Climate Change and Forest Ecosystems in the Philippines: Vulnerability, Adaptation and Mitigation

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ABSTRACT

Climate change and Philippine forests are directly linked to each other. Changes in climate are affecting the forests and its ability to deliver its environmental services. In the same manner, degradation of the forest resources results to emission of carbon dioxide (CO_2) in the atmosphere which contributes to climate change. To enhance the mitigation role of the forests and at the same time increase their resilience to climate change, policies and programs must be put in place. Such policies and programs must however be science-based. This paper reviewed one decade of research on climate change and forest ecosystems in the Philippines. Limited research suggests that dry forest types are the most vulnerable to climate change. Potential adaptation strategies do exist but have not yet been adequately studied. Most of the past research has focused on the mitigation potential of terrestrial ecosystems. Significant amount of carbon is conserved in natural forests (up to 250 MgC/ha). These stored carbon can be emitted to the atmosphere as CO_2 gas through deforestation. Planted trees have a high rate of carbon sequestration (mean of 4.3 MgC/ha/yr) and could help mitigate greenhouse gas concentration. Lessons that are relevant to forest management in the country are extracted. Future research needs are suggested.

Key words: tropical forests , climate change impacts, vulnerability, adaptation, mitigation

INTRODUCTION

Climate change is becoming a present reality. The most recent Inter-governmental Panel for Climate Change (IPCC) report concludes that warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, wide-spread melting of snow and ice, and rising global average sea level (*IPCC WG I, 2007*).

In the Philippines, climate change is also occurring as evidenced by the increasing mean temperature observed over time. For instance, from 1951 to 2006, records of the national weather bureau (PAGASA) show that warming has occurred in the country (*Hilario 2008*). Rising sea levels, one of the indicators that climate change is occurring, have also been observed to happen from five major stations (Manila, Legazpi, Cebu, Davao and Jolo). Annual mean sea level is observed to increase in Manila since 1960s while for the rest of the stations, sea level rise occurred in 1970s. In the Manila, Legazpi and Davao stations, an increase of almost 15 cm was observed from 1980-1989.

Among the ecosystems that will be greatly affected by climate change are the forests. Projected adverse impacts of climate change on forests include increased occurrence of forest fires, which will put the forests at risk and increased occurrence of pests and diseases and loss of thousands of species (*IPCC, 2007*). With the reduction of the forest area, ecosystem services such as biodiversity, water, carbon, climate regulation, soil and water protection or purification, recreational, cultural and spiritual benefits provided by the forests will also decrease. For instance, Fischlin *et al.* (*2007*) mentioned that globally, about 20% to 30% of species (global uncertainty range from 10% to 40%, but varying among regional biota from as low as 1% to as high as 80%) will be at increasingly high risk of extinction, possibly by 2100, as global mean temperatures exceed 2 to 3°C above pre-industrial levels.

Since forest ecosystems have important

environmental services to deliver, it is imperative that they are protected not only from human interventions but from the impacts of climate change. Sound measures i.e. policies and programs to increase the resiliency of the forest ecosystems to climate change and enhance their mitigation role can be crafted if they are based on researches. In the Philippines however, there are not much studies undertaken that investigate the interaction between forests and climate change. While forests and climate change studies started about ten years ago, most of the research effort focused on the role of these ecosystems in carbon sequestration and climate change mitigation. Only more recently that the impacts of climate change on forest ecosystems and potential adaptation measures have also been investigated. The purpose of this paper is to review these researches and distill lessons from them relevant to forest management in the Philippines.

REVIEW OF RESEARCHES ON FORESTS AND CLIMATE CHANGE

Potential Impacts of Climate Change to Forest Ecosystems in the Philippines

Philippine forests have extremely high floral and faunal diversity (*PAWB-DENR 2006*). They harbor about 13,000 species of plants, comprising 5% of the world's total of plant species (*DENR/ UNEP 1997*). For terrestrial vertebrate fauna, it is estimated around 927 species of which, 594 are endemic (64 percent) to the country (*de Leon 2007*). Indeed, the Philippines is one of the biodiversity "hot spots" and "megadiversity areas" of the world (*McNeely et al. 1990*). Moreover, the archipelagic characteristic of the country is highly vulnerable to climate change which could threaten the extinction of the so many island-endemic/specific flora and fauna.

The main strategy in biodiversity conservation in the Philippines is through the implementation of the National Integrated Protected Area System (NIPAS) Law in 1992, giving a stronger legal basis for the establishment and management of protected areas. Of the 290 protected areas in the country, 203 were initial component under NIPAS and another 87 others as additional components were recognized (*DENR 1997*). However, many of these areas are protected merely on paper due to lack of resources and externalities. These externalities include patterns of resource use, societal values or political patronage systems existing within the context of poverty, insurgency and state sponsored resource extraction (*van der Ploeg & Mesipiqueña, 2005*). *Ong* (*2002*) further enumerated specific issues under this system such as lack of national land use policy that delineate clearly the boundaries, limited number of conservation professionals, limited management and enforcement capacity of the protected area managemeit board to name some. Accordingly, there are 91 critical areas, which have no protection at all.

The Philippines is considered a biodiversity hotspot in two major ways. First, threats and their impacts change, e.g. some places may become more threatened while others, if conservation efforts are successful may eventually recover. Second, knowledge of biodiversity, threats, and costs is continually improving, e.g. new species and populations are discovered, and higher-resolution land cover data is collected (*Mittermeier et al. 2004*). Numerous efforts have been done to determine how biodiversity will change over time as a result of climate change through global ecosystem models. Real-world dynamic situations are usually very difficult to model and so the information from these models are still quite limited.

Not all global vegetation models agree on whether tropical forests will increase or decrease as a result of climate change. But any major shift in rainfall pattern will affect distribution of vegetation types. Shifts in rainfall patterns could increase conversion of forests to agricultural land by increasing migration from areas affected by drought, erosion, etc. Productivity will increase or decrease depending on rainfall. Temperature change affects the climate of a certain area drastically leading to a loss of a few species of plants and animals that may significantly drain the biodiversity of these forests. A 2-3°C increase in temperature will have marginal effects in the tropics but extended exposure to temperatures of 35-40°C combined with water shortage may damage plant tissue (*Hudson and Brown 2006*).

A decade ago, it was hypothesized that tropical forest areas in the Philippines will likely expand as temperature and precipitation increase in many parts of the country (*Cruz 1997*). Temperature change may lead to a loss of a few species of plants and animals that may significantly erode the biodiversity of these forests. Although it is also possible that these species may adapt to the stresses in the environment over the period of time climate change occurs, it is also possible to speculate that there will not be significant changes in the biodiversity of the forests.

Since that time, only two studies have been conducted on the potential impacts of climate change to Philippine forests. The first study employed the Holdridge Life Zone system (*Lasco et al. 2007*). The Holdridge Life Zone is an ecological classification system based on the three climatic factors, i.e. precipitation, heat (biotemperature) and humidity (potential evapotranspiration ratio (*Holdridge 1967*). Holdridge defined a life zone as a group of associations related through the effects of these three major climatic factors. The current vegetation types in the Philippines fall under dry forest, moist forest and wet forest. Using GIS, we simulated how these forest types will change under increasing rainfall and temperature consistent with earlier projections as contained in the Philippines' Initial National Communication (*1999*) to the UN Framework Convention on Climate Change. Early General Circulation Models (GCM) simulations showed that the Philippines will experience up to $3^{\circ}C$ rise in temperature and 100% rise in precipitation (more recent GCMs simulations showed that precipitation will rise but at a much lower rate). Our results showed that the dry forests are the most vulnerable terrestrial ecosystems in the Philippines which will disappear even with just 25% increase in rainfall (**Figure 1**). These forests types are found in Northern Luzon, Negros, Cebu, Palawan, Basilan and General Santos.

Climate change is hardly being considered at all in the planning process of the government for forest resources. More often than not, government plans to address climate risks and vulnerabilities have a time span of around 10-20 years. This is still not sufficient to address climate change issue. Usually, the more urgent concern is to save remaining forests from human exploitation that is the more imminent threat.
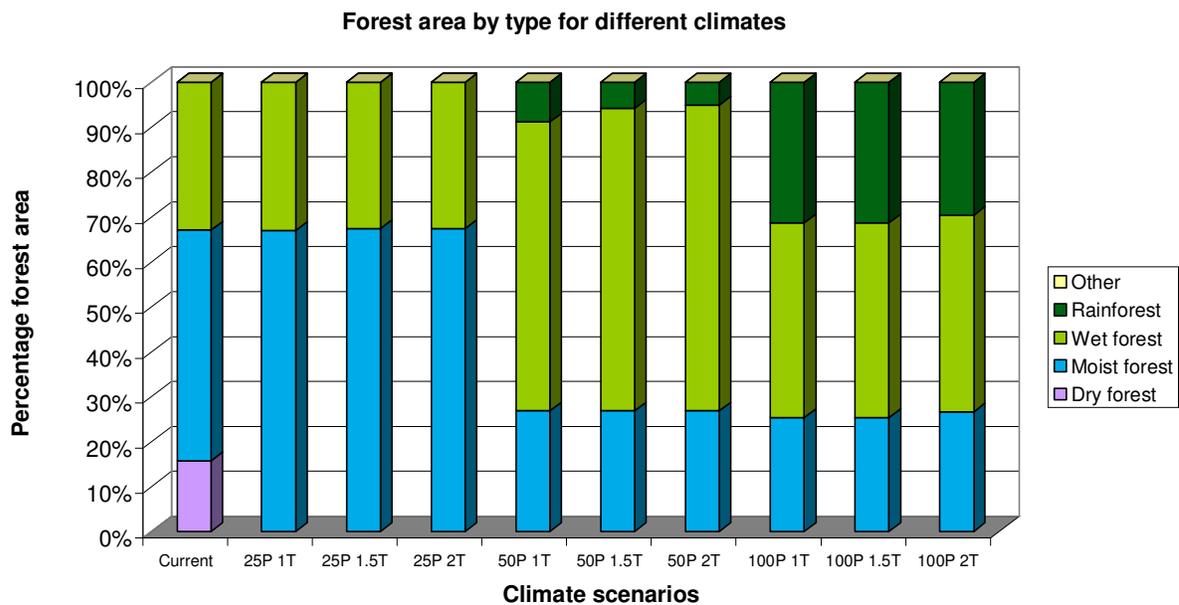

Figure 1. Projected change in area of existing life zones in the Philippines under rising temperature a precipitation X-axis legend: Number before P is the % increase in precipitation; number before T is the increase in temperature in $^{\circ}C$.

Current laws and regulations such as the National Integrated Protected Areas System (NIPAS) law, Executive Order No. 318 (Promoting Sustainable Forest Management in the Philippines), Revised Master plan for Forest Development, Wildlife Resources Conservation and Protection Act (RA 9147) and the Indigenous People's Rights Act (RA 8371 or the IPRA) among others may need to be re-assessed and updated to focus more on how forest management can be improved to mitigate climate change, with special interest in areas classified as dry forests. A national adaptation strategy should probably focus on identifying forested areas that are more at risk and the unique species these areas harbor. Specific adaptation options could include conservation and management of vulnerable species, assisting local communities that are highly dependent on forests at risk and others.

More generally, the Philippines can explore other means of reducing the impacts of climate change on biodiversity by adopting biodiversity-based adaptive and mitigative strategies such as: maintaining and restoring native ecosystems, protecting and enhancing ecosystem services, managing habitats of endangered species, creating refuges and buffer zones, and establishing networks of terrestrial, freshwater and marine protected areas taking into account climate change (*CBD 2007*). These are consistent with the National Biodiversity Strategy and Action Plan (NBSAP), the Philippines' program to conserve biodiversity. NBSAP has identified six strategies to conserve biodiversity in the country: expanding and improving knowledge on the characteristics, uses and values of biological diversity; enhancing and integrating existing planned biodiversity conservation efforts with emphasis on in-situ activities; formulating and integrating policy and legislative framework for conservation, sustainable use and equitable sharing of benefits of biological diversity; strengthening capacities for integrating and institutionalizing biodiversity conservation and management; mobilizing and integrated information, education and communication (IEC) system for biodiversity conservation; and advocating stronger international cooperation on biodiversity conservation management. (*PAWB-DENR 2006*).

Future studies need to look at how climate change and the accompanying change in forest types will affect the biodiversity at the species level with special emphasis on rare, threatened and endangered species. It is also recommended that a thorough review of existing policies on managing forest ecosystems in the country should be conducted. This is to address the projected impacts of climate change and safeguard the country's forest resources from irreparable damage. In addition, more refined climate change scenarios using downscaling techniques are needed to better estimate changes in precipitation and temperatures.

The IPCC suggested the following potential adaptation strategies for forest ecosystems in Asia: improved technologies for tree plantation development and reforestation, improvement of protection from fires, insects and diseases, comprehensive intersectoral programs that combine measures to control deforestation and forest degradation with measures to increase agricultural productivity and sustainability, extending rotation cycles, reducing damage to remaining trees, reducing logging waste, implementing soil conservation practices, and using wood in a more carbon-efficient way such that a large fraction of their carbon is conserved (*Cruz et al. 2007*).

The Role of Terrestrial Ecosystems in Mitigating Climate Change in the Philippines

There is considerable interest on the role of terrestrial ecosystems in climate change, more specifically on the global carbon cycle. The world's tropical forests covering 17.6M km^2 contain 428Gt C in vegetation and soils. It is estimated that about 60Gt C is exchanged between terrestrial ecosystems and the atmosphere every year, with a net terrestrial uptake of 0.7 ±1.0Gt C. However, land use, land-use change and forestry (LULUCF) activities, mainly tropical deforestation, are also significant net sources of CO_2, accounting for 1.6Gt C/yr of anthropogenic emissions (*Denman et al. 2007; Watson et al. 2000*).

Tropical forests have the largest potential to mitigate climate change amongst the world's forests through conservation of existing carbon pools (e.g. reduced impact logging), expansion of carbon sinks (e.g. reforestation, agroforestry),

Table 1. Carbon storage and sequestration of forest landuse in the Philippines (Lasco and Pulhin, 2000).

Landuse Type	Area (M ha)	Carbon storage (Mg/ha)	Total C in Biomass (Tg)	C sequestration rate (Mgha^{-1}yr^{-1})	Total C sequestration (Tg/yr)
Protection Forest	2.7	113.7	306.99	1.5	4.05
Second-growth forest	3.4	111.1	377.74	2.2	7.48
Brushlands	2.3	35	80.5	0.5	1.15
Grasslands	1.2	5	6	0	0
Tree Plantations	0.6	55.6	33.36	4	2.4
Agroforestry	5.7	50.3	286.71	2.7	15.39
TOTAL	15.9		1091.3		30.47

Note: 1 Tg C= 1 x 10^{12} gC= 1 M tC

and substitution of wood products for fossil fuels. In tropical Asia, it is estimated that forestation, agroforestry, regeneration and avoided deforestation activities have the potential to sequester 7.50, 2.03, 3.8-7.7, and 3.3-5.8 billion tons C between 1995 and 2050 (*Brown et al. 1996*).

There are three general ways by which forest management in the Philippines can be employed to curb the rate of CO_2 increase in the atmosphere: conserving existing carbon pools, expanding the amount of carbon stored, and substituting wood products for fossil-fuel products.

Conservation of Existing Carbon Sinks

The goal of this approach is to maintain or improve existing carbon pools in Philippine forests by protecting forest reserves, the use of appropriate silvicultural practices and controlling deforestation. Studies in the last ten years have shown that natural forests in the Philippines contain significant amounts of carbon with old growth forests having the highest carbon density of more than 250 tC per ha (*Lasco et al. 2003*). Overall, we estimate that Philippines forest lands contain more than 1,000 TgC (**Table 1**).

Protected (mainly old-growth and mossy) and second-growth forests cover 6.1 M ha in the Philippines. The NIPAS Law provides the legal foundation for the conservation of protected forests. However, there are fears that a substantial portion of protected areas are still without adequate protection. Activities that promote the conservation of these forest areas will contribute positively by preventing the release of carbon to the atmosphere. In the past, deforestation rate in the Philippines was about 100,000 ha which translates to a loss of about 8.8 M tons C every year (*Lasco 1998*). Strategies that will reduce the rate of forest loss will contribute to the reduction of carbon emitted to the atmosphere.

While much of the attention is focused on plant C storage, tropical forest soils are significant sinks of C. It is estimated that up to 30% (90 t/ha) of C in the forest ecosystem is tied up in the soil (*Moura-Costa 1996*). Consequently, practices that help maintain or improve soil organic C will have positive benefits. Examples of these practices are (*Dixon et al. 1993*): soil erosion control measures, improving soil fertility, reducing shifting agriculture, and retaining forest litter and debris after logging.

Expansion of Carbon Stocks in Forest Lands

The goal of this approach is to expand the amount of C stored in forest ecosystems by increasing the area and/or C density of natural and plantation forests and increasing storage in durable wood products.

Since C sequestration is a function of biomass accumulation, the simplest way to expand C stocks is to plant trees. Philippine forests and trees sequester carbon at various rates with plantations of fast growing species having the largest rates approaching 10 tC/ha/yr (*Lasco et al. 2003*). It is estimated that annual carbon sequestration of all forest lands in the Philippines to be in the order of 30 Tg C/yr (**Table 1**).

However, it is also estimated that Philippine forests release 0.3 and 11.1 TgC/yr because of wood harvest and deforestation, respectively (*Lasco 1998*). Thus, the net C sequestration is 19.6 TgC/yr. This is about midway between the two previous estimates of 7.1 TgC/yr (*Lasco 1998*) and 27.2 TgC/yr (*Lasco and Pulhin 1998*).

The total Philippine CO_2-e emissions from fossil fuel is about 100 Tg/yr (*The Philippines Initial National Communication to the UNFCCC 1999*). Based on the above calculations, forest lands maybe able to sequester an equivalent of about 71.7 Tg of CO_2 per year (19.63 TgC/yr x 3.67) or 55 % of the total CO_2 emitted by the whole country. In the first national GHG inventory using the 1996 IPCC guidelines, forest lands in the Philippines were estimated to have a gross CO_2 uptake of 99 Tg/yr (*Francisco 1997*) compared to our estimate of 110 Tg/yr (30 TgC/yr x 3.67). However, CO_2 emissions from forest lands (decay and harvest) were calculated to be 120 Tg/yr in the national GHG inventory (*Francisco 1997*) so that forest lands become net emitter of C (-21 Tg/yr). Thus, while forest lands are a net sink of C in our estimate, it is a net source of C in the first national GHG inventory. This difference is significant considering that emissions from forest land use is the largest component (50%) of total Philippine C emissions.

In terms of land area that could be used to expand carbon stocks through tree planting, the Philippines has at least 1.18 M ha of grassland areas that could be reforested. Aside from the many benefits associated with forests, these areas have the potential to sequester a substantial amount of C. Assuming a C fixation rate of 4.4 t/ha/yr (*Lasco 1998*) for Philippine plantations, a minimum of 5.2 M tons C can be sequestered every year if all these areas are reforested. This rate is already equal to 15 % of total current annual C emissions of the entire Philippines.

Aside from the grassland areas, brushland and agricultural areas could provide additional areas for rehabilitation (up to 8 M ha.). Most of these areas have low C densities as a result of less than optimum use of the land. In shifting cultivation areas, the use of agroforestry is usually recommended. The introduction of woody perennial species will expand the C storage capability of cultivated areas. The choice of species to be planted will affect the potential to sequester C. In the Philippines, fast-growing species such as *Gmelina arborea*, *Acacia mangium* and *Eucalyptus* spp are commonly used. They accumulate more biomass and C than slow growing species for the same period of time. However, fast-growing species typically have lower wood density and thus contain less C than wood of slow-growing species.

Substitution of Wood Products for Fossil Fuels-based Products

Substitution aims at increasing the transfer of forest biomass C into products (e.g. construction materials and biofuels) that can replace fossil fuel-based energy and products, cement-based products and other building materials (*IPCC 1995*). This approach is considered to have the greatest mitigation potential in the long term (> 50 years). For instance, the substitution of wood grown in plantations for coal in power generation can avoid C emissions by an amount up to four times that of C sequestered in the plantation.

Opportunities Under the Emerging Carbon Market

In the last five years, there has been a rising interest on climate change mitigation projects in the Philippines. Much of this interest is probably due to the hype associated with climate change in general (as a result of recent media coverage) and CDM in particular. Three things influence whether this interest advance further: the strict requirements for a CDM project, the level of transaction costs (up to US$100,000 per project), and the current price of carbon from forestry projects (about US$15 per ton C) vis-à-vis the development cost. Three CDM forestry projects under development are presented below.

a) The LLDA-Tanay Streambank Rehabilitation Project (Lasco and Pulhin 2006)

The main proponents/sellers of this project are the Municipality of Tanay and the Laguna Lake Development Authority (LLDA). The implementers will be farmers in the Tanay watershed.

The main objective of the project is to reduce greenhouse gases (i.e. CO_2) in the atmosphere while helping rehabilitate the Tanay watershed and providing socio-economic benefits to the local people. Specifically, the project aims to initially:

- Reforest 70 ha of private lands
- Established 25 ha of agroforestry farms in public lands
- Sequester 10,000 to 20,000 t of CO2 from the atmosphere in 20 years

The project area is expected to eventually cover 1,000ha.

Streambank rehabilitation. The purpose of this activity is to increase the riparian forest cover of the Tanay river in order to reduce erosion. Under this component, owners of private lands will be encouraged to plant trees along river banks within their property. Seedlings will be given for free after an information and education campaign and a pledge of commitment to the project. Provision of seedlings and support services will be contracted through the Katutubo village, an upland village comprised of indigenous Dumagat and Remontado groups. A total of 20 ha will be reforested with 33,333 trees.

Ecological Enhancement in Upland Areas. The purpose of this second sub-component will be to reforest upland areas near the headwaters of the Tanay river in order to reduce erosion. A total of 50 ha of denuded and grassland areas will be reforested at 2 x 3 m spacing with 83,333 trees. Provision of seedlings, planting and maintenance will be implemented by the Katutubo village. The species will be chosen by the community and will provide them timber, fruit and medicinal resources.

Agroforestry orchard. The purpose of this sub-component is to provide income for the Katutubo village through agroforestry while reducing erosion in the upland areas. This component will be undertaken in an area of 25 ha of communal land belonging to this IP community. It will integrate mango trees at 10 x 10 m spacing with cash crops using a alley cropping design. A total of 2,500 trees will be planted.

The expected GHG benefits were calculated using a high and low scenario. For the project period (2004-2014), the project will have total net carbon benefits of 3,204 tC (11,759 tCO$_2$-e) and 1,424 (5,230 tCO$_2$-e) under the high and low scenarios, respectively (*Santos-Borja et al. 2003*). The anticipated Total Emission Reduction Purchase Agreement (ERPA) Value is US$ 31,380 for the low scenario and US$70,554 for the high scenario. For the 20 year project duration, total carbon sequestration is shown in **Figure 2**

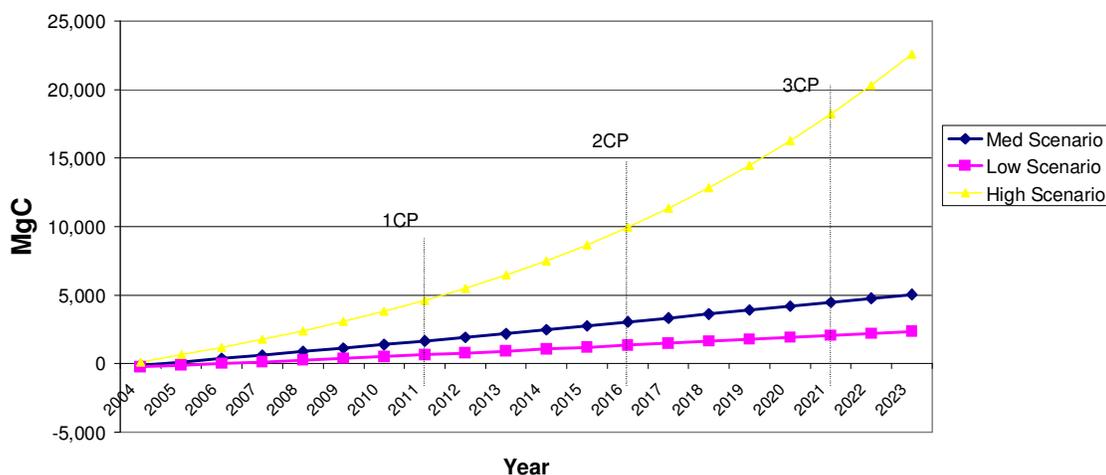**Net Carbon Sequestration over a 20-year period in Tanay, Philippines**

Figure 2. Net carbon sequestration under various scenarios of the LLDA project in Tanay, Rizal.

under various scenarios. The buyer of the carbon credits is the World Bank carbon fund which is also providing technical assistance to the LLDA and its partners.

b) Kalahan Forestry Carbon Projects (from Villamor and Lasco 2007)

The Ikalahan Ancestral Domain covering 58,000 hectares of mountainous forest and farmlands is found in the provinces of Pangasinan, Nueva Ecija and Nueva Vizcaya, in the northern Luzon. In 2003, Kalahan was selected to be the first RUPES-ICRAF pilot site in the country to develop a carbon sequestration payment mechanism. The Kalahan Educational Foundation (KEF) is targeting the two types of carbon markets– the regulated market through Kyoto's Clean Development Mechanism (CDM) and the voluntary carbon market. To date, the KEF has done preliminary activities in preparation for these markets notably the preparation of project idea notes (PINs) and awareness building among the members of the indigenous group. Through the PINs, KEF is actively seeking potential partners and buyers of carbon.

For the Kyoto market, KEF aims to convert the 900 hectares of marginal and abandoned agriculture land to more productive tree-based system through reforestation, the only "sinks" project allowed under the CDM. More specifically, the project aims to: convert the 900 ha of marginal and abandoned agriculture land to more productive tree-based system; enhance the livelihood of the communities in the proposed area through agroforestry; and protect the watershed, enhance the biodiversity, and improve land beauty of tourism area. The main strategy of the project will be community-based forest management. The key stakeholders of the project will be as follows: the Ikalahan-Kalanguya indigenous communities, local NGOs, the DENR, project monitoring team, and the funding organization. All the project activities will be developed with the participation of indigenous communities in the project area. KEF will catalyze the community organizing and development process; and manage and implement the project. The project monitoring team will quantify the carbon sequestered and assess the impacts of the project. The funding organization will provide the financial resources for the project.

The project will employ two rehabilitation technologies: agroforestry and reforestation. The agroforestry component will involve the introduction of fruit trees to existing upland farms (typically with annual crops such as corn and rice). Aside from its environmental benefits, fruit trees will also be able to provide livelihood for poor upland farmers. On the other hand, reforestation will target degraded areas that have been covered with grasses for many decades. Only native species and those that have been introduced in the Philippines for the last 10 years will be used, with priority for those species already growing in and around the project area. For reforestation, the following species have initially been identified: mostly indigenous Dipterocarp species, with *Bischofia javanica* and *Alnus nepalensis* which are observed to be favorable to wildlife. The fast growing species *A. nepalensis* is intended to rapidly establish vegetative cover to the area especially in highly degraded areas. Indigenous species will be planted in more favorable areas and underneath fast growing nurse trees.

It is estimated that the 900 ha area will be able to sequester 89,776 t CO_2-e for 20 years under the medium tree growth scenario (**Figure 3**). This estimate is based on Philippines tree growth rates (*Lasco et al. 2004*) and is consistent with IPCC values. More site-specific based estimates can be done in the future since local growth rates are being analyzed at present.

For the voluntary carbon-offset markets, the objective is to maintain 10,000 hectares of secondary forests as production and carbon sequestrating forests. At present, this type of project is not allowed under the CDM, thus they plan to tap the voluntary market. The KEF is preparing a PIN with focus on enrichment planting and rigid implementation of Forest Improvement Technology developed by the Ikalahans to enhance carbon sequestration. Initial estimates show that the forest area can sequester 1.7 million tons of CO_2 for a period of 20 years. Growth-rate studies of the indigenous trees of Kalahan forests are currently being completed which can be used to calculate site-specific carbon sequestration rates.

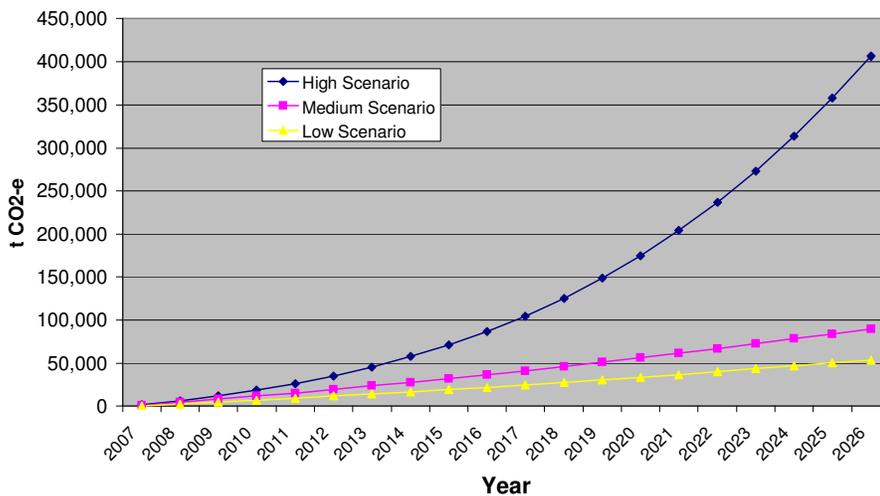**Net Cumulative CO$_2$-e Removals by the Kalahan Reforestation Project, Philippines**

Figure 3. Estimated net cumulative CO$_2$-e removals by the proposed Kalahan Reforestation Project, Philippines (*Villamor and Lasco 2006*).

c) CI-Philippines Sierra Madre Project (from Lasco and Pulhin. 2006)

The proposed carbon sequestration project is part of Conservation International (CI)- Philippines' concerted efforts to build alliances with local communities, private sector, government agencies and NGOs to facilitate the management of the Sierra Madre Biodiversity Corridor and strengthen enforcement of environmental laws. It uses a multifaceted approach to alleviate threats and to restore and protect 12,500 hectares of land within the Corridor.

The CI's ultimate objective for the project is to demonstrate that a properly designed and implemented carbon offset project not only offers an economically attractive, risk-managed portfolio option, but also generates multiple benefits such as biodiversity protection, watershed restoration, soil conservation, and local income-generation. It will also demonstrate that tradeoffs such as soil erosion, water table decrease, and loss of livelihoods can be avoided.

Specifically, the project has the following objectives:

- In order to conserve biodiversity in the term, the project will protect 5,000 hectares of natural forests (old growth and second growth) slated for cutting;

- To reduce pressure to the natural forest and provide incentives for local communities, the project will work to establish an agroforestry project on 2000 hectares brushland areas that will supply a more stable income to the population and lessen the reliance on forest projects, and

- In aiding the sequestration of carbon dioxide from the atmosphere and increasing the connectivity of sensitive habitats for the world's most threatened species, the project will restore 5,500 hectares of grassland areas to original hardwood forests using a mix of fast-growing species and native species.

The main strategy of the project will be community-based forest management. The key stakeholders of the project will be as follows: the local community/PO, local NGOs, Local Government Unit (LGU), the DENR, the project monitoring team, and the funding organization. After 30 years, it is expected that a total of 512,000 tC will be sequestered by the project most of which will come from the reforestation

component (453,000 tC).

Reducing emissions from deforestation and degradation (REDD)

More recently, several sectors are advocating payments for avoiding deforestation in developing countries under the so-called "Reducing emissions from deforestation and degradation" or REDD perhaps in the post-2012 Kyoto Protocol. This is in recognition that deforestation mainly in the tropics account for 20% of all greenhouse gas emissions (*Denman et al. 2007*). However, "the design and implementation of REDD policies will be neither simple nor straightforward, given the complexity of the social, economic, environmental and political dimensions of deforestation. Many of the underlying causes of deforestation are generated outside the forestry sector and alternative land uses tend to be more profitable than conserving forests" (*Kanninen et al. 2007*).

In the Philippines, research on REDD is just starting. As shown above, various Philippine forest types contain significant amount of carbon stocks which could be released to the atmosphere. Indeed, we estimate that since the 1500s, deforestation of 20.9 million ha of Philippine forests contributed 3.7 Pg (10^{15} g) of C to the atmosphere of which 2.6 Pg tons were released this century (*Lasco and Pulhin 2000*). However, recent data from the DENR show that the rate of deforestation has tapered off and that forest cover is on the rise (*FMB 2004*). If this is the case, then the country cannot expect payments for reducing deforestation since the baseline will show that deforestation is already on the decline even without carbon payments.

However, a case may be made that while total forest area is increasing, forest degradation is taking place. Cutting of trees inside the forest by various forms of logging could lead to lower biomass and carbon stocks. For example, in Mindanao logging led to a decline of above-ground C stocks by about 50% (100 Mg C ha^{-1}) (*Lasco et al. 2006*). There is hardly any data available on the extent of biomass degradation in Philippine forests.

FUTURE RESEARCH NEEDS

Ten years of research have shown the important link between climate change and forest ecosystems in the Philippines. Projected changes in climate change will have impacts on forests and their biodiversity resources. Conversely, the protection of the natural ecosystems and its biodiversity can strengthen its resilience against these projected changes thus improving its ability to provide critical environmental services. These ecosystems have a great potential for climate change mitigation through conservation of carbon stocks contained in the various plant species as well as increase carbon sequestration. In spite of a number of researches that have been conducted, there remains a wide knowledge gap. There is very limited information on the impacts of climate change on natural ecosystems and their biodiversity pool. Better climate change projections are needed through downscaling of GCM results. Potential impacts to endangered species and ecosystems need to be prioritized. In addition, priority should also be given to those ecosystems that support important livelihood needs. The hypothesis that systems with high biological diversity are more resilient to global change than less diverse systems requires testing.

There are also remaining information gaps on the climate change mitigation role of forest ecosystems. Among the knowledge gaps that need to be filled include:

• Carbon sequestration rates of Philippine trees, especially in various agro-ecological zones of the country;

• Economic analysis of forestry carbon projects; Models of production systems (eg agroforestry) that will optimize carbon and biodiversity benefits

On the national scale, there is a need to assess the forestry sector contribution to the national GHG emissions and sinks using the new 2006 IPCC guidelines.

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