PRELIMINARY REPORT ON SUSTAINABLE HARVESTING OF *PRUNUS AFRICANA* (ROSACEAE) IN THE MOUNTS TCHABAL GANG DABA AND TCHABAL MBABO CAMEROON

Report prepared for the National Forestry Development Agency (ANAFOR), the Cameroon CITES Scientific Authority for flora, in the frame of the project "Non-detriment findings for *Prunus africana* (Hook.f.) Kalkman in Cameroon"

By

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August 2011

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RESUME EXECUTIF

Prunus africana (Rosaceae) globalement connu sous le vocable *Pygeum*, est un arbre qui pousse dans les forêts afromontagnardes entre 1500 et 3000 m d'altitude, sur sol volcanique et sous climat frais d'altitude. Son aire de distribution englobe la Côte d'Ivoire, la Guinée Équatoriale (ile de Bioko), Sao Tome ?, Éthiopie, Kenya, Ouganda, Afrique du Sud, Madagascar, Congo, République Démocratique du Congo et Cameroun.

Au Cameroun, *Prunus* a été signalée principalement dans 4 régions (provinces) à savoir, le Nord Ouest, l'Ouest, le Sud Ouest, et l'Adamaoua.

Des extraits de l'écorce de cette plante ont été identifiés et patentés comme étant actifs dans le traitement de l'hypertrophie prostatique bénigne. Des capsules contenant des extraits d'écorce sont en vente en Europe depuis plus de 30 ans.

Prunus africana a été classée par l'Union Internationale pour la Conservation de la Nature comme espèce vulnérable. Ce fait a conduit à son classement dans l'annexe II de la Convention sur le Commerce International des espèces de faune et de flore sauvage menacées d'extinction (CITES) en 1995. Le quota annuel a subi des fluctuations jusqu'à la suspension du commerce en 2007 (entre 500 et 2000 tonnes). Depuis 2010, l'OIBT et la CITES développent en collaboration avec le Gouvernement du Cameroun un projet intitulé « **Avis de Commerce Non Préjudiciable sur *Prunus africana* (Hook.f.) Kalkman au Cameroun ».** Les travaux entrepris dans le cadre dudit projet ont permis la reprise de l'exploitation de *Prunus africana* au Cameroun, avec un quota partiel de 150 tonnes pour la région du Nord ouest et de 200 tonnes pour la région du mont Cameroun.

Le présent document rapporte la suite des résultats obtenus dans le cadre de ce projet pour la région de l'Adamaoua, dans les monts Tchabal Gang Daba et Tchabal Mbabo plus particulièrement.

La région de l'Adamaoua dont le chef lieu est Ngaoundéré a une superficie de 63 701 km² et compte cinq départements notamment, le Djérem, le Mbéré, la Vina, le Mayo-Banyo et le Faro et Déo. Le Mayo-Banyo et le Faro et Déo sont les deux départements dans lesquels l'on trouve les forêts à *Prunus africana*, plus précisément dans les sites de Tchabal Mbabo et Tchabal Gang Daba. Le climat caractéristique des départements de Mayo-Banyo et du Faro et Déo est un climat subtropical de transition. Le relief est très accidenté, constitué d'une succession de montagnes et de plateaux aux sommets. Tchabal Mbabo, culmine à 2240 mètres d'altitude, tandis que Tchabal Gang Daba culmine à 1960 mètres d'altitude. La végétation principale est constituée des galeries forestières, des savanes herbeuses, des forêts sèches d'altitude, et des savanes boisées. Les galeries forestières sont des sites de prédilection par excellence de *Prunus africana*.

L'inventaire de *Prunus africana* a couvert une zone de 123 560,31 ha, dont 120 994,1 ha dans le mont Tchabal Mbabo et 2 566,23 ha dans le mont Tchabal Gang Daba. La superficie réellement sondée est de 146,5 ha, soit un taux de sondage moyen de 0,12%. La méthode qui a été utilisée est celle dite « Adaptive Clusters Sampling (ACS) » ou échantillonnage adapté aux grappes. Elle a pour base la méthode conventionnelle d'inventaire d'aménagement généralement utilisée en forêt dense au Cameroun. La méthode ACS est indiquée en ce sens qu'elle permet de capter les grappes ou « clusters » de *Prunus* comme espèce grégaire.

La densité moyenne *Prunus africana* dans les monts Tchabal Gang Daba et Tchabal Mbabo, toutes tiges confondues (vivantes ou mortes) est de 7,55 arbres/ha. La densité la plus forte se trouve dans le Tchabal Mbabo (7,94 arbres/ha). La densité des tiges vivantes est de 3,90 arbres/ha avec seulement 0,71 arbres/ha considérés comme exploitables. 48% des tiges recensées sont mortes ou dépérissantes et toutes ces tiges ont été recensées dans le mont Tchabal Mbabo. Le mont Tchabal Gang Daba n'a pas encore fait l'objet d'une exploitation de Prunus. Un total de 489 341,01 tiges vivantes de *Prunus* a été estimé pour les 123 560,3 ha

de forêts à Prunus estimées pour l'Adamaoua. Seulement 79 700,82 tiges soit 16,28% de ces tiges sont exploitables.

Une simulation du rendement annuel soutenu de l'écorce de *Prunus* a été faite sur la base du nombre de tiges exploitables, du rendement moyen par arbre et du temps nécessaire entre deux passages successifs sur le même arbre. Un quota annuel de **502,11 tonnes d'écorce sèche** de *Prunus* peut être défini pour l'Adamaoua dont 28.8708 tonnes/an kg dans le Tchabal Gang Daba et 473.24 tonnes/an pour Tchabal Mbabo. Le quota annuel de 502,11 tonnes est considéré comme une moyenne entre le quota de 460 272,24 tonnes/an sous-estimé du fait notamment du long temps de rotation pour la couverture complète de l'écorce (6 ans) et celui de 552,32 tonnes/an sur-évaluée du fait du court temps de rotation qui devra séparer deux récoltes (5 ans) successives sur le même arbre.

Pour permettre la conservation de *Prunus africana* dans la région du mont Cameroun, il serait intéressant de :

- Renforcer tous les services forestiers dans zones des monts Tchabal Gang Daba et Tchabal Mbabo en capacités humaines, logistiques et en motivations financières pour mieux contrôler et suivre les opérations de récolte, de transformation et de transport de *Prunus* ;
- Faire un toilettage du nombre des opérateurs économiques qui font dans l'exploitation de *Prunus africana*, pour ne garder que des opérateurs soucieux de la gestion durable de la ressource ;
- Accélérer la mise en place des procédures d'attribution des Unités d'Allocation de *Prunus* ;
- Revoir les modalités d'accès à la ressource en terme de prix de vente de ce produit conformément à la réglementation forestière ;
- Revaloriser la taxe de régénération qui du reste est très faible. Les 10 FCFA/kg perçus par l'administration forestière ne peuvent en aucune façon permettre à l'Etat de garantir une gestion durable de ce produit;
- Mettre sur pied un bon système de traçabilité des produits qui seront récoltés;
- Encourager la création des plantations à *Prunus africana* dans la région de l'Adamaoua;
- Accompagner les populations locales à développer les pratiques agricoles ou d'élevage qui limitent l'extension des surfaces cultivées au détriment de la perte des forêts à *Prunus*.

EXECUTIVE SUMMARY

Prunus africana is a species of the Rosaceae family, known under its commercial name as pygeum or African chery. It is a montane tree species of the tropical Africa including the Côte d'Ivoire, Equatorial Guinea (Bioko island), Sao Tome, Ethiopia, Kenya, Uganda, South Africa, Madagascar, Congo, the Democratic Republic of Congo, and Cameroon.

Concerns on the future of *Prunus africana* led to its listing in Appendix II of the Convention on International Trade in Endangered Species of wild Fauna and Flora (CITES) in 1994, becoming effective in 1995.

Recognizing the shortcomings in scientific information related to the sustainable harvesting of *Prunus africana*, the government of Cameroon submitted to the International Tropical Timber Organization (ITTO) for funding the project entitled **"Non-detriment findings (NDF) for *Prunus africana* (Hook.f.) Kalman in Cameroon".**

The first important outputs of the project was the production of the partial NDF reports on *Prunus africana* for the mount Oku, in the North west region and for Mount Cameroon in the South west region of Cameroon. Annual quotas of 150 tons and 200 tons of dried barks were defined for the two regions, which lifted the ban on the exportation of *Prunus* barks from Cameroon.

This third document reports results of specific activities conducted within this project in the Adamaoua region, in Tchabal Gang Daba and Tchabal Mbabo mountains to be precised.

The adamaoua region is vast of 63 701 square kilometre (km^2) and comprises five divisions including: Djerem, Mbéré, Vina, Faro and Déo, and Mayo – Banyo. Faro and Déo and Mayo – Banyo are the two divisions which contain *Prunus* forests, in Tchabal Gang Daba and Tchabal Mbabo mountain forests respectively. There are four forest types: forest galleries, herbaceous savannahs, dried mountain forests, and woody savannahs. Forest galleries are found in valleys and along rivers. They constitute are the main domain/habitat of *Prunus africana.*

The total area covered by *Prunus africana* in the Adamaoua region is 123 560.31 ha distributed in 120 994.1 ha in Tchabal Mbabo and 2 566.23 ha in Tchabal Gang Daba. The method used to evaluate the abundance of *Prunus* in the two mountains is called "Adaptive Clusters Sampling (ACS)". This method is the same used in mount Oku (North west region) and mount Cameroon (South west region) and has its basis in the conventional forest inventory method often used to design the management plan in dense forests. The ACS method is advised since it captures the *Prunus* clustering characteristics. The sampling intensity obtained is 0.12%.

The average density of *Prunus* living trees is 3.90 stems/ha, with 0.71 stems/ha being exploitable trees. About 48.3% of trees recorded are dead or wilt, and all those trees were recorded in Tchabal Mbabo. A total of 489 341.01 *Prunus* living trees can be estimated for the Adamaoua region.

The annual quota estimated for the Adamaoua region is **502.11 tons/year of dried barks**. This quota is considered as the medium, obtained from the lowest estimated with a rate of recovery of 6 years (460 272.24 tons/year) and the highest estimate with a rate of recovery of 5 years (552 326.69 tons/year).

To ensure the conservation of *Prunus africana* in Tchabal gang Daba and Tchabal Mbabo areas, following actions should be taken:

- Re-enforce capacities of all decentralised forest units found in the two areas in terms of human resources, logistics, and financial incentives in order to allow them to better control and monitor the exploitation, processing, and transport of *Prunus* products;

- filter the number of companies who are working in the field of *Prunus africana* as to keep those who are interested in sustainable management of the resource;
- address the issue of equity in the trade exchanges on *Prunus africana*. This should ensure that local communities are well motivated to conserve *Prunus africana* in their forests;
- accelerate the implementation of the procedures for the attribution of the Prunus Allocation Units (PAU);
- revise the modalities of access to the resource in terms of the selling price in accordance with the current forest law;
- propose a better system of taxation of *Prunus* products. The current 10 FCFA/kilogram perceived by the Cameroon Government as the regeneration tax cannot ensure the activities required for the sustainable management of the resource;
- develop and implement a fair tracking system to trace *Prunus* products from the forest till the exit points;
- encourage local people to develop *Prunus* plantations;
- assist local people in developing fair farming system that do not harm *Prunus* habitat.

1. INTRODUCTION

1.1. Context and Problem

Prunus africana is a species of the Rosaceae family, known under its commercial name as pygeum or African chery. It is a mountane tree species of the tropical Africa including the Côte d'Ivoire, Guinea equatorial (Bioko island), Sao Tome, Ethiopia, Kenya, Uganda, South Africa, Madagascar, Congo, the Democratic Republic of Congo, and Cameroon (Vivien et Faure 1985).

In Cameroon, *Prunus* bark exploitation started in 1972, and many trees around the Mt Cameroon have been exploited several times with four-year intervals. Legally for all trees above 30 cm diameter at breast high (bh, only two quarters of the bark are taken from the main stem up to the first branch. However, since 1985, many people were involved in the exploitation and the harvesting was done by untrained villagers. Many trees were debarked up to the smallest branches and others were felled with negative impact on the limited wild population of this tree species.

Concerns on the future of *Prunus africana* led to its listing in Appendix II of the Convention on International Trade in Endangered Species of wild Fauna and Flora (CITES) in 1994, becoming effective in 1995 (Sunderland and Tako1999 cit. Tieguhong and Ndoye 2004). The impact of listing *Prunus africana* by CITES has been partially effective in reducing threats because it has helped to raise awareness about the problems posed by international trade.

The partial ban of *Prunus* exploitation in 1991, which was lifted in 1992; the ban on felling decided in 1993; and the reduction of quotas in 2008 were followed by the ban on the importation of Cameroon's *Prunus* into Europe space as a result of the decision undertaken by the European Commission in October 2007. This measure impacts both the economic operators and the local people for whom *Prunus* represents an important non timber forest product.

A key requirement of CITES is the non-detriment findings made by the Scientific Authority of the range State prior to export, certifying that export is not detrimental to the survival of the species. This requires information on the location, stock, growth and conditions of the species and on its ecology, regeneration and subsequent protection. Such information is often lacking, incomplete or imprecise making a proper evaluation of the sustainable levels of utilisation and conditions attached to be difficult. The Scientific Authorities also face obstacles due to inadequately trained staff or shortage of resources.

Recognizing the shortcomings in scientific information related to the sustainable harvesting of *Prunus africana*, the government of Cameroon has submitted to the International Tropical Timber Organization (ITTO) for funding one project entitled **"Non-detriment findings for *Prunus africana* (Hook.f.) Kalman in Cameroon".** This project is being implemented by the National Forest Development Agency (ANAFOR), the Cameroon's CITES Scientific Authority for plants issues. Field specific activities started in July 2010 following the first meeting of the Steering Committee held on 20th July 2010. The first important output of the activity was the production of the partial NDF reports on *Prunus africana* for the Mount Oku and Mount Cameroon in the North west and South west regions of Cameroon respectively. Annual quotas of 150 tons and 200 tons of dried barks were defined for the two regions (Amougou et al. 2010, 2011), which lifted the ban on the exportation of *Prunus* barks from Cameroon.

This third document reports results of specific activities conducted within that project in the Adamaoua region, on the Mounts Tchabal Gang Daba and Tchabal Mbabo areas to be précised.

1.2. Importance and compliance of the activity with the existing policies and strategies

As already mentioned in the previous reports (Amougou et al. 2010, 2011), the work goes in line with the Cameroon's Forest and Environment Sectorial Program (FESP) developed in 2003 (MINEF 2003). The FESP is a tool developed by the Cameroon Government as to bring strategic responses in the implementation of the 1994 forest law. The FESP is structured around 5 components. This initiative meets the objectives of two of the five components, including: Component 2 (Sub-component 2.4/Activity 2.4.1/Sub-activity 2.4.1.2: to undertake inventories to know the stock of Non timber forest products (NTFP) in each ecological zone, Sub-activity 2.4.1.3: to identify production sites and the trade chain of principal NTFP, Sub-activity 2.4.1.4: to create a database on NTFP, Sub-activity, activity 2.4.2./Sub-activity 2.4.2.1: to develop and disseminate the sustainable harvest methods, processing and domestication, Sub-activity 2.4.2.3: to build CITES organs capacities and Component 5 (Sub-component 5.3: research and monitoring).

The work is in compliance with the recent guidelines developed for *Prunus* management plan in Cameroon (Ingram et al. 2009).

The work also goes in line with the ITTO/CITES program "ensuring that the international trade in CITES tropical listed tree species is non detrimental to their conservation" (ITTO – CITES 2006).

1.3. Objectives

This work aims to gather and analyse data for sustaining *Prunus africana* together with its natural habitats in the Mounts Tchabal Gang Daba and Tchabal Mbabo, in the Adamaoua region, Cameroon. The specific objectives are to gather the basic information on the distribution, and abundance of this plant species and to present a comprehensive procedure followed to determine the stock and annual quota as useful tools for sustaining *P. africana* in the Adamaoua region

2. SUSTAINING *PRUNUS AFRICANA* IN MOUNT TCHABAL GANG DABA AND MOUNT TCHABAL MBABO, ADAMAOUA REGION, CAMEROON

This section presents the milieu and the logical steps and procedures followed to ensure sustainable harvesting of *Prunus africana* in the Adamaoua region of Cameroon.

2.1. Study area

Among the ten regions of Cameroon, six, namely Adamaoua (Ngaoundéré being the capital), the Centre (Yaoundé), Littoral (Douala), North West (Bamenda), Southwest (Buea), and West (Bafoussam), are those where populations of *Prunus africana* occur. But the main reserves of *Prunus africana* are observed in the Adamaoua, North West and South West regions. The major landscapes of Cameroon containing *Prunus* (Ingram et al. 2009) have been defined and consolidated into *Prunus* Allocation Units (PAUs) that cover six mountane areas (figure 2).

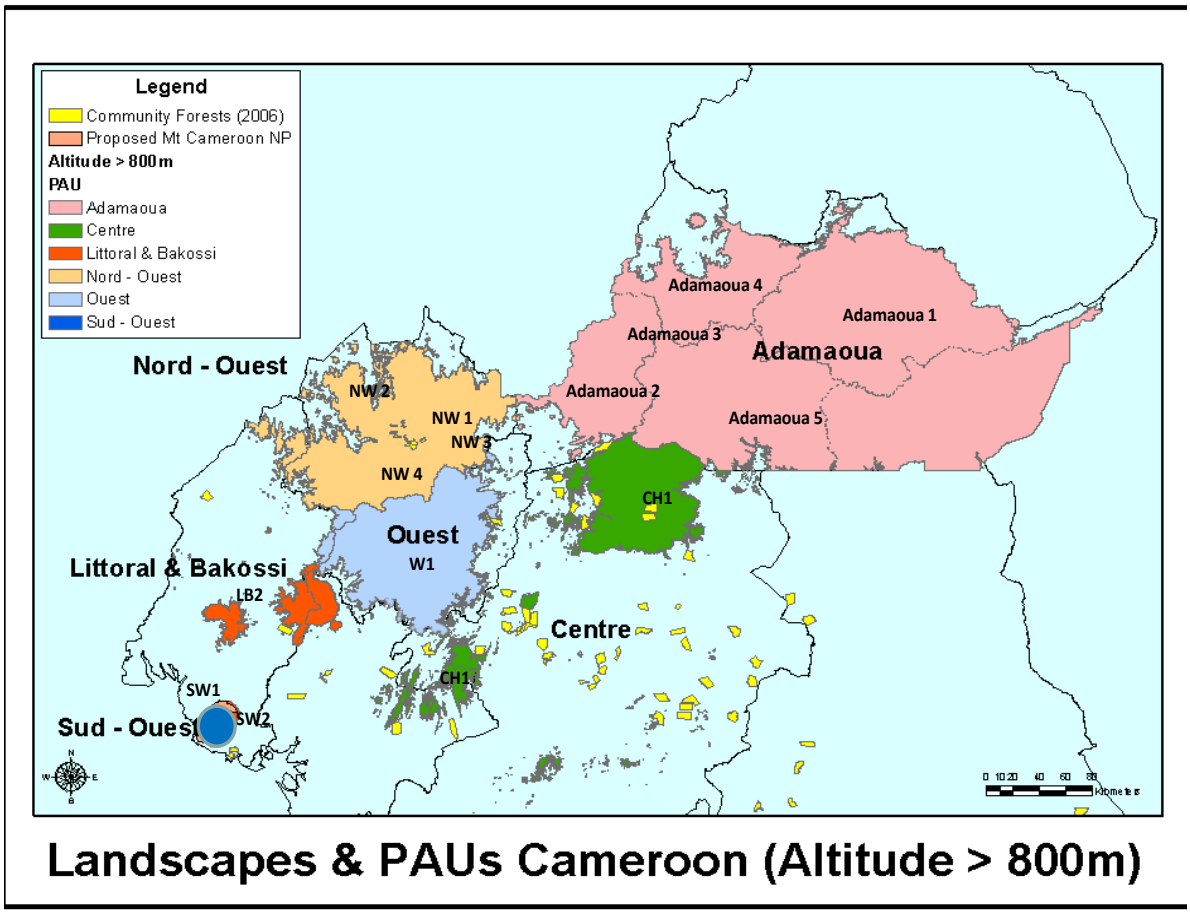

Figure 1: The six regions of *Prunus africana* in Cameroon

The adamaoua region is vast of 63 701 square kilometre (km²) and comprises five divisions including: Djerem, Mbéré, Vina, Faro and Déo, and Mayo – Banyo. Faro and Déo and Mayo – Banyo are the two divisions which contain Prunus forests, in Tchabal Gang Daba and Tchabal Mbabo mountain forests respectively to be précised. These areas are composed of a succession of mountains or "Horé" in local language. Tchabal Mbabo mountains are up to 2 240 m. The main high levels include: Horé Lassel, Horé Mayo Kélélé, Horé Yangaré, Horé Ngouri, Horé Garbaya, Fongoy, Nanaré. Tchabal Gang Daba mountain is up to 1 960 m and is located at 10 km from Tignère, the capital of the Faro and Déo division. The climate is a transition - subtropical type, characterized by two equal seasons: a dried season from November to March and a rainy season from April to October. The average temperature is 23°C. The maximum average temperature is 30°C in March and the minimum is 15°C in December – January. The wind is dried and wet in rainy season and dried and hot in dried season. The average annual rainfall varies between 1 000 and 2 000 m. August and September being the most rainy months. Two types of soils are found in the region. Red and yellow iron soils resulting from the decomposition of metamorphic rocks on the slopes, and black alluvial soils in the bottom and in forest galleries found along rivers. These soils are regularly degraded due to the fluvial erosion, the bush fires, and the grazing. The Tchabal Mbabo and Tchabal Gang Daba mountains have a high diversity of plant species. In Tchabal Mbabo there are four forest types: forest galleries, herbaceous savannahs, dried mountain forests, and woody savannahs. forest galleries are found in valleys and along rivers. They contain *Prunus africana* and other plant species. Herbaceous savannahs are composed of meadows dominated by Hyparhenia sp and Andropogon sp. Dried mountain forests are found in Dodéo, Fongoy, Nanaré, and Yangaré. They contain *Prunus africana* and characteristic savannah species such as *Khaya senegalensis, Daniella oliveri, Isoberlima doka, Cedrela odorata, Combretum sp, Burkea africana, Lophira laceolata, Prosopis sp, Syzygium guineense, Terminalia laviflora* and *T. mcroptera*. Woody savannahs are found in Dodéo, Fongoy and Mbabo. They are also composed of the same species found in dried mountain forests. In Tchabal Gang Daba, there are not high trees in the summits. There are some forest galleries which contain *P. africana*. The Samlekti valley gets forests which are dominated by *Isoberlima doka* and *I. tomentosa*.

2.2. History of Prunus *bark harvesting in Adamaoua region*

Prunus bark exploitation started in 1997, and an important number of trees around the Mount Tchabal Mbabo have been exploited several times. The previous sites of exploitation have totally been destroyed due to inadequate and irrational techniques of harvesting used by the harvesters. The techniques of harvesting used were the systematic felling of trees and total debarking of stems. Consequently *Prunus* population declined drastically. Two forests have in such away, been totally damaged including the site of Danwark and that of Dadawal, next to Sambo Labo. The permit holders used to go into the forest without contacting local authorities (the Mayor, the Lamido and the chiefs of villages). These declarations were confirmed by the local Chief of forest and wildlife control post of Sambo Labo (Betti 2008). According to one representative of AFRIMED, one of the two main companies which use to harvest *Prunus* barks in the Adamaoua province, legally for all trees above 30 cm dbh, only two quarters of the bark are taken from the main stem up to the first branch. The first harvester collects the first ½ of the stems at opposite sides. The harvester may be careful and should avoid to injure the sapwood. The second harvester comes to the same stem after 4-5 years to collect the remaining ½ of the barks at the other opposite sides. This time (4-5 years) is known to be enough to allow the two former sides which were debarked to regenerate a little bit as to permit the tree to resist to the second harvesting. The regenerate side can also be used, but according to Julius, the juice (active compound) is not yet good for medicines. Also, the quantity of the barks is still small for exploitation. The minimum period required for a bark to regenerate and be good for harvesting is 8 years.

Several threats can be observed for *Prunus africana* in Cameroon: habitat loss/degradation, inadequate techniques of harvesting and over harvesting (Akagou et Betti 2007; Ndam 1996).

2.3. Material and methods

Prunus inventories were carried out in Tchabal Gang Daba and Tchabal Mbabo mountains (Belinga 2011). The method used is called “Adaptive Clusters Sampling (ACS)” method.

This method has its basis in the known conventional forest inventory method often used in dense forests. In Cameroon, the classical forest inventory method is standardised for management inventories (MINEF, see arête n° 222).

2.3.1. Description of the classical method

2.3.1.1 Mapping

Materials used for mapping are made up of: a GPS Garmin C76 x, a topographic map at scale 1:200 000 produced by the National Institute for Cartography (INC), the forest photo interpretation manual produced by the former National Forest Development Agency (ONADEF 2007), aerial photos at scale 1:20 000 covering years 1983 to 1987 (5 to 6 sq km over 21 sq km analysed) obtained from the Forest Mapping and Remote Sensing Centre (CETELCAF), aerial photos at 1:50 000 ranging from 1949 to 1970 (28 sq km over 81 sq km) acquired from INC, a 30 m-resolution-Landsat image of 2007 (15 m panchromatic), the report of Prunus inventory produced by CIFOR in 2007. The GIS software used includes the ERDAS IMAGINE 9.3 and ARC GIS 9.3 computer packages.

The method used is: photo-interpretation by stereoscopy, supervised classification of the geo referenced satellite image in view of having the strata shown by the forest map updated, the classification of the Landsat image (supervised classification using 7 multi-spectral bands) and field visits for habitats description (Samba, 2011).

2.3.1.2. Sampling design and intensity

According to the national standards, the sampling is systematic and stratified to 1 degree when the statistical unit is the plot. The samples or plots of 0,5 ha (250 m long x 200 m large) are distributed systematically throughout the entire population and not by stratum (forest type). The stratification is done definitively after the sampling. The systematic disposal of plots allows to assume that the intensity of sampling for each stratum is proportional to its area in the forest. Results of the inventory and their accuracy are calculated for each stratum.

In practice, sampling is carried along straight and continuous axes called “layons” or lines or transects. These “layons” are oriented along a predetermined magnetic direction but are systematically arranged in such a way that they are mostly parallel, equidistant and perpendicular to the general direction of both drainage and slopes.

Rectangular plots arranged along a “layon” are contiguous (without alley or corridor of separation) and measure 250 m in the direction of the “layon” (length) and 20 m in the direction perpendicular to the “layon” (width). This gives a surface area of 0.5 ha for each plot. For the ACS method, additional circular plots of 0,2 ha will be added in respect of the conditions that will be clarified later.

The formula which allows to calculate the distance or interval between two “layons” is as follows:

$$\text{interval} = \frac{\text{Net Area to probe or to survey (ha)} \times 20\ \text{m}}{\text{Area actually probed (ha)}}$$

The sampling intensity is the ratio between the area surveyed and the total area of the Forest. It must provide for the parameters studied, values which are representative of the general population and this, according to precisions criteria set in advance. But this precision of the results obtained with a given sampling intensity depends on the variability of the parameters measured in this population. Fixing in advance the desired precision, one must have some idea of this variability as to calculate the number of samples which will be collected (choosen). The Prunus forest of mount Tchabal gang Daba is vast of 2 566,23 ha, while that of mount Tchabal Mbabo is vast of 120 994,08 ha.

A total of 88 lines were proposed to cover the two areas. The sampling design is illustrated in figure 2a and 2b.

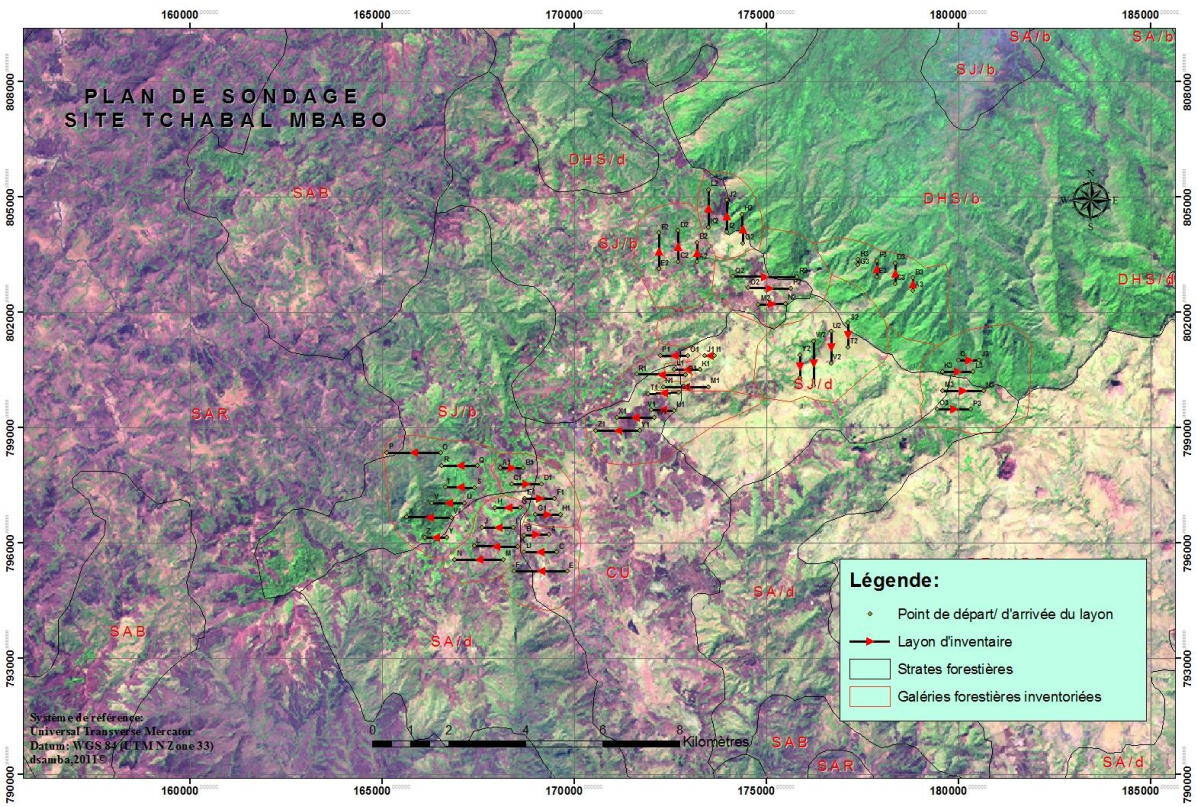

Figure 2a : Map of sampling design for *Prunus* inventory on the Mount Tchabal Mbabo

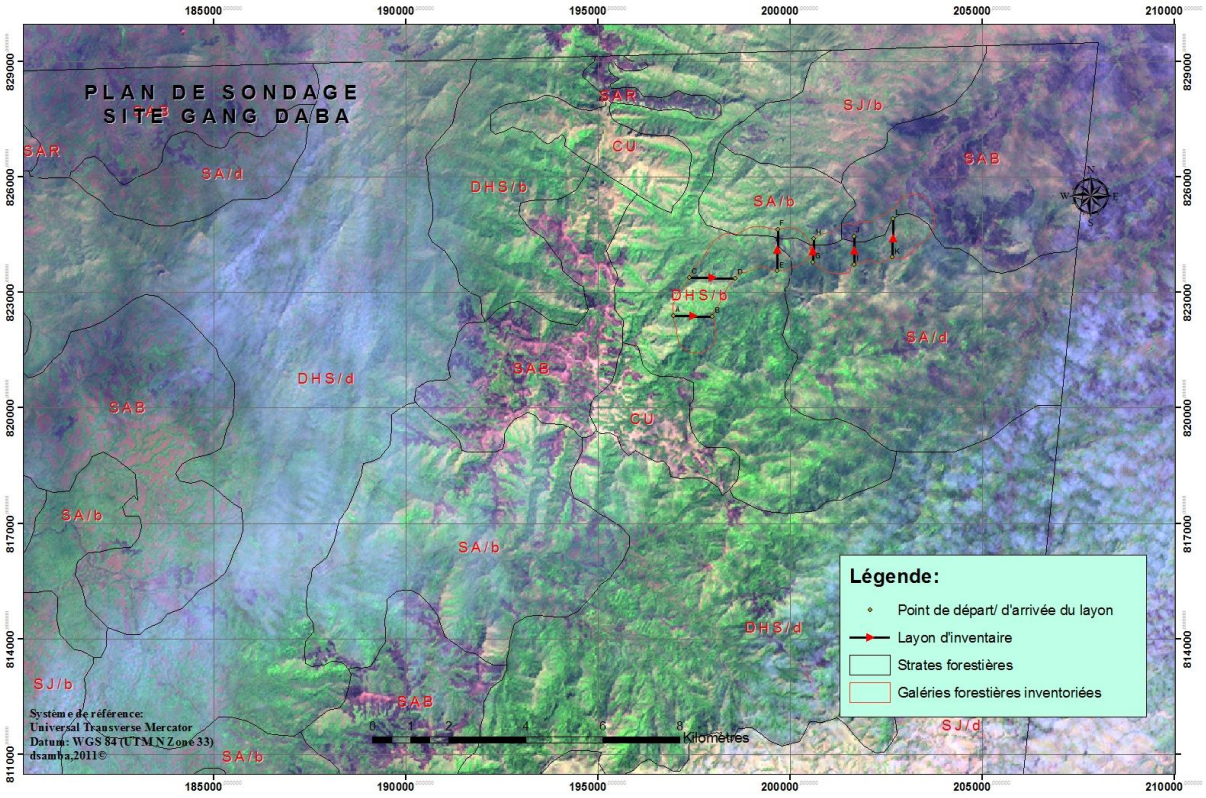

Figure 2b : Map of sampling design for *Prunus* inventory on the Mount Tchabal Gang Daba

2.3.1.3. Implementing the sampling design

The inventory consists of two stages : “layons” or line opening/transect cutting and counting (Belinga 2011).

a) Line opening/transect cutting

This step consists of opening or cutting according to a defined magnetic direction, corridors or alleys of 1.5 m wide. These corridors are clearly cleaned by cutting shrubs, vines and branches that obstruct the passage. They are then identified by marks. “Layons” constitute the reference system which will be used by the subsequent counting team. It is during the “layons” opening that details on topography, habitat types, rivers and the corrected horizontal distance of the “layon” (after reading the slopes) are given. It is also during this stage that the sample plots are identified and numbered. The data collected are recorded on specific sheet.

b) Counting

The counting step includes all operations relating to dendrological and dendrometric records. During the counting in rectangular and circular plots, several operations are made including: identification of stems of *Prunus africana*, the measurement of stems with diameter at breast height (dbh = 1.50 m) >= 5 cm, appreciation of the health state of the tree in three classes (dead trees, damaged trees, and living trees). The appreciation of the healthy status of the tree is mainly based on the health of the leaves and number of dried branches. Lines and plots are identified and numbered with their geographical coordinates and altitudes.

2.3.2. Theoretical basis of the “Adaptive Clusters Sampling (ACS)” method

The ACS method is advised to capture the *Prunus* clustering characteristics.

Considering y (total number of stems for example), the value of the parameter in the sampling unit (plot) of the traditional method, and C the condition (a limit number of stems for example) required to initiate an adaptive sampling. If y > C in the indicated plot, additional circular plots are established in its periphery. If other units (circular plots) of the periphery have their y > C, then the process continues till obtaining a network of circular plots. The process stops when the condition can no longer be verified (y < C). If many units satisfy the conditions, then the sample will have many units in the entire population. The ACS sampling device is illustrated in figure 3.

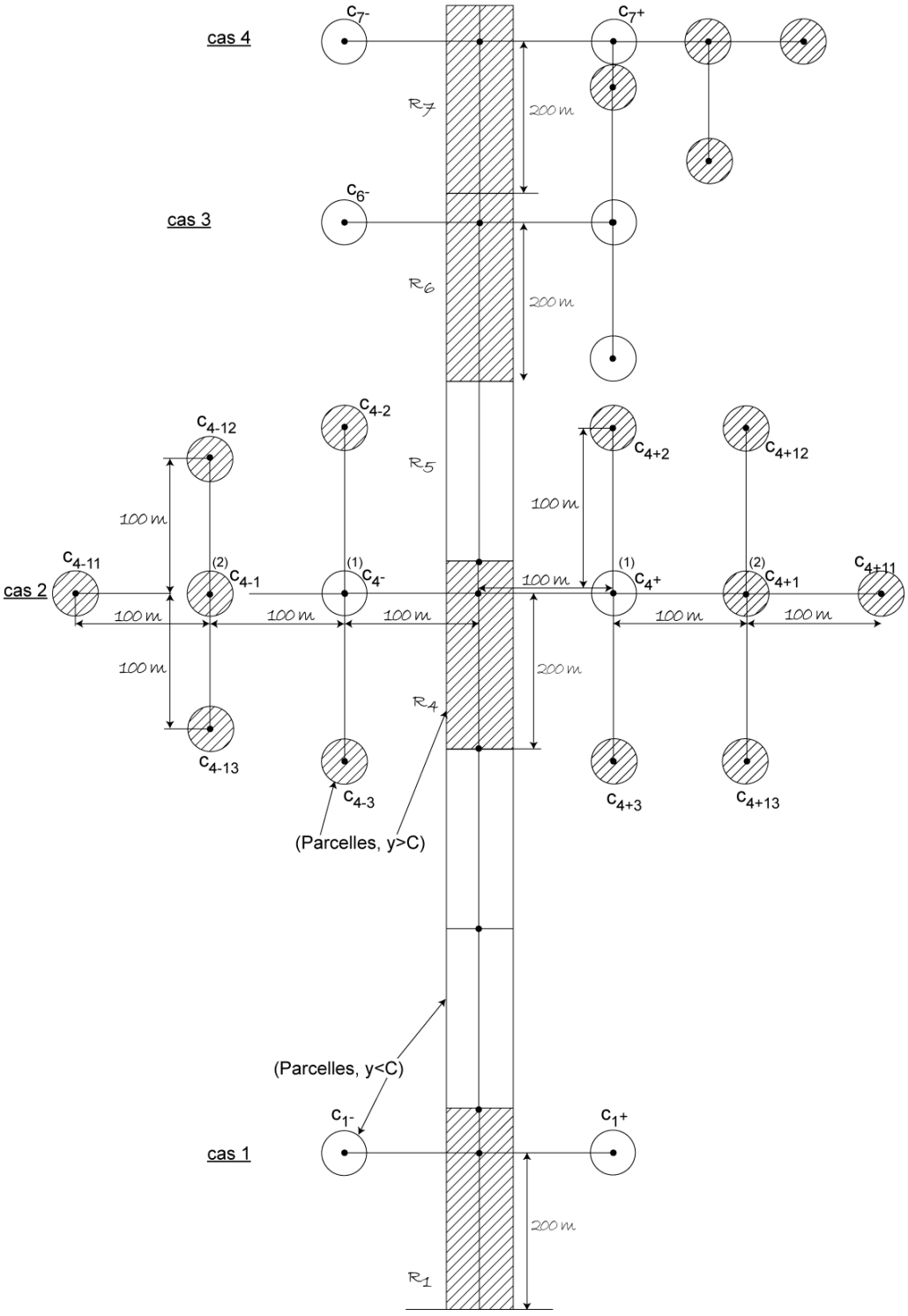

Figure 4: Sampling design of the ACS method

The ACS method has many advantages: it allows to have a good idea on the distribution of *Prunus* clusters, it provides many data, and good precisions, it is almost similar to a systematic or total inventory mostly when the sample becomes too large, it is more efficient on statistical basis compared to the traditional method (Fiona and al. 2000). The problem with the ACS method is that it is difficult to determine in advance the sampling intensity, and also that the method requires a mobilisation of human resource-efforts and funds.

For the inventory carried out in the mounts Tchabal Gang Daba and Tchabal Mbabo, all the area was assessed following the traditional inventory approach. Data analysis led to fix the

condition C at 4 stems. This means that, all plots with C > = 4 stems were subjected to ACS method. It is in such a way that ACS method was applied in the Adamaoua region.

2.3.3. Simulation of sustainable yield of *Prunus africana*

This study was conducted by Ambara (2011) in may 2011 in Tchabal Mbabo and Tchabal Gang Daba mountain forests. To estimate the mass of the stem barks of *Prunus africana*, the author used an indirect method and proceeded in three steps: establishment of the relation linking the diameter at breast high (DBH) of each tree with the thickness of its stem bark, establishment of the relation linking the volume of the stem bark and its mass (weigh), and determination of the mass of the fresh bark for exploitable trees. Exploitable trees being trees with DBH ≥ 30 cm. A DBH is high at 1.5 m.

2.3.3.1. Relation diameter at DBH – thickness of volume of the stem bark: cubic tariff or volume based tariff

The volume based tariff or “Tariff de cubage” in French is a mathematical formula which gives the unit volume of a given tree according to different variables. These variables can be the diameter, the circumference, the high..... The tariff is more valid for the area where the samples were collected (College of Forest Engineers of Quebec, 1996).

Diameters and highs of each Prunus tree section were collected using the “Bitterlich’s Relascope with large bands” or “SPIEGEL RELASKOP nach Dr W. Bitterlich. RELASKOP-TECHNIK VERTRIEBGES. M.b.h. Salzburg, made in Austria”. For each tree selected, we chose the best position which allows to see clearly the trunk. In this paper, the trunk refers to the distance between the DBH and the first big branch of the tree. We measured the horizontal distance and the distance according to the slope between our position and the tree. We measured the logging high which is the DBH and the useful high which is the high of the trunk. We measured the diameter and the percentage of the slope at logging high (DBH) and the diameter and the percentage of the slope at the first big branch level. After these measures, we determined the intermediary levels or measures for the percentage of the slope (P1, P2, P3) using the equi-distance formula which is: Eq = (Pu – Pa)/4, with P1 = Pa + Eq, P2 = P1 + Eq, P3 = P2 + Eq, and Pu = P3 + Eq. We measured the slopes and diameters at intermediary levels.

For each tree, we measured the thickness of the stem bark using the “Tarrière of Pressler”. The unit volume (on or under the bark) was calculated using the formula of Relascope of Bitterlich of large bands (National Office for Forest Development, 1992) which is:

$V = (\pi dh^2/8.106)*((P1-Pa)*(D1^2+Da^2) + (P2-P1)*(D2^2+D1^2) + (P3-P2)*(D3^2+D2^2) + (Pu-P3)*(Du^2+D3^2))$.

Where:

dh = ds x cosα = corrected horizontal distance;

ds = distance following the slope;

Pa, Pu, P1, P2, P3 = percentage of the slope at the logging level (or useful level), at the first big branch level, at point 1, 2, and 3 respectively;

Da, Du, D1, D2 and D3: diameter in Relascope unit (RU) obtained at the logging level, at the first big branch level, at point 1, 2, and 3 respectively

We also used the Smalian’s formula to estimate the volume:

$V = \pi/8 (Da^2 + Du^2) \times h$

Where:

Da = diameter at the logging level of the tree = DBH ;

Du = diameter at the first big branch level;

h = high of the trunk = distance between the logging level and the first big branch.

The volume of the bark was deduced from the following equation: Vb = V – Vo,

Where:

Vb = volume of the stem bark;

V = volume of the tree over the bark = with the bark;

Vo = volume of the tree under the bark = without the bark.

Assuming that Do = D – 2e with e = the thickness of the bark, Do = diameter of the tree under the bark and D = diameter of the tree over the bark, the volume of the bark can be determined through the following equation:

$Vb = (\pi h/2)*(e \times (Da + Du) – 2e^2)$.

The cubic tariff or the relation between the diameter and the volume of the stem bark was performed using linear regression. The best equation is that for which the correlation coefficient (R^2) is near to 1.

2.3.3.2. Relation linking the volume of the stem bark and its mass (weigh) = cubic mass

The mass per volume metre or cubic mass or “masse volumique” in French of an entity is the ratio of the mass of that entity and the volume occupied by that mass. Samples of the fresh bark were collected in all exploitable trees of the sample used to establish the cubic tariff (see above). For each sample we noted the volume, we weighted and found the equivalent mass. Equivalencies were made between the average volume of the samples and their corresponding fresh mass/weight. From those equivalencies, we deduced the cubic/volumic mass of *Prunus* barks in Tchabal Mbabo and Tchabal Gang Daba mountain forests. The cubic mass is Cm = m/V with m = mass in kilogramme (kg) and V = volume of the stem bark in cubic meter (m3).

2.3.3.3. Mass of the fresh bark for exploitable trees

In Cameroon, the minimum exploitable diameter (MED) for *Prunus* is 30 cm; this means that the stem bark can only be harvested from trees with diameter at DBH equal or more than 30 cm. We selected exploitable trees from the sample of trees used to yield the cubic tariff. Having the volume of the bark for each tree, we estimated the mass using the formula of the cubic mass (m = V x Cm). The average mass of all the exploitable trees was considered as the mass of an exploitable tree of *Prunus africana* for Tchabal Mbabo and Tchabal Gang Daba mountain forests.

In this paper, indirect method was preferred to direct method. A direct method would require diameter tape and bark thickness measurements at the critical heights (BH, first branch, etc), with some degree of verification through destructive sampling.

2.4. Results

2.4.1. Sampling intensity

Mount Tchabal Gang Daba and mount Tchabal Mbabo cover a total area of 239 938.42 ha. A total of 123 560.31 ha out of this area is considered to be a productive forest that contains *Prunus africana*. A total of 146.5 ha out of that productive forest was covered by inventories giving an average sampling intensity is 0.12% (table 1). This sampling intensity is low compared to the 1% obtained in mount Cameroon. The main reasons of this low sampling intensity is the dispersal character of the forest galleries which host *Prunus* and also the insecurity in some areas. It was not easy for some labourers (counters) to attend some areas due to the high accidental features (slopes more than 60%); this was mostly observed at the frontier/border between Cameroon and Nigeria, the Pinkou forest to be precise.

Table 1. number of galleries, number of plots per forest and sampling intensity

Forest	Galery	Layon	Number of classical plots (0.5 ha)	Number of ACS plots (0.2 ha)	Sampling area	Total area	Sampling intensity
Tchabal Gang Daba	1	6	20	6	11.2	2 566.23	0.44
Tchabal Mbabo	39	82	261	24	135.3	120 994.08	0.11
Total/medium	40	88	281	30	146.5	123 560.31	0.12

Source: Belinga 2011

2.4.2. Density of *Prunus* stems

2.4.2.1. All trees

A total of 1106 trees of *Prunus africana* were recorded in the 146.5 ha of the forest inventoried in mounts Tchabal Gang Daba and Tchabal Mbabo. One thousand seventy four (1074) of those trees were recorded in Tchabal Mbabo while 32 were recorded in Tchabal Gang Daba (Table 2).

Table 2. Distribution of number of trees recorded in the sample in Tchabal Gang Daba and Tchabal Mbabo

MED: Minimum exploitable diameter

Mount	C<10	C10-20	C20-30	C30-40	C40-50	C50-60	C60-70	C70-80	C80-90	C>90	Non exploitable stems (< MED)	Exploitable stems (≥ MED)	Total
Gang Daba	5	4	3	6	2	4	1	3	4		12	20	32
Mbabo	212	230	269	176	96	42	33	12	3	1	711	363	1 074
Total	217	234	272	182	98	46	34	15	7	1	723	383	1 106

Table 3 shows the distribution of density of trees in different diameter classes. The average density obtained is 7.55 stems/ha with 2.61 exploitable stems/ha. Inventories carried out with the traditional method by the National Office for Forest Development (Pouna & Belinga 2001) in the two harvesting sites found 12.29 stems/ha with 8.22 exploitable stems/ha at Tchabal Mbabo and 2.15 stems/ha with 0.99 exploitable stems/ha at Tchabal Gang Daba.

- :.

The highest density of *Prunus* trees is recorded in Tchabal Mbabo (7.94 stems/ha).

Table 3. Density of *Prunus* trees per diameter classes in Gang Daba and Mbabo

Mount	C<10	C10-20	C20-30	C30-40	C40-50	C50-60	C60-70	C70-80	C80-90	C>90	Non exploitable stems (< MED)	Exploitable stems (≥ MED)	Total
Gang Daba	0.45	0.36	0.27	0.54	0.18	0.36	0.09	0.27	0.36	-	1.07	1.79	2.86
Mbabo	1.57	1.70	1.99	1.30	0.71	0.31	0.24	0.09	0.02	0.01	5.25	2.68	7.94
Total	1.48	1.60	1.86	1.24	0.67	0.31	0.23	0.10	0.05	0.01	4.94	2.61	7.55

2.4.2.2. Living (healthy) trees

In this work, living (healthy) trees are those which are looking well, without dried branches. A total of 571 living trees were recorded, representing 51.6 of the total trees of the sample. (table 4). This result is largely different from the 89.1% of living trees recorded in mount Cameroon (Amougou et al. 2011).

Table 4. Distribution of Living *Prunus* stems in different diameter classes (C<10, C10-20, ...C>120)

Mount	C<10	C10-20	C20-30	C30-40	C40-50	C50-60	C60-70	C70-80	C80-90	C>90	Non exploitable stems (< MED)	Exploitable stems (≥ MED)	Total
Gang Daba	5	4	3	6	2	4	1	3	4		12	20	32
Mbabo	206	163	86	39	23	7	12		2	1	455	84	539
Total	211	167	89	45	25	11	13	3	6	1	467	104	571

Table 5 shows the density of living stems in different diameter classes. The average density of *Prunus* living trees is 3.90 stems/ha, with 0.71 stems/ha being exploitable trees.

Table 5. Distribution of density of living *Prunus* stems in different diameter classes (C<10, C10-20, ...C>120)

Mount	C<10	C10-20	C20-30	C30-40	C40-50	C50-60	C60-70	C70-80	C80-90	C>90	Non exploitable stems (< MED)	Exploitable stems (≥ MED)	Total
Gang Daba	0.45	0.36	0.27	0.54	0.18	0.36	0.09	0.27	0.36	-	1.07	1.79	2.86
Mbabo	1.52	1.20	0.64	0.29	0.17	0.05	0.09	-	0.01	0.01	3.36	0.62	3.98
Total	1.44	1.14	0.61	0.31	0.17	0.08	0.09	0.02	0.04	0.01	3.19	0.71	3.90

Figure 3 and 4 illustrates the specific curve of living *Prunus* stems in the natural forest of the mount Tchabal Gang Daba and mount Tchabal Mbabo respectively. We are in front of a normal situation where young individuals abund. This shows that *Prunus africana* population does not globally encounter problems of regeneration in the Adamaoua region. There is an important number of young trees.

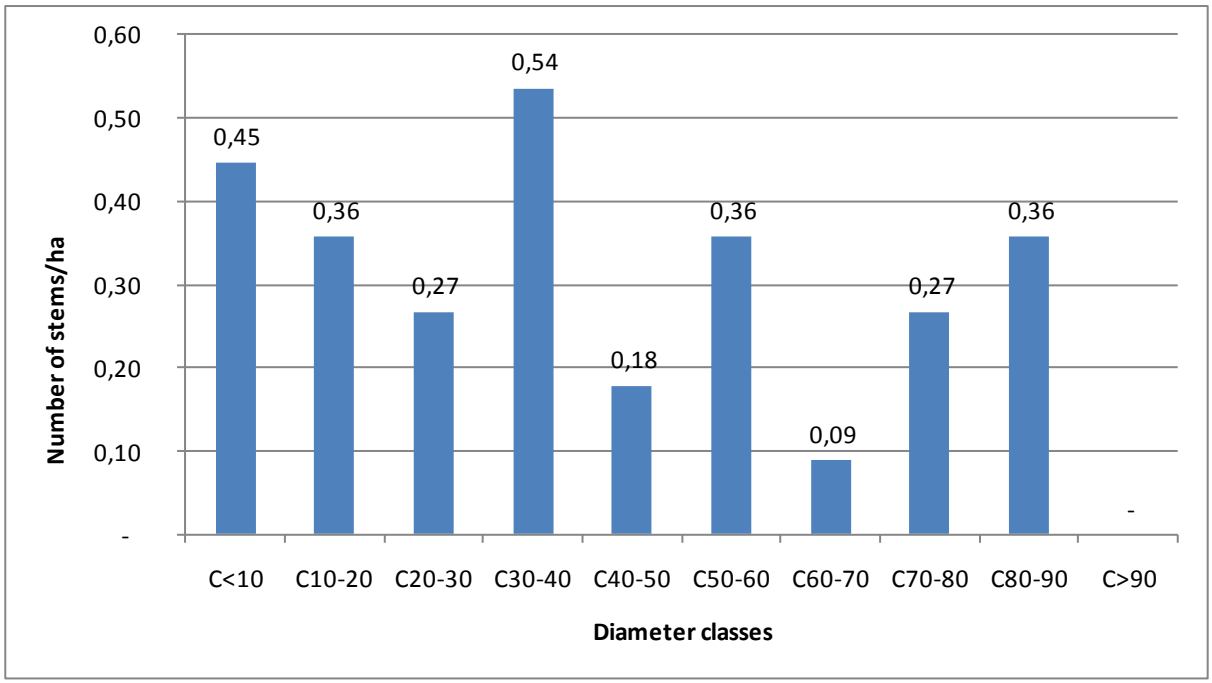

Figure 3. Distribution of living *Prunus* trees per diameter classes in the mount Tchabal Gang Daba

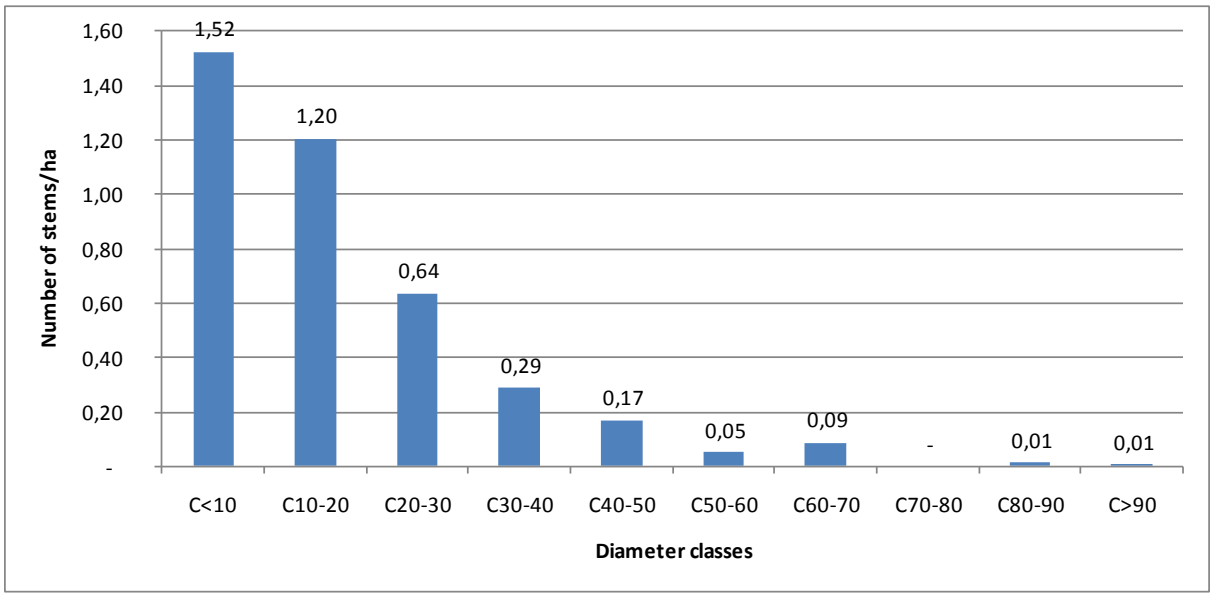

Figure 4. Distribution of living *Prunus* trees per diameter classes in the mount Tchabal Mbabo

2.4.2.3. Dead trees

In this analysis, we group all stems described in the field as being wilt (with some branches dried) or died in one category. A total of 445 dead or wilt *Prunus* trees were recorded in the mount Tchabal Mbabo. The average density of those trees is 3.69 stems/ha. The percentage of dead or wilt trees is 100 x 535/1106 = 48.3%, which is too much than the results obtained in Mount Oku (10%) and mount Cameroon (8%) using the same method (Amougou et al. 2010, 2011). All the 535 dead or wilt trees were recorded in Tchabal Mbabo. *Prunus*

harvesting has not yet started in Tchabal Gang Daba. *Prunus* bark exploitation started in Tchabal Mbabo in 1997, and an important number of trees have been exploited several times. The previous sites of exploitation such as Danwark and Dadawal have totally been destroyed due to inadequate and irrational techniques of harvesting used by the harvesters. The techniques of harvesting used were the systematic felling of trees and total debarking of stems (Betti 2008).

2.4.3. Total number of stems

Estimation of number of stems at the scale of the all mount Cameroon forest is presented in table 6. A total number of *Prunus* living trees estimated for the whole mount Cameroon area is 489 341,01 trees. The minimum exploitable diameter (MED) applied for *Prunus* in Cameroon is 30 cm. Among those trees, only 79 700,82 trees representing 16.28% of the total living trees have reached the MED and can therefore be harvested.

If we consider wilt and dead *Prunus* trees as the bonus that should be harvested, then the total number of trees to be harvested in the mount Cameroon is 41 042 trees which is high than what was obtained in mount Oku area (Amougou et al. 2010). The total number of *Prunus* trees retained for the simulation of the sustainable yield or harvesting quota is 41 042 trees.

Table 6. total number of *Prunus* stems estimated in the Adamaoua region

Mont	<10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	>90	Tige<DME	Tige>=DME	Total
Gang Daba	1155	924	693	1386	462	924	231	693	924	0	2746	4594	7339
Mbabo	183911	145193	77436	35088	20569	6050	10889	0	1210	1210	406540	75016	481556
Total	**185066**	**146117**	**78129**	**36474**	**21031**	**6974**	**11120**	**693**	**2134**	**1210**	**409286**	**79610**	**488896**

2.4.4. Simulation of sustainable yield

Cubic tariff

A total of 129 trees of *Prunus africana* were measured for the estimation of the cubic tariff or the relation linking the diameter of the tree with the volume of its bark. These trees are distributed in two main diameter classes as follow: 24 trees with DBH < 30 cm and 105 trees with DBH ≥ 30 cm. Measures regarding the diameters, the percentages of the slope, the thickness of the bark were collected on all the 129 trees. Appendix 1 shows the data recorded and the corresponding volume per tree. The relation diameter of the tree at breast high – volume of the stem bark is illustrated in figure 5. The best equation which links the diameter and the stem bark of the *Prunus* tree is: $Vb = 0.00001*D^{2.283}$, where : Vb is the volume of the stem bark in m^3 and D is the diameter of the tree at breast high in cm. The correlation coefficient is high, $R^2 = 0.82$.

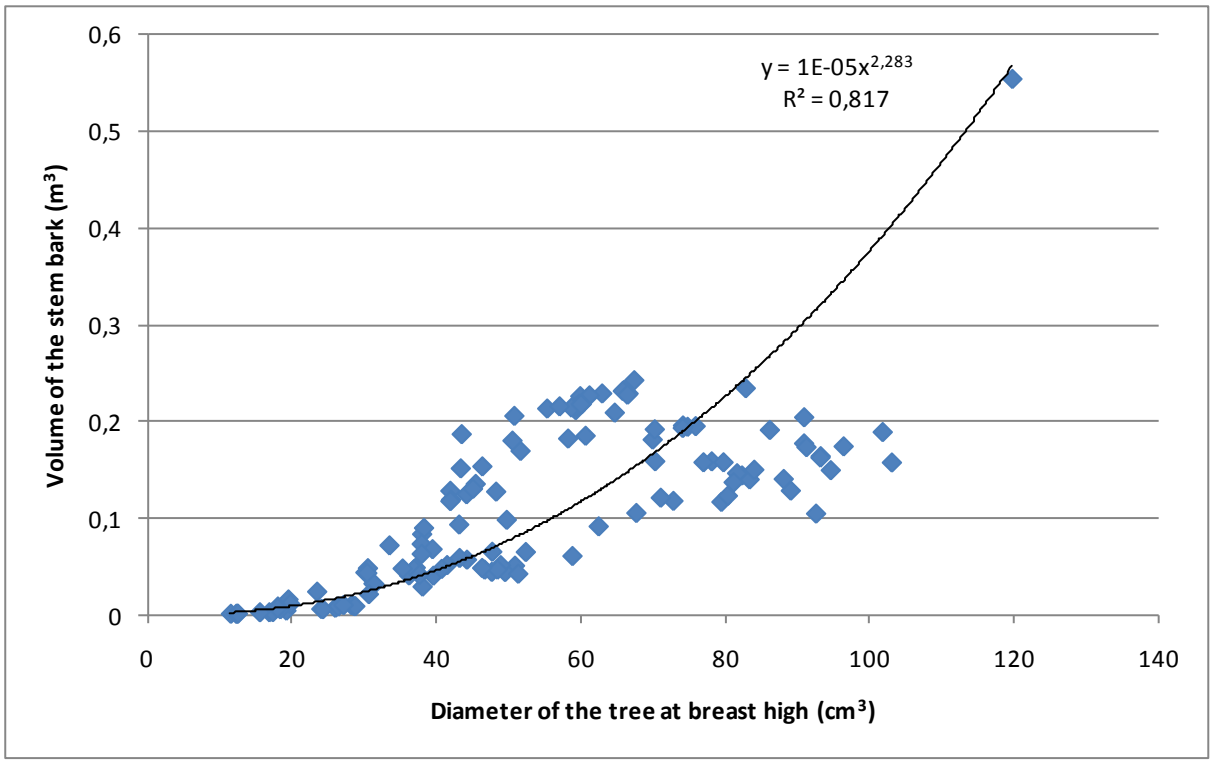

Figure 1. Volume of the fresh bark according to the diameter at breast high of the *Prunus* tree.

Cubic mass

A total of 105 samples of stem barks were collected for weighing, to determine the relation linking the volume of the bark with its mass. These samples were collected only on all the same 105 trees with DBH ≥ 30 cm used to yield the cubic tariff. Appendix 2 shows for each sample, its volume and the corresponding fresh mass in kilogram. The mean value of the ratio mass/volume is 1014.80 ± 9 Kg/m3.

The equation which links the volume of the stem bark and its mass is Mb = Vb* 1014.80 Kg/m3, where Mb = mass of the fresh bark in Kg and Vb = volume of the stem bark in m3.

Mass of exploitable trees

The 105 trees with DBH ≥ 30 cm were also selected to simulate the average fresh mass of *Prunus* barks. Appendix 3 presents for each exploitable tree, its volume and the corresponding mass in kilogram. From the table, it can be deduced that an exploitable tree of *Prunus africana* has an average mass of 138.6 ± 78.74 Kg in Tchabal Mbabo and Tchabal Gang Daba mountain forests. This represents the fresh weight or fresh mass for the total stem bark of a given exploitable trunk/tree.

Considering that for all trees above 30 cm DBH, only two quarters of the bark are taken from the main stem up to the first branch (Amougou et al., 2010; 2011; Ingram and al., 2009) the sustainable weight or mass of *Prunus* tree in Tchabal Mbabo and Tchabal Gang Daba mountain forests will be about 69.3 kg of fresh bark per tree.

In Tchabal Mbabo, the harvester can return to the same tree after 4-6 years (Betti 2008). Simulation of sustainable yield of *Prunus africana* in the Adamaoua region will therefore be based on two figures according to the rate of recovery: lowest estimate will be calculated using the rate of recovery of 6 years, while the highest estimate will be calculated based on the rate of 5 years. The average medium of the two figures will be used to simulate the sustainable yield or annual yield of bark.

The sustainable yield of fresh bark per annum for each forest will be = ((exploitable stems x average sustainable yield of bark per tree (= 69.3 kg))/ rate of total recovery of the bark (5 or 6 years).

Table 7 shows the simulation of the sustainable yield of fresh bark per annum for each forest according to different level of estimates. From the table, it can be established that the annual yield of fresh bark of *Prunus* in the Adamaoua region is 5 523 266.90 kg/year or 5 523.288 tons of fresh bark/year.

Table 7. Simulation of the sustainable yield of fresh bark of *Prunus africana* per annum for each forest in the Adamaoua region

Mont	Total area (ha)	Stem>=DME	Average mass /Stem (Kg fresh)	Total humid mass (Kg)
Gang Daba	2566,23	4594	69,3	318333
Mbabo	120 994,08	75016	69,3	5198632
Total	**123560,31**	**79610**		**5516965**

2.4.5. Simulation of the annual quota

In Cameroon, *Prunus africana* is exported in two forms: the raw bark and the “powder”. Powder here is referred to the bark shavings or the grinded barks. Whatever be the form, *Prunus* is exported in dried matter. The dried weight of *Prunus* barks to be exported is = 50% of fresh weight.

Table 8 shows the simulation of the annual quota according to different levels of estimates. From the table, it can be established that the annual quota of wild *Prunus* in mount Cameroon is 502 115.17 kg/year or **501.54 tons/year**. This quota is considered as the medium, obtained from the lowest estimated with a rate of recovery of 6 years (460 272.24 tons/year) and the highest estimate with a rate of recovery of 5 years (552 326.69 tons/year). This quota is less compared to the 700 tons estimated by Pouna & Belinga (2001) in the same region using classical inventory method.

Table 8. Simulation of the annual quota for *Prunus africana* in Tchabal Gang Daba and Tchabal Mbabo mountains

Mont	Tige>=DME	Redement moyen (Kg humide)	Poids humide des écorces(Kg)	Quota annuel (Kg humide)		
					Rotation	
				5ans	5,5 ans	6 ans
Gang Daba			159166,57	31833,31	28939,38	26527,76
Mbabo			2599315,82	519863,16	472602,88	433219,30
Total			**2758482,39**	**551696,48**	**501542,25**	**459747,06**

3. MONITORING SYSTEM

The main services working in the exploitation, transport, and exportation of special products belong to the Ministry of Forestry and Wildlife/Fauna (MINFOF), Ministry of Agriculture and Rural Development (MINADER), and Ministry of Economy and Finances (MINEFI). This chain has been described in details in the previous reports together with the relevant problems encountered in the field (Betti 2008; Amougou et al. 2010).

Adamaoua region is made of several decentralised forest units belonging to the Ministry of Forestry and Wildlife. At the regional level, there exists a delegation which comprises a forest department and a control and monitoring department. At the divisional level, the forest unit is coordinated by a delegation which comprises a forest section. Each subdivision hosts a local forest control post. The regional Delegation of Forestry and Wildlife is located in Ngaoundéré city and divisional Delegations are located in Banyo for Tchabal Mbabo and in Tignere for Tchabal Gang Daba. There exist a control post at Sambo Labo, in the bottom of Tchabal Mbabo. All those measures show that the harvesting of *Prunus africana* can be carefully controlled and monitored, in order to avoid over exploitation.

To enhance the sustainable harvesting of *Prunus africana* in Adamaoua region, the Government of Cameroon should tackle key problems observed on the control as proposed by the previous report of *Prunus* drafted for the North west region (Amougou et al. 2010). The development of a fair tracking system will be very helpful to sustain the harvesting of *Prunus* in the whole region of Adamaoua.

CONCLUSIONS

Since July 2010, the National Forestry Development Agency (ANAFOR) launched a specific project with the support of ITTO and CITES to sustain *Prunus africana* in Cameroon. Mount Tchabal Gang Daba and mount Tchabal Mbabo are the two areas which host *Prunus* population in the Adamaoua region of Cameroon. The average density of *Prunus* living trees is 3.90 stems/ha, with 0.71 stems/ha being exploitable trees. This density is high compared to what was obtained in North west and mount Cameroon areas. About 48.3% of trees recorded are dead or wilt, which is too much than the results obtained in Mount Oku (10%) and mount Cameroon (8%) using the same method (Amougou et al. 2010, 2011). All the 535 dead or wilt trees were recorded in Tchabal Mbabo which confirms the over exploitation mentioned for that area.

The annual quota estimated for the Adamaoua region is **502.11 tons/year**. This quota is considered as the medium, obtained from the lowest estimated with a rate of recovery of 6 years (460 272.24 tons/year) and the highest estimate with a rate of recovery of 5 years (552 326.69 tons/year).

To ensure the conservation of *Prunus africana* in Tchabal gang Daba and Tchabal Mbabo areas, following actions should be taken:

- Re-enforce capacities of all decentralised forest units found in the two areas in terms of human resources, logistics, and financial incentives in order to allow them to better control and monitor the exploitation, processing, and transport of *Prunus* products;
- filter the number of companies who are working in the field of *Prunus africana* as to keep those who are interested in sustainable management of the resource;
- address the issue of equity in the trade exchanges on *Prunus africana*. This should ensure that local communities are well motivated to conserve *Prunus africana* in their forests;
- accelerate the implementation of the procedures for the attribution of the Prunus Allocation Units (PAU);
- revise the modalities of access to the resource in terms of the selling price in accordance with the current forest law;

- propose a better system of taxation of *Prunus* products. The current 10 FCFA/kilogram perceived by the Cameroon Government as the regeneration tax cannot ensure the activities required for the sustainable management of the resource;
- develop and implement a fair tracking system to trace *Prunus* products from the forest till the exit points;
- encourage local people to develop *Prunus* plantations;
- assist local people in developing fair farming system that do not harm *Prunus* habitat.

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Appendix

Appendix 1. Data recorded and the corresponding volume per tree in Tchabal Mbabo and Tchabal Gang Daba (Ambara 2011)

DBH: diameter of the tree at breast high, Pa: percentage of the slope at the logging level or at breast high, Pu: percentage of the slope at the first big branch level, dh: horizontal distance, h: high, LB: number of large bands in relascope unit, SB: small band: number of small bands, Du: diameter of the tree at the first big branch level, e: thickness of the bark, V: volume of the bark.

N°_tree	DBH (cm)	P_a	P_u	d_h	h (m)	LB	SB	D_u (cm)	e (mm)	V (m^3)
1	39.49	-39	10	7	3.43	2	1	31.50	11	0.041
2	59.84	-28	37	10	6.50	2	3	55.00	20	0.226
3	36.13				4.00			31.20	10	0.041
4	59.68	-24	52	8	6.08	3	0	48.00	22	0.217
5	37.05	-42	14	9	5.04	1	2	27.00	10	0.049
6	43.42	10	127	9.3	10.88	1	3	32.55	15	0.187
7	31.20	27	62	10	3.50	1	1	25.00	11	0.033
8	59.21	-28	57	8	6.80	2	3	44.00	20	0.212
9	65.89	-19	28	11	5.17	2	3.5	63.25	23	0.233
10	33.42	-29	42	10.4	7.38	0	4	20.80	12	0.072
11	58.16	-17	38	10.8	5.94	2	1	48.60	19	0.183
12	30.43	-86	-16	8.23	5.76	1	1	20.58	11	0.049
13	62.87	-16	57	11.3	8.25	2	1	50.85	16	0.229
14	37.88	-13	80	6	5.58	2	2	30.00	11	0.063
15	41.40	-11	36	10.3	4.84	1	3	36.05	9	0.052
16	64.62	-16	39	11	6.05	2	1	49.50	20	0.209
17	40.64	17	64	9.6	4.51	1	2	28.80	10	0.048
18	41.85	35	137	8	8.16	1	3	28.00	15	0.129
19	51.57	-36	68	8	8.32	2	3	44.00	14	0.170
20	67.32	-24	48	10.5	7.56	2	1.5	49.88	18	0.243
21	66.53				5.80			63.19	20	0.229
22	43.29	-23	57	11.5	9.20	1	2	34.50	14	0.152

N°_tree	DBH (cm)	P_a	P_u	d_h	h (m)	LB	SB	D_u (cm)	e (mm)	V (m^3)
23	82.76	-24	39	7.4	4.66	5	2	81.40	20	0.235
24	65.73	-35	25	9.8	5.88	3	1	63.70	20	0.232
25	46.28	11	82	10.7	7.60	1	3	37.45	16	0.154
26	45.36	3	69	10	6.60	1	3	35.00	17	0.136
27	37.94	-69	4	7.55	5.51	2	1	33.98	14	0.084
28	59.72	-37	23	11	6.60	2	2	55.00	19	0.218
29	50.45	-26	51	10.5	8.09	2	1	47.25	15	0.180
30	61.12	-42	108	10.5	6.93	2	2	52.50	19	0.227
31	41.85	-27	28	11.5	6.33	1	3	40.25	15	0.118
32	60.04	1	63	12	7.44	1	3	42.00	19	0.218
33	49.66	-30	101	8	5.68	1	4	32.00	14	0.099
34	59.21	-16	49	9.7	6.31	2	2	48.50	21	0.215
35	119.69	-53	162	7	7.63	8	1	115.50	20	0.554
36	30.08	-22	26	8.5	4.08	1	3	29.75	12	0.044
37	48.19	-8	69	10	7.70	1	2	30.00	14	0.128
38	38.20	-17	56	9	6.57	1	2	27.00	14	0.090
39	58.63	-36	36	10	7.20	2	1	45.00	19	0.215
40	37.88	8	73	8.5	5.53	1	2	25.50	14	0.074
41	66.37	-84	36	7.13	8.56	2	4	42.78	16	0.228
42	59.94	-31	17	13	6.24	1	3	45.50	22	0.218
43	43.07	-20	37	10	5.70	1	4	40.00	13	0.094
44	50.71				9.60			49.65	14	0.206
45	55.26	16	83	11.6	7.77	1	3	40.60	19	0.214
46	56.98	-17	61	9.3	7.25	2	2	46.50	19	0.216
47	30.34	-31	16	9.5	4.47	1	1	23.75	12	0.044
48	44.09	0	74	9	6.66	1	3.5	33.75	16	0.125
49	41.95	-62	12	10.42	7.71	1	3	36.47	13	0.119
50	44.98	7	76	10.8	7.45	1	2	32.40	15	0.131
51	46.60	41	84	10.6	4.56	1	3	37.10	8	0.047
52	58.76	-26	18	12.5	5.50	1	3	43.75	7	0.061

N°_tree	DBH (cm)	P_a	P_u	d_h	h (m)	LB	SB	D_u (cm)	e (mm)	V (m^3)
53	36.80	37	94	11.7	6.67	1	1	29.25	7	0.047
54	52.30	3	36	11.6	3.83	1	3	40.60	12	0.065
55	50.80				3.40			46.98	10	0.051
56	49.43	3	41	12	4.56	1	1	30.00	8	0.045
57	78.05	31	120	12	10.68	1	3	42.00	8	0.159
58	93.14	12	78	14	9.24	2	2	70.00	7	0.164
59	48.83	17	38	8	4.40	2	1	36.00	9	0.052
60	79.68	77	11	11.51	10.13	2	0	46.04	8	0.158
61	44.15	16	52	9.5	6.46	1	4	38.00	7	0.057
62	94.54	26	78	9	9.36	4	1	76.50	6	0.150
63	101.73	23	56	13.5	10.67	3	1	87.75	6	0.189
64	47.59	8	38	11.6	3.48	1	1	29.00	11	0.045
65	81.08	33	48	11	8.91	2	3	60.50	7	0.137
66	47.65	3	57	10	5.40	1	4	40.00	9	0.066
67	82.25	5	73	11.4	7.75	2	1	51.30	9	0.144
68	35.24	23	38	9.7	5.92	1	1	24.25	9	0.048
69	103.00	21	86	12.5	8.13	2	4	75.00	7	0.158
70	90.84	9	87	13.7	10.69	2	1	61.65	7	0.178
71	31.32				3.60			27.47	10	0.032
72	96.32	17	84	11	11.11	3	1	71.50	6	0.174
73	39.38	24	41	10.5	6.83	1	1	26.25	10	0.068
74	51.25				2.29			50.29	12	0.043
75	62.39	44	37	9.5	7.70	2	2	47.50	7	0.092
76	67.61	13	42	12.5	6.88	2	1	56.25	8	0.106
77	86.10	34	48	13.4	10.99	2	3	73.70	7	0.191
78	69.87	6	84	13	10.14	2	1	58.50	9	0.181
79	38.00				2.36			36.48	11	0.029
80	83.30	14	107	10.6	9.86	3	1	68.90	6	0.140
81	74.71	13	64	11	8.47	2	3	60.50	11	0.195
82	91.17	3	81	15	11.70	2	1	67.50	6	0.174
83	89.00	22	81	13	7.67	2	2	65.00	7	0.129
84	60.58	27	143	11	12.76	1	4	44.00	9	0.185
85	37.56	-	18	10.5	4.31	1	1	26.25	10	0.042

N°_tree	DBH (cm)	P_a	P_u	d_h	h (m)	LB	SB	D_u (cm)	e (mm)	V (m^3)
		23								
86	70.22	-6	87	9.6	8.93	3	0	57.60	9	0.159
87	75.82	27	86	13.7	8.08	2	0	54.80	12	0.195
88	81.56	7	109	10.6	10.81	2	4	63.60	6	0.147
		-								
89	74.07	11	52	15	9.45	1	4	60.00	10	0.196
90	92.50	-3	53	10.4	5.82	3	2	72.80	7	0.105
		-								
91	72.74	30	81	8.5	9.44	2	2	42.50	7	0.118
92	30.56				2.53			26.10	10	0.022
93	93.11	17	68	13.6	6.94	2	3	74.80	9	0.163
94	74.04	-4	69	11.4	8.32	2	3	62.70	11	0.193
		-								
95	43.13	72	14	6.89	5.93	2	3	37.90	8	0.059
		-								
96	90.85	42	51	12.6	11.72	2	3	69.30	7	0.205
97	79.39	18	82	9.7	6.21	2	3.5	55.78	9	0.117
98	80.28	11	71	13	7.80	2	2	65.00	7	0.123
99	48.38				2.70			46.47	12	0.047
100	70.99	8	101	10.6	9.86	1	4	42.40	7	0.121
		-								
101	88.02	34	23	14.7	8.38	2	1	66.15	7	0.141
		-								
102	46.25	10	34	8	3.52	2	3	44.00	10	0.049
		-								
103	70.16	13	51	13	8.32	1	3	45.50	13	0.192
104	76.91	26	84	12.6	7.31	2	0	50.40	11	0.158
105	83.94	8	104	8.7	8.35	3	2	60.90	8	0.150
106	18.89	6	48	8.7	3.65	0	3	13.05	6	0.011
107	17.96				3.50			15.76	5	0.009
108	19.14				1.20			17.77	7	0.005
109	18.11	-2	36	9	3.42	0	3.5	15.75	4	0.007
110	12.32				0.76			11.72	5	0.001
111	16.78				1.35			12.75	5	0.003
112	11.45				0.89			9.72	5	0.001
113	12.20				0.85			10.84	5	0.001
114	12.42				0.87			11.61	5	0.002
		-								
115	19.43	13	26	10	3.90	0	3.5	17.50	7.5	0.016
116	19.68				3.40			17.94	6	0.012
117	17.26				1.23			16.59	5	0.003
118	18.31				2.30			16.43	5	0.006
119	17.93				2.30			17.00	6	0.007
120	15.48				1.40			12.73	5	0.003
121	24.20				1.30			20.37	7	0.006
122	28.68				1.82			26.74	6	0.009

N°_tree	DBH (cm)	P_a	P_u	d_h	h (m)	LB	SB	D_u (cm)	e (mm)	V (m^3)
123	27.06				1.85			25.78	7	0.010
124	23.40				3.26			21.96	11	0.024
125	23.97				2.34			20.53	4	0.006
126	25.91				1.42			24.29	7	0.008
127	28.49				1.63			25.91	7	0.009
128	26.33				1.64			24.77	7	0.009
129	28.17				1.77			26.10	7	0.010

Appendix 2. volumes of stem bark samples with their corresponding mass (Ambara 2011)

N°_Tree	Long (cm)	Large (cm)	Thickness (mm)	Volume (m3)	Mass (Kg)	Ratio (m/v)
1	25	7.8	13.00	0.000	0.26	1025.641
2	16.5	11	13.76	0.000	0.25	1001.272
3	31.2	10.25	16.00	0.001	0.53	1035.804
4	27.3	7.6	13.25	0.000	0.28	1018.511
5	35.5	7.4	19.20	0.001	0.51	1011.134
6	16	11.7	21.15	0.000	0.4	1010.285
7	32	9.87	17.00	0.001	0.54	1005.721
8	31	10.7	16.45	0.001	0.55	1007.979
9	27	7.5	14.80	0.000	0.3	1001.001
10	31.6	8.5	16.85	0.000	0.46	1016.370
11	22.6	7	18.75	0.000	0.3	1011.378
12	30	7.4	14.76	0.000	0.33	1007.419
13	21	9.3	18.15	0.000	0.36	1015.792
14	36	6.8	18.00	0.000	0.45	1021.242
15	16	8.5	21.75	0.000	0.3	1014.199
16	16	11.5	16.25	0.000	0.3	1003.344
17	18	14.3	18.00	0.000	0.47	1014.418
18	17.5	14	19.50	0.000	0.48	1004.710
19	19	9.25	20.00	0.000	0.36	1024.182
20	25.7	8.5	10.80	0.000	0.24	1017.268
21	25.4	9	12.00	0.000	0.28	1020.706
22	16.5	11	9.25	0.000	0.17	1012.583
23	29.7	8.2	18.00	0.000	0.44	1003.714
24	13	12.7	8.35	0.000	0.14	1015.534
25	26.5	6	21.00	0.000	0.34	1018.269
26	22	6.5	24.45	0.000	0.35	1001.044
27	24	8.3	12.00	0.000	0.24	1004.016
28	29.6	8	13.33	0.000	0.32	1013.514
29	21.5	9.2	22.70	0.000	0.46	1024.485
30	24	9.8	11.67	0.000	0.28	1020.408
31	17.8	13	17.05	0.000	0.4	1013.847
32	23	6.5	18.25	0.000	0.28	1026.252

N°_Tree	Long (cm)	Large (cm)	Thickness (mm)	Volume (m3)	Mass (Kg)	Ratio (m/v)
33	30	7	19.65	0.000	0.42	1017.812
34	26	8	24.45	0.001	0.52	1022.328
35	30	8.1	14.67	0.000	0.36	1010.101
36	32.5	9	14.25	0.000	0.42	1007.647
37	28.5	4.75	19.00	0.000	0.26	1010.837
38	19	6	19.75	0.000	0.23	1021.334
39	18	9.3	20.00	0.000	0.34	1015.532
40	16.4	10.2	19.00	0.000	0.32	1006.821
41	28.5	7.5	14.70	0.000	0.32	1018.419
42	15.5	10.1	15.00	0.000	0.24	1022.038
43	27	7.5	15.60	0.000	0.32	1012.979
44	16	12	16.80	0.000	0.33	1023.065
45	26	5.5	19.25	0.000	0.28	1016.953
46	15.5	10.8	17.65	0.000	0.3	1015.362
47	29.7	7	16.33	0.000	0.34	1001.266
48	18.7	11.6	22.75	0.000	0.5	1013.186
49	18.5	12	21.54	0.000	0.49	1024.702
50	17	11.7	13.85	0.000	0.28	1016.274
51	13.4	9	9.00	0.000	0.11	1013.451
52	27.7	8	7.15	0.000	0.16	1009.821
53	14	10	9.00	0.000	0.13	1031.746
54	19	6.5	6.45	0.000	0.08	1004.300
55	12.5	9	6.65	0.000	0.075	1002.506
56	14.5	10	8.00	0.000	0.12	1034.483
57	16	9.5	7.65	0.000	0.12	1031.992
58	15	8.5	13.65	0.000	0.18	1034.260
59	13.5	11	11.80	0.000	0.18	1027.221
60	18	9	10.70	0.000	0.18	1038.422
61	17	10.5	6.54	0.000	0.12	1027.934
62	20.1	10.6	10.00	0.000	0.22	1032.573
63	17.4	10.4	7.00	0.000	0.13	1026.273
64	14.5	9.6	11.25	0.000	0.16	1021.711
65	16.5	9.2	8.50	0.000	0.13	1007.518
66	18.3	9	9.56	0.000	0.16	1016.175
67	24	8.5	9.67	0.000	0.2	1014.206
68	16.5	7.6	12.50	0.000	0.16	1020.734
69	25	9.5	8.00	0.000	0.19	1000.000
70	18.4	8	8.65	0.000	0.13	1020.985
71	24.6	6.7	6.00	0.000	0.1	1011.204
72	23	7.5	8.00	0.000	0.14	1014.493
73	28	6	7.50	0.000	0.13	1031.746
74	16.5	8	9.00	0.000	0.12	1010.101
75	14.5	10.3	7.25	0.000	0.11	1015.896
76	18.6	8.3	11.00	0.000	0.17	1001.072

N°_Tree	Long (cm)	Large (cm)	Thickness (mm)	Volume (m3)	Mass (Kg)	Ratio (m/v)
77	18	12	12.00	0.000	0.26	1003.086
78	15	9.5	10.26	0.000	0.15	1026.297
79	25	8.5	7.50	0.000	0.16	1003.922
80	17.7	8.3	12.00	0.000	0.18	1021.033
81	16	8.5	11.00	0.000	0.15	1002.674
82	21	7.6	11.00	0.000	0.18	1025.290
83	20.5	7.5	9.00	0.000	0.14	1011.743
84	20	6	9.00	0.000	0.11	1018.519
85	17.3	9.2	10.00	0.000	0.16	1005.278
86	26.5	7.5	9.00	0.000	0.18	1006.289
87	15	10	6.56	0.000	0.1	1016.260
88	20.5	8.8	12.00	0.000	0.22	1016.260
89	15	8	11.50	0.000	0.14	1014.493
90	16.5	8.9	9.50	0.000	0.14	1003.530
91	25	8.5	7.00	0.000	0.15	1008.403
92	16	12.4	10.00	0.000	0.2	1008.065
93	20.3	8.8	10.00	0.000	0.18	1007.613
94	26.7	9.4	7.00	0.000	0.18	1024.555
95	16.6	8	13.50	0.000	0.18	1004.016
96	17.4	11.3	8.00	0.000	0.16	1017.191
97	16.5	11.5	9.40	0.000	0.18	1009.167
98	18.7	7.2	10.25	0.000	0.14	1014.449
99	17	7.6	13.75	0.000	0.18	1013.228
100	28	8.1	7.00	0.000	0.16	1007.811
101	16	9.6	12.85	0.000	0.2	1013.294
102	14.7	10.2	7.30	0.000	0.11	1004.968
103	20.4	8.5	8.00	0.000	0.14	1009.227
104	17.8	6.7	10.00	0.000	0.12	1006.205
105	20	7	12.00	0.000	0.17	1011.905
Mean						**1014.803**

Appendix 3. Productivity of exploitable Prunus *trees in term of the mass of the fresh bark (Ambara 2011).*

N°	DBH (cm)	Volume (m^3)	Masse (Kg)
1	39.49	0.041	41.371
2	59.84	0.226	229.682
3	36.13	0.041	41.654
4	59.68	0.217	220.206
5	37.05	0.049	49.849
6	43.42	0.187	189.842
7	31.2	0.033	33.139
8	59.21	0.212	215.071

N°	DBH (cm)	Volume (m^3)	Masse (Kg)
9	65.89	0.233	236.056
10	33.42	0.072	73.191
11	58.16	0.183	185.224
12	30.43	0.049	49.299
13	62.87	0.229	232.514
14	37.88	0.063	64.261
15	41.4	0.052	52.538
16	64.62	0.209	212.392
17	40.64	0.048	48.504
18	41.85	0.129	130.428
19	51.57	0.170	172.245
20	67.32	0.243	246.400
21	66.53	0.229	232.461
22	43.29	0.152	153.960
23	82.76	0.235	238.037
24	65.73	0.232	235.124
25	46.28	0.154	156.030
26	45.36	0.136	137.640
27	37.94	0.084	85.008
28	59.72	0.218	221.715
29	50.45	0.180	183.066
30	61.12	0.227	230.492
31	41.85	0.118	119.623
32	60.04	0.218	221.362
33	49.66	0.099	99.959
34	59.21	0.215	218.461
35	119.69	0.554	562.356
36	30.08	0.044	44.820
37	48.19	0.128	129.545
38	38.2	0.090	91.488
39	58.63	0.215	217.688
40	37.88	0.074	74.693
41	66.37	0.228	231.195
42	59.94	0.218	221.100
43	43.07	0.094	95.047
44	50.71	0.206	209.006
45	55.26	0.214	216.693
46	56.98	0.216	218.991
47	30.34	0.044	44.147
48	44.09	0.125	126.781
49	41.95	0.119	121.147
50	44.98	0.131	132.528
51	46.6	0.047	47.719
52	58.76	0.061	62.050

N°	DBH (cm)	Volume (m^3)	Masse (Kg)
53	36.8	0.047	48.108
54	52.3	0.065	66.266
55	50.8	0.051	51.909
56	49.43	0.045	45.257
57	78.05	0.159	161.318
58	93.14	0.164	166.754
59	48.83	0.052	52.410
60	79.68	0.158	160.316
61	44.15	0.057	58.205
62	94.54	0.150	152.039
63	101.73	0.189	192.045
64	47.59	0.045	45.391
65	81.08	0.137	139.364
66	47.65	0.066	66.507
67	82.25	0.144	146.519
68	35.24	0.048	48.970
69	103	0.158	160.103
70	90.84	0.178	180.151
71	31.32	0.032	32.588
72	96.32	0.174	177.043
73	39.38	0.068	69.223
74	51.25	0.043	43.426
75	62.39	0.092	93.150
76	67.61	0.106	107.185
77	86.1	0.191	194.205
78	69.87	0.181	184.119
79	38	0.029	29.910
80	83.3	0.140	142.365
81	74.71	0.195	197.537
82	91.17	0.174	176.207
83	89	0.129	130.598
84	60.58	0.185	188.144
85	37.56	0.042	42.415
86	70.22	0.159	161.407
87	75.82	0.195	198.243
88	81.56	0.147	148.863
89	74.07	0.196	198.941
90	92.5	0.105	106.509
91	72.74	0.118	119.846
92	30.56	0.022	22.043
93	93.11	0.163	165.286
94	74.04	0.193	196.318
95	43.13	0.059	60.014
96	90.85	0.205	207.564

N°	DBH (cm)	Volume (m^3)	Masse (Kg)
97	79.39	0.117	118.775
98	80.28	0.123	125.222
99	48.38	0.047	47.746
100	70.99	0.121	123.184
101	88.02	0.141	142.829
102	46.25	0.049	49.516
103	70.16	0.192	194.923
104	76.91	0.158	160.314
105	83.94	0.150	152.557
Mean			138,606
SE			78,74