CP: $1230/ha/yr. CP+T AVPC: $62/ha/yr. more than CP	AVPC: NT: $1197/ha/yr. NT+T: $11374/ha/yr.	AVPC: Ksh 130,941/ha/yr.	AVPC: BT: Frw 667,428/ha/yr NT: FrW 405,755/ha/yr.	Not given
Annualized revenue (AR)	Not given	AR: $336-$612/ha/yr. compared to $220-$463/ha/yr. for sloping fields	AR: CP: $ 2396/ha/yr. CP+T:$2276/ha/yr.	AR: NT: $ 2339/ha/yr. NT+T:$2222/ha/yr.	AR: Ksh 196, 412/ha/yr.	AR: BT: 927,043/ha/yr. NT: Frw 637,619/ha/yr.	Not given
Net Present Value (NPV) per ha. (currency) or Annualized Present Value (APV) or Internal Rate of Return (IRR)	NPV : NT: $2400/ha. BT range: $1400/ ha to $3200/ha	NPV at market labor rates: -$2344 to +$603/ha/yr. IRR at one-half market labor rates: -5% to + 27%	APV: CP: $1028/ha/yr. CP+T: $97/ha/yr. NPV (10% 20yrs.): CP: $8753/ha CP+T: $7924/ha	APV: NT: $1123/ha/yr. NT+T: $944/ha/yr. NPV (10%, 20yrs.): CP: $9557/ha CP+T: $8033/ha	"Incremental net benefit" of Bench Terraces (APP) 10% Ksh 3557/ha/yr. 12% Ksh 3168/ha/yr. 14% Ksh 2841/ha/yr.	NPV (at 13% for 20 yrs.): Non-Subsidized BT : Frw 1,197,038/ha. Non-subsidized NT: Frw 1,628,787/ha	NPV (8 %, 13 %, 20yrs.) BT(8 %) $354/ha BT(13 %) $143/ha FJ (8%) $116/ha FJ (12%) $ 5/ha
Effect on Rural income	Up to 15% increase in per capita income depending on carbon price an productivity	Not estimated	Not estimated	Not estimated	Not estimated	Not estimated	Not estimated

TABLE A3.1. 1: (Continued)

Comments	Returns based on private market revenues and carbon subsidies on 1000 fields. Costs and benefits depend highly on initial land condition, which effects how long it takes for soil erosion to begin to stabilize	Bench terraces increase crop yields and revenues, but reduce cultivated area. The net result is that bench terrace costs are greater than benefits, unless agriculture is intensified or labor costs are lowered. This is a common problem.	Soil erosion costs on and off farm were included in the study, but off farm damages were not included in the calculations in this table.	Same as previous study. These are estimates of on-farm benefits and costs from market activities	Incremental net benefits of bench terraces are relative to fields with same crops without bench terraces. Terraces are profitable when high value crops are used to stabilize terraces and planted	Estimates of financial results assume labor and manure opportunity costs are 50% of market value for BT. While existing practices (NT) have higher NPV than BT, BT substantially reduces soil erosion, whose benefits were not valued.	NPV includes both damage costs of "pollution" and benefits of avoiding pollution through terraces. These values are not recorded in private financial flows and institutional mechanisms need to be established to capture these costs and benefits

TABLE A3.1.2: Summary of Results for Terracing Options

Information Source	Teshome et al. (2013)	Adgo et al. (2013)
Location	Debre Mewi and Anjeni watersheds, Ethiopian Highlands	Anjenie watershed, Ethiopia
Methodology	CBA based on universal soil loss equation	CBA
Technology/Activity	Soil bunds (SB), stone bunds (STB) and Fanya juu (FJ)	Fanya juu terraces (FJ) vs. No terraces (NT)
Present value of capital cost/ha (PVCC) or Annualized cost/ha/yr. (ACC)	PVCC: SB: EtB 1315/ha STB: EtB 1132/ha FJ: EtB 1463/ha	PVCC: FJ: $163.64/ha NT $0,0/ha
Annualized variable production cost (AVPC)	Not given	Max AVPC: FJ: $197/ha/yr NT: $140/ha/yr
Annualized revenue (AR)	% Δ Crop Yield: SB: - 7.4% to + 10.6% STB: -36.7% to +2.4% FJ: -21.9%	Max AR: FJ: $382/ha/yr NT: $99/ha/yr
Net Present Value (NPV) per ha. (currency) or Annualized Present Value (APV) or Internal Rate of Return (IRR)	NPV (12.5%, 20yrs): SB: - ETB 158/ha to +1902/ha STB: +EtB 1265/ha to 2217/ha FJ: +EtB 1345/ha to + 2718/ha	Max NPV (10%, 50 yrs) : FJ: $1355/ha to $1784/ha NT: - $408/ha
Effect on Rural income	Not estimated	Not estimated
Comments	NPV results were not very sensitive to labor cost assumptions, but were very sensitive to yields, lower yields sharply reduced NPV, but had no effect on ecosystem services which are not included in private financial flows. Therefore, the social net returns may also be positive for low yield cases.	Returns to labor were positive for all crops The construction of terraces made it possible to grow Maize, a higher valued crop, due to greater soil water conservation

Table A4.1.1: Summary of Results for Agro-forestry Options

Information Source	Chia-Ling Chang et al. (2011)	A.R. Sharma, et al. (2011)	Kibria and Saha (2011)	Dunn et al. (1990)	Nissen at al. (2001)	G. Rasul (2006)	Current and Scheer (1995)
Location	Shihmen reservoir watershed, Taiwan	Western Himalayan region, India	Madhupur Sal Forest, Tangail District, Bangladesh	Southern Ecuador	Mindanao, Philippines	Chittagong Hill Tracts, Bangladesh	Central American and Caribbean countries
Methodology	Cost-benefit analysis (CBA), based on empirical model of pollutant-trapping efficiency levels	CBA based on inputs from bio-economic model	CBA based on inputs from bio-economic model	CBA	CBA based on inputs from bio-economic model	CBA based on bio-economic model	CBA based on observation and typical project level analysis
Technology/ Activity	Riparian buffer strips to trap sediments and pollutants. Width: 10M, 50M, 100M	Mulching rain fed maize and wheat with Kudzu, wild sage and subabul to conserve soil moisture and nutrients	Comparison of private returns for pineapple (PA), lemon (LE) and banana agroforestry (BA)	Planting of Alder on field boundaries in pastures and on crop land To provide fuelwood, live fencing and decreased soil erosion on 2 ha	Comparison of private returns for all-cropping (AC), all-timber (AT) and intercropping systems (IC)	Comparison of private and social returns for four land use systems - cash crops (cc), horticulture (ho), agroforestry (af) and farm forestry (ff)	Comparison of five land use systems: agricultural intercropping (ai), alley cropping (ac), contour planting (cp), perennial intercropping (pi), Taungya (ta) and woodlot (wl)
Present value of capital cost/ha (PVCC) or Annualized cost/ha/yr. (ACC)	PVCC (millions): 10M: NTD 100 50M: NTD 502 100M: NTD 1,005	NA - no additional capital expenditure	PVCC + PV of production cost: PA: 687,380 Tk/ha LE: 665,555 Tk/ha BA: 1,125,834 Tk/ha	PVCC: 45,480 ECS	PVCC: AC: 60,035 Ps/ha AT: 5,035 Ps/ha IC: 63,789 Ps/ha	PVCC: cc: $0.0/ha ho: $312/ha af : $235/ha ff : $559/ha	Private NPV[1] only calculated for 10% and 20% interest rates (See other values below)
Annualized variable production cost (AVPC)	NA	AVPC x 1000: Control 19.8 Rs/ha Kudzu 21.3R s/ha W. sage 21.3 Rs/ha Subabul 21.3 Rs/ha	Production and capital costs were not separated out. See above cell for combined total.	Not included in tables	AVPC: AC: 97,996 Ps/ha AT: 4,826 Ps/ha IC: 48,005 Ps/ha	AVPC: cc: $3,925/ha ho: $1,414/ha af: $1,145/ha ff : $1,233/ha	NPV (10 and 20%) Cont. 10% 20% ai: $2,863/ha $1,300/ha ac :$1,335/ha $847/ha
Annualized revenue (AR) or Present Value of Revenue (PVR)	Value of trapped sediment (millions) 10M: NTD 111/yr 50M: NTD 118/yr 100M: NTD 121/yr	AR x1000: control 23.6 Bs/ha/yr Kudzu 28.9 Rs/ha /yr W. sage 27.9 Rs/ha/yr Subabul 28.5 Rs/ha/yr	PVR x millions: PA: 2.31 Tk/ha LE: 2.158 Tk/ha BA: 3.336 Tk/ha	Only NPV/year is included in the tables. Variable and fixed and variable costs are not broken out on an annual basis.	AR: AC: 192,786 Ps/ha AT: 17,126 Ps/ha IC: 86,140 Ps/ha	AR: cc: $4,867/ha ho: $2,332/ha af: $1,768/ha ff : $2,315/ha	NPV Cont. 10% 20% ct: $,1426/ha $1,761/ha pi: $2,867 $1,405

Table A4.1.1: (Continued)

Net Present Value (NPV) per ha. (currency) or Annualized Present Value (APV) or Internal Rate of Return (IRR)	NPV of sediment trapping (millions): 10M: NTD 754 50 M: NTD 408 100M: - NTD 63	NPV x 1000: Control 3.8 Rs/ha/yr. Kudzu 7.6 Rs/ha/yr. W. sage 6.6 Rs/ha/yr. Subabul 7.2Rs/ha/yr.	NPV x millions: PA: 1.613 Tk/ha LE: 1.492 Tk/ha BA: 2.110 Tk/ha	NPV at 15% for 20 years (Optimal - thin at 10 years; harvest at 20 years): 26,224 ECS. At lower interest rates the no-thin scenario prevails due to large terminal harvests	NPV: AC: 473,950 Ps/ha AT: 61,501 Ps/ha IC: 190,675 Ps/ha	NPV: cc: $943/ha ho: $606/ha af: $388/ha ff : $523/ha	NPV Cont. 10% 20% ta: $6,797/ha $2,868/ha wl: $764/ha $ 33/ha
Effect on Rural income	Not estimated	Not estimated	Not estimated	Not Estimated	Not estimated	Not estimated	Not estimated
Comments	This is a social benefit cost analysis. No crops or trees planted in buffer strips	The private benefits of mulching were due to higher yields, resulting in higher revenues that more than offset higher costs of mulching, but long term positive effects were not included.	There was no comparison with a control case. Banana forestry gave the highest NPV, but intensive use of fertilizer and pesticides severely degraded soil quality over time.	Initial capital costs are beyond the means of most farmers, even though NPV is positive. The study illustrates that the selection of management regimes is sensitive to discount rates, fencing subsidies and fuelwood prices..	Overall, net returns from vegetables are higher than for intercropping. But the benefit to cost ratio of intercropping is 80% than for growing crops, as returns to labor and capital are larger for trees than returns to land for crops	Social NPV cc $499/ha ho $874/ha af $860/ha ff $550/ha. Social accounting changes the picture and leads to greater sustainability, but mechanisms to capture social values in private decisions are weak	Like many early studies, this one was intended to get the message across that sustainable land-use practices could be justified (adopted?) on the basis of their net present value.

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[1] It was not possible to determine from the text if the NPV values in Current and Scheer were for a single ha or not, but it was assumed this was the case based on the magnitude of the estimates.

Table A4.1.2: Summary of Results for Agro-forestry Options

Information Source	Hoch et al. (2012)	Quintero et al. (2009)	Rice (2011)	Mir and Kahn (2008)	de Souza et al. (2012)	Lojka et al. (2008)		
Location	Amazon regions of Brazil, Bolivia, Peru and Ecuador	Moyobamba (Peru) and Pimampiro (Ecuador) watersheds	Guatemala and Peru	Shalimar; Pakistan	Zona da Mata of Minas Gerais State, Brazil	Peruvian Amazon		
Methodology	CBA based on observed data and interviews	Social CBA based on inputs from hydrologic and socio-economic models	CBA based on inputs from bio-economic model (SWAT)	CBA based on plot data	CBA based on financial data and interviews	Social CBA based on inputs from an agroforestry model (SCUAF)		
Technology/ Activity	Comparison of private returns for balsa (bp), agroforestry (ag) plantations with complementary tree (ct) growing	Comparison of business-as-usual (CP) agriculture with mixture of agroforestry options (AF) to reduce sediment transport, without and with PES (AFP)	Comparison of gross incomes from coffee (CO) plantations shaded by fruit trees (CF) in Guatemala and Peru.	Comparison of private net benefits from intercropping in willow stands (CW), compared to growing willows alone (WO).	Comparison private benefits and costs of mixed agroforestry (AF) and sun coffee (SC) plots	Assessment of bio-physical and economic performance of planted leguminous tree fallow (Inga fallow-InF) compared to the traditional Imperata fallow (ImF) system		
Present value of capital cost/ha (PVCC) or Annualized cost/ha/yr. (ACC)	PVCC: bp: $500/ha ag: $1,155/ha ct: $0.00/ha	Not included in tables	Not estimated	Not included in tables. See below for capital and production costs	ACC: AF: $285/ha/yr SC: $243/ha/yr	Not included in Tables		
Annualized variable production cost (AVPC)	Not reported	Not included in tables	Not estimated	PV of total costs/ha CW: Rs491,949/ha WO: Rs433,479/ha	AVPC: AF: $2,826/ha/yr SC: $2,064/ha/yr	PV of total costs/ha at 25% : InF: PEN 7,262/ha ImF: PEN 6,585/ha		
Annualized revenue (AR), or Total Revenue, or PV of Revenue, or Gross Margin (GM)	GM/ha bp : $1,320/ha ca: $2,070/ha ct: >$1,500/ha	Not included in tables	Peru – GM: CO: $2198/ha CF: $119/ha Shade Value: $224/ha	PV of Total Revenue/ha CW: Rs1,372,370/ha WO: Rs1,153,842/ha	AR: AF: $5463/ha/yr SC: $3811/ha/yr	PV of Total Revenue at 25% InF: PEN 9,290/ha ImF: PEN 6,585/ha		
Net Present Value (NPV) per ha. or Annualized Present Value (APV) or Internal Rate of Return (IRR)	NPV 12% 3% bp -$538 - $378/ha ca -$649 -$393/ha ct -$84 +$360/ha	NPV:1 15% 20% CP: $29,848 $24,471 AF: $23,052 $19,432 AFP: $24,328 $20,423	Not estimated	NPV: CW: Rs880,421/ha WW:Rs720,363/ha	APV: AF: $2352/ha/yr SC: $1506/ha/yr NPV (12%, 15 yrs) AF: $17,570/ha SC: $11,246/ha	NPV at 25% InF: PEN 2,028/ha ImF: PEN 1,780/ha		

Table A4.1.2: (Continued)

Effect on Rural income	Not estimated	Not estimated	Not estimated	Not Estimated	Not estimated	Not estimated		
Comments	Small freeholders substantially overestimate their revenues and underestimate their costs for NGO-promoted programs. However, there is growing evidence of greater success for low-input systems based on co-benefits.	The social benefits of reducing sedimentation are probably higher than the NPV of the business-as-usual practice (CP), but ecosystem payments under AFP do not make up for the difference.	Potential fruit revenue is almost 4 times higher than actual consumption. Intercropping increases farm income by about 25%, not including the increase in coffee yields..	The net benefit of intercropping in willow stands is about Rs16,000/ha (or approx. $4,000/ha), a 22% increase in net benefits over raising willows, alone There was no analysis of a control (business-as-usual) practice.	Land productivity and Total Revenue were about 43% higher for mixed agroforestry than sun coffee, while costs for agroforestry were about 35% higher than for sun coffee. Agroforestry also provides considerable, additional ecosystem benefits that were not valued.	While Inga fallow dominates Imperata, the fact that adoption rates of Inga is lower than Imperata is due to longer payback period of Inga and low opportunity cost of small holder labor.		

1 NPV estimates in Quintero et al. (2009) are for an entire standard farm area, not per ha.

TABLE A5.1.1: Summary of Results for Rainwater Capture Options

Information Source	Tuinhof et al (2012)	Tuinhof et al (2012)	Swami et al. (2012) and Tuinhof et al (2012)	Tuinhof et al. (2012)	Tuinhof et al. (2012)	Tuinhof et al. (2012)	Hatibu et al. 2006
Location	Kitui, Kenya	Pasak Ngam, Thailand	Terai India	India and China (various)	Amhara, Ethiopia	Andes, Peru	Northern Tanzania
Methodology	CBA Ex Post project assessment	CBA Ex Post project assessment	CBA Ex Post project assessment	CBA Ex Post project assessment	CBA Ex Post project assessment	CBA Ex Post project assessment	CBA RWH for paddy rice based on farm records of 120 households 1998-2003
Technology/ Activity	Sand storage dams, in-stream, to provide drinking water	Check dams to increase water supply and reduce sediment flows due to afforestation	Gully plugs and bunds to increase groundwater recharge and water supply for irrigation	Increased soil water and nutrient retention (often used in conjunction with drip irrigation)	Surface water harvesting tanks to increase water supply in the dry season	High-altitude surface retention dams to buffer water supplies	RWH from 4 systems:(1) micro-catchment, (2)macro-catchment, (3)macro-catchment linked to road drainage and (4) small ponds
Present value of capital cost/ha (PVCC) or Annualized cost/ha/yr. (ACC)	PVCC: USD 10,000-15,000 with 35% contribution of community labor for dam construction pumps and wells. Average storage capacity is 1,500-2,000 m^3/yr.	PVCC: $17 - $334 depending on type and availability of materials	PVCC: $ 90/ha.	PVCC: USD 800-1500/ha depending on labor costs.	PVCC for tank with storage capacity of 113-130 m3 and pumping mechanism: USD 450-1850	PVCC for large reservoirs of 110,000-200,00 m^3: $ 3,600; PVCC for small lower-elevation reservoirs of 360-300 m^3 was around $ 1,000.	Not shown
Annualized variable production cost (AVPC)	AVPC for operation and maintenance: $1,000 to $1500/yr.	Maintenance cost not estimated. Annual maintenance depends on effects of floods	Not estimated	Not estimated, but production cost is reduced due to lower water use and weed competition.	Not estimated	Not estimated	Not estimated
Annualized revenue (AR) or Annualized Gross Margin (GM)	Net family income increase: $ 3,000/yr. due to reduced access time	Increased water supply for irrigation and stock watering. was not estimated	Annualized Gross Margins increased from $370/ha to $3500/ha/yr.	Not estimated, but reported yield increases are in the 25-50% range.	Not estimated. Annualized Gross Margin increased an average of $ 150/yr.	Not estimated Each reservoir adds about 5 ha. of cultivated area	not estimated
Net Present Value (NPV) per ha. (currency) or Annualized Present Value (APV) or Internal Rate of Return (IRR)	NPV Approx.: $6,000 after 15 years and $ 10,000 after 20 years at 5% interest rate	Generally, not estimated in the literature for rock dams.	Not estimated, but was large due to intensification of agriculture and greater ground water avail-ability in the dry season.	Not estimated. In China and India, capital costs are subsidized by payments of around 25-50% of the mulch cost	Not estimated. Capital cost is partly subsidized and increase in net household income was $50/hh/yr.	Not estimated. Break even net annual return for large dams is about $845/ha at 10% and $1475/ha with a payback of 15 yrs.	NPV/ha at 15% for an infinite period: (1) $3.700/ha (2) $4660/ha (3) $500/ha (4) $3,800/ha

TABLE A5.1.1: (Continued)

Effect on Rural income	Ksh 9,000/yr./ household	Increased local income from farmer, reduced outmigration to cities, eco-tourism trails have been built along rejuvenated streams.	Incremental increase in household incomes of USD 250/yr.	Substantial qualitative, but un-quantified community benefits due to increased farm income	Small effect on households that adopt the practice, but led to increased purchases of fertilizer and basic goods.	Not estimated, but small unless net returns/ha are very high	Not estimated
Comments	These are community based structures, financed by the national government. At higher interest rates, the projects may not have been economically feasible.	Increased vegetation and biodiversity, reduced sediment flows and forest fires	Materials cost is very low and labor cost of construction is high, but reduced by community contribution of labor	The practice is profitable in developed countries, but less so in developing countries due to high capital costs	The practice is only marginally profitable in Ethiopia, even when subsidized	The costs of the dams in this study were fully subsidized; otherwise the project would not have been economically feasible.	For investments in rainwater harvesting to have an impact on poverty reduction, increased linkages to profitable markets is critical

TABLE A5.1.2: Summary of Results for Rain Water Capture Options

Information Source	Nigigi et al. (2005)	Yuan et al. (2003)	Senkondo et al. (2004)	Panagrahi et al. (2007)	Mushtaq et al. (2007)	Oron et al. (1983)	Goel et al. (2005)
Location	Laikipia district, Kenya	Gansu, China	Semi-arid regions of Tanzania	Eastern India	Zhangi Irrigation System, China	Israel	Northwest Himalayas, India
Methodology	CBA Ex Ante project assessment	CBA EX Ante project assessment	CBA (Gross margin and investment analysis) EX Ante project assessment	CBA Ex Post project assessment of field data experiments	CBA Ex Ante project analysis using hydro-economic model	CBA Ex Post Cost-Benefit Analysis	CBA Ex Ante analysis of proposed WH system - different structure sizes and crops
Technology/ Activity	Construction and operation of farm ponds to increase water supply in the dry season, plus drip irrigation and plastic mulch	Project considers expanding supplemental irrigation area with on-farm and off-farm hard surface collection and on-farm storage in cellars	Excavated bunded basins to capture water. The study is not particularly clear about the technology included under each RWH case study	On-farm reservoirs to provide supplemental irrigation to a 800 m^2 field	Small, medium and large ponds for supplemental irrigation	Micro-catchment water harvesting (MCWH) with and without vertical infiltration pipes (inserts) in dry and highly dry zones	Different size of water harvesting structures and crops irrigated
Present value of capital cost/ha (PVCC) or Annualized cost/ha/yr. (ACC)	PVCC: $ 650 for 50m2 pond + drip system to irrigate 300m2 garden: $21,665/ha.	PVCC: roughly 7500 - 9200 RMB/ha for collection and distribution system	Not displayed	PVCC: Rs 2,743	Average PVCC for ponds, small: $ 1,743, medium: $ 2,645, large: $7,146	All costs, both fixed and capital are averaged per ha per year and appear not to be discounted. See cell below	PVCC for small, medium and large structures Small: $1,503/ha Medium: $1,315/ha; Large: $ 1,128/ha
Annualized variable production cost (AVPC)	AVPC: $ 100/yr., or $3,333/ha/yr	AVPC: 150 RMB/ha to 300 RMB/ha	Not presented	AVPC: RS 255/ha	AVPC for ponds, small: $377; medium: $ 696; large: $ 1,114	AVCC + AVPC: MCWH: $61/ha/yr to $64/ha/yr.; MCWH+ Inserts: $ /ha/yr to $116/ha/yr	Not presented
Annualized revenue (AR) or Present value of revenues (PVR)	Incremental AR: USD 300/yr. Net revenue: $200/yr.	AR: 1550 RMB/yr to 3000 RMB/yr. depending on crop	Annualized Gross Margins increased from -54,200 to 121,100 Tsh/ha/yr. for maize, an increase of 175,300 Tsh/ha/yr. For onions, the additional gross margin is over 2.15 million Ths/ha/yr.	PVR: Rs 4,689/ha	AR: irrigated: $ 490/ha; rain-fed: $290/ha	AR: MCWH: $ 31/ha/yr to $ 107/ha/yr.; MCWH +Inserts: $ 48/ha/yr to $422/ha/yr.	Incremental AR for proposed project ranged from $600/ha to $ 1505/ha depending on crop, structure size and life of investment.
Net Present Value (NPV) per ha. (currency) or Annualized Present Value (APV) or Internal Rate of Return (IRR)	NPV per ha (12% interest rate over 5 years): $2365/ha. IRR: 16.5% Payback period at 12%: 41/3 years.	NPV: At 10 years: NPV <1,000 RMB/ha to 14,000 RMB/ha . Break-even period at 6% interest rate: 2.5 - 8 yrs. Depends on crop being irrigated and catchment technology	NPV (at 10% interest rate): Maize: -380,000 Ths, Paddy R: 20,600 Ths, Onion: 2.58 million Ths. However, the NPV of the control practice, Maize, is not given, only the gross margin.	NPV: Rs 700/ha Payback period (14.8%): 16 years	NPV varies widely, depending on amount of full irrigation supplied, interest rates and cost of family labor: NPV/ha at 10%: - $ 2,040 /ha to $ 5,931/ha	APV: only positive for MCWH + Inserts in dry zones: USD 41/ha/yr. -141.2/ha/yr. Net returns are negative for both options in very dry climates	NPV: -866/ha to $377/ha Only 5/18 project designs had a positive NPV, implying a cost benefit ratio of 1 or greater. Only large structures met this criterion.

TABLE A5.1.2: (Continued)

Effect on Rural income	Not Estimated	Not estimated	Not Estimated	Not Estimated	Not Estimated	Not estimated	
Comments	The incremental benefits of ponds + cabbage cultivate around \$200/yr. on a 300 m^2 plot, the size of a typical farm. Incremental returns to higher valued crops, made possible by ponds would be higher.	The economic results showed highly variable net returns. However, crop water efficiency followed by maximizing collection area were the most important factors.	The Gross Margin analysis only accounts for revenues minus variable costs. The assumptions of investment (NPV) assessment were not consistent with the investment analysis and the two are hard to compare	The study is not transparent enough to follow the accounting. It is unclear if the net returns from Maize in the Gross Margin account will cover the loan cost and still leave the family with a sufficient surplus	NPV is directly related to size; however if opportunity cost of labor is included NPV of all ponds is almost always < 0, except for large ponds at interest rates < 12%	Positive net returns for MCWH + Inserts in dry zones increase as catchment area decreases. However, the use of average costs and lack of discounting makes results problematic. Losses are probably higher.	Large water harvesting structures are preferred. Wheat is preferred to Maize for supplemental irrigation. Longer life times increase the NPV, but marginally.

TABLE A6.1.1: Summary of Results for Ecotourism Options

Information Source	Tobias and Mendelsohn (1991)	Chase et al. (1998)	Ellingson and Siedel (2003)	Wang and Jia (2012)	Lee and Hahn (2002)	Naido and Adamowicz (2005)	Wilson and McLean (2010)
Location	Monte Verde Cloud Forest, Costa Rica	Three national parks in Costa- Rica	Eduardo Avora Reserve, Bolivia	Dalai Lake Protected Area, China	South Korean national parks	National Forest Reserves, Uganda	Acadia National Forest, B. C.,Canada
Methodology	Participation model to determine visits; Travel Cost Model (TCM) to determine Willingness to Pay (WTP)/trip	Ex-ante analysis of effects of differential fee pricing at different national parks to increase revenues	Comparing two stated preference methods for estimating WTP to visit this PA: Contingent valuation and contingent behaviour approaches - CV and CB	Ex-Ante CV study of increased entrance fees	Ex-Ante CV study of use and preservation values to increase park entrance fees for individual tourists	Ex-Ante choice experiment to determine how park fees can prevent biodiversity loss	Ex-ante analysis of social costs and benefits of reducing commercial logging and establishing protected areas (PA) with Contingent Valuation Method (CVM)
Technology/ Activity	Protected area tourism	Efficient pricing for access to ecotourism activities	Calculation of entrance fees based on stated preferences	Calculation of entrance fees using stated preferences	Calculation of use and preservation values for 5 national parks	Calculation of effects of park entrance fees on biodiversity conservation	Land use change from logging to protected areas
Annual WTP/trip and/or park entry fee	Annual WTP/trip: $ 35/visit/yr.	Annual WTP/trip: $ 21.60 - $24.90. Existing entry fee: $ 9.56 - $12.28. Optimal multi-tier fees: $ 6.48 - $7.37	Payment for entry fee and package tour: $ 35 to $ 77	User fee only: Old fee: 20 RMB; New fee 71.8 RMB; Recommended fee: 50 RMB	Average value for use (entrance fee): 12,800 won/visitor; Average preservation value (taxes and fees): 14,400 won/visitor	Entrance fee Existing fee: $ 2.75 to $ 3.50. Optimal fee: $47 to $53	Average WTP/person/yr. for 3% increases in protected area: CDN 56 - CDN 171
Annual revenue from users (or social value) =Annual Expenditures by visitors	At USD 35/visit, Total revenue. $ 400,000/yr to 500,000/yr., based on projected participation in the range of roughly 11,400 visitors/yr. to 14,200 visitors/yr.	Total Annual Revenue from fees: Existing entry fee: $ 343,260/yr Optimal multi-tier fees: $ 2,566,475/yr	Annual Expenditures by visitors: $ 1.9 million/yr to $ 2.2 million/yr	2010-2011 Ave.: Old fee : 3.9 million RMB/yr; New fee: 6.0 million RMB/yr	Total revenue could not be calculated, since the model did not include visitation	Annual Revenue, based on visitation 1996-2001: Existing fee, AR: $ 7,000/yr Optimal fee, AR: $ 18,000 - 40,000/yr. depending on number of bird species	Annual WTP for 3% increase in protected area (PA) for 80 years (r=5% & 10%) 5%: CDN 360 million; 10%: CDN 184 million
Total NPV or PV of Consumer Surplus (PVCS) from users (or total social value)	PVCS: ADD Domestic visitors: $97500 /yr to $116200/yr Foreign visitors: $400,000/yr to $500,000/yr	No net welfare or cash flow calculations were made, as the purpose of the study was to show how efficient pricing could increase revenues.	Not calculated.	NPV of income from fees, 2% visitation growth rate, 4% interest rate: Old fee: 195 million RMB. New fee: 300 million RMB	Total revenue could not be calculated, since the model did not include visitation	Not calculated from model results, as focus was on market values (user fees). Also visitation rates were held constant at 1996-2001 levels	NPV for lost value from commercial forests + 3% increased PA: 5%: CDN 270 million; 10%: CDN 136 million.

TABLE A6.1.1: (Continued)

Effect on Rural income	Direct effect only = revenue estimate, an upper bound on direct effects.	Not discussed. However, at efficient prices, projected visitation fell, lowering demand for local ecotourism services and the number of bed-nights.	Not treated or discussed. While efficient pricing would increase visitation, translating the calculated NPV values into revenue would require price discrimination on the part of operators .	Not treated or discussed. Primary impact would be through increased revenue from entry fees, depending on how the higher revenues are distributed by the operator.	Since the study did not estimate how increases in fees affected visitation, no revenue impacts could be calculated.	The simulated increase in revenue would be additional to current incomes. However, the impact on local income depends on how the higher revenues are distributed by the operator.	Not treated or discussed, since private income from fees and concessions was not investigated.
Comments	The USD 35/visit estimate is based on average consumer surplus (WTP). The park operators could not capture all of this surplus in park entrance fees.	Higher revenues and profits could be dedicated to enhance conservation, but might also be expropriated as rents by public sector owners for non-ecosystem and welfare improvement purposes outside the region.	While these studies reflect user values, there are large differences between the two methods that would impact revenues heavily.	26.4 % of the survey respondents gave protest bids. Indirect impacts due to increase might be lower as tourist visits as fee is increased.	Current fee is 1,000 won/visitor. Ave. maintenance cost/visitor is 3,700 won. Increasing fees in line with WTP would make the parks profitable. Local impacts would depend on how profits were distributed by the operators.	Average land values in the park based on entrance revenues would be from $0.60/ha to $1.35/ha. The value of the forest in its best alternative commercial use is not estimated.	Results are affected heavily by shorter project life-times and discount rates, as expected. After accounting for costs, most project designs had a positive NPV.

TABLE A6.1.2: Summary of Results for Ecotourism Options

Information Source	Hearne and Salinas (2002)	Wunder (2000)	Ohl- Shacher et al. (2008)	Gossling (1999)	Bookbinder et al. (1998)	Kirby et al. (2011)	Kremen et al. (2003)
Location	Barva Volcano Area, Costa Rica	Cuyabeno Wildlife Reserve, Ecuador	Casa Matsigenka Lodge Manu National Park, Peru	Global by country	Royal Chitwan National Park, Nepal	Tambopata region, Peruvian amazon	Masoala National Park Integrated Development Plan (IDCP) Madagascar
Methodology	En Ante choice experiment to determine what attributes of ecotourism visits were most important to visitors	Ex post analysis of revenue impacts from Ecotourism on local income and employment based on field surveys and tourist operator information	Ex Post analysis of income generation and distribution and profitability from tourism revenues using local documents and field surveys	Literature summary of benefits and costs of conservation activities (prior to 1999)	Ex post survey analysis of revenues and income effects of tourist visits on local population in 1994	Financial cost benefit analysis of ecotourism and competing land uses in the region for 16 lodges	Local, national, global cost benefit analysis of land use options under the ICDP development program.
Technology/ Activity	Selection of site attributes to capture WTP of visitors in upgrading facilities	Protected area tourism	Casa Matsiguenka Lodge income, costs and profits	Ecotourism financial flows Financial flows of conservation and alternatives	Protected area tourism	Multiple land uses, including ecotourism	Multiple land uses, including ecotourism
Value per visit	Not calculated, the purpose of the study was to determine the relative importance of different park attributes	Not calculated	Ave. revenue/tourist/yr, 1999-2005: $ 56. **Remaining column entries are specific to a financial cost benefit study of the lodge**	Ave. benefits from protected areas: Costa Rica: $458/ha Ecuador: $ 17/ha **Remaining column entries are specific to study**	Not calculated. **Remaining column entries are specific to impact of park on local economy**	Not Calculated. **Remaining column entries are specific to a financial cost benefit study of the lodges**.	Not Calculated. **Remaining column entries are specific to this study, comparing *Local NPV* of alternative land uses at interest rates of 10% for 30 years**.
Annual Revenue from all visits	No revenue calculations were made. The Marginal WTP for park attributes differed depending on tourist origin: foreign (FT) or Costa Rican (CT)	Total annual income from tourism from 5 areas: $ 128,100/yr.	**PV of annual revenue** 1999-2005: $ 179,654 **PV of annual costs** 1995-2005: $ 169,077	**Ave Costs:** Costa Rica: $22/ha) **Global opportunity costs:** Forestry: $900/ha to$2500/ha Agriculture: $148/ha to $1034/ha	**Annual revenue of park operators in 1994:** $4.5 million/yr **Total visitation (1994):** 58,934 visitors	**Annual Revenue:** $5.995 million/yr **Annual Expenses:** $4.807 million/yr	**NPV of local ecotourism**: $ 6,100. **NPV of other conservation activity benefits**: $ 244,600.
NPV of all visits	FT rankings: (1) More trail restrictions, (2) Better views from trails, (3) Better information about the park. CT Rankings: (1) Views, (2) Information, (3) Use restrictions	Not calculated. At a visitation growth rate of 2%/yr. and interest rate of 4%, NPV of total income is $ 6.4 million.	**NPV Profit (4%, 7yrs):** $ 10,577 **Average Profit/yr:** $ 1,834/yr **Average Profit/local hh/yr:** $9.67/hh/yr	**Ave. NPV of protected areas:** Costa Rica $426/ha	**Total local employment in 1994:** 1084 persons **Total local household (hh) income from park (1994):** $ 3092	**Annual Profit:** $844,472/yr **NPV (10%, 20 yrs):** $ 7,19 million	**NPV of local alternatives**: Large scale forestry and agriculture: $ 14,200.

TABLE A6.1.2: (Continued)

Effect on Rural income	No revenue impacts were calculated, as the study did not analyse the effects of changes in park characteristics on visitation.	Increase in average monthly household income of local residents was USD 84/month, accounting for about 77% of income	The computed average amount needed by every local household was $42/hh/yr. To meet this need, average annual revenues would have to increase by $32.33/hh/yr	Of the total revenue from tourism, only about 20-40% remains in-country and the fraction of that spent in rural areas is generally far smaller. Where international destinations are involved, much of the revenue is returned to the national government	**Increased local income/household from park (1994):** $ 50/hh/yr **Share of park revenues distributed locally:** < 1%	**Income shares from lodge expenses:** Local 28% to 45% National: 55% to 71%	The total PV of local conservation options relative to the opportunity cost of commercial forestry is large, but ecotourism is only a small (3%) portion of total NPV, locally.
Comments	The study raises questions about which groups ecotourism reserves should be designed for: foreigners or citizens. However, the study did not link visitation and revenues to the WTP of different tourist groups.	Tourism revenues created somewhat more equal distribution of income; higher wages; larger cash economy; no severe environmental impacts, and better environmental management.	Economic impact on indigenous people is limited. Projections for future profitability and higher income generation to meet the "needs deficit" of local households are based on eliminating monopolistic competition and investing profits in a sinking fund.	Conservation and ecotourism have high opportunity costs, based on commercial agricultural and timber values. Incentives and mechanism to capture conservation values are weak compared to market values of alternatives.	Despite visitation of about 60,000 tourists in 1994, less than 6% of all households in the region were affected by tourism revenues. Of 87,000 members of the labor force living close to the park, less than 1000 were employed by the tourism industry. However, income from park operation was a major share of these household' incomes.	The study concludes: that while the lodges are currently profitable, well-managed, and their environmental impact is low, deforestation by external sources and rising land prices are a challenge that needs to be faced to sustain this.	At the national scale ecotourism benefits were far larger than the local benefits through spending and employment impacts. Also, the opportunity cost of replacing commercial forestry and agriculture with ecotourism activities was high at the national level.