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*Full Length Research Paper*

# Mass of *Prunus africana* stem barks on Tchabal mbabo and Tchabal Gang Daba Mountain Forests, Cameroon

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***Prunus africana* is a species of the Rosaceae family, known under its common name as pygeum or African cherry. The bark is the major source of an extract used to treat benign prostatic hyperplasia, an increasingly common health problem in older men in the western world. A study which aimed to produce a formula for establishing the mass of the bark of *Prunus africana* specimens was carried out in May 2011 on Tchabal Mbabo and Tchabal Gang Daba mountain forests, in the Adamaoua region of Cameroon. The diameter at breast height (DBH), the height of the tree and the thickness of the stem bark of each pygeum tree were recorded in order to establish the cubic volume of each specimen. This data was used to calculate the relationship between the diameter and the volume of the bark. Samples of bark were collected in order to establish the relationship between the volume of the bark and its mass (measure mass per cubic metre). A total of 105 pygeum trees were sampled, including 50 trees in Gang Daba considered as an un-exploited production site and 55 trees in Mbabo referred to an exploited production site. The best equation which links the volume (Vb) of fresh barks to the diameter (D) of each pygeum tree is Vb=a/(1+b*exp(-cD)) with a = 1.79588278896E-001, b = 5.29124992540E+002, c = 1.45488065368E-001. The average thickness of the bark is 13.01 ± 4.8 mm. This value is comprised between that of unexploited (16.99 ± 3.7 mm) and exploited (9.40 ± 2.07 mm) pygeum trees. 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, the average sustainable mass of pygeum tree in Adamaoua region will be about 69.3 kg of fresh bark per tree. This value is comprised between that of unexploited (80 kg) and exploited (60 kg) pygeum trees in Ganga Daba and Mbabo respectively.**

**Key words:** Threatened species, *Prunus africana*, pygeum, Tchabal mountain forests, Bitterlich's Relascope, cubic tariff, CITES.

## INTRODUCTION

*Prunus africana* (Hook.f.) Kalkman (formerly *Pygeum africanum* Hook.f.) is a species of the Rosaceae family, known under its trade/pilot name as pygeum or African cherry. It is a mountain tree species of the tropical Africa including Côte d'Ivoire, Bioko, Sao Tome, Ethiopia, Kenya, Uganda, South Africa, Madagascar, Congo, the Democratic Republic of Congo, Mozambique, Tanzania, Burundi and Cameroon. *P . africana* grows well in the sub-mountain and mountain forests at an altitude of 800 – 3000 m. In Cameroon, the plant is largely found in five regions including Adamaoua, North west, Littoral, South west, and West. *P. africana* is an evergreen canopy tree to 30 m tall with thick, fissured bark and straight bole that can reach a diameter of 1.5 m. It is light demanding and responds well to cultivation (Hall et al., 2000; Vivien and Faure, 1985; Fraser et al., 1996; Tchouto, 1996).

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The bark is black to brown, corrugated or fissured and scaly, fissuring in a characteristic rectangular pattern. The fruits of *P. africana* are drupaceous, fleshy and red-purple in colours and are said to be eaten by a variety of birds and mammals (Cunningham and Mbenkum, 1993).

The bark is the major source of an extract used to treat benign prostatic hyperplasia, an increasingly common health problem in older men in the western world. Prostate-related diseases increase in prevalence as men age. And as the average age of the world's population increases, the incidences of prostate diseases will increase as well, triggering a corresponding rise in demand for therapies. According to the World Cancer Research Fund International, prostate cancer is the second most common cancer in men worldwide. Around 910,000 cases of prostate cancer were recorded in 2008, accounting for approximately 14% of all new cancer cases in men (World Agroforestry Centre, 2012). Bark extracts contain fatty acids, sterols and pentacyclic terpenoids (Cunningham and Mbenkum, 1993). The drugs processed from the bark extracts are sold under the brand-name of "Tadenan" in France by Laboratoire Debat, "Pygenil" in Italy by Indena Spa, and "Proscar" in UK by Merck Sharp and Dohme Ltd (ICRAF cit. Ndam, 1996). The United Nations Food and Agriculture Organization (FAO) reported as far back as 1996 that the demand for the species' bark, which is used to produce treatments for prostate gland disorders, could lead to its over-exploitation (FAO, 1996). In 1997, the global need is about 4 000 tons of dried barks per year for a value of 220 millions of USD. Two hundred kilogram of dried bark yield 5 kilogram of extract (Cunningham et al., 1997). The trade in dried pygeum bark and bark extract is in the order of 3 000 to 5 000 tonnes a year (Page, 2003) and the main sources are in Cameroon, Madagascar, Equatorial Guinea, Kenya, Uganda, and Tanzania. Cameroon was one of the major sources of Pygeum supply from the early 1970s, when the French company laboratoire Debat established a factory at Mutengene, on the lower slopes of Mount Cameroon. Operating as Plantecam Medicam, the company prepared bark extracts in tablets form from bark harvested in the wild. Between 1972 and 1985, Plantecam had a monopoly of the harvesting licenses for Pygeum and as a result was able to control exploitation. After 1985, when Plantecam's monopoly was revoked and many additional harvesting licenses were provided to Cameroonian entrepreneurs, the level of regulation of bark harvesting declined (Ndibi and Kay, 1997). Harvesting permits for a total of 2 558.37 tons of pygeum dried bark was granted to 33 trade companies by the Cameroon forest administration in 2005 (2 000 tons) and 2006 (1 260 tons). A total of 2 558.37 tons of pygeum bark (78.5% of the granted pygeum) exported from the Douala port was recorded by the national database on trade forest products. The most important quantity of the barks was exported in 2005 (1 498.5 tons) and the remaining (1 059.87 tons) was exported in 2006 (Betti, 2008).

*P. africana* is classified by the World Alliance for Nature (IUCN) as vulnerable species, which led to its listing in the Appendix II of the Convention on International Trade in Endangered Species of Fauna and Flora (CITES) in 1994, becoming effective in 1995 (Sunderland and Tako, 1999). Once a species is listed in Appendix II of CITES, its exportation is regulated in terms of quota. In Cameroon the minimum exploitable diameter (MED) for *Prunus* trees is 30 cm and till 2006, the national CITES quota for *P. africana* dried barks was 2000 tons/year. The data are not available to give precise figures, however it is clear from the increasing level of exploitation that the pygeum population is declining over time in terms of tree size, density of stand and overall tree population, resulting in declining habitat quality (Betti, 2008). *P. africana* can be considered at least as an endangered plant species in Cameroon according to population reduction as outlined in the IUCN check list for Non-Detriment Findings (IUCN, 2001). This explains the ban pronounced on October 2007 by the European Commission on Cameroon's pygeum. The pygeum ban impacts both the economic operators and the local people for whom *P. africana* represents an important non timber forest product. Cameroon was proposed for ban as there are concerns that some provisions regarding the sustainable harvesting of *P. africana* barks are not being fully met.

A key requirement of CITES is the non-detriment findings (NDF) made by the Scientific Authority of the range State prior to export, certifying that export is not detrimental to the survival of the species in its natural habitat. This requires information on the location, stocking, growth and condition 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, establishment of quota and conditions attached to be difficult.

Recognizing the shortcomings in scientific information related to the sustainable harvesting of *P. africana*, the government of Cameroon submitted to the International Tropical Timber Organization (ITTO) for funding the project entitled "Non-detriment findings (NDF) for *P. africana* (Hook.f.) Kalman in Cameroon". The first important outputs of the project were the production of the partial NDF reports on *P. africana* for the mount Oku and mount Cameroon, respectively in the North west and South west regions of Cameroon. An annual quota of 350 tons of dried barks were estimated for the two regions (Akoa et al., 2010, 2011), which lifted the partial ban on the exportation of *P. africana* barks from Cameroon.

This paper aims to estimate the mass of the fresh bark of *P. africana* on Tchabal Mbabo and Tchabal Gang Daba mountain forests, Adamaoua region of Cameroon, as a contribution for making non-detriment findings on *P. africana* for that region.

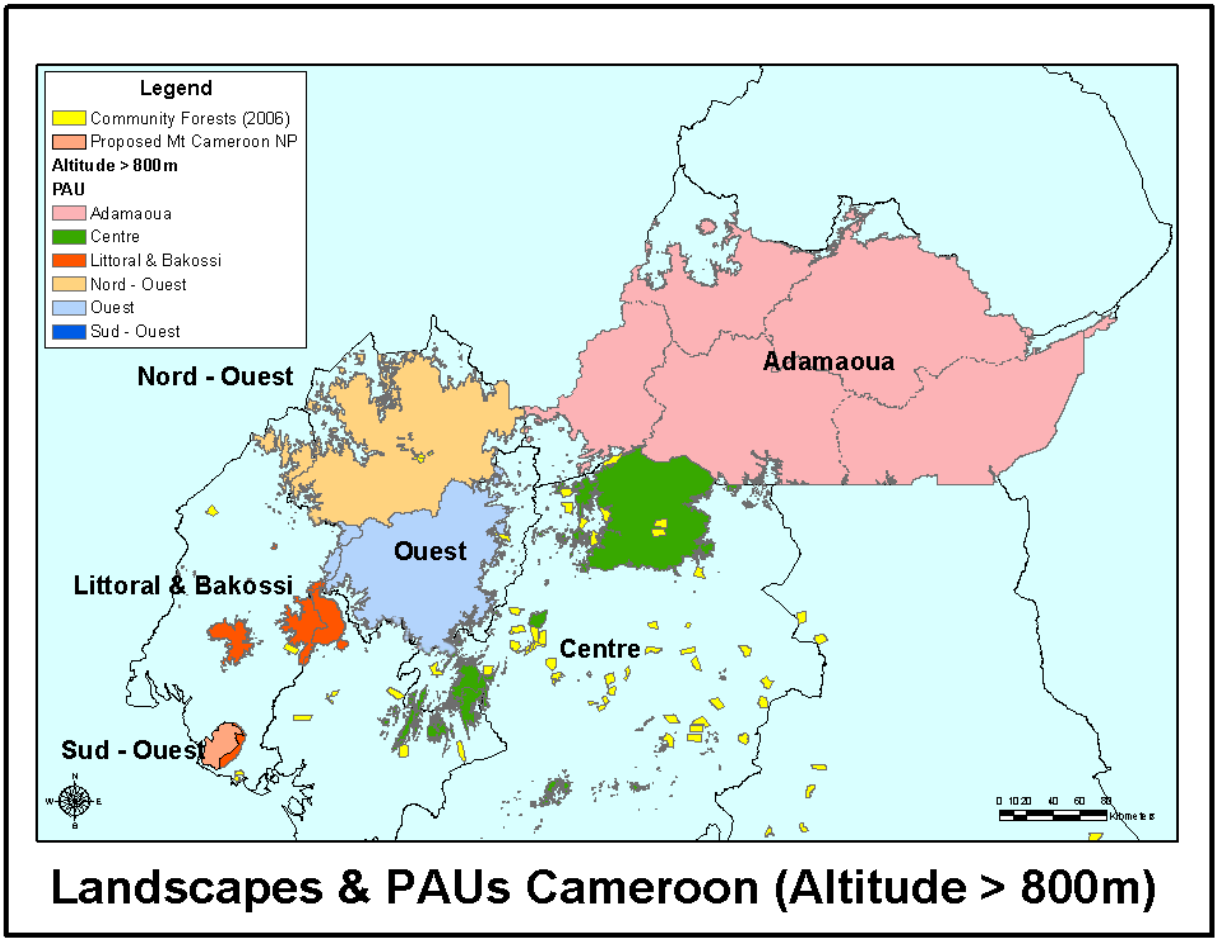


**Figure 1.** Landscapes and *Prunus* Allocation Units (PAUs) in Cameroon.

## MATERIALS AND METHODS

### Study site

Cameroon is located in Central Africa, in the bottom of the Guinean gulf. Cameroon is divided into ten regions including: centre, east, far north, north, north west, south, south west, west, and Adamaoua. Among the ten regions, six, namely Adamaoua (Ngaoundéré being the capital), the Centre (Yaoundé), Littoral (Douala), North West (Bamenda), Southwest (Buea), and West (Bafoussam), are regions where populations of *P. africana* occur. But the main reserves of *P. africana* are found in the Adamaoua, North West and South West regions. The major landscapes of Cameroon containing *P. africana* have been agreed, defined and consolidated into *Prunus* Allocation Units (PAUs) that cover six mountain areas (Figure 1).

The Adamaoua region is vast of 63 701 $km^2$ 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 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, situated between 7°10’ to 7°40’ latitude Nord, and 11°7’ to 12°20’ longitude East. 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, situated between 7°40’ to 7°55’ latitude Nord and 12°38’ to 12°56’ longitude East. Gang Daba is located at 10 km from Tignère city, 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 *P. 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 *P. 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. The harvesting of *P. africana* started in Tchabal Mbabo by the year 2000 by two national trade companies including AFRIMED and ERIMON (Akagou and Betti, 2007).

In Tchabal Gang Daba, there are no 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*. Tchabal Gang Daba has never been subject to *P. africana* exploitation.

## Method

### *Selection of trees*

This study was conducted in may 2011 in Tchabal Mbabo and Tchabal Gang Daba mountain forests, Adamaoua region, Cameroon. The study was conducted in the frame of the project "Non-detriment findings for *P. africana* (Hook.f.) Kalman in Cameroon" implemented by the Cameroon's National Forestry Development Agency, with the support of the International Tropical Timber Organization (ITTO), the Convention on International Trade in Endangered Species of Fauna and Flora (CITES), and the European Commission (EC). The study started one month later after the team in charge of assessing the abundance of *P. africana* trees in Mbabo and Gang Daba has finalised their work. The sheets of the team in charge of counting were used to select the best trees that can allow to better appreciate the mass of the stem bark of *P. africana* trees. Practically, trees were randomly selected according to their diameter, their accessibility, their healthy and their conformity (only straight stems were selected). Once a given stem was identified in a counting sheet, we noted its geographical data (latitude and longitude) and we went with the global position system (GPS) in the field to take appropriated measures of that stem. A total of 105 *P. africana* trees were sampled including: 50 trees in Gang Daba and 55 trees in Mbabo.

To estimate the mass of the stem barks of *P. africana*, we used an indirect method and proceeded in three steps: establishment of the relation linking the diameter at breast height (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.

### *Relation diameter at DBH – thickness of volume of the stem bark: volume based tariff*

The volume based tariff 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 height,...... The tariff is more valid for the area where the samples were collected (College of Forest Engineers of Quebec, 1996).

The diameter and the height of each *P. africana* tree section were measured using the "Bitterlich's Relascope with large bands" or "SPIEGEL RELASKOP". 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 breast height and the useful height which is the height of the trunk. We measured the diameter and the percentage of the slope at logging height (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 ($P_1$, $P_2$, $P_3$) using the equi-distance formula which is: $Eq = (P_u - P_a)/4$, with $P_1 = P_a + Eq$, $P_2 = P_1 + Eq$, $P_3 = P_2 + Eq$, and $P_u = P_3 + Eq$. We measured the slopes and diameters at intermediary levels. For short trees, we estimated directly the volume by measuring the DBH, the height of the tree, and the diameter at the first big branch level. We did not measured the intermediary levels, which explains the absence of some data as shown in Table 1. Their volumes were determined directly through the Smalian's formula (see below).

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, V is the unit volume (on or under the bark); $d_h = d_s \times \cos\alpha$ = corrected horizontal distance; $d_s$ is the distance following the slope; $P_a$, $P_u$, $P_1$, $P_2$, $P_3$ are the percentage of the slope at the logging level (or useful level), at the first big branch level, at point 1, 2, and 3 respectively; $D_a$, $D_u$, $D_1$, $D_2$ and $D_3$: 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:

$$V = \pi/8\ (D_a^2 + D_u^2) \times h$$

Where, $D_a$ is the diameter at the logging level of the tree = DBH; $D_u$ is the diameter at the first big branch level; h is the height of the trunk = distance between the logging level and the first big branch.

The volume of the bark was deduced from the following equation:

$$V_b = V - V_o,$$

Where: $V_b$ is the volume of the stem bark; V is the volume of the tree over the bark = with the bark; $V_o$ is the volume of the tree under the bark = without the bark.

Assuming that $D_o = D - 2e$ with e = the thickness of the bark, $D_o$ = 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:

$$V_b = (\pi h/2)*(e \times (D_a + D_u) - 2e^2).$$

### Relation linking the volume of the stem bark and its mass = cubic mass

The cubic mass 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 volume based tariff (see above). For each sample we noted the length (cm), the width (cm), and the thickness (mm). The thickness of the bark in this section was measured using the calliper rule. The three measures including the length, the width, and the thickness allowed us to obtain the volume of the bark sample. We weighted the sample 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 *P. africana* 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 ($m^3$).

**Table 1.** Data recorded and the corresponding volume per tree in Tchabal Mbabo and Tchabal Gang Daba.

| N°_tree | DBH (cm) | $P_a$ | $P_u$ | $d_h$ | h (m) | LB | SB | $D_u$ (cm) | e (mm) | V ($m^3$) | Site |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 39.49 | -39 | 10 | 7 | 3.43 | 2 | 1 | 31.50 | 11 | 0.041 | Gang Daba |
| 2 | 59.84 | -28 | 37 | 10 | 6.50 | 2 | 3 | 55.00 | 20 | 0.226 | Gang Daba |
| 3 | 36.13 | | | | 4.00 | | | 31.20 | 10 | 0.041 | Gang Daba |
| 4 | 59.68 | -24 | 52 | 8 | 6.08 | 3 | 0 | 48.00 | 22 | 0.217 | Gang Daba |
| 5 | 37.05 | -42 | 14 | 9 | 5.04 | 1 | 2 | 27.00 | 10 | 0.049 | Gang Daba |
| 6 | 43.42 | 10 | 127 | 9.3 | 10.88 | 1 | 3 | 32.55 | 15 | 0.187 | Gang Daba |
| 7 | 31.20 | 27 | 62 | 10 | 3.50 | 1 | 1 | 25.00 | 11 | 0.033 | Gang Daba |
| 8 | 59.21 | -28 | 57 | 8 | 6.80 | 2 | 3 | 44.00 | 20 | 0.212 | Gang Daba |
| 9 | 65.89 | -19 | 28 | 11 | 5.17 | 2 | 3.5 | 63.25 | 23 | 0.233 | Gang Daba |
| 10 | 33.42 | -29 | 42 | 10.4 | 7.38 | 0 | 4 | 20.80 | 12 | 0.072 | Gang Daba |
| 11 | 58.16 | -17 | 38 | 10.8 | 5.94 | 2 | 1 | 48.60 | 19 | 0.183 | Gang Daba |
| 12 | 30.43 | -86 | -16 | 8.23 | 5.76 | 1 | 1 | 20.58 | 11 | 0.049 | Gang Daba |
| 13 | 62.87 | -16 | 57 | 11.3 | 8.25 | 2 | 1 | 50.85 | 16 | 0.229 | Gang Daba |
| 14 | 37.88 | -13 | 80 | 6 | 5.58 | 2 | 2 | 30.00 | 11 | 0.063 | Gang Daba |
| 15 | 41.40 | -11 | 36 | 10.3 | 4.84 | 1 | 3 | 36.05 | 9 | 0.052 | Gang Daba |
| 16 | 64.62 | -16 | 39 | 11 | 6.05 | 2 | 1 | 49.50 | 20 | 0.209 | Gang Daba |
| 17 | 40.64 | 17 | 64 | 9.6 | 4.51 | 1 | 2 | 28.80 | 10 | 0.048 | Gang Daba |
| 18 | 41.85 | 35 | 137 | 8 | 8.16 | 1 | 3 | 28.00 | 15 | 0.129 | Gang Daba |
| 19 | 51.57 | -36 | 68 | 8 | 8.32 | 2 | 3 | 44.00 | 14 | 0.170 | Gang Daba |
| 20 | 67.32 | -24 | 48 | 10.5 | 7.56 | 2 | 1.5 | 49.88 | 18 | 0.243 | Gang Daba |
| 21 | 66.53 | | | | 5.80 | | | 63.19 | 20 | 0.229 | Gang Daba |
| 22 | 43.29 | -23 | 57 | 11.5 | 9.20 | 1 | 2 | 34.50 | 14 | 0.152 | Gang Daba |
| 23 | 82.76 | -24 | 39 | 7.4 | 4.66 | 5 | 2 | 81.40 | 20 | 0.235 | Gang Daba |
| 24 | 65.73 | -35 | 25 | 9.8 | 5.88 | 3 | 1 | 63.70 | 20 | 0.232 | Gang Daba |
| 25 | 46.28 | 11 | 82 | 10.7 | 7.60 | 1 | 3 | 37.45 | 16 | 0.154 | Gang Daba |
| 26 | 45.36 | 3 | 69 | 10 | 6.60 | 1 | 3 | 35.00 | 17 | 0.136 | Gang Daba |
| 27 | 37.94 | -69 | 4 | 7.55 | 5.51 | 2 | 1 | 33.98 | 14 | 0.084 | Gang Daba |
| 28 | 59.72 | -37 | 23 | 11 | 6.60 | 2 | 2 | 55.00 | 19 | 0.218 | Gang Daba |
| 29 | 50.45 | -26 | 51 | 10.5 | 8.09 | 2 | 1 | 47.25 | 15 | 0.180 | Gang Daba |
| 30 | 61.12 | 42 | 108 | 10.5 | 6.93 | 2 | 2 | 52.50 | 19 | 0.227 | Gang Daba |
| 31 | 41.85 | -27 | 28 | 11.5 | 6.33 | 1 | 3 | 40.25 | 15 | 0.118 | Gang Daba |
| 32 | 60.04 | 1 | 63 | 12 | 7.44 | 1 | 3 | 42.00 | 19 | 0.218 | Gang Daba |
| 33 | 49.66 | 30 | 101 | 8 | 5.68 | 1 | 4 | 32.00 | 14 | 0.099 | Gang Daba |
| 34 | 59.21 | -16 | 49 | 9.7 | 6.31 | 2 | 2 | 48.50 | 21 | 0.215 | Gang Daba |
| 35 | 119.69 | 53 | 162 | 7 | 7.63 | 8 | 1 | 115.50 | 20 | 0.554 | Gang Daba |
| 36 | 30.08 | -22 | 26 | 8.5 | 4.08 | 1 | 3 | 29.75 | 12 | 0.044 | Gang Daba |
| 37 | 48.19 | -8 | 69 | 10 | 7.70 | 1 | 2 | 30.00 | 14 | 0.128 | Gang Daba |
| 38 | 38.20 | -17 | 56 | 9 | 6.57 | 1 | 2 | 27.00 | 14 | 0.090 | Gang Daba |
| 39 | 58.63 | -36 | 36 | 10 | 7.20 | 2 | 1 | 45.00 | 19 | 0.215 | Gang Daba |
| 40 | 37.88 | 8 | 73 | 8.5 | 5.53 | 1 | 2 | 25.50 | 14 | 0.074 | Gang Daba |
| 41 | 66.37 | -84 | 36 | 7.13 | 8.56 | 2 | 4 | 42.78 | 16 | 0.228 | Gang Daba |
| 42 | 59.94 | -31 | 17 | 13 | 6.24 | 1 | 3 | 45.50 | 22 | 0.218 | Gang Daba |
| 43 | 43.07 | -20 | 37 | 10 | 5.70 | 1 | 4 | 40.00 | 13 | 0.094 | Gang Daba |
| 44 | 50.71 | | | | 9.60 | | | 49.65 | 14 | 0.206 | Gang Daba |
| 45 | 55.26 | 16 | 83 | 11.6 | 7.77 | 1 | 3 | 40.60 | 19 | 0.214 | Gang Daba |
| 46 | 56.98 | -17 | 61 | 9.3 | 7.25 | 2 | 2 | 46.50 | 19 | 0.216 | Gang Daba |
| 47 | 30.34 | -31 | 16 | 9.5 | 4.47 | 1 | 1 | 23.75 | 12 | 0.044 | Gang Daba |
| 48 | 44.09 | 0 | 74 | 9 | 6.66 | 1 | 3.5 | 33.75 | 16 | 0.125 | Gang Daba |
| 49 | 41.95 | -62 | 12 | 10.42 | 7.71 | 1 | 3 | 36.47 | 13 | 0.119 | Gang Daba |
| 50 | 44.98 | 7 | 76 | 10.8 | 7.45 | 1 | 2 | 32.40 | 15 | 0.131 | Gang Daba |
| 51 | 46.60 | 41 | 84 | 10.6 | 4.56 | 1 | 3 | 37.10 | 8 | 0.047 | Mbabo |

**Table 1.** Contd.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 52 | 58.76 | -26 | 18 | 12.5 | 5.50 | 1 | 3 | 43.75 | 7 | 0.061 | Mbabo |
| 53 | 36.80 | 37 | 94 | 11.7 | 6.67 | 1 | 1 | 29.25 | 7 | 0.047 | Mbabo |
| 54 | 52.30 | 3 | 36 | 11.6 | 3.83 | 1 | 3 | 40.60 | 12 | 0.065 | Mbabo |
| 55 | 50.80 | | | | 3.40 | | | 46.98 | 10 | 0.051 | Mbabo |
| 56 | 49.43 | 3 | 41 | 12 | 4.56 | 1 | 1 | 30.00 | 8 | 0.045 | Mbabo |
| 57 | 78.05 | 31 | 120 | 12 | 10.68 | 1 | 3 | 42.00 | 8 | 0.159 | Mbabo |
| 58 | 93.14 | 12 | 78 | 14 | 9.24 | 2 | 2 | 70.00 | 7 | 0.164 | Mbabo |
| 59 | 48.83 | -17 | 38 | 8 | 4.40 | 2 | 1 | 36.00 | 9 | 0.052 | Mbabo |
| 60 | 79.68 | -77 | 11 | 11.51 | 10.13 | 2 | 0 | 46.04 | 8 | 0.158 | Mbabo |
| 61 | 44.15 | -16 | 52 | 9.5 | 6.46 | 1 | 4 | 38.00 | 7 | 0.057 | Mbabo |
| 62 | 94.54 | -26 | 78 | 9 | 9.36 | 4 | 1 | 76.50 | 6 | 0.150 | Mbabo |
| 63 | 101.73 | -23 | 56 | 13.5 | 10.67 | 3 | 1 | 87.75 | 6 | 0.189 | Mbabo |
| 64 | 47.59 | 8 | 38 | 11.6 | 3.48 | 1 | 1 | 29.00 | 11 | 0.045 | Mbabo |
| 65 | 81.08 | -33 | 48 | 11 | 8.91 | 2 | 3 | 60.50 | 7 | 0.137 | Mbabo |
| 66 | 47.65 | 3 | 57 | 10 | 5.40 | 1 | 4 | 40.00 | 9 | 0.066 | Mbabo |
| 67 | 82.25 | 5 | 73 | 11.4 | 7.75 | 2 | 1 | 51.30 | 9 | 0.144 | Mbabo |
| 68 | 35.24 | -23 | 38 | 9.7 | 5.92 | 1 | 1 | 24.25 | 9 | 0.048 | Mbabo |
| 69 | 103.00 | 21 | 86 | 12.5 | 8.13 | 2 | 4 | 75.00 | 7 | 0.158 | Mbabo |
| 70 | 90.84 | 9 | 87 | 13.7 | 10.69 | 2 | 1 | 61.65 | 7 | 0.178 | Mbabo |
| 71 | 31.32 | | | | 3.60 | | | 27.47 | 10 | 0.032 | Mbabo |
| 72 | 96.32 | -17 | 84 | 11 | 11.11 | 3 | 1 | 71.50 | 6 | 0.174 | Mbabo |
| 73 | 39.38 | -24 | 41 | 10.5 | 6.83 | 1 | 1 | 26.25 | 10 | 0.068 | Mbabo |
| 74 | 51.25 | | | | 2.29 | | | 50.29 | 12 | 0.043 | Mbabo |
| 75 | 62.39 | -44 | 37 | 9.5 | 7.70 | 2 | 2 | 47.50 | 7 | 0.092 | Mbabo |
| 76 | 67.61 | -13 | 42 | 12.5 | 6.88 | 2 | 1 | 56.25 | 8 | 0.106 | Mbabo |
| 77 | 86.10 | -34 | 48 | 13.4 | 10.99 | 2 | 3 | 73.70 | 7 | 0.191 | Mbabo |
| 78 | 69.87 | 6 | 84 | 13 | 10.14 | 2 | 1 | 58.50 | 9 | 0.181 | Mbabo |
| 79 | 38.00 | | | | 2.36 | | | 36.48 | 11 | 0.029 | Mbabo |
| 80 | 83.30 | 14 | 107 | 10.6 | 9.86 | 3 | 1 | 68.90 | 6 | 0.140 | Mbabo |
| 81 | 74.71 | -13 | 64 | 11 | 8.47 | 2 | 3 | 60.50 | 11 | 0.195 | Mbabo |
| 82 | 91.17 | 3 | 81 | 15 | 11.70 | 2 | 1 | 67.50 | 6 | 0.174 | Mbabo |
| 83 | 89.00 | 22 | 81 | 13 | 7.67 | 2 | 2 | 65.00 | 7 | 0.129 | Mbabo |
| 84 | 60.58 | 27 | 143 | 11 | 12.76 | 1 | 4 | 44.00 | 9 | 0.185 | Mbabo |
| 85 | 37.56 | -23 | 18 | 10.5 | 4.31 | 1 | 1 | 26.25 | 10 | 0.042 | Mbabo |
| 86 | 70.22 | -6 | 87 | 9.6 | 8.93 | 3 | 0 | 57.60 | 9 | 0.159 | Mbabo |
| 87 | 75.82 | 27 | 86 | 13.7 | 8.08 | 2 | 0 | 54.80 | 12 | 0.195 | Mbabo |
| 88 | 81.56 | 7 | 109 | 10.6 | 10.81 | 2 | 4 | 63.60 | 6 | 0.147 | Mbabo |
| 89 | 74.07 | -11 | 52 | 15 | 9.45 | 1 | 4 | 60.00 | 10 | 0.196 | Mbabo |
| 90 | 92.50 | -3 | 53 | 10.4 | 5.82 | 3 | 2 | 72.80 | 7 | 0.105 | Mbabo |
| 91 | 72.74 | -30 | 81 | 8.5 | 9.44 | 2 | 2 | 42.50 | 7 | 0.118 | Mbabo |
| 92 | 30.56 | | | | 2.53 | | | 26.10 | 10 | 0.022 | Mbabo |
| 93 | 93.11 | 17 | 68 | 13.6 | 6.94 | 2 | 3 | 74.80 | 9 | 0.163 | Mbabo |
| 94 | 74.04 | -4 | 69 | 11.4 | 8.32 | 2 | 3 | 62.70 | 11 | 0.193 | Mbabo |
| 95 | 43.13 | -72 | 14 | 6.89 | 5.93 | 2 | 3 | 37.90 | 8 | 0.059 | Mbabo |
| 96 | 90.85 | -42 | 51 | 12.6 | 11.72 | 2 | 3 | 69.30 | 7 | 0.205 | Mbabo |
| 97 | 79.39 | 18 | 82 | 9.7 | 6.21 | 2 | 3.5 | 55.78 | 9 | 0.117 | Mbabo |
| 98 | 80.28 | 11 | 71 | 13 | 7.80 | 2 | 2 | 65.00 | 7 | 0.123 | Mbabo |
| 99 | 48.38 | | | | 2.70 | | | 46.47 | 12 | 0.047 | Mbabo |
| 100 | 70.99 | 8 | 101 | 10.6 | 9.86 | 1 | 4 | 42.40 | 7 | 0.121 | Mbabo |
| 101 | 88.02 | -34 | 23 | 14.7 | 8.38 | 2 | 1 | 66.15 | 7 | 0.141 | Mbabo |
| 102 | 46.25 | -10 | 34 | 8 | 3.52 | 2 | 3 | 44.00 | 10 | 0.049 | Mbabo |
| 103 | 70.16 | -13 | 51 | 13 | 8.32 | 1 | 3 | 45.50 | 13 | 0.192 | Mbabo |

**Table 1.** Contd.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 104 | 76.91 | 26 | 84 | 12.6 | 7.31 | 2 | 0 | 50.40 | 11 | 0.158 | Mbabo |
| 105 | 83.94 | 8 | 104 | 8.7 | 8.35 | 3 | 2 | 60.90 | 8 | 0.150 | Mbabo |

DBH: Diameter of the tree at breast height; $P_a$: percentage of the slope at the logging level or at breast high; $P_u$: percentage of the slope at the first big branch level; $d_h$: horizontal distance; h: high; LB: number of large bands in relascope unit SB: small band: number of small bands; $D_u$: diameter of the tree at the first big branch level; e: thickness of the bark; V: volume of the bark.

**Table 2.** Comparison of the thickness of the *Prunus* bark measured using the Tarrière de Pressler between Gang Daba and Mbabo in the Adamaoua region.

| Parameter | Mean | sd | n F value = 162.63 Pr < 2.2e-16 *** |
|---|---|---|---|
| Gang Daba | 15.84 | 3.73 | 50 |
| Mbabo | 8.56 | 1.89 | 55 |
| All sites | 12.03 | 4.6 | 105 |

The F value and Pr are from the comparison between Gang Daba and Mbabo. Signifiance. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1.

### Mass of the fresh bark for exploitable trees

In Cameroon, the minimum exploitable diameter (MED) for *P. africana* 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 *P. 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. This can yield précised data compared to indirect method. We preferred indirect method because it is non-destructive, and this method can easily be applied in the field by foresters during forest management inventories.

### Data analysis

The volume based tariff or the relation between the diameter and the volume of the stem bark was performed using linear regression with the CurveExpert 1.4 package. The best equation is that for which the correlation coefficient (R) is near to 1.

Data analysis was performed using the R2.10.0 statistical package. Different sites, volumes, and materials used for measuring the thickness of the stem bark, were compared using the One way ANOVA. For what concerns the comparison of the two materials used for measuring the thickness of the *P. africana* barks, or the comparison of the observed (measured) and theoretical (obtained from the cubic tariff equation) volumes of the bark, the tree sample was considered as the unique factor (Dagnelie, 1998).

## RESULTS

### Cubic tariff

All the 105 sample trees were exploitable, this is, trees with DBH ≥ 30 cm. Measures regarding the diameters, the percentages of the slope, the thickness of the bark were collected on all the 105 trees. Table 1 shows the data recorded and the corresponding volume per tree. The thickness of the bark was measured using the “Tarrière de Pressler”. The average thickness of the bark is 12.03 ± 4.6 mm. This value is comprised between that of unexploited (15.84 ± 3.7 mm) and exploited (8.56 ± 1.9 mm) *P. africana* trees observed respectively in Gang Daba and Mbabo. The means of the thickness of the bark between the un-exploited and the exploited sites, illustrated in Table 2 are significantly different ($p < 0.05$).

The relation diameter of the tree at breast height – volume of the stem bark is illustrated in Figures 2, 3, and 4 for Gang Daba, Mbabo, and the two sites together respectively. Table 3 presents for each site, the best equation which links the diameter and the stem bark of the *P. africana* tree. To examine the credibility of our equations, we compared the volume of the bark measured in the field with the volume of the bark simulated by the equations. Table 4 shows the results obtained. What ever be the site, there is no significant difference ($p > 0.05$) between the theoretical volume and the observed volume; which gives credibility to the cubage tariffs proposed for each site or for all the two sites considered together.

### 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 on all the same 105 trees used to yield the cubic tariff. Table 5 shows for each sample, its volume and the corresponding fresh mass in kilogram. The thickness of the bark was measured using the calliper rule. The

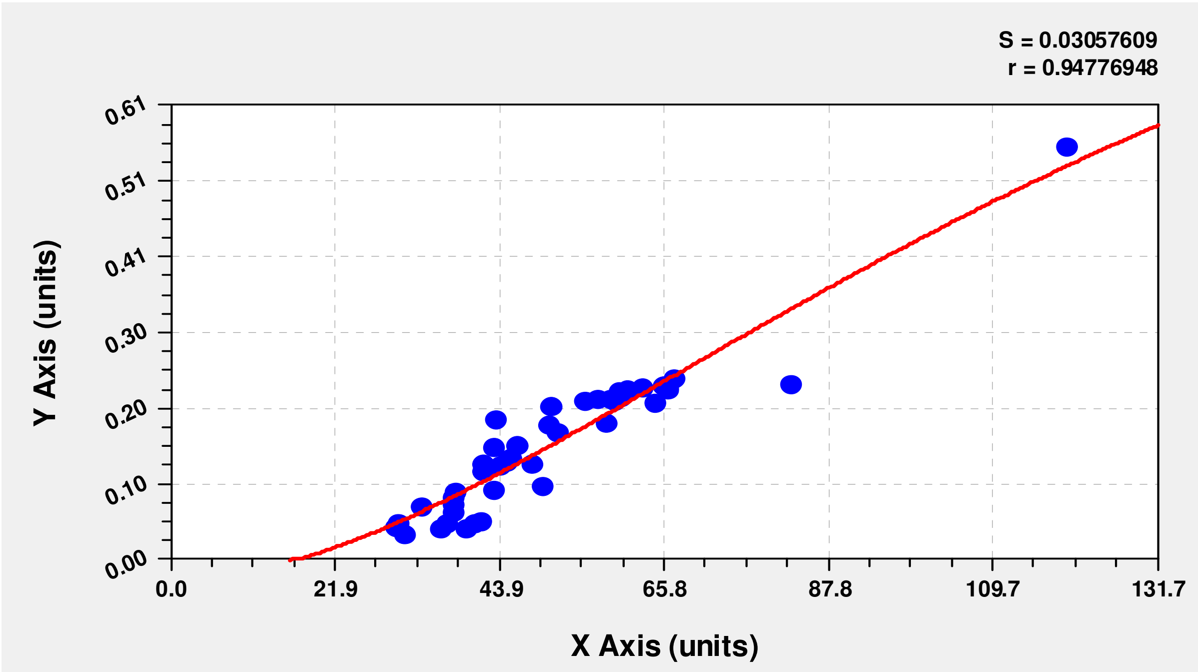


**Figure 2a.** evolution of the volume of the fresh bark with that of the diameter at breast high of the *Prunus* tree in Gang Daba area. MMF Model: y=(a*b+c*x^d)/(b+x^d); Coefficient Data: a = -2.85924630130E-002; b = 6.91062016528E+003; c =1.23499012989E+000; d = 1.79843264745E+000.

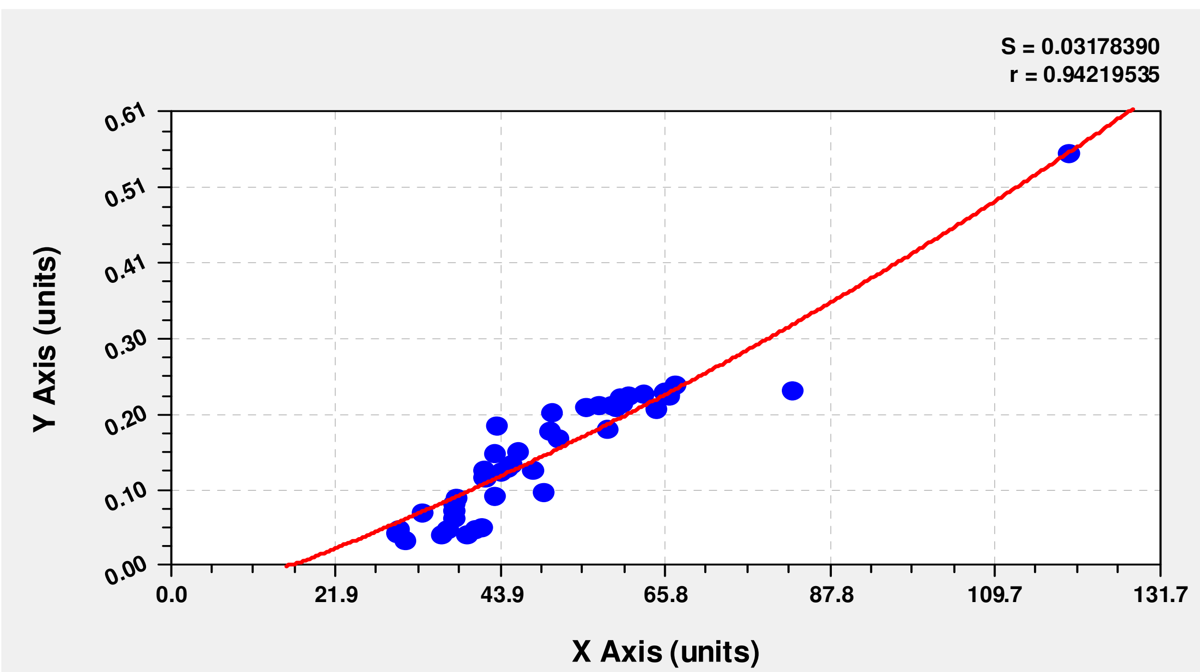


**Figure 2b.** evolution of the volume of the fresh bark with that of the diameter at breast high of the *Prunus* tree in Gang Daba (linear regression**)** Quadratic Fit: y=a+bx+cx^2. Coefficient Data: a = -5.98191756094E-002; b = 3.50369652890E-003; c =1.37448422378E-005.

average thickness of the bark is 13.01 ± 4.8 mm. This value is comprised between that of unexploited *P. africana* trees found in Gang Daba (16.99 ± 3.7 mm) and exploited *P. Africana* trees observed in Mbabo (9.40

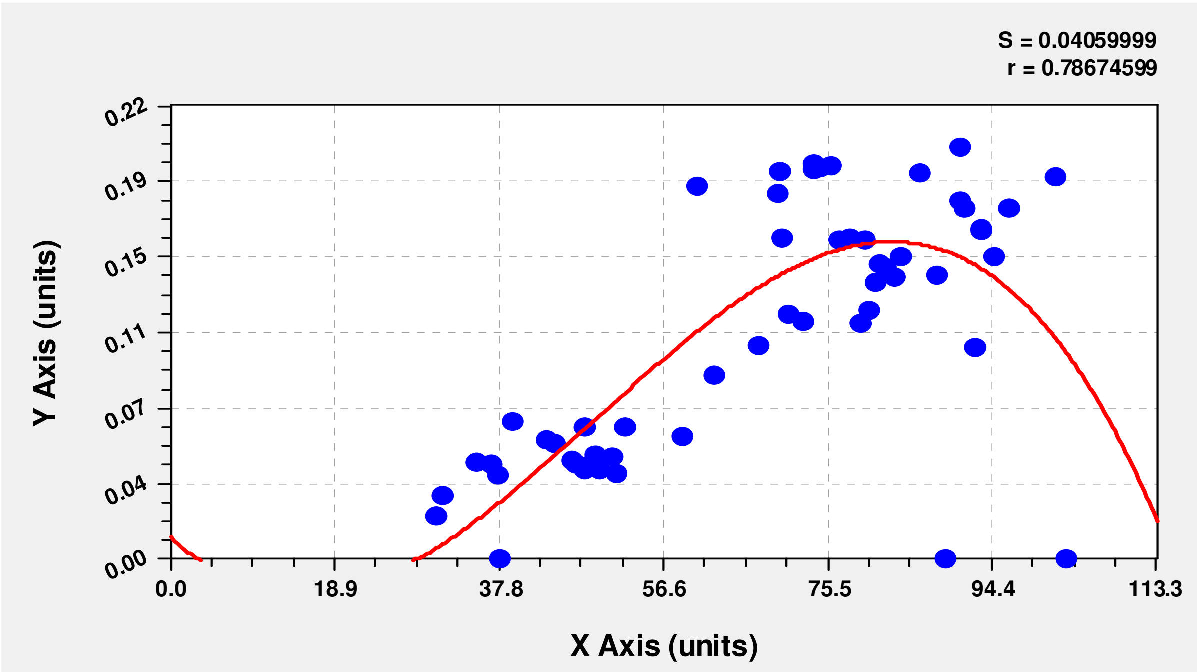


**Figure 3.** Evolution of the volume of the fresh bark with that of the diameter at breast high of the *Prunus* tree in Mbabo area. 3rd degree Polynomial Fit: y=a+bx+cx^2+dx^3. Coefficient Data: a = 1.10943074390E-002; b= -4.14622627475E-003; c =1.64301318294E-004; d = -1.12161703386E-006.

**Table 3.** Cubic tariff of *Prunus* trees in each production site in the Adamaoua region in Cameroon.

| Site | Tarif | a | b | C | D |
|---|---|---|---|---|---|
| Gang Daba | Vb=(a*b+c*D^d)/(b+D^d) | -2.85924630130E-002 | 6.91062016528E+003 | 1.23499012989E+000 | 1.79843264745E+000 |
| Gang Daba | Linear regression Vb=a+bD+cD^2 | -5.98191756094E-002 | 3.50369652890E-003 | 1.37448422378E-005 | |
| Mbabo | Vb=a+bD+cD^2+dD^3 | 1.10943074390E-002 | -4.14622627475E-003 | 1.64301318294E-004 | -1.12161703386E-006 |
| All sites together | Vb=a/(1+b*exp(-cD)) | 1.79588278896E-001 | 5.29124992540E+002 | 1.45488065368E-001 | |

$V_b$ is the volume of the stem bark in $m^3$ and D is the diameter of the tree at breast high in cm a, b, c, d, are coefficients of the equations.

± 2.07 mm). The means of the thickness of the bark between the un-exploited and the exploited sites, illustrated in Table 6 are significantly different ($p < 0.05$ ).

There is no significant difference ($p > 0.05$) between the two sites for what concerns the ratio mass/volume of the bark (Table 7). The average value of the ratio mass/volume obtained from the samples is 1014.80 ± 9 $kg/m^3$ for the two sites (Table 7). This value is comprised between that of unexploited *P. africana* trees found in Gang Daba (1014.37 ± 7.78 $kg/m^3$) and exploited *P. africana* trees observed in Mbabo (1015.19 ± 10.11 $kg/m^3$). For the two sites considered together, the equation which links the volume of the stem bark and its mass is Mb = Vb* 1014.80 $kg/m^3$, where Mb = mass of the fresh bark in kg and Vb = volume of the stem bark in $m^3$.

## Mass of exploitable trees

The 105 trees were also selected to simulate the average fresh mass of *P. africana* barks. Table 8 presents for each exploitable tree, its volume and the corresponding mass in kilogram. There is a significant difference ($p < 0.05$) between the total mass of the bark of exploitable *P. africana* trees found in un-exploited and exploited sites (Table 9). It can be deduced that, an exploitable tree of *P. africana* has an average mass of 138.61 ± 79.11 Kg of stem barks. This value is comprised between that of unexploited (159.88 ± 92.55 kg) and exploited (119.27 ±

**Table 4.** Comparison of the two cubage tariffs (observed volume or mean 1 vs theoretical volume or mean 2) in different sites.

| Parameter | Mean1 | mean 2 | sd1 | sd2 | n | F value | Pr |
|---|---|---|---|---|---|---|---|
| Gang Daba | 0.1575489 | 0.1584337 | 0.09120302 | 0.08504862 | 50 | 0.0025 | 0.96 |
| Mbabo | 0.1003238 | 0.1115804 | 0.06550722 | 0.048937 | 55 | 1.0423 | 0.3096 |
| All sites together | 0.1275738 | 0.1338915 | 0.08349759 | 0.07214084 | 105 | 0.3442 | 0.5581 |

**Table 5.** Volumes of bark samples with their corresponding mass.

| N°_Tree | Length (cm) | Width (cm) | Thickness (mm) | Volume (m3) | Mass (Kg) | Ratio (m/v) | Site |
|---|---|---|---|---|---|---|---|
| 1 | 25 | 7.8 | 13.00 | 0.000 | 0.26 | 1025.641 | Gang Daba |
| 2 | 16.5 | 11 | 13.76 | 0.000 | 0.25 | 1001.272 | Gang Daba |
| 3 | 31.2 | 10.25 | 16.00 | 0.001 | 0.53 | 1035.804 | Gang Daba |
| 4 | 27.3 | 7.6 | 13.25 | 0.000 | 0.28 | 1018.511 | Gang Daba |
| 5 | 35.5 | 7.4 | 19.20 | 0.001 | 0.51 | 1011.134 | Gang Daba |
| 6 | 16 | 11.7 | 21.15 | 0.000 | 0.4 | 1010.285 | Gang Daba |
| 7 | 32 | 9.87 | 17.00 | 0.001 | 0.54 | 1005.721 | Gang Daba |
| 8 | 31 | 10.7 | 16.45 | 0.001 | 0.55 | 1007.979 | Gang Daba |
| 9 | 27 | 7.5 | 14.80 | 0.000 | 0.3 | 1001.001 | Gang Daba |
| 10 | 31.6 | 8.5 | 16.85 | 0.000 | 0.46 | 1016.370 | Gang Daba |
| 11 | 22.6 | 7 | 18.75 | 0.000 | 0.3 | 1011.378 | Gang Daba |
| 12 | 30 | 7.4 | 14.76 | 0.000 | 0.33 | 1007.419 | Gang Daba |
| 13 | 21 | 9.3 | 18.15 | 0.000 | 0.36 | 1015.792 | Gang Daba |
| 14 | 36 | 6.8 | 18.00 | 0.000 | 0.45 | 1021.242 | Gang Daba |
| 15 | 16 | 8.5 | 21.75 | 0.000 | 0.3 | 1014.199 | Gang Daba |
| 16 | 16 | 11.5 | 16.25 | 0.000 | 0.3 | 1003.344 | Gang Daba |
| 17 | 18 | 14.3 | 18.00 | 0.000 | 0.47 | 1014.418 | Gang Daba |
| 18 | 17.5 | 14 | 19.50 | 0.000 | 0.48 | 1004.710 | Gang Daba |
| 19 | 19 | 9.25 | 20.00 | 0.000 | 0.36 | 1024.182 | Gang Daba |
| 20 | 25.7 | 8.5 | 10.80 | 0.000 | 0.24 | 1017.268 | Gang Daba |
| 21 | 25.4 | 9 | 12.00 | 0.000 | 0.28 | 1020.706 | Gang Daba |
| 22 | 16.5 | 11 | 9.25 | 0.000 | 0.17 | 1012.583 | Gang Daba |
| 23 | 29.7 | 8.2 | 18.00 | 0.000 | 0.44 | 1003.714 | Gang Daba |
| 24 | 13 | 12.7 | 8.35 | 0.000 | 0.14 | 1015.534 | Gang Daba |
| 25 | 26.5 | 6 | 21.00 | 0.000 | 0.34 | 1018.269 | Gang Daba |
| 26 | 22 | 6.5 | 24.45 | 0.000 | 0.35 | 1001.044 | Gang Daba |
| 27 | 24 | 8.3 | 12.00 | 0.000 | 0.24 | 1004.016 | Gang Daba |
| 28 | 29.6 | 8 | 13.33 | 0.000 | 0.32 | 1013.514 | Gang Daba |
| 29 | 21.5 | 9.2 | 22.70 | 0.000 | 0.46 | 1024.485 | Gang Daba |
| 30 | 24 | 9.8 | 11.67 | 0.000 | 0.28 | 1020.408 | Gang Daba |
| 31 | 17.8 | 13 | 17.05 | 0.000 | 0.4 | 1013.847 | Gang Daba |
| 32 | 23 | 6.5 | 18.25 | 0.000 | 0.28 | 1026.252 | Gang Daba |
| 33 | 30 | 7 | 19.65 | 0.000 | 0.42 | 1017.812 | Gang Daba |
| 34 | 26 | 8 | 24.45 | 0.001 | 0.52 | 1022.328 | Gang Daba |
| 35 | 30 | 8.1 | 14.67 | 0.000 | 0.36 | 1010.101 | Gang Daba |
| 36 | 32.5 | 9 | 14.25 | 0.000 | 0.42 | 1007.647 | Gang Daba |
| 37 | 28.5 | 4.75 | 19.00 | 0.000 | 0.26 | 1010.837 | Gang Daba |
| 38 | 19 | 6 | 19.75 | 0.000 | 0.23 | 1021.334 | Gang Daba |
| 39 | 18 | 9.3 | 20.00 | 0.000 | 0.34 | 1015.532 | Gang Daba |
| 40 | 16.4 | 10.2 | 19.00 | 0.000 | 0.32 | 1006.821 | Gang Daba |

**Table 5.** Contd.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 41 | 28.5 | 7.5 | 14.70 | 0.000 | 0.32 | 1018.419 | Gang Daba |
| 42 | 15.5 | 10.1 | 15.00 | 0.000 | 0.24 | 1022.038 | Gang Daba |
| 43 | 27 | 7.5 | 15.60 | 0.000 | 0.32 | 1012.979 | Gang Daba |
| 44 | 16 | 12 | 16.80 | 0.000 | 0.33 | 1023.065 | Gang Daba |
| 45 | 26 | 5.5 | 19.25 | 0.000 | 0.28 | 1016.953 | Gang Daba |
| 46 | 15.5 | 10.8 | 17.65 | 0.000 | 0.3 | 1015.362 | Gang Daba |
| 47 | 29.7 | 7 | 16.33 | 0.000 | 0.34 | 1001.266 | Gang Daba |
| 48 | 18.7 | 11.6 | 22.75 | 0.000 | 0.5 | 1013.186 | Gang Daba |
| 49 | 18.5 | 12 | 21.54 | 0.000 | 0.49 | 1024.702 | Gang Daba |
| 50 | 17 | 11.7 | 13.85 | 0.000 | 0.28 | 1016.274 | Gang Daba |
| 51 | 13.4 | 9 | 9.00 | 0.000 | 0.11 | 1013.451 | Mbabo |
| 52 | 27.7 | 8 | 7.15 | 0.000 | 0.16 | 1009.821 | Mbabo |
| 53 | 14 | 10 | 9.00 | 0.000 | 0.13 | 1031.746 | Mbabo |
| 54 | 19 | 6.5 | 6.45 | 0.000 | 0.08 | 1004.300 | Mbabo |
| 55 | 12.5 | 9 | 6.65 | 0.000 | 0.075 | 1002.506 | Mbabo |
| 56 | 14.5 | 10 | 8.00 | 0.000 | 0.12 | 1034.483 | Mbabo |
| 57 | 16 | 9.5 | 7.65 | 0.000 | 0.12 | 1031.992 | Mbabo |
| 58 | 15 | 8.5 | 13.65 | 0.000 | 0.18 | 1034.260 | Mbabo |
| 59 | 13.5 | 11 | 11.80 | 0.000 | 0.18 | 1027.221 | Mbabo |
| 60 | 18 | 9 | 10.70 | 0.000 | 0.18 | 1038.422 | Mbabo |
| 61 | 17 | 10.5 | 6.54 | 0.000 | 0.12 | 1027.934 | Mbabo |
| 62 | 20.1 | 10.6 | 10.00 | 0.000 | 0.22 | 1032.573 | Mbabo |
| 63 | 17.4 | 10.4 | 7.00 | 0.000 | 0.13 | 1026.273 | Mbabo |
| 64 | 14.5 | 9.6 | 11.25 | 0.000 | 0.16 | 1021.711 | Mbabo |
| 65 | 16.5 | 9.2 | 8.50 | 0.000 | 0.13 | 1007.518 | Mbabo |
| 66 | 18.3 | 9 | 9.56 | 0.000 | 0.16 | 1016.175 | Mbabo |
| 67 | 24 | 8.5 | 9.67 | 0.000 | 0.2 | 1014.206 | Mbabo |
| 68 | 16.5 | 7.6 | 12.50 | 0.000 | 0.16 | 1020.734 | Mbabo |
| 69 | 25 | 9.5 | 8.00 | 0.000 | 0.19 | 1000.000 | Mbabo |
| 70 | 18.4 | 8 | 8.65 | 0.000 | 0.13 | 1020.985 | Mbabo |
| 71 | 24.6 | 6.7 | 6.00 | 0.000 | 0.1 | 1011.204 | Mbabo |
| 72 | 23 | 7.5 | 8.00 | 0.000 | 0.14 | 1014.493 | Mbabo |
| 73 | 28 | 6 | 7.50 | 0.000 | 0.13 | 1031.746 | Mbabo |
| 74 | 16.5 | 8 | 9.00 | 0.000 | 0.12 | 1010.101 | Mbabo |
| 75 | 14.5 | 10.3 | 7.25 | 0.000 | 0.11 | 1015.896 | Mbabo |
| 76 | 18.6 | 8.3 | 11.00 | 0.000 | 0.17 | 1001.072 | Mbabo |
| 77 | 18 | 12 | 12.00 | 0.000 | 0.26 | 1003.086 | Mbabo |
| 78 | 15 | 9.5 | 10.26 | 0.000 | 0.15 | 1026.297 | Mbabo |
| 79 | 25 | 8.5 | 7.50 | 0.000 | 0.16 | 1003.922 | Mbabo |
| 80 | 17.7 | 8.3 | 12.00 | 0.000 | 0.18 | 1021.033 | Mbabo |
| 81 | 16 | 8.5 | 11.00 | 0.000 | 0.15 | 1002.674 | Mbabo |
| 82 | 21 | 7.6 | 11.00 | 0.000 | 0.18 | 1025.290 | Mbabo |
| 83 | 20.5 | 7.5 | 9.00 | 0.000 | 0.14 | 1011.743 | Mbabo |
| 84 | 20 | 6 | 9.00 | 0.000 | 0.11 | 1018.519 | Mbabo |
| 85 | 17.3 | 9.2 | 10.00 | 0.000 | 0.16 | 1005.278 | Mbabo |
| 86 | 26.5 | 7.5 | 9.00 | 0.000 | 0.18 | 1006.289 | Mbabo |
| 87 | 15 | 10 | 6.56 | 0.000 | 0.1 | 1016.260 | Mbabo |
| 88 | 20.5 | 8.8 | 12.00 | 0.000 | 0.22 | 1016.260 | Mbabo |
| 89 | 15 | 8 | 11.50 | 0.000 | 0.14 | 1014.493 | Mbabo |
| 90 | 16.5 | 8.9 | 9.50 | 0.000 | 0.14 | 1003.530 | Mbabo |
| 91 | 25 | 8.5 | 7.00 | 0.000 | 0.15 | 1008.403 | Mbabo |
| 92 | 16 | 12.4 | 10.00 | 0.000 | 0.2 | 1008.065 | Mbabo |

**Table 5.** Contd.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 93 | 20.3 | 8.8 | 10.00 | 0.000 | 0.18 | 1007.613 | Mbabo |
| | 94 | 26.7 | 9.4 | 7.00 | 0.000 | 0.18 | 1024.555 | Mbabo |
| | 95 | 16.6 | 8 | 13.50 | 0.000 | 0.18 | 1004.016 | Mbabo |
| | 96 | 17.4 | 11.3 | 8.00 | 0.000 | 0.16 | 1017.191 | Mbabo |
| | 97 | 16.5 | 11.5 | 9.40 | 0.000 | 0.18 | 1009.167 | Mbabo |
| | 98 | 18.7 | 7.2 | 10.25 | 0.000 | 0.14 | 1014.449 | Mbabo |
| | 99 | 17 | 7.6 | 13.75 | 0.000 | 0.18 | 1013.228 | Mbabo |
| | 100 | 28 | 8.1 | 7.00 | 0.000 | 0.16 | 1007.811 | Mbabo |
| | 101 | 16 | 9.6 | 12.85 | 0.000 | 0.2 | 1013.294 | Mbabo |
| | 102 | 14.7 | 10.2 | 7.30 | 0.000 | 0.11 | 1004.968 | Mbabo |
| | 103 | 20.4 | 8.5 | 8.00 | 0.000 | 0.14 | 1009.227 | Mbabo |
| | 104 | 17.8 | 6.7 | 10.00 | 0.000 | 0.12 | 1006.205 | Mbabo |
| | 105 | 20 | 7 | 12.00 | 0.000 | 0.17 | 1011.905 | Mbabo |
| **All sites** | | | | | | | | |
| N | 105 | | | | | | | |
| Mean | | | | 13.01 | 0.00 | 0.25 | 1014.80 | |
| Sd | | | | 4.81917358 | 0.00012258 | 0.1243444 | 9.04330906 | |
| Max | | | | 24.45 | 0.00 | 0.55 | 1038.42 | |
| Min | | | | 6.00 | 0.00 | 0.08 | 1000.00 | |

**Table 6.** Comparison of the thickness of the *Prunus* bark measured using the Calliper rule between Gang Daba and Mbabo in the Adamaoua region.

| Parameter | Mean | sd | n | F = 172.30 | Pr < 2.2e-16 *** |
|---|---|---|---|---|---|
| Gang Daba | 16.99 | 3.70 | 50 | | |
| Mbabo | 9.39 | 2.07 | 55 | | |
| All sites | 13.01 | 4.8 | 105 | | |

The F value and Pr are from the comparison between Gang Daba and Mbabo. Signifance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1.

**Table 7.** Comparison of the ratio mass/volume of the *Prunus* bark measured using the Calliper rule between Gang Daba and Mbabo in the Adamaoua region.

| Parameter | Mean | sd | n | F = 0.213 | Pr = 0.6454 |
|---|---|---|---|---|---|
| Gang Daba | 1014.37 | 7.78 | 50 | | |
| Mbabo | 1015.19 | 10.11 | 55 | | |
| All sites | 1014.08 | 9.04 | | | |

59.00 kg) *P. africana* trees observed respectively in Gang Daba and Mbabo.

**Comparison between the measures of the thickness of the stem barks obtained with the "Tarrière de Pressler" and those obtained with the calliper rule**

Table 10 shows the results of the comparison made on the thickness of the bark measured with different materials. From the table, it can be deduced that there is no significant difference (p > 0.05) between the thickness of the stem bark obtained with the "Tarrière de Pressler" and that obtained with the calliper rule.

## DISCUSSION

*P. africana* extracts that can help alleviate some prostate disorders are in high demand. The *P. africana* tree, a primary source of medicine, has become threatened as a result. Without the conservation of high yielding populations, these trees could be harvested to extinction.

**Table 8.** Productivity of exploitable *Prunus* trees in term of the mass of the fresh bark.

| N° | DBH (cm) | Volume ($m^3$) | Mass (kg) | Site |
|---|---|---|---|---|
| 1 | 39.49 | 0.041 | 41.371 | Gang Daba |
| 2 | 59.84 | 0.226 | 229.682 | Gang Daba |
| 3 | 36.13 | 0.041 | 41.654 | Gang Daba |
| 4 | 59.68 | 0.217 | 220.206 | Gang Daba |
| 5 | 37.05 | 0.049 | 49.849 | Gang Daba |
| 6 | 43.42 | 0.187 | 189.842 | Gang Daba |
| 7 | 31.2 | 0.033 | 33.139 | Gang Daba |
| 8 | 59.21 | 0.212 | 215.071 | Gang Daba |
| 9 | 65.89 | 0.233 | 236.056 | Gang Daba |
| 10 | 33.42 | 0.072 | 73.191 | Gang Daba |
| 11 | 58.16 | 0.183 | 185.224 | Gang Daba |
| 12 | 30.43 | 0.049 | 49.299 | Gang Daba |
| 13 | 62.87 | 0.229 | 232.514 | Gang Daba |
| 14 | 37.88 | 0.063 | 64.261 | Gang Daba |
| 15 | 41.4 | 0.052 | 52.538 | Gang Daba |
| 16 | 64.62 | 0.209 | 212.392 | Gang Daba |
| 17 | 40.64 | 0.048 | 48.504 | Gang Daba |
| 18 | 41.85 | 0.129 | 130.428 | Gang Daba |
| 19 | 51.57 | 0.170 | 172.245 | Gang Daba |
| 20 | 67.32 | 0.243 | 246.400 | Gang Daba |
| 21 | 66.53 | 0.229 | 232.461 | Gang Daba |
| 22 | 43.29 | 0.152 | 153.960 | Gang Daba |
| 23 | 82.76 | 0.235 | 238.037 | Gang Daba |
| 24 | 65.73 | 0.232 | 235.124 | Gang Daba |
| 25 | 46.28 | 0.154 | 156.030 | Gang Daba |
| 26 | 45.36 | 0.136 | 137.640 | Gang Daba |
| 27 | 37.94 | 0.084 | 85.008 | Gang Daba |
| 28 | 59.72 | 0.218 | 221.715 | Gang Daba |
| 29 | 50.45 | 0.180 | 183.066 | Gang Daba |
| 30 | 61.12 | 0.227 | 230.492 | Gang Daba |
| 31 | 41.85 | 0.118 | 119.623 | Gang Daba |
| 32 | 60.04 | 0.218 | 221.362 | Gang Daba |
| 33 | 49.66 | 0.099 | 99.959 | Gang Daba |
| 34 | 59.21 | 0.215 | 218.461 | Gang Daba |
| 35 | 119.69 | 0.554 | 562.356 | Gang Daba |
| 36 | 30.08 | 0.044 | 44.820 | Gang Daba |
| 37 | 48.19 | 0.128 | 129.545 | Gang Daba |
| 38 | 38.2 | 0.090 | 91.488 | Gang Daba |
| 39 | 58.63 | 0.215 | 217.688 | Gang Daba |
| 40 | 37.88 | 0.074 | 74.693 | Gang Daba |
| 41 | 66.37 | 0.228 | 231.195 | Gang Daba |
| 42 | 59.94 | 0.218 | 221.100 | Gang Daba |
| 43 | 43.07 | 0.094 | 95.047 | Gang Daba |
| 44 | 50.71 | 0.206 | 209.006 | Gang Daba |
| 45 | 55.26 | 0.214 | 216.693 | Gang Daba |
| 46 | 56.98 | 0.216 | 218.991 | Gang Daba |
| 47 | 30.34 | 0.044 | 44.147 | Gang Daba |
| 48 | 44.09 | 0.125 | 126.781 | Gang Daba |
| 49 | 41.95 | 0.119 | 121.147 | Gang Daba |
| 50 | 44.98 | 0.131 | 132.528 | Gang Daba |
| 51 | 46.6 | 0.047 | 47.719 | Mbabo |

**Table 8.** Contd.

| | | | | |
|---|---|---|---|---|
| 52 | 58.76 | 0.061 | 62.050 | Mbabo |
| 53 | 36.8 | 0.047 | 48.108 | Mbabo |
| 54 | 52.3 | 0.065 | 66.266 | Mbabo |
| 55 | 50.8 | 0.051 | 51.909 | Mbabo |
| 56 | 49.43 | 0.045 | 45.257 | Mbabo |
| 57 | 78.05 | 0.159 | 161.318 | Mbabo |
| 58 | 93.14 | 0.164 | 166.754 | Mbabo |
| 59 | 48.83 | 0.052 | 52.410 | Mbabo |
| 60 | 79.68 | 0.158 | 160.316 | Mbabo |
| 61 | 44.15 | 0.057 | 58.205 | Mbabo |
| 62 | 94.54 | 0.150 | 152.039 | Mbabo |
| 63 | 101.73 | 0.189 | 192.045 | Mbabo |
| 64 | 47.59 | 0.045 | 45.391 | Mbabo |
| 65 | 81.08 | 0.137 | 139.364 | Mbabo |
| 66 | 47.65 | 0.066 | 66.507 | Mbabo |
| 67 | 82.25 | 0.144 | 146.519 | Mbabo |
| 68 | 35.24 | 0.048 | 48.970 | Mbabo |
| 69 | 103 | 0.158 | 160.103 | Mbabo |
| 70 | 90.84 | 0.178 | 180.151 | Mbabo |
| 71 | 31.32 | 0.032 | 32.588 | Mbabo |
| 72 | 96.32 | 0.174 | 177.043 | Mbabo |
| 73 | 39.38 | 0.068 | 69.223 | Mbabo |
| 74 | 51.25 | 0.043 | 43.426 | Mbabo |
| 75 | 62.39 | 0.092 | 93.150 | Mbabo |
| 76 | 67.61 | 0.106 | 107.185 | Mbabo |
| 77 | 86.1 | 0.191 | 194.205 | Mbabo |
| 78 | 69.87 | 0.181 | 184.119 | Mbabo |
| 79 | 38 | 0.029 | 29.910 | Mbabo |
| 80 | 83.3 | 0.140 | 142.365 | Mbabo |
| 81 | 74.71 | 0.195 | 197.537 | Mbabo |
| 82 | 91.17 | 0.174 | 176.207 | Mbabo |
| 83 | 89 | 0.129 | 130.598 | Mbabo |
| 84 | 60.58 | 0.185 | 188.144 | Mbabo |
| 85 | 37.56 | 0.042 | 42.415 | Mbabo |
| 86 | 70.22 | 0.159 | 161.407 | Mbabo |
| 87 | 75.82 | 0.195 | 198.243 | Mbabo |
| 88 | 81.56 | 0.147 | 148.863 | Mbabo |
| 89 | 74.07 | 0.196 | 198.941 | Mbabo |
| 90 | 92.5 | 0.105 | 106.509 | Mbabo |
| 91 | 72.74 | 0.118 | 119.846 | Mbabo |
| 92 | 30.56 | 0.022 | 22.043 | Mbabo |
| 93 | 93.11 | 0.163 | 165.286 | Mbabo |
| 94 | 74.04 | 0.193 | 196.318 | Mbabo |
| 95 | 43.13 | 0.059 | 60.014 | Mbabo |
| 96 | 90.85 | 0.205 | 207.564 | Mbabo |
| 97 | 79.39 | 0.117 | 118.775 | Mbabo |
| 98 | 80.28 | 0.123 | 125.222 | Mbabo |
| 99 | 48.38 | 0.047 | 47.746 | Mbabo |
| 100 | 70.99 | 0.121 | 123.184 | Mbabo |
| 101 | 88.02 | 0.141 | 142.829 | Mbabo |
| 102 | 46.25 | 0.049 | 49.516 | Mbabo |
| 103 | 70.16 | 0.192 | 194.923 | Mbabo |

**Table 8.** Contd.

| | | | | |
|---|---|---|---|---|
| 104 | 76.91 | 0.158 | 160.314 | Mbabo |
| 105 | 83.94 | 0.150 | 152.557 | Mbabo |
| **All sites** | | | | |
| N | 105 | 105 | 105 | |
| Mean | 60.02 | 0.14 | 138.61 | |
| Sd | 20.18 | 0.08 | 79.11 | |
| Max | 119.69 | 0.55 | 562.36 | |
| Min | 30.08 | 0.02 | 22.04 | |
| **Gang Daba** | | | | |
| N | 50 | 50 | 50 | |
| Mean | 51.17 | 0.16 | 159.88 | |
| Sd | 15.66 | 0.09 | 92.55 | |
| Max | 119.69 | 0.55 | 562.36 | |
| Min | 30.08 | 0.03 | 33.14 | |
| **Mbabo** | | | | |
| N | 55 | 55 | 55 | |
| Mean | 68.07 | 0.12 | 119.27 | |
| Sd | 20.56 | 0.06 | 59.00 | |
| Max | 103.00 | 0.20 | 207.56 | |
| Min | 30.56 | 0.02 | 22.04 | |

DBH: Diameter at breast high.

**Table 9.** Comparison of the mass of the bark of a total *Prunus* tree between Gang Daba and Mbabo in the Adamaoua region.

| Parameter | Mean | sd | n | F= 7.3221 | Pr= 0.007973 ** |
|---|---|---|---|---|---|
| Gang Daba | 159.88 | 92.55 | 50 | | |
| Mbabo | 119.26 | 59.00 | 55 | | |
| All sites | 138.61 | 79.11 | 105 | | |

The F value and Pr are from the comparison between Gang Daba and Mbabo. Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1.

**Table 10.** Comparison of the thickness of the bark measured with different material (Tarrière de Pressler vs Calliper rule).

| Parameter | Mean | sd | n | F = 2.269 | Pr = 0.1335 |
|---|---|---|---|---|---|
| Calliper rule | 13.01 | 4.819 | 105 | | |
| Tarrière | 12.02 | 4.66 | 105 | | |

This will have a negative effect on the economic livelihoods of smallholder farmers and narrow the options for those suffering from prostate disorders. According to the World Agroforestry study published in the January-March 2012 issue of the journal Forests, Trees and Livelihoods, cultivating the tree on farms will alleviate the threat of extinction caused by unsustainable wild harvests. It takes 12 to 15 years for the tree to produce the bark that contains the prostate remedy’s active ingredient (World Agroforestry Centre, 2012; Gachie et al., 2012).

Since 2008, ITTO and CITES have been working together to develop a large capacity-building program for range countries in Africa regarding tree species listed in

Appendix II of CITES. The program entitled “Ensuring international trade on CITES listing tree species is non detrimental to their conservation in the wild” aims to assist local CITES authorities in range countries in making non-detriment findings for those species. Conservation of the specimens in their natural habitat being the main target, which is not necessary the same outlined above for the World Agroforestry Centre.

Cubic tariffs are often used in forestry in three main areas including trade on forest products, forest management, and forest research, mainly oriented on forest productivity. The cubic tariff is an indispensable tool in forest management and forest inventories since it allows to quickly estimate the stand volume of trees (Pardé and Bouchon, 1988; Rondeux et al., 1991). Important things to consider in the construction of the cubic tariff is to decide on the number of entries (parameters) to use and to select the best mathematical formula (College of Forest Engineers of Quebec, 1996). The choice of the entries is guided by their simplicity and their link with the volume. Most of cubic tariffs constructed in forest management are those which yield the standing volume of the timber based on its diameter at high breast. Our cubic tariff is built from one entry, the diameter at breast heoght to be précised. It yields the volume of the stem bark of a given *P. africana* tree according to its diameter at breast height. We could also decide to use the thickness of the stem bark as another entry (parameter) for building our cubic tariff. But we found that, this parameter cannot be easy for forest officers to collect it in the field. It is more easier to measure the diameter at breast height than measuring the thickness of the tree. For a cubic tariff which concern a limit area with relatively homogenous growth conditions, the number of trees should vary from 30 to 100 (Rondeux, 1993; College of Forest Engineers of Quebec, 1996). This condition is respected in our study, since we worked on 105 trees of *P. africana* comprising 50 trees in Tchabal Gang Daba considered as an unexploited site and 55 trees in Tchabal Mbabo considered as an exploited site.

Cameroon’s *P. africana* barks are exported in two forms: the raw bark and the “powder”. Powder here is referred to the bark shavings or the ground barks. Whatever be the form, *P. africana* is exported in dried matter. The dried weight of *P. africana* barks to be exported is = 50% of Fresh weigh (Ingram and al., 2009). The minimum diameter of exploitation (MED) adopted by the Cameroon forest administration for *P. africana* barks is 30 cm at breast height. In Kenya, Gachie et al. (2012) revealed that there is a positive correlation between tree age and the extract yield. However, the trend is not linear, since at old age (> 50 cm DBH), *P. africana* trees were seen to have a drop on the crude bark extract yield. This implies that the best source of the bark is from medium-sized trees (30 to 50 cm DBH). We can therefore agree that the DBH 30 cm adopted by the Cameroon is good for maximising the extract yield. The question to ask is, if the adopted MED is enough to ensure the regeneration? Further studies are requested for defining the best MED that encompasses both the extracts yield and the regeneration concerns.

The relation diameter of the tree at breast height – volume of the stem bark varies from one site to another. In the un-exploited site (Gang Daba), this relation is almost linear, which is different to what is observed in the exploited site. We conclude that, in an un-exploited site, there is a positive correlation between tree age (diameter size) and the extract yield as suggested by Gachie et al. (2012). This hypothesis can no longer been verified in the case of an exploited site.

*P. africana* can survive the removal of some bark and there is the possibility, therefore, for harvesting bark without felling or killing the tree. Plantecam collectors were trained to gather the bark in the least damaging way. They were not permitted to fell the trees and they were expected to remove bark from up to only 50% of the circumference of the tree and from opposite sides of the trunk in order to prevent girdling, which could kill that specimen. Nor, were they permitted to return to the same tree for further harvesting for five years. The claim that the collection techniques described was sustainable, if properly followed, was endorsed by the botanists and conservationists working at Limbé and Buea, in the South West Cameroon. This elaborate harvesting process was a product of the species particulars characteristics (Ndibi and Kay, 1997; Marcelin et al., 2000; Page, 2003).

There is no significant difference between the thickness of the stem bark obtained with the “Tarrière de Pressler” and that obtained with the calliper rule. This means that the two materials can be used indifferently for the measurement of the thickness of the bark. Whatever be the material used, the difference between the un-exploited site and an exploited site is at least 7.3 mm. If we consider the results obtained with the calliper rule, the average thickness of the bark is 13.01 ± 4.8 mm. This value is comprised between that of unexploited *P. africana* trees found in Gang Daba (16.99 ± 3.7 mm) and exploited *P. africana* trees observed in Mbabo (9.40 ± 2.07 mm). This value is high than the 8.49 ± 2.41 mm (n = 117 trees) obtained in the mount Cameroon (Betti and Ambara, 2011), what ever be the site. The value of 9.40 mm of the Mbabo is closed to that of the Mount Cameroon, considered also as an un-exploited site (Betti and Ambara, 2011). Our findings are quite similar to those obtained in Equatorial Guinea (Sunderland and Tako, 1999). In fact, in the Bioko island, in Equatorial Guinea, Sunderland and Tako (1999) obtained an average thickness of 13.01 mm. This value was comprised between that of un-exploited (16. 21 mm) and exploited (9.94 mm) *P. africana* trees.

An exploitable tree of *P. africana* of the Adamaoua region has an average mass of 138.61 ± 79.11 kg of stem barks. This value comprise between that of un-exploited (159.88 ± 92.55 kg) and exploited (119.27 ± 59.00 kg) *P. africana* trees observed respectively in Gang Daba and Mbabo. These values represent the 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, the average sustainable mass of *Prunus* tree in Tchabal Mbabo and Tchabal Gang Daba mountain forests will be about 69.3 kg of fresh bark per tree. This value is comprised between that of un-exploited (80 kg) and exploited (60 kg) *P. africana* trees in Ganga Daba and Mbabo respectively. Previous studies conducted in the same area using a destructive approach (cutting of trees) revealed that an exploitable *P. africana* tree harvested in sustainable manner can yield about 75 kg of fresh bark (Cunningham and Mbenkum, 1993 ; Hall et al., 2000). Sustainable manner in this paper means, as explained above, taking only two quarters of the bark from the main stem up to the first big branch. On Mount Oku in the North west region of Cameroon, Ondigui (2001) using the destructive method found that the average sustainable mass of fresh bark of *P. africana* was 55 kg/tree with four-year intervals. Results obtained in mount Cameroon using the same method suggested that the sustainable weight or mass of *P. africana* is 50 kg of fresh bark with five year intervals (Betti and Ambara, 2011). What ever be the case (exploited or un-exploited trees), the average mass of fresh bark yielded by an exploitable *P. africana* tree in Adamaoua is high than those obtained in Mont Cameroon and Mont Oku. The difference observed between different zones may be due to the environmental conditions such as soils, altitude, temperature.

Following what precedes and based on indirect method used, we suggest that for Tchabal Mbabo and Tchabal Gang Daba mountain forests, the sustainable mass/yield of an exploitable *P. africana* tree is 69.3 kg of fresh bark with at least five-year intervals. This means that to sustain *P. africana* in Adamaoua region of Cameroon, trade companies or villagers should harvest, trees of at least 30 cm of diameter at breast height, move the 69.3 kg of stem bark on the ½ opposite sides, and return at least 5 years later to move the remaining sides on the same tree, or return 10 years latter to move the same side on the same tree. Five years interval should be considered with some precautions, since quantitative studies have not yet been conducted in the Adamaoua region to monitor the rate of recovery of the stem bark after harvesting. Environmental conditions such as altitude, soils, temperature seem to have significant impact on extract yield and quality of active compounds of *P. africana*. Temperature differences may cause chilling injury in plants, which encompasses imbalances in metabolism, accumulation of toxic compounds, and increased membrane permeability (Gachie et al., 2012). Mount Cameroon is up to 4095 m and the average temperature is 22°C (Betti and Ambara, 2011; Betti et al., 2011), while Mbabo and Gang Daba may not reach even 2 500 m and the average temperature is 23°C. The high temperature observed in Adamaoua may suggest to increase the rotation period, or the time that separates two harvesting campaigns on the same tree. Further studies are required for this item.

## Conclusion

The single data used for the construction of our cubic tariff is the diameter of tree at breast high. This data is well known by many foresters and is easy to collect in the field. The cubic tariff and the average mass of exploitable trees are two tools which can ease the estimation of stand bark volume for *P. africana* trees. Those two data can be used to quickly estimate the export quota of *P. africana* for Cameroon for the Tchabal Mbabo and Tchabal Gang Daba mountain forests. Our study reveals that, for these mountain forests, the sustainable mass of an exploitable *P. africana* tree is 69.3 kg of fresh bark with at least five-year intervals, this is harvesting trees of at least 30 cm of diameter at breast height, move the ½ opposite side, and return at least 5 years later to move the remaining sides on the same tree, or return 10 years latter to move the same side on the same tree. The 69.3 kg should be considered as an average, comprised between that of un-exploited (80 kg) and exploited (60 kg) *P. africana* trees in Ganga Daba and Mbabo respectively. This information is crucial for making non-detriment findings for *P. africana* barks harvested in Adamaoua mountain forests.

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