Journal of Agriculture and Rural Development in the Tropics and Subtropics
Vol. 116 No. 2 (2015) 143–156

urn:nbn:de:hebis:34-2015061048473 ISSN: 2363-6033 (online); 1612-9830 (print) – website: www.jarts.info

# Determination of the silvo-melliferous regions of Benin: a nationwide categorisation of the land based on melliferous plants suitable for timber production

Felicien Amakpe [a], Gaston S. Akouehou [b], Dirk C. de Graaf [a,*], Brice Sinsin [c]

[a] *Laboratory of Molecular Entomology and Bee Pathology, Ghent University, Ghent, Belgium*
[b] *General Directorate of Forest and Natural Resources, Cotonou, Republic of Benin*
[c] *Laboratory of Applied Ecology, University of Abomey-Calavi, Cotonou, Republic of Benin*

**Abstract**

Perennial plants are the main pollen and nectar sources for bees in the tropical areas where most of the annual flora are burned in dry seasons. Therefore perennial plants constitute the most reliable bio materials for determining and evaluating the beekeeping regions of the Republic of Benin. A silvo-melliferous region (S-MR) is a geographical area characterised by a particular set of homogenous melliferous plants that can produce timber. Using both the prevailing climatic and the agro-ecological conditions six S-MRs could be identified, i.e. the South region, the Common Central region, the Central West region, the Central North region, the Middle North region and the Extreme North region. At the country level, the melliferous plants were dominated by *Vitellaria paradoxa* which is common to all regions. The most diversified family was the Caesalpiniaceae (12 species) followed by the Combretaceae (10 species) and *Combretum* being the richest genus. The effect of dominance is particularly high in the South region where *Elaeis guineensis* alone represented 72.6 % of the tree density and 140 % of the total plant importance. The total melliferous plant density varied from 99.3 plants ha$^{-1}$ in the Common Central region to 178.0 plants ha$^{-1}$ in the Central West region. On the basis of nectar and pollen source, the best region for beekeeping is the Central West region with 46.7 % of nectar producing trees, 9.4 % of pollen producing trees and 40.6 % of plants that issue both, this in opposition to the South region which was characterised by an unbalanced distribution of melliferous trees.

*Keywords:* apiculture, *Apis mellifera*, beekeeping potentiality, forestry, melliferous plants, non-timber product, tropical, Republic of Benin, West Africa

Abbreviations

S-MR: silvo-melliferous region

UTM/WGS1984 zone 31N: Universal Transverse Mercator of the 31 northern meridian geographical coordinates

* Corresponding author
Laboratory of Molecular Entomology and Bee Pathology, Ghent University, Krijgslaan 281 S2, B-9000 Ghent, Belgium
Email: Dirk.deGraaf@UGent.be
Phone: +32 9 264 8732; Fax: +32 9 264 5242

## 1 Introduction

The deep relationship between bees, climate and flora of any ecological area makes the bees almost an ecological factor at the same state as temperature, rainfall, humidity and sunstroke with which they interact and cope (Shimanuki & Knox, 2000). The necessity for studying the linkage of the biotic community as a determinant of the ecosystem dynamics and stability is well recognised by the scientific community which also agrees on the spatial distribution pattern of living organisms as key

Published online: October 7, 2015

attribute of the ecological factors (Loreau *et al.*, 2001). However, very little is known on the particular function of the melliferous plants and their distribution as a part of the multi-functionality of the ecosystem (Amakpe, 2008).

Beekeeping is a very old activity carried out by humans to ensure livelihood. In poor countries such as the Republic of Benin, it is one of those rare niche activities that needs little investment, provides substantial incomes to local people and has at the same time positive impacts on the global environment.

Apart from the prevailing climatic conditions, the most important factor that determine the hive productivity in any ecological area, are the available floral resources from which the bees collect the bulk of nectar, pollen and propolis (Shimanuki & Knox, 2000). The study of melliferous plants available to bees becomes then the heart of decision making as far as the beekeeping development is concerned in any socio-economic area.

In dry tropical areas, most of the annual plants are being burned during the dry season by recurrent bush fires (Biaou, 2009). The main nutritional source for bees during the dry season where the bees are more active, is covered by perennial melliferous trees that represent more than 40 % of the total pollen collection (Dongock *et al.*, 2004). Thus, sustainable beekeeping in these areas is an enterprise that mainly relies on perennial trees. In the Republic of Benin where the savannah zone reaches the Atlantic Ocean in the south and with more than 87 % of the territory in the Sudanian zone (Akoègninou, 2004), the dependence of the beekeeping on the perennial melliferous trees is even more crucial. We therefore decided to determine the distribution of those trees at a nationwide level in order to categorize the land based on its potential for beekeeping.

The vegetation, its structure and dynamics of the different stands from the coastal zone in the south till the dry savannah in the north is well documented for Benin (Sinsin, 1993). Moreover, in 2007 the General Directorate of Forest and Natural Resources conducted a countrywide forest survey and a database is available on the different timber species. At the regional and international levels, we could rely on excellent descriptive works on tropical melliferous plants and the resources they issue to bees (pollen, honey dew or nectar) (Adjare, 1990; Dongock *et al.*, 2011). Although there is plenty of information on the vegetation in general, the knowledge of the melliferous resources of the country is sparse and limited at local or village levels (Yédomonhan *et al.*, 2012). Some institutions and projects conducted empiric inventories on the plants visited by bees in order to set a beekeeping plan of selected areas but a nationwide study that categorizes the land based on its potential for the beekeeping sector is still lacking. This study was aimed to fill this gap in order to improve the living standards of the beekeepers by extending their working field and to evaluate the underestimated honey production function of trees beside the timber that is commonly known for forests in tropical areas.

## 2 Materials and methods

### *2.1 Study area*

The study area is the entire Republic of Benin (112,622 km$^2$) located in the so called "Dahomean Gap" where the savannah reaches the coast. The climate is sub-tropical in the south till the parallel 7°10'N and evolves progressively to the dry tropical climate in the north, dividing the country in three main climatic areas (Akoègninou *et al.*, 2006; ASECNA, 2012). From the coast till the 7$^{th}$ parallel, stands the littoral and sub-littoral climatic area with 900 mm annual rainfall (in the west) to 1400 mm annual rainfall in the east. The transitional tropical humid zone stands from the 7$^{th}$ to the 9$^{th}$ parallel with 1200 mm to 1300 mm annual rainfall. Above the 9$^{th}$ parallel exists the dry tropical climate in the north with one rainy season of 900 mm to 1200 mm annual rainfall.

The vegetation varies from the Guinean forest in the south east to the semi-desert vegetation in the extreme north. The diversity of the vegetation in the different ecological area leads to 10 phyto-geographic districts, each with a specific floristic composition (Adomou, 2005).

### *2.2 Sampling and plots*

The forest surveys were conducted from April 2010 to July 2011 on systematic fixed area plots established all over the country at a regular distance of 15 km. The first point from which the other points were generated was located in the south eastern extremity of the country as near as possible to the Nigerian southern border. The Universal Transverse Mercator (UTM/WGS1984) of the 31 northern meridian (zone 31N) geographical coordinates of this first point were X = 465,000 east and Y = 705,000 north.

The geographical coordinates of the other points were automatically generated by the software "grille d'échantillonnage 1.5" of 22/08/02 developed by the

Forestry Economy and Management Unit of the Faculty of Agronomy Sciences of Gembloux, Belgium. On the base of the shape of the country and its total area, a theoretic number of 507 plots were determined. However, 25 plots located at peaks of mountains were not reachable. Thus, the surveys were conducted on 482 fixed area circular plots of 18 m radius (1017.3 $m^2$ each) distributed all over the country. The centre of each plot was determined by its UTM/WGS1984 zone 31N geographical coordinates. The navigation for finding the different plot centres was performed using a GPS (Garmin) with 0.7 m precision. The distribution of the survey plots was illustrated on figure 1.

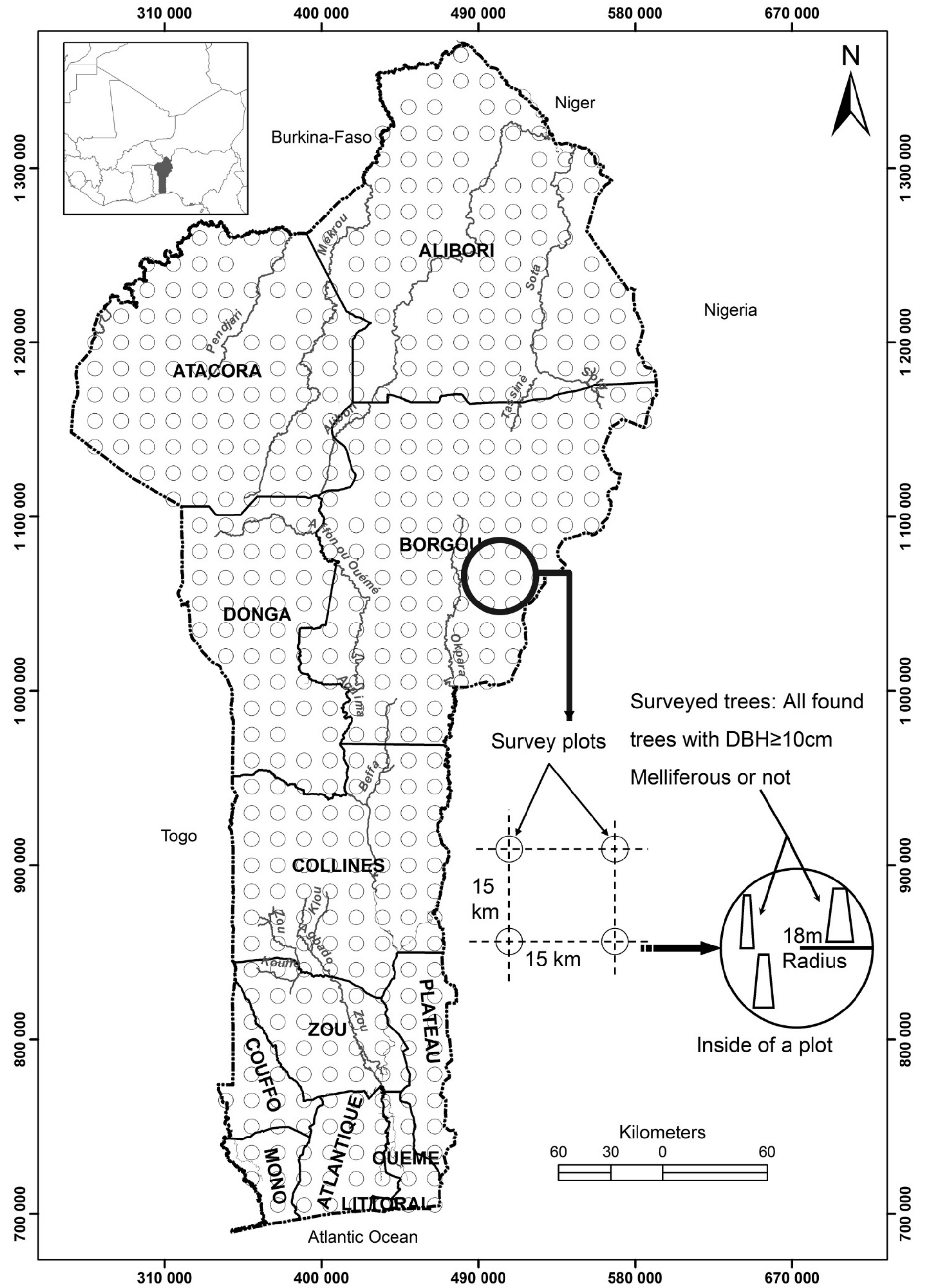


**Fig. 1:** *Distribution map of the survey plots all over the country. The international border was marked by a black dotted line; departmental borders by black lines; perennial water by grey lines; survey plots by grey circles. In the left corner you will find a map of West Africa with the Republic of Benin marked.*

### 2.3 Surveyed population and data collection

The surveyed population consisted of any perennial plant that had a minimum Diameter at Breast Height (DBH) of 10 cm (DBH ≥ 10 cm) with the exception of climbing plants and bamboos. For palm trees, only those that had their stem free of leaves at a minimum height of 1.3 m were counted and no diameter was measured from them. In this publication, we define as silvo-melliferous plant, any live plant that is known to produce resources for the honey bee (melliferous plants) and with a minimum DBH of 10 cm (timber). Different publications dealt already with the melliferous plants identification in tropical areas and in Benin in particular (Gadbin, 1980; Koudegnan *et al.*, 2012; Dongock *et al.*, 2008, 2011; Adjare, 1990). We used these sources for determining whether the found perennial plants were melliferous plants or not. Depending on the two main feeds they produce for bees, the melliferous plants were then classified as follows: pollen source (P) for those plants that mainly produce pollen; nectar sources (N) for the pants that produce mainly nectar; nectar and pollen sources (NP) for plants that produce the two sources of feeds for the bees.

In this survey, dead plants were not taken into account as they have no nutritional value for the honey bees. The accurate determination of the plant species was performed by using the botanical works of Ern (1988) and Akoègninou *et al.* (2006); and when required, by comparing the collected plant with the specimen available at the National Herbarium of the Republic of Benin. The different data collected at each plot were: [1] general information on the plot such as the administrative location, the geographic coordinates, etc., [2] the number of stems per species and [3] the DBH of each living tree or stem with a diameter of more than 10 cm.

### 2.4 Data processing

Statistical analysis was conducted with the GraphPAD PRISM® version 6.01 in order to perform the classification of the plots and their distribution in the gradient axis. The classification consisted in grouping the survey plots in homogenate clusters based on the melliferous plant species composition, the abundance and the DBH. The distribution of the clusters in the gradient axis and their geographical projection in the country helped to identify their determinant ecological factors.

Empty plots located on roads, tilled lands, houses, rocky areas and in water plans, were excluded from the classification analysis. The plots that had no melliferous plants were also excluded from the analyses which were finally performed on 248 plots that bore at least one melliferous plant.

The classification and ordination of the plots in clusters were performed by the Bray-Curtis similarity using the nearest neighbour cluster method (Cottam & Curtis, 1956; Bray & Curtis, 1957). In order to reduce the influence of species which had too high abundance in some plots, we performed a Log10 transformation of the row abundance values per plot before the Bray-Curtis similarity value $BC_{jk}$ was calculated (Jongman *et al.*, 1995; Legendre & Gallagher, 2001):

$$BC_{jk} = \frac{2\sum_{i=1}^{p} min(N_{ij}, N_{ik})}{\sum_{i=1}^{p}(N_{ij} + N_{ik})} \tag{1}$$

In the equation (1) $N_{ij}$ is the Log10 of the abundance of the species $i$ in the plot $j$; $N_{ik}$ is the Log10 of the abundance of the same species $i$ in the plot $k$; $min$ is the minimum of the two values; and the sum of the numerator and denominators are for all the species encountered in the two plots. The $BC_{jk}$ value was calculated per pair of plots in a matrix of 248 plots × 248 plots and served in automatically comparing the Euclidean distance between each pair of plots.

The primary clusters identified from the ordination graph were projected on the shape file of the country by ArcGis 9.02 to visualise their geographical distribution. The geographical area of concentration of each cluster in the country map feature was used as a background for cutting a polygon that represented a particular silvo-melliferous region, of which we determined the area with the "Xtool Pro 4.0" functions of the ArcGIS 9.02.

The spectrum of the melliferous plants for each region was characterised by the diametric structure and by the relative total plant importance (IP %) of melliferous plants in order to identify the leading melliferous plants and the relative contribution of each species to the entire melliferous potentiality of the region. The IP % of a determined melliferous plant was calculated by the following equation (Cottam & Curtis, 1956):

$$IP\,\% = \frac{n_s}{N_T} + \frac{n_p}{N_P} + \frac{\sum_{i=1}^{n} G_i}{G} \tag{2}$$

In the equation (2) $n_s$ is the number of stems of the species in the region; $N_T$ is the total number of stems present in the region; $n_p$ is the number of plots that bear the species; $N_P$ is the total number of species in the region; $G$ is the total basal area of all the found species in the region; $G_i = (\pi/4)(DBH)^2$ is the tree individual basal area of the species and DBH was the measured diameter at Human Breast by a tape, graduated in diameter-equivalence of the tree circumference.

Other parameters we used for characterising the different S-MRs were: (i) the tree basal area per ha of the region which equals the total of the individual tree area divided by the total surface of the survey plots of the region; (ii) the tree density per ha of a region which is the total number of tree stems encountered in the region divided by the total surface of the survey plots of the region; and (iii) the species diversity which is the number of different species encountered in the region (also determined for the different genera and families).

## 3 Results

### 3.1 Climatic gradient and silvo-melliferous regions

The distribution chart of the plots in the different Euclidean axes indicated that there was a strong correlation between the values of the ecological gradient and the ecological distance of Bray-Curtis matrix. The correlation value is 0.678 and the significance level for the test of zero correlation was very low ($P = 0.000$). The plot pattern in the Euclidean distances and the ordination indicated three main clusters, one below the ordination value 100, another between 100 and 200 and the third above the value 200 (figures 2 and 3). Those primary plots clusters were distributed in the different parts of the country as follows.

The first plot cluster (triangles in figure 3) was exclusively concentrated in the south of the country under the latitude of Aplahoue (department of Couffo) and Covè (department of Zou) in the Sudano-Guinean climate area. It was dominated by entropic plantations of *Elaeis guineensis*, *Gmelina arborea*, *Tectona grandis* and *Acacia auriculiformis*.

The second cluster (dots on figure 3) was made of plots that were absent in the south and the central-west which benefit by a better annual rainfall. They were almost absent in the band of Bembèrèkè-Sinende to Segbana, known as the *Vitellaria paradoxa* (butter tree) region. Apart from this particular area, they were spread all over the transitional climatic region of the country in a mixture of some scattered plots from the first and the third clusters.

The third plot cluster (stars in figure 3) was divided in two pure ecotypes located in two distinct geographical regions in the south and the north of the second cluster. One was located in the central-west humid climatic region of the country (region of Bassila) with an annual rainfall of 1300 mm. The second geographical type of this cluster covered a region that stood from the northeast of the department of Borgou to the central-west border of the department of Atacora with de Republic of Burkina-Faso.

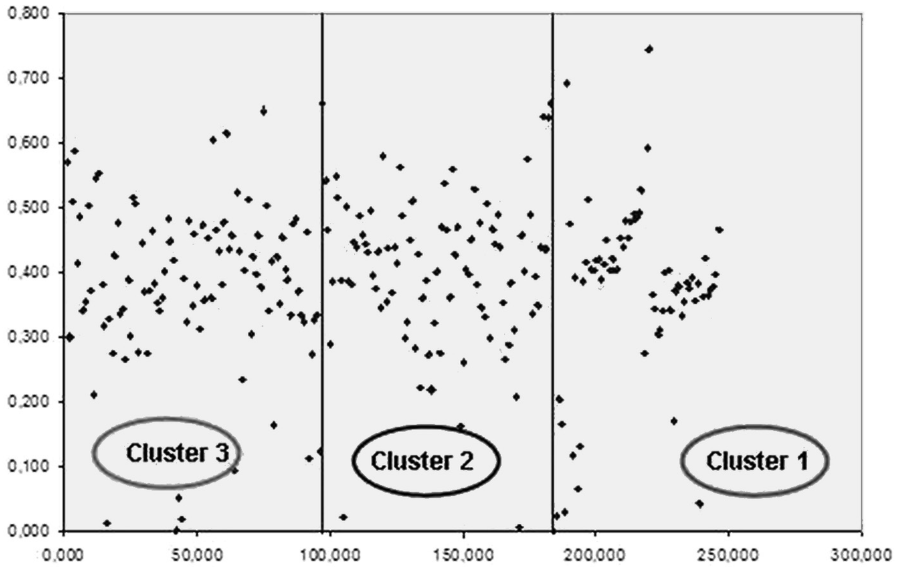


**Fig. 2:** *Distribution of the plots in the Euclidean axes. The plots of cluster 1 were presented as triangles in the shape file of the country. The plots of the cluster 2 were presented as dots and those of the cluster 3 were presented as stars in the country shape file (see Fig.3).*

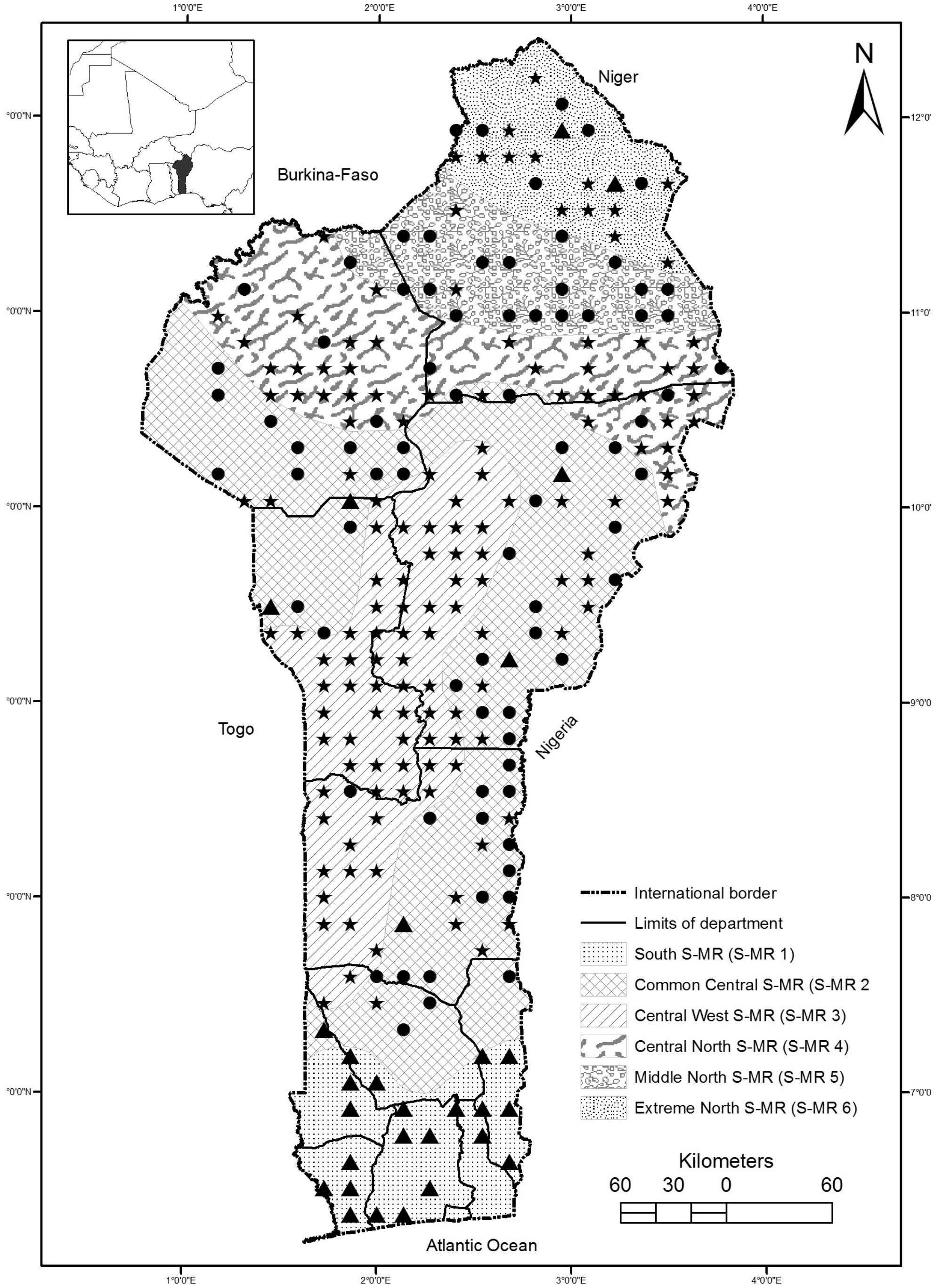


**Fig. 3:** *Location map of the 3 main plot clusters on the country map: the triangles (▲) are the plots that constituted the first cluster from the ordination analysis. Their concentration corresponded to the silvo-melliferous region (S-MR) of the South. The dots (•) are for the second cluster. Their concentration in the north corresponded to the Middle North S-MR. The stars (⋆) constitute the third cluster, the concentration of which constitute the Central West S-MR and the Central North S-MR. The mixture of triangles, dots and stars corresponded to the Common Central S-MR and the Extreme North S-MR.*

### 3.2 *Spectrum of the silvo-melliferous regions*

The geographic distribution of the plot clusters indicated that the Republic of Benin can be divided in six S-MRs with different beekeeping potential (Fig. 3). The dendrogram generated from the Euclidean distance pair comparison (Fig. 4) indicated the segregation between the different regions ($R = 0.669$ and $P = 0.000$).

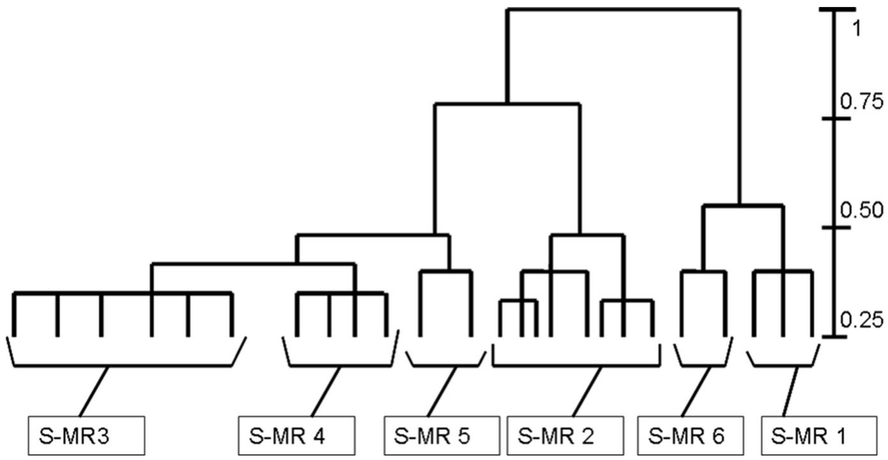


**Fig. 4:** *Dendrogram of the plots at Bray-Curtis distance of 0.25 (S-MR: silvo-melliferous region).*

The first region is the South Silvo-melliferous Region (S-MR 1) which covered 1,102,906.23 ha and was totally located in the south. It bore six exclusive melliferous tree species (thus only found in the concerned area) which were *Acacia auriculiformis*, *Ceiba pentandra*, *Eucalyptus* sp., *Gmelina arborea*, *Newbouldia laevis* and *Phoenix reclinata*. It was dominated by *Elaeis guineensis*, *Gmelina areborea*, *Cola* sp. and *Tectona grandis* which represented 196 % of the total tree importance. The melliferous tree density was 140.4 trees ha$^{-1}$ represented by 24 species distributed in 20 genera and 14 families sharing 299.1 % of the total tree importance. This total importance was dominated by pollen producing trees (211.0 %) while the share of nectar producing trees was with only 31.8 %. In this region, the feed production is unbalanced and the bulk of the melliferous plants density was made of pollen producing trees (mainly *Elaeis guineensis* and *Tectona grandis*) that represented 87.7 % of the melliferous density. The nectar producing plants represented 5.3 % and the plants that produced nectar and pollen to bees represented 6.7 % of the plant density. The richest genus was the *Acacia* with 3 species (third species could not be determined at the species level) and the Arecaceae family was the most diversified in this region with 3 genera and 3 species. The average diameter of the melliferous trees in this region was 18.6 cm (±7.5 cm) and varied from 10 to 34 cm. There was one non-melliferous plant (*Ficus* sp.) of the Moraceae familiy that represented some 0.3 % of the total tree density.

The second region is the Common Central Silvo-Melliferous region (S-MR 2) that covered 4,175,094.9 ha. It is an elongated area that covers the north of the department of Couffo, the department of Plateau in the east, the department of Zou, the east of Colline, the east of Borgou, the north-west of Donga and the west of the department of Atacora. It bore 68 melliferous tree species of 26 families and 59 genera which represented 203.2 % of the total tree importance (141.0 % of nectar plants, 113.5 % of plants that produce both and 39.1 % of pollen plants). The total density of melliferous plants was 99.3 plants ha$^{-1}$ distributed in 40.6 % of nectar producing plants, 14.5 % of pollen producing plants and 41.5 % of plants that issue pollen and nectar to bees. The most important melliferous plants here were *Vitellaria paradoxa*, *Anogeissus leiocarpa*, *Pterocarpus erinaceus* and *Daniellia oliveri* that mainly produce nectar. The Caesalpiniaceae was the most diversified family with 10 species distributed in 8 genera. The richest genus in this region was the *Combretum* that bore 4 species. The exclusive species were *Adansonia digitata*, *Blighia sapida*, *Borassus aethiopum*, *Dalbergia* sp., *Daniellia* sp., *Feretia* sp., *Phyllanthus amarus*, *Ximenia americana*. The average diameter of the melliferous trees in this region was 20.3 cm (±16.8 cm) and varied from 10 to 135 cm. The non-melliferous plants species were found in the families of Melicaceae, Mimosaceae, Moraceae, Sapindaceae and Simaroubaceae which shared 3.4 % of the total tree density.

The third region is the Central West Silvo-Melliferous Region (S-MR 3) that covers 2,162,444.24 ha. It was an area standing from the north of the district of Djidja (department of Zou) and covered the west of the department of Collines, the west of Borgou and the east of the department of Donga. In this region, the species were evenly distributed and there is no dominance effect although *Vitellaria paradoxa* is the most important plant with 14.9 % of the total melliferous density. The exclusive silvo-melliferous species were *Albizia* sp., *Chrysobalanus icaco*, *Dialium guineense*, *Garcinia ovalifolia*, *Morelia senegalensis*, *Parkia bicolour*, *Pterocarpus santalinoides* and *Uvaria* sp. The total melliferous density was 178.0 plants ha$^{-1}$ distributed in 46.7 % of nectar sources, 9.4 % of pollen producing plants and 40.6 % of plants that issue both feeds for the honey bees. The diversity of the melliferous plants was distributed between 60 species of 53 genera and 21 families that shared 293.8 % of the total tree importance distributed in 144.0 % of nectar sources, 30.1 % of pollen source and 119.7 % of plants that produced both feed to bees. The most diversified family was the Caesalpiniaceae that bore 9 genera and 10 species. The *Combretum* genus was the richest genus with 4 species. Those melliferous trees had an average diameter of 19.8 cm (±8.7 cm) which varied from 10 to 57.5 cm. The non-melliferous plants were found in the families of Anacardiaceae, Anonaceae, Caesalpiniaceae, Asteraceae, Euphorbiaceae, Fabaceae and Moraceae which represented some 3 % of the total tree density.

The fourth region is the Central North Silvo-Melliferous Region (S-MR 4) that covered 1,966,018.80 ha located in the Central part of the north of the country. It was a geographic ecotype of the third region which covered the north-east of the department of Borgou, the South of the department of Alibori and centre of the department of Atacora. The only exclusive species of this region was the *Albizia zigia*. The most important species were *Anogeissus leiocarpa*, *Burkea africana*, *Crossopteryx febrifuga* and *Detarium microcarpum*, representing 85,0 % of the total importance. The total melliferous tree density was 157.0 plants ha$^{-1}$ shared by 27.9 % of nectar plants, 10.3 % of pollen plants and 57.4 % of plants that issue both (nectar and pollen) to bees. The diversity was shared between 53 species belonging to 20 families and 44 genera which represented 291.8 % of the total tree importance with 104.53 % of nectar source, 36.7 % of pollen sources and 122.8 % of plants that produce both products for bees. The most diversified family remained the Caesalpiniaceae that bore 7 genera and 9 species. The Combretaceae was also the richest genus with 4 species. The melliferous trees had an average diameter of 17.9 cm (±7.0 cm) which varied from 10 to 38 cm. The non-melliferous plant species are found in the families of Caesalpiniaceae, Clastraceae, Fabaceae, Moraceae and Ulmaceae representing 4.2 % of the total tree density of the area.

The fifth region is the Middle North Silvo-Melliferous Region (S-MR 5) which covers 1,084,913.10 ha. It was dominated by *Vitellaria paradoxa* and *Anogeissus leiocarpa* which represented 22.0 % of the total melliferous tree density. No exclusive species were found in this region which is a geographic subdivision of the second (the Common Central Silvo-Melliferous) region with which it shared all the species. The total melliferous density was 108.12 ha$^{-1}$ distributed in 31.9 % of nectar producing trees, 15.2 % pollen producing trees and 48.6 % that produce nectar and pollen for bees. The most important species were *Vitellaria paradoxa*, *Isoberlinia doka*, *Terminalia* sp. and *Anogeissus leiocarpa* which share 95 % of the total importance. There were 42 species of 18 families and the most diversified family was the Caesalpiniaceae that had 7 genera and 8 species which represented 288.0 % of the total tree importance distributed in 111.5 % of nectar sources, 53.7 % of pollen sources and 122.8 % of plants that produce both feeds for bees. The *Combretum* genus was also the richest genus with 4 species. The average diameter of the melliferous trees was 18.7 cm (±9.4 cm) and varied from 10 to 63.7 cm. Three non-melliferous plants were found in this region and belonged to the Moraceae, Sapotaceae and Caesalpiniaceae families representing 4.1 % of the plant density.

The sixth region is the Extreme North Silvo-Melliferous Region (S-MR 6). It covered 1,044,625.1 ha in the sub-saharian climate type and bore two exclusive species (*Balanites aegyptiaca* and *Stereospermum* sp.). There were 29 melliferous species here, distributed over 14 families and 23 genera which represented 292.0 % of the total melliferous tree importance. This melliferous importance was shared by 77.3 % of nectar sources, 43.2 of pollen sources and 171.4 % of plants that produce both resources for bees. The most diversified family was the Caesalpiniaceae with 5 genera and 6 species. The *Combretum* was the richest genus with 5 species. *Vitellaria paradoxa*, *Anogeissus leiocarpa*, *Terminalia* sp. and *Detarium micropcarpum* were the most important species here with 111 % of the total importance. The total melliferous tree density was 101.4 ha$^{-1}$ represented by 22.1 % of nectar producing trees, 15.2 % of pollen producing trees and 59.0 % of pollen and nectar producing trees. The average diameter of those melliferous trees was 19.4 cm (±11.0 cm) varying from 10 cm to 66 cm. The non-melliferous plants species encountered here belonged to the Anacardiaceae, Anonaceae, Caesalpiniaceae and the Fabaceae families which share 3.9 % of the total tree density.

**Table 1:** *Dendrometric parameters of the first twenty most important melliferous species per silvo-melliferous region (S-MR). N: nectar producing trees; NP: nectar and pollen producing trees; P: pollen producing trees; RBA, relative basal area; D %: relative density; F %, relative frequency; IP %, total importance.*

| Species | Food type | Silvo-melliferous region (S-MR) | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | South S-MR | | | | Common Central S-MR | | | | Central West S-MR | | | | Central North S-MR | | | | Middle North S-MR | | | | Extreme North S-MR | | | |
| | | D % | RBA | F % | IP % | D % | RBA | F % | IP % | D % | RBA | F % | IP % | D % | RBA | F % | IP % | D % | RBA | F % | IP % | D % | RBA | F % | IP % |
| *Acacia auriculiformis* | P | 0.3 | 0.7 | 3.3 | 4.3 | | | | | | | | | | | | | | | | | | | | |
| *Acacia polyacantha* | P | 1.7 | 2.4 | 3.3 | 7.4 | | | | | | | | | | | | | | | | | 1.0 | 1.1 | 2.0 | 4.0 |
| *Acacia sp.* | P | 3.9 | 7.7 | 1.7 | 13.2 | | | | | | | | | | | | | 1.5 | 0.8 | 2.3 | 5.0 | 9.8 | 5.1 | 5.2 | 20.0 |
| *Afzelia africana* | N | | | | | | | | | 1.2 | 3.1 | 1.7 | 6.0 | 1.2 | 3.2 | <0.1 | 6.0 | | | | | 1.2 | 3.2 | 2.0 | 6.0 |
| *Anacardium occidentale* | N | | | | | 3.1 | 1.6 | 2.3 | 7.0 | 7.1 | 3.6 | 1.7 | 12.0 | | | | | | | | | | | | |
| *Anogeissus* sp. | NP | | | | | | | | | | | | | | | | | 7.8 | 4.4 | 2.3 | 14.0 | | | | |
| *Anogeissus leiocarpa* | NP | | | | | 8.2 | 9.8 | 5.1 | 23.0 | 2.2 | 5.0 | 2.2 | 9.0 | 5.8 | 6.2 | <0.1 | 14.0 | | | | | 8.1 | 10.0 | 6.5 | 25.0 |
| *Azadirachta indica* | N | 1.3 | 2.5 | 6.7 | 10.4 | | | | | | | | | | | | | | | | | | | | |
| *Bombax costatum* | NP | | | | | | | | | | | | | | | | | 2.4 | 6.7 | 4.0 | 13.0 | | | | |
| *Bridelia ferruginea* | P | | | | | 1.9 | 0.6 | 0.4 | 3.0 | | | | | | | | | | | | | | | | |
| *Burkea africana* | N | | | | | 3.3 | 3.0 | 2.8 | 9.0 | 4.8 | 5.5 | 6.0 | 16.0 | 4.1 | 5.3 | <0.1 | 14.0 | 1.9 | 2.1 | 1.7 | 6.0 | 1.7 | 1.7 | 2.6 | 6.0 |
| *Ceiba pentandra* | NP | 0.1 | 1.3 | 1.7 | 3.1 | | | | | | | | | | | | | | | | | | | | |
| *Cola* sp. | P | 2.2 | 23.5 | 1.7 | 27.4 | | | | | | | | | | | | | | | | | | | | |
| *Combretum collinum* | NP | | | | | | | | | | | | | | | | | 2.9 | 1.4 | 3.5 | 8.0 | 3.4 | 1.5 | 3.9 | 9.0 |
| *Combretum glutinosum* | NP | | | | | | | | | | | | | | | | | 6.1 | 2.6 | 5.8 | 14.0 | 5.9 | 2.6 | 9.2 | 18.0 |
| *Combretum micranthum* | NP | | | | | | | | | | | | | | | | | | | | | 1.0 | 0.3 | 1.3 | 3.0 |
| *Combretum nigricans* | NP | | | | | | | | | | | | | | | | | 2.4 | 1.5 | 1.7 | 6.0 | 3.2 | 1.1 | 3.9 | 8.0 |
| *Combretum* sp. | NP | | | | | | | | | | | | | | | | | 4.4 | 2.3 | 4.6 | 11.0 | 3.9 | 2.0 | 5.2 | 11.0 |
| *Crossopteryx febrifuga* | NP | | | | | 1.8 | 0.8 | 1.8 | 4.0 | 2.8 | 1.9 | 3.1 | 8.0 | 12.8 | 8.3 | <0.1 | 31.0 | 6.3 | 2.2 | 5.8 | 14.0 | 7.1 | 3.9 | 7.8 | 19.0 |
| *Daniellia oliveri* | N | | | | | 3.3 | 7.3 | 4.8 | 15.0 | 2.4 | 5.7 | 3.8 | 12.0 | 1.1 | 4.4 | <0.1 | 8.0 | | | | | | | | |
| *Detarium microcarpum* | NP | | | | | 1.9 | 0.9 | 1.0 | 4.0 | 1.6 | 0.6 | 1.9 | 4.0 | 11.0 | 5.2 | <0.1 | 24.0 | 5.3 | 2.0 | 3.5 | 11.0 | 9.6 | 5.1 | 5.9 | 21.0 |
| *Diospyros mespiliformis* | N | 0.1 | 0.5 | 1.7 | 2.3 | | | | | | | | | 1.1 | 1.7 | <0.1 | 4.0 | | | | | | | | |
| *Elaeis guineensis* | P | 72.6 | 0.0 | 43.3 | 116.0 | 2.4 | 0.0 | 0.1 | 3.0 | | | | | | | | | | | | | | | | |
| *Entada* sp. | P | | | | | | | | | | | | | 3.5 | 2.1 | <0.1 | 9.0 | | | | | | | | |
| *Eucalyptus* sp. | N | 3.2 | 7.0 | 1.7 | 11.9 | | | | | | | | | | | | | | | | | | | | |
| *Gmelina arborea* | NP | 3.6 | 23.1 | 1.7 | 28.4 | | | | | | | | | | | | | | | | | | | | |
| *Grewia* sp. | P | 0.1 | 0.3 | 1.7 | 2.1 | | | | | | | | | | | | | | | | | | | | |

(Table 1 continuation)

| *Species* | *Food type* | *South S-MR* | | | | *Common Central S-MR* | | | | *Central West S-MR* | | | | *Central North S-MR* | | | | *Middle North S-MR* | | | | *Extreme North S-MR* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | D % | RBA | F % | IP % | D % | RBA | F % | IP % | D % | RBA | F % | IP % | D % | RBA | F % | IP % | D % | RBA | F % | IP % | D % | RBA | F % | IP % |
| *Isoberlinia doka* | N | | | | | 3.9 | 5.3 | 3.2 | 12.0 | 7.4 | 10.7 | 3.3 | 21.0 | | | | | 5.3 | 10.4 | 5.2 | 21.0 | 1.7 | 7.2 | 2.6 | 11.0 |
| *Isoberlina tomentosa* | N | | | | | | | | | 3.0 | 5.0 | 1.6 | 10.0 | | | | | 2.4 | 5.6 | 0.6 | 9.0 | | | | |
| *Lannea* sp. | P | 0.4 | 0.7 | 1.7 | 2.8 | | | | | | | | | 2.9 | 3.7 | <0.1 | 13.0 | 2.2 | 5.7 | 4.6 | 12.0 | 3.7 | 5.4 | 7.2 | 16.0 |
| *Lannea* other sp. | P | | | | | 3.5 | 3.2 | 2.8 | 9.0 | 3.1 | 3.1 | 6.4 | 13.0 | | | | | | | | | | | | |
| *Lonchocarpus sericeus* | NP | 1.8 | 4.3 | 5.0 | 11.1 | | | | | | | | | | | | | | | | | | | | |
| *Maranthes polyandra* | NP | | | | | | | | | 4.3 | 2.1 | 3.3 | 10.0 | 2.1 | 1.6 | <0.1 | 5.0 | | | | | | | | |
| *Mitragyna inermis* | NP | 0.6 | 1.4 | 1.7 | 3.6 | | | | | | | | | 6.3 | 4.0 | 0.0 | 11.0 | 2.7 | 2.6 | 0.6 | 6.0 | 5.4 | 10.0 | 1.3 | 17.0 |
| *Monotes kerstingii* | NP | | | | | 1.8 | 1.0 | 2.1 | 5.0 | 4.0 | 2.3 | 2.1 | 8.0 | 1.6 | 0.9 | <0.1 | 3.0 | | | | | | | | |
| *Nauclea latifolia* | NP | | | | | | | | | | | | | | | | | 1.9 | 0.6 | 1.7 | 4.0 | | | | |
| *Parinari curatellifolia* | NP | | | | | 1.9 | 1.5 | 1.3 | 5.0 | 3.8 | 2.2 | 4.7 | 11.0 | | | | | | | | | | | | |
| *Parkia biglobosa* | NP | 0.1 | 0.8 | 1.7 | 2.6 | 2.2 | 3.9 | 4.8 | 11.0 | | | | | 1.0 | 3.6 | <0.1 | 7.0 | | | | | | | | |
| *Pericopsis laxiflora* | NP | | | | | 1.8 | 1.0 | 0.7 | 3.0 | | | | | 1.6 | 1.1 | <0.1 | 4.0 | | | | | | | | |
| *Piliostigma* sp. | NP | | | | | 3.0 | 1.1 | 1.4 | 6.0 | 2.3 | 1.0 | 3.5 | 7.0 | 2.0 | 0.9 | <0.1 | 6.0 | | | | | 2.7 | 2.7 | 3.3 | 9.0 |
| *Prosopis africana* | N | | | | | 1.7 | 1.5 | 2.11 | 5.0 | 1.64 | 2.9 | 2.9 | 8,0 | 1.36 | 2.1 | 0.01 | 5,0 | 1.4 | 1.7 | 2.8 | 6,0 | 1.2 | 0.9 | 2.6 | 5,0 |
| *Pseudocedrella kotschyi* | NP | | | | | | | | | 1.1 | 1.1 | 2.4 | 5.0 | | | | | | | | | | | | |
| *Pteleopsis suberosa* | NP | | | | | | | | | | | | | 1.1 | 0.8 | <0.1 | 3.0 | | | | | | | | |
| *Pterocarpus erinaceus* | N | | | | | 4.3 | 5.4 | 5.8 | 16.0 | 2.8 | 5.3 | 3.8 | 12.0 | 2.8 | 7.1 | <0.1 | 15.0 | 1.7 | 4.2 | 4.0 | 10.0 | | | | |
| *Spondias mombin* | N | 0.1 | 0.8 | 1.7 | 2.6 | | | | | | | | | | | | | | | | | | | | |
| *Sterculia setigera* | P | 1.4 | 7.3 | 1.7 | 10.3 | | | | | | | | | | | | | 1.7 | 3.7 | 2.9 | 8.0 | | | | |
| *Strychnos spinosa* | N | | | | | | | | | | | | | | | | | | | | | 2.2 | 0.8 | 1.3 | 4.0 |
| *Tectona grandis* | P | 4.8 | 12.5 | 6.7 | 24.0 | 2.0 | 0.9 | 1.0 | 4.0 | | | | | | | | | | | | | | | | |
| *Terminalia* sp | NP | | | | | 6.5 | 4.5 | 2.3 | 13.0 | 8.2 | 4.8 | 7.1 | 20.0 | 5.5 | 3.8 | <0.1 | 17.0 | 5.8 | 3.4 | 6.3 | 16.0 | 7.1 | 9.3 | 6.5 | 23.0 |
| *Trichilia prieureana* | NP | 0.1 | 1.5 | 1.7 | 3.3 | | | | | | | | | | | | | | | | | | | | |
| *Uapaca togoensis* | P | | | | | | | | | 1.9 | 0.9 | 1.7 | 5.0 | | | | | | | | | | | | |
| *Vitellaria paradoxa* | N | 0.6 | 0.8 | 3.3 | 4.7 | 13.6 | 15.4 | 12.4 | 41.0 | 14.9 | 13.2 | 10.9 | 39.0 | 13.8 | 16.0 | 0.1 | 42.0 | 14.3 | 15.2 | 10.3 | 40.0 | 11.8 | 14.2 | 9.2 | 35.0 |

## 4 Discussion

From the total of 2807 floral species distributed over 1129 genera and 185 families found in Benin (Akoègninou *et al.*, 2006) the first national forest survey found 186 timber trees (IFN, 2010). Our study identified 90 perennial melliferous plants, distributed over 29 families and 73 genera. At the country level, this represented a tiny part of 3.2 % of the total floral diversity. But when taking into account the timber trees only, the melliferous plants found in this study represented 48.4 % of the timber tree diversity. Though the silvo-melliferous plant density over the country is low (40.0 plants $ha^{-1}$) the tree distribution is well balanced to make pollen and nectar available for the bees. In fact, our investigation found that there are almost as much pollen producing trees as nectar producing trees all over the country (29.1 % of nectar trees, 25.4 % of pollen trees and 42.3 % of trees that produced both resources for bees) with only 3.2 % of non-melliferous trees. Beekeeping is then an activity that can at first sight thrive all over the country. The diversity in melliferous species appeared to be higher than found by Dongock and colleagues (Dongock *et al.*, 2004) in Cameroon which had 78 melliferous species distributed in 33 families. In Benin the most important families found were Caesalpiniaceae (13.3 %) and the Mimosaceae (11.1 %) where as Asteraceae and Solanaceae dominated the melliferous families in Cameroon (Dongock *et al.*, 2004) and the Combretaceae were the dominant family in Senegal (Ricciardelli & Compagnucci, 1991).

The availability and the balance of pollen and nectar from which the bees elaborate the hive products varied from region to region and the distribution of the melliferous trees over the country was also determined by the south-north ecological gradient as Adomou (2005) and Sinsin *et al.* (2004) found in the global flora of the country. In that system, the Central West and the Central North regions located in greener areas had also the highest melliferous tree density which was also well balanced in pollen and nectar source. But our findings proved that the availability and diversity in melliferous plants and the beekeeping potentiality of a region were not necessarily correlated to the global prevailing floral diversity and climate. In fact the Common Central Region (located in the centre of the country with the highest tree diversity) had less melliferous trees per hectare than the Extreme and Middle North regions located in more difficult climate conditions with poorer global floral diversity. In the same way, the south that benefits by a better rainfall distribution during the year had the best global floral biodiversity of the country (Adjanohoun *et al.*, 1989; Akoègninou *et al.*, 2006). Unfortunately this was the poorest apicultural region because the perennial melliferous flora was simplified and reduced to industrial plantations of *Elaeis guineensis*, *Tectona grandis* and *Acacia* trees which mainly produce pollen (Yédomonhan *et al.*, 2012). In addition to the poorer nectar production, the South Region is very cloudy and had a high air humidity all the year long. This meant as indicated by Louveaux *et al.* (1966) and Klein *et al.* (2007) that the bees will stay less active leading to bad hive product yields and this region was less suitable to beekeeping than the other melliferous regions.

The total relative importance of the different species showed that *Vitellaria paradoxa* was the most important species in the entire melliferous regions except the south where *Elaeis guinensis* dominated the melliferous flora. This dominance of *Vitellaria paradoxa* which is endemic to the country (Jürgens *et al.*, 2012) is due to its high economic value. In fact the species is usually conserved by peasant during the slash and burn cropping system (Glèlè Kakaï *et al.*, 2011) and the landscape evolve sometimes in “pure *Vitellaria paradoxa* plantations” in most S-MRs. The honey flow periods in the country will then be very influenced by the blossoming dynamics of this species. The exclusive species that produce nectar could give their specific signature to the honey that would be produced in the region. In that we found that the south regions honey will be characterised by *Gmelina arborea*, *Eucalyptus* spp. and *Newbouldia laevis*. The honey from the Common central regions will be characterised by nectar from *Borassus aethipium*, *Ximenia maricana*, *Daniellia* sp., *Bloghia sapida*, *Phyllantus* sp. and *Feretia* sp.; the honey from the Central West regions will be characterised by *Garcinia ovalifolia*, *Dialium guinense*, *Peterocarpus santalinoides* and *Chrysoblalanites icaco*; the honey from the extreme north regions will be characterised by the nectar from *Balanites aegyptiaca* and *Stereospermum* sp. The Middle North and the Central North had no exclusive tree that produces nectar and our finding suggested that the honey from those two areas could have no particularity that could distinguish them from other surrounding regions.

The diversity of the melliferous trees per regions indicated that the Common Central regions which had the lowest melliferous density was the most diversified area with 68 species of 26 families. It is followed by the Central West region and the Central and Middle North regions that respectively bore 60 species 53 and 42 melliferous tree species. This diversity in the melliferous trees was the main reason why those three areas had the best balance in nectar and pollen sources. Thought the Extreme North region was less diversified compared to those four first regions, it is far better than the South region with its 29 melliferous species and a good balance in nectar and pollen sources. In addition to that, it was located in better climatic conditions for the bees and we classified this region as the fifth S-MR of the country.

The dry season is the period when the bees are most active (Adjare, 1990) and this period ecologically coincides with the blossoming of more than 70 % of the tropical trees (Arbonier, 2002; Akoègninou *et al.*, 2006), With this positive ecological synchronization between the active period and the plant blossoming, the annual pollen or nectar production of a region will be mainly determined by the size of the trees that it bears but we found that all the regions were dominated by small sized trees of less than 40 cm DBH as the country is located in a savannah area from the north to the south and where human pressure on the trees are very hight. The best parameters for characterising the different regions were then the tree relative density (or total importance) and the different pollen and nectar sources as indicated on figure 5.

As a whole, by integrating all those parameters, we suggest the following classification of different regions of the country as far as their beekeeping potentiality is concerned: the first beekeeping area of the country is the Central West known as the Bassila honey belt all other the country. It is followed by Central North and the Common Central Region which was characterised by a good balance and diversity in nectar and pollen producing trees. In those area, there are enough trees that can sustain nectar and pollen to the bees and their good frequency will help the bees spend less energy searching for their raw material. The Middle and Extreme North regions are similar regions with some fare beekeeping potentiality. But the Middle North region is still better than the Extreme North with its higher melliferous density. The marginal region in beekeeping was the South region which is in addition to a poor melliferous flora, too much humid and cloudy all the year long.

This classification is really conform to what is commonly adopted from the field works of different actors implicated in the beekeeping industry in Benin and the findings of Adjinakou (2000) and Kokoye (1991) suggesting that real beekeeping in Benin starts from the latitude of Abomey (north limit of South S-MR) to the north and that the area of Bassila (corresponding to the Central West S-MR) is the best beekeeping area, with also the highest hive density in Benin.

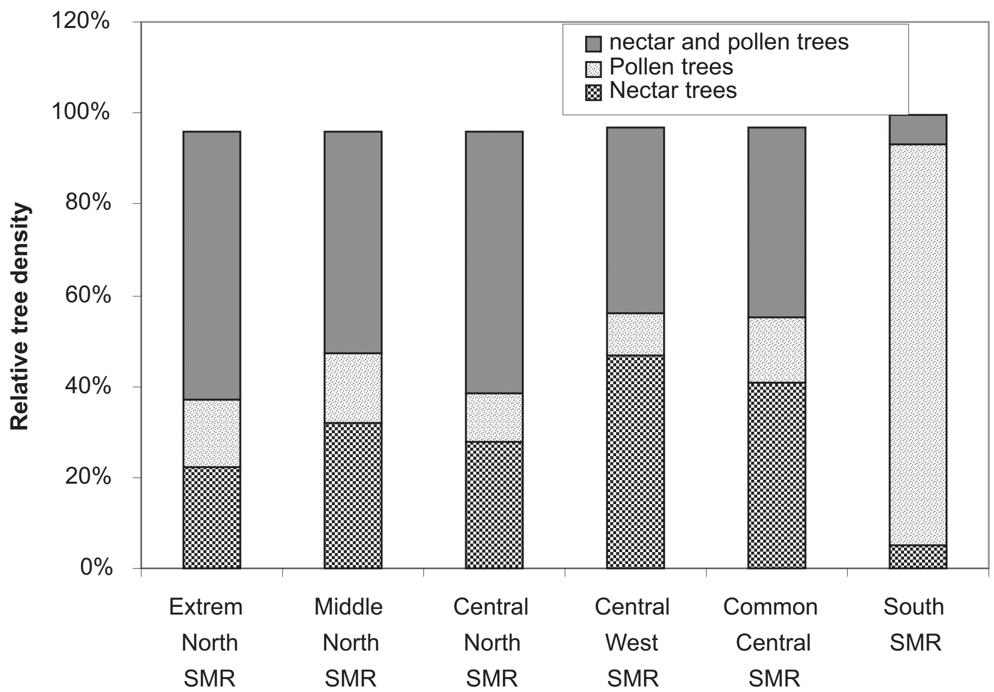


**Fig. 5:** *Distribution of the nectar and pollen production per silvo-melliferous region (S-MR). The South S-MR had too much pollen trees and very few nectar sources; the other regions had a mixture of pollen and nectar producing trees for bees.*

## 5 Conclusions

This research indicated that the distribution of the perennial melliferous resources lead to six distinct regions of particular apicultural potentiality. The density of the melliferous resources and their quality indicated that the south is the poorest while the best melliferous region of the country is located in the Centre West known as the Bassila honey belt. Even if the silvo-melliferous conditions of the other regions are fare, they benefit by a good climatic conditions to the bees and a beekeeping enterprise can well thrive in those areas. The research was limited to the perennial plants that issue the bulk of the pollen and nectar to bees in the tropical areas during the dry season when the bulk of the trees blossom. But it is known that the bees don't only rely on perennial trees or timber trees of more than 10 cm diameter at breast height and also many annual plants produce nectars and pollen for bees. The hive product yields are also determined by the colony management and pest or bee enemies' control. Other researches should include the annual plants and the bee and their pests' management in order to have an overview on the total beekeeping potentiality of the country.

**Acknowledgements**

F. Amakpe thanks the staff of the Projet Bois de Feu Phase 2 for their kind contribution in the field data collection and also Dr. Biaou S. Honore of the University of Parakou for his contribution in the data analysis.

## References

Adjanohoun, E. J., Adjakidjè, V., Ahyi, M. R. A., Aké-Assi, L., Akoègninou, A., d'Almeida, J., Apovo, F., Boukef, K., Chadare, M., Cusset, G., Dramane, K., Eyme, J., Gassista, J. N., Gbaguidi, N., Goudote, E., Guinko, S., Houngnon, P., Lo, I., Keita, A., Kiniffo, H. V., Koné-Bamba, D., Musampa Nseyya, A., Saadou, M., Sodogandji, T., De Souza, S., Tchabi, A., Zinsou Dossa, C. & Zohoun, T. (1989). *Contribution aux études ethnobotaniques et floristiques en République Populaire du Bénin*. Agence de Coopération Culturelle et Techniques (ACCT), Paris.

Adjare, S. O. (1990). *Beekeeping in Africa*. FAO Agricultural Service Bulletin 68/6, Rome.

Adjinakou, A. R. S. (2000). Etude de quelques facteurs influençant l'apiculture au sud du Bénin. Mémoire DIT/CPU/UNB/Cotonou-Bénin.

Adomou, A. C. (2005). *Vegetation patterns and environment gradients in Benin: Implication for biogegraphy and conservation*. Ph.D. thesis Wageningen University, Wageningen.

Akoègninou, A. (2004). *Recherches botaniques et écologiques sur les forêts actuelles du Bénin*. Ph.D. thesis Université de Cocody-Abidjan, Côte d'Ivoire.

Akoègninou, A., Van der Burg, W. J., Van der Maesen, L. J. G., Adjakidjè, V. J. P. E., Sinsin, B. & Yédomonhan, H. (2006). *Flore analytique du Bénin*. Backuys Publishers, Leiden, The Netherlands.

Amakpe, F. (2008). Beekeeping in the strategies of Biodiversity conservation desertification control and poverty alleviation in Benin: A monograph of the honey bees in the district of Djidja. MA Thesis; University of Liège and Faculty of Agronomy Sciences of Gembloux, Gemboux.

Arbonier, A. (2002). Arbres, arbustes et lianes des zones sèhes de l'Afrique de l'Ouest. CIRAD, Deuxième Edition Muséum National d'Histoire Naturelle.

ASECNA (2012). Fiche météorologique du Benin. Agence de la Sécurité et du Contrôle de la Navigation Aérienne (ASECNA), Agence Régionale de Bohicon.

Biaou, S. S. H. (2009). *Tree recruitment in West African dry woodlands: The interactive effects of climate, soil, fire and grazing*. Ph.D. thesis Wageningen University, Wageningen.

Bray, J. R. & Curtis, J. T. (1957). An ordination of the upland forest communities of southern Wisconsin. *Ecological Monographs*, 27 (4), 325–349.

Cottam, G. & Curtis, J. T. (1956). The use of distance measurements in phytosociological sampling. *Ecology*, 37, 451–460.

Dongock, N. D., Tchoumboue, J., Youmbi, E., Zapfack, L., Mapongmentsem, P. & Tchuenguem, F. F. N. (2004). Inventaire et identification des plantes mellifères de la zone soudano-guinéene d'altitude de l'ouest Cameroun. *Tropicultura*, 22 (3), 139–145.

Dongock, N. D., Tchoumboue, J., Youmbi, E., Zapfack, L., Mapongmentsem, P. & Tchuenguem, F. F. N. (2008). Caractéristiques polliniques des plantes mellifères de la zone soudano-guinéenne d'altitude de l'ouest Cameroun. *Tropicultura*, 26 (3), 150–154.

Dongock, N. D., Tchoumboue, J., Youmbi, E., Zapfack, L., Mapongmentsem, P. & Tchuenguem, F. F. N. (2011). Predominant melliferous plants of the western Sudano Guinean zone of Cameroon. *African Journal of Environmental Science and Technology*, 5 (6), 443–447.

Ern, H. (1988). Flora and vegetation of the Dahomey Gap. A contribution to the plant geography of West tropical Africa. *Annals of the Missouri Botanical Garden*, 25, 520–571.

Gadbin, C. (1980). Les plantes utilisées par les abeilles au Tchad méridional. *Apidologie*, 10 (2), 217–254.

Glèlè Kakaï, R., Akpona, T. J. D., Assogbadjo, A. E., Gaoué, O. G., Chakeredza, S., Gnanglè, P. C., Mensah, G. A. & Sinsin, B. (2011). Ecological adaptation of the shea butter tree (*Vitellaria paradoxa* C.F. Gaertn.) along climatic gradient in Benin, West Africa. *African Journal of Ecology*, 49 (4), 440–449.

IFN (2010). Rapport final de l'Inventaires Forestiers National au Benin. Méthodologies, résultats et annexes. Inventaire Forestier National (IFN), Projet Bois de Feu Phase 2, Direction Générale des Forêts et Ressources Naturelles.

Jongman, R. H., ter Braak, C. J. L. F. & Van Tongeren, O. F. R. (1995). *Data analysis in community and landscape ecology*. Cambridge University Press, Cambridge.

Jürgens, N., Schmiedel, U., Haarmeyer, D. H., Dengler, J., Finckh, M., Goetze, D., Gröngröft, A., Hahn, K., Koulibaly, A., Luther-Mosebach, J., Muche, G., Oldeland, J., Petersen, A., Porembski, S., Rutherford, M. C., Schmidt, M., Sinsin, B., Strohbach, B. J., Thiombiano, A., Wittig, R. & Zizka, G. (2012). The BIOTA Biodiversity Observatories in Africa: a standardized framework for large-scale environmental monitoring. *Environmental Monitoring and Assessment*, 184 (2), 655—678.

Klein, A.-M., Vaissière, B. E., Cane, J. H., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C. & Tscharntke, T. (2007). Importance of pollinator in changing landscapes for world crops. *Proceedings of the Royal Society B: Biological Sciences*, 274 (1608), 303–313.

Kokoye, S. J. (1991). Guide pratique d'initiation à l'apiculture tropicale. Service production animale du CARDER-Atacora, Ministère du Développement Rural, Benin.

Koudegnan, C. M., Edorh, T. M., Guelly, A. K., Batawilla, K. & Akpagana, K. (2012). Inventaire des taxons polliniques des miels de la zone guinéenne du Togo: Cas des zones ecofloristiques IV et V. *European Scientific Journal*, 8 (26), 37–50.

Legendre, P. & Gallagher, E. D. (2001). Ecologically meaningful transformations for ordination of species data. *Oecologia*, 129, 271–280.

Loreau, M., Naeem, S., Inchausti, P., Bengtsson, J., Grime, J. P., Hector, A., Hooper, D. U., Huston, M. A., Raffaelli, D., Schmid, B., Tilman, D. & Wardle, D. A. (2001). Biodiversity and ecosystem functioning current knowledge and future challenges. *Science*, 294, 804–808.

Louveaux, J., Albisetti, M., Delangue, M. & Theurkauff, J. (1966). Les modalités de l'adaptation des abeilles (*Apis mellifica* L.) au milieu naturel. *Les Annales de l'Abeille*, 9 (4), 323–350.

Ricciardelli, D. G. & Compagnucci, R. (1991). Apicultura e spettro pollinico di alcuni mieli del Senegal. *Apicoltura*, 7, 33–49.

Shimanuki, H. & Knox, D. A. (2000). Diagnosis of Honey Bee Diseases. United States Department of Agriculture Agricultural Research Service. Agriculture Handbook Number 690.

Sinsin, B. (1993). *Phytosociologie, écologie, valeur pastorale, production et capacité de charge des pâturages du périmètre Nikki-Kalalé au Nord-Bénin*. Ph.D. thesis Laboratoire de Botanique, Systématique et de Phytosociologie, Université Libre de Bruxelles, Belgique.

Sinsin, B., Eyog, M. O., Assogbadjo, A. E., Gaoué, O. G. & Sinadouwirou, T. (2004). Dendrometric characteristics as indicators of pressure of *Afzelia africana* Sm. dynamic changes in trees found in different climate zones of Benin. *Biodiversity and Conservation*, 13 (8), 1555–1570.

Yédomonhan, H., Houenon, G. J., Akoègninou, A., Adomou, A. C., Tossou, G. M. & Van der Maesen, L. J. G. (2012). The woody flora and its importance for honey production in the Sudano-Guinean zone in Benin. *International Journal of Science and Advanced Technology*, 2 (3), 64–74.