Working Paper

# Rapid carbon stock appraisal

## Kalahan, Nueva Vizcaya, Philippines

*Grace B. Villamor, Nelson Pampolina, Reginald Forcadilla, Nonoy Bugtong, Jerome Alano, Delbert Rice, Tina Omas, Reymar Castillo, Dennis Pulan*

Southeast Asia

World Agroforestry Centre
TRANSFORMING LIVES AND LANDSCAPES

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Working Paper 106

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# Abstract

A research method called Rapid Carbon Stock Appraisal (RaCSA) was conducted in Kalahan Forest Reserve (KFR), in Nueva Vizcaya Province, Northern Luzon, Philippines from August 2009 to January 2010. The aim of this activity was to support communities, such as the Ikalahan people, to establish basic data needed in negotiating with carbon markets in a cost-effective and time-efficient manner. The appraisal involved a combination of methods and activities (for example, plot-level carbon measurement, spatial analysis of land-use cover, focus group discussions, key informant interviews and a review of the literature).

There were several key results of the appraisal.

- *Land-use types and farming practices*. The majority of Ikalahan are swidden farmers practising traditional farming (for example, *pang-omis*, which involves integrating tree seedlings of species such as *Alnus* in the swidden farms). Five major land-use and land-cover types were identified and assessed, that is, agriculture, agroforest, grassland, reforestation and secondary forests.
- *Plot-level carbon stocks*. The estimated carbon stock of land-use systems in the KFR ranged 0.61–77.86 Mg/ha for aboveground carbon; and 21.8–67.4 Mg/ha for belowground. Total (above- and belowground) carbon stock was estimated to range 54.31–151.13 Mg/ha. These results are low compared to other carbon assessments conducted in the country.
- *Land-use and land-cover changes*. Land-use and land-cover changes within KFR between 1981 and 2001 were assessed. A decrease in forest, pine and agriculture occurred while there was an increase in old pine and reforestation (for example, mahogany). Carbon values from monitoring plots in 1994 and 2003 were used to extrapolate the land-cover types of the 1981 and 2001 maps, respectively. Based on the results, total carbon stock was approximately 375.8 Gg in 1994 and 452.1 Gg in 2003, that is, a 21% increase in 12 years.
- *Carbon emissions*. From the land-cover changes, we estimated that the KFR sequestered carbon annually at an average of 0.5 Gg and that 1.4 Gg of carbon was emitted each year over the period 1989 to 2001.
- The Kalahan Educational Foundation is the major stakeholder in the KFR. It has established its own rules and regulations related to natural resources development and has supported traditional farming practices and management strategies (for example, their ‘forest improvement technology’) to enhance the carbon stock within the KFR. Currently, the Foundation is exploring the Clean Development Mechanism market. Future options and their implications for the KFR are included in the paper.

**Keywords**

*carbon stock assessment, farming practices, Ikalahan Ancestral Domain, land-use change*

## Acknowledgements

The RaCSA implementation was conducted by the Kalahan Educational Foundation in collaboration with the Forest Biological Sciences Department, College of Forestry and Natural Resources, University of the Philippines at Los Baños, Laguna, and the World Agroforestry Centre (ICRAF) Southeast Asia Program through the Trees in Multi-Use Landscapes in Southeast Asia project (funded by the German Federal Ministry for Economic Cooperation and Development (BMZ)) and the Rewards for, Use of, and Shared Investment in Pro-poor Environmental Services phase 2 program.

# Contents

## List of Tables

## List of Figures

# 1. Introduction

The Ikalahans are the indigenous people of the province of Nueva Vizcaya, northeastern Philippines. They belong to the Kalanguya-Ikalahan tribe and inhabit the Ikalahan Ancestral Domain. They are largely swiddeners who plant sweet potato, ginger, gabi, cassava and vegetables and build terraces to grow upland rice.

Encompassing a total of 38 000 ha, the Ikalahan Ancestral Domain, of which the Kalahan Forest Reserve comprises 14 730 ha, lies in the Cordillera and Caraballo mountains and is overlooked by Mt Akbob (1658 m) in the northwest and Mt Talabing (1717 m) in the southwest (KEF 1993). Dividing the watershed between the two peaks and determining the water flow lies a ridge known as Bantay Lakay. Elevation varies 600–1717 m above sea level, with average annual rainfall recorded at over 4000 mm and temperatures ranging 8–24 ˚C (RUPES website[1]). The majority of the forests are secondary and for the most part tree species found in this entirely mountainous region are endemic dipterocarps. There are also areas where the coverage is predominantly pine or oak on the western and apex zones of the ridge respectively. The study covered approximately 10 000 ha, excluding the grasslands and sanctuary regions.

In 1973, the Kalahan Educational Foundation (KEF) was established by the Ikalahan tribal elders to protect their communities from possible eviction because the Government at that time was unable to defend their rights. The Foundation’s mission is to promote the education of the Ikalahan people and protect the environment of their ancestral domain. Among its aims is to provide sustainable, forest-based livelihoods, improved watersheds and biodiversity (KEF 1993). From its inception, KEF has been recognised as a community-based organization. It legally represents the Ikalahans in their community-based forest management agreement, in which they are the pioneers in the Philippines.

[1] http://rupes.worldagroforestry.org/researchsite_kalahan/2

# 2. Land tenure and ownership

The *Indigenous Peoples' Rights Act* of 1997 (RA 8371) strengthens the rights of the Ikalahan to their ancestral land and led to the approval in 1999 of their ancestral domain claims that cover 58 000 ha.

Other laws such as the *Wildlife Resources Conservation and Protection Act* of 2001 (RA 9147) and the *National Integrated Protected Areas System* of 1992 (RA 7586) are legal mandates to establish and protect critical habitats and species.

Further, the Memorandum of Agreement No. 1 of 1973 is an agreement between the KEF and the Bureau of Forest Development that recognizes the rights of the Ikalahans to manage their ancestral land and 'utilize the area to the exclusion of all other parties not already "subsisting" within the area at the time of signing'. The agreement specifically allocated 14 730 ha of land to be managed directly by the Ikalahan through the KEF for a period of 25 years, renewable for another 25 years.

## 2.1 Carbon-stock appraisal

The KEF is currently developing a 900 ha Clean Development Mechanism (CDM) project inside the ancestral domain. The results of a Rapid Carbon Stock Appraisal (RaCSA) were intended to provide essential baseline information for the negotiation of carbon credits with potential carbon buyers. The appraisal would also help provide experience and insight into reducing the transaction cost of such projects.

RaCSA is part of a 'negotiation support toolbox' for rapid appraisal of landscapes developed by the World Agroforestry Centre (ICRAF) Southeast Asia Program through the Trees in Multi-Use Landscapes in Southeast Asia project. The project had several aims.

1) Bridge the gaps between local, public/policy and scientific modellers' knowledge.
2) Increase recognition and respect for these multiple knowledge systems.
3) Provide quantification of trade-offs between economic and environmental impacts at landscape scale.
4) Enable joint analysis of plausible scenarios based on available data and information.

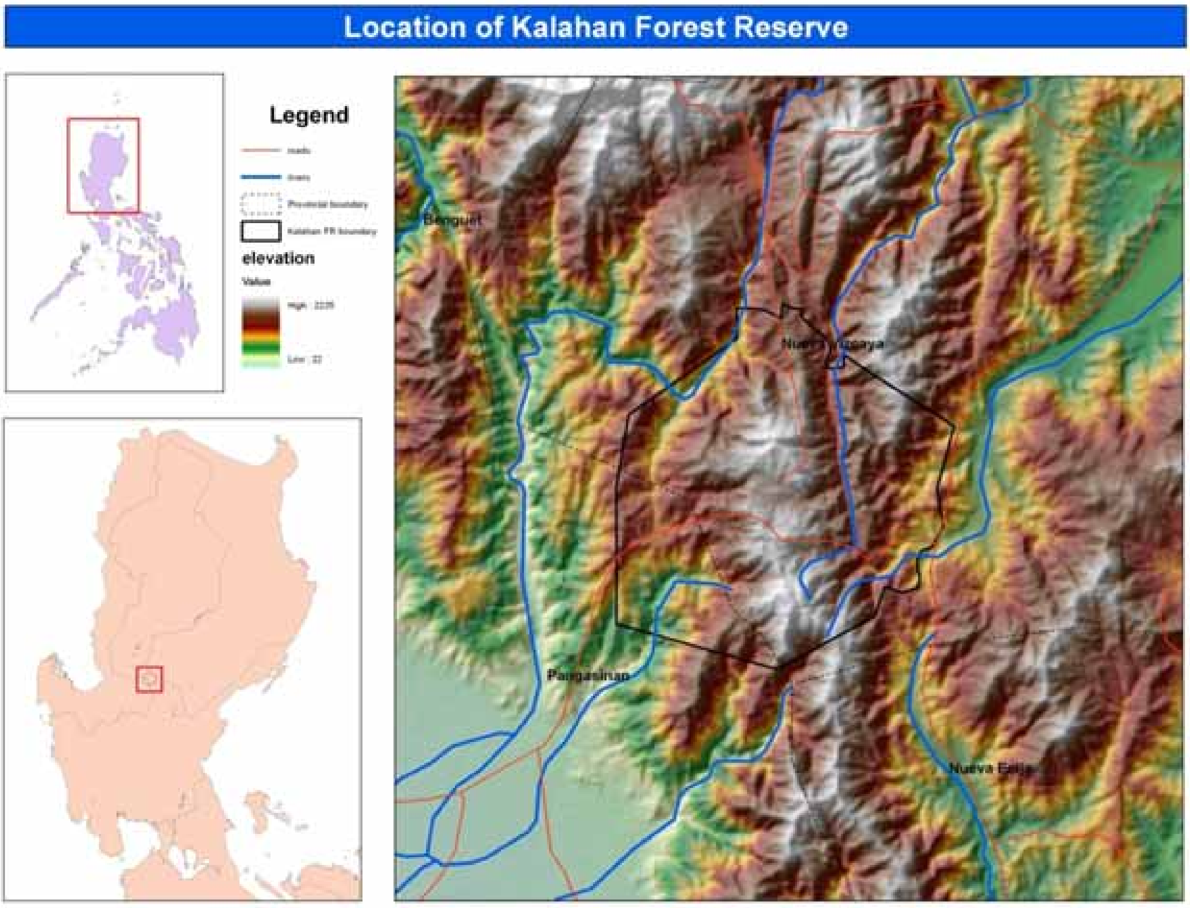


**Figure 1.** Location of Kalahan Forest Reserve.

# 3. Objectives of the study and expected outputs

## 3.1 Objectives

1. To identify the different land-use practices at the site and the key drivers of change in the landscape.
2. To estimate the carbon stocks of the main land uses at plot and landscape levels.
3. To assess the opportunity to use or adjust policy frameworks to enhance or maintain the carbon stocks in the area.
4. To complete the modelling of land-use and carbon dynamics of the Kalahan using GIS and/or remote sensing.

## 3.2 Expected outputs

1. Carbon stock per land-cover and land-use assessed and calculated.
2. Land-use practices that enhance or maintain carbon stocks identified and documented.
3. Results from the carbon-stock appraisal used as the baseline for the CDM project (initial stage of development of the project design document).
4. Scenarios featuring different drivers of change in the landscape (using remote sensing) presented and assessed.

# 4. Methodology

## 4.1 Site orientation and reconnaissance

The research team was oriented by community representatives regarding the purpose of the carbon-stock study and the coverage of the project site (Figure 1). Available maps (for example, topographic and vegetation) were useful in identifying the various land uses within the 48 000 ha ancestral domain. A three-dimensional model of the area was instrumental in gaining appreciation of the whole site and approximating logistics and costings prior to fieldwork (Figure 2). Reconnaissance was conducted in September 2009 to finalise the carbon-stock study sites.

## 4.2 Selection of sites

The major land uses in the study area were first identified using the vegetation maps and the results of the reconnaissance with farmers and through secondary data. The sites were selected by locating areas that had high conservation values in the context of the appraisal. This step involved identifying areas with one or more features such as a high richness of species; featured 'flagship' species; enjoyed a unique habitat; or were experiencing rapid resource or habitat degradation. These features were considered against the various land uses and local human populations. The secondary data available from the KEF were used as baseline information. Participatory mapping was conducted involving the community and other stakeholders, forming part of the capacity-building strategy of the project. A total of five land uses from fifteen *barangays* (smallest government unit in the Philippines) within the KEF were identified. All sites were classified as secondary forest, agroforest farm, agricultural area, grassland or reforestation (Table 1). The corresponding land uses were situated in two or more sites.

## 4.3 Site preparation and establishment of sampling transects

The sampling sites and transects were prepared by measuring and pegging 20 m x 100 m plots in the various land uses (Figure 3). Two sampling transects were established for each land use to estimate carbon stock above- and belowground. We used a metre tape to measure distance and GPS Garmin to locate the coordinates. Each sampling transect was demarcated to obtain the following.

- Tree species, with diameter at breast height of 5.0 cm and above within the whole transect.
- Plants in the intermediate layer, with diameter below 5.0 cm and height of above 1 m sampled in a 3 m x 3 m sub-plot within the transect plot.
- Undergrowth vegetation, with height below 1 m sampled within four smaller sub-plots measuring 1 m x 1 m each.

- Necromass or litter fall, collected from one plot in the intermediate layer and four plots in the undergrowth, with each plot measuring 0.25 m x 0.25 m.
- Soil, sampled using a trowel (5 cm diameter and 30 cm length), at depths of 0–20 and 20–30 cm.

For each of the land-use samples, the team used a slightly modified protocol from the ASB Lecture Note 4b (Hairiah et al. 2001).

## 4.4 Sampling sites and major land uses

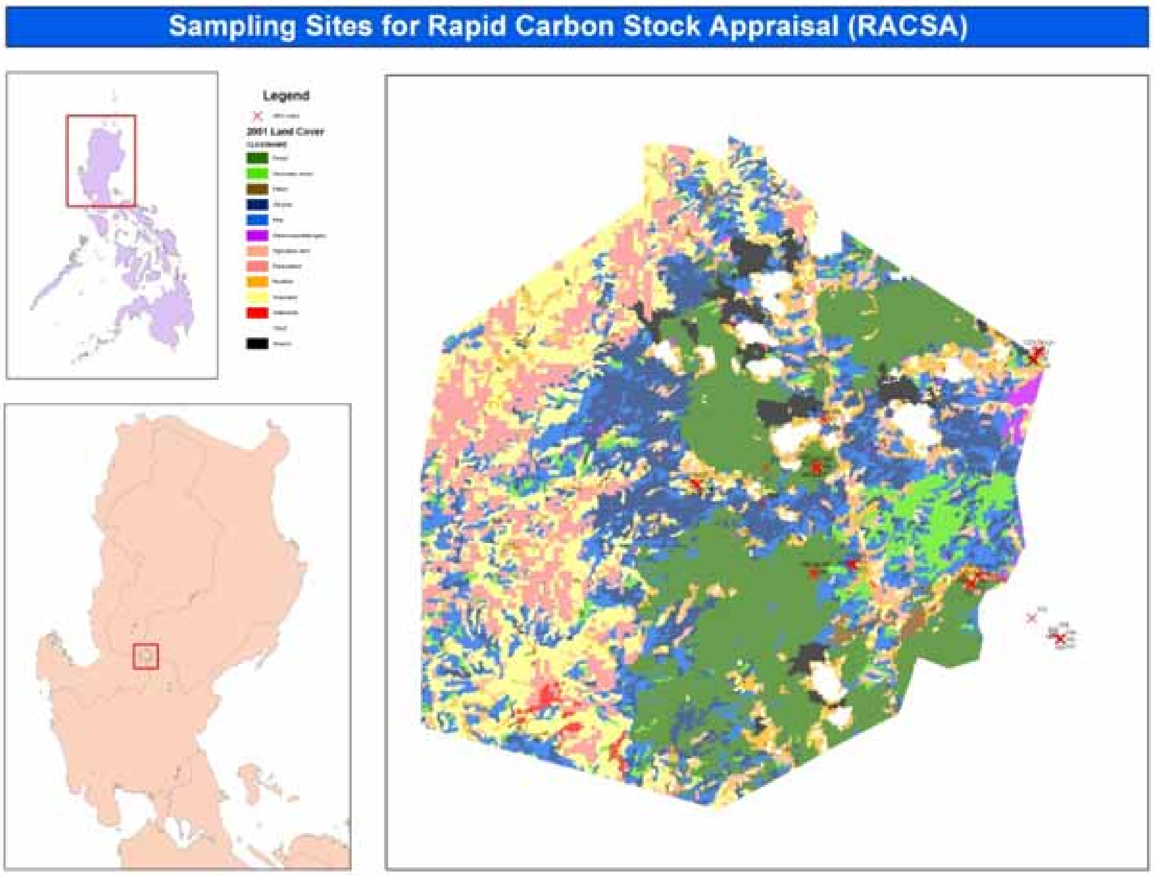


**Figure 2.** Sampling sites where five major land uses were observed.

**Table 1**. Major land-use types identified

| No. | Identified land uses | Subsets | Barangay | Plot Code |
|---|---|---|---|---|
| 1. | Secondary forest | • Pine-dominated<br>• Dipterocarp-dominated<br>• Myrtaceous oak-dominated | Sta. Rosa<br>Baracbac<br>Malico | S1T1<br>S4T1<br>S2T1 |
| 2. | Agroforest | • Tree-crop/fruit-crop | Sta. Rosa<br>Baracbac<br>Bacneng | S1T2<br>S4T2<br>S5T1 |
| 3. | Agriculture | • Garden/vegetable<br>• Swidden/fallow | Bacneng<br>Tactac<br>Atbu | S5T2<br>S6T2<br>S7T1 |
| 4. | Grassland | • Abandoned<br>• Pasture<br>• Pure grassland | Atbu<br>Sta. Rosa<br>Malico | S7T2<br>S2T4<br>S2T3 |
| 5. | Reforestation | • Old rehabilitated<br>• Pine- and *Alnus*-dominated | Bacneng<br>Imugan | S5T1<br>S8T3<br>S8T1 |

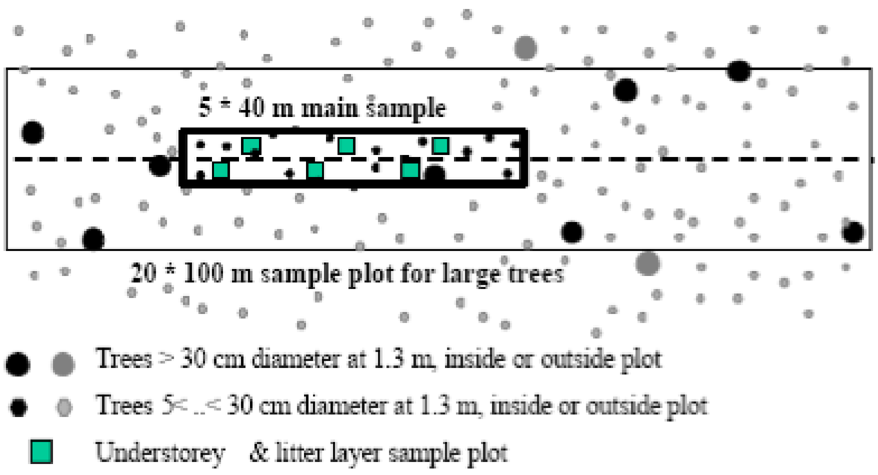


**Figure 3.** Nested plot design for sampling various carbon stocks.

## 4.5 Primary and secondary data collection and processing

### 4.5.1 Taxonomic characterisation

All vascular plants within the established transect were identified using local names and were verified using morphological characteristics from the field and herbarium collection at the KEF and the University of the Philippines at Los Baños museum. The identity of plants was further verified from references. Unknown plants were kept for future verification and their codes were used in the computation of parameters. Sterile samples of known and unknown species were collected for herbarium purposes and were preserved at the KEF and the university. The taxonomic list was prepared showing local, scientific and family names and plant habitat.

### 4.5.2 Measurement of biometrics and biomass

The height and diameter of trees at breast height (DBH) in the canopy and intermediate layers within the transect plot were estimated in metres and measured with a diameter tape, respectively, for proper encoding in an MS Excel spreadsheet (Figure 4).

Plant density, or the number of individuals in each layer, and transect plots were counted using the formula:

$$\textbf{Plant Density (N)} = \frac{\textbf{Density of each plant species}}{\textbf{Unit Area of Sampling Plot}}$$

The biomass of each plant in the canopy, intermediate and undergrowth layers, together with leaf litter, was computed using the following:

a. Allometric regression for aboveground biomass of all trees greater than 5.0 cm DBH using the equation prepared by Ketterings et al. (2001):

$$\mathbf{y = 0.11\ p\ D\ 2.62}$$

where y = aboveground tree biomass

p = average wood density equivalent to 0.9035 $gram.cc^{-1}$ (Pulhin 2008)

D = tree DBH

b. Estimated belowground biomass in trees and intermediate layers was equivalent to 15% of the aboveground tree biomass as proposed by Delany (1999).

c. Destructive harvesting of randomly sampled above- and belowground biomass of undergrowth plants represented by mean values of 5–10 samples of either wildling indigenous tree and agroforestry species, agricultural crops, grass, shrubs, vines, ferns or palms.

d. Actual samplings of litter fall to represent necromass from all structural layers.

e. Soil samples were placed in labelled plastic bags, air dried and taken to the Soils Laboratory of the Soil Science Department of the College of Agriculture, University of the Philippines at Los Baños for analysis. The method used for the analysis was the Walkey-Black method (PCARR 1981). The mean bulk density of the 2006 soil carbon calculation in the KFR was used (Appendix 2). The dry weight of the soil and the equivalent carbon stock was determined using the following formula:

Soil mass at specified depth (Mg) = Bulk density at specified depth ($Mg/m^3$) x 10 000 $m^2$ x depth (m)

Soil carbon at specified depth (Mg) = Soil mass at specified depth (Mg) x % organic carbon at specified depth/100

### 4.5.3 Carbon-stock estimations at plot and landscape levels

With the values of biomass computed from plants and litter fall obtained from five different land uses, the amount of carbon stock at plot and landscape levels was estimated. This was achieved by using the mean carbon value from plant tissues obtained by Dixon et al. (1993) from similar sites and ecosystem, together with the 45% generic carbon value commonly used in much of the literature as a carbon estimate for plant cells (Raven et al. 1999). On average, the percentage of carbon in agricultural farm and grassland ecosystems was 40% while in agroforest, reforestation and secondary forest it was 45%.

At the landscape level, the method used for estimation of carbon stock was extrapolation based on a land-cover map. Two ‘snapshots’ over time for each of the landscapes’ carbon stocks were made by re-attributing the land-cover map of the particular year with corresponding plot-level carbon stock. The output was a carbon-stock estimation based on aboveground biomass calculations from land cover in 1994 and 2003.

# 5. Results and discussion

## 5.1 Farming and livelihoods' conditions[2]

### 5.1.1 Land access

The average size of landholding per household was 3 ha, one-third of which was cultivated while the rest was forested. Water was the determining factor in whether or not to cultivate the land, especially for rice production (tables 2 and 5). Community access was allowed in production forests and prohibited in the watersheds and sanctuaries. Land tenure was based on the ancestral domain claim, which was approved in 1999.

**Table 2.** Physical areas devoted to rice by production environment (in hectare), selected barangays, Sta. Fe, Nueva Vizcaya, 2000

| No. | Barangay | Irrigated | Rainfed | Upland | Total |
|---|---|---|---|---|---|
| 1. | Bacneng | 10 | 0 | 7 | 17 |
| 2. | Baracbac | 20 | 0 | 10 | 30 |
| 3. | Imugan | 15 | 0 | 2 | 17 |
| 4. | Malico | 0 | 0 | 10 | 10 |
| 5. | Sta. Rosa | 25 | 6 | 2 | 33 |
| 6. | Unib | 20 | 0 | 3 | 23 |
| | Total | 90 | 6 | 34 | 130 |

Source: Department of Agriculture, Sta. Fe, Nueva Vizcaya

### 5.1.2 Livelihood options

The majority of the people in the study area were farmers (Table 3). They were indigenous swiddeners with *camote* (sweet potato) and upland rice as their staple crops. Off-farm activities consisted of forest-fruit processing and soft-broom production (from tiger grass). Others were employed as professionals in the local government offices, Kalahan Academy and the KEF.

A livelihoods' assessment was conducted through the KEF's involvement with the Non-Timber Forest Products Exchange Program[3]. Table 3 shows that more than 50% of farmers in Bacneng, Baracbac, Imugan and Unib were more engaged with off-farm activities compared to the other barangays. Table 4 shows the barangays that are most concentrated on broom making. Table 5 shows the areas devoted to fruit and vegetable production.

[2] Most of the information provided in this section was taken from Villamor and Pindog (2008).
[3] A regional non-governmental organization.

**Table 3.** Livelihoods of the people (percentage)

| Major Occupation | Barangays/Villages | | | | | | |
|---|---|---|---|---|---|---|---|
| | Imugan | Malico | Sta. Rosa | Unib | Bacneng | Baracbac | Tactac |
| Farmers | 70 | 90 | 94 | 100 | 90 | 96 | 80 |
| Professionals * | 25 | 5 | 1 | 0 | 6 | 2 | 10 |
| Business/ Traders | 5 | 5 | 5 | 0 | 4 | 2 | 10 |
| | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

* For example, teachers, government bureaucrats, soldiers, health workers and police

Source: Stakeholder analysis conducted in 2009

**Table 4.** Summary of livelihoods' assessment in the KFR

| | Barangays | | | | | |
|---|---|---|---|---|---|---|
| | Bacneng | Baracbac | Imugan | Unib | Malico | Sta. Rosa |
| Number of households<br>Crafts population | 250<br>70%: broom making | 115<br>90%: broom making | 149<br>29%: broom making;<br>23%: basket weaving | 40<br>50%: broom making | 67<br>15%: broom making | 57<br>18%: broom making |
| Geographical accessibility (distance from town) | 5 km | 3 km | 7 km | ~15 km | ~15 km | ~20 km |
| Sources of income | Broom making<br>Swidden<br>Farming | Broom making<br>Swidden<br>Farming | Supplier of tiger grass (as raw material)<br>Broom making<br>Farming | Supplier of tiger grass (as raw material)<br>Broom making<br>Farming | Supplier of tiger grass (as raw material)<br>Broom making<br>Farming | Supplier of tiger grass (as raw material)<br>Broom making<br>Farming |
| Market (current) | Local traders<br>Solano*<br>Baguio | Local traders<br>Solano | Local traders<br>Consolidators | Local traders<br>Consolidators | Local traders<br>Consolidators | Local traders<br>Consolidators |
| Craft products | Brooms, baskets | Brooms | Brooms, baskets, quilts | Brooms, baskets | Brooms, baskets | Brooms, baskets |

* Neighbouring town or city

Source: Non-timber forest product (NTFP) project 2009, unpublished

**Table 5.** Physical area devoted to fruits and vegetable production (in hectare), selected barangays, Sta. Fe, Nueva Vizcaya, 2000

| | Total Area (ha) | Vegetables | | Root Crops | Permanent Crops | | | | | Temporary Crops | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Upland | Lowland | | Mango | Citrus | Coffee | Guava | Other fruits | Papaya | Banana |
| Bacneng | 229.08 | 45.0 | 10.25 | 85.25 | 70.0 | 1.07 | 5.03 | 6.8 | 5.0 | 0.14 | 0.54 |
| Baracbac | 105.73 | 37.5 | 27.1 | 35.0 | 0.47 | 0.43 | 0.20 | 3.36 | 0.10 | - | 1.17 |
| Imugan | 51.57 | 13.75 | 12.50 | 20.60 | 0.04 | 0.44 | 0.40 | 2.29 | 1.24 | - | 0.31 |
| Malico | 37.51 | 17.75 | 7.0 | 11.50 | 0.13 | 0.06 | 0.20 | 0.67 | 0.08 | - | 0.12 |
| Sta. Rosa | 25.40 | 11.00 | 1.50 | 12.00 | 0.09 | 0.05 | 0.16 | 0.50 | - | 0.01 | 0.09 |
| Unib | 30.09 | 8.75 | 4.00 | 2.50 | 0.23 | 0.30 | 0.80 | 2.26 | 0.89 | - | 0.36 |
| Total | | | | | | | | | | | |

(-) no data

Source: Department of Agriculture, Sta. Fe, 2000

### 5.1.3 Farming practices

The Ikalahan are known for their indigenous knowledge practice systems that are environmentally sustainable. These include:

- *Day-og* and *gengen* are composting techniques on level and sloping land respectively.
- *Balkah* is a contour line of deep-rooted plants, which trap eroded topsoil at the belt line (Rice 2000).
- *Pang-omis* is a method of expediting the fallow. It was invented by one of the tribal elders after attending an ecology seminar. Farmers intercrop tree seedlings, for example, *Alnus nepalensis*, in their swidden farms along with sweet potato.

A study of the farming systems and fallow management of households within the KFR (Banaticla et al. 2008) indicated that families use a much smaller area of land (around 2.93 ha) than the limit imposed by the community (10 ha) for farming and other purposes. The inherent physical limitations in the amount of land suitable for farming, declining population densities (except in villages nearest to the urban centre) and current cropping and fallow cycles (Table 6) also indicated the tendency towards sedentarization of agriculture. Former swidden fields were under long fallow and these were further protected by direct interventions of the community through regulation of forest clearing and other forest protection and rehabilitation activities (Appendix 4).

**Table 6.** Mean cropping, fallow periods and cycle lengths employed by selected farmers in the KFR

| Res-pondent No. | Age | Residence (barangay) | Time span reported (years)* | No. of swiddens opened through time | No. of swiddens with more than one cropping cycle | Mean cropping period (years) | Mean fallow period (years) | Mean crop:fallow ratio | Mean crop-fallow cycle length (years) |
|---|---|---|---|---|---|---|---|---|---|
| 1. | 59 | Baracbac | 1974–2008 (34) | 9 | 1 | 7.00 (1–14) | 15.13 (1–29) | 0.46 | 22.13 |
| 2. | 62 | Baracbac | 1960–2008 (48) | 3 | 0 | 9.33 (3–16) | 7.33 (0–22) | 1.27 | 16.66 |
| 3. | 70 | Unib | 1959–2008 (49) | 5 | 2 | 13.17 (4–26) | 17.00 (1–45) | 0.77 | 30.17 |
| 4. | 75 | Baracbac | 1951–2008 (57) | 3 | 3 | 8.25 (3–16) | 5.30 (1.5–14) | 1.56 | 13.55 |
| 5. | 48 | Imugan | 1978–2008 (30) | 3 | 2 | 8.40 (1–13) | 16.50 (16–17) | 0.51 | 24.90 |
| 6. | 60 | Malico | 1984–2008 (24) | 2 | 0 | 8.50 (4–16) | 8.50 (6–11) | 1.00 | 17.00 |
| 7. | 75 | Unib | 1950–2008 (58) | 2 | 1 | 13.25 (4–39) | 14.33 (5–23) | 0.92 | 27.58 |
| 8. | 70 | Malico | 1986–2008 (22) | 4 | 0 | 3.50 (2–5) | 16.50 (10–23) | 0.21 | 20.00 |
| 9. | 45 | Unib | 1985–2008 (23) | 2 | 0 | 8.5 (3–14) | 11.00 (2–20) | 0.77 | 19.50 |
| Mean | | | | | | 8.88 | 12.40 | 0.83 | 21.28 |

* An initial list of 20 respondents were chosen but was narrowed down to 9 because of the difficulty of obtaining complete histories from each respondent. All nine respondents, except one, were female, residents of the KFR from birth, had no formal education or reached only the primary level, married or widowed, with farming as primary occupation up to the time of interview
Source: Banaticla et al. 2008

## 5.2 Land-use characteristics and practices

The major land uses in the Kalahan mountain ecosystem were classified into five, based on the dominant vegetation and community activities, as shown in Table 1 and described below.

### 5.2.1 Agriculture

The agricultural areas were represented in barangays Bacneng, Tactac and Atbu. The agriculture at these sites was generally situated in an open condition located on relatively flat-to-sloping terrain. Structurally, the vegetation was more undergrowth with few trees and an intermediate layer on the perimeter of farms, represented by a mix of crops (camote, cassava, beans, rice, corn, taro, okra, ginger) planted in patches, grown using a combination of traditional swidden farming and non-traditional systems that used inputs to increase production.

### 5.2.2 Agroforest

This land use in barangays Sta. Rosa, Baracbac and Unib was dominated by a mixture of agricultural fruit crops (avocado, mango, guava, citrus, papaya) planted in-between forest trees (for example, mahogany, *Gmelina*, *narra*) and was, hence, classified as agroforest. The land use was basically situated on moderate slopes with a semi-open canopy created by fruit and large trees, with little intermediate growth but abundant undergrowth layers. Minimal practices were applied, such as brush-cutting to clear some land for favoured crops and no tilling of the soil.

### 5.2.3 Grassland

The grassland at two sites in barangay Malico and another area in barangay Atbu were usually abundantly stocked in open areas on moderate-to-steep terrain. The areas were dominated by *Imperata cylindrica*, with several species of ferns, shrubs and a few patches of small trees. The main land-use practice was pasturing, although other areas were already abandoned, inviting fires.

### 5.2.4 Reforestation

This land use was established about 10–15 years ago in barangay Imugan using either *Alnus* or *Gmelina* and in barangay Bacneng with Benguet pine combined with mahogany. Reforestation sites were situated on moderate-to-steep slopes with a semi-open canopy with little intermediate growth but abundant undergrowth layers. There was some intercropping of coffee in reforested areas planted with *Alnus* and agricultural farming adjacent to the *Gmelina* plots but pure planting of mixed trees in other areas.

### 5.2.5 Secondary forest

This land use was dominated by either dipterocarp pine or myrtaceous oak forest ecosystems. Areas in barangay Baracbac, Sta. Rosa and Malico that featured this type of land use were covered with large diameter trees ranging 20–70 cm DBH. The forests were located on middle-to-higher elevated land with semi-closed canopy and fewer understorey layers. The dipterocarp forest was dominated by *palosapis* (*Anisoptera thurifera*), white *lauan* (*Shorea contorta*), *bagtikan* (*Parashorea malaanonan*) and *guijo* (*Shorea guiso*). Non-dipterocarp species included Benguet pine (*Pinus kesiya*), Philippine oak (*Lithocarpus ovalis*), legume (*Pterocarpus indicus*) and myrtaceae (*Syzygium* sp.). There were no practices recorded for this land use.

**Table 7.** Characteristics of the different land uses and practices of local communities in the KEF mountain ecosystem

| Land use | Community (GPS reading) | Physical features | Dominant species | Land-use practices |
|---|---|---|---|---|
| Agriculture | Bacneng N16°11'57.6''; E 120°56'19.6''<br><br>Tactac N16°08'42.1'' E 120°56'32.4''<br><br>Atbu N16°08'26.4' E 120°56'345.0'' | Generally in an open condition located on relatively flat-to-sloping terrain structurally showing more undergrowth and few trees and with an intermediate layer on the perimeter of farms | Mixed agricultural crops (camote, cassava, beans, rice, corn, taro, okra, ginger) planted in patches | Agricultural farming using combined traditional swidden farming and non-traditional systems |
| Agroforest | Sta Rosa N 16°10'50.7'' E120°51'36.0''<br><br>Baracbac N 16°11'08.2'' E120°55'32.6''<br><br>Unib N 16°09'26.2'' E120°55'32.6'' | Largely situated on moderate slopes with a semi-open canopy with little intermediate but abundant undergrowth layers | Fruit-bearing (avocado, mango, guava, citrus, papaya) and tree (mahogany, *Gmelina*, *narra*) crops | Intercropping with mostly fruit-bearing and tree crops |
| Grassland | Malico 1 N16°08'118.2' E 120°56'58.3''<br><br>Malico 2 N 16°10'10.9' E 120°51'24.4''<br><br>Atbu N 16°10'27.9'' E 120°52'09.7'' | Usually abundant in open areas along moderate-to-steep terrain. Structurally, undergrowth layer dominated with abundance of grasses with very few patches of small trees | Mostly *Imperata cylindrica* and *Themed triandra* but with some species of ferns, shrubs and other grasses | Commonly used as pasture though some areas were left abandoned making them prone to grassfire |
| Reforestation | Bacneng N 16°08'56.7'' E 120°56'11.5''<br><br>Imugan1 N 16°09'18.6'' E 120°54'25.7'' | On steep-to-very steep slopes with slightly open canopy with dominant trees and intermediate and undergrowth layers | Dominance of 10–15 year-old plantation of either *Alnus*, Benguet pine or *Gmelina* | Intercropping of coffee in reforested areas planted with *Alnus* and agricultural farming adjacent to *Gmelina* areas |

| Land use | Community (GPS reading) | Physical features | Dominant species | Land-use practices |
|---|---|---|---|---|
| | Imugan2<br>N 16°09'08.0''<br>E 120°54'11.8'' | | | but pure planting of mixed trees in other areas |
| Secondary forest | Baracbac<br>N 16°10'14.6''<br>E 120°51'55.4''<br><br>Sta Rosa<br>N 16°10'37.4''<br>E 120°51'07.2''<br><br>Malico<br>N 16°09'26.2'<br>E 120°55'32.6'' | Located on middle-to-higher elevated areas with a semi-closed canopy and fewer understorey layers | Dominance of dipterocarps (*palosapis*, white *lauan*, *guijo*) and non-dipterocarp (pine, Philippine oak, legume, *Syzygium*) trees | Absence of any land-use practices within, except for tree planting in pine forest |

### 5.2.6 Key drivers of change

The key players that could contribute to changes (either positive or negative) in the landscape were households, the KEF organization, local political leaders and conservationists (Table 8). 'Households' includes all family members residing in the ancestral domain. 'The KEF' refers to the foundation that manages the mountain ecosystem, together with key barangay leaders that oversee the political existence of the community. 'Conservationists' includes bird watchers, academics, researchers and ecotourists.

The changes that influence the landscape of the mountainous ecosystem were categorized as socio-economic and political, biophysical and chemical, anthropogenic, and indirectly natural. The implementation of laws related to the environment—such as those pertaining to clean air, solid waste management, chemical application, protected area management, bio-invasion and threatened species—falls under socioeconomic and political activities.

**Table 8.** Characteristics and activities of various key drivers of change in the Kalahan landscape

| Stakeholders | Composition | Function | Activities that drive change in landscape |
|---|---|---|---|
| Households | Members of the family | Provides basic family role | Intermarriage of local to foreigners<br>Introduction of verified or unverified upland farming technologies |
| KEF | Board and members | Manage mountain ecosystem | Implementation of KEF policies regarding the overall use and management of natural resources in the area (Appendix 4) |
| Local political leaders | Barangay captains and youth leaders | Oversee the political needs of the community as legal owners of the ancestral domain | Making decisions with regards to political activities that affect or are related to land ownership, use of farm land and natural resources, entry of outsiders to the area, and implementation of environmental laws ( clean air, solid waste management, chemical application, protected area management, bio-invasion, threatened species etc) |
| Conservationists | Bird watchers, ecotourists, researchers, academics | Conduct conservation research | Frequency of visits to the different areas by conservationists; activities that could be against bio-prospecting, solid waste management and other environmental laws |

## 5.3 Plant diversity and composition

The diversity and composition of plants—particularly those in the canopy, intermediate and undergrowth layers that capture carbon physiologically during photosynthetic activities—varied depending on location, plot and land use, as presented below and in Table 7 above. Table 9 shows the percentage of trees with various diameters. Figure 4 shows the proportion of species' composition in three structural layers in various land uses. Table 10 presents the percentage of population density of plants in the different structural layers.

**Table 9.** Percentage of trees with different diameter ranges from various land uses

| Type of land use | < 5 cm | 5–30 cm | > 30 cm |
|---|---|---|---|
| Agriculture | 14.81 | 81.48 | 3.70 |
| Agroforest | 20.16 | 74.31 | 5.53 |
| Grassland | 43.24 | 51.35 | 5.41 |
| Reforestation | 44.70 | 48.84 | 6.46 |
| Secondary forest | 16.49 | 72.68 | 10.82 |

### 5.3.1 Agriculture

In agricultural areas, stocks of carbon were pooled in common cultivated crops like upland and hybrid rice (*Oryza sativa*), beans (*Vigna sesquipedalis*), corn (*Zea mays*), taro (*Colocasia esculentum*), *luya* (*Zingiber officinale*), *saging* (*Musa sapientum*) and okra (*Abelmoschus esculentus*). Although classified as agricultural, there were, however, trees with diameters ranging 5–30 cm, representing about 81.5% of all trees, such as mango (*Mangifera indica*), *suha* (*Citrus maxima*) and *hamak*. All other trees in this category that had less than 5 cm and greater than 30 cm comprised 14.8 and 3.7%, respectively.

### 5.3.2 Agroforest

Carbon stocks in plants in agroforestry systems were represented by fruit (*Citrus* sp., *Psidium guajava, Mangifera indica*) and tree crops (*Ficus nota, Alnus nepalensis, Eriobotrya japonica*, *Leucaena lueocephala, Pinus kesiya* and *Ficus septica*). Among these, the most dominant was *Citrus* sp. (29.51%), followed by *Ficus nota* (5.33%) and *Alnus nepalensis* (4.92 %). The diameters of trees varied: 20.2% were at less than 5 cm DBH; 74.3% had DBH of 5–30 cm; while only 5.5% were greater than 30 cm DBH.

### 5.3.3 Grassland

The grassland ecosystem was characterised as 'purely grassland' or 'abandoned pastureland'. The former was dominated by *Paspalum conjugatum*, *Crassocephallum crepidioides* and a local grass named *tab-an*. The latter ecosystem had an abundance of *Pennisetum alopecuroides*, *Oleandra pistillaris* and *Imperata cylindrica*. Sparsely interspersed through the ecosystem were patches of trees (*Ficus septica, Boehmeria densiflora, Ficus nota, Saurauia latibractea, Persea americana* and *Mangifera indica*). There were also species of moss (*Portulaca grandiflora*), *busikad* (*Cyperus kyllingia*), *kilob* (*Dicranopteris linearis*), *cogon* (*Cyperus kyllingia*), *landrina* (*Borreria ocymoides*), *pal-ot* (*Miscanthus sinensis*), *dilang baka* (*Elephantopus tomentosus*), *kawad-kawad* (*Polytrias amaura*) and two unknown local plants (*buyot* and *galakgak*). The percentages of trees with respect to DBH was 43.2% (> 5 cm), 51.4% (5–30 cm) and 5.4% (> 50 cm).

### 5.3.4 Reforestation

In reforestation areas, the species used were Benguet pine (*Pinus kesiya*), citrus (*Citrus* sp.), coffee (*Coffea arabica*), *Alnus* (*Alnus nepalensis*), *narra* (*Pterocarpus indicus*), guava (*Psidium guajava*), mahogany (*Swietenia macrophylla*) and *amuwag* (*Clethra* sp.). The dominant species for the whole land use were coffee (*Coffea arabica*), *amuwag* (*Clethra* sp.) and *Alnus* (*Alnus nepalensis*), composing 21.45%, 13.30% and 11.18% of the total of observed tree species, respectively.

### 5.3.5 Secondary forest

In secondary forest, the dominant species were Benguet pine (*Pinus kesiya*), *is-is* (*Ficus ulmofolia*) and white *lauan* (*Shorea contorta*) with values of 15.54%, 13.47% and 12.44%, respectively. Large trees in the sampled plots of secondary forest—exemplified by *Pinus kesiya*, *Shorea contorta* and *Anisoptera thurifera*–had greater percentages of individuals with DBH of small (44.7%) and medium (48.8%) than those with large DBH, that is, greater than 50 cm (6.4%).

**Table 10.** Population density per plot in the canopy, intermediate and undergrowth layers in different land uses

| Type of land use | Trees | Intermediate | Undergrowth |
|---|---|---|---|
| Agriculture | 24 | 279 | 1296 |
| Agroforest | 244 | 299 | 864 |
| Grassland | 39 | 286 | 1593 |
| Reforestation | 564 | 112 | 1075 |
| Secondary forest | 193 | 80 | 366 |

Note: Plot size for canopy, intermediate and undergrowth layers were 2000 $m^2$, 9 $m^2$ and 1 $m^2$, respectively.

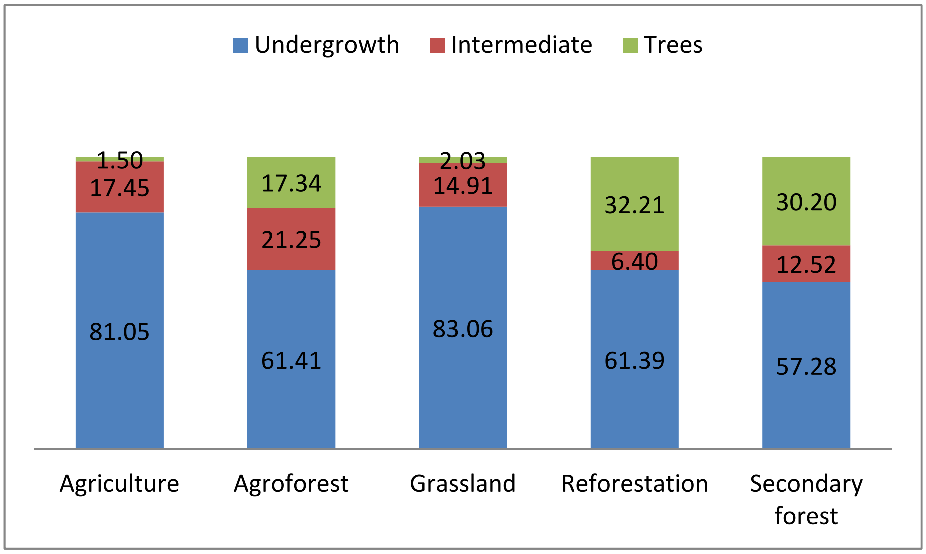


**Figure 4.** Percentage of species' composition in three structural layers in various land uses.

## 5.4 Carbon stocks

### 5.4.1 Aboveground

Aboveground carbon stock in land-use systems in the KFR were estimated to range 0.61–77.86 Mg/ha (Table 11). The highest value recorded was in the reforestation area, with 32% of trees contributing to total aboveground carbon stock (Figure 4).

**Table 11.** Plot-level aboveground biomass carbon stocks

| Land use | Sample plot code | Tree Mg/ha | Intermediate Mg/ha | Understorey Mg/ha | Total Mg/ha |
|---|---|---|---|---|---|
| Agriculture | S5T2 | 10.042 | 0.207 | 0.025 | 10.274 |
| | S6T2 | 0.000 | 0.577 | 0.037 | 0.614 |
| | S7T1 | 0.754 | 0.663 | 0.014 | 1.430 |
| Agroforest | S1T2 | 1.682 | 0.310 | 0.002 | 1.994 |
| | S3T1 | 30.588 | 0.093 | 0.073 | 30.753 |
| | S4T2 | 19.025 | 0.547 | 0.028 | 19.599 |
| Grassland | S2T3 | 0.000 | 0.604 | 0.095 | 0.699 |
| | S2T4 | 9.807 | 0.575 | 0.031 | 10.412 |
| | S7T2 | 0.760 | 0.556 | 0.026 | 1.342 |
| Reforestation | S5T1 | 77.479 | 0.324 | 0.055 | 77.857 |
| | S8T1 | 25.890 | 0.119 | 0.030 | 26.039 |
| | S8T3 | 62.293 | 0.149 | 0.037 | 62.479 |
| Secondary forest | S1T1 | 37.054 | 0.409 | 0.038 | 37.502 |
| | S2T1 | 4.541 | 0.028 | 0.041 | 4.611 |
| | S4T1 | 44.652 | 0.035 | 0.037 | 44.723 |

**Table 12.** Mean aboveground carbon stocks in land uses sampled in the KFR

| Land use | Tree | Intermediate | Understorey | Total |
|---|---|---|---|---|
| | Mg/ha | Mg/ha | Mg/ha | Mg/ha |
| Agriculture | 3.599 | 0.482 | 0.025 | 4.106 |
| Agroforest | 17.098 | 17.098 | 0.034 | 34.230 |
| Grassland | 3.522 | 0.578 | 0.050 | 4.151 |
| Reforestation | 55.220 | 0.197 | 0.041 | 55.458 |
| Secondary Forest | 28.749 | 0.157 | 0.039 | 28.945 |

The mean aboveground carbon stock for each land use ranges 4.11–55.46 Mg/ha (Table 12). Land uses such as reforestation, agroforest and secondary forest have higher carbon content where trees are a higher proportion compared to other plant forms (Figure 4).

The carbon-stock values generated are far smaller compared to the values of similar land cover. Lasco and Pulhin (2003) recorded average carbon densities of 207.9 Mg/ha for secondary forest, 45.4 Mg/ha for agroforest, 12.1 Mg/ha for grassland and 59.0 Mg/ha for tree plantations. This observation could be attributed to the tree composition of the sampled plots. For example, large trees in the sampled plots of secondary forest—exemplified by *Pinus kesiya*, *Shorea contorta* and *Anisoptera thurifera*–had greater percentages of individuals with DBH of small (44.7%) and medium (48.8%) than those with large DBH, that is, greater than 50 cm (6.4%).

### 5.4.2 Belowground

Delany (1999) proposed belowground biomass of trees and intermediate layers equivalent to 15% of the aboveground tree biomass. The carbon content is presented in Table 13, while the mean land-use carbon stock is shown in Table 14.

**Table 13.** Plot-level belowground biomass carbon-stock

| Land use | Sample plot code | Stump & roots Mg/ha | Intermediate Mg/ha | Understorey Litter Mg/ha | Total Mg/ha |
|---|---|---|---|---|---|
| Agriculture | S5T2 | 3.766 | 0.078 | 0.035 | 3.879 |
| | S6T2 | 0.000 | 0.216 | 0.035 | 0.251 |
| | S7T1 | 0.283 | 0.248 | 0.025 | 0.557 |
| Agroforest | S1T2 | 5.606 | 1.035 | 0.028 | 6.668 |
| | S3T1 | 10.196 | 0.031 | 0.040 | 10.266 |
| | S4T2 | 6.342 | 0.182 | 0.027 | 6.551 |
| Grassland | S2T3 | 0.000 | 0.201 | 0.049 | 0.250 |
| | S2T4 | 3.677 | 0.216 | 0.025 | 3.918 |
| | S7T2 | 0.285 | 0.209 | 0.030 | 0.523 |
| Reforestation | S5T1 | 25.826 | 0.108 | 0.017 | 25.951 |
| | S8T1 | 8.630 | 0.040 | 0.012 | 8.682 |
| | S8T3 | 20.764 | 0.050 | 0.016 | 20.830 |
| Secondary forest | S1T1 | 12.351 | 0.136 | 0.021 | 12.509 |
| | S2T1 | 1.514 | 0.009 | 0.032 | 1.555 |
| | S4T1 | 14.884 | 0.012 | 0.018 | 14.913 |

**Table 14.** Mean belowground carbon stocks in land uses sampled in the KFR

| Land use | Stump & roots Mg/ha | Intermediate Mg/ha | Understorey Mg/ha | Total Mg/ha |
|---|---|---|---|---|
| Agriculture | 1.349 | 0.181 | 0.032 | 1.562 |
| Agroforest | 7.381 | 0.416 | 0.032 | 7.829 |
| Grassland | 1.321 | 0.208 | 0.034 | 1.564 |
| Reforestation | 18.407 | 0.066 | 0.015 | 18.488 |
| Secondary Forest | 9.583 | 0.052 | 0.024 | 9.659 |

### 5.4.3 Soil Carbon

The organic soil carbon of the various land uses is presented in Table 15. The estimated belowground carbon stocks are between 21.8 and 67.4 Mg/ha. Reforestation has the highest soil carbon stock in the area. In 2006, the soil carbon density values of grassland ranged from 35.36–47.22 Mg/ha (Pulhin et al. 2006). The current value (39.09 Mg/ha) of grassland falls in the middle of that range.

**Table 15.** Soil carbon and carbon stock

| Sample plot code | Land uses | OM% | OC% | Carbon stock Mg/ha |
|---|---|---|---|---|
| S6T2 | Agriculture | 4.74 | 2.76 | 49.87 |
| S5T2 | | 4.53 | 2.63 | 47.52 |
| S7T1 | | 3.15 | 1.83 | 33.07 |
| S3T1 | Agroforest | 4.54 | 2.64 | 47.70 |
| S4T2 | | 4.00 | 2.33 | 42.10 |
| S1T2 | | 4.93 | 2.87 | 51.86 |
| S2T4 | Grassland | 2.59 | 1.51 | 27.29 |
| S2T3 | | 4.52 | 2.63 | 47.52 |
| S7T2 | | 4.05 | 2.35 | 42.46 |
| S5T1 | Reforestation | 4.82 | 2.8 | 50.60 |
| S8T3 | | 6.39 | 3.71 | 67.40 |
| S8T1 | | 5.80 | 3.37 | 60.90 |
| S2T1 | Secondary forest | 3.56 | 2.07 | 48.79 |
| S1T1 | | 2.08 | 1.21 | 21.86 |
| S4T1 | | 3.37 | 1.96 | 35.42 |

The mean soil carbon of the KFR (Table 16) was lower compared to other studies conducted in Leyte and Tanay, Rizal, which were 52.70 Mg/ha and 55 Mg/ha, respectively (Lasco et al. 1999).

**Table 16.** Mean soil carbon-stock per land use

| Land use | Mean total Mg/ha |
|---|---|
| Agriculture | 43.49 |
| Agroforest | 47.22 |
| Grassland | 39.09 |
| Reforestation | 59.63 |
| Secondary Forest | 35.36 |
| **Mean total** | **44.96** |

### 5.4.4 Total carbon stock

The estimated total (above- and belowground) carbon stock of different land-use systems in the KFR ranged 54.31–151.13 Mg/ha (Table 17). The results were low compared to assessments conducted in other areas of the country.

**Table 17.** Plot-level mean carbon-stock of each land use

| Land use | Tree Mg/ha | Intermediate Mg/ha | Understorey Mg/ha | Litter Mg/ha | Soil & litter Mg/ha | Total Mg/ha |
|---|---|---|---|---|---|---|
| Agriculture | 3.60 | 0.48 | 0.03 | 5.15 | 45.05 | **54.31** |
| Agroforest | 17.10 | 0.32 | 0.03 | 6.06 | 55.05 | **78.56** |
| Grassland | 3.52 | 0.58 | 0.05 | 10.06 | 40.65 | **54.87** |
| Reforestation | 55.22 | 0.20 | 0.04 | 17.67 | 78.00 | **151.13** |
| Secondary forest | 28.75 | 0.16 | 0.04 | 20.59 | 45.02 | **94.55** |

**Table 18.** Total carbon stock at plot-level in the KFR

| Land use | Sample plot code | Aboveground | | | | Below-ground | Total Mg/ha |
|---|---|---|---|---|---|---|---|
| | | Tree Mg/ha | Intermediate Mg/ha | Understorey Mg/ha | Litter Mg/ha | Soil & litter Mg/ha | |
| Agriculture | S5T2 | 10.04 | 0.21 | 0.03 | 5.61 | 51.40 | **67.29** |
| | S6T2 | 0.00 | 0.58 | 0.04 | 3.01 | 50.12 | **53.74** |
| | S7T1 | 0.75 | 0.66 | 0.01 | 6.84 | 33.63 | **41.90** |
| Agroforest | S1T2 | 1.68 | 0.31 | 0.00 | 0.55 | 58.53 | **61.07** |
| | S3T1 | 30.59 | 0.09 | 0.07 | 14.82 | 57.97 | **103.54** |
| | S4T2 | 19.03 | 0.55 | 0.03 | 2.82 | 48.65 | **71.07** |
| Grassland | S2T3 | 0.00 | 0.60 | 0.10 | 6.59 | 47.77 | **55.06** |
| | S2T4 | 9.81 | 0.57 | 0.03 | 19.23 | 31.21 | **60.85** |
| | S7T2 | 0.76 | 0.56 | 0.03 | 4.37 | 42.98 | **48.70** |
| Reforestation | S5T1 | 77.48 | 0.32 | 0.05 | 23.39 | 76.55 | **177.80** |
| | S8T1 | 25.89 | 0.12 | 0.03 | 18.17 | 69.58 | **113.79** |
| | S8T3 | 62.29 | 0.15 | 0.04 | 11.45 | 87.87 | **161.80** |

| Land use | Sample plot code | Aboveground | | | | Below-ground | Total Mg/ha |
|---|---|---|---|---|---|---|---|
| | | Tree Mg/ha | Intermediate Mg/ha | Understorey Mg/ha | Litter Mg/ha | Soil & litter Mg/ha | |
| Secondary forest | S1T1 | 37.05 | 0.41 | 0.04 | 7.49 | 34.37 | **79.36** |
| | S2T1 | 4.54 | 0.03 | 0.04 | 30.15 | 50.34 | **85.11** |
| | S4T1 | 44.65 | 0.03 | 0.04 | 24.12 | 50.33 | **119.18** |

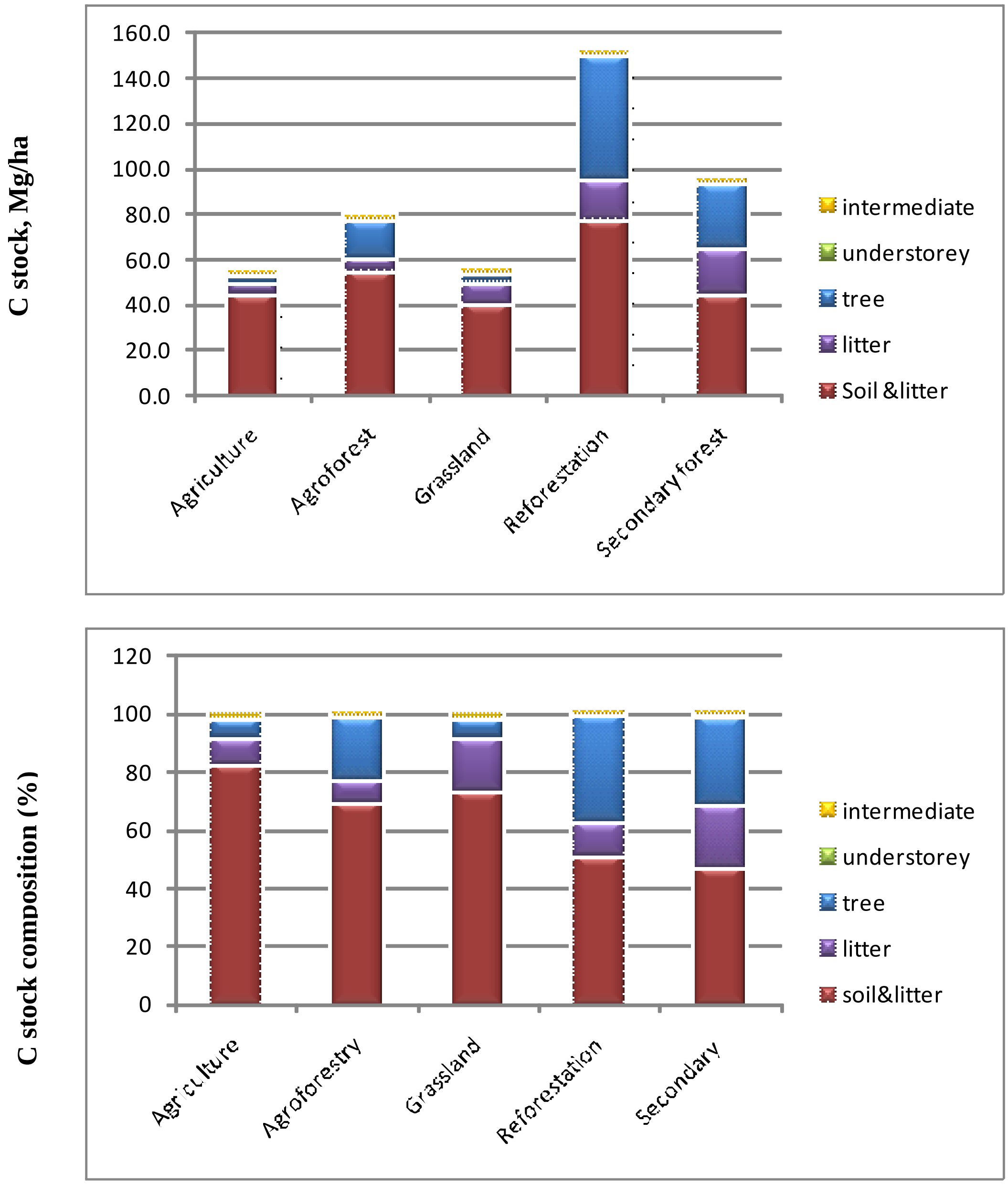


**Figure 5.** Total (above- and belowground) carbon stocks and their relative composition in the KFR (Upper panel: absolute values in Mg/ha. Lower panel: as percentage).

Carbon stocks from soil and litter contribute about 50–80 percent of the total carbon (Figure 5). The reforestation area has the highest total carbon stock both from soil and tree components.

### 5.4.5 Landscape carbon-stock estimation

The estimated mean carbon stocks (Table 17) of the major land-use types was plotted in the land cover map of 2001[4] to view the distribution of carbon density (Figure 6).

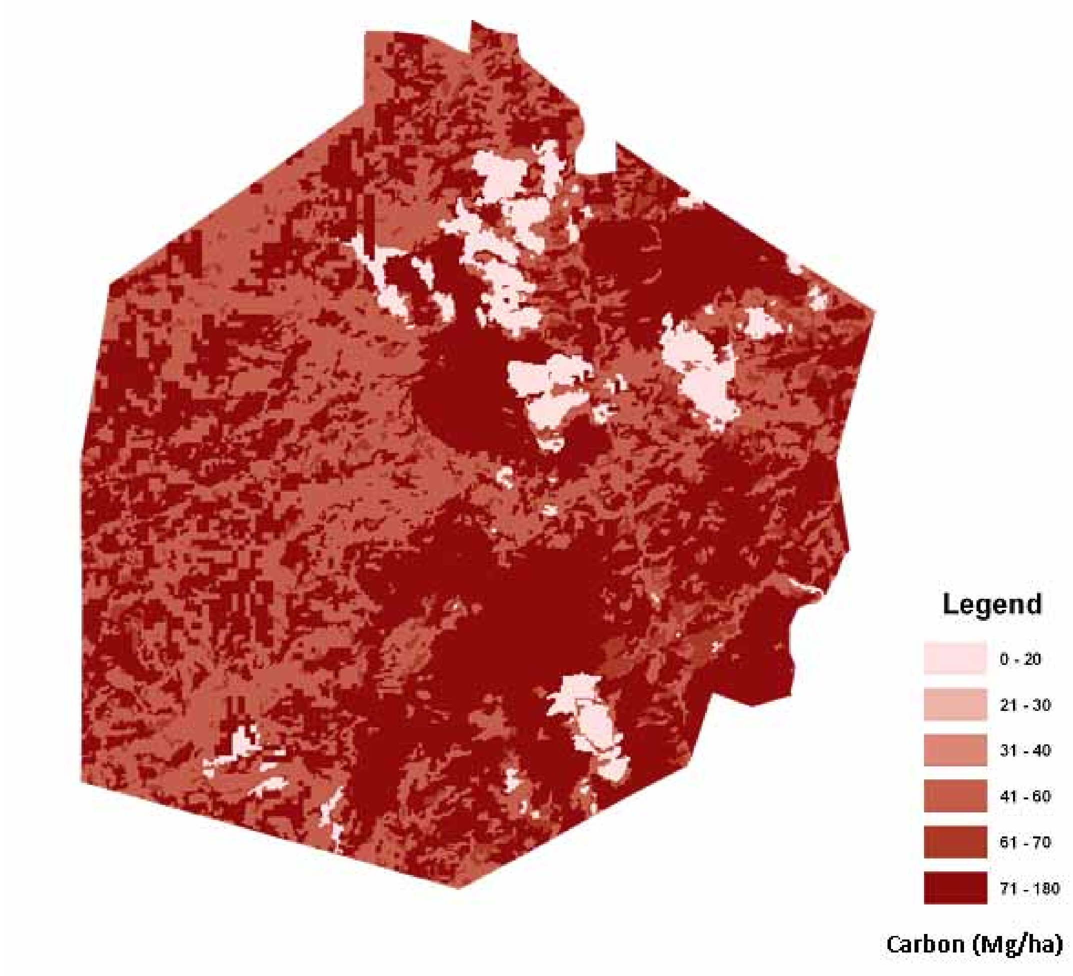


**Figure 6.** Distribution of land-cover-derived carbon density in the KFR, based on a carbon-stock estimate (2009).

[4] At the time of writing, the latest satellite image of this area awaits processing

## 5.5 Land-use change dynamics in the KFR

Landscape-level carbon-stocks were estimated from land-cover types. By integrating the changes in vegetation cover with carbon-stock measurements at plot level, changes in carbon stock in the landscape can be estimated. Land-cover maps of 1989 and 2001 that were processed by Ekadinata and Nugroho (in preparation) were used for this estimation. There were seven major land-cover classes identified.

1) Forest: characterised by more or less dense and extensive natural tree cover.
2) Secondary forest: re-grown woodland area.
3) Mahogany: areas dominated by *Swietenia mahogany* with ages of 10–30 years.
4) Pine:– areas dominated by *Pinus kesiya* (Benguet pine).
5) Agricultural land: areas with less trees and cultivated by sweet potato, ginger, potato, banana and corn.
6) Rice fields: both irrigated and non-irrigated, cultivated with hybrid and native rice varieties.
7) Fallow: areas that are left idle to regain soil productivity and planted with *Alnus nepalensis.*

### *5.5.1 Land cover in 1989*

About 39% (8500 ha) of the area was classified as agricultural land. Natural and secondary forest covered 20% (4300 ha) and 3% (670 ha) of the area, respectively (Table 19). About 27% (5800 ha) of the study area was covered by pine forest. Figure 8 shows the land cover map of 1989.

**Table 19.** Land-cover classes in the KFR, 1989

| Classes | Area (ha) | % |
|---|---|---|
| Forest | 4162.6 | 19 |
| Secondary forest | 670.9 | 3 |
| Old pine | 1513.3 | 7 |
| Pine | 4256.0 | 20 |
| Mahogany | 321.4 | 1 |
| Agriculture | 8473.9 | 39 |
| Fallow | 359.5 | 2 |
| Rice field | 976.4 | 4 |
| Settlement | 458.1 | 2 |
| Grassland | 28.1 | 0.1 |
| Cloud | 401.3 | 2 |
| Shadow | 172.7 | 1 |
| Total | 21794.0 | 100.0 |

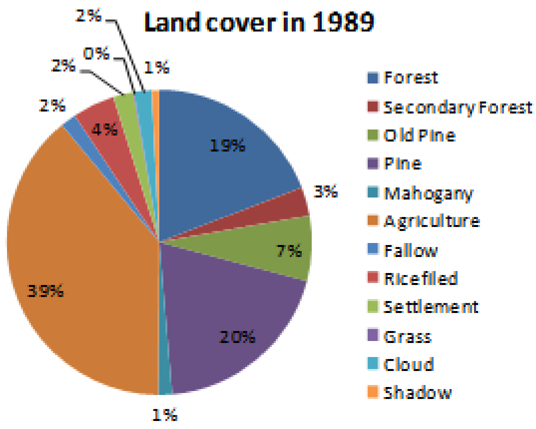


**Figure 7.** Land-cover classes in the KFR, 1989.

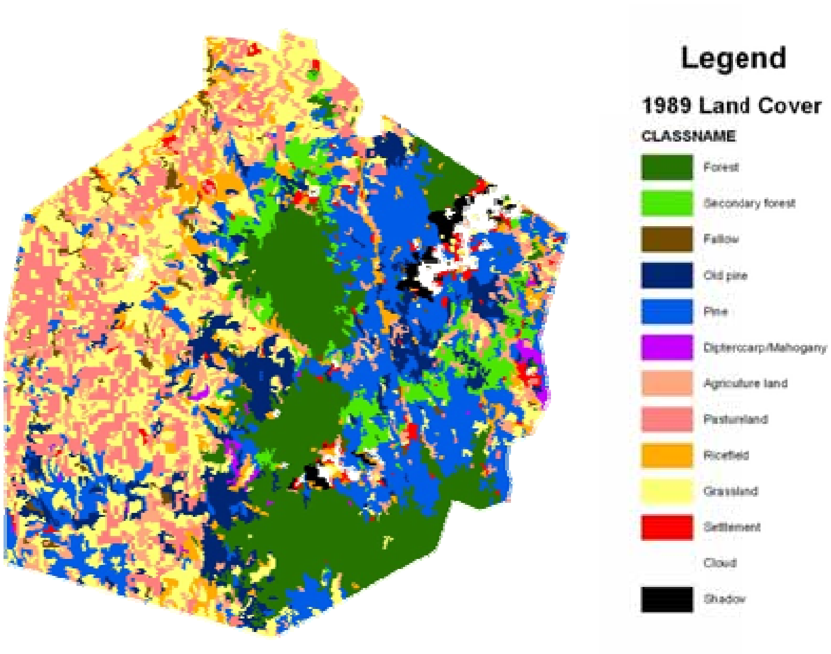


**Figure 8.** Land-cover map of the KFR, 1989.
Source: ICRAF

### *5.5.2 Land cover in 2001*

About 15.6 % (3400 ha) of area was classified as natural forest, a 3.5% decrease from 1989. Agriculture area covered around 8150 ha, a decrease from 39% to 37% of the total area, while old pine increased 7% to 10%. Figure 10 shows the land-cover map of 2001.

**Table 20.** Land-cover classes in the KFR, 2001

| Classes | Area (ha) | % |
|---|---|---|
| Forest | 3394.1 | 15.6 |
| Secondary forest | 373.6 | 1.7 |
| Old pine | 2125.1 | 9.8 |
| Pine | 3978.8 | 18.3 |
| Mahogany | 529.9 | 2.4 |
| Agriculture | 8154.8 | 37.4 |
| Fallow | 340.9 | 1.6 |
| Rice field | 1516.4 | 7.0 |
| Settlement | 514.4 | 2.4 |
| Grassland | 35.9 | 0.2 |
| Cloud | 601.7 | 2.8 |
| Shadow | 228.4 | 1.0 |
| Total | 21 794.0 | 100.0 |

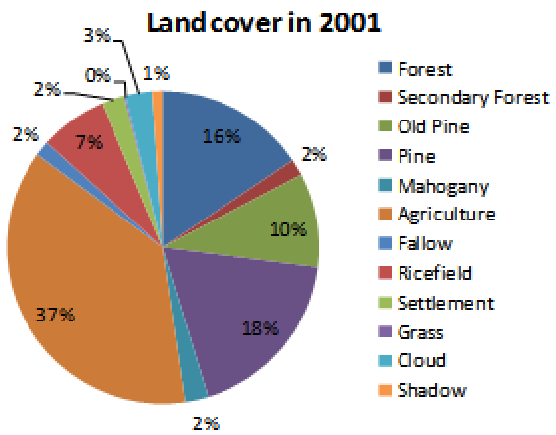


**Figure 9.** Land-cover classes in the KFR, 2001.

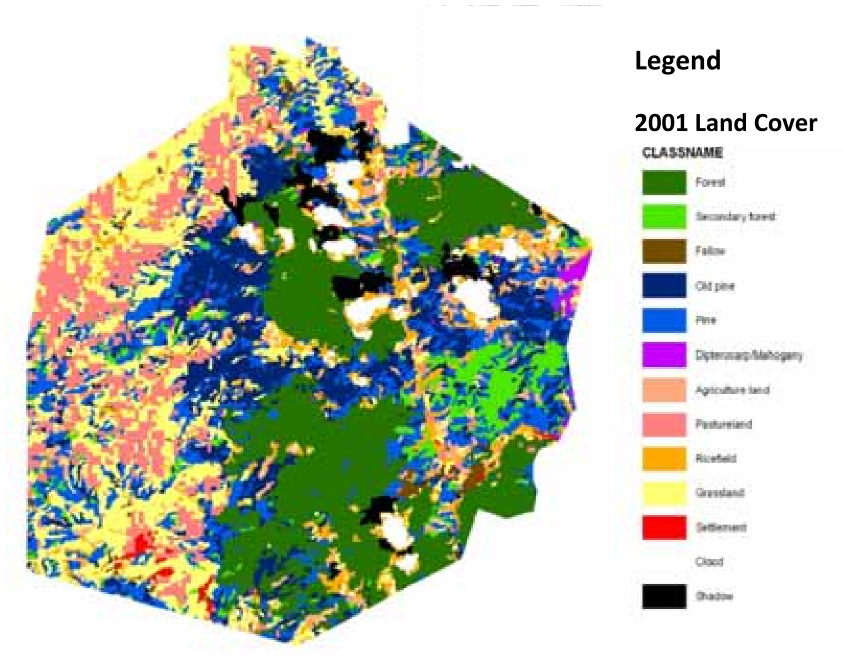


**Figure 10.** Land-cover map of the KFR, 2001.
Source: ICRAF

### 5.5.3 Land-cover change matrix

A land-cover change matrix is presented in Table 21. There was a considerable decrease of mature forest, secondary forest, pine forest and agriculture areas. On the other hand, there was an increase in old pine forest, mahogany plantation, rice field, grassland and settlement areas.

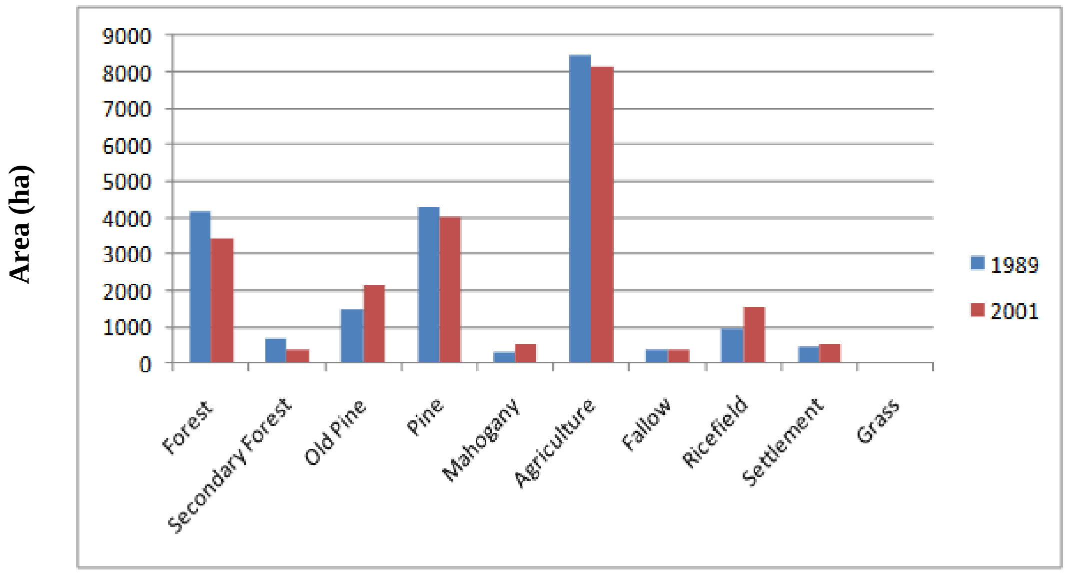


**Figure 11.** Overall land-cover change within the KFR.

**Table 21.** Land-cover changes between 1989 and 2001 (area in ha)

| | | 2001 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Land use** | **Forest** | **Secondary forest** | **Old pine** | **Pine** | **Mahogany** | **Agriculture** | **Fallow** | **Rice field** | **Settle-ment** | **Grass land** | **Cloud** | **Shadow** | **Total** |
| **1989** | **Forest** | 3145.23 | | | 308.88 | 8.64 | 209.43 | 20.7 | 187.11 | 1.62 | 9.27 | 271.71 | | 4162.6 |
| | **Secondary forest** | | 370.08 | | 126.63 | 6.03 | 47.52 | 0.81 | 37.71 | 0.09 | 1.8 | 52.56 | 27.63 | 670.9 |
| | **Old pine** | | | 1134.9 | | 28.8 | 257.4 | 5.94 | 61.02 | 0.9 | 1.17 | 10.53 | 12.6 | 1513.3 |
| | **Pine** | | | 945.18 | 1897.2 | 87.57 | 784.44 | 74.61 | 279.45 | 17.37 | 8.91 | 107.64 | 53.64 | 4256.0 |
| | **Mahogany** | | | | | 302.22 | 8.91 | 0.09 | 6.3 | | 0.18 | 2.97 | 0.72 | 321.4 |
| | **Agriculture** | | | | 1362.42 | 90.18 | 6257.97 | 149.85 | 421.56 | 69.3 | 9.72 | 67.23 | 45.63 | 8473.9 |
| | **Fallow** | | | | 56.34 | 4.77 | 185.4 | 73.8 | 33.3 | 0.09 | 0.54 | 4.5 | 0.72 | 359.5 |
| | **Rice field** | | | | 166.77 | | 317.97 | 5.13 | 432.45 | 9.18 | 2.07 | 14.76 | 28.08 | 976.4 |
| | **Settlement** | | | | | | | | | 415.08 | | 29.34 | 13.68 | 458.1 |
| | **Grassland** | | | | 10.8 | | 7.38 | 6.75 | 1.71 | 0.18 | 0.18 | 0.63 | 0.45 | 28.1 |
| | **Cloud** | 165.51 | 1.98 | 23.13 | 34.02 | 0.54 | 62.91 | 3.24 | 45.36 | 0.54 | 1.98 | 26.19 | 35.91 | 401.3 |
| | **Shadow** | 83.34 | 1.53 | 21.87 | 15.75 | 1.17 | 15.48 | | 10.44 | | 0.09 | 13.68 | 9.36 | 172.7 |
| | **Total** | 3394.1 | 373.6 | 2125.1 | 3978.8 | 529.9 | 8154.8 | 340.9 | 1516.4 | 514.4 | 35.9 | 601.7 | 228.4 | |

Source: ICRAF

### 5.5.4 Carbon monitoring plots

KEF's agroforestry program monitored plant biomass in 106 plots within the KFR between 1994 and 2003 (Figure 11). Table 22 shows the biomass generated.

**Table 22.** Mean biomass in 1994 and 2003 and the blocks and plots sampled

| Land use | No. of blocks | No. of plots | 1994 Mean biomass (Mg/ha) | 2003 Mean biomass (Mg/ha) |
|---|---|---|---|---|
| Agriculture | 13 | 30 | 32.73 | 47.55 |
| Forest | 7 | 20 | 20.76 | 28.65 |
| Secondary forest | 3 | 8 | 39.89 | 56.71 |
| Old pine | 13 | 19 | 28.00 | 40.71 |
| Pine | 16 | 23 | 30.35 | 41.48 |
| Rice field | 4 | 5 | 17.14 | 23.73 |
| Mahogany* | 1 | 1 | 30.79 | 53.50 |
| Total | 57 | 106 | | |

*Only one mahogany plot appeared after the plot's coordinates were intersected on the 1989 and 2001 land-cover maps

The carbon densities for 1994 and 2003 were obtained from these plots (Table 23). The total carbon budget estimated from the land cover was obtained from the total area of each land-cover type (excluding the areas under cloud and shadow). Figure 10 shows the land-cover density maps that indicate increases of carbon stock over the period 1994–2003.

**Table 23.** Carbon densities based on biomass-monitoring plots in the KFR

| Land use | 1994 Carbon density (Mg/ha) | 2003 Carbon density (Mg/ha) |
|---|---|---|
| Agriculture | 14.73 | 21.40 |
| Forest | 9.34 | 12.89 |
| Secondary forest | 17.95 | 25.52 |
| Old pine | 13.66 | 19.87 |
| Pine | 14.81 | 19.91 |
| Rice field | 6.86 | 9.49 |
| Mahogany | 13.86 | 21.07 |

It was estimated that the total carbon stock was approximately 375.8 Gg[5] in 1994 and 452.1 Gg in 2003 or a 21% increase in 9 years. This may be due to the increase of old pine and reforestation and the decrease of agricultural areas.

[5] 1 Gg (Gigagram) = 1000 Mg (Megagram)