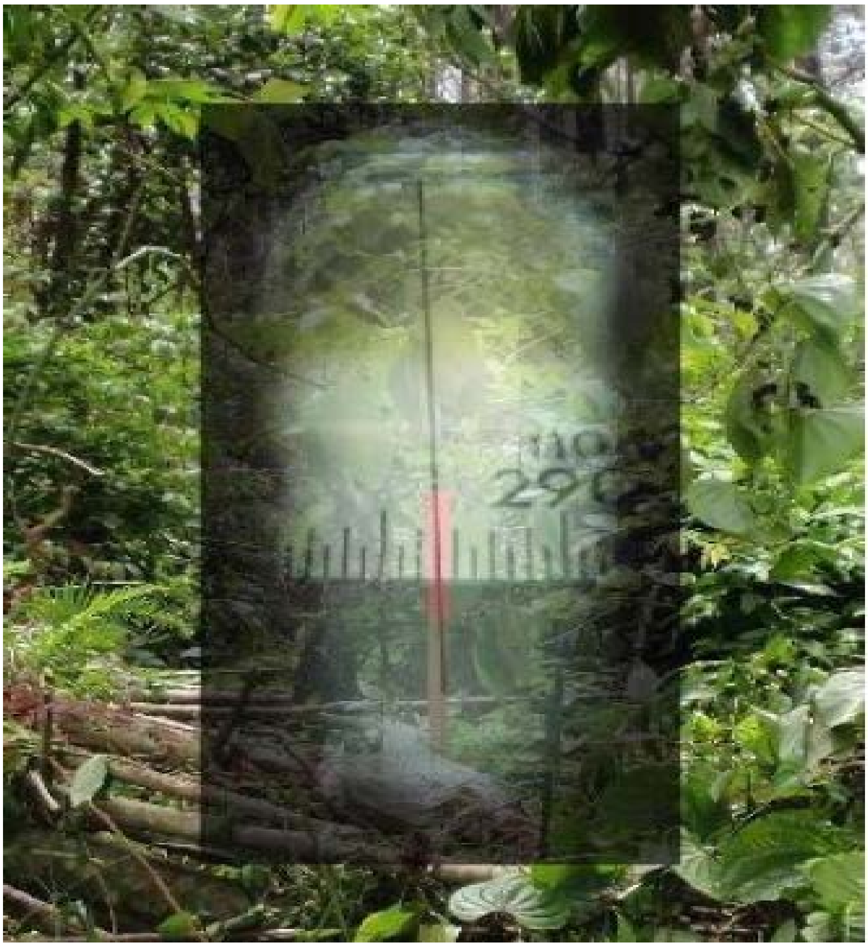
INTERNATIONAL CLIMATE INITIATIVE

On behalf of

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

of the Federal Republic of Germany

Regional project
Climate Protection through Forest Conservation in Pacific Island Countries



Development of technical parameters for the integration of SFM and REDD+

Field activities and first results at the demonstration area in Nakavu (Fiji)

June 2012

SPC Secretariat of the Pacific Community

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Report prepared by Michael Mussong and Stephan Hoffmann

HNE Eberswalde/Germany

e-mail: mmussong@hnee.de

On behalf of SPC/GIZ Regional Project "Climate Protection through Forest Conservation in Pacific Island Countries"

P.O. Box 14041, SUVA, Fiji

e-mail: karl-peter.kirsch-jung@giz.de

Content

Summary

The SPC/GIZ-Project Climate protection through Forest Conservation in Pacific Island Countries in co-operation with the Fiji Forestry Department intends to carry out investigations in a demonstration area in order to elaborate technical planning parameters for the integration of SFM (sustainable forest management) and REDD+ (Reducing Emissions from Deforestation and Forest Degradation).

The SFM-REDD+ project is scheduled for 2 years and was launched in January 2012. Until end of March 2012 the first 5 activities (boundary opening/mapping, socio-economic base line study, maintenance of infrastructure, pre-harvest inventory and tree selection) were started in the Nakavu pilot area. For methodology development, an "average" compartment was chosen. A full enumeration of all trees with dbh >= 35 cm and a detailed inventory of in total 12 Carbon pools (living trees (4 sub-pools), other vegetation (grass/ferns), standing and lying deadwood (3 sub-pools each) and litter) was carried out.

First results show that a sustainable increment on harvestable wood of 1.0-1.5 m^3/y/ha can be expected after a "medium logging". The carbon inventory (which is not yet completed in the first compartment) found in total 106 t C/ha (soil carbon is not included). The biggest share (ca. 40 %) stems from the trees with dbh >= 35 cm. Other main sources are the trees with dbh 10-34 cm and the below-ground carbon (estimated by a prediction model). Deadwood seems to be under-represented up to now and litter and other vegetation (which require a time consuming survey) contribute with a very small share only (<5%).

Several recommendations were made for further optimizing the carbon inventory and for developing a suitable pre-harvest inventory system. The diameter limit tables (DLT) seem to work quite well but modifications for single species might become necessary. More compartments with different treatments need to be surveyed before final conclusions can be drawn.

Zusammenfassung

Das SPC/GIZ-Projekt „Klimaschutz durch Walderhalt in pazfischen Inselstaaten" beabsichtigt, in Zusammenarbeit mit der Fidschianischen Forstverwaltung in einem Demonstrationsgebiet Erhebungen durchzuführen, die zur Entwicklung von technischen Planungsparametern für die Integration nachhaltiger Forstwirtschaft (SFM) und REDD+ (Reducing Emissions from Deforestation and Forest Degradation) unterstützen sollen.

Das insgesamt zweijährige SFM-REDD+ Projekt startete im Januar 2012. Bis Ende März 2012 konnten 5 Projektaktivitäten (Grenzmarkierung/Kartierung, Sozio-ökonomische Erhebungen, Instandsetzung der Infrastruktur, pre-harvest Inventur, Baumauswahl) im Demonstrationsgebiet in Nakavu begonnen werden. Zur Methodenentwicklung wurde eine „durchschnittliche" Abteilung ausgewählt, in der eine Vollkluppung aller Bäume mit einen BHD >= 35 cm sowie eine detaillierte Inventur von insgesamt 12 Kohlenstoff-Pools (lebende Bäume (4 Sub-Pools), andere Vegetation (Grass/Farn), stehendes und liegendes Todholz (jeweils 3 Sub-Pools), Streu) durchgeführt wurde.

Erste Ergebnisse zeigen, dass als nachhaltiger Zuwachs an erntefähigem Holz ca. 1,0-1,5 m^3/J/ha nach einem „mittleren" Holzernteeingriff erwartet werden kann. Die Kohlenstoffinventur in der ersten Abteilung (noch nicht abgeschlossen) ergab insgesamt 106 t C/ha (ohne Bodenkohlenstoff).

Der größte Anteil (ca. 40 %) entfällt auf die Bäume mit BHD >= 35 cm. Weitere Hauptquellen sind die Bäume mit einem BHD zwischen 10 und 34 cm und der Kohlenstoff in Wurzeln (geschätzt mittels eingeführtem Regressionsmodell). Todholz erscheint z.Z. noch unterrepräsentiert. Streu und Bodenvegetation tragen nur gering (<5%) zum Gesamtkohlenstoff bei, benötigen aber eine aufwändige (und teure) Probennahme.

Vorschläge zur weiteren Optimierung der Kohlenstoffinventur und für die Entwicklung eines geeigneten pre-harvest Inventur wurden gegeben. Die Zieldurchmesserlisten (DLT) scheinen bisher relativ gut zu funktionieren, aber für einzelne Baumarten könnten noch Änderungen erforderlich sein. Die Versuche sollten in weiteren, unterschiedlich behandelten Abteilungen fortgesetzt werden bevor endgültige Aussagen getroffen werden können.

1. Introduction

1.1 SPC/GIZ Regional REDD+ Project and objectives

To develop regional and national policies as well as institutional capacities for the implementation of REDD+, the Land Resources Division (LRD) of the Secretariat of the Pacific Community (SPC) receives support from Germany's International Climate Initiative (ICI)[1] for the regional project 'Climate protection through Forest Conservation in Pacific Island Countries' (PIC)[2]. On the German site, the project partner for the implementation of the project is the *Deutsche Gesellschaft für Internationale Zusammenarbeit* (GIZ)[3].

The overarching goal of the project is defined as: 'The conservation of forest ecosystems in the Pacific Islands Countries is supported in order to mitigate climate change and preserve biodiversity'.

The three specific objectives of the project are:

1. Regional REDD+ policy: The PIC have a joint, coherent regional framework for the implementation of REDD+;
2. REDD+ information and support platform: The implementation of REDD+ activities in the PIC is strengthened through the use of a regional and supra-regional information and support platform;
3. REDD+ readiness: Substantial REDD+ components are implemented in three countries leading to a complete REDD+ readiness in one country.

1.2 REDD+ and SFM demonstration activities

One out of five eligible activities under the REDD+ scheme is the sustainable management of forests which includes the implementation of logging practises following the criteria of sustainable forest management (SFM)[4]. Due to the fact that the only forest in the region that has been managed in compliance with these criteria stems from the former Fiji-German Forestry Project, the activity shall be demonstrated in the former NFMPP[5] area at Nakavu village in Fiji.

Within the frame of a demonstration project it is intended (a.o.) to develop technical parameters for the integration of SFM and REDD+. Therefore, the following project tasks are to be conducted in three consecutive steps whereas the first and the second step are already completed in 2011. During the first step a preliminary concept on activities to demonstrate in the Nakavu pilot area was developed[6]. After that, the concept was discussed during an inception

[1] ICI is financing climate protection projects of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) in developing countries

[2] www.spc.int/lrd/index.php?option=com_content&view=article&id=818&Itemid=527

[3] German Development Cooperation; c.f. www.giz.de

[4] The five eligible activities under the REDD+ mechanism are: stopping deforestation, stopping degradation, conservation of forest carbon stocks, sustainable management of forest, and enhancement of carbon stocks (Article 70, Draft Decision [-/COP16] of the Ad-hoc Working Group on Long-term Cooperative Action (AWG-LCA)).

[5] During 1989 and 1994 one major activity under the Fiji-German Forestry Project was the development of SFM in the Natural Forest Management Pilot Project (NFMPP) at Nakavu village.

[6] Mussong, 2011a

workshop with the relevant stakeholders and modified according to the results of the discussion. The final outcome of the second step is documented in a project report[7]. During the third step practical measures shall be carried out in the demonstration area. In particular, the following tasks were defined.

1.3 Objectives of the mission

Goal of the mission during the initial project phase from January to March 2012 is

1. to initiate the field activities no. 1 to 5, listed in Tab.1[8];
2. if necessary, to develop or adapt suitable methodologies;
3. to analyze the first collected data;
4. to derive recommendations for the further course of the project.

No.	Activity	Key Outputs
1	Site inspection, boundary opening, mapping	boundaries opened, maps (compartment, whole area)
2	socio-economic base line study	information on change of socio-economic situation in Nakavu village
3	Maintenance of infrastructure	accessibility for off-road vehicles (phase1) full accessibility (phase 2)
4 + 5	PHI + tree selection	stock map for simulation, PHI-design (incl. regeneration, carbon), expected volume, carbon

Table 1: Activities and expected outputs of the project

All following statements are based on experiences and data collected until end of March 2012.

2. Activities

2.1 Boundary opening and mapping

Boundary opening was carried out with bush knifes by teams of casuals from Nakavu village. In parallel, the boundaries were surveyed with a handheld GPS[9] and transferred into a GIS database[10].

Until end of March the boundaries of the compartments 1, 4, 6 and 7 were cleared, demarcated with coloured tape and surveyed (Fig. 1). Due to the fact that the south-western border is the Waiyanitu creek which need not to be demarcated, approx. 50 % of the demarcation work was already completed. The remaining boundary demarcations can also be considered as a low-physical activity since the open lines of the boundaries have been still intact from previous clearings and mainly only tree ferns and bigger herbal vegetation had to be removed. Time measurements showed that the required time for demarcation takes in average 20 min per 100 m for a team of 3 casuals.

[7] Mussong, 2011b
[8] The full list of activities, expected outputs and responsibilities is attached as Annex 1
[9] Global Positioning System: GARMIN GPSmap 62s, Garmin Ltd. 2011
[10] Giographical Information System: ArcGIS® Desktop 9.3, ESRI 2008

While the demarcation proceeded largely without problems, the GPS measurements showed larger deviations especially in the narrow river valleys. A poor satellite reception caused offsets between 10 and 15 m which have been aligned through comparison with GPS measurements executed by the Fiji FD earlier. Also for the transferring of the data into the data base several technical problems had to be solved. Figure 2 shows the GIS maps for the four survey compartments. As first and important result, the gross areas of the compartments could be determined and used for further calculations with the PHI and tree selection data (Activities 4 and 5).

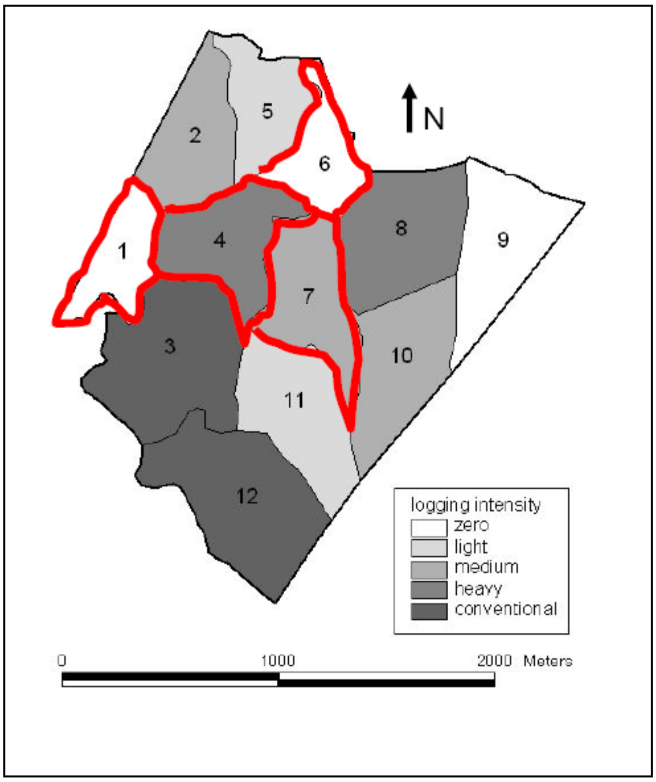


Figure 1: Nakavu demonstration area: compartments (no.), treatments 1992-94 (colour) and demarcated boundaries (red lines)

Compartment (no.)	Gross area (ha)
1	16,65
4	25,24
6	17,56
7	28,88

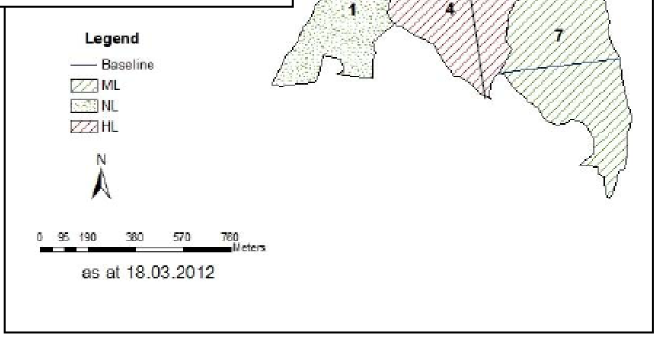


Figure 2: GIS-map of the surveyed compartments and area sizes

Recommendations: compartment-wise continuation of demarcation and GIS survey, (improving the performance in demarcation work); including other existing measurement (e.g. skid tracks, forest roads, location and condition of current culverts and proposal for additional ones), survey on open areas (former log landings) and identification and demarcation of the 1992 non-logged areas within the compartments (esp. Comp. 4,8, 12).

2.2 Socio-economic baseline study

The intention of this activity is to collect information on change of the socio-economic situation in Nakavu village since the last project (1990-1995) and during the current one. In addition the awareness on SFM and the expectations on SFM and REDD+ shall be investigated.

Several discussions with GIZ experts were held. As a result, it was agreed to establish a working group, to select Nakavu village for the testing purposes only[11] and to extend the survey to other forest owning communities (10 to 20 all over Fiji) with and without project and/or forest harvesting experience.

Due to lack of time resources of the involved persons the start of this activity was postponed for the time being.

Recommendations: first half of 2012: installation of the working group, selection of suitable forest owing communities; second half of 2012: development of a suitable questionnaire and start of survey. The activity could be supported by a project intern.

2.3 Maintenance of infrastructure

Despite the fact that rare but continuous use of the forest road with off-road vehicles took place over the years, almost no road maintenance was carried out since the logging of the area closed down in 1994. Minor maintenance measures like tending of lead-off ditches and cutting / spraying of vegetation was performed few times only. In consequence the road is partly in very bad conditions but, surprisingly, partly also in good shape.

According to the project plan (Tab. 1, Activity 3) the accessibility for off-road vehicles was restored from own resources, using gravel from the Waiyanitu creek and carrying the gravel with the project pickup to the needed spots. This first case-by-case-improvement allowed the accessibility up to the upper board in Compartment 7. Because the road situation is still fragile, especially during wet periods, that situation is expected to get worse again. Therefore, it is suggested to use the now available foreseen budget[12] for a more systematic maintenance of the critical sections. The final full accessibility (trucks etc.) will be in the responsibility of the logging company.

[11] After the discussions with GIZ experts it was agreed that Nakavu village with more than 20 year more or less continuous project experience is hardly representative for rural communities in Fiji. But it could be helpful for methodology development (e.g. questionnaire)

[12] the project budget was released only in March

Recommendations: as soon as work schedule and weather allow, a grader should be hired and several loads of gravel from the Navua river pits should be transported to the NFMPP forest road. Especially the vegetation on the shoulder has to be cleared and the ditches have to be opened (grader). On sections with insufficient gravel surface, especially on steep slopes, the gravel layer should be restored. For the time being the road shall be relieved through introducing better accessible "wet weather compartments" (e.g. Compartment 1).

2.4 Pre-harvest inventory and tree selection

2.4.1 Requirements

Pre-harvest inventory (PHI) and tree selection (TS) are two sustainable forest management tools required in the Fijian Forest Harvesting Code (FFHCoP)[13]. But for both, there are currently no binding specifications for practical implementation. The SFM-REDD+ project shall contribute in developing and testing adapted PHI and TS measures.

2.4.1.1 Pre-harvest inventory and Community Carbon Accounting

Currently, prior to logging operations a PHI is hardly carried out and the methodology seems to be ineffective regarding time consumption, costs or the precision of the results[14]. There is a strong demand for a PHI methodology which leads to satisfying precise results[15] while being cost effective and easy to apply in the field[16]. Similar to TS, also a community approach is sought for the PHI application[17]. Furthermore and on demand, the REDD+ component requires that the originally timber-orientated PHI is extended to an inventory system for different carbon pools which leads to a "Community Carbon Accounting" (CCA)[18] system. Therefore, some specific measurements need to be added but without changing the basic design. The proposed methodologies are orientated to the respective documentation in the Pacific MAR manual[19]. For the community approach, the procedure has to be kept as simple as possible. The easy application for forest owners includes:

- simple, systematic sampling design (to avoid biases);

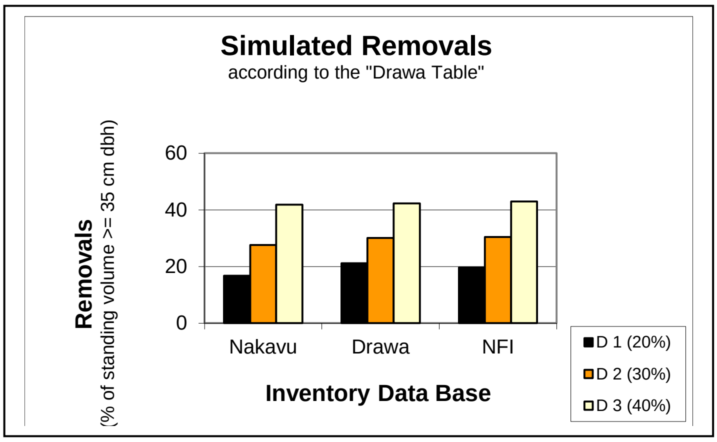
[13] in addition, PHI is required according to the general reduced impact logging (RIL) standards
[14] FFI is using a PHI-design where 4 plots (each 50x25 m) were randomly located on a 100 ha area, which results in a sampling intensity of 0.5% only (Ruboiliku, 2012, verbal communication). The cost efficiency as well as the applicability seems to be good but the precision seems to be very low. In opposite the stripline design, used e.g. in the Drawa Block (De Vletter and Mussong 2001) works relatively precise and is easy to apply but is very labor and cost intensive.
[15] e.g. standard errors < 20 %
[16] In case the precision of the TS-system (DLT) regarding volume removals is verified in field tests the PHI might be reduced to a (one day/brief) field inspection.
[17] GOF/MOFF, 2010: FFHCoP, chapter 4, first paragraph: PHI is in responsibility of the licence applicant but the landowners should be involved in PHI where possible
[18] CCA: community carbon accounting; c.f. IGES homepage: http://www.iges.or.jp/en/fc/activity_cca.html and http://enviroscope.iges.or.jp/modules/envirolib/upload/3258/attach/3258_cca_leaflet.pdf
[19] Thiele et al., 2010

- minimized error sources (simple diameter and distance measurements using simple tools, no tree height measurements[20], avoiding correction factors etc.);
- fast going procedure (psychological advantage of quick work progress);
- clear field forms for recording (to avoid mistakes in recording);
- standardized evaluation forms for rough calculation of the results by the forest owners (to promote the identification with work and results).

2.4.1.2 Tree selection (TS)

For TS two sets of selection tables (DLT) were developed during the past 20 years. During NFMPP three tables for different logging intensities[21] were set up (Annex 2) and successfully tested in the Nakavu forest[22]. The second set of tables stems from the Drawa project[23] (Annex 3) and was also successfully tested but in simulations with different data sets only (Fig. 3). Both DLT will be used during field work without any changes. In case the DLT will finally lead to acceptable precise results it might be possible to reduce PHI to a brief site inspection.

Figure 3: Simulation results with Drawa tree selection table (De Vletter and Mussong 2001)



2.4.2 Methodology development

2.4.2.1 Basic inventory design

For methodology development, compartment 7 was chosen as a representative "average" [24] and relatively easily accessible compartment. A base line was demarcated to open up the compartment. Rectangular to the base line, inventory lines were cut[25] and demarcated with numbered pegs in 20 m distances (Fig. 4). The required time for line cutting for a team of 3 casuals was on average 60 min per 100 m. Later on, the PHI/CCA plots were established along

[20] existing dbh-to-height correlation models shall be used (acc. to De Vletter 1994a)
[21] Diameter Limit Tables (DLT) are designed for 3 logging intensities: light logging (LL): removal of 15-20 % of the standing volume of trees with dbh>=35, , medium logging (ML) removal of 30-35 % and heavy logging (HL) removal of 50-60 % (Mussong 1992)
[22] c.f. De Vletter and Mussong 1996
[23] the target removals are: LL: 20 %, ML: 30 %, HL: 40 % (De Vletter and Mussong 2001)
[24] regarding standing volume, topography, treatment
[25] in compartment 7 the distance between the lines was 40 m. Due to the fact that the statistical figures varies less than originally expected the distances between the lines were extended in the following compartments to 80 m.

the inventory lines. In addition, the lines were used to determine the tree locations for stock map creation. The lines also allow a better orientation during TS.

After line establishing a full enumeration of all trees with dbh >= 35 cm was carried out, collecting data on dbh, species, log length, quality and location of the respective tree.

The developed field form is attached as Annex 4.

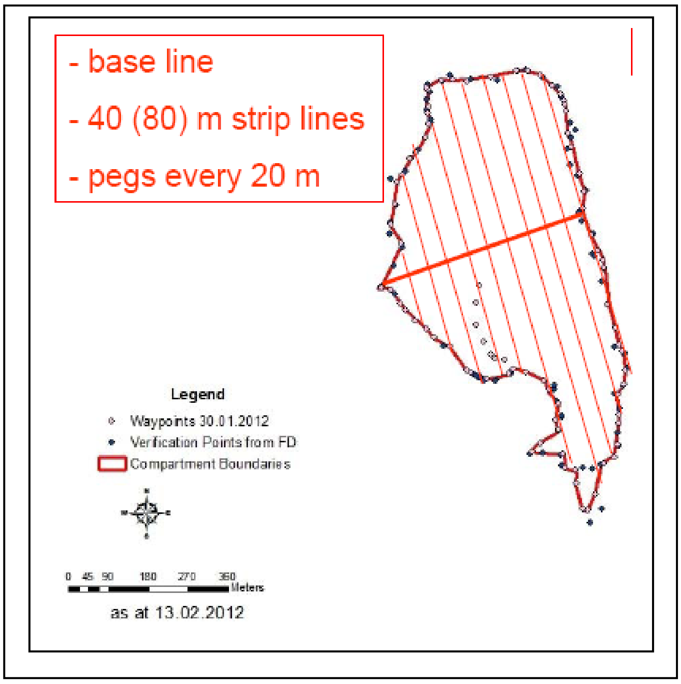


Figure 4: Survey infrastructure for CCA and PHI development

2.4.2.2 Pre-harvest inventory (PHI)

Regarding a final PHI, no specific design is preferred in advance. The data collected during TS will be transferred in a GIS based stock map and used for simulation purposes. The goal is to identify an optimal PHI design suitable to be carried out by forest owners and fulfilling the same criteria as mentioned under CCA (c.f. Chap. 2.4.1.1). Due to technical problems the GIS map is not yet prepared. Figure 5 as an Excel-chart gives an impression of the foreseen GIS stock map.

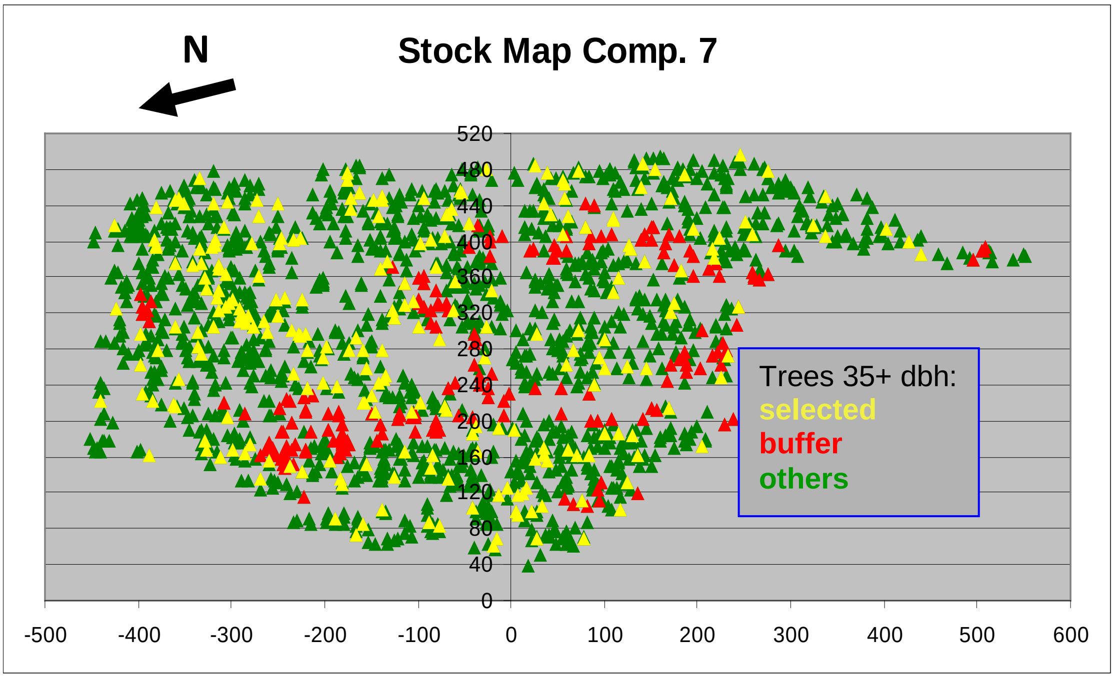


Figure 5: Stock map of Compartment 7; co-ordinates (m) from base line start (0/0); Excel-chart

Recommendations: solving of the technical problems to link the tape-measured tree co-ordinates with the GPS-measured geographical co-ordinates. Developing an Access data base and transferring the data for simulation purposes. Elaborating an optimal (cost-effective, sufficient precise, easy applicable) methodology for PHI. The subject suits as a Master-thesis for a student/project intern.

2.4.2.3 Community Carbon Accounting (CCA)

2.4.2.3.1 Carbon pool determination

The optional extension of PHI to CCA will be reached through adding specific measurements for determining the different carbon pools, carbon sub-pools, and sub-sub pools. The biggest carbon contribution is expected from the trees where former investigations show that also "small" trees (<35 cm dbh) hold approx. half of the tree-born carbon stock (Fig. 6). Also deadwood seems to contribute significantly[26]. Problematic for measuring are shrubs, climbers, bamboo, tree ferns, seedlings, non-wood vegetation and litter. Because shrubs, climbers, bamboo, and tree ferns are relatively rare in comparison with the trees, it was decided, for the time being, to treat this fraction as trees (volume determined via dbh). The seedlings (up to 1.3 m height) were cut close to the ground and scaled and also non-wood vegetation, litter, and deadwood (1-10 cm diameter) were separately scaled.

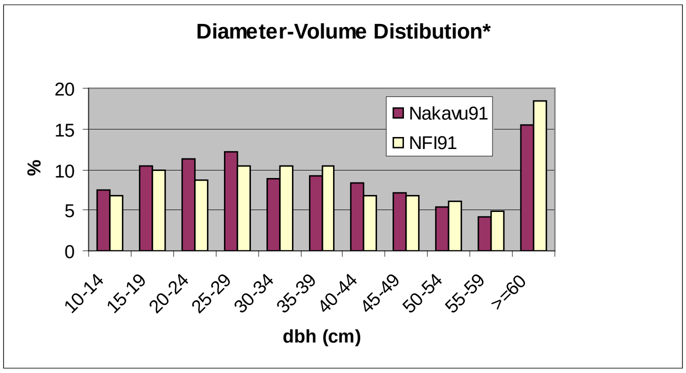


Figure 6: Diameter-volume distribution in NFMPP, Nakavu (1991) and in the Fiji NFI (1991)

Due to the enormous effort for obtaining and analysing the samples, the determination of below-ground biomass (BGB) and soil carbon will not be part of the field investigations. For Below-ground biomass, introduced estimation models based on the above-ground living biomass (AGL) will be used:

I. BGB = AGL*0.24 [27]

II. BGB = exp(-1.0587+0.8836*Ln(AGL)) [28]

[26] according to Ulbig (2005) approx. 7 m³ standing and 10 m³ lying deadwood (35 cm and above) was found in the Nakavu forest

[27] Cairns et al. 1997: shoot to root ratio: 1:0.24

[28] Pearson et al. 2007

For the time being no soil carbon estimation is carried out. Literature research showed that under tropical rainforest 100-240 t of Carbon/ha is possible. In cooperation with the SPC/JICA project there might be the possibility to develop specific soil carbon estimation models.

In total, 16 pools were determined. Table 2 shows the complexity and underlines the technical difficulties of a broad carbon inventory.

Carbon Pool	Sub-Pool	Sub-Sub-Pool	Data to Collect
Above-ground living biomass (AGL)	Trees and other woody plants (shrubs, climbers, bamboo, tree ferns)	dbh >= 35 cm	species, dbh, (loglength, quality)
		dbh 10-34 cm	species, dbh
		dbh 0-9 cm (rounded)	Dbh
		seedlings/saplings <1.3 m height	number, weight
	Non-wood vegetation (grass, ferns, herbs etc.)		weight
Dead wood	Standing	dbh >= 35 cm	dbh, decay class
		dbh 10-34 cm	dbh, decay class
		dbh 0-9 cm (rounded)	dbh, decay class
		seedlings/saplings <1.3 m height	weight
		Stumps	height, top diameter, decay class
	Lying	diameter >= 35 cm	diameter, decay class
		diameter 10-34 cm	diameter, decay class
		diameter 1-9 cm	diameter, decay class
Litter	Fine woody debris, dead seedlings, leaves, humus etc.		weight
Below-ground biomass (BGB)	not to be measured; estimation acc. to - shoot to root ration: 1 : 0.24 or - BGB= exp(-1.0587+0.8836*Ln(AGL))		
Soil carbon	Not to be measured; eventually investigated from the SPC/JICA project		

Table 2: Carbon pools and parameter to measure

Recommendations: Both BGB models shall be tested over the whole diameter rage. Due to the fact that the soil carbon seems to be the dominating carbon fraction investigations together with the SPC/JICA project would be highly desirable.

2.4.2.3.2 Tree height estimation

Because tree height measurements are very time consuming and often imprecise[29], one goal of the method development was to avoid height measurement during later practical implementation. Therefore, pre-determined diameter-to-height models shall be used to estimate the height of a tree by its dbh.

[29] in addition relatively expensive equipment is required which might be critical from the community approach

During the former Nakavu project two diameter-to-height models were developed already which could be used for height estimation. The first model, covering the dbh-range from 10 to 80 cm, is based on measurements of the 48 permanent sample plots (PSP) in the NFMPP area with a total of 896 trees measured; $R^2 = 0.58$ [30]:

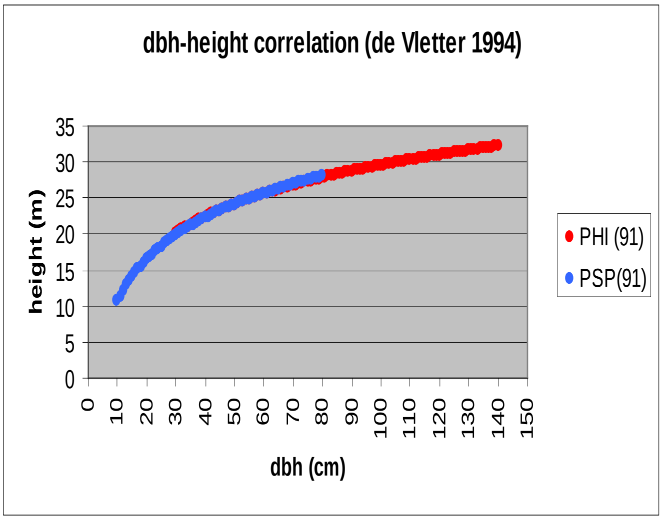
$$h[m] = -8.673797 + 8.378126 * \mathrm{Ln}(dbh)$$

The second model was derived from the PHI data in 1991 and covers a dbh-range from 30 to 140 cm; n=595, $R^2 = 0.25$ [31]:

$$h[m] = -6.589231 + 7.846389 * \mathrm{Ln}(dbh)$$

Both curves overlap in the range from 30 to 80 cm almost exactly (Fig. 7) so that unerring height estimations seem to be supported by both models.

Figure 7: Dbh-height correlations for PHI and PSP data in NFMPP, Nakavu acc. to De Vletter (1994a)



For estimating the height of trees with dbh < 10 cm, a separate diameter-to-height correlation model was developed, measuring (almost) all trees in the respective subplots of the four PSP in Compartment 7. In total 192 trees > 1.3 m height and 0.5 to 10 cm dbh were measured[32]. To avoid negative estimation results close to 0 cm dbh a polynomic model instead of a logarithmic model was chosen (Fig. 8):

$$h[m] = -0.0651*dbh^2+1.6331*dbh+0.7885$$

The model has an excellent correlation value (R=0.89) and shows a very good link to the model for trees >= 10 cm dbh (Fig. 9[33]).

[30] De Vletter, 1994a
[31] De Vletter, 1994a
[32] another 13 trees with dbh 0.1 to 0.4 cm were excludes from the data set, due to the fact that the model would estimate the heights < 1.3 m. Therefore, for all trees with dbh < 0.5 cm a height of 1.3 m will be used.
[33] the height difference between both models at 10 cm dbh is just 1.8 cm

Figure 8: diameter-to-height model for trees < 10 cm dbh

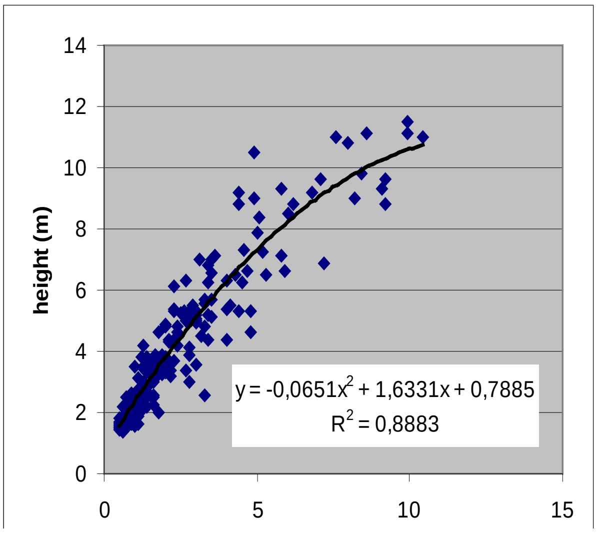
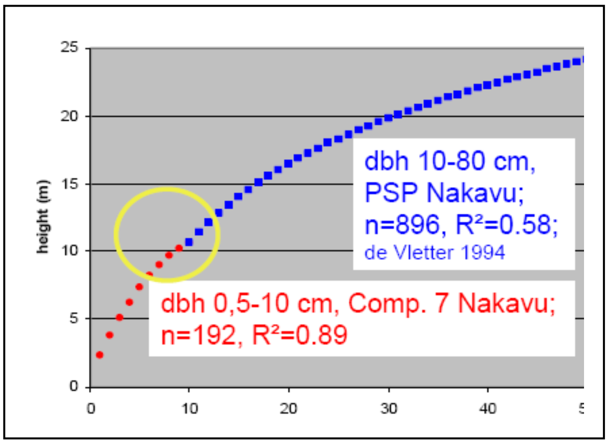


Figure 9: diameter-height curve of trees < 10 cm dbh and connection to trees >= 10 cm dbh



The final result shows that good height estimations over the whole diameter range seem to be possible using the following equations; h[m], dbh [cm]:

- for dbh < 0.5 cm: h = 1.3
- for dbh 0.5 to < 10 cm: h = -0.0651*dbh²+0.1633*dbh+0.7885
- for dbh >= 10 cm: h = -8.6738 + 8.3781*Ln(dbh)

2.4.2.3.3 Biomass and carbon estimation

For biomass estimation recognized estimation models shall be used. Thiele et al.[34] proposed for monitoring purposes in the Pacific a model after Brown[35] using the dbh as input parameter only. This goes very much in line with the community approach, but first tests with the collected data show that the model seems to over-predict the biomass significantly. The reason might be that the model was developed with data from other regions where trees grow taller while having similar dbh like in Fiji.

[34] Thiele et al., 2010
[35] Brown, 1997

A more precise prediction seems to be possible with the model after Chave et al. [36] using dbh [cm], height [m] and wood density (wd) [g/cm³] as input parameters[37]:

$$AGL[kg] = 0.0509 * dbh^2 * h * wd$$

Due to the fact that dbh-to-height correlations are available for Nakavu, the height needs not to be measured but estimated via the measured dbh. Thus, the community approach will be met.

Chave's model starts from 5 cm dbh only, so the own height estimation model for trees < 10 cm dbh was further developed into a biomass estimation model for small trees.[38] Due to the strong correlation between dbh and height of small trees (c.f. Fig. 8) the volume can be estimated by the dbh [cm] only. For AGL-estimation, in addition the (average) wood density [g/cm³] is needed:

$$AGL[kg] = (460.04 * dbh^2 - 213.86 * dbh + 17.25) * wd / 1000$$

For practical recording the dbh is rounded to full cm. Trees with dbh < 0.5 cm are rounded down to 0 cm. The corresponding volume is 0.00004 m³ and the biomass is 0.018 kg.

In summary, the whole dbh range is covered by the 3 equations; AGL [kg], dbh[cm], wd [g/cm]:

- for dbh < 0.5 cm: AGL = 0.018
- for dbh 0.5 to < 10 cm: $AGL = (460,04*dbh^2-213,86*dbh +17,25)*wd/1000$
- for dbh >= 10 cm: $AGL = 0.0509*dbh^2*h*wd$

For biomass estimation from deadwood, the calculated volume was divided by the decay class (1: recently died; 2: moderately decomposed; 3: very soft) and multiplied by the average wood density (<35 cm dbh/diam.: 0.450; >=35 cm dbh/diam.: 0.523). This rough estimation shall be used as long as no conversion figures are available from laboratory analyses.

To derive carbon from biomass the commonly used conversion factor of 0.5 is applied[39]. The conversion factor C to CO_2 is 3.667.

Recommendations: A simple method for deadwood estimation (volume to carbon content) shall be developed. This requires that representative deadwood samples need to be analysed in the laboratory.

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[36] Chave et al., 2005

[37] Another and very simple option for biomass estimation is proposed by Brodbeck (2008) and leads to always to 15.2 % less biomass compared to Chave et al. (2005):

AGL= basal area *height*0.5(form factor)*1.1(for leaves and branches) *wood density.

[38] the volume was calculated either via dbh, height and form factor (0.5) or, where available, via mid diameter without form factor. For both calculations a volume factor for branches/litter (1.1) was used (c.f. Brodbeck, 2008).

[39] mostly an average conversation factor of 0.5 is used (e.g. MacDicken, 1997, Perarson et al., 2007) but slightly different factor are also found (e.g. IPCC, 2006: 0.47)

2.4.2.3.4 Preliminary lay-out

The current status of the CCA method development shows Figure 10. The plot design is basically orientated on the Pacific MAR design[40] but adapted to the specific needs. It consists of 2 concentric plots with fixed radius in combination with 2 concentric plots with variable radius:

Every 20 m and rectangular 3 m altering to the right and left hand site of the inventory line the plot center is to be located.

The first plot has a radius of 0.3 m. Inside this plot all non-wood vegetation and litter as well as seedlings up to 1.3 m height are collected and separately scaled (weight-sample); the number of seedlings are also recorded.

In the second plot with a radius of 2.0 m (horizontally measured with a 2-m-stick) all living or standing dead trees >= 1.3 m height are measured (including tree ferns, bamboo, climbers etc.). For all trees the dbh is recorded. The local species name is recorded for the trees with dbh >=10 only. The tree heights were not measured in the field but later on estimated according to the mentioned dbh-to-height correlation models.

The 2 plots with variable radius are determined by the closest trees to the plot center but outside the 2-m radius plot. One variable plot represents the trees 10-34 cm dbh and the other plot the trees with a dbh >= 35 cm. The inventorised parameters are the same as inside the 2 m plots, but in addition the specific distance from the plot center to the tree center has to be measured (if a horizontal distance measuring is not possible also the slope has to be measured for correction purposes).

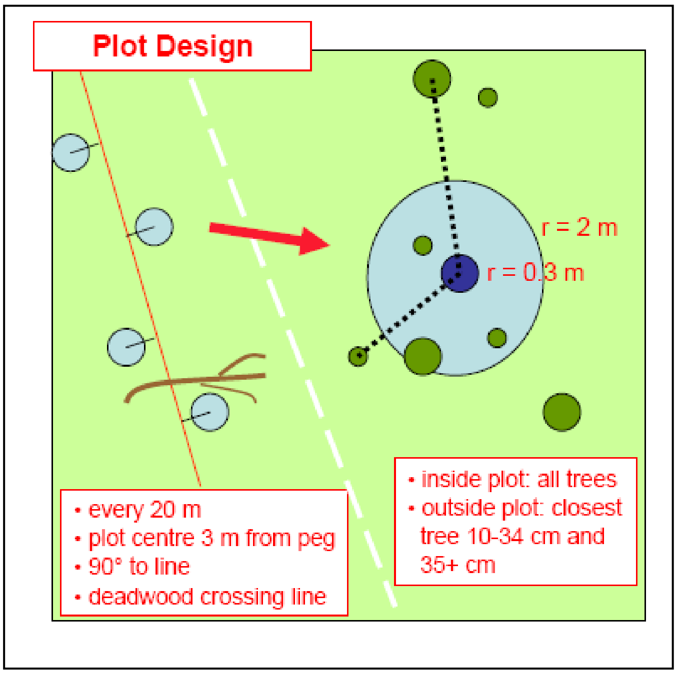

Figure 10: Plot design for carbon inventory

[40] Thiele et al., 2010

All lying deadwood (diameter 10 cm and above) crossing the main inventory line (strip line) is to be measured according to the “line intersect method“[41]. For all deadwood, decay classes have to be estimated.

During field tests and first data analyses, several changes were made. Due to the fact that for some parameter not sufficient replications could be carried out during the reporting period, more changes might be necessary after collecting more data. The elaborated field manual as full description of the preliminary CCA design is attached as Annex 5.

Recommendations: continuation of optimizing the lay-out according to the gained experiences during completing Compartment 7 and according to the stock map simulations.

2.4.2.4 Tree Selection

For TS the whole compartments were covered by the TS-crews in the proven working procedure[42]. For method development purposes some measures had to be added:

- Due to the previous created 40 m PHI/CCA lines in Compartment 7, a better orientation for surveyors and recorder (walking along the line) was possible;
- For ALL trees >= 35 cm dbh the required data are collected (dbh, species, log length (estimated or measured), log quality);
- During the ”double selection” the “old” (Nakavu) and the “new” (Drawa) DLT were used parallel in the same compartments. In consequence, some trees received one mark only (old or new DLT) whereas other trees received marks for both tables.
- For PHI simulation purposes it was decided to create a stock map of Compartment 7. Therefore, for all selected trees their location data (coordinates from starting point of base line) were measured with distance tape[43] (rectangular distance from PHI/CCA line and distance from starting point of inventory line and from starting point of base line)

3. Results

3.1 Current work status

During reporting time approx. 8000 m of lines (base line and inventory lines) were cut. Along the lines and in 20 m horizontal distances approx. 400 pegs were established. During TS for 1853 trees >= 35 cm dbh the relevant tree parameter as well as tree location were recorded. In total 56 CCA plots were established, measuring 1351 trees > 1.3 m height and carrying out 174 weight samples for litter, non-wood vegetation, regeneration and deadwood (1-10 cm diameter). For the development of the diameter-to-height curve for trees up to 10 cm dbh 205 trees were measured and analysed.

[41] Shiver and Borders, 1996
[42] c.f. Mussong, 1992
[43] and if necessary with clinometer (slope correction)

3.2 Carbon pools

3.2.1 Litter, non-wood vegetation, regeneration and small deadwood

In the small concentric plot (r = 0.3 m) all litter, non-wood vegetation, regeneration and deadwood (1-10 cm diameter) was separately scaled. No laboratory analyses were carried out so far so that the fresh weight is used for calculation purposes. Due to the fact that 51 out of 56 samples were collected during (more or less) dry weather conditions the influence of precipitation water seems to be limited. For the time being a conversion factor of 0.25 is used to transfer the fresh weight into dry biomass.

Table 3 shows that approx 20 t fresh biomass per ha can be expected. Using the mentioned conversion factor approx. 5 t/ha of dry biomass and 2.5 t/ha of carbon will result. Approximately half of the carbon stems from the litter, approx. one quarter from the "small" deadwood and the other quarter from living "ground vegetation".

Stat. param.	Litter (g/plot)	Deadwood (g/plot)	Grass/Ferns (g/plot)	Regeneration (g/plot)	Total (g/plot)	Total (t/ha)	Dry Biomass (t/ha)
Avg	296	162	68	45	572	20.2	5.1
S	301	313	251	69	545	19.3	4.8
Cv%	102	193	371	151	95	95.3	95.3
N20%	103	373	1375	229	91	91	91

Tab. 3: Results of carbon inventory in litter, non-wood vegetation, regeneration and deadwood < 10 cm mid-diameter. Conversion factor from plot to ha: 35367.8 and from fresh to dry biomass: 0.25)

The statistical analysis shows that the coefficient of variation is very high (151-371%) for all fractions except the litter. Here the variation is moderate (103%). Taking all fractions together the variation is also moderate leading to a required number of 91 samples when accepting a standard error of 20 %[44].

Recommendations: In the further course of the project typical samples shall be analyzed in the laboratory. Based on the results a quick reference guide for immediate estimation in the field shall be developed. This simplified community approach method seems to be acceptable because of the relative small proportion of carbon in this fraction.

3.2.2 Living small trees (> 1.3 m height and < 10 cm dbh)

For the second carbon pool 1286 trees were recorded in the 56 corresponding plots (r=2 m). For dry biomass estimation the developed own biomass model is used. As input variables the dbh was measured and for wood density the weighted average of the trees 10-34 cm dbh (0.45 g/cm^3) is used. Table 4 shows that approx. 20 t of dry biomass (10 t of carbon) is to be expected,

[44] a standard error of 10 % would require 364 samples

whereas the variation is moderate with a cv of 73 %. Accepting a standard error of 20 % 53 plots are required. Using Chave's model for comparison purposes and extrapolating down to 0 cm dbh approx. 15 % less biomass (17.8 t/ha) results. Due to higher variation 64 plots would be required.

Statistical parameters	Volume (m^3/ha)	Dry Biomass (t/ha)
Avg	45.6	20.2
S	32.5	14.7
Cv%	71.1	73.0
N20%	51	53

Table 4: Results of carbon inventory in living small trees ((> 1.3 m height and < 10 cm dbh). (Conversion factor from plot to ha: 795.775; average wood density 0.45 g/cm^3)

3.2.3 Living medium sized trees (10-34 cm dbh)

For the medium sized trees the individual plot size was determined by the distance of the nearest tree to the plot centre. In case the tree was closer than 1.0 m to the centre the distance to the closest tree outside the 1 m radius was measured and for all medium sized trees inside the extended radius the dbh and species name was recorded[45].

Due to the fact that the plot radius differs from plot to plot, a conventional statistical analysis is not possible. Especially small plot sizes tend to overestimate the volume/ha. Therefore, the area off all plots as well as the volume in all plots is summed up and from both figures an average is calculated. The total inventorised plot area is 0.2335 ha. Using a form factor of 0.5, a total volume of 19.96 m^3 and an average stocking of 85.5 m^3/ha is found. According to Chave's model the corresponding biomass (AGL) is 49.9 t/ha or approx. 25 t of carbon per hectare.

The disadvantage of this method is that, due to missing replications, no confidence interval around the average can be determined. On the other hand, the result seems to be in a realistic range (possibly at the lower end), comparing with former investigations on standing volume of medium sized trees: In 1991, for the NFMPP area 120 m^3/ha was found and during NFI an average stocking of 75 m^3/ha was recorded for rainforests in Fiji (see also Fig. 6.).

3.2.4 Living big trees (>= 35 cm dbh)

For the big tree survey, the same method was used as for the medium sized trees. The only difference is that all trees inside the 2 m radius and the next tree outside the radius were measured.

[45] due to experiences during the first 50 plots the lay-out was changed: now all medium sized trees inside the 2 m radius as well as the closest tree outside the 2 m radius are measured. Therefore, the results do not fully represent the actual inventory design for medium sized trees.

The total volume in the plots is 135.1 m³ and the total plot area is 1.0076 ha. Thus, the average stocking is estimated to 134.1 m³/ha. As corresponding biomass (AGL) it results 90.9 t/ha including approx. 45.5 t of carbon per hectare.

The results are close to the results of the TS for the whole compartment (c.f. Chapt. 3.3). Using the same height estimation model and a form factor of 0.5, a total volume of 131.9 m³ and according to Chaves model 94.4 t of biomass and 47.2 t of carbon/ha are calculated.

3.2.5 Deadwood

Standing and lying deadwood up to 34 cm dbh respective diameter is measured in the 2 m radius plots[46]. Standing deadwood and stumps >= 10 cm dbh or top-diameter will be recorded only if it is closer to the centre than the (last) inventorised living tree in the two respective strata (10-34 cm and >=35 cm). Because the methodology to inventorise lying deadwood >= 35 cm dbh along the inventory line is introduced after analyzing the first 50 plots, no data is available at the moment.

Without the standing big deadwood trees, in total 19.59 m³ of deadwood per hectare were surveyed (Table 5). Using Ulbig's figure that in the NFMPP area for big trees approx. 10 m³/ha of standing deadwood and approx. 7 m³/ha of lying deadwood was found in 2004[47], in total 35 m³ can be expected. Transferring the volume into dry biomass approx. 7t/ha (4.13 t/ha acc. to Table 5 and approx. 3 t/ha for big trees) and 3.5 t of carbon shall be used for orientation for the time being.

Stat. param.	Standing 1.3m h , <10 cm dbh (m³/ha)	(t/ha)	Standing (incl. Stumps) >=10cm dbh (m³/ha)	(t/ha)	Lying 10-34 cm diam. (m³/ha)	(t/ha)	Lying >=35 cm diam. (m³/ha)	(t/ha)
Avg	3.17	0.71	4.04	1.02	12.28	2.40	nil	nil
S	7.78	1.75	23.90	6.18	35.59	6.90	-	-
Cv%	245.4	245.4	591.3	605.0	289.8	287.1	-	-
n20%	602	602	3497	3660	840	824	-	-

Table 5: Results of deadwood inventory

Due to the fact that especially bigger deadwood is found sporadically only, cv is very high (245 to 605 %) so that the statistically required (standard error 20 %) number of plots are beyond any practical implementation possibilities. Hopefully, the establishment of more plots and the introduction of the line intersect method for lying big deadwood will improve the statistical evidence.

Recommendations: Starting data collection with the line-intersect method for all lying deadwood with 10 cm diameter and above.

[46] In a modified inventory design the lying deadwood with 10-34 cm mid-diameter will be measured according to the procedure fort he lying deadwood of 35 cm and above (along the inventory (strip) line

[47] Ulbig, 2005

3.2.6 Below ground and soil carbon

For below-ground carbon estimation both possible equations differ significantly in the results. According to Cairns root to shoot ratio of living biomass 18.6 t of carbon per ha and according to Pearson's model 26.6 t/ha are estimated. The difference between both models is moderate for big trees but for small trees the difference increases significantly.

Soil carbon is not part of this investigation[48].

Recommendations: Due to the problematic significant increase for the small diameters the more conservative model (Cairns) shall be used for BGC estimation for the time being. With the support of the JICA project it might be possible to develop own reference values for soil carbon, probably also over a longer observation period after a logging operation.

3.2.7 Summarized results of carbon estimation

In total approx. 105 t of carbon per hectare can be expected. This is more than twice the amount Payton and Weaver[49] calculated from the NFI and PSP data (approx 48 t/ha). Fig. 10 summarizes the results of the carbon inventory.

The biggest share of carbon (ca. 75 %) is accumulated in the living trees. After measuring 56 plots only, the dominating volume of big trees seems to be realistically estimated. The medium sized trees seem to be underestimated at the moment. According to former investigations it is expected that the medium-sized trees will finally have a similar share as the big trees. The presented figures for deadwood are already increased by former results and seem to reach hardly 5 %. Also, the weight samples (litter etc.) contribute to the carbon stock with very few percent only. Below ground carbon contributes about 20 % and soil carbon is not included.

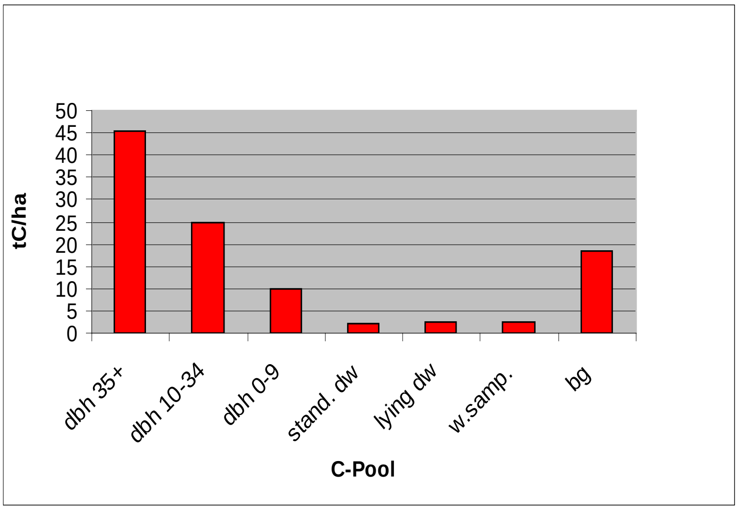

Figure 10: Carbon stock in different carbon pools after analyzing 56 plots (figures for deadwood increased acc. to former investigations).

[48] According to Buringh (1984) in Oxisols under primary forests approx. 240 tC/ha and under secondary forest approx. 180 tC/ha can be expected.

[49] Payton and Weaver, 2011

3.3 Tree selection

3.3.1 Stand Characteristics

In Compartment 7 a full enumeration was carried out, inventorising all trees >= 35 cm dbh, including all trees inside the buffer areas. In total 1853 trees were measured (Tab. 6).

<table>
<tr><th>DBH</th><th colspan="3">Trees</th><th colspan="2">Basal Area</th><th colspan="3">Volume$_{LLest.}$</th></tr>
<tr><td>(cm)</td><td>(n)</td><td>(%)</td><td>(% 1991)</td><td>(m²)</td><td>(%)</td><td>(m³)</td><td>(%)</td><td>(% 1991)</td></tr>
<tr><td>35-39</td><td>649</td><td>*35*</td><td>34</td><td>70</td><td>*22*</td><td>538</td><td>*21*</td><td>17</td></tr>
<tr><td>40-44</td><td>459</td><td>*25*</td><td>20</td><td>62</td><td>*20*</td><td>506</td><td>*19*</td><td>13</td></tr>
<tr><td>45-49</td><td>276</td><td>*15*</td><td>13</td><td>47</td><td>*15*</td><td>396</td><td>*15*</td><td>11</td></tr>
<tr><td>50-54</td><td>182</td><td>*10*</td><td>11</td><td>38</td><td>*12*</td><td>326</td><td>*12*</td><td>12</td></tr>
<tr><td>55-59</td><td>90</td><td>*5*</td><td>8</td><td>23</td><td>*7*</td><td>193</td><td>*7*</td><td>11</td></tr>
<tr><td>60-64</td><td>78</td><td>*4*</td><td>5</td><td>23</td><td>*7*</td><td>198</td><td>*8*</td><td>8</td></tr>
<tr><td>65-69</td><td>40</td><td>*2*</td><td rowspan="4">10</td><td>14</td><td>*4*</td><td>127</td><td>*5*</td><td rowspan="4">29</td></tr>
<tr><td>70-74</td><td>26</td><td>*1*</td><td>11</td><td>*3*</td><td>91</td><td>*3*</td></tr>
<tr><td>75-79</td><td>28</td><td>*2*</td><td>13</td><td>*4*</td><td>110</td><td>*4*</td></tr>
<tr><td>>=80</td><td>25</td><td>*1*</td><td>16</td><td>*5*</td><td>130</td><td>*5*</td></tr>
<tr><td>**Total**</td><td>**1853**</td><td>***100***</td><td>**100**</td><td>**317**</td><td>***100***</td><td>**2614**</td><td>***100***</td><td>**100**</td></tr>
<tr><td>Inside Buffer</td><td>191</td><td>*10.3*</td><td></td><td>33</td><td>*10.5*</td><td>278</td><td>*10.7*</td><td></td></tr>
<tr><td>Net Area (24.9 ha)</td><td>1662</td><td>*89.7*</td><td></td><td>284</td><td>*89.5*</td><td>2336</td><td>*89.3*</td><td></td></tr>
<tr><td>per ha (net area)</td><td>66,7</td><td></td><td></td><td>11,4</td><td></td><td>93,8</td><td></td><td></td></tr>
</table>

Table 6: Results of full enumeration in Compartment 7 and comparison with PHI results from 1991

Approximately 10 % of trees, basal area and volume were located in buffer areas. The diameter distribution shows the characteristic digressive trend for (close to) natural forests. Per hectare (net area) approx. 67 trees with a basal area of approx. 11 m² and a log volume of almost 94 m³ were recorded.

In comparison to the PHI results from 1991 it gets obvious that the shares regarding number and volume of the smaller trees (up to 50 cm dbh) are higher in the recent inventory while the bigger trees occur less frequent than 20 years ago. This result can be explained by the removal of over-matured trees during the logging operation and indicates that a full regeneration to the former situation is not yet reached[50].

For trees with dbh 35 cm and above, in total 59 species are found in Compartment 7. During the plot based PHI in 1991 (sampling intensity 14.3 %) only 46 species were found. Most frequent species are Kaudamu, Sacau, and Yasiyasi, contributing with more than 10 % each to tree number, basal area, and standing volume (Tab. 7). Damanu, Kauvula, and Mavota hold a share of more than 5 % each. The 15 most prominent species contribute in total with almost 95 % to the

[50] according to the opinion of the authors it is also not advisable to reach the "over-matured" stand condition again because the increment will decrease and the loss of big trees through natural mortality will increase

standing volume and hold a similar share like 20 years ago. Exceptions are Sacau which has doubled its share since 1991 whereas for Dakua salusalu less than half of the volume is recorded now. Those results might indicate the growth behaviour of this species but due to the limited number of observations and the different inventory design such conclusions can only be drawn after analysing more compartments.

Only one of the frequent species (Sa: 4.6 %) has currently a limited market value and is not selected (Tab. 7).

Species	% of standing volume		% of selected volume
	1991	2012	
Kaudamu	*13.9*	16.9	14.7
Sacau	*6,6*	12.8	8.9
Yasiyasi	*8.1*	10.1	5.9
Damanu	*7.1*	9.0	3.2
Kauvula	*8.6*	7.0	10.3
Mavota	*4.3*	6.3	10.8
Sa	*4.1*	4.6	0
Bauvudi	*5.2*	4.0	1.9
Dakua s	*8.1*	3.0	1.1
Vutu kana	*1.7*	2.7	1.1
Damabi	*0.9*	2.5	3.8
Laubu	*4.0*	2.4	5.7
Kaunigai	*2.8*	2.2	5.7
Moivi	*1.3*	2.1	2.7
Dakua m	*0.4*	1.7	0
OTHERS	*22.9*	6.7	15.5

Table 7: Species-related results of full enumeration and tree selection in Compartment 7

The other species were partly selected with approximately the same share like they occur in the recent inventory. Other species are over- or underrepresented in the selection which might also indicate that the DLT need to be modified in this case. But more experience is needed from other compartments as well.

3.3.2 Selected volume

The tree selection carried out with the "old" Nakavu DLT led to the removal of 245 trees (9.8/ha) and 60.7 m² basal area (2.4 m²/ha) (Tab. 8). The corresponding volume removal is 489.5 m³ (19.7 m³/ha) when using the visual estimated log height and a form factor of 0.7 for volume calculation. When using the log height models from 1991 removals of 699.4 m³ (28.1 m³/ha) and 670.8 m³ (26.9 m³/ha) result. The significant differences led in consequence to measuring the log height in the following compartments instead of guessing it. Over all the results are in the expected frame of 20 to 30 m³ of removals.

The “new” Drawa table led to approx. 20 % less removal (16-22 m³/ha). This is mainly caused by the species Kaunigai, Laubu, Moivi, Rosarosa, Bausa, and Dalovoci which are elevated in into a higher DLT-class in the new table.

	Trees (n)	basal area (m^2)	$volume_{LLest12}$ (m^3)	$volume_{LLPHI91}$ (m^3)	$volume_{LLPSP91}$ (m^3)
Full enumeration	1662	284.1	2338	3114	2955
Tree selection	245	60.7	489.5	699.4	670.8
selected %	14.7	21.4	20.9	22.5	22.7
selected/ha	9.8	2.4	19.7	28.1	26.9

Table 8: Inventorised and selected tree numbers, basal area and volume (volume estimation according to 3 different height prediction methods: LLest12: log length visual estimated during the full enumeration in 2012; LLPHI91: log length calculated acc. to the diameter-to-log height model derived from the PHI data in 1991; LLPSP91: log length calculated acc. to the diameter-to-log height model derived from the PSP data in 1991)

Regarding the species composition of the selected trees it gets visible that some species were selected in (more or less) the same share like they contribute to the standing volume. For other species over- or under-proportional volume is selected which could lead to the conclusion that for this species the diameter limits need to be lifted up or moved down. More observations are necessary to verify such changes in DLT.

Regarding the visual quality assessment 33 % of the volume is classified as quality class 1, 47 % as class 2, 17 % as class 3 and 4% as class 4. The result differs significantly from the assessment in 1991 where 80% was classified as class 1 and 20 % as class 2. It is unlikely that the quality has decreased to such an extent. Rather, it can be assumed that the quality criteria differ between both assessments.

Regarding the royalty classes there is much less difference between the inventory in 1991 and today (Tab. 9). Significant differences are for the royalty class 1 only. The average Royalties to be expected from Compartment 7 are ca. 23 F$/m³.

Royalty Class	% of selected Volume	% of selected Volume in 1991
1	1	8
2	51	46
3	23	26
4	10	9
5	14	11

Table 9: Shares of selected volume (1991, 2012) and corresponding Royalty classes

3.3.3 Volume Increment

The volume increment can be estimated in two ways:

1. Taking the assumption that all trees were cut during the first logging according to their diameter limits, the volume of all trees which have crossed the limits today can be counted as net increment.

   Table 10 shows that the basal area as well as the volume has increased by approx. 21 %. When using the log height prediction models the relative increment is slightly higher (ca. 23 %) but due to the higher absolute increment this leads to approx. 1.5 m³ increment per year and hectare. Taking the actual visual height estimation the increment is slightly more than 1.0 m³ only.

	trees (n)	basal area (m²)	$volume_{LLest12}$ (m³)	$volume_{LLPHI91}$ (m³)	$volume_{LLPSP91}$ (m³)
Full enumer. 2012	1662	284	2338	3114	2955
Increment	245	60.7	489.5	699.4	670.8
Increment/ha	9.8	2.4	19.7	28.1	26.9
Increment %	14.7	21.4	20.9	22.5	22.7
Increment/y/ha	0.53	0.13	1.06	1.52	1.45

Table 10: Increment estimation based on the DLT-ingrowth (volume increment according to different height estimation methods; c.f. Tab. 9)

2. Using the PHI results from 1991 and subtracting the logged trees, the remaining stand can be compared with the recent results of the full enumeration[51]. The difference can be counted as net increment.

   It gets visible that the increment regarding number of trees which are qualified for logging is almost identical to the first calculation method (Tab. 11). Also the basal area differs rather slightly. Similar to the first calculation method are the two options based on the log height prediction models: 23 % and 29 % increment leading to an average increment of 1.2 and 1.5 m³/y/ha. In opposite, the volume calculated with the visual height estimation shows an unrealistic negative increment.

	trees (n/ha)	basal area (m²/ha)	$volume_{LLest12}$ (m³/ha)	$volume_{LLPHI91}$ (m³/ha)	$volume_{LLPSP91}$ (m³/ha)
PHI 1991	74.7	14.6	145.7		
TS 1992	16.3	5.0	49.0		
After Logg. 1993	58.4	9.6	96.7		
Full Enumer. 2012	66.8	11.4	93.8	125.0	118.7
Increment/ha	8.4	1.8	-2.9	28.3	22.0
Increment %	14.4	18.8	-3.0	29.3	22.8
Increment/y/ha	0.53	0.13	-0.16	1.53	1.19

Table 11: Increment estimation based on the PHI 1991 and the TS 1992 (volume increment according to different height estimation methods)

[51] approx 5 % loss of standing volume after hurricane Kina in 1993 (De Vletter, 1994b) are neglected here

The reason for the different increment results is likely the different height prediction which led to an overestimated volume in 1991 or to an underestimated actual standing volume. But due to the fact that the first method leads to an increment of 1.06 m³/y/ha, which is in the same range like the other variants the negative increment of the second method is unlikely. As real net increment 1.0 to 1.5 m³/y/ha can be expected. Within this frame the increment of non-commercial species is not included. Especially, for Sa as one of the prominent species an additional increment of 0.05-0.1 m³/y/ha can be expected.

3.3.4 Comparison of tree selection tables

According to the simulations with the NFMPP PHI data from 1991 it was expected in advance that the “Drawa” DLT applied in Nakavu will lead to 10-20 % lesser removals than the original “Nakavu” table. (c.f. Fig. 3) . This estimation was fully confirmed: While the Nakavu table leads to removals of 20-28 m³/ha (1.0-1.5 m³/y/ha), the Drawa table results in a removal of 16-22 m³/ha (0.8-1.2 m³/y/ha). The reason for the lesser removal is that 20 species, representing approx. 30 % of the standing volume, are lifted up in the limits while 24 species (ca. 70 % of stocking) are staying on their limits (Tab. 12).

Species with same removals	(% of sel. vol.)	Species with less removals	(% of sel. vol.)
Kaudamu	15	Kaunigai	6
Mavota	11	Laubu	6
Kauvula	10	Moivi	3
Sacau	9	Rosarosa	2
Yasiyasi	6	Bausa	2
Damabi	4	Dalovoci	2
Damanu	3		
Bauvudi	2		
Dakua s	1		
Vutu kana	1		
Baumika	1		
Kaunicina	1		
12 others	5	14 others	10
Total	69		31

Table 12: Comparison of volume removals between Nakavu-DLT and Drawa-DLT

4. Preliminary Economic Parameter

The following chapter provides some basic economic figures for the development of a SFM-REDD+ financing model. Currently, the development of a concrete model is hardly possible as long as the modalities of payments are not determined in Fiji. It must also be noted that the Nakavu pilot area is used only to determine the underlying assets but due to its small size it is unlikely to become an independent REDD+ project.

The net increment after medium logging in Compartment 7 was estimated to 1.0 - 1.5 m^3/y/ha over the observation period of approx. 20 years. For the time being this figure can be expected as sustainable net increment.

The corresponding (sustainable) net income from Royalties is 23 - 35 F$/y/ha. In addition, some separate payments from loggers to landowners are quiet common in Fiji. Therefore, the total net income is estimated on average to at least 25 F$/$m^3$ and 25-50 F$/y/ha. Taking into consideration that the full income is realized always in the beginning of the felling cycle some interest rates might be added to the gained capital which may lead to higher income figures[52].

For avoiding the loss of CO_2 in comparison to less sustainable land use schemes, additional funding under a national REDD+ mechanism could potentially increase the income per ha. This has to be seen as gross income only, because significant costs (e.g. for administration, inventory, monitoring) rise, which have to be deducted. On the other hand, interest might be added. REDD+ payments could cover the possible difference between the actual situation (e.g. carbon storage in undisturbed forest) and the “usual” treatment (e.g. carbon loss through logging). However, a national REDD+ programme has to be established first, under which more area than only the research site has to be included in a national accounting system. The current research are of 316 ha is too small to develop a forest carbon project.

An open question is how much carbon from other carbon pools than big trees is lost after logging. If after logging the forest is not further disturbed by farming, burning etc. it can be assumed that also the understory trees and other vegetation will react with a higher increment and carbon sequestration. Also, for some years carbon from decomposing organic material might be additionally stored in the soil.

During the further course of the project more specific information is expected.

5. Outlook

Due to logistical and administrative difficulties the project has a delay of several weeks. As soon as possible a second team should be established so that tree selection and Carbon inventory can be carried out in parallel.

For final methodology development more carbon plots are required in Compartment 7 before moving to other compartments. Litter samples need to be analysed in the laboratory and a field

[52] Interest rates of only 1 % above inflation rate will lead to an average income of 25-38 F$/y (20 y period), 3 % net interest rate to an average income of 32-48 F$/y and 5 % net interest rate to 40-60 F$/y.

estimation method ("quick reference guide") shall be developed[53]. Soil carbon investigations supported by the SPC/JICA project would be helpful as well. The significant differences in log heights between the recent visual estimations and the former diameter-to-height models require more careful log height checks. To develop a suitable PHI-method (via simulations) the technical problems regarding the GIS stock map need to be solved.

The tree selection shall be continued in the other compartment. First goal is to inventorise one compartment from each treatment before starting the replications.

The accessibility shall be further improved. To avoid big road damages during rainy periods, wet weather compartments (e.g. Comp. 1) shall be identified.

Using the first results on log production contacts to potential logging companies shall be made.

After finishing the inventory activities a workshop with all relevant stakeholders are advised to discuss the further course of the project[54].

The full list of recommendations is attached as Annex 6.

[53] this activity could be supported from September on by a German project intern
[54] the current plan of operation is attached as Annex 1

6. Literature

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7. Annexes

Annex 1: Project schedule

No.	ACTIVITY	MONTH 1	2	3	4	5	6	7	8	9	10	11	12	13-18	19-24
1	Site inspection and mapping														
2	Socio-economic baseline study														
3	Maintenance infrastructure														
4	PHI														
5	Tree selection														
6	Logger identification														
7	Tactical planning														
8	PSP re-measurement														
9	Logging														
10	Transport														
11	Post harvest assessment														
12	NFMPP management plan														
13	Model calculations														
14	Scientific attendance														
15	Monthly reports														
16	Final analysis + report writing														
17	optional: Carbon financing model														

Annex 2: Diameter limit tables

DLT Nakavu

LIGHT LOGGING	MEDIUM LOGGING	HEAVY LOGGING
>=110 cm DBH Dakua makadre Dakua salusalu Yaka	>=105 cm DBH Dakua makadre Dakua salusalu Yaka	>=100 cm DBH Dakua makadre Dakua salusalu Yaka
>=80 cm DBH Bauvudi Damanu Kauvula Koka Sacau Yasiyasi	>=75 cm DBH Amunu Bauvudi Buabua Damanu Kauvula Koka Sacau Yasiyasi	>=60 cm DBH Amunu Baumika Bauvudi Buabua Damabi Damanu Kaunicina Kauvula Koka Malamala Rosarosa Rosawa Sacau Tavoloa Tivi Vesi Yasiyasi
>=65 cm DBH Amunu Bauloa Baumika Buabua Damabi Kaudamu Kaunicina Malamala Mavota Moivi Rosarosa Tavoloa Tivi Vesi		
>=50 cm DBH Bo(sawa) Bulei Duvula Kaunigai Kuluva Laubu Marasa Masiratu Rosawa Sasawira Vutu kana	>=50 cm DBH Bauloa Baumika Bo(sawa) Bulei Damabi Kaudamu Kaunicina Malamala Marasa Mavota Moivi Rosarosa Rosawa Sasawira Tavoloa Tivi Vesi Vutu kana	
>=40 cm DBH OTHERS	>=40 cm DBH OTHERS	>=35 cm DBH OTHERS

N O T Q U A L I F I E D
Mako Nunu Sa Tiri vanua

Annex 3:

DIAMETER LIMIT TABLE

The following listed tree species are only allowed to cut if their **DBH** is equal or bigger than the mentioned figure:

105 cm	75 cm	50 cm	40 cm
Dakua makadre	Amunu	Bau	ALL OTHER SPECIES NOT EXCLUDED →
Dakua salusalu	Anita	Bauloa	
	Bauvudi	Baumika	
	Boloa	Bausa	
	Bosawa	Bo	
	Dalovoci	Buabau	
	Damanu	Bulei	
	Dawa*	Corikula	
	Kauvula	Damabi	
	Koka	Doi	
	Kuasi	Duvula	
	Mako	Kabi	
	Manawi	Kauceuti	
	Rosarosa	Kaudamu (all spec.)	
	Rosawa	Kaunicina	
	Sa	Kaunigai	
	Sacau	Kautoa	
	Tarawau	Kavika*	
	Velau	Laubu	
	Vesi	Lauci	
	Vesida	Malamala	
	Waciwaci	Marasa	
	Yaka	Masiratu	
	Yasiyasi	Mavota	
		Moivi (all spec.)	
		Sarosaro	
		Sasawira	
		Sikeci	
		Tabadamu	
		Tavoloa	
		Tivi	
		Tomanu	
		Totowiwi	
		Vaivai	
		Vaivai niveikau	
		Vauceva	
		Vutu kana	
		Yasidraumomoto	
		Yasidravu	
		Yasimoli	

EXCLUSION TABLE

The following trees and species are excluded from any logging:

1. ALL PROTECTED species

2. ALL trees or species **UNKNOWN** by the tree spotter

3. Species with relevant **NON TIMBER USES**
(unless approved by the landowner):

Dawa	Kavika	Qumu
Drala	Kuluva	Sivia
Ivi	Makosoi	Vacea
	Maqo	Vure

4. ALL species **UNSUITABLE** for timber:
(unless in interest of the logger):

Bacou	Macou	Sorua
Bulu	Makita	Sorua levu
Bulu m	Manui	Sosoniura
Buluwai	Maqo niveikau	Tadalo
Cevua	Mariko	Tavola
Dava	Midra	Tiri
Degedege	Molaca	Tirivanua
Didi	Molau	Tokatolu
Diriniu	Nunu	Ucaca
Dokonisau	Okeoke	Ulanisau
Drausasa	Qaiqai	Vasa niveikau
Drautolu	Roro	Vota
Gadi	Salato	Vutu
Gadoa	Selavo	Vutu niveikau
Kadi	Sevua	Yaro
Kaukaro	Sevula	Yasi
Lidi	Sisisi	Yasikavika
	Sole lailai	Yasileba

Annex 4:

Date	Recorder	Survey Team **Right**	Time start TS
Comp. No.	Strip No.	Survey Team **Left**	Time finish TS

	Tree Parameter				Coordinates						
Tree No.	DBH (cm)	Species (local name)	Log Length (m)	Quality (class)	Strip Line **Length** (m)	Distance **Left** (m)	Distance **Right** (m)	Slope (°)	Selected (**O**ld and/or **N**ew DLT)	moving direction fr. baseline (**up/down**)	Remarks (**B**uffer, Steep **Sl**ope (°), overlooked tree etc.)

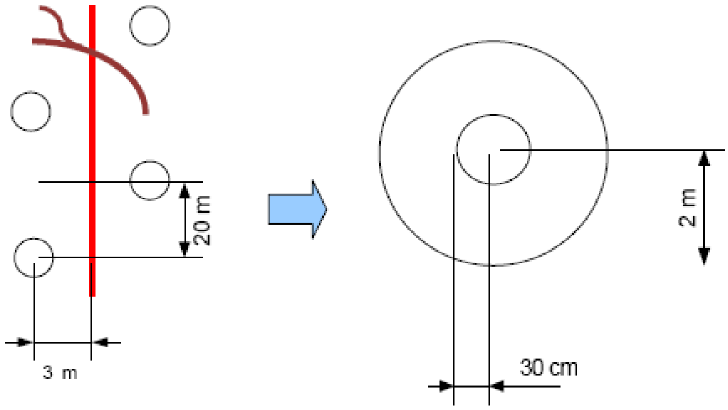
Annex 5:

Carbon Accounting Field Manual

Location and design of plots

Plots have to be allocated every 20 m along the strip line with a rectangular offset of 3 m alternately left and right. The plots are circular with a 2 m radius and a sub plot of 30 cm, see sketch below. Lying deadwood with diameter > 9.9 cm is not measured inside the plots but along the strip line.

Location of plots along the strip line: measuring lying deadwood **Plot design**



Please note that sketch is not up to scale!

Measurements

Lying dead wood with a diameter > 9,9 cm which is intersecting with the strip line has to be measured along the entire strip line (distance on strip line, diameter, decay class (1: recently died, 2: moderately decomposed, 3: very soft)).

<u>Sub-plot (r = 30 cm):</u>

1. entire **litter** (leafs/dead herbal material, twigs diameter < 1 cm) has to be separately collected and weighed. In case litter material exceeds the border line of the sub-plot it has to be cut off along the border. Only the parts inside is weighed.
2. all living **herbs, ferns and grasses** rooted within the plot have to be cut and weighed together (without roots).
3. all **lying dead wood with diameter 1** - **9,9 cm** has to be weighed (only the portions located within the sub-plot).
4. all **living trees height < 1,3 m** have to be counted, cut close to the ground and weighed (without roots).

<u>Main-plot (r = 2 m):</u>

1. all trees **height > 1,3 m and DBH < 9,9 cm** have to be tallied according to diameter class (rounded down to full cm in classes 0 – 9 cm) and separated in dead and alive.
2. all trees **DBH 10 – 34,9 cm** have to be recorded (species, DBH, dead/alive – for dead trees height and decay class is required). Additionally the closest tree of that class outside the plot centre has to be recorded too. For this tree the horizontal distance from plot center to the tree center is required (beside the other data).
3. all trees **DBH > 35 cm** have to be recorded (species, DBH, log length parameters, quality, dead/alive; for dead trees: decay class instead of quality will be recorded). Additionally the closest tree of that class outside the plot centre has to be recorded too. For this tree the horizontal distance from plot center to the tree center is required (beside the other data).
4. **stumps** (>= 10 cm top diam.) within the radius of the furthermost tree of DBH 10-34 cm and > 35 cm respective will be recorded in the same manner as standing dead trees (top diam., height, decay class).

FIELD FORM CARBON INVENTORY CarbonPlot

Date:	Surveyor/Team:			Time start plot
Compartment No.:	Strip No.:	Plot No.:	Weather:	Time finish plot

Biomass Sample	H >= 1.3 m and DBH < 10 cm			DBH 10 – 34.9 cm		outside r=2m:		if dead:	Lying Dead Wood>= 10 cm		
Weight (g)	DBH (cm)	Alive No.	Dead No.	Species/Stump	DBH (cm)	Distance (m)	Alive/Dead,DC	Hight (m)	Strip Line No.		
Litter+DW<1cm	0 cm								Diameter (cm)	Decay Class	Distance (m)
	1 cm										
Grass/Ferns	2 cm										
	3 cm										
Dead Wood 1-9.9 cm	4 cm										
	5 cm										
Trees H < 1.3 m	6 cm										
No. (weight g)	7 cm										
	8 cm										
	9 cm										

DBH >= 35 cm		outside r=2m:				for log length measurement:				Remarks:
Species/Stump	DBH (cm)	Distance (m)	Al./Dead,DC	Quality	Log Length (m)	Distance (m)	Slope (°)	Top reading (%)	Down reading (%)	

Date:	Surveyor/Team:			Time start plot
Compartment No.:	Strip No.:	Plot No.:	Weather:	Time finish plot

Biomass Sample	H >= 1.3 m and DBH <= 10 cm			DBH 10 – 34.9 cm		outside r=2m:		if dead:	Lying Dead Wood>=10 cm		
Weight (g)	DBH (cm)	Alive No.	Dead No.	Species/Stump	DBH (cm)	Distance (m)	Alive/Dead,DC	Hight (m)	Strip Line No.		
Litter+DW<1cm	0 cm								Diameter (cm)	Decay Class	Distance (m)
	1 cm										
Grass/Ferns	2 cm										
	3 cm										
Dead Wood 1-9.9 cm	4 cm										
	5 cm										
Trees H < 1.3 m	6 cm										
No. (weight g)	7 cm										
	8 cm										
	9 cm										

DBH >= 35 cm		outside r=2m:				for log length measurement:				Remarks:
Species/Stump	DBH (cm)	Distance (m)	Al./Dead,DC	Quality	Log Length (m)	Distance (m)	Slope (°)	Top reading (%)	Down reading (%)	

Date:	Surveyor/Team:			Time start plot
Compartment No.:	Strip No.:	Plot No.:	Weather:	Time finish plot

Biomass Sample	H >= 1.3 m and DBH < 10 cm			DBH 10 – 34.9 cm		outside r=2m:		if dead:	Lying Dead Wood>= 10 cm		
Weight (g)	DBH (cm)	Alive No.	Dead No.	Species/Stump	DBH (cm)	Distance (m)	Alive/Dead,DC	Hight (m)	Strip Line No.		
Litter+DW<1cm	0 cm								Diameter (cm)	Decay Class	Distance (m)
	1 cm										
Grass/Ferns	2 cm										
	3 cm										
Dead Wood 1-9.9 cm	4 cm										
	5 cm										
Trees H < 1.3 m	6 cm										
No. (weight g)	7 cm										
	8 cm										
	9 cm										

DBH >= 35 cm		outside r=2m:				for log length measurement:				Remarks:
Species/Stump	DBH (cm)	Distance (m)	Al./Dead,DC	Quality	Log Length (m)	Distance (m)	Slope (°)	Top reading (%)	Down reading (%)	

Annex 6: Summarized recommendations:

- Compartment-wise continuation of demarcation and GIS survey, (improving the performance in demarcation work); including other existing measurement (e.g. skid tracks, forest roads, location and condition of current culverts and proposal for additional ones), survey on open areas (former log landings) and identification and demarcation of the 1992 non-logged areas within the compartments (esp. Comp. 4,8, 12).
- First half of 2012: installation of the working group, selection of suitable forest owing communities; second half of 2012: development of a suitable questionnaire and start of survey. The activity could be supported by a project intern.
- As soon as work schedule and weather allow, a grader should be hired and several loads of gravel from the Navua river pits should be transported to the NFMPP forest road. Especially the vegetation on the shoulder has to be cleared and the ditches have to be opened (grader). On sections with insufficient gravel surface, especially on steep slopes, the gravel layer should be restored. For the time being the road shall be relieved through introducing better accessible “wet weather compartments” (e.g. Compartment 1).
- Solving of the technical problems to link the tape-measured tree co-ordinates with the GPS-measured geographical co-ordinates. Developing an Access data base and transferring the data for simulation purposes. Elaborating an optimal (cost-effective, sufficient precise, easy applicable) methodology for PHI. The subject suits as a Master-thesis for a student/project intern.
- Both below-ground biomass (BGB) models shall be tested over the whole diameter rage. Due to the fact that the soil carbon seems to be the dominating carbon fraction investigations together with the SPC/JICA project would be highly desirable.
- A simple method for deadwood estimation (volume to carbon content) shall be developed. This requires that representative deadwood samples need to be analysed in the laboratory.
- Continuation of optimizing the lay-out according to the gained experiences during completing Compartment 7 and according to the stock map simulations.
- In the further course of the project typical samples shall be analyzed in the laboratory. Based on the results a quick reference guide for immediate estimation in the field shall be developed. This simplified community approach method seems to be acceptable because of the relatively small proportion of carbon in this fraction.
- Starting data collection with the line-intersect method for all lying deadwood with 10 cm diameter and above.
- Due to the problematic significant increase for the small diameters the more conservative model (Cairns) shall be used for below-ground carbon (BGC) estimation for the time being. With the support of the JICA project it might be possible to develop own reference values for soil carbon, probably also over a longer observation period after a logging operation.
- After analysing the completed tree selection data and the first sets of carbon plots, the further course of the project shall be discussed during a workshop (November 2012?) with the involved stakeholders.