FUTURE CLIMATE AND LAND USE IMPACTS ON THE GEOGRAPHIC DISTRIBUTION AND CONSERVATION OF *KIGELIA AFRICANA* IN BENIN, WEST AFRICA

BY

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MTech/SPS/2015/6070

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THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF TECHNOLOGY (MTECH) IN CLIMATE CHANGE AND ADAPTED LAND USE

MARCH, 2018

DECLARATION

I hereby declare that this thesis titled: "**Future Climate and Land Use Impacts on the Geographic Distribution and Conservation of *Kigelia africana* in Benin, West Africa"** is a documentation of my original research work and it has not been presented for any other qualification anywhere. Information from other sources (published or unpublished) has been duly acknowledged.

GUIDIGAN Gildas Landry Mèminvègni ……………………………….

MTech/SPS/2015/6070 SIGNATURE & DATE
FEDERAL UNIVERSITY OF TECHNOLOGY,
MINNA, NIGERIA.

CERTIFICATION

The thesis titled: "**Future Climate and Land Use Impacts on the Geographic Distribution and Conservation of *Kigelia africana* in Benin, West Africa**" by GUIDIGAN Gildas Landry Mèminvègni, (MTech/SPS/2015/6070) meets the regulations governing the award of the degree of Master of Technology (MTech) of the Federal University of Technology, Minna and it is approved for its contribution to scientific knowledge and literary presentation.

Prof. A. A. Okhimamhe ……………………………
Major Supervisor Signature & Date

Prof. A. A. Okhimamhe ……………………………
Director WASCAL, FUT Minna Signature & Date

Prof. M.G. M. Kolo ……………………………
Dean, Postgraduate School Signature & Date

DEDICATION

I dedicate this research work to the Supreme God and to my family especially, my loving daughter and her late mother, to my mother and to my late father who departed during my field work.

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ABSTRACT

*Kigelia africana (*Bignoniaceae) is a Non-Timber Forest Products (NTFPs) that makes major contribution to the subsistence of West Africa household through their multiple purposes (medicinal, nutritional, economic and socio-cultural). However, these ecosystem services are threatened by climate and land use change. Data collection and household survey were performed in Benin, West Africa, to assess the species distribution and use. Current and future (CNRM-CM5 and HadGEM2-ES model base on RCP 8.5 by 2050 time horizons) climate data were retrieved from WorldClim, Soil layer from World Soil Database version 1.2 and Climate Change Initiative Land Cover (CCI_LC) maps of 1992, 2003 and 2015 from the European Space Agency (ESA). Additionally, MaxEnt species distribution modelling (SDM) was used to model species ecological niche in combination with a Geographic Information System (GIS). The modeled occurrence areas of *K. Africana* was implemented based on a total of 466 species records, from which 416 were collected on the field and 50 from the National Herbarium of Benin. Seventy one (71) households were interviewed using a semi-structured questionnaire for ethnobotanical and socio-economic studies which were analysed using quantitative ethnobotanical methods. Principal Component Analysis (PCA) with R software was also applied to describe the use value and use forms of *K. africana* according to different tribes. The maps obtained from the model were overlaid on the existing protected areas network. The result depicted that 52% of the national area and 81 % of the national protected area network were found to be highly suitable for the cultivation and conservation of *K. Africana* and the greater part of the distribution of the species is expected to remain largely stable in Soudano-guinean zone and Guinean zone with some exception in the Soudanian zone. Despite the expansion and retraction in *Kigelia africana* species, the relationships with protected areas networks suggest that protected area networks of species distribution will also remain stable. All these corroborates with the assessment of CCI-LC map obtained. For the economic uses three categories were identified (Medicinal, Charcoal and Firewood).The result reflects that for *K. africana* medicinal use is more cited. The economical use value of the different parts of the *K. africana*, showed that the fruits (50 %) are sold more than the bark (29.17 %) followed by the leaf 16.67 % while the root has the lowest percentage of 4.17 %. Ethnobotanical Use Values (EUVt), the bark is more mentioned (100 %) by all the socio-cultural groups; the fruit 93%, leaf 86%, flower 14% and root 8% only in medicinal and magic uses; and contribution to yearly cash income ranging from 4.17 % to 50 %. Further development and research on *K. Africana* should be enhanced in order to conserve the genetic diversity within and among the population and also to expand the market channels to have more assess on the economic value of *K. africana*.

TABLE OF CONTENT

LIST OF FIGURES

Figure **Page**

LIST OF TABLES

LIST OF PLATES

LIST OF ABBREVIATIONS

ANN	Artificial Neural Network
AVHRR	Advanced Very High Resolution Radiometer
CCI	Climate Change Initiative
CNRM-CM5	Centre National de Recherches Météorologiques-Coupled Model Intercomparison Project phase 5
ENM	Ecological Niche Modelling
ESA	European Space Agency
FAO	Food and Agricultural partsisation
FCC	False Color Composite
FR	Full Resolution
GAM	Generalised Additive Models
GHG	Greenhouses Gas
GIEC	Groupe d'experts Intergouvernemental sur l'Evolution du Climat
GIS	Geographic Information System
GLM	Generalised Linear Model
GPS	Geography Position System
HadGEM2-ES	Hadley Centre Global Environment Model version 2
HSI	Habitat Suitable Index
LC	Land Cover
LCCS	Land Cover Classification System
LS	Land Surface
LULCC	Land Use Land Cover Change
MEHU	Ministère de l'Environnement de l'Habitat et de l'Urbanisme
MERIS	Medium Resolution Imagery Spectrometer
MLPNN	Multi-Layer Perception Neural Network
NTFP	Non-Timber Forest Product
PROBA-V	Project for On-Board Autonomy with the V Standing for Vegetation
RR	Reduced Resolution
SDM	Species Distribution Model
SPOT-VGT	SPOT Vegetation
UTM	Universal Transverse Mercator
WGS	World Geodesic System

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

The entire globe for the last 30 years, has experienced climate change through increased temperature and decrease in the number and length of rainfall. West African countries are among the most affected regions (Dotchamou *et al*., 2016). In addition, while changes in tropical climate such as rise in the average temperature are now clearly established, some other parameters as rainfall are subjected to less clear or contradictory forecasts Guibert *et al*., (2010). Climate change is nowadays distinguished as one of the major threats on species survival and the integrity of the ecosystems around the world. Specific properties knowledge of these changes, which may have some impact on species or their habitats, is a pivotal element of adaptation strategies (Fandohan *et al*., 2013). Indeed, it is more and more likely that fluctuations of climate variability will affect biodiversity and the geographical distribution of species (Treut *et al*., 2007). Geographical distribution of plant species is driven by the complex interaction of climatic elements, soil attribute component with biotic agents, and dissemination restriction (Fandohan *et al*., 2013).

Land use and Land cover change (LULCC) is a strong indicator of ecosystems disturbances and global change process especially in the tropics (Aboubakar, 2015). It is probably the major effect of regional anthropogenic and natural distress to the environment. LULCC is an important factor that affects different processes and changes in environment through management and its power to affect biodiversity, water budget, carbon cycling, gas emissions and livelihoods.

During the last millennia, West African community, mainly rural housekeeping has depended on goods and services supply by the biodiversity. The products of indigenous plant species (bark, root, leaves, and fruits) have played significant role in comforting women socio-economic activity and household subsistence needs, such as medicinal uses, nutrition and energy supply among others (Heubes *et al*., 2012). using

1.2 Statement of Research Problem

Kigelia africana is an important medicinal tree exploited by both rural household and the industrial sector in the world. The increasing population growth, the anthropogenic activities linked to land use increase, the pollution and the effect of climate change have since the 20th century, put high pressure on the ecosystems especially *Kigelia africana species*. This pressure makes them unbalanced and vulnerable and causes their degradation (Neuenschwander *et al*., 2011; Djonlonkou, 2014). In addition, some biological species are decreasing and have been classified under the International Union for Conservation of Nature (IUCN), and or national red lists of vulnerable species. *Kigelia africana* is classified as vulnerable in Benin (Neuenschwander *et al*., 2011). The main threats on the species reduction are also included relic forest size, change in land use (loss of habitats due to extensive agriculture, the destruction of natural habitats due to urbanization, the exploitation of wood and the excessive harvesting of medicinal plants).

1.3 Aim and objectives

The study aimed to examine the potential impact of climate change and land use change on the geographic distribution of desirable habitats for cultivation and conservation of *Kigelia africana* in Benin.

The specific objectives of the study were to:

i. model the current and future distribution of suitable habitats for the cultivation and conservation of *Kigelia africana* in Benin,

ii. examine the effectiveness of the current network of protected areas in Benin to conserve *Kigelia africana* by 2050,

iii. evaluate the effect of land use change on the geographic distribution of *Kigelia africana* and

iv. assess the socio-cultural and economic importance of *Kigelia africana* in Benin.

1.4 Research question

In order to achieve these objectives, the following research questions were used as guides:

i. What could be the current and future distribution of suitable habitats for the cultivation and conservation of *Kigelia africana* in Benin?

ii. How effective will be the current network of protected areas in Benin for conservation of *Kigelia africana* by 2050 ?

iii. How did land use change impact the geographic distribution of *Kigelia* *africana*?

iv. How important is *Kigelia africana* to the socio-culture and economy of households in Benin Republic?

1.5 Justification of the study

Although many research works have been carried out in the past, most of them concentrated largely on he health benefits of *Kigelia africana.* Literature could be found in Owolabi *et al*. (2007); Olatunji and Olubunmi (2009); Azu (2013); Eyong *et al*. (2013); Atawodi and Olowoniyi (2015); Bello *et al*. (2016) There are little or no research on the economic, ethnobotanical and species distribution aspects. Thus, the motivation of this research which also feel that gauging the knowledge of the locals could go a long way towards enhancing the biodiversity conservation of *K. africana*.

For this reason, the research deemed it necessary to assess the knowledge of the local people on the production, conservation and distribution of *K. africana*. Furthermore, with the knowledge on the effects of climate variability on *K. africana*, this study provides discreet model to assess the suitable areas for the production and conservation of *K. africana*. For Endogenous knowledge is an essential component of local biodiversity conservation (Pilgrim *et al*., 2007). Likewise, information on the traditional forms of use of each parts of *K. africana* is important for a better valuation and conservation by local population and even by the scientists.

1.6 Scope and limitation of the Study

The present study focused on three aspects: modelling the future climate impact on the geographical distribution of *K. africana.* Assessing the socio-cultural and economic importance of *Kigelia africana* for household and finally, assessing the LUC impact on the species distribution.

1.7 Description of Study Area

1.7.1 Geographical location

The work was conducted in Benin Republic (West Africa). (6° -12° N, 0.4° -3° E). Benin Republic is located in the Dahomey Gaps, a corridor of savannah ecosystems inter-cropping the West Africa block of evergreen forests (0° - 3° E), due to climate changes during the Holocene. It covers three climatic zones in Benin: the semi-arid, the dry sub humid, and the sub humid geographical region. Thus, this research was conducted across the country (114 673 km²). Table 1.1 summarizes the different climatic zones and their characteristics. Benin Republic is characterized by ten (10) phytogeographical districts and seventy-seven (77) administrative districts (Fandohan *et al*., 2013).

1.7.2 Climate

The Sudanian region (9°45'–12°25' N) part of Benin is characterised by uni-modal rainfall. Average yearly precipitation is frequently lower than 1000 mm, the relative humidity ranges from 18 % to 99 % (highest in August) with a minimum temperature of 24°C and a maximum temperature of 31 °C. In the Sudano-Guinean region (7°30'–9°45' N), rainfall is uni-modal and starts from May and ends in October lasting for about 113 days with a yearly total range rainfall from 900 mm to 1110 mm. Mean yearly temperature is between 25 °C and 29 °C, whereas relative humidity is approximate between 31 % and 98 %. Rainfall in the Guineo-Congolian region (6°25'– 7°30' N), is bimodal with an average of 1200 mm. Average yearly temperature ranges from 25 °C to 29 °C and the relative humidity ranges from 30% and 98% (Fandohan *et al*., 2013).

The Northern part of the Benin Republic has a continental tropical climate with both a dry and rainy season; and the southern part has a sub-equatorial climate, with two rainy and two dry seasons. Mean annual rainfall is often less than 1000 mm, the relative humid it varies between 18% and 99% (highest in August) and temperature varies between 24 °C and 31 °C. Over the last two decades, the rainfall patterns occasionally fluctuate in the midst of the seasons (MEHU, 2011).

1.7.3 Water resources

Water resources in Benin's Republic are composed of surface water and groundwater. The surface water resources are distributed through six watersheds, grouped into four major hydrographic units the hydrographic sets of the Niger River, Ouémé-Yeoua, Volta and Mono-Couffo. The annual potential for surface water is estimated at 13.106 billion m^3. Discontinuous aquifers in the rocky region and continuous aquifers are the predominant sources of groundwater, covering 80 and 20 percent, respectively, of the total area of Benin. The total annual recharge of both aquifers is 1.87 billion m^3 of water (MEHU, 2011).

1.7.4 Soil

About the soil, there are five main soil categories in Benin and they include: (1) lateritic soils (7 to 10 percent of the country's area); (2) tropical ferruginous soils (82 percent of the total land area according to MAEP, 2002); (3) raw mineral soils, less evolved and developed than hard materials (granito-gneiss and schist); (4) hydromorphic soils, which are found in the delta of Ouémé, along the Niger River and Pendjari River, and in the valleys of Mono and Couffo; and (5) ‘vertisols’ usually found in the Lama depression (Table 1.1). Land degradation is a problem in Benin due a combination of physical (erosion) and anthropogenic (destruction of vegetation, poor agricultural practices) factors (MEHU, 2011).

Table 1.1: Climatic zones and their characteristics

	Guineo Congolian	**Sudano-Guineoan**	**Sudanian**
Average rainfall (mm/year)	1200	1200	675
Temperature range (oC)	18-33	20-36	24-31
Relative humidity range (%)	30-98	31-98	18-99
Climate type	Sub-humid	Sub-humid	Sudanian dry
Soil type	Ferralitic without concretions	Ferralitic with concretions	Ferruginous on sedimentary rocks

Source: Author's compilation (2017)

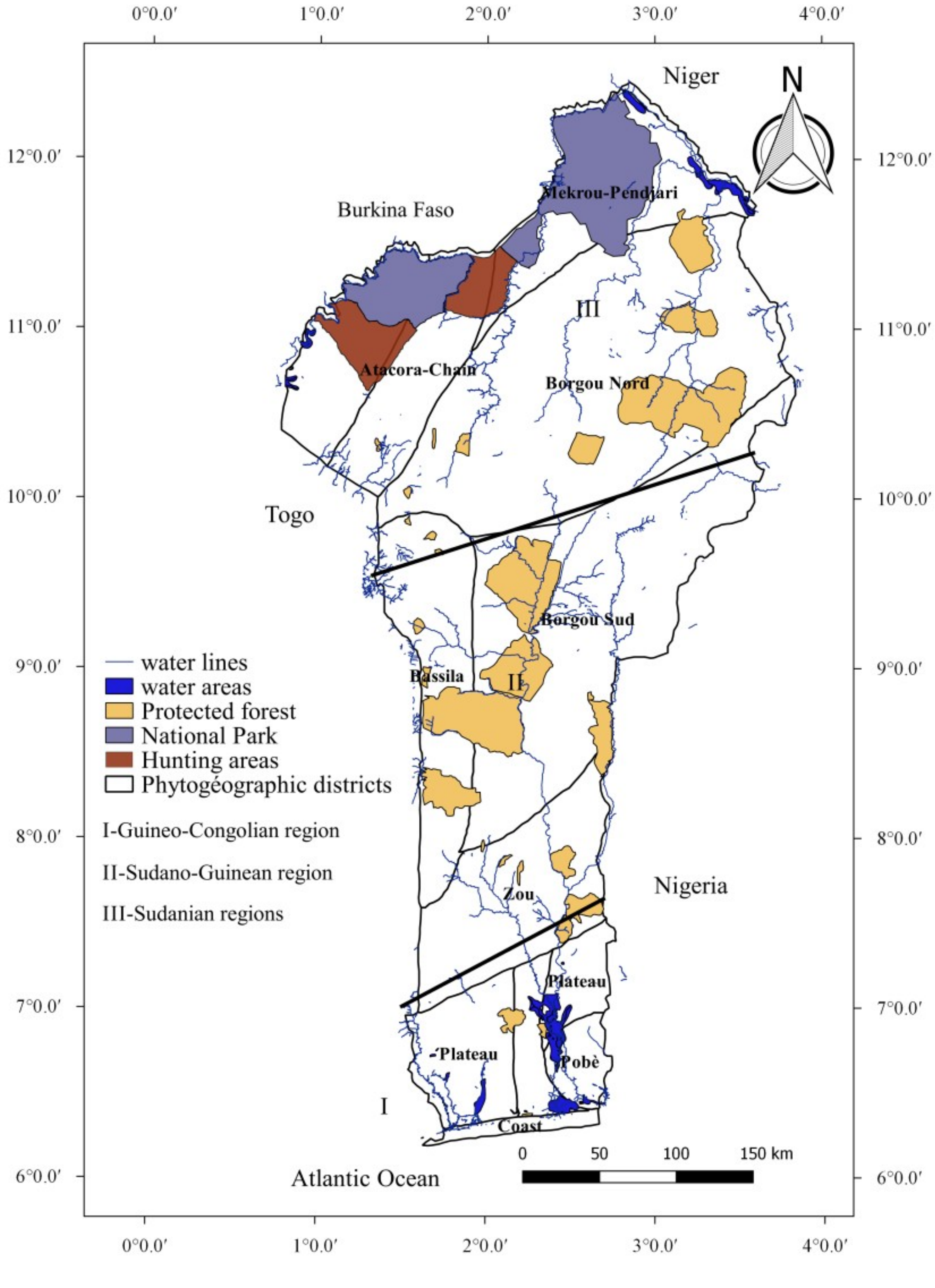


Figure 1.1: Benin Republic showing different climatic region, classified forest, the National park and the hunting areas

1.7.5 Vegetation and fauna

In terms of biological resources, the primary forest formations found in Benin are mainly woodlands and Savannahs (centre and northern parts), and semi-deciduous and deciduous rain forests (southern parts). The protected areas are divided into two (2) National Parks (869,867 ha), three (3) hunting zones (443,679 ha), 46 classified forests (1,302,863 ha), 7 reforestation areas, and sacred forests covering about 0.2 percent of the territory. The fauna is quite diverse and contains several species of mammals, reptiles, birds and invertebrates (MEHU, 2011).

1.7.6 Socio-economic activities

Benin Republic is a developing country with an economy that is mainly based on the primary and tertiary sectors. It is marked by a change in gross domestic product (GDP) ranging from 2 to 6 percent during the period 1990 to 2010. The population of Benin increased from 4,915,555 inhabitants in 1992 to 6,769,914 inhabitants in 2002, with an average population density of 59 inhabitants/km^2 (INSAE, 2014), and an annual average population growth of 3.25 percent. The Fourth General Population and Housing Census, carried out from 11 May to 31 May 2013, recorded 9,983,884 residents of both sexes, including 5,115,704 women, i.e. 51.2 per cent of the total population, which corresponds to a sex ratio of 95.3 men per 100 women (MEHU, 2011).

1.8 Knowledge on *Kigelia africana*

1.8.1 Density and distribution

Kigelia africana tree was first discovered in Africa's wet Savannah woodland and propagated into gallery woodland along rivers in moist forests likewise in clear timber land and in riverine periphery where it happen at depression altitudes (Orwa *et al*., 2009). The tree is found along riversides, where it may reach a height of 20 m, along streams and on floodplains. *Kigelia africana* distributed throughout tropical Africa, peculiarly in the drier zones (Azu, 2013). It is also found in different parts of Africa. The countries which this plant is found are: Angola, Benin, Botswana, Burkina, Burundi, Cameroon, Caprivi Strip, Central African Republic, Chad, Congo, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Gulf of Guinea Island, Ivory Coast, Kenya, KwaZulu-Natal, Liberia, Malawi, Mali, Mozambique, Namibia, Niger, Nigeria, Northern Provinces, Rwanda, Senegal, Sierra Leone, Somalia, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia, Zaïre, Zimbabwe, however, it is not found Mauritania, São Tomé and Principe, or the Indian Ocean islands. In Cape Verde, Madagascar, Iraq, Pakistan, India, China, South-East Asia, Australia, Hawaii and Central and South America, the tree is introduced for decoration (Bello *et al*., 2016b). The Figure 1.2 shows the geographic distribution of *Kigelia africana* throughout the Africa.

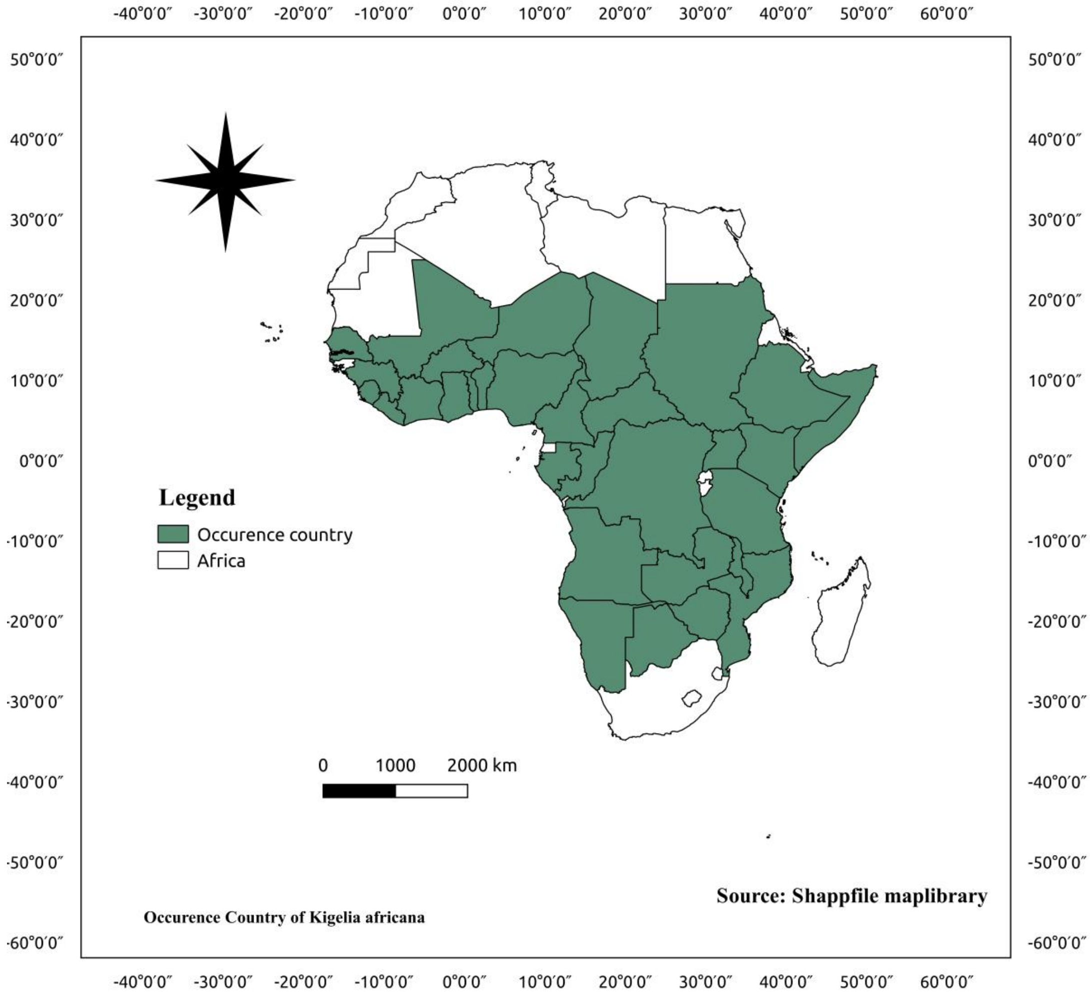


Figure 1.2: Distribution of *Kigelia africana* in Africa [adopted from (FAO, 1986) with authors modification]

1.8.2 Description of *K. africana* tree, fruit, and seed

The height of *K. africana* can be taller than 20 m , the bark is about 5 mm thick and is usually coloured in grey at first spoon but develop skin on more mature trees. The bark can be as thick as 5 mm. The wood is pale brown or yellowish in colour, and not prostate to snap (Roodot, 1992). The leaves are opposite or in whorls of 30 to 50 cm in length, pinnate, with six to ten oval leaflets each up to 20 cm in length and 6 cm wide. It is noticed that birds/insects drew the flowers using the strong stems as bridgehead. Flowering occurs from August to November and their scent being most noticeable during night. For this reason, bats visit them for pollen and nectar, which is an indication of their reliance on pollination. Flowers are heterosexual, with curved; pedicel at the tip that can be as long as 11 cm (Azu, 2013).

Its has large, Grey-brown fruits, weighing 4 to 10 kg and ligneous berry that is about 18 cm wide and 30 to 100 cm long (Azu *et al*., 2010). The fruit is sinewy and squashy, holding many hard seeds, uneatable to Man but wild animals like baboons, bush pigs, monkeys, porcupines, savannah elephants, giraffes and hippopotamus eat the fruits or seeds thus spreading the seeds via their dungs. However, Owolabi *et al*. (2007) reported that the seeds were roast and eaten by humans in Malawi during the famine.

Plate II: Tree of *Kigelia africana* which bark are extracted for some purposes

Plate II: Leaves and fruit of *Kigelia africana tree*

Plate I: *Kigelia africana* tree in waterlogged environment

1.8.3 Traditional uses of *K. africana*

1.8.3.1 Medicinal uses

The tree is famous for its traditional and herbal usage, generally in the intervention of many different skin related infections such as eczema, fungal infections, psoriasis and boils and diseases such as leprosy, impetigo, syphilis and skin cancer. It is also used in the treatment of dysentery, malaria, diabetes, pneumonia, worm-infestations, venereal diseases, convulsions, toothache and as antidote for snakebite. According to Bello *et al*. (2016) the fruit is effective against all gynaecological complications.

1.8.3.2 Non-medicinal uses

K. africana has lot of uses in the African communities. Indeed, the plant is used as a traditional medicinal and for animal food. The fresh fruit is said to be poisonous to humans because of its laxative effect. In Zimbabwe, *K. africana* have sacred values; used to hunt sorceress and control black magic. In preparing witch-confession medicine, the bark is used. Bello *et al*. (2016) demonstrated that the fruit is used by the Luo tribe in western Kenya for funeral rites. *K. africana* is one of the two plants in Africa with non comestible fruit that improves soil fertility. Producers of the alcohol (*dengelua*) use the fruit as one of the ingredients. Carpenters and wood cavers also use the tree trunk for making tables, fruit boxes and bunkert canoe (Venter *et al*., 1996).

CHAPTER TWO

2.0 LITERATURE REVIEW

In this chapter some concepts such as climate change, ecological niche, Species Distribution Model (SDM), spatial description and environment, species localisation, models limitation in presence/absence of climate model, climate scenarios, motivation on scenarios choices, land-use change concept, definition of land-use land cover change, are reviewed. These concepts are very useful to the understanding of this study. Some relevant literatures cited in the present study were also reviewed. They encompass the type of model used to show the geographic distribution of *Kigelia africana* under the future climate change, the challenge of land use dynamic through, climate scenario and climate projection and land use land cover change dynamic in the future. These literatures materials helped in identifying the gaps in the current body of the knowledge.

2.1 Conceptual Framework

2.1.1 Non-Timber Forest Product (NTFPs)

FAO (2004) defines NTFPs as biological origin products, beside wood, obtained from forests, other wood land and trees outside forest. NTFPs can be harvested in the wild, in forest plantation or in agroforestry perimeters, or by trees outside forest. Several uses are derived from the NTFPs: nutritional (food additives), fibres used in the making of many other products (FAO, 2005).

2.1.2 Ecological Niche

The ecological niche is one of the theoretical concepts of ecology. It refers to the "position" of an organism, a population or, more generally, a species in an ecosystem, the sum of the conditions necessary for a viable population of that organism. The description of such a "niche" (or "ecological envelope") is based on two types of parameters physical and chemical parameters characterizing the environment in which the organism evolves (and sometimes significantly modified by this organism), and biological parameters, including relationships with neighbouring species and habitat modification by the organism and the community of species in which it occurs (sustainable interactions) (Webstar, 2015).

Hutchinson (1957) defines the ecological niche as the hyper-volume “an envelope” where each dimension of space represents a resource (food, material, spatial, hidden supply, substrates or perches) or a condition (temperature, precipitation and acidity) of the environment. The amount of resource changes in space and in time depending on the activity of the species. Resources and condition are the most limited conditions that can be prioritized to study the vulnerability of species in an environment. The same author distinguishes two kinds of niches. The first is the basic niche that contains all the components and all the environmental conditions necessary for the existence of organism. The second is the niche realized which often is included in the fundamental niche, reduced to the space. Thus, Ecological-Niche Modelling (ENM) after many research, is regarded as the most powerful means presently available for calculation of present and potential geographic ranges of species. Furthermore, ENM approach is being used more and more in preservation process and decision making (Domínguez-Domínguez *et al*., 2006). However, Hall *et al*. (1997) showed that habitat use is the source of ambiguities and inaccuracies. The first is wildlife-habitat relationships which can be placed in the proper spatial and temporal scales; the second, if wildlife ecology wants to advance, we must make sure that the fundamental concepts with which we work are well defined, and hence, well understood. The third problem identifies the use of habitat terminology which is imprecise and ambiguous. The evaluation of the quality of the habitat must be judicious to design conservation measures of biodiversity in particular to delimit priority zones for the intervention.

2.1.3 Relationship between species niche and Species Distribution Model (SDM).

The interesting question of how species (plants and animals) are distributed on Earth in location and period had been in existence for a while. This serves as motivation for many bibliographers and ecologists to find more explanations. In trying to answer this question, many researchers have employed species distribution modelling as one of their approaches. Most modelling concepts formulated for foretelling species distributions have their bases in determining the species relationship with their environment (Guisan and Thuiller, 2009).

2.1.4 Species Distribution model (SDM): What do we model with it?

Guisan and Thuiller (2009) showed that most predicted maps run by the Species Distribution Modelling present the realized niche. According to Elith and Leathwick (2009) a better understanding and/or prediction of species is provided by the model distribution used across a landscape. SDM have many term of designation: bioclimatic models, climate envelopes, Ecological Niche Models (ENMs), habitat models, Resource Selection Functions (RSFs), range maps, and more correlative models or spatial models. Moreover, Guisan and Thuiller (2005) demonstrated that three aspects appear to have starred the history of SDMs: (i) non-spatial statistical quantification of species environment relationship based on empirical data, (ii) expert-based (non-statistical, non-empirical) spatial modelling of species distribution, and (iii) spatially explicit statistical and empirical modelling of species distribution.

2.1.5 Species Distribution Model (SDM)

Elith and Leathwick (2009) defined SDM as a model which has the connection with the species dispersion information (happening or quantity at specific way-point) with some spatial characteristics and/or environmental information of those place. SDM focuses on the niche concept and the need of species, particularly on the abiotic components that influence directly species dispersion. The understanding of Habitats Suitability Index (HSI) models are usually used concomitant with species usage. HSI models derive from a connection among species existence or copiousness and environ measures for such factors as canopy cover for trees, shrubs, grasses, forbs and canopy height. The model should be able to provide more comprehension and/or to forecast the distribution of the species across a landscape. According to Guisan and Thuiller (2005) SDM basically are experience models that relate field experiments to environmental independent variables, supported on datum or empirically surface answer obtained. Simple presence, presence absence or abundance observations are the three species data manifested by stochastic or class field data, or observations obtained opportunistically, like the ones in earthy past collections. Environmental foretells can have vigorous action on species. These effects could be undeviating or mediate effects, placed on a position from near to far forecasters.

Three phases have marked SDM history: (i) limiting factors (or regulators), regarded as elements causing species eco-physiologic; (ii) disturbances, outlined as the varieties of distracts disturbing environmental systems and (iii) resources, which include factors that can be ascribed by partsisms (Guisan and Thuiller, 2005). The difference in spatial pattern can be due to the relations between species and their overall environment. Geographic Information System (GIS) can manipulate environmental data that are related to the factors that influence species distribution.

2.1.6 Species localisation

The spatial data for plant species distribution are generally available in two forms namely point data and distribution map. They depend on the elements like the origin of the species under consideration, the ecological circumstances about the study area, the way this model was employed and the final purpose about the distribution map. In order to model the plant species distribution for large spatial scale, various methods have been adopted. The different approaches are: i) spatial coverage: which will take into account all the phytodistricts where the species is present, ii) spatial accuracy: based on accuracy and correctness, iii) biological significance: to indicate regions where the species is present lastingly and naturally, iv) currency: relative to the reflecting tendency distribution and habitat, v) credibility: scientific credibility of the source (including correct taxonomic identification) and vi) availability: point locations made available to the public for scrutiny and use (Boitani *et al*., 2011). Similarly other approaches have also been adopted and they include i) spatial accuracy: which involves the reduction of error of commission and omission, ii) spatial scale: this matches the intended conservation application, iii) credibility: to assess with non-contingent data or to look broadly over by the foremost practice for the taxon, iv) availability: maps made usable for the consumer for scrutiny and use. Given to the geographic purpose study, to their coverage and the standardization of their representative sample process, a bound collection of the maps (atlases) are the most powerful among the tools used for analysing species distribution (Sergio and Pedrini, 2007). However, most map collections have focused on the present of the plant species but produce inadequate information on abundance or plant species location. (Rondinini *et al*., 2006). However, most of location point collections are often discontinuous, they are temporally and spatially biased and require before being used for conservation planning extensive processing (Boitani *et al*., 2011).

2.1.7 Models based on presence / absence data

Particular awareness about ecological and geographical plant species distribution is fundamental for conservation planning and forecasting. Various approaches are accessible to create environs suitability maps for plant species. The type of data is the major difference between them. The most eminent methods include Generalised Linear Models (GLM), Generalised Additive Models (GAM), classification and regression tree analyses, and Artificial Neural Networks (ANN) (Guisan and Thuiller, 2005). Good quality data availability are required in other to create statistical role or critical rules that permit environment suitability to be stratified relating presence and absence of species distributions (Brotons *et al*., 2004). Thus, this will allow obtaining the probability value of presence or absence in the study area which is between 0 and 1 for each cell.

2.1.8 Model limitation

Despite the widespread use of these models, they present some limitations, especially the regression model, which models the species ecological niche (Guisan and

Zimmerman, 2000). Spatial scale influences the predictive capacity of the models and the indicator should be integrated at different scales where they are available and computable. This model is also very difficult to compare at different scales of the work. In addition, the question of validation and performance of these binary models is that they often overestimate the quality of the habitat (Elith *et al*., 2006).

2.1.9 Model based on present data

To deal with the limitation of absence data and reliability, new modelling methods have been developed. These methods are based on presence only data to predict the distribution of species and to extrapolate local observations over the entire study site according to eco-geographic variables (Guisan *et al*., 2002; Elith *et al*., 2010). SDM which incorporate this new approach are indifferent to sources and modes of data collection. These methods do not therefore require rigorous field sampling particularly in areas with difficult accessibility.

2.1.10 Climate change concept, climate model and climate scenarios

2.1.10.1 Climate change

Climate is generally referred to as the “average weather”. It is a statistical description of the mean and variability of surface variables such as temperature, precipitation and wind, over a period ranging from months to thousands of years (Dahal and Ojha, 2009). According to IPCC (2007) climate change could be define as a change in the statistical properties over time such as whether due to natural variability or also as result of anthropogenic actions. The United Nation (UN) in its framework convention on climate change similarly referred to climate change as alteration of climate which is associated to man-made effects. The effects of these human induced changes include changes in global atmosphere composition as well as natural climate variability. Climatic variability is perceived through changes in the mean state and other statistical variables (standard deviations and extreme phenomena) of the climate at all temporal and spatial scales. The variance could be as a result of natural processes within the climate system or to differences in external.

According to IPCC's most recent assessment reports, climate change is referred to as any alteration in the state of the climate that is identifiable by change in its properties, in the average and/or its variability, which prevails for a lengthy time interval, usually decades or grater" (IPCC, 2013). Climate change arises from earthy global cycles and from outside drivers of change like changes in solar cycles, volcanic eruptions, anthropogenic activity on components of the atmosphere or land cover. Generally, climate change as a term is frequently employed to report the alterations associated entirely or mainly to human activities. This could be at different scales including local, regional and global that is mostly taken as having started at the beginning of the Industrial Revolution in the 18th century (Foden and Young, 2016). Indeed, it is quite possible that the variations of climate parameters such as temperature and precipitation may have an impact on the biological diversity and on the geographical distribution of the suitable habitats of the species (Dotchamou *et al.*, 2016).

2.1.10.2 Climate models

Climate models could be defined as mathematical representations of the climate deducted based on principles that could be physical, biological and chemical. As a matter of fact, almost all climate models which contain the land surface as an interaction element imitate the ‘‘latent vegetation’’ regarded as the flora that is in balance with the climate forecast. Human activities bring about alterations in flora (urbanization, land clearing, and agriculture) which are mostly not taken into account in future climate change simulations (Lamptey *et al*., 2005).

According to IPPC (2007, 2013) climate model is a numerical representation of the natural Earth's systems. It is used to examine how this climate responds to changes in natural and anthropogenic activity. Climate models are numerous and complex among them are Atmosphere, ocean and General Circulation Models (GCM). Atmosphere and oceans are divided into many (thousands) of grid cells, and comprise synergistic land-surface and biophysical processes. Regional climate models (RCM) centred on geographies sub continental standard at smaller resolution.

The model based on Earth System and the one concerning to physical climate models are linked. This contains supplemental ecological and chemical processes, for example vegetation and atmospheric chemistry, the land and ocean carbon cycle that react to alteration in models that imitate climate. Earth system models symbolize many fundamental schemes and processes, however, with simple equations and decreased spatial resolution. The questions involving boring period scales, sensitivity experiments or when a considerable number of models are needed are some of parameters on which these models are useful. The single aspect of climate models include less elaborate processes in the atmosphere, ocean system and at bigger spatial scales. All of us are very notable for investigating crucial ambiguous and have been integrated into many evaluation models. Thus, for our study, climate change could have some impact in the abundance and the geographic distribution of *Kigelia africana*.

2.1.10.3 Climate scenarios

IPCC (2000) defines the climate scenario as a probable illustration of the future climate that has been built up for determining the likely consequences of human induced climate change. Climate scenarios could be used to map future conditions that report for both artificially elicited climate change and earthy climate variability. Climate scenario is differentiated from the climate prediction through the delineation of climates system that responds to a scenario of GHG and aerosol emissions, as simulated by a climate model. Climate projections do not supply adequate information so as appraise emerging impacts of climate change; The results of the model normally have arranged and merged with observed climate data to be usable. Therefore, future GHG emissions are the results of very complicated changing systems, influenced by forces like human ecology evolution, socio-economic evolution, and technological change. Their future development is extremely changeable. Scenarios are suitable mechanism used to examine how thrust would determine upcoming emission result and to evaluate the connected uncertainties and mutually exclusive bitmap of how the future may happen (Klein *et al*., 2015). They help in climate change investigation, which include climate modelling and the evaluation of impacts, adaptation, and mitigation. The hypothesis is that emissions path will happen as delineated in scenarios is highly uncertain.

According to van Vuuren and Carter (2014) climate research uses socio-economic and emission scenarios provide credible interpretation of how the future may develop regarding range of variables that include changes in socio-economic, technology, energy and land use, and emissions GHG and air pollutants. The purpose of scenarios using is not to predict the future, but to explore the scientific implication and the different plausible future real world. In terms, of habitat modelling useful for species, scenarios allow us to project the likely effect that different levels of anthropogenic or natural forcing might have on the ability to produce or conserve a species in a given area. Thus, our study will focus on the scenario 8.5 (Table 2.1). and two climatic models HadGEM2-ES and CNRM-CM5 (Groupe Intergouvernemental d'Experts sur l'Évolution du Climat, 2013).

2.1.10.4 Guidance in the choice of Scenarios

The research community creates and uses scenario to better appreciate the interactions amongst human conditions and activities, the climate system and ecosystems (Ayihouenou, 2014). There is the need for selecting and processing new scenarios despite IPCC scenarios and process are productive. Emerging technologies and observations of environmental factors of new economic data, should be hypothesized in new scenarios. The information needs from end users, including policy makers, necessitate changes in scenario focus.

As a result, few scenarios were acquired to research conditions concordant with climate results that is managed in the long run, which involved global surface temperature of 2º C maximum increase during pre-industrial period. It also includes 'overshoot' scenarios in which radiative forcing increase to the highest level and then drops to a reference point. Moreover, the focus to the impacts of climate change and necessity to manage these impacts arose interest in climate scenarios that looks on the next decades that has grater spatial and temporal resolutions and reinforced representation of intense events. Investigation of management strategies (adaptation) demands the establishment of desirable socio-economic scenarios to back vulnerability analysis (Moss *et al*., 2010). Scientific progress has also indicated the need for new scenarios. Since the fourth assessment report, significant improvements have been made in climate models and emission scenarios.

Table 2.1: Process and criteria description of RCPs Scenario (Moss *et al*., 2010)

Scenario names		Forcing radiative Wm^{-2}	Greenhouses Gases concentration (CO_2)ppm	Path
SRES	RCP			
A1F1			1550 to 2100	
	RCP 8.5	> 8.5 to 2100		Rising

Source: Author's compilation (2017)

2.1.10.5 Representative Concentration Pathway (RCP)

The RCP is one of important step in climate research and provide the basis for impact assessment and mitigation. In considering possible futures for changes in the composition of the atmosphere, researchers have adapted RCPs (Meinshausen *et al*., 2011). It is the latest generation of the 5th report which provide inputs to more sophisticated climate models. These RCPs do not only enhance but for some reasons replace previous scenarios based on prediction of components of the atmosphere. The RCPs were employed to cause climate model simulations planned as part of the Fifth Coupled Model Inter-comparing Project (CMIP5) and other comparison exercises. The four RCPs (2.5, 4.5, 6.0 and 8.5) are based on multi-gas emission scenarios that were driven from the publicized literature and modified for release (Thomson *et al*., 2011; van Vuuren *et al*., 2011).

RCPs were carefully selected considering climate scenario developers and users needs. According to van Vuuren and Carter (2014) the IPCC was interested in new scenarios that were uptodate with literature and mitigation scenarios that facilitated the selection process. The community considered compatibility 'with the full range of stabilization, mitigation, and reference emissions scenarios accessible in the present-day scientific literature. It also considered scenarios management and number and availability of radiative forcing pathways that were separated for the climate models to be provided with distinguishable pathways and outputs relevant for all forcing agents and land use. Four radiative forcing path- ways, and a new Integrated Assessment Modelling Consortium (IAMC) (http://www.iamconsortium.org) were identified using these criteria. The past evaluation of the IPCC Working Group III provided the basis for selecting 32 of the 324 scenarios (Moss *et al*., 2010).

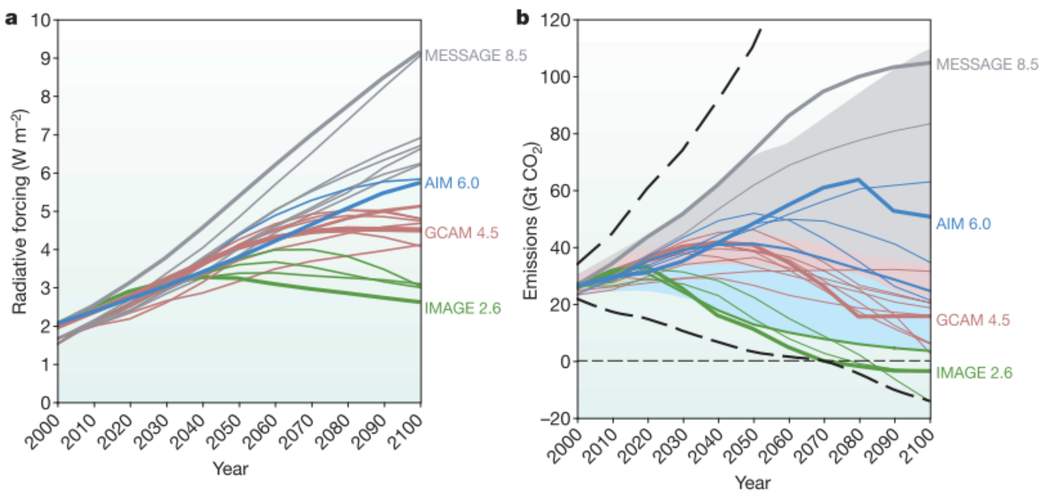


Figure 2.1: Representative concentration pathways of the radiative forcing trend and the emission of CO_2 between 2000 and 2100 years (Moss *et al*., 2010)

Moss *et al*., 2010 (Figure 2.1-**a**) showed alteration in radiative forcing relative to pre-industrial conditions with bold coloured lines indicating the four RCPs; thin lines show individual scenarios from approximately 30 candidate RCP scenarios that provide information on all key factors affecting radiative forcing and the larger set analysed by

IPCC Working Group III during development of the Fourth Assessment Report; Figure 2.1 **-b** showing, energy and industry CO2 emissions for the RCP candidates. The range of emissions in the post- SRES literature is presented for the maximum and minimum (thick dashed curve) and 10^{th} to 90^{th} percentile (shaded area). Blue shaded area corresponds to mitigation scenarios; grey shaded area corresponds.

2.1.11 Land use and land cover change

The utilization and context of usage determine the definition and description of LULC change. Conversion and modification are the two forms of LULC change. Land cover conversion means the move from one land cover category to another, for example in agricultural expansion. On the other hand, land cover modifications alters character of the land cover without varying its whole classification (Lambin *et al*., 2003). To increase food production and other need related to the land, farm land have increased in Africa. This increase in land cover lead to deforestation and land degradation. Thus increase in agricultural land is the principal factor modifying land cover in Africa, Benin is not an exception. The fast transformation of forestlands into agricultural lands and urban areas coupled with the high occurrence of forest fires make Africa the second highest deforestation continent in the world (FAO, 2010).For our study, the land cover conversion concepts was used to categorise the different classes identifiable in Benin. This was done using MOLUSCE in QGIS.

2.2 Review of other Related Studies

Abalo *et al*. (2010) conducted a study on "Diversity of Edible Wild Fruit Tree Species of Togo". This study addresses the issue associated to the progressive reduction of knowledge related to the wild fruit which is due to the rapid change in socio-cultural behaviour, the diminished contact with the nature and the disappearance of natural ecosystem. The study objectives were (1) to create a directory for woody fruit species in Togo for all potentially edible, (2) to inventory all fruits species uses and (3) to analyse the contribution of plant species formation for the diversity of the fruit flora in Togo. The data collection used for this study was, ethnobotanical surveys, Semi-structured interviews. The analysis of this study show considering the parts of wild fruit consumed that it can be subdivided into five groups: those whose fruits are consumed fully, those sought for fruit pulp, those which are sought both for pulp and seed and those whose arilla is appreciated. This study is therefore a perfect example for the forth objective oof this work which deals with the socio-cultural and economic importance of *Kigelia africana* for household community in the Benin Republic.

Moupela *et al*. (2011) carried out a study on African walnut (Coula edulis Baill.) an unknown non- timber forest product.. Through this study, the authors showed the importance of the NTFPs. Its plays food security role and has commercial importance. This study aimed to draw up the state of knowledge on one of these unknown species: the African hazel (Coula edulis Baill.). The first part of this study deal with the Non-Timber Forest Products and his importance for central Africa population. It highlights that NTFPs are the most obvious manifestation of forest value to the local people. They are useful to them from a double point of view: they are source of income and provide many products for food, pharmacopoeia, construction and crafts. The second part deal with thebiology of hazel of Africa with emphasis on its botanical and ecological characteristics. Propagation attempts of Coula edulis was discussed followed by a review of ethnobotanical aspects of the plant species, including the multiple uses of the species. Finally, the research perspectives which were identified with a view to enhancing the value of the plant species. This study therefore is another perfect example for our forth objectives which deal with the socio-cultural and economic importance of *Kigelia africana* for household community.

Sanchez *et al*. (2010) in their study on "Identifying the global potential for baobab tree cultivation using ecological niche modelling" showed the socio-economic and cultural importance of baobab. The study aimed to investigate the potential sites for cultivation and the sustainable commercialisation of the baobab tree. Species data (fieldwork and Herbarium records), environment data (climatic data from the WorldClim dataset included altitude and 19 bioclimatic variables derived from temperature and rainfall, soil data) were used. MaxEnt (version 3.2) was used to generate the species distribution modelling with present only data. The result showed that the Model succeeded efficiently in forecasting conditions that were suited conditions in test location, for AUC values and in areas where no records were used to build the model but are found to have the baobab tree. In investigating the potential global cultivation of the baobab tree, MaxEnt was found appropriate.

Naughton *et al*. (2015) conducted a study on "Land suitability modelling of shea (*Vitellaria paradoxa*) distribution across sub-Saharan Africa", with the objective to identify suitability model that can estimate the potential of shea production based on a scope of environmental factors. From eleven binary and/or suitability layers, land suitability model for shea distribution were developed; (1) precipitation, (2) elevation, (3) temperature, (4) fire, (5) land-use, (6) soil-type, (7) soil-drainage, (8) Normalized Difference Vegetation Index (NDVI), (9) coastal, (10) ecological suitability, and (11) urban areas. The study used maps from global data set, thus limiting the study.

Heubes *et al*. (2012) evaluated the effect of future climate change and land use change on the NTFPs provision in Benin, West Africa and make the linking Niche-based modelling with ecosystem. The aim of the study was the quantification and monetary mapping of importance of NTFPs and the study objective was to raise the knowledge of present and future benefits obtained from Savannah species to improve management plan of actions. Therefore, for the different principal component analysis on future project 2050, the future climate projection (2050) from Miroc3.2medres was used. Moreover, they used three well known modelling techniques from regression methods and classification methods to model species distributions: GAM, GBMs and FDA. R software was also used for data analysis. The land use models were created by LandSHIFT a changing and spatially explicit land use and land cover model. The authors found out that the monetary annual benefits increased respectively from *A. digitata* (USD 9,514±6,243/cell) and *P. biglobosa* (USD 32,246 ±16,526/cell) to *V. paradoxa* (USD 54,111± 28,126/cell). Furthermore, the projection models used had good performance (0.88 for *A. digitata*, 0.84 for *P. biglobosa* and 0.86 for *V. paradoxa*). Otherwise, Projected climate and land use change (2050) have primarily negative effects on the value flows which losses amount of 1–50 %. All in all, the study fails to establish and map a proper link between climate change and land use changing well detailed and mapping. The advantages and disadvantages niche-based modelling methods are not looked at in this work, as many researches have mentioned their setbacks and methodological uncertainties.

Fandohan *et al*., (2013) carried out study on the "impact of climate change on the geographical distribution of suitable areas for cultivation and conservation of underutilized fruit trees: case study of the *tamarind* tree conducted in Benin". The research aimed to assessing the potential impact of climate change on the geographical distribution and conservation of tamarind an underutilized indigenous fruit. The data collected for this study were the geographic coordinates of occurrence points of the species. Data on current climate conditions were derived from the climate data for 1950-2000, downloaded from the WorldClim. For future climate projection, three Global Climate models (GCMs) were used: CCCMA, HadCM3, CSIRO under IPCC scenario A2. For all these projection for 2050 were used in preference. The climate layer used has a resolution of 0.05°. The MaxEnt algorithm was used to run the model and ArcGIS to map geographic distribution. The results showed that the two models (CCCMA and HadCM3) predicted a significant regression of habitats where local tamarind ecotypes will maintain their current level of production by 2050, whereas the CSIRO model predicts an extension of these habitats. However, the models presenta weakness: NTFPs, generally regarded edible products other than commercial timber derived from forest is a potential meeting point between conservation and rural development priorities. The failure of NTFPs to sometimes positively contribute to sustainable development necessitate analysis of factors responsible for the success of its commercialization.

Dotchamou *et al*., (2016) in the study on the "density and spatial distribution of *Parkia biglobosa* pattern in Benin under climate change". The main objective of this study was to define the interaction between the tree density and climate change effects. MaxEnt was used to model geographical distribution of the species using a total of 286 occurrence points from field work and the Global Biodiversity Information Facility GBIF-Data Portal. Two climatic models (HadGEM2_ES and Csiro_mk3_6_0) were used under two scenarios RCP 2.6 and RCP 8.5 for the projection of the species distribution at the horizon 2050. The results at the temporal horizon 2050, showed that the scenarios have projected loss of habitats, which are currently very suitable for *P. biglobosa*. the highest habitat lost rate were 51 % and 57 % obtained with the HadGEM2_ES model under two scenarios.

Khosravi *et al*., (2016) used the MaxEnt model to predict the potential distribution of goitered gazelle in central Iran and present the effect of extent and grain size on performance of the model. In this study, MaxEnt was used for several reasons. It only required species occurrences points, it uses continuous and categorical data and the interactions between environmental variables, the results probability distribution are easy to analyse but over-fitting can be avoided by using regularization, and it is very robust at detailed scales. The authors highlighted that the distribution modelling has the ability to detect suitable areas for pioneering goitered gazelle. This study has many objectives, including but not limited to modelling the habitat distribution and effects of environmental variables on the species distribution. The data collected for this study was the climatic data from the WorldClim database included all of 19 bioclimatic variables in SDM. In 2012, separately using MODIS (Moderate Resolution Imaging Spectroradiometer) with 250 m resolution, NDVI values were calculated for 12 months. The result of this study revealed that seasonal temperature is highly associated to goitered gazelle presence. In addition, the PCI was correlated with the NDVI. Receiver operating characteristic (ROC) curve, known as the AUC, analyses uncovered the uncorrelated model based on 12 biogeographic predictors performed better than random AUC.

Mishra *et al*. (2014) conducted the study on the "Prediction of land use changes based on land change modeller (LCM) using remote sensing: a case study of muzaffarpur

(BIHAR), India". The study investigated the importance of land use and land cover change as a driver of environmental change on all spatial and temporal scales. Using Landsat satellite images from 1988 to 2010, the study forecast the growth of muzaffarpur city and its surrounding Bihar (India). The data collected for this study were Landsat TM images of 1988 and 2010. ERDAS imagine (version 9.3) was used to carry out land use/cover classification. IDRISI Selva was used to analyse land cover changes. The results of this study showed that land use/land cover significantly changed, particularly for vegetation, agriculture and built up areas. The Multi-Layer Perceptron (MLP) neural network show that the RMS error declines as the weight is adjusted. The transition potential maps were obtained after the MLP has finished 10000 iterations of training with an accuracy of 50.80 %. The prediction model showed increase in built up areas and agriculture and fluctuating trend for other land categories in 2025 and 2035. This study is therefore a model of how changes in LULC impact on the geographic distribution of *Kigelia africana*.

All the literature discussed about the distribution of forest species other about land use dynamic, but none of them don't work about climate change and land use change on the forest distribution species. That was the reason of our topic.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Material

This study accomplishment required the use of the following equipment (Table 3.1).

Table 3.1: Field work material and their uses

S/N	Materials	Used
1	Maps of phytodistricts and agroe-cological zone	Find the location of *Kigelia africana* occurrence
2	Field book	Note down GPS coordinate and any observation
3	Camera	Illustration
4	GPS MAP64 Garmin	To record geographic coordinate
5	Journal papers	For possible Herbarium vouchers
6	Maps of Agroforestry zone of Benin	To records GPS coordinate points

Source: Author's field work, 2017

3.2 Methodology

3.2.1 Data collection

Ecological niche modelling requires a set of data associated to occurrence data of the species which can be presence/absence data and environmental data which may be the present condition of the species.

3.2.2 Occurrence data

The geographical coordinates (longitude and latitude) of individual *Kigelia africana* trees have been recorded all over Benin Republic regions. Indeed, two main types of occurrence data are often used to model the dispersion of the species. It is the presence data alone (geographic coordinates of the points where the species was observed) or the presence /absence data. However, it should be pointed out that cases of false absence may appear and lead to biases in the model since points of true absences are often not available. Even though MaxEnt is a presence-only algorithm, it looks like methods such as logistic regression. Maxent models were developed using 10,000 background points, a maximum of 1000 iterations, a convergence threshold of 0.00001. MaxEnt appraisal probability dispersion that are near to maximum entropy or unvarying afford restraints deduce from the occurrence data and purposes of the environmental alterable (Carroll, 2010). Table 3.2 indicates the sources of the data and location.

Table 3.2: Points of presence used and sources

Sources	Number	Percentages(%)	Sources
Field work	416	62	Collect over all the country Benin
University of Abomey-Calavi	50	7	National Herbarium of Benin (UAC)
Global Biodiversity Information Facility GBIF	205	31	Data portal (www.gbif.org)
Total	671	100	

Source: Author's field work (2017)

To obtain a good accuracy of modelling results, the occurrence of the studied species should cover the most possible area where it is influenced by the same climatic factors (Fitzpatrick and Hargrove, 2009). This area is known as background where additional occurrence of species is recorded and pseudo-absence are selected during modelling process. In this study, occurrences of *Kigelia africana* have been collected as additional data throughout its occurrence area in West Africa by exploring the database of GBIF (Global Biodiversity Information Facility: www.gbif.org) (Fandohan *et al*., 2013). Figure 3.1 presented the different points of distribution used for the modelling in the whole of West Africa.

The temporal bias and matching occurrence data effects were minimised by removing the GBIF from records collected before running the model.

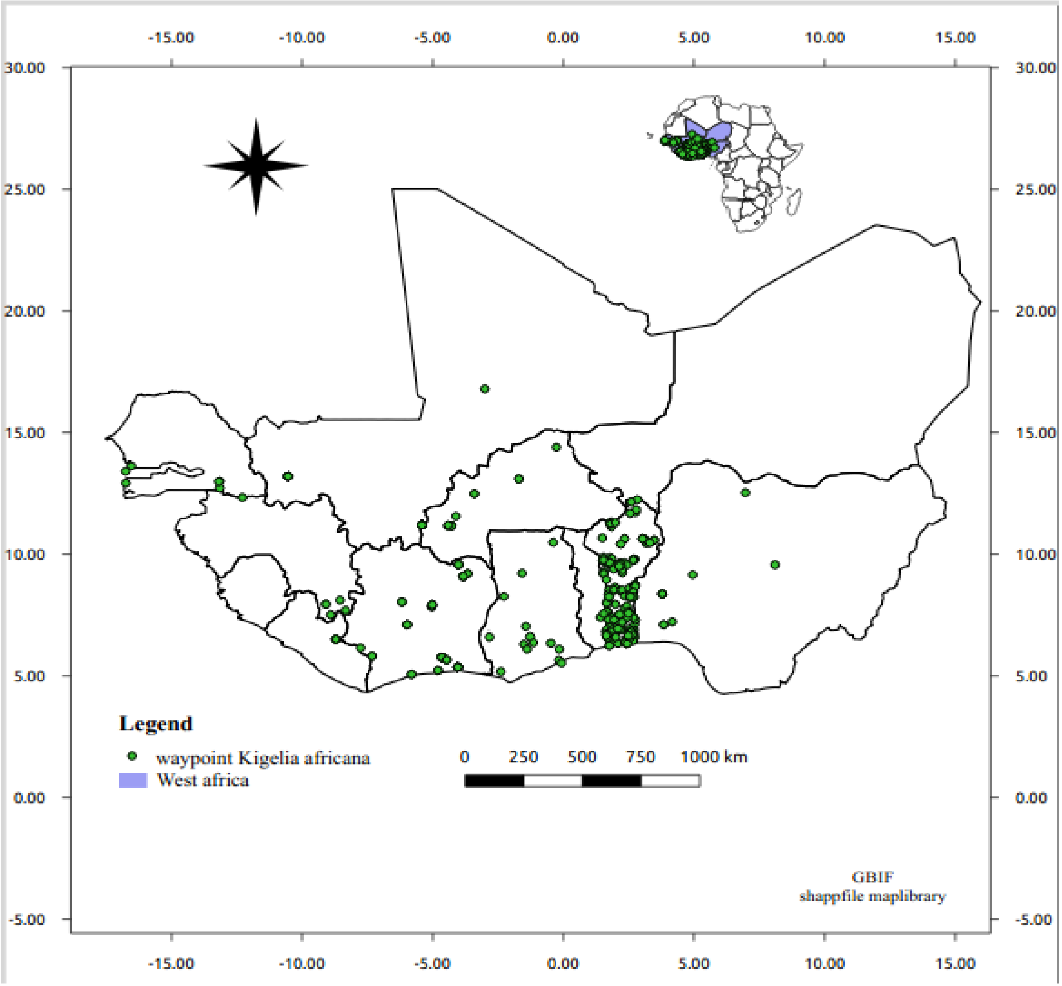


Figure 3.1: Location of *Kigelia africana* point used for modelling

3.2.3 Environmental data

The current and future climate data were downloaded from WorldClim website (www.worldclim.org) to predict the suitable conditions for *Kigelia africana*. The current climatic data obtained from WorldClim web site are derived from interpolation of average monthly, maximum and minimum temperature and rainfall, considering the historical series 1950-2000. WorldClim is a big database. Although, their data are of coarse resolution they offer the possibility of extracting environmental data with interpolated climate data in fine resolution for large geographical areas.

HadGEM2-ES and CNRM-CM5 models were lately used in West Africa to evaluate possible impacts of climate changes on *Kigelia africana* (Good *et al*., 2013; Panitz *et al*., 2013). These climate models comparatively with severe aspect of futurity status are based on the Representative Concentration Pathway (RCP) 8.5 for the 2050 time skyline. RCPs are the third generation of storyline and are preferred to Special Report on Emissions Scenarios (SRES) for sake they permit more flexibility (and reduced costs) in modelling procedure (van Vuuren *et al*., 2011). RCPs connote co-action between impacts, adaptation, and vulnerability research, and climate and incorporate appraisal modelling The Future climate variables for 2050 were extracted from WorldClim database. These variables are converted and put into compatible formats (ASCII format) with MaxEnt software before building the model. The choice of environmental variables to be integrated into the potential distribution model of *Kigelia africana* was based on the experience and on the availability of variables that show the correlations with the species distributions and could be substituted for more proximal variables. However, for the good relevance and quality of ecological niche models, a specific care was given to the selection of the spatial scale of the calibration data set. However, it is important that the resolution of the network observation sites is sufficiently fine to capture environmental parameters that determine the presence of the species (Guisan and Thuiller, 2005). All the environmental data used were 2.5 minutes' resolution (approximately a grid of 4.62 km x 4.62 km). Moreover, the different categories of environmental parameters (direct and indirect) influence differently the distribution of the species according to the scale modelling. Direct parameters, mean factor which have direct physiological effects on the species (for example temperature, rainfall or solar radiation) are critical when modelling on coarse resolution (for example regional scale). Whereas indirect parameters (altitude, slope) are recommended for small areas. To do this, environment variable such as soil, elevation, maximum soil available moisture and vegetation cover are extracted from different databases (Table 3.3). All these variables were extracted at a resolution of 1 km (0.5 minutes to the equator), it has been necessary to convert them to the same resolution as the bioclimatic variables. Table 3.4 present the 19 bioclimatic variables preselected.

3.2.4 Modelling the species distribution

Various statistical methods were used to model plant species distribution, or to estimate the probability of presence /absence of a specific plant species at a special geographical location (Fandohan *et al*., 2013). In sum, 466 observation points in Benin Republic were used for the modelling. The 19 bioclimatic variables were subjected to a correlation test using the ENMT Tools program and R software version 3.4.1 with the packages (raster; maptools; sqldf; fields; rgdal; dismo; ENMGadgets) to select the less correlated variables ($r < 0.85$) and avoid collinearity. The climate model used for future projections is CNRM-CM5: a global mate climate model developed by CNRM/ CERFACS (France) and HadGEM2 represent the Hadley Centre Global Environment Model version 2. The HadGEM2 family comprehend a coupled atmosphere-ocean constellation, with or without an upright denotation in the atmosphere to admit a well-resolved stratosphere, and an Earth-System constellation which admit dynamical vegetation, ocean biology and atmospheric chemistry. For this model, the future distribution of the species was projected into 2050 under RCP 8.5 emission scenarios.

The combined map of present-day and future model distribution was overlaid on the protected area network to ascertain the potential of protected areas across Benin Republic using ArcGIS 10.1. In the end the priority areas for *Kigelia africana* conservation was identified by means of spatial conservation.

Table 3.3: Environmental variable used: resolution and sources

Environmental data	Version	Original resolution	Sources
Bioclimatic variable	1.4	2.5	http://www.worldclim.org
Future biochemical variable	1.4	2.5	www.ccafs-climate.org
Soil	1.0	2.5	http://www.isric.org

(~) = Substantially equal; (Min) = minutes
Source: Author's compilation (2017)

Table 3.4: List of 19 bioclimatic variables (www.worldclim.com)

Variables bioclimates	Means of the variable
Bio1	Annual Mean Temperature
Bio2	Mean Diurnal Range (Mean of monthly (max temp - min temp))
Bio3	Isothermality (BIO2/BIO7) (* 100)
Bio4	Temperature Seasonality (standard deviation *100)
Bio5	Max Temperature of Warmest Month
Bio6	Min Temperature of Coldest Month
Bio7	Temperature Annual Range (BIO5-BIO6)
Bio8	Mean Temperature of Wettest Quarter
Bio9	Mean Temperature of Driest Quarter
Bio10	Mean Temperature of Warmest Quarter
Bio11	Mean Temperature of Coldest Quarter
Bio12	Annual Precipitation
Bio13	Precipitation of Wettest Month
Bio14	Precipitation of Driest Month
Bio15	Precipitation Seasonality (Coefficient of Variation)
Bio 16	Precipitation of Wettest Quarter
Bio 17	Precipitation of Driest Quarter
Bio 18	Precipitation of Warmest Quarter
Bio 19	Precipitation of Coldest Quarter

Source: Author's compilation (2017)

3.2.5 Choice of MaxEnt

MaxEnt is a recently developed ecological modelling method with ability to achieve high predictive performance using the presence data of a given plant species (Manyangadze *et al*., 2016). However, there are scarcity of presence data for most species, which resulted in insufficient information about the distributions of species. Ferrier and Guisan (2006) highlighted that models for species distribution try to give elaborated predictions of distributions by associating presence or abundance of species to environmental forecasting. According to Fandohan *et al*. (2013) MaxEnt (maximum entropy modelling) is one of the best modelling methods capable of generating very good biogeographic information while offering good discrimination of habitats that are favourable and not favourable to a plant species from a bioclimatic point of view. MaxEnt is a species distribution model (SDM) used for modelling species ecological niche. It is applied to the plant species presence-only data and it approximates both a set of functions that link environmental variables to habitat suitability and the potential geographical distribution of a plant species (Phillips and Anderson, 2006).

The interest in this method for the study is that it combines presence data of a given plant species with current bioclimatic characteristics coming from observations points. It is able to generate: (i) a map of potential habitat suitability of the plant species in the considered area, and (ii) a map of future suitable habitats distribution according to the projected climatic conditions. Loosening constituent, called regularization, has been joined to MaxEnt to confine assessing frequencies of occurrence thereby permit the mean value of each specimen flexible to estimate its verifiable mean though unequal to it. This regularization constituent can be set for each sampling area (Phillips and Anderson, 2006). The procedure of SDM building ideally follows six (06) steps: (i) conceptualization, (ii) data preparation, (iii) model adjustment, (iv) model evaluation, (v) spatial predictions, and (vi) assessment of model applicability. Figure 3.2 shows the general approach and procedure to run the model MaxEnt.

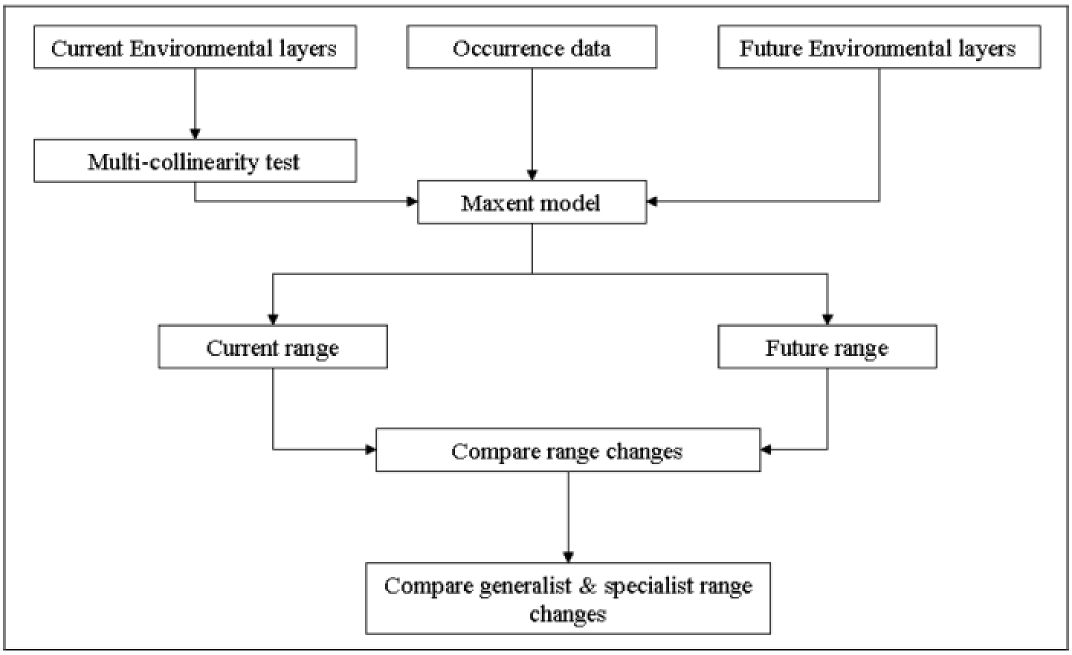


Figure 3.2: The general research approach of the model MaxEnt

3.2.6 Model evaluation

The Area Under the Receiver operating characteristic (ROC) Curve, recognize as the AUC, is generally used to evaluate the prognostic correctness of dispersion models. First, model execution was estimated by dividing the presence data profitable for each species randomly into calibration. When building the model, 75 % of the points were used to calibrate and 25 % to assess subset. The goodness of the model is required to predict with greatest accuracy the presence of *K. africana* tree at the assessment places (Phillips and Anderson, 2006). The cross validation of the model was repeated five times to evaluate MaxEnt's ability to predict the species distribution. To assess the execution, the model was run with the index called "Receiver Operating Characteristics" by calculating the AUC (Area Under the Curve) statistic. AUC measures the success of the model by maximizing true positive prediction and minimizing false position. The prediction which have AUC value close to 1.0 could be considered like a good model. Consequently, if the model has AUC value close to 0.5 it is considered less precise than the random one (Hernandez *et al*., 2008). The AUC characteristic gives it the advantage over the derivative traditional matrix evaluation metric since it is not affected by the arbitrary choice of threshold, which can bias the model evaluations. This value can be interpreted as indicating the probability that, when a presence and the absences site are randomly drawn, the former will have a higher predicted value than the latter. AUC is related closely to a Mann-Whitney statistic, and in this context, it is viewed as a ranking-based statistic (Elith *et al*., 2006). According to Phillips and Anderson (2006) the important explanation of a given species distribution of each variable is determine by a Jackknife test. In explaining the potential distribution of *Kigelia africana,* AUC was to evaluate the significance of each environmental alterable.

The AUC values were interpreted as proposed by Araújo *et al*. (2006)

- ✗ AUC > 0.90 the model is excellent
- ✗ 0.80 < AUC < 0.90 the model is good
- ✗ 0.70 <AUC < 0.80 the model is acceptable
- ✗ 0.60 < AUC < 0.70 the model is bad
- ✗ 0.50 < AUC < 0.60 the model is invalid

3.2.7 Mapping, spatial analysis and Gap analysis

The MaxEnt result was obtained as ASCII format files and imported into Arcgis 10.3 to classify the different habitat suitability levels for *Kigelia africana* from the thresholds logistic chance of occurrence ranging from 0 to 1 (Liu *et al*., 2013). The probability value under the minimum training presence were considered as “non-habitat”, those between minimum training presence and maximum test sensitivity and specificity were considered as “weakly favourable habitat”, while those between maximum testing sensitivity and specificity, and 10 percentile training presence were considered “moderately favourable habitat”. Furthermore, with the spatial analysis tool, the extent of each habitat level under both current and future conditions has been calculated and the gain or loss of favourable environment for the species in the future compared to the present were evaluated. To evaluate the actual and future capacity of the national system protected areas for species conservation, gaps analysis in representation of protected areas (Gap analysis) was carried out superimposing the national map of protected areas networks of Benin to the distribution maps obtained.

3.2.8 Endogenous Knowledge and Uses of *Kigelia africana*

3.2.8.1 Sampling and data collection

Endogenous knowledge study was conducted in three phytogeographical districts: Tanguieta in Atacora phytodistrict, Bohicon in the Zou phytodistrict and Pobè in Plateau phytodistrict that differ from one to another, by their environmental conditions such as climate, soils and vegetation (Adomou *et al*., 2012). The phytodistricts were selected to cover all the 3 climatic zones (Sudanian region, Sudano-Guinean, Guineo-Congolian region). Face to face interview were conducted in seven (07) villages. Table 3.5 presents the different phytodistricts, administrative districts and villages in which the survey was conducted. The ethnicity of the communities was also illustrated (Fandohan *et al.*, 2010).

Table 3.5: Phytodistricts, villages and ethnics groups presented by districts

Phytodistricts	Administrative districts	Villages	Ethnics
Atacora	Tanguiéta	Tanougou	Gourmantché
Zou	Bohicon	Avogbanan Bohicon2 Todo	Fon
Plateau	Pobè	Eguelou Igbo-ocho Onigbolo	Holli-Ifè

Source: Author's field work (2017)

The residents were asked if they knew where *Kigelia africana* was usually found. The photo of the plant species was carried along for the identification by the respondents during the survey. Sample population was estimated using the formula.

(1)

$$n=\frac{U_{1-\frac{\alpha}{2}}^{2}*a(1-a)}{h^{2}}$$

where a refers to frequency of persons knowing the species from the initials study, U1-α/2= 1.96 (normal distribution, α = 0.05) and h means the expected error margin of any parameter to be computed, which we fixed here at 0.05. Thus, 71 was the sample size used for the full survey. Respondents were arbitrarily selected from seven communities. Table 3.6 summarizes the sampling dimensions of respondents studied by ethnic group, gender and age category. With the help of a translator depending on the case, a structured interview based on a survey questionnaire (Appendix A) was then conducted. This including the collection of GPS points throughout Benin, by sex Male (M) and Female (F) and by age group: (A) 15 to 30 years; (B) 30 to 45 years; .(c) 45 to 60 years; (D) 60 to 75 years and (E) <75 years.

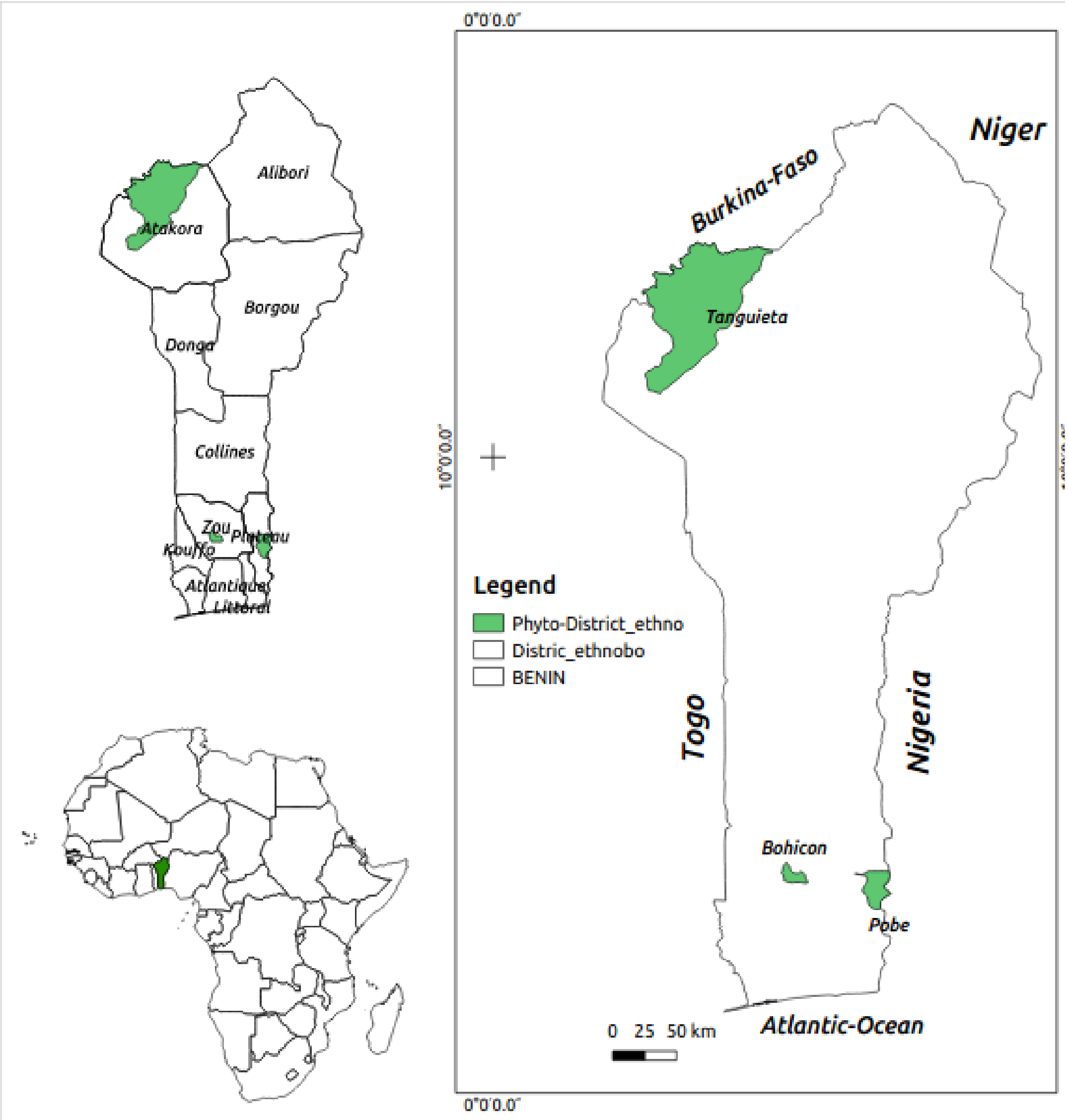


Figure 3.3: Ethnobotanic Study Area

3.2.8.2 Statistical processing and data analysis

The data was entered into the Microsoft Excel spreadsheet and R statistical software version 3.4. Frequency analysis was performed for categorical variables (traditional nomenclature, taboos, habitats of the species the perception and dynamic of the species). To evaluate the uses of the species and analyse their variation according to the characteristics (gender, age and socio-cultural group) of the respondents, some ethnobotanical indexes were used. These indexes have been adapted from Gomez-beloz (2011).

i. **Reported use value of the plant (VURi)** is the total use number of *K. africana* reported (RU) by the respondent i. Because, these were count data, a generalized linear model based on the Poisson distribution was performed to evaluate the effect of the socio-cultural group, sex and age on use value change. The analysis were carried out with the R software version (3.4) using the package "MASS"

ii. **The** parts **reported Use value (VUR** parts**, ij):** Is the total use number of *Kigelia africana* reported by the respondent i for a given parts j. These results have been reported in the histograms.

iii. **The** parts **use value (VUO)**: Is the value for each parts to each surveyed. For each respondent, this equal to the ratio of the total number of reported uses for each parts plant (VUR parts, ij) to the total number of plant (VURi). The parts with high value are often the most requested by the respondents (VUO).

The results relative for this index have been reported in the histograms and projection system after the Principal Component Analysis performed to describe the similarities between the socio-cultural group based on the importance use parts.

iv. **Use value of each Category (VUC)**: was determined to measure the significance of the identified use categories for *Kigelia africana* for each respondent. The use value for usage category k (VUCk) is given by the formula:

(2)

$$VUC_k = \frac{\sum_{i=1}^{N} RU_{ik}}{N}$$

VUCk is the category usage value k, RUik is the use number of use reported by respondent I in the j category, N is the total number of respondent in the socio-cultural group. These results have been reported in histograms. Projection of category use value also was made with the socio-cultural by the Principal Component Analysis (PCA) in order to see the similarities of species uses

v. **Specific Use reported (US)**: is the use of *Kigelia africana* as described by the respondent. This is simplified to facility analysis. For each specific use for each parts, the fidelity level or frequencies of citation (FC) was calculated. Here, it refers to the number of times the respondent cited a given specific use in relation with the total number respondent affected. The FC allows the ordering of the importance of uses inside the parts. It allows identification of a given parts the most use specific reported by the respondent. High level value FC for a use specific usually reflect a consensus for this use of the parts in the community.

3.2.8.3 Socio-demographic characteristics of respondents

Table 3.6 presents the size of the sampled population and the socio-demographic characteristics of the surveyed by the socio-cultural group. Analysis of this table shows that the Holli and Fon ethnic group are the most representative socio-cultural group of this sampling. This last on is dominated by men (92.96 %) and aged at least 45 years old

(66.67 %).

Table 3.6: Size of sampled population and persons socio-demographic characteristics surveyed by socio-cultural group (N = size of population surveyed per socio-cultural)

Ethnic group	N	Gender		Age in year (y)				Relative frequencies (%)
		Male	Female	[15, 30]	]30, 60]	]60, 75]	<75	
Gourmantché	10	9	1	0	6	4	0	14.08
Fon	30	26	4	2	22	5	1	42.25
Holli-Ifè	31	31	0	1	27	3	0	43.66
Total	71	66	5	3	55	12	1	100

Source: Author's field work (2017)

3.2.8.4 Socio-professional characteristics of respondents

Most of the interviewed people are healers and farmers (practices agriculture) (45.07%), and those who are only healer (28.17%), trader and trader healer respectively (08.45%).

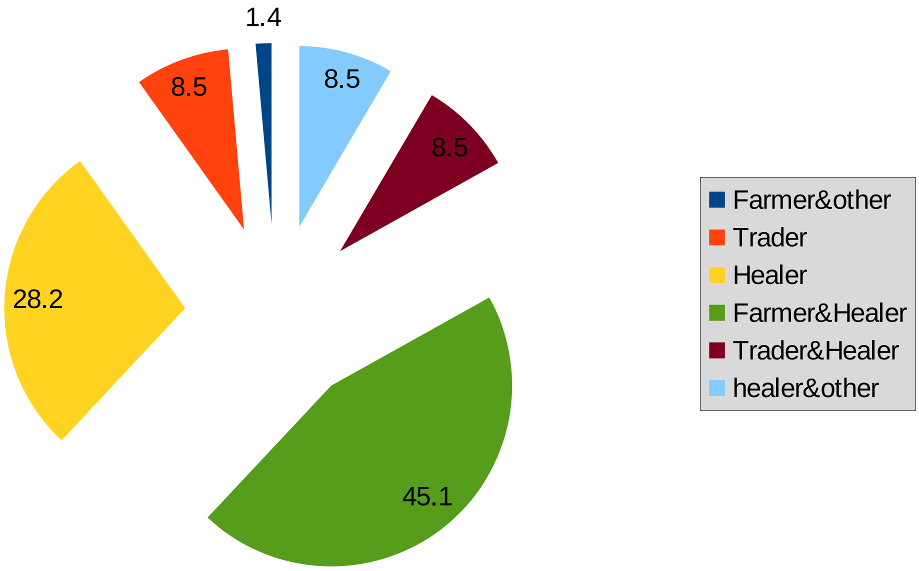


Figure 3.4: Socio-professional categories of respondents

3.2.8.5 Socio-economic importance of *Kigelia africana*

3.2.8.5.1 Sampling and data collection

The assessment of the socio-economic importance and contribution of *Kigelia africana* to household income in Benin was carried out by systematic sampling of households involved in the sale species. A structured interview based on the same survey questionnaire (Appendix A) was conducted in the same period among men and women who marketed at least one of the *Kigelia africana* parts. At the end of this survey, among the 71 surveyed, 52 traders were identified and constituted our study sample.

3.2.8.5.2 Statistical processing and data analysis

The fieldwork data analysis was carried out by calculating frequencies of the way of sale or use of parts (Bonou, 2008). The Gross Margin (GM) of any activity is equal to the difference between the Gross Product (GP), resulting from the activity and the variable charges (CV) (Bonou, 2013). It is expressed by the following relation: GM = GP – CV Where PB = Σ Qi*Pi., Qi = Quantity of product i sell, and Pi the unit price of the product i. CV is directly linked to the production / marketing activities for a given period. These include input costs (seeds, fertilizers, insecticides, transportation costs) and occasional labour. In this study on *Kigelia africana*, there were no variable loads related to the production / marketing of *Kigelia africana*. Thus, the Gross Margin considered was limited to the calculation of the Gross Product.

3.2.8.5.3 Socio-demographic characteristics and status of respondents

Table 3.7 presents the socio-demographic characteristics of the respondents. The analysis of this table shows globally that *Kigelia africana* parts are more marketed in the Zou district (85.71 %) than the two other Atacora (07.14 %) and Plateau (07.14 %). People involved in marketing of the parts of *Kigelia africana* are more men (64.29 %) than women (35.71 %). The high surveyed rate of *Kigelia africana* parts in Zou is due to the use for the bark to treat children illness.

Table 3.7: Socio-demographic characteristics

	Trader	Frequency (%)
Atacora	1	7.14
Zou	12	85.71
Plateau	1	7.14
Total	14	100

Source: Author's field work (2017)

3.2.9 Land Use and Land Cover Change Model

For this study, LULC change is regarded as the most crucial Man-made upset to the environment at local level, and it also causes various micro-climatic alterations. Geographic information system (GIS) in LULC change model have been known to be very appropriate and usable means managing land and other natural resources. For this study, past and present trends of LULC were analysed and the future trends were also simulated by using information from remote sensing applications. The Climate Change Initiative Land Cover (CCI_LC) map from the European Space Agency (ESA) was acquired for three periods of years: 1992, 2003 and 2015. This project delivers consistent global LC annual map at 300 m spatial resolution from 1992 to 2015at ttps://www.esa-landcover-cci.org/?q=node/175 and http://maps.elie.ucl.ac.be/CCI/viewer/index.php. The coordinate Reference System used for the global land cover database is a Geographic Coordinate System (GCS) based on the 1984 World Geodetic System(WGS84). The Table 3.8 summarises the CCI-LC products and the Figure 3.5 show an example of the Land cover map of the world.

Table 3.8: CCI Land Cover products

Data	Spatial coverage	Temporal coverage	Spatial resolution	Temporal resolution	Sensor	Projection and Format
CCI-LC	Global	1992	300 m	1 year	MERIS; FR/RR SPOT-VGT; AVHRR; PROBA-V	WGS84 Geotiff
CCI-LC	Global	2003	300 m	1 year	MERIS; FR/RR SPOT-VGT; AVHRR; PROBA-V	WGS84 Geotiff
CCI-LC	Global	2015	300 m	1 year	MERIS; FR/RR SPOT-VGT; AVHRR; PROBA-V	WGS84, Geotiff

Source: Author's compilation (2017)

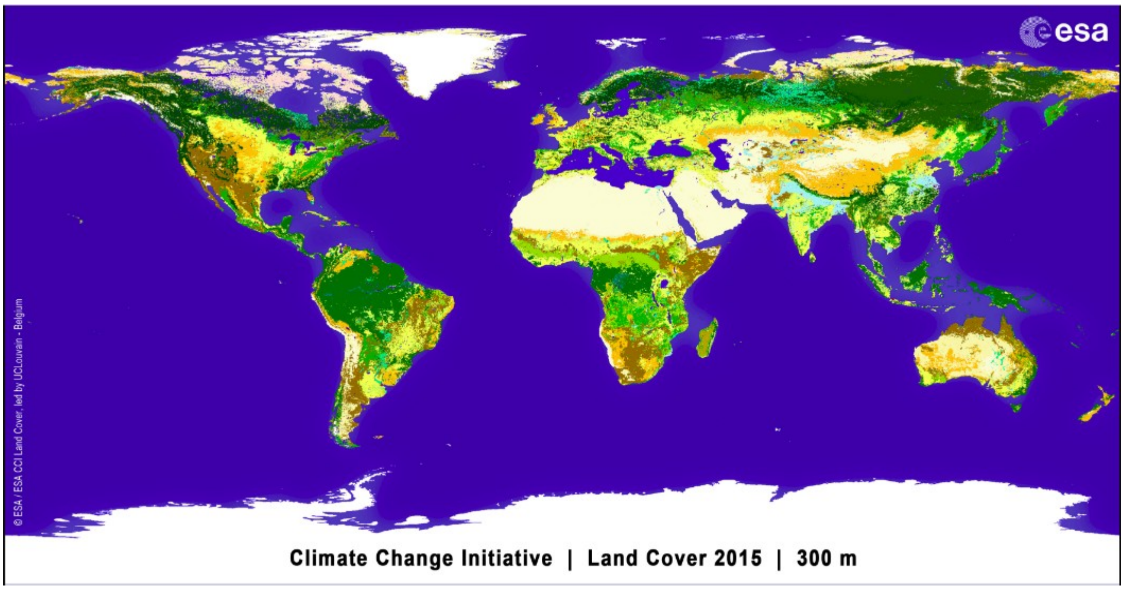


Figure 3.5: CCI-LC classify map series from 2015, at 300 m spatial resolution.

3.2.9.1 Image classification

They are deduced from a unique baseline LC map which bring forth thanks to the entire MERIS FR and RR archive from 2003 to 2012. Severally from this baseline, LC modifications are observed at 1 km based on the AVHRR time series between 1992 to 1999, SPOT-VGT time series between 1999 and 2013 and PROBA-V data for 2013, 2014 and 2015. When MERIS FR or PROBA-V time series are available, changes detected at 1 km are re-mapped at 300 m.Figure 3.6 shows the procedure used by CCI-LC for the classification of the images.

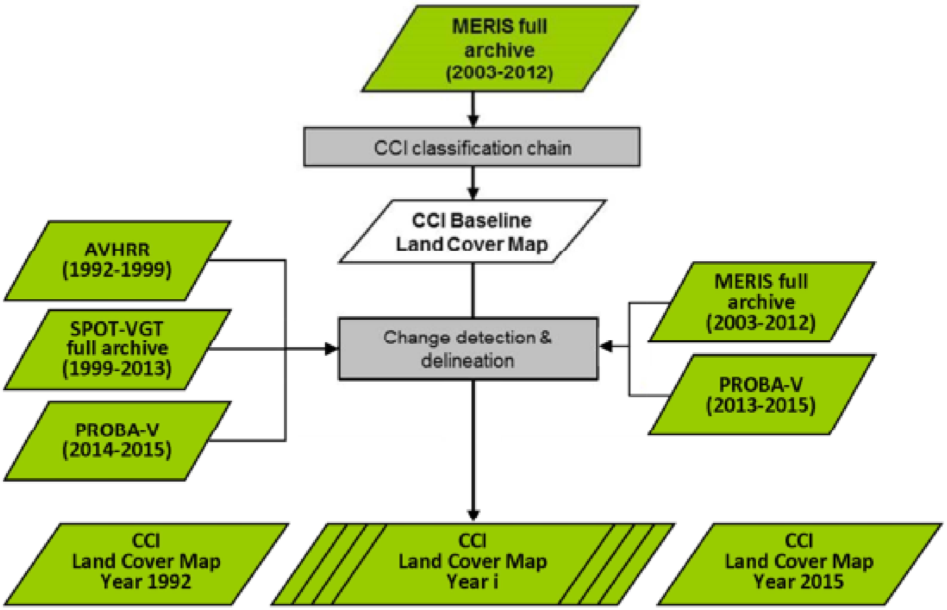


Figure 3.6: Schematic representation from CCI-LC classification chain that generates global annual LC maps.The chain is made of 2 main processes and makes use of the entire archives of Envisat MERIS (2003 -2012), AVHRR (1992 - 1999), SPOT-VGT (1999 - 2013) and PROBA-V data for 2013, 2014 and 2015.

This classification shows the modification observed in the interval of CCI land cover grouped into the six IPCC land categories (cropland, forest, grassland, wetland, settlement and other land). For Benin republic image classification, Table 3.9 defines the agreement between these IPCC land classes and the land cover classification system (LCCS) legend used in the CCI-LC maps for the Benin classes.

Table 3.9: IPCC land classes and the LCCS legend used in the CCI-LC maps

IPCC CLASSES CONSIDERED FOR THE CHANGE DETECTION FOR BENIN	LCCS LEGEND USED IN THE CCI-LC MAPS	
Agricultural Land	10, 11	Rainfed cropland
	20	Irrigated cropland
	30	Mosaic cropland (>50%) / natural vegetation (tree, shrub, herbaceous cover) (<50%)
	40	Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) / cropland (< 50%)
Forest Land	50	Tree cover, broadleaved, evergreen, closed to open (>15%)
	60, 62	Tree cover, broadleaved, deciduous, closed to open (> 15%)
	100	Mosaic tree and shrub (>50%) / herbaceous cover (< 50%)
	170	Tree cover, flooded, saline water
Grassland	110	Mosaic herbaceous cover (>50%) / tree and shrub (<50%)
	130	Grassland
Shrubland	120, 122	Shrubland
Sparse vegetation	153	Sparse vegetation (tree, shrub, herbaceous cover)
Wetland	180	Shrub or herbaceous cover, flooded, fresh-saline or brakish water
Urban	190	Urban
Bare soil	200, 201	Bare areas
Water body	210	Water

Source: Author's compilation (2017)

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

This chapter contains the results of the analysis of data collected throughout the study to address the objectives. The results are presented in a logical and meaningful way, according to the objectives.

4.1 Current and future distribution of suitable habitats for the conservation of *Kigelia africana* in Benin

4.1.1 Variables Contribution and Model validation

Correlation analysis and the Jackknife test identified eight (08) bioclimatic variables less correlated (r<0.85) that were used to run the model. Sum of maximum temperature of the warmest month and minimum temperature of the coldest month (bio7) highly contributed to the model at 21.5 %. Precipitation seasonality (bio15), soil abiotic variable, temperature seasonality (bio4), maximum temperature of the warmest month (bio5) proved also to be important contributors to the model with at 19.04%, 15.6 %, 13.1 % and 11.8 % respectively (Table 4.1, Figure 4.1). Precipitation of warmest quarter (bio18), precipitation seasonality (bio19), isothermally (bio3) and annual precipitation (bio12) had shown low contribution at 5.8 %, 5.7 %, 4 % and 3 % respectively (Table 4.1).

In summary, the bioclimatic variables “some of the maximum temperature of warmest month and minimum temperature of coldest month, precipitation seasonality” and abiotic variables “soil” were the most important environmental variables in the favourable habitat prediction to *K. africana*. The average training AUC was 0.904 and

0.013 for the replicated runs and the standard deviation respectively. This value demonstrates the very good quality of the models in predicting the geographical distribution of areas favourable to the cultivation and conservation of the species. The Jackknife test of variable importance was presented in Table 4.1 and Figure 4.1. Bio7 has the highest environmental variable when used in isolation, which indicates that it has the most useful information by itself. When omitted, bio 18 was the environmental variable that decreased most, implying that it has the most information that is not present in the other variables. In general, the areas with the highest potential of *K. africana* presence were those characterized by greater availability of water coupled with mean temperature.

For each environmental variable, the green bar that represents “without variable” in the Jackknife test of regularized training gain, shows how much the total gain is decreased if this specific variable is excluded from the analysis. On the contrary, the blue bar representing “with only variable” shows the obtained gain if the considered variable is used in isolation and the other ones are excluded from the model (Figure 4.1).

Table 4.1: Used bioclimatic variables and their contributions to the model

Code	Bioclimatic variables	Contribution(%)
Bio 7	Temperature Annual Range (BIO5 BIO6)	21.5
Bio 15	Precipitation Seasonality (Coefficient of Variation)	19.4
Soil	Abiotic variables	15.6
Bio 4	Temperature Seasonality (Standard Deviation)	13.1
Bio 5	Maximum Temperature of Warmest Month	11.8
Bio 18	Precipitation of Warmest Quarter	5.8
Bio 19	Precipitation of Coldest Quarter	5.7
Bio 3	Isothermality (BIO2/BIO7)	4
Bio 2	Mean Diurnal Range (Mean of monthly (max temp min temp))	3

Source: Author's compilation (2017)

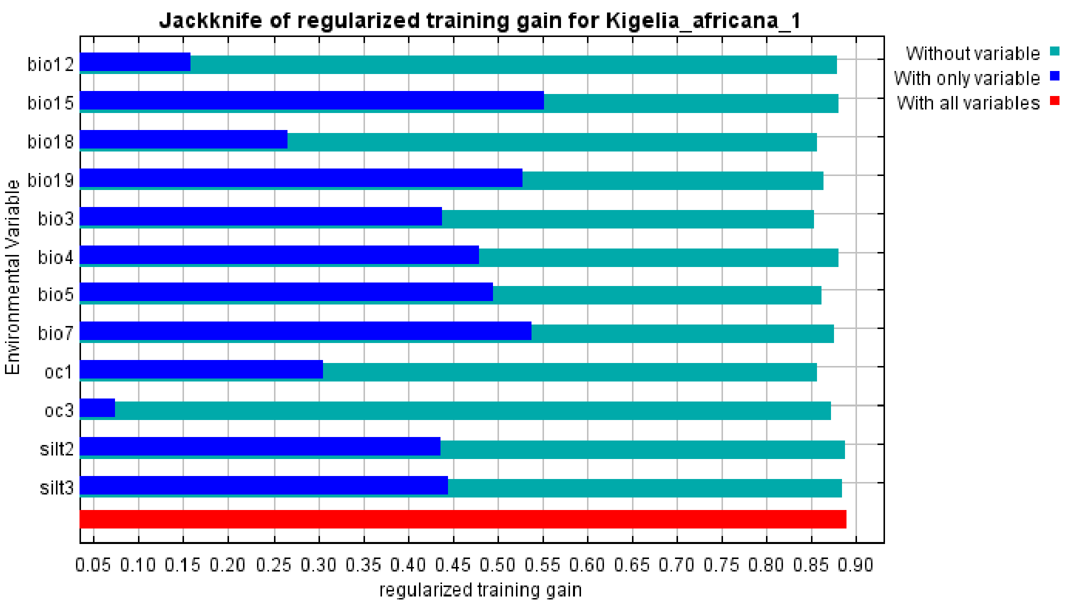


Figure 4.1: Jackknife test on the importance of individual variable in MaxEnt final model development for the quality of the model as a whole or total gain.

4.1.2 Current distribution of favourable habitats for the cultivation of *Kigelia africana* in Benin and impact of climate change (horizon 2050)

According to the model output, it comes out that about an area of 60,000 km^2, corresponding to about 52 % of Benin (114,763 km^2) are presently very favourable for the production and preservation of *Kigelia africana* (Table 4.2, Figure 4.2), while about 30 % of Benin is revealed to be moderately suitable for *Kigelia africana*. These habitats, which are very favourable for the cultivation of this species corresponds to the Guineo-Congolian region and Sudano-Guinean region. Habitats that are less favourable to the species are primarily seen in the Sudanian region (dry sub-humid zone) located between 10° and 12° North.

Table 4.2: Dynamic of suitable areas for the culture and conservation of *K. africana*

Species	Models	Scenarios	High suitable area		Medium suitable area		Low suitable area	
			Area (km^2)	Tendances (%)	Area (km^2)	Tendances (%)	Area (km^2)	Tendances (%)
Kigelia africana	Present	-	59282.4	-	41203	-	27699.9	-
	CNRM-CM5	RCP8.5	58932.0	+0.6	30096.8	+27.0	27298.2	+1.5
	HadGEM2-ES	RCP8.5	59553.6	-0.5	25568.1	+37.9	27721.1	-0.1
	Protected areas							
	Present	-	21803.25	-	4609.17	-	587.57	-
	CNRM-CM5	RCP8.5	21795.62	+0.03	4655.99	-1.02	548.38	+6.67
	HadGEM2-ES	RCP8.5	21385.96	+1.91	5033.27	-9.20	580.76	+1.16

(-) indicates a loss of suitable areas and (+) a gain in habitat suitability

Source: Author's computation (2017)

According to the bioclimatic projections, the suitable areas for *Kigelia africana* in Benin are more into the RCP scenarios. Indeed, the model CNRM-CM5 under the RCP 8.5 scenario, predicts a gain of only 0.6 % of the current highly suitable habitats and about 27 % of his moderate suitable habitat in the very highly suitable habitat for *Kigelia africana* (Table 4.2). These habitats will be converted into highly suitable area, increasing their areas to about 53 % (Table 4.2, Figure 4.3). Likewise, the HadGEM2-ES model shows the opposite trends to the model CNRM-CM5 which is projected to be very severe (Figure 4.4). The projection of the model HadGEM2-ES suggested a loss of 0.5 % of his highly suitable habitat for *Kigelia africana* under the scenarios RCP 8.5 by 2050 especially in phytodistricts of Zou, a part of Atakora chain, North and South Borgou and Bassila. The suitable habitat will be converted to moderate and poor suitable area. These areas will increase to around 38 % under the scenarios RCP 8.5, and a loss of the poorly suitable area to 0.1 % by 2050 under the scenarios RCP 8.5 (Table 4.2, Figure 4.5). Thus, the model CNRM-CM5 performed good model than HadGEM2-ES

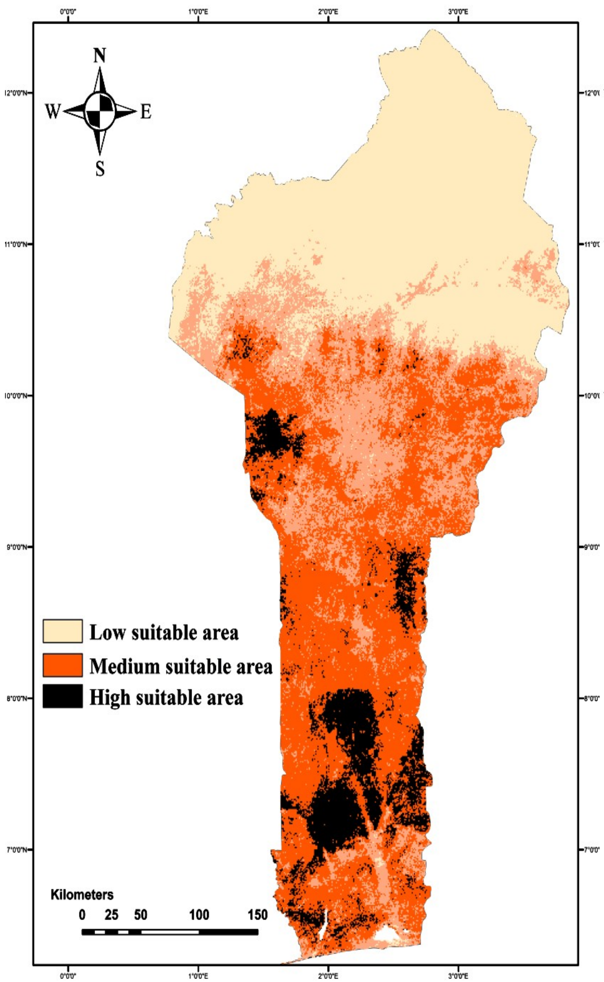


Figure 4.2: Current suitable habitat for *Kigelia africana* conservation as predicted by the model

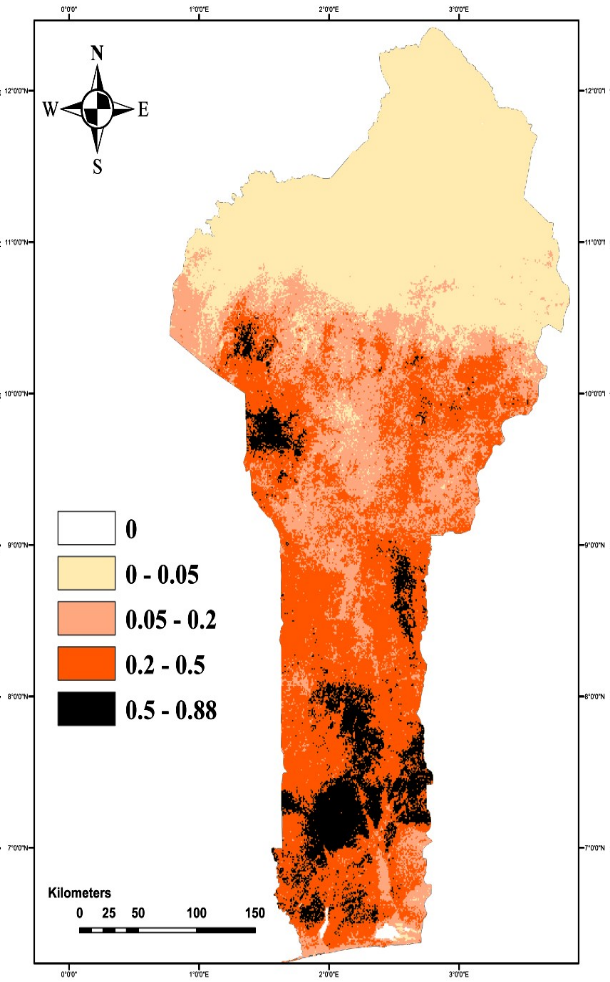


Figure 4.3: Future (2050) suitable habitat for *Kigelia africana* conservation as predicted by the model CNRM-CM5 under RCP 8.5

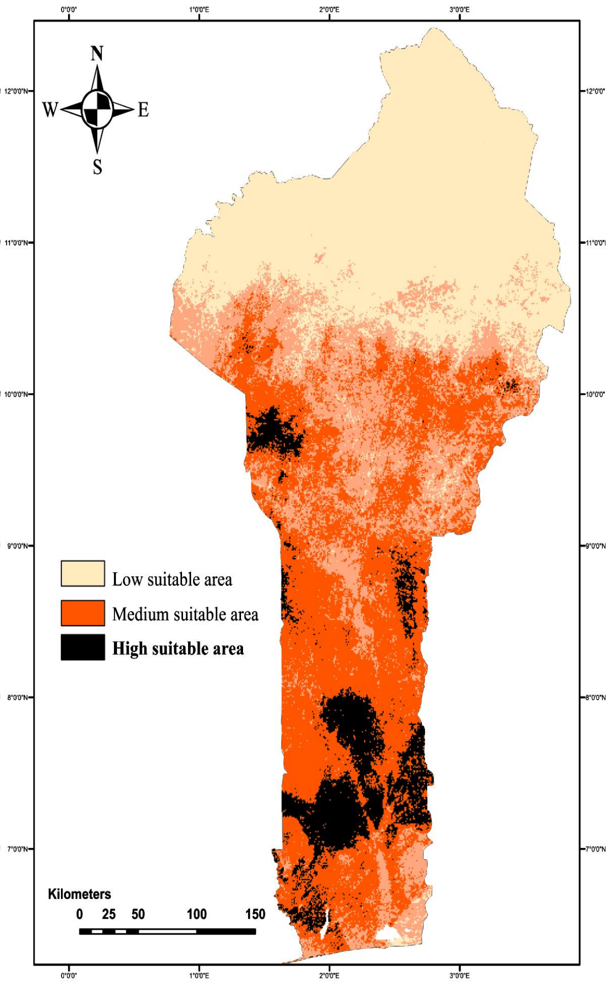


Figure 4.4: Future (2050) suitable habitat for *Kigelia africana* conservation as predicted by the model HadGEM2-ES under RCP 8.5

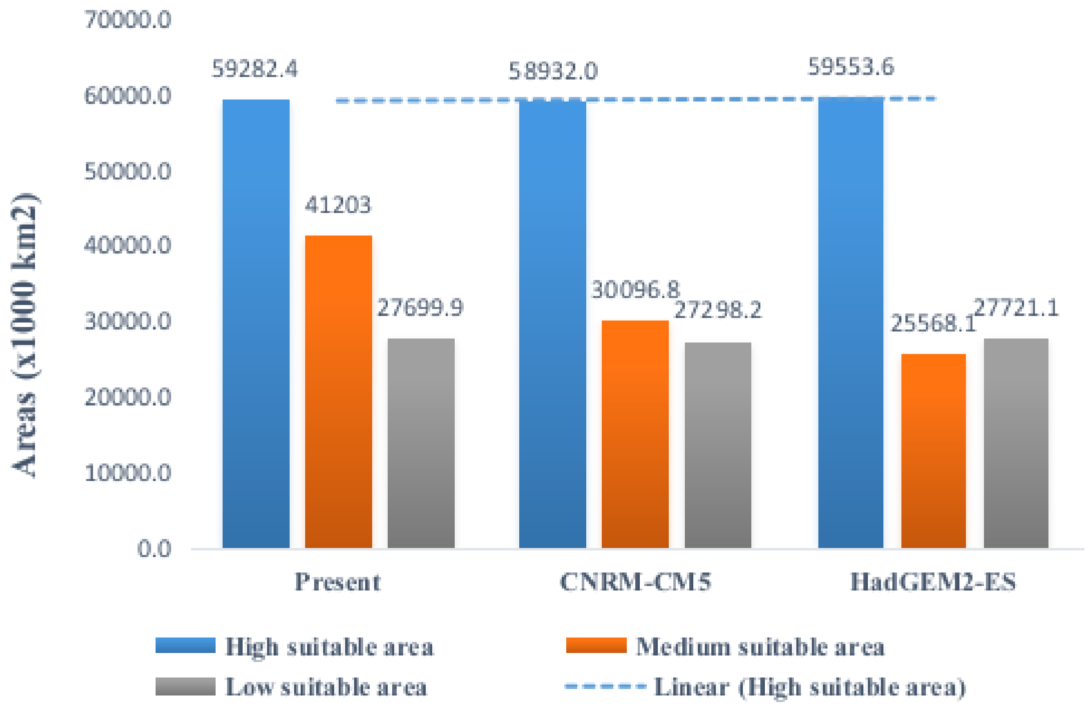


Figure 4.5: Variation in suitable areas to the cultivation and conservation of *Kigelia africana* by 2050, according to the scenarios RCP 8.5 used in the two models CNRM-CM5 and HadGEM2-ES.

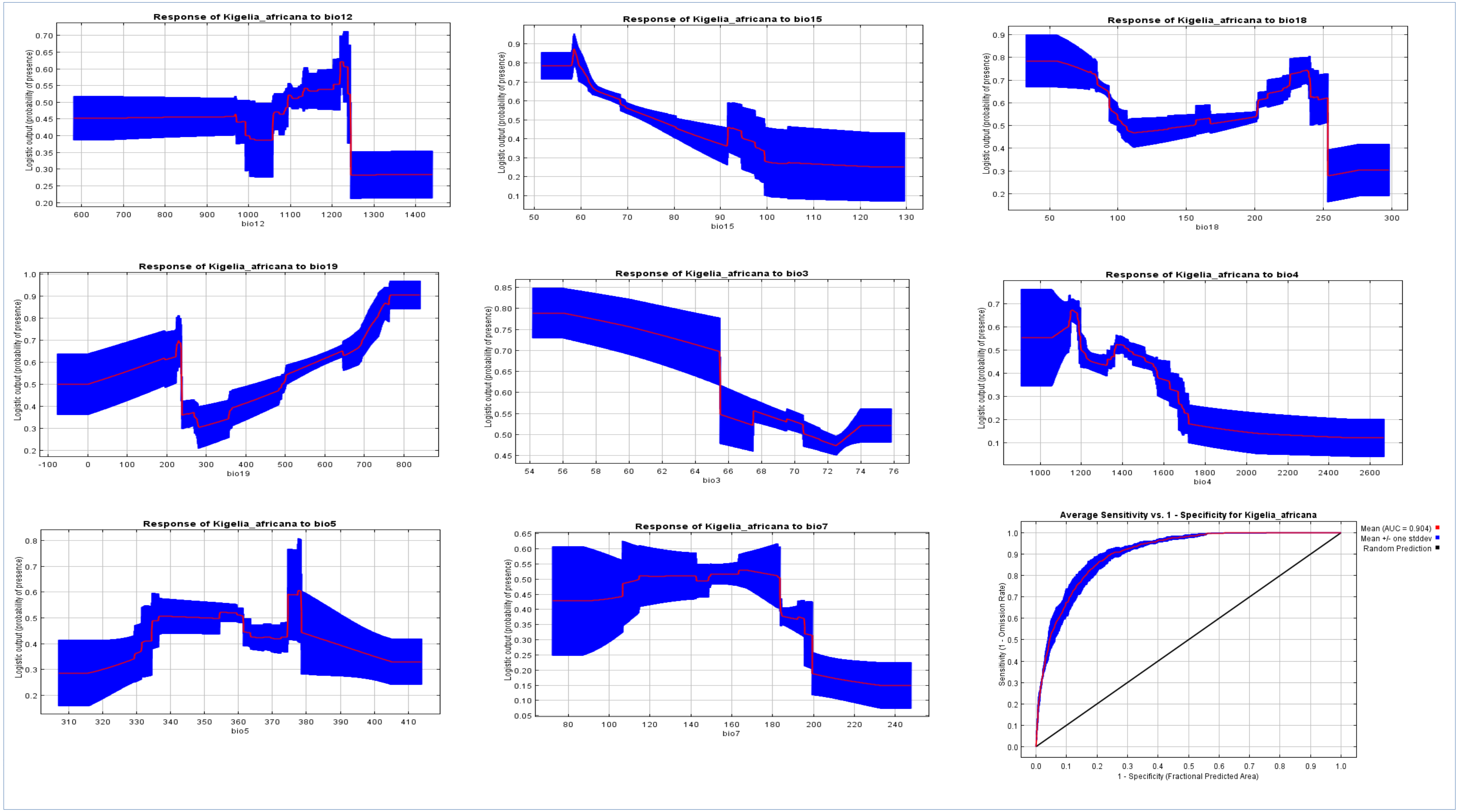


Figure 4.6: Curves showing the responses of predicted presence probability of *Kigelia africana* to environmental variables.

4.1.3 Modelling and reliability of Predictions

In assessing climate change effect on species distribution and to estimate the potential distribution of plant and animal, the predictive models are used. These models allow the linking of statistically significance distribution of the species observed over a given period to the different ecological and climatic factors which may structure its observed range (Piedallu *et al*., 2009). Thus, the niche modelling has frequently been cited as a potent instrument for predicting climate change impact on their distribution and mapping the current and future species distribution (van Zonneveld *et al*., 2009). The model used, which were future CNRM-CM5 (CNR) and HadGEM2-ES (HAD) under RCP 8.5 performed well in predicting suitable conditions for *Kigelia africana* species population. For these species, the AUC proportion was high, 1.0. Therefore the models used were regarded as performing better than random (Idohou *et al*., 2017). These models also participated in uniting statistically the observed distributions of a species for a given period, different ecological factors and climate variable to arrange its area of observed distribution (Piedallu *et al*., 2009). However, these models have also been criticized for their weaknesses in the climate change impact prediction on the geographic dispersion of the species. Among the weaknesses are: uncertainties related to the models used, difficulties in ecological interactions setting, individual idiosyncratic responses of the species to climate change, limitations of species-specific dissemination, plasticity of physiological limits and disseminating agents responses (Fandohan *et al*., 2013). Thus, the impact of soil is not generally integrated into the models, despite their long-time importance in forest composition and productivity (van Zonneveld *et al*., 2009).

Moreover, the postulate base on the current climate where a species is encountered (its current niche), is also debatable. Ecological niches modelling has many applications and it is used to propose a particular sustainable scenarios use of the environment (Beaumont *et al*., 2007) to assess the climate change impact on biodiversity, to identify priority conservation areas and define new locations for reintroductions of the species (Stockman *et al*., 2006). As for *Kigelia africana* geographical location, the literature mentioned in four continents namely Africa, Asia, central and south America and Oceania (Bello *et al*., 2016). All the information from literature confirmed the obtained result of *Kigelia africana* according to which 52.28 % of Benin Republic National area (excluding the Niger river Island) are favourable to the cultivation of *Kigelia africana.*

4.1.4 Analysis of environmental variables and their contribution

Twelve (12) environmental variables contributed to the prediction of the geographical distribution of *Kigelia africana* at different percentages although not all were equally important. Only eight (08) were used for our study. The annual temperature range (Bio5 – Bio6), Precipitation seasonality (coefficient of variation and soil have mostly contributed to this prediction. These results were confirmed by the work of Badeau *et al*. (2005) and Berry *et al*. (2007) where the model incorporated for the first time climatic, trophic and water factors giving consistent results knowledge of the fire tree and spruce species studies in France. Previous literature showed unfavourable judgement of the peculiar study on the climate storyline led to development of a new set of storyline. This last one is referred to as RCP (van Vuuren and Carter, 2014). *Kigelia africana* individual dispersion is sensible to environmental variability at multiple spatial scales. Among these, it was established that the two parameters, precipitation and temperature had varying contribution to the models. The last parameter indicated the scale influence of these variables on the species distribution (Idohou *et al*., 2017). This equilibrium effect of environmental component its physical quality with the two component water availability and temperature are important factor controlled species presence patterns in two zones: subtropical and tropical. Although, *Kigelia africana* species is also affected by biophysical variables (soil) at various levels, the significance of this element in controlling *Kigelia africana* species distribution has been documented (Blach-overgaard *et al*., 2010). Generally, the finding revealed that climatic variable (temperature and precipitation) and biophysical variables (soil) predict *Kigelia africana* distribution. This result corroborates with Peterson and Soberón (2012) who stipulate that climatic factors including soil conditions and abiotic conditions are distinguished as one of the most important factors determining the area where a species is found.

4.1.5 Impact of climate change on the distribution of *Kigelia africana* in 2050

According to bioclimatic projections of CNRM-CM5 model under the scenario RCP 8.5, *Kigelia africana* will only gain small portion of its habitats (Table 4.2) which are currently very favourable (High) and will gain a big portion which are currently medium suitable (moderate) by 2050. Likewise, the low favourable (Poor) habitats will become relatively suitable (Moderate) habitats by 2050. Consequently, according to the model CNRM-CM5 under the scenario RCP 8.5, the production and conservation of *Kigelia africana* is possible in Benin by 2050. Thus, the variation of suitable area presented in our results is in line with previous studies that have modelled the evolution of potential range of species under the rapid climate change assumption (Bourou *et al*., 2012; Fandohan *et al*., 2013). Furthermore, decrease in the distribution of the species in Benin due to anthropogenic disturbance was observed.

4.1.6 Impact of climate change on the *Kigelia africana* cultivation in 2050

According to the results, 52.28 % of the Benin territory particularly in semi-arid and dry sub-humid zones, it is possible to cultivate *Kigelia africana*. These zones offer to the species a great hygrometry that it would need for growth, a good maturation of the fruits and a good yield. In fact, these species are found in the wet savannah woodland spreading into gallery forests and along rivers in moist forests; in open woodland and riverine fringes (Orwa *et al*., 2009), these allow a good distribution and presence of the species. The model CNRM-CM5 predicted a small increase of the favourable suitable area of species cultivation, unlike the model HadGEM2-ES. On the contrary, the last model predicts an increasing precipitation in currently very favourable for the species. Nevertheless, the model HadGEM2-ES also predicted a small reduction in favourable habitats to the species but rather by rainfall reduction (Table 4.2).

In summary, the model CNRM-CM5 predict significant extension habitats, while HadGEM2-ES predict significant regression habitats where *Kigelia africana* will maintain their current production level by 2050.

4.2 Effectiveness of the current network of protected areas in Benin to conserve *Kigelia africana* by 2050

4.2.1 Impact of climate change on the area occupied by habitats favourable to *K. africana* conservation in protected areas

The result revealed that 81 % of Benin protected network area currently are favourable to the conservation of *Kigelia africana* (Table 4.2, Figure 4.8). The protected areas in the south of Benin Republic present a higher convenience level for the conservation of

Kigelia africana than those of northern in Benin. The Pendjari Biosphere Reserve in the North West of Benin is currently a very low favourable area for *Kigelia africana* specifically the Pendjari and Mekrou hunting areas. According to the CNRM-CM5 model under the scenario RCP 8.5, 80 % of this area will remain very favourable to the species conservation by 2050, with 1 % loss of the very favourable habitat (Table 4.2, Figure 4.9). The HadGEM2-ES model under RCP 8.5, predict loss of 9 % of moderate favourable habitat to *Kigelia africana* conservation. It also predicts conversion of 2 % of low favourable suitable area to a very favourable habitat by 2050 below 10° North in the protected area located in the Borgou (Figure 4.10). However, it also predicts very favourable habitat conversion in Pendjari and Mékrou (between 10° and 12° 2' North of the Benin Republic) (Figure 4.7)

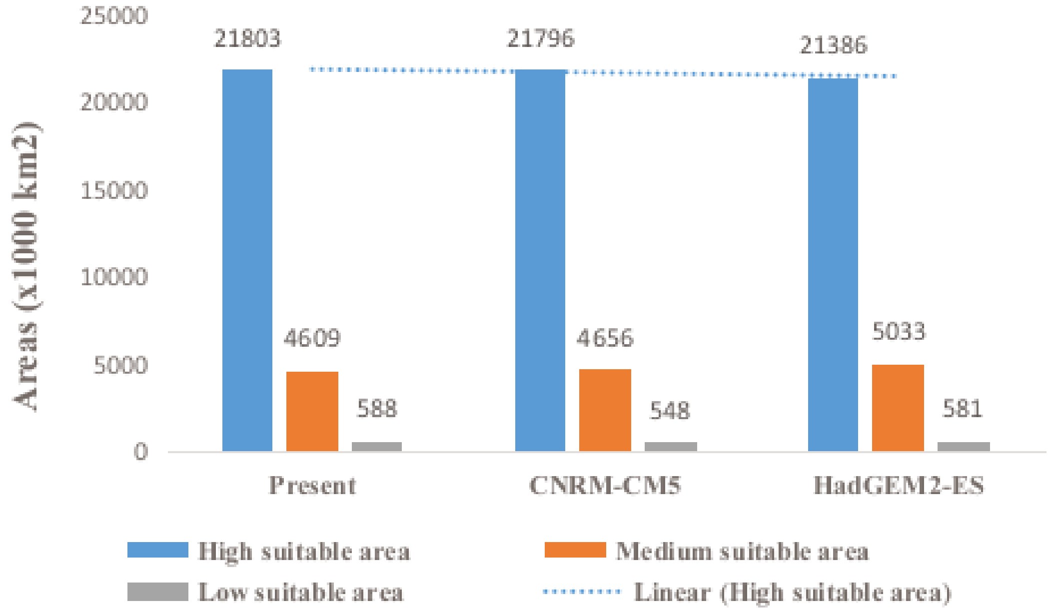
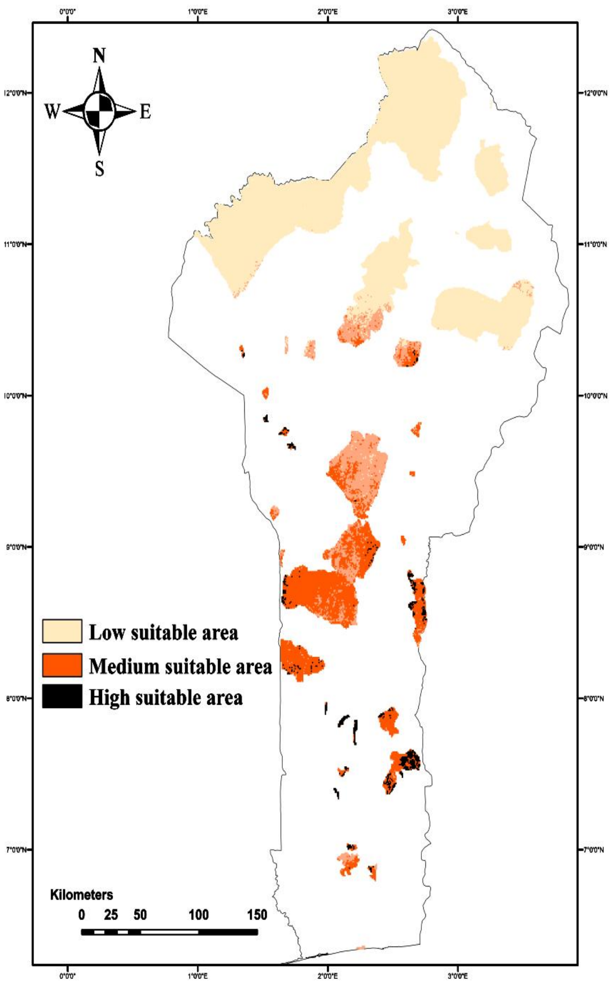
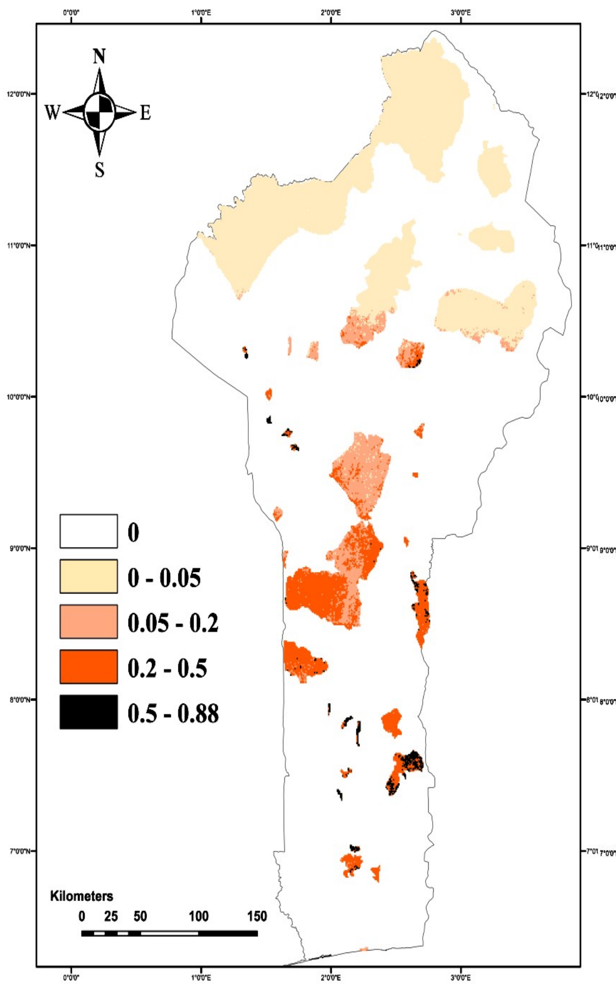


Figure 4.7: Variation in suitable areas to the cultivation and conservation of *Kigelia africana* by 2050, according to the scenarios RCP 8.5 used in the two models CNRM-CM5 &HadGEM2-ES.





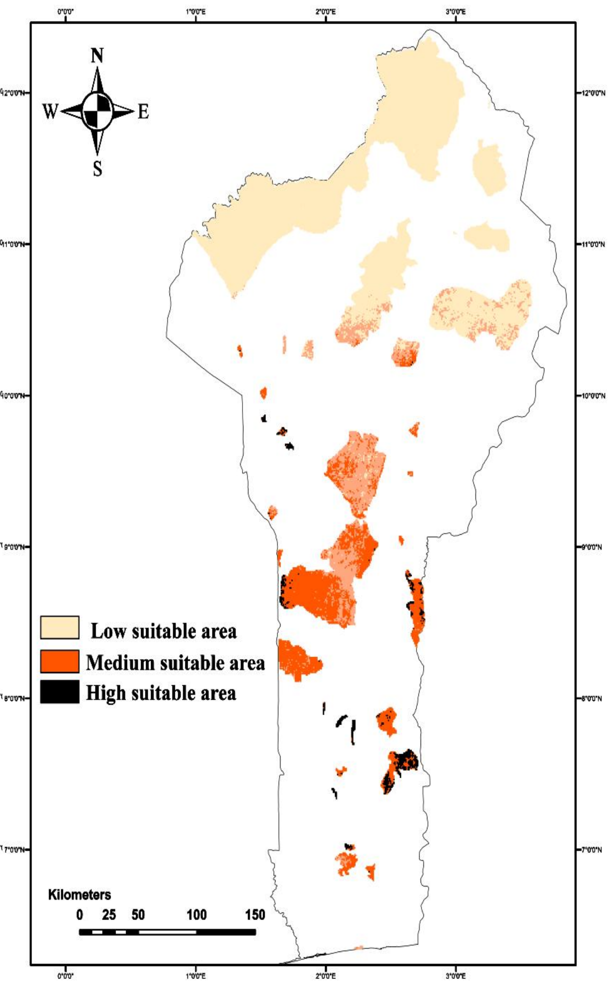


Figure 4.8: Current suitable habitat of *Kigelia africana* conservation

Figure 4.9: Future (2050) suitable habitat of *Kigelia africana* conservation as predicted by CNRM-CM5 climatic model under RCP8.5

Figure 4.10: Future (2050) suitable habitat of *Kigelia africana* conservation as predicted by HadGEM2-ES climatic model under RCP8.5

4.2.2 Impact of climate change of the favourable habitats of *Kigelia africana* in protected areas by 2050.

Protected areas are the only reserves which still are favourable to the conservation of the biodiversity (Houinato *et al*., 2001). The output of this study revealed that the current protected areas networks is very favourable to the conservation of *Kigelia africana* population. CNRM-CM5 and HadGEM2-ES model predicted a decrease in moderate favourable habitats to the species within Benin's networks of protected areas while both model at the same time predicts their extension. Evaluation of the relationship of *Kigelia africana* species distributed and the protected areas demonstrated a good possibility to preserve species population. Moreover, the future model projections predict constancy in protected areas species distributions connection, despite the fact that expansion and reduction may happen just about cases. These result corroborate the hypothesis that protected areas effectively conserve *Kigelia africana* currently and in the future. Most species distribution remain static to face a future climate change, even under the most forceful storyline. However, anthropogenic factor on species habitats continues sometimes causing unpredictable change to landscapes that can lead to extinction of species and conversion of current protected areas to an Agroforestry scheme.

4.2.3 Implications for the conservation of *Kigelia africana*

One of the principal factor chased by the researchers in biodiversity and biological conservation is designation and execution of preventive measures that help to reduce the risk of extinction. Ecological niche modelling can be seen as a powerful tool for achieving this goal though this tool has some weaknesses. In spite of these weaknesses, it provides important bioclimatic information in decision-making (Ayihouenou, 2014). The current favourable condition for cultivation and conservation of *Kigelia africana* relate to the environment variables as annual temperature, seasonality precipitation and soil with its physico-chemical characteristics, temperature seasonality, max temperature of warmest month. Bioclimatic variation conditions over time can change areas very favourable to relatively favourable areas for the conservation and cultivation of *Kigelia africana* and in some cases area that are currently very favourable to areas that are not favourable to the conservation of *Kigelia africana*. Indeed, fluctuations in climate variables such as precipitation and temperature will affect biodiversity and geographic distribution of the species-friendly habitats (IPCC, 2007). Thus, it should be noted that anthropogenic actions influencing greatly climate factors and soil condition by increasing greenhouse gases (GHG) and radiative forcing rates,determine the species distribution habitats.

Although having degradation experiences over the time, the protected networks areas of Benin present a favourable areas to the conservation of the *Kigelia africana* species but at smaller proportion. This is the case of Pendjari Biosphere Reserve, the W park and the Lama forest (Figure 4.9). The climatic conditions prevailing in the current semi-arid and dry sub-humid zones are very favourable to the conservation of *Kigelia africana*. Considering the increase of precipitation (CNRM-CM5 models), the zones that are currently very favourable to their cultivation and conservation (semi-arid and dry sub-humid) could remain very favourable by 2050. In case of decreases in precipitation (model HadGEM2-ES), the areas that are currently very favourable (wet sub-humid) may become less favourable. In the dryness scheme (HadGEM2-ES), the culture and preservation of the species population would be likely throughout the study area.

Similarly, the national protected networks areas offer very favourable conditions for the conservation of the species population. Despite projected reduction, whatever the projection, this network keeps providing habitats that are highly favourable to the local species by 2050. Thus, it will be more appropriate to develop a new model able to predict the dynamics of landscapes of protected areas and the species with great socio-economic importance, taking into account the effects of climate change and land use change. It will be necessary to revise the management of existing protected areas if we need that their role to be the conservation of biodiversity and support adaptation to climates change based on complete result. Moreover, the establishment of up-to-date databases on the potential impact of climate change species in relation to the different scenarios usable could support researchers and conservation decision-making in culture and conservation context. Among the protected areas networks in Benin, the Pendjari Biosphere Reserve, the hunting areas of Park W (Djona and Mékrou), the classified forest of Goungoun and the classified forest of the Lama (Figure 4.9, Figure 4.10) will better guarantee the conservation of *Kigelia africana* by 2050. To this end, it would be important to create in the southern part of the country other Protected Areas that will certainly remain more humid by 2050 in order to guarantee the conservation of the species in these environments. Also, it is very important to the decision makers to increase the protected areas, which remain the guarantee of the species. In addition, weathering adverse effect on protected areas will be combined with other forms of stress, including anthropogenic affect such as over-consumption (bark of *Kigelia africana*), pollution of urbanization. Biodiversity in protected areas, that are already threatened by human activity, risks a more rapid and sever impoverishment due to climate change.

4.3 Assessment of the impact of land use change on the geographic distribution of *Kigelia africana*.

4.3.1 Land use and land cover categories in year 1999

Using Arc Map version 10, we generated the classification image of CCI-LC map of Benin after clipping. The thematic map generated from the classified CCI-LC image, shows that Benin Republic areas was dominated by the agricultural land (37.85 %), follow by the Shrubland (33.93 %) and the Forest (27.64 %). Water, Urban areas occupied 0.33 % and 0.16 % respectively (see Table 4.3 and Figure 4.11).

Table 4.3: Surface area and proportion of land use categories in 1992

LULC class	Year_1992 (km^2)	P (%)
Agriculture	43,440.92	37.85
Forest	31,724.18	27.64
Grassland	22.14	0.02
Wetland	25.96	0.02
Urban	188.96	0.16
Bares soil	38.42	0.03
Water	377.45	0.33
Sparse vegetation	1.30	0.00
Shrubland	38,943.67	33.93
Total	114763	100.00

Source: Author's computation (2017)

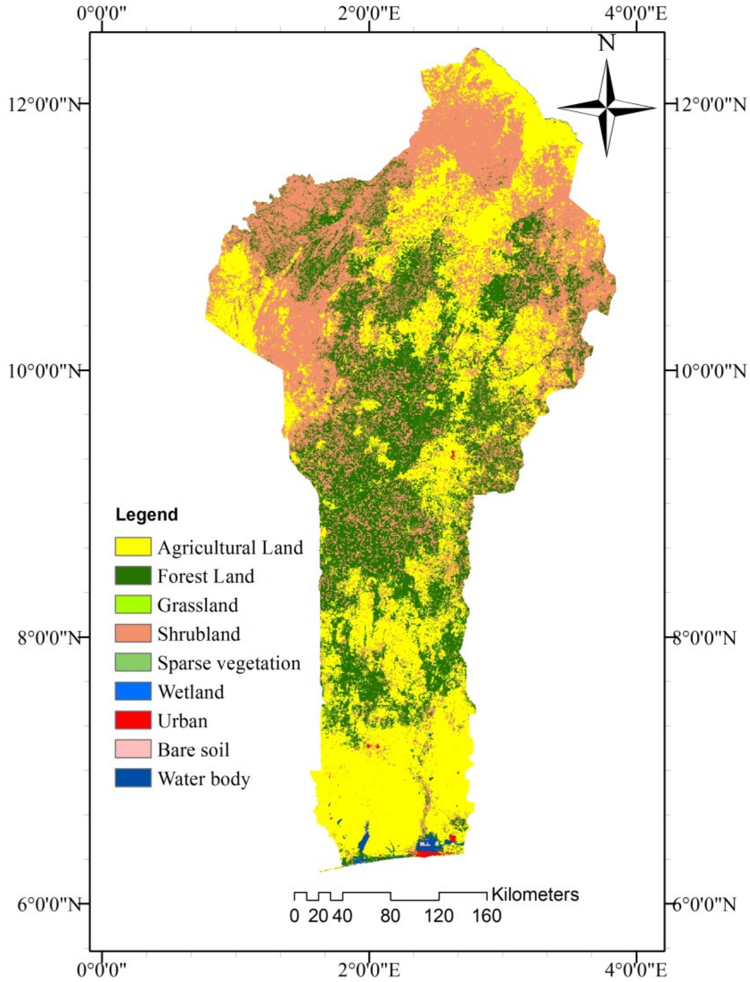


Figure 4.11: Classified LULC map of Benin Republic in1992

4.3.2 Land use and land cover categories in 2003

LULC categories proportion in the classified map of Benin in 2003 is shown in Table 4.4. In 2003, Shrubland decreased. The proportion of area is 28.12 % while agricultural land and forest areas increased. The proportion of land use of each of them is respectively 39.77 % and 31.47 % (Figure 4.12).

Table 4.4: Surface area and proportion of land use categories in 2003

LULC class	Year_2003 (km^2)	P (%)
Agriculture	45,642.84	39.77
Forest	36,118.43	31.47
Grassland	15.64	0.01
Wetland	28.67	0.02
Urban	268.31	0.23
Bares soil	2.51	0.00
Water	411.69	0.36
Sparse vegetation	0.47	0.00
Shrubland	32,274.43	28.12
Total	114763	100.00

Source: Author's computation (2017)

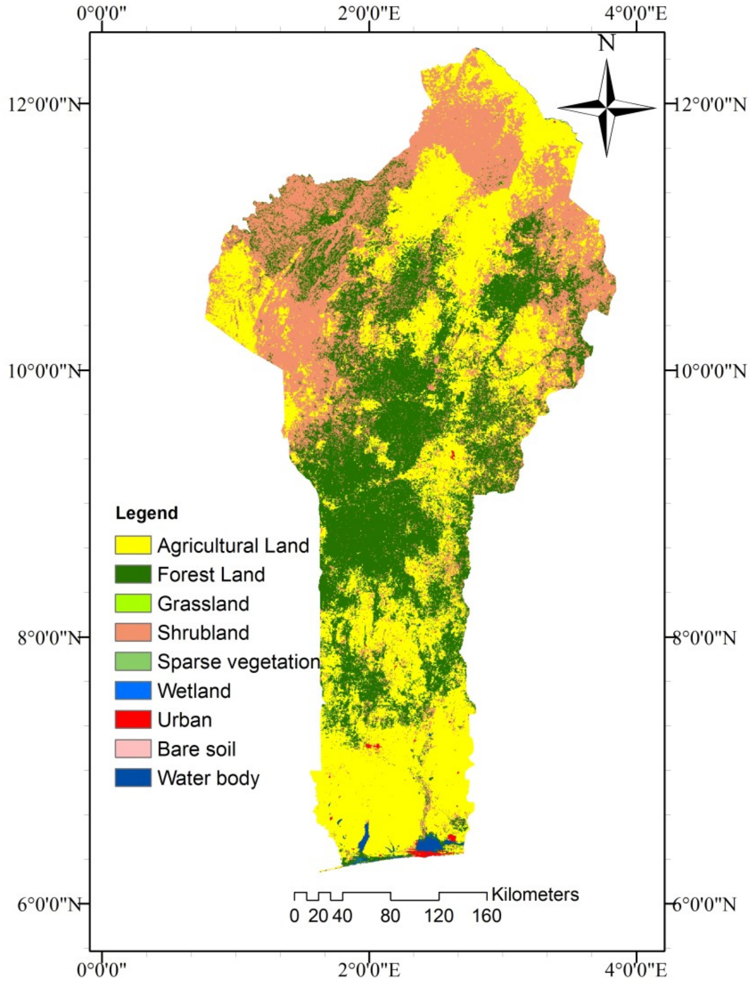


Figure 4.12: Classify LULCC map of Benin Republic in 2003

4.3.3 Land use and land cover categories in 2015

The dimension of the classified map of Benin in 2015 is shown in table 4.8. This table shows that the largest LULC type remain agricultural land which had increased to 41.38 % followed by the forest land which also had increased to 32.34 %, and by the shrub land (25.43 %) even if it undergo regression, water (0.34 %) and urban (0.46 %). Figure 4.12 shows that the shrub land still decreased in the northern part of Benin (Sudanian region) and some of part of the middle and south part of Benin Sudano-Guinean and Guineo-Congolian respectively. The decreased of shrubland and Bares soil may be due to increase of agricultural land and urban areas. Most of the Benin protected area in the Sudano-Guinean and Guineo-Congolian are dominated by the shrub land.

Table 4.5: Surface area and proportion of land use categories in 2015

LULC class	Year_2015 (km2)	P (%)
Agriculture	47,493.21	41.38
Forest	37,117.58	32.34
Grassland	11.08	0.01
Wetland	33.70	0.03
Urban	527.69	0.46
Bares soil	2.23	0.00
Water	387.30	0.34
Sparse vegetation	0.47	0.00
Shrubland	29,189.74	25.43
Total	114763	100.00

Source: Author's computation (2017)

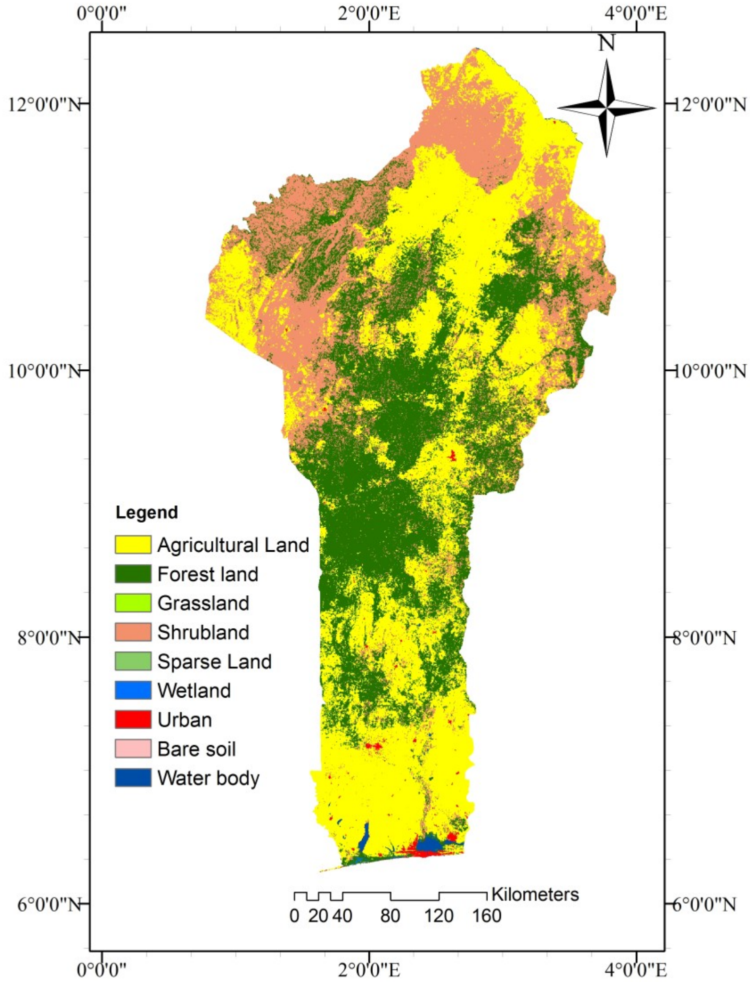


Figure 4.13: Land use and land cover classify map of Benin Republic in 2015

4.3.4 Change analysis for 1992 to 2003

A cross-tabulation of the LULC changes was analysed during 1992–2003 (period 1), 2003–2015 (period 2), and 1992–2015 (period 3), respectively. For this study, the gain and loss by LULC category, namely Agricultural land and a net change of Forest land in period 1 was examined. From Table 4.6 the agricultural land increased in size by 1.92 % and the annually rate of change between 1992 and 2003 is 0.17 %

Most of the gallery forest in Benin Republic are located in the Sudano-Guinean and Guineo-Congolian region. Most of the Benin protected areas are dominated by the gallery forest, shrub land and the plantations of Benin National Wood Office (ONAB). The Forest area increased in size by 3.83 % between 1992 and 2003 with annual rate of 0.35 %. This greater size may be due to decision ONAB project took to afforest most of the deforestation areas. Grassland and Bare soil did not increase. In fact, they decreased respectively by 0.01 % and 0.03 %. The driving factors of greater size of agricultural land is due to the growth of the population which was 5,371,226 inhabitants in 1992 with 3.78 % growth rate; in year 2003 the population was 7,665,681 inhabitants with 3.38 % growth rate. This mean that the rate of population growth between 1992-2003 was 2,294,455 and the rate of growth is 1.01 % (INSAE_Benin, 2014). Thus, these are most of the land use change which impact negatively the land cover. Likewise, the decrease of shrubland may be due to the rate of density of inhabitants per km^2. In Benin Republic, the population density in 1992 was 43 inhabitants/km^2 and in 2002, it rose to 59 inhabitants /km^2. The variability between 1992 and 2002 is 16 inhabitants /km^2. This growth rate of density led to the decrease of the land cover surface.

Other increased LULC category was water body within the period under consideration. The areas covered by water bodies in Benin was 34.24 km^2 between 1992 and 2003. The rate of change was 0.03 %. Although water body increases, water supply still scarce resource in some areas in Benin. This largely associated to the inadequate number of water reservoirs coupled with early drying up of water bodies during the dry season. Table 4.6 presents the change from a land use to the other. In the diagonal, the proportion of unchanged land use categories from 1992 to 2003 were represented. The initial and final images were represented in the class total value of the column and the row total columns respectively. The Appendix C shows the change that occurred through each year on each class.

Table 4.6: Amount of changes in LULC during 1992–2003

Years	1992		2003		Change 1992-2003		change
LULC class	Area (km2)	P (%)	Area (km2)	P (%)	Area (km2)	P (%)	
Agriculture	43,440.92	37.85	45,642.84	39.77	2,201.92	1.92	5%
Forest	31,724.18	27.64	36,118.43	31.47	4,394.25	3.83	13.85%
Grassland	22.14	0.02	15.64	0.01	-6.50	-0.01	-29.36%
Wetland	25.96	0.02	28.67	0.02	2.72	0.00	0.00
Urban	188.96	0.16	268.31	0.23	79.36	0.07	0.01
Bares soil	38.42	0.03	2.51	0.00	-35.91	-0.03	0.00
Water	377.45	0.33	411.69	0.36	34.24	0.03	0.00
Sparse vegetation	1.30	0.00	0.47	0.00	-0.84	0.00	0.00
Shrubland	38,943.67	33.93	32,274.43	28.12	-6,669.24	-5.81	-0.53

Source: Author's computation (2017)

4.3.5 Change analysis for 2003 to 2015

The different statistics of LULC class between 2003 and 2015 is given in Table 4.11. From 2003 to 2015, agricultural land, forest and urban increased by 1.61 %, 0.87 % and 0.23 % respectively, while shrub land and water had decreased by 2.69 % and 0.02 % respectively. Shrubland constitute the most regressing LULC class in Benin between 2003 and 2015. These changes may be due to the increase in urban and agricultural lands. The density of population was 87 inhabitants /km2 in 2013 (INSAE_Benin, 2014). The expansion of agricultural land is in tandem with the distribution of population from the intensively cultivated areas in the north which is more dominated by the cotton cultivated (Figure 4.12, Figure 4.13). In Benin, water body decreased by 0.02 during the period 2003 to 2015. This decrease may be due to climate impact on rainfall or as well as the siltation of some water body mostly the areas or region where the human activities pressure were certified.

4.3.6 Change analysis for 1992 and 2015

The significance changes of land cover occurred in Benin Republic from 1992 and 2015 is shown in the Table 4.11. From this statistic, the land use categories that had decreased between 1992 and 2015 in Benin are shrubland. For instance, the shrubland which occupied 33.93 % of Benin decreased by 8.50 % during the last 23 years with 0.37 % of annual rate. Regarding grassland and bare soil, they passed from 0.02 % and 0.03 % of the landscape in 1992 to 0.01 % and 0 % in 2015. Grassland lost 0.01 % of its cover in favour of agricultural land. The change that occurred in different periods is showed in Figure 4.14

Table 4.7: Land use and land cover change from 2003 to 2015

Years	**2003**		**2015**		**Change 2003-2015**		**Rate of change**
LULC class	**Area (km2)**	**P (%)**	**Area (km2)**	**P (%)**	**Area (km2)**	**P (%)**	
Agriculture	45,642.84	39.77	47,493.21	41.38	1,850.36	1.61	0.13
Forest	36,118.43	31.47	37,117.58	32.34	999.15	0.87	0.07
Grassland	15.64	0.01	11.08	0.01	-4.56	0.00	0.00
Wetland	28.67	0.02	33.70	0.03	5.03	0.00	0.00
Urban	268.31	0.23	527.69	0.46	259.38	0.23	0.02
Bares soil	2.51	0.00	2.23	0.00	-0.28	0.00	0.00
Water	411.69	0.36	387.30	0.34	-24.39	-0.02	0.00
Sparse vegetation	0.47	0.00	0.47	0.00	0.00	0.00	0.00
Shrubland	32,274.43	28.12	29,189.74	25.43	-3,084.68	-2.69	-0.22

Source: Author's computation (2017)

Table 4.8: Land use and land cover change from 1992 to 2015

Years	1992		2015		Change 1992-2015		Rate of change
LULC class	**Area (km2)**	**P (%)**	**Area (km2)**	**P (%)**	**Area (km2)**	**P (%)**	
Agriculture	43,440.92	37.85	47,493.21	41.38	4,052.28	3.53	0.15
Forest	31,724.18	27.64	37,117.58	32.34	5,393.40	4.70	0.20
Grassland	22.14	0.02	11.08	0.01	-11.06	-0.01	0.00
Wetland	25.96	0.02	33.70	0.03	7.75	0.01	0.00
Urban	188.96	0.16	527.69	0.46	338.74	0.30	0.01
Bares soil	38.42	0.03	2.23	0.00	-36.19	-0.03	0.00
Water	377.45	0.33	387.30	0.34	9.85	0.01	0.00
Sparse vegetation	1.30	0.00	0.47	0.00	-0.84	0.00	0.00
Shrubland	38,943.67	33.93	29,189.74	25.43	-9,753.92	-8.50	-0.37

Source: Author's computation (2017)

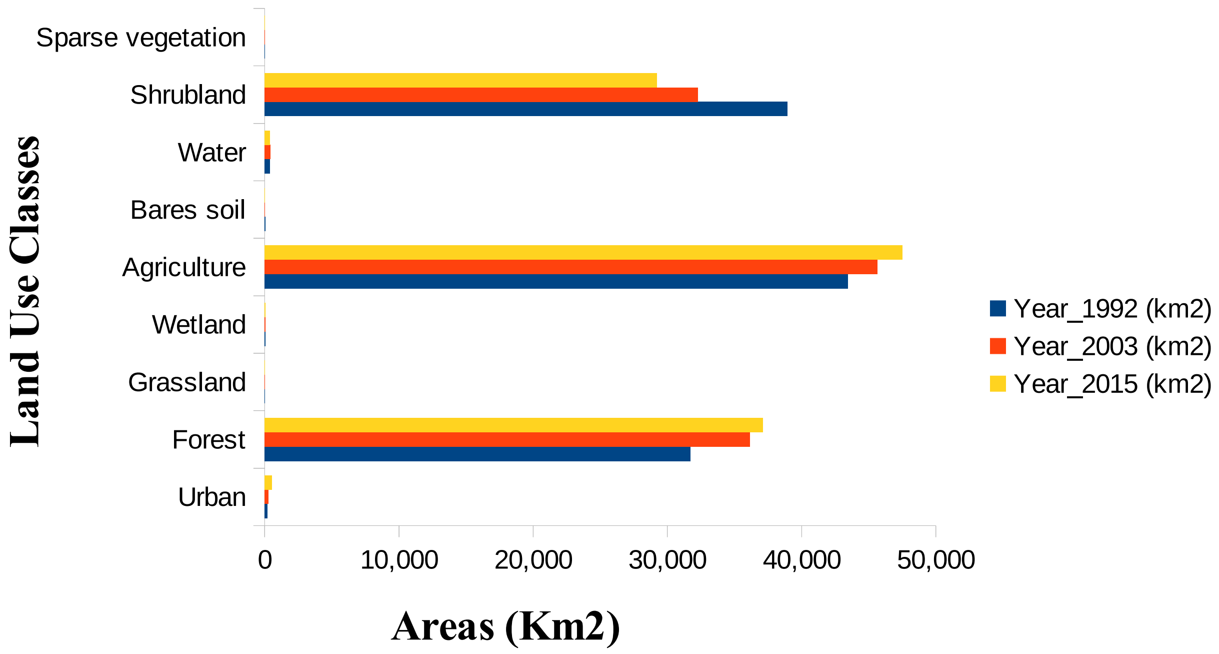


Figure 4.14: Change detection of 1992, 2003 and 2015

Unlike grassland and bares soils, agricultural land and forest had increased. Agricultural lands are the most increasing land class during these 23 years. The agricultural lands which occupied 37.85 % of the Benin areain 1992, grew up to 41.38 % in 2015. It increased by 3.53 % and the annual rate of change is 0.15 %. The second most important increase in land cover category was the forest land.

Forest land covers 27.64 % of Benin total areas in 1992, it increased to 32.34 % in 2015 representing an annual increase rate of 0.20 %. This increase may be due to the policies to protect the National Parks and gallery forest in protected areas over the whole of the country and the ONAB project to afforest most of the Benin areas by the artificial forest. The third and last increase in land class was the water bodies. Water bodies, which occupied 0.33 % of the overall area of the Benin Republic in 1992, increased by 0.34 % in 2015. It increased up to 0.01 %.

4.3.7 Impacts of land use change in the geographic distribution of *K. africana*

The result revealed that shrub land, wooded savannah, grassland and bare soil have decreased in size over the last 23 years in favour of agricultural land and urban (Figure 4.11, Figure 4.12, Figure 4.13). Gallery forests are the only one formation that do not experienced degradation. Indeed, in view of their distinctiveness, vulnerability and diversity, the forest in Benin is strictly protected by Benin forest legislation (Issiaka, 2016).

In addition, agricultural lands have increased in land occupation the last 23 years because of the extensive cultivation of cotton mainly in the Sudano-Guinean region. This extension of agricultural lands is logical with the high rate of human population growth in Benin. Djenontin (2011) used landsat images and showed that in Sudanian and Sudano-Guinean regions the decrease rate of annual average of forest and shrubland was approximated 2.8 %. This regression of land use class is mainly due to wide cotton productions and the seasonal movement of pastures in gallery forest and shrubland, hunting fodders resources and water. Similarly, Toko *et al*. (2010) came to the same decision showing that the rate of vegetation area decrease is principally due to agricultural activities, over grazing, wildfires, carbonization and cutting trees. All these results are similar to the results of our model HadGEM2-ES and CNRM-CM5 under the scenario RCP 8.5. The flora is composed of several plant species and represents critical resources for fauna and people. The degradation of this vegetation cover has negative impacts on the biodiversity. Thus, Benin Republic biodiversity is threatened by the degradation of the flora.

4.4 Assess the socio-cultural and economic importance of *Kigelia africana* in Benin.

4.4.1 Traditional nomenclature and ethnoecological knowledge on *Kigelia africana*

In Benin Republic, West Africa, various names are given to *Kigelia africana* according to the surveyed socio-cultural groups. These names vary from a socio-cultural group to another and within certain socio-cultural groups including Gourmantché, Fon, Idatcha, Nago, Yoruba, Holli, Adja, Dendi. However, the meaning of these names, refers either to the mystic dangerous side of the tree fruit and its ecology (occurrence in wetland and woodland) (Table 4.9). Regardless to the socio-cultural groups and the different respondents, *Kigelia africana* is found in different habitats: the house due to the domestication of the species, the farm due to the natural growing or the domestication, along river side, in the gallery forest with ferruginous soil, in the Wet dense forest semi-deciduous, vertisol and woodland Savannah. The woodland savannah and gallery forest were more mentioned by the Fon (100 %), Gourmantché (100 %) and Holli-Ifè (93.55 %) ethnic groups. Alongside river was more mentioned by the Holli-Ifè (96.77 %), Fon (93.33 %) and Gourmantché (80 %) (Figure 4.15). Alongside river was more mentioned by the Holli-Ifè (96.77 %), Fon (93.33 %) and Gourmantché (80 %). Plate III and Plate IV show the ecological habitats of *Kigelia africana*.

Table 4.9: Local name of *Kigelia africana* in the different socio-cultural group.

Socio-cultural group	Language	Locale name	Meaning	P(%)
Fon	Fon/ Mahi	Gnanblikpo		100
Yoruba	Idaasha/ tchabe	Gnanblikpo	Tree whose fruit is like the breast of the woman Dendi	-
Dendi	Dendi	Fafaberi	Tree whose fruit is like the breast of the woman Dendi	-
Gourmantche	Ottamari	Boukpentouho	species whose fruit is like baobab but longer than baobab	100
Yoruba	Holli-Ife	omongnan	fruit looklike woman breast	-
		Kpandoro	fruit looklike woman breast	100
Dompago	Yaum	N'numahum	fruit looklike woman breast	68

P = Proportion of local name citation
Source: Author's field work (2017)

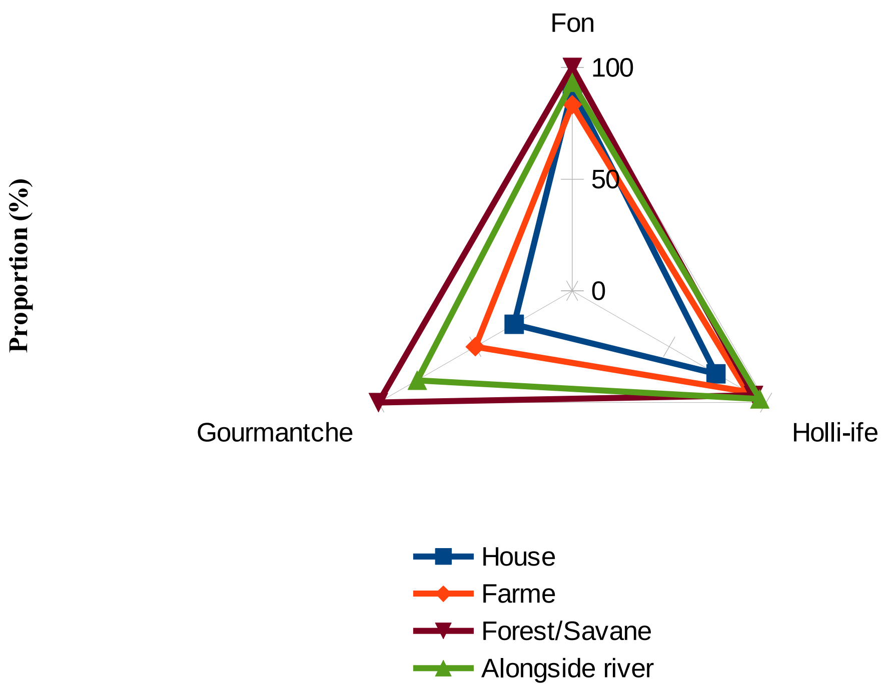


Figure 4.15: *Kigelia africana* habitats mentioned by the socio-cultural groups

Plate III: Habitat of *Kigelia africana* in wetland savannah

Plate IV: Habitat of *Kigelia africana* in settlement

Thus, these result are consistent with the field observations where *Kigelia africana* is predominantly recorded. The different characteristic related to the dynamic and cause of finding of *Kigelia africana* everywhere were mentioned by each socio-cultural group. All these confirmed that this species *Kigelia africana* is an Agroforestry tree. The Figure 4.16 shows the habitats characteristic of *Kigelia africana* between the socio-cultural groups. Among the different causes, are the ability to grow everywhere, easy adaptation to any habitats and they like also water because of its fruit.

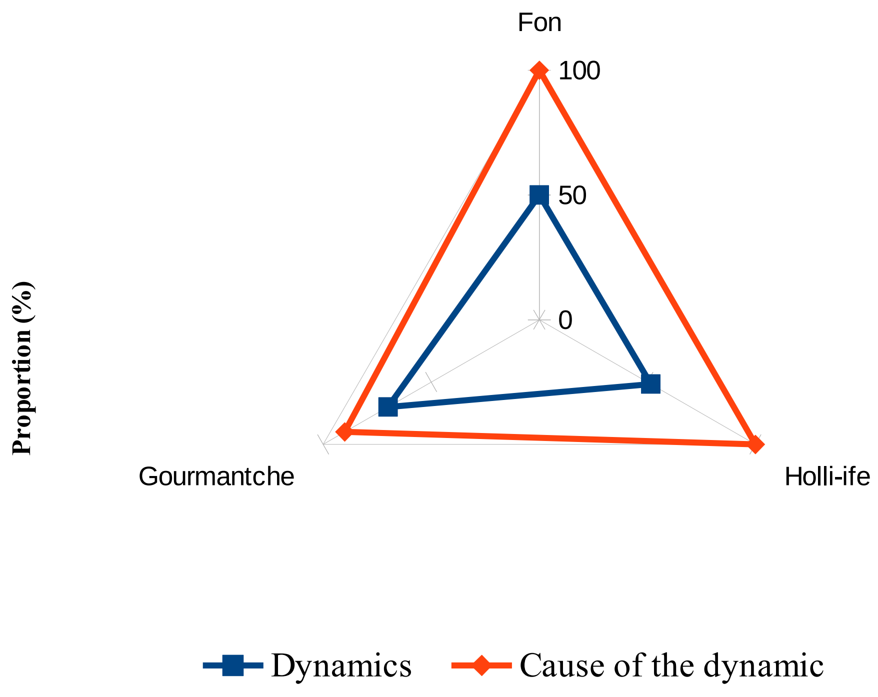


Figure 4.16: Characteristic of these dynamic of *Kigelia africana*.

4.4.2 History and taboos of *Kigelia africana*

There are no taboos linked to *Kigelia africana* harvesting (100 % of interviewees). The different taboos mentioned by the different socio-cultural group were the prohibition of a man to cross the fruit of *Kigelia africana* otherwise his penis will take a considerable length. There is also prohibition for a young woman breast to touch the fruit of *Kigelia africana* because her breast might also take a considerable length.

4.4.3 Local perceptions on *Kigelia africana* regression and underlying causes

During data collection, all the people surveyed acknowledge that they have registered regression in the dynamic of *Kigelia africana* in the recent last thirty years. Several causes were mentioned. The Table 4.10 summarizes these different causes

Table 4.10: Causes of regression in the dynamic of *Kigelia africana*

No	Causes
1	Population growth which decreased forest area
2	Increased in agricultural land-cover
3	Deforestation
4	Degradation of the water resource (river and waterbody) where *Kigelia africana* is most found
5	Anarchic removal of parts of *Kigelia africana*
6	Low economic value of fruit of *Kigelia africana*
7	Fires of vegetation

Source: Author's computation (2017)

4.4.4 Uses value of *Kigelia africana*

4.4.4.1 Reported use value variation in relation with the age, sex and socio-cultural group

The Reported Use Value (RUV) is the total number of *Kigelia africana* reported by each respondent. Poisson regression (Table 4.11) shows that the overall number of reported uses do not significantly vary (Prob> 0.05) across socio-cultural group, sex and age.

Table 4.11: Effect of ethnicity groups, sex and age on RUV: Poisson regression result

Parameter	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.3253	0.3831	0.849	0.399
Sex M	-0.253	0.2143	-1.181	0.2422
Age B	0.16	0.3425	0.467	0.642
Age C	0.3625	0.3351	1.082	0.2835
Age D	0.2246	0.3543	0.634	0.5284
Ethnic group Gourmantché	0.2738	0.1596	1.715	0.0912
Ethnic group Holli-Ifè	-0.235	0.1352	-1.738	0.0871

Source: Author's computation (2017)

4.4.4.2 Variation of the reported use value (RUV) in relation with the parts

According to our survey, five *Kigelia africana* parts have been reported to be useful: the leaf, the fruit, the flower, the root and the bark. The reported analysis on the average of the frequency use of the parts by surveyed respondent indicates that the bark, the fruit and the leaf are more used than the flower and the root (Figure 4.17). However, considering the total number of uses mentioned for each parts for all respondents (Figure 4.18), it was also observed that the number of use mentioned for the bark (71) is greater than the number mentioned for the fruit (66), for the leaves (61), for the flower (10) and for the root (6). From the analysis of these results, it appeared that in terms of use of *Kigelia africana* parts, the consensus is more established between the respondents on the bark than the fruit, leaf, flower and root.

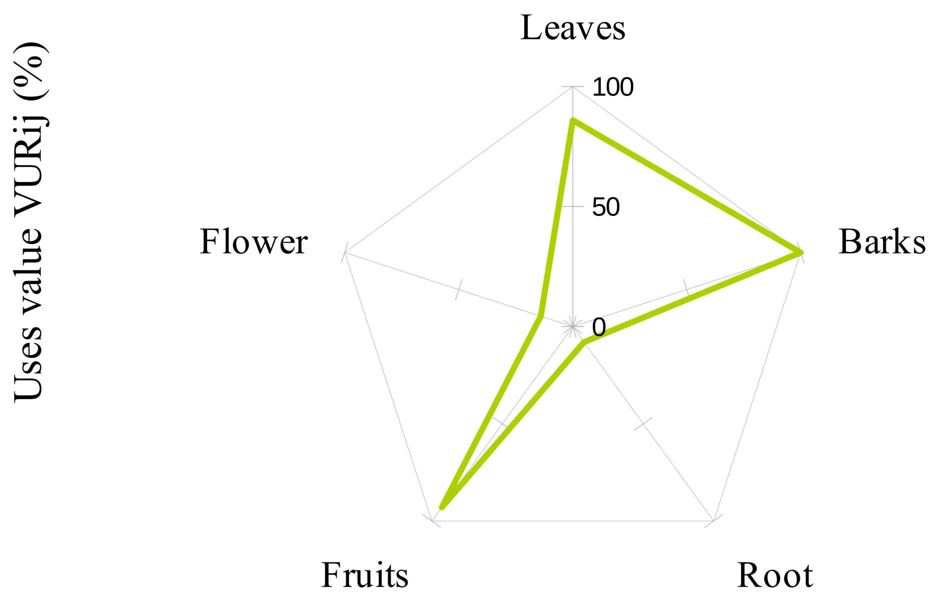


Figure 4.17: Average ethnobotanical Use frequency reported per parts of *Kigelia africana*

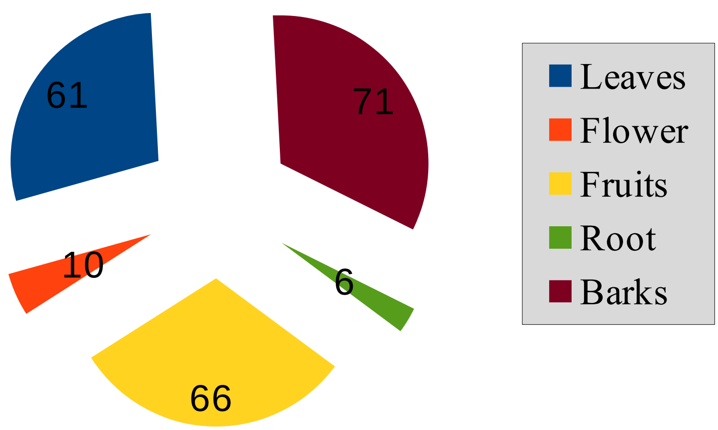


Figure 4.18: Total ethnobotanical use number mentioned per parts of *Kigelia africana*

The Principal Component Analysis (PCA) performed to describe the relationships between the Ethnobotanical Use Values reported for the different parts/ organs of *Kigelia africana* and the different parameters (socio-cultural group, age, sex) reveals that 66.65 % of the initials information is controlled by the first two axes. These last one are retained for the interpretation of the results. The correlation between the parts use value and the axes (Figure 4.19) reveals that high use value of the bark is associated with high use value of the fruit and the leaves. (Dim1). Therefore, high use value of flower is associated with high use value of root but with low use value of the bark (Dim2). In summery, large use value of bark is often associated with an important use of fruit and flower but with little use of root. The different parts and parameter associated (socio-cultural group, age and sex) (Figure 4.20) reveals that the Fon and Gourmantché socio-cultural group value the leaves, the fruits and barks more, but very little the flower and the root. The Holli-Ifè value more the bark and little the flower. Thus, it conclude that the parts use reported vary according to the socio-cultural groups.

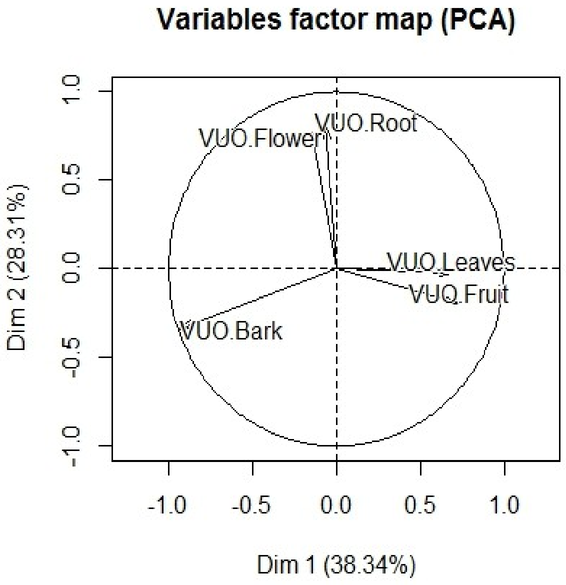


Figure 4.19: parts use value projection

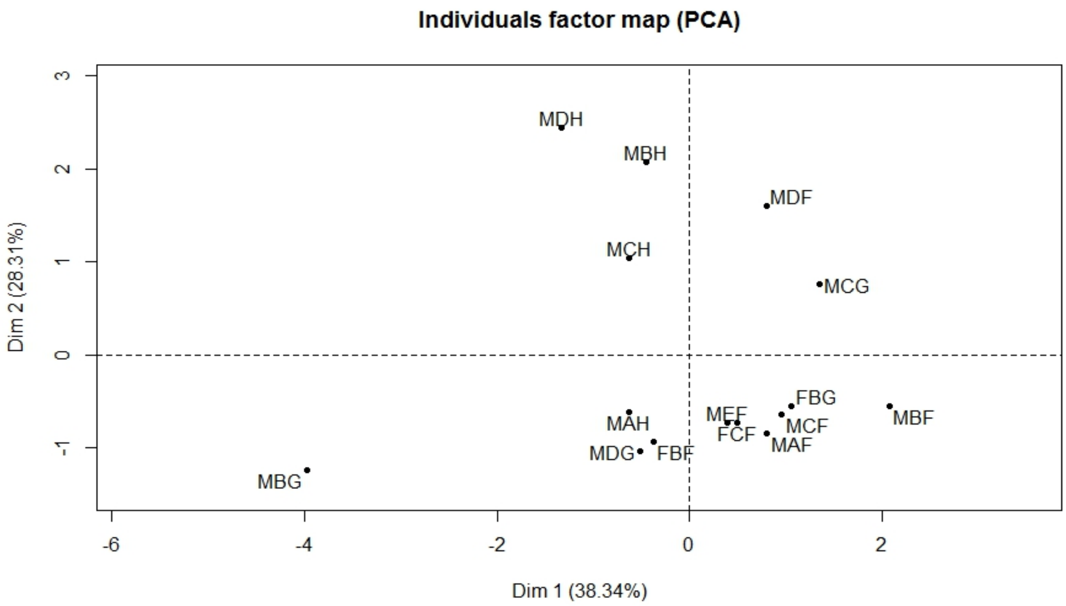


Figure 4.20: Socio-cultural group projection according to the parts use value with sex on the left of each abbreviation, ages at the middle and ethnicity on the right. MBG= Male, age B, Gourmantché; MDG= Male, age D, Gourmantché; FBF= Female, age B, Fon; MAH= Male, age A, Holli-Ifè.

4.4.4.3 Variation of reported use value in relation with use categories

Three (03) use categories were identified for *Kigelia africana* during our survey. These include medicinal use, firewood use and charcoal. The analysis of average use number reported per respondent for each category (Figure 4.21) indicates that *Kigelia africana* is more used in medicinal than the charcoal and firewood. The total uses number of distribution reported by all the respondents according to the use categories (Figure 4.21) reveals that 71 scores were granted to medicinal use by all the respondents against 10 for firewood and 8 for charcoal use. In summary, in terms of *Kigelia africana* use, the consensus is well established in terms of medicinal compared with firewood and charcoal uses.

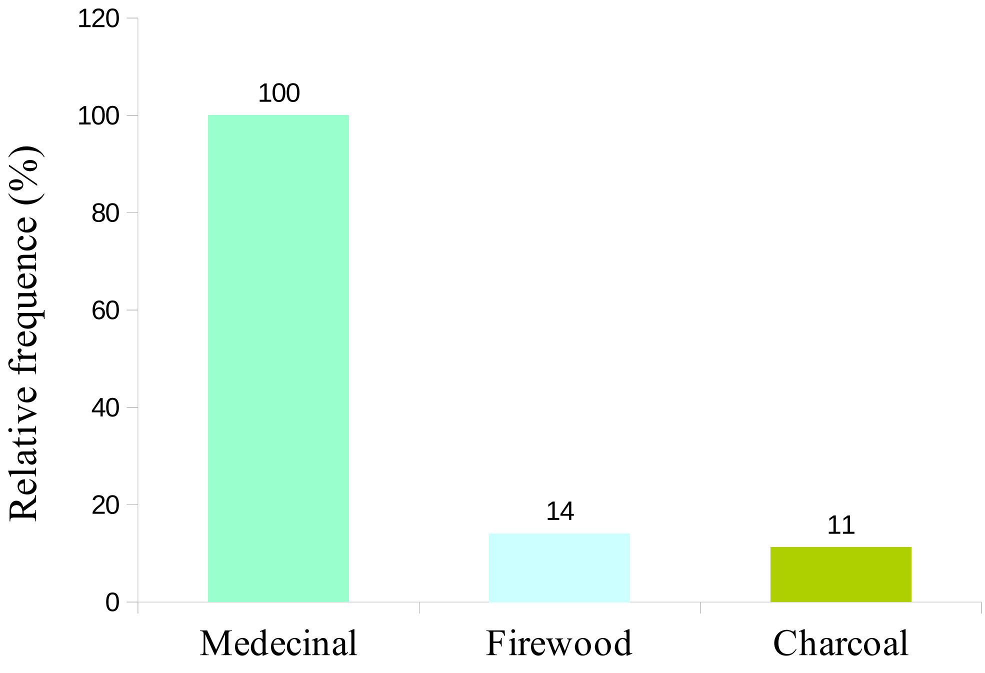


Figure 4.21: Average frequency of use categories citation of *Kigelia africana*

The Principal Component Analysis (PCA) performed to describe the relationships between the use categories and the socio-cultural group of *Kigelia africana* revealed that 100 % of the initials information is controlled by the first two axes. This is due to the socio-cultural group value use link only to the medicinal. Thus, it is not used in food and other categories. The value use in firewood and charcoal is not negligible.

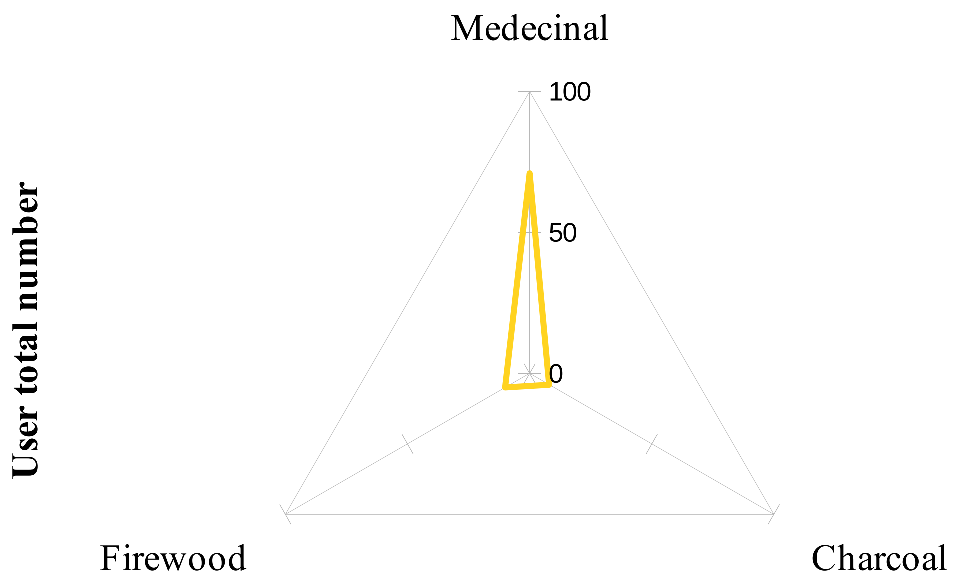


Figure 4.22: Overall use category mentioned per use category for *Kigelia africana*

4.4.4.4 Specific uses of *Kigelia africana*

The specific uses for *Kigelia africana* according to the parts of the species, the use categories, the preparation methods or use, the dosages and the frequencies of citation. It reveals that 71 uses are made for barks, 66 for the fruits, 61 for leaves, 10 for the flowers and 6 for roots.

4.4.5 Socio-economic importance of *Kigelia africana*

4.4.5.1 Economic value of *Kigelia africana* parts

In Benin, the different *Kigelia africana* parts sold are: the leaves, the fruits and the bark. The sales frequency analysis for each parts indicates that 50 % of the fruit is sold and this frequence is higher than the bark (29.17 %), the leaf (16.67 %) and the root (4.17 %) (Figure 4.23) The sale form which is generally noted for fruits of *Kigelia africana* is the fresh form (100 %). For the leaves, it were sold in the fresh state (50 %) and in the dry state (50 %). It was revealed that the leaves are sold in the fresh state (50 %) and in the dry state (50 %). However, the main acquisition mode of *Kigelia africana* parts (the leaf or the fruit and bark) is through purchase and donation. Picking is also mentioned but mean proportion. All the respondents knew and used different *Kigelia africana* parts. *Kigelia africana* specific uses are summarized in Table 4.12.

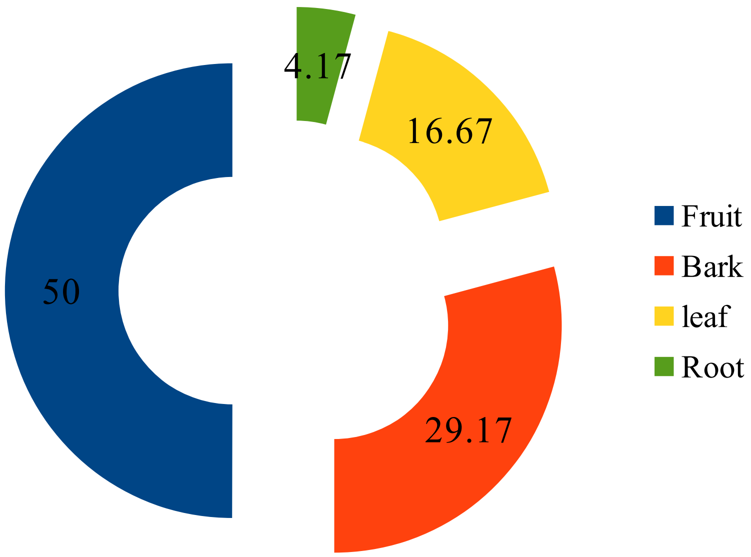


Figure 4.23: Economics value of the parts of *Kigelia africana* in Benin

Table 4.12: Category use of Kigelia africana plant parts; specific uses and tribes using for different purposes

Organs	Category use	Specific uses	Method of preparation (s)	Potential adjuvant	Instruction manual and posology
	food	-	-	-	-
		diarrhoea	pound (powder)	Powder of *Kigelia africana* + gruel	1 spoon morning and evening
		Cancer of breast	fruit cut up and pound	butter of *Butyrospermum parkii* (Shea tree)	apply around the breast
		ulcer	dry fruit cut up and water	water	drink
		Prostate	powder of *Kigelia africana* fruit toast	drunk with gruel	1 spoon morning and evening
		Malaria, convulsions	powder of *Kigelia africana* fruit toast	drunk with gruel	1 spoon morning and evening
Fruit	medicinal		fruit cut up	water	
		Menstruate issue	Infusion of lump of *Kigelia africana* fruit	Water + ginger	2 cup(0.5l) per day
		unknown illness	decoction	sheet + *xylopia aethiopica* + *myristica fragrans* + didi + *Richeria grandis* + tchikoundo + ayadahado + water	drink it warm
		Itere	fruit cut up	water	3 cup (0.5l) /

				day
	Painful	pound (powder)	powder of *Kigelia africana* + *Xliopia etiopical*+ butter of *Butyrospermum parkii*	2 application, two per days
		decoction	water	take bathe
	Wound	pound (powder)	powder of *Kigelia africana* + *Xliopia etiopical*+ butter of *Butyrospermum parkii*	2 application, two per days
	sinusitis	fruit pound	Kpatado (local plant) + alcohol	2 cup / day
			Fruit(*Garcinia kola*) + Alcohol	
	Sexual stimulant	maceration	root (Mondiawhitei) + root (*Caesalpinia bonduc*) + *Cyperus esculentus*	1 cup (0.5l) per day
			Root (*Caesalpinia bonduc*) + fruit (*Phoenix dactylifera*) + Preference alcohol	
Magic	protection of	insert cotton in	-	haul up in the

		farm protection of Gynaecological	the fruit fruit divide in 4 friction during 3 days	-	farm bathe the pregnant woman
		bewitchment	infusion	leaf of palm tree + *cactus beniseed* + yekoumedji	wash foot
		lost of memory	powder of leaves dry with the embers	-	inhalation
		headeck	knead the sheet	-	take bath and drunk 1 cup/day
		Stomachs upset	leaf of *Kigelia africana*	water ferment of maize soaked	drunk
		Painful	infusion	-	3 handshake for man and 4 handshake for woman before shower during seven days
leaf	medicinal	Haemorrhoid	decoction	leaf + bark of kigelia + *Nepeta spp* + natural win palm	3 cup (0.5l) / day
		spot on the children body	infusion	-	3 handshake for man and 4 handshake for woman before shower during seven days
		ulcer	infusion	Leaf + bark of *Kigelia africana*	3 cup (0.5l) / day
		Malaria,	infusion	-	3 cup (0.5l) /

		convulsions			day
	Magic	protect again sorcery	infusion	*Aframomum melegueta* + *myristica fragrants* + didi + *Richeria grandis* + tchikoundo + ayadahado + water	2 cup (0.5l) per day
Bark	medicinal	lost of memory	Decoction	-	3 handshake for man and 4 h for woman before shower
		Kiss and fibroses	infusion	Epice (*aframomum melegueta* + *myristica fragrans* + *syzygium aromaticum* + ayokpe + potassium)	Drunk lukewarm 2 cup/day
		Stomach upset	infusion	leaf of *Kigelia africana* + water Water + *colas garcinia*	Drunk lukewarm 2 cup/day
		Menstruate issue	decoction	Hounlihounli + degbedegbe + *Zingiber officinale*	Drunk lukewarm 4 cup/day
				Water + potassium	Drunk lukewarm 2 cup/day

		Infertility	decoction	Water + potassium	Drunk lukewarm 2 cup/day
		spot on the children body	infusion	Water + yinta +hontronzousunma + hissihissi	1 cup (0.5l) per day and take bath
		Disinfection of wound	decoction	water	wash the wound
		malaria	infusion	Water + leaf of *Kigelia africana*	3 cup (0.5l) / day
		Hernia	pound the dry bark an powder	black pepper	drunk with gruel
	Magic	bewitchment	decoction	water + potassium	½ cup/day
Flowers	medicinal	Mumps	knead the sheet and extract the liquid	-	apply on the ear
Root	medicinal	unknown illness	decoction	*colas garcinia* + water	3 cup (0.5l) / day
			infusion	water	take bath
		panary	decoction	root of atar + *myristica fragrans*	Drunk 3 cup/day and watch the wound
	Magic	Protection again snake and scorpion bite	toast	Nkpatchibima (local name) + seven eggshell + ring (depend of the number of people want to protect)	put on finger
Flowers	medicinal	Mumps	knead the sheet and extract the liquid	-	apply on the ear

Root	medicinal	unknown illness	decoction	*colas garcinia* + water	3 cup (0.5l) / day
			infusion	water	take bath
		panary	decoction	root of atar + *myristica fragrans*	Drunk 3 cup/day and watch the wound
	Magic	Protection again snake and scorpion bite	toast	Nkpatchibima (local name) + seven eggshell + ring (depend of the number of people want to protect)	put on finger

Source: Author's field work (2017)

4.4.5.2 Parts sale system of *Kigelia africana*

Regarding the sales of *Kigelia africana* parts it was found out by the respondents that there is no measures for leaf sale of the species. Leaves are sold between 0.05 USD and 0.27 USD unit price without any measures of number of sheet quantification to be taken. As to the *Kigelia africana* fruit concern, it was noted that it is sold per unit. The unity costs between 0.18 USD and 0.36 USD. In the northern part of the country where the species is scarce, the fruit costs between 0.9 USD to 1.8 USD. With regard to the bark, it is also sold to the unit price which cost between 0.18 and 0.36 USD.

4.4.5.3 Monetary income or seasonal gross margin from the marketing of *Kigelia africana*.

In this study, monetary income /gross margin was only computed on the fruit and bark marketing. The lack of precision on the leaves marketed quantity did not make it possible to calculate their gross margin. Likewise, low sampling rates and surveys obtained throughout the country did not allow us to obtain more detailes on the marketing. The respondents (small retailers) gave an overall estimate of the seasonal income generated by the parts sale. The amount revealed by them is about 3.6 USD to 27 USD for the fruit and about 7 USD to 36 USD for the bark as annual seasonal income.

4.4.5.4 Actors categories interested with *Kigelia africana* parts purchase and related constraints to the parts sale

Three (03) categories of actors who are still interested in *Kigelia africana* parts selling were mentioned by the respondents. These are the traders (parts seller), the traditional healers and the farmers. For these actors, the farmers (14.08 %), traders (19.72 %) and the traditional healers (66.20 %) were most mentioned (Figure 4.24). Regarding the constraints related to the selling aspect of *Kigelia africana* parts, two major constraints were mentioned. The first is related to the low demand for the parts and the second is related to the free access to parts to potential buyers.

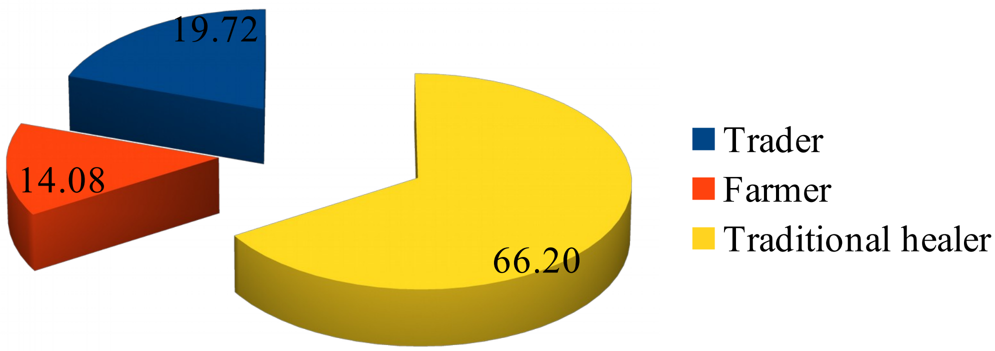


Figure 4.24: Actors categories interested with *Kigelia africana* parts purchase

4.4.6 Endogenous Knowledge and Uses of *Kigelia africana* in Benin

4.4.6.1 Traditional taxonomy and ethnological knowledge of *Kigelia africana*

Traditional taxonomy analysis of *Kigelia africana* has revealed various calling which was all linked to the fruit aspect. This observation justifies the fact that linguistic trends are expressive of traditional knowledge held by the local population on the species. From the field results, we notice as Orwa *et al*. (2009) that *Kigelia africana* is present primarily in wet savannah woodland spreading into gallery woodland and along rivers in moist forests. In open woodland and in riverine fringes, it is present in the fields and gardens. In this case, we can say that water is an important factor in the development of *Kigelia africana*.

4.4.6.2 Impact of socio-cultural considerations on the viability of *Kigelia africana* in agroforestry systems in Benin.

Endogenous knowledge evaluation held by local population of Tanguiéta, Bohicon and Pobè of Benin on the dynamics, history and taboos of *K. africana* we noted among all the respondents (100 %) that *K. africana* is disappearing and that it has its taboos. This means that there is a transmission of knowledge about the species and taboos from generation to generation. However, we noted that these taboos hinder conservation of the species in Benin’s agroforestry systems. This is justified by the fact that man must not cross the fruit to avoid deformities of the sexual part. It is also prohibited that the fruit must not touch the breasts of young girl if not it will increase and take abnormal size. This taboo is one of the major causes of the regression of *K. africana* in Benin.

4.4.6.3 Use value and ethnobotanical knowledge of *K. africana*

Ethnobotanical results on *K. africana* reveal its various potential in medicine and magic. In terms of uses of *K. africana* we note as Bello *et al*. (2016) that the fruit, the flower, the bark, the root and the leaf of *K. africana* are used for many purposes by the local population. These numerous uses, make it possible to classify the species as *Adansonia digitata* and *Irvingia gabonnensis* in the category of multi-purpose species (Assogbadjo, 2006).

On the medicinal and magical levels, multiple uses are noted on the parts of the species in the treatment of illness such as: malaria, ulcer, diarrhoea, prostate, lost of memory, kiss, fibroma, women sterility, spot on the children body, breast illness, typhoid, haemorrhoid, protection again snake and scorpion bites and spiritual protection testify the multiple purpose use of the species mentioned by the local populations. Quantitative analysis on the infection treated with the parts of *K. africana* allowed to note that most of the infection had been already mentioned by Agbahungba *et al*. (2001); Owolabi *et al*. (2007); Azu *et al*. (2010); Eyong *et al*. (2013); Maregesi *et al*. (2013); Siddiqui *et al*. (2015); Atawodi and Olowoniyi (2015). However, other diseases such as sterility, poor libido, sexual asthenia and impotence are handled with preparations comprising the fruits, roots or leaves of *K. africana* (Azu, 2013). Also, most of investigations were done by scientists from Nigeria on the composition of the species and the diseases treatment as antimicrobial activity, anti-inflammatory activity, wound healing effect, hepatoma protective effect, analgesic activity, antidiabetic activity, antiulcer activity, antidiarrheic activity, cytotoxic and anticancer activity, effect on male and female reproductive parts, dermatological and cosmetic uses, and toxicity (Bello *et al*., 2016).

About the reported use of *K. africana*, it was noted that, although the reported uses number per respondent was not variable according to the socio-cultural group, sex and age, the reported parts uses and categories of uses are not distributed homogeneously across the sampled population. This diversity of traditional knowledge therefore noted between groups deserves to be taken into account in the strategies associated with the valuation of *K. africana*.

4.4.6.4 Socio-economic importance of *K. africana*

Socio-economic value analysis of *K. africana* in Benin has made to note that the men are more interested by the parts than the women. This is contrary to the result of *T. indica* and baobab where women are the categories of actors who are more interested in their parts selling (Assogbadjo, 2006; Fandohan *et al*., 2010). Parts of *K. africana* which have economic value in order are: fruit, bark, the leaf and seedlings. Therefore, the root is not sold in any of our ethnobotanical study areas.

As far as the gross margin profit is concerned, its evaluation varies according to the marketed parts. The gross margin of the leaf could not be calculated due to the absence of consensual quantification measure of parts sale. About the fruit, we have noted that it is the most sold parts. The fact that the fruit and the bark are not perishable, people can use the fruit, the bark and the leaf several time; this is one of the most important factor of the decrease of the market and the income of the household indeed.

Therefore, we cannot say that the commercialization of the *K. africana* parts could constitute a profitable activity enabling these actors to combat poverty. Because, the gross margin average resulting from the marketing of the fruit and the bark is very low. Also, the fact that the fruit is not used in food security, it is most of the time available on the tree.

In nutshell, exploitation at the present stage of *K. africana* species, the actors involved in the commercialization of these species cannot choose it like the main activity to be exploited given that their resources are low and most of time available and also easy to found in the higher concentrated area. Thus, commercialization of the fruit, bark and may be the leaf of *K. africana* is therefore only an alternative to improve poorly the incomes of rural women and household (FAO, 2004b).

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

Climate change is known today as one of the main factor which contributes to the alteration of the overall structure of *K. africana*. To assess the importance of such changing, the present study has attempted to provide some useful information about its distribution, culture and conservation. MaxEnt, the software to modelling ecological niche is use to predict *K. africana* distribution area and helped to link statistically the present distribution throughout the future scenario RCP 8.5 by 2050. This species is currently present in almost all the three phytogeographical zone (Soudano-Guinean zone, Soudanian zone and Guinean zone) with some exception in the Soudanian zone. Therefore, the two other Zones (Guineo-Congolian and Soudano-Guinean) represent the most suitable habitats for *K. africana* cultivation and conservation.

The land cover is the most important thing for the biodiversity. According to the ESA, CCI land cover map, the degradation of shrubland could lead to the degradation of the forest. This, have negative impact on the Benin biodiversity. Likewise, the CCI-LC maps at world scale don't allow to discriminating the different types of forest and savannah.

5.2 Recommendations

Policy makers should concentrate on Guineo-Congolian and Sudano-Guinean zone for higher production of *K. africana* plant as it is a very suitable habitat for the plant to grow. However, its habitats could expand or fall depending on whether climate policies are geared towards greenhouse gas (GHG) emissions or reductions.

Further research works should be done in the same areas for a long-term period (2080-2100) not with only the soil and the two model CNRM-CM5 and HadGEM2-ES under the scenario RCP 8.5 but with other abiotic variables such as: Terrain (elevation, slopes, aspect), Land cover (rain-Fed, irrigation cultivated land, forest land, built-up land, barren and water). This will allow observing the impact of land use on the distribution of the species. The soil, added to the bio-climatic variables is not enough to explain the expansion or reduction of habitats of *K. africana* habitats.

New model that will be capable to predict the dynamics of landscapes, protected areas and species of great socioeconomic importance, taking into account the climate change effect combined to land use should be Develop.

Revise the management of the protected areas through the integration of the result get from effective models for predicting the evolution of protected areas in order to benefit conservation role from in situ of the species.

More research should be Carry out on the ethnobotanical survey of all the 77 phytodistricts of Benin in order to better understand the different uses made with the species, identify the factors of its regression and evaluate the income of the women sellers of *K. africana*.

REFERENCES

Abalo, A., Wala, K., Batawila, K., Woegan, A. Y., & Akpangana, K. (2010). Diversité des fruitiers ligneux spontanés du Togo. *Fruit, Vegetable and Cereal Science and Biotechnology*, *4*(1), 1–9.

Aboubakar, K. (2015). *Land Use -Land Cover Change and their implications in Nigeria using geospatial technique*. *Statewide Agricultural Land Use Baseline*. https://doi.org/10.1017/CBO9781107415324.004

Adomou, a. C., Yedomonhan, H., Djossa, B., Legba, S. I., Oumorou, M., & Akoegninou, a. (2012). Etude Ethnobotanique des plantes médicinales vendues dans le marché d'Abomey-Calavi au Bénin. *International Journal of Biological and Chemical Sciences*, *6*(April), 745–772.

Agbahungba, G., Sokpon, N., & Gaoué, O. G. (2001). Situation des ressources génétiques forestières du Bénin. *Atelier Sous-Régional FAO/IPGRI/ICRAF Sur La Conservation, La Gestion, L'utilisation Durable et La Mise En Valeur Des Ressources Génétiques Forestières de La Zone Sahélienne (Ouagadougou, 22-24 Sept. 1998)*, 36.

Araújo, M. B. and G. A. (2006). "Five (or so) challenges for species distribution modelling." *Journal of Biogeography*, *33*(10), 1677–1688.

Assogbadjo, A. E. (2006). *Importance socio-économique et étude de la variabilité écologique, morphologique, génétique et biochimique du baobab (Adansonia digitata L.) au Bénin*. *Th. Doc., Faculty of Bioscience Engineering, Ghent Univ., Belgium*. Ghent University, Belgium. 213p

Atawodi, S., & Olowoniyi, O. (2015). Pharmacological and Therapeutic Activities of Kigelia africana (Lam.) Benth. *Annual Research & Review in Biology*, *5*(1), 1–17. https://doi.org/10.9734/ARRB/2015/8632

Ayihouenou, E. B. (2014). *Modélisation de la répartition géographique des aires favorables à la culture et à la conservation de Parkia biglobosa sous influence des changements climatiques au Bénin*. University of Abomey-Calavi (UAC), 89p

Azu, O. O. (2013). The sausage plant (Kigelia africana): Have we finally discovered a male sperm booster? *Journal of Medicinal Plant Research*, *7*(15), 903–910. https://doi.org/10.5897/JMPR12.0746

Azu, O. O., Duru, F. I. O., Osinubi, A. A., Noronha, C. C., Elesha, S. O., & Okanlawon, A. O. (2010). Protective agent, kigelia africana fruit extract, against cisplatininduced kidney oxidant injury in spraguedawley rats. *Asian Journal of Pharmaceutical and Clinical Research*, *3*(2), 84–88.

Badeau, V., Dupouey, J. L., Cluzeau, C., & Drapier, J. (2005). Aires potentielles de répartition des essences forestières d'ici 2100. *Forêt Entreprise*, *162*(162), 25–29.

Beaumont, L. J., Pitman, A. J., Poulsen, M., & Hughes, L. (2007). Where will species go? Incorporating new advances in climate modelling into projections of species distributions. *Global Change Biology*, *13*(7), 1368–1385. https://doi.org/10.1111/j.1365-2486.2007.01357.x

Bello, I., Shehu, M. W., Musa, M., Zaini Asmawi, M., & Mahmud, R. (2016). Kigelia africana (Lam.) Benth. (Sausage tree): Phytochemistry and pharmacological review of a quintessential African traditional medicinal plant. *Journal of Ethnopharmacology*, *189*(May), 253–276. https://doi.org/10.1016/j.jep.2016.05.049

Berry P. M., Jones, A. P., Nicholls, R. J., VOS, C. C. (2007). Assessment of the vulnerability of terrestrial and coastal habitats and species in Europe to climate change, Annex 2 of Planning for biodiversity in a changing climate - BRANCH: project Final Report. *Natural England, UK*.

Blach-overgaard, A., Svenning, J., Dransfield, J., Greve, M., & Balslev, H. (2010). Determinants of palm species distributions across Africa : the relative roles of climate , non-climatic environmental factors , and spatial constraints. *Ecography*, *33*(3), 380–391. https://doi.org/10.1111/j.1600-0587.2010.06273.x

Boitani, L., Maiorano, L., Baisero, D., Falcucci, A., Visconti, P., & Rondinini, C. (2011). What spatial data do we need to develop global mammal conservation strategies? *Philosophical Transactions of the Royal Society B: Biological Sciences*, *366*(1578), 2623–2632. https://doi.org/10.1098/rstb.2011.0117

Bonou, A. (2008). *Estimation de la valeur économique des Produits Forestiers Non Ligneux (PFNL) d'origine végétale dans le village de Sampéto (commune de Banikoara)*. University of Abomey-Calavi. Retrieved from https://www.researchgate.net/profile/Alice_Bonou/publication/283725480_Estimation_de_la_valeur_economique_des_Produits_Forestiers_Non_Ligneux_PFNL_d'origine_vegetale_dans_le_village_de_Sampeto_commune_de_Banikoara/links/5645aac908ae54697fb91cbb.pdf

Bonou, A. (2013). *Valeur économique des Produits Forestiers Non Ligneux (PFNL) au Bénin* (Editions u). Senegal. https://doi.org/10.13140/2.1.4470.2406

Bourou, S., Bowe, C., Diouf, M., & Van Damme, P. (2012). Ecological and human impacts on stand density and distribution of tamarind (Tamarindus indica L.) in Senegal. *African Journal of Ecology*, *50*(3), 253–265. https://doi.org/10.1111/j.1365-2028.2012.01319.x

Brotons, L., Thuiller, W., Araujo, M. B., & Hirzel, A. H. (2004). Presence-absence versus presence-only modelling methods for predicting bird habitat suitability. *Ecography*, *27*(1), 437–448.

Carroll, C. (2010). Role of climatic niche models in focal-species-based conservation planning: Assessing potential effects of climate change on Northern Spotted Owl in the Pacific Northwest, USA. *Biological Conservation*, *143*(6), 1432–1437. https://doi.org/10.1016/j.biocon.2010.03.018

Dahal, N., & Ojha, H. (2009). Impact of climate change on forests livelihoods: issues and options for Nepal. *Livelihoods and Forestry Programme*, (January), 17–25.

Djenontin, J. (2011). Dynamique des stratégies et des pratiques d ' utilisation des parcours naturels pour l ' alimentation de des troupeaux bovins au Nord-Est du Benin. *Gestion*.

Djonlonkou, S. F. B. (2014). *Etude ethnobotanique, économie- botanique et modélisation de l'impact potentiel des changements climatiques sur la distribution des habitats favorables des fruitiers sous-utilisés : cas de Synsepalum dulcificum Daniell (Sapotaceae) au Sud-Bénin*. University of Abomey-Calavi (UAC).

Domínguez-Domínguez, O., Martínez-Meyer, E., Zambrano, L., & De León, G. P. P. (2006). Using ecological-niche modeling as a conservation tool for freshwater species: Live-bearing fishes in central Mexico. *Conservation Biology*, *20*(6), 1730–1739. https://doi.org/10.1111/j.1523-1739.2006.00588.x

Dotchamou, F. T., Atindogbe, G., Sode, A. I., & Fonton, H. N. (2016). Density and spatial distribution of Parkia biglobosa pattern in Benin under climate change. *Journal of Agriculture and Environment for International Development (JAEID)*, *110*(1), 173–194. https://doi.org/10.12895/JAEID.20161.447

Elith, J., H. Graham, C., P. Anderson, R., Dudík, M., Ferrier, S., Guisan, A., … E. Zimmermann, N. (2006). Novel methods improve prediction of species' distributions from occurrence data. *Ecography*, *29*(2), 129–151. https://doi.org/10.1111/j.2006.0906-7590.04596.x

Elith, J., Kearney, M., & Phillips, S. (2010). The art of modelling range-shifting species. *Methods in Ecology and Evolution*, *1*(4), 330–342. https://doi.org/10.1111/j.2041-210X.2010.00036.x

Elith, J., & Leathwick, J. R. (2009). Species Distribution Models: Ecological Explanation and Prediction Across Space and Time. *Annual Review of Ecology, Evolution, and Systematics*, *40*(1), 677–697. https://doi.org/10.1146/annurev.ecolsys.110308.120159

Elith, J., & Leathwick, J. R. (2009). *Species Distribution Models: Ecological Explanation and Prediction Across Space and Time*. *Annual Review of Ecology Evolution and Systematics* (Vol. 40). https://doi.org/10.1146/annurev.ecolsys.110308.120159

Eyong, K. O., Foyet, H. S., Eyong, C. A., Sidjui, L. S., Yimdjo, M. C., Nwembe, S. N., … Nastasa, V. (2013). Neurological activities of lapachol and its furano derivatives from Kigelia africana. *Medicinal Chemistry Research*, *22*(6), 2902–2911. https://doi.org/10.1007/s00044-012-0284-7

Fandohan, B., Assogbadjo, A. E., Kakaï, R. G., Kyndt, T., Caluwé, E. De, Codjia, J. T. C., & Sinsin, B. (2010). Women's Traditional Knowledge, Use Value, and the Contribution of Tamarind (Tamarindus indica L.) to Rural Households' Cash Income in Benin. *Economic Botany*, *64*(3), 248–259. https://doi.org/10.1007/s12231-010-9123-2

Fandohan, B., Gouwakinnou, G. N., Fonton, N. H., Sinsin, B., & Liu, J. (2013). Impacts des changements climatiques sur la répartition géographique des aires favorables à la culture et à la conservation des fruitiers sous-utilisés: cas du tamarinier au Bénin. *Biotechnologie, Agronomie, Société et Environnement*, *17*(3), 450–462. Retrieved from http://popups.ulg.ac.be/Base/document.php?id=10186&format=print

FAO. (1986). *Some medicinal forest plants of Africa and Latin America*. Forest Resources Development Branch, Forest Resources Division, FAO Forestry Department.

FAO. (2004a). *Forest genetic resources conservation and management EX SITU*.

FAO. (2004b). The State of Food and Agriculture: Meeting the needs of the poor? Retrieved from http://www.fao.org/docrep/006/Y5160E/Y5160E00.htm

FAO. (2005). State of the World's forests 2005. *Management*, *29*(4), v. https://doi.org/10.1016/j.ijfoodmicro.2003.12.013

FAO. (2010). Global forest resources assessment 2010 - Country report Bosnia and Herzagovina. *Food and Argicultural* parts*ization of the UN*, *34*, 1–50.

Ferrier, S., & Guisan, A. (2006). Spatial modelling of biodiversity at the community level. *Journal of Applied Ecology*, *43*(3), 393–404. https://doi.org/10.1111/j.1365-2664.2006.01149.x

Fitzpatrick, M. C., & Hargrove, W. W. (2009). The projection of species distribution models and the problem of non-analog climate. *Biodiversity and Conservation*, *18*(8), 2255–2261. https://doi.org/10.1007/s10531-009-9584-8

Foden, E. W. B., & Young, B. E. (2016). *IUCN SSC Guidelines for Assessing Species ' Vulnerability to Climate Change*. https://doi.org/Version 1.0. Occasional Paper of the IUCN Species Survival Commission No. 59. Cambridge, UK and Gland, Switzerland: IUCN Species Survival Commission. x+114pp.

Gomez-beloz, A. A. (2011). Plant Use Knowledge of the Winikina Warao : The Case for Questionnaires in Ethnobotany. *Economic Botany*, *56*(3), 231–241.

Good, P., Jones, C., Lowe, J., Betts, R., & Gedney, N. (2013). Comparing tropical forest projections from two generations of hadley centre earth system models, HadGEM2-ES and HadCM3LC. *Journal of Climate*, *26*(2), 495–511. https://doi.org/10.1175/JCLI-D-11-00366.1

Groupe D'Experts IntergouvernementalL sur L'Évolution du Climat. (2013). *Changements climatiques 2013 Les éléments scientifiques*. *Giec*. https://doi.org/doi:10.1017/CBO9781107415324.024

Guibert, H., Alle, U. C., Dimon, R. O., Vissoh, P. V, Vodouhe, S. D., Tossou, R. C., & Agbossou, E. K. (2010). Correspondances entre savoirs locaux et scientifiques : perceptions des changements climatiques et adaptations, étude en région cotonnière du Bird du Benin. *Isda*, 10.

Guisan, A., Edwards, T. C., & Hastie, T. (2002). Generalized linear and generalized additive models in studies of species distributions : setting the scene. *Ecological Modelling*, *157*, 89–100. https://doi.org/10.1016/S0304-3800(02)00204-1

Guisan, A., & Thuiller, W. (2009). Predicting species distribution: Offering more than simple habitat models. *Ecology Letters*, *8*(9), 993–1009. https://doi.org/10.1111/j.1461-0248.2005.00792.x

Guisan, A., & Zimmerman, N. (2000). Predictive habitat distribution models in ecology. *Ecological Modelling*, *135*(2–3), 147–186. https://doi.org/10.1016/S0304-3800(00)00354-9

Hall, L. S., Krausman, P. R., & Morrison, M. L. (1997). The habitat concept and a plea for standard terminology. *Wildlife Society Bulletin*, *25*(1), 173–182. https://doi.org/10.2307/3783301

Hernandez, Y., Nicolosi, V., Lotya, M., Blighe, F. M., Sun, Z., De, S., … Coleman, J. N. (2008). High-yield production of graphene by liquid-phase exfoliation of graphite. *Nature Nanotechnology*, *3*(9), 563–568. https://doi.org/10.1038/nnano.2008.215

Heubes, J., Heubach, K., Schmidt, M., Wittig, R., Zizka, G., Nuppenau, E.-A. a, & Hahn, K. (2012). Impact of Future Climate and Land Use Change on Non-timber Forest Product Provision in Benin, West Africa: Linking Niche-based Modeling with Ecosystem Service Values. *Economic Botany*, *66*(4), 383–397. https://doi.org/DOI 10.1007/s12231-012-9216-1

Heubes, J., Heubach, K., Schmidt, M., Wittig, R., Zizka, G., Nuppenau, E. a, & Hahn, K. (2012). Impact of Future Climate and Land Use Change on Non-timber Forest Product Provision in Benin, West Africa: Linking Niche-based Modeling with Ecosystem Service Values. *Economic Botany*, *66*(4), 383–397. https://doi.org/DOI 10.1007/s12231-012-9216-1

Hirzel, A. H., Helfer, V., & Metral, F. (2001). Assessing habitat-suitability models with a virtual species. *Ecological Modelling*, *145*(2–3), 111–121. https://doi.org/10.1016/S0304-3800(01)00396-9

Houinato, M., Sinsin, B., & Lejoly, J. (2001). Acta Botanica Gallica Impact des feux de brousse sur la dynamique des communautés végétales dans la forêt de Bassila (Bénin), *8078*(March 2014), 37–41. https://doi.org/10.1080/12538078.2001.10515891

Hutchinson, G. E. (1957). Concluding Remarks. *Cold Spring Harbor Symposia on Quantitative Biology*, *22*(0), 415–427. https://doi.org/10.1101/SQB.1957.022.01.039

Idohou, R., Assogbadjo, A. E., Kakaï, R. G., & Peterson, A. T. (2016). Spatio-temporal dynamic of suitable areas for species conservation in West Africa: eight economically important wild palms under present and future climates. *Agroforestry Systems*, *91*(3), 527–540. https://doi.org/10.1007/s10457-016-9955-6

Idohou, R., Townsend Peterson, A., Assogbadjo, A. E., Vihotogbe, R. L., Padonou, E., & Glèlè Kakaï, R. (2017). Identification of potential areas for wild palm cultivation in the Republic of Benin through remote sensing and ecological niche modeling. *Genetic Resources and Crop Evolution*, *64*(6), 1383–1393. https://doi.org/10.1007/s10722-016-0443-7

INSAE. (2014). *Bénin - Troisieme Recensement General de la Population et de l ' Habitation 2002*. BENIN. Retrieved from http://nada.insae-bj.org/index.php

INSAE_Benin. (2014). Densite de la population, 1–39.

IPCC. (2000). Summary for Policymakers: Emissions Scenarios. A Special Report of Working Group III of the Intergovernmental Panel on Climate Change. *Group*, 20. https://doi.org/92-9169-113-5

IPCC. (2007). *Climate Change 2007: impacts, adaptation and vulnerability: contribution of Working Group II to the fourth assessment report of the Intergovernmental Panel. Genebra, Suíça*. https://doi.org/10.1256/004316502320517344

IPCC. (2013). *Summary for Policymakers*. *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. https://doi.org/10.1017/CBO9781107415324

Issiaka, N. T. (2016). Cartographie De La Dynamique Spatio-Temporelle Des Parcours Naturels Des Troupeaux Transhumants Dans Les Communes De Banikoara Et De Karimama Au Bénin (Afrique De L ' ouest), *12*(32), 251–268. https://doi.org/10.19044/esj.2016.v12n32p251

Khosravi, R., Hemami, M. R., Malekian, M., Flint, A. L., & Flint, L. E. (2016). Maxent modeling for predicting potential distribution of goitered gazelle in central Iran: The effect of extent and grain size on performance of the model. *Turkish Journal of Zoology*, *40*(4), 574–585. https://doi.org/10.3906/zoo-1505-38

Klein Tank, A., Beersma, J. J., Bessembinder, J., van den Hurk, B., & Lenderink, G. (2015). *KNMI, 2015: KNMI'14 climate scenarios for the Netherlands - A guide for professionals in climate adaptation*. Retrieved from http://www.klimaatscenarios.nl/brochures/images/Brochure_KNMI14_EN_2015.pdf

Lambin, E. F., Geist, H. J. & Lepers, E. (2003). Dynamics of land use and land cover change in tropical regions. *Annual Review of Environment and Resources*, *28*, 205–241.

Lamptey, B. L., Barron, E. J., & Pollard, D. (2005). Simulation of the relative impact of land cover and carbon dioxide to climate change from 1700 to 2100. *Journal of Geophysical Research D: Atmospheres*, *110*(20), 1–17. https://doi.org/10.1029/2005JD005916

Liu, C., White, M., & Newell, G. (2013). Selecting thresholds for the prediction of species occurrence with presence-only data. *Journal of Biogeography*, *40*(4), 778–789. https://doi.org/10.1111/jbi.12058

Manyangadze, T., Chimbari, M. J., Gebreslasie, M., Ceccato, P., & Mukaratirwa, S. (2016). Modelling the spatial and seasonal distribution of suitable habitats of schistosomiasis intermediate host snails using Maxent in Ndumo area, KwaZulu-Natal Province, South Africa. *Parasites & Vectors*, *9*(1), 572.

https://doi.org/10.1186/s13071-016-1834-5

Maregesi, S., Kagashe, G., & Dhokia, D. (2013). Determination of iron contents in Hibiscus sabdariffa calyces and Kigelia africana fruit. *Sch. Acad. J. Biosci*, *1*(4), 108–111.

MEHU. (2011). *Deuxième Communication Nationale de la République du Bénin sur les Changements Climatique*. Retrieved from http://www.agrhymet.ne/portailCC/images/pdf/nc2benin.pdf

Meinshausen, M., Smith, S. J., Calvin, K., Daniel, J. S., Kainuma, M. L. T., Lamarque, J., … van Vuuren, D. P. P. (2011). The RCP greenhouse gas concentrations and their extensions from 1765 to 2300. *Climatic Change*, *109*(1), 213–241. https://doi.org/10.1007/s10584-011-0156-z

Mishra, V., Rai, P., & Mohan, K. (2014). Prediction of land use changes based on land change modeler (LCM) using remote sensing: A case study of Muzaffarpur (Bihar), India. *Journal of the Geographical Institute Jovan Cvijic, SASA*, *64*(1), 111–127. https://doi.org/10.2298/IJGI1401111M

Moss, R. H. R. H., Edmonds, J. A. J. A., Hibbard, K. A. K. A., Manning, M. R., Rose, S. K. S. K., van Vuuren, D. P. D. P., … Nakicenovic, N. (2010). The next generation of scenarios for climate change research and assessment. *Nature*, *463*(7282), 747–756. https://doi.org/10.1038/nature08823

Moupela, C., Vermeulen, C., Daïnou, K., & Doucet, J. L. (2011). Le noisetier d'Afrique (Coula edulis Baill). Un produit forestier non ligneux meconnu. *Biotechnology, Agronomy and Society and Environment*, *15*(3), 485–495.

Naughton, C. C., Lovett, P. N., & Mihelcic, J. R. (2015). Land suitability modeling of shea (Vitellaria paradoxa) distribution across sub-Saharan Africa. *Applied Geography*, *58*, 217–227. https://doi.org/10.1016/j.apgeog.2015.02.007

Neuenschwander, P., Sinsin, B., & Goergen, G. (eds). (2011). Protection de la Nature en Afrique de l'Ouest: Une Liste Rouge pour le Bénin. Nature Conservation in West Africa: Red List for Benin. In *International Institute of Tropical Agriculture* (p. 365 pages). Ibadan, Nigeria. Retrieved from www.iita.org

Olatunji, G. a, & Olubunmi, A. (2009). Comprehensive scientific demystification of Kigelia africana : A review. *Pure and Applied Chemistry*, *3*(9), 158–164.

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R., & Anthony, S. (2009). Vitex doniana Sweet. *Agroforestree Database:a Tree Reference and Selection Guide*, *0*(4.0), 1–5.

Orwa C, A Mutua, Kindt R , Jamnadass R, S. A. (2009). Kigelia pinnata Kigelia pinnata (Jacq .) DC . *Agroforestree Database:a Tree Reference and Selection Guide Version 4.0*, *0*, 1–5. Retrieved from http://www.worldagroforestry.org/sites/treedbs/treedatabases.asp

Owolabi, O. J., Omogbai, E. K. I., & Obasuyi, O. (2007). Antifungal and antibacterial activities of the ethanolic and aqueous extract of Kigelia africana (Bignoniaceae) stem bark. *African Journal of Biotechnology*, *6*(14), 1677–1680. https://doi.org/10.4314/ajb.v6i14.57749

Panitz, H., Schubert-frisius, M., Meier-fleischer, K., Lenzen, P., Keuler, K., Luethi, D., … Dosio, A. (2013). CORDEX Climate Simulations for Africa using COSMO-CLM (CCLM). *Geophysical Research Abstracts*, *15*(Cclm), 2013.

Peterson, A. T., & Soberón, J. (2012). Species distribution modeling and ecological niche modeling: Getting the Concepts Right. *Natureza a Conservacao*, *10*(2), 102–107. https://doi.org/10.4322/natcon.2012.019

Phillips S.J., Anderson R.P., S. R. . (2006). Maximum entropy modeling of species geographic distributions. *Ecological Modelling*, *190*, 231–259.

Piedallu, C., Perez, V., Gégout, J.-C., Lebourgeois, F., & Bertrand, R. (2009). Impact potentiel du changement climatique sur la distribution de l'Epicéa, du Sapin, du Hêtre et du Chêne sessile en France. *Revue Forestière Française*, *LXI*(6), 567–593. https://doi.org/10.4267/2042/32924

Pilgrim Sarah, Smith David, and P. J. (2007). A CROSS-REGIONAL ASSESSMENT OF THE FACTORS AFFECTING ECOLITERACY : IMPLICATIONS FOR POLICY AND PRACTICE. *Ecological Applications*, *17*(6), 1742–1751. https://doi.org/10.1890/06-1358.1

Robert J. Hijmans, Susan Cameron, J. P. (2005). Bioclim | WorldClim - Global Climate Data.

Rondinini, C., Chiozza, F., & Boitani, L. (2006). High human density in the irreplaceable sites for African vertebrates conservation. *Biological Conservation*, *133*(3), 358–363. https://doi.org/10.1016/j.biocon.2006.06.013

Roodot, V. (1992). Kigelia africana in: The Shell Field Guide to the Common Trees of the Okavango Delta and Moremi Game Reserve. Gaborone, Botswana: Shell Oil Botswana, 1–43.

Sanchez, A. C., Osborne, P. E., & Haq, N. (2010). Identifying the global potential for baobab tree cultivation using ecological niche modelling. *Agroforestry Systems*, *80*(2), 191–201. https://doi.org/10.1007/s10457-010-9282-2

Sergio, F., & Pedrini, P. (2007). Biodiversity gradients in the Alps: The overriding importance of elevation. *Biodiversity and Conservation*, *16*(12), 3243–3254. https://doi.org/10.1007/s10531-006-9113-y

Siddiqui, K., Mazumder, A., & Chakraborthy, G. (2015). A Review on Phytopharmacological Profile of Kigelia pinnata (Jacq .). *International Journal of Pharma Research and Review*, *4*(9), 34–38.

Stockman, A. K., Beamer, D. A., & Bond, J. E. (2006). An evaluation of a GARP model as an approach to predicting the spatial distribution of non-vagile invertebrate species. *Diversity and Distributions*, *12*(1), 81–89. https://doi.org/10.1111/j.1366-9516.2006.00225.x

Thomson, A. M., Calvin, K. V., Smith, S. J., Kyle, G. P., Volke, A., Patel, P., … Edmonds, J. A. (2011). RCP4.5: A pathway for stabilization of radiative forcing by 2100. *Climatic Change*, *109*(1), 77–94. https://doi.org/10.1007/s10584-011-0151-4

Toko I., A. O. & S. B. (2010). Cartographie des changements spatio-temporels de l'occupation du sol dans la forêt classée de l'Alibori supérieur au Nord-Bénin. *BenGéo*, *7*, 22–39.

Treut, H. Le, Cubasch, U., & Allen, M. (2007). Historical Overview of Climate Change Science. *Meteosat.com*, FAQ 1.3. Retrieved from http://www.meteosat.com/ipcc4/Ch01_SOD_Text_TSU_FINAL.pdf

van Vuuren, D. P., & Carter, T. R. (2014a). Climate and socio-economic scenarios for climate change research and assessment: Reconciling the new with the ol. *Climatic Change*, *122*(3), 415–429. https://doi.org/10.1007/s10584-013-0974-2

van Vuuren, D. P., & Carter, T. R. (2014b). Climate and socio-economic scenarios for climate change research and assessment: reconciling the new with the old. *Climatic Change*, *122*(3), 415–429. https://doi.org/10.1007/s10584-013-0974-2

van Vuuren, D. P., Edmonds, J., Kainuma, M., Riahi, K., Thomson, A., Hibbard, K., … Rose, S. K. (2011). The representative concentration pathways: An overview. *Climatic Change*, *109*(1), 5–31. https://doi.org/10.1007/s10584-011-0148-z

van Zonneveld, M., Koskela, J., Vinceti, B., & Jarvis, A. (2009). Impact of climate change on the distribution of tropical pines in Southeast Asia. *Unasylva*, *60*(January 2009), 24–29.

Venter, F. Venter, J. A. (1996). Making the most of indigenous trees. *Briza Publications*, 305.

Webstar, M. (2015). Sentiment | Definition of Sentiment by Merriam-Webster. Retrieved from https://www.merriam-webster.com/dictionary/sentiment

APPENDICES

Appendix A: Questionnaire Administration

Section 0: General information about the Community

S/N° /__/__/__/ Date: /__/__/ /__/__/ /2017

District ____________ Phyto-district ___________

Arrondissement _________ Village/Locality ___________

Village Coordinates _____________/___________

Section 1: Socio-Economic Characteristics of the Respondents

1. Name of respond _____________ Ethnic group __________

2. Sex of respond: Male/__/ female /__/

3. Age of household 15-30 /__/ 30-45 /__/ 45-60 /__/ 60-75/__/ >75 /__/

4. Religion practice /________/

5. Household size /__/__/ Level of education /_____/

6. Profession farmer/__/ Trader /__/, Others /____________/

7. Period of leaving the village /__/__/ (year) month /__/__/

Section 2: Ethnobotanical study and cultural perception

1. How do you call in your language the tree medium to large tree, up to 25 m in height which fruit is heavy, weighing up to 12 kg and up to 1 to 18 cm large. Have beautiful red flower?

2. what is the meaning of this name?/__________________________

3. Do you know other name? /________________________________

4. Are there any taboos around *Kigelia africana*

5. What is it founding (habitat)?

Savannah /__/ Wet dense Forest /__/ Dwelling /__/ In the field /__/

6. Why this typw of habitat? /___________________________________

7. How did you appreciate the dynamic of *Kigelia africana* /______________________

8. Do you save it on your farm? ___ Why?.................................…

9. Is it use to feed the livestock? Yes /__/ No /__/ Do not know /__/

10. What are the different uses of *K. Africana*?

Nutritional and food use /__/, Medicinal use in pharmacopoeia /__/, Firewood/__/, Charcoal/__/

Lumber/__ /, Crafts/__/, Vegetable brush/__/, other/__/

11. What are the parts of the tree did you extract?

Sheets/__/, Flowers/__/, Fruits/__/, Seeds/__/, Pod teguments/__/, Roots/__/, Bark/__/, Young stems/__/

12. which part of parts of the *Kigelia africana* tree did you used for nutritional and what are the user?

	Leaves	**Flowers**	**Fruits**	**Roots**	**Barks**	**The pods**	**Young stems / branches**	**Woods**
Vegetables								
Potash								
Porridge								
Mustard								
Dough								
Sauce								
Spice								
Juice / beverage								
Forage								
Vegetable brush								
Medication								

diseases treated
Others

Example: vegetable, potash, Porridge, Mustard, Dough, Sauce, Spice, Juice / beverage, Forage, Vegetable brush, Medication, diseases treated, Others _____________

13. Which parts of *Kigelia africana* did you use in pharmacopoeia?

parts	Miscellaneous treated	Preparation methos	Dosage
parts			
Sheets			
Flowers			
Fruits			
Seeds			
Roots			
Stems			
Pod			
Bark			

Preparation methods: infusion- Decortion- cataplasm- Marceration – Inhalation – Friction – injection – Powder (dry/pasty) – Pain- Wound – Mouth – Eyes – Ear – Genital – parts – Incantations.

Section 3: Socio-economic evaluation

1. What are the different *Kigelia africana* parts did you sell?

parts	FS	CU	USP	QS/S	Inp Sp/AI
Sheets					
Flowers					
Fruits					
Seeds					
Roots					
Stems					
Pod					
Bark					
Others					

FS: Forms of parts selling- CU: Commercial unit – USP: Unit Sale Price – QS/S: Quantity sell/season – input of the species to the annual overall income. (1-Very low 2-

Low 3-Medium 4-Fort 2. Very strong)

2. How did you collect the different parts for sell? Fresh /__/ dry /__/

3. Have you face any problem to sell the different parts of *Kigelia africana*? …………………………………………………………………………...

4. Do you think that the marketing of *Kigelia africana* parts contributes to the improvement of your life?…………………………………………………………...

5. If yes, what are the different needs did you meet with the income generated?

Section 4: Farmers perception on climate change

1. Have you any information about climate change? Yes /__/ No /__/

2. If yes, from where have you heard about climate change? (a) own observation (b) radio station (c) NGO (d) Researchers (e) told by friend

3. What did you notice about the climate factor (intensity of sun, raining season, experienced drought) over the last 30 years.

4. Intensity of sun: a) very hot, b) Hot, c) Middle, d) Normal, e) Do not know

5. Raining season: a) Earlier, b) late, c) No change, d) Fluctuating e) Do not know

6. Experienced drought: a) Yes b) No c) Do not know

7. (If yes), 6- When did this flooding occur? /___________________________

6- The end of the rain season:1) Earlier, 2) late, 3) No change,) Fluctuating 5) Do not know

Section 5: Land-use land cover change

1. What major type of land use occurred in this area in the last 30 years?

Cropland land /__/ Fallow land /__/ Grazing land /__/ Busch /__/

Busch /__/Water /__/ Others /__/

2. What was the evolution of this land unit?

Increased /__/ Decreased /__/ Unchanged /__/

Cropland land /__/ Pasturer /__/ forest /__/ Bare land /__/ Water body /__/

3. Over the last 30 years which type of land use has mostly decreased?

Cropland land /__/ Pasturer /__/ forest /__/ Bare land /__/ Water body /__/

4. What are the causes of land cover (vegetation) change?

Population growth: Yes /__/ No /__/ Do not know

Increased agricultural land: Yes /__/ No /__/ Do not know

Collect in fire woods: Yes /__/ No /__/ Do not know

5. What can be the consequences of land use/cover change?

a) Reduction of water point accessibility: Yes /__/ No /__/ Do not know

b) Land degradation: Yes /__/ No /__/ Do not know

c) Reduction of crop yield: Yes /__/ No /__/ Do not know

d) eduction of forest area: Yes /__/ No /__/ Do not know

e) Did *Kigelia africana* population decreased or increased this last 30 years?

Increased: Yes /__/ No /__/ Do not know

Decreased: Yes /__/ No /__/ Do not know

f) What are the consequences of this decreased?

Population growth: Yes /__/ No /__/ Do not know

Increased agricultural land: Yes /__/ No /__/ Do not know

Collect in fire woods: Yes /__/ No /__/ Do not know

Land Use /Land cover	Trends				Causes			*Kigelia africana* population this last 30 years
	Increased	Decreased	Stable	Do not know	Yes	No	Do not know	
Farmes								
Fallow								

Crop land
Grazing land
Forest
Bare land
Water body
Population growth

Appendix B: Detail about the Models uses

Nº	Models	Information	References
1	MaxEnt (maximum ntropy)	It applies the principle of maximum entropy to the plant species presence- only data. It estimates both a set of functions that relate environmental variables to habitat suitability and the potential geographical distribution of a plant species.	
2	ENFA (Ecological Niche Factorial Analysis)	This method is develop by IZEA Lausanne- Suisse. ENFA compares the ecogeographical predictor distribution for a presence data set consisting of locations where the species has been detected with the predictor distribution of the whole area. Like the Principal Component Analysis, ENFA summarises all predictors into a few uncorrelated factors retaining most of collective properties such as species richness. In addition, ENFA only needs presence data. ENFA sum- marises all predictors into a few uncorrelated factors retaining most of the information	(Hirzel *et al*., 2001)
3	GARP (Genetic Algorithm for Rule set Prediction) is a niche ecological model	Is a spatial analysis system which predicts the distribution of animals and plant species. Its quantitatives method for ecological niche modeling of the species based on occurrence data.	
4	BIOCLIM	Bioclimatic variables are derived from the monthly temperature and rainfall values in order to generate more biologically meaningful variables. These are often used in species distribution modeling and related ecological modeling techniques. The bioclimatic variables represent annual trends (e.g., mean annual temperature, annual precipitation) seasonality (e.g., annual range in temperature and precipitation) and extreme or limiting environmental factors (e.g., temperature of the coldest and warmest month, and precipitation of the wet and dry quarters)	(Robert J. Hijmans and Susan Cameron, 2005)
5	Generalised Linear Model (GLM)	GLM is a generalisation of multiple regression analysis with a binomial distribution and logisticlink that may fit polynomials of higher degree link that may fit polynomials of higher degree than linear. The dependent variable (presence/absence of the species) is explained by a sum of weighted ecogeographical predictors. GLM needs presence/absence data.	

Appendix C: Transition matrix of LULC categories from 1992 to 2003

1992 \ 2003	10	11	20	30	40	50	60	62	100	110	120	122	130	153	170	180	190	200	201	210	Totals	Accuracy
10	282166	0	0	0	0	19	365	0	17	0	40	2	0	0	21	0	355	0	0	0	282985	100
11	0	3918	0	0	0	17	25	0	2	0	0	0	0	0	1	0	0	0	0	0	3963	99
20	0	0	2859	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	2864	100
30	0	0	0	100691	0	50	448	24	31	0	106	13	0	0	16	0	104	0	0	0	101483	99
40	0	0	0	0	74462	49	719	141	86	0	33	0	0	0	48	0	68	0	0	26	75632	98
50	0	0	0	0	0	1046	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1047	100
60	75	0	0	35	43	0	284	0	3	0	89	8	0	0	0	0	0	0	0	0	537	53
62	0	2	0	17	20	0	0	335558	7	0	59	0	0	0	0	0	32	0	0	0	335695	100
100	0	0	0	0	0	0	0	0	1994	0	0	0	0	0	0	0	14	0	0	0	2008	99
110	2	0	0	0	0	0	0	12	0	27	0	0	0	0	0	0	0	0	0	0	41	66
120	21558	1046	98	2099	1075	222	4321	40426	382	2	311938	0	7	0	5	0	182	3	1	4	383369	81
122	1	20	0	19	8	1	786	0	4	0	0	34360	0	0	0	0	20	0	0	0	35219	98
130	0	0	0	0	0	0	0	0	0	0	0	0	132	0	0	0	17	0	0	48	197	67
153	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	9	0	0	0	14	36
170	5	0	0	28	0	0	0	0	10	0	15	1	0	0	684	0	40	0	0	68	851	80
180	0	0	0	0	0	2	0	0	0	0	0	0	0	0	9	266	1	0	0	1	279	95
190	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2031	0	0	0	2031	100
200	9	0	0	0	0	0	0	11	1	0	0	0	0	0	3	0	0	3	0	366	393	1
201	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	20	100
210	0	0	0	0	0	10	0	11	13	0	0	0	0	0	69	42	3	0	0	3909	4057	96
Totals	303816	4986	2957	102889	75608	1416	6948	376183	2550	29	312280	34384	139	5	856	308	2882	6	21	4422	1232685	
Accuracy	93	79	97	98	98	74	4	89	78	93	100	100	95	100	80	86	70	50	95	88		94

Quantity Di	72414
Allocation	3918