Agriculture, Forestry and Fisheries
2014; 3(6-1): 10-22
Published online September 23, 2014 (http://www.sciencepublishinggroup.com/j/aff)
doi: 10.11648/j.aff.s.2014030601.13
ISSN: 2328-563X (Print); ISSN:2328-5648 (Online)

Sustainable harvesting of *Alstonia boonei* De Wild. (Apocynaceae) in the community forest of Mbeth II, East Region of Cameroon

Jean Lagarde Betti[1], Joseph Ambara[2]

[1]Department of Botany, Faculty of Sciences, University of Douala, BP 24 157 Cameroon
[2]Ministry of Environment and Nature Protection, Cameroon

Email address:
lagardeprunus@gmail.com (J. L. Betti), ambara.joseph@yahoo.fr (J. Ambara)

To cite this article:
Jean Lagarde Betti, Joseph Ambara. Sustainable Harvesting of *Alstonia boonei* De Wild. (Apocynaceae) in the Community Forest of Mbeth II, East Region of Cameroon. *Agriculture, Forestry and Fisheries.* Special Issue: Agriculture Ecosystems and Environment. Vol. 3, No. 6-1, 2014, pp. 10-22. doi: 10.11648/j.aff.s.2014030601.13

Abstract: This paper aims to analyze the traditional usages and, assess the abundance of stems and the mass of the barks of *Alstonia boonei* for its use as a medicinal plant in the community forest of Mbeth II, East region of Cameroon. Ethnobotanical surveys were conducted among the community of Mbeth II and in city markets in Bertoua and Yaoundé between January and April 2012. The management inventory was conducted in July 2012 to assess the abundance of *A. boonei* stems in the forest. During the inventory, samples of barks were collected from mature trees and the mass of the stem barks of *A. boonei* was estimated using an indirect method. *A. boonei* was cited by 26 informants in the village and markets in the treatment of six ailments. Malaria, typhoid fever and intestinal worms were largely cited. The stem bark is confirmed for its activity against malaria/fever. The density (number of stems/ha) of *A. boonei* obtained in the Community forest of Mbeth II was 0.89 stems/ha. The density of exploitable stems was therefore 0.744 stems/ha. The average volume of fresh bark for an exploitable tree is 0.0356 m^3, while the average fresh mass of the bark of an exploitable tree was 34.4 kg. Considering that for all trees above 30 cm diameter at breast high (considered as a minimum exploitable diameter for the harvesting of barks), only two quarters of the bark are taken from the main stem up to the first branch, the average sustainable mass of *Alstonia boonei* in Mbeth II is 17.2 kg. Results discussed in this paper can be summarized, in a specific document called "the simple management plan of *A. boonei* as a medicinal plant in the community forest of Mbeth II". The glaring development challenge at the back ground of what precedes is the urgent need to achieve the recommendations proposed in such a document.

Keywords: Sustainable Harvesting, *Alstonia Boonei*, Community Forests, Simple Management Plan, Fresh Mass, Management Inventories, Exploitable Tree, Cameroon

1. Introduction

The tropical rainforests of the Congo Basin cover an area of approximately 170 million hectares, and constitutes the world's second largest tract of rainforests after that of the Amazon River Basin. Cameroon belongs to the Congo Basin and takes the third position in terms of biodiversity richness behind the Democratic Republic of Congo and Gabon. The total surface area of the forests in Cameroon is 19 916 000 ha, representing about 42% of the national territory [1].

More than 25 years ago, Cameroon Government decided with the help of the international Community, to tackle the general problematic of sustainable forest development. The Government therefore first focused its efforts on the knowledge of the timber resource of the forest zone of the country. A national forest inventory has therefore been conducted with the assistance of the Canadian cooperation (ACDI), comprising 7 phases. Four out of these phases have yet been finalized by the years 80, for a total forest bloc of 14 000 000 hectares, with the north limit situated at about 4th parallel. In fact, the basis work undertook within the national inventory conducted during the years 1980 [2; 3] led to the elaboration of principal norms and technical tools for the management of the forest domain. These tools include: (1) the zoning plan of the forest area (phases 1-4 of national inventory) which led to the division of the forest zone in two main domain types, namely the permanent

domain and the non-permanent domain, and (2) all norms related to the interventions in the forest milieu (production forests to be précised).

The permanent domain [4] is composed of two areas including (1) the state-owned forests, which belong to the State, (2) and communal forests which belong to the private domain of the council. The state-owned forests are themselves divided into production forests, protected areas, and forest reserves. Production forests are the most important in terms of surface area, 64% of the permanent domain, and 40% of the meridional zone. Production forests are mainly composed of big forest concessions. Each forest concession is composed of one or many forests of more than 5,000 ha, called the forest management unit (FMU).

The non-permanent domain comprises the community forests, sales of standing volume (small forest concessions of not more than 2,500 ha), and mining zones. It is also composed of lands affected for agricultural and other agroforestry activities [4]. Rigorous management schemes are not applied to the non-permanent domain.

Cameroon is considered as one of the most advanced in terms of forest sector policy in the Central Africa region [5; 6]. This means that, Cameroon is one of the first countries to have produced and started implementing a good and coherent forest code in the sub-region, after the summit of the world on sustainable development held in Rio de Janeiro (Brazil) in 1992 [4]. Compared with past policies (the last one promulgated in 1981), the 1994 forest policy makes the involvement of rural populations lawfull, partners and stakeholders in its implementation, notably by the ownership of community forests and hunting zones. This innovation is intended to encourage people to better protect their wildlife and vegetation cover. In forest management, one of the concerns of the state has always been the involvement of the surrounding population to enable them have a fair and equitable share from forest exploitation. Although the populations enjoy usufruct rights, they do not have a substantial share from the commercial exploitation of forest resources. A better implication of local communities in forest activities may not only lead to the sustainable use of forest resources, but also help those communities through the revenues gained to enhance the struggle for poverty alleviation.

The 1994 forest law and its application tools allowed the beginning of many experiences of community forestry, conceding to communities the right of managing the resources of their own territories. A manual of procedures of attribution together with standards of the management of community forests was produced in 1998, and revised in 2009. This manual constitutes a fair juridical basis of the application of the concept of community forestry. It also represents an important tool showing clearly the modalities and the practical steps of the acquisition and management of community forests. A community forest is a block of 2 500 ha to 5 000 ha of forest, that the community requests from the government. Community forests are assigned to the sustainable production of the wood and other resources (for e.g. non timber forest resources) in respect to the conditions that allow the preservation of ecological, environmental, and sociological functions of the forests. To own a forest, the community must: (1) organize itself in a Common Initiative Group (GIC), (2) produce a map of the forest requested or desired, (3) organize a meeting of collaboration in presence of the forest administration's officers and the civil authorities, (4) describe activities already done in the forest, (5) designate a resource person who will be responsible for the management of the forest, (6) address a letter of application to the forest administration, giving details on the specific objectives that the group intend to rich through the exploitation of the forest. When the community forest is attributed based on the elements listed above, the community is now requested to produce the Simple Management Plan (SMP) of the forest before its exploitation. This Simple Management Plan is the only document that leads to the signature of the common agreement of twenty five years between the forest administration and the community.

The first community forest was attributed by the Government in 1997, about 27 years ago. By December 2010, some 378 forests were reserved as community forests, covering about 142 470 ha. Community forests are largely used for the harvesting of timber. Little community forests are used for the harvesting of food, medicine, material culture and items for many other material and spiritual benefits, that are generally called Non-Timber Forest Products (NTFP).

This paper aims to analyze the traditional usages, assess the abundance of stems and the mass of the barks of *Alstonia boonei* for its use and trade as a medicinal plant in the community forest of Mbeth II in the East region of Cameroon.

2. Material and Method

2.1. Study Site

Mbeth II is a village located in the Diang subdivision, the Lom and Djerem Division, in the East region of Cameroon. Mbeth II is situated at 25 km to Bertoua, the capital of the east region. The village is situated between 04°35' - 04°36' latitude nord, and 31°44' – … longitude east. The community forest of Mbeth II is vast of 5 000 ha.

The climate is an equatorial and Guinean type, characterized by four in-equal seasons: a big dried season from December to mi-March, a small rainy season from mi-March to May, a small dried season from June to August, and a big rainy season from September to November. The average temperature is 24.3°C, with the maximum at 25.8°C in March. The average annual rainfall varies between 1 000 and 1 500 m. Soils are iron soils type.

The community forest of Mbeth II is located in the Guinean Congolese floristic region, in the low and medium altitude, in the domain of dense and rain semi-deciduous

forest of Sterculiaceae (*Sterculia spp* and *Cola spp*) and Ulmaceae. Situated closed to the forest-savannah contact zone, Mbeth II forest presents phytogeographic features belonging to the two small domains or sectors including the Guineo-Soudanian sector with its different savannah stands and the typical semi-deciduous forest sector [7]. This forest has already been subjected to forest logging by the year 1970, which explains the general feature of old secondary forests observed in the field. Principal timber species include: *Triplochiton scleroxylon, Ceiba pentandra, Uapaca guineensis, Sterculia rhinopetala, Ricinodendron heudelotii, Alstonia boonei, Afzelia africana, Entandrophragma cylindricum, Hymenocardia lyrata*. Typical secondary forests of *Musanga cecropioides* and *Albizia spp* also exist in former farms and fallows.

Mbeth II hosts about 964 inhabitants, with a density of 8 inhabitants/km2. Agriculture, poaching, pit sawing and gathering NTFPs are the main activities conducted in that village. Cash tree crops include cocoa and coffee. The slash and burn type of cultivation system is practized, with maize, groundnuts, cassava, bananas and cocoyam being the main crops. Both timber and NTFP are found in Mbeth II. Some years ago, pit sawing practized mainly by young people was the unique way of exploiting timber resource, due to the lack of community forests and other forms of logging permits. Tradesmen used to buy the wood at a very low price (6 US$/tree or 2US$/m3) from each villager. The same wood was sold at Bertoua market at 50 – 60 US$/ m^3, which was not profitable to the villagers [8]. In 2011, the community of Mbeth II decided to better valorize their surrounding forest. They organized themselves within a Community Initiative Group (CIG) called "BWOK" and applied to obtain their community forest. The certificate of the measurements of the forest and the preliminary two years convention were signed by the Minister of Forestry and Wildlife in 2011 and 2012 respectively, allowing the community to own their 5 000 ha of forest. By doing this, the Government intended to halt illegal logging in this village.

The genus *Alstonia* belongs to the Apocynaceae family. It comprises about 40 species and has a pantropical distribution. It is a large deciduous tree, up to 45 m tall and 1.2 m in diameter; bole often deeply fluted to 7 m, small buttresses present; bark greyish-green or grey, rough; slash rough-ranular, ochre-yellow, exuding a copious milky latex; branches in whorls. *Alstonia boonei* is found in dry, peripheral, semi-evergreen Guineo-Congolian forest and transitional rainforest. In Cameroon, the plant occurs elsewhere in similar habitats and in swamp and riverine forests. *A. boonei* requires large amounts of light and colonizes gaps in the forest. It has plenty of natural regeneration in young secondary forest. Growth is rapid, and it is not uncommon for an annual increment of 1.8 m to occur in the sapling stage. It grows in a succession of crowns and should not be pruned but left to develop secondary crowns, which will later kill off the lower ones. Mature trees are often damaged by wind and decay but are fast growing and coppice readily from the base. The tree snaps easily in strong wind and therefore should not be planted near buildings [9; 10]. The sapwood, which is not differentiated from the heartwood, is very wide, up to 200 mm, soft, and light in weight when dried. The wood weighs about 400 kg/cubic m. nearly yellowish-white when freshly cut, the timber darkens on exposure. It has a low luster and no characteristic odour or taste. The wood can be glued, stained and polished satisfactory. Export prospects are doubtful, although it has a local potential for stools, carvings, domestic utensils, toys, masks, canoes, horns, light carpentry, boxes [11]

2.2. Methods

The method used in this study consists of ethnobotanical surveys, assessment of the abundance and stock, and biomass determination.

2.2.1. Ethnobotanical Survey

Ethnobotanical surveys were conducted among the community of Mbeth II and in city markets in Bertoua and Yaoundé between January and April 2012.

The method used among the community is known as the "method for the popular pharmacopoeia", consisting of gathering data on the popular use of medicinal plants in a given area [12]. Following this method, the data for this study were obtained from direct interviews with the Mbeth II people. The survey aimed at identifying plants used in the popular pharmacopoeia among local people. The household was considered as the sample unit. In each household who accepted to answer to our questions, data were mostly recorded from adult women (mothers), because they usually knew the plants better than men and younger people. They provided useful and first-hand information on the popular use of medicinal plants. During the survey, we made enquiry "as to what ailments were treated by which plant species" rather than asking "which plants were used to treat which ailments". For each health problem cited, the name of the plants and the plant parts used were carefully recorded. The vernacular names of the plants were recorded as much as possible, and we tried to collect the plants mentioned by the informants. The final identification of plants was made at National Herbarium of Cameroon (YA) with the help of Dr. Onana and Mr. Paul Mezili. Voucher herbal specimens, collected in three samples are kept at the YA. The therapeutic statements were made of a specific disease, a symptom or a physiological effect. Information on the diagnosis of ailments was provided through a semi-structured interview of nurses or local health officials. In this paper, anti-malarial plants refer to the plants used for treating malaria or fever on a broad scale. To classify the data according to the world system, the ailments were grouped according to the classification proposed by the World Health Organization and adapted by the African Unity Organization (AUO) for the Cameroonian pharmacopoeia [13].

The second ethnobotanical survey was conducted from March to April 2012 in the Bertoua and Yaoundé markets. The survey aimed in identifying plant parts which were sold at the market for their medicinal purpose. The method used is the same as used in 2002 in Yaoundé markets [14]. Bertoua is suitable since it is the big market situated closed to Mbeth II village. Youndé is far from Mbeth II, at about 350 km in the South west. But Yaoundé is the political capital of Cameroon and was identified as one of the main point which receives forest products harvested in the Centre, East, and South regions of Cameroon [14]. The data collected among sellers in markets can easily be compared with those recorded among people living in Mbeth II village. For any plant species sold at the market, the vernacular names of the plant and the name and ethnic group of the seller were recorded. Then we asked the seller questions concerning plant parts used and their therapeutic indication. These indications (therapeutic statements or ailments or judgments) were made on a specific disease, a symptom or a physiological effect. The plant parts were then weighed and the prices were recorded. We bought one sample of the plant parts for information set and from each seller. The plants identified were kept in the National Herbarium of Cameroon (YA).

2.2.2. Assessment of the Abundance and Stock of A. Boonei in the Community Forest of Mbeth II

2.2.2.1. Sampling Design

The assessment of the abundance of *Alstonia boonei* was conducted in July 2012. It consisted of gathering qualitative and quantitative data on the stems of *A. boonei* found in the Community forest of Mbeth II. This is a mixture of primary and secondary forests, extended on 5 000 ha. We used a Global Positioning System (GPS) and vegetation maps to settle our sampling plots. The sampling was systematic and stratified to 1 degree when the statistical unit is the plot. The samples or plots of 0.5 ha are distributed systematically throughout the entire population. The systematic disposal of plots allows to assume that the intensity of sampling for each stratum is proportional to its area in the forest.

In practice, sampling was carried out along straight and continuous axes or transects. These transects are oriented along a predetermined cardinal direction but are systematically arranged in such a way that they are mostly parallel, equidistant and perpendicular to the general direction of the drainage. Rectangular plots arranged along a transect are contiguous and measure 250 m in the direction of the transect (length) and 20 m in the direction perpendicular to the transect (width). This gives a surface area of 0.5 ha for each plot. The mapping activity allowed us to distinguish four main forest types inside the perimeter of the Mbeth II community forest including: the primary forest (891 ha), the secondary forest (3 961 ha), the temporary drained forest (100 ha), and the permanent drained forest (48 ha). Primary forests or less perturbed forest are forests where human activities are less observed. Secondary forests are forests which have already been subjected to forest logging activities more than 30 years ago. Temporary drained forests are forests which are drained during the rainy seasons, and dried during the dried season and suitable for logging activities. Primary, secondary and temporary drained forests totalize 4 952 ha and constitute the production forests. These are the forests where the community of Mbeth II will harvest forest products. Permanent drained forests are forests which are drained all the year and cannot be suitable for timber or non-timber harvesting activities. These areas are often considered as vulnerable ecosystems, un-productive forests which are devoted to the conservation/protection targets.

Table 1 presents the sampling design which was used. Each line opened is presented with its number of plots and the corresponding sampling area. A total of 274 plots of 0.5 ha each were inventoried in 20 lines. A total of 137 ha out of the 5 000 ha was totally covered by forest inventories giving an average sampling intensity of 2.74%, which is good and in conformity with the national standards (for surface areas ≤ 5 000 ha, the sampling rate should be at least = 2%).

Figure 1 illustrates the sampling design described above. The distance between two consecutive lines is 900 m.

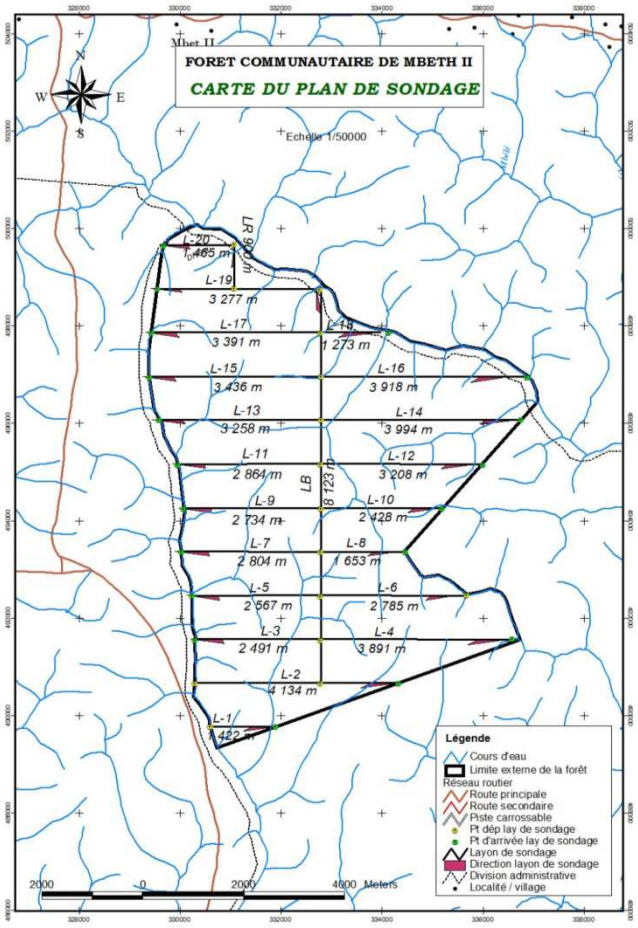

Figure 1. *Sampling map of the inventory of Alstonia boonei used for the community forest of Mbeth II.*

Table 1. *Number of lines, plots and the sampling rate used to assess the abundance of Alstonia boonei in the community forests of Mbeth II.*

Line number	Number of plots of 0.5 ha	Sampling area per line (ha)	Sampling rate (%)
L1	7	3.5	0.07
L2	20	10	0.2
L3	12	6	0.12
L4	19	9.5	0.19
L5	12	6	0.12
L6	12	6	0.12
L7	14	7	0.14
L8	8	4	0.08
L9	13	6.5	0.13
L10	12	6	0.12
L11	14	7	0.14
L12	16	8	0.16
L13	16	8	0.16
L14	19	9.5	0.19
L15	16	8	0.16
L16	19	9.5	0.19
L17	16	8	0.16
L18	6	3	0.06
L19	16	8	0.16
L20	7	3.5	0.07
Total	274	137	2.74

2.2.2.2. Implementing the Sampling Design

The inventory consists of two steps: line opening/transect cutting and counting. This is done by a production team of about 20 people composed of two sub-teams of ten people each including the lining sub-team and the counting sub-team.

2.2.2.3. Line Opening/Transect Cutting

This step consists of opening or cutting according to a defined magnetic direction, corridors or alleys of 1.5 m width. These corridors are clearly cleaned by cutting shrubs, vines and branches that obstruct the passage. They are identified by marks. “Layons” constitute the reference system which will be used for counting by the subsequent team. It is during the line opening that details on topography, habitat types, rivers and the corrected horizontal distance of the transect (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 sheets.

2.2.2.4. Counting

Alstonia boonei is a high tree species which can reach 45 m height and 1.2 m in diameter. In Cameroon, the minimum exploitable diameter (MED) for *A. boonei* has been fixed by the forest administration at 50 cm for timber logging purpose. In the field, villagers prefer harvesting the barks on trees that are easily accessible, with diameter less than 40 cm. In this paper, we adopted the minimum diameter of 30 cm for stem barks, as fixed by the forest administration for *Prunus africana*, another important medicinal plant in Cameroon. This is, only trees with diameter equal or high than that value (30 cm) are authorized to be harvested by villagers.

The counting step includes all operations relating to dendrological and dendrometric records. During the counting, several operations are made including: identification of stems of trees, the measurement of stems with diameter at breast height (dbh = 1.50 m) >= 20 cm.

2.2.3. Estimation of the Average Mass of the Bark of an Exploitable Tree

2.2.3.1. Selection of Trees

This part of the study started two weeks later after the team in charge of assessing the abundance of *Alstonia boonei* trees has finalized their work. The sheets of the sub-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 *Alstonia boonei* trees. Practically, trees were 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 identify it and take appropriated measures of the stem. A total of 37 *Alstonia boonei* trees with diameter at breast high ≥ 30 cm were sampled.

To estimate the mass of the stem barks of *Alstonia boonei*, we used an indirect method. In fact, a direct method would require diameter tape and bark thickness measurements at the critical heights (breast high, first branch, etc), with some degree of verification through destructive sampling. This can yield précised data compared to indirect method. We preferred indirect method for two main reasons: (1) it is non-destructive, and (2) it can easily be applied in the field by foresters during forest management inventories.

We proceeded in three steps to estimate the mass of the stem barks: (1) establishment of the relation linking the diameter at breast high (DBH) of each tree with the thickness of its stem bark, (2) establishment of the relation linking the volume of the stem bark and its mass (weigh), and (3) determination of the mass of the fresh bark for exploitable (mature) trees.

2.2.3.2. Relation Diameter – Thickness of Volume of the Stem Bark: Volume Based Tariff (VBT)

The volume based tariff (VBT) 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, or the height,. The tariff is more valid for the area where the samples were collected [15]. The volume of the tree can be estimated with or without the stem bark.

To estimate the volume of the stem bark of *Alstonia boonei*, we used the VBT developed for *Alstonia boonei* in the same area during the fourth phase (phase IV) of the national forest inventory. This phase was conducted from 1989 to 1990 on a total area of 2 355 313 ha. The VBT for *Alstonia boonei* under (without) the stem bark was established as follow [2; 3]:

$V = aDb$

V = Volume of the tree with the stem bark;

D = diameter of the tree with the stem bark.

a = 0.00461 ; b = 2.166608, a and b are parameters of the formula.

The diameter of the tree with the stem bark (D) is: D = Dns + 2t

With Dns = diameter of the tree without the stem bark;

t = thickness of the stem bark.

In the same order, the volume of the tree with the stem bark is V = Vns + Vs;

Vns = volume of the tree without the stem bark;

Vs = volume of the stem bark.

Vs = V – Vns

Vs = aDb – a(D – 2t)b

Vs = a[Db – (D – 2t)b]

2.2.3.3. 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 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 was measured using the calliper rule. Collecting the samples was not easy since *Alstonia*'s bark is more stick to the cambium. 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 *Alstonia boonei* barks in the community forest of Mbeth II. The cubic mass is Cm = m/V with m = mass in kilogram (kg) and V = volume of the stem bark in cubic meter (m3).

2.2.3.4. Mass of the Fresh Bark for Exploitable Trees

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 *Alstonia boonei* in Mbeth II.

2.2.4. Data Analysis

Data were analyzed using the Microsoft Excell 2010 software. For analysis, we determined the number of citations of *Alstonia boonei* in inquiries, the price per gram, the number of stems in different diameter classes and the density (number of stems/surface area). The total number of stems (stock) of the forest is the product of the density by the surface area.

3. Results

3.1. Ethnobotanical Survey

Table 2. *Informants interviewed in Mbeth II and markets of bertoua and Yaoundé.*

Order number	village	Code informant	age	market
1	Mb	Mmb1	51	
2	Mb	Fmb1	55	
3	Mb	Mmb2	57	
4	Mb	Fmb2	80	
5	Mb	Fmb3	81	
6	Mb	Mmb3	58	
7	Mb	Fmb4	52	
8	Mb	Mmb4	61	
9	Mb	Mmb5	62	
10	Mb	Fmb5	54	
11	Mb	Fmb6	55	
12	Mb	Fmb7	63	
13	Mb	Fmb8	60	
14	Mb	Fmb9	49	
15	Mb	Fmb10	57	
16	Mb	Fmb11	58	
17	Br	Mbr1	43	Mandjou
18	Br	Fbr1	39	Sous-prefecture
19	Br	Mbr2	36	Marché central
20	Br	Mbr3	38	Marché central
21	Ya	Fya1	32	Garre
22	Ya	Fya2	33	Garre
23	Ya	Mya1	60	mvogmbi
24	Ya	Mya2		Mokolo
25	Ya	Mya3	64	Mokolo
26	Ya	Mya4	63	poste centrale

City/village: Br = Bertoua; Mb = Mbeth II; Ya = Yaoundé,

Code informant: the first letter indicates the gender (M = male, F = female), the second and third letters indicate the city/village, and the number indicates the order number of the informant in the gender and the city,

A total of 26 persons provided information on the use of *Alstonia boonei* as a medicinal plant including 16 informants in Mbeth II, 6 in Yaoundé and 4 in Bertoua (table 2). In Yaoundé, the informants are distributed in four markets, while in Bertoua, they are distributed in three markets. The local name used varies from one place to another. In Mbeth II, it is called "Kougeu", in Bertoua, sellers use its trade name which is "Emien", while in Yaoundé markets, and sellers call it "Ekouk".

Table 3. *Citations of medicinal plants in Mbeth II and markets of Bertoua and Yaoundé*

Order n of citations	Code_ Informant	Ailment	Latin name	Associated (Ass) plant species	Plant part	Mass (gram)	Price of selling (FCFA)	Ratio Price/mass
1	Mmb1	Ma/Fe	*A. boonei*	*C. frutescens*	Bark			
2	Mmb1	Ma/Fe	*C. frutescens*	*Ass_with Alstonia*	fruit			
3	Mmb1	Ma/Fe	*A. boonei*	*C. frutescens*	Bark			
4	Mmb1	Ma/Fe	*C. frutescens*	*Ass_with Alstonia*	fruit			
5	Fmb1	Ma/Fe	*A. boonei*		Bark			
6	Mmb2	Ma/Fe	*A. boonei*	*A. chlorantha* + *S. magnificum* + *P. nitida*	Bark			
7	Mmb2	Ma/Fe	*A. chlorantha*	*Ass_with Alstonia*	Bark			
8	Mmb2	Ma/Fe	*S. magnificum*	*Ass_with Alstonia*	Bark			
9	Mmb2	Ma/Fe	*P. nitida*	*Ass_with Alstonia*	Bark			
10	Mmb2	Ma/Fe	*A. boonei*	*A. chlorantha* + *S. magnificum* + *P. nitida*	Bark			
11	Mmb2	Ma/Fe	*A. chlorantha*	*Ass_with Alstonia*	Bark			
12	Mmb2	Ma/Fe	*S. magnificum*	*Ass_with Alstonia*	Bark			
13	Mmb2	Ma/Fe	*P. nitida*	*Ass_with Alstonia*	Bark			
14	Fmb2	Worms	*A. boonei*		Bark			
15	Fmb3	Ma/Fe	*A. boonei*		Bark			
16	Fmb3	Ma/Fe	*B.*	*Ass_with Alstonia*	leaf			
17	Mmb3	Worms	*A. boonei*		Bark			
18	Mmb3	Ma/Fe	*A. boonei*	*B. pilosa*	Bark			
19	Mmb3	Ma/Fe	*B.*	*Ass_with Alstonia*	leaf			
20	Fmb4	Ma/Fe	*A. boonei*		Bark			
21	Mmb4	Ma/Fe	*A. boonei*		Bark			
22	Mmb5	Typh	*A. boonei*		Bark			
23	Fmb5	Ma/Fe	*A. boonei*		Bark			
24	Fmb5	Ma/Fe	*B.*	*Ass_with Alstonia*	leaf			
25	Fmb6	Typh	*A. boonei*		Bark			
26	Fmb7	Ma/Fe	*A. boonei*		Bark			
27	Fmb8	Ma/Fe	*A. boonei*	*B. pilosa*	Bark			
28	Fmb8	Ma/Fe	*B.*	*Ass_with Alstonia*	leaf			
29	Fmb9	Ma/Fe	*A. boonei*		Bark			
30	Fmb10	Jaund	*A. boonei*		Bark			
31	Fmb11	Worms	*A. boonei*		Bark			
32	Mbr1	Typh	*A. boonei*		Bark			
33	Mbr1	Ma/Fe	*A. boonei*		Bark			
34	Mbr1	Ma/Fe	*A. boonei*		Bark			
35	Fbr1	Ma/Fe	*A. boonei*		Bark	300	100	3
36	Fbr1	Typh	*A. boonei*		Bark	300	100	3
37	Fbr1	Ma/Fe	*A. boonei*		Bark	300	100	3
38	Mbr2	Typh	*A. boonei*		Bark			
39	Mbr3	Ma/Fe	*A. boonei*		Bark	300	300	1
40	Mbr3	Worms	*A. boonei*		Bark	300	300	1
41	Mbr3	Typh	*A. boonei*	*P. nitida*	Bark	300	300	1
42	Mbr3	Typh	*P. nitida*	*Ass_with Alstonia*	fruit			

Order n of citations	Code_ Informant	Ailment	Latin name	Associated (Ass) plant species	Plant part	Mass (gram)	Price of selling (FCFA)	Ratio Price/mass
43	Mbr3	Typh	*A. boonei*		Bark			
44	Mbr3	Diabetis	*A. boonei*		Bark			
45	Fya1	Ma/Fe	*A. boonei*		Bark	1000	1000	1
46	Fya2	Worms	*A. boonei*		Bark	1000	1000	1
47	Mya1	Jaund	*A. boonei*		Bark	1000	1000	1
48	Mya1	Jaund	*A. boonei*		Bark	1000	1000	1
49	Mya1	Ma/Fe	*A. boonei*		Bark	1000	1000	1
50	Mya1	Ma/Fe	*A. boonei*		Bark	1000	1000	1
51	Mya1	Typh	*A. boonei*		Bark	1000	1000	1
52	Mya1	Typh	*A. boonei*		Bark			
53	Mya2	Ma/Fe	*A. boonei*		Bark	500	500	1
54	Mya2	Snake	*A. boonei*		Sap	500	500	1
55	Mya3	Worms	*A. boonei*		Bark			
56	Mya3	Worms	*A. boonei*		Bark			
57	Mya3	Ma/Fe	*A. boonei*		Bark	1000	1300	0.77
58	Mya3	Ma/Fe	*A. boonei*		Bark	1000	1300	0.77
59	Mya3	Typh	*A. boonei*		Bark			
60	Mya3	Typh	*A. boonei*		Bark			
61	Mya4	Ma/Fe	*A. boonei*		Bark	1000	1000	1
62	Mya4	Ma/Fe	*A. boonei*		Bark	1000	1000	1

Ailment: Ma/Fe = malaria/fever; worms = intestinal worms ; Typh = typhoid fever ; Jaund = jaundice; Snake = snake bite,
Price of selling: 1 USD = 494.618
C. frutescens : Capsicum frutescens ; A. boonei ; A. chlorantha : Annickia chlorantha;
S. magnificum : Schumanniophyton magnificum; P. nitida: Picralima nitida; B. pilosa: Bidens pilosa

A total of 62 citations were prescribed with *A. boonei* in the treatment of six ailments (table 3). The distribution of citations in different ailments is as follow: malaria/fever (38 citations; 61.3%), typhoid fever (12; 19.4%), intestinal worms (7; 11.3%), jaundice (3; 4.8%), and diabetes and snake bite (1; 1.6%) each. Malaria, typhoid fever and intestinal worms are cited in all the three localities.

Alstonia boonei is cited in association with five other plant species in recipes: *Anickia chlorantha, Bidens pilosa, Capsicum frutescens, Picralima nitida,* and *Schumanniophyton magnificum*. The plant part used is the stems bark (98% of citations).

The average price per gram varies from one city to another. In Yaoundé, one gram of the bark of *Alstonia boonei* is sold at 0.964 FCFA. In Bertoua, the same quantity of the bark is sold at 2 FCFA. The average price per gram for the two cities is 1.29 FCFA

3.2. Abundance of Alstonia Boonei in the Community Forest of Mbeth II

Figure 2 illustrates the specific curve of *A. boonei* stems found in the community forest of Mbeth II. It is interesting to note that all diameter classes are represented in this figure which shows a good regeneration of this tree species in the forest.

A total of 122 stems of *Alstonia boonei* were counted in the 137 ha of the forest serving as the sample in the whole forest of Mbeth II. This gives a density of 0.89 stems/ha. One hundred and two (102) out of those stems have reach the exploitable diameter (30 cm) adopted for the use of bark. The density of exploitable stems is therefore 0.744 stems/ha.

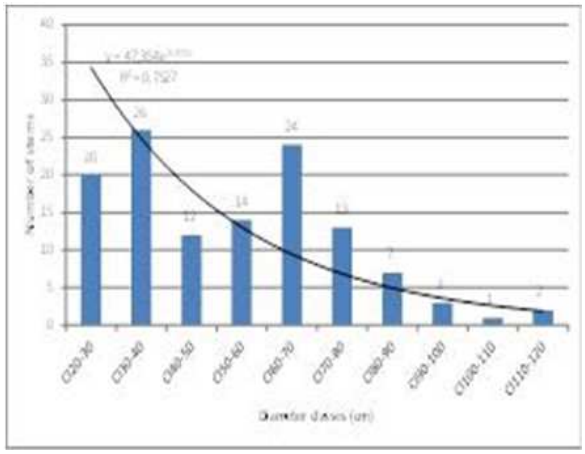

Figure 2. *Distribution of number of stems of Alstonia boonei in different diameter classes (class 20 -30 cm; cl30-40; cl40-50; …cl110-120 cm) in the community forest of Mbeth II: Y = number of stems, X = diameter classes*

3.3. Exploitable Stock of A. Boonei

In Mbeth II, primary, secondary and temporary drained forests totalize 4 952 ha and constitute the production forests. Thus, the total number of *Alstonia boonei* stems estimated for the community forest of Mbeth II is 4 408 stems. The number of exploitable trees is 3 664 and constitutes the exploitable stock of *Alstonia boonei* in the community forest of Mbeth II.

3.4. Relation Diameter – Thickness of the Volume of the Stem Bark: Volume Based Tariff

The 37 sample trees measured are shown in table 4 together with the thickness of the bark and the corresponding estimated volume of the bark for the whole tree. The average volume of a stem bark of an exploitable *A. boonei* tree is 0.0356 ± 0.01 m^3.

3.5. Relation Volume – Mass of the Stem Bark: Cubic Mass

Table 5 presents for each sample, its volume and the corresponding fresh mass. The average cubic mass of a given *Alstonia* tree is 966.555 ± 0.015 Kg/m3. This means that one cubic meter of the fresh bark corresponds to 966.555 kg.

Table 4. *Relation thickness – volume of the bark*

N°	Diameter (D) in cm	Thickness of the bark (t) in mm	a	b	Vs = a[Db - (D – 2t)b] (m3)
1	43.79	14.67	0.000461	2.166608	0.0240
2	70	11	0.000461	2.166608	0.0312
3	90	12	0.000461	2.166608	0.0456
4	94.33	12.5	0.000461	2.166608	0.0502
5	45	10	0.000461	2.166608	0.0169
6	67.5	12.5	0.000461	2.166608	0.0339
7	88.6	8	0.000461	2.166608	0.0299
8	117.4	12.66	0.000461	2.166608	0.0656
9	86	16.83	0.000461	2.166608	0.0606
10	84	16	0.000461	2.166608	0.0560
11	65	12.17	0.000461	2.166608	0.0316
12	73	12.33	0.000461	2.166608	0.0367
13	78	12	0.000461	2.166608	0.0386
14	50.7	8.83	0.000461	2.166608	0.0172
15	56.7	7.83	0.000461	2.166608	0.0174
16	112.6	11.5	0.000461	2.166608	0.0568
17	96.4	8.33	0.000461	2.166608	0.0343
18	92.4	13	0.000461	2.166608	0.0509
19	84.6	13	0.000461	2.166608	0.0459
20	66.4	12.3	0.000461	2.166608	0.0328
21	105.4	11.35	0.000461	2.166608	0.0519
22	47.4	11.8	0.000461	2.166608	0.0212
23	76.25	11.85	0.000461	2.166608	0.0371
24	34.2	10.6	0.000461	2.166608	0.0130
25	108.3	12.76	0.000461	2.166608	0.0602
26	48.3	12.7	0.000461	2.166608	0.0233
27	38.7	9	0.000461	2.166608	0.0128
28	61.3	11	0.000461	2.166608	0.0267
29	53.4	11	0.000461	2.166608	0.0227
30	64.25	13	0.000461	2.166608	0.0333
31	56.45	11.25	0.000461	2.166608	0.0248
32	84.35	12	0.000461	2.166608	0.0423
33	37.4	9.4	0.000461	2.166608	0.0128
34	95	8	0.000461	2.166608	0.0324
35	68.47	10.67	0.000461	2.166608	0.0295
36	71.46	12.65	0.000461	2.166608	0.0367
37	103.2	13.3	0.000461	2.166608	0.0593
Max	117.4	16.83	0.000461	2.166608	0.0656
Min	34.2	7.83	0.000461	2.166608	0.0128
Mean	73.4121622	11.62	0.000461	2.166608	0.0356
Standard deviation	2.03	0.00	0.00	0.01	

a = 0.00461 ; b = 2.166608; Vs = volume of the stem bark

Table 5. *Ratio Mass/volume for the bark of A. boonei in the community forest of Mbeth II*

N°	Diameter (cm)	Thickness (mm)	Width (cm)	Length (cm)	Volume = V (m3)	Mass = M (Kg)	Ratio (M/V)
1	43.79	14.67	16.67	23.67	0.0006	0.53	916.133
2	70	11	17.25	25	0.0005	0.44	927.536
3	90	12	21	32	0.0008	0.76	942.460
4	94.33	12.5	22.25	25.5	0.0007	0.68	958.802
5	45	10	14.3	27	0.0004	0.4	1036.001
6	67.5	12.5	26	32.75	0.0011	1.04	977.099
7	88.6	8	19	24.67	0.0004	0.36	960.171
8	117.4	12.66	20.4	25.5	0.0007	0.64	971.798
9	86	16.83	17.33	27.25	0.0008	0.78	981.016
10	84	16	24	36.75	0.0014	1.28	907.030
11	65	12.17	20.25	26.83	0.0007	0.62	937.822
12	73	12.33	18.63	30.83	0.0007	0.64	903.210
13	78	12	17.83	29.5	0.0006	0.58	918.739
14	50.7	8.83	12.83	25.33	0.0003	0.3	1044.636
15	56.7	7.83	12.33	29.5	0.0003	0.26	912.272
16	112.6	11.5	14.25	16.45	0.0003	0.27	1001.579
17	96.4	8.33	16.33	29.83	0.0004	0.375	923.867
18	92.4	13	23.63	36.25	0.0011	1.26	1131.742
19	84.6	13	17.8	32.6	0.0008	0.72	954.446
20	66.4	12.3	17.3	31.5	0.0007	0.58	865.299
21	105.4	11.35	16.5	28.56	0.0005	0.52	972.358
22	47.4	11.8	21.3	34.6	0.0009	0.84	965.921
23	76.25	11.85	16.2	20.25	0.0004	0.36	926.071
24	34.2	10.6	9.4	26	0.0003	0.26	1003.613
25	108.3	12.76	23.4	31.7	0.0009	0.94	993.121
26	48.3	12.7	16.45	28.4	0.0006	0.58	977.552
27	38.7	9	11.4	24.52	0.0003	0.248	985.668
28	61.3	11	14.59	26.33	0.0004	0.42	993.918
29	53.4	11	19.64	33.8	0.0007	0.72	986.011
30	64.25	13	22.13	28.36	0.0008	0.78	956.229
31	56.45	11.25	13.47	24.2	0.0004	0.35	954.405
32	84.35	12	14.5	21.6	0.0004	0.38	1011.069
33	37.4	9.4	12.3	16.5	0.0002	0.18	943.530
34	95	8	25.17	33.75	0.0007	0.68	1000.736
35	68.47	10.67	10.5	21.63	0.0002	0.22	908.340
36	71.46	12.65	20.47	24.2	0.0006	0.62	989.391
37	103.2	13.3	15.6	24.5	0.0005	0.52	1022.966
Max	117.4	16.83	26	36.75	0.0014	1.28	1131.742
Min	34.2	7.83	9.4	16.45	0.0002	0.18	865.299
Mean	73.41	11.62	17.63	27.50	0.001	0.571	966.555
Standard deviation		2.03	0.00	3.52	3.503	0.015	

3.6. Mass and Total Stock of Fresh Barks of Exploitable (mature) Trees

The average volume of fresh bark for an exploitable tree is 0.0356 m3, while the cubic mass is 966.555 m3/kg. This gives the average fresh mass of the bark of an exploitable tree of 34.4 kg.

The rotation (time between two consecutive harvesting steps) adopted by the Cameroon forest administration for logging in community forests is 25 years. This is, for each harvesting plot delimitated, to cut trees above 50 cm (Minimum exploitable diameter fixed for timber logging of *Alstonia*), and return 25 years later in the same plot to move the reconstituted stems. The surface area of an annual plot is 5 000 /25 = 200 ha and the five years bloc or sector is about 5 000/5 = 1 000 ha. The community forest of Mbeth II has been divided in five sectors as shown in figure 3.

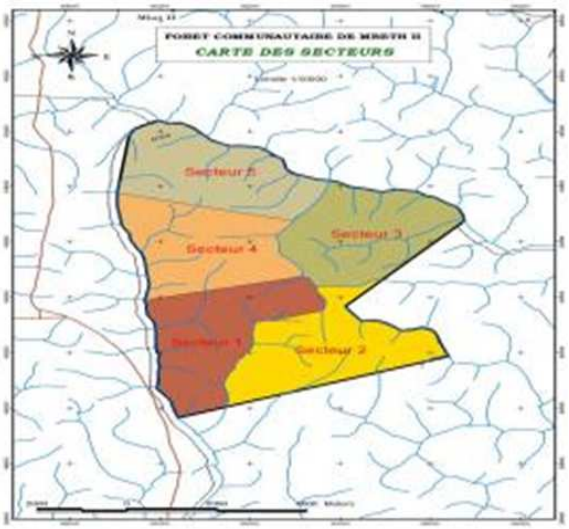

Figure 3. *The five sectors (five years blocs) of the community forest of Mbeth II.*

In this paper, we adopt the rotation of 10 years and the mid-rotation of 5 years for the harvesting of the stem barks. We consider them for sustainable purposes, and it is recommended to harvest trees of at least 30 cm of diameter at breast high, move the two quarters (1/4) opposite sides of stem bark, and return 5 years later to move the remaining two quarters opposite sides on the same tree, or return 10 years latter to move the same two quarters opposite sides on the same tree. This means that, in each mid-rotation, the harvesting of the bark will be done in the whole five years plot (bloc = 1 000 ha). The harvesting of the two quarters opposite sides gives an average fresh mass of a mature tree of 34.4/2 = 17.2 kg. The total number of mature trees estimated in the community forest of Mbeth II is 3 664 trees. This gives a total stock of the fresh bark of *Alstonia boonei* of 63 020.8 kg. The stock of the fresh bark of *Alstonia boonei* to be harvested in each sector in the community forest of Mbeth II is 63 020.8/5 = 12 604.16 kg. Knowing that the price per gram of the fresh bark of *Alstonia boonei* in markets is 1.29 FCFA, the total bark harvested in each sector (1000 ha) will be sold at about 16 259 366.4 FCFA which is about 32 872.5732 USD.

4. Discussion

4.1. Traditional Use and Pharmacological Activity of Alstonia Boonei

Alstonia boonei is cited in the treatment of six ailments including: malaria/fever, typhoid fever, intestinal worms, jaundice, diabetes and snake bite. Malaria, typhoid fever and intestinal worms are cited in all the three localities. In Makokou, Gabon, *Alstonia boonei* was cited for treating 14 ailments [12]. Malaria/fever and intestinal worms are commonly cited in the two countries. The usages against malaria/fever are mentioned in 9 countries: Cameroon, Congo-Brazzaville, Gabon, Ivory Coast, Equatorial Guinea, Nigeria, Senegal, Togo, and Democratic Republic of Congo [12]. The usages against intestinal worms are mentioned in four countries including Cameroon, Congo-Brazzaville, the Central African Republic and the Democratic Republic of Congo [12]. The Mbuti and Efe hunter-gatherers based in the Ituri forest, Democratic Republic of Congo apply the white sap on snakebites and wounds, while the bark-decoction is taken for stomach disorder and malaria [16].

Alstonia boonei is cited in the markets of Bertoua and Yaoundé for treating jaundice, diabetes, malaria, typhoid fever, and intestinal worms. The treatment against jaundice, malaria, and typhoid fever has also been cited by sellers in the Yaoundé markets in 2002 [14].

The stem bark of *A. boonei* contains antipyretic (against fever) properties [17; 18; 19] and has revealed a good activity (IC50 < 4 µg/ml) against *Plasmodium falciparum* FcB1/Colombia [20]. The prescriptions of *A. boonei* against snake bites can be explained by its analgesic [17]. or anti-inflammatory [17; 19; 21; 22; 23] properties. *Alstonia boonei* is largely cited against intestinal worms; but the anthelminthic properties of this plant were not established [24].

Alstonia boonei is cited in association with three other plant species for treating malaria/fever: *Anickia chlorantha, Picralima nitida,* and *Schumanniophyton magnificum. Anickia chlorantha* and *Picralima nitida* are confirmed in the literature for their activity in the treatment of malaria [25].

The average price per gram of the stem bark of *A. boonei* in the two markets is 1.29 FCFA (n = 19 sellers). That of the Yaoundé markets only is 0.96 FCFA (n = 13). Surveys conducted in 2002 revealed that the average price per gram for *A. boonei* in the Yaoundé markets was 1.64 FCFA [14].

4.2. Abundance, Stock, and Biomass of Alstonia Boonei

Figure 3 illustrates the distribution of *A. boonei* trees in different diameter classes or the specific curve. Almost all diameter classes are represented, which shows no specific problem of regeneration for that tree specie in the Mbeth II community forest. The density obtained is 0.89 stems/ha, which is twice compared to the 0.4 stems/ha obtained in the Makokou forest in Gabon [12]. *A. boonei* is a light demanding tree species [9]. As most of light demanding tree species such as Ayous (*Triplochiton scleroxylon*) or Afrormosia (*Pericopsis elata*), the number of small stems is often low in primary or non-perturbed forest, due to the lack of light. A high number of stems of small diameter found in Mbeth II community forest may be caused by the fact that, those forests have already been subjected to forest logging in past years.

The average thickness of stem bark of an exploitable tree of *Alstonia boonei* in Mbeth II is 11.62 mm. this value is high than those obtained for *Prunus africana* in mount Cameroon (8.49 mm), but less than those obtained with *Prunus* in Adamaoua Cameroon (13.01 mm), 12.1 mm in the Kibira national park in Burundi, and Bioko island in Equatorial Guinea (13.01 mm) [26; 27; 28; 29].

The average ratio mass/volume of *Alstonia boonei* in Mbeth II is 966.55 kg/m3. This value is less than the 1014.80 kg/m^3 and 1013.16 kg/m3 obtained for *Prunus africana* in Adamaoua and mount Cameroon [26; 27] respectively. Considering that for all trees above 30 cm DBH, only two opposite quarters of the bark are taken from the main stem up to the first branch, the average sustainable mass of *Alstonia boonei* in Mbeth II is 17.2 kg. This value is very less than those obtained for *Prunus africana* in different sites including 50 kg in mount Cameroon, and 69.3 kg in Adamaoua Cameroon [26; 27]. The difference can be linked to the ratio mass/volume of the bark which is high for *Prunus africana*. In fact, the bark of *Alstonia boonei* is granular [10]. If we consider the mid- rotation of 5 years and the price of the stem barks practized in the markets of Bertoua and Yaoundé, the community forest of Mbeth II can produce a total of 12 604.16 kg fresh mass of stem bark every five years in each five years bloc of forest (1 000 ha) and which can be sold at about 16 259 366.4 FCFA or 32 872.5732 USD. These funds can be used to enhance local development if well managed. The advantage of harvesting only two quarters of the bark from the main stem up to the

first branch is that it leaves the tree alive, compared to its exploitation as timber.

Cameroon's current forest policy introduced statutory involvement of rural populations, partners and stakeholders in its implementation, notably by the ownership of community forests and hunting zones [4]. This is intended to encourage people to become better stewards of wildlife and forests. Community forests and hunting zones are used by local communities, who can sign specific agreements with the forest administration and private sector partners to harvest their forest resources. Excepted for the north west region where people use community forest for the exploitation of *Prunus africana* barks, most of the community forests found in the meridional zone of Cameroon are assigned for the exploitation of timber resource. Mbeth II is one of the scarce community in the meridional zone, which is enhancing and promoting the use of community forests for non-timber forest products.

5. Conclusion

Ethnobotanical surveys and inventories conducted on *Alstonia boonei* in Mbeth II and in the markets of Bertoua and Yaoundé revealed the medicinal and economic importance of the stem bark of that tree species. The stem bark is confirmed for its activity against malaria/fever. *Alstonia* can no longer only be harvested and sold by villagers as a timber, but also for its medicinal value. The usage for its medicinal value can be more sustainable since it avoids cutting the trees, it keeps the trees alive. Results discussed in this paper can be summarized according to the manual of procedures of attribution of community forests, in a specific document called "the simple management plan of *A. boonei* as a medicinal plant in the community forest of Mbeth II". The glaring development challenge at the back ground of what precedes is the urgent need to implement the simple management plan including: (1) conducting the systematic inventory of exploitable stems of *A. boonei* (stems with diameter high than 30 cm) in the first five years bloc, (2) for each mature tree identified, harvesting only the two opposite quarters of the bark from the main stem up to the first big branch and begin cutting at a height of approximately 1 m above the ground, (3) conducting further studies to analyze the activity of the stem bark against typhoid fever and diabetes, (4) and also to study the total market chain of *A. boonei*'s usage as a commercial medicinal plant. The bark should be removed with machetes, since they seem to be the tools the workers handle best, giving them better control so as not to damage the cambium. Use of any tool that damages to the cambium should not be permitted.

Acknowledgment

We thank all the villagers who collaborated with us in this study. This work has been conducted with the financial assistance of the Cameroon Government and the International Tropical Timber Organization (ITTO) under the TFL-PD 014/09 « Reduction of illegal logging through better governance of community forests in the Lom et Djerem Division, East region, Cameroon" in one hand and the financial assistance of the Cameroon Government and the Japanese Cooperation (JICA) under the "FOSAS Forest-Savanna Sustainability Project, Cameroon

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