Czech University of Life Sciences Prague

Faculty of Forestry and Wood Sciences

Assessment of Forest Inventory methods: Experience from Angola

Bachelor thesis

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BACHELOR THESIS ASSIGNMENT

Arylson Caetano

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Thesis title

Assessment of Forest Inventory methods: Experience from Angola

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Objectives of thesis

The objective of the work is to review and describe the current situation in forest inventory in Angola with special attention to existing datasets and compare with inventory methods and protocols in Czech republic more specifically with second round of national inventory (NIL2).

Methodology

Review the history of forestry and forest inventories in Angola, focus on the methodological approaches in forest mensuration.

Gather the protocol of data acquisition and sampling design in Angola forest inventory. Describe the individual steps and procedures for sampling and data acquisition.

Gather the protocol of data acquisition and sampling design in Czech Republic for the national inventory (NIL1 and NIL2).

Compare the two inventories, evaluate technical aspects, ergonomic aspects and outputs.

The proposed extent of the thesis

35

Keywords

forest inventory, Angola

Recommended information sources

FAO, IDF. 2009. Monitorização e Avaliação de Recursos Florestais Nacionais de Angola – Guia para recolha de dados

Kangas, A., Maltamo, M. (2006): Forest inventory: methodology and applications. Springer. 362pp

Van Laar, A., Akca, A. (2007): Forest mensuration. Springer. 383pp

West, PW 2009,Tree and forest measurement, Springer, Berlin; Heidelberg

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Affirmation

I hereby declare truly that this bachelor thesis is my own work and quoted per the references listed within and the materials acquired from the Institute for Forest Development in Angola. Moreover, contributions of others are involved, especially under the guidance of my supervisor Priv.Doz. Ing. Peter Surovy, Ph.D.

Prague, April 2017.

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Arylson Diogo Salvador Caetano

Abstract

The main objective of the work is to review and describe the forest inventory in Angola with special attention to the comparison of the methodology used in Angola with the one used in Czech Republic more concretely the NIL1 and NIL2. For this work the information gathered derived from literature review and the direct contact with the institution in charge of the forest inventory process. The thesis also makes an analysis of few sampling plots data collected. The description of the methodology of NIL1 in this project is only described to give a follow up to NIL 2 which is the target for the comparison with Angolan methodology. The work is an assessment of past and present forest inventories done in Angola.

Key words: natural resources, Angolan national forest inventory, forest survey, national forest inventory, Czech national forest inventory.

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I also thankfully recognize the efforts of Pedro Panda, who works for the Forestry Development Institute for helping me on data acquisition of Angolan forest inventory.

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1. INTRODUCTION

Forests in Angola are estimated to be 53 million hectares which represents 43% of the total land area. The current productive forest area is 2.2 million hectares mainly located in the northern part of the country. The production capacity of these forests is 326 000 m^3 of round wood per year. Moreover, there were also introduced plantation of about 140 00 ha mainly eucalyptus and pines (FAO I. , 2009). The civil war in Angola lasted for 27 years and during this time forest sector was completely disarray and no efforts were made to collect information from forest and put the forest resources under control (FAO, 2010). Today, there is a need of detailed, reliable and up-to-date information for optimum management of forests. For example, structural descriptions of forests such as growing stock, as of the stand are required for mid-term forest management. This required information in Forestry is obtained from terrestrial sample-based forest inventories (Immitzer et al, 2016). In Angola, documents and reports of forestry information are over 30-year-old and inconsistent. Angola lacks proper information about forestry resources. Forest inventory have not yet been completed, the first attempt was done 30 year ago and since that time no other forest data were collected by offices institutions. The forest sector depends completely on Government budget and the budget mostly does not cover costs for data field collection. From the institution point of view, there is a need to conduct the forest inventory and actually the Angolan Government through the Ministry of Agriculture with the New Partnership for African's Development (NEPAD) and FAO initiated a project in 2006 to revitalise Angola's forestry sector and also preparation to execute the National Forest Inventory where the all methodology was designed by FAO.

1.2. Background and concepts of forest inventories

There is wide latitude in designing an inventory to meet the variety of forest vegetation, topographic, economic and transportation conditions in the ground. A complete forest inventory provides information on estimated area, description of topography, forest ownership, accessibility, species composition etc. The Scopus of the inventory always depend on the objectives set, because it is usually impossible in forest to have a complete census of forest due to large area involved (Kangas, Gove, & Scott, 2006; De Vries, 1986).

The definition of forest inventory has many concepts. For instance, Asrat & Tesfaye (2013) mentioned two definitions; (i) tool that provides the information about size and shape of the area (ii) tabulated, reliable and satisfactory tree information, related to the required units of assessment in hierarchical order. At the international level, various definitions have been established for the compilation and publication of forest resources assessment results. Moreover, these international definitions frequently rely on terms that are not precisely specified for inventory purposes and do not completely cover the requirements arising from the application of National Forest Inventory (NFI) data (Gschwantne, et al., 2009). One last definition of forest inventory that can be added to the subject is from Scott & Gove (2002) and it says that is the accounting of trees and their related characteristics of interest over a well defined land area.

Scott & Gove (2002) stated that forest inventory designs can be from simple methods such as systematical sampling every *n*th tree found in a given area, to very complex multi-stage design multiphase sampling methods implementing remote sensing and unequal probability sampling.

The idea behind forest inventory is to measure the trees inside the forest. But there is only one problem. It is hard and sometimes impossible to count every single tree inside of the forest. That is why it is done by concentrating trees in small groups or areas in the forest called sample plots and then the information about the forest can be gathered to be processed. The definition of what a sampling is, has various concepts but all with same objective which is collection of representative information from a certain area.

Random sampling is the basic theoretical sampling technique. All sampling methods have their origin in this technique which means that they are modifications to achieve greater economy or precision (Asrat & Tesfaye, 2013). In simple words every plot in the population has equal chances of being selected for measurements. Random sampling can be used when:

- The population is finite
- The characteristics of the population in interest is homogenous
- The main aim is not precision
- There is frame (frame is refered has the list of sampling units that will be drawn un the population).

Systematic sampling is a technique in which the selection of sample follows a systematic pattern or uses a systematic pattern after the random selection of the first plot we choose. It is the most used sampling technique in forest inventory due to:

- Easy to apply in the field and easy explain to the field crews
- Also easy for the ones interested in the results to comprehend this sampling procedure
- It has more precise results than random sampling with the same number of sample points.

Stratified sampling, in this case the population is divided in subpopulations of known size. The advantage of this technique is that it can be applied in each subpopulation. In the guide for forest inventory written by Asrat & Tesfaye (2013) three methodologies of forest inventory are proposed: reconnaissance inventory, management inventory and operational inventory. **Reconnaissance inventory**, this class of inventory is based upon an exploratory investigation of the forest population. The information derived is primarily intended for preliminary management decisions. The inventory data are summarized on a regional or total area basis. **Management inventory**, this inventory represents a low intensity investigation of a large tract of forested area; for example, a forest reserve. The information produced is primarily intended for broad-based management decisions, allowable cut calculations and long range planning. **Operational inventory**: an optional inventory is based upon an intensive investigation of a relatively small area. The information is primarily intended for use in short term or ‘operational’ planning, e.g. related to the harvesting of timber volumes within local cutting compartments or logging units.

In another hand Scott & Gove (2002) three more methods can be taken into account: **harvest or operational inventory**, **strategic inventory** and **regional and national inventories.** *Harvest or operational inventory* requires more precisely estimate of volumes and values of an area prior to a commercial harvest, while *strategic inventory* is for large-scale inventories for strategic planning such as determining allowable harvest rates or optimal harvest scheduling plans. *Regional and national inventories* is often mandated by law in the case of countrywide surveys, these inventories are commonly used for making high-level policy decisions and broad-scale resource monitoring. This last type of inventory represent the focus of this thesis, basing on comparing methodologies of two countries and also augmented with other localized data to provide specific information.

2. OBJECTIVES

The main objective of this thesis is to access the methodological approach used for the first forest inventory in Angola. The specific objects are here summarized into following point:

- Review and describe the current situation in forest inventory in Angola with special attention to existing datasets and compare with inventory methods and protocols in Czech Republic more specifically with second round of national inventory (NIL2).

3. LITERATURE REVIEW

The following chapter will discuss the history of forest inventory in several countries, modern techniques for forest inventory, the history of forest in Angola, the first attempt of NFI and the actual NFI.

3.1. Brief history of forest inventory

3.1.1. Europe

The first inventories were carried out in Europe in the 14^{th} and 15^{th} centuries. The reason behind it, was the growth of the population, and it led to the increase of fuel wood consumption and thus, the fear that forests would be exhausted. Foresters in the beginning of the 19th century were estimating the volume and stocking of forest areas with ocular techniques, which were effective if the area could be surveyed as a whole from one spot. The first inventories were rudimentary assessments and do not compare to today’s standards (Asrat & Tesfaye, 2013).

According to Zeng et al (2015) in the 19^{th} century, forest inventories were a confirmed asset of forest planning. Sample-based national inventories were initiated in Nordic countries in 1910 and only later after the Second World War the methods were introduced to other European countries. Data acquisition was based on visual estimation, and during this period statistical sampling was not available yet, it was only developed around 1900. The first Forest Inventory was carried out as a belt-survey in 1830 (Fridman, et al., 2014). In Scandinavia and Norway the NFI was done in 1919, in Sweeden between 1923-1929, in Finland in 1921 and in France in 1960. In Germany in 1940s. Since 1993 the European NFI has being executed according to Bastrup-Birk (2010), it involves 5 countries known has regional offices: Spain, Germany, France, Croatia and Sweden), with the interval for inventory left to the each countries specifications (Zeng et al., 2015). At that time forest inventories gave important information in the development of statistical sampling theory. Forest inventory benefited a lot from the developments of statistics as discipline (sampling and modelling), remote sensing (air photos and satellite images), computers, measurement devices, road infrastructure (access to remote areas) and transportation (Park, et al., 2016; Scott & Gove, 2002; Zeng, Tomppo, Healey, & Gadow, 2015).

The importance of accessing forest inventory can be to evaluate and monitor forest resources and other natural resources, the soil usage and the management practices, to provide new quantitative and qualitative information about the state, usage, management and tendencies of these resources and ecosystems. The information can be used to plan, develop and implement national and international policies and strategies for the usage and sustainable conservation of natural ecosystems and to comprehend the relation between resources and their respective users. Periodic monitoring (for example every 5 years) will contribute to the development of more harmonized policies to ensure sustainable management of soils and their contribution to the conservation of biodiversity and the improvement of food security and livelihoods of rural populations.

3.1.2. United States

The first record of a state wide forest inventory was in 1830 in Massachusetts. The reason behind it was the concern for the resources at that time. During the period of the mid-1800s to early 1900s massive amounts of wood resources were removed in the northeastern and north central regions of the country (LaBau, Bones, Kingsley, Lund, & Smith, 2007; Zeng, Tomppo, Healey, & Gadow, 2015).

3.1.3. China

The NFI in China was early in the making. In 1949, the time when the Republic of China was being established, selected national institutions were established for the survey in the northeastern region of the country. The Changbai Mountain and Xiaoxinganling forest areas were the chosen areas for the survey, and subsequently forest surveys were extended throughout the country. According to (Zeng, Tomppo, Healey, & Gadow, 2015) the first compilation of data from various inventories by the provincial forestry departments, such as scouting surveys and forest management inventories were done during the period of 1950-1962, organized by the former Agriculture and Forestry Ministry (AFM) in 1962. Until now eight Nation Forest Inventories were conducted in China and from the first inventory china used a systematic sampling design (Park, et al., 2016).

3.2. Modern techniques for forest inventory

Modern techniques for forest inventory are being developed every year, the goal is to make forest assessment easier, more environment friendly, cheaper and less time consuming. One of these breakthroughs is in remote sensing area. Remote sensing is the ability to perform forest inventories and assessments without the need of having a worker in the local. Jensen (2007) defined remote sensing has the noncontact recording of information from the ultraviolet, visible, infrared and microwave regions of the electromagnetic spectrum by means of intruments such as cameras, scanners, lasers, linear arrays and area arrays located on platform such as aircraft or spacecraft, and the analysis of aquired information by means of visual and digital image processing. In other way Franklin (2010), accentuated remote sensing as both technology (sensors, platforms, transmission and storage devices) and methodology (radiometry, geometry, image analysis and data fusion). The final definition given by Samarakoon says that it is defined as the science and technology by which characteristics of objects of interest can be identified without direct contact.

Remote sensing predates to 17th century when Galileo made the first observations with the telescope in 1609. The first aerial photographer was taken in 1859 by Gaspard Felix Tournachon who was a famous french photographer and balloonist which had the goal to make land surveys from aerial photographs.

Why remote sensing is valuable these days? As said before it has to do with making forest assessment easier, environment friendly, cheaper and less time consuming. We can find some of the reasons of why remote sensing has great value:

- Regular updates of inventories
- Assessments of woodlots
- Fire surveillance
- Species identification
- Fast acquisition of data
- Surveillance
- Mapping and vegetation monitoring
- 3D modeling – with the potential to extract valuable forest characteristics – further analysis and processing by using particular software's.

Remote sensing data can be obtained by satellites, manned aerial vehicles, unmanned aerial vehicles (UAV's) which is most used and known technology in remote sensing and terrestrial scanners. What are UAV's? Unmanned aerial vehicle commonly known as drone, are usually multirotor or multicopter and aeroplanes. There are different categories according to size and purpose of use. The drone unit for Geomatic purposes can cost from 1000 Euros up to 50000 Euros, depending on the on-board instruments, payload, flight autonomy and other factors. All of the actions of the UAV's are controlled by the radio control that possesses a transmitter which sends the signal in a specific frequency to a receiver. UAV's can be multi-rotor or fixed wing.

Because of their enormous advantages, countries around the world adopted UAV'S as their primary tools for forest assessment. These are some of the reasons:

- Relatively low cost systems
- UAV's can be used in high risk situations without endangering a human life and inaccessible areas
- In cloudy and rough weather conditions, the data obtained with UAV's is still possible, when the distance to the object allows flight bellow the clouds
- They are not burdened with the physiological limitations and economic expenses of human pilots
- Highly spatial and temporal resolution
- General lower expenses for example crew cover
- And time saving.

UAV's have a big contribution in recent years in forest inventory. Some examples of their usage in forest inventory come from different studies. According to Strigul, Gatziolis, Liénard, & Vogs (2015) UAV gives support to this advance in forest inventory, with an affordable method to obtain precise and comprehensive 3D models of trees. Wallace, et all. (2016) were two techniques (ariborne laser scanning) and structure from motion to capture 3D structural information. The study gives an explanation on the capabilities of both technologies to access absolute terrain height, the horizontal and vertical distribution of forest canopy elements. Finally Paneque-Gálvez, McCall, Napoletano, Wich, & Koh (2014) used a different aproach, by using data gathered trough community-based forest monitoring (CBFM) programs, which have the potential to be as accurate as those gathered by scientists, with the advantage of being aquired at lower costs and capable of providing more detailed data about drivers of forest loss, degradation and regrowth at the community level. The three pillars of the concept are: 1- the hability of using small and low cost drones; 2- their advantages and disadvantages for communities, partner organizations and users of the data; 3- and improve the tropical forest monitoring with ground surveys and local ecological knowledge.

3.3. History of forestry in Angola - natural forestry and plantation forest

In African countries, the different communities and ethnic groups have the forest has their way of life. Before any source of income, it's from the forest that they get the basic resources for their sustenance. The classified system of Angolan forest mentioned roughly 32 types of natural formations, being grouped in 7 big groups (Huntley & Matos, 1994) following their composition and localization:

- **Dense high productivity wet forest corresponding to 2% of the total forest area** - Coats the rugged relief of the Atlantic flap, from Cabinda until the river Balombo, with Accentuated expression in the Upper Maiombe (north of Cabinda) and in Dembos (provinces of Uíge, Bengo and Kwanza-Norte), of very varied floristic composition, with diverse with several higher tree strata. Many species of *Albizia*, *Celtis*, *Ficus*, *Chlorophora campanula*, *Pycnantus angolensis*, *combretodendron africanum* and *Sterculia purpurea* are highlighted. The humid forest of the Maiombe is, in turn, richer in arboreal species, where they are found *Gilbertiodendron ogoonense, Gossweileidendron balsamiferum, Pentadesma leptonema, Oxystigma oxyphillum* (MINADER, 2011).
- **Guinean savanna mosaic, occupies around 20% of the total area, characterizing the northern part and part of the humid zone of the national territory –** The domain is savannah of the Guinean type, with trees and shrubs, more frequently of *Nauclea latifolia*, *Hymenocordia acida*, *Annona arenaria*, *Maprouena Africana*, *Psorospermum febrifugum* and *Piliostigma thonningii*, alternating with gallery forest (MINADER, 2011).
- **Open forest of Miombo, occupies around 45,2% of total surface, dispersing for many zones of the country –** including the provinces of Huíla, Kuando Kubango, Moxico, Benguela and Kwanza-Sul. Presents countless dominant

associations, where the most frequent is formed by genres *Isoberlínea-Brachysteria* e *Julbernardia*. In terms of commercial wood is of average productivity. But also possess a high social value in terms of wood fuel, construction materials, food and medicinal plants (MINADER, 2011).

- **Dry savannah, with trees and/or shrubs, occupies around 24,2% of the total forest surface –** extending mainly in the coastal provinces and some in the interior. It's a type of forest of very low productivity in terms of commercial wood. The remaining forest formations are low productivity in every level and are formed by: meadows and shrub lands, herbaceous formations of flooded areas as well as mangroves (5,3% of total forest surface) (MINADER, 2011).
- **Steppes of the sub-coastal strip (3%) and desert plant formations (0,3%) as well as mangroves –** mangrove forests occupy a estimated area of 1250 Km² and are found in the estuaries of large rivers and along the Angolan coast, especially among the rivers Chiloango (Cabinda), Zaire and M'bridge (Zaire), Dande (Bengo), including the mangrove adjacent to the Kwanza River (Bengo and Luanda). These transition ecosystems constitute an important reservoir of marine biodiversity, by being the preferential sanctuary for spawning, breeding and feeding of thousands of marine species, including birds (MINADER, 2011).

Angola has forest plantations of exotic species, such as *Eucaliptus sp*. (128.000 ha), *Pinus sp*. (16.000 ha) and *Cupressus* (4.000 ha), which totalizes an area of 148.000 ha, making it the African country with the biggest extension of plantations of exotic species. Forest plantations were established in provinces of Huambo (Kuima, Sanguengue, Ukuma, and Tchinjenje), Benguela (Ganda, Babaiera and Alto Catumbela), Huíla (Bunjei) and Malanje (Matari Ya Ginga). These plantations belong to the ex-Company of Cellulose and Paper of Angola with 47.3% of plantations, and the Benguela Railroad with 20.3% of forest perimeter along almost all the railway line. The plantations had the goal to produce biomass for the energetic consumption of the locomotives. The remaining 32.5% of forest plantation were established in several other provinces as a result of Government initiatives and other private companies.

According to the constitution law of Angola, the Land Law, natural forest with the exception of the artificial or planted is property of the state and declared as national heritage. According to the article 16º of the Constitution Law, 'the natural resources, solid, liquid and gas that exist in the soil, ocean are property of the state, which determines the conditions for its grant, research and exploration in the terms of the constitution'.

3.4. The national forest inventory in Angola

3.4.1. Forest sector in Angola - Institutions, responsibilities, decisions

Inside of the structure of executive power of Angola, the management of forests and wildlife it's under the tutelage of two ministerial departments: Ministry of Agriculture and Rural Development (MARD) and the Ministry of the Environment (ME) (MINADER, 2011).

The MARD prosecutes its functions in the management of the forests and wildlife, outside of the conservation areas, through the Institute for Forestry Development (IFD), by the other hand the ME manages the conservation areas (national parks and natural reserves) through the Natural Resources and the Environment National Department.

In the point of view of conservation biodiversity some areas needs some clarification, specially the jurisdiction of each institution in regards to the management, protection and conservation of the wildlife. The IFD fits within the scope of public institutes. It has a main headquarter and branches in every province of Angola. One of the biggest difficulties that the organization faces is the lack of qualified staff, equipment, and the right budget to execute its rightful activities (MINADER, 2011).

3.4.2. First attempts of forest inventory in Angola.

The first attempt of forest inventory in Angola dates from 1927, during the colonial period. It was mainly an exposition of the local conditions of the provinces during that period. The document issued in that year was the Provincial ordinance n. º30 of January 29th 1927 which characterized the District of Moxico for its mesological conditions and putting into evidence the need to have a strong forest cover to ensure a good usage of the soil. It was also the first time that concerns about illegal felling of trees were put in consideration, allowing a strong inspection. Another concern was with the building of the railroad, resulting with the felling of several trees and the possible disturbance to the climate and the hydrographic regime causing problems to the local agriculture and forest production. According to oral sources from Institute of Forest Development in Angola, the authority of the High Commissary of the Republic and the Governor of Angola, by proposal of the Provincial Secretary of Agriculture and Technical Division of Forest 11 forest reserves were created in the District of Moxico. That was the beginning of forest control in Angola (Ministério da Agricultura, 1983).

3.4.3. Present forest inventory

The guide of the national forest inventory of Angola, provides the guiding principles and descriptions of the methodology and procedures used for the inventory and monitoring of forest resources and land usage, following the approach developed by the FAO's National Forest Resources Monitoring and Assessment Support Program. The methodology, based on samplings throughout the country and the collection of data in the field, has been implemented, since 2000 in several countries through Monitoring and Assessment Support Program (MASP), in countries as Bangladesh, Cameroon, Congo, Costa Rica, Guatemala, Honduras, Lebanon, Nicaragua and the Philippines (FAO, 2009).

The objective of a Monitoring and Assessment Support Program is to evaluate and monitor forest resources and other natural resources, the soil usage and the management practices, to provide new quantitative and qualitative information about the state, usage, management and tendencies of these resources and ecosystems. The information can be used to plan, develop and implement national and international policies and strategies for the usage and sustainable conservation of natural ecosystems and to comprehend the relation between resources and their respective users. Periodic monitoring (for example every 5 years) will contribute to the development of more harmonized policies to ensure sustainable management of soils and their contribution to the conservation of biodiversity and the improvement of food security and livelihoods of rural population (FAO I. , 2009).

The project of the National Forest Inventory (NFI) of Angola (TCP/ANG/3103 and UTF/ANG/040/ANG) emerges as a response to forest policy issues, information management, institutional capacity building, valorization of wood and non-wood forest products, as well as the conservation and sustainable use of resources. This inventory will provide the necessary data for the processes essential to the criteria and the indicators required to the monitoring and preservation of the forests which will result in the development of a cartographic and statistical databases on forests (FAO, 2007).

The first part describes the sampling plan adopted, the distribution of the sampling areas where the measurements are made and their configuration. The second part deals with the classification for land use adopted as the basis of the assessment. The third part introduces the organizational structure and the responsibilities of the field technicians.

The methods and procedures for the data collection are presented in the fourth part meanwhile the fifth part presents in detail the field forms that are used for recording data from field measurements, observations and interviews with land users. The sampling plan adopted for the NFI of Angola is systematic and stratified. The sampling units are selected at least each intersection of each degree of the latitude – longitude grid (FAO I. , 2009).

3.5. National Forest Inventory (NIL) in the Czech Republic.

The NFI carried in the Czech Republic is considered as an independent survey of the actual state of forests and of forest development. Having this independence means that the intentions and the state administration do not influence the methodology of establishing the forest conditions. Its execution gives priority to the collection of data on tree species composition, standing volume, health condition and forest functions with the help of modern methods (UHUL, 2007).

The Czech National Forest Inventory has three main goals:

- To provide required information about forests for the need of state administration;
- To provide information for the evaluation of forest activities and fulfillment of forest management goals;
- To provide information for long-term control of forest conditions by applying the state forestry policy and subsidiary policy.

After the World War II, the project called Forest Inventory 1950 started. It was carried out according to Decree No. 3021 of the Ministry of Agriculture of November 8, 1948. The need behind it was that during the war, the forest management plans were not revised or renewed. The forest inventories carried in 1960 and 1970 had similar methodology of obtaining data and had spacing of 10 years apart. These inventories provided data on forest condition only once in ten years, other values were calculated every year. In 1979, the following inventories were substituted by Comprehensive Forest Management Plans (CFMP), renewed every year with a summarized data of each individual forest management plans. CFMP were processed and published until 1998, being replaced by Information on the Status of Forests (UHUL, 2007).

Forestry Act No. 289/1995 Sb. was adopted in the middle of 1995, being used until today with Section 28 providing for the execution of the inventory. During that time it was agreed that the inventory will be based on special field surveys and will be based in the same forest management plans. Since that period, technology of data collection for the Czech Republic has been developed with different intensity within pilot projects. On June 2000 marked the declaration of the execution of a forest inventory for the period 2001 – 2004, with the Govern Regulation No. 193/2000 Sb (UHUL, 2007). This regulation gave a new meaning to forest inventory, by approaching the forest as an integral component of the environment within its ecosystem relations (UHUL, 2007).

Various benefits of NFI can be seen in many ways, research being one that is connected directly to forest inventory, there are some clear examples of this benefit. One of the researches is from Mansfeld (2011); the research was set to analyze the representation of Norway spruce (*Picea abies*) in relation to different conditions of forest sites. With the results of the analysis, there was the possibility to provide a structured image of the share of spruce. The results of this study can be used to help in forest management decision making and the study of biological diversity of forest ecosystems (Mansfeld, 2011). Another research related to NFI in the Czech Republic is from Podrázský, et al (2013), which is focused on the productivity and analysis of the Douglas-Fir (*Pseudotsuga menziesii*) one of the principal tree species introduced in the country also being compared to other introduced species. Estimations of the forest land area, standing volumen annual and total increments, distribution of age classes, average ages and site indexes for the period 1979-2010 (Podrázský et al, 2013). The Korf growth function was used for the assessment of current and mean annual increments of Douglas-Fir compared to other species. The final results presented a decline in annual area afforest by Douglas-Fir, due to adminstrative management choices leading to low rate of increase in the forest land and increasing average age of the forests, but in the other hand, a dramatic increase in standing volume as well as high annual increments in volume (Podrázský et al, 2013).

4. METHODOLOGY

The methodology of this thesis is a combination of scientific literature review and a collection of official's forest reports from institute for forest development in Angola. The scientific articles were reviewed from science direct and Scopus through the university system. The main focus on researching the articles (secondary data) was to develop the main background of this thesis on the topic of forest inventory, from the history of the first inventory to the latest technology used today.

4.1. Study site selection

Angola is located in south western Africa. The country has rectangular shape and surface of 1,246,700 km^2. There is higher diversity of landscape, where the main dominant is a step-like plantaus (Beernaert, 1997). The forest area is approximately estimated to be 53 million hectares corresponding 43% of total area in the country. The forestry vegetation is widely diversified. However, the tropical moist forest of high productivity represent only 2 percent of the total forest area with higher biodiversity, mostly located in the North provinces of Cabinda, Zaire, Bengo e Kwanza-Norte and Uige. Open dry forests and Savannah or Miombo woodlands occupy about 80 percent of the forest estate. This woodland is considered of medium productivity but valuable resource from the social point of view (e.g. fuel wood, building material, fodder, food, medicinal plants, etc.) to spiritual values and services to the local population. Miombo is located in the plateau in the central and eastern parts of the country. Angola is divided into 18 administrative provinces. However, for the purpose of this study we selected only one province (Uige province) located in Northern part of Angola (Figure 1), where we selected two plots where forest inventory was done.

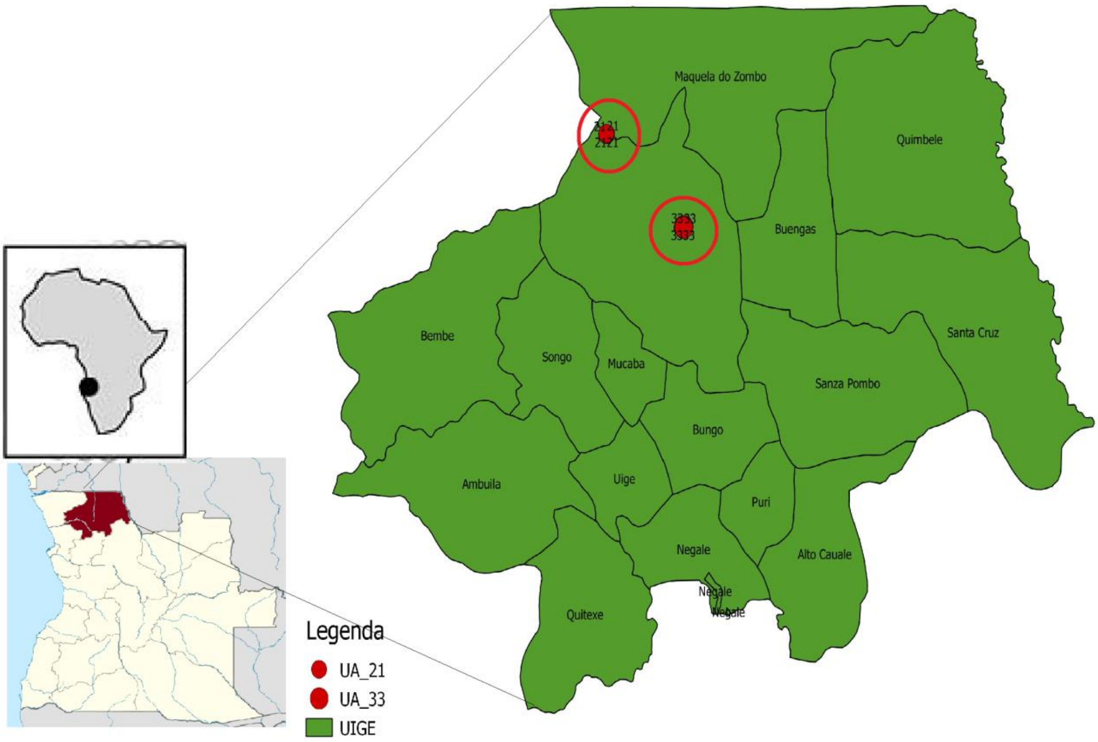


Figure 1 Geographic location of the study area and study

4.2. Data collection

The collection of primary data on national forestry Inventory was done in cooperation Institute for Forest Development in Angola whose is executing the actual process of forestry inventory. The collection of data was limited on quantities due to the fact that the original data of the forest inventory are not yet officially published. We collected data from two plots (figure 1) where we have biometric parameter of the variables in stand (DBH, Height, number of species etc) (MINADER, 2011).

4.3. Data processing

Due to the Scopus of data we used qualitative methods to describe and argument the methodology used for forest inventory in Angola. For quantitative methods we processed the data using excel to make simplified tables of the data collected in those two plots. From the data collected calculated the basal area per plot for each represented species as well as the volume per hectare of each species.

5. RESULTS AND DISCUSSION

In this part of the work the results of the comparison of both national inventories from Angola and Czech Republic are displayed, compared and consequently the discussion will be mentioned at the end.

5.1. Angola

5.1.1. Development of National Forest Inventory in Angola

Table 1. Comparison of sampling design for National Forest Inventory between Czech Republic and Angola

Country	1st year of inventory	Survey interval (year)	Sampling distance (km)	Plot shape
Angola	2011	Every 5 years	1x1 km	Square
Czech Rep.	NIL1 2001 - 2004	Every 10 years	2x2 km	Circular
	NIL2 2011 - 2015	Every 10 years	2x2 km	Circular

The sampling plan adopted for the forest inventory in Angola was the systematic and stratified. The sample units were selected at least at each intersection of each degree of the latitude / longitude grid. The stratification was adopted with base in the stable strata or ecological zones (figure 2). The number of sampling units in Angola was 591. The total number was determined by the statistical accuracy desired and by the availability of human resources and financial.

Table 2. Characterisation of the sampling design

Stratum	Number of sampling units	Distance between sampling units	
		Minutes (latitude x longitude)	Km (latitude x longitude)
Ecological zone of evergreen rainforest	105	20’ x 20’	28 x 28 km
Ecological zones of: - Deciduous tropical rainforest - Tropical mountain	376	20’ x 30’	28 x 50 km
Ecological zones of: - Dry tropical forest - Shrubs - Desert	110	30’ x 30’	50 x 50 km
Total	591		

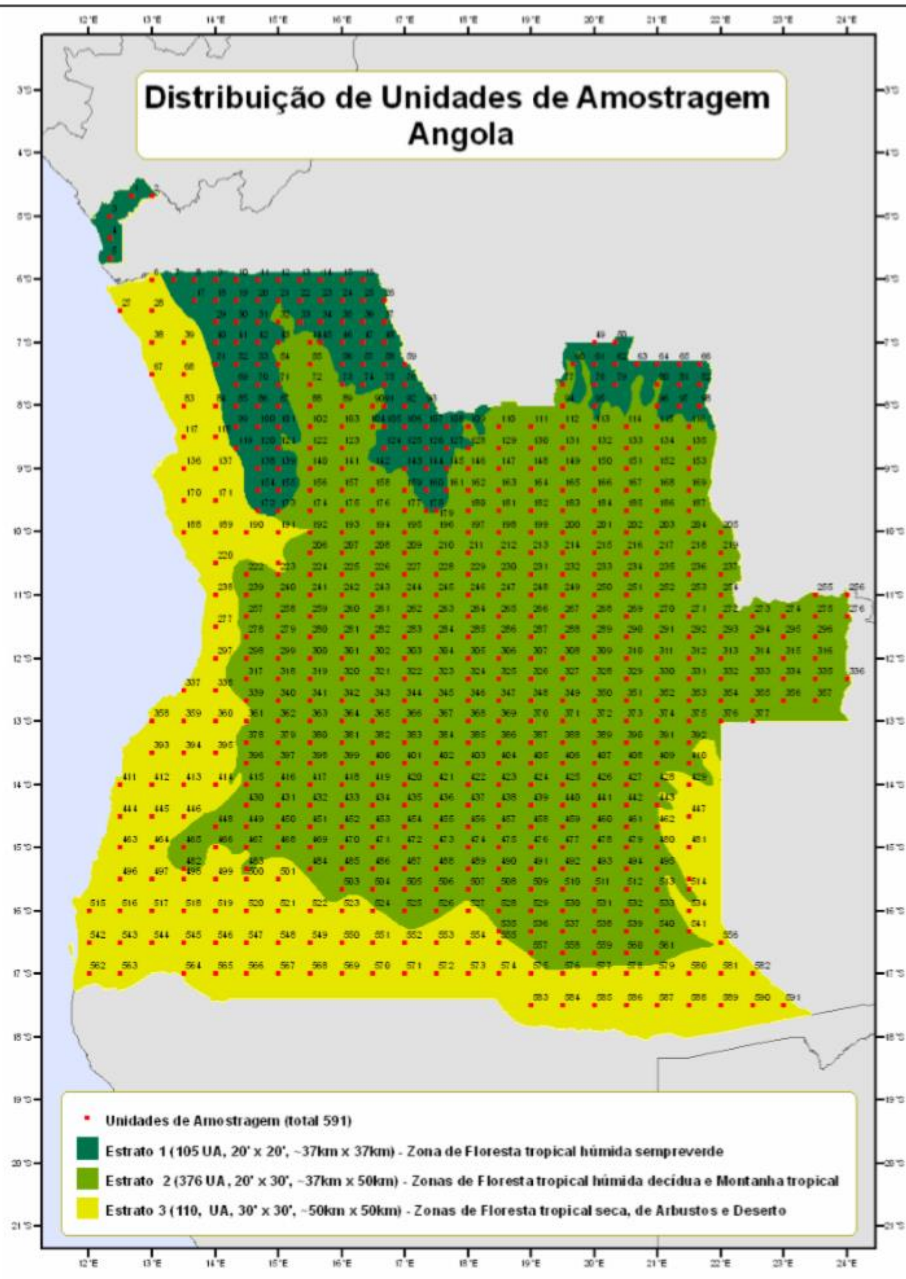


Figure 2. Representation of sampled ecological zones for Angola. (Url 1, 2009)

5.1.2. Scope and Method of Angola Forest Inventory

The field data is obtained through observations, measuring and interviews to different levels inside of the limits of the sampling area, and in much smaller units (sub-units), plots and sub-plots, soil use section and its soil use class.

Sample unit - was a square surface area of 1 km x 1 km. The coordinates of the south-west corner corresponds to the selected points in the systematic sampling grid. Each sampling unit has 4 plots. The plots were rectangular with surface areas of 20 m wide and 250 m long inside of the sample unit. They start in each corner of an inner square of 500m the same as the sample units and are numerated clockwise from 1 to 4 (figure 3).

Table 3. Location and orientation of the plots

Portion	Location of the starting point of the plot, inside of the square of 500m	Orientation	Heading
Plot 1	South-east corner	South-north	0 / 360 degrees
Plot 2	North-west corner	West-east	90 degrees
Plot 3	North-east corner	North-south	180 degrees
Plot 4	South-east corner	East-west	270 degrees

In each plot three groups of subplots are bordered inside resultant to different levels of data gathering:

- Three (3) rectangular subplots, 20 m x 10 m, corresponding to level 1; In each rectangular subplot were measured edaphic and topographic parameters. At the end of rectangular subplot a transect of fallen above ground biomass was measured.
- Three (3) circular subplots, with a radius of 3.99 m (50 m^2), corresponding to level 2, situated in the middle of the rectangular subplots
- Three (3) litter subplots, also circular with a radius of 18 cm (0.1 m^2), corresponding to level 3, situated in the middle of the circular subplots

Subplots in the starting point were given the number 1 and subplots in the extremity of it were given the number 3.

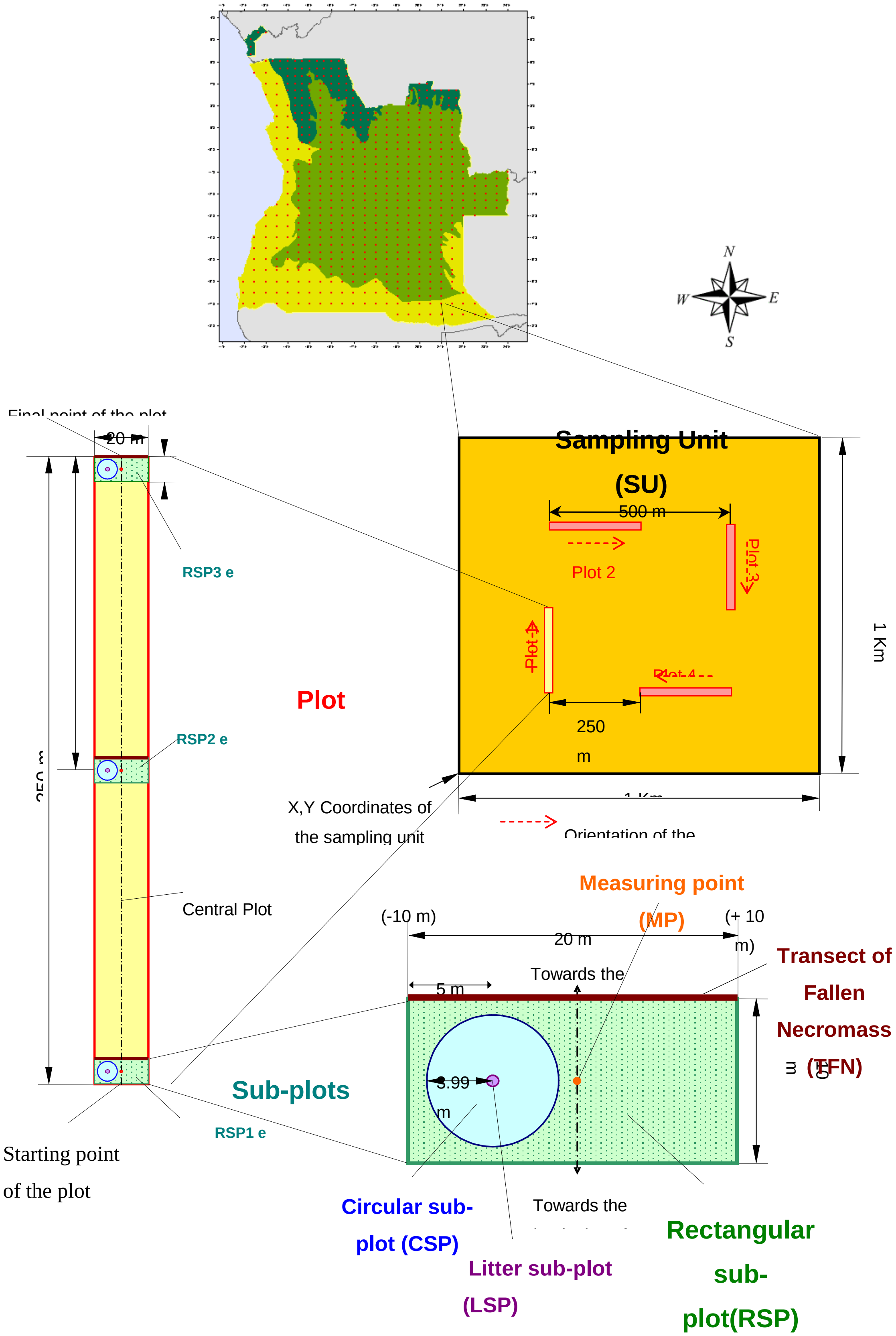


Figure 3 Design of the sampling unit, plot and sub-plot (picture above) (Url 2, 2009).

- Each plot was divided in land use sections (LUS) which represent its homogenous usage, soil/vegetation cover units (forest, cultivation, grass) with variable sizes and formats which were identified. Data related to farming, cultivation and characteristics of forests, management resources usage and users were collected in the LUS (Figure 4).

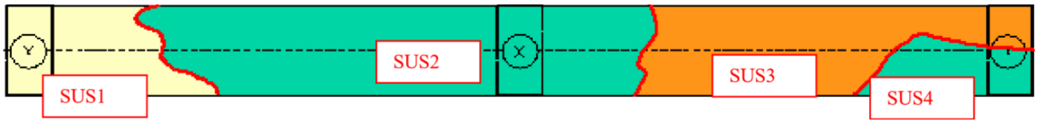


Figure 4. Example of the land use sections distribution inside of the plot. **there are 4 LUS sections in this plot. Their limits are shown by the wavy lines. Numbers 2 and 4 belong to the same LUS (Url 3,2009).*

- Every 4 LUS found in the sampling area was used to get data about products and services.

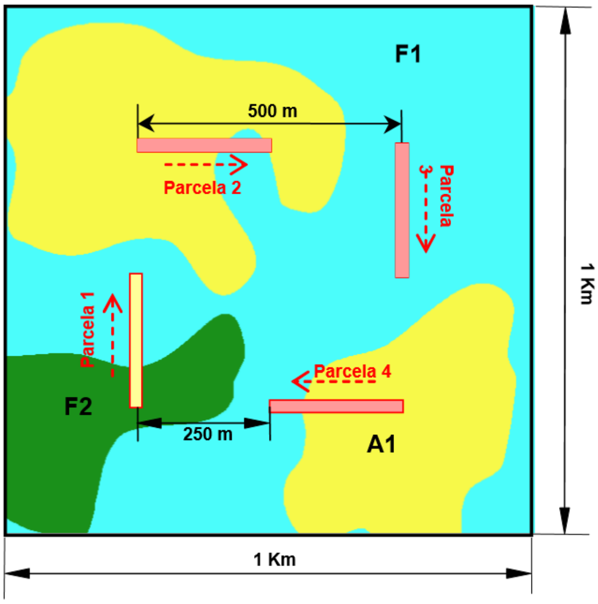


Figure 5. Distribution of the land use sections LUS inside of a sampling unit (Url 4, 2009).

5.1.3. Measured variables in Angolan Inventory

The data were collected by the field teams for the sampling units, subplots, measuring points and land use sections (LUS). For each sampling unit, the plots were located through Universal Transverse Mercator (UTM) coordinates and topographic maps (aerial photographs and satellite images when available) and with GPS. The biophysical and hydrological properties of the soil are analyzed in the measuring points (figure 5).

Regeneration of trees (height ≥ 1.30 m and Dbh < 10 cm) was only accounted inside of the circular plot and tree species with at least 5 m height in situ were registered. For trees with larger diameter (Dbh ≥ 10 cm), inside the rectangular plot or inside of the plot were recorded. Dead trees, standing or fallen are measured as living trees. Fallen dead branches are measured along the line of the transect of fallen necromass (TFN). Litter is defined as the dead organic material found on the ground.

5.1.3.1. Tree measurements

The instruments used for tree measurement were Blume-Leiss dendrometer, Blitterlich relascope, measuring tape and calliper.

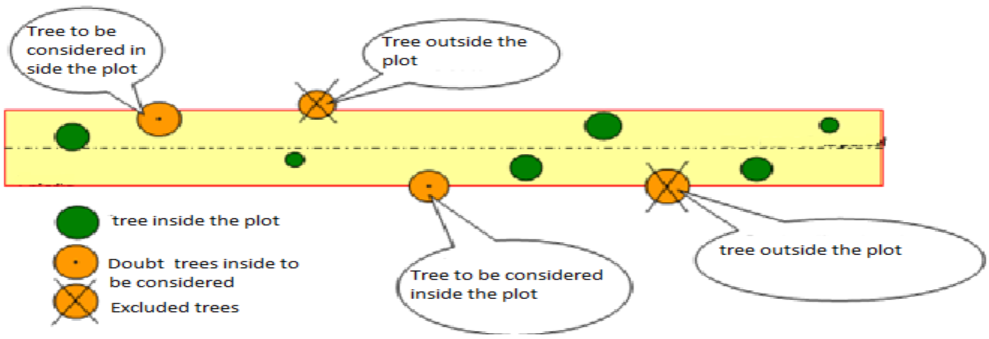


Figure 6. Representation of tree measurements inside the plots (Url 5, 2009)

Table 4. Representation of data collection inside the plots

Level	Trees/stumps measured		Measuring
	Forest	Other section of land use	
Plot	Dbh ≥ 20 cm	Dbh ≥ 10 cm	Species, location, diameter, total height, health, quality
Rectangular sub-plot (RSP)	Dbh ≥ 10 cm	none	Species, location, diameter, total height, health, quality
Circular sub-plot (CSP)	Tree height ≥1.30m and Dbh < 10 cm	Tree height ≥ 1.30 m and Dbh < 10 cm	Number of trees by specie

5.1.3.2. Processed data of two sampling units

Table x. General characteristics of the stand UNIT of the forest parameters in Uíge - Unit 21

PLOT	TREE	LOCAL NAME	LATIN NAME	TREE BASAL AREA/Plot	BASAL AREA PER HECTARE	VOLUME (m^3)
	2	Mbiiwa		0,062831853	0,031415927	0,21991149
		Mbiiwa		0,106185832	0,053092916	0,42474333
	1	Ntseke Ntseke		0,062831853	0,031415927	0,15707963
	2	Bubu		0,076026542	0,038013271	0,15205308
		Bubu		0,304106169	0,152053084	1,21642468
1		Nkala	*Xylopia aethiopica*	0,069272118	0,034636059	0,27708847
	3	Nkala	*Xylopia aethiopica*	0,069272118	0,034636059	0,27708847
		Nkala	*Xylopia aethiopica*	0,062831853	0,031415927	0,25132741
	1	Muindo		0,015707963	0,007853982	0,02356195
	1	Ncosinte		0,015707963	0,007853982	0,03926991
	1	Lolo		0,015707963	0,007853982	0,03926991
2	1	Lolo		0,015707963	0,007853982	0,03141593
3	1	Lolo		0,015707963	0,007853982	0,03141593
4	2	Lolo		0,015707963	0,007853982	0,03926991

	Lolo	0,015707963	0,007853982	0,03926991
1	Nkumbi	0,050893801	0,0254469	0,2035752
1	Muindo	0,015707963	0,007853982	0,04712389
1	Munvumby-Vumbi	0,019006636	0,009503318	0,05701991

From the all unit 21, the most representative species was Lolo (local name) and the average tree Basal Area per plot/hectare was 0,036128. The highest tree Basal Area was found on the species Bubu (local name) with volume of 1.21 m^3 per hectare. The major problem with the species recorded was the correlation of the local names with scientific names.

Table x. Mean Values of the of the main forest variables at UA 21

Plot	Height mean +- SD (m)	DBH mean +- SD (cm)	BASL ARE/tree (m^2)	BASAL AREA/ha	Volume (m^3)
1	5,7 (+-1,8)	16,3 (+-8,5)	0,052527429	0,001645409	0,180032894
2	4	10	0,015707963	0,00007853	0,031415927
3	4	10	0,015707963	0,000078539	0,031415927
4	6,7 (+-1,15)	13 (4.3)	0,02854	0,000078539	0,103

The highest trees DBH were found in plot one (16,3 cm) while the highest height was in plot four (6,7 m).

Table 5. Representation of forest parameter at UA 33

Plots	Number of tree	Local name	L.Name	Tree Basal Area/plot	Basal area per hectare	Volume (m^3)
1	2	Luvete	*Hymenocardia acida*	0,226194671	0,011309734	0,4071504
	3	Nkelombulo		0,830951257	0,041547563	3,8223758
	4	Nkelombulo		0,628318531	0,031415927	2,5132741
	5	Nsophi		0,157079633	0,007853982	0,1570796
	1	Mbunza		0,190066356	0,009503318	0,0036125
2	4	Nkelombulo		2,513274123	0,125663706	1,7370504
	3	Nkelombulo		0,628318531	0,031415927	0,0789568
	1	Nkelombulo		1,23150432	0,061575216	0,3412357
	2	Nkelombulo		0,628318531	0,031415927	0,0592176
3	1	Nsokila		0,904778684	0,045238934	0,1227937
4	1	Soky		0,567057474	0,028352874	0,056272
	2	Luvete	*Hymenocardia acida*	0,30787608	0,015393804	0,0142182
	3	Nkosso		0,760265422	0,038013271	0,1156007
	4	Mubusanda		0,830951257	0,041547563	0,17262
	5	Bubusanda		0,904778684	0,045238934	0,2046561

The trees with highest DBH were found in plot two on the species Nkelombulo (local name) with average DBH of 27 cm. While the tree height was more representative in plot four. The most representative tree species in the all sapling unit was Nkelombulo (local name) where is seen also the highest volume per hectare (3.514 m^3 and 2. 51 m^3).

5.2. Czech Republic

5.2.1. Development of National Forest Inventory in Czech Republic

The National Forest Inventory (NFI) carried out on the territory of the Czech Republic is an independent survey of the actual state of forests and of forest development. The development of the National Forest Inventory (NIL) in Czech Republic is based in accordance with Czech regulation No. 193/2000 sb. and section 28 of Act No.289/1995 sb, on forest. The principle is based on repeated measurements on ground inventory areas distributed over all country. The results of the measurements are evaluated for each inventory plot, but only for large territorial units. The first statistical inventory in Czech Republic took place between 2001 and 2004.

The first NIL 1 was deployed in a grid randomly placed. The inventory area had a circular shape with a radius of 12.62m, the area about 500m². In this area were evaluated site conditions, the occurrence of recovery and other items. All media surfaces area were stabilised with geodetic harpoon so that it can be re-trace to perform repeated measurements**.** In the first NIL1 was carried out on 14 220 inventories plots and all classified as forest area.

5.2.2. Sampling design of Czech Forest Inventory

The unit area was 2 km x 2 km situated in regular network over all forests area. Each plot consists of two mutually independent parts of circular shape with a radius of 12.62 m with a distance between the centres of 300m. Each inventory plot can be divided into further fragments called sub-plots. On each sub-plots in the category Forest two inventory circles are established for the purpose of forest inventory. The first circle has a radius of 2 m and is used for monitoring forest regeneration. While the second in circle has a radius of 3m used to measure the thinning tree with breast height diameter from 7-11.9 cm. Then comes a double plot **(**Figure 7**)** which is done when two inventory plots are connected by a transect that belong to same Forest. The sampling used was stratified sampling in the dimension of 500 x 500m from which successively derived random sub-selected sub- network. The second NIL2 in CR was done in 2011-2015. The inventory areas were deployed in grid of randomly placed early of 500 m oriented north-south, east-west. In 500 x 500m in the densest network, only photogrammetric evaluation categories were made. While in 1x1 km compared to the net of 500x500mm a photogrammetric transect was included which was used to derive the characteristic of many tree species.

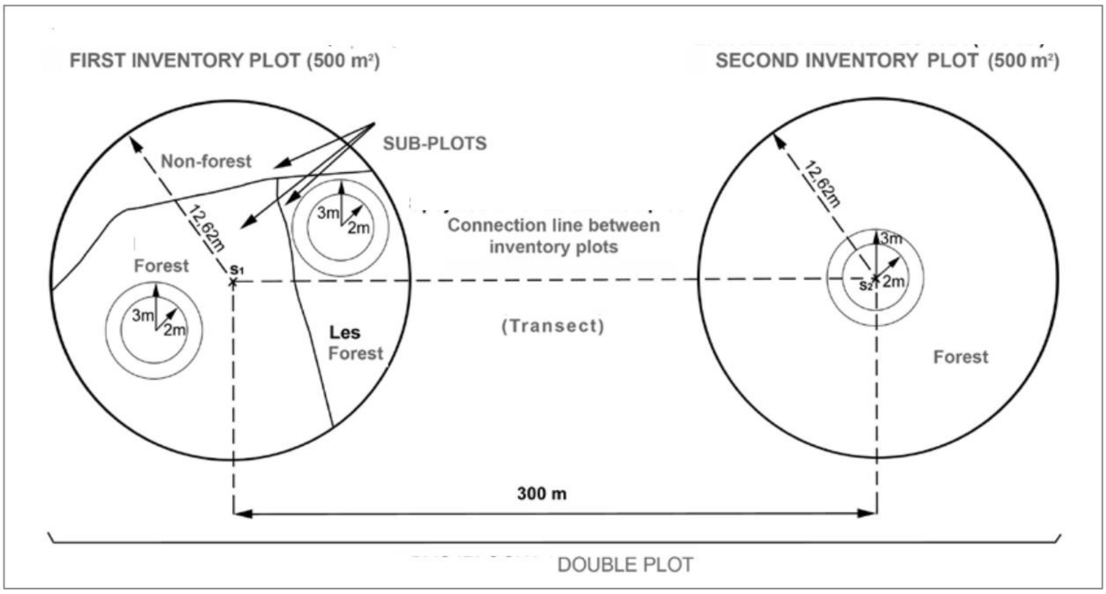
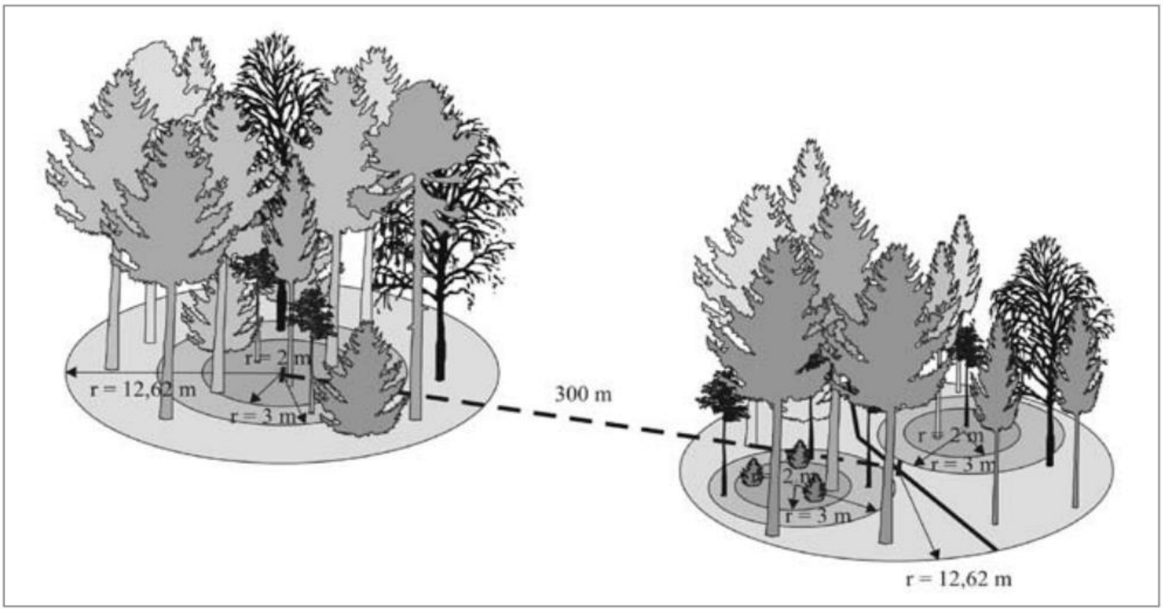


Figure 7 Representation of situation on double plot (Url 6, 2007)



S1,2 is the centre of inventory plot, radius=12,62 m is the inventory circle where trees with breast height diameter more than 12cm were measured. Radius= 2m is the inventory circle where trees higher than 10cm with breast height diameter (DBH) lower than 6.7 cm (forest regeneration) were measured. Radius= 3m is the inventory circle where tree with DBH from 7.0 to 11.9 cm are measured.

The length of the transect is 300m, this was done taking into consideration the average size of forest stands in Czech Republic. The transect serves for saving entries related to intersection between transects and forest roads, streams, drainages, important points in the terrain and forest edges.

5.2.3. Measured variables in Czech forest Inventory

When accessing the plot, the first step is to locate the position of the plot by using GPS with external antenna and a field computer and these field computers were connected with rangefinder and an electromagnetic compass. Position of inventory circles plots, measuring tree values, saving descriptive characteristic for tree as well as sub-plots where were collected information on soil, lying dead trees, plant species and their degree of coverage, regeneration etc. All the data are saved in digital format already in the field. In the sub-plots were measured: silviculture systems, richness of the stand structure, water erosion, tree species, age of the regeneration tree species, etc.

The survey on the inventory plots consisted on the following procedures: identification number of the inventory plot, coordinates of the centre of the inventory plot, coordinates of the alternative centre of the inventory plot, altitude, terrain topography of the inventory plot and its surroundings, names of inventory group members, data of measuring, type of forest ownership, region, natural forest zone, forest category according to its function and group of forest types. The description on the tree base accessed the following: location of the tree, nature of the tree, position of the tree within the micro relief, tree species, community status of the tree, stand layer the tree belongs to, presence of stiff roots, presence of standing dead tree and shape of the crown.

5.2.3.1. Tree measurements

The instruments used for tree measurements are the following: MapStar, field computer Hammerhead P-233, ForestPro, GPS Geoexplorer 3, reference computer PSION, electronic calliper Mantax, metal detector CARRETT, measuring tape and mini-calliper. The equipment used is part of technology Fieldmap Technology, which was used in NIL1 and NIL2 and was built by the company named IFER. The data collection was accompanied using Fieldmap Data Collector and afterwards installed in the field computer (Url 8, 2016). The principle behind Fieldmap Technology is that it was designed so that teams can work together and at same time, having the data coming from different sources and being added to a database and the data is added to the Information System (IS) of the organization in charge of the project.

Figure 8 instruments used for tree measurements (Url 7, 2007)

Table 6. comparison of tree measurements between Angolan and Czech NFI

Country	**Level**	**Trees/stumps measured**		**Measuring**
		Forest	Other section of land use	
Angola	Plot	Dbh ≥ 20 cm	Dbh ≥ 10 cm	Species; location; diameter; total height, quality
	Rectangular sub-plot (RSP)	Dbh ≥ 10 cm	none	Species; location; diameter; total height; health; quality
	Circular sub-plot	Tree height ≥ 1.30 m and Dbh < 10 cm	Tree height ≥ 1.30 m and Dbh < 10 cm	Number of trees by specie
Czech Republic (NIL 2)	S1 radius = 12.62 m	Dbh > 12.62 cm		Thinning measurement
	S1 radius = 2 m	Tree height > 10 cm and Dbh < 6.7		
	S1 radius = 2 m			
	S1 radius = 3 m	Dbh from 7 to 11.9 cm		Forest regeneration

	S1 radius = 3 m		
	S2 radius = 12.62 m	Dbh > 12.62 cm	Thinning measurement
	S2 radius = 2 m	Tree height > 10 cm and Dbh < 6.7	
	S2 radius = 3 m	Dbh from 7 to 11.9 cm	Forest regeneration

The subject of discussion of this thesis is based upon the comparison of NFI in Angola and NIL2 in Czech Republic. The first topic for comparison was the time of execution of each NFI (the Angolan inventory it’s a work in progress and the Czech NFI has two finished editions). The Angolan NFI started in the year of 2011 and the prevision of its conclusion is yet unknown. As for the Czech NFI, the NIL1 was from 2001-2004 and NIL2 from 2011-2015. Another comparison is the number of sampling units; Angola has 591 against the 14 220 inventories plots (NIL1) in the Czech Republic.

On the sampling modelling; the Angolan NFI opted for the systematic and stratified, as for the Czech NFI the sampling used was stratified sampling in the dimension of 500 x 500m from which successively derived random sub-selected sub- network. The composition of the sampling unit; Angola sample unit that is a square surface area of 1 km x 1 km, with each sampling unit having 4 plots; the plots have rectangular shape with 20 m wide and 250 m long inside of the sampling unit, starting in the corner of an inner square of 500 m with the same size as the sample unit and are numerated clockwise from 1 to 4. While, in Czech Republic, the unit area was 2km x 2km in regular network over all forest area; each plot consists of two mutually independent circles with a radius of 12.62 m, with a distance between the cores of 300 m (the sizing was done according to the average size of forest stands in; it also serves saving entries related to intersection between transects and forest roads, streams, drainages) both parts are divided in sub-plots and on each sub-plot in the category ‘Forest two inventory’ circles are established for the purpose of forest inventory.

The comparison for the description on the tree measurements in the plots and sub-plots; In the Angolan NFI in every plot the location of the trees, nature of the trees, tree species, regeneration of trees is measured and for trees with larger diameter inside of the rectangular plot or inside of the plot were recorded; biophysical and hydrological properties of the soil are analyzed in the measuring points; for the dead trees, standing or fallen were measured as living trees, but fallen dead branches are measured along the line of the transect of fallen necromass; and finally the litter is defined as the dead organic material found on the ground. For the Czech NIL2, the location of the trees, nature of the tree, position of the tree within the micro relief, tree species, community status of the tree, stand layer that the tree belongs to, presence of stiff roots, presence of standing dead tree and shape of the crown. For the last comparison point, it's the equipment used for the tree measurement by both parts. The equipment used in the Angolan NFI for the tree measurements consists basically of Blume-Leiss dendrometer, Blitterlich relascope, measuring tape and calliper, but in the Czech NFI the equipment for tree measurements consists of MaaStar, field Computer Hammerhead P-233, ForestPro, GPS Geoexplorer 3, reference computer PSION, electronic calliper Mantax, metal detector CARRETT, measuring tape and mini-calliper; which forms the Fieldmap technology and is the most crucial variable that is missing the Angolan NFI for the technological aspect. Unfortunately this method is available for the Angolan NFI.

6. CONCLUSION

Forests have always been important for the benefits of every society and the planet. Having the power and knowledge to manage and control this resource is a responsibility of every country and nation in the world. We stated in the beginning of this work '*Regional and national inventories* are often mandated by law in the case of countrywide surveys'; in which both countries follow the idea, that is why for the realization of this thesis the focus was to understand how the countries managed this process in their individual ways and compare their ideas and possibly arrange ways to improve or collaborate in the near future.

After the review and analysis of both countries national forest inventories, the final statement that can be given is that each forest inventory is unique in many ways. They can follow the same guidelines, but the differences appear later during the execution because of several factors. The national forest inventories of Angola and Czech Republic are very different in many ways i.e. sampling modelling, composition of the sampling unit, tree base measurements in the plots and sub-plots and equipment used for the tree measurement. The most noticeable difference is the modern equipment used by the Czech counterpart; on example is when getting access to the position of the plot; in Czech NFI it is done with the assistance of an external antenna and a field computer and having all of the data saved in digital format in real time in the field, but the Angolan NFI this does not happen, because this procedure is still executed with paper forms which takes longer and can sometimes make the data analysis complicated. One solution is to introduce newer technologies to help improve and facilitate the work.

The hope is that this experience can inspire future NFI to embrace modern technologies like UAVs (for the reasons mentioned earlier in the work), electronic equipment for general measurements, Fieldmap Technology and modern forest management techniques to help protect and safeguard the precious forest resources of the country.

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