Technical Assistance for a Study on Forest Biomass Energy Conversion: Second Progress Report

Delivery Report Output 2.2: Report on geographical location of the hot spots of wood waste generation in the countries mapped supply chains

2nd Progress Report

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List of Abbreviations

AFP	Associated Forestry Permit
CAR	Central African Republic
COMIFAC	Commission des Forêtsd'Afrique Centrale
CTCN	Climate Technology Centre and Network
ETM	Enhanced Thematic Mapper
FAO	Food and Agriculture Organization
FRA	Forest Resources Assessment
GHG	Green House Gas
GIS	Geographical Information Systems
IFN	National Forest Inventory
INDC	Intended Nationally Determined Contributions
MCA	Multi-Criteria Analysis
NDE	National Designated Entities
PEA	Operating and Development Permit
PMG	Participative Management Group
SDG	Sustainable Development Goals
TM	Thematic Mapper
UGF	Forest Management Units
UNEP	United Nations Environment Program
USD	United States Dollars
WPU	Wood Processing Units

Definitions of commonly used terms

Term	Description
Deforestation	The conversion of forest to other land use independently whether human-induced or not.
Forest	Land covering an area of more than 0.5 hectares (5,000m^2) with trees growing to a height of more than 5 meters and a forest cover of more than 10%, or with trees capable of meeting these criteria (FAO). The definition excludes land whose predominant use is agricultural or urban.
Forest biomass	The term includes (i) primary forest residues generated during conventional forestry operations such as site preparation, salvage harvesting, thinning and final felling, (ii) secondary forest residues generated during industrial wood processing, (iii) tertiary residues from construction, renovation and demolition, and (iv) traditional fuelwood
Forest ownership	Generally refers to the legal right to freely and exclusively use, control, transfer, or otherwise benefit from a forest. Ownership can be acquired through transfers such as sales, donations, and inheritance.
Forest policy	A set of orientations and principles of actions adopted by public authorities in harmony with national socio-economic and environmental policies in a given country to guide future decisions in relation to the management, use and conservation of forest for the benefit of society.
Forest residue	Forest residues are a byproduct from forest harvesting, which is a major source of biomass for energy. This includes thinning, cutting stands for timber or pulp, clearing lands for construction or other use that also yields tops and branches usable for bioenergy.
Industrial roundwood	The wood removed for the production of goods and services other than energy production (woodfuel)
Logging residue	Logging residue means the wood left in the forest after logging, such as the tree crowns and the parts of stem which cannot be used for processing.
Other wooded land	Land not classified as “Forest”, spanning more than 0.5 hectares; with trees higher than 5 meters and a canopy cover of 5-10 percent, or trees able to reach these thresholds in situ; or with a combined cover of shrubs, bushes and trees above 10 percent. It does not include land that is predominantly under agricultural or urban land use.
Plantation forest	Planted Forest that is intensively managed and meet all the following criteria at planting and stand maturity: one or two species, even age class, and regular spacing. • Specifically includes: short rotation plantation for wood, fibre and energy. • Specifically excludes: forest planted for protection or ecosystem restoration. • Specifically excludes: Forest established through planting or seeding which at stand maturity resembles or will resemble naturally regenerating forest
Planted forest	Forest predominantly composed of trees established through planting and/or deliberate seeding.
Processing residue	A processing residue is a substance that is not the end product(s) that a production process directly seeks to produce. It is not a primary aim of the production process and the process has not been deliberately modified to produce it

Term	Description
Production	Forest where the management objective is production of wood, fibre, bio-energy and/or non wood forest products.
Removals	Average annual of those fellings that are removed from the forest, other wooded land or other felling sites during the given reference period (FAO, 2010).
Roundwood	All roundwood felled or otherwise harvested and removed. It comprises all wood obtained from removals, i.e. the quantities removed from forests and from trees outside the forest, including wood recovered from natural, felling and logging losses during the period, calendar year or forest year. It includes all wood removed with or without bark, including wood removed in its round form, or split, roughly squared or in other forms (e.g. branches, roots, stumps and burls (where these are harvested)) and wood that is roughly shaped or pointed. It is an aggregate comprising woodfuel (including wood for charcoal) and industrial roundwood (wood in the rough). For FAOSTAT, it is reported in cubic metres solid volume under bark (i.e. excluding bark) (FAO, 2010).
Sustainable Forest Management	A dynamic and evolving concept, [that] is intended to maintain and enhance the economic, social and environmental value of all types of forests, for the benefit of present and future generations.
Tree	A woody perennial with a single main stem, or in the case of coppice with several stems, having a more or less definite crown.
Woodfuel	The wood removed for energy production purposes, regardless whether for industrial, commercial or domestic use

1 INTRODUCTION

93% of rural households and 58 percent of urban households in Africa depend on wood biomass. Currently, the wood biomass conversion is highly inefficient and has very low recovery rates, yet there are various technologies that could be used to convert biomass to provide more convenient forms of bioenergy. Increasing use of traditional biomass, charcoal and firewood, is a direct cause of deforestation and forest degradation in many countries of West, Central and East Africa. Food and Agriculture Organization Global Forest Resources Assessment (FRA, 2005) has estimated that the demand for energy wood in the African Forest Commission or Commission des Forêtsd'Afrique Centrale (COMIFAC) countries in 2005 was 1,317,000 m^3 of wood in the rough, or 441,572 tonnes of firewood, and it took 611,995 tonnes of wood to produce 73,734 tonnes of wood charcoal. The use of firewood and wood charcoal will continue to be essential in the coming decades, both in cities and in rural settings. This growing demand is due to the combined effect of the following three underlying causes: (i) population growth, (ii) the absence of alternative energy sources appropriate for low-income populations, and (iii) inefficient production and use of wood charcoal. To address the wood biomass inefficiency challenge the Government of the Republic of the Congo, the Democratic Republic of the Congo, the Central African Republic, the Republic of Cameroon, the Gabonese Republic, the Republic of Equatorial Guinea, the Republic of Chad, the Republic of Burundi, the Republic of Senegal, the Republic of Côte d'Ivoire, the Republic of Mali, Burkina Faso, the Togolese Republic, the Republic of Benin and the Republic of Djibouti approached the Climate Centre for Technology and Network (CTCN) for a technical assistance (TA) aimed at identifying various options for economical industrial conversion of forest waste through projects with a significant positive climatic and social impact.

1.1 Objectives and Scope of the Study

The objective of the Study is to:

- Assess the bioenergy potential from sustainable biomass sources across 15 African countries, such as wood waste from forest harvesting operations and industry;
- Improve afforestation and forest sector residues energy conversion; and
- Identify market opportunities for the private sector that will bypass the exploitation of traditional biomass sources.

The CTCN technical assistance is intended to promote projects that establish a sustainable industrial chain for forest biomass energy conversion using planted forest as raw material and forestry biomass and sawmill waste. It is anticipated to bring about the following impacts and co-benefits and contribute to country obligations to the Paris agreement through the Intended Nationally Determined Contributions (INDCs) and Sustainable Development Goals (SDGs) (Table 1).

Table 1: Project impacts, co-benefits, and contribution to INDCs and SDGs

Project Impacts	Co-benefits	Contribution to INDCs
• Sustainable industrial chain for forest biomass energy conversion using planted forest as raw material and forestry biomass and sawmill waste. • Reduction of pressure on native forests. • Increase the final bio-energy use options such as cogeneration plants that use pyrolysis gases and waste. • Significant reduction of greenhouse gas emissions thanks to more efficient charcoal production, waste conversion, increased forest cover, and decreased deforestation rates.	• Reduced greenhouse gas emissions, creation of employment through sustainable bio-energy projects. • Sustainable and efficient use of wood biomass, reduced discarded forest residues in wood processing value chains. • Contribution to the development of the COMIFAC Convergence Plan and national REDD+ processes. • Gender mainstreaming in the forestry sector.	• Reduced GHG emissions from deforestation and forest degradation • Improved forest site conditions for regeneration and planting thereby increasing carbon sequestration. • Production of electricity from sustainable sources such as forest biomass energy conversion and/or cogeneration. • Creation of a system of forest eco-industrialization in the sector

Contribution to SDGs

SDG 5 : Gender equality

- End of all forms of discrimination against all women and girls in selected countries.

SDG 7: Ensure access to affordable, reliable, sustainable, and modern energy for all

- Industrial scale wood fuel will lower costs of production and improve its access; an d
- Industrial scale wood fuel and organization of artisanal producers will provide viable andsustainable wages for rural populations.

SDG 13: Take urgent action to combat climate change and its impact

- The information generated could be the base of new policies that promote the modern bio-energy sources from wood as a substitute to traditional biomass;
- Planted forests as source of raw material will strengthen the adaptation option and land restoration; and
- Industrial scale wood fuel will reduce the GHG emissions from current inefficient wood fuel production.

SDG 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

- Industrial scale wood fuel will reduce the pressure on natural forests and thus help to forest recovery; and
- Reduced deforestation and degradation will lower GHG emissions by each of the 15 countries supported.

1.2 Technical Approach and Methodology

The TA covers six outputs, each with a set of activities:

1. Output 1: Development of implementation planning and communication documents
2. Output 2: Identification of the source of forest residues in the forest supply chain. Identification of hot spots of wastes in the supply chain in order to map the sites where the greatest amount of waste is generated
3. Output 3: Determine the requirements for and availability of technologies for converting the identified biomass resources. Bioenergy technologies to be selected must be specific for feasible solutions according to the specific context of each country
4. Output 4: Sustainability Assessment. Many factors may influence the final performance of the bioenergy end solutions proposed. The analysis must focus on risk and benefits vis a vis environmental, socio-economic, policies, business model, and funding sources factors
5. Output 5: Selection and the implementation of pilot projects (one per country)
6. Output 6: A final (1 day) workshop will be organized to present the activities of the technical assistance.

A detailed approach and methodology for each output and associated activities is provided in the proposal to CTCN. Here below we outline an abridged version of the approach and methodology. It involves three main aspects:

1. **Literature and document reviews:** This is being carried out through a review of policies, country development priority reports, past and ongoing project reports in the 15 countries focusing on the following sectors--Agriculture, Forestry, Energy, Environment, Gender and climate change processes. The aim of this exercise is to ensure that we understand countries priorities and policies regarding use of biomass energy, how the utilization of biomass in these countries affects related sectors such as agriculture, environment and socio-economic implication including gender.
2. **Consultation with main Stakeholders:** This is being carried out through intense consultations with the countries National Designated Entities (NDEs), project proponents and other key stakeholders. In this regards we have divided the 15 countries into three main areas and identified coordinators of these regions, for ease of implementation:
   - Central Africa Countries - Government of the Republic of the Congo, the Democratic Republic of the Congo, the Central African Republic, the Republic of Cameroon, the Gabonese Republic, the Republic of Equatorial Guinea and the Republic of Chad
   - West Africa Countries -the Republic of Senegal, the Republic of Côte d'Ivoire, the Republic of Mali, Burkina Faso, the Togolese Republic, the Republic of Benin and
   - East and Horn of Africa - the Republic of Burundi and the Republic of Djibouti
3. **Collection of primary data where applicable and field visits:** We have identified country contacts who are assisting in the collection of the required field data. However, due to Covid-19 pandemic very limited visits are being carried out in the initial period, with more focus on available secondary data.

This report covers Output 2.2 of Output 2: Maps that presents the geographical location of the hot spots of wood waste generation in the mapped supply chains. The main elements covered in this report are:

1. Quantification of waste generated at forest biomass value chains in target countries including:
   - Classification of biomass residues; and
   - Evaluation and definition of formulas for quantification of forest biomass residue and wood waste.
2. Mapping of potential forest biomass availability including:
   - Biomass stock and forest function by country;
   - Mapping of potential residues in production forests and sawmills by regions and countries; and forest biomass estimation of national forest stocks and total residue production.

3. Sources of residues.

2 QUANTIFICATION OF WASTE GENERATED AT EACH LINK IN THE SUPPLY CHAIN

The assessment of forest supply chains suggests a better understanding of the typology of related products generated by sawmills, the organisation of production lines but also the activities carried out in the different units.

3.1 Classification of biomass residues

Optimizing material yields is the primary objective of sawmills, which must therefore minimize the volume of related products. However, export market requirements in terms of quality and the weakness of local markets lead companies to eliminate many pieces of wood with slight defects.
According to Barry-Lenger (1999), the total percentage of wood scrap may vary depending on several factors, including species, size of cut, station, exposure, type of equipment, etc. The percentage of wood scrap may vary depending on a number of factors. According to a study conducted by Philippe Girard et *al.* (2003), of a given volume of logs entering the sawmill line, 69% are counted as related products. Table 1 below illustrates the distribution.

Table 2: Distribution of related products per log[1]

Related Products	Percentage / log processed
Trimming offcuts	13 %
Slabs, edgings and sapwood	25 %
Heart defects	10 %
Sawdust	16 %
Cutting offcuts or runners	5 %
Total	69

3.1.1 Sawdust

Sawdust is the dust produced by the work of the saw blades on the logs during cutting. The production of sawdust in a sawmill depends very much on the type of cut. The sawdust is generally defined according to market demands, the nature of the wood and especially the quality of the logs.
More specifically, sawing losses due to the passage of saw blades fall into two categories. For sawing the thickness of the cuttings, band saw blades are 3 or 5 mm wide for 140 cm and 180 cm bands respectively, i.e. an average passage of 4 mm.

- For sawing a 25 mm thick plank, the loss due to the saw is therefore 16 %; 8 % for a 50 mm plank and 5.3 % for a 75 mm plank. This gives an average loss of 10%.

[1] WOODS AND FORESTS OF THE TROPICS, 2003, N°277, Energy recovery from sawmill by-products (Energy recovery from sawmill by-products)

- For edging in width, there are usually 1 or 2 dimensions of 1.5 on average. The blades make an average passage of 10.5 mm (7 mm x 1.5), which means a loss of 4.6% for the average width of 230 mm.

This results in a minimum total loss of 15% in the form of sawdust from the passage of the blades. These losses are totally incompressible; approximately 1% should be added from trimming.

3.1.2 Scrap wood

The off-cuts consist of slabs, edgings and trimmings. The length of the slabs and edgings depends on the cutting of the logs.

Generally, the slabs are about 6m long. When the sapwood is 5 cm on the radius and the average diameter of logs entering the sawmill is 100 cm, the volume lost is 20%, for export grades that do not accept sapwood. The edgings, of lengths less than or equal to those of the slabs, do not have a well-defined cross-section. The trimmings come from the cutting of previously edged cuttings. Their thickness and width are therefore the same as those of the cuttings from which they are taken. Their length depends on the nature of the defect to be eliminated and the commercial length required. This represents a loss of 6.6% for an average board length of 3 m. In addition to these losses, there are also losses due to external knots or rot, which make it necessary to cut some board planks shorter than the length of the initial log, resulting in about 6% more losses. This represents a total loss volume of nearly 13%. The volume of all solid wood off-cuts is commonly around 30% of the log volume and can sometimes be as high as 40%.

3.1.3 Heartwood defects

The heartwood, especially the red wood, has cracks in the heartwood that lead to significant losses, depending on the diameter of the logs. For example, a 100 cm diameter log, which splits when sawing up to 15 cm from the centre on average, can lead to a loss of 10% of the wood volume. This waste is assimilated to slabs and edgings because they have the same characteristics in terms of conformation. Overall, the table below shows the various sawmill scraps or related products.

Table 3: Related cuttings products[2]

Valuing products	Characteristic of Valuated Scrap
Cutting offcuts / spur	Of variable length, the spur are obtained by cutting the logs into logs of specific lengths. They are considered as scrap due to defects or inappropriate dimensions.
Sawdust	Sawdust is the dust produced by the work of the saw blades on the logs during cutting.
Bark	Bark is the outer covering or protective covering of the trunk and branches of a tree. These parts are removed from the log during debarking and preparation for peeling.
Slabs	A related product from generally thick, coarsely squared timber, sawn along the end of a log.
Delignures	These are wood waste obtained during the edging operation (pieces of bark, dosing, heartwood, etc.).
Trimming offcuts	Parts removed from planks for cutting to length for export sales and to remove defects such as pitting, discoloration and splits.

3.1.4 Sawmill processing activities

The table below highlights the operations that produce wood scrap that can be recovered.

Table 4: Operations generating related wood products

N°	OPERATIONS	ROLES	Related products generated
1	CUTTING SORTING LOGS	Cutting, cutting to length according to shape, diameter, quality and orders (section of the parts to be obtained). - Sorting of timber and industrial wood, if not done in the forest; by species, length and diameter.	Cutting offcuts or spur
2	CUBAGE	Reception, cubing of balls for : - Compare the volume purchased, estimated, and the volume actually delivered. - To know the daily, monthly, annual volume of timber that will actually be sawn, which allows the calculation of the various yield percentages (material and by quality).	
3	SCOTTING	Remove bark in ridges after cutting or in long lengths before cutting to : - take care of the blades, - avoid fungal and insect attacks.	Bark
4	HEAD SAWING OR 1ST CUT	Its role is to receive the ridge and to transform it into finished or unfinished products (blocks, beams): slabs, planks, trays, cores which will be taken up and finished by resaws.	Sawdust, slabs, heart defects

[2] Project ATIBT / FGEF / AFD.2011. Valorization of sawmill waste in Central Africa. PROVISIONAL REPORT ON THE STATE OF RECOVERY

5	REWORK SAWING OR 2ND CUT	Its role is to resume and complete the 1st flow to obtain the missing rating and the final sections : - The thickness for a slab, a core... - The width for a plank, a tray; and the recovery of thick slabs.	Sawdust, edging
6	CUTTING TO LENGTH	Cutting to length, squaring of the products (other name: trimming) : - Cutting of wobbly, curved planks or planks with big defects ; - Squaring to respect and obtain a quality label corresponding to a set of specifications	Trimming offcuts
7	SORTING AND CONTROL	- Dimensions: thickness, width, length. - Qualitative: according to choices (standards). - Orders: number of pieces and destinations.	Filing Scrap
8	STACKING	The stacking of the packages is done before : - Natural or artificial drying, or treatment, or shipping with battens. - And after drying "in dead pile" without battens.	
9	TREATMENT	Possible wood treatment: preventive protection against insect and fungal attacks, especially for softwood framing and anti-blue stain for pine trees.	
10	STORAGE - DRYING	-Storage in a park for natural drying or possibly artificial drying for : - Obtain a low % moisture content (8 to 12%) for interior wood applications. - Accelerate drying time. - To allow the planning of products.	
11	PLANING	Grinding, moulding to enhance the value of the sawn timber and obtain : - Planed framework, graded on 4 sides. - Frieze, parquet, baseboards, grooved bastings... - A higher selling price for wood (capital gain).	Chips, sawdust, offcuts
12	EXPEDITION	Cubing, bundling, strapping, loading, shipping of products. Establishment of cubing sheets and packing slips.	Filing Scrap

3.2 Defining formulas for the quantification of wood waste in each link of the wood supply chain

3.2.1 Evaluation of approaches to quantify forest residues

Although sources of wood residues may come from forests, sawmills and building demolition, this study focused on residues from forests and **primary** wood processing sawmills.

Logging residues: When forests are harvested for timber, human activities generate different types of residues throughout the tree to wood processing chain. In the forest, the logger removes from the trees the part that is easily transportable and suitable for mechanical processing and refining in a factory. Thus, from a tree felled in the forest for timber, the logger cuts the cylindrical part of the trunk (from the top of the buttresses to the first branch), leaving the canopy (top of the trees from the first branch). The tree's buttresses (from the ground to the first cut), the stump and the trees dragged by the fall of the tree removed in the felling area. This cylinder of wood is unloaded at the log yard, where it is cut to length to make it suitable for transport to the sawmill.

Wood processing residues: During sawmill cutting, sawing and peeling produce wood offcuts as well as sawdust. The sawdust, slabs and chips generated as wood processing residues are a valuable resource that can be used as a raw material for other products or for energy production.

To assess approaches for quantification of forest biomass along the wood supply chain, previous studies on biomass utilization were reviewed with a focus on supply chain models and the most productive and cost-effective forest biomass recovery technologies.

3.2.2 Forest harvesting residues

Several methods for estimating exploitation residues have been investigated and used in the biomass pre-feasibility research**. Direct or destructive methods** use felled trees to weight its components (branches, twigs, stems, leaves, etc.) separately (Fonseca et al. 2009). Instead, **non-destructive or indirect methods** use equations or mathematical models adjusted by regression analysis to construct the best relationship between several independent variables, such as diameter at breast height, basal area, wood volume or specific density, and tree biomass. These techniques have been applied to various forest types and planning levels.

3.2.3 Direct or destructive methods

With this approach, logging residues are estimated on forest harvesting sites. Logging residues are classified according to criteria such as the form of storage, the modes of dispersal of residues and the type of material.

At non-dispersed harvesting sites, residues are primarily divided into staked or dispersed piles (Kizha, and Han, 2017; Nurmi, 1999). Hardy (1998) studied these guidelines to estimate the volume of forest residue piles stacked in various pile forms. The forms of forest residue piles are classified into five generalized pile formats such as: half-sphere, paraboloid, half cylinder, cone, half round-ended cone, semi-ellipsoid and solid. Volumetric formulae were then developed and used to estimate the gross volume of the stacked heaps.

At dispersed harvest sites, the most commonly used method for estimating cuttings is the line-intersect sampling technique based on the coarse woody debris inventory sampling method (Oneil and Lippke, 2009). Authors such as Warren and Olsen (1964) and Kizha and Han (2017) have introduced this technique to estimate the volume of logging residues in harvesting sites and the amount of logging residues recovered from whole-tree harvesting sites in Northern California. The general finding is that, as expected, these methods are expensive but more accurate.

3.2.4 Indirect non-destructive methods

3.2.5 Remote sensing

Estimating biomass from remote sensing data was described in Lu (2006) and Patenau et al. (2005). The relationship between spectral response and biomass is investigated using multiple regression analysis and other neural network learning techniques. Geographic Information Systems (GIS), remote sensing and yield growth models have been favoured (Andersen et al. 2011; Huang et al. 2009; Woo et al., 2018) for biomass estimation at state and national levels.

In addition, indirect relationships estimated from remotely sensed data such as leaf area index and structure (crown closure) have been used to develop biomass estimation models (Feng et al. 2007; Luther et al. 2006). Labrecque et al. (2006) evaluated four different approaches to the use of remotely sensed data to investigate its advantage for estimating above-ground biomass. **This study revealed that the selection of the method depends on the level of precision and data availability. Several data sources exist for developing biomass availability**

maps using remote sensing. The most commonly used remote sensing image sources for forest biomass estimates are Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM) data.
Remote sensing data have the advantage of a large spatial coverage beyond that of national or state-level biomass estimates from forest inventories (Fournier et al. 2003). In addition, remotely sensed data can fill gaps in forest inventory data with attributes that can accurately predict biomass and carbon stock (Birdsey, 2004).

3.2.6 The geographical information system

Geographic Information System (GIS) is a tool that can be widely used to estimate biomass availability at the state or national level (Beccali et al. 2009), and to study optimal logistics planning for minimum biomass transport costs through a low-cost matrix (Montgomery et al. 2016). Most GIS approaches to biomass estimation are based on the use of agricultural, forestry, economic, climatic, reserve and infrastructure data. The restriction and suitability models developed were mainly used to define the potential availability of biomass and the areas for potential forest harvest residues.
For example, Woo et al (2018) studied biomass availability in Tasmania using integrated GIS, analytical hierarchy process and multi-criteria analysis (MCA) techniques. Potential biomass availability was estimated based on the model of private non-industrial native forest in Tasmania. Delivand et al (2015) investigated optimal locations for bioenergy facilities and biomass potential using an integrated approach combining GIS and MCA. **The potential availability of biomass was investigated in three consecutive steps: land availability, land suitability and geographical distribution of biomass plants.**

3.2.7 Biomass estimation model

A combination of allometric equations and forest inventory data models such as the EVALIDator, NIPNF and FIA DataMart tools has been studied to estimate the national level of forest residues and biomass availability in many countries (Fehrmann and Kleinn (2006). Peltola et al (2011) used these models and studied the recovery rates of logging residues recovered from stands dominated by Norway spruce. They found that average recovery rates differed slightly between the different models; however, the variation between logging residue collection sites was high.
The general finding from the literature review of previous studies is that these estimation models are heavily influenced by assumptions and are difficult to apply at the operational level of the biomass supply chain.
The benefits and identified limitations of these methods for estimating logging residues are summarized in the table below:

Table 5: Constraints and advantages of logging residue estimation methods

Methods of estimation	Remote Sensing	GIS	Estimating model	Direct methods
Required datas	Remotely detected images (e.g. MODI, AVHRR, etc.)	Geo data spatial (e.g. forest inventory card, and infrastructure card)	Model of regression based on data from on-site destructive measurement	On-site measurement
Spatial coverage	National level	Up to the level national	Specific conditions (for example, the species and their	Sampling Sites

			locations)	
Advantages	Fills gaps in forest inventory data with spatial data, and temporal	Studies optimal logistics planning Integrated into the decision support techniques	High precision in species and specific locations	The largest accuracy
Limits	-Highly dependent on the availability of data -Need to moderate spatial resolution to increase accuracy	Heavily dependent on assumed data	Requires field data (height, branch size, etc.). -Limited application	Long -High cost - Small scale only

Source: Adapted from Heesung Woo et al. (2019)

3.2.8 Residues from wood processing plants

Estimating process residues in the biomass industry is a challenge because the residue is generated as a by-product of sawmill operations and the availability of residues depends largely on the type of mill and its techniques (Fonseca, 2005). In addition, recovery rates depend on the species processed, equipment configuration, log quality, sawing methods, grading, storage, drying, and level of horizontal and vertical integration (Globe and Jarvis, 2007).

3.2.9 Calculation method

Generally, the estimate of sawmill residues is calculated using **volume and weight factors** developed from the literature and research (Kizhakkepurakkal, 2008). Sawmills recover wood according to various factors, namely: diameter, cone length and quality, sawing configuration, mill processing quality, size of dry treated wood and saw width (Steele et al. 2008). Sawmill residue **production rates** are highly dependent on sawing technology, wood processing rate, sawmill residue price and residue utilization options (Keegan et al. 1999).
Several methods exist for estimating the availability of residues in treatment plants. In California, United States, Yang and Jenkins (2008) estimated the production of sawmill residues using sawmill residue volume and weight factors that were developed from literature and survey data under specific conditions and for specific years.

- The volume factor was defined as the dry volume of residue per cubic meter of processed sawlogs;
- the weight factor was the ratio of the dry weight of residue produced to the dry weight of treated sawlogs;
- General information and statistical data regarding timber harvesting and saw log processing production in the California forest products industry were collected from the literature and published reports.

Residue quantities were calculated based on the average production rate of conventionally harvested U.S. wood, taking into account only one general type of sawmill operation for the estimates (Yang and Jenkins, 2008).
Also in the United States, Setzer (1971) reviewed a number of plant residue estimates. In this research, most studies focused on estimated residues from veneer and plywood plants located in Colorado, Idaho and Montana. The portion of plant residues of lumber was derived by subtracting the veneer and plywood residue estimates from the total mill residue estimate.

3.2.10 Survey methodology

Wood processing plant residue estimates from a survey or data are compiled from oral and written interviews with representatives of the wood processing industry. Information and data on the amount of wood processed, the production of wood processing residues, the current use of residues and the potential availability of residues are usually collected and discussed during the interview process.

A. Identification of Approaches Selected to Quantify Forest Residues

Based on the literature review above, the most accurate method for estimating wood biomass is the direct destructive method. This method involves harvesting a tree and measuring the weight of the various components of the tree (branches, leaves, trunk, etc.), including line-intercept sampling techniques and (*pre- and post-harvest downed woody debris)* sampling techniques. However, the destructive method is time-consuming, with limited application at the national and state levels and is very expensive.
In the present study, which aims to quantify forest biomass residues along the wood supply chain, indirect methods such as GIS will be used to provide large-scale information on biomass availability under different geographical and environmental conditions. This method will be combined with an estimation approach using formulas that quantify residues at the state and national levels with acceptable precision.
In the literature on secondary forest resources, limitations and challenges have been identified in the processing of mill residues. Biomass recovery rates differ according to mill configuration, species processed, log quality and other factors. In this study, secondary forest resources will be quantified using calculation methods and surveys, as these techniques provide reliable information on the availability of processing residues.

3.2.11 Formulas and assumptions used to quantify forest residues

This section describes the formulas used to estimate forest harvest and wood processing residues. It also includes a description of the databases used in the study.

3.2.12 Logging Residues

3.2.13 Assumptions made and other methodological elements

In this part of the analysis, a forest is defined as any wooded area that is capable of producing wood. This term therefore includes primary forests, secondary forests, semi-natural forests (planted forests) and production plantations. Only protection forests (nature parks, reserves) will not be considered.
After the felling of industrial roundwood, stems and top logs are debarked in the forest and then removed from the forests. After the felling of firewood, the stems of the upper logs and large branches are removed from the forest (without debarking). In both cases, the foliage and stumps are left in the forest for soil fertility and biodiversity conservation. A certain amount of logging residue is already being used. Only that part of the unused residues that can be collected at a reasonable cost is available for bioenergy production.

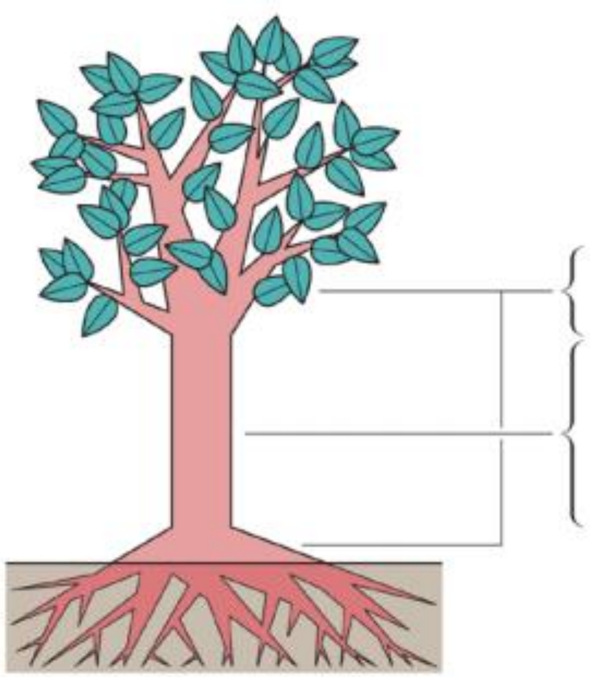
The total amount of harvest residues available is based on annual roundwood and fuelwood production, the felling rate and the percentage of residues already used.

Residues are classified into branches and miscellaneous cuts, foliage and bark. Bark is calculated only for industrial round wood. The ratio of each class reflects the representative tree composition (stem-to-crown ratio, crown-foliage, stem-to-bark) in the predominant forest type in the analysis area. Foliage is then excluded from further analysis. It is assumed that foliage will be left in forests for soil fertility and biodiversity conservation, and is therefore not considered a potential resource for energy production.

3.2.14 Methodology for measuring logging residues

The analysis carried out attempts to identify resources in two ways: first, calculate the amount of forest that would be treated as residue if it were used. This determines the total resource within the living forest stock. A second assessment identifies the residues produced each year by current forestry activities, based on roundwood production data. This provides an estimate of the current annual supply of waste and residues that could be used to produce biomass pellets.

To calculate the total amount of harvest residues available, statistical data on **annual industrial roundwood production and annual fuelwood production, usually expressed in** m^3, are used.
With regard to **the percentage of recoverable roundwood residues**, according to FAO (2010) 45% of the tree is assumed to be used for wood products, 55% of the tree is residue or waste, not all of which will be recovered due perhaps to 4% of various losses. Other unused parts of a tree that can be technically recovered include 23% branches and tops (including foliage), 10% stumps (above ground), 5% sawdust (forestry), 7.5% sawdust and fines (sawmill) and 5.5% bark (see figure).



tree part or product	portion %
top, branches and foliage	23.0
stump (excluding roots)	10.0
sawdust	5.0
slabs, edgings and off-cuts	17.0
sawdust and fines	7.5
various losses	4.0
bark	5.5
sawn timber	28.0
total	100.0

Figure 1: The different parts of the tree and potential residues

This would reduce the overall potential material of the tree available for energy production to 46% if it is not used, it would be left to decompose or be incinerated. This proportion of residues is a reasonable starting point from which to produce the fuel stock.

The quantity of logging residues available for bioenergy is therefore calculated as follows:

For industrial round wood:

Current logging residues (ton/year) = Volume of roundwood produced (m3) x 0.5 (because recoverable residues = 50% timber) x 0.45 (to go from cubic meters to tons)

For the firewood:

Current logging residues (ton/year) = Volume of fuelwood (m3) x 0.5 (because recoverable residues = 50% timber) x 0.45 (to go from cubic meters to tons)

The calculation of available wood processing residues is based on annual sawn wood production, the average efficiency of the country's sawmills and the proportion of residues already used.
First, the roundwood used for sawn wood production is calculated and based on the average recovery rate of sawmills. Then, by applying the output/input ratio, the volumes of sawdust and slabs and chips from sawn wood production are determined. By subtracting the portion currently used, the quantities of sawdust and slabs and chips potentially available for bioenergy are determined.

3.2.15 Method for measuring wood processing residues

For the calculation of the total available wood processing residues, statistical data are used on the quantity of roundwood used for sawn wood production, annual sawn wood production, the sawmill recovery rate, which is the ratio of sawn wood to roundwood (sawdust recovery rate and recovery rate of slabs and chips).
The amount of wood processing residues available for bioenergy is calculated as follows:

Total amount of wood processing residues (m^3 /year) = Roundwood used for sawn wood production (t/year) ∗ recovery rate of sawdust available for bioenergy (%) + Roundwood used for sawn wood production (t/year) ∗ recovery rate of slabs and chips (%)

3.2.16 Data sources and resources for spatialization of residue potentials

Data on forest sources, roundwood and fuelwood production are from official national FAO sources. FAOSTAT, which is the database maintained by FAO, provides global figures on forest products. The figures are measured in cubic metres (m^3) or tonnes (t) on an annual basis.
Every five years, FAO publishes data on the world's forests and the latest Forest Resource Assessment report was released in July 2020, this report refers to the data found in the 2020 edition. Data are presented in terms of area in hectares (ha) or multiples of hectares, while biomass is provided in tonnes. Different measures of forest are therefore used based on an appropriate unit of measurement.
Data have also been obtained at the level of individual countries. Due to a lack of detailed data on residues generated at sawmill sites, the main data on primary wood processing have been collected from the ministries of forests, energy, etc., but the data are not yet available for all countries.

3.2.17 Priority Chain Links with Greater Potential to Generate Bioenergy Products

3.2.18 Results of the quantification of forest residues

Due to the different regions (Central Africa, East Africa and West Africa) and the associated variation in tree species and wood quality, a differentiation will be made on the types of forests and sawmills in the different study countries.

Central African mills process large, high quality logs to produce a wide range of specialized products while East and West African mills use smaller, lower quality logs to produce commodity type products.

To support the objective of quantifying residues in the study countries, specific factors such as residue utilization and actual raw material availability by country were analysed. The main purpose of this section is globally : To give an overview of all potentially available plant sites and their close distances in km, as they could also serve as bioenergy plant sites. Estimate mill capacity in relation to roundwood production in order to estimate the supply of residues. Calculate distances close to transportation costs. Identify mills based on cost rankings and highlight existing and new bioenergy facilities that may be better located along the cost curve.

4 MAPPING OF POTENTIAL FOREST BIOMASS AVAILABILITY

The objective of this part is to estimate orders of magnitude of the biomass in the countries concerned by carrying out a spatial analysis, which infers the characteristics of the areas studied using spatially referenced data. The cartographic extent of these areas is illustrated through maps.

5.1 Biomass stock and forest function by country

Factors affecting a country's biomass stock include species and climate that have a significant impact on the biomass density per forest area. The tonnes of biomass per hectare in forests will vary according to the type of forest. The table below shows how the tonnes per hectare for tropical forests in Central Africa are significantly higher than for western and eastern countries.

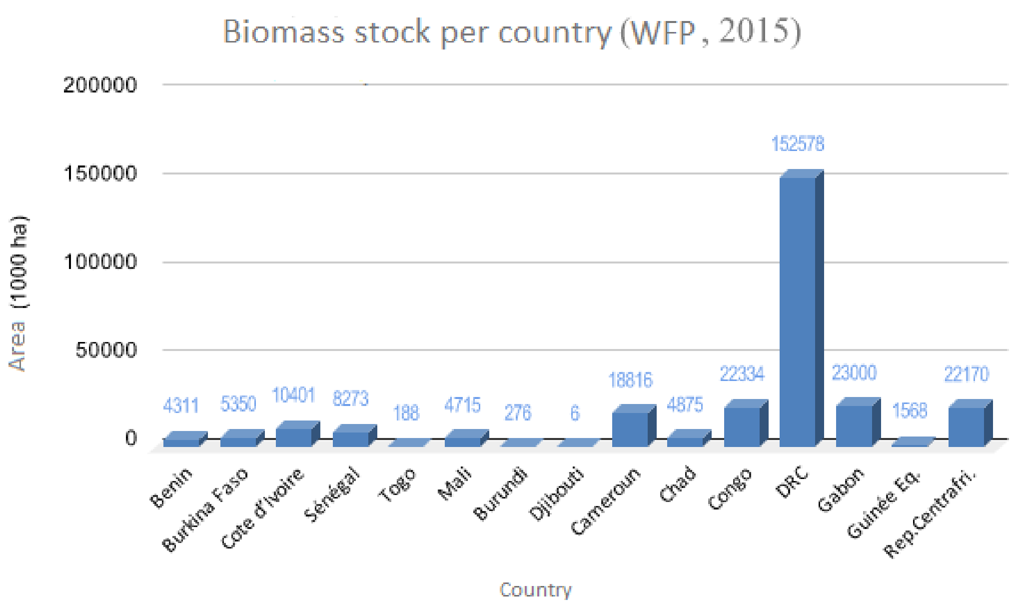


Figure 2: Biomass stock by country

Central Africa is the region with the most abundant forest biomass with vast areas of tropical forest, including 245,341 million hectares of biomass stock. The combination of large areas and very dense biomass forest is due to high rainfall and excellent growing conditions for tropical tree species.

5.1.1 Forest designated for industrial production by country

Approximately 86,532 million hectares of forest are managed for the production of wood and non-wood forest products, representing 28% of the total forest area.

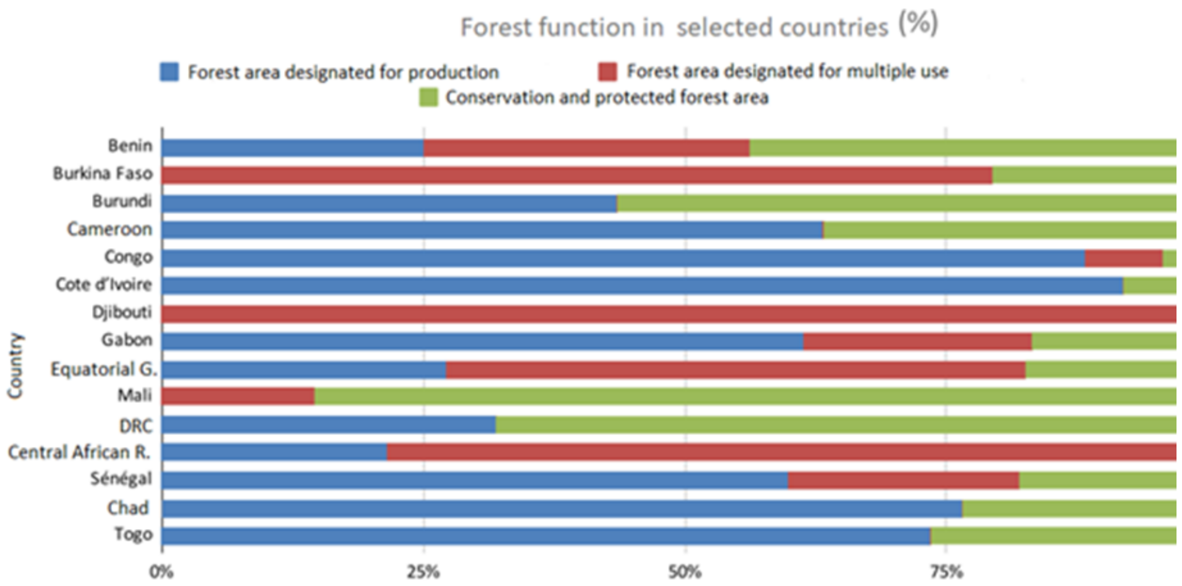


Figure 3: Forest function in selected countries

Source : FAO (2015)

The figure above shows that in countries such as Djibouti and Mali, forest areas designated for production are non-existent.

5.2 Mapping of potential residues in production forests and Sawmills by region

5.2.1 Central Africa

5.2.2 Case of Cameroon

5.2.3 Production forests

Production forests refer to forests that can be used to produce wood. In Cameroon, forest legislation provides for nine logging titles giving access to forest resources:

- Timber Permits.
- Personal Cutting Permit;
- Community Forest;
- Sale of timber;
- Communal Forest;
- Forest concession (Forest Development Unit).

The map below shows the geographical distribution of these different logging titles for the year 2019. The following graph provides a statistical summary.

Table 6: Distribution of the different logging titles for the year 2019

Forest titles	Number	GIS area (km^2)
Forestry Concessions	**120**	**69 488.74**
Communal forests	**67**	**18 808.20**
Cutting sales	**156**	**2 337.01**
Community Forests	**669**	**23 447.12**
Total	**1 012**	**114 081.15**

It can be seen that most of the production forests are concentrated in Eastern Cameroon. One might think that this Region has, in fact, the greatest potential for logging residues. However, this hypothesis should be confirmed by the volumes of timber felled for the period in question.

Cameroon's log production remains more or less constant, thanks in particular to the diversity of its production, which enables it to cope with market fluctuations more easily than forest massifs heavily dependent on one or a few species. This also implies consistency in the availability of logging residues. The table below shows, for example, the residues potentially available by forest title in 2013.

Table 7: Residues potentially available by forest title in 2013

Forest titles	Volume slaughtered in 2013 (m^3/year)	Total Residue Potential
Forestry Concessions	1 860 043	855 619.78
Cutting sales	616 198	283 451.08
Provisional Concession	168 287	77 412.02
Community Forests	54 531	25 084.26
Authorization for wood recovery	9 183	4 224.18
Total	**2 708 242**	**1 245 791.32**

Source:

https://www.observatoirecomifac.net/monitoring_system/national_indicators?year=2020&country=CMR&step=3

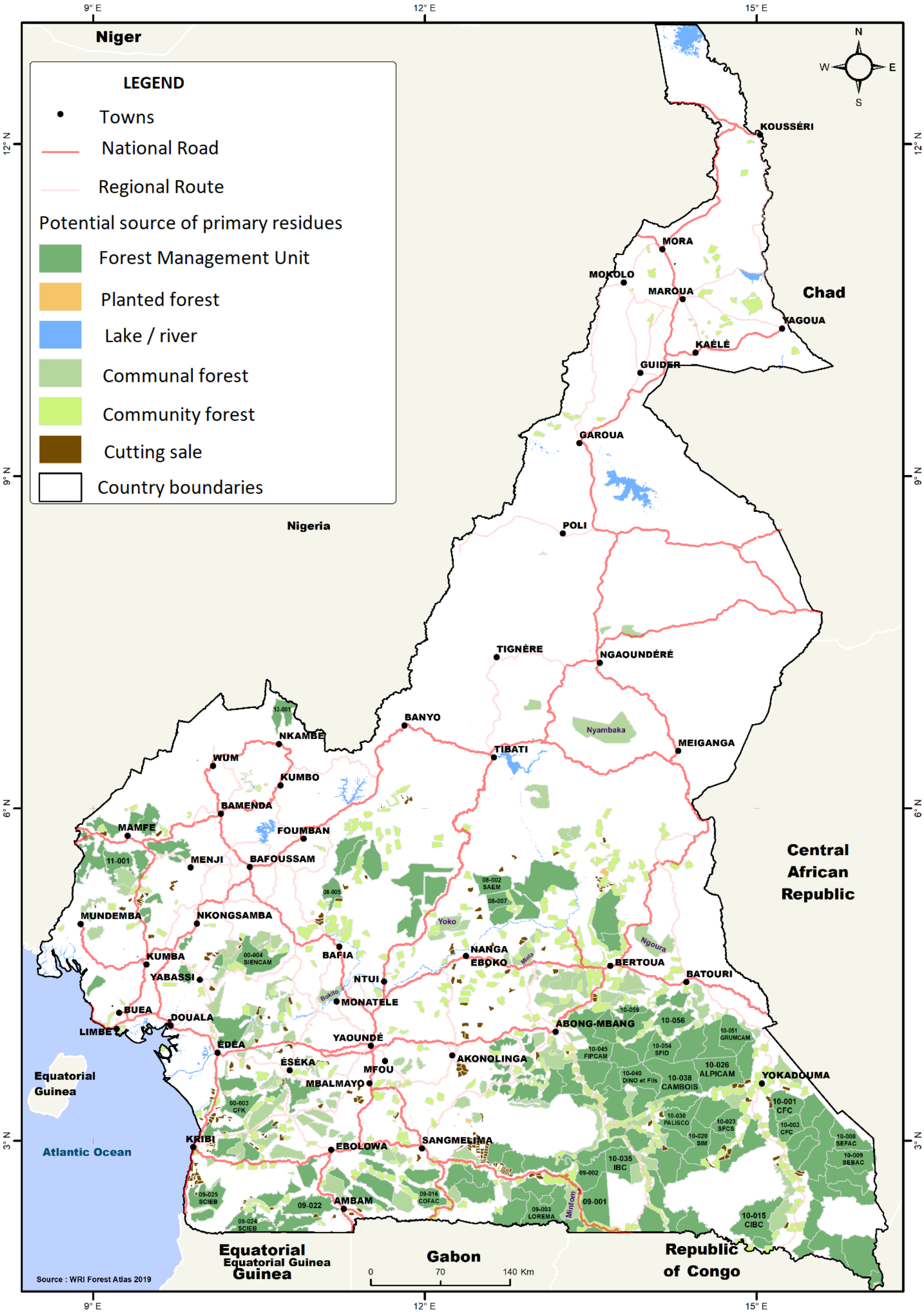


Figure 4: Forest mapping in Cameroon

5.2.4 Wood Processing Units (Sawmills)

There are about 203 Raw Wood Processing Units (UTBBs) in Cameroon for the processing of raw wood into various products (including sawn timber, veneers, plywood, furniture, etc.). According to Decision N° 353/D/MINFOF of 27 February 2012, these TPUs are classified into four categories according to the level and capacity of processing as shown in the table below.

Table 8: Categories of Wood Processing Units (UTB) in Cameroon

Type	Processing capacity	Number
First category	> à 5000 m^3	48
Second category	From 1000 - 5000 m^3	93
Third category	< à 1000 m^3	62
Fourth category	Craft units registered as transformers	/
Total		**203**

Table 9: Estimated carbonizable scrap potential per sawmill in 2015 in selected sawmills in Cameroon

Related sawmill	Volume of sawmill scrap wood generated (m^3)
PM	25200
STBC	27000
SIM	52000
PALLISCO	57 000
SFID	87100
GRUMCAM	31159
STBK (Batouri)	24730
SEBC	28000
SFIL	26 047
CFC	36 545
SEFAC	61 000
GVI	23 430
STBK (Sengbot)	37 500
MBI	11 667
DINO &FILS	0
Total	**528 378**

The figure below shows the location of these WPUs

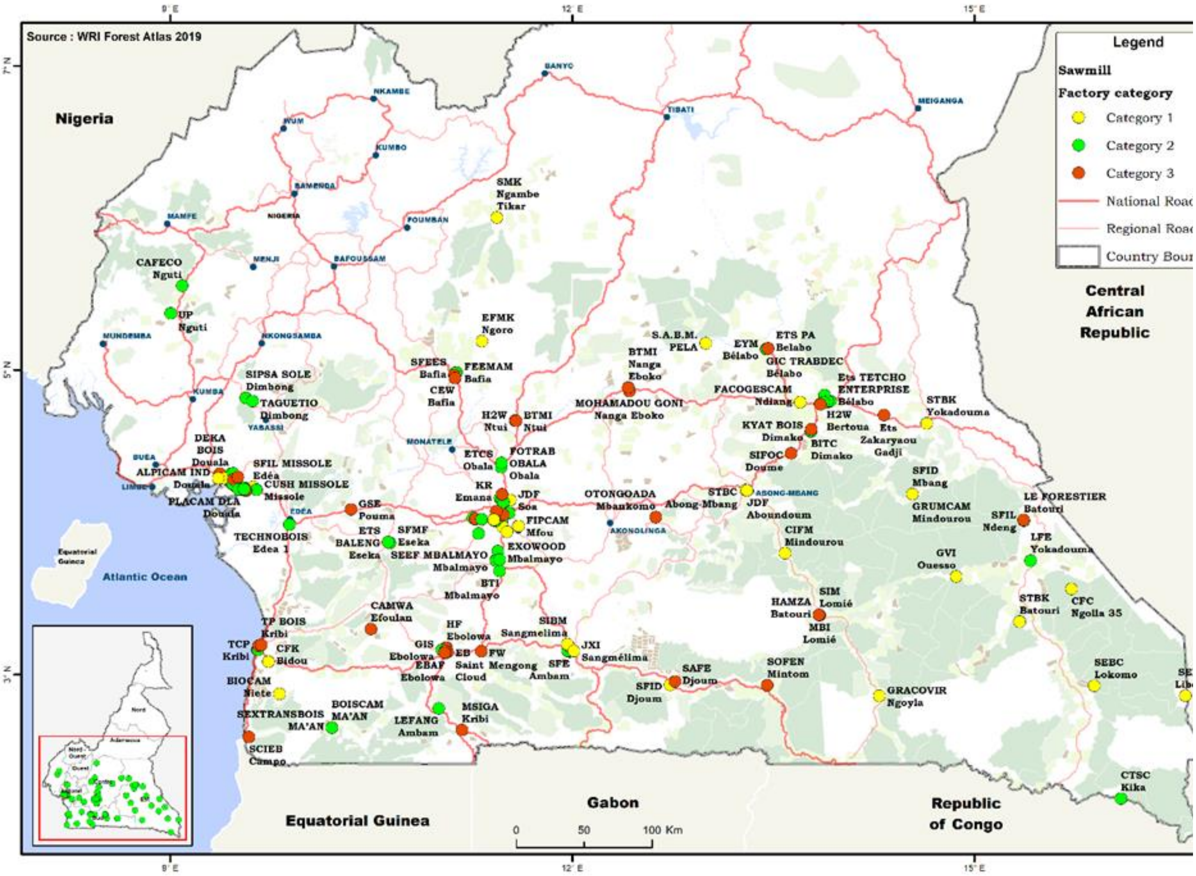
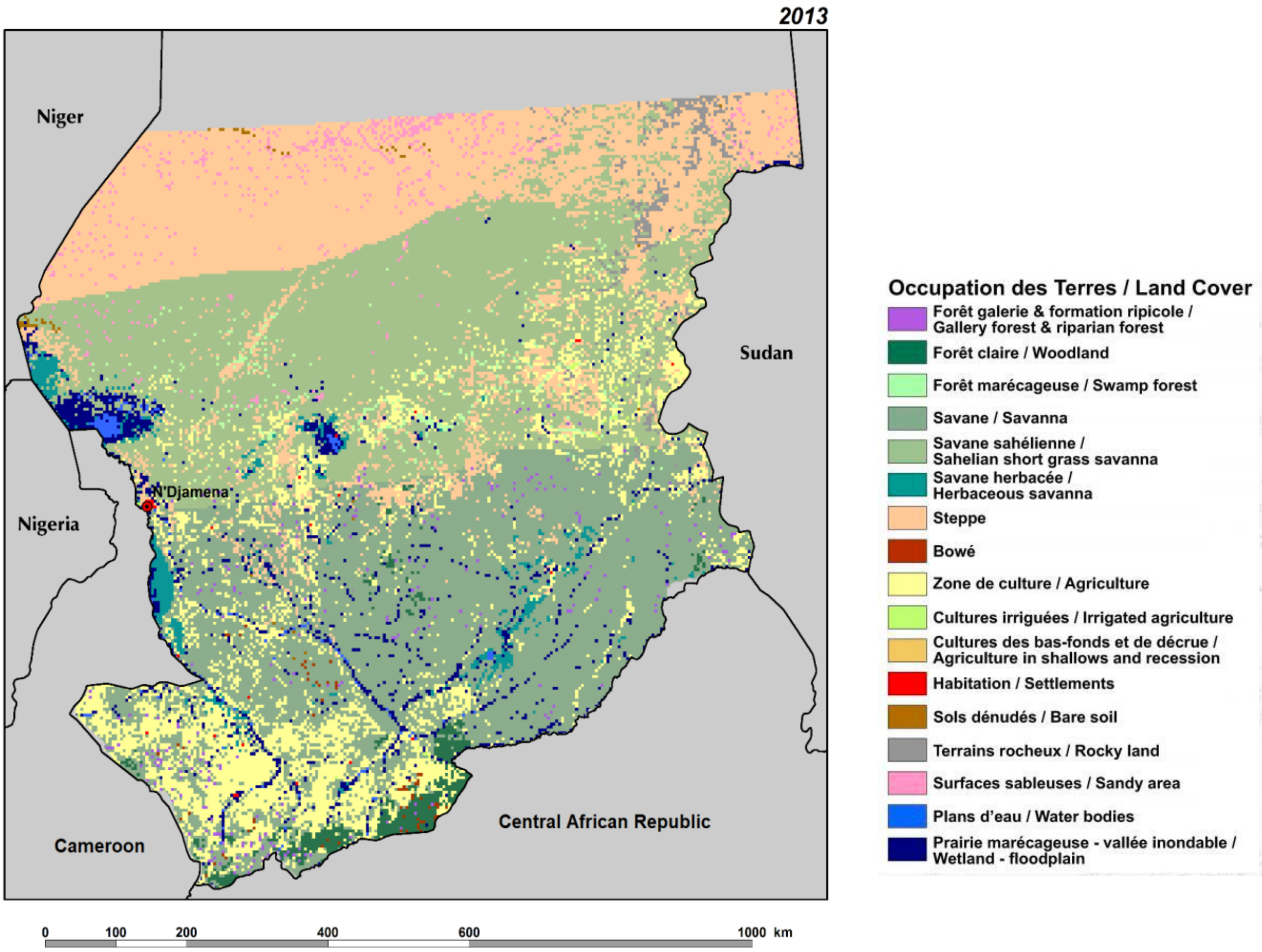


Figure 5: Location of Wood Processing Units (WPUs) in Cameroon

5.2.5 Case of Chad

5.2.6 Production forests

Although we do not have data on production forests, we found it useful to present land use in order to visualize forest areas. As shown on the map below, savannah is the dominant plant formation in the country. Most of the forest is located in the south of the country, on the border with CAR. According to FAO data, in 2015 Chad had 4.88 Mha of natural regenerated forest, or 3.8% of its territory.



Source: https://eros.usgs.gov/westafrica/land-cover/land-use-land-cover-and-trends-chad

5.2.7 Wood processing units (Sawmills)

5.2.8 Republic of Congo

5.2.9 Production Forests

The forest estate is composed of two large areas, north and south, with a wide variety of forest types. Nearly 75% of the Congolese forest, i.e. more than 15 million hectares, belongs to the production forest estate, including 14.4 million hectares currently allocated as forest concessions. Logging is conditional on obtaining logging permits, which are either:

- Industrial Transformation Agreements (ATI),
- Development and Conversion Agreements (ADC),
- Plantation Timber Cutting Permits (PPBC) and Special Permits (PS).

The average area allocated per operator is nearly 400,000 ha, with strong disparities. Concessions in Northern Congo are larger than those in the South. The map below shows the spatial distribution of these production forests. The 62 forest concessions in the Republic of Congo are exploited by 35 logging and industrial companies. In 2018, these companies produced **1,831,746.52 m^3**, or a potential **842,603.40 of residues.** The table below gives details by logging company.

Table 10: Residues potentially available by forest title in 2018

Company	Log volumes m^3	Potential Waste by Company
CIB	308 855.48	142 073.52
SICOFOR	213 091.00	98 021.86
IFO	200 926.00	92 425.96
SEFYD	192 803.72	88 689.71
TAMAN IND	173 929.29	80 007.47
ASIA CONGO	168 736.81	77 618.93
LIKOUALA T	112 112	51 571.52
CIBN	95 346.12	43 859.22
THANRY CONGO I	84 767	38 992.82
E Christelle	58 734.55	27 017.89
BPL	47 357	21 784.22
SIFCO	32 369.46	14 889.95
CDWI	26 966.47	12 404.58
AFRIWOOD	17 350.52	7 981.24
FORALAC	15 287	7 032.02
SIPAM	13 472	6 197.12
MOKABI	11 446	5 265.16
ADL	9 519.43	4 378.94
SOFIA	8 675	3 990.50

CFF	7 041.07	3 238.89
COTRANS	6 016	2 767.36
BTC	5 630.85	2 590.19
WANG SAM	4 827.25	2 220.54
BOIS KASSA	3 693	1 698.78
COFIBOIS	3 566.35	1 640.52
SFIB	3 061.11	1 408.11
SPIEX	2 159	993.14
GLOBAL W	1 574.56	724.30
SADEF	1 527.74	702.76
CITB QUATOR	728.17	334.96
K & C	133.57	61.44
ETBM	43	19.78
G H Sarlu	/	/
MIRAF	/	/
Scierie de la plage	/	/
Total	**1 831 746.52**	**842 603.40**
Source: Status report on private sector players in the forest-wood sector in Congo, 2019		

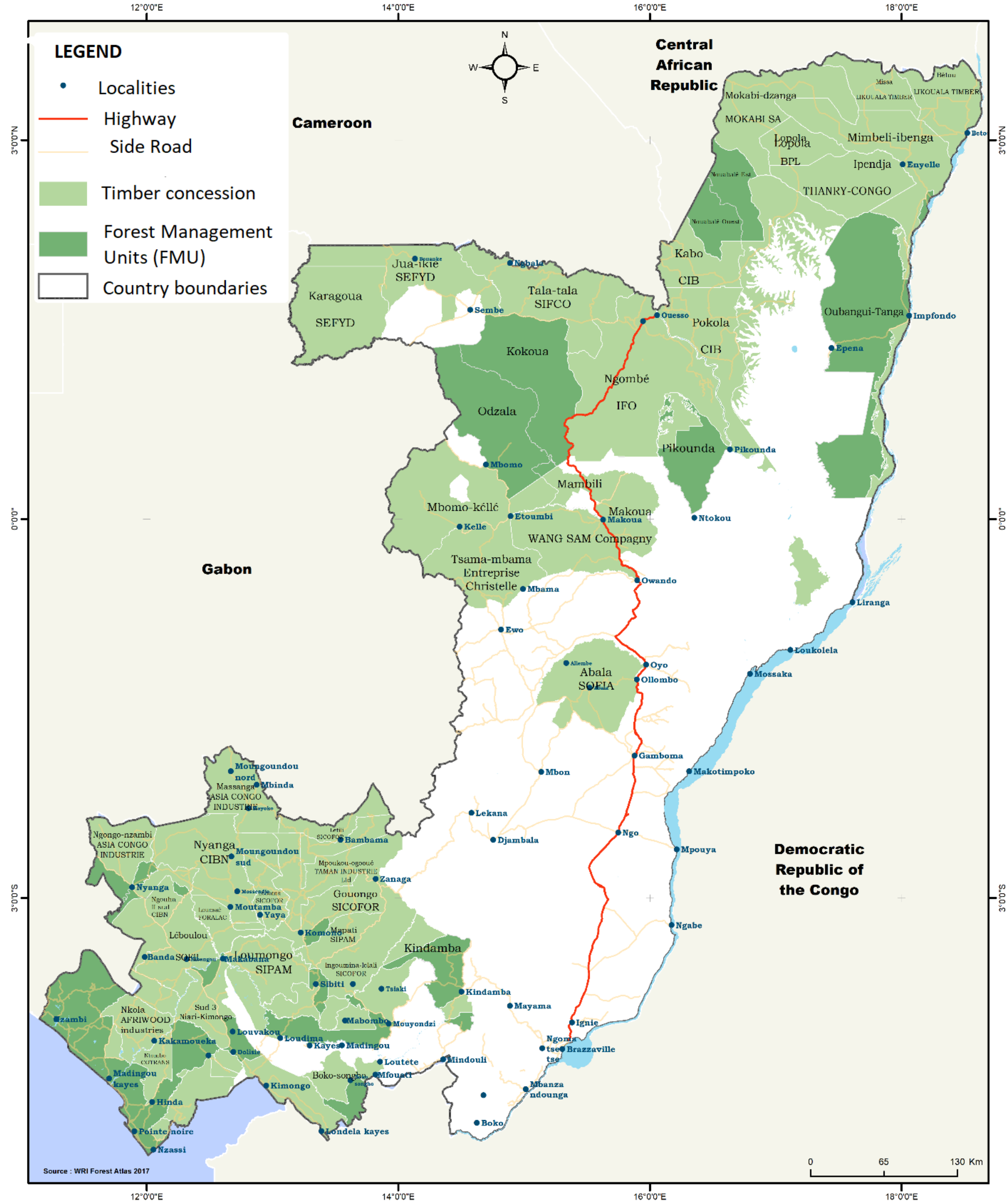


Figure 6: Forest management units and concessions in Cameroon

5.2.10 Wood processing units (Sawmills)

There are currently 61 wood-processing units of all types, although almost all log production, mainly industrial, is destined for export to Asia and Europe, depriving local industries of quality raw material. In figures, Congo has the following WPUs:

- sawmills;
- 12 drying units;
- 6 peeling units;

- 5 plywood units;
- 1 slicing unit;
- 2 high-capacity industrial joinery mills;
- 2 medium-capacity industrial joineries;
- glued laminated units;
- 1 parquet flooring unit;
- 1 moulding unit;
- 2 cogeneration units;
- 1 impregnated wood unit;
- 1 eucalyptus chip production unit;

According to the General Management of Forest Operations of the Republic of Congo, the UTBs achieved in 2018 a production of in 2018 they produced:

- 1,831,746.49 m^3 of logs in 2018,
- 242,558.75m^3 of sawn timber,
- 45,352.68m^3 peeled veneer and
- 8,064.43m^3 of plywood.

The map below shows the spatial distribution of the different UTBs.

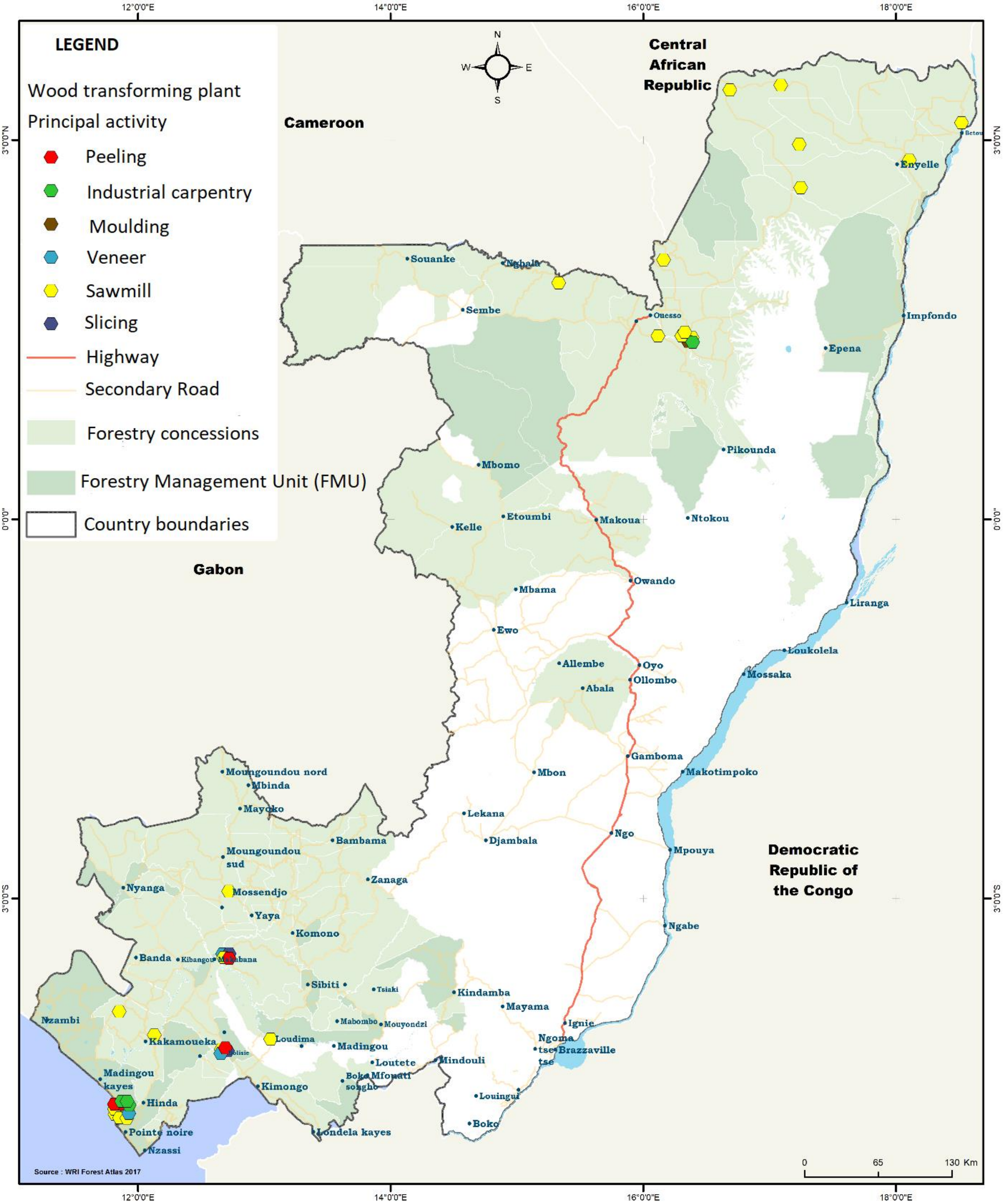


Figure 7: Spatial distribution of the different Wood Processing Units in Congo-Brazaville

5.2.11 Case of the Democratic Republic of Congo

5.2.12 Production Forests

The DRC is a country subdivided into 26 provinces, eight of which contain forests for industrial logging. These include Ituri, Kasai, Equateur, Maï-Ndombe, Mongala, Shuapa, Tshopo and South-Ubangi provinces. These eight forest provinces form a privileged basin for the supply of wood for international and national markets. The total forest titles cover an area of approximately 10,715,678 hectares. The Tshopo, Equateur and Maï-Nombe provinces alone contain 71% of the forest concession contracts granted by the Congolese state to companies, with the remaining 29% divided among the five remaining provinces.

Table 11: Geographical distribution of forest concession contracts in 2019

Province	Number of Forest Title	Area
Tshopo	14	2 957 661
Mai-ndombe	16	2 635 520
Equator	12	1 939626
Mongala	7	1 258 217
Mai-ndombe/Equateur	2	569 517
Mongala/Tshuapa	2	499 643
Equator/South Ubangi	1	284 323
Tshuapa	1	275 064
Ituri	1	60 182
Kasai	1	13 925
Total	57	10 715 678

Source: Quarterly Report of 31 May 2019 AGEDUFOR

The map below gives an overview of the location of the different logging permits and logging concessions.

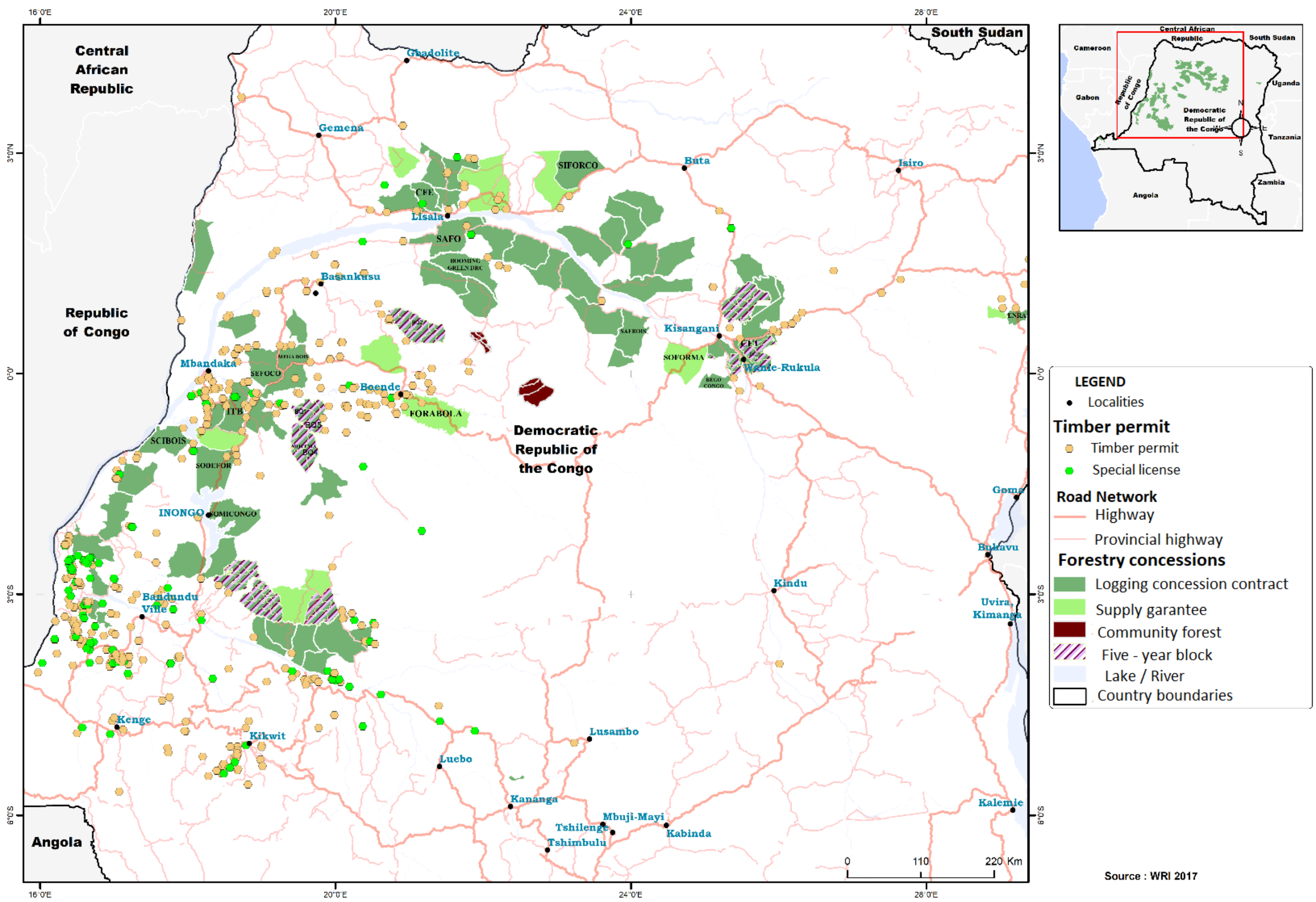


Figure 8: Location of the different logging permits and logging concessions

5.2.13 Wood processing units (Sawmills)

In DRC, the wood processing industry does not seem to be very developed. The companies would limit themselves much more to primary processing in order to produce edged or sliced sawn timber and peeled veneers. Both secondary and tertiary processing are extremely rare. (https://www.institut-numerique.org/12-transformation-du-bois-en-rdc-52f090366f16a). The table below shows the different UTBs and their location.

Table 12: The different Wood Processing Units (WPUs) and their production capacity

Company	Location	Type of products	Capacity m^3
SODEFOR	Nioki and Kinshasa	Edged sawing & trenching and plating unfolded	From 30 000 to 40 000
COMPAGNIE des BOIS	Oshwe and Kinshasa	Edged sawing and peeled veneer	From 2 000 to 6 000
FORABOLA	Congo central	Edged sawing and Peeled veneer	From 20 000 to 10 000
SIFORCO	Kinshasa	Edged sawing and	10 000 à 12 000

		Peeled veneer	
IFCO	Kinshasa	Sciage + parquet, lambris	24,000 (i.e. 2,000 per month)
CFT	PK9 R Bangoka	Edged sawing and Peeled veneer	30 000
FODECO		Sawing and uncoiling	
SOMIFOR	Kinshasa	Edged sawing and Peeled veneer	
MOTEMA	Kinshasa	Sciage	63 397
SCIBOIS	Equateur	Sciage	18 000
ENRA	Beni	Sawing, veneer, flooring, lumber, section, slat, swimming pool slat + other products from carpentry	

Due to lack of data the location map of the transformation units is not available.

5.2.14 The Case of Gabon

5.2.15 Production Forests

The Gabonese forestry code provides three types of forest permits, Forest concession under sustainable development (CFAD), the Associated Forestry Permit (AFP), the Permit to Ore to Ore (PGG) and the Community Forests.

Table 13: Distribution of the different logging titles for the year 2019

Forestry Permits	Number	Area GIS Km^2
CFAD	**56**	**98 609.48**
PFA	**26**	**3 816.94**
CPAE	**46**	**50 915.07**
Forêts Communautaires	**13**	**580.25**

Source :

The location map is shown below.

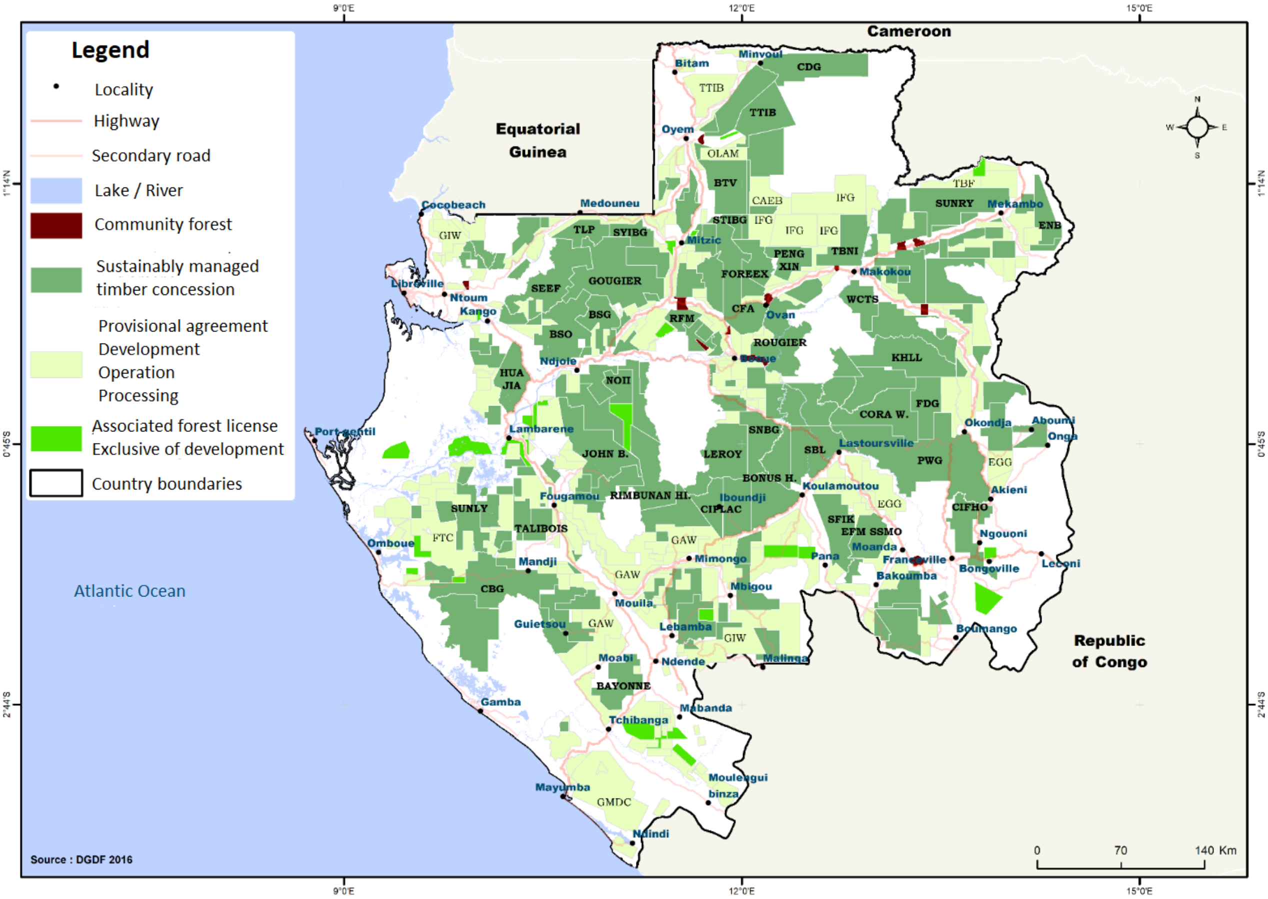


Figure 9: Location map of production forests

The table below shows production by type of title (m^3/year)

Table 14: Waste generation by type of title (m^3/year)

Type of Title	Production 2011 (m^3)	Potential wastes
CFAD	1 410 949	649 036.54
CPAE	186 940	85 992.4

Source : https://www.observatoire comifac.net/monitoring_system/national_indicators?year=2020&country=GAB&step=3

5.2.16 Wood processing units (Sawmills)

In Gabon, there are one hundred and sixty-two (162) logging and industrial companies. In terms of geographical distribution, the Estuary Province alone has 76 wood processing units with sawing and veneer as the main transformation. The Ougooué Lolo and Ougooué Maritime regions each hold 9 WPUs. The rest of the WPUs are distributed differently in the other regions, as shown on the map below.

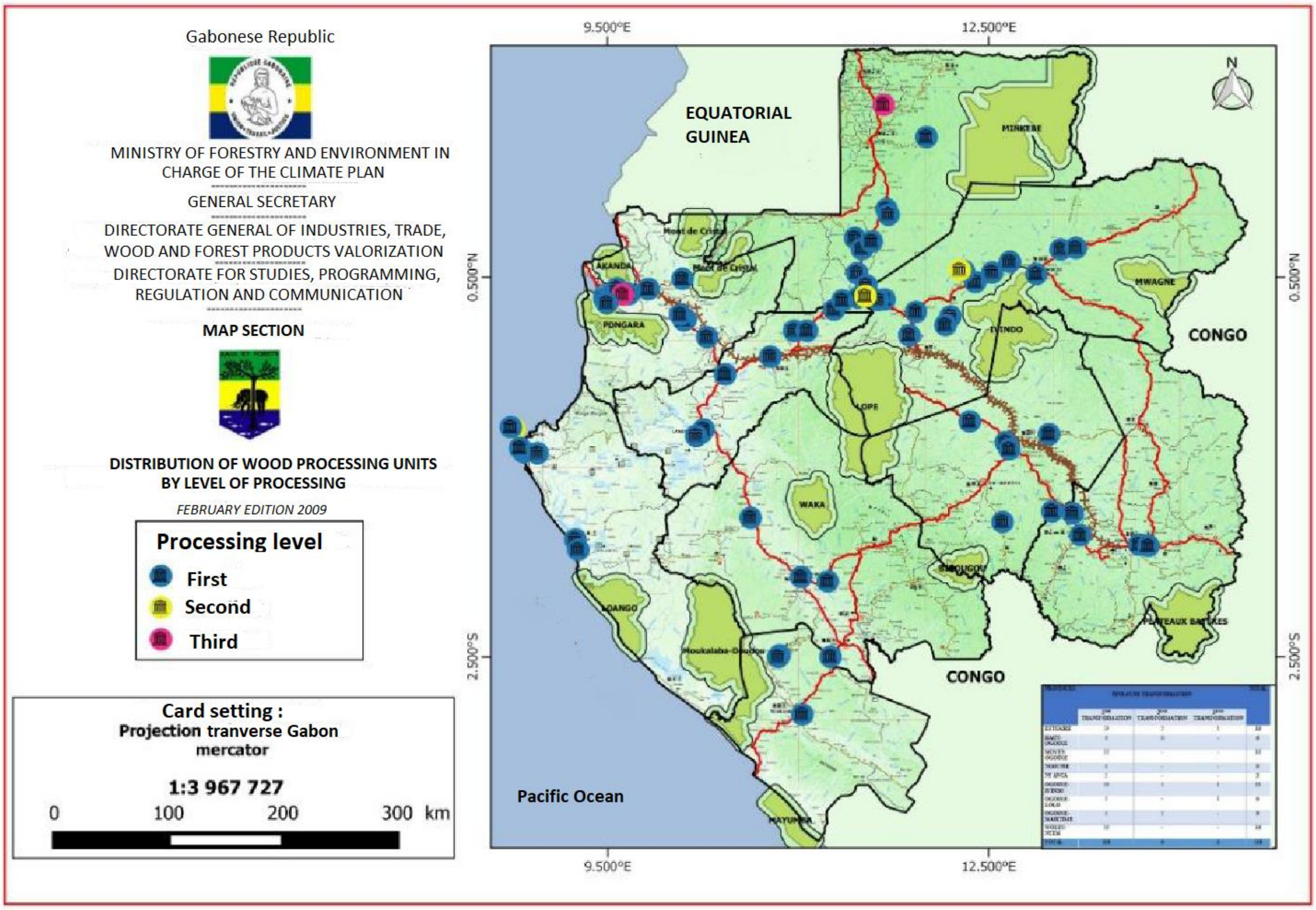


Figure 10: List of Wood Processing Units in Gabon

5.2.17 Case of Equatorial Guinea

5.2.18 Production Forests

In 2008, Equatorial Guinea had an estimated forest potential of 1,972,044 hectares. Its forest estate is subdivided into a Forest Production Estate and a Conservation and Protection Estate. The Forest Production Domain is also subdivided into three types of land status: (need production figures if possible)

Table 15: Types of land status

Land status	Nomber	Surface GIS (Ha)
Forest plot	46	67 900
Communal forest	77	107 185
National forest	98	1 064 962

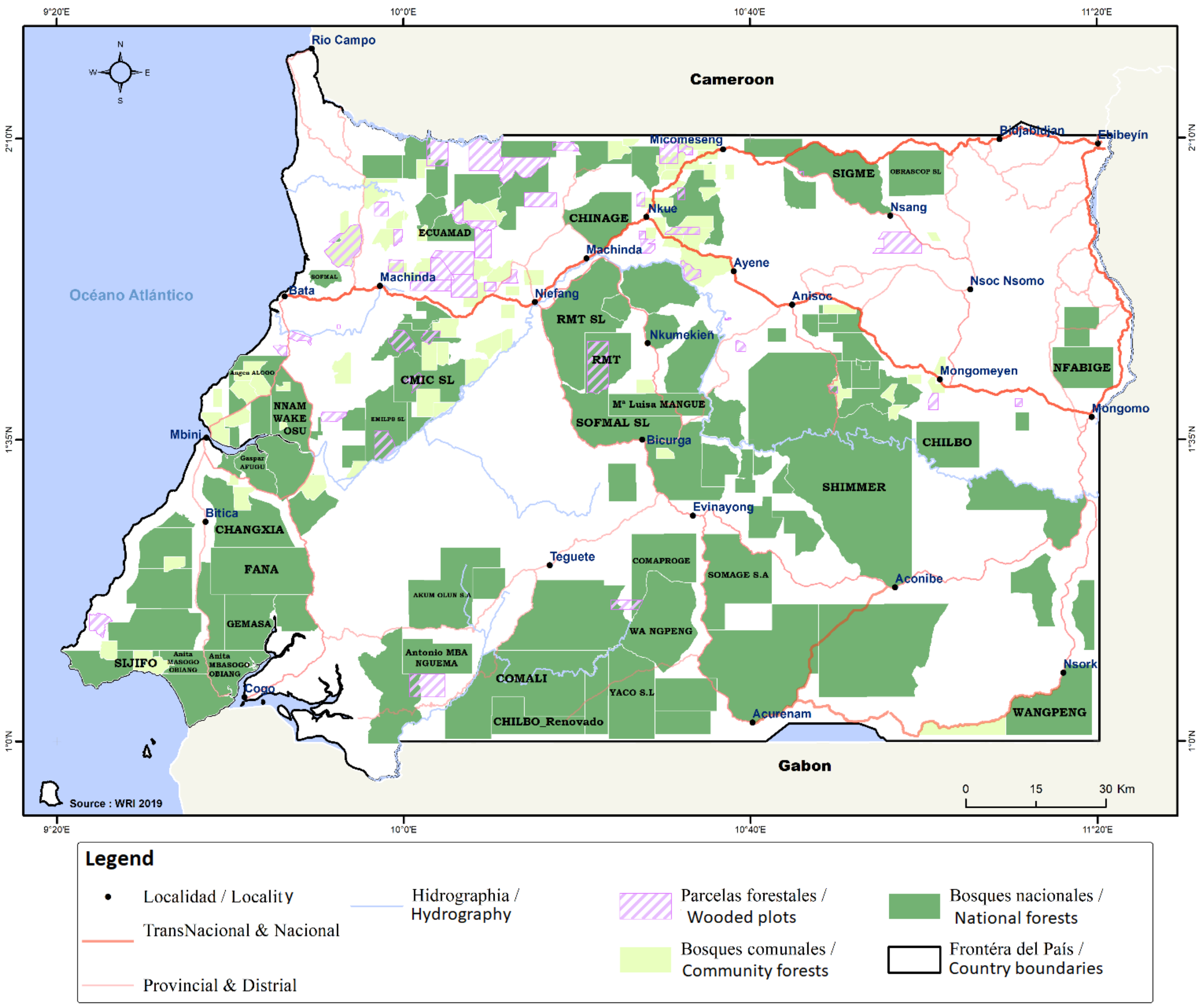


Figure 11: Forest concession in Equatorial Guinea

5.2.19 Wood processing units (Sawmills)

The country has about five industrial units (veneer and sawmill), four of which are located in Bata. There are also some small sawmills that supply the local market with sawn timber.

5.2.20 Case of the Central African Republic

5.2.21 Production Forests

In CAR, logging titles are called Operating and Development Permit (PEA) and they grant the right to operate with industrial means, subject to compliance with national laws and regulations. In 2016, out of 14 PEAs allocated, nine were operational, three were dormant and two were newly allocated (Table). In addition to the PEAs, 16 artisanal permits were granted from 2010 to 2016. (http://www.fao.org/3/I8596FR/i8596fr.pdf)

Table 16: Distribution of the different exploitation permits for the year 2013

Situation	Name PEA	Name of operating companies	Area km^2

Assigned	SEFCA 174	Société d'Exploitation Forestière de Centrafrique	3 963.03
Assigned	VICA 184	Vicwood Centrafrique	3 702.75
Assigned	SCAF 185	Société Centrafricaine Forestière	2 694.17
Assigned	THANRY 164	Thanry	2 253.23
Assigned	SOFOKAD 175	Société Forestière de la Kadéi	1 880.39
Assigned	IFB 169	Industrie Forestière de Batalimo	1 863.52
Assigned	SCAD 171	Société Centrafricaine d'Agriculture et de Déroulage	4 730.89
Assigned	SEFCA 183	Société d'Exploitation Forestière de Centrafrique	3 253.58
Assigned	IFB 165	Industrie Forestière de Batalimo	2 075.81
Assigned	SCD 187	Sociètè Centrafricaine de Développement	1 568.17
Assigned	IFB 186	Industrie Forestière de Batalimo	2 169.71
unallocated	B 188	/	2 111.31
unallocated	C 189	/	2 346.34
unallocated	A 167	/	2 283.40
Total			**36 896.31**

The map below shows the location of the various operating permits in the CAR.

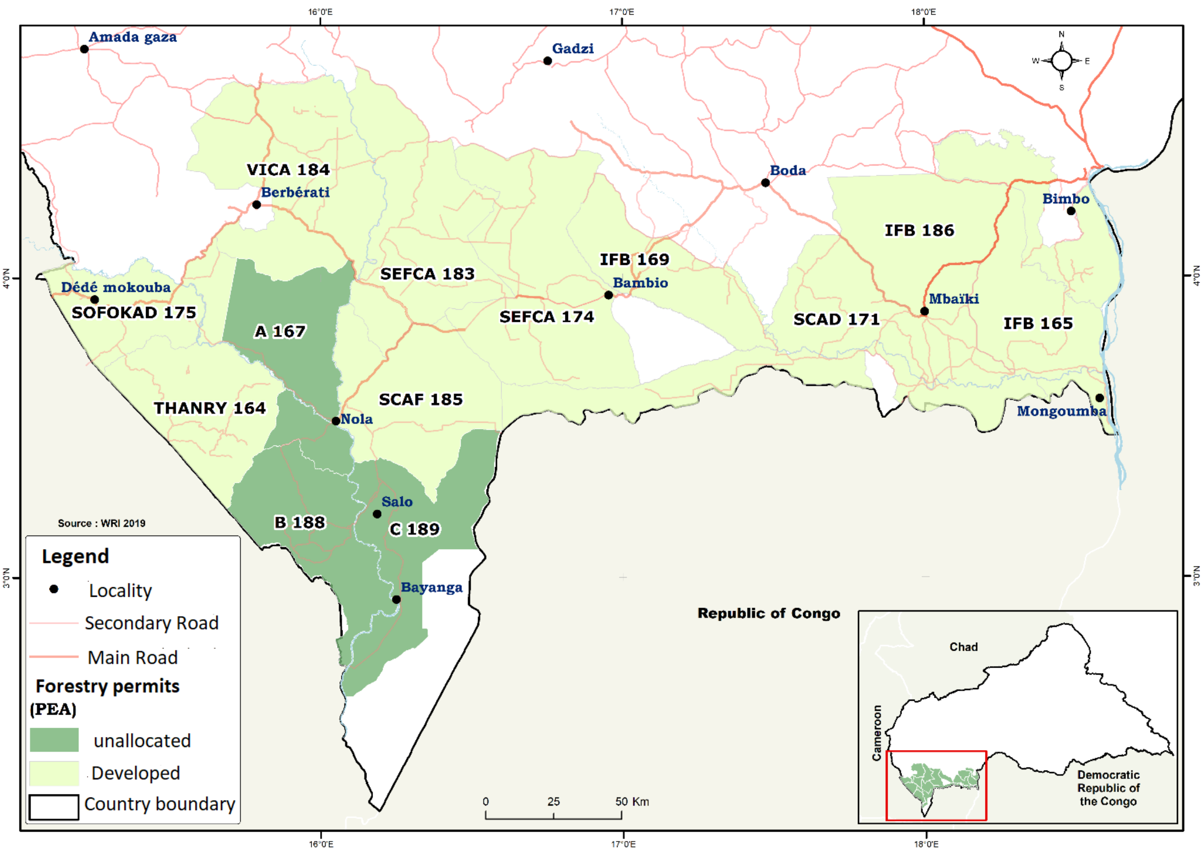


Figure 12: Location of the different operating licences in the Central African Republic

5.2.22 Wood processing units (Sawmills)

We have identified 10 WPUs in the CAR. The table below summarizes them by type of activity.

Table 17: Wood processing units by type of activities

Company	Type of activity	Year	Capacaity m^3
SOFOKAD	sawmill	1970	3 800
THANRY	sawmill	1998	600
SCAD Loko	Sawmill, peeling	1950	1 875
SCAD Ndolobo	sawmill	1967	2 917
IFB Ngotto	sawmill	2005	700
SEFCA	sawmill	2005	0
SEFCA	sawmill	1995	10 000
SCAF	sawmill	2001	4 500
IFB Batalimo	sawmill	1997	5 500
SCD	mobile saw	2010	450

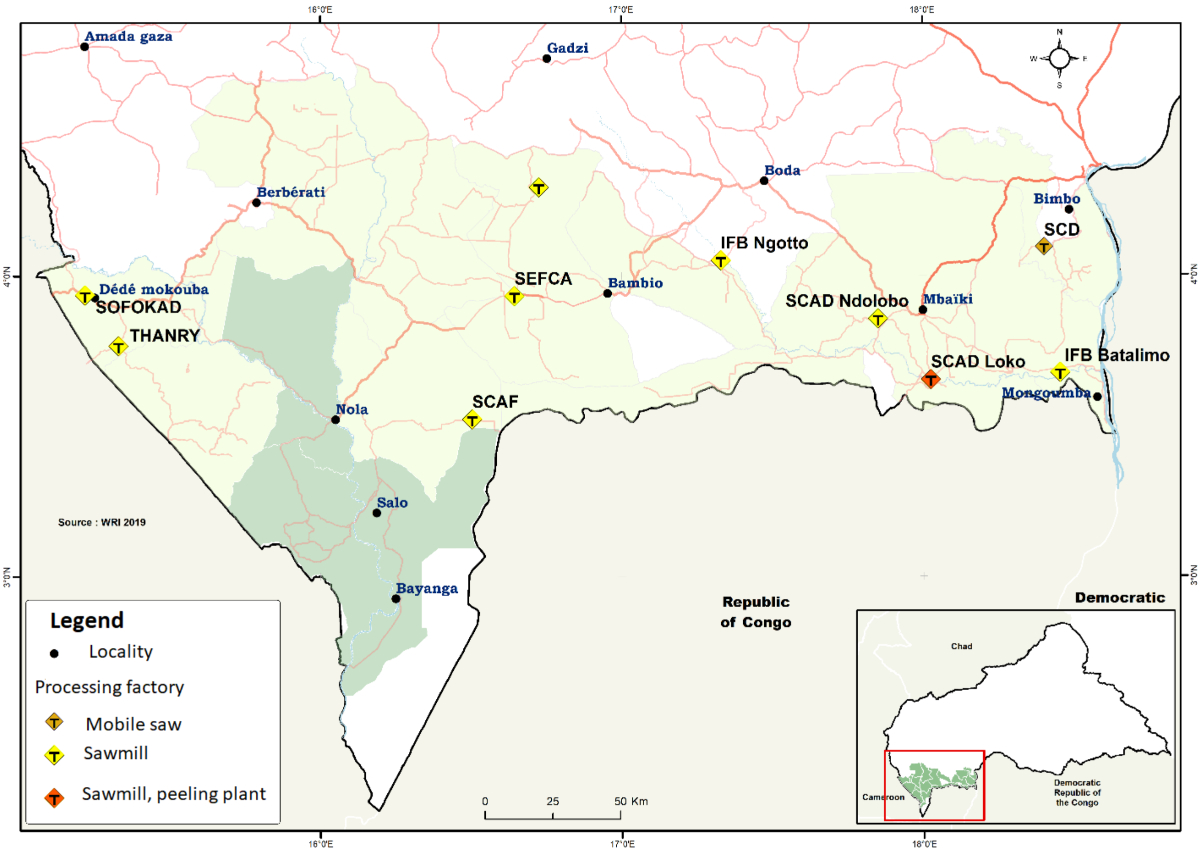


Figure 13: Location of processing plants

5.2.23 West Africa

5.2.24 Case of Benin

Based on the productivity assumptions for natural formations and agricultural terroirs, an assessment of forest productivity was established.

Table 18: Forest productivity assessments for Benin

Stratum	Productivity assumptions[1]	Annual wood production per stratum	
	M³/ha/year	M³/year	T/year
Dense forest	2	137 304	96 113
Forest gallery	2	576 846	403 792
Clear forest/Wooded savannah	1,2	1 806 884	1 264 819
Savannah with trees and shrubs	0 ,8	4 648 513	3 253 959
Mosaic of crops and fallow land	0,6	1 671 236	1 169 865
Mosaic of crops and fallow under palm trees	0,4	197 505	138 254
TOTAL		9 038 289	6 326 802

Productivity assumptions[1] : Source: IFN 2007, Hubert Forster estimates.

Annual wood production was therefore estimated at 9,038,289 m^3. This production, as can be seen, does not take into account that of plantations, which cover very heterogeneous realities such as timber plantations, orchards, cashew tree plantations and fuelwood plantations.

The mission considered in its report that 90% of the production (excluding plantations) is potentially usable as wood energy. So to speak, from the above estimated value, the annual production of wood energy can be estimated at around 5,700,000 tonnes (8,134,460 m^3) in 2007. This value is not very far from that of the EIS 2015 report of the Directorate General for Energy. Indeed, in this report, it is estimated that the total quantity of fuelwood taken from the forest amounts to 7,125,996.4 tonnes. This productivity is determined on the basis of values of 5 tons/ha for dense forests, 1.2 tons/ha for clear forests and wooded savannas and 0.6 tons/ha for wooded savannas, weighted with the percentage represented by each type of forest formation[3].

[3] **Invalid source specified.**

Figure 14: Classified Forests in Benin

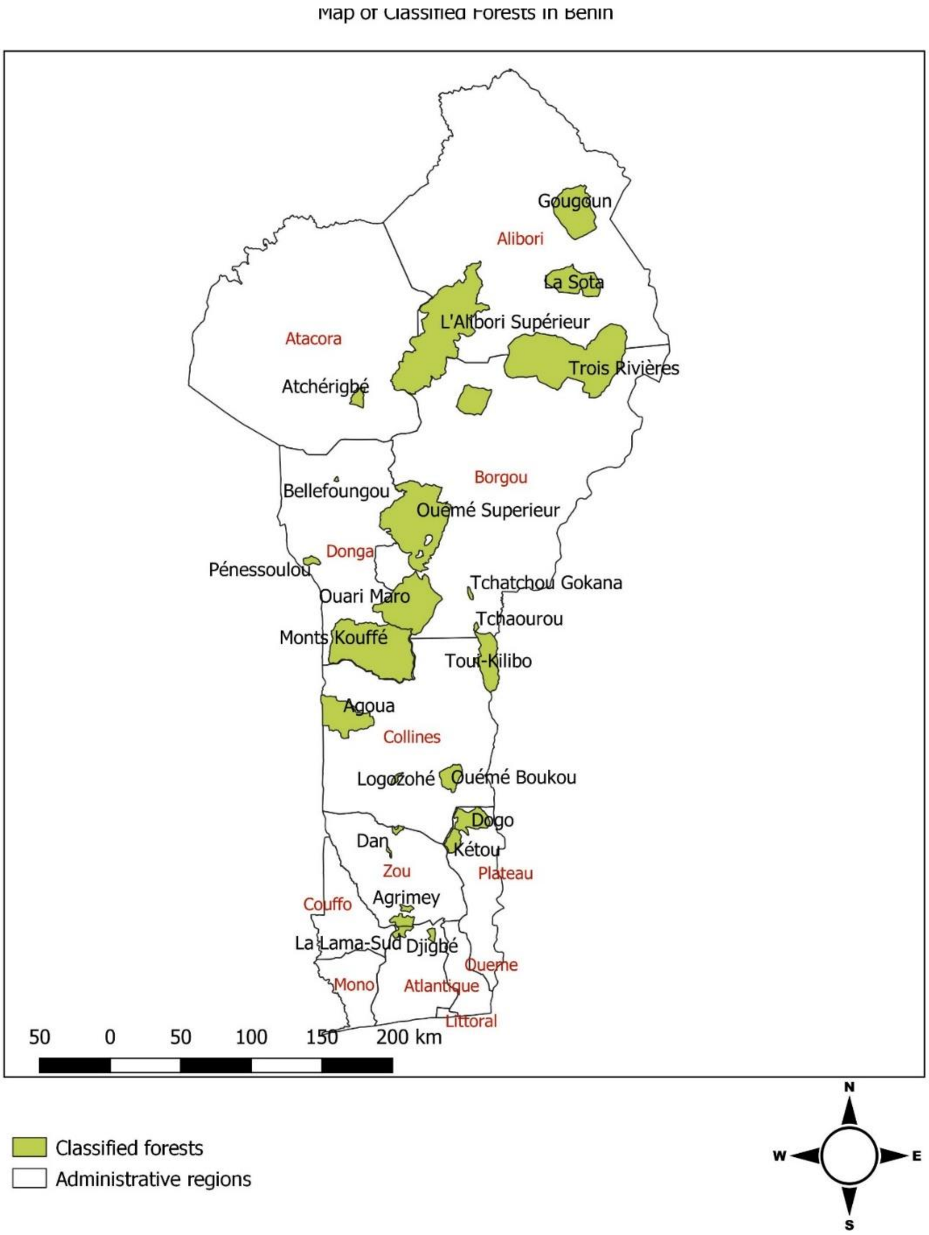


Table 19: Classified Forests in Benin

NAME	Area_Sq
Kétou	130.84680
La Lama Nord	106.41094
Agrimey	30.55302
Atchérigbé	125.67806
Djigbé	38.40128
Ouémé Boukou	206.62830
Gougoun	766.28414

La Sota	555.12822
Dan	11.72883
La Lama-Sud	65.43787
Logozohé	26.51820
Pénessoulou	52.62935
Tchaourou	14.51723
Tchatchou Gokana	20.03015
Toui-Kilibo	476.47126
Trois Rivières	2700.39135
L'Alibori Supérieur	2601.86629
Ouémé Superieur	2222.68039
Ouari Maro	1176.90133
Monts Kouffé	1895.90643
Agoua	655.09212
Dogo	309.07771
Bellefoungou	6.94350

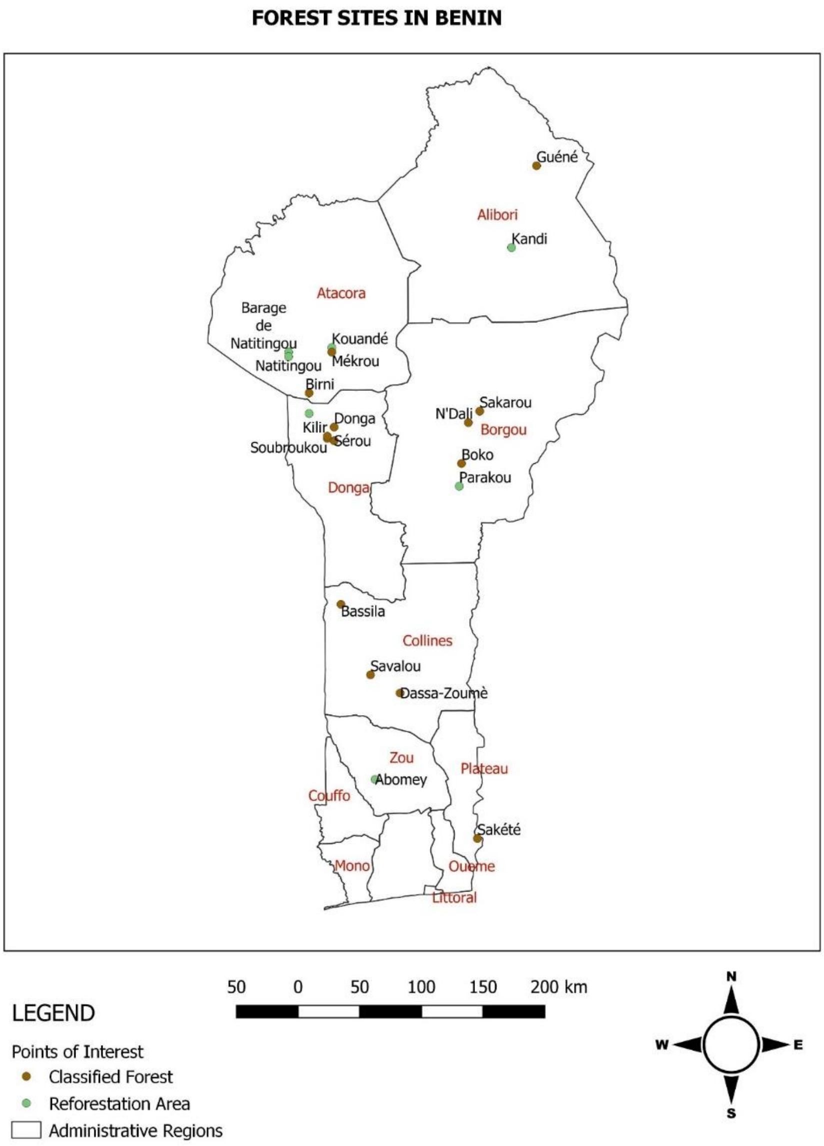


Table 20: Location of forest sites in Benin

Figure 15: Forest sites in Benin

NAME	TYPE	X_coord	Y_coord
Kouandé	Reforestation Area	355844.3571	1144407.756
Sakarou	Classified Forest	474418.6151	1092522.362
Sakété	Classified Forest	472372.7226	746119.4618
Savalou	Classified Forest	386107.7338	878912.339
Sérou	Classified Forest	357371.4061	1068830.119
Soubroukou	Classified Forest	351892.044	1070694.531
Abomey	Reforestation Area	389587.1754	794136.2665

NAME	TYPE	X_coord	Y_coord
Kandi	Reforestation Area	500000	1225193.627
Mékrou	Classified Forest	355829.1588	1140721.351
Bassila	Classified Forest	362401.6863	936110.2221
Birni	Classified Forest	337424.4791	1107621.354
Boko	Classified Forest	459754.7711	1050152.799
Dassa-Zoumè	Classified Forest	409961.257	864117.4694
Donga	Classified Forest	357413.7625	1079888.989
Guéné	Classified Forest	519980.4871	1291544.084
Kilir	Classified Forest	351899.3566	1072537.745
N'Dali	Classified Forest	465273.5394	1083316.252
Parakou	Reforestation Area	457905.3207	1031727.718
Barage de Natitingou	Reforestation Area	321147.2475	1140881.284
Natitingou	Reforestation Area	321128.4492	1137194.281
Taneka	Reforestation Area	337350.3123	1091031.62

Source: Author, data used retrieved from (UNEP-WCMC, 2020)

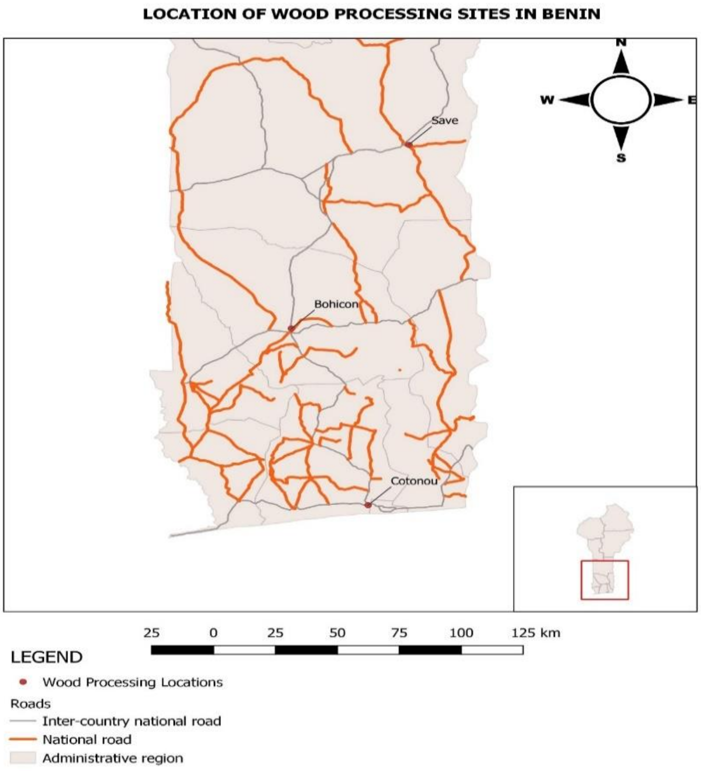


Table 21: Location of Wood Processing Sites in Benin

Figure 16: Wood Processing Sites in Benin

Place	Purpose	X_Coord	Y_Coord
Save	Defforestation	2.502152	8.034764
Cotonou	Sawmills and wood transport hub	2.353842	6.378731
Bohicon	Mahukpenou Sawmill Location	2.07437	7.19064

5.2.25 Case of Cote d'Ivoire

5.2.26 Production Forests

The average area for the last three years is 3000 ha. Thus, 105,000 ha have been planted in classified forest or in the rural domain in 18 years, i.e. an average of 5,640 ha per year, not counting the year 2011. This does not include private reforestation, school projects or SODEFOR reforestation. The reforested species are essentially Teak, Samba, Gmelina, Cedrela, *Acacia mangium, Frake,* Framiré, Cheese.... The proportion of Teak is higher in rural areas than in classified forests (BNETD, 31 July 2015).

There has been a dramatic decrease in forest cover, a decrease in the wealth of forests that extend over the southern half of the country. From 16 million hectares in 1900, the dense forest increased to 10.3 million hectares in 1969[4]. Today,(Orstom, 1969)the dense rainforest would represent only 2 million hectares of natural forest. The decrease in forest area is estimated at almost 80% in 30 years.[5]

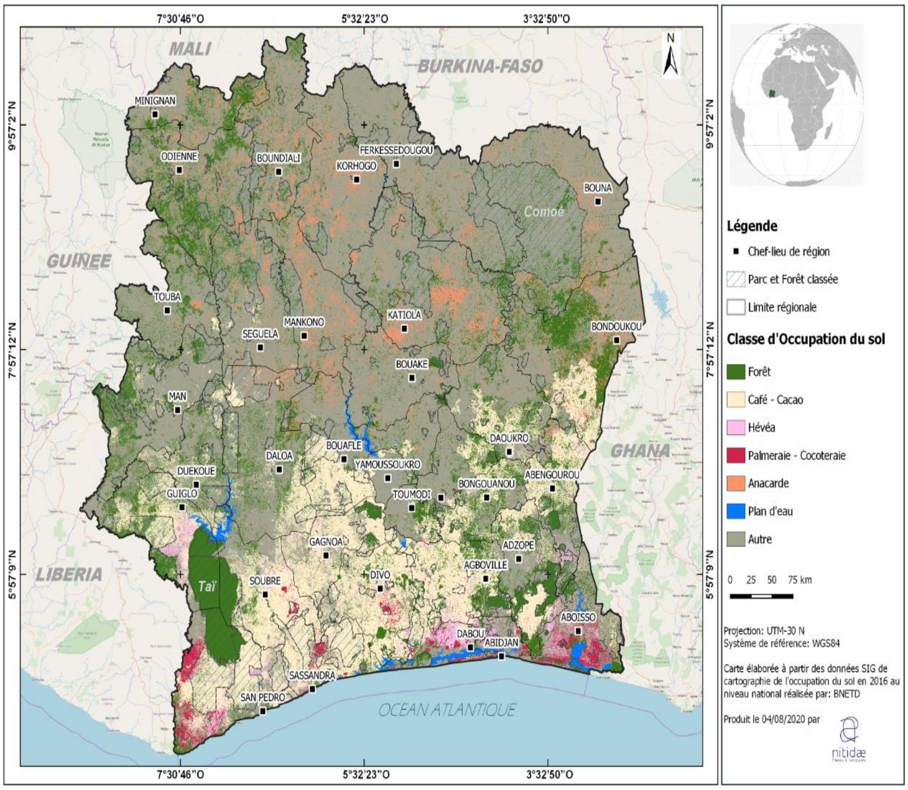


Figure 17: Land use classes map for Cote d'Ivoire

Estimates range from 2.5 Mha in 2000 to 10.4 Mha, passing through 7.2 Mha and 10 Mha. These very wide differences are due to the use of different definitions for forests and the absence of the National Forest Inventory (IFN) since 1978. The most optimistic estimates today show 2.5 million hectares of scattered forest islets, severely degraded by itinerant agriculture and impoverished by mining-type exploitation (FAO, 2001; FAO, FRA, 2010; MINEF, 2010; FAO, FRA, 1990; BNETD, 31 Juillet 2015).

The **Permanent Forest Estate** currently covers 6,268,204 hectares, or 19% of the national territory, and includes all classified forests (FC) and protected areas (national parks and reserves)(Forest Investment Plan, May 2016)

- The country's 233 **Classified Forests,** owned by the state's private domain, cover a total area of 4,196,000 hectares. Operated mainly for timber, they are severely degraded, partly due to the development of agriculture and large urban areas within the forest area.
- **The protected areas network** comprises 8 national parks and 5 nature reserves (fauna or flora), all belonging to the public domain of the State. They cover a total area of 2,072,204 hectares and are home to a representative sample of the country's ecosystems. The rate of degradation of these habitats varies considerably from region to region.

The two main ones (Comoé and Taï) are infiltrated at less than 1%, according to the Ivorian Office of Parks and Reserves. On the other hand, Marahoué and Mont Peko are seriously under way.

[4] *Source: ITTO workshop on ITTO guidelines for restoration of degraded forests*
[5] *Source: MINEF; opening remarks by the Minister of Water and Forestry for the government's meetings*

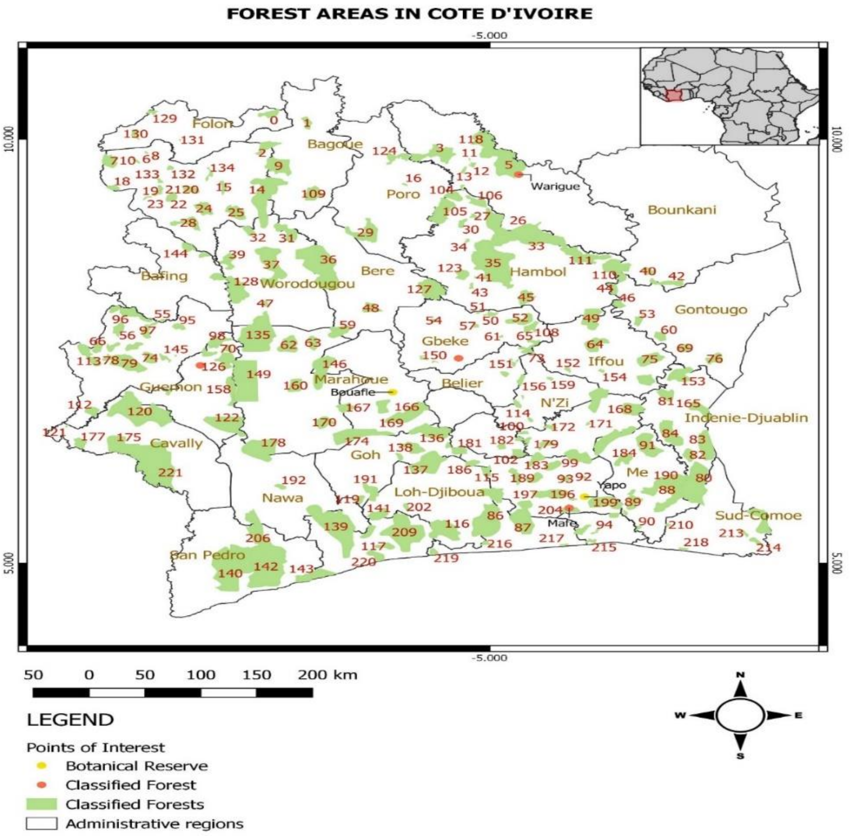


Figure 18: Forest areas in Cote d'Ivoire

Source: Author, data used retrieved from (UNEP-WCMC, 2020)

Table 22: Forest areas in Cote d'Ivoire

Map ID No.	NAME	Area_Sq
0	Soukourou	123.288
1	Pouniokele	94.47
2	Classified Forest Name Unknown (CIV) No.1	180.02
3	Classified Forest Name Unknown (CIV) No.2	465.837
4	Lougbo	227.543
5	Ouarigue	659.339
6	Tinrido	8.373
7	Gbanala	186.373
8	Samatiguila	10.864
9	Lapale	387.629
10	Konza Kourou	21.453
11	Classified Forest Name Unknown (CIV) No.3	4.58
12	Classified Forest Name Unknown (CIV) No.4	28.263
13	Lopboho	27.563
14	Boundiali	916.4
15	Classified Forest Name Unknown (CIV) No.5	65.586
16	Classified Forest Name Unknown (CIV) No.6	11.2
17	Classified Forest Name Unknown (CIV) No.7	21.943

18	Classified Forest Name Unknown (CIV) No.8	61.779
19	Odinne	63.53
20	Bdoule	115.865
21	Classified Forest Name Unknown (CIV) No.9	42.697
22	Classified Forest Name Unknown (CIV) No.10	54.72
23	Foula	17.772
24	Gouari	189.856
25	Zandougou	229.79
26	N'zi Supérieure	818.994
27	Classified Forest Name Unknown (CIV) No.11	29.568
28	Classified Forest Name Unknown (CIV) No.12	215.065
29	Foumbou	426.031
30	Classified Forest Name Unknown (CIV) No.13	59.944
31	Classified Forest Name Unknown (CIV) No.14	247.147
32	Yani	99.162
33	Nyellepuo	656.077
34	Classified Forest Name Unknown (CIV) No.15	18.458
35	Classified Forest Name Unknown (CIV) No.16	1470.583
36	Bandama Rouge	1329.889
37	Yarani	731.122
38	Boa	48.298
39	Tyemba	177.523
40	Log-boyo	74.877
41	Classified Forest Name Unknown (CIV) No.17	8.998
42	Classified Forest Name Unknown (CIV) No.18	170.37
43	Classified Forest Name Unknown (CIV) No.19	24.853
44	Classified Forest Name Unknown (CIV) No.20	87.519
45	Nangbyon	203.789
46	Classified Forest Name Unknown (CIV) No.21	82.642
47	Classified Forest Name Unknown (CIV) No.22	34.144
48	Bere	151.648
49	Kamesso	361.512
50	Foro Foro	55.762
51	Classified Forest Name Unknown (CIV) No.23	8.603
52	Classified Forest Name Unknown (CIV) No.24	74.16
53	Dora Diaro	80.912
54	Classified Forest Name Unknown (CIV) No.25	25.736
55	Classified Forest Name Unknown (CIV) No.26	14.939
56	Bableu	120.547
57	Classified Forest Name Unknown (CIV) No.27	21.881

58	Classified Forest Name Unknown (CIV) No.28	46.671
59	Moyenne Marahoue	224.926
60	Kouadikro	104.123
61	Classified Forest Name Unknown (CIV) No.29	11.201
62	Classified Forest Name Unknown (CIV) No.30	291.206
63	Mt. De	135.337
64	Classified Forest Name Unknown (CIV) No.31	250.41
65	Classified Forest Name Unknown (CIV) No.32	69.225
66	Classified Forest Name Unknown (CIV) No.33	94.45
67	Classified Forest Name Unknown (CIV) No.34	104.769
68	Classified Forest Name Unknown (CIV) No.35	78.05
69	Classified Forest Name Unknown (CIV) No.36	102.07
70	Klouamian	53.78
71	Classified Forest Name Unknown (CIV) No.37	37.591
72	Classified Forest Name Unknown (CIV) No.38	87.514
73	Soungounau	47.254
74	Classified Forest Name Unknown (CIV) No.39	133.927

75	Classified Forest Name Unknown (CIV) No.40	282.22
76	Tankesse	150.645
77	Classified Forest Name Unknown (CIV) No.41	52.066
78	Classified Forest Name Unknown (CIV) No.42	105.294
79	Classified Forest Name Unknown (CIV) No.43	405.038
80	Songan/Tamin	920.409
81	Brassue	175.421
82	Manzan	140.768
83	Diambarakrou	415.241
84	Beki Bosse Matie	420.679
85	Mopri	272.504
86	Go Bodienou	823.034
87	Irobo	524.838
88	Mabi/Yaya	900.38
89	Hein	183.918
90	Nguechie	23.68
91	Besso	447.648
92	Rasso	18.436
93	Gorke	57.551
94	Anguededou	25.764
95	Mt. Ba	72.83
96	Yalo	296.755
97	Ira	142.976
98	Semien Flansobly	174.518
99	Seguie	297.072
100	Abouderessou	29.226
101	Bodio Doubele	82.526
102	Mando	107.874

103	Matiemba	31.321
104	Kogha	135.928
105	Silue	427.864
106	Badikaha	144.276
107	Mafa	188.423
108	Laka	66.25
109	Nyamgboue	227.147
110	Suitoro	429.795
111	Kinkene	514.768
112	Krozalie	112.91
113	Tiapleu	252.618
114	Ahua	21.779
115	Goudi	90.883
116	Dogodou	536.822
117	Bolo	99.701
118	Leraba	316.339
119	Davo	73.192
120	Scio	1328.249
121	Goulaleu	7.904
122	Duekoue	610.703
123	Kobo	125.426
124	Badonou	161.06
125	Teonle	33.331
126	Mt. Tia	240.263
127	Bandama-Blanc	478.884
128	Mt. Ko	573.239
129	Mt. Manda	40.851
130	Tienny	64.225
131	Sananferedougou	3.888
132	Kimbirila	28.573
133	Dyengele	23.747
134	Tieme	48.911
135	Seguela	1148.882
136	Tene	468.708
137	Sangoue	594.98
138	Zuoke	208.554
139	Niegre	1330.456
140	Haute Dodo	1476.296
141	Niouniourou	192.782
142	Rapide Grah	1608.619
143	Monogaga	326.136
144	Borotou	104.678
145	Classified Forest Name Unknown (CIV) No.44	4.461
146	De	521.415
147	Classified Forest Name Unknown (CIV) No.45	6.859
148	Classified Forest Name Unknown (CIV) No.46	6.802
149	Mt. Sassandra	1122.149
150	Classified Forest Name Unknown (CIV) No.47	11.354
151	Classified Forest Name Unknown (CIV) No.48	22.228
152	Classified Forest Name Unknown (CIV) No.49	28.19
153	Classified Forest Name Unknown (CIV) No.50	296.383
154	Classified Forest Name Unknown (CIV) No.51	19.784
155	Classified Forest Name Unknown (CIV) No.52	39.672
156	Boli	63.905
157	Elroukro	173.885

158	Classified Forest Name Unknown (CIV) No.53	210.047
159	Classified Forest Name Unknown (CIV) No.54	20.956
160	Vavoua	176.188
161	Abeanou	335.26
162	Ndokouassikro	9.055
163	Tete	53.412
164	Tos	165.495
165	Ebrinenou	238.496
166	Marahoue	155.563
167	Bouafle	135.042
168	Arrah	264.025
169	Plaine des Elephants	372.055
170	Zagoreta	177.303
171	Bongouanou	13.219
172	Classified Forest Name Unknown (CIV) No.55	49.805
173	Classified Forest Name Unknown (CIV) No.56	254.949
174	Bayota	580.149
175	Gouin	313.732
176	Agbo	208.724
177	Mt. Sainte/Cavally	121.993
178	Issia	668.166
179	Classified Forest Name Unknown (CIV) No.57	90.448
180	Classified Forest Name Unknown (CIV) No.58	865.885
181	Oume Doka	156.34
182	Orumbo Boka	48.212
183	Kravassou	147.667
184	Adzope	170.453
185	Classified Forest Name Unknown (CIV) No.59	44.775
186	Taabo	87.678
187	Ananguie	127.931
188	Kassa	132.22
189	Offumpo	130.049
190	Classified Forest Name Unknown (CIV) No.60	16.81
191	Classified Forest Name Unknown (CIV) No.61	27.737
192	Classified Forest Name Unknown (CIV) No.62	52.444
193	Nizoro	126.327
194	Kavi	158.398
195	Massa Me	30.445
196	Classified Forest Name Unknown (CIV) No.63	86.07
197	Classified Forest Name Unknown (CIV) No.64	67.136
198	Classified Forest Name Unknown (CIV) No.65	42.24
199	Classified Forest Name Unknown (CIV) No.66	377.542
200	Classified Forest Name Unknown (CIV) No.67	25.131
201	Classified Forest Name Unknown (CIV) No.68	112.367
202	Zakpaberi	39.419

203	Classified Forest Name Unknown (CIV) No.69	42.418
204	Classified Forest Name Unknown (CIV) No.70	33.796
205	Tanoe	330.6
206	Nibi Hana	623.753
207	N. Zodji	21.22
208	Classified Forest Name Unknown (CIV) No.71	56.244
209	Classified Forest Name Unknown (CIV) No.72	1053.042
210	Classified Forest Name Unknown (CIV) No.73	16.57
211	Classified Forest Name Unknown (CIV) No.74	96.611
212	Mt. Bolo	112.515
213	Classified Forest Name Unknown (CIV) No.75	32.467
214	Classified Forest Name Unknown (CIV) No.76	62.758
215	Audoin	38.747
216	Nzida	47.425
217	Kokoh	17.789
218	Nganda Nganda	22.843
219	Port Gautier	52.348
220	Dassieko	135.764
221	Classified Forest Name Unknown (CIV) No.77	903.053

Table 23: Points of Interest in Cote d'Ivoire

NAME	X_Coord	Y_Coord
Mafe	349614.1619	624761.3932
Yapo	363444.3751	639401.9737
Bouafle	192470.7382	776504.3257
Haut-Sassandra	21281.88932	812911.99
Warigue	306184.0465	1059916.056
Bandama Superieur	251650.0284	820440.0374

5.2.27 Wood Processing Units (Sawmills)

The timber industry, once the country's third-largest exporter, has seen its weight in the country's economic growth decline due to demand for agricultural land, particularly for cocoa and coffee. This decrease in the resource causes enormous difficulties in the supply of factories and has led to the closure of some of them. The production of timber and woodwork in the rural sector increased from 1.3 million m^3 in 2005 to 1.1 million m^3 in 2015 (Ministry of Water and Forestry). Wood exports also declined from 650,559 m3 in 2010 to 479,755 m^3 in 2015 (Activity Reports, DEIF). In 2012, the wood industry still accounted for about 50,000 jobs, including 12,000 direct jobs. Industrial exploitation however has a negative impact on the forest. The scarcity of the resource leads to the use of small diameter wood. This leads to a steady decline in industrial slicing production. These woods come mostly from the Rural Forest Estate, which provides 90%of the wood harvested by industrialists (Kadio, 2009).

In Côte d'Ivoire, the primary processing industry is dominated by three types of activities: sawing, unwinding andranching. The second transformation includes plywood, mouldings, parquets, friezes and pallets, etc. Industrial carpentry products, such as windows, doors and cabottis and many other finished products,, are the result of the third processing. Since the adoption of Decree 95-682 of 6 September 1995 banning the export of raw, squared and studded timber, Côte d'Ivoire has seen a dramatic development in the forest resource processing industry. As a result, all naturals forest antlers are systematically processed at least once before they are exported or marketed outdoors.

However, exports of raw timber existed until Decree No. 2014-179 of 09 April 2014 repealing Article 2 of Decree 95-682 of 6 September 1995 prohibiting the export of raw timber, squared and studded and concerned only plantation woods, in particular, Teck and Gmelina. Since then, the export of these woods requires a first transformation.

Table 24: Aggregated Operators and Industries from 2010 to 2017

		2010	2011	2012	2013	2014	2015	2016	2017
Foresters	**Total**	184	125	112	119	122	122	123	124
	Groups Operators Forest	*69*	*44*	*41*	*39*	*41*	*41*	*36*	*36*
	Approved industrialists Foresters	*61*	*53*	*51*	*57*	*61*	*65*	*61*	*61*
	Civil Societies Partnership	*53*	*27*	*19*	*22*	*19*	*15*	*26*	*26*

Source: (MEF, February 2018)

The 2014 data cover 104 active plants that together had 127 first-processing and 42 second-processing (see table below). The number of plants in operation seemed to increase because in 2013 they were only 98, on the other hand it seems that there is less activity at the level of the second transformation. In 2014, the volume of processed wood was 1.3 million m^3, while the installed processing capacity was 3.1 million m^3. The first processing activities generated a volume ofabout 0.77 million m^3, more than half of which involved sawing and the other half, unwinding with a very small slicing share(nearly 0.004 million m^3 of slicing).

Table 25: First and second transformation wood industries in Cote d'Ivoire

	First transformation: 127 workshops			Second transformation: 42 workshops					
Activities	Sawing	Unwinding	Slicing	C/P	Moldings	Floors	Friezes	Pallets	Other
Number of workshops	96	25	6	21	2	2	3	5	9

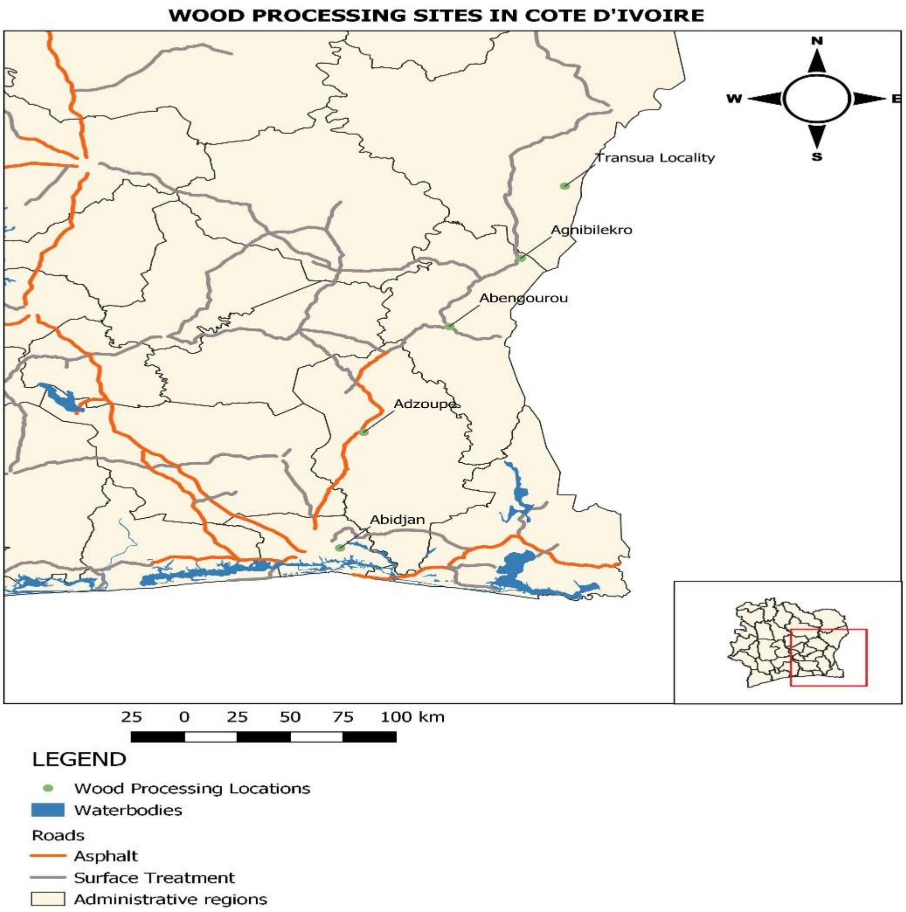


Figure 19: Wood processing sites in Cote d'Ivoire

Table 26: Wood processing locations in Cote d'Ivoire

Place	Purpose	X_Coord	Y_Coord
Adzoupe	Nouvelle Scierie D'Adzopé Hardwood Sawmill	-3.859927	6.087597
Abengourou	Nsefi SARL Tropical Hardwood Sawmill	-3.495319	6.723679
Abidjan	Dingshang Developpement Tropical Hardwood Sawmill	-3.960887	5.392102
Agnibilekro	SITBAI Wood Processing Company	-3.190732	7.133497
Transua Locality	SMCI Company	-3.003374	7.566822

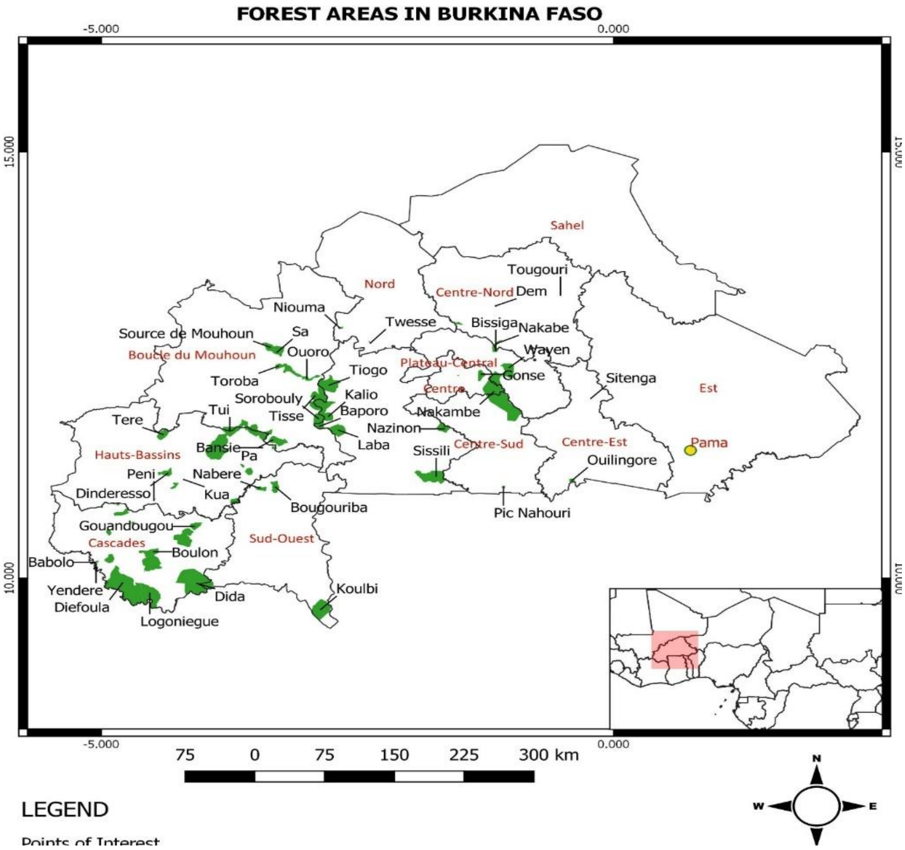


Figure 20: Forest areas in Burkina Faso

5.2.28 Case of Burkina Faso

This study, based on the second National Forest Inventory (NFI 2 - 2017), indicates that the total volume of live trees with a diameter greater than or equal to 5 cm (D1, 30 m ≥ 5 cm), is estimated at a national level at 467.9 million m^3, or 374.32 million tons. And to deduce that the volume of potentially exploitable firewood is estimated at 207 million m^3 or 165.6 million tons.

Table 27: Forest areas in Burkina Faso

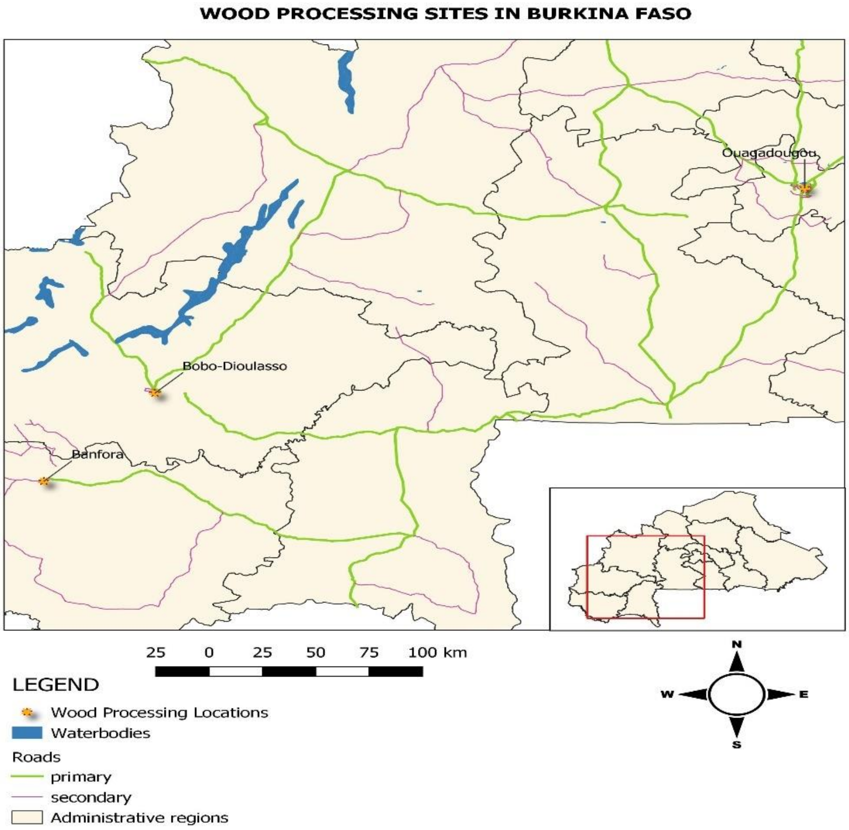
NAME	Area_Sq
Tui	447.6444
Bougouriba	96.3805
Koulbi	349.9135
Tougouri	0.8461
Dem	5.705
Nakabe	16.0338
Baporo	70.463
Laba	202.0507
Tiogo	314.3201
Nazinon	106.9101
Sissili	364.2469
Niouma	12.4998
Twesse	5.5166
Babolo	13.4968
Beregadougou	79.3977
Boulon	135.2313
Bounouna	9.9446
Gouandougou	81.5819
Logoniegue	430.609
Niangoloko	81.843
Source de Mouhoun	161.4002
Bambou	12.6227
Bansie	4.2142
Dan (Burkina Faso)	57.0394
Dinderesso	86.5751
Kapo	56.7301

Koulima	33.6736
Maro	538.0925
Peni	4.8311
Koflande	308.0304
Dida	853.6738
Diefoula	1011.0154
Kari	105.7104
Noussebou	68.9223
Pa	146.7241
Sa	41.9485
Sorobouly	119.6308
Tisse	196.5216
Toroba	45.1417
Wayen	193.9419
Barrage	1.8745
Pic Nahouri	9.8794
Bissiga	38.8339
Gonse	76.9137
Ouilingore	24.9114
Sitenga	1.7375
Tere	108.2014
Toumousseni	29.5048
Yendere	6.8995
Sources de la Volta Noire	8.2496
Kua	2.712
Nabere	52.9189
Bounou	34.1443
Bouahoum	12.3618
Kalio	315.0805
Ouoro	75.9025
Yabo	17.6712
Nakambe	1018.4358
Kongouko	311.5978

Table 28: Points of Forestry Interests in Burkina Faso

NAME	TYPE	X_coord	Y_Coord
Pama	Classified Forest	909229.3108	1273938.352

Source: Author, data used retrieved from (UNEP-WCMC, 2020)



Source : Author

Table 29: Wood Processing Locations in Burkina Faso

Place	Purpose	X_Coord	Y_Coord
Ouagadougou	Intertrade SA - Logging contractor	-1.513983	12.360203
Bobo-Dioulasso	Faso-Negose - Lumber wholesale	-4.29008	11.16348
Banfora	Two-unnamed sawmills	-4.765004	10.648469

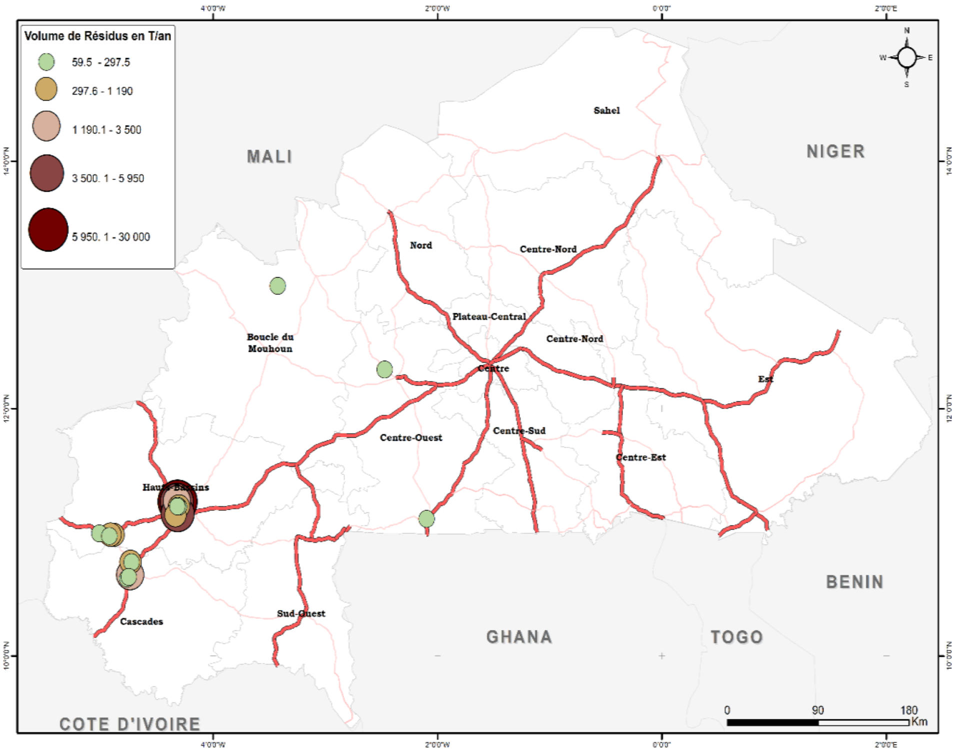


Figure 22: Annual potential residue amounts for each site in Burkina Faso

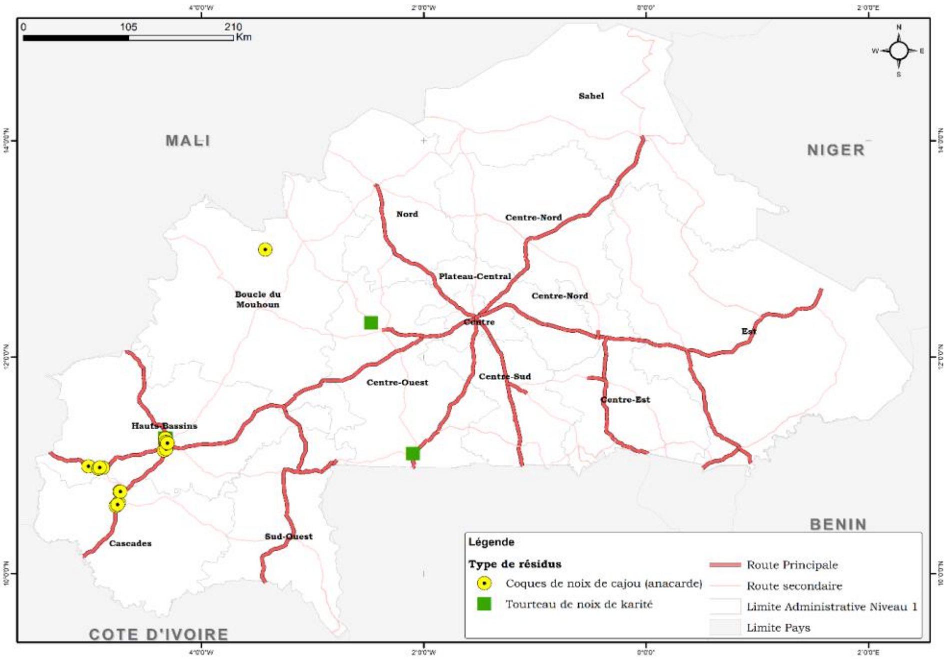


Figure 23: Location of the different residue types in Burkina Faso

5.2.29 Case of Senegal

In Senegal, as in other Sahelian countries, traditional fuels (firewood and charcoal) are the main sources of household energy. Indeed, Senegal depends on more than 70% of forest resources to meet its cooking energy needs (Frank Richter, Marion and Abdoul A SOW, August 2014). This logging is one of the causes of the degradation of forest resources, especially when combined with agricultural clearing and bush fires.

In 2013, with the support of PROGEDE 2, a national survey was conducted on domestic fuel consumption and household practices. The results of the 2013 household survey met with the consensus of all national stakeholders. They reveal that the quantities of cooking fuels used in Senegal are :

- 1,735,219 tonnes for firewood ;
- 482,248 tonnes for charcoal ;
- 108,001 tonnes for butane gas.

The maps below show the forest reserves and areas that are in continuous danger of total deforestation for charcoal and woodfuel.

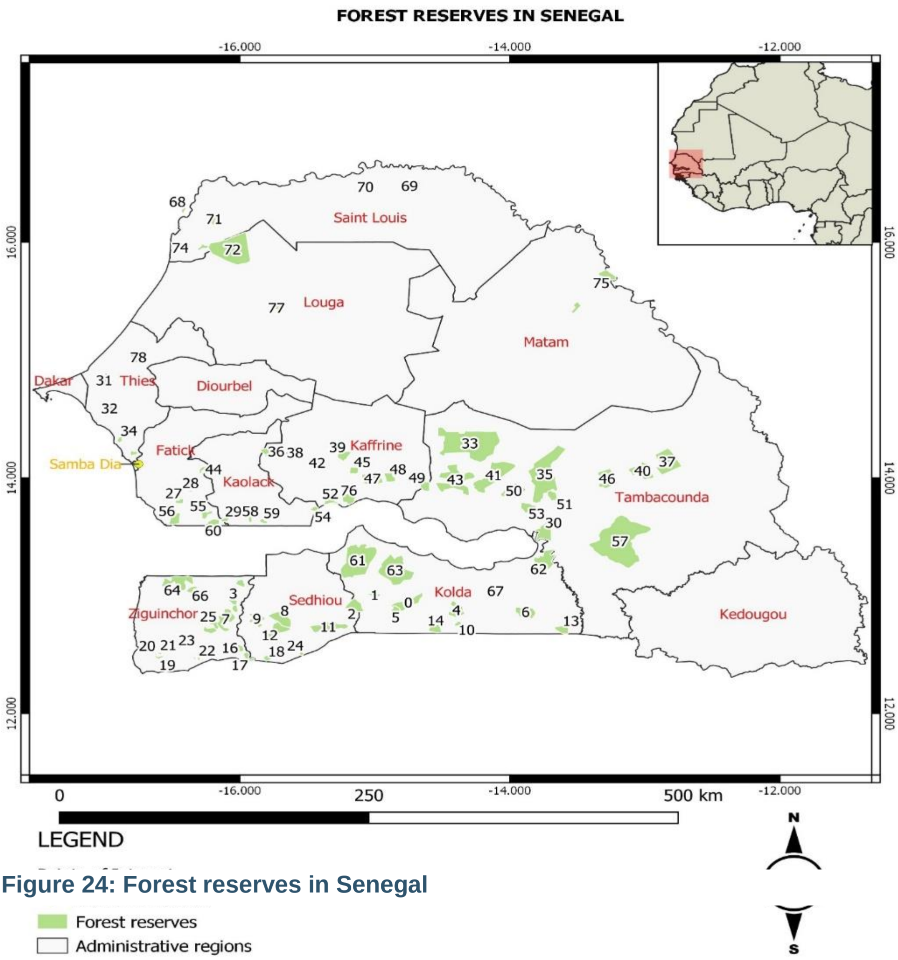


Figure 24: Forest reserves in Senegal

Table 30: Forest reserves in Senegal

ID_No	NAME	Area_Sq
0	Foret de Bakor	164.0627
1	Foret de Diatouma	30.1781
2	Foret de Sadiata	116.3288
3	Foret de Koulaye	27.8074
4	Foret de Dabo	130.803
5	Foret de Mahon	30.1356
6	Foret de la Kayanga	121.1555
7	Foret de Kalounayes	165.4164
8	Foret de Bari	156.6141
9	Foret de Yassine	104.9699
10	Foret de Toutoune	20.8331
11	Foret du Balmadou	193.123
12	Foret du Boudie	119.879
13	Foret de Mampaye	69.8898
14	Foret de Koudora	61.0555
15	Foret de Tobor	47.8312
16	Foret de Bissine	48.041
17	Foret de Blaz	38.9768
18	Foret de Bafata	31.3692
19	Foret de Boukitingo	15.3905
20	Foret de Diantene	2.8625
21	Foret d'Oukout	5.2142
22	Foret des Bayot	12.8889
23	Foret de Djibelor	1.7513
24	Foret de Mangaroungou	9.9168

25	Foret de Bignona	32.8209
26	Foret de Djipakoum	25.9387
27	Foret de Sangako	24.7623
28	Foret de Sokone	5.3875
29	Foret de Saboya	20.6043
30	Foret de Gouloumbou	179.2522
31	Foret de Thies	68.8904
32	Foret de Bandia	104.5541
33	Foret de Panal	1044.1368
34	Foret de Narangs	22.6534
35	Foret de Tamba- Nord	742.3796
36	Foret de Birkelane	66.64
37	Foret de Goudiri	312.542
38	Foret de Kassas	107.6681
39	Foret de Delbi	67.588
40	Foret de Bala- Est	198.2047
41	Foret des Paniates	415.484
42	Foret de Sagna	22.683
43	Foret de Malem Niani	434.0815
44	Foret de Wélor	47.2196
45	Foret de Malem-Hodar	42.0372
46	Foret de Bala- Ouest	199.5437
47	Foret de Maka Yop-ouest	144.7206
48	Foret de Maka Yop-est	60.3658
49	Khogue	58.5242
50	Foret du Ouli	140.0824
51	Foret de Botou	95.4865
52	Foret de Ndankou	34.401
53	Foret de Tamba-sud	93.5204
54	Foret de Ngayene	22.2871
55	Foret de Patako	42.9414
56	Foret de Fathala	72.1914
57	Foret de Diambour	1273.6133
58	Foret de Pane	16.3574
59	Foret de Mambi	19.5919
60	Foret de Baria	53.6001
61	Foret de Pata	636.8059
62	Foret de Kantora	225.3416
63	Foret du Guimara	494.9992
64	Foret des Narangs	206.3637
65	Foret de Kandiadiou	37.1756
66	Foret d'Essom	35.985
67	Foret de l'Anambe	28.1309
68	Foret de Maka-Diama	12.7401
69	Foret de Ndioum Dieri	87.8
70	Foret de Amboura	20.08
71	Foret de Tilene et Ndiaye	38.7567
72	Foret de Keur Momar Sarr	650.7832
73	Foret de Mpal	26.0484
74	Foret de Leybar	2.7127
75	Foret de Diamel	76.737
76	Foret de Pate	120.6698
77	Foret de Boulierobe	17.283
78	Foret de Pire-Goureye	88.9839

Table 31: Points of Forestry Interest in Senegal

NAME	DESIG	X_Coord	Y_Coord
Samba Dia	Classified Forest	311085.8129	1561332.969

Source: Author, the data used was retrieved from (UNEP-WCMC, 2020)

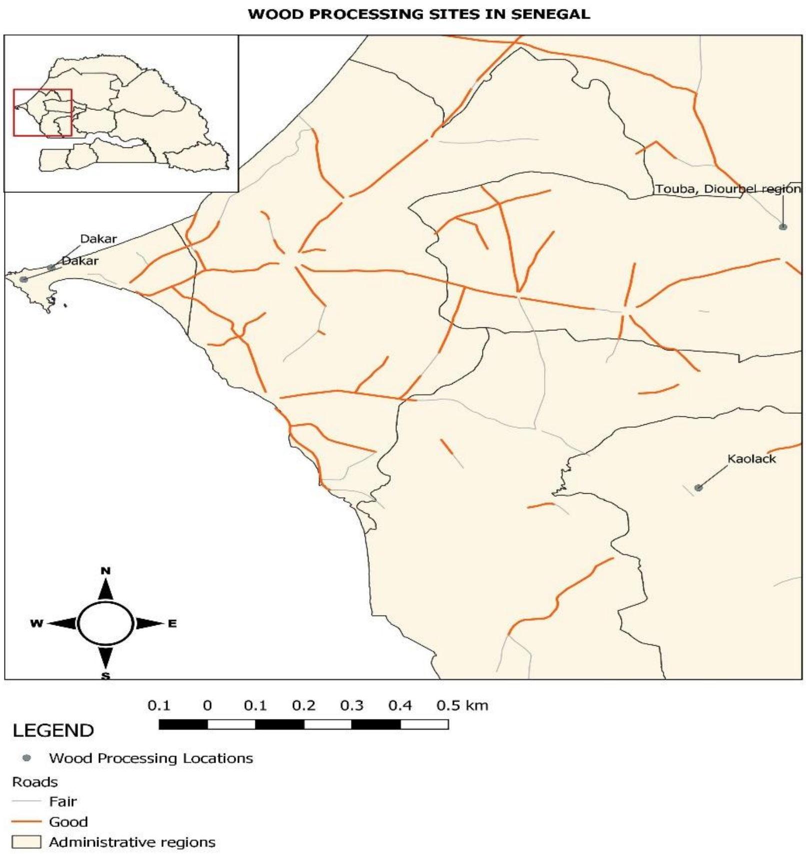
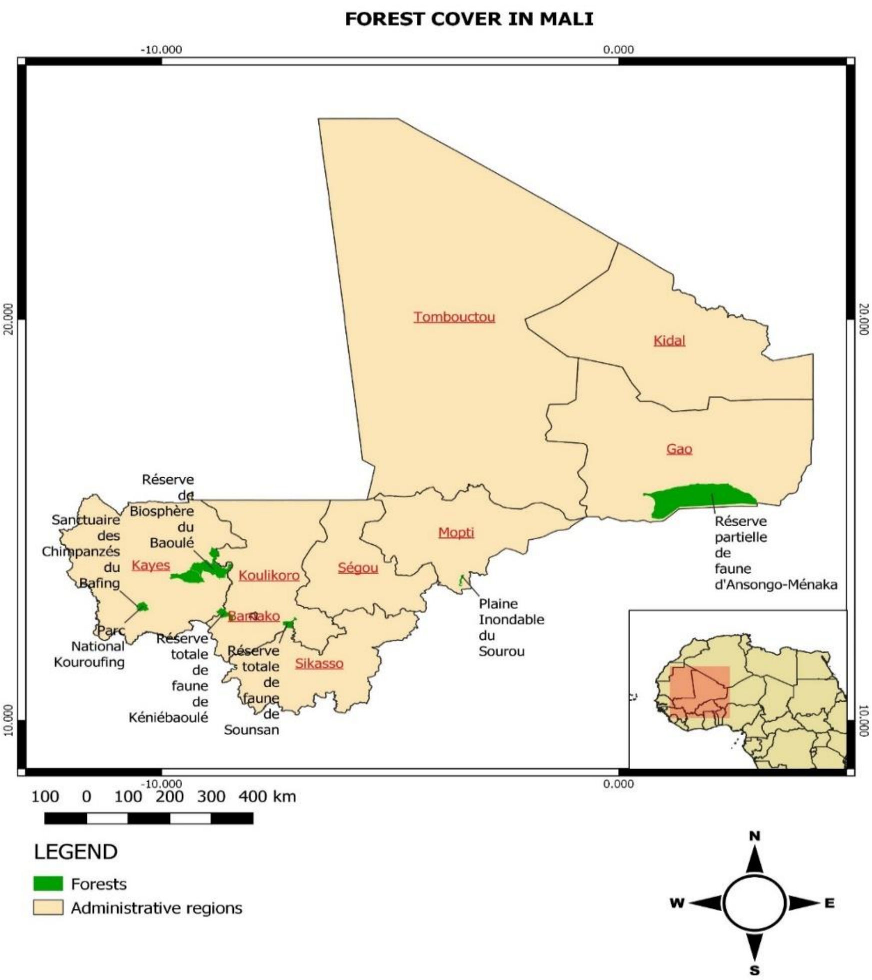


Figure 25: Wood processing sites in Senegal

Table 32: Location of wood processing sites in Senegal

Place	Purpose	X_Coord	Y_Coord
Dakar	Pikine Sawmilling Compound	-17.484551	14.737246
Kaolack	Lagal Sawmillingl Compound	-16.083911	14.177963
Dakar	Victoria Star Darkar- Logger, timber exporter	-17.427827	14.768601
Touba, Diourbel region	Wood-mizer Branch (wood product processing)	-15.908333	14.877921

5.2.30 Case of Mali



FAO estimates the need for wood energy at 7 million tonnes in 2003. The regeneration potential (productivity) is estimated at 7 million tonnes per year (FAO, December 2003), which clearly shows that there is currently a strong imbalance between supply and demand for wood energy in the country.

Table 33: Forest cover areas of Mali

Figure 26: Forest cover in Mali

NAME	DESIG_ENG	Area_Sq
Sanctuaire des Chimpanzés du Bafing	Chimpanzee Sanctuary	44.593
Parc National Kouroufing	National Park	482.106
Réserve totale de faune de Kéniébaoulé	Total Wildlife Reserve	0.843
Réserve totale de faune de Talikourou	Total Wildlife Reserve	11.331
Réserve totale de faune de Kéniébaoulé	Total Wildlife Reserve	579.156
Réserve totale de faune de Talikourou	Total Wildlife Reserve	81.786
Réserve totale de faune de Sounsan	Total Wildlife Reserve	317.316
Réserve partielle de faune du Banifing-Baoulé	Partial Wildlife Reserve	106.432
Réserve de Biosphère du Baoulé	UNESCO-MAB Biosphere Reserve	1777.048

Réserve de Biosphère du Baoulé	UNESCO-MAB Biosphere Reserve	3032.888
Plaine Inondable du Sourou	Ramsar Site, Wetland of International Importance	144.353
Réserve partielle de faune d'Ansongo-Ménaka	Partial Wildlife Reserve	13535.237

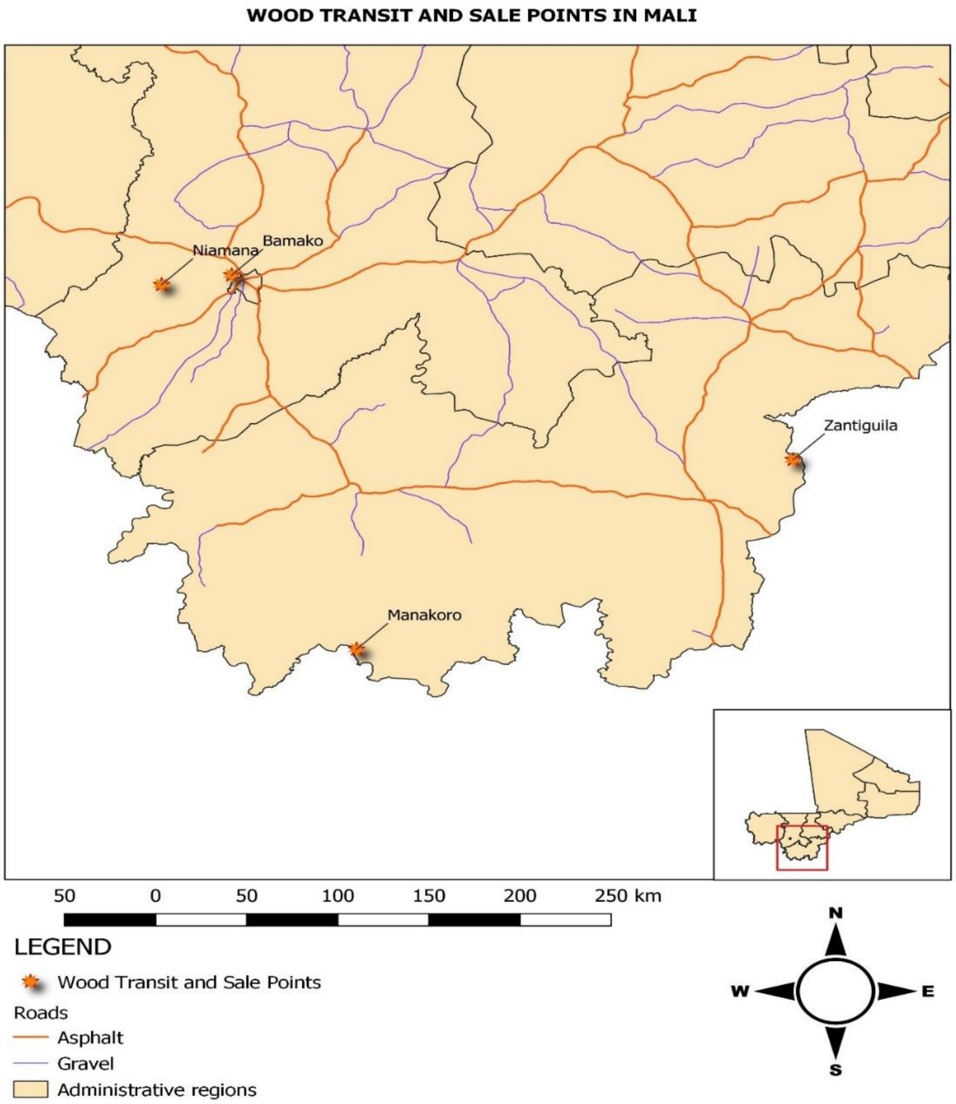


Table 34: Wood transit and sale points in Mali

Figure 27: Wood transit and sale points in Mali

Place	Purpose	X_Coord	Y_Coord
Zantiguila	Wood Source	-5.25796	11.56681
Manakoro	Wood Supply Source	-7.437493	10.427311
Bamako	Remodel Mali Contractors	-8.060838	12.676394
Niamana	Wood Transit Point	-8.411043	12.618292

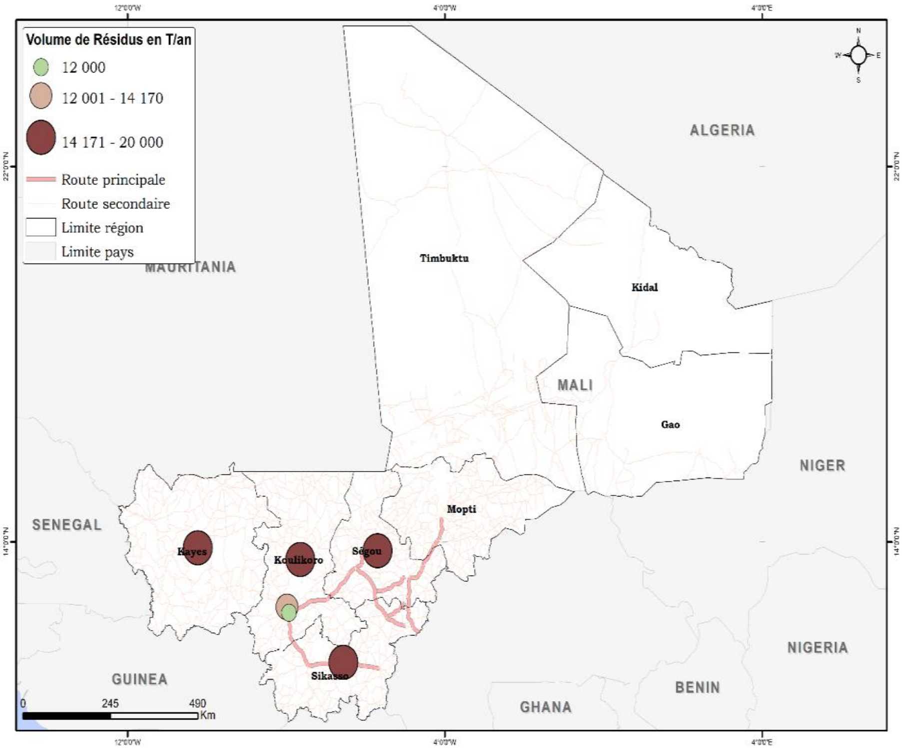


Figure 28: Annual potential residue amounts for selected sites in Mali

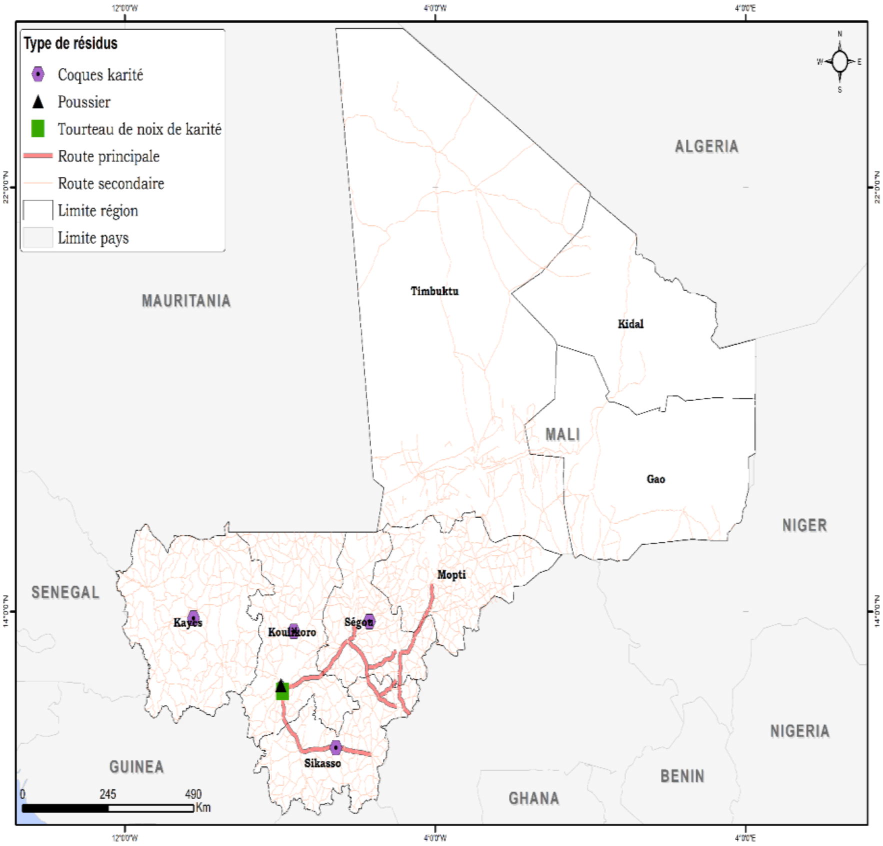


Figure 29: The residue types and their locations in Mali

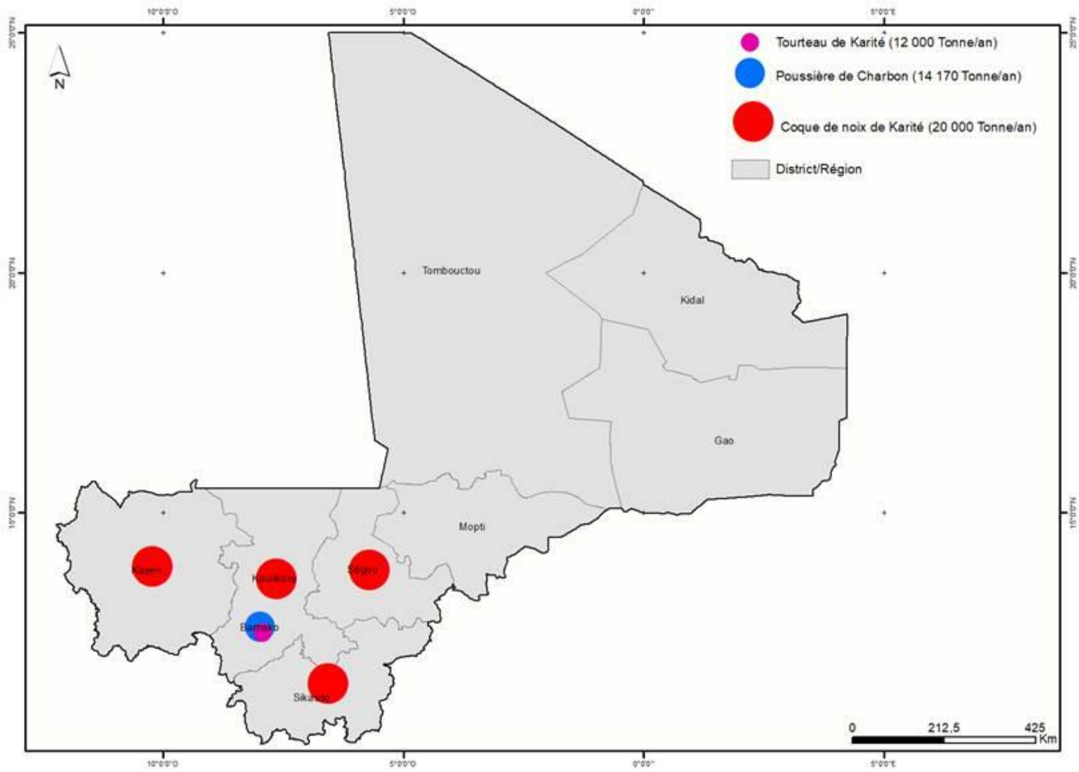


Figure 30: The different residue types and their locations in Mali

5.2.31 Case of Togo

The ECO Consult firm has estimated, in 2017, the total consumption of wood energy in Togo at 7.576 million cubic meters per year. This estimate is made using an elaborate simulation model and on the basis of total household consumption and that of professional consumers.

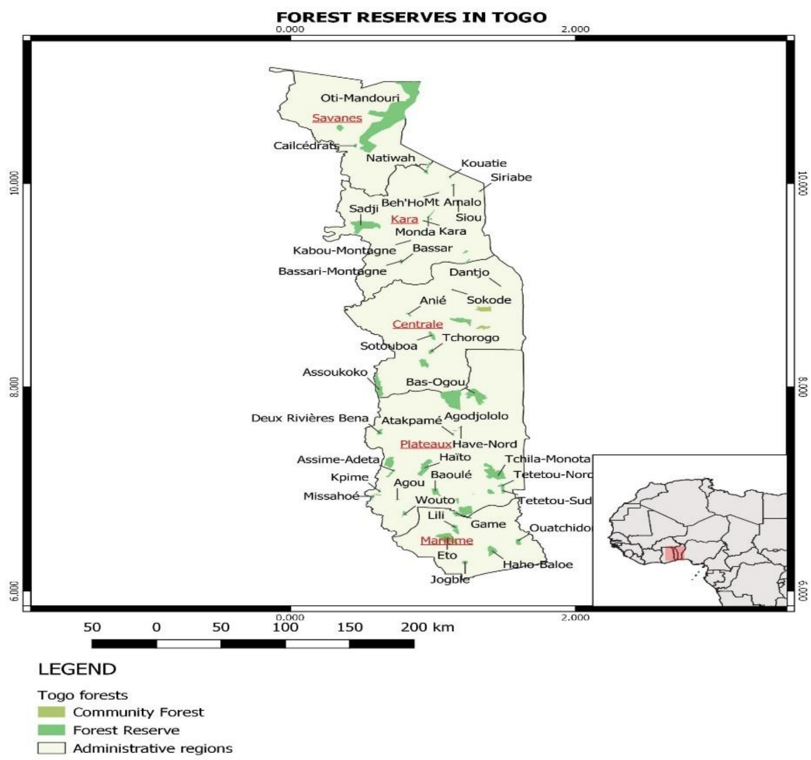


Figure 31: Forest reserves in Togo

Table 35: Forest areas in Togo

NAME	DESIG_ENG	Area_Sq
Tetetou-Nord	Forest Reserve	34.30061
Tetetou-Sud	Forest Reserve	16.39613
Wouto	Forest Reserve	16.30797
Cailcédrats	Forest Reserve	8.96332
Kouatie	Forest Reserve	4.48049
Mt Amalo	Forest Reserve	5.32925
Balam Nord	Forest Reserve	47.55758
Have-Nord	Forest Reserve	5.12846
Deux Rivières Bena	Forest Reserve	21.47451
Haïto	Forest Reserve	92.703
Nuatja Sud (Notsè)	Forest Reserve	12.56251
Jogble	Forest Reserve	14.79328
Oti-Mandouri	Forest Reserve	1013.79336
Bago	Community Forest	31.14787
Alibi 1	Community Forest	54.13638
Agbonou-Nord	Forest Reserve	3.65145
Agodjololo	Forest Reserve	238.14938
Agou	Forest Reserve	3.84337
Amakpave	Forest Reserve	91.08867
Anié	Forest Reserve	9.6804
Aou-Mono	Forest Reserve	71.36023
Asrama	Forest Reserve	22.8402
Assime-Adeta	Forest Reserve	19.69633
Assoukoko	Forest Reserve	91.22201
Atakpamé	Forest Reserve	5.20328
Atilakoutse	Forest Reserve	67.36267
Baoulé	Forest Reserve	39.19869
Barkoissi	Forest Reserve	27.35263
Bas-Ogou	Forest Reserve	148.82441
Bassar	Forest Reserve	8.57449
Bassari-Montagne	Forest Reserve	8.06589
Beh'Ho	Forest Reserve	2.7257
Dantjo	Forest Reserve	1.62269
Djemegni	Forest Reserve	1.11965
Dumbua	Forest Reserve	7.9449
Eto	Forest Reserve	115.26155
Game	Forest Reserve	24.85161
Haho-Baloe	Forest Reserve	54.02113
Kabou-Montagne	Forest Reserve	0.92781
Kémini	Forest Reserve	7.16034
Kpime	Forest Reserve	5.4769
Lili	Forest Reserve	38.74028
Koularo	Forest Reserve	3.7231
Kara	Forest Reserve	5.17155
Missahoé	Forest Reserve	14.84434
Monda	Forest Reserve	13.10933
Natiwah	Forest Reserve	21.86753
Ouatchidome	Forest Reserve	25.80918
Sadji	Forest Reserve	182.45035
Siou	Forest Reserve	1.24521
Siriabe	Forest Reserve	3.35526
Sokode	Forest Reserve	2.57385
Sotouboa	Forest Reserve	30.1065
Tchila-Monota	Forest Reserve	163.06122
Tchorogo	Forest Reserve	17.90002

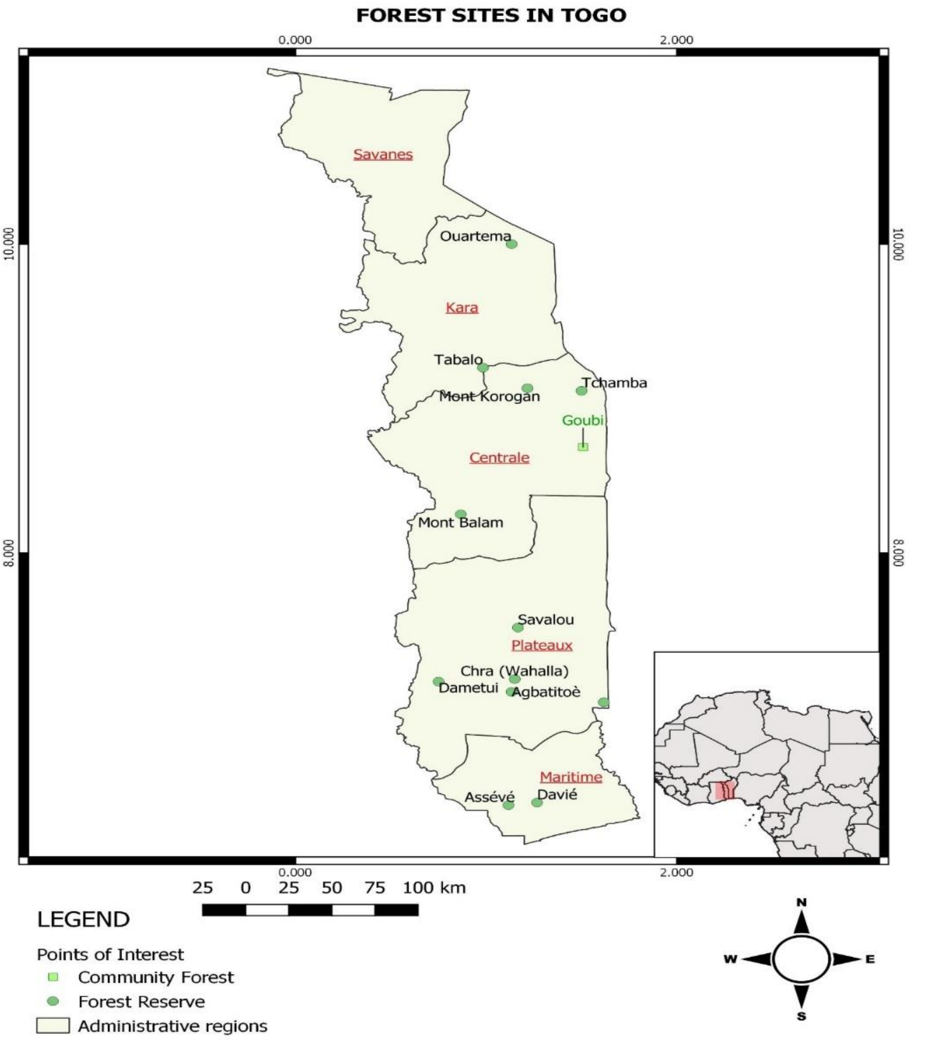


Figure 32: Forest sites in Togo

NAME	DESIG_ENG	X_Coord	Y_Coord
Agbatitoè	Forest Reserve	293829.672	785218.771
Assévé	Forest Reserve	291682.929	704120.417
Dametui	Forest Reserve	251512.106	792782.317
Davié	Forest Reserve	308282.565	705901.823
Mont Korogan	Forest Reserve	303996.144	1002707.145
Chra (Wahalla)	Forest Reserve	295711.752	794424.639
Goubi	Community Forest	335912.015	960435.032
Mont Balam	Forest Reserve	265001.46	912563.895
Ouartema	Forest Reserve	295383.817	1105991.449
Savalou	Forest Reserve	297707.482	831292.377
Tabalo	Forest Reserve	278415.843	1017587.416

Tchamba	Forest Reserve	335133.698	1000719.564
Tohoun	Forest Reserve	347209.455	777655.943

Figure 33: Forest sites in Togo

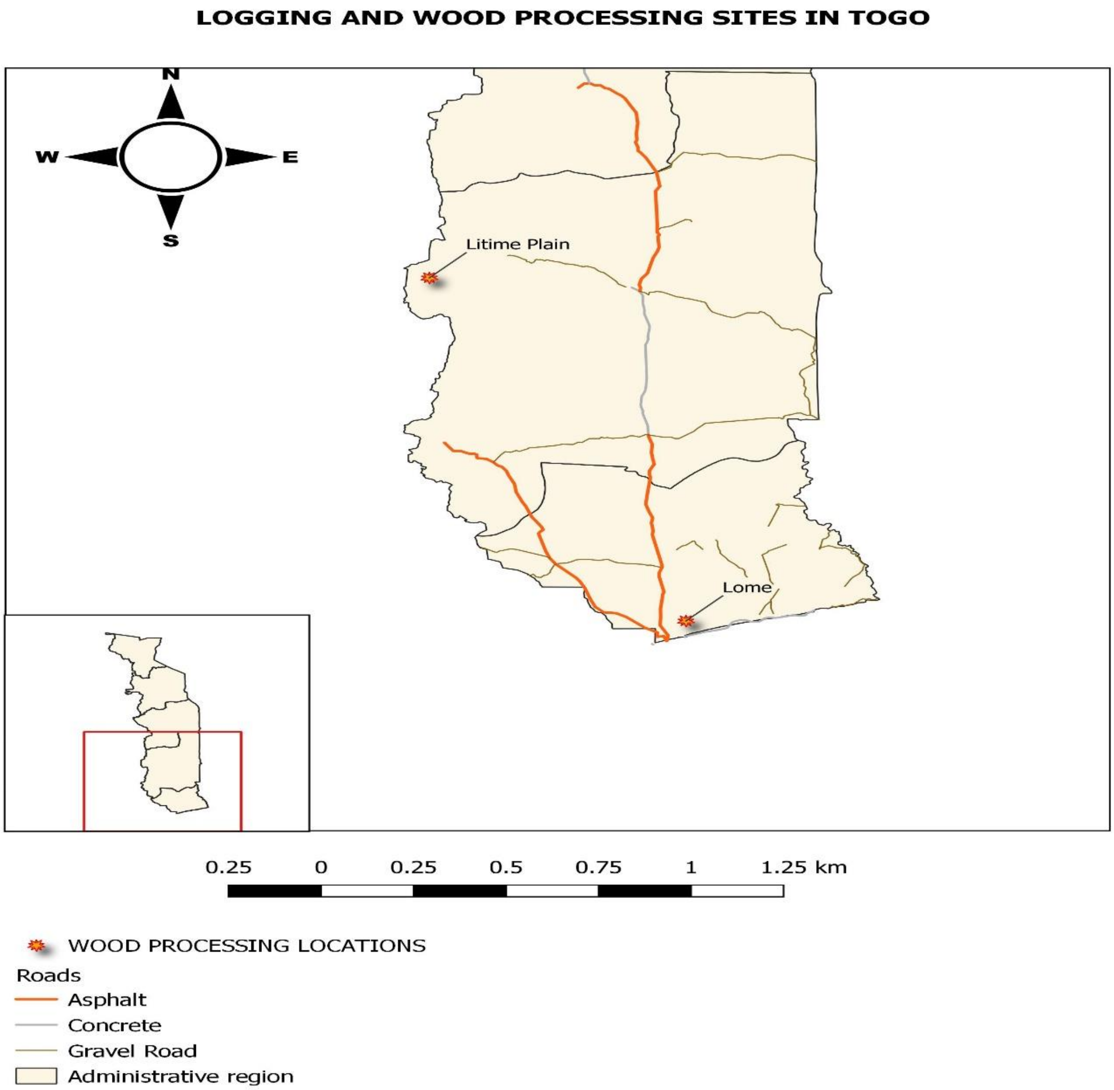


Figure 34: Logging and wood processing sites in Togo

Table 36: Sites of wood processing and logging in Togo

Place	Purpose	X_Coord	Y_Coord
Lome	NKSIM GR SARL U -wood exporter, sawing services	1.283032	6.198871
Litime Plain	Artisanal, Logging, Illegal Logging	0.589335	7.556391

Table 37: Annual consumption of wood energy by socio-professional categories in Togo (2017)

Wording	Wooden Demand		
	(m³/year)	(t/year)	(%)
Urban and rural households			
Firewood	2 150 294	1 505 206	28,4

Charcoal[6]	4 074 923	2 852 450	53,8
Sub-total household consumption	**6 225 217**	**4 357 656**	**82,2**
Professional consumers			
Firewood	883 125	618 188	11,7
Charcoal6	468 580	328 010	6,2
Sub-total consumption of professionals	**1 351 705**	**946 198**	**17,8**
Total	**7 576 922**	**5 303 854**	**100,0**

Thus, in 2017, demand exceeds potential wood energy production in Togo and the theoretical deficit between supply and demand amounts to 4,296,216 m³/year, a factor of 2.3.

5.2.32 East Africa

5.2.33 Burundi

5.2.34 Production Forests

The main sources of forest biomass production are: the Gakara-Gahuni State Forest, the co-managed afforestation of Magara in Ngozi, the co-managed afforestation of Ntamba in Muyinga, the VYANDA-BURI State Forest, the Rugazi State Forest [3] and private afforestation. Geographic location and key variables in forest resource assessment.

The total forest (Gakara-Gahuni) covers about 2000 hectares, of which about 1150 hectares are jointly managed. The tree species are eucalyptus trees. The volume of usable wood in the co-managed area is estimated at an average of 670,197 m^3 (six hundred and seventy thousand one hundred and ninety-seven.) In terms of management, the Gakara-Gahuni block is co-managed between the State represented by the Forestry Department and groups of people known as the Participative Management Group (GGP), i.e.:

1. Mashambaramba
2. Dukingiribidukikije
3. Rwanyubukene
4. Garukirigiti

Co-managed afforestation in Magara de Ngozi where the tree species are eucalyptus, the area is 60.45 hectares. The total volume is 2891 m^3,

Co-managed afforestation in Ntamba de Muyinga with eucalyptus as tree species. Area of 30 hectares and unknown volume.

Rugazi State Forest with the following tree species: deciduous and coniferous including pine, callitris, eucalyptus, grevillea, etc. The area is 2175 hectares. The usable volume remains unknown.

[6] In wood equivalent, calculated with a carbonisation efficiency of 10% and a wood density of 0.7 t/m³.

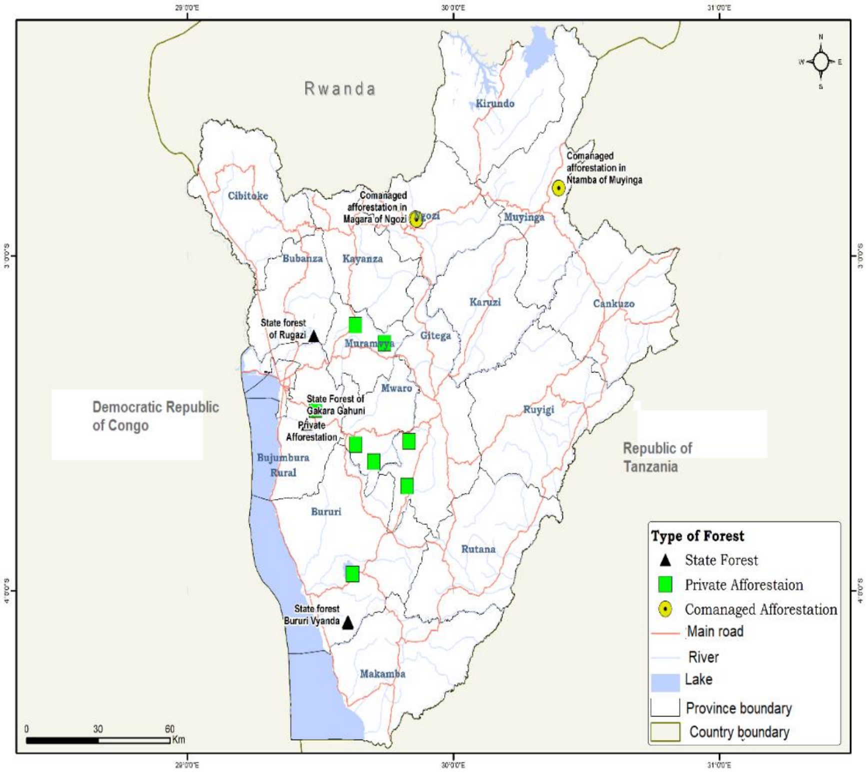


Figure 35: Location of Production Drills or Primary Residue Sources

Private afforestation: Private forest plantations are highly concentrated in the medium and high altitude regions (1200 and 2000 meters above sea level) and precisely in the provinces of Bururi, Bujumbura rural (nyabiraba), Muramvya (Bugarama and Ryarusera), Mwaro (Bisoro and Gisozi) and Gitega (Ryansoro and nyarusange), etc. The main variables in the assessment include tree species: several varied species. The area and volume remains unknown.

5.2.35 Wood Processing (Sawmills)

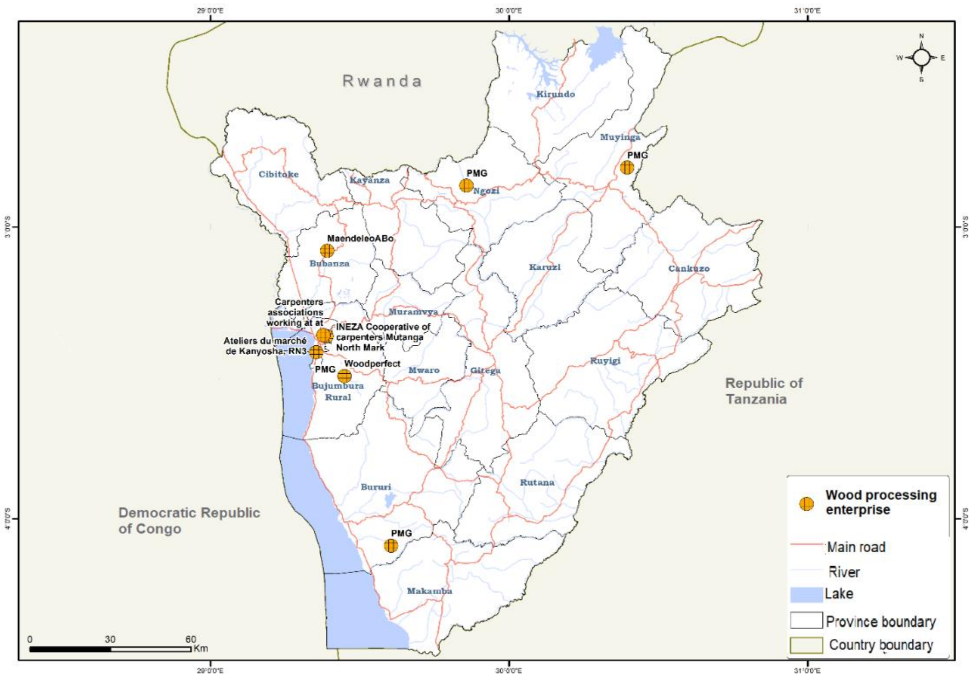


Figure 36: Wood processing companies in Burundi

5.3 Estimates residues in the national forest stock of study Countries

Multiplying the percentage of residues available in a single tree (50%) by the tonnes of biomass in a country's productive forest will give a reasonable estimate of the stock of residues in a given forest mass. The table below shows the results of the analysis, listing the total residue stocks in productive forests for all countries in the sample.

Table 38: Estimated residues from the national forest stock

Country/Region	Forest area (1000 ha)	Potential residues in the productive forest stock, 46% of the total stock
Benin	3135.15	1442,169
Burkina Faso	6616.5	3043,59
Ivory Coast	2518	1158,28
Senegal	8068.1	3711,326
Togo	195.90	90,114
Mali	13296	6116,16
Burundi	279.64	128,6344
Djibouti	5.80	2,668
Cameroon	20340.4	9356,584
Chad	4313	1983,98
Congo	21946	10095,16
DRC	126155	58031,3
Gabon	23530	10823,8
Guinea Eq.	2448	1126,08
Rep.Centrafri.	22303	10259,38

Source: Calculations using FAO data (2020).

This estimate remains theoretical and does not take into account at this level that, among the forests identified, some areas may be inaccessible to exploitation (steep slopes, wetlands, protected areas, local use areas). Moreover, the forest does not necessarily represent an interest for exploitation.

5.4 Estimated total residue production

This sub-section assesses the amount of residues available for energy use.

5.4.1 Results based on industrial roundwood production

According to FAO (2011), industrial roundwood is used for purposes other than energy. It includes pulpwood for paper; saw logs and veneer logs for construction and furniture; and other industrial roundwood (e.g. fence posts and telegraph poles). Industrial roundwood will be a product of the section of the tree trunk and contains the source of most sawmill residues. Sawmill residues are easily derived from the blue section of the table in the figure above, but as mentioned above, excludes waste left in the forest from the initial felling and cutting (e.g. tops, branches, foliage, sawdust and stumps). For FAOSTAT, it is reported in cubic meters of solid volume under bark (i.e. excluding bark) (FAO, 2010).

The amount of crop residues that plantations could produce for bioenergy production is directly related to the usable volume of wood from the plantations. In order to quantify the potential volume of crop residues that could be generated annually by plantations, the simple allometric formulas presented above and developed by Dovey (2005) for estimating crop residues of various wood species were used in combination with the projected annual usable wood volume table.
The estimate of the potential for available sawmill scrap wood was made by taking into account the following data: volume of logs entering the mill; sawmill production; material yield; gross volume of sawmill scrap wood; carbonizable volume after deduction of intermediate recoveries made.

The Potential Residue Supply uses the latest data on industrial roundwood production from FAO. Where forest biomass is reported in tonnes, roundwood production is reported in volume units (1,000 m^3). Residues from annual roundwood production can be estimated using the following approaches:

- FAO global and national roundwood production is expressed in 1000 m^3 (2013); the volume of roundwood (1000 m3) in mass (tonnes) is converted using average densities as follows: 700 kg / m3 for coniferous species and 756 kg / m^3 for non-coniferous species.

- During the timber production process, only 28% of the tree is recovered for sawn timber products and 17% for smaller sections such as slabs, curbs and off-cuts, the original purpose for which the tree was originally intended.

- The total residue potential per tonne of roundwood is then determined by adding to the sawmill residues that would have been produced during felling.

Table 39: Expected yield of forest harvest residues in a year

Country	Domestic log production (1000 m^3)	Industrial roundwood production *, Mt	Logging and Forest Cutting Residues, Mt	Sawmill residues, Mt	Total Residue Potential from Industrial Wood Production, ** Mt
Benin	150,014	0,10	0,05	0,02	0,07
Burundi (2018)	318	0,23	0,13	0,05	0,18
Cameroon (2014)	2 747 38,0	192,3	103,8	39,8	143,6
Congo (2018)	1 831 74,6	128,2	69,2	26,5	95,7
Ivory Coast	1554,013	1,08	0,57	0,22	0,79
Gabon (2014)	1 705 15,0	119,3	64,4	24,7	88,9
Guinea Eq (2010)	309 84,8	21,6	11,6	4,5	16,1

Mali (2015-2017)	50,640	0,03	0,01	0,009	0,01
DRC (2014)	289 163	202,4	109,2	41,8	151
RCA (2014)	237489	166,2	89,7	34,4	124,1
Togo (2015-2017)	56,312	0,02	0,01	0,004	0,01
Total	**239617,979**	**831,46**	**448,67**	**172,003**	**620,46**

* derived from industrial roundwood production data (adjusted for softwood/non-softwood roundwood)

** excludes losses, sawn wood, edges and sawdust

Source: Authors' calculations

It is best to interpret the above table using a country example. In 2014, the largest producer of industrial roundwood was the DRC with a production of 202.4 Mt / year (289.163 million m3). Cutting and shaping of roundwood gives an estimated level of residues and waste of 41.8 Mt / year. A large amount of residues is produced at the logging stage and could represent 109.2 Mt / year; the combined total of logging and sawmill residues amounts to 151 Mt / year. The potential residue to be produced by the DRC is 151 Mt / year. This means that with effective recovery, even with some losses, more than 151 Mt / year of wood residues and waste from roundwood production could be used as renewable fuel.

These calculations will also be made for all countries producing industrial wood as soon as data are available.

5.4.2 Roundwood Production Limits

Wood residues used for charcoal or wood briquettes are highly dependent on forest industrial activity and the demand for wood products. Some analyses assume that the projected production of charcoal or wood briquettes will increase in the coming years, implying an increase in wood production.

Table 40: Wood energy production by country

Country	Wood Energy Production, Mt
Benin (2015)	7,10
Burkina Faso (2018)	8,30
Burundi	4,10
Mali (2010)	7,00
Senegal (2013)	2,20
Togo (2017)	2,20
Cameroon (2009)	12,36
RCA (2009)	2,20
Congo	0,90
Ivory Coast (2010)	26,70
DRC	52,80
Equatorial Guinea	0,10
Gabon	0,70
Senegal (2003)	3,80
Total	130,46

Source: Authors' calculations

5.5 Prioritize chain links where there is greater potential to generate bioenergy products by quantity, costs and current uses

This section seeks to provide policy makers such as government officials, the wood processing industry and bioenergy project developers with relevant information and a valuable visual database designed to support the decision-making process regarding resource availability and feedstock use.

The economically competitive production of bioenergy from biomass residues depends on the availability and price of wood residues. Based on this premise, it is necessary to locate all major forest and sawmill residues in the study countries and identify the cheapest deposit locations for wood-residue based bioenergy processes. As the availability of wood residues is spatially localized, a Geographic Information System (GIS) assessment will allow for the geographic capture of excess residues generated during logging and sawmill operations.

Data required to determine the cost of biomass supply include: road network, transportation cost, cost of feedstock, and source of residue (i.e., forest production area and main wood processing plant location). For each collection point, the analysis provided detailed information, including road maps, distance data, residue types, transportation costs, and net available quantities of residue generated per site.

In this subsection, the methods used to estimate the cost of production of bioenergy are described. This is followed by a results and discussion section and concludes with brief conclusions.

5.5.1 Methods to estimate the generation costs of different products and bi-products

The following waste-to-energy practices were identified in this study:

- Carbonization for charcoal production. This activity is often run by local craftsmen who operate charcoal kilns near sawmills. In African countries in general, the charcoal production system, transport and distribution are still provided by the informal sector.
- The manufacture of energy briquettes from sawdust.

6 THE SOURCE OF RESIDUES

In this section, the forest production areas and the main location of wood processing plants are identified. This component provides a cartographic overview of all potentially available mill sites and their close distances in km, and could also serve as a potential site for bioenergy plants (see graphs above).

4.1 Case of Cameroon

As observed on the production forest location map in the sub-section above, the majority of Forest Management Units (UGFs) and community forests are located in the eastern region of the country, with a high concentration in the departments of Boumba and Ngoko and Haut Nyong; followed by the southern region and then the centre to a lesser extent. As regards communal forests, 15 of the 36 communal forests are in the Eastern region, with the Southern region coming in second place with 14 municipalities holding a forest estate. "During the 2016-2019 period, MINFOF granted 142 VC to economic operators for their supplies of timber resources. More than 65 of the 142 VCs were allocated in the Southern region, followed respectively by the Eastern region with 29 VCs, the Centre (22 VCs), the Littoral (19 VCs)' (State of play of the actors of the private sector of the forest-based sector in Cameroon, Report 2019).

In short, the eastern (UGFs, community forests, communal forests) and southern regions (log sales, communal forests, UGFs) are the production and therefore potential waste concentration basins.

As for UTBs, they are unevenly distributed among 4 Regions (East, South, Centre, Coastal), with the greatest concentration in the cities of Douala and Yaoundé. The first category plants are mainly located in the Eastern and Central Regions. Given the spatial dispersion of the different production forests, we identified several potential locations for bioenergy plants (see table below). The selection of these locations is based on several criteria:

- They are served by at least one route of the three ^{1st} categories (National, Regional or Departmental).
- Their fairly strategic geographical positioning makes them obligatory crossing points for production forests located within a radius of 100 km flight of birds.

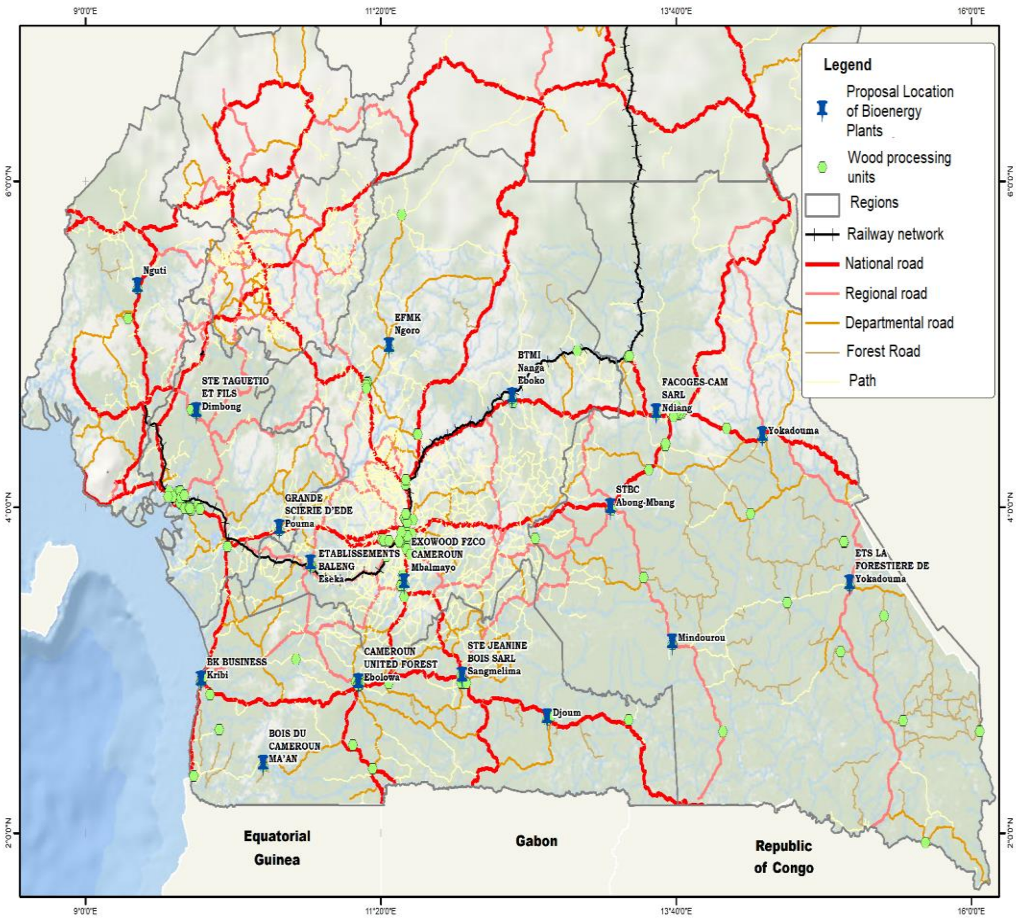


Figure 37: Sources of residues in Cameroon

These locations are in close proximity to wood processing plants as illustrated in the table below. This is not because they generate more residues, but because of their geographical location in relation to the production forests.

Table 41: Wood processing plants in Cameroon

Acronym	locality	Category	Region
STBC	Abong-Mbang	C1	East
SFID	Djoum	C1	East
CUF	Ebolowa	C1	South
FACOGESCAM	Ndiang	C1	East
BKB	Kribi	C2	South
TAGUETIO	Dimbong	C2	Littoral
BOISCAM	MA'AN	C2	South
CAFECO	Nguti	C2	South-west
EFMK	Ngoro	C1	Center
GSE	Pouma	C3	Littoral
ETS BALENG	Eseka	C2	Littoral
SJB	Sangmelima	C3	South
EXOWOOD	Mbalmayo	C2	Center
BTMI	Nanga Eboko	C3	Center
STBK	Yokadouma	C1	East
LFE	Yokadouma	C2	East

PALLISCO	Mindourou	C2	East

4.2 Case of Congo

We have identified six potential sites for bioenergy plants, respectively in the localities of Likoula, Sangha, Lekoumou, Niari North, Niari South and Kouilou. These locations are all accessible by a secondary road, as Congo has very few national roads. As in the case of other countries, we took into account the positioning of these sites in relation to the surrounding production forests. In the case of Congo, each location strategically touches about ten production forests within a radius of 100 km. The map below gives us a view of these sites in relation to the road network.

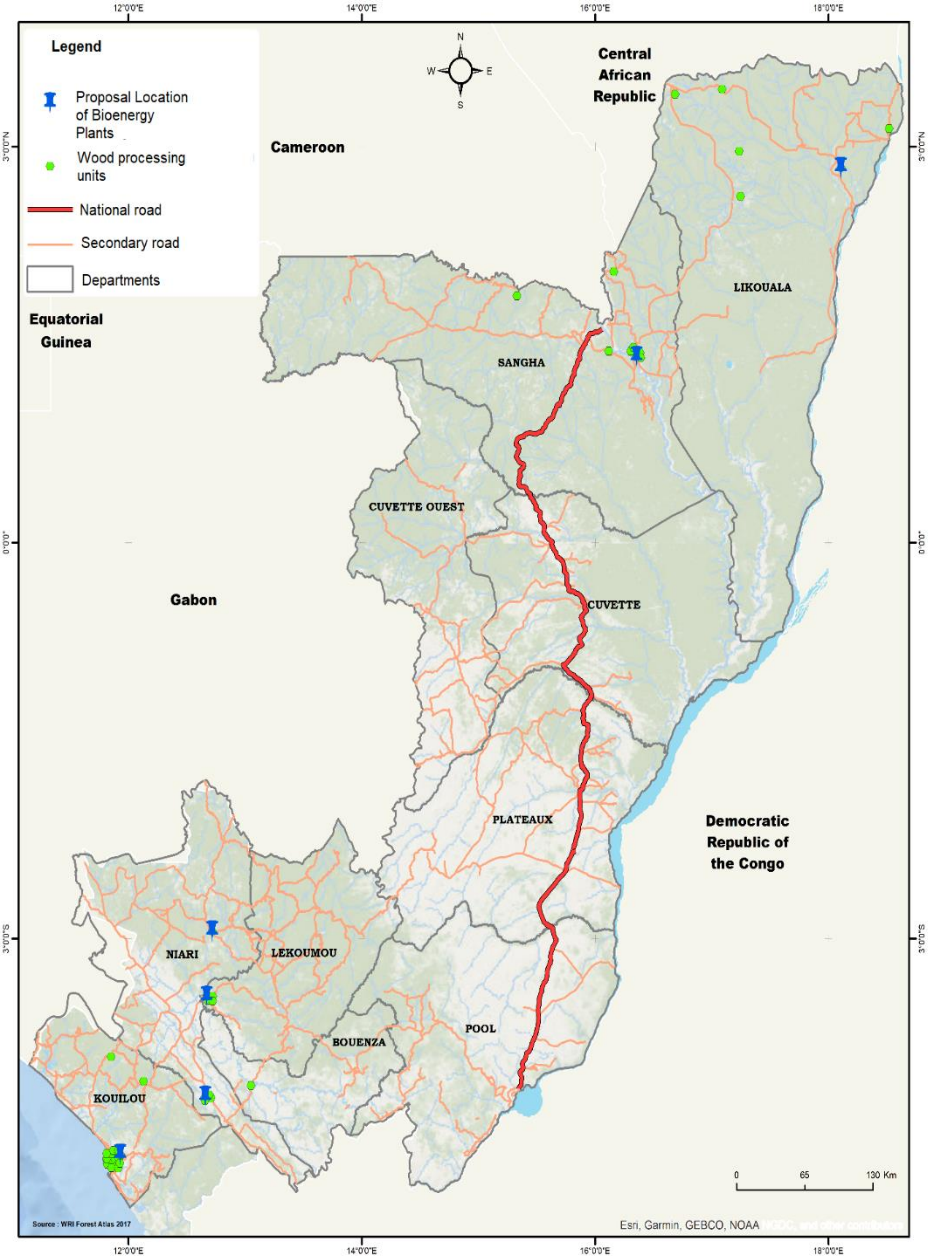


Figure 38: Potential sites of bioenergy plants in Congo-Brazaville

4.3 The Case of Gabon

We have identified 08 sites that could serve as locations for bioenergy plants. These sites are located in seven provinces, and are all close to major roads, which implies relatively good accessibility. Likewise, these sites are located in areas or sectors where production forests are concentrated, notably the localities of Mtzic (Woleu Ntem), Makokou and in the vicinity of Ovan (Ogoue Ivindo), Ndjole (Moyen Ogoue), Fougamou (Ngounie), Kango (Estuary) and Lastoursville (Ogoue Lolo).

Figure 39: Potential sites for bioenergy plants in Gabon

4.4 Case of the Central African Republic

The three site proposals we have chosen in CAR are near UTB Thanry in the Mambéré-kadei prefecture, SEFCA in the Sangha Mbaéré prefecture, and SCAD Ndolobo in the Lobaye prefecture. These sites are accessible either by a main road or a secondary road. In addition, they are an important geographic footprint in relation to the positioning of production forests.

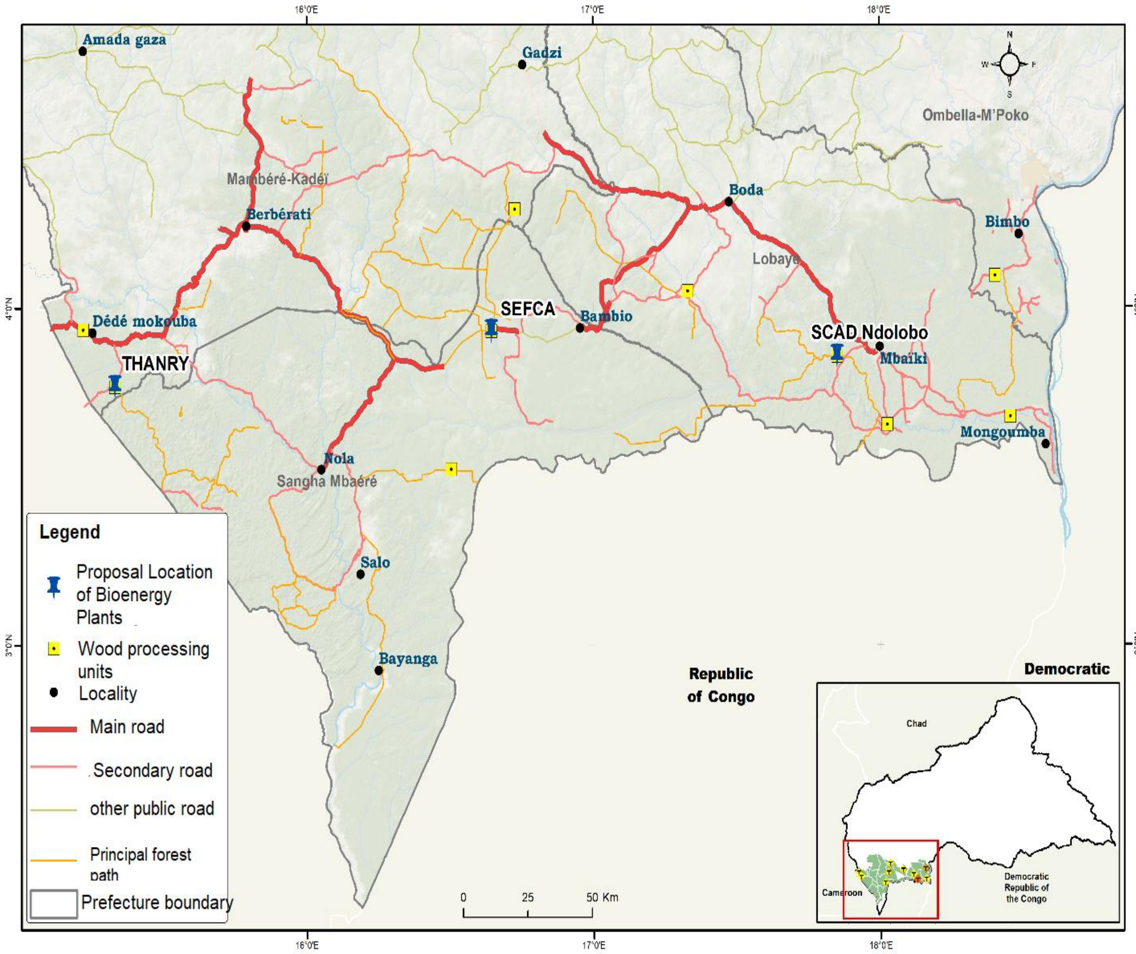


Figure 40: Potential sites of bioenergy plants in Central African Republic

4.5 Cost of residues necessary for the production of products and bi-products

4.5.1 Residues required for charcoal production

Table 42: Biomass that can be used in the coal-fired system

Raw material (PM)	Source	Raw materials that may be used
Wood fire	Forest extraction	from natural forests
	Non-forest trees	out of the forest
	Energy Plantations dedicated	Dedicated energy plantations Acacia spp, Cunninghamia lanceolata, Eucalyptus spp, Pinus spp, Populus spp. (poplars) and Salix spp. (willows)
Residues	Forest residues and	Limbs, stump, roots, etc.

	plantations	
	Wood industry residues	Wood chips and bark, etc.
Briquettes	Briquetting industry	Pretreatment of small pieces of wood to make them suitable for charcoal production

4.5.2 Specific residue for use in a briquette system

Table 43: Residues that can be used in a briquette system

Source	**Specific raw material that can be used**
Agroforestry residues	Fruit tree waste
Forest and plantation residues	leaves, limbs, stumps, roots, etc.
Wood industry residues	Sawdust
Dedicated energy plants	Acacia spp, Cunninghamia lanceolata, Eucalyptus spp, Pinus spp, Populus spp. (poplars) and Salix spp. (willows)

The raw materials selected for this study are: wood processing residues, forest harvesting residues and firewood, and agroforestry residues.
For these 4 types of biomass the following information is necessary to calculate the costs:

- Quantity of biomass available (t / year)
- the biomass density of each selected feedstock (t / m3)
- The market price of forest harvest residues, firewood ($/t), wood processing residues ($/kg) and agricultural residues.

The cost of residues for the different countries is summarized in the table below. The costs of sawdust, shavings and cuttings were averaged to determine the cost of residues.

Table 44: A summary of the cost of purchasing residues by country

Country	Unit	Residue purchase cost per country (USD)
Benin		
Burkina Faso		
Burundi		
Cameroon		

Congo		
Ivory Coast		
Djibouti		
Gabon		
Guinea Eq.		
Mali		
DRC		
RCA		
Senegal		
Chad		
Togo		

The table above contains the type of information we are looking for. Once this information has been obtained, this is the formula we will use to get the results we expect.

Transport cost

The marginal cost of transporting biomass is determined by the fixed cost (loading and unloading costs) and the variable cost (cost per km transported). This study only considered the variable cost, which is the cost of the residues and the distances transported in kilometres. Although the cost of purchasing, transporting and handling residues varies from country to country, this study uses published average values because commercial sensitivity precludes the use of actual cost data. Road types and terrain (road slope) were not considered in this study and only major roads were considered. Thus, a single value for the cost of road transport was assumed for each country:

The tonne of residue to a preferred collection point was determined using the following equation:

Table 45: Biomass transport costs per kilometre per country (in USD)

Country	Cost of road transport
Benin	
Burkina Faso	
Burundi	
Cameroon	
Congo	
Ivory Coast	
Djibouti	
Gabon	
Guinea Eq.	
Mali	
DRC	
RCA	
Senegal	
Chad	
Togo	

The table above contains the type of information we are looking for. Once this information has been obtained, it is the formula that we will use to get the results we expect.

4.6 Total Residue Supply Cost

The total cost is the sum of the tailings cost ($ / BDt) and the transportation cost ($ / km.BDt).

4.7 Conclusion

The volumes measured in this study were intended to estimate the net amount of residues available for bioenergy after deduction of existing consumers. Wood residue supply and demand are both dynamic and this study was designed as a project that would demonstrate the potential benefits of this type of methodology. This section also focused on determining the cost of residues delivered from new and existing bioenergy plants in countries. Consumers of wood residues are more concerned about security of supply and cost-effective on-site delivery and are not necessarily concerned about the origin of the residues.

In this study, the shortest distances of the excess residue were estimated for the countries covered by the study. The cost of transport is one of the most important cost components of biomass logistics and is essential for the development of a successful wood-residue based bioenergy industry (Ileleji, 2007). All cost curves were calculated in current US dollars.

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