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POTENTIALS AND CONSERVATION OF MAHOGANY IN NIGERIAN FOREST ECOSYSTEM

Professor I. B. Chimbekujwo
Federal University of Technology, Yola, Nigeria
Correspondence: chimbekujwo2010@gmail.com
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INTRODUCTION

Forests occupy one-third of the world's land area and govern carbon transfer fluxes through photosynthesis and respiration, representing an important carbon pool in particular ecosystem compartments (Marková *et al.*, 2011).

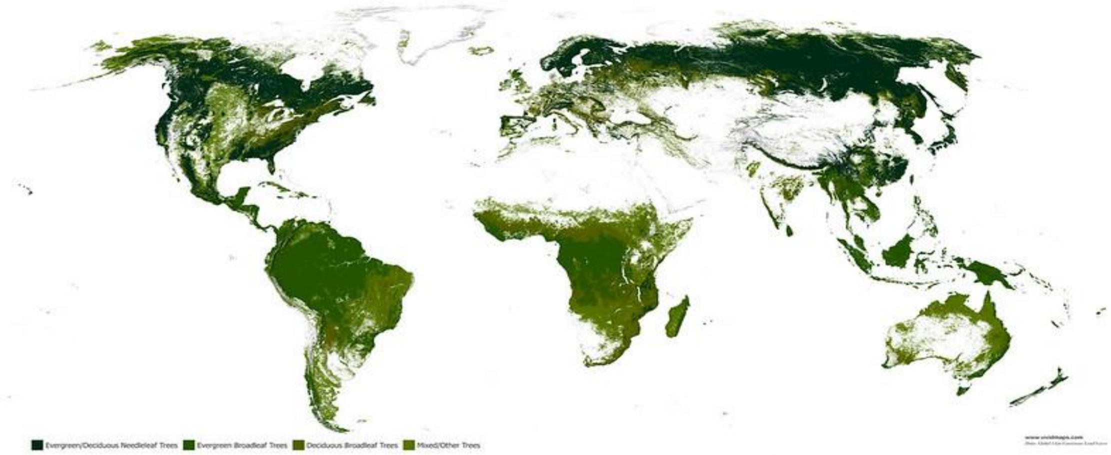

Fig 1: World map showing forest areas

Fig 2: Map of Africa showing forest areas

Fig 3: Map of Nigeria showing forest areas

Khaya senegalensis (Desr.) A. Juss is a species of tree in the Meliaceae family that is native to Africa. Common names include African mahogany, dry zone mahogany, Gambia mahogany, *Khaya* wood, Senegal mahogany, Cailcedrat, Acajou, Djalla and Bois rouge. The importance of *Khaya senegalensis* both in furniture and in traditional medicine cannot be over-emphasised. It has contributed immensely to our economy because of the high production of wood content in its tree species. This has enabled its use conventionally for carpentry, interior trim and construction (Lemmens *et al.,* 2008). *Khaya senegalensis* is a deciduous evergreen tree with the common name African mahogany tree. *Khaya senegalensis* is a tree, 15 – 30 m high and up to 1 m in diameter with a clean bole to 8 – 16 m, buttress not prominent or absent, bark dark grey, with small thin, reddish, tinged scale, slosh dark pink to bright crimson, exuding a red sap (Orwa *et al.,* 2009).

Fig 4: Mahogany tree (*Khaya senegalensis*)

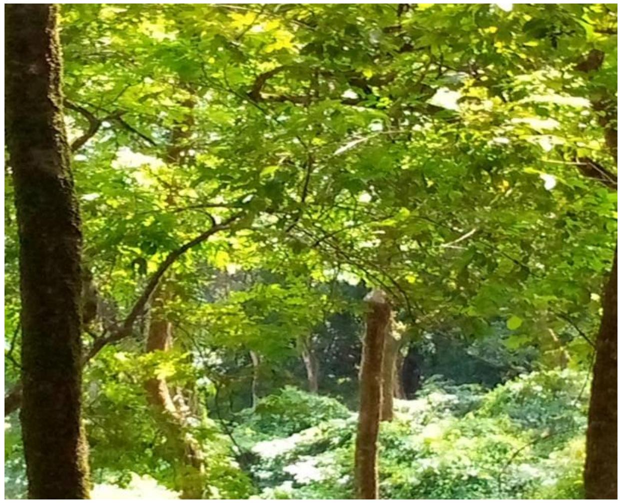

Fig 5: Thick forest showing *K. senegalensis* in southern part of Taraba State

KHAYA SPECIES

The gems *Khaya* comprises four (4) species in mainland Africa of which one or two of them are endemic to the Comoros and Madagascar. *Khaya* species strongly resemble each other in flower and fruit; differences are more prominent in their leaflet (Arbonnier, 2004). Some of the species in the genus of *Khaya* are: *Khaya senegalensis, Khaya grandifolia, Khaya ivorensis* and *Khaya anthotheca*.

Fig 6: *Khaya grandifolia*

Fig 7: *Khaya senegalensis*

Fig 8: *Khaya ivorensis*

Fig 9: *Khaya anthotheca*

LOCAL NAMES

Arabic (homraya, homra, murraya, mahogoni); English (African mahogany, dry zone mahogany, Gambia mahogany, Khaya wood, Senegal mahogany); French (Cailcedrat, Acajou d'Afrique, acajou du Sénégal); Fula (dalehi); German (*Afrikanisches Mahagoni*); Hausa (madachi); Igbo (ono); Indonesia (kaya); Trade name (khaya wood, African mahogany); Vietnamese (x[af] c[uwf]); Yoruba (ogonwo) (Orwa *et al*., 2009).

BOTANICAL DESCRIPTION

Khaya senegalensis is a deciduous evergreen tree, 15-30 m high, up to 1 m in diameter, with a clean bole 8-16 m, buttresses not prominent or absent; bark dark grey, with small, thin, reddish-tinged scales; slash dark pink to bright crimson, exuding a red sap. Leaves alternate, compound, stipules absent; petiole and rachis 13-33 cm long; leaflets 3-4 (max. 7) usually opposite pairs, oblong to narrowly oblong-elliptic, 4-12 x 2-5 cm, apex acute to shortly acuminate, base rounded, margins entire, pale green, lateral nerves 8-16, petiolules about 3.5 cm long.

Fig 10: Mahogany Tree

Fig 11: Tree showing bark and leaves

Inflorescence a lax, much-branched axillary panicle up to 17 cm long; flowers tetramerous, monoecious but with well-developed vestiges of those of the opposite sex with very little external differences between sexes. Calyx pale green, lobed almost to the base, lobes sub circular about 1 x 1 mm, imbricate; petals cream, free, oblong-ovate, 4 x 2.5 mm, contorted in bud; orange disk around the ovary.

Fig 12: Inflorescence of Mahogany tree

Fig 13: *Khaya senegalensis*, foliage and flowers

Fruit an upright, almost spherical, woody capsule, 4-6 cm in diameter, opening by 4 valves from the apex (a distinction from *K. ivorensis*, which is closely related but has 5 valves). Seeds brown, 6 or more per cell, broadly transversely ellipsoid to flat, about 25 x 18 mm, margins narrowly winged. The specific name means 'of Senegal', which is where the type specimen was collected (Sosef *et al.*, 1998).

Fig 14: Mahogany fruits showing the seeds

Fig 15: Mahogany fruits attached to the plant

BIOLOGY

K. senegalensis is insect-pollinated. Flowering shortly before or early in the rainy season, the fruit apparently remaining on the tree throughout the dry season. When the fruit ripens, the colour changes from grey to black. Begins to bear seed when the tree is 20-25 years old. Seeds may be dispersed up to 100 m by wind.

Fig16: Khaya senegalensis flower

Fig 17: *Khaya senegalensis* foliage

Ecology

Khaya senegalensis occurs in savanna woodland, often in moist localities and along watercourses, in areas with 650–1300 (1800) mm annual rainfall and a dry season of 4–7 months. It occurs up to 1500–1800 m altitude. In riparian forest it can sometimes be found together with *Khaya grandifolia*. It prefers deep and well-drained alluvial soils and termite mounds, but can also be found on shallow, rocky soils, where it usually remains much smaller. It tolerates flooding in the rainy season.

Fig 18*: Khaya senegalensis* plantation

K. senegalensis occurs in riverine forests and is scattered within the higher-rainfall savannah woodlands. In moister areas, *K. senegalensis* is found on uplands, but it is restricted to riparian habitats or stream bottoms that first extend into the savannah in the drier portions of the range. During the first year, the seedling develops a strong, deep taproot, which makes it the most drought-hardy of all the *Khaya* species. It is also very resistant to flooding and can be considered for planting on swampy soils. It is moderately shade-tolerant. Except where selectively removed by logging, dry-zone mahogany remains a dominant species in most of its range. Successful plantations of dry-zone mahogany in other parts of the world have generally been in areas with short dry seasons and high rainfall (Orwa *et al.*, 2009).

Biophysical Limits

Altitude: 0-1800 m, mean annual temperature: 24.5-31.5^{o}C, mean annual rainfall: 400-1750 mm. Soil type: Tolerant to a wide range of soil conditions, from neutral to very strongly acidic and from very well-drained, coarse sandy loam to somewhat poorly drained clay. Prefers neutral, deep, sandy loam soil that is well drained. Such fertile conditions are often found in alluvial soils.

ECOLOGICAL ZONES AND MAHOGANY DISTRIBUTION

Ecological zones

Mahogany is mainly found in the tropical rain forest and tropical moist deciduous forest, in Central America, Mexico and South America (FAO, 2002). Rain forest is found in the coastal plains of the Gulf of Mexico region; in the Sierra Madre range in Chiapas, Mexico; and in the Caribbean coast along the Pacific coast in Central America. Tropical moist deciduous forest stretches along the lower region of the central mountain ranges of Central America, located towards the Pacific Ocean; the plains and hills of the Yucatan peninsula and the Gulf of Mexico. The tropical ecological zones in this region cover 134 million hectares (FAO, 2002).

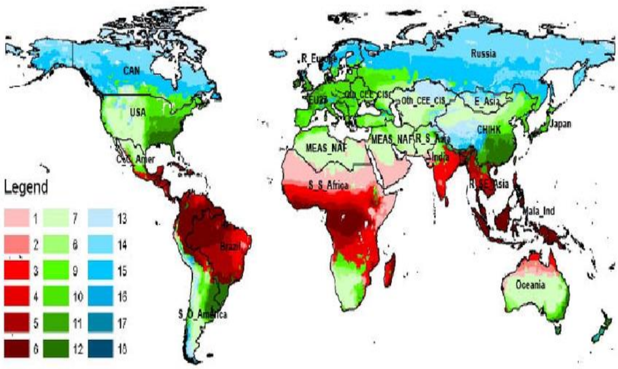

Fig 19: The ecological regions of the World

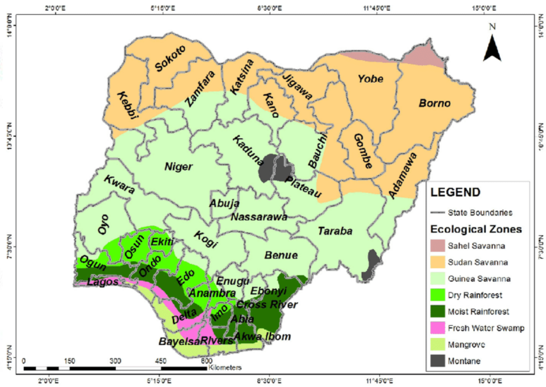

Fig 20: The ecological regions of Nigeria

These ecological zones are characterised by an average annual temperature ranging between 20 and 26º C, while rainfall in the tropical rain forest varies between 1500 and 3000 mm, and reaches up to 4000 mm in certain areas. The tropical moist deciduous forest receives between 1000 and 1500 mm average annual rainfall. The dry season in these areas lasts up to three months because they are not affected by the tropical depressions occurring between August and November, which produce rainfall during that season (FAO, 2002). The forest in these areas is high and dense. The crown covers in the tropical rain forest reaches between 30 and 40 m height, with emerging trees growing over 50 m, while trees in the Tropical moist deciduous forest reach a 30 m height. The lower storey of the crown cover is dense, with trees reaching between 5 and 25 m, strata in the under storey present a large variety of palms, ferns, climbers and grasses. Both ecological zones share many tree species and are characterised by a complex and varied flora, with approximately 5000 vascular plant species and more than 60 different tree species per hectare (FAO, 2002).

Documented Species Distribution and Habitat

Native: Cameroon, Central African Republic, Chad, Cote d'Ivoire, Equatorial Guinea, Gambia, Ghana, Guinea, Guinea-Bissau, Mali, Niger, Nigeria, Senegal, Sierra Leone, Sudan, Togo, Uganda.

Exotic: Australia, Cuba, India, Indonesia, Puerto Rico, Singapore, South Africa, Vietnam

The tree can grow in almost all habitats but it mostly occurs in riverine forests and is scattered within the higher-rainfall savannah woodlands. In moister areas, it is found on uplands, but it is restricted to riparian habitats or stream bottoms that extend into the savannah in the drier portions of the range. During the first year, the seedling develops a strong, deep taproot, which makes it the most drought-hardy of all the *Khaya* species. It is also very resistant to flooding and can be considered for planting on swampy soils. It is moderately shade-tolerant. Except where selectively removed by logging, dry-zone mahogany remains a dominant species in most of its range. Successful plantations of dry-zone mahogany in other parts of the world have generally been in areas with short dry seasons and high rainfall (Orwa *et al*., 2009).

Forests are one of the world's most precious natural resources. From Tropical Rainforests to the Boreal Forests of North America and Russia, forests are under threat from too much logging / harvesting and too little replanting. This is due to world demand for natural woods, from pine to exotic hardwoods such as rosewood. The world map below shows the distribution of forests across the world. There are three main forest types, Tropical Rainforest, Boreal Forest and Temperate Forest.

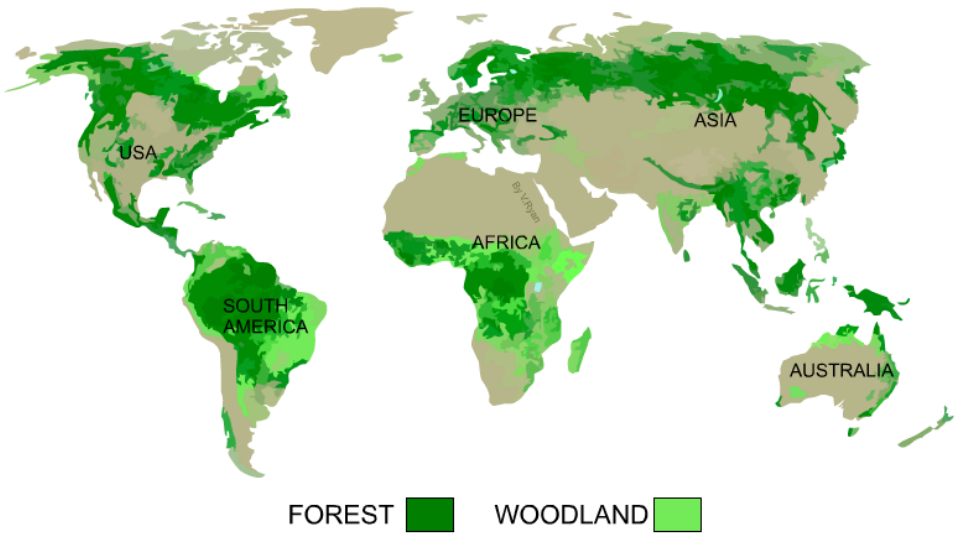

Fig 21: Forests and Woodlands: World Distribution of Natural Woods

The forest in these areas is high and dense. The crown cover in the tropical rain forest reaches between 30 to 40 m height, with emerging trees growing over 50 m, while trees in the Tropical moist deciduous forest reach a 30 m height. The lower storey of the crown cover is dense, with trees reaching between 5 and 25 m, strata in the under storey present a large variety of palms, ferns, climbers and grasses. Both ecological zones share many tree species and are characterised by a complex and varied flora, with approximately 5000 vascular plant species and more than 60 different tree species per hectare.

The most common tree species associated to Mahogany in a natural distribution range are *Dialium guianense*, *Pimenta dioica*, *Brosimum alicastrum*, *Ampelocera hottlei*, *Pseudolmedia spurea*, *Cordia alliodora*, *C. dodecandra*, *C. bicolor*, *Calophyllum brasiliense*, *Castilla elastica*, *Dendropanax arboreus*, *Tabebuia* spp, *Manilkara* spp, *Terminalia* spp, *Ochroma* spp, among others (FAO, 2002).

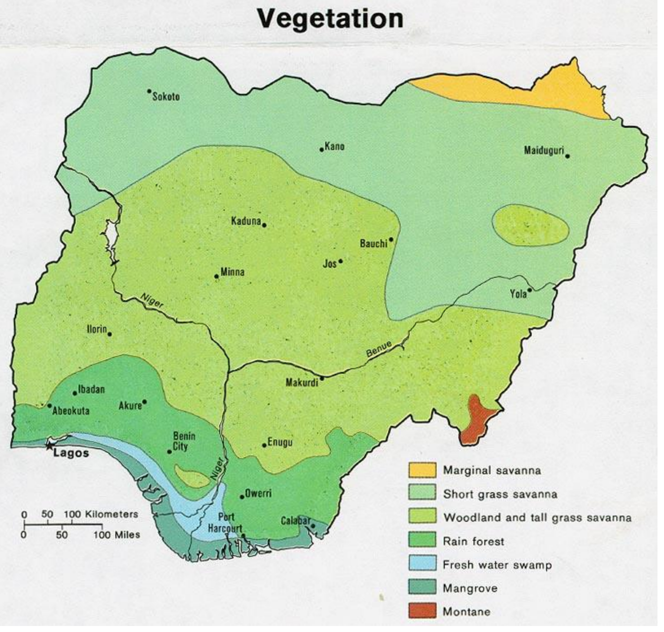

Fig 22: Natural distribution of Mahogany

THREAT AND NEED FOR CONSERVATION

Khaya senegalensis has experienced high amounts of exploitation, and little regeneration takes place once disturbance occurs. Because of this, the IUCN Red List of Threatened Species considers it a vulnerable species. The only conservation which takes place is log export bans and legal protection in some countries. Life on Earth without plant resources is quite impossible (Pamlin and Armstrong, 2015). However, threats on these plant resources nowadays are numerous, huge, and likely to threaten human life itself (Myers *et al.,* 2009).
The sources of the threats are mainly twofold:

i. Anthropic causes, and
ii. Global changes.

These factors together are combining to magnify threats on both resources and human security (Myers *et al.,* 2009; Bello *et al.,* 2017).

Khaya senegalensis is one of the species exposed to anthropic pressure (Houehanou *et al.,* 2013) because of its different beneficial uses (Sokpon and Ouinsavi, 2002):

i. The wood of *Khaya senegalensis* is of high quality (Sokpon *et al*., 2004) and is selectively harvested (Glèlè *et al.,* 2009).
ii. According to Botha *et al*. (2004), the pressures on the species may expose it to threats.
iii. *Khaya senegalensis*, a West African urban tree (Orwa *et al*. 2009), plays important roles in the livelihoods of hundreds of millions of rural and urban peoples across the globe (Emanuel *et al*., 2005).

iv. The species is harvested by Fulani herders across the country for fodder (Gaoue and Ticktin, 2016).

In a study (McClean *et al*., 2005) modelling 5197 tree species using the Hadley Centreʹs third generation coupled ocean-atmosphere General predicted the diminution of the repartition areas for about 81%-97%

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of the 5197 African tree species, including *Khaya senegalensis*. *Khaya senegalensis* is likely to be exposed to the impacts of climate change on some ways.

The same species is expected to be exposed to higher rates of insect attack and mortality (Botha *et al*., 2004). Most of these attacks come from *Hypsipyla robusta* Moore (Sokpon and Ouinsavi, 2004). A recent study revealed that insects develop resistance to pesticide and that it is also difficult to access adequate materials to handle and apply those pesticides (Agboyi *et al.,* 2015). It is, therefore, urgent to seek for practical ways to conserve and manage this resource.

Methods for characterising environmental requirements of species have been used over the past two decades, to forecast species distributional potential in novel regions or under scenarios of environmental change (Owens *et al.,* 2013). Known globally as Biodiversity Informatics, the domain of computation is helping many scientists from many fields all over the world. Its use (Gbesso *et al*., 2013; Saliou *et al.,* 2014) has enhanced the conservation and sustainable management of natural resources.

With increasing drought and grazing pressure, savanna systems in West Africa are experiencing an increasing reduction in availability of grass and trees. Frequent seasonal bush fires further reduce the availability of herbaceous fodder in pasturelands dominated by annual grasses. Consequently, in parts of Benin, Niger, Nigeria, Burkina Faso, Senegal and Cameroon, various species of trees are heavily and increasingly harvested by indigenous Fulani people as sources of fodder (Gaoue and Ticktin 2007). The reported decline in populations of several of these species (Lykke *et al.,* 2004) has both biological and cultural implications, as cattle are an integral part of Fulani culture and livelihoods.

Moreover, many of these species are subject to additional uses by loggers and farmers. Sustainable management and conservation of these common pool resources require an understanding of local ecological features and perceptions of the impacts of harvest and other sources of disturbance, and how these influence resource use patterns. This information is critical for designing and implementing management plans that fit local cultural practices and perceptions.

Figs 23: Logs of Mahogany cut to be transported out of Taraba State

Fig 24: Logs of Mahogany cut and prepared to be transported out of Taraba State

Fig 25: Examples of deforestation of *Khaya senegalensis* for timber production in Taraba State

Fig 26: Felling of *Khaya senegalensis* for timber production in Taraba State

Fig 27: Loading of the log of Mahogany into a lorry to be taken to the factory

PRODUCTS

The wood is used for a variety of purposes. It is used conventionally for carpentry, interior trim and construction. Traditionally, the wood was used for dugout canoes, household implements, djembe, and as fuel wood. The bitter tasting bark is used for a variety medicinal purposes; it is taken against fever caused by malaria, stomach pain and headache. It is applied externally to cure skin rashes, wounds, or any abnormality. It has been exported from West Africa (Gambia) to Europe since the first half of the 19th century and has been exploited heavily for its timber. It is now used more locally and is planted ornamentally as a roadside tree.

Fodder: Young leaves contain fairly large amounts of digestible crude protein. The leaves are used as a fodder for cattle and camels, although they are not very palatable.

Fig 28: Mohagany plant with (a) leaves and (b) fruits

Fuel: Only limited quantities are available for fuelwood, and trees of larger dimensions are undesirable because of difficulties with splitting and crosscutting. Hence, even if fuelwood is in short supply, larger-diameter sections are not utilised. The gross energy value of the wood is 19 990 kJ/kg.

Fibre: The wood is used in West Africa for pulp.

Fig 29: African Mahogany wood

Timber: It is one of the hardest African mahoganies and the hardest of the *Khaya* species. It is widely used on a commercial scale, particularly in West Africa. The wood density ranges from 0.6 to 0.85, depending on location. The sapwood is pinkish-tan in colour and the heartwood is dark, red-brown and attractive. It is moderately resistant to fungi, insects and termites. The sapwood is moderately resistant to preservation treatment, while the heartwood is highly resistant. The timber saws well except for a tendency to be woolly in cross grain. It seasons rapidly with little degradation; however, tension may occasionally cause splitting and warping. It is favoured for furniture, high-class joinery, trim and boat building. The wood is also used locally for railroad ties, flooring, turnery and veneer. Because of its decorative appearance, the wood of *Khaya senegalensis* is a very popular timber.

Fig 30*:* Timber from Mahogany

Gum or resin: The presence of oleoresin in the vessels of *Khaya* species accounts for the durability of the timber and its resistance to insect and fungal attack.

Fig 31: Gum or resin produced by wounded Mahogany tree

Tannin or dyestuff: The bark is used in tanning.

Lipids: The seeds have an oil content of 67% and are rich in oleic acid (66%). The oil is used in West Africa for cooking.

Poison: *Khaya senegalensis* is used in Cote d'Ivoire as an ingredient in arrow poison. Bark scales are sometimes used as fish poison.

Medicine: The very bitter bark has a considerable reputation in its natural range as a fever remedy. The bark is also used as a vermifuge, taenicide, depurative and for treating syphilis. Bark extract is used for treating jaundice, dermatoses, scorpion bite, allergies, infection of the gums, hookworm, bleeding wounds (disinfectant), and as a laxative. Seeds and leaves are used for treating fever and headache; roots are used against sterility and for the treatment of mental illness, syphilis, leprosy and as an aphrodisiac. Crushed bark and seeds are regarded as emmenagogue. Bark is also used in traditional veterinary practice, for example, for cattle suffering from liver fluke, for ulcers in camels, donkeys and horses, and in horses for internal ailments associated with mucous diarrhoea (Orwa *et al.,* 2009).

Fig 32: Barks are removed for medicinal purposes

Other products: Wood ashes are used for conserving millet seed.

Reclamation Services: It largely reproduces itself from suckers and is recommended for reforestation purposes.

Ornamental: Dry-zone mahogany is an important ornamental tree in West Africa.

Fig 33: Mahogany plant used as ornamental

Fig 34: *Khaya senegalensis* being used as a street tree for beautification

Conservation of Genetic Resources

Genetic loss within and between populations, due to the exploitation of the species and the fragmentation and reduction of its populations, is a critical factor to evaluate the conservation state of the populations. Genetic loss is a critical factor to assess the conservation state of Meliaceae populations in their natural distribution range in neotropical regions, including Mexico. One of the main concerns of the scientific community is the prevention of certain species, such as *Swietenia macrophylla* and S. *macrophylla* from genetic erosion. Due to a series of causes, *S. macrophylla* lost the best individuals in the past and now their descendants are bifurcated, deformed, with many branches and are very different from the original populations.

In spite of *in situ* and *ex situ Swietenia macrophylla* conservation projects on-going in the Central American region and Mexico, there is no doubt that more efforts are needed to better understand what the distribution and dimension of the biological diversity are, in order to correctly plan, manage, use and boost mahogany conservation. It is important to gather information, especially on themes like geographic distribution and size, damage and hazard level, number of individuals per hectare, dispersion and growth behaviour, phenology, reproductive biology, interaction with pollinators, seed characteristics, seed and sapling damage and natural regeneration. These factors can help to define the location and size of protection areas, and facilitate other necessary tasks for genetic improvement, seed collection, and species' propagation for plantation and orientation of activities towards the sustainable management of the species.

Importance of *K. senegalensis* in afforestation

i. It has positive influence on the soil physical characteristics which are important for the maintenance of soil stability.
ii. It has a major influence on increasing the soil porosity, by decreasing the reduced bulk density and increasing capillary and gravitational pores, which is crucial.

iii. It is positively related to increase in soil organic matter content in different forms, both stable and unstable, and has a tendency to increase soil organic matter accumulation not only in the layer of surface humus but also in the entire soil profiles of the research sites.

Management

In general, *Khaya senegalensis* occurs scattered under natural conditions, often as single individuals. Enrichment planting in woodland has been applied successfully in Vietnam. Plantations in northern Togo established in 1918 showed 70 years later an average tree height of only 12 m and an average bole diameter of 32 cm; possibly they failed due to poor silvicultural management. In Benin the first plantations were established in 1935, but they also failed , not only because of poor management, but probably also because of illegal logging of the largest individuals.

Tree Management

Strategies to obtain sufficient regeneration on poor sites should include liberation cutting of stands with advanced regeneration. Common spacings on cleared and prepared sites are 5 m x 5 m and 5 m x 10 m. A spacing of 5 m x 20 m is used when planting in riparian forests. Hoeing and weeding are recommended at the onset of the dry season. Although older trees are resistant to fire, seedlings are fairly susceptible.

Germplasm Management

Seed storage behaviour is intermediate; seeds tolerate desiccation to 6% mc; 81% germinate following 3 years of subsequent storage at 2ºC; seeds tolerate desiccation to 5.7% mc (in equilibrium with 54.4% rh), little loss (about 3%) on desiccation to 2.1% mc (in equilibrium with 11.8% rh at 20ºC), complete loss in viability following 24 months of hermetic storage at 10ºC, 0ºC and -20ºC with 10% mc; it appears 0ºC is optimal storage temperature for seeds at 2.2-5.6% mc, whereas -20ºC is damaging. Normally, there are 6000-7000 seeds/kg, but occasionally as few as 3000.

Diseases and pests

In plantations *Khaya senegalensis* suffers seriously from *Hypsipyla robusta* shoot borers that kill the main stem of young trees, causing excessive branching and contributing to mortality. Silvicultural techniques such as overhead shading of saplings, mixed planting and removal of lateral shoots can reduce damage by shoot borers. Products based on methidathion have proved effective in plantations of up to 2 years old, but the costs are very high. In Burkina Faso roadside trees have been attacked by leaf-eating caterpillars, e.g. *Bourgognea microcera*. Seeds are commonly attacked by seed-boring beetles and eaten by small rodents, whereas young plants can be heavily browsed by cattle, antelopes and other herbivores. A bacterial disease of dry-zone mahogany in the Sudan caused by *Xanthomonus khaye* results in rough, scabby leaf spots and knobby stem cankers.

Fig 35: Mahogany shoot borer

Fig 36: Disease of leaf caused by *Fusarium* species

Management and use of Mahogany populations

The use of mahogany within its natural distribution range started many centuries ago. For instance, the Mayans in Central America built large canoes to carry out trading activities in the region (Hammond, 1982). In more recent times, during the Spanish colonisation, tropical forests were used to extract timber of different species, including *Haematoxylon campechanum* and *Swietenia macrophylla,* which were exported to Europe for cabinet-making and furniture. Mahogany in the region was generally used for ship construction and repair, and for domestic use.

Production and international trade

Logs of *Khaya senegalensis* have been exported from West Africa since the first half of the 19th century, e.g. from Gambia. *Khaya senegalensis* has been heavily exploited for its timber since then. Nowadays, the wood is mainly used locally, and statistics on production and trade are not available. In several countries in the African savanna area *Khaya senegalensis* wood is very important, e.g. in Burkina Faso and Mali, where it may contribute up to 80% of all logs entering local sawmills. Probably the wood of *Khaya senegalensis* is occasionally mixed with the wood of other *Khaya* spp. and traded on the international timber market. The bark is in high demand for medicinal purposes and can be found on many local markets. Seeds are harvested from natural stands and traded worldwide, e.g. 400–600 kg of seed is distributed per year from the Centre National de Semences Forestières (CNSF) in Burkina Faso, of which more than 80% is exported.

In Mexico, mahogany timber extraction began in large scale in the 20th century in many areas, mainly in the southern region of the country, including Oaxaca, Chiapas and the Yucatan peninsula. During this period, large transnational companies were established and were granted concessions by the Government to exploit natural resources. The use of mahogany timber intensified during the Second World War, when the companies expanded extensive exploitation. These activities continued throughout the 70s.

Silvicultural aspects

Species of the Meliaceae family differ in terms of silvicultural characteristics. *Cedrela odorata* is considered a fast- growing species, belonging to the more advanced stages of succession and a shade-tolerant species. One of the shade-tolerant main problems arising from the management of mahogany populations is the scarce natural regeneration it shows in natural communities where the species grows. Besides the problem related to the decreasing number of mature individuals that could contribute to seed dispersion, an additional difficulty is due to the scarce quality of the remaining trees after the timber has been extracted, as well as the lack of information on the processes that regulate the natural regeneration.

Rodríguez *et al.* (1994) carried out a study to assess the capacity for *S. macrophylla* seed dispersion and reported the successive establishment of saplings. Seed dispersion occurred from February to April, and a total of 6861 seeds were found, that is to say 84 per cent of the potential production of a tree. The per cent maximum dispersion distance was 60 m from the mother tree. In August, when the first germination and survival appraisal was made, the authors found a total of 1608 saplings. It was concluded that 20 per cent of the dispersed seeds were able to germinate and establish in the next two months. Gullison and Hardner (1993) noted that selective use of tropical forests is damaging to the remaining trees in stands with large numbers of tree species with commercial value. The authors of this paper assessed the damage provoked by selective exploitation of *S. macrophylla*, a species with very low density, located in the Chimanes forest in Bolivia. Damages occurred mainly along the main roads and access tracks for extraction. Minor damage reached 4.4 per cent of the total area of extraction assessed.

The main obstacle to increased use practices through selective harvesting methods in Latin America is the lack of international markets for many of the less known species, although in some cases local or national markets exist and could absorb the timber produced. García *et al.* (1993) carried out a study in sub-deciduous forest in Quintana Roo, Mexico, in order to observe the effects of partial removal of the first storey on natural regeneration of mahogany (*Swietenia macrophylla King*). Five plots of 0.5 ha were established, where different intensity clearings were carried out, taking the original basal area of the population as a basis and removing 0, 8, 28, 45 and 55 per cent of it. The work was assessed four years after the clearings were carried out. The authors observed marked differences in the average number of young mahogany individuals per hectare, varying from 500 in the reference sample (0 per cent) to 2100 in the 45 per cent intensity clearing. Seven hundred (700) individuals were obtained in the 8 per cent intensity clearing, 1400 in the 28 per cent clearing and 900 in the 55 per cent. The authors reported the outstanding effect of different clearing intensities on regenerating saplings. Although significant statistical differences were observed when comparing the 45 per cent intensity clearing to the 0 per cent clearing of reference, in absolute numbers the former showed up to 4.2 times more individuals than the 0 clearing reference sample, while it was three times more numerous than the 8 per cent clearing, 1.5 times more numerous than the 28 per cent clearing and 2.3 times more than the 55 per cent one. These figures suggest that a direct relation exists between the opening of the first *S. macrophylla* storey and the quantity of regenerating saplings produced in experimental plot conditions. Nevertheless, in the 55 per cent clearing treatment, the number of regenerating saplings decreased, because the species requires shade during the first growth stages. In terms of maximum height, the study showed that the largest average tree dimensions were obtained in the demonstration plot where 45 per cent of the existing basal area had been removed. These trees were 2.1 times higher than the reference sample, 2.4 times higher than the sample at 8 per cent clearing, 1.9 times more than the sample at 28 per cent clearing and 1.4 times more than at 55 per cent clearing.

Negreros and Mize (1993) resorted the result of a study which was aimed to measure the effect of partial clearings (creation of multiple clearings) in the natural regeneration with special emphasis on tree species of commercial value, such as mahogany (*S. macrophylla*). After three years, the population obtained by regeneration was similar in density and composition to the original population before the clearings were made. Regeneration of commercial tree species (with or without tolerance to shade), non-commercial species and those which are not tree species, were compared with the residual basal area and the percentage of basal area removed. The frequency of commercial, shade-tolerant species was not affected by residual basal area or by the percentage of basal area removed.

Sustainable management perspectives

One of the main challenges that forest management programmes face in tropical regions consists in maintaining both timber productivity under long-term management, and conservation of biodiversity in the populations subject to management. Today, an international trend associates management of forest resources with the sustainable development of communities, while conserving those communities and the genetic diversity within and between plant species' populations. Sustainable management may be defined as the management capable of maintaining timber productivity of the species in the management cycle. In a wider interpretation, sustainable management may also be considered as the management that preserves productivity, the forest structure, diversity and the basic ecological process of populations, communities and the ecosystem. In many tropical regions, a wide range of forest management methods may be identified, including those that carry out selective use of the best individuals of some species and those that aim at using the resources in the framework of sustainable management and encourage its natural regeneration. One of the few examples of sustainable forest management is rubber tree (*Hevea brasiliensis*) latex extraction in the Brazilian Amazon region, by rubber collectors, who do not damage the trees and conserve the genetic resources of the species under management, while maintaining the diversity and structure of the natural forest (Kageyama, 1991). Another example is the latex extraction of "chicle" gum obtained from several species of *Manilkara*. in the neotropical regions, where trees are maintained while carrying out a non-wood forest use, as well as timber use of other species.

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Mahogany forests located in south-eastern Mexico are one example of sustainable forest management carried out in the Ejidos of Quintana Roo state, where the use of forests in the past was carried out through concessions that excluded the owners of the resources, a phenomenon that according to Arguelles (1999), produced a social claim arising from the ejidos and communities to directly manage the forest themselves, as well as the commercialisation of its products. The result was a change in government policy that granted licenses directly to forest owners, while a project known as the Forest Pilot Project was set up at a later stage. These measures filled a gap in forest management left by the forestry concessions in southern Quintana Roo. The greatest success of this project is that 45 ejidos established 500 thousand hectares for permanent forest use, thus stopping uncontrolled clearings that had prevailed during decades.

The success of the Forest Pilot Plan encouraged researchers to replicate it in other regions such as Marqués de Comillas in Chiapas and the Calakmul region in Campeche. Nevertheless, these programmes did not have the expected success, because they were implemented under the influence of political considerations and not according to a productive organisation of the users, in order to achieve a rural economic setting based on good management of forest resources. The importance of a socially oriented initiative in terms of conservation efforts and development of forest populations stems from the forest lands registration system in Mexico, where 80 per cent of the forest land is managed by the communities, 15 per cent by private enterprises and only five per cent is still under the control of the Federal and State Governments. In terms of participation in productive activities, it is interesting to note that today 40 per cent of timber production is provided by communal forest enterprises. In 1975, only 2-3 per cent of timber production was directly managed by the communities. In 1985, this figure increased to 17 per cent.

Role of forest plantations in conservation

The natural forests considered available for wood production, including mahogany, are experiencing heavy pressures for harvesting. These, in addition to continuing deforestation, resulted in "presently unavailable" forests from the production point of view. The expected harvest from the natural forests is expected to decline. On the other hand, global consumption of timber is projected to increase. Total round wood consumption was projected as increasing at an annual rate of 1.12 per cent between 1994-2010, from 3.21 billion m^3 to 3.84 billion m^3 (FAO, 1997a). Industrial round wood was projected to increase by 1.20 per cent annually, from 1.47 billion m^3 to over 1.78 billion m^3. This increase of over 300 million m^3 by 2010 far exceeds the estimated net current growth from industrial plantations of 84 million m^3 (FAO, 2000).

An optimistic estimate of the permanent loss of existing natural forest production through further deforestation and degradation, based on recent deforestation rates, suggests that the annual decline in production from disturbed forests could be 6.2-7.0 million m^3 ha^{-1} yr^{-1}. Removing additional areas of natural forests through the establishment of new protected areas or expanded logging bans would further reduce harvests. Much of this protected area would likely be taken from available undisturbed forests that have higher current growth and productivity (approximately double) than the disturbed forests (FAO, 2000). Without significant increases in both the available area and productivity of industrial plantations of commercial species, the present net growth of 84 million m^3 annually would be overtaken by reductions due to deforestation alone within 12-14 years, a shorter period than the growing cycle of most industrial plantations (FAO, 2000). Forest plantations grown to supply raw material for industry and for other uses, such as fuelwood. They also provide additional non-wood forest products and benefits from the trees planted or from other elements of the ecosystem that they help create. They contribute environmental, social, cultural and economic benefits (Carle *et al.*, 2002).

The potential for forest plantations to partially meet the demand for wood and fiber for industrial uses is increasing. In several countries, a significant portion of the wood supply for industrial uses comes from plantations, rather than natural forest resources. A majority of timber production is harvested from currently available natural forest. Globally, an estimated 3354 million m^3 is removed from the world's forests of which 56 per cent is fuelwood. Fuelwood is most significant in Asia and Africa while industrial roundwood production is heavily concentrated in North America, Asia and Europe (FAO, 2000). The global forest plantation estate has increased from 17.8 million hectares in 1980 and 43.6 million hectares in 1990 to 187 million hectares in 2000. Although in

2000, 26 per cent of plantations continued to be for unspecified purposes, there was a significant increase in plantations for industrial purposes in the past decade, from 39 per cent in 1980 and 36 per cent in 1990 to 48 per cent in 2000. There has been a corresponding decrease in forest plantations for non-industrial purposes (*Carle et al.* 2002).

FAO (2001) reported that 326,007 hectares of mahogany plantations have been established in 18 countries of the world. The main plantation area occurs in Indonesia (187,500 ha), Fiji (42,000 ha), Philippines (34,000 ha) and Mexico (21,400 ha). Sri Lanka, Bangladesh, Solomon Islands, Guadeloupe and Samoa have already been planted with 33,300 hectares (10.21 per cent of total) and another nine countries have been planted with 7807 hectares (2.4 per cent).

Forest plantations make up only 3.5 per cent of the global forest area and tropical plantations, including those of Meliaceae species, which make up 45 per cent of the estimated 187 million hectares of plantations. The role of planted forests in increasing forest areas, including trees on farms and trees outside the forests, is very important in order to meet the rising demand for wood and non-wood products and ecological services, including carbon sequestration. In countries with low forest cover, the planted forests are an option for rehabilitating degraded areas and, where possible, the base for re-establishing natural forests. The planted forests will be established taking into account all the practicable steps to avoid replacing natural communities and ecosystems of high ecological, economic, social and cultural value.

In the case of mahogany, the density of trees in nature is an average of one tree per hectare (Patiño, 1987; Snook, 1993; Snook, 1996; Patiño, 1997) and the final density of mahogany trees in Mexico in a 25-year rotation length, is on average 250 trees per hectare. In that case, one hectare of plantation corresponds to 250 hectares of natural forests. This shows the importance of promoting forest plantations in previously deforested lands to produce wood to meet rising demand and help the protection of natural forests.

Initiatives to regulate the use and Conservation of Mahogany

For several decades FAO has made increasing efforts to link national, regional and international institutions in order to facilitate and promote better knowledge, management and use of mahogany genetic resources. Several years ago, the FAO Panel of Experts on Forest Genetic Resources included mahogany (*Swietenia macrophylla* King) improvement and genetic conservation as one of its priorities. FAO (1994, 1997, 2001) noted that *in situ* conservation is a high priority and it has suggested strengthening activities to carry out studies on genetic diversity and promote improvement and *ex situ* conservation.

In neotropical regions, where mahogany naturally occurs, national and regional institutions, as well as non-governmental organisations work to improve the knowledge, enhance management, use and conservation of mahogany genetic resources. These efforts are carried out in collaboration with international organisations and governmental institutions of all the countries. Central American countries are working jointly to deal with common issues to strengthen regional integration in environmental matters, with the aim of promoting a regional approach oriented towards economic, social and ecological sustainability. One of these efforts is the Comisión Centroamericana de Ambiente y Desarrollo (CCAD) (Central American Commission for Environment and Development). The organisations act on a regional basis and aim at harmonising policies and management systems and promotes like-minded positions in all extra-regional and world fora. One of the most important projects developed under the umbrella of CCAD is the study carried out on the biological corridor in Mesoamerica, as well as issues related to species that have a conservation interest, such as mahogany.

Several non-governmental organisations, both national and international are also present in the region. These organisations have, as part of their most important mandate, to obtain information on the status, management, use and commercialisation of wildlife species, and to give more emphasis to those related to the CITES Convention. These organisations are the World wide Fund for Nature (WWF) and the World Conservation Union (IUCN) which jointly manage the programme TRAFFIC, established to regulate the trade of plants and animals and thus monitor wildlife trade in the world. TRAFFIC works in cooperation with the CITES Secretariat.

Since the 1990s, attempts have been made to include mahogany in the Appendix lists of CITES. These attempts were based on studies carried out by several authors, who have analysed the deforestation rates within the geographical distribution area in the neotropicall regions, as well as the commercialisation and general state of the species. In 1994 a proposal was presented to include *Swietenia macrophylla* King in Annex II of CITES, but it was rejected by CITES parties. In 1997, the proposal made by Bolivia and the United States to include this species in Appendix II of CITES was rejected by few votes. Nevertheless, the most notorious agreement was reached in 1997 by exporting countries like Brazil and Bolivia and the largest importer country, the United States, to create a working group in order to examine the state, management and trade of this species along all of its geographic distribution areas.

Other countries belonging to the distribution area where mahogany grows expressed their support for this initiative. Bolivia, Brazil and Mexico also engaged to include their mahogany logging practices in accordance with Appendix III of CITES. Bolivia has included its mahogany population in Appendix III, as of 19 March 1998. Brazil also adopted this decision on 26 July 1998. Mexico included mahogany in Appendix III in November 1997. The working group on mahogany, integrated by governmental organisations of countries belonging to the geographical area of mahogany distribution and importer countries, as well as non-governmental organisations working in the domain of conservation of natural resources, is currently working to develop text and content to present a renewed proposal to include mahogany in Appendix II of CITES, during its meeting in Chile in 2002.

PROSPECTS

The overexploitation of *Khaya senegalensis* for timber, fodder and medicine is a serious threat for many of its populations. Therefore, sustainable methods of harvesting should be established and implemented as soon as possible. However, much research is still needed to realise this, whereas the environmental conditions and traditional land use are complications that should be considered. The fair growth rate under appropriate conditions makes extensive establishment of plantations an option, but *Hypsipyla* attack is a serious drawback. The combined effects of selection of provenances with genetic resistance and appropriate silvicultural practices could have a substantial positive impact on the damage caused by *Hypsipyla robusta* stem borers. Research priority should be given to range-wide selection of genotypes which are resistant to stem-borer attack, are fast-growing and have acceptable wood quality. The establishment of appropriate methods of vegetative propagation including tissue culture is urgently needed. The bark demonstrated several interesting pharmacological properties, such as antimalarial, anti-inflammatory and anticancer effects. This deserves more research attention for possible development into new drugs. The insecticidal and anthelmintic activities of the bark are also noteworthy.

Mohagany plantation can enrich the soil by increasing the chemical characteristics of the soil [the soil pH, Ca, Mg, base saturation, total exchangeable base (TEB) and Cation Exchange Capacity (CEC), organic carbon, organic matter and organic N] for soils sampled from mixed mahogany plantation stands when compared to the adjacent unreforested degraded site. Mixed plantation of African mahogany species could be used as a tool to catalyse natural regeneration and to facilitate restoration of degraded forest ecosystems in Ghana. (Danquah *et al*. 2012). Deforestation activities are key factors threatening the extinction of species within the ecosystem, including flag species such as Dark - Brown Iris and the Beersheba Fringe-fingered Lizard.

CONCLUSION

From a historical point of view, mahogany has undergone many stages of degredation. This is due to, on one side, the advantages that the species has with regard to its wood colour and homogeneous wood grain, and on the other, its friendly processing properties that allow excellent finishing. A large part of mahogany genetic resources, with few exceptions, is in danger. It is, therefore, urgent to make a joint effort to decrease deforestation as much as possible and to include clear guidelines in forest management and use plans that allow concrete conservation of genetic resources.The knowledge of genetic diversity and the factors linked to the reproduction of the species will enable researchers to take some important measures to achieve its natural regeneration. These include conservation of the number of individuals necessary to maintain appropriate levels of allogamy and crossing; identification of the most adequate distance between parent trees in order to effectively achieve those results; pollen and seed

dispersion patterns and other aspects that allow maintenance of genetic diversity and avoid endogamy in fragmented populations.

REFERENCES

Agboyi, L.K., Djade, K. M., Ahadji-Dabla, K. M., Ketoh, G. K., Nuto, Y. and Glitho, I. M. (2015). Vegetable production in Togo and potential impact of pesticide use practices on the environment. *International Journal of Biology and Chemical Science*, 9(2): 723-736. DOI: http://dx.doi.org/10.4314/ijbcs.v9i2.13

Arbonnier, M. (2004). *Trees, shrubs and lianas of West African dry zones*. CIRAD, Margraf Publishers Gmbh, MNHN, Paris, France. 573 p.

Arguelles, A. (1999). Diagnóstico de la caoba en Mesoamérica: México. Centro Científico Tropical. PROARCA/CAPAS.

Bello, D.O., Ahoton, L.E., Saidou, A., Akponikpè, I. B., Ezin, V.A., Balogoun, I. and Aho, N. (2017). Climate change and cashew (*Anacardium occidentale L.*) productivity in Benin (West Africa): Perceptions and endogenous measures of adaptation. *International Journal Biology and Chemical Science,* 11(3): 924-946.

Botha, J., Witkowski, E.T. F. and Shackleton, C.M. (2004). The impact of commercial harvesting on *Waburgia salutaris* (“pepper-bark tree‟) in Mpumalanga, *South Africa*. *Biodiversity and Conservation* 13(9): 1675–1698. DOI: https://doi.org/10.1023/B:BIOC.0000029 333.72945.b0

Carle, J., Vourinen, P. and Del Lungo, A. (2002). Status and trends in global forest plantations development. *Forest Products Journal*, 52(7), 2-13.

Danquah, J.A., Appiah, M. and Pappinen, A. (2012). The effect of African mahogany species on soil chemical properties in degraded dry semi-deciduous forest ecosystems in Ghana. *International Journal of Agricultural Biology*, 14: 321–328.

Emanuel, P. L., Shackleton, C.M. and Baxter. J. S. (2005). Modelling the sustainable harvest of *Sclerocarya birrea subsp*. caffra fruits in the South African lowveld. *Forest Ecology and Management*, 214: 91–103. DOI: https://doi.org/10.1016/j.foreco. 2005.03.066.

FAO (1994). Informe: Cuadro de Expertos de la FAO en recursos genéticos forestales. Octava Reunión. FO: FGR/8/Rep. Roma, Italia, 28-30 de junio de 1993. 57p.

FAO (1997). Informe: Cuadro de Expertos de la FAO en recursos genéticos forestales. Novena Reunión. FO: FGR/8/Rep. Roma, Italia, 28-30 de junio de 1996. 57p.

FAO (1997a). *FAO Yearbook: Forest Products*, 1995. Food and Agriculture Organisation of the United Nations, Rome, 442 p.

FAO (2000). Global Forest Products Outlook Study: Thematic Study on Plantations by C. Brown. Working Paper No. GFPOS/WP/03. Food and Agriculture Organisation of the United Nations, Rome, 129 pp.

FAO (2001). Situación de los Bosques del Mundo 2001. Organización de las Naciones Unidas para la Agricultura y la Alimentación, Roma, Italia

FAO (2002). Global Forest Resources Assessment 2000, Main Report, FAO Forestry Paper N.140, Food and Agriculture Organisation of the United Nations, Rome, Italy.

García-Cuevas, X., Negreros, C.P. and Rodríguez-Santiago, B. (1993). Regeneración natural de caoba (*Swietenia macrophylla King)* bajo diferentes densidades de dosel. Ciencia Forestal en México, INIFAP, Coyoacán, 18 (74): 25 - 44.

Gaoue, O.G. and Ticktin, T. (2007). Patterns of harvesting non-timber forest product from the multipurpose tree, *Khaya senegalensis in Benin*: Variation across climatic regions and its impacts on population structure. *Biological Conservation*, 137, 424-436.

Gaoue, O. G. and Ticktin, T. (2016). Fulani Knowledge of the Ecological Impacts of Khaya senegalensis (Meliaceae) Foliage Harvest in Benin and its Implications for Sustainable Harvest. Economic Botany, 63: 256-270 DOI: 10.1007/s12231-0099091-6.

Gbesso, F. H.G., Tente, B. H. A., Gouwakinnou, N. G. and Sinsin, B. A. (2013). Influence des changements climatiques sur la distribution géographique de Chrysophyllum albidum G. Don (Sapotaceae) au Benin. *Int. J. Biol. Chem. Sci.*, 7(5): 2007-2018. DOI: http://dx.doi.org/10.4314/ijbcs.v7i5.18

Glèlè Kakaï, R. and Sinsin, B. (2009). Structural description of two Isoberlinia-dominated communities in the Wari-Maro forest reserve (Benin). *South African Journal of Botany*, 75(1): 43–51.

Gullison, R. E. Y. and Hardner, J.J. (1993). The effects of road design and harvest intensity on forest damage caused by selective logging: Empirical results and a simulation model from The Bosque Chimanes, Bolivia. Forest Ecology and Management, 59 (1-2): 1-14.

Hounkpèvi, A., Tosso, F., Gbèmavo, D.S.J.C., Kouassi, E. K., Koné, D. and Glèlè Kakaï, R. (2016). Climate and potential habitat suitability for cultivation and *in situ* conservation of the black plum (*Vitex doniana* Sweet) in Benin, *West Africa. International Journal Agricultural Research*, 8: 67-80.

Kageyama, P.Y. (1991). Extractive reserves in brasilian Amazonia and genetic resources conservation. Tenth World Forestry Congress, September, Paris

Lemmens, R. H. M. J. (2008). Khaya ivorensis A. Chev. In: Louppe, D., Oteng-Amoako, A.A. & Brink, M. (Editors). PROTA (Plant Resources of Tropical Africa /Resources vegetables de l'Afrique tropicale), Wageningen, Netherlands. Accessed 11 April 2019.

Lykke, A.M., Kristensen, M.K. and Ganaba, S. (2004). Valuation of local use and dynamics of 56 woody species in the Sahel based on 100 ethnobotanical interviews. *Biodiversity and Conservation*, 13:1961-1990.

Makova, S., Dufresne, F., Manca, M. and Kotlik, P. (2011). Carbon exchange between ecosystems and atmosphere in the Czech Republic is affected by climatic factors. *Environment and Pollution*, 159 (5): 1023-1460.

McClean, C.J., Lovett, J.C., Küper, W., Hannah, L., Sommer, J. H., Barthlott, W., Termansen, M., Smith, G. F, .Tokumine, S. and Taplin, J.R.D. (2005). African plant diversity and climate change. *Annals of the Missouri Botanical Garden*, 9(2): 139-152.

Negreros Castillo, P. and Mize, C. (1993). Effects of partial overstory removal on the natural regeneration of a tropical forest in Quintana Roo, México. *Forest Ecology and Management, 58 (3-4): 259-272*.

Orwa, C. A., Mutua, K. R., Jamnadass, R. and Anthony, S. (2009). Agroforestree Data base: A tree reference and selection guide version 4.0 (http://www.worldagroforestry.org/sites/treedbs/treedatabases.asp)

Owens, H. L., Campbell, L.P., Dornak, L.L., Saupe, E.E., Barve, N., Soberón, J., Ingenloff, K., Lira-Noriega, A., Hensz, C.M., Myers, C.E. and Peterson, A.T. (2013). Constraints on interpretation of ecological niche models by limited environmental ranges on calibration areas. *Ecological* Modelling, 263:10–18. DOI: https://doi.org/10.1016/j.ecolmodel.2013 .04.011.

Pamlin, D. and Armstrong, S. (2015). Twelve risks that threaten human civilisation – The case for a new category of risks. Report for the Global Challenges Foundation.

Patiño, V.F. (1987). Los inventarios forestales y la conservación *in- situ* de los bosques tropicales. In: Lund, H.G. *et al.*, Evaluación de tierras y recursos para la planeación nacional en las zonas tropicales. Gen. Tech. Rep. WO-39. 99-104, Washington, USDA, FS.

Patiño, F. (1997). Genetic resources of *Swietenia* and *Cedrela* in the neotropics: Proposals for co-ordinated action. Food and Agriculture Oganisation of the United Nations, Rome, Italy.

Rodríguez, S.B., Chavelas, P.J. and García, C.X. (1994). Dispersión de semillas y establecimiento de caoba (*Swietenia macrophylla*) después de un tratamiento mecánico del sitio. In: Snook, K.L. y Barrera, A. (Editor as) Madera, Chicle, Caza y Milpa. Contribuciones al manejo integral de las selvas de Quintana Roo, México: 81 - 90.

Saliou, A. R. A., Oumorou, M. and Sinsin, A. B. (2014). Variabilités bioclimatiques et distribution spatiale des herbacées fourragères dans le Moyen-Bénin (Afrique de l‟Ouest). Int. J. Biol. Chem. Sci., 8(6): 2696-2708. DOI: http://dx.doi.org/10.4314/ijbcs.v8i6.29.

Snook, L. K. (1993). Stand dynamics of mahogany (*Swietenia macrophylla* King) and associated species after fire and hurricane in the tropical forest of the Yucatan Peninsula, Mexico. Doctoral Dissertation. Yale School of Forestry and Environmental Studies. University Microfilms International 9317535, Ann Arbor, MI, USA.

Snook, L.K. (1996). Catastrophic disturbance, logging and the ecology of mahogany (*Swietenia macrophylla* King): grounds for listing a major tropical timber species in CITES. *Botanical Journal Linnean Society* 122:35-46.

Sokpon, N. and Ouinsavi, C. (2002). Utilisations du *Khaya senegalensis* en médecine traditionnelle au Bénin. Revue de Médecine et Pharmacopée *Africaine*, 16:9-16.

Sokpon, N. and Ouinsavi, C. (2004). Gestion des plantations de *Khaya senegalensis* au Bénin, Bois et Forêts des Tropiques, 279(1): 37-46. DOI: https://doi.org/10.19182/bft2004.279.a20 247.

Sosef, M. S. M., Hong, L.T. and Prawirohatmodjo, S. (eds.). (1998). PROSEA 5(3) Timber trees: lesser known species. Backhuys Publishers, Leiden.