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Ecosystem services and agricultural land-use practices: a case study of the Chittagong Hill Tracts of Bangladesh

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Land degradation due to inappropriate agricultural activities, as well as the environmental and social effects associated with these practices, is accelerating in many developing regions of the world. This trend underlines the importance of measuring environmental costs and benefits to improve policy making with respect to land use and agriculture. Using nonmarket valuation techniques, this article estimates the value of environmental services associated with four agricultural land-use systems in the Chittagong Hill Tracts of Bangladesh and compares their relative profitability from private and social perspectives. The financial analysis reveals that annual cash crops are the most profitable short-term land use and agroforestry is the least profitable, with horticulture and farm forestry providing benefits intermediate between these two systems. However, the relatively larger returns from annual cash cropping lead to higher environmental costs such as soil erosion, forfeited carbon sequestration, and biodiversity loss. When the environmental costs are taken into account, annual cash crops appear to be the most costly land-use system, with agroforestry and farm forestry becoming more profitable. The findings demonstrate the tradeoffs and synergies between relatively more environmentally sustainable and harmful land-use practices. Financial incentives to encourage more prudent agricultural activities are needed to transform tradeoffs into synergies. This article examines different financial incentive mechanisms—including payments for environmental services—and makes several policy recommendations.

KEYWORDS: agricultural practices, land use, cost-benefit analysis, contingent valuation, socioeconomics, environmental effects

Introduction

Degradation of natural resources, particularly land and forests, has become a serious concern in developing countries where most rural people depend on these resources for sustenance (FAO, 1999). Deforestation and inappropriate agricultural practices have undermined the productive capacity of approximately two billion hectares (ha) of the world's agricultural land (Pinstrup-Andersen & Pandya-Lorch, 1998). The pace of impairment is highest in mountain areas because of steep slopes and fragile environments (Rasul, 2006).

Like other mountainous areas in South and Southeast Asia, the Chittagong Hill Tracts (CHT), a hilly region in Bangladesh, face serious problems of agricultural land degradation (Shoaib et al. 1998; Gafur, 2001; Rasul, 2006). Four-fifths of the CHT region is steeply sloped. Combined with heavy seasonal rainfall (2,032 to 3,810 millimeters per year) and poor soil structure, the topography poses a serious impediment to annual cultivation in most of the region (96%) that is otherwise suitable for tree farming, agroforestry, horticulture and the cultivation of other perennial crops (FFEI, 1966; SRDI, 1986).

Although several biophysical and geomorphological factors are responsible for land degradation, inappropriate land-use practices have accelerated the rate of harm (Rambo, 1998; Pagiola, 2001). According to the World Resources Institute (1992), over two-thirds of land impairment in Asia is caused by deforestation and poorly suited agricultural practices. Land-use change, including conversion of forestland into agricultural land, not only accelerates land degradation, but also intensifies carbon-dioxide (CO_2) emissions and loss of biological resources (Kremen et al. 2000; Jackson et al. 2007). Kremen et al. (2000) estimate that about 20–30% of CO_2 emissions worldwide are due to tropical deforestation and land-use changes. Change in land use, particularly conversion to monocropping, has accelerated the loss of agrobiodiversity (Partap & Sthapit, 1998; Jackson et al. 2007).

In CHT, spurred by higher profit opportunities, the cultivation of annual cash crops, particularly ginger, turmeric, and other root products, is steadily increasing on hill slopes. For example, ginger grown under such topographical conditions with intensive tillage practices has increased more than four times, from 1,305 ha in 2003 to 5,764 ha in 2008 (Ahmed, 2008). Soil loss under annual crops on hill slopes exceeds 100 tons/hectare/year (t/ha/year) (Shoaib et al. 1998; Gafur, 2001; Rasul, 2006). Land degradation and the loss of biological resources raises concerns about the long-term viability of agricultural systems as sustainable development requires that human exploitation of natural resources not exceed the renewal capacity of the Earth's biosphere (WCED, 1987). The principles of sustainability demand that the stock of natural resources and environmental services be maintained to ensure that future generations will be able to meet their needs as we have met ours (Turner et al. 1993; Alauddin, 2004).

While some agricultural practices degrade natural capital, others provide economic benefits and conserve it (Pimentel et al. 1997; Bjoeurklund et al. 1999; Zhang et al. 2007). If public institutions cannot provide incentives for agricultural practices that conserve natural capital, the productive base of a country will shrink (Dasgupta, 2007).

The most important challenge facing developing countries today is how to promote agricultural practices that provide necessary goods and services while conserving natural capital. To design appropriate policies and strategies that encourage sustainable land uses, it is important to recognize the economic value of environmental services and disservices generated by alternative agricultural practices. Policy makers often do not perceive and value these services due to a lack of information in the form of market prices that reflect the monetary value they provide (Barbier, 1999; Bräuer, 2003; Swinton et al. 2007; Nijkamp et al. 2008). Failure to recognize the use and nonuse value of environmental services provided by different land-use systems, such as soil conservation, carbon sequestration, and biodiversity protection, often encourages the implementation of policies that lack incentives for sustainable agricultural practices. As a result, the supply of environmental services remains inadequate. It is, therefore, crucial to estimate the monetary value of alternative agricultural practices to facilitate the integration of environmental costs and benefits into policy making (Bjoueurklund et al. 1999; Bräuer, 2003; Ninan & Sathyapalan, 2005; Swinton et al. 2007).

While quantifying the economic value of environmental services and disservices is useful for informed decision making (Dale & Polasky 2007; Swinton et al. 2007), methodological difficulties remain an obstacle to the making of true comparisons (Bräuer, 2003; Nijkamp et al. 2008). Although several recent attempts have been made to evaluate alternative land-use practices, the focus has remained narrowly centered on specific aspects (Engel et al. 2007). While some studies focus on the economic valuation of soil conservation of alternative agricultural practices (e.g., Rasul & Thapa, 2006; Marta-Pedroso et al. 2007), others consider carbon emission/sequestration (Kremen et al. 2000; Huang & Kronrad, 2001; Olschewski & Benítez, 2005; Zbinden & Lee, 2005; Azqueta & Sotelsek 2007; Tschakert, 2007). Additionally, a few scholars over the last several years have carried out economic valuations of biodiversity conservation (Ninan & Sathyapalan, 2005, Jackson et al. 2007). However, agriculture is a multifunctional activity. Along with producing food, fiber, and other economic goods, an effectively operated farm also protects the environment, generates employment, and sustains rural landscapes (Dale & Polasky 2007; Madureira et al. 2007; Swinton et al. 2007; Zhang et al. 2007). To allow a true comparison of this range of activities, it is necessary to capture key environmental services such as soil conservation, carbon sequestration, and biodiversity protection, along with marketable goods and services (Zbinden & Lee, 2005; Swinton et al. 2007).

In view of this situation, the current study estimates the costs and benefits of four major land-use systems in the CHT region of Bangladesh using nonmarket valuation techniques to account for the soil conservation, carbon sequestration, and biodiversity services and disservices from both private and social perspectives.[1] However, this investigation does not provide a fully detailed valuation of ecosystem services. Instead, the focus is on an assessment of selected ecosystem services based on existing information to facilitate comparative analysis of four alternative land-use systems. The findings of the study have potential value in the design of policies and strategies for promoting sustainable land-use systems and sustaining ecosystem services in the CHT region and elsewhere.

Valuation of Environmental Services: Methodological Approaches

The introduction of nonmarket valuation of environmental services can be traced back five decades to Hotelling's estimate of travel demand (1949) and to Ciracy-Wantrup's willingness-to-pay (WTP) method (1962). Until recently, application of this approach has been limited by philosophical and methodological obstacles involved in assigning monetary value to nonmarket goods and services. The first challenge that the economist faces in implementing such a procedure is to determine which goods and services to

[1] The private perspective is measured by financial returns while the social perspective is assessed from the standpoint of long-term agronomic sustainability and environmental services and disservices such as soil conservation, carbon sequestration, and biodiversity protection.

assign an economic value. Due to standard assumptions regarding welfare maximization, economists do not normally assign value to goods and services that do not have direct or indirect value to human beings. Accordingly, the goods and services that are not valued by human beings, or are not directly instrumental for enhancing welfare, are not assigned economic value (see Goulder & Kennedy, 1997). This anthropocentric view has been contested by "environmentalists" who believe that all living and nonliving things have "intrinsic" value (i.e., value for their own sake, independent of human utility) (e.g., Barr, 1972; Gill, 1987).

Although this fundamental debate is still ongoing, economists and environmentalists have developed at least a tacit understanding about the major categories of values to be considered in economic valuation (e.g., Pearce & Moran, 1994; Bräuer, 2003). This approach entails the use of a "total economic value" (TEV) framework that incorporates both the "use value" and the "nonuse value" of ecosystem services.[2]

Estimating monetary value for direct-use values is relatively straightforward and involves reliance on existing market prices. More challenging, however, is assigning monetary value to indirect use values and nonuse values that have no market. Over the last several decades, economists have developed methodologies to reveal and measure the intangible benefits of ecosystem services that do not have explicit market values. Several valuation methods have been devised and these techniques can be divided into two broad categories: revealed preference or indirect methods and stated preference or direct methods (Boxall et al. 1996; de Groot et al. 2002; Bräuer, 2003). The revealed preference methods rely on surrogate markets for environmental services to estimate monetary value based on indirect use values (Pearce & Moran, 1994). Inferred values are calculated from data on behavioral changes in genuine markets using the actual purchase and consumption of marketed goods and services that are variously related to the items for which there is no market (Paccagnan, 2007). The following techniques provide the most common strategies for assessing revealed preferences: replacement costs (the cost of replacing a service with a human-made system); changes in productivity; costs of illness; avoided costs (costs that would be incurred if the service were absent); hedonic prices (and estimates of the value of nonmarket goods and services determined by observing behavior in the market for related goods and services); and travel-cost method (de Groot et al. 2002; Paccagnan, 2007).

The "stated preference" method estimates the monetary value of environmental services by asking people how much money they are willing to pay for a particular environmental service or how much they are willing to accept as compensation if the service were to be eliminated (Boxall et al. 1996; Birol et al. 2006). The two primary types of stated preference methods are the contingent valuation method (CVM) and conjoint analysis. CVM, which is useful for estimating the values for goods and services that have neither explicit nor implicit prices, is the most commonly used of the two options. Conjoint analysis is conceptually similar to CVM, but it asks respondents to rank alternatives rather than make direct statements relating to value (Arifin et al. 2009).

An alternative way to elicit stated preferences asks people how many times they are willing to visit a given recreational site instead of how much they are willing to pay to have such a facility (Birol et al. 2006). This technique is usually referred to as "contingent behavior" as it focuses on hypothetical activities. Another stated preference method now gaining attention is "group valuation," or "discourse-based valuation," in which a group of stakeholders is brought together to discuss ecosystem-service values (de Groot et al. 2002; Wilson & Howarth, 2002).

Various techniques are used to elicit the value of nonmarket goods and services. The most common are the bidding game, payment card, and open-ended and dichotomous choice (Boyle et al. 1998; Boyle, 2003). These methodologies, however, are still in their development stages and are being refined to improve estimations of the values of nonmarketed ecosystem services.

In stated preference methods, special care needs to be given to the design of questions and the selection of the appropriate approach. There can sometimes be a bias in WTP toward consumer rather than producer preferences since the value of environmental services may differ between them. When the supply of environmental services is less than socially desired, it is advisable to estimate the value from the

[2] Use values are further divided into direct use values, indirect use values, and option values. Direct use values derive from both consumptive uses of ecosystem goods and services such as food, fibers, fuel woods, medicine, and nonconsumptive uses such as satisfaction and recreation. Indirect use values arise from indirect ecosystem support in production, regulation, and supporting services such as nutrient cycling, climate regulation, hydrological recycling, and flood control (MEA, 2005). Option values are associated with the social value of maintaining the availability of certain ecosystem services as it is difficult to definitely anticipate future demand for such resources and their availability. Nonuse values are commonly divided into existence values and bequest values. Existence values derive from the economic value people place on knowledge that certain ecosystems resources exist, even if they have no intention of actually using them. Bequest values are related to the satisfaction that people derive from ensuring the continued existence of ecosystem resources for future generations (Swinton et al. 2007).

producers' willingness to supply those services (known as "willingness to accept") rather than from the standpoint of consumers' WTP (Swinton et al. 2007).

Both stated and revealed preference methods have advantages and disadvantages. The revealed preference method has a higher general acceptance, as values are estimates based on certain physical parameters or data and these approximations engender greater confidence than data generated by interviews about a hypothetical situation (Paccagnan, 2007). With hypothetical questions, stated preference may differ from a real situation (Diamond & Hasuman, 1994; Paccagnan, 2007). It is, however, not always possible to get a physical reference point, or proxy indicator, when estimating nonuse values. This problem emerges, for example, when estimating decreased agricultural productivity due to increased soil erosion or declining property value due to deteriorating environmental quality. When no surrogate can be found, the stated preference method is the only option (Boxall et al. 1996). The choice of valuation methods, therefore, depends upon the nature of the goods and services, and/or the type of benefits being measured. Recent approaches to improve estimation combine revealed and stated preference methods (Paccagnan, 2007) and a few empirical studies use both methods (e.g. Whitehead et al. 2000; Andersson, 2007).

Research Methods

Study Area

The study is conducted in the CHT region located in the southeastern part of Bangladesh and covering three hill districts—Rangamanti, Bandarban, and Khagrachari (Figure 1). With an area of 5,089 square miles, CHT covers about one-tenth of the Bangladeshi territory and is surrounded by India in the north and east, Myanmar in the southeast, the Chittagong district in the west, and Cox's Bazar in the southwest. This area is geographically and culturally distinct from the rest of the country and is inhabited by a variety of tribal ethnic groups. According to the 2001 census, 1,400,000 people live in the region. Twelve ethnic groups (*Chakma*, *Marma*, *Tripura*, *Mro*, *Bawm*, *Tanchangya*, *Kheyang*, *Pankhu*, *Chak*, *Lushai*, *Khumi*, and *Rakhain*) comprise the majority. The remaining residents are Bengalis who have migrated from the adjacent plain region over the last several decades. Agriculture is the main source of livelihood of both tribal and nontribal residents. Nonfarm income opportunities are very limited, and in some areas nonexistent. The agricultural land in CHT can be broadly divided into three classes. Class I lands (normally located in the valleys) account for a small percentage of the total area and are considered appropriate for all types of agriculture. Class II lands have gentle slopes and are suitable for terrace cultivation. Class III lands are steeply sloping and are regarded as only usable for nonarable activities such as forestry and horticulture (Rasul, 2006).

Detailed fieldwork was conducted in the Bandarban district from January to July 2002. The *Marma* and *Mro* are the largest tribal communities in Bandarban, followed by the *Bawm*. These three groups account for about 80% of the district's total tribal population. The *Marma* normally live near streams and rivers and the *Mro* and *Bawm* peoples usually live in higher elevations on hill slopes. *Marmas* are Buddhist and *Bawms* are Christian. In terms of comparative socioeconomic status, the *Marmas* and *Bawms* are relatively more affluent than the *Mros*.

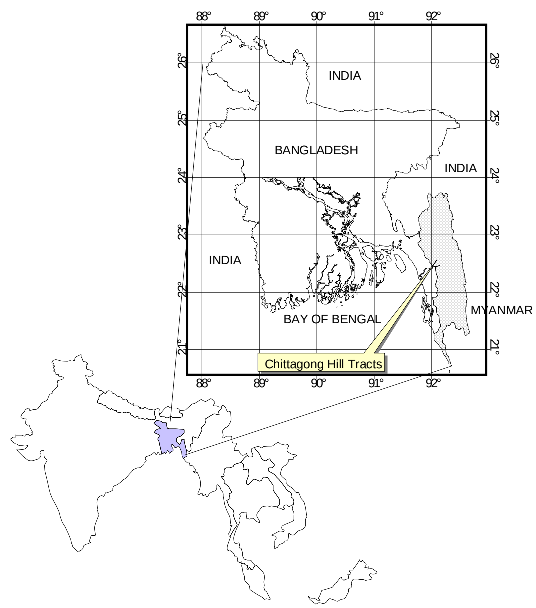

Figure 1 The study area: the Chittagong Hill Tracts of Bangladesh.

Data Collection Methods

This study is based on both primary and secondary data. Primary data were assembled through a household survey, focus groups, key informant interviews, and case studies. The research was carried out in two stages in two representative subdistricts, namely *Bandarban Sadar* and *Alikadam* in the Bandarban district of CHT. Initial information on farmers' socioeconomic conditions, land-use practices, land-management activities, farming systems, employment, income, and personal experiences in the four different land-use types was collected from 304 randomly sampled farm households using a standard questionnaire. This phase was followed by the collection of additional information on more specific land-use practices such as area under cultivation, volumes and prices of inputs and outputs, and land-management activities and time spent on each activity. Data were collected through detailed interviews administered to a random sample of farm households that had participated in the first stage of research. The information provided by individual farmers was verified through focus groups and interviews with key informants, agricultural extension agents, forestry officials, local nongovernmental organization (NGO) workers, and, particularly, land-user groups through focus-group discussions.

Specification of Land-Use Systems Under Study

Several land-use practices are currently evinced in the study area. Although once *Jhum* (shifting cultivation) was the dominant type of agriculture in the CHT region, it is increasingly being replaced by more financially attractive alternatives. Due to their growing importance, this study considers four land-use systems: annual cash crops (such as turmeric and ginger), horticulture, agroforestry, and farm forestry.

Although these land-use systems are distinct economic activities, farmers variously engage in several of them on a concurrent basis. For example, a farmer who primarily cultivates cash crops for market may also plant trees near the house or on a dyke or devote some farmland to fruit trees for household consumption. Farmers rarely keep records of inputs, outputs, and prices associated with these types of minor activities and this situation presents a challenge for the comprehensive collection of quality data on each land-use system. Through examination of local conditions, it was deemed expedient to use certain criteria in determining samples to ensure that they reflected the genuine characteristics of the entire land-use group.

Sampling Procedures

Agroforestry is characterized by a blend of trees and several field crops. The analysis therefore accounts for the costs and benefits of all major crops and tree species within the agroforestry system. Farmers who planted trees deliberately in association with field crops and earned some amount of income from them during the year 2001 were considered eligible for the interview. From a total of 103 farmers who had initially been interviewed and had planted trees, 27 farmers met these criteria. One-third of these farmers, chosen at random, were interviewed.[3]

For the other three types of land uses, the most dominant crop or tree species was selected. Ginger was thus chosen from among the annual cash crops, pineapple for the horticulture system, and *gamar* (*Gmelina arborea Roxb.*) for timber plantations. The methodology used to determine representative crops or tree species, as well as the procedures employed to identify eligible households for each land-use system, is described below.

Ginger, aroid, and turmeric are the major cash crops grown in the study area, with ginger the most important both in terms of its contribution to household income and the proportion of land under cultivation. Farmers cultivating ginger for the last twelve years and earning at least 10% of their household income from annual cash crops were considered for evaluation. Of the 86 farm households cultivating annual cash crops, 32 met the relevant criteria. Eleven of them were randomly selected for more detailed consideration.

Pineapple, banana, and papaya are the main crops farmed under the horticulture system. Pineapple was chosen for evaluation as it is dominant in terms of proportion of land under cultivation and contribution to household income. Farmers whose proceeds from horticulture accounted for at least one-fourth of total household income and who had been cultivating pineapple for at least twelve years were considered for interviews. Of the 112 farmers practicing horticulture, 52 met these criteria and eighteen were randomly selected for interviews.

The major timber species grown in the study area are *gamar* (*Gmelina arborea Roxb.*), teak (*Tectona grandis*), *akashmoni* (*Acacia auriculiformis*), *mangium* (*Acacia mangium*), *koroi* (*Albizia sp.*), *kanak* (*Schima wallichii*), *goda* (*Vitex sp.*), *chapalish* (*Artocarpus chama*), mahogany (*Swietenia macrophylla*), and *simul* (*Bombax ceiba*). The most commonly grown of these are *gamar* and teak. Most small farmers grow *gamar* because it matures relatively quickly—after only ten to twelve years—and is well adapted to local conditions with the wood used mainly for construction. Teak is a hardwood species that matures in 30–40 years and is used mainly for furniture and construction. We therefore considered *gamar* as representative of the tree-farming land-use system. Farmers who had planted at least 200 *gamar* trees and harvested timber during 2001 were included in the research design. Of 74 farmers growing trees for commercial purposes, 25 met these criteria. One-third of them were chosen at random for interviews.[4]

[3] It is generally expected that a sampling protocol involving one-third of the overall population will represent the sample characteristics properly. When the population is large, a sample size that is less than one-third can suffice.

[4] One may question why different criteria have been used for selecting samples from different land-use groups. Given the diversity of land uses practiced by farmers in the study area, adopting

Estimation of Financial Costs and Benefits

The various land-use systems each have different production cycles. For annual crops, the production cycle is one year, horticulture is five to six years, and farm forestry is twelve years. To compare the costs and benefits of land-use systems, a twelve-year time horizon was considered in an analysis based on inputs, outputs, and farm-gate prices of produce.[5] To facilitate the comparison, all costs and benefits were brought to present value by using a discounting method. The opportunity cost of labor in the study area varies by gender and season. Following the prevailing wage-labor rates, US$1.57 (Taka 90) and US$1.05 (Taka 60) were considered to be the daily per capita opportunity costs of adult male and female workers, respectively.[6] The national interest rate for agricultural credit is 11% and farmers incur additional administrative costs of about 1% to secure credit. Following Kumar (2002), a discount rate of 12% was considered to reflect the cost of capital.

Estimation of Returns to Land

The return to land was a criterion to evaluate each land-use system. Given the scarcity of land in the CHT region, both private and social objectives aim to maximize returns from a unit of land. Returns to land are expressed by net present value (NPV) which discounts the streams of benefits and costs back to a base year. The NPV of each land-use system over a period of twelve years was calculated using the following equation:

$$NPV = \sum_{t=1}^{n} \frac{(B_t - C_t)}{(1+r)^t} \qquad (1)$$

Where,

B_t = land-use specific benefits accrued over the twelve years,
C_t = land-use specific costs incurred over the twelve years,
r = the discount rate, 12%, and
t = time period, twelve years

sample criteria was found to be useful. Although this approach reduced sample size, it helped to identify representative samples and more representative data.

5 Because different land uses have different time horizons, without a twelve-year window, assessing certain costs and benefits would have been difficult.

6 Some scholars argue that the wage rate does not always reflect the true opportunity cost of time. In the CHT region, other than wage labor, tribal people engage in extractive activities whereby men collect bamboo and women harvest wild vegetables, fruits, nuts, and firewood to sell to the market. However, income from extractive activities varies considerably by resource availability and seasonality. Given this variability, wage labor has been considered as the opportunity cost of labor. The exchange rate at the time of publication was 69 Bangladeshi taka to one US dollar.

Estimation of Environmental Services

Agricultural land use can generate both positive and negative externalities. The common positive externalities are soil and water conservation, carbon sequestration, biodiversity protection, and scenic beauty. Negative externalities are soil erosion, land degradation, biodiversity loss, carbon emissions, and water-quality deterioration (Zbiden & Lee, 2005). As the externalities vary from one land use to another, it is necessary to value the environmental services in competitive land-use systems. In view of this situation, estimates were made of the value of carbon sequestration and biodiversity protection and the cost of soil erosion associated with each land-use system.

Estimation of Soil Erosion

Soil erosion has both onsite and offsite effects. The onsite effects include soil-nutrient depletion and deterioration in the physical and biological structure of the soil that cannot be easily replenished in the short term (Attaviroj, 1990; Alfsen & Franco, 1996). Since no other data were available to capture the onsite and offsite effects of soil erosion, only the cost of nutrient depletion was considered. Some scholars (e.g., Barbier, 1999; Gafur, 2001; Wiebe, 2002) have argued that though partial, such an analysis provides a better idea about the environmental costs and benefits of alternative land uses than simple subjective assessment. The most significant onsite effect of soil erosion is the loss of soil fertility that results from the depletion of organic matter and decreased availability of phosphorous, nitrogen, potassium, and other trace elements (Attaviroj, 1990; Alfsen & Franco, 1996; Barbier, 1999). Different approaches have been developed to estimate the value of such nonmarket goods and services (Costanza et al. 1997; Daily et al. 2000; Gunatilake & Vieth, 2000; de Groot et al. 2002). Following several other studies in Asia (e.g., Salzer, 1993; Samarakoon & Abeygunawardena, 1995; Marta-Pedroso et al. 2007), the replacement-cost method for valuation of soil erosion was adopted. To estimate the reliable value of soil loss, the natural rate of soil formation is deducted from the rate of erosion. Salzer (1993) reported that the natural rate of soil formation in temperate climates is about ten tons/ha/year. In Thailand, the same author estimated that the rate of soil formation was fifteen tons/ha/year. Since this study area is similar to CHT in terms of climatic condition and topography, a soil formation rate of fifteen tons/ha/year was assumed.[7]

7 While the rate of soil formation varies from one land use to another, I use the uniform rate of soil formation due to lack of land-use specific soil formation data.

Estimation of Carbon Sequestration and Biodiversity Services

In addition to soil conservation, the different land uses have varying impacts on many other environmental and social services (Pagiola et al. 2007; Schrag, 2007). The monetary value of biodiversity services and carbon sequestration associated with each land-use system was estimated following Pagiola et al. (2004) and Pagiola et al. (2007). While estimation of carbon sequestration is relatively straightforward (Huang & Kronrad, 2001; Olschewski & Benítez, 2005; Zbinden & Lee, 2005; Azqueta & Sotelsek, 2007), approximating the economic value of biodiversity is extremely difficult (Pagiola et al. 2004, Jackson et al. 2007; Nijkamp et al. 2008). Realizing the difficulties, Pagiola et al. (2004) developed an index of biodiversity for different land uses that ranges from 0 to 1, with 0 for annual crops (e.g., grains, tubers) and 1 for primary forest. Other land uses reside between these two extremes. Although this index is a proxy measure and may vary considerably depending on biophysical conditions, it is used to estimate the value of biodiversity services and carbon sequestration as no other precise method is available within the confines of this study. Following the work of Pagiola and his colleagues, the values of carbon sequestration and biodiversity services were estimated with the following formulas.

Index of carbon sequestration services (ICSS) =
Point of carbon sequestration in specific land use x Price of carbon (ton/year)

Index of biodiversity services (IBS) =
Point of biodiversity in specific land use x Price of biodiversity services (ha/year)

Separate indices were developed for the carbon-sequestration and biodiversity-protection benefits of each land-use system and then aggregated. This approach is similar to that of the environmental benefit index used in the United States Conservation Reserve Program.

Although these indices have been used in several studies to value environmental services, the rate of payment has varied. While Pagiola et al. (2004) estimated US$75 point/year payment for environmental services, Costa Rica's *pagos por servicios ambientales* (payments for environmental services) program pays US$45 ha/year for environmental services (Zbinden & Lee, 2005). This study uses US$45 per point of environmental services, with 25% of the value discounted on the basis that some of the products and biomass will be used by the farm households themselves for fuel, fodder, and other subsistence purposes. This adjustment yields US$33.75 point/ha for environmental services, reflecting the sum of the carbon-sequestration and biodiversity-protection services. The sum, in fact, is equivalent to farmers' willingness to accept (WTA) to manage/supply environmental services in exchange for a given amount of remuneration.

Results and Discussion

Financial Performance of Alternative Land-Use Systems: Private Perspective

The financial analysis (excluding environmental costs) to estimate the discounted costs and benefits of products produced under the four land-use systems demonstrates that the highest gross benefit (measured as US$/ha/year) is from annual cash crops followed by horticulture and tree farming (Table 1). Gross benefit is lowest for the agroforestry land-use system. Although the gross benefit reflects the relative benefit size, it does not indicate the financial performance of the respective land-use systems because costs are not considered. The NPV is the common indicator of financial performance as it takes into account both costs and income of different activities (Tomich et al. 1998). In terms of NPV, annual cash crops appear to be the best performer followed by horticulture and tree farming. Agroforestry has the lowest NPV. The return from annual cash crops is about three times higher than that from agroforestry. Similarly, return to labor is highest in annual cash crops and lowest in agroforestry, with horticulture and tree farming falling between these two alternatives. The cultivation of annual cash crops also provides relatively quick returns and tree farming requires the longest time to begin generating an income stream. As discussed above, this situation has serious implications for the adoption of more sustainable land-use practices. The smallholders, who have limited capital and need to realize immediate returns, may not be able to alter current cultivation patterns without external support. The price of labor inputs is lowest in tree farming and highest in annual cash crops. This result suggests that moving from cash crops to perennial crops may not be viable for households with surplus labor in the absence of alternative employment opportunities.

Economic Performance of Alternative Land-Use Systems: Social Perspective

The preceding financial analysis, however, does not address the long-term environmental and social benefits such as soil conservation, agronomic sustainability, carbon sequestration, and biodiversity protection of contemporary land-use practices. In the CHT region, the soil-loss rate is very high (Table 2) and this situation accelerates nutrient depletion and

Table 1 Financial performance of alternative land-use systems.

	Annual Cash Crops[a]	Horticulture[b]	Agroforestry[c]	Farm Forestry[d]
Gross benefits (US$/ha)	4,867.20	2,331.77	1,768.12	2,314.86[e]
Total costs (US$/ha)	3,924.70	1,725.40	1,379.77	1,791.67
Labor costs (US$/ha)[f]	2,176.19 (55%)	1,057.37 (61%)	992.86 (72%)	962.91 (51%)
Non-labor costs (US$/ha)[g]	1,748.51 (45%)	668.03 (39%)	386.88 (28%)	872.08 (49%)
Financial performance				
Net financial benefits (NPV) (US$/ha)[h]	942.51	606.36	388.40	523.21
Initial establishment costs (US$/ha)	0	311.56	234.91	559.00

[a] Ginger is considered as a representative annual cash crop.
[b] Pineapple is considered as a representative horticultural crop.
[c] A typical agroforestry farm has annual crops and tree crops. The latter includes both fruit trees and timber trees. Average production of each crop and corresponding farm-gate prices were used to calculate gross benefits.
[e] Average production was 2,100 cubic feet (cft) of timber over twelve years. Average farm-gate price was US$1.58/cft. Seven or eight years after planting, farmers undertake a major thinning from which material is sold as fuel wood to brick factories and tobacco processors. Average return per household from thinning was US$526.
[f] Labor costs include selection, slashing, burning, cleaning, land preparing, planting, weeding, fertilizing, harvesting, and carrying.
[g] Non-labor costs include seeds, seedlings, fertilizers, pesticides, and interest on capital.
[h] With opportunity cost of household labor.

threatens the long-term sustainability of agricultural systems. To assess the actual costs and benefits of alternative land-use systems, the monetary value of positive and negative externalities associated with each cultivation alternative is estimated based on the methodologies explained above. When the economic costs and benefits of externalities associated with each land-use system are taken into account, the economic value of soil-nutrient depletion ranges from US$16 ha/year under horticulture to US$443 ha/year under annual cash crops (Table 3). Efforts to replenish the lost soil fertility would entail substantial increases in production costs. However, individual farmers generally ignore soil-nutrient loss when making land-use decisions due to the lack of explicit market value, although these nutrients are essential to production and ensure long-term sustainability.

Table 2 Soil erosion in different agricultural land-use systems.

Land use		Soil loss (tons/ha/year)	Average soil loss (tons/ha/year)
Annual crops (mainly root crops such as ginger, *mukhi kachu (Colocasia esculanta)*, turmeric)	Conventional tillage: hoeing without mulch	88.85[a] 109.45[b]	99.15
	Conventional tillage: hoeing with mulch	35.43[c] 34.89[b]	35.16
Pineapple (horticulture)		18.05[c]	18.05
Agroforestry, tree farming, mixed plantation/fallow *jhum* (five-year rotation)		10.00[d]	10.00

[a] Shaheed, 1995 and Shoaib et al. 1998; [b] Uddin et al. 1992;
[c] Chowdhury, 2001; [d] Gafur, 2001

The cost of soil erosion under the annual cash-crop system accounts for about 11% of the total production costs. However, under the agroforestry and tree-farming systems, farmers have savings of about US$26 ha/year, as the soil-formation rate exceeds the erosion rate. This benefit substantially changes the profitability of these land-use systems (Table 3 and Table 4) and horticulture emerges as the most profitable land use with tree farming in the second position. By contrast, the profitability of annual cash cropping is considerably reduced because of a high rate of nutrient depletion through soil erosion. This estimate is, however, conservative. The actual cost of nutrient loss may be higher as the price that farmers are paying for inorganic fertilizers is normally higher than the border price used in the analysis.

Carbon Sequestration and Biodiversity Protection

The value of biodiversity services varies considerably across the land-use systems. In terms of species conservation, annual cash crops do not provide any positive environmental services and agroforestry provides the highest benefits. Farm forestry generates the largest environmental services and the highest benefits in terms of carbon sequestration. Agroforestry and horticulture fall between these two alternatives (Table 5). There are, however, considerable variations among agroforestry, farm forestry, and horticulture with respect to carbon sequestration and biodiversity protection. When the benefits of environmental services are taken into account, annual cash crops become the least profitable land-use practice and farm forestry the most profitable option, with

Table 3 Economic valuation of soil loss by land-use systems.

		Annual Cash Crops	Horticulture	Agroforestry	Farm Forestry
Soil-loss rate (tons/ha/year)[a]		99.15	18.05	10.00	10.00
Natural rate of soil formation (tons/ha/year)		15.00	15.00	15.00	15.00
Net soil loss/gain (tons/ha/year)		- 84.15	- 3.05	5.00	5.00
Loss equivalent to inorganic fertilizers (kg/ton/eroded material)[b]	N (total) – Urea	755.98	27.40	44.91	44.91
	P (available) – TSP	38.47	1.39	2.29	2.29
	K (exchangeable) – MP	58.90	2.14	3.50	3.50
	Ca lime	332.39	12.05	19.75	19.75
	Organic Matter (kg)	5,370.45	194.65	319.10	319.10
	Total	6,556.19	237.63	389.55	389.55
Economic loss/gain (US$/ha)[c]	N (total)	127.32	4.61	7.56	7.56
	P (available)	7.70	0.28	0.46	0.46
	K (exchangeable)	8.53	0.32	0.51	0.51
	Ca lime	17.49	0.63	1.04	1.04
	Organic Matter	282.63	10.25	16.79	16.79
	Total	- 443.67	-16.09	26.35	26.35

[a] For source of average soil-loss rate under different land-use systems, see last column of Table 1.

[b] Loss equivalent to inorganic fertilizers = the net soil-loss rate x nutrient lost per ton eroded soil x nutrient: fertilizer-conversion factor. According to Gafur (2001), nutrient loss (kg/ton of eroded soil) is: N (total) = 4.14; P (available) = 0.09; K (exchangeable) = 0.35; Ca = 1.58, and OM = 63.82. Nutrient: fertilizer-conversion factors are adopted from Bangladesh Agricultural Research Council (1997) and are as follows: N – urea 2.17; P (available) – TSP 5.08; K (exchangeable) – MP 2.00; Ca – lime 2.50.

[c] Economic loss was calculated based on the border price of inorganic fertilizers. Border prices were determined by taking average of c.i.f. prices. The prices used were as follows: Urea = 0.168 US$/kg, P = 0.20 US$/kg, K = 0.145 US$/kg, lime = 0.05 US$/kg, and OM = 0.05 US$/kg.

the returns from agroforestry almost twice those from annual crops.

The analysis reveals a tradeoff between short-term profitability and environmental sustainability. For the individual farmer who wants to maximize his returns, the cultivation of annual cash crops is the preferable option. However, from an environmental and long-term economic perspective, annual cash crops provide the least desirable land use as they decrease natural capital through high rates of soil erosion and biodiversity loss. The tradeoff is highest in agroforestry and lowest in horticulture. If farmers move from annual cash crops to agroforestry, the opportunity cost is US$554 ha/year (not accounting for soil and nutrient depletion). To minimize this tradeoff, such a move needs to be examined from both a sustainability and a stakeholder perspective. Table 6 presents the relationship among profitability, sustainability, and various stakeholders' interests and reveals a conflict among the three major stakeholders, namely local land users, national government, and the global community. Financial return is the prime concern of private land users. Agronomic sustainability also affects them, of course, as soil erosion depletes on-farm nutrient status and reduces longer-term productivity. However, due to a short time horizon and a high discount rate, farmers generally do not consider the value of soil conservation. Moreover, many farmers in CHT use common property land for growing annual crops, shifting their plots every two to three years, and thus do not incur the costs of nutrient depletion and soil erosion. Nevertheless, this land-use practice depletes natural capital at the national scale, a trend that government has a strong interest in avoiding. Likewise, local land users have little interest in carbon sequestration and biodiversity protection, as they receive little benefit in the short term from these activities, although the global community as a whole does benefit. The land-use systems that provide higher benefits at an international scale do not generate higher annual economic returns for the farmer. Therefore, there is no straightforward

Table 4 Economic performance of alternative land use systems.

	Annual Cash Crops	Horticulture	Agroforestry	Farm Forestry
Gross benefits (US$/ha)	4,867.20	2,331.77	1,768.12	2,314.86
Net financial benefits (NPV) (US$/ha)	942.50	606.36	388.40	523.21
Net soil loss/gain (ton/ha)	- 84.15	- 3.05	5.00	5.00
Economic loss/gain due to soil loss (US$/ha)	-443.67	-16.09	26.35	26.35
Net economic benefits (NPV) (US$/ha)	498.84	590.28	414.75	549.56
Return to labor (US$/person-day)	1.95	1.77	2.07	1.93

Table 5 Performance of alternative land-use systems with biodiversity and carbon sequestration value.

	Annual Cash Crops	Horticulture	Agroforestry	Farm Forestry
Net financial benefits (NPV) (US$/ha)[a]	942.50	606.36	388.40	523.21
Net soil loss/gain (tons/ha)[a]	-84.15	-3.05	5.00	5.00
Economic loss/gain due to soil loss (US$/ha)[a]	-443.67	-6.09	26.35	26.35
Biodiversity index[b]	0.00	0.30	0.60	0.40
Biodiversity services (US$/ha)	0.00	121.5	243.00	162.00
Carbon sequestration[b]	0.00	0.40	0.50	0.80
Carbon sequestration services (US$/ha)	0.00	162.00	202.50	324.00
Total economic benefits (NPV) (US$/ha)	498.33	873.77	860.25	1,035.56

[a] Figures are derived from the third row of Table 4
[b] Indices of biodiversity and carbon sequestration are from Pagiola et al. (2004). For details, see Pagiola et al. 2004 and Pagiola et al. 2007.

win-win situation. The results suggest a need for a strong role for national government, and perhaps the global community, to reduce the divergence between private and social profitability by providing financial incentives for environmental services, as there is no market value for them.

Conclusions and Recommendations

This study estimates the costs and benefits of four major land-use systems in the CHT region of Bangladesh. It examines the environmental costs and benefits of soil conservation, carbon sequestration, and biodiversity protection of agricultural practices to facilitate improved policy decisions through a comparison of alternative land-use practices. An integrated approach of combining revealed and stated preferences for the determination of nonmarket values was used to estimate the monetary value of environmental services and disservices generated by the various agricultural practices.

The analyses show that when environmental impacts are disregarded, annual cash crops are financially more attractive than agroforestry, farm forestry, and horticulture. The financial benefits from the cultivation of cash crops exceed the benefits of agroforestry and farm forestry even after the monetary values of soil erosion are accounted for. Along with measuring costs and benefits of agricultural practices, this article also estimates the financial tradeoffs for farmers of moving from one land use to another and provides useful information on the amount of reward/compensation that might be required to minimize the tradeoff. The results demonstrate a significant opportunity cost, from a private perspective, associated with producing and sustaining environmental services within agricultural production systems.

The higher financial benefits associated with annual cash crops, however, are offset by high environmental costs, specifically in terms of soil erosion, carbon emissions, and biodiversity loss, which are major social concerns. The high rate of soil erosion associated with annual cash crops accelerates nutrient depletion and undermines the long-term sustainability of agricultural systems. The foregoing analysis demonstrates that private and social interests diverge, a

Table 6 Profitability, sustainability, and stakeholders' interest.

		Land Use Types				Stakeholders Interest
		Annual Cash Crops	Horticulture	Agroforestry	Farm Forestry	
Private Perspective	Private profitability[a]	High	Medium	Low	Medium	Land users
Social Perspective	Soil conservation[b]	Low	Medium	High	High	Land users and national government
	Biodiversity services[c]	Low	Medium	High	Medium	Primarily global community
	Carbon sequestration services[d]	Low	Medium	High	High	Primarily global community
	Agronomic sustainability[e]	Low	Medium	High	High	Land users and national government

[a] See Table 3, Row 7.
[b] See Table 5, Row 6.
[c] See Table 5, Row 6.
[d] See Table 5, Row 8.
[e] Agronomic sustainability is understood as soil erosion, soil formation, and biodiversity protection.

pervasive problem in most developing countries (Monke & Pearson, 1989; Pagiola, 2001). This study, however, reveals that the divergence is not genuine in the long term. When the social costs and benefits of soil conservation, carbon sequestration, and biodiversity protection are taken into account, the results show that more sustainable land-use practices are, ultimately, more profitable. From a long-term economic and social perspective, therefore, no tradeoff exists between sustainable and unsustainable land-use practices. This finding is consistent with several theoretical and empirical studies produced to date (Tomich et al. 1998; Rasul & Thapa 2006; Marta-Pedroso et al. 2007; Swinton et al. 2007).

However, the problem remains that no market exists for environmental services. Farmers do not receive any monetary reward for engaging in the production of positive environmental services and so do not take into account these services when making land-use decisions. It is, therefore, important to create a market for environmental services or to develop mechanisms that compensate land users for them. If such mechanisms are not developed farmers in the CHT region (as well as in other mountainous areas of developing countries) are likely to continue to respond to the existing financial incentives and perpetuate unsustainable land-use practices.

The findings of this study are potentially applicable to other mountain areas of South Asia where rural populations depend heavily on land resources for their sustenance and natural resource degradation is extensive. The novelty of this investigation is that it not only estimates use and nonuse values of alternative land-use practices, but also shows the monetary value of different environmental services separately, allowing decision makers to compare alternative land-use practices more precisely. The current analysis, however, uses an environmental service index developed in Latin America to estimate WTA for maintaining environmental services. Eliciting farmers' WTA through a local survey would likely provide a more precise estimate and should be considered in future research.

This evaluation leads to several recommendations to facilitate a shift to more sustainable agricultural practices. An appropriate mechanism should be developed to compensate farmers for the environmental services that their practices generate. Payments for environmental services (PES), if properly implemented, can provide additional income and enhance the profitability of more sustainable land use for small farmers (Pagiola, 2004; Dudley, 2007; Pagiola et al. 2007; Tschakert, 2007). While some environmental services are site specific, others such as carbon sequestration and biodiversity protection are public goods (Dale & Polasky, 2007; Swinton et al. 2007). Moreover, future generations, arguably the beneficiaries of certain measures to promote environmental conservation, are absent from the market. Therefore, the government of Bangladesh should develop appropriate mechanisms to provide remuneration to land users for more sustainable practices following the conservation programs developed elsewhere (Pagiola et al. 2004; Zbinden & Lee, 2005; Pagiola et al. 2007).

In addition, the international community should step forward with the necessary financial and technical support to facilitate a shift from unsustainable to sustainable land-use practices that generate public goods and have global benefits (Kremen et al. 2000; DeFries & Bounoua, 2004). The Kyoto Protocol, specifically the afforestation/reforestation provisions within the clean development mechanisms, has unfortunately to date failed to encourage strategies to capture the environmental benefits generated by smallholders through more sustainable agricultural practices such as farm and community forestry.

Given the complexity of agricultural land use, it may take time to develop appropriate institutional mechanisms for PES. However, governments may immediately provide direct or indirect financial incentives to encourage the adoption of conservation technologies such as nontillage cultivation, mulching, contour planting, alley farming, and terrace construction that can reduce soil erosion and other environmental costs engendered by the cultivation of annual crops. Along with financial incentives, governments may also impose restrictions on growing root crops on steep slopes to generate desired environmental outcomes.

In developing countries such as Bangladesh, financial incentives alone may not be enough to motivate farmers to move from annual crops to perennial crops due to the long phase-in period and the relatively high initial investment costs. Necessary support services, including long-term credit, knowledge transfer, and information on the adoption of perennial crops may need to be provided, as the returns from tree plantations only come after many years.

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