Carbon inventory of rehabilitated dipterocarp forest in Sabah, Malaysia

February 2009

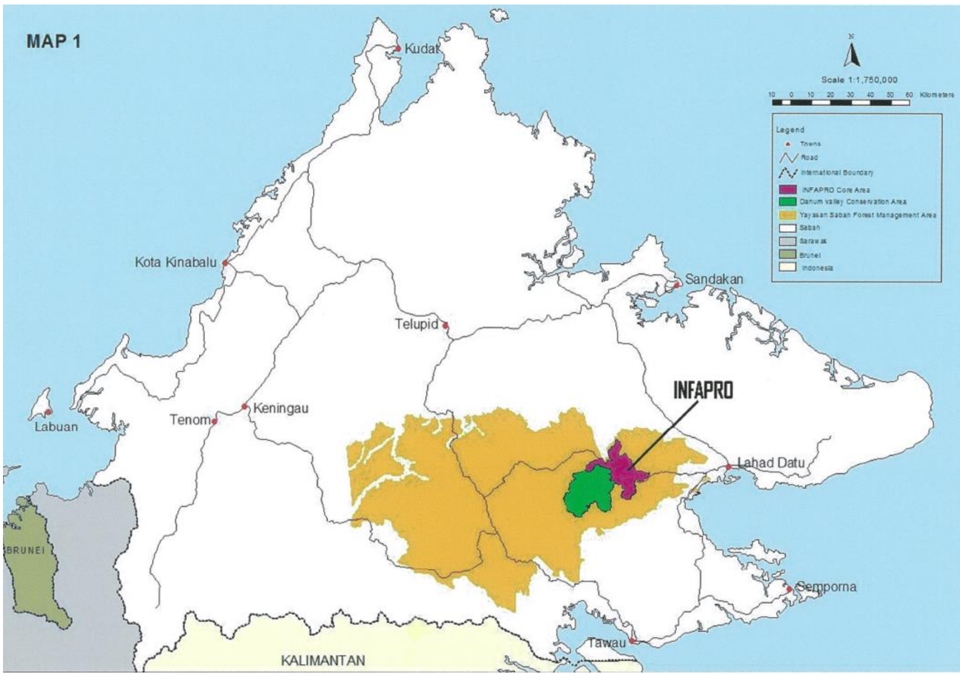
1 Introduction

In 2007 Face Foundation commissioned a forest carbon inventory in the Infapro rehabilitation project area. This carbon monitoring campaign was a joint effort of IFER, Infapro and Face Foundation. IFER (Institute for Forest Ecosystem Research) is a Czech company specialized in forest inventories. Innoprise-Face Foundation Rainforest Rehabilitation Project (Infapro) is a collaboration project between Rakyat Berjaya Sdn.Bhd., an operational subsidiary of Innoprise Corporation Sdn.Bhd., an investment arm of Yayasan Sabah Group, and the Face (Forests Absorbing Carbon dioxide Emissions) Foundation of the Netherlands and by doing so, sequester CO_2 from the atmosphere and enhancing the timber stock. The project started in 1992.

The objective of the project is to rehabilitate 25,000 ha of heavily degraded rainforest with liberating the remaining forest matrix and with enrichment planting of indigenous dipterocarps, fast growing pioneers and forest fruit trees. The technique is used to promote artificial regeneration of these seedlings in the existing logged rainforest and preferable silvicultural treatments are then given to encourage the growth of these seedlings. The objectives to plant indigenous fruit tree species are to increase the biodiversity of the planting compartments and to attract wildlife. Up to now about 11,000 ha have been rehabilitated.

Picture 1 A planting line in one of the earliest established compartments. By that time 100% enrichment planting was carried out, whereas nowadays planting only takes place when natural regeneration is lacking.

Infapro is located in the Lahad Datu District in the Malaysian state of Sabah. It adjoins the Danum Valley Conservation Area – a protected primary forest with a size of 43,800 ha. The area is renowned for its rich biodiversity of flora and fauna. The dipterocarp forest contains a large variety of valuable tree species. The most important genera of tree species are the *Hopea*, *Dryobalanops*, Dipterocarpus, *Shorea* and *Parashorea*. Studies conducted on faunal diversity in Danum Valley adjacent to Infapro revealed that the area has high density and diversity of fauna compared to other parts of Sabah and Sarawak. Amongst mammals, primate diversity is relatively rich, comprising Orang utan (*Pongo pygmaeus*), Borneo gibbon (*Hylobates muelleri*), red leaf monkey, long-tailed and pig-tailed macaques. Other remarkable animals are the Sumatran rhinoceros (*Dicerorhinus sumatrensis*), Borneo pygmy elephant (*Elephas maximus borneensis*), Sun bear (*Helarctos malayanus*) and the Bornean clouded leopard (*Neofelis diardi*). Rehabilitation of the degraded forest results in the restoration of the habitats of these often rare and endangered species.



Picture 2 Location of Infapro (purple) within the Yayasan Sabah concession area (yellow) on Sabah, Malaysia.

It is estimated that lowland dipterocarp primary forest stores roughly about 147 to 325 tonnes of carbon per hectare in aboveground biomass. After logging of the current Infapro area in the '70s and '80s the carbon stocks varied between 26 and 129 tonnes of carbon per hectare (above and belowground biomass), depending upon the remaining type of vegetation. The terrain is very rugged and has been logged using two techniques: cable yarding and tractor yarding. This has resulted in a mosaic pattern of disturbance, ranging from open canopy vegetation type to remnant forest patches. The forest re-growth is very much hampered by the infestation of vines, weeds and climbers. The project intervention speeds up the recovery of the forest. Through the Infapro rehabilitation an additional amount of atmospheric CO_2 is being sequestered in the forest, contributing to climate change mitigation. The carbon inventory is intended to determine the amount of sequestered carbon in the rehabilitated area compared with the untreated area and this way to quantify the project benefits in terms of carbon.

Picture 3 Typical situation of the degraded forest without the project intervention. This picture has been taken 20 years after logging – there is hardly any recovery.

This article describes the carbon inventory methodology as it has been applied for the monitoring campaign in Infapro. The methodology has been developed by IFER in collaboration with Infapro and Face Foundation. The data collection was carried out by Infapro staff.

2 Methodology

The aim of this study was to design a statistical carbon inventory and to yield plausibly precise estimation of carbon absorbed by the restored forest ecosystem. It must be applicable for long term monitoring and permit independent rigorous verification at any time.

The methodology of the proposed carbon offset monitoring was based on combination of aerial photo interpretation and ground based survey on the grid of monitoring plots.

2.1 First-phase sampling grid

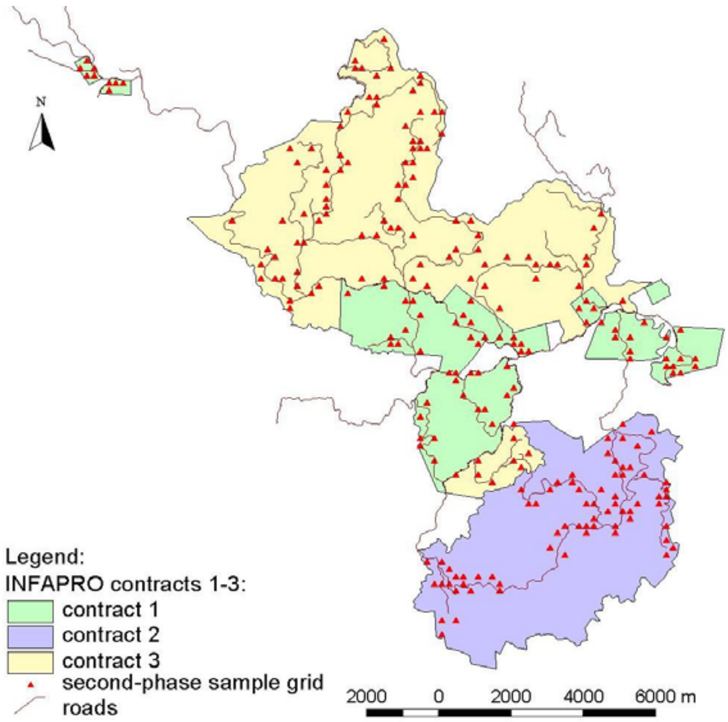
Grid 200x200 m of virtual inventory plots was over imposed on aerial photos (resolution 1 m) in order to classify forest type for each point of the grid. Virtual plots were then manually classified into five forest type classes (e.g. Open canopy, Pioneer dominated, Remnant or pioneer trees, Non-forest and Unrecognizable).

The total number of first-phase sample points was 7,322.

2.2 Second-phase sampling grid

Forest type stratification of the first-phase sample units was used for drawing the field sample, together with restricted random drawing to concentrate the fieldwork in specific areas. The condition for second-phase unit to be drawn out of first-phase sample was the location of plot within 250 m wide buffer on either side of the mapped roads. Such a design of second-phase grid considered inaccessibility or inefficient accessibility of substantial part of investigated area and also limited time allocated to field survey. As a result the costs of field survey were moderate.

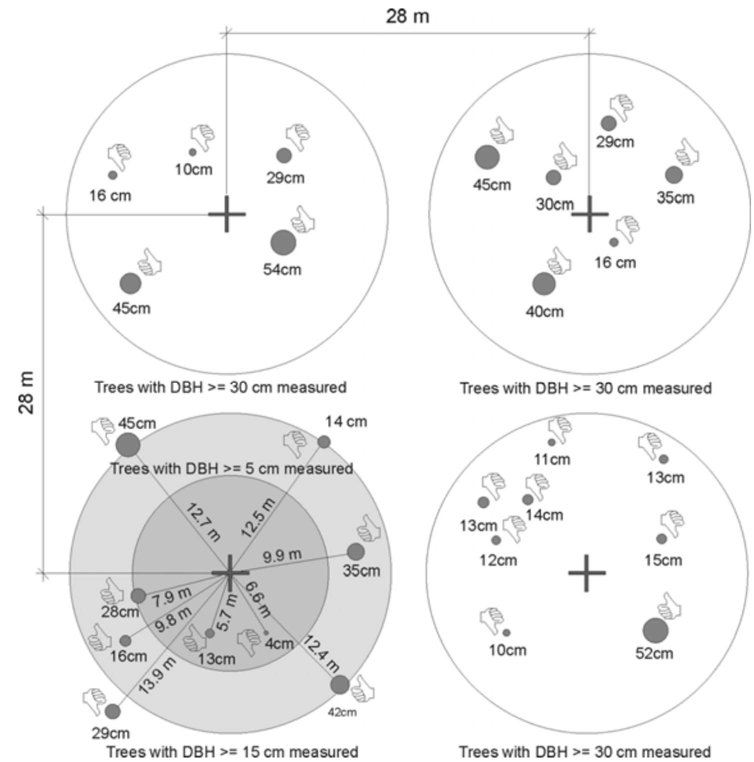
The total number of second-phase inventory plots was estimated to 290, which was based on available time, number of field teams and affordable daily norm for one team. Of the total amount of plots, 240 inventory plots were established inside Infapro compartment area (i.e. with project scenario) and 50 inventory plots were distributed outside the contract area, but still within the Infapro project area (i.e. without project scenario = baseline scenario) – see picture 4.



Picture 4 Second-phase sample plots (INFAPRO contract area)

2.3 Size and shape of inventory plots

Inventory plot consisted of four 500m² circles. The distance between the circle centers was 28 m and they formed a square looking shape (see picture 5). The first of them, the key circle, is split to tree size categories. In regeneration circle with radius of 2m located aside the center, the trees with height between 0.2 and 1.3m are recorded. The smallest trees (with DBH>= 50 mm) are measured on the concentric sub-circle of the key circle (radius 5 m), medium trees (with DBH>= 100 m) are measured on the whole area on the key circle and the largest trees (with DBH >= 200 mm) are measured on the entire area of the quadruplet (see table 1).



Picture 5 Schema of inventory plot

Table 1 Parameters of sub-circles

Tree type	Tree dimensions	Sample area	Circle radius
regeneration	(>0,2 m of height; 50 mm of DBH)	12,56 m^2	2 m, key circle
small trees	(50 mm of DBH; 100 mm of DBH)	78,5 m^2	5 m, key circle
medium trees	(100 mm of DBH; 200 mm of DBH)	500 m^2	12,62 m, key circle
large trees (DBH>70cm)	(200 mm of DBH and more)	2000 m^2	whole inventory plot

2.4 Methods of field survey

The team first navigated to the closest point on the road using GPS, Hammerhead and Field-Map with road map and aerial photos. Then the navigation continued both with GPS and laser rangefinder in order to find center of the plot.

On each plot, position and diameter at breast height (DBH) were recorded. Total height of the trees was not measured. For the trees with DBH below 10 cm, the total height was estimated. For larger trees, the merchantable height was automatically calculated by Field-Map upon entering the data of DBH (general models describing relation between DBH and merchantable height are used and enter in Field-Map scripting).

For the trees with DBH above 70 cm, additional measurement of stem profile features was performed.

On the first circle of the inventory plot, the coverage of vines, climbing bamboo and herbs were recorded in percent.

Some baseline plots for future comparison of carbon stock of treated and non-treated areas were chosen.

2.5 Carbon content calculation for individual trees

For processing, Field-Map Data Processing Tools were used. The statistics were calculated using Field-Map Inventory Analyst.

The procedure of carbon stock calculation involves several steps. Field measurements provided data of practically measurable biomass components. These variables were used to compute either volume or mass of whole trees or tree components. Such computation involved some error and uncertainty, which depends on components that were calculated. Tree stems represented the biomass component that can be assessed most accurately. Usually, diameter and height were sufficient descriptors to calculate stem volume for regularly shaped trees. For better accuracy and for atypically shaped trees, Field-Map offers a more accurate estimation.

1. Calculation of merchantable volume for trees above 100 mm of DBH

The calculation of merchantable volume was based on species, DBH and merchantable height.

For every qualified tree in the inventory plot the species were recorded and DBH measured. The merchantable height was either measured (for large trees with DBH > 700 mm) or assessed/estimated directly in the field using existing model (Yap 2007). Model was implemented as script in field database application (Field-Map Data Collector) and it was based on species and DBH. Modeled value of merchantable height was checked and corrected if necessary by field teams.

First all species were re-classified into 15 species groups (Yap 2007) and then species group specific volume equations were used to calculate merchantable volume directly in the field.

2. Calculation of total volume for trees above 100 mm of DBH

Merchantable volume does not represent whole volume of the wood of aboveground part of the tree. Therefore the expansion factor (*EF*) of 1.895 was used in order to obtain the total (volume-biomass-carbon) of aboveground biomass (Yap 2007).

3. Conversion of total volume into dry matter of wood biomass for trees above 100 mm of DBH

Wood volume was converted into dry matter of wood biomass using wood density constants (Yap 2007). However, carbon stock assessment requires total tree biomass to be counted, and biomass must be expressed in terms of dry mass (weight) units. Various types of allometric equations exist to facilitate these calculations. Obviously, the conversion will be specific for different regions, species and site conditions.

4. Calculation of total carbon content for trees above 100 mm of DBH

Carbon content is calculated by multiplying dry matter of biomass by a constant conversion factor (CF) of 0.5.

Hence, the overall estimation of carbon stock held in aboveground biomass follows the following equation:

$$c_{AB} = V \times EF \times D_{(SP)} \times CF$$

where

c_{AB} carbon content in aboveground tree biomass (t)

V	merchantable volume of a tree (m^3)
EF	expansion factor (1.895)
$D_{(SP)}$	specific wood density for tree species (t/m^3)
CF	carbon conversion factor (0.50 t C/t biomass)

Finally, carbon held in belowground biomass component was estimated conservatively as 16 % of aboveground part. Thus the total carbon content was calculated using:

$$c_{Tot} = 1.16 \times c_{AB}$$

where

c_{Tot}	carbon content in whole tree biomass (t).

5. Calculation of carbon content for small trees (DBH < 100 mm)

The estimation of carbon content for trees below 100 mm of DBH was based on application of allometric equations derived for beech (Cienciala *et al*. 2005).

Picture 6 Infapro staff is doing the fieldwork by means of the Field-Map equipment

3 Results of statistical data processing

In the contract area (9,734 ha), the carbon stock held in the aboveground and belowground tree biomass was assessed to be 1,418,500±86,800 tons, i.e., with a confidence interval of ±6.1 %. This corresponds to an average carbon stock of 145.7±9 t per hectare held in trees. In the contract area, the carbon stock held in trees was also expressed separately for different forest type, planting year and tree type.

In the baseline area (20,679 ha), the carbon stock held in the aboveground and belowground tree biomass was estimated to be 1,912,300±251,700 tons, i.e., with a confidence interval of ±13.2 %. This corresponds to an average carbon stock of 92.5±12.3 t per hectare held in trees. In the baseline area, the carbon stock held in trees was also expressed separately for different forest type and tree type.

References

Cienciala, E., Apltauer, J., Cerny, M. & Exnerova, Z. 2005. Biomass functions applicable for European beech. *Journal of Forest Science* 51: 147-154.

Yap, S.W. 2007. Carbon stock of enrichment planted seedlings in logged-over forest at Ulu Segama Forest Reserve, Lahad Datu, Sabah, Malaysia. Technical Report No.15, Innoprise – Face Foundation Rainforest Rehabilitation Project (Infapro), Sabah, Malaysia.