Valuing Ecosystem Services from Forests: A Multidisplinary Field-Based Approach

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Abstract

Land-use regimes vary throughout the world. Within the forest land-use regime there are several broad management strategies. Diverse views are prevalent about the superiority of one forest management strategy over the others, especially in relation to net benefits. These debates about net benefit cannot be solved from the current body of literature as they are mostly concluded by summing market values. Non-market values are usually not taken into account mainly because of the uncertainty of methodology and the difficulty in estimating those values. Consequently, total goods and services from forests are undervalued and their contribution to the national output has been grossly underestimated. As a result, land use decisions are generally biased in favour of land-use options other than forests. This paper analysed major issues on valuation of community forestry, an important forest management strategy in developing countries, and then developed methods for estimating net carbon sequestration amount, option value of biodiversity and onsite soil protection value of community forests after its handover to the designated communities.

Key words: carbon sequestration, biodiversity, soil protection, community forestry

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1. Introduction

Several forest management strategies including increasing protected areas, involvement of armed forces and establishment of new funds have been tried over the past decades to overcome the problem of deforestation (White and Martin, 2002). However, community forestry (CF) seems well suited to reducing resource degradation while improving rural livelihoods (Dev et al., 2003; Jodha, 1990; Malla et al., 2003). It is most popular in developing countries where at least 22 percent of the forests is community reserved or owned by communities compared to only three percent in developed countries (White and Martin, 2002). Around 32 percent of the total forest area of Benin and Cameroon, 37 percent of Burkina Faso, 46 percent of Zimbabwe, 90 percent of Congo (Potters et al., 2003), 18.42 percent in India (Government of India, 2002) and more than 18 percent in Nepal (CFDP, 2003) are under community management system. On current trends community forestry will be the dominant forest management strategy in developing countries (Maraseni *et al*., 2005).

There is widespread concern about the deforestation in tropical areas. Forest land continues to be cleared for soybean in Brazil, for oil palm in Indonesia and Malaysia (Filho, 2004) and for agriculture and pastureland in Australia (University of New South Wales, 1999). The massive shift in land use paradigms is mainly due to poor recognition of non-market values of forest arising from uncertainty of methodology and difficulty in calculations (Karki, 2002; Khanal, 2001; Maharjan, 2001; Pandit, 2002) and the consequent inability to develop appropriate incentives or payments to reflect non-market values. The emerging consensus is that 'without paying for ecosystem services, protection of forest is very difficult'. Several Bilateral, Regional and Multilateral Environmental Agreements including Kyoto Protocol and Convention on Biological Diversity show some recognition of this problem. Developing methodologies for non market values is important to develop payment regimes for regional and global environmental services thereby preventing the forest from being converted to non forest land.

Some mechanisms to pay for environmental services are in practice, for example, the Bush Tender Initiative and the Environmental Service Scheme in Australia (Cacho *et al*., 2003), National Forestry Finance Fund in Costa Rica (Zuniga, 2003) and an Emission-Biodiversity Exchange Project for the 21st Century (EBEX21) in New Zealand (Carswell *et al*., 2003). Due to different context and management strategies, these mechanisms as such are hard to apply in community forestry. In particular, these approaches rely on an individual having clear title to a designated area of land.

Nepal is a pioneering country in community forestry in the South Asian Region (Karki, 2002; Khanal, 2001; Maharjan, 2001; Pandit, 2002). Because of community forestry's increasing popularity it has been the mainstream of forest policy and programs since 1978, and Nepal plans to handover around 61 percent of its total forest to the communities (Chapaigai et al., 1999). Community forests are not only important for the livelihood of Nepalese people but also are equally important for carbon sequestration, biodiversity conservation and soil protection (Maraseni *et al*., 2005; NPC, 2001). At a national level, comparing the 1994 level to the 1960 level, the degraded environment recuperated, deforestation rate decreased (from 2.1 to 0.5 percent), mean stem volume of trees increased from 85 m^3/ha to 131 m^3/ha and the number of stems per hectare increased from 313 to 408. This is mainly because of community forestry programs (MFSC, 2003).

By examining relevant literatures and using the primary author's own extensive field experiences, this study developed methods for estimating net carbon sequestration amount, option value of biodiversity and onsite soil protection value of forest after its handover to communities. The study is organized as follows: Section two analyses literatures and presents some vital issues in valuation in community forestry. Section three presents methodologies for the estimation of net carbon sequestration amounts, option value of biodiversity and onsite soil protection values of community forest. Finally, Section four presents the key conclusion of the study. Earlier we had planned this methodology to test in the field before presenting in the World Forestry Congress but because of Maoist problem in Nepal we have deferred the idea until the problem is settled down.

2. Issues in the Valuation of Community Forest

This Section is divided into several Sub-Sections and major issues are discussed in each Sub-Section. Some minor technical issues are noted and the major methodological issues are considered more fully.

2.1 Issues in the Estimation of Biomass of Harvested Wood

One technical issue is that in Nepal, government and community forests are using the Quarter Girth (Hoppus) formula for the estimation of volume of harvested products. This formula assumes the value of pie (π) as 4 not 3.14. Therefore, it underestimates the volume of trees by 21.46 percent. For example, for a 5m long and 1m diameter log, Huber's formula (Volume= π x Diameter^2 x length/4) estimates 3.9267m^3 whereas Quarter Girth formula (Volume= Girth x Girth x length/16) estimates 3.0842m^3, around 21.46 percent less than Huber's estimate. Since biomass is the product of volume and density, underestimation of volume also underestimates the biomass. Therefore, to avoid this miscalculation, Smalian, Huber and Newton formula could be applied depending upon the availability of small end, mid end and large end diameter. These formula assumed the value of pie (π) as 3.14 not 4.

This tradition of using Quarter Girth formula has technical and administrative hassles too. In 1993, the main author was working as a government forest officer in the southern border of Nepal. A businessman imported logs from Malaysia, where Quarter Girth formula was not in use. They paid the custom as per Malaysian measurements. While giving the permission for sawing the author followed Nepalese rules for measurement of the logs. As a result, the volume of log reduced by 21.5 percent. It created a big technical issue and also incurred big transection costs. Again, an administrative problem started when measured volume of sawn timber (V=length x breadth x width) came around 110 percent. This was because of the administrative understanding that the volume of sawn timber should be around 70-80 percent if the log is in good condition.

2.2 Issues in the Estimation of Carbon Retention in Harvested Forest Products

The carbon sequestration rates of forests at the global and national levels are well researched but are poorly understood at a community level. Most studies are not empirical and have used different models, based on varying assumptions; consequently, the results are not consistent (Haripriya, 2001). For example, the Intergovernmental Panel on Climate Change (IPCC) uses a default approach and assumes that all harvested products emit carbon immediately after harvesting into the atmosphere. In fact, carbon may lock up in ranges of products, especially those who has long decay period (Haripriya, 2001). Locking carbon in wood products that has long decay period is a better option than locking carbon in the standing biomass that misses the opportunity of sequestrating carbon in the newly grown plantation (Jaakko Poyry, 2000). Depending on time period the forest products can retain carbon, they are classified into four different categories: very short (1 yr), short (3 years), medium (12 yrs) and long (30 yrs) (Haripriya, 2003).

Since most of the studies are of national or global level they have not considered household level pattern of forest products consumption. There are at least two issues that need to be analysed to undertake more accurate local estimations. First, at the community level, people use forest products as timbers, logs, poles, furniture etc. for some years and then use them for other purposes (such as for pole, fuel wood etc) when they become useless for those particular purposes. For each forest product, except fuel wood, we have to calculate carbon retention for the main uses then recalculate again and again for subsequent uses until it ends up as fuel wood. Second, *Shorea robusta* in Nepal (major timber species in lowland communities) is highly durable wood so its life span is at least around 300 years. Even for pine species, which is the main timber species in hill communities, the life span is not less than 100 years, this is because of smoke (from fuel wood burning) which acts as a natural preservative. Therefore, taking single value of life span for the same uses (e.g., for timbers) regardless of species is quite unreasonable. In addition, species specific values are highly recommended for the estimation of life span of each type of forest products.

2.3 Issues in the Estimation of Soil Carbon

Since the very beginning of this type of research, two methods (Walky and Black (W&B) and Combustion methods) of soil organic carbon (SOC) determination have been used. Some researcher claimed that the W&B method of wet oxidation, which uses potassium dichromate ($K_2Cr_2O_7$) as an oxidising agent, is not capable of measuring the total SOC but only that part which is easily oxidisable (e.g., Arrouays *et al*, 2001; Rayment, 1992). Others claim that the combustion method overestimates the carbon as it also burns the other material including organic matter (Frogbroook and Oliver, 2001; Rayment, 1992). There are scientific grounds for each of these conclusions. Currently, a more accurate method, Laboratory Equipment Corporation (LECO) combustion furnace model developed by St Joseph, Michigan, USA, is widely used throughout the world. In Australia, in order to make comparison more realistic, a number of conversion factors (1.07 to 1.34) for total soil organic carbon are developed to allow conversion of data generated in various analytical laboratories over a wide time span to values equivalent to LECO combustion values

(Skjemstad et al., 2000, although the LECO method is costly and rarely available in developing countries such as Nepal.

In soils, there are two forms of carbon; organic and inorganic. Available literatures have mainly focused on organic carbon but because of the improved forest cover (due to community forests), soil erosion may be decreased, thereby, inorganic soil compound may not be exposed to the rain and sun. Thus, because of the hindrance of hydration and thermochemical reactions, emission of CO_2 from inorganic compounds may be reduced. Further, erosion processes (detachment and transport) also expose the carbon to the atmosphere (Lal, 2001). Since carbon sequestration (CS) is the increase in carbon stocks other than in the atmosphere (IPPC, 2000) these functions of forests also come under CS. Therefore, while estimating the net carbon sequestration rates of forests soil, we should consider both organic and inorganic carbon.

2.4 Issues in the Valuation of Biodiversity

Valuing biodiversity is the most challenging task and what economic studies normally measure is the economic value of 'biological resources' rather than biodiversity (Bann, 1998; Nunes and Bergh, 2001; Pearce and Moran, 1994). Biodiversity is the ‘whole of life on earth’ whereas biological resources are simply those components of biodiversity which maintain current and potential human use (Pearce and Moran, 1994). Contingent valuation (CV) approaches are perhaps the most promising approach for the valuation of biodiversity (Nunes and Bergh, 2001), however, it has not been attempted in developing countries (Bann, 1998; Jakobsson and Dragon, 1996). This method has suffered from several methodological issues and criticisms (Gowdy, 1997; Hanemann, 1994; Jakobsson and Dragon, 1996; Nunes and Bergh 2001; Portney, 1994). Recently one criticism has been emerging; whether the respondents respond to questions as ‘consumer or citizen’ (Jakobsson and Dragon, 1996). If so, it is not rational to compare ‘citizen’ willingness to pay (WTP) value with ‘consumer’ value. Some of the concerns about the CV method could be overcome by following a comprehensive set of guidelines of the National Oceanic and Atmospheric Administration (NOAA) Panel (Gowdy, 1997; Hanemann, 1994; Jakobsson and Dragon, 1996; Portney, 1994) which is also accepted by the US legal system and World Bank (Hanemann, 1994).

The current studies on comparison of biodiversity are based only on species richness and estimation of different index values. These analyses do not reveal how closely these species are interrelated, an important feature of ecosystems. Further, there is virtually no research on the impact of community forestry (CF) on ecosystem level of biodiversity. In the case of CF, the original chunk of forest (ecosystem) is often divided into small patches during the course of handover to the different user groups. Since each user group has its own choices of species for their particular purposes, the management strategy of one user group may be different from those of nearby user groups. Thus, even if the species richness may be the same (by planting one and removing another) in both communities, it has a greater impact at the ecosystem level. The impact is more critical if keystone species of original ecosystem are lost during the course of management and species manipulation.

There is also a big knowledge gap in the estimation of the bequest value of biodiversity. Though bequest value is categorised as non-use value, it is really a special case of option value as it represents the value (to current users) of being able to bequeath the forest to future generations (Davies and Richards, 1999; Pearce and Turner, 1990). It is not like existence values which are certainly fuzzy values (Pearce and Turner, 1990) and which accrue mainly to people who do not use the forest, and may never see it except in books (Davies and Richards, 1999). If the bequest is for immediate descendents, preferences will be higher than for future generations in general (Pearce and Turner, 1990). In the communities of developing countries (like Nepal, India, etc.), where people are more religious and believe in incarnation and saving much for future generations, forest users may have significant amount of willingness to pay to bequeath the forest to their children and grandchildren.

Finally, the option value of medicinal benefit of plants estimated so far (e.g. by Pearce and Puroshothaman, 1992; Pearce and Moran, 1994) are highly speculative as this value typically lies in undiscovered species of unknown uses (Bann, 1998). Major criticism surrounds estimations of the ex-ante values to products that have not been identified (Bann, 1998; Gregersen, 1995) and even if we like to apply this concept in developing worlds, those parameters are not available (EEP, 2003).

2.5 Issues in the Estimation of Onsite Soil Protection Value

Protection of soil inside the forest is important in several ways. It reduces flooding and siltation problems in the downstream area. The protected nutrients can be utilised by plants and thereby maintain strength of the ecosystem. Therefore, we also need to find the onsite soil protection value of forest. However, it is poorly researched and whatever has been done, even in the developed countries, is generally related to offsite or downstream benefits and costs rather than onsite effects (Davies and Richards, 1999). There is then the problem of accuracy in measurements of the nutrients in soils. While comparing 16 phosphorus extraction methods practiced in Europe, Neyroud and Lischer (2003) found different results. Also, a large variability was observed in the results obtained by laboratories using the same method, highlighting the importance of using identical lab procedures in any comparison.

Finally, there is the issue of the form of the nutrients. In soil, macronutrients are found in different forms. For example, nitrogen may be in organic form (immobilised) or inorganic form (mineralised in NH_4^+, NO_3^-, NO_2^- forms) or in de-nitrated form (trapped in air space). Similarly, phosphorus may be in extractable, available or non available forms, and Ca, Mg, and K may be in the exchangeable and non exchangeable form. Since each nutrient has its own cycle, one form of nutrient may convert to another form once conditions are suitable. While estimating the soil protection value with the help of nutrient analysis we must estimate the total amount of each nutrient rather than estimating the available or exchangeable forms; otherwise we may underestimate the soil protection value. The problem is that most of the current research is focussed only on available or exchangeable or extractable forms of nutrients because their major focus is on the agricultural sector, where these forms are most important. This leads to incomplete 'accounting'.

3. Proposed Methods for Evaluating Net Benefits from Community Forests

Under this Section we present the methods for the estimation of net carbon sequestration amount, option value of biodiversity and onsite soil protection value of community forests. On top of that, a format of estimating bequest value of biodiversity using contingent valuation method is presented in Annex-1.

3.1 Net Carbon Sequestration Rate of Community Forests

3.1.1 Estimation of Net Carbon Stock in Soil

In order to cover the varieties of forests and soil types, the sample plots could be designed along the elevation gradient. The randomization and probabilistic sampling should be followed as it is considered better than purposive sampling to reduce human biases. Number of sample plots in a community forest depends on its size and variation in terms of forest and soil types. Five samples could be taken in each sampling plot (25m x25m), four at a regular interval of 90^0 and one at the centre, by digging a hole in the ground to a depth of 30 cm. The soil could be sieved using two mm sieve, and stones and roots should be separated and their masses should be taken. Stone volume could be determined using a specific gravity of 2.65 Mg/M^3. The volume occupied by the fine (<2 mm) material of each horizon should be quantified by subtracting stone volume from total sampled volume. Soil samples taken under the same dominant species and similar elevation gradation should be mixed-up homogeneously and final composite soil samples of 200 gm should be prepared. The oven dry mass of soil should be determined using an oven at 104^0C. Then, using oven dry weight and volume of soil, the bulk density (BD) of soil could be determined. Alternatively, disturb soil method (Tan, 1996) could be followed for the estimation of Bulk Density. For the estimation of soil carbon, the best available methods in the respective country that could account both organic and inorganic carbon could be used. Then the amount of carbon (C in gm/m^2) could be estimated (Garten, 2002) as follows:

$$C = B \times S \times D$$

where, B is the bulk density of soil (kg dry soil/m^3), S is the soil carbon concentration (gm carbon per kg dry soil) and D is the depth of the soil sample taken in meter (D = 0.3m)

The foundation members of community forest could be consulted to know the previous condition of community forests and to identify the reference sites in the same locality. Then, the same sampling methodology could be applied for reference samples (pair sample). The carbon content of reference sites could be deducted from the carbon content of current forest soil to get the net carbon stock in soil because of the community forest.

3.1.2 Estimation of Total Carbon Stock in Standing Biomass, Coarse Debris, Stumps and Surface Litter

Standing Biomass: For the inventory, the whole area of community forest could be divided into different strata based on their forest types and regeneration conditions, and stratified random sampling (SRS) could be carried out. Based on the homogeneity of forest strata, and national and international guidelines for the desired precision, sampling intensity could be fixed. It is better to use circular plots rather than rectangular and square sample plots for the minimisation of edge effects. Higher the slope lower will be the horizontal length for a given slope length. Therefore, slope correction, especially in hilly area, while laying out sample plot is highly recommended. Otherwise even in the identical forest, the estimated biomass in the sloppy area would be lower than the flat area.

For the estimation of biomass, it is better to use allometric equations or local biomass table prepared for that species and for that community. Applying general biomass table could be detrimental especially in the country of highly variable topographic and edaphic sites like Nepal. If the biomass estimated as above is not oven dry biomass, it could be estimated with the adjustment of moisture content. For example, if the biomass calculated as above method is at 12 percent moisture content (usually given in the biomass/volume table) the oven dry biomass could be estimated by dividing the total biomass by 1.12. The above ground biomass of the standing stock could be converted into total biomass (both above and underground) multiplying by certain factor which depends on climatic zone (for detail see Haripriya, 2000). Then, the total carbon in forest standing biomass could be estimated by using a conversion factor of 0.5 for biomass (Haripriya, 2001; IPCC, 1996)

Coarse wood (CW): In cases of community forest, there are fewer chances of having coarse wood, stump and leaf litter because of frequent collecting by users. Diameter of coarse wood (>25 mm diameter) found in each sample plot should be measured. The volume of each piece could be determined by using Newton's formula (if able to measure both ends and middle diameters of CW), Smalian's formula (if able to measure only both end diameters) and Huber's formula (if able to measure only at mid diameter).

Two samples of each debris type could be cut by pruning saw for density and carbon analysis. The oven dry weight of wood should be taken by putting in an oven for 24 hours only at 65-75^{0}C as higher temperature causes pyrolysis and decomposition of organic compound and volatilization of vegetable oils. Once the volume of coarse wood is known it should be multiplied by density to get the biomass. But the total biomass should be adjusted with the degree of deterioration of woods. The total biomass (t/ha) could then be converted into the total carbon mass (t/ha) by adjusting dry weight mass, carbon percentage and expansion factor for sampling area.

Stumps: Stumps are considered as coarse wood debris (McKenzie *et al.*, 2002; McKenzie *et al.*, 2000). However, for the simplicity of explanation, it is better to put in different headings. The biomass of stump could be determined with the help of age of stump (time after harvest) and its volume by applying carbon retention formula (Row and Phelps, 1990; Haripriya, 2001; Haripriya, 2003). The age of stumps in community forest could be determined by consultation with elder people of community. In many cases stumps would be much older or they might caught by fire so the age could not be established. In such cases we could do as follows.

Diameters of all stumps found in the sample plot should be measured at two places; at the ground level (DGH) and at the top of the stump (DTH). Total heights of all stumps and their deteriorating conditions should be recorded. Two samples of each stump type should be cut by pruning saw for density and carbon analysis. The above ground volume of each stump should then be estimated using Smalian formula. The percent lost should be deducted to get net aboveground volume of stump. The biomass of stump should be estimated by multiplying density and net volume of the stump.

Below ground biomass of stump could be difficult to determine as there is no methodology developed so far. For this, we could determine the tapering factor of each stump with the help of diameters {diameters at ground height (DGH) and top height (DTH)} and height of the stump, which, in turn could be used to estimate the diameter at breast height (DBH) of stump as follows:

$$\text{DBH} = \text{DGH} - \frac{\text{DGH} - \text{DTH}}{\text{H}} \times 130$$

For example, if the diameters of stump at ground and top height are 40 cm and 30 cm and the height of stump is 100 cm then the tapering and diameter at breast height become 10 cm/100 cm and 27 cm, respectively.

While estimating the DBH from this method it is assumed that the tapering factor between the two diameters also applied up to the breast height (130cm). With the diameter at breast height known we could apply the allometric formula or biomass table of that species to get above ground gross biomass. As we have no any alternatives, we could assume that the percentage loss of stump would be equally applicable to the percentage loss of above ground biomass and below ground biomass. On the basis of this assumption, we could estimate the net above ground biomass. Then, the net root biomass of stump could be determined by applying an appropriate root shoot ratio of that particular eco-climatic zone (see Haripriya, 2000).

Leaf-litter: The amount of leaf litter (2-25 mm) in the forests could be determined with the help of a regression equation prepared for that locality, with the above ground biomass as independent variable and litter amount as a dependent variable (Mohns et al., 1988). More precisely, it could be estimated by making a five meter radius circular plot at the central point of soil/biomass sample plot. The sample plot then could be divided into three parts on the basis of light, medium and heavy litter content types. The fraction of area of each litter content type could be estimated. In each litter content type four quadrants of 50cm x 50cm could be selected randomly and a steel frame of that size could be laid over the plot. All surface litter within the steel frame should be collected and weighed in the field with the help of calibrated spring balance and bucket. The fresh weight of surface litter per ha could be calculated as follows.

$$\text{Fresh weight (kg/ha)} = \sum \text{Ai} \times \text{Wi} \times 10{,}000$$

where 'A' is the fraction of area (in percentage) and 'W' is fresh weight (from four quadrants) of surface litter (in kg) of a given surface litter content type (i). If there are more than one sample plot, then the average of all sample plots should be taken for the estimation of fresh weight (kg/ha). One sample could be prepared and transferred to the lab for estimation of dry weight and carbon content. The fresh weight could then be converted to dry weight using conversion factor (by multiplying fresh weight with dry weight and fresh weight ratio) and per ha carbon content could be estimated by simply multiplying dry weight with percent of carbon content by weight.

$$\text{Dry weight (kg/ha)} = \text{fresh wt (kg/ha) x dry wt fresh wt ratio}$$

$$\text{Carbon content (kg/ha)} = \text{dry weight (kg/ha) x carbon percent by dry weight}$$

3.1.3 Estimation of Carbon Retention in Forest Products

Community records could be used to estimate the annual harvesting rates and the end use of the products. If records are not available, a detailed household survey could be carried out. Users may not recall the amount of forest products harvested and used for different purpose in different years since the handover of forest to them. Therefore, if the household size is the same, the harvested amount and their different uses could be assumed to be the same in each year as current year. If the household size is different it could be estimated on the basis of current and past proportions of household size. The life span of those particular end-uses and their subsequent uses could be identified by organising a teashop meeting. Even for a given use (for example, for timber) the life span of each species should be considered separately as each species could have different life span. With the help of life span and end uses and their subsequent uses, the amount of carbon retention in the harvested products since the initiation of community forestry could be determined by using the formula given by Row and Phelps (1990) as follows.

$$\text{Carbon retention (proportion)} = d - \frac{a}{1 + b\,e^{-CT}}$$

where, 'a', 'b' and 'd' are unit less quantities. 'C' is the decay rate which varies with ecoclimatic zone, species used, condition of uses and end uses (which determines half life period) and 'T' is the age (time) of pools and products in year (see Haripriya, 2001).

3.1.4 Net Carbon Sequestration Rate of Community Forests

The amount of carbon in the forest (including coarse wood, stumps and standing trees) before community forest (M) could be taken from the operational plan of community forest while the soil carbon (N) could be estimated from the soil analysis of reference sites (pair sites). If the community had not inventoried the forest before handover or if they have lost the records, imagery or aerial photograph can be used for the estimation of before handover biomass. If that is not possible, select the reference site (that had similar forest biomass before handover) with the consultation of elder people of the communities and apply the same method of biomass estimation as discussed above. However, it is not recommended unless there is any alternative, because of accuracy reasons. The current amount of carbon stock in the forest biomass (J) and in soil (K) and total carbon retention in harvested biomass (L) since the initiation of community forest could be estimated as above. Then, the net carbon sequestration rate of CF could be estimated as follows:

$$\text{Net carbon sequestration} = \text{J} + \text{K} + \text{L} - \text{M} - \text{N}$$

$$\text{Net carbon sequestration/yr} = \frac{\text{J} + \text{K} + \text{L} - \text{M} - \text{N}}{\text{Age of Fommunity Forest (yr)}}$$

3.2 Valuation of Biodiversity

Many investigators agree that the species richness is one of the main indicators of biodiversity. Species richness increases from pole to equator (Pearce, 2001) and decreases with elevation (Bhattarai and Vetaas, 2003 cited in Kikawa and Williams, 1971; Gentry, 1988; Patterson et al., 1998; Wolda, 1987). Considering this, in the community forests, the transect lines for the estimation of species richness could best be made along the elevation gradient. Many studies suggested the plot size of 0.1 ha for biogeographical comparison of species richness (Bhattarai and Vetaas, 2003 cited in Whittakar 1963, 1996; Whittaker; Woodwell, 1969). Since we are interested in the community forests and usually they are small in size and cover limited elevation range a smaller plot size could be used (for e.g., 0.05 ha). As there will be several sample plots in a community forest in the small elevation range, it may be possible to document all the available species in the community forest.

The name and number of the individual species could be recorded with the help of local experts (local dendrologist). There may not be species recording system prior to handover of community forest. Therefore, a workshop could be organized to 'recall' the name of species occurred prior to handover of community forests. Simpson's and Shannon's diversity indices and their equitabilities could be calculated which not only show the species richness but also the evenness among the different species. Similarly, Sorensen's index could be used to reveal the relative dissimilarity in diversity between any pair of communities under study and to know whether there is a similarity of diversity between the exterior and interior sample plots of the same community forest (see biodiversity related books for the calculation of indices).

3.2.1 Option Value of Biodiversity

Option value is the value for possibility of using species in the future. Loosing species means loosing its potential use values too. For the option value of biodiversity, the formula given by Pearce and Puroshothaman (1992), and Pearce and Moran (1994) could be modified. We could find the number of species in-/decreases (NR) in past years because of community forest and current number of medicinal plants out of total plants by organising a workshop, which gives probability of successful medicinal plant (P) lost/achieved. As these medicinal plants are used locally, the royalty rate and coefficient of rent captured by community is 100 percent (R =1 and A = 1). The average value of medicinal plant (Vi/n) is the value perceived by users that could be found while finding the medicinal use value (substitute method) of plant through household survey. Then, the option value of biodiversity conservation could be calculated using the following formula where 'H' represents the area of community forest in ha.

$$\text{Medicinal value of biodiversity land/ha} = \frac{\text{NR x P x R x A x Vi/n}}{\text{H}}$$

3.2.2 Estimation of Bequest Value of Biodiversity

Bequest value of biodiversity refers to the value of leaving current biodiversity for the coming generation. For the estimation of this value, contingent valuation method (CVM) could be used. In every step of CVM, the guidelines of National Oceanic and Atmospheric Administration panel (Portney, 1994) could be followed. Some important steps and explanations, as for an example, are presented in Annex-1.

3.3 Onsite Soil Protection Value of Community Forest

For the estimation of onsite soil protection value, first, we should estimate the net amount of soil protected from erosion because of community forests. Then, we can estimate the onsite soil protection value with the help of this data and soil nutrient analysis.

3.3.1 Estimation of Net Onsite Soil Protection Amount

If a country has good records of different layers we can use GIS and then the Universal Soil Loss Equation to determine the erosion rate of different types of forest in a given locality. In such cases the conditions of forest before handover (as a references site) should be identified very precisely. Considering the cost and time requirements, the soil erosion data could be taken from past studies of the larger area which may be the district or watershed area to which the area in question belonged.

As most of the studies (for example see, Balla, 1983; Gerrard, 2002; Impat, 1978; Raghunath, 2002; Shrestha and Zinck, 1999) followed the Universal Soil Loss Equation (i.e., RKLSCP), the values of rainfall erosivity factor (R), soil erodibility factors (K) and conservation practices factor (P) could be more or less similar to the current situation. Since the topographical factor (slope length, L and slope gradient, S) plays the major role in soil erosion, the average topographical factor value (LS value) used for each category of land (in past study) could be readjusted by the exact average topographical factor value of that particular community forest. The average LS factor can be found by using a digital elevation model or roughly it can be done by measurement. The crop management factors (C) which represent the combined effects of crown cover (CC) and ground cover (GC), is expected to change because of community forest. Current and before community forest, CC and GC could be determined by image analysis of two different time periods or alternatively older people of community could be consulted. Then, after adjusting crop management factor (C) and topographical factor (LS) values of each community forest, the soil erosion rate of current and before handover could be estimated. Then, the differences of erosion rate of current forest and references site gives the amount of onsite soil protected due to community forest.

3.3.2 Onsite Soil Protection Value from Nutrient Analysis

The same soil sampling method used for the estimation of carbon could be used in this case too. By suitable methods (that could account total amount of each nutrient regardless of their forms), the total amount of each nutrients found in the soil could be calculated. The market price of frequently used fertilizers for N, P, K, Ca, Mg, S and lime could be the starting point and adjusted with the labor cost of transportation. The molecular weight of fertilizer and the atomic weight of that macronutrient under valuation could be determined easily with the consultation of inorganic chemistry book. In many fertilizer bags the total weight of fertilizer and amount (or percentage) of main nutrient is written clearly. Once having all those information, the price of that particular nutrient could be determined by applying following formula.

$$\text{Price of nutrient/kg} = \frac{\text{price of one bag fertiliser} + \text{labor costs}}{\dfrac{\text{atomic weight of nutrient x weight of one bag fertiliser}}{\text{molecular weight of fertiliser}}}$$

By multiplying the amount of nutrient found in that soil (kg/ha) and the price of that fertilizer we can easily estimate the onsite soil protection value of forest. For example, if the fertilizer is Muriate of Potash (KCl), the hypothetical market price is \$50 per 50 kg bag and the labor costs from market to village is \$5/bag then, the value of each kg of Potassium (K) will be calculated as follows.

$$\text{Price of potassium (K)} = \frac{\$50 + \$5}{\dfrac{39.0983\text{ gm x }50\text{ Kg}}{74.55\text{ gm}}} = \$2.097/\text{kg}$$

As most of the fertilizers are not pure, their purity could be found out with the consultation of factory personnel. We should find the exact value (price) of nutrients by dividing the prices by the fraction of purity. For example, if the purity of muriate of potash fertilizer is 80 percent, then the price of one kg potassium would be \$2.62 (\$2.09/ 0.8).

After finding the current and before handover soil erosion rates of community forests we can estimate the amount of net onsite soil protected. By multiplying the amount of nutrients found in the protected soil and their equivalent fertilizer prices (purity corrected) we can calculate the net onsite soil protection value of community forest.

4. Conclusion

Community forestry (CF) is gaining popularity as a better forest management option especially in developing countries. Being a dominant management strategy, it is equally important for the livelihood of local people and regional and global environmental services. Lack of recognition of non-market value of forest, rapid globalization, improved communication system, easy market access and improved transport infrastructure could lead the CF towards commodity production oriented systems, which may ultimately reduce the local/regional/global environmental services. Considering this, the global beneficiaries can be persuaded or induced by policies and agreements to pay for their contribution. Even at national and regional levels demands for environmental services have been increasing.

The major problem in pricing non-market values in forests is the ‘unavailability of suitable contextual methodologies’. Our study developed methods for the estimation of net carbon sequestration, option value and bequest value of biodiversity and onsite soil protection value of CF. These methods have important implications at a local level, where communities can collect and use these data to develop optimal production regimes. They may also be used to set appropriate prices. Although these methods are developed for CF, they could be equally applied for any types of forest if the context is similar.

References

Arrouays, D., W. Deslais, et al. (2001). "The Carbon Content of Topsoil and its Geographical Distribution in France." Soil Use and Management 17(1): 7-11.

Balla, M.K. (1983). *Developing a Scheme for Application of the USLE in Nepal*, MFR-Applied Research Report, UGA, Georgia, USA,

Bann, C. (1998). The Economic Valuation of Tropical Forest Land Use Options: A Manual for Researchers.

Bann, C. (2003). An Economic Analysis of Tropical Forest Land Use Options. Ratanakiri Province Cambodia.

Bhattarai, K. R. and O. R. Vetaas (2003). "Variation in Plant Species Richness of Different Life Forms Along a Subtropical Elevation Gradient in the Himalayas, East Nepal." Global Ecology and Biogeography 12(327-340).

Chapagai, D. P., K. R. Kanel, et al. (1999). Current Policy and Legal Context of the Forestry Sector with Reference to the Community Forestry Program in Nepal, A working over view. Kathmandu, Nepal, Nepal-UK Community Forestry Project.

Davies, J. and M. Richards (1999). The Use of Economics to Assess Stakeholder Incentives in Participatory Forest Management, European Union Tropical Paper 5, Overseas Development Institute. London.

Dev, O. P., N. P. Yadav, et al. (2003). "Impact of Community Forestry on Livelihoods in the Middle Hills of Nepal." Journal of Forest and Livelihood 3(1): 64-77.

Environmental Economic Program (EEP, 2003). Valuing Forests, A Review of Methods and Applications in Developing Countries. London, International Institute for Environment and Development: 167.

Filho, M. S. (2004). Opening Address. Climate Change and Forest Sector: Clean Development Mechanism in Tropical Countries, September 21-23, 2004, Seoul, Korea, Seoul National University, Seoul, Korea.

Frogbrook, Z. L. and M. A. Oliver (2001). "Comparing the spatial predictions of soil organic matter determined by two laboratory methods." Soil Use and Management 17(4): 235-244.

Garten, C. T. C. T. (2002). "Soil carbon storage beneath recently established tree plantations in Tennessee and South Carolina, USA." Biomass and Bioenergy 23(2): 93-102.

Gerrard, J. (2002). *Land Sliding, Runoff and Soil Loss, Middle Hills, Nepal*, viewed 12/9/ 2003, <http:/www.mtnforum.org>.

Government of India (2002). Joint Forest Management: A Decade of Partnership, Ministry of Environment and Forests, New Delhi.

Gowdy, J. M. (1997). "The Value of Biodiversity: Markets, Society, and Ecosystems." Land Economics 73(1): 25-41.

Gregersen, H. M., J. E. M. Arnold, et al. (1995). Valuing Forests: Context, Issues and Guidelines, Forestry Paper no 127. Food and Agriculture Organization of the United Nations, Rome.

Hanemann, M. H. (1994). "Valuing the Environment Through Contingent Valuation." Journal of Economic Perspectives 8: 19-43.
Haripriya, G. S. (2000). "Estimates of Biomass in Indian Forests." Biomass and Bioenergy 19: 245-258.
Haripriya, G. S. (2001). Carbon Budget of Indian Forest (Revised Version Submitted to Climate Change on 20.6.2001). Andhra Pradesh, India.
Haripriya, G. S. (2001). "Managing Forests in India to Mitigate Carbon." Journal of Environmental Planning & Management 44(5): 701-720.
Haripriya, G. S. (2003). "Carbon Budget of the Indian Forest Ecosystem." Climate Change 56: 291-319.
Impat, P. (1978). *Hydrometeorology and Sediment Data for Phewa Watershed: 1979 Data, Project Field Document, IWM/PTR #15*, HMG/UNDP/FAO, IWM Project, Nep/74/020, Ministry of Forest and Soil Conservation, Nepal,
Intergovernmental Panel on Climate Change (IPCC) (1996). Chapter 5, Land-Use Change and Forestry, Revised Guidelines for National Greenhouse Gas Inventories: Reference Manual.
Intergovernmental Panel on Climate Change (IPCC) (2000). Land use, Land-use Change and Forestry. A Special Report of the Intergovernmental Panel on Climate Change. R. T. Watson, I. R. Noble, B. Bolinet al, Cambridge University Press, Cambridge, UK.
Jaakko Poyry Consulting (2000). Analysis of Wood Product Accounting Options for the National Carbon Accounting System, National Carbon Accounting System, Technical Report no 24, Greenhouse Office, Canberra.
Jakobssan, K. M. and A. K. Dragun (1996). Contingent Valuation and Endangered Species: Methodological Issues and Application. The Contingent Valuation Method. Wallace E. Oates. Britain, Cheltenham, UK. Broodfield US.
Jodha, N. S. (1990). Rural Common Property Resources: Contributions and Crisis. Economic and Political Weekly, 21:A65-A78.
Karki, D. (2002). Economic Assessment of Community Forestry in Inner *Terai* of Nepal: A Case Study from Chitwan District, Asian Institute of Technology, Thailand.
Khanal, K. P. (2001). Economic Evaluation of Community Forestry in Nepal and its Equity Distribution Effect, The Royal Veterinary and Agricultural University, Denmark.
Lal, R. (2001). "Soil Degradation by Erosion." land Degradation & Development 12: 519-539.
Maharjan, M. R. (2001). Cost and Benefit Sharing for Equitable and Sustainable Community Forest Management in the Eastern Region of Nepal, Faculty of Humanities and Social sciences, Tribhuwan University, Kathmandu, Nepal: 531.
Malla, Y. B., R. N. Hari, et al. (2003). "Why aren't Poor People Benefiting More from Community Forestry." Journal of Forest and Livelihood 3(1): 78-92.
Maraseni, T. N., G. Cockfield, et al. (2005). "Community Based Forest Management Systems in Developing Countries and Eligibility for Clean Development Mechanism." Journal of Forest and Livelihood 4: 31-42.
Maraseni, T. N. (2002). Harvesting Techniques and Market Analysis of Selected Non-Timber Forests Products in Makawanpur District, Nepal, Asian Institute of Technology, Thailand.
Ministry of Forest and Soil Conservation (MFSC) (2003). National Report to the Third Session of the United Nations Forum on Forests. Singhdurbar, Kathmandu, Nepal, Ministry of Forest and Soil Conservation.
NPC (2001). Mid-Term Evaluation of the Ninth Five Year Plan, National Planning Commission, Kathmandu, Nepal.

Nunes, P. A. L. D. and J. C. J. M. V. D. Bergh (2001). "Economic Valuation of Biodiversity: Sense or Nonsense?" Ecological Economics 39: 203-222.
Pandit, R. (2002). Institutionalizing Forest User Groups Through the Practice of Community Forestry in Nepal: A Case Study in Tanahun District, Western Development Region, Asian Institute of Technology, Thailand.
Pearce, D. W. and D. Moran (1994). The Economic Value of Biodiversity. London, Biodiversity Program of IUCN, Earthscan Publications Ltd.
Pearce, D. W. and S. Puroshothaman (1992). Protecting Biological Diversity: the Economic Value of Pharmaceutical Plants., Global Environmental Working Paper 92-27. CSERGE, UEA and UCL, London.
Pearce, D. W. and R. K. Turner (1990). Economics of the Natural Resources and the Environment, Harvester Wheatsheaf, Britain.
Portney, P. R. (1994). "The Contingent Valuation Debate: Why Economists Should Care." Journal of Economic Perspectives 8(4): 3-17.
Potters, J., D. Reeb, et al. (2003). The Process of Participatory Forestry in Africa. Second International Workshop on Participatory Forestry in Africa, FAO (http://www.fao.org/DOCREP/006).
Raghunath, J. (2002). 'Potential Erosion Map for Bagmati Basin Using GRASS GIS', paper presented to Open Source GIS-GRASS Users' Conference,11-13 September, Toronto, Italy
Rayment, G. E. (1992). Australian Laboratory Handbook of Soil and Water Chemical Methods. Melbourne, Australia, Inkata Press.
Row, C. and R. B. Phelps (1990). Tracing the Flow of Carbon through U.S. Forest Product Sector, Prepared for the 19th World Congress, International Union of Forestry, Research Organizations, Montreal, Canada, August 11, 1990.
Shrestha, D.P. & J.A. Zinck (1999). 'Land Degradation Assessment Using Geographic Information System: A Case Study in the Middle Mountain Region of the Nepalese Himalaya.' paper presented to International Conference on Geoinformatics for Natural Resource Assessment, Monitoring and Management, 9-11 March 1999, IIRS, Dehradun, India.
Skjemstad, J. O., L. R. Spouncer, et al. (2000). Carbon Conversion Factors for Historical Soil Carbon Data, National Carbon Accounting System, Technical Report no 15, Australian Greenhouse Office, Canberra, Australia.
University of New South Wales (1999). Australian Environmental Policy 2. University of New South Wales, Sydney Australia.
White, A. and A. Martin (2002). Who Owns the World's Forests? Forest Tenure and Public Forests in Transition, Forest Trend, Washington, D.C.
Zuniga, J. M. R. (2003). "Paying for Forest Environmental Services: the Costa Rican Experience." Unasylva 54: 3.

Annex-1: Format for the Determination of Bequest Value of Biodiversity

1. The Scenario Development

In general, endemic species are most endangered to extinct. There may be several known and unknown endemic or endangered species in your community forest. Who knows, with the advancement of science and technology the germ plasm of these known and unknown species may have great financial significance. Moreover, there are about thousands of known and unknown chemical compounds occur in plant and animal tissues. Nobody knows what invaluable use could be made from them in the future.

Species loss is irreversible (Gowdy, 1997; Hanemann, 1994; Jakobsson and Dragon 1996; Portney, 1994) and we can not estimate the marginal value of biodiversity, as one species may affect the whole ecosystem (Gowdy, 1997). Please remember that your children and grandchildren have equal right of enjoying species as we have. As a religious people and responsible citizen, you may respect their right and the principle of intergenerational equity. Also, the earth is not only a home of *Homo sapiens*; it is a home of millions of species including us. All species have equal right to live in and maintain their existence as we have and do. To conserve them and to respect the right of future generation is our moral and ethical responsibility too. There are several types of community forests with different species composition that you might have seen around your territory. It is assumed that you know the species found in your community forest and their importance as direct use, indirect use, option, quasi-option, existence and bequest values better then the users of other community forest. However, please be informed that we are not going to find out the direct and indirect use values through this process. We are interested only on bequest value.

2. Pre-testing of Questionnaire and its Final Setting

To reduce the outlier responses and to find the iterative values, discrete choice (dichotomous choice or bidding game or referendum) questionnaire could be asked. During the reconnaissance survey the questionnaire could be pre-tested using an open-ended willingness to pay question in a group of users, to find out the average of bidding range (dollar amount/labour-days).

The exact wording of the question could be as follows*: Would you vote in favour to increase in your annual community forest fee in terms of money……. $ (or ……….labour-days) each year to maintain the current species composition (biodiversity) for its bequest value (for your children and grandchildren)?*

Yes (   )   No   (   )

If 'yes' what highest amount/labour-days you would pay?

If 'no' why you say 'no'? What lower amount/labour-days you would pay?

3. Elicitation Methods and Analysis

Face-to-face interview is most preferred survey method for the elicitation of willingness to pay (WTP) value which could help respondents to make understanding of the scenario and thereby minimizes the chances of non-response. The vehicle of the payment may be either in the form of labor-days (as the communities may not be familiar with market mechanism) or increase in annual fee to the community forest. As the household (HH) could be the unit of the measurement, the HH income should be considered as reference income, and the characteristic of respondent like gender, caste, education, occupation and age should be noted for statistical and empirical analysis. The better way of comparison of WTP value with other countries' (other users) value could be the WTP as a percent of total income.