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Analysis of leakage in carbon sequestration projects in forestry: a case study of upper magat watershed, Philippines

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Abstract The role of forestry projects in carbon conservation and sequestration is receiving much attention because of their role in the mitigation of climate change. The main objective of the study is to analyze the potential of the Upper Magat Watershed for a carbon sequestration project.

The three main development components of the project are forest conservation: tree plantations, and agroforestry farm development. At Year 30, the watershed can attain a net carbon benefit of 19.5 M tC at a cost of US$ 34.5 M.

The potential leakage of the project is estimated using historical experience in technology adoption in watershed areas in the Philippines and a high adoption rate. Two leakage scenarios were used: baseline and project leakage scenarios. Most of the leakage occurs in the first 10 years of the project as displacement of livelihood occurs during this time. The carbon lost via leakage is estimated to be 3.7 M tC in the historical adoption scenario, and 8.1 M tC under the enhanced adoption scenario.

Keywords Upper Magat · Carbon sequestration · Carbon benefit · Net carbon · Leakage · Forestry

1 Introduction

The Earth's surface temperature this century is as warm or warmer than any century since at least 1400 AD (Nicholls et al. 1996). By the year 2100, the average surface temperature is projected to increase by 1.4°–5.8° while sea level is expected to rise by 9–88 cm (IPCC 2001). Greenhouse gases (GHGs) such as (CO_2), methane (NH_4), nitrous oxides (N_2O) and chlorofluorocarbons (CFCs) absorb thermal radiation emitted by the earth's surface. If more GHGs are emitted into the atmosphere they absorb more heat, which, in turn, could lead to a change in the world's climate.

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Among the GHGs, CO_2 is the most abundant and is responsible for more than half the radiative forcing associated with the greenhouse effect (Watson et al. 2000; Schimell et al. 1995). Forest ecosystems play an important role in the climate change problem because they can both be sources and sinks of atmospheric CO_2. They can be managed to assimilate CO_2 via photosynthesis, and store carbon in biomass and in soil (Watson et al. 2000; Brown 1998; Brown et al. 1996). Great attention is focused on tropical forestry to offset carbon emission due to its cost-effectiveness, high potential rates of carbon uptake, and associated environmental and social benefits (Brown et al. 2000; Moura-Costa 1996; Myers 1996). Tropical forests have the biggest long-term potential to sequester atmospheric carbon (80% of the world's forests total) by protecting forested lands, reforestation, slowing down deforestation, and agroforestry (Brown et al. 1996). However, at present, the world's tropical forests are estimated to be a net source of 1.8 Gt of C per year primarily because of deforestation, harvesting and forest degradation (Watson et al. 2000). At least 20% of all atmospheric CO_2 emissions are from tropical deforestation.

The Clean Development Mechanism (CDM) of the Kyoto Protocol provides for collaboration between Annex 1 countries and developing countries like the Philippines. The recent meeting of the Parties to the Protocol approved the inclusion of afforestation and reforestation projects under the CDM.

We have earlier estimated the national potential of the Philippines for land-use, land-use change and forestry (LULUCF) projects (Lasco and Pulhin 2001; Lasco and Pulhin 2000). However, there are still no studies on the potential carbon benefits at the project level. The main objective of this study is to analyze the potential of the Magat Watershed for a carbon sequestration project. Specifically, the study aims to: (a) quantify the potential carbon benefits of the watershed, and (b) identify the causes and quantify the potential leakage of the project.

2 Description of site project

The Magat Watershed is one of the most important watersheds of the Philippines. In recognitions of this, it was declared a forest reservation by virtue of Proclamation Number 573 in June 26, 1969. The watershed supports the Magat multipurpose dam which supplies water for power generation and irrigation as well help control floods.

The watershed is also a dynamic one reflecting the multidimensional problems in most of the country's upland areas. An open access resource, there is rapid in-migration of people in search of land to cultivate. Vast areas of forests have been denuded resulting to heavy siltation of waterways. The life span of the dam has been significantly shortened by siltation of the reservoir. Floods have also become more frequent.

2.1 Biophysical condition

The Magat watershed has a total land area of about 229,000 ha and located between latitude 16°05′ and 17°01′ and longitude 120°51′ and 121°27′. It belongs to the Philippine climatic type III characterized by a lack of pronounced rainfall pattern. It is relatively wet from May to October, with rainfall gradually decreasing from November to February. Total annual rainfall ranges from about 1400 mm in low altitude to about 2400 mm in high altitude.

The dominant soil texture in the watershed is clay loam except along river terraces where silt loam dominates. Upland soils are well drained. Soil fertility is generally high except in grassland areas that have been subjected to high erosion rates. The underlying parent materials are igneous and sedimentary rocks.

The watershed is characterized by a complex web of rivers, streams, creeks and springs. The surface runoff generally follows the rainfall pattern.

2.2 Socio-economic Profile

A 1989 census revealed there were 19,375 families in the upland areas. Little is known about the socio-economic profile of the upland dwellers. However, there is an on-going study in the watershed as part of a master planning effort. The results of this study will be available in the next few months.

3 Methods

The main approach of the study was to quantify the potential net carbon benefits by comparing the baseline scenario with a proposed project scenario. This was done using a combination of primary data gathering in the field and secondary information. In addition, the potential leakage from the project was estimated using historical experience on technology adoption in community forestry projects in the Philippines.

3.1 Development of baseline and project scenarios

The study compared two scenarios: a baseline scenario and a project development scenario under a 30-year period (2001–2030). The former is a projection of the condition of the watershed under a business-as-usual scenario while the latter takes into account proposed project activities to rehabilitate and develop the watershed area. Land use and cover data for the last ten years obtained from the National Mapping and Resources Information Authority (NAMRIA) was used to develop the baseline scenario. For the project scenario, the proposed rate of land development was used.

3.2 Carbon stocks of study area

The carbon density of the dominant land cover in the watershed was determined using field data collection and secondary data using the methods described by MacDicken (1997) and Hairiah et al., (1998) which we have previously applied in the Philippines. Field data gathering was conducted on August 2001.

For live tree biomass, four 5×40 m (200 m^2) quadrants were established in each study site except for the Lucban site where only 2 plots were established. Trees >5 cm dbh (1.3 above the ground) that were within 2.5 m of each side of the 40-m centerline were sampled. The species name and dbh were determined, the latter through the use of a diameter tape. If trees >30 cm dbh were present in the sampling area, whether they were inside the 5×40 m transect or not, an additional sample quadrant of 20×100 m was established where all trees with dbh of >30 cm were measured. The 5×40 m quadrant was nested in the lower left hand corner of the bigger plot.

For tree necromass (coarse woody debris, CWD), all dead trees on the ground and dead standing trees >5 cm diameter and >0.5 m in length were sampled by measuring the height/length and diameter at the mid-point.

For understorey biomass and litter layer, destructive sampling techniques were used. Within the 5 × 40 m quadrants, 1 × 1 m and 0.5 × 0.5 m quadrants were randomly laid out for understorey and litter, respectively. Total number of samples for understorey is four while the coarse and fine litter have eight samples each. All vegetation less than 5 cm dbh was harvested within the 1 × 1 m quadrant. The total fresh sample was weighed in the field after which a sub-sample of about 300 g was taken for oven-drying in the University of the College of Forestry and Natural Resources (UPLB-CFNR) laboratory.

Coarse litter is defined as any tree necromass <5 cm in diameter and/or <30 cm length, undecomposed plant materials or crop residues, and all unburned leaves and branches). This was collected in the 0.5 × 0.5 m quadrant on a random location within the understorey sample plot. All undecomposed (green or brown) material was collected and weighed. Similar to understorey, sub-sample of about 300 g was taken for oven drying and carbon content analysis.

After collecting the coarse litter, fine litter is collected in the same 0.5 × 0.5 m quadrant. This was done by collecting about 1000 g of the thoroughly mixed 0–5 cm soil layer (including all woody roots). The sample was then taken in the laboratory where roots and partly decomposed dark litter was dry sieved.

Biomass and necromass samples were oven-dried for 40 hours or until the samples reached their constant oven-dried weight.

About 500 g of soil samples were taken from each of the 5 × 40 m quadrant. The soil samples were obtained at 0–30 cm depth in the 0.5 × 0.5 m quadrant used for litter collection. Bulk density was determined by collecting undisturbed soil cores with a diameter of 5.3 cm and length of 10 cm. The soil samples were initially air-dried and oven dried to constant weight for 40 hours at ±102 °C.

Tree biomass was calculated using the following allometric equation (from Brown 1997):

$$
\begin{aligned}
Y(\text{Kg}) &= \exp\{-2.134 + 2.530^{*} \ln^{*} D\} \text{ for natural forest and plantation} \\
Y(\text{Kg}) &= 42.69 - 12.8^{*} D + 1.242^{*} D2 \text{ for natural forest and plantation} \\
& \quad > 70\,\text{cm dbh}
\end{aligned}
$$

The coarse woody debris was also determined using Brown's equation.

Wood samples were collected from the most dominant tree species in the area. Ground samples were analyzed at the International Rice Research Institute Analytical Service Laboratory (IRRI-ASL) for C content determination using the ROBOPREP C-N Biological Sample Converter. Moreover, available data, based on the previous studies by ENFOR, were used on the carbon content of trees in Makiling and QNP for carbon density determination.

SOC was analyzed using the Walkey-Black method (PCARR, 1980). Total SOC (Mg/ha) = Bulk Density (Mg/m^3) $^{*}2000$ *%SOC.

3.3 Calculation of carbon benefits

Change in carbon stocks over the time was calculated for each land cover type. The net change in each land cover type was aggregated to estimate the total carbon stocks for the whole watershed. The net carbon benefits were determined by subtracting carbon stocks in the baseline scenario from those in the project scenario.

$$\text{Total carbon benefits} = \sum (C_p - C_b)_i$$

where C_p = net carbon stocks with project for year iC_b = net carbon stocks at baseline for year *i*.

3.4 Leakage analysis

One of the most critical concerns about forestry projects under the Kyoto Protocol is leakage. The IPCC Special Report on LULUCF defines leakage as the decrease or increase in greenhouse gas benefits outside the project's accounting boundary as a result of project activities (Watson et al. 2000; Brown et al. 2000). It is more commonly understood in its negative sense, i.e. an anticipated loss of net carbon benefits (Brown et al. 1997). For example, a forest protection project may lead to the cutting of trees in an adjacent forest resulting to minimal net carbon sequestration. Bass et al. (2000) consider leakage as an externality of a project and they differentiated between leakage and slippage. The former occurs when ‘‘a project's activities and outputs create incentives to increase GHG emissions from processes taking place elsewhere''. Slippage occurs when the estimated GHG benefits are negated by an increase in GHG emissions in another area from similar processes. Aukland et al. (2001) divided leakage into two categories: primary and secondary leakage. Primary leakage is synonymous to ‘‘slippage'' while secondary leakage occurs when the project creates incentives to increase GHG emissions elsewhere.

Recently, an experts' workshop on LULUCF and the CDM has identified leakage as one of the major research issues (CIFOR 2001). In this study, we analyzed and quantified the potential leakage from the project. The main assumption of the study is that leakage in the project area is largely a function of the degree of adoption of alternative livelihood options of the local communities. In the absence of data from the project site, we conducted a comprehensive literature review of the rate of adoptions of agroforestry and other upland technologies in the Philippines. The values obtained from this review were utilized as a basis for estimating the potential leakage from this project.

4 Baseline conditions

Baseline land use and cover change

The UMW has a total land area of about 228,000 ha which fluctuates depending on the level water body. Five major land cover types have been identified in the area: built-up/open, (closed-canopy) forest, grassland, non-tree agriculture, and secondary forest/tree plantation (Fig. 1). Built-up areas include human settlements and infrastructure. Forests are presumably closed-canopy forests or old-growth forests. Grassland areas are the result of deforestation and continuous cultivation and grazing. A previous study showed that 20% of all grassland areas are covered with grazing permits. In agricultural area, the favored crops are cereals and sugarcane.

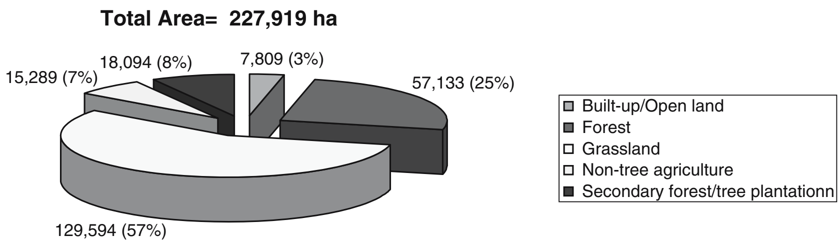

Fig. 1 Present land cover of Upper Magat watershed (in ha). Total area 227,919 ha

From 1988 to 1998, there had been a marked change in the land cover and landuse of the watershed (Table 1 and Fig. 2). Built-up/open areas registered the greatest relative increase (5.7%) while non-tree agriculture areas (annual crops) had the biggest area decrease (–13%). It is also noteworthy that closed canopy forests increased suggesting recovery of disturbed forests.

On the other hand, secondary forests declined fastest indicating a high deforestation rate in the area. Most of these lands become grasslands while others regenerate back to closed-canopy forests. Similarly, non-tree agriculture is also declining over time. Agricultural lands become grasslands when they are too infertile.

The possible land cover of the watershed for the next 30 years was projected using the average rates of change for the last 10 years (Table 2). This will serve as the baseline scenario for the project. Without intervention, it will be noted that grasslands will continue to increase while secondary forests continue to decline. The combined effect of these two changes will further exacerbate the condition of the watershed. It will mean far greater soil erosion and siltation of water bodies in the watershed.

Clearly then, there is a need to arrest the degradation that is happening in the watershed. This project is designed to reverse this downward spiral and promote sustainable watershed development.

4.1 Drivers of baseline condition

From the above discussion of land use change, the baseline condition that can be addressed by the project include the loss of carbon in secondary forests and the low carbon density in grassland areas and upland farms (Table 3).

Destruction of secondary forests is mainly due to deforestation and small-scale logging activities by small agriculturalists and loggers, respectively. There is no information as to the exact proportion of the annual loss of secondary forests that could be attributed to the two agents.

The low carbon content of grassland areas is first of all due to the lack of economic activity such as tree farming or reforestation. This in turn is brought about by lack of government resources and people who bought the rights to the land because of the hope of using or selling it later. Other causes that perpetuate low carbon stocks are farming and ranching activities.

Similarly, the low carbon stocks of upland farms are maintained by farmers who are dependent of the land for subsistence and cash.

Table 1 Historical land cover of Upper Magat watershed (ha)

Land cover	1988	1990	1992	1993	1994	1996	1997	1998	Annual change
Built-up/Open land	1,066	5,799	5,067	3,578	4,163	6,895	5,574	7,809	674
Forest	52,166	45,295	41,718	44,358	41,052	51,113	58,252	57,133	497
Grassland	118,143	148,810	126,792	118,168	105,441	96,037	126,380	129,594	1,145
Non-tree agriculture	23,391	13,766	11,777	13,354	23,441	28,578	8,004	15,289	–810
Secondary forest/tree plantation	33,563	14,562	42,994	49,377	53,899	45,969	30,081	18,094	–1,547
Land Total	228328.83	228232.17	228348.99	228835.35	227995.65	228591.54	228291.75	227919.15	–41
Water body	789.3	894.96	778.14	291.78	1131.48	535.59	835.38	1207.98	42
Grand Total	229118.13	229127.13	229127.13	229127.13	229127.13	229127.13	229127.13	229127.13	

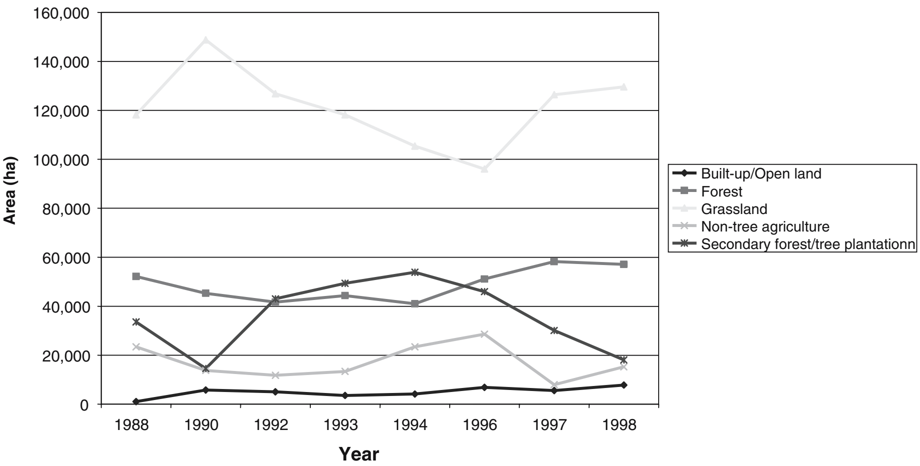

Fig. 2 Historical land cover of Upper Magat watershed (1988–1998)

5 Project development activities

5.1 Strategy

The main strategy of the project will be community-based forest management (CBFM). CBFM is a new paradigm that replaced the old mode of forest management in the Philippines. In CBFM, upland communities are given the right to manage and utilize the forest resources on a sustainable basis. It was launched through the issuance of DENR Administrative Order No. 123 on November 28, 1989 to hopefully address the problems of poverty and sustainable management and protection of the remaining second growth forests. Initial experiences on project implementation indicate that given the proper incentives and social and technical preparation, CBFM as a strategy is effective in attaining sustainable forest resource management (La Vina 1997). Successful CBFM sites in the Philippines are listed in Table 4.

Assessments made by Borlagdan et al. in 2001 reveal that major impacts of community forestry include: (1) protection of both natural and plantation forests; (2) conversion of grasslands into forests through natural regeneration, tree farms, plantations; (3) biodiversity conservation; and (4) increased productivity of upland farms as a result of gradual restoration of eroded soils.

The main strategy of the project will be community-based forest management. The key actors of the project will be as follows: the local community/PO, an NGO, the DENR, private developer (local firm), project monitoring team, and the investor firm (carbon "buyer").

All the project activities will be developed with the participation of local communities in the project area. The NGO partner will catalyze the community organizing and development process. The DENR will provide the appropriate land tenure for the project. The private developer will manage and implement the project. The project monitoring team will quantify the carbon sequestered and assess the impacts of the project. The project investor will provide the funds for the project.

Table 2 Projected land cover change of Upper Magat Watershed without project intervention (1999–2030)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	
Built-up/Open land	9459	10894	12143	13229	14174	14996	15712	16334	16334	16334	
Forest	57249	57363	57474	57583	57690	57794	57897	57998	58096	58193	
Grassland	130178	130713	131205	131659	132079	132470	132835	133176	133385	133590	
Non-tree agriculture	13301	11572	10068	8759	7620	6630	5768	5018	5018	5018	
Secondary forest/tree plantation	17732	17377	17030	16689	16355	16028	15708	15394	15086	14784	
TOTAL	227919	227919	227919	227919	227919	227919	227919	227919	227919	227919	
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Built-up/Open land	16334	16334	16334	16334	16334	16334	16334	16334	16334	16334	16334
Forest	58287	58380	58471	58560	58647	58733	58816	58899	58979	59058	59135
Grassland	133791	133988	134182	134371	134556	134738	134916	135091	135262	135429	135594
Non-tree agriculture	5018	5018	5018	5018	5018	5018	5018	5018	5018	5018	5018
Secondary forest/tree plantation	14488	14199	13915	13636	13364	13096	12834	12578	12326	12080	11838
TOTAL	227919	227919	227919	227919	227919	227919	227919	227919	227919	227919	227919
	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Built-up/Open land	16334	16334	16334	16334	16334	16334	16334	16334	16334	16334	16334
Forest	59211	59285	59358	59429	59499	59568	59635	59701	59765	59828	59890
Grassland	135755	135912	136067	136219	136367	136513	136655	136795	136932	137066	137198
Non-tree agriculture	5018	5018	5018	5018	5018	5018	5018	5018	5018	5018	5018
Secondary forest/tree plantation	11601	11369	11142	10919	10701	10487	10277	10071	9870	9673	9479
TOTAL	227919	227919	227919	227919	227919	227919	227919	227919	227919	227919	227919

Note. Totals may not add due to rounding

Table 3 Baseline drivers, agents and causes of the baseline condition in UMW

Project area	Baseline condition	Baseline driver	Baseline agents	Causes/Motivations	Indicator
Secondary forests	Loss of stored carbon in vegetation via tree cutting	Deforestation	Subsistence farmers Cattle ranchers	Subsistence Financial returns	Forest cover
		Small-scale logging	Loggers (local community?; outsiders?)	Financial returns	Forest cover Timber stock
Grasslands	Low carbon stocks in grassland areas	No economic activity	Government Absentee owners	Lack of resources for reforestation Land speculation	Current use of land Rate of planting at landscape level
		Agriculture	Small farmers	Subsistence Financial returns	Current use of land Rate of planting a landscape level
		Ranching	Cattle ranchers	Financial	Current use of land Rate of planting at landscape level
Upland agriculture	Low carbon stocks in upland farms	Agriculture/ Slash-and-burn	Small farmers	Subsistence Financial returns	Current use of land Rate of planting at landscape level

Table 4 List of successful community forestry sites in the Philippines (Borlagdan et al. 2001)

Site	Year started	Remarks
Ifugao Province (muyong)		Self-initiated
Sagada, Mt. Province (saguday)		Self-initiated
Bontoc, Mt. Province (tayan)		Self-initiated
Ikalahan, Sta Fe, Nueva Vizcaya	1974	Self-initiated
Minalwang, Claveria, Misamis Oriental	1996	Self-initiated
Barobbob Watershed, Nueva Vizcaya	1992	Locally assisted
Lantapan, Bukidnon (Landcare)	1997	Locally assisted
Guba, Cebu City (Mag-Uugmad Foundation, Inc)	1981	Locally assisted
Lunga, Valencia (Bukidnon Integrated Framing System Development Project)	1994	Locally assisted
Malaybalay, Bukidnon (BEST Project-BENRO)	1993	Locally assisted
Apolong, Valencia, Negros Oriental	1994	Locally assisted
Buhi, Camarines Sur (BLUDPP)	1981	Locally assisted
Senator Ninoy Aquino Kabulnan Watershed, Davao del Sur	1996	Locally assisted
Don Victoriano, Misamis Occidental	1993	Locally assisted
Mt. Kitanglad National Park, Bukidnon	1996	National program
Magdungao, Passi City, Iloilo	1985	National program
Maasin Watershed, Iloilo	1990	National program
Bamban, Ayungon, Negros Oriental (CVRP-CFP)	1984	National program
Bulolacao, Nug-as, Alcoy, Cebu (ISFP/UDP)	1984	National program
Mt. Isarog National Park	1997	National program
Labo, Camarines Norte (TKFPI)	1992	National program
Mat-i, Claveria, Misamis Oriental (CFP)	1992	National program
Upper Bala, Magsaysay, Davao, del Sur	1989	National program
Monkayo, Compostela Valley (NPPFRDC)	1994	National program
Kiblawan, Davao del Sur (Kiblawan Agroforestry Project)	1987	National program
Quirino (CFP)	1993	National program
Claveria, Misamis Oriental (ASPECTS)	1997	National program
Bayombong, Nueva Vizcaya (DENR-ITTO)	1995	National program
Claveria, Misamis Oriental (Landcare)	1996	National program

5.2 Project components and rate of development

The three main components of the project are:

- Protection of secondary forests = 7,430 ha (total area to be conserved in 30 years)
- Reforestation of grassland areas = 100,000 ha
- Agroforestry farms development = 10,000 ha

5.2.1 Protection of secondary forests

Secondary forests are the result of severe disturbance which is typically initiated by logging activities in the Philippines (Lasco et al. 2001). These forests are the most dynamic and economically important forests of the country because they can be exploited through logging. They are also the most vulnerable to deforestation being closer to human settlements and accessible by road.

When these forests are deforested or logged, carbon stored in the biomass is released through oxidation by burning and decomposition. Thus, the main strategy of the project will be to implement protection measures to prevent forest destruction.

The protection of natural forests will be done through a multi-pronged approach. At the local level, farmers will be provided a more stable source of income through agroforestry development so that they will not rely on small-scale logging activities. The organized community will also work with the DENR and local government units in the conservation of natural forests. At the municipal level, a multi-sectoral forest protection committee patterned after the highly successful model in the region will be formed. This committee will be composed of the various sectors of government and civil society. Its primary function is to facilitate coordination and cooperation among the various sectors in the prevention of forest destruction in the target area.

5.2.2 Reforestation of grassland areas

In the Philippines, there are more than 2 M ha of grassland areas. These are not natural but are the results of a degradation process that typically starts with logging of natural forests followed by continuous cultivation and finally grasses like *Imperata cylindrica*. These grassland areas are maintained by a vicious grass-fire-grass cycle preventing natural succession to proceed. The main approach of the government to rehabilitate these areas is through reforestation activities. However, the success of state reforestation efforts is mediocre at best. This is due in large part to the lack of incentives by major actors to keep the trees alive once the project contract is over (usually after three years).

In contrast, planting trees for carbon sequestration will provide the needed incentives to all actors to keep the trees alive. Since the income stream depends on the existence of carbon stocks, there will be a strong incentive to ensure that they survive.

Reforestation will be done by planting a combination of fast-growing and indigenous species in grassland areas. The fast growing species will be planted ahead to provide shade and improved microclimate for the indigenous species. The species to be planted are: *Gmelina arborea*, teak (*Tectona grandis*), pine (*Pinus kesiya*), narra, and dipterocarp species.

5.2.3 Agroforestry farm development

Upland farms planted to annual crops have high erosion rates and are therefore not sustainable. They will eventually end up as degraded grassland area without any intervention.

Agroforestry will involve the introduction of fruit trees to upland farms that are devoted to annual crops. This will help reduce erosion and increase income of farmers.

As a result of the project activities, the land cover is predicted to change as shown in Table 5.

6 Potential carbon benefits

6.1 Baseline scenario

To project the land cover change under the baseline scenario, the 10-year average change for each land cover was used (see Fig. 2). Figure 3 shows the predicted land cover under the baseline scenario.

Table 5 Predicted land area of the UMW under the project scenario with zero leakage

Land cover	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Built-up/Open	11831	11831	11831	11831	11831	11831	11831	11831	11831	11831
Forest	57478	57564	57651	57651	57651	57651	57651	57651	57651	57651
Grassland	121011	106084	96084	86084	76084	66084	56084	46084	36084	26084
Non-tree Ag	5444	5444	5444	5444	5444	5444	5444	5444	5444	5444
SGF/TP	17155	16996	16909	16909	16909	16909	16909	16909	16909	16909
Tree plantation	10000	20000	30000	40000	50000	60000	70000	80000	90000	100000
Agroforestry	5000	10000	10000	10000	10000	10000	10000	10000	10000	10000
TOTAL	227919	227919	227919	227919	227919	227919	227919	227919	227919	227919
Land cover	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Built-up/Open	11831	11831	11831	11831	11831	11831	11831	11831	11831	11831
Forest	57651	57651	57651	57651	57651	57651	57651	57651	57651	57651
Grassland	26084	26084	26084	26084	26084	26084	26084	26084	26084	26084
Non-tree Ag	5444	5444	5444	5444	5444	5444	5444	5444	5444	5444
SGF/TP	16909	16909	16909	16909	16909	16909	16909	16909	16909	16909
Tree plantation	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000
Agroforestry	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
TOTAL	227919	227919	227919	227919	227919	227919	227919	227919	227919	227919
Land cover	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Built-up/Open	11831	11831	11831	11831	11831	11831	11831	11831	11831	11831
Forest	57651	57651	57651	57651	57651	57651	57651	57651	57651	57651
Grassland	26084	26084	26084	26084	26084	26084	26084	26084	26084	26084
Non-tree Ag	5444	5444	5444	5444	5444	5444	5444	5444	5444	5444
SGF/TP	16909	16909	16909	16909	16909	16909	16909	16909	16909	16909
Tree plantation	100000	100000	100000	100000	100000	100000	100000	100000	100000	100000
Agroforestry	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
TOTAL	227919	227919	227919	227919	227919	227919	227919	227919	227919	227919

Carbon density under each land cover ranges from zero in built up areas to about 200 MgC/ha in closed-canopy forests (Fig. 4). In the next 30 years, carbon stocks will have a net loss of a total of 586,896 MgC (Fig. 5). Most of the carbon will be stored in closed canopy forests.

Secondary forests carbon will decline the most while grassland carbon will remain steady through time (Fig. 6). On the other hand, closed canopy forest will have a net increase in carbon stored.

6.2 Project scenario

Under the project scenario, the land cover will change dramatically (Fig. 7). The total area of grasslands will progressively decline as a result of massive reforestation efforts. As a result, the area of tree plantations will correspondingly increase.

Net carbon benefits will steadily increase to 19.5 Mt C in 2030 (Fig. 8). Of these, the reforestation component will contribute the most increase (Fig. 9).

7 Financial costs and benefits

The total project cost for 30 years will amount to US$ 34.5 million (Fig. 10). Most of these will be devoted to the reforestation component. This value is undiscounted (socialized rate is 12% in the Philippines (Lasco and Pulhin 2001).

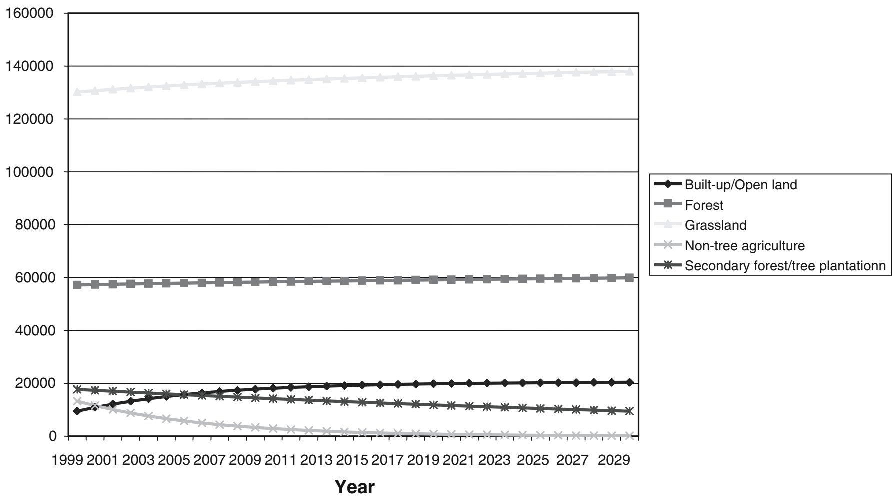

Fig. 3 Land cover change in Upper Magat Watershed under the baseline Scenario (1999–2030)

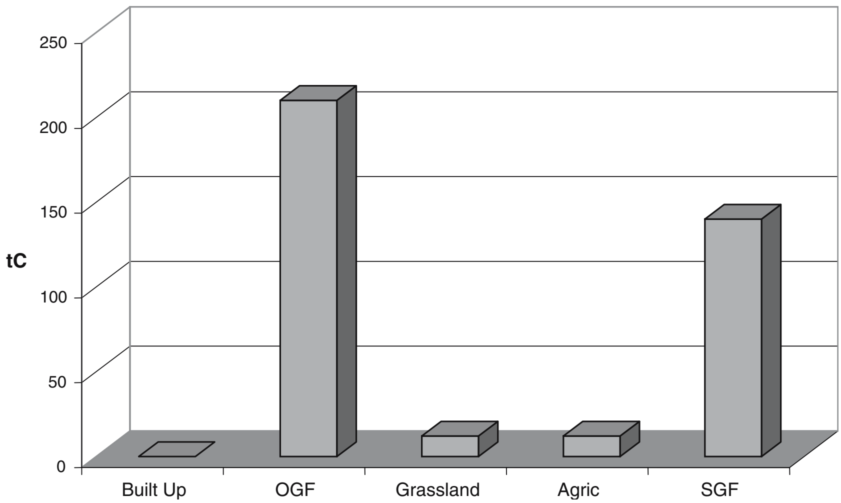

Fig. 4 Carbon stocks of land cover in UMW

Using the total carbon stocks at Year 30, the cost per ton of C will amount to US$ 1.77. This is within the lower range of the life cycle cost of potential forestry projects in the Philippines (about $ 0.12 per tC to $ 7.60 per tC) (Lasco and Pulhin 2001). It is lower than the cost of protecting a geothermal forest reservation in the island of Leyte (US$ 2.94 per tC) (Lasco et al. 2002).

8 Estimate of potential leakage

As stated earlier, leakage is the decrease or increase in greenhouse gas benefits outside the project's accounting boundary as a result of project activities (Watson

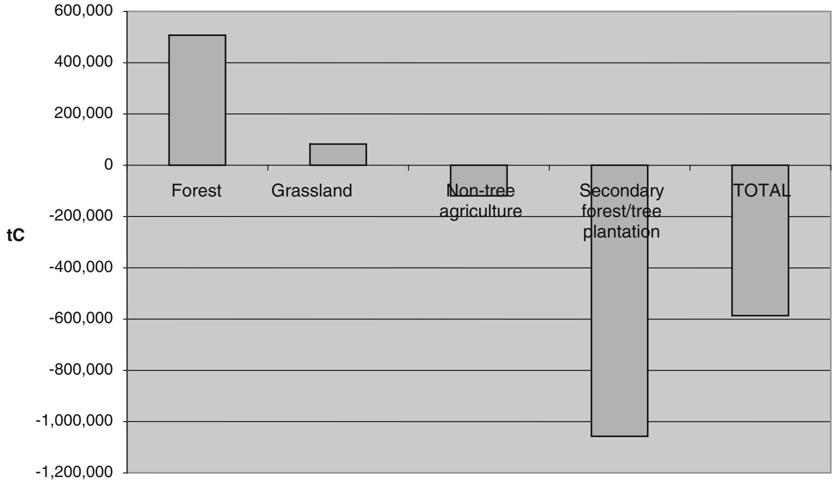

Fig. 5 Net carbon gain/loss from 2001 to 2030 under the baseline scenario

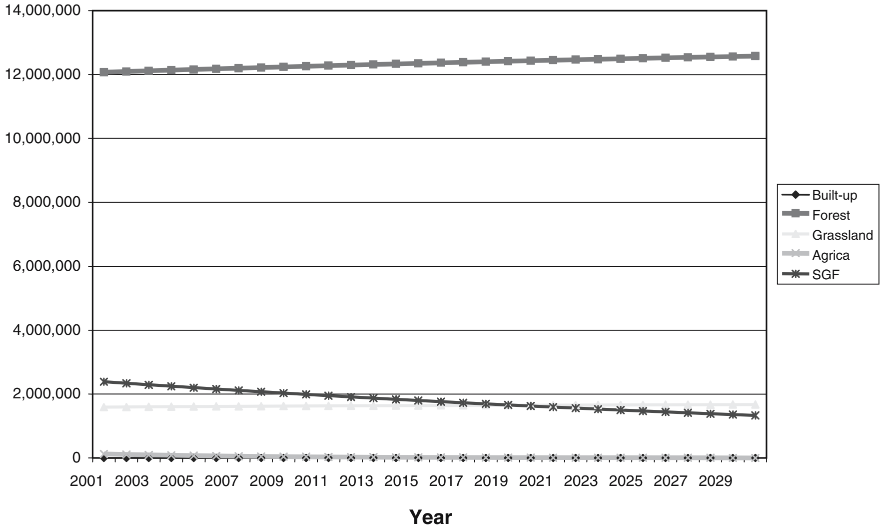

Fig. 6 Carbon stocks of UMW under the baseline scenario

et al. 2000; Brown et al. 2000). The likely source of leakage for each project component is summarized in Table 6. For the forest conservation component, the main types of leakage will be clearing of adjacent forests by people whose livelihood depended on the preserved forest. Similarly, for the tree plantation and agroforestry farm development components, the main type of leakage is activity shifting by farmers depended on the developed land.

For reforestation, under baseline condition, grasslands are being used for farming and ranching activity. Thus, if these areas are reforested, it would result to the loss of

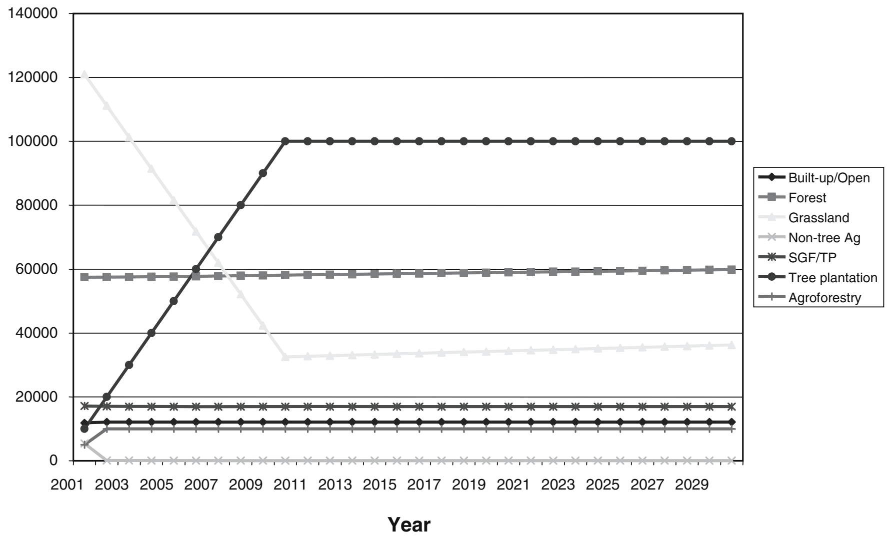

Fig. 7 Land cover change under the project scenario

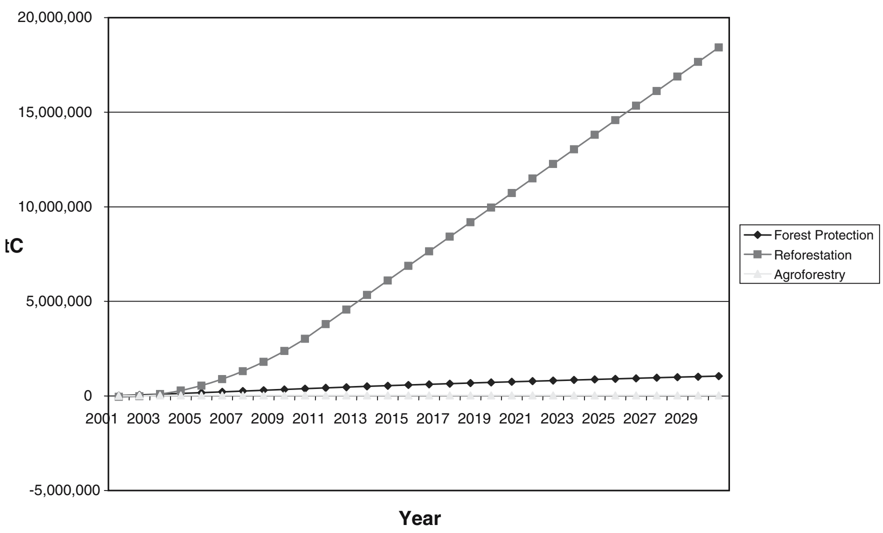

Fig. 8 Net carbon benefits from the project components

land for farmers/ranchers. This may lead them to clear adjacent forests so that they can continue farming/grazing. For potential agroforestry lands, these are currently utilized for some form of non-sustainable farming. If these are developed for agroforestry, some farmers who don't adopt the technology may clear forest lands so that they continue their traditional way of farming.

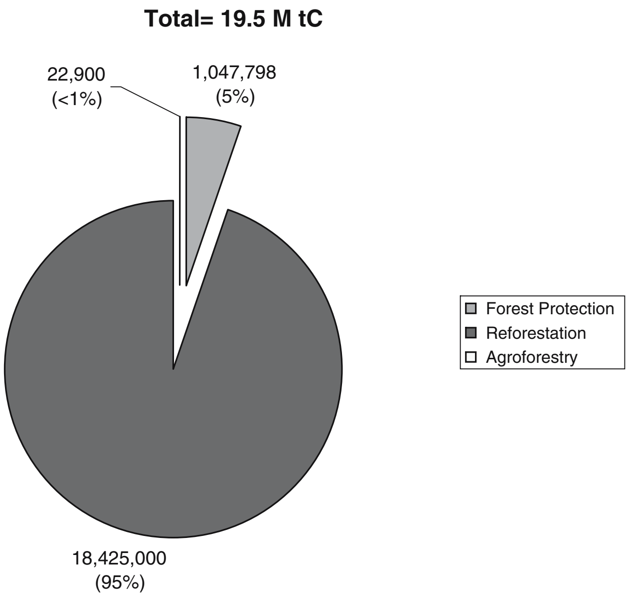

Fig. 9 Total net carbon benefits from project components at 2030, tC

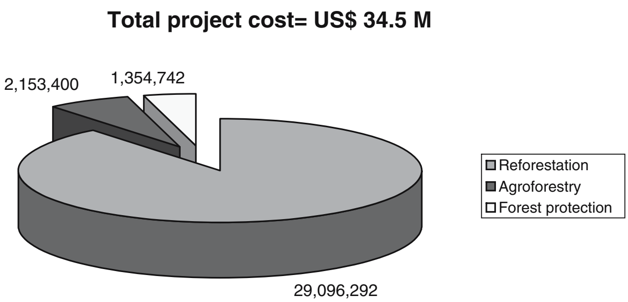

Fig. 10 Total cost of each component (2001–2025), in US$

For all project activities, it is noteworthy that the failure to adopt alternative livelihood options is the most important cause of leakage. Thus, the rate of alternative technology adoption is a key factor that will determine the amount of leakage from the project.

In this study, we estimated the potential leakage in the proposed project by taking into account the historical experience in forestry projects in the Philippines. We conducted a literature review of the adoption rate of disseminated technologies and practices in upland watershed areas in the Philippines. Actual rate of adoption ranges from 17–98% with a mean rate of 63% for social forestry projects while agroforestry projects has a mean adoption rate of 71% (Table 7).

It is worthy to note that most of the technologies adopted representing mean adoption rate of 64% are agroforestry, soil conservation measures and social forestry while technology adopted representing low adoption rate of 17% was reforestation. These indicate that local communities are likely to adopt a technology that will

Table 6 Types and causes of likely leakage associated with each of the project component

Project component	Baseline driver	Type of leakage	Causes of leakage
Conservation of secondary forests	Deforestation	1. Primary	
		• Shifting of tree cutting to adjacent forest areas because of inappropriate livelihood option	• Livelihood options not attractive; loss of livelihood from land
		• Shifting of tree cutting because of refusal to adopt alternative livelihood options	
		2. Secondary	
		• "super-acceptance" of the alternative livelihood options	• Alternative options attractive to outsiders
	Small-scale logging	1. Primary	
		• Logging activities shifted by the same agents to adjacent forests	• Livelihood options not attractive
			• High market demand for logs
Reforestation of grasslands	No economic activity Agriculture Ranching	1. Primary	
		• Farming and ranching activity may be shifted by clearing adjacent forests	• Livelihood options not attractive
Agroforestry farm development	Agriculture/ Slash-and-burn	1. Primary	
		• Farming and ranching activity may be shifted by clearing adjacent forests	• Livelihood options not attractive

augment their income. For instance in the study conducted by Nasayao and Zara (1997) results showed that increased income of the farmers motivated them to adopt agroforestry technology. One advantage of practicing agroforestry is its ability to

Table 7 Rate of adoption of various technologies in upland watersheds in the Philippines

Province/Region	Technology	Rate of adoption	Reference
Regions 7 and 8 (Provinces in Central and Western Visayas)	Soil conservation measures	61 %	Dolom (1990)
Iloilo	Social forestry	52%, 98%, 64% in three project sites	Mamaril (1991)
Rizal	Social Forestry	86%	Langit (1988)
Isabela	Reforestation	17%	Tagana (1992)
Mean		63%	
Ifugao	Agroforestry	83%	Ngidlo (1990)
Quezon	Agroforestry	99%	Villanueva (1995)
Davao del Sur	Agroforestry	67%	SEARCA-UQ Survey Team (1995)
Mindoro	Agroforestry	Full adopter = 53% Partial = 47%	Sayami (1994)
Selected ISF areas in the Philippines	Agroforestry	77%	Calanog and Austria (1991)
Mean		71%	

address the concern of the farmers i. e. ready income from the cash crop or agricultural component of the technology and at the same time its capacity to maintain the ecological stability of the system through its tree component.

Castillo (1991) in her study of farmers adopting agroforestry technology in Ilocos Norte revealed that respondents noted an improvement in their economic status as evident in the changes in the housing materials used (from light materials to semi-concrete).

To increase adoption rate of technology such as reforestation, alternative livelihood should be provided to local communities to reduce their dependence on forest resources. Likewise, studies conducted on adoption noted that factors such as increasing awareness of the local communities of the benefits that can be derived from planting trees (Calanog and Austria 1991; Gerrits et al. 1997, Dolom 1990, Pulhin et al. 2002), security of tenure (Palijon 1988; Chiong-Javier 1997), and size of farms (Chiong-Javier 1997) among others dictate the rate of adoption of the farmers of agroforestry technology. Increased awareness of local communities of the decreased erosion, increased productivity, and sustained water resources due to presence of trees results to higher adoption of the agroforestry technology.

Farmers possessing larger farms are more keen on adopting agroforestry technology because they can devote a certain portion of their land to agricultural crops which can be the source of their immediate cash income while devoting the rest to trees. Local communities with greater security of tenure of the land they are tilling are likely to plant permanent crops such as trees.

Although no study on rate of adoption has been conducted on UMW, rate of adoption from existing studies can be used because upland areas and communities in the Philippines have almost the same characteristics. Upland communities are often characterized by low income, low educational attainment, and dependence on upland farms for their living.

In this study, two leakage scenarios were used: (a) baseline leakage representing the typical rate of adoption for upland development projects; and (b) project case which is based on a high adoption rate (Table 8). The latter is premised on improved adoption as a result of strategies to encourage higher adoption rate such as increased awareness and security of land tenure. These strategies have been shown to be effective in enhancing the rate of adoption in the Philippines.

Table 8 Projected rates of adoption of various technologies in UWM

Project component	Proposed practice/ technology	Observed rate of adoption elsewhere in the Philippines	Options that will improve adoption rate in UWM	Improved rate of adoption in UWM
Conservation of Secondary Forests	Agroforestry	71	Improve land tenure, increase awareness, etc. f	83
Reforestation of grasslands	Reforestation	63	Increase awareness of farmers	86
Agroforestry farm development	Agroforestry	71	Security of land tenure; increase awareness of farmers	83

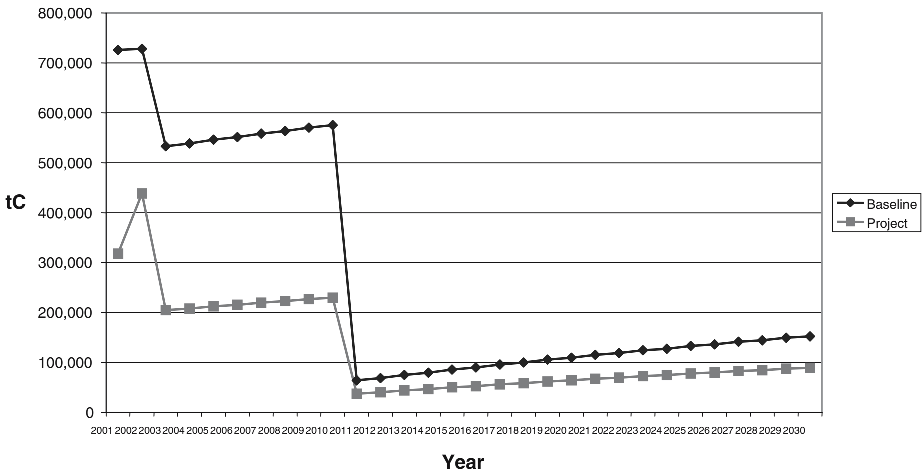

Fig. 11 Amount of carbon lost due to leakage in UMW

The two leakage scenarios (36% and 83%) have similar and contrasting effects on the carbon stocks of the watershed (Fig. 11). Both of them, resulted to a high leakage in the first ten years of the project. This is because tree planting activities will last up to ten years only. The baseline scenario resulted to a much higher loss of carbon than the moderate leakage scenario.

Amount of leakage was calculated by summing up the annual difference in carbon stocks between the zero leakage and a positive leakage scenario:

$$\text{Leakage} = \sum (C_0 - C_L)$$

Total leakage under the project scenario was 3.7 M tC while under the baseline scenario was 8.1 M tC (Table 9).

9 Summary and conclusions

The study has shown the potential of the UMW to conserve and sequester carbon. The three main development components of the project are forest conservation, tree plantations, and agroforestry farm development. At Year 30, the watershed can attain a net carbon benefit of 19.5 M tC at a cost of US$ 34.5 M.

The potential leakage of the project is estimated using historical experience in technology adoption in watershed areas in the Philippines. Two leakage scenarios where used: baseline and project scenario. Most of the leakage will occur in the first

Table 9 Total leakage (tC) by project component at UMW

Component	Baseline	Project
Forest	2,523,875	1,479,513
Tree plantation	5,180,000	1,960,000
Agroforestry	406,000	357,000
Total	8,109,875	3,796,513

10 years of the project as displacement of livelihood will occur during this time. The carbon lost via leakage will amount to 3.7 M tC and 8.1 M tC under the baseline and project scenarios, respectively.

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References

Austria IV (1991/2) Progress Reports on the Philippine Field Test of the Marketing Information System. Department of Environment and Natural Resources, Government of the Philippines, Quezon City, Philippines. (unpublished)

Aukland L, Moura Costa P, Brown S (2001) A conceptual framework and its application for addressing leakage on avoided deforestation projects. Draft Paper. Winrock International, 29 pp

Bass S, Dubois O, Moura-Costa P, Pinard M, Tipper R, Wilson C (2000) Rural livelihoods and carbon management. IIED Natural Resources Issues Paper No.1. International Institute for Environment and Development. London, UK, 94 pp

Borlagdan S, Guiang ES, Pulhin JM (2001) Community-based forest management in the Philippines: a preliminary assessment. Terminal Report. Institute of Philippine Culture, Ateneo de Manila University. Diliman, Quezon City and Department of Social Forestry and Forest Governance, College of Forestry and Natural Resources, University of the Philippines Los Baños. College, Laguna, 210 pp

Brown S (1997) Estimating biomass and biomass change of tropical forest: a primer. Forestry paper 134, FAO. Rome

Brown P (1998) Climate, biodiversity and forests: issues and opportunities emerging from the Kyoto Protocol. Washington DC, World Resources Institute, 35 pp

Brown P, Cabarle B, Livernash R (1997) Carbon counts: estimating climate change mitigation in forestry projects. World Resources Institute, Washington DC, USA, 25 pp

Brown S, Masera O, Sathaye J (2000) Project-based activities, Chapter 5, Land Use, Land-use Change, and Forestry, Published for the Intergovermental Panel for Climate Change, Cambridge University Press, Cambridge, pp 284–338

Brown S, Sathaye J, Cannel M, Kauppi P (1996) Management of forests for mitigation of greenhouse gas emissions In: Watson RT, Zinyowera MC, Moss RH (eds) Climate Change 1995: impacts, adaptations, and mitigation of climate change: Scientific-Technical Analyses, Chapter 24. Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge and New York, CambridgeUniversity Press, pp 775–797

Calanog LA, Austria MVO (1991) Extension strategies for the adoption of agroforestry farming systems in selected areas in the Philippines. Terminal report. Upland Farms Ecosystem Research Division. Ecosystems Research and Development Bureau. Department of Environment and Natural resources. College, Laguna, 72 pp

Castillo ER (1991) The adoption of agroforestry technology: the Case of the Hilly Land households. Unpublished Ph. D. Dissertation. University of the Philippines Los Baños. College, Laguna, 146 pp

Chiong-Javier ME (1997) Agroforestry intervention among the Hanunuo: lesson for program development. Developments in Agroforestry research. Book series No. 160. PCARRD. Los Baños, Laguna

CIFOR (2001) A shared research agenda for landuse, landuse change, forestry and the Clean Development Mechanism. Center for International Forestry Research. Bogor, Indonesia, 74 pp

Dolom B. DL (1990) Determinants of soil conservation measures adoption among upland farmers of selected integrated social forestry projects in regions VII and VIII. Unpublished MS Thesis. University of the Philippines Los Baños College, Laguna, 119 pp

Gerrits RV, Garcia JNM, Cramb RA (1997) Hedgerow adoption in the Hinterland of Cebu City: a reconnaissance survey. Working Paper No. 20. Los Banos, Philippines: SEARCA-UQ Uplands Research Project

Hairaiah K, van Noordwijk M, Palm C (1998) Methods for sampling above-ground organic pools. Paper presented during the Training-Workshop on Modelling Global Change Impacts on the Soil Environment. BOTROP-GCTE/Impacts Centre for Southeast Asia (IC-SEA). Bogor, Indonesia, pp 46–77

IPCC (2001) Climate change 2001: impacts, adaptation and vulnerability. Summary for policy makers and technical summary of the working group II Report

Langit DM (1988) A study on adoption oftechnologies introduced by the socail forestry program in Pagkalinawan, Jalajala, Rizal. Learning Site Series in Social Forestry No. 3, Social Forestry Program, Department of Social Forestry, College of Forestry, University of the Philippines Los Baños. College, Laguna, Philippines

Lasco RD, Pulhin FB (2000) Forest land-use change in the Philippines and climate change mitigation. Mitigation and Adaptation to Global Change Journal 5:81–97

Lasco RD, Pulhin FB (2001) Forestry mitigation options in the Philippines: application of the COMAP model. Mitigation and Adaptation Strategies to Global Change 6:313–334

Lasco RD, Pulhin FB, Sales RF, Guillermo IQ (2001) Carbon stocks assessment of secondary forests and tree plantations in the Philippines: towards improving GHG inventory. Terminal Report. Environmental Forestry Programme, College of Forestry and Natural Resources, University of the Philippines Los Baños. College, Laguna

Lasco RD, Lales JS, Arnuevo MT, Guillermo IQ, de Jesus AC, Medrano R, Bajar OF, Mendoza CV (2002) Carbon dioxide (CO_2) storage and sequestration of land cover in the Leyte Geothermal Reservation. Renew Ener 25:307–315

La Viña AGM (1997) Seeing with clear eyes: the challenge of community-based resource management and the role of academe. In: Castro C, Pulhin FB, Reyes LC (eds) Community-based resource management: a paradigm shift in forestry. FDC Policy Paper No. 97-01-06, UPLB, Philippines

MacDicken KG (1997) A guide to monitoring carbon storage in forestry and agroforestry projects. Winrock International Institute for Agricultural Development, Arlington, VA, USA, 87 pp

Mamaril RJ (1991) A systems evaluation of the performance and impact of selected integrated social forestry projects in Iloilo. Unpublished MS Thesis. Institute of Environmental Science, University of the Philippines Los Baños. College, Laguna, Philippines

Moura-Costa P (1996) Tropical forestry practices for carbon sequestration. In: Zchulte A, Schone D (eds) Dipterocarp forest ecosystems: towards sustainable management. World Scientific, Singapore, pp 308–334

Myers N (1996) The world's forests: problems and potentials. Environmental Conservation 23:156–168

Nasayao E, Zara MA (1997) Perceptions, attitude and behavior of CARP-ISF farmer-beneficiaries and their influence on agroforestry technology adoption in Eastern Visayas. Developments in Agroforestry Research. Book Series No. 160. PCARRD. Los Baños, Laguna, pp 318–327

Ngidlo RT (1990) Factors associated with farmer's adoption of agroforestry: a study of four selected ISF projects in Ifugao Province. Unpublished MS Thesis. College of Forestry, University of the Philippines Los Baños. College, Laguna, Philippines

Nicholls N, Gruza GV, Jouzel J, Karl TR, Ogallo LA, Parker DE (1996) Observed climatic variability and change, Chapter 3. In Houghton JT, Meira Filho LG, Callander BA, Harris N, Kettenberg A, Maskell K (eds) Climate Change 1995: impacts, adaptations, and mitigation of climate change: scientific-technical analyses, contribution of working group I to the second assessment report of the intergovernmental panel on climate change, Cambridge and New York, Cambridge University Press, pp 137–192

Palijon AM (1988) Contour farming: a documentation of technology introduction and adoption in a social forestry learning site. Learning Site Series in Social Forestry No. 5, Social Forestry Program, Department of Social Forestry, College of Forestry, UP Los Baños. College, Laguna, Philippines, 16 pp

PCARR (1980) Standard methods of analysis for soil, plant tissue, water and fertilizer. Philippine council for agriculture and resources research. Los Baños, Laguna, Philippines, 194 pp

Pulhin JM, Rondal JD, Quiton JD, Tapia MA (2002) Adoption of soil and water conservation technology in Impasug-ong, Bukidnon, Philippines. Journal of Environmental Science and Management 5(1–2):27–38

Sayami P (1994) Agroforestry adoption patterns in three selected integrated social forestry projects in Oriental Mindoro, Philippines. Unpublished MS Thesis. College of Forestry, University of the Philippines Los Baños. College, Laguna, Philippines

Schimmel D, Enting IG, Heimann M, Wigley TML, Rayneud D, Alves D. and Seigenthler U (1995) CO_2 and the carbon cycle. In: Houghton JT, Meira Filho LG, Bruce J, Lee H, Callander BA, Haites E, Harris N, Maskell K (eds) Climate change 1994: radiative forcing of climate change and an evaluation of the IPCC IS92 Emision Scenarios, Published for the IPCC, Cambridge University Press, pp 35–71

SEARCA-UQ Survey Team Los Banos: SEARCA (1995) Soil conservation in an upland farming system in Cebu : a socio-economic survey [Survey report No.1] / SEAMEO. Regional Centre for Graduate Study and Research in Agriculture, College, Laguna PH. Project: SEARCA-UQ Uplands Research Project. Descriptors: SOIL CONSERVATION; PHILIPPINES MFN 614 Language: En SEARCA TR 1995, 104 p

Tagana RM (1992)Some correlates of people's participation in family and community contract reforestation in Isabela.Unpublished MS Thesis.College of Forestry and Natural Resources, University of the Philippines Los Banos, College, Laguna, 143 pp

Villanueva SP (1995) Impact analysis of a community-based agroforestry farm development projects in atimonan, Quezon. Unpublished MS Thesis. Institute of Environmental Science, University of the Philippines Los Baños. College, Laguna, Philippines

Watson RT, Noble IR, Bolin B, Ravindranath NH, Verado DJ, Dokken DJ (eds) (2000) Land use, land-use change, and forestry, published for the intergovernmental panel for climate change, Cambridge University Press, 377 pp