Chapter 4

Opportunity costs of reducing CO_2e emissions from deforestation and forest degradation in the Terai Arc Landscape of Nepal

Abstract

Estimation of opportunity cost of avoided deforestation and forest degradation is the crucial step to understanding the economic viability of C emissions reductions through the proposed incentive mechanism REDD+ (Reducing emissions from deforestation and forest degradation, conservation, sustainable management of forests, and enhancement of forest carbon stocks). We applied a bottom-up approach using forest, carbon density and agriculture data from 15 districts in the Terai Arc Landscape of Nepal to estimate the costs of CO_2e emissions reductions. After considering the most likely areas of forest conversion into agricultural crop production integrated with livestock farming, we calculated the opportunity cost of emissions reduction from avoided deforestation is US$ 8.95 per Mg CO_2e.The study reveals that emissions reduction from avoided forest degradation is cheaper (US$ 3.77 per Mg CO_2e) than emission reduction from avoided deforestation. Our estimated opportunity costs are higher than those reported in earlier global studies and are attributed to higher agricultural returns and lower carbon density in the forest of the Terai Arc Landscape. Levels of financing based on earlier estimates may be insufficient for effective emissions reductions from avoided deforestation and forest degradation. Policy makers need to be cautious when using available global estimates and values to design any REDD+ strategy and framework.

Keywords: Opportunity cost, REDD+, Emissions Reduction, Deforestation, Forest Degradation

4.1 Background

The potential roles of the proposed REDD+ mechanism to reduce emissions from deforestation and forest degradation, conservation, sustainable management of forests, and enhancement of forest carbon stocks in developing countries require economic evaluation in the process of developing national and sub-national REDD+ frameworks. The starting point is an assessment of the costs per unit of emissions reductions. This information on REDD+ is important for both investors and policy makers because it helps both parties assess how much benefit is received in return for investments made, that ultimately will determine the attractiveness of REDD+ for greenhouse gas (GHG) emissions reductions. Broadly, the cost information allows potential investors to judge if REDD+ payments will make efforts to avoid deforestation and forest degradation attractive in the particular region or country. The profitability of the REDD+ program is determined by the costs associated with the program and payment per unit of emission reduction.

Although the estimates (Blaser & Robledo, 2007; Grieg-Gran, 2009; Strassburg et al., 2009) vary greatly, they suggest that the potential for reducing emissions through avoided deforestation is massive and inexpensive. They were estimated using different costs; viz., opportunity cost, implementation cost, transaction cost and institutional cost (Merger, Held, Tennigkeit, & Blomley, 2012; Pagiola & Bosquet, 2009; White et al., 2011) associated with the REDD+ program. Opportunity cost is the foregone benefit; e.g., from agricultural crop production, on conserved forest land that could have been used for other economic activities. The costs directly associated with the activities required to reduce the deforestation and forest degradation and to enhance carbon stocks are the implementation costs. These costs include capacity building activities, patrolling and guarding against illegal logging and encroachment, intensifying agriculture and promotion of alternative energy supplies to substitute for fuel wood amongst others.

The expenditures incurred during the design and contracting process of REDD project, monitoring, reporting and verifying (MRV) emissions and other carbon market related compliance costs are covered under transaction costs. These are separate from implementation costs because such activities do not directly contribute to reduce deforestation and forest degradation. These expenditures are crucial to access and realise REDD+ payments through the interactions of buyer and sellers, or donors and recipients and external third parties. Institutional costs are related to building and enabling environment to make REDD+ operational. These costs vary from regulatory processes to building institutions, strengthening land tenure, to national stakeholder consultations and decision making costs. This is the additional REDD+ related institutional investment besides the business-as-usual traditional forestry activity budget.

Deforestation and forest degradation are not always harmful. These activities can bring benefits to the land owner or resource manager. Timber from logging is still a major source of revenue in most of the forest-rich tropical countries. Forest land cleared for agricultural crop production will often provide more profit than would occur with sustained timber production. Cattle ranching and fuel wood harvesting are major sources of incomes in many forest-dependent communities. Avoiding these activities means foregoing these benefits. The benefits foregone by avoiding deforestation and forest degradation are known as the opportunity costs of REDD+. Opportunity cost is usually the single most important and largest element of REDD+ costs (Pagiola & Bosquet, 2009). Estimating the magnitude of these costs is critical in order to understand the causes and the motivations of agents to deforest, and are a part of each REDD+ pilot activity nationally and sub-nationally.

Several studies (Boucher et al., 2008; Kindermann et al., 2008; Stern, 2007) have used global simulations and empirical models to estimate aggregate costs of REDD+; they focused on top down approach using highly aggregated data. These studies found opportunity costs of REDD+ in the range of US$ 0.84 – 4.18 tCO_2e with a mean of US$ 2.51 tCO_2e (Boucher et al., 2008) to US$ 3.76 – 9.28 tCO_2e with average of US$ 6.52 tCO_2e (Stern, 2007) to US$ 17.2 – 28 tCO2e (Kindermann et al., 2008). Some other studies (UNFCCC, 2009; Blaser and Robledo, 2007; Eliasch, 2008; UNEP, 2011) have estimated mean opportunity costs within this range. Review of regional empirical estimates found that the mean opportunity costs for the Americas was US$ 2.37 tCO_2e, for Africa US$ 2.22 tCO_2e, and that for Asia US4 2.90 tCO_2e (Boucher et al., 2008). While site and project specific opportunity costs vary from place to place, from US$ 0.76 tCO2e in Brazilian Amazon (Nepstad et al., 2009) to between US$ 10.1 – 12.5 tCO_2e in Tanzania (Merger et al., 2012), costs can also differ within a country level, i.e.; from US$ 1.90 – 13.40 tCO_2e with a median of US$ 3.90 tCO_2e as evidenced in Tanzania.

Global estimates are based on simulation of the global economy and REDD+ costs using models such as Global Timber Model (GTM), Dynamic Integrated Model of Forestry and alternative Land Use (DIMA) and Generalized Comprehensive Mitigation Assessment Process

Model (GCOMAP). These models take into account forestry, agriculture and energy sectors. Simulations provide supply curves of emissions reductions against prices. Such estimates have limited use at the national or sub-national REDD+ because carbon stocks in forests, and drivers of deforestation and forest degradation that would have to be managed, vary from country to country and place to place. These estimates are based on highly aggregated data and do not reflect local economic and agro-ecological conditions, climate, market access, technology and yields, inputs and scale of operation (Merger et al., 2012), hence, the values provided may be misleading (Chomitz et al., 2006).

Fosci (Fosci, 2013) argues that the current global estimates of REDD+ costs are made less accurate by uncertain methodologies and untested assumptions that ignore the evolution of drivers of deforestation. Such drivers of deforestation and forest degradation are likely to vary significantly from place to place. While these estimates have not prevented policy-makers from making important policy decisions based on the available estimates, investors are more interested at sub-national or national levels, where the impact of drivers is better understood and where implementation mechanisms are used consistently (Olsen & Bishop, 2009). The more site-specific empirical estimates available, the more accurate can global-scale estimates are, if these are assembled from the bottom up using empirical data. This enforces the case for studies on the economics of REDD+ at sub-national and national scales.

4.2 The Terai Arc Landscape of Nepal

Understanding the economics of reducing emissions from deforestation and forest degradation in the Terai Arc Landscape of Nepal is especially important where land use change is prominent and is strongly linked to agricultural expansion and forest products extraction. The high rate of deforestation and forest degradation observed in the landscape is emitting CO_2 emissions, and also decreasing the capacity of the forest to sink or sequester global carbon emissions. This highly fertile region is likely to lose its commercially exploitable forest more rapidly than other parts of country to meet the livelihood requirements of a rapidly growing population of over 7 million people, many of whom are dependent on forest. Some forms of payment for the ecosystem services provided by forests are crucial to protect this globally significant biodiversity hotspot.

The study identified three major drivers of deforestation including population growth, agricultural production and property rights and two drivers of forest degradation; fuel wood and timber extraction as discussed in chapter 2. A major policy shift is required to address the deforestation and forest degradation in the landscape. Changes needed include intensifying agricultural production, ensuring good forest governance and switching to alternative energy sources. Because agriculture is the best alternative land use in this flat and fertile region of the country, it is imperative to estimate the foregone benefits from that land use if the forest is to be protected for REDD+ purposes. Similarly, strict protection of forest means forest owners in the landscape will forgo benefits from the sale of timber and fuel wood revenue which are also opportunity costs of retaining intact forest areas.

Carbon density is a key determining factor when estimating the opportunity costs of retaining forests under the REDD+ mechanism. Estimated mean carbon density in the Terai Arc forests is 228.76±19.61 Mg ha^{-1}. However, it varies across the management regime with protected areas having higher density of 291.55 Mg ha^{-1} but is much lowers at 126.76 Mg ha^{-1} in other forest land regimes. These estimates are consistent with similar site and forest-type specific studies but differ from earlier biome-average datasets used for global opportunity cost estimation. The carbon density study in the forest of the Terai Arc landscape also evidenced strong association of carbon density with management regime. This disaggregated data provides valuable information to estimate opportunity costs that are close to a real world scenario. Details of the carbon stock and emissions reduction potential of the Terai Arc forest are discussed in chapter 3.

Nepal has been a participating country in the World Bank's Forest Carbon Partnership Facility (FCPF) since 2009. The country prepared its Readiness Plan Idea Note (R-PIN) in 2008, implemented readiness activities as per Readiness Preparation Proposal (RPP) prepared in 2010, and currently in Readiness Package evaluation phase. Early action pilot projects in the Terai Arc Landscape; Sacred Himalayan Landscape and Chitwan-Annapurna Landscape with support from the Finland Government; and three watershed projects supported by ICIMOD and Norway are all being implemented. The country has developed an Emissions Reduction (ER) Program for the Terai Arc Landscape and proposed it for implementation as a performance-based sub-national REDD+ project. The proposed program area encompasses 2.3 million ha, of which 1.2 million ha is under forest cover. The landscape is also known as the 'rice bowl' of the country because of its highly fertile soil. It is the home of 7.35 million people and has high ecological, social, economic and cultural significance.

4.3 Methodology

We assumed that arable farming integrated with livestock farming is the best alternative land use in the landscape. Protecting the forests of the landscape means losing the benefits of agricultural production from that particular unit of land. However, forests can often provide a variety of goods and services. Some revenues can continue be attained through sustainable harvesting of timber and fuel wood. Thus, the opportunity cost of retaining the forest equates to the difference between the net benefits provided by the forest and those foregone net benefits from agricultural crops that could have been earned if the forest had been cleared and the land used for agricultural activities. Thus, opportunity costs of avoiding deforestation and forest degradation consists of two components; net present value (NPV) of timber, fuel wood and other benefits from sustainable forestry, and NPV of the revenue stream from agricultural crops production and or livestock farming or other alternative land uses (OLU).

To derive NPV for the land uses considered their net revenue streams were discounted at 10 percent rate for the period of 30 years. We used the average inputs, costs, yields and revenues at farm gate for one hectare of land associated with each alternative land use. A typical farming system in the Terai Arc Landscape produces three crops per unit area of land each year. Rice is the major cereal crop; the planting season is July and harvesting in November, followed by cultivation of wheat or maize along with pulses like lentil, peas, and cow peas among others (Gautam, 2011). To estimate net profit from agricultural land use, we used the net farm gate profit from a crop composition of rice, wheat and cowpea. These three are the most likely future crop composition on the next hectare of converted forest land.

We valued the total production, including those for household level consumption which do not result in cash revenues, but have values to the land owner and could have been sold to local markets. The agricultural yield data for 15 districts was provided by Ministry of Agricultural Development (MoAD), Government of Nepal. Net surplus from the crops at farm gate were derived from the cost data available at Agribusiness Promotion and Marketing Development Directorate (APMDD), Nepal. The total costs of production cover both fixed and variable costs, both in cash and kind including household labour, incurred during the production process. Fixed costs include land revenue, depreciation costs of tools and interest on fixed assets. Variable costs include human labour, fertilizers, seed, transportation charges and others. The data on net farm gate surplus from each crop in each district are based on best available information. In districts where cost information was missing, data from an adjacent district with similar agro-ecological condition were used as proxies for the missing information.

Livestock is the integral part of the traditional farming system of the study area. Livestock component contributes 20% of gross household income from agriculture and 35 % in agricultural GDP of Nepal (Rushton, Tulachan, & Anderson, 2005). Milk (62.6% of livestock GDP) and Meat (32.4%) are the most important products within the livestock sector (Mandip, Rushton, Anderson, & Tulachan, 2004). The study considered these two main products to estimate net return from livestock farming. We used Central Bureau of Statistics(CBS) data on meat production and price in 2010/11 and percentage of net farm-gate return estimated by Shrestha et al. (Shrestha & Evans, 1984). CBS milk production data for 15 districts was used to derive net return from milk production using market price, cost of production, percentage of market margin and net farm-gate profit collected from (MoAD, 2011), Joshi (Joshi, 2002), and FAO (FAO, 1997) respectively.

Revenue from forests can be derived from sales of timber and fuel wood and from entrance fees and concessions to national parks of the landscape. Timber and fuel wood production and sales data were collected from Department of Forest (DoF) publications, and from community forestry records. Mean timber and fuel wood production per hectare were calculated from time series data. Net return from timber and fuel wood were calculated using values derived from Kanel et al (Kanel, Shrestha, Tuladhar, & Regmi, 2012), and WEC (WEC, 2010). Revenues from national parks of the landscape are used as proxies for the biodiversity benefits of the forest. Disaggregated time series data of National Park revenues available at Department of National Parks and Wildlife Conservation (DNPWC) were used to derive average annual revenue per hectare of forest. All values in Nepalese Rupees (NPR) were converted into 2010 US Dollar (1 US$= 72.42 NPR). Calculation of opportunity cost of Terai Arc forests was completed using the following equation;

$$OC_{for} = \left[\frac{NPV_{for} - NPV_{olu}}{C_{olu} - C_{for}}\right] \qquad \text{(i)}$$

Where; OC_{for} is the opportunity cost (US$/tCO2e) of avoiding the conversion of forest area to another land use. NPV_{for} are the discounted revenue from forest (*for*), while NPV_{olu} are the net income from other land use (*olu*). NPVs were calculated using following formula;

$$NPV = FV/(1 + r)^n \quad \text{(ii)}$$

Where,

FV = Future value

r = Discount rate (10 percent or 0.10)

n = Number of years

On the basis of drivers of deforestation and forest degradation in the landscape discussed in chapter 2, we use arable farming integrated with livestock farming as the best alternative land use for deforestation and selective logging and fuel wood harvesting for forest degradation. C_{olu} and C_{for} are the total carbon stock, expressed in terms of carbon dioxide equivalent (CO_2e), per hectare of alternative land use and forest area respectively. We converted opportunity cost of reduced deforestation and forest degradation per hectare into costs per tons of CO2e using carbon densities in the forests of the landscape as discussed in chapter *3*.

4.4 Results

Agricultural yield was one of the main factors influencing extent of deforestation in the landscape. Low agricultural yield, as explained in an earlier chapter, has historically triggered deforestation as people cleared land to meet the food demands of an increasing population. Traditional farming practice in the Terai region of Nepal shows cultivation of three crops per unit area of land within a year. In the current crop composition, rice is the major crop, followed by wheat or maize and pulse crops. Yields of these agricultural products, however, vary from district to district. For example, Bara district has the highest rice yield (3279 Kg/ha) and Arghakhanchi has the lowest with about 1900 Kg per hectare. Hence, the NPV of net farm gate surplus from agricultural products varies from US$ 2126.53 to 4034.48 per hectare of land across the Terai Arc over the 30 years period. Mean NPV from agriculture is US$ 2953.81per hectare with a standard deviation of US$ 639.51.

Crop yields have tended to increase over the last 20 years in the study area. Mean rice yield, for instance, has increased from 2013.87 Kg per hectare in 1992 to 2897.73 Kg per hectare in 2009. Similarly, wheat yield (mean) also increased significantly from 1356.47 Kg per hectare to 2494.47 Kg per hectare during the period. Yield growth is attributed to increased mechanisation, cultivation of high yielding varieties, and improved irrigation, amongst others (Gautam, 2011). The land of the study area still has ample potential to increase current agricultural yield. According to Agribusiness Promotion and Marketing Development (APMDD, 2013), mean crop yields can be increased to 3834.00 Kg per hectare of rice, and 3288.00 Kg per hectare of wheat by improving farming practices that includes use of currently available improved varieties. These increased yields, if achieved can provide NPV of US$ 3485.01 per hectare during the 30 year period.

Livestock is an integral part of the traditional farming system in the study area. The livestock component contributes 20 percent of gross household income from agriculture and 35 percent of the agricultural GDP of Nepal (Rushton et al., 2005). Milk (62.6% of livestock GDP) and Meat (32.4%) are the most important products within the livestock sector (Mandip et al., 2004). The study considered these two main products to estimate net return from livestock farming. Kapilbastu district has the lowest net return at farm gate per unit area of milk production (NPV US$ 14.70 /ha/yr) and meat production (NPV US$ 32.18/ha/yr). We estimated the combined average NPV of US$ 911.89 per hectare of agricultural land from these two livestock products for the next 30 years period. However, overall livestock NPV estimates vary from US$ 488.81 per hectare in Kapilbastu to US$ 1419.64 per hectare in Chitwan district.

We estimated NPV of US$ 514.11 per hectare from forestry that included timber, fuel wood and revenue from national parks as a biodiversity benefit. With average of 3.23 cft timber harvest from each hectare of forest land, the landscape generates US$ 503.00 net return (NPV) during the 30 year period. However, it varies greatly from district to district; from US$ 84.98 per hectare in Bardia district to US$ 2085.57 per hectare in Kanchanpur district. Similarly, Palpa district derives the least net return (US$ 1.40 per ha) from fuel wood harvest, while Rautahat district earns the highest (US$ 17.28 per ha) from fuel wood. An average return from fuel wood in the landscape is US$ 5.88 per hectare. Biodiversity benefits in term of revenue from national parks contribute just 1.02 percentage of total forest revenue in the landscape. District-wise distribution of NPV from the forest sector for the 30 years period is illustrated in the figure 4.1.

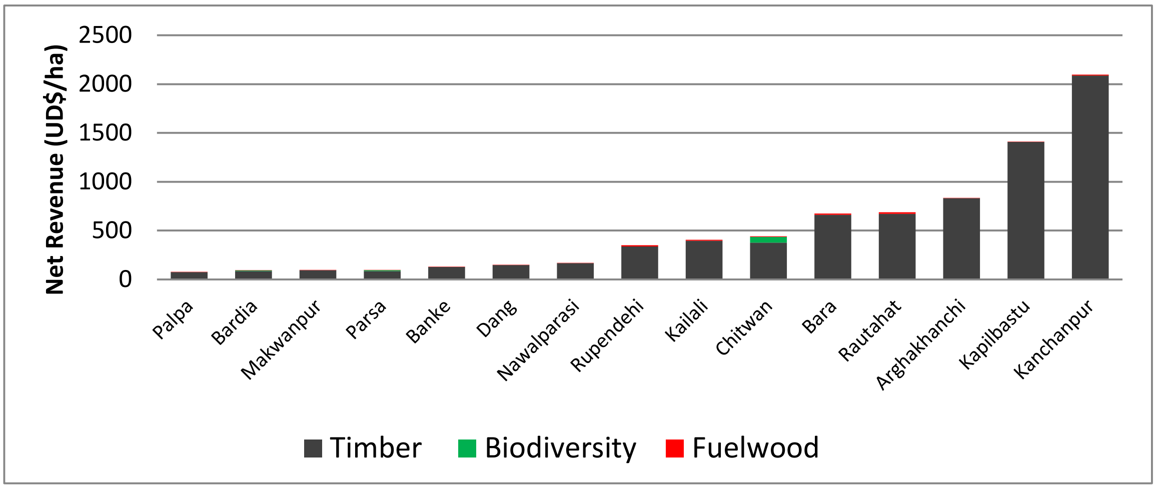

Figure 4.1 Distribution of forest sector NPV by district

The study included five carbon pools viz; aboveground biomass, belowground biomass, shrub biomass, litter biomass and soil organic carbon (SOC) to estimate carbon stock in the forest of the landscape. Mean carbon stock in the forest is 228.76±19.61 Mg per hectare which is equivalent to 839.55 Mg CO_2e per hectare. Protected areas have the highest stocking of carbon (1069.99 Mg CO2e per hectare) while community, government managed, and other land use (agricultural land) have 870.35 Mg/ha, 694.20 Mg/ha, and 465.21 Mg/ha of CO_2e respectively. The study calculated CO_2e emissions of 604.78 Mg per hectare if an intact protected area is converted into agricultural land use. With deforestation of one hectare of forest land with an average carbon stock, 374.34 Mg CO_2e are emitted. If forest degradation occurs, for example following conversion of protected areas into government managed forest, then emission of average 375.77 Mg CO_2e per hectare will occur. We considered conversion of forest land to agricultural land use as deforestation, and conversion of protected forest areas to government managed forest as forest degradation. We completed separate estimations of opportunity costs of forest degradation.

Based on the aforementioned net revenues and projected emissions from each land use, opportunity costs of avoiding deforestation and forest degradation were calculated and are presented in figure *4.2* The estimation is based on agricultural cereal crops and livestock yields, and forest product harvest data of the last two decades all inflated to 2010 US dollars. *Fig. 4.2* illustrates that cattle ranching alone has the lowest opportunity cost (US$ 1.06 per

Mg of CO2e) and conservation for biodiversity has the highest opportunity cost. Conserving all of the forests on the landscape has huge emissions reduction potential (604.78 Mg CO2e/ha) but is a very expensive option with marginal opportunity cost of US$ 22.00 per Mg of CO2e. Forests of the landscape could be converted into agricultural land and the current crop composition in the region cultivated. The marginal opportunity cost of avoiding such conversion or deforestation over a 30 years period is US$ 8.95 per Mg of CO2e. Introduction of improved farming practices combined with use of available improved crop varieties considerably increases crops yields, and hence, increases the opportunity costs to US $ 13.92 per Mg of CO_2e.

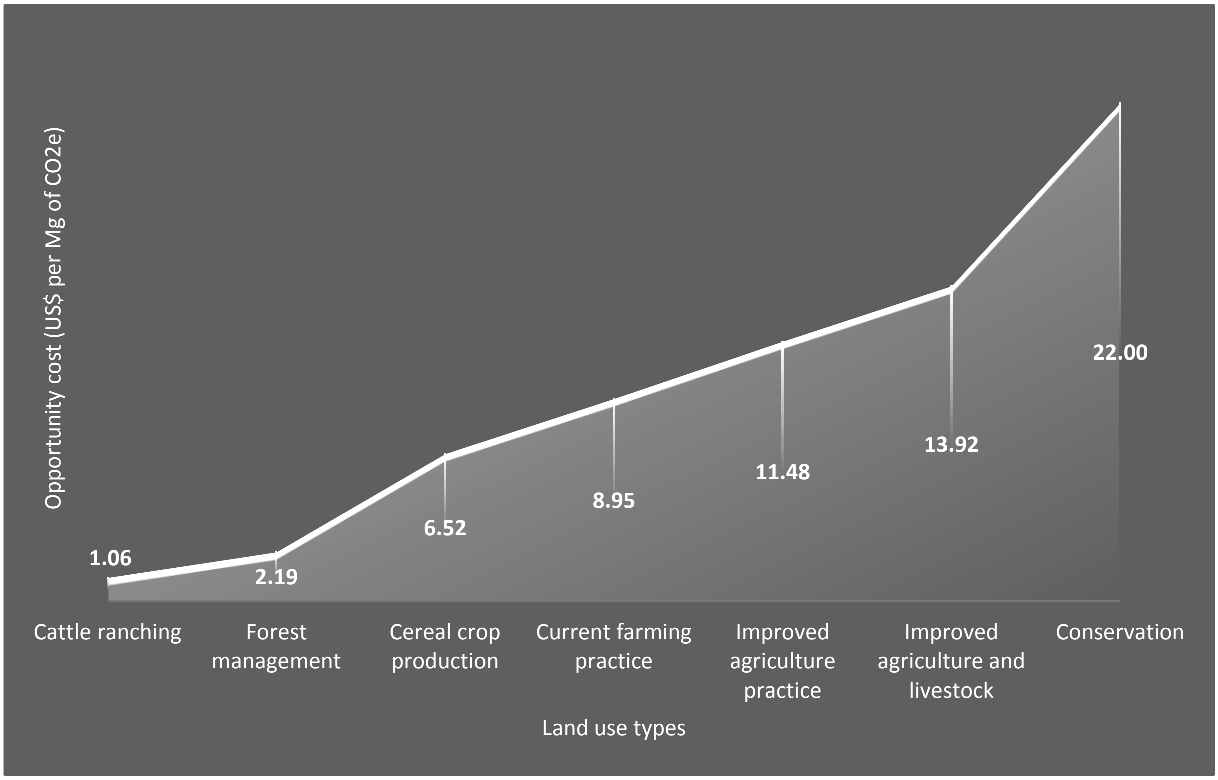

Figure 4.2 Opportunity costs of CO_2e emissions reduction by land use in the Terai Arc Landscape

Protected areas of forest provide other ecosystem services, as well as earning small amounts of revenue from visitors to the site. On the other hand, this land use loses benefits from forest product harvesting and cattle ranching as these activities are strictly prohibited inside protected areas. Conversion of protected areas, which have the highest carbon stocks, into government managed forest containing lower carbon stock, where these activities are permitted is assumed as forest degradation. Such conversion of forest could be avoided but at an average opportunity cost of US$ 3.77 per Mg of CO2e. That policy reduces emissions per hectare by 375.77 Mg CO2e. Across districts, opportunity costs of avoiding such forest degradation, varies from as low as US$ 1.77 per Mg of CO_2e in Parsa district to as high as US$ 8.55 per Mg of CO_2e in Kanchanpur district.

4.5 Discussion

Earlier attempts to estimate opportunity cost of REDD+ at global or regional level have been limited by the highly aggregated nature of data available and its use at coarse scales. In contrast, our empirical estimates of opportunity costs are based on carefully collected carbon stocks data and disaggregated time series data of forest and agriculture production at district level. Most of the global estimates, like Grieg-Gran (Grieg-Gran, 2009) and Stern (Stern, 2007) used uniform carbon density of 390 Mg C per hectare which clearly over estimates emissions reductions and leads to a lower estimate of opportunity cost in the study site case which has low carbon density. All earlier studies estimated opportunity costs solely of avoided deforestation. We have estimated opportunity costs for seven different land use combinations. In this study, we applied a practical approach to estimate opportunity costs of forest degradation looking into differences in emissions reduction potential and varying net revenues from different forest management regimes.

Our estimates of opportunity costs of CO_2e emissions reduction vary according to the alternative land uses practices. Cattle ranching have the lowest opportunity cost of US$ 1.06 per Mg CO2e while agriculture that applies improved practices has the highest opportunity cost of US$ 13.92 per Mg CO2e. Our estimate of an average opportunity cost considering current agricultural practice (US$ 8.95 per Mg CO2e) in the landscape is higher than most of the global estimates; US$ 6.52 per Mg CO2e of Stern (Stern, 2007), US$ 5.52 per Mg CO2e of Grieg-Gran (Grieg-Gran, 2009) and US$ 2.51 per Mg CO2e of Boucher (Boucher et al., 2008), but lower than US$ 17.2 – 28 per Mg CO2e of Kinderman et al. (Kindermann et al., 2008).The result is comparable with a more recent site and project specific estimate of Tanzania that has US$ 10.1 – 12.5 per Mg CO2e (Merger et al., 2012). Our estimated opportunity cost of US$ 6.52 per Mg CO2e emissions reduction from cereal crops production alone is close to earlier two estimates of Stern (Stern, 2007) and Grieg-Gran (Grieg-Gran, 2009). Agricultural productivity of land in the Terai Arc landscape is higher than in other areas of Nepal; but carbon stock and emissions reduction potential of forest tends to be lower. Hence, country level estimates should be close to the estimates of the Terai Arc Landscape.

Variations observed across districts are large, owing to the differences in agro-ecological conditions, crop yield, market access, and forest growing stock. Net profit from agriculture is driven primarily by crop yield. For example rice yield in Bara is 3279 Kg per hectare, while Arghakhanchi has the lowest rice yield of 1931 Kg per hectare. Bara district derives US$ 2973.28 per hectare NPV from agriculture with an opportunity cost of US$ 9.49 per Mg of CO2e of emissions reduction. On the other hand, Arghakhanchi district that has more hilly terrain with less productive land for rice cultivation generates only US$ 2306.05 per hectare NPV from agriculture with opportunity cost of US$ 4.77 per Mg of CO2e emissions reduction. This evidence suggests that as land productivity varies from place to place even within the Terai Arc landscape so too does the opportunity costs of emissions reduction.

To meet the food requirement of rapidly increasing population in the Terai Arc landscape, increased agricultural yield is essential. Crop yield data for 1992-2009 shows an increasing yield trend, but in many districts of the landscape, the use of chemical fertilizers, improved seed, irrigation facilities, and access to credit are still low. Hence, there is considerable scope for further yield increases in future with the introduction of new agricultural technologies. Increased crop yield will reduce the area demanded for agricultural land hence reduces pressure for deforestation. However, increased yield will also result in higher returns per hectare, resulting in increased opportunity costs of emissions reduction. For example, a 53 percent boost in rice yield per hectare will result in 63 percent higher net return (NPV) from agricultural crops during the next 30 years which ultimately increases opportunity cost per Mg of CO2e emissions reduction by 76 percent. Opportunity costs will significantly increase if all farming practices, including livestock farming, apply improved technologies. Therefore, there is a trade-off, increased agricultural yield increases the cost of REDD+ but may reduce rate of forest land conversion to agricultural land.

Strict protection of forest from timber and fuel wood harvesting and cattle ranching have resulted in more carbon stock in the protected areas than in other government-managed forests. While some districts have protected areas that earn revenues from tourists, they miss out on benefits from timber, fuel wood and cattle ranching. Using reduced carbon stock as an indicator of forest degradation, we analysed the opportunity cost of maintaining protected areas instead of managing them for timber, fuel wood production and cattle ranching. The opportunity cost of US$ 3.77 per Mg CO2e emissions reduced through avoiding forest degradation is a cheaper option than US$ 8.95 per Mg CO2e cost of reduced emissions through avoided deforestation. Mitigation potential of avoided forest degradation (375.77 Mg CO2e per hectare) is also higher than avoiding deforestation (374.34 Mg CO2e per hectare). This shows the significance of forest degradation to reduce emissions in the landscape. However, as discussed in chapter 2, more protected areas without substitution of timber and fuel wood will trigger activity leakage, resulting in deforestation elsewhere.

We derived seven different opportunity costs from different possible combinations of land uses. Costs vary from US$ 1.06 to US$ 22.00 per Mg CO2e emissions reduction in the landscape. Each land use option has a trade-off between mitigation potential and opportunity cost. Livestock farming is the cheapest option followed by sustainable forest management for the purpose of timber and fuel wood production, agricultural crop production, a combination of current composition of crops and livestock, cropping of high yielding varieties, a combination of high yielding crops and livestock and strict protection for biodiversity conservation. Despite the higher costs of emissions reduction, a combination of high yield cropping with livestock farming is the best feasible option for the landscape considering the increasing demands for agricultural and forest products and its mitigation potential. By considering only the cheapest option, without taking account of those unmet demands, deforestation and forest degradation activities will shift to other parts of the country affecting net emissions reduction. Therefore, choice of any alternative land use option to estimate costs should be made with caution in the context of country-wise reporting of net emissions reductions.

4.6 Conclusion

Estimation of the foregone benefits from avoided deforestation and forest degradation under REDD+ is the crucial step to understand the economic viability of emissions reduction at national or sub-national scale. Opportunity cost estimates at a global scale using highly aggregated data, mostly from forest carbon rich countries in the tropics, do not reflect the economic conditions, agro-ecology, farming system, land productivity and forest carbon densities prevalent in the South Asian sub-continent such as Nepal. Those studies tend to underestimate the cost of REDD+ in sites and countries which have lower forest carbon densities but higher returns from alternative land uses. The study highlights the importance of site specific, bottom-up studies that includes widely neglected aspects of forest degradation when examining and comparing the potential for REDD+ in specific sites.

The results from this study reveal a strong motivation exists to clear forest for agriculture in the region. Average return per unit area from traditional agricultural practices easily surpass the return from forestry business that includes timber, fuel wood sales and revenues from protected areas. On the fertile land of the Terai Arc landscape there is scope to increase yield substantially through use of improved agricultural technologies. The potential for substantial agricultural productivity increase has obvious implications for the costs of REDD+ in the Terai Arc landscape. Evidence suggests that substantial compensation will be required to make forest conservation more attractive than agricultural land use and to achieve effective emissions reduction. The study reveals that emissions reduction by avoiding forest degradation is cheaper than it is by avoiding deforestation. The result highlights the potential role of avoided forest degradation to reduce CO_2e emissions.

Our estimates of opportunity cost of emissions reductions are high in comparison to those of most global studies. Higher agricultural returns and lower carbon density in the forest land are the main factors leading to the higher estimates. However, costs vary substantially from district to district as the economic and agro-ecological circumstances differ. There is no single numerical value of opportunity cost of emissions reduction for the Terai Arc landscape. We derived seven different opportunity costs from different possible combinations of land uses. The results of the analysis consist of a range of costs applicable to different situations and sites. All possible options, however, will require trade-offs between opportunity costs, mitigation potential and practical feasibility.

Considering the likelihood of future forest conversion into agricultural cropping with the current crop composition integrated with livestock farming, REDD+ payments equal to or above US$ 8.95 per Mg CO2e emission reduction, plus implementation and transaction costs, are realistic for the Terai Arc region. In contrast, incentive payments based on most of the global opportunity cost estimates are likely to be insufficient for effective emissions reductions from avoided deforestation and forest degradation. Policy makers need to be cautious when using current global estimates and values to design any sub-national REDD+ framework and budget. Although estimation of opportunity cost (the major cost element of REDD+), is the vital first step, the study notes that an important second step is to estimate the remaining cost components, particularly implementation costs, to obtain a more comprehensive scope of the economic feasibility of REDD+ in the Terai Arc landscape.