CONSEIL AFRICAIN ET MALGACHE POUR L'ENSEIGNEMENT SUPERIEUR

(C.A.M.E.S.)

01 BP 134 OUAGADOUGOU 01 (BURKINA FASO)

TEL (226) 50 36 81 46 - FAX (226) 50 36 85 73 - Email:*cames@lecames.org*

INSCRIPTION SUR LA LISTE D'APTITUDE

AUX FONCTIONS DE MAÎTRE - ASSISTANT (LAFMA)

C.T.S. SCIENCES NATURELLES/AGRONOMIE

Monsieur FOLEGA Fousséni

Email : ffolegamez@live.fr

EXEMPLAIRE DE THESE

UNIVERSITE DE LOME

FACULTE DES SCIENCES/DEPARTEMENT DE BOTANIQUE

LABORATOIRE DE BOTANIQUE ET BIOLOGIE VEGETALE

01BP1515, LOME (TOGO) ; TEL : (228) 22 25 50 94 ; FAX : (228) 22 21 85 95

分类号

密级　　　　　　　　　　　　　　　　　UDC

学位论文

多哥北部自然保护区土地变化，植被状态及人类干扰的研究

(中文题名)

RESEARCH ON LAND USE CHANGE, VEGETATION DYNAMIC AND HUMAN DISTURBANCES OF PROTECTED AREAS IN NORTHERN TOGO

(英文题名)

FOLEGA FOUSSENI

(作者姓名)

指 导 教 师　　赵秀海 教授

合 作 导 师　　**AKPAGANA Koffi** 教授

申 请 学 位 级 别　　博 士

学 科 专 业 名 称　　生 态 学

研 究 方 向　　土地利用变化与生物多样性

论 文 提 交 日 期　　**2012** 年 **02** 月

论 文 答 辩 日 期　　**2012** 年 **06** 月

学 位 授 予 日 期　　**.........**年**.......**月

答 辩 委 员 会 主 席 ：

评 阅 人 ：

北京林业大学

Class Number

Category **UDC**

Degree Thesis

多哥北部自然保护区土地变化，植被状态及人类干扰的研究

(Chinese Title)

RESEARCH ON LAND USE CHANGE, VEGETATION DYNAMIC AND HUMAN DISTURBANCES OF PROTECTED AREAS IN NORTHERN TOGO

(English Title)

FOLEGA FOUSSENI

(Author)

Supervisor **Prof. ZHAO Xiu Hai**

Co-promotor **Prof. AKPAGANA Koffi**

Applied Degree Level **PhD**

Major **Forest Ecology**

Research Field **Land Use change and Plant Biodiversity**

Thesis submission date **2012 Y 02M**

Thesis defense date **2012 Y 06 M 01D**

Degree awarding date **...........Y.....M**

Chairman of defense commission：

Member of the commission：

Beijing Forestry University

独 创 性 声 明

本人声明所呈交的论文是我个人在导师指导下（或我个人……）进行的研究工作及取得的研究成果。尽我所知，除了文中特别加以标注和致谢的地方外，论文中不包含其他人已经发表或撰写过的研究成果，也不包含为获得北京林业大学或其它教育机构的学位或证书而使用过的材料。与我一同工作的同志对本研究所做的任何贡献均已在论文中作了明确的说明并表示了谢意。

签 名：________________________ 日 期：_____________

关于论文使用授权的说明

本人完全了解北京林业大学有关保留、使用学位论文的规定，即：学校有权保留送交论文的复印件，允许论文被查阅和借阅；学校可以公布论文的全部或部分内容，可以采用影印、缩印或其他复制手段保存论文。

(保密的论文在解密后应遵守此规定)

签 名：____________导师签名：____________日 期：____________

This thesis is dedicated

To my parents and to my uncles, who taught me that the best kind of knowledge to have is that which is learned for its own sake.

To my beloved grandparents who played also a crucial role in my education.

To my Brothers, Sisters and my Fiancé who has been a great source of motivation and inspiration.

To all those who believe in the richness of learning.

ABSTRACT

RESEARCH ON LAND USE CHANGE, VEGETATION DYNAMIC AND HUMAN DISTURBANCES OF PROTECTED AREAS IN NORTHERN TOGO

Basic scientific research in Northern Togo protected areas is fundamental to ensure the sustainability of land resource management. Knowledge of the changes in land uses and present land cover is crucial to be able to determine which areas require more attention from conservation and restoration programs. Knowledge and better understanding of plant species distributions and influential environmental factors is important for the conservation and management of plant communities. Chorological analysis of plant species is helpful for understanding the factors determining the geographic range and particularly the role played by human in species introduction. Collection of tree data is important to understand their age structure. Assessment of the effects of human activities is necessary to plan the monitoring of protected ecosystems using the framework of sustainable management.

Several purposes have guided the realization of this research. Among them the thesis aims firstly to present an analysis and interpretation of the changes of land cover and land use during the past 20 years using Landsat remote sensed satellite imagery. Then presents the vegetation of the three protected areas based on the phytosociology concept of Braun Blanquet and biodiversity analysis followed by the analysis of the woody vegetation of the three protected areas by using phytosociological methods, which aimed to understand the age distribution of trees and perennial species. And finally to evaluate the major human activities which affecting the vegetation integrity of the three protected areas in order to suggest recommendation for these areas management.

For remote sensed data interpretation and analysis; based on the RGB-normalized difference vegetation index method with unsupervised classification, three Landsat images were analyzed to produce a land use change map. Supervised classification using the maximum likelihood classification technique was applied to the 2007 Landsat image to produce a land cover map. After the above method the floristic data collected were analyzed. In that regards the classification and description of the major plant community types based on species composition was applied to 170 samples. Detrended correspondence analyses of the samples found five main grouping along a moisture gradient. The clustering of a mosaic group (“G3”) generated three subgroups.

Indicator species of the seven major plant communities were determined by examining the indicator value. Clustering methods were applied to the matrix of species × samples generated from the data of a forest inventory to discriminate the main woody community per protected area. This step was followed by an ordination in direct gradient of samples and their floristic processing. The last part of methodology consist of the collection of data about human activities disturbances including their assessment by sampling using the land cover map previously got. After the analysis and interpretation of the batch of data the results were summary as mentioned below.

Nine colors were used to represent the changes occurring in the three protected areas during the last 20 years, which included periods of vegetation harvesting, clearing, regrowth and stability. The changes were large in most of the ecosystems of the protected areas except for in the riparian forests. Despite difficulties in defining land cover and vegetation type in the three protected areas, seven land cover types were defined and the classification of the land cover map was satisfactory. The overall accuracy and kappa statistic was 72.51% and 0.67 respectively. This chapter reveals the high anthropogenic pressure on these three protected areas, particularly Barkoissi that mostly comprised parkland and cropland. The findings also indicate that the riparian forests have the most conserved vegetation and are not subjected to as many disturbances as other ecosystems.

In total, 274 plants species were recorded, belonging to 247 genera and 63 families. Chorological analysis confirmed that the area belongs to the tropical Sudanian zone; however, the influence of the Guineo-Congolian and Sudano-Congolian climates means that there is sufficient water availability for the establishment of forest ecosystems. This water availability results in a high abundance of phanerophytes and forest trees. Phytosociology and phytogeography were found to be complementary approaches that can describe the vegetation distribution and identify the factors affecting the distribution. Human activities were found to be associated with the introduction of alien species. In this study, I identified one species of concern, Strelitzia reginae Banks ex Aiton, which was new to Togo flora.

In the three protected areas, 12 tree communities were identified based on an analysis of their floristic composition, and the indicator value was computed for each of them to determine their indicator species. Canonical correspondence analysis confirmed that the species distribution depends on water availability and human activities. The role of water availability is also shown by the presence of a cluster containing more lianas species, indicating the presence of wooded vegetation. Across the 12 woody plant communities, there were 68 plant species, belonging to 47 genera and 25 families. Most species were phanerophytes. The main phytogeographical type was Sudano-Zambezian. The area was dominated by shrubby savanna, which explains the small size of dendrometric parameters. However, the dendrometric parameters were smaller than those that evolve under the tropical Guinean climate. The high proportion of young individuals suggests there is natural regeneration of plant communities in the area.

After preprocessing of the 220 samples, eight major land disturbance types were defined, which included pasture (31.88%), plant cutting (30.35%) and bush fire (30.13%) as the most important ones causing ecosystem degradation. Shrubby and wooded savanna areas were the most disturbed, which was recognized by local people. Human activities also affected the protected areas but their impacts on ecosystem integrity were interdependent. Some disturbance arose as a consequence of the socioeconomic activities of the local people.

This study, in overall would be a baseline tool for planner and local developer at local or regional scale to sustaining the management of the PA especially in northern Togo, to plan or program (monitor) well the human activities in the ecosystem under high pressure and to achieve the project of consensual rehabilitation of PA (Northern Togo).

Key words: Protected areas, Land use change, Biodiversity, Plant community, Human disturbances.

摘要

多哥北部自然保护区土地利用变化，植被状态及人类干扰的研究

多哥北部保护区的基础研究是保证该区土地资源可持续利用的关键。了解土地利用变化并保护土地覆盖可以确定哪些区域需要进行重点保护和土地恢复。对于植物群落的保护和管理而言，很重要的一点就是要更多地了解植物种群的分布及影响其分布的环境因素。植物物种的分布学分析有助于理解影响物种地理分布，特别是人类对物种入侵所发挥作用的关键因子。我们需要对人类活动的影响效应进行评估并在可持续经营的框架下制定监测受保护生态系统的方案。

本文有以下一些研究目的，其中第一个目标是利用卫星遥感影像分析多哥过去20年土地覆盖和土地利用的变化。然后在法瑞学派的植物社会学理论以及生物多样性分析基础上研究三个保护区的植被情况，接着利用植物社会学方法分析这三个保护区的木本植物并了解该区域乔木和多年生树种的年龄分布。最后评价主要的人类活动对这三个保护区植被完整性的影响并为该地区的可持续管理提供建议。

基于RGB归一化植被指数方法并对三期卫星遥感图像进行非监督分类，生成了土地利用变化地图。再运用极大似然估计法对2007年的卫星遥感图像进行监督分类生成土地覆盖地图。在上述方法基础上在物种组成基础上对植被数据进行分析。在植物物种组成基础上，我们筛选了170个主要植物群落类型并对这些群落进行描述和分类。不同群落的除趋势对应分析（DCA）表明，5个群落随着水分梯度而聚集。镶嵌群落（“G3”）聚集从而产生三个亚群落。根据指示值确定7个主要群落的指示种。根据森林清查数据生成的矩阵，利用聚类分析的方法区分出每个保护区的主要木本群落。最后通过趋势对应分析（CCA）对所有群落进行排序。在排序的过程中，根据之前获得的土地覆盖图，我们也加入了有关人类活动干扰的数据。研究结果如下：

使用九种颜色表示过去20年中三个保护区植被采伐、植被开垦、植被再生长及稳定性方面已经发生和未来的变化。除了保护完好的滨河森林生态系统外，三个保护区中大多数生态系统的土地覆盖和利用变化都很明显。尽管界定三个保护区的土地覆盖和植被类型存在一定的难度，我们确定了7个土地覆盖类型并对

土地覆盖图进行了分类。由于整体精度和卡帕统计指数分别为72.51% 和 0.67，生成的土地覆盖地图的分类还是令人满意的。本章揭示了人类活动对三个保护区的极大影响，尤其对以温带稀树草原和农田为主的巴尔克西保护区。同时研究结果也表明滨河森林似乎是最不需要保护的植被并且不易受到各种干扰因子的影响。

记录的植物种群有274个植物物种，分属于247个属，63个科。植物分布学研究表明，该区域属于热带苏丹地区，但是受几内亚-刚果和苏丹-刚果地区的气候影响，该区域拥有足够的水资源用以森林生态系统的建立。充足的水资源使得该地区高位芽植物和木本植物的比例很高。同时利用植物社会学和植物地理学描述植被分布并确定影响植被分布的环境因子。在外来物种入侵的同时，人类活动对植被分布亦产生重要的影响。研究中，我们发现一种新物种，该物种为鹤望兰 (*Strelizia reginae* Banks ex Aiton)，已经入侵到多哥境内。

根据植物群落的区系组成，我们划分出了三个保护区中的12个木本植物群落并计算每个植物群落的指示种以确定群落的指示种。趋势对应分析（CCA）表明，植物物种分布受水分可利用性及人类活动的影响。 12个木本植物群落中有68个植物物种，分属于47个属25个科。这些物种以高位芽植物作为生命形态，在植物地理学上主要分布在苏丹- 赞比亚地区。该地区主要以灌木型热带稀树草原为主，这也正好解释了该区为什么测树参数比较小。然而对比热带几内亚气候，该区测树参数要更小，而较高比例的年轻个体较高表明该区植物群落可以自然更新。

对 220 个样本进行预处理，确定了 8 个主要干扰因素。其中，过度放牧占31.88%，滥垦滥伐占 30.35%，丛林火灾占 30.13%，这些因素在生态系统退化中占据非常重要的地位。本章发现灌木稀树草原和乔木稀树草原破坏最为严重，这两点的干扰因素相同，并且都和该区域有记载的人类活动相关。人类活动同样影响保护区而且人类活动对各保护区的影响是相互独立的。由于受当地社会经济的影响，一些人类活动对保护区的影响产生了。

该研究将为政策制定者，当地及区域开发者们提供一个标准从而可以对多哥北部的保护区进行可持续经营，可以帮助他们监测脆弱生态系统中的人类活动并完成多哥北部保护区的重建工程。

关键词：保护区，土地利用，多样性，植物群落，人类干扰。

RESUME

RECHERCHE SUR L'EVOLUTION DE L'OCCUPATION DES TERRES, DE LA VEGETATION ET DES PERTURBATIONS HUMAINES DANS LES AIRES PROTEGEES DU NORD TOGO

La recherche scientifique de base sur les aires protégées du Nord Togo est fondamentale à tous les niveaux dans le cadre de la gestion durable des ressources disponibles. Connaissant les changements qui se sont produits dans l'affectation et l'utilisation des terres, il serait inutile de rappeler que la maitrise l'état actuel de la couverture des sols est crucial pour déterminer rapidement les zones qui doivent faire l'objet d'une attention à travers les différents programmes de conservation et de restauration des terres. Connaitre et maitriser la distribution de la flore ainsi que les facteurs environnementaux inhérents à cette distribution, est importante pour la conservation et l'aménagement des paysages végétaux. L'analyse phytogéographique des espèces végétales est très utile pour déduire de la géographie, l'origine des espèces dans le milieu, impliquant quelques fois le rôle joué par l'humain. L'état de la composante arborescent et son appréhension sont également essentiel pour comprendre la répartition des âges des espèces ligneuses. Cependant l'évaluation des activités anthropogènes et leur compréhension est plus que nécessaire pour réussir les différents plans de surveillance et de gestion des écosystème protégés dans le cadre globale de leur gestion durable. Plusieurs objectifs ont orientés la realisation de cette thèse. Parmi ceux ci le premier a eu pour premier objectif d'analyser et interpréter la couverture des sols et les changements qui se sont opérés dans l'utilisation de ces derniers au cours des 20 dernières années par le biais des images Landsat. En suite de traiter floristiquement les données issues de l'inventaire floristique des trois aires protégées par le biais du concept phytosociologique de Braun Blanquet. Suivis de l'analyse de la végétation boisée des trois aires protégées en employant la méthode communément utilisée en phytosociologie. Il a vise également à comprendre la distribution des classes d'âge au sein des espèces ligneuses. En fin d'évaluer les principales activités humaines qui affectent l'intégrité de la végétation des trois aires protégées afin de suggérer des recommandations pour une bonne planification dans la gestion de ces écosystèmes.

Sur la base de la méthode de RGB NDVI associée à la classification non supervisée, des images Landsat couvrant trois périodes ont été analysées pour produire la carte des changements d'utilisation des terre tandis que la classification dirigée a été appliquée à l’ image Landsat de 2007 en utilisant la technique de la classification de maximum de vraisemblance (MLC) pour générer la carte de couverture du sol. Apres analyse et interprétation des images Landsat, la classification et la description des principaux groupements végétaux basés sur la composition spécifique ont été appliquées aux 170 relevés. La DCA (Detrended Correspondence Analyses) des 170 relevés ont conduit à l'identification de cinq groupements principaux suivant un gradient d'humidité croissant. De la classification hiérarchique du groupement mosaïque G3, est issues trois sous-groupements végétaux. Les sept communautés végétales définie, ont été soumises aux calcules de leur *INDVAL* (valeur d'indicatrice) pour déterminer les espèces indicatrices. Une approche méthodologique par classification hiérarchique a été appliquée aux matrices générées après le prétraitement des données obtenues lors de l’inventaire forestier pour identifier les groupements ligneux par aires protégées suivis de l'ordination en gradient direct. Les facteurs de perturbation, principalement ceux issues des activités anthropogènes ont été relevées par la méthode d’échantillonnage orientée en rapport avec les différents types de couverture du sol définis grâce la carte de couverture des sols.

Neuf couleurs correspondent aux changements qui se sont produits dans les trois aires protégées durant les 20 dernières années. Ces changements sont liés à l’exploitation, à la croissance de la végétation, suivie de sa dégradation. Les changements sont très prononcés dans la plupart des écosystèmes présents dans ces aires protégées, cependant les forêts galeries des zones bien protégées semblent ne pas être soumises aux changements majeurs. Malgré les difficultés pour établir les différents types de couverture des sols dans les trois aires protégées ainsi que la confusion entre certains composants de la vegetation. Sept différentes classes de couverture du sol ont été définies et la classification pour générer la carte d’occupation du sol s’est révélée satisfaisante. Dans ce sens l'exactitude globale de la classification et l'index statistique de Kappa est respectivement égale à 72.51% et à 0.67. Ce chapitre révèle que la pression anthropique est importante sur ces trois aires protégées, en particulier celle de Barkoissi qui est occupé plus par les parcs agroforestiers, des jachères et des champs. Il indique également que les forêts ripicoles qui semblent être une végétation bien conservée; ne le sont guerre et sont soumises à diverses perturbations.

Pour l'ensemble des groupements végétaux, 274 espèces sont reparties entre 247 genres et 63 familles. L'étude confirme par l'analyse des types phytogéographique que la zone d'étude fait partie intégrante des régions tropicale Soudanienne mais l'importance relative des espèces Guinéo- Congolaise et Soudano- Congolaise impliquent et expriment également la disponibilité en eau dans le milieu favorable à l'établissement d'écosystème de forestier. Cette disponibilité en eau qui s'exprime par le gradient d'humidité explique le taux élevé de phanerophytes qui donne un caractère boisé au milieu. La Phytosociologie et la Phytogeography s'avèrent être deux approches complémentaires pour expliquer la distribution des espèces au sein d'une végétation et les facteurs qui influencent cette distribution. Parmi celle-ci l'une des activités humaines tel que l'introduction d'espèces exotiques peut être mentionnée. L'étude signale une nouvelle espèce pour la flore du Togo, celle-ci concerne *Strelizia reginae* Banks ex Aiton qui a été introduit au Togo.

Pour l'ensemble des trois aires protégées douze groupements végétaux ligneux ont pu être établie sur la base de la composition floristique. L'indice d'*INDVAL* a été calculé pour chaque groupement pour déterminer les espèces indicatrices. L'analyse canonique de Correspondance (CCA) a confirmée également que la distribution des espèces dépend de la disponibilité en eau associé à l'impact des activités humaines. Cette disponibilité en eau est confirmée par le regroupement sur l'axe 1 des relevés ayant plus d'espèces lianescentes indiquant alors une végétation boisée en reconstitution. Pour l'ensemble des douze groupements boisés 68 espèces appartenant à 47 genres et 25 familles ont été déterminées. Comme type biologique les phanerophytes sont dominantes, cependant les espèces Soudano-Zambéziennes représentent le type phytogéographique majeur. Le milieu est dominé par les savanes arbustives ce qui expliquerait la faiblesse des paramètres dendrométriques. Bien que les paramètres dendrométriques dans ces écosystèmes sont relativement faible comparés à ceux évoluant sous le climat tropical guinéen; la proportion élevée d'individus juvéniles suggère un dynamique équilibré dans la régénération naturelle des communautés végétales de ces zones.

Les prétraitements des 220 échantillons ont permis de définir huit perturbations majeurs parmi lesquelles le pâturage 31.88%, la coupe de bois 30.35% et les feux 30.13% occupent une place important dans le maintien et la dégradation des écosystèmes surtout savanicoles. Le chapitre confirme que les savanes arbustives et arborées présentent un degré de perturbation élevé et que tous les perturbations énumérées s'y trouvent et confirmées par les sondés rencontrées à l'intérieur des aires protégées. Les activités anthropogènes mentionnées semblent perturber séparément les aires protégées, mais leurs actions et impacts sur l'intégrité des écosystèmes sont interdépendants. Certaines perturbations sont considérées comme faisant partie intégrante des activités socio-économiques des personnes qui y vivent dans le milieu.

Cette étude dans l' ensemble pourrait être un outil de base pour les planificateurs et aménageurs dans les cadres suivants. Au plan local ou régional, il serait utile dans les programmes d'aménagement durable aires protégées surtout ceux du nord Togo. Pour programmer ou planifier les activités anthropogènes et de pourrait être très important lors de l'application du plan de gestion concertée des aires protégées.

Mots clés : Aires protégées, Utilisation et occupation des Terre, Biodiversite, Groupement végétale, Pertubations anthropogènes

目录

CONTENTS

LIST OF FIGURES

LIST OF TABLES

PHOTOS

CHAPTER 1- GENERAL INTRODUCTION

1.1 BACKGROUND AND STATEMENT

Forests and woodland remain the major place where the biological diversity evolves without huge pressure. The Earth summit of Rio (1992) and the Convention on Biological Diversity (1993) have confirmed the role played by the ecosystem in biodiversity protection and conservation; and encourage the countries which have ratified these agreements to setup a framework in that regards. In spite of the resolutions and strategies took both on international and national level, there still are great concerns about biodiversity sustainability because of the heavy pressure induced by increased urban development and modern farming practices (Celia *et al*.,2008; Michael, 2002; Treu *et al*., 2000).The impacts of these disturbances can be exacerbated by the intensification of surrounding land use management and terrestrial ecosystems which are expected to be affected mainly by changes in land-use (Luca, 2006; Virginia *et al.*, 2001). Climate change may further compound these effects (Watts *et al*., 2007).

Actually the contribution of protected areas system to nature conservation is more known, but the statute of protected areas in most of West African countries is more theoretic than practice because of the economics interest of rural people (Bernard *et al*., 2003).This situation is well present in Togo and is characterized by forest logging, farming, pastoralism, poaching, fishing and none woody resources harvests interest. Since the management of protected areas has faced to important lack of their resources and land monitoring by the planners, the rate of forest or woodland lost in Togo still increase.

Togo is not a great forest country, the major forest areas which are under the label of protected areas and sacred forest are both illegally invade by forest harvester. The annual rate lost of natural forest and woodland were estimated to 3.5% in 2000 (Sessi, 2001). Among the 65 countries which have the high rate of deforestation and forest degradation listed by ITTO, Togo has the highest one followed by Nigeria and Ghana. Between 2005-2010 the country lost 5.75% of its forest and woodlands (ITTO, 2011).

This forest lost goes with plant diversity and some fauna species migration to safe areas. In recent years the erosion of plant diversity and wild animal which associated to protected ecosystem becomes big concern for authorities. To manage and to monitor the landscape ecological resources several legal dispositions were took in that regard. Among them the standard framework for protected area management can be cited (IUCN/PACO, 2008).

Among the 43 protected areas retained out of the 83 proposed for the project of consensual rehabilitation of the protected areas, only few of them was subjected to basic researches on the available resources (Woegan, 2007). The situation is far more alarming in the north of Togo where one out of 6 protected areas have been subjected to scientific investigation (Folega *et al*., 2010).The acute lack of primary data on biodiversity, the insufficiency in the monitoring of changes in land use in this zone of the Togo, which has a higher rate of protected areas compared to the other areas, is a handicap to the long-awaited sustainable management process.

Today, there is a great need to assess the change occurred in land cover, to do an inventory of the existing plants resources and to explore various forms of the human pressures in the protected areas in order to contribute to update the existing database for eventual management use.

1.2 RESEARCH OBJECTIVES

The main objective of this study is to contribute to the protection and to the conservation *in situ* of plant biodiversity, to determine the main plant communities' patterns, to assess the major anthropogenous disturbances and to evaluate the change in land use which can be use as a baseline work for Togo protected areas sustainable management, particularly that of Barkoissi, Galangashi and Oti-Keran.

The specifics objectives were consisted in:

- ❖ The analysis and the assessment of the change occurred in land use and land cover by using multi-temporal remote sensing data.
- ❖ The design of the actual land cover map through the most recent remote sensed images.
- ❖ The assessment of the overall plant diversity and to establish plants communities in relation with the environments factors which determine species distribution.
- ❖ The establishment of wooded plant communities features including their relation with ecological factors.
- ❖ The evaluation of the recurrent human activities and their impact on the protected areas integrity.

1.3 STUDY AREA

1.3.1 Location and area statue

The Republic of Togo is a stretched country of West Africa, situated between Latitudes 6°06'N and 11°08'N and longitudes 0°09 W and 1°49. The country is bordered by Republic of Burkina Faso in North, Atlantic Ocean in the South, Republic of Benin and Republic of Ghana in West. It total area is 56600 Km^2, while the population is equal to 6191155 inhabitants with a density of 119 inhabitants per Km^2 (DGSCN, 2011) (Figure 1-1).

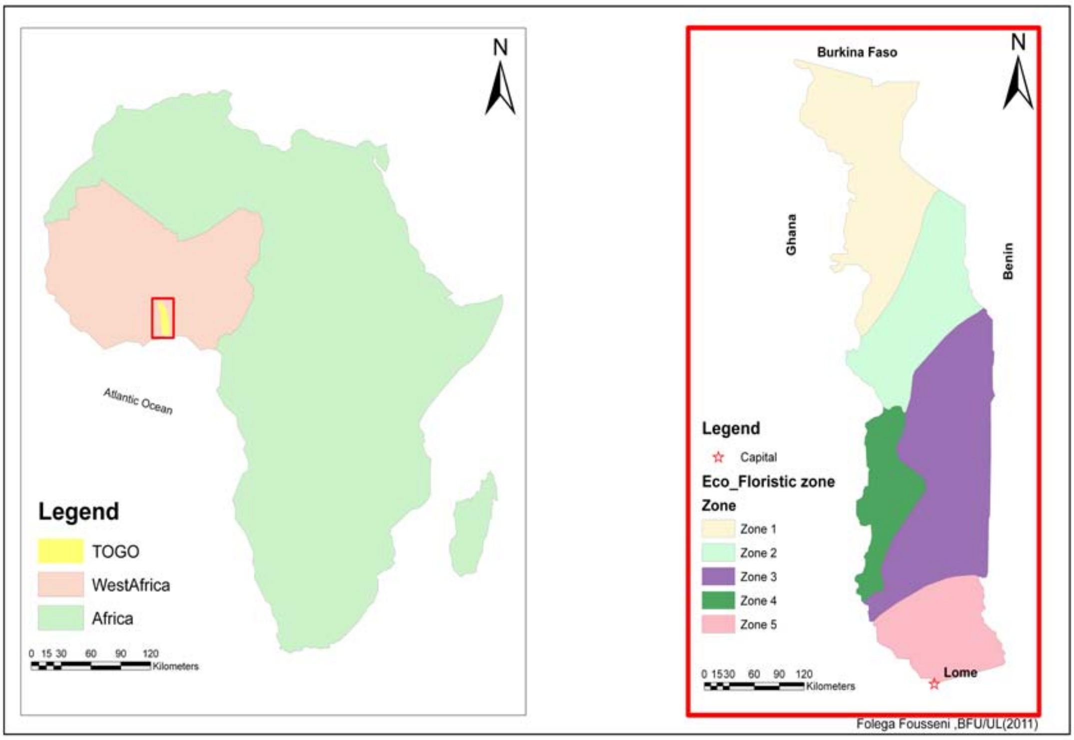


Figure 1-1: Country location

Base on the following features: geomorphology, climate subdivision, soils and the vegetation which cover; Ern (1979) has divided the country from the North to South into five Ecofloristic zone (Figure 1-2).

The sites of investigation are located in Ecofloristic zone 1 or the Northern plain. This area is characterized by encrusted lateritic soils interspersed by dembos or flooded river valleys with azonal plant communities. The administrative region "Region des Savanes'' is localized in this area which include six protected areas (Figure 1-2 and 1-3).

The investigation area has concerned three of the six protected areas such as Barkoissi, Galangashi and Oti-Keran (Figure 1-3).

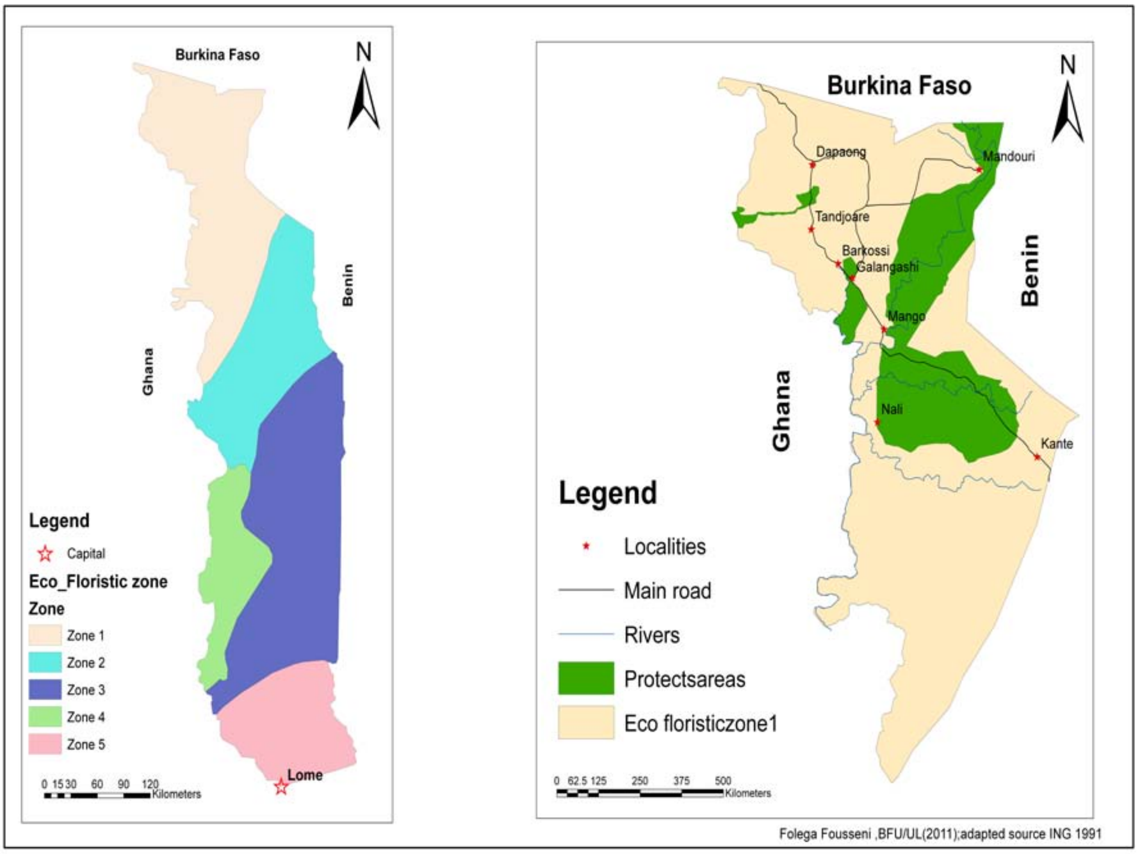


Figure 1-2: The Ecofloristic zone distribution

The protected area of Barkoissi (2000 ha) was gazetted as protected area in 01 January 1954. It has the statute of Forest Reserve and labeled in category IV of IUCN list.

The protected area of Galangashi (7500 ha) was classified as wildlife reserve by Decree No. 865 of 14-09-1954 and then requalified as a classified forest by Order No. 006/MERF/case of 02-02-2005. It is labeled in category III of IUCN list.

The protected area of Oti-Keran formally was set as Forest reserve of Keran (6000 ha) in 28 September 1950. It boundaries were extended to reach 163 640 ha by the decree No 77-117 of 25 April 1977 and requalified as National Park. Between 1981 and 1982 the area was extended to 179 550 ha. This National Park is labeled in category II of IUCN list and classified as RAMSAR site (IUCN/PACO, 2008).

The boundaries of the survey area were those of the year of their first demarcation (Sournia *et al.*, 1998).

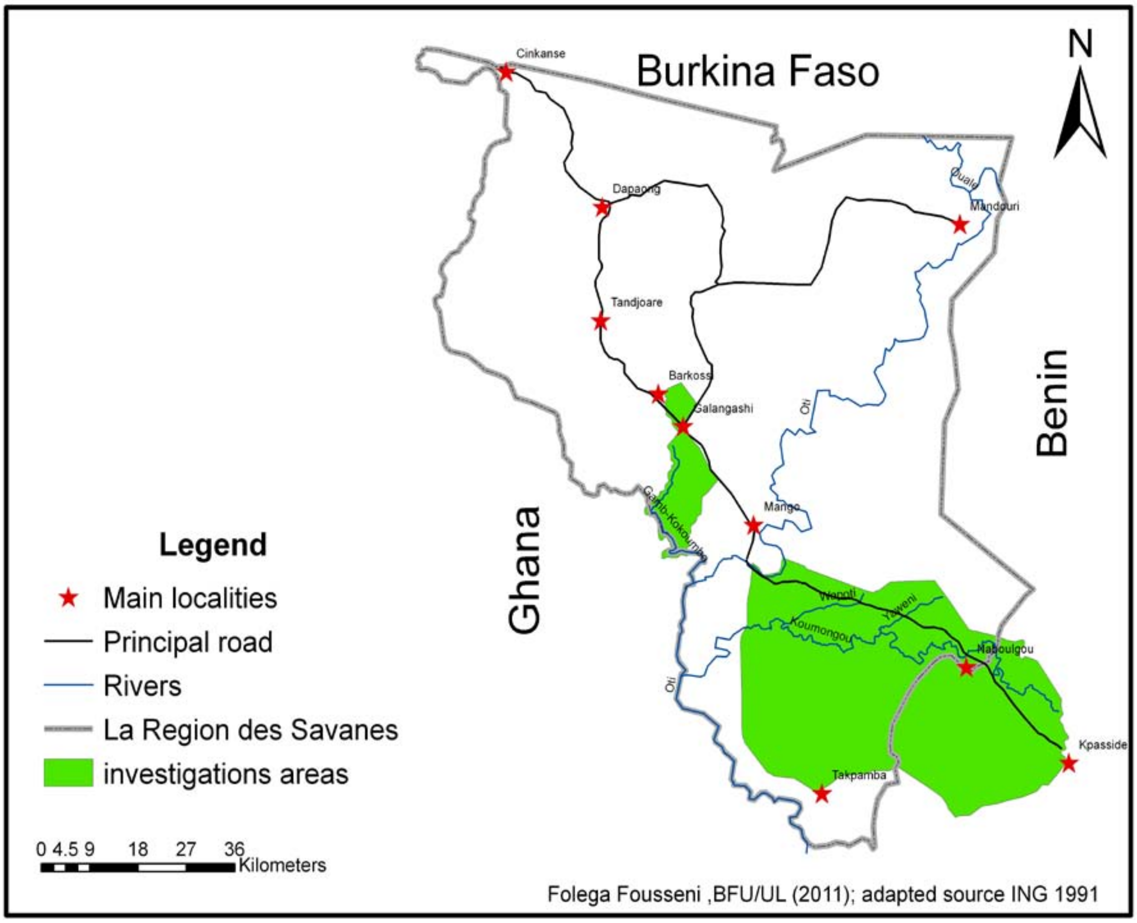


Figure 1-3: The investigation areas

Since 2003 the planners and policies maker setup a standard framework for the management, the requalification and redemarcation of protected area. This project know under the label of project of consensual rehabilitation of protected areas has the objective to protect and to conserve the most diversified and less subjected to anthropogenous activities part of these three protected areas (Figure 1-4). In that regard, their boundaries have been redesigned and the zone more disturbed were surrendered to bordering population.

1.3.2 Geomorphology and geologic unit

The relief of the area is mainly dominated by a vast peneplain. The principal geomorphologic aspect met the Ecofloristic zone 1 are: ① the extreme North West peneplain constituted of crystalline rocks with an altitude comprise between 200 and 400 m.② The sandstones plateau of Dapaong and Bombouaka with their cuestas relief about 500m of altitude caused by differential erosion.③ The Oti plains with an altitude of 100m (Roland, 1996).

Three geologic units are remarkable in the environment. They consist of: ① The West African craton composed of crystalline rocks such as (Figure 1-5):

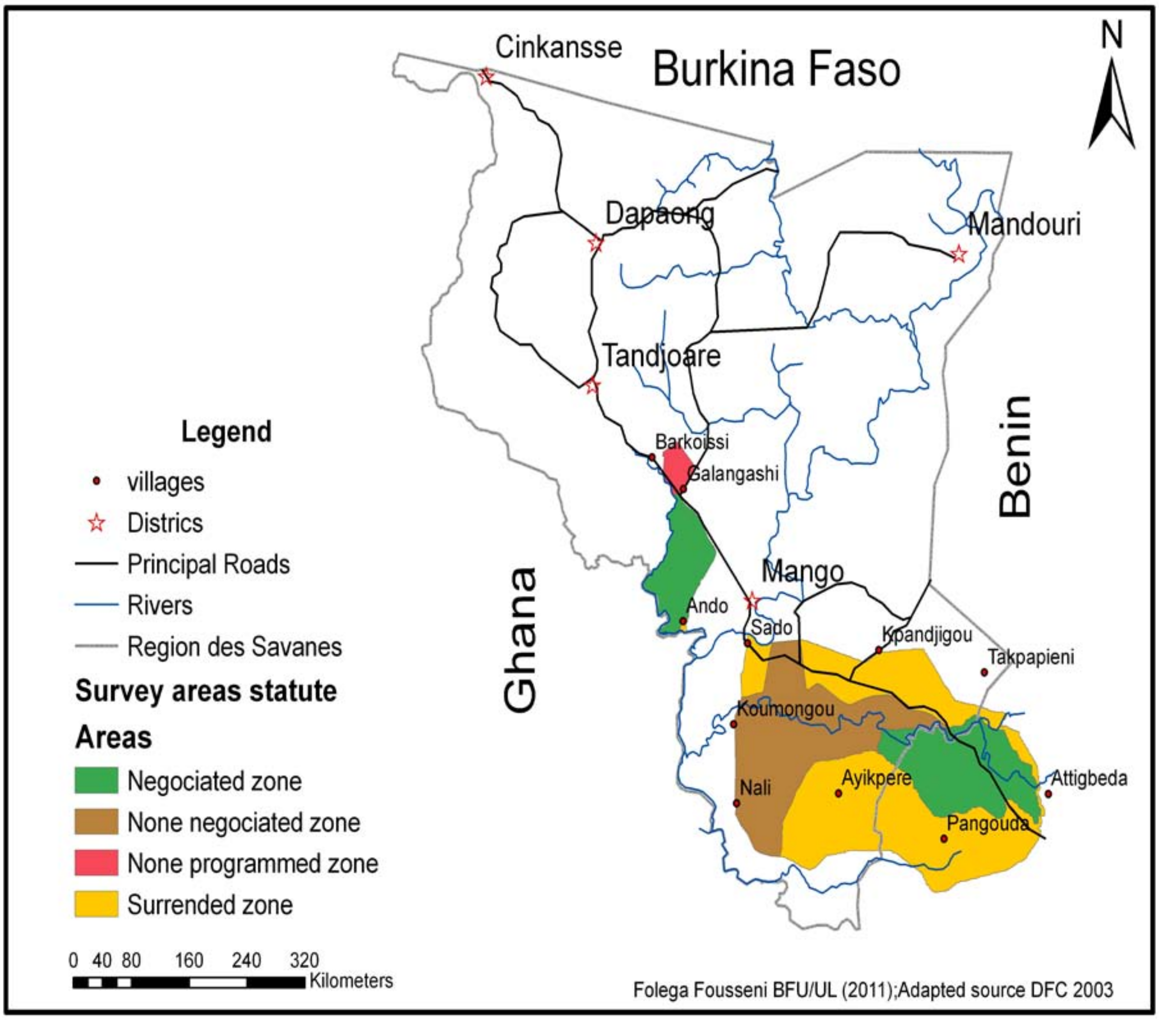


Figure 1-4: Actual statute of the investigation area

Gneiss, migmatites, amphibolites, granites and granodiorites. ② The none metamorphosed primary sedimentary of Volta basin is constituted of Infra-tillitic supergroup of Dapaong and Bombouaka (sandstones, pelites and silica) and Supra-tillitic supergroup of Mango and Gando (tillite, carbonates, chert and shales). ③ The Dahomeyid chain represented by it north extremity which include the main part of the Buem (Schist's and quartzites) and few part of Atacora (Schist and quartzitic sandstones) (Affaton, 1975; Affaton *et al.*, 1990; Simpara, 1978).

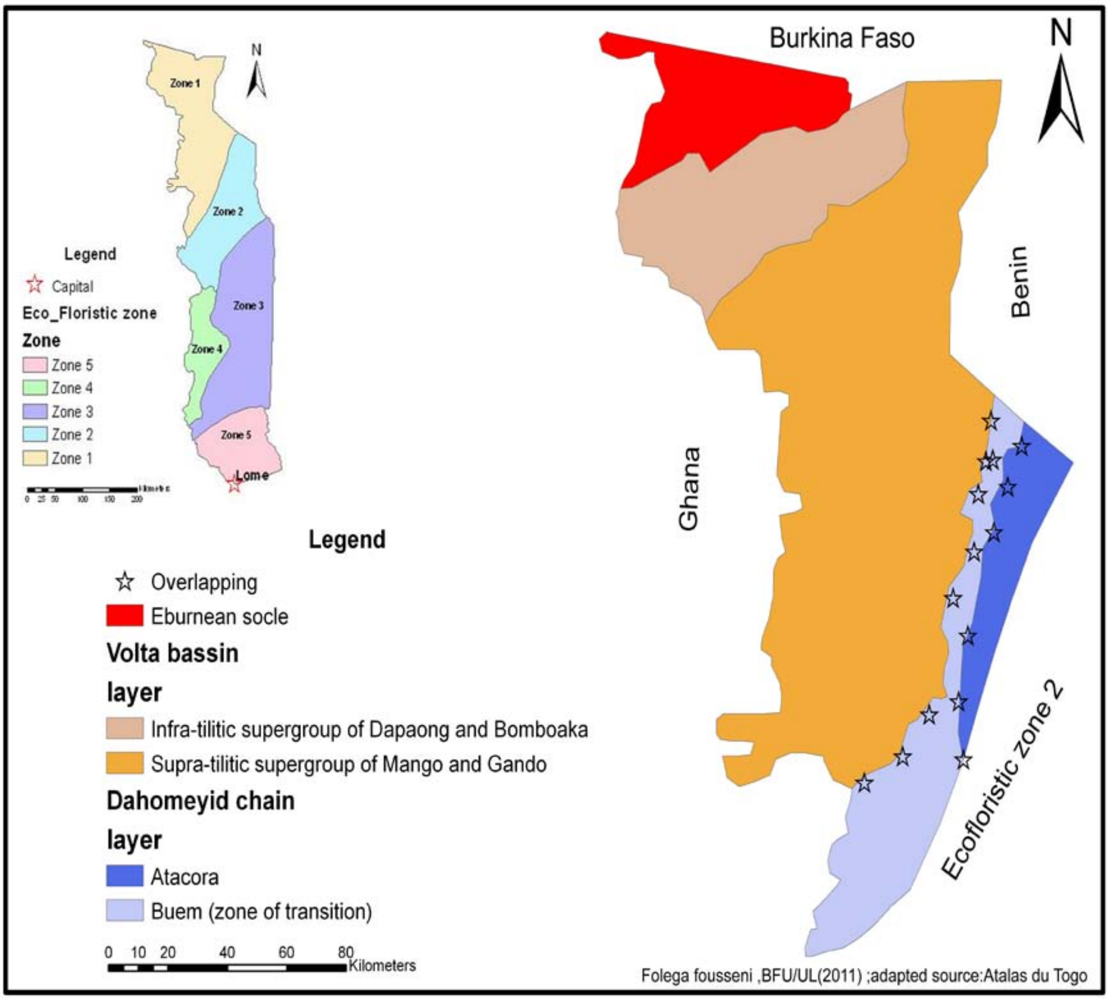


Figure 1-5: Main geologic unit

1.3.3 Soils features

The soils of the Ecofloristic zone are generally mediocre and inappropriate for agriculture practices. The soils with good potential for crops production have black or brown color and localized in the rare valley of the areas. This ecoregion is dominated by leached tropical soils (Lamouroux, 1969).The following different types of soils can be found in that region: ① Tropical ferruginous deeply leached soils with concretion, ② Tropical ferruginous less leached soils with harden and or concretion, ③Eroded soils poorly evolved and ④ Hydromorphic soils composed of fluvial alluvium (Figure 1-6) (Roland,1996).

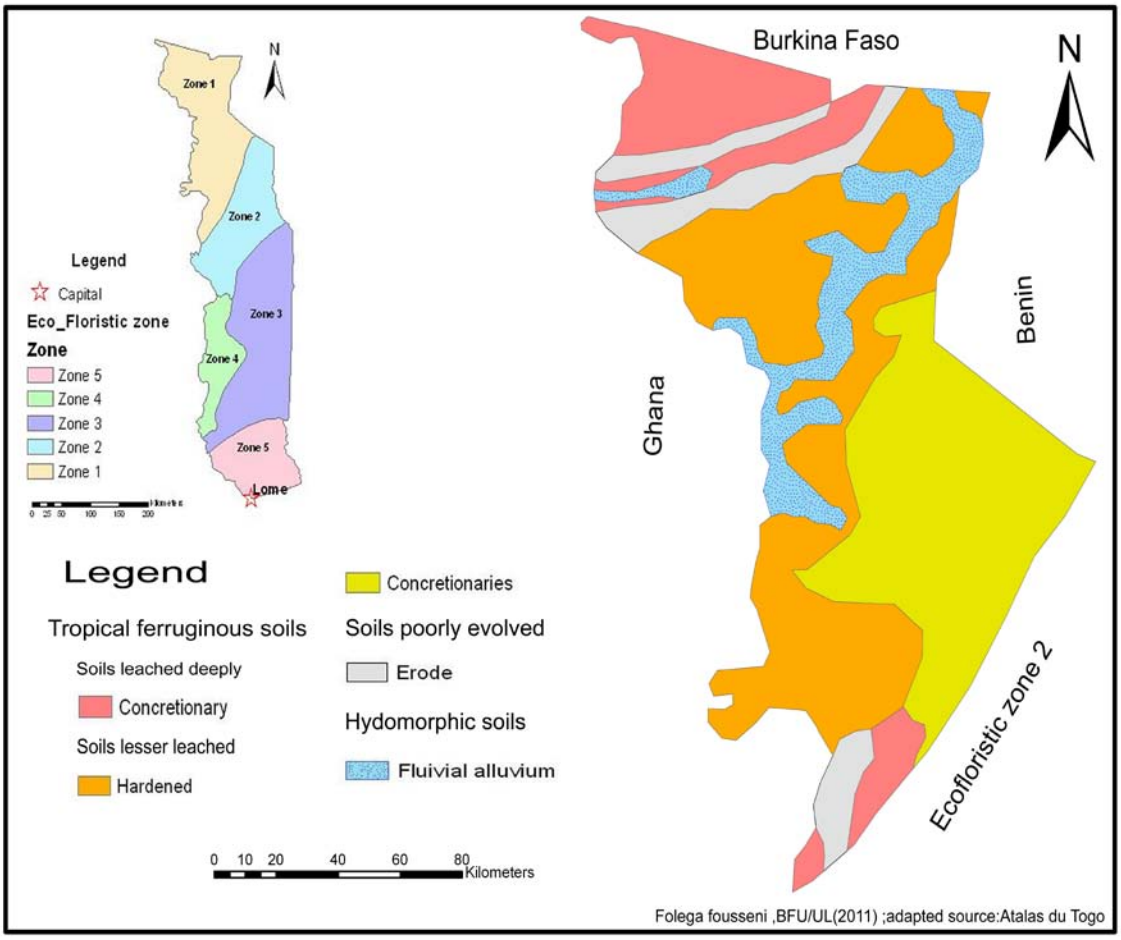


Figure 1-6: Main types of soils

1.3.4 Climate and hydrographic network

Three isohyets areas are distributed in the Ecofloristic zone 1(Figure 1-7). The annual mean rainfall varies between 1000 and 1300 mm. The climate is a tropical sudanian one, characterized by the alternation of long dry season (October–April) and rainy season (May–October) (Yema *et al.*, 1981). A heavy rainfall used to be recorded in August, but in recent decades there has been a sharp decrease in rainfall (Figure 1-10) that rotates around 1058.9 mm/year (Moussa, 2008).The two seasons are more influenced by the common two trade winds as Harmattan and the Equatorial marine monsoon. The rainfall and temperatures gradient decrease from North to the South (Figure 1-7). The mean annual temperatures range from 20 and 35°C with an average of 27.91°C and 28.5°C respectively for the station of Dapaong and Mango (Figure 1-8) (Moussa,2008). The potential evapotranspiration (PET) and the real evapotranspiration (ETR) are 12.8 and 993.0, respectively. It is even more marked during the harmattan period. The interannual temperatures (Figure 1-9) tendency shows also that, these areas are affected by the global warming. Since 1960 the temperatures are still increasing and may reinforce the impact of dry season on the areas which is known to more droughts in Togo.

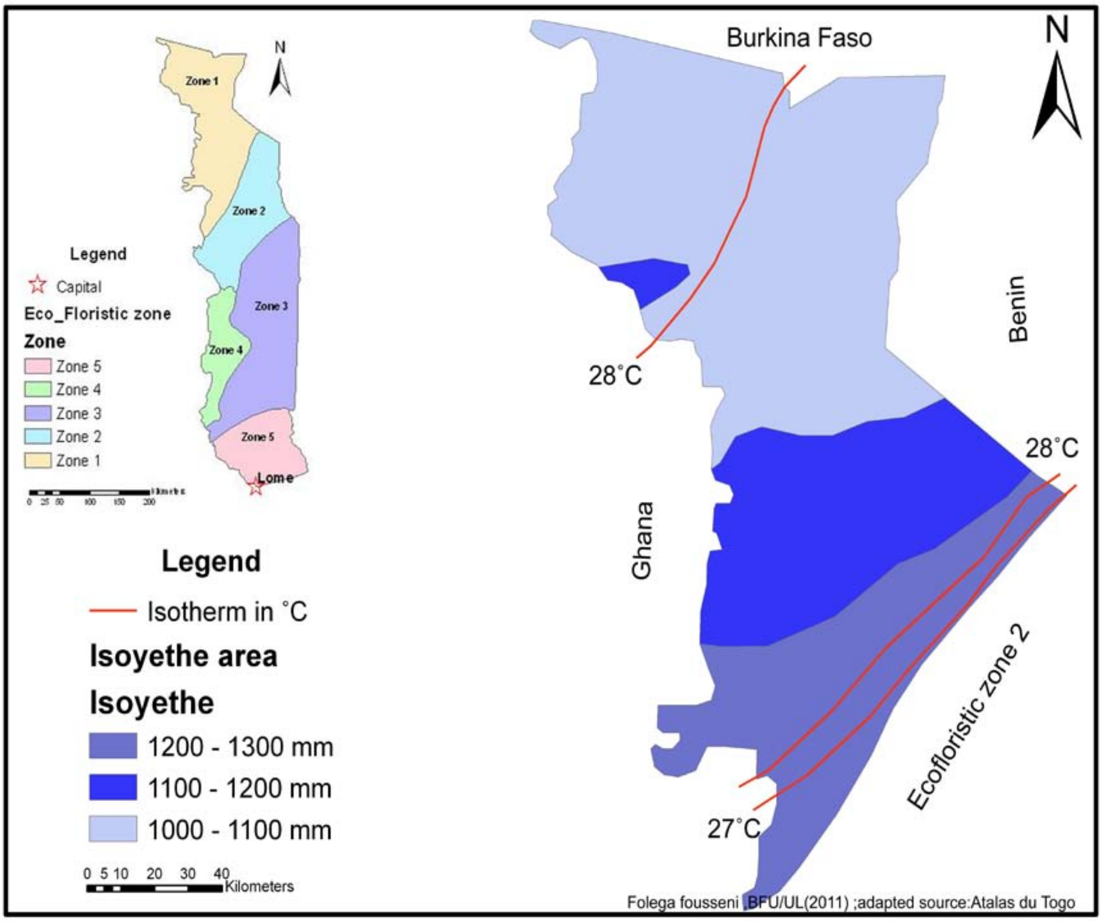


Figure 1-7: Isohyets and isotherms distribution

The hydrographic network of the areas is very dense. They are drained by two important rivers Oti, Koumongou, Kara and Mo. A number of smaller rivers of seasonal regime such as: Gambara, Yawéni, Wapoti, Koukombou, Koupéni and Namoukoué also exist in the area (Figure 1-11).

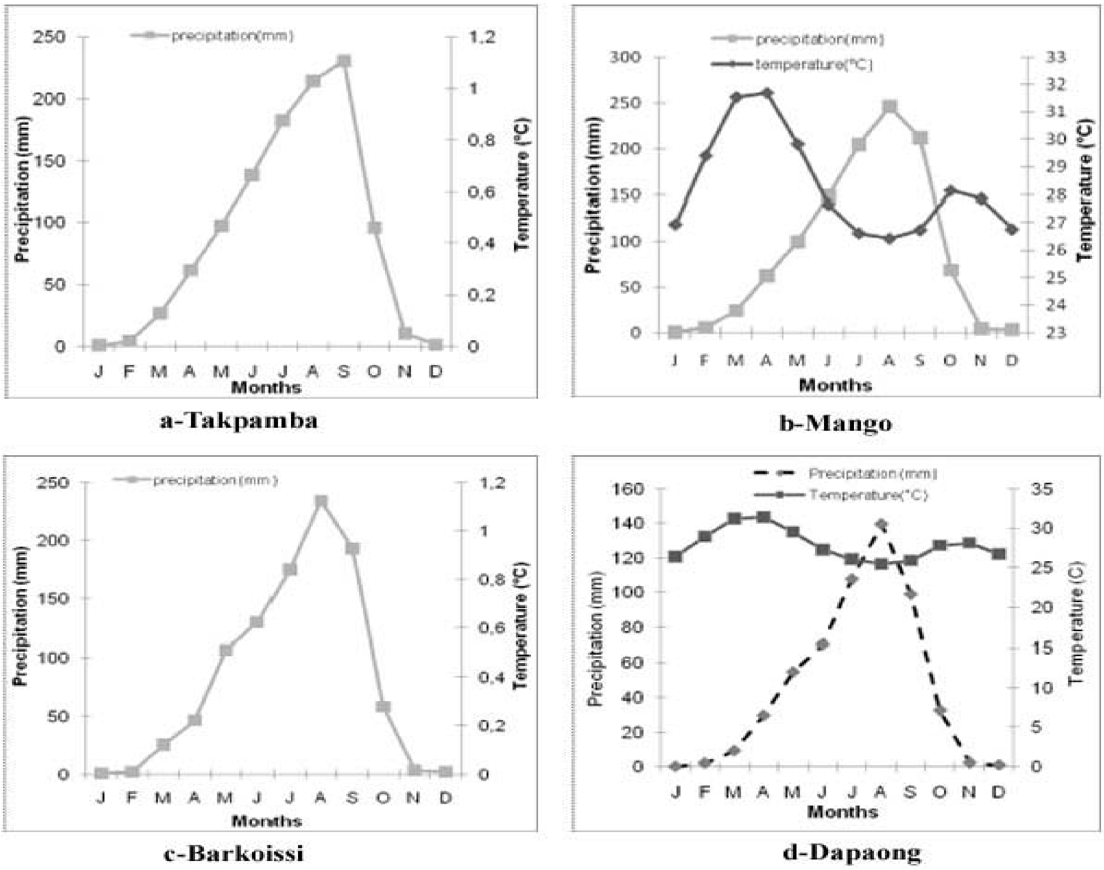


Figure 1-8: Climographs of the main meteorological station in the study area

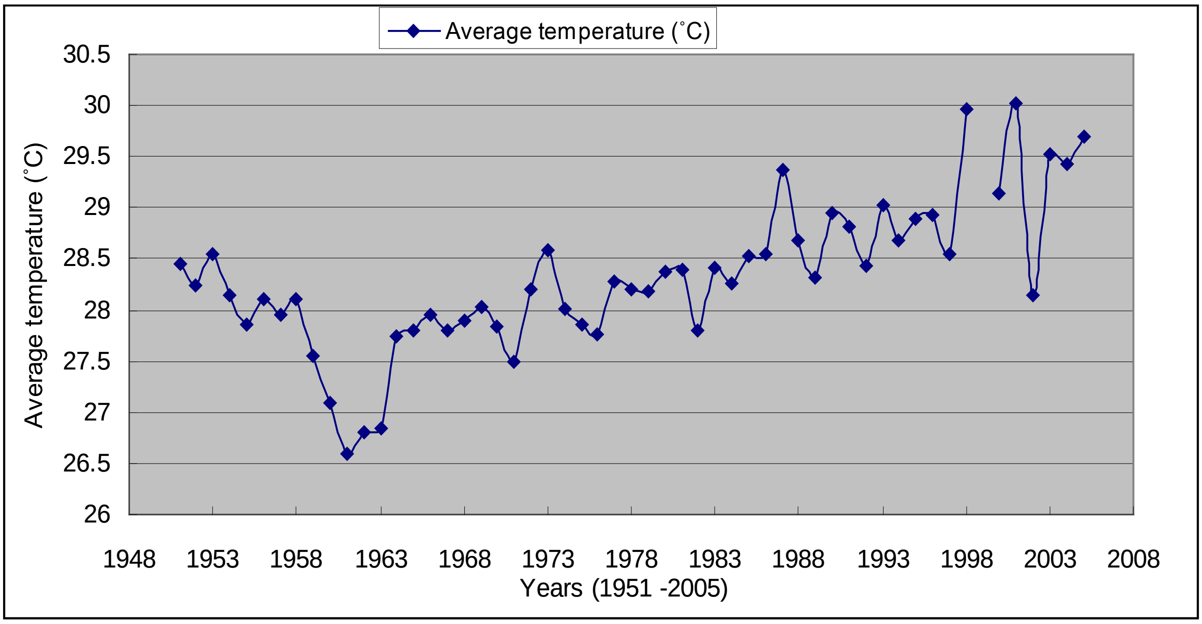


Figure 1-9: Tendency of interannual temperatures ***(Source: Direction de la Météorologie Nationale Lomé)***

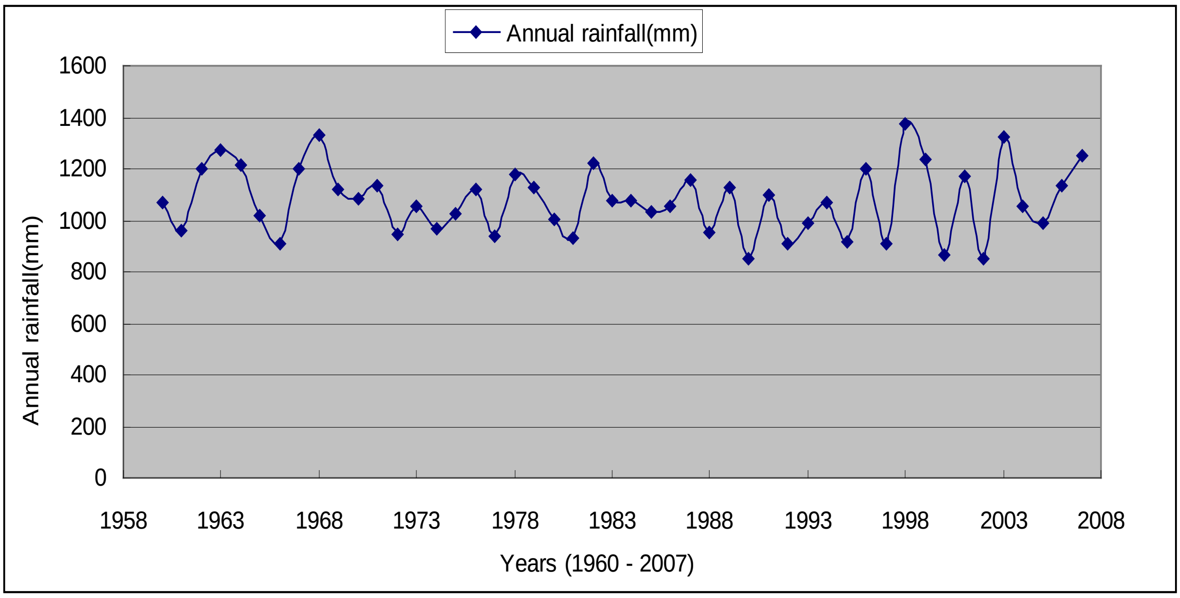


Figure 1-10: Tendency of interannual rainfalls ***(Source: Direction de la Météorologie Nationale Lomé*****)**

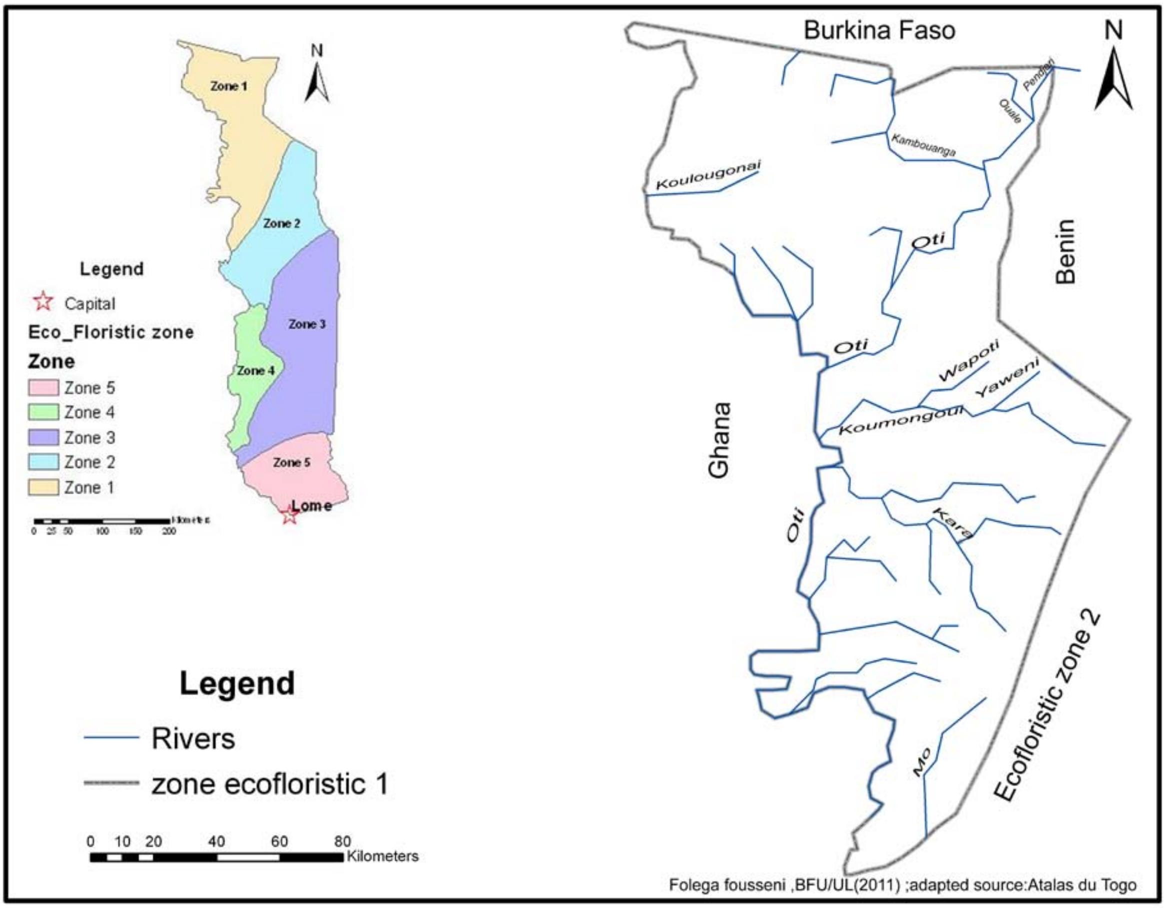


Figure 1-11: Hydrographic network

1.3.5 The vegetation

In general, the area is dominated by degraded Sudanian savanna very grazed (IUCN/PACO, 2008). The study area includes the following vegetation types: ① The riparian forest dominated by *Celtis integrifolia, Cola laurifolia, Diospyros mespiliformis, Parinari congensis, Vitex madiensis, Crataeva adansonii Parinari curatelifolia, Pterocarpus santalinoides, Ficus exesperata, Eugenia kerstingii* are the most conserved plant formation.② The dry forest contiguous to riparian forest and the wooded vegetation (wooded savanna and tree savanna) are dominated by *A. leiocarpus, P. erinaceus, Entada africana, Lonchocarpus laxiflorus, Parkia clappertoniana, Sclerocarya birrea, Sterculia setigera, Stereospermum kunthianum, Tamarindus indica, Terminalia laxiflora, Vitellaria paradoxa.* ③ The shrubby savanna characterized by the important presence of *Combretum glutinosum, C. collinum, C. sericeum, Piliostigma thonningii, Pteleopsis suberosa.*④The flooded savanna with *Mytragyna inermis* and *Andropogon gayanus var bisquamulatus*. The herbaceous layer is almost occupied by *Aristida kerrskingii, Chloris pilosa, Loudetia sp, Hypparrhenia sp.*

Vitellaria paradoxa, Parkia biglobosa, Diospyros mespiliformis, Tamarindus indica, Sclerocarya birrea, Lannea microcarpum, L. kerstingii species characterized more fallows, parkland and the croplands presented in the area.

1.3.6 The fauna

The most common fauna species, recorded during the investigation are: buffalo, hippopotamus, hypotragues, bubales, guibs, primates such as the cynocephali, wart hogs, hedgehogs, porcupine and a variety of rodents. Reptiles included python sebae, Nile crocodile, savannah varan, Nile varan. Examples of avifauna species in the study are wild guinea fowls, common francolins, bustards, turtledoves, touracos, hornbills and swans (Anonyme [PNAE-TOGO], 2002. Monographie nationale sur la biodiversité). The photos (1-10) illustrate the fauna and prints met during the investigation.

The fauna once was much diversified, a part of this fauna has probably disappeared; for the project of protected areas rehabilitation, it may be necessary to reintroduce them.

1.3.7 People

The region has a strong anthropogenic influence on vegetation. The population of Oti District, located in the bulk of the investigation zone, had 126.000 inhabitants in 2000, that increased to 135.000 in 2006 (DGSCN, 2006)**.** The ethnic groups living around the study area include the following: Ngamgam, Tchokossi, Lamba, Fulani, Tamberma, Gnande, Moba, and Mossi.

The major human activities are pasture, agriculture, firewood collection and initiation of bush fires during the dry season. The main crops species are millet, sorghum, maize, groundnuts, cowpeas and yams. Livestock include caprine, sheep and poultries.

Photo 1: Spider

Photo 2: Toad

Photo 3: egg of undetermined bird

Photo 4: Guinea fowl eggs

Photo 5: Bird nest

Photo 6: Bird nest

Photo 7: Heron on Oti river

Photo 8: Antelope on Koumongou side

Photo 9: Antelope footprint

Photo 10: Monkey feces

CHAPTER 2 - CHANGES IN LAND USES AND LAND COVER OF THE MAIN PROTECTED AREAS IN NORTHERN TOGO

2.1 INTRODUCTION

The current reduction and degradation of vegetation cover in sub-Saharan Africa, particularly in its Sudanian zone, have become a major concern for scientists, decision-makers and local stakeholders. The reduction of vegetation cover appears to be related to climate variability (Oba *et al*., 2001), but also to the social and economic changes and policies for rural systems experienced across the African continent in recent decades.

Wooded vegetation zones, around settlements in Africa, especially in the western part, used to be protected by traditional management systems, organized around local divinities that were associated with the woodland (Kouami and Nestor, 2006). Formal boundaries, around such wooded areas in Togo, were put in place during and after colonization (Folega *et al*., 2010; Tchamie, 1994).

In Togo, three important periods with respect to the dynamics and demarcation of protected areas can be highlighted. The first one, which extended up to 1990, was characterized by conservation and protection of plant and animal resources. However, the management system used at this time was semi-military and very repressive for local human populations. The second period, which extended from 1990 to 2000, was marked by illegal and anarchic exploitation of protected resources by human populations bordering the protected areas. This situation resulted from the political, economic and social troubles of 1990. Illegal activities during this period included forestry harvest, poaching, transhumance, slash and burn, and farming. The last period, which began after 2000, was characterized by the limitation of illegal practices associated with the project of consensual rehabilitation of protected areas (UICN/PACO, 2008). The project re-demarked existing protected areas to conserve and protect the areas that had been least disturbed during the previous decade (1990–2000). The most disturbed areas were handed over to the populations bordering the areas (Folega *et al.*, 2011).

Land use/cover data are a valuable source of information for assessment of the natural resources in a country and as a basis for environmental planning (Attanda *et al.*, 2006; Wang *et al.*, 2002). They provide a better understanding of landscape dynamics and thus allow better management of their resources. Up-to-date analyses of the land cover dynamics for these redefined, protected areas in Togo are required, particularly given the variety of techniques currently available.

Remotely sensed, moderate resolution data (i.e. Landsat imagery, Spot imagery) are suitable for mapping the status of land cover features (Julien and Catherine, 2008; Baldyga *et al.*, 2007). Land cover and land change maps at moderate scales enable researchers to characterize spatial distribution patterns of land cover. The patterns of land cover change that have occurred over time can also be quantified. These maps can serve as baseline data for future land cover, ecology, landscape and area management studies.

This chapter aims to provide preliminary information on land use and land cover essential for vegetation monitoring and management. The objectives were to assess changes in land cover using a vegetation index and to generate a map of current land cover types from recent remotely sensed data. Knowledge of the land cover features of these protected areas in Togo in the context of their re-qualification and re-demarcation are essential for their sustainable management.

2.2 MATERIAL AND METHODS

2.2.1 Study Areas

The survey area covers the protected areas of Barkoissi, Galangashi and Oti-Keran. The study area is mainly localizing in the region des Savanes (North Togo). Both; they were respectively gazette as protected areas in 01/01/1954, 14/09/1954 and 28/09/1950. The area concerned the limit of the years of their classification (Sournia *et al.*, 1998) and covered 2000 ha for Barkoissi, 7500 ha for Galangashi and 163640 ha for Oti-Keran.

These protected areas are situated in eco-floristic zone 1 or northern plain (Ern, 1979) .They are located between 11° and 10° of northern latitude and between 0° and 1° of eastern longitude (Figure 1-1 to 1-11). The main relief of the investigation area is formed by a vast plain, which is dominated by tropical leached ferruginous soils covering a cuirass. The study area is drained by two famous rivers, Oti and Koumongou. The region has a Sudanese tropical climate marked by the alternation of a long dry season (Yema *et al.*, 1981). Heavy rains occur in August (Moussa, 2008) .The rainfall oscillates around 1058.9 mm per year. Temperatures vary between 20°C and 35°C while the annual average is 28.5°C for Mango meteorological station (Moussa, 2008).

The region faced to a strong anthropogenic influence on vegetation. The major human activities around the protected areas are agriculture, firewood collection and initiation of bush fires during the dry season. These activities are well present in the protected areas and denote their level of disturbance. The main crops species are millet, sorghum, groundnuts, maize, cowpeas, and yams. Livestock include caprine, sheep, and poultries. The zone is also face to the transhumance which implied it availability to produce more bovine. On national plan the region is the first provider in term animal protein.

The principal ethnic groups living in and around the study area include the following: Ngamgam, Tchokossi, Tamberma, Lamba, Moba, Gnande, Mossi, and Fulani.

2.2.2 Remote sensing data ,ancillary data and ground truth

The remotely sensed data used were Landsat images. These were downloaded from the website of the Global Land Cover Facility.

(http://www.glcf.umd.edu/data/;http://glcfapp.glcf.umd.edu:8080/esdi/index.jsp)

The remotely sensed data covered three periods and consisted of (Table 2-1):

- Thematic Mapper (TM) of 30/10/1987_p193/r052
- Enhanced Thematic Mapper plus (ETM+) of 04/12/2000_p193/r053
- Enhanced Thematic Mapper plus (ETM+) of 06/11/2007_p193/r053

Three criteria guided the choice of remotely sensed images: the coverage, the spatial resolution and the availability. Landsat images were preferred to high-resolution images with reduced scene size such as IKONOS and Quickbird. Landsat images with a spatial resolution of 30×30 m were suitable to determine land cover type, and one scene (185×185 km) covered the whole study area. The high cost of Spot scenes and their coverage also motivated the choice of Landsat images, which are freely downloadable.

Table 2-1: Table showing the proprieties of remote sensing data

Data type	Acquisition date	Paths/Rows	Spatial resolution	Projection	Producer
TM	30/10/1987	193/052	30 m	UTM/WGS 84	USGS
ETM+	04/12/2000	193/053	30 m	UTM/WGS 84	USGS
ETM+	06/11/2007	193/053	30 m	UTM/WGS 84	USGS

USGS: United State Geological Survey

Most Landsat 7 images present some problems since the sensor started malfunctioning in May

2003, resulting in images that are striped. For the Landsat 7 scene (06/11/2007_p193/r053) used in this study, stripes were located at the edge of the image but did not affect the study areas, for which data were extracted with a mask using Arcgis 9.2.

Ancillary data used to recognize the patterns and features of the remotely sensed data which were mainly composed of ground reference data obtained from land surveys carried out with a handheld GPS (Garmin, GPSMAP® 60CS), Google earth online resources, a general map of Togo (ING/DCNC,1991) and a vegetation map of Togo (Afidegnon *et al*., 2003).

Ground-truthing from field data provided training data for the classified image and testing data for accuracy assessment of the classification output. The field work took place over two periods, first in the rainy season (August 2009) and second in the dry season (March 2011). It also provided *in situ* information on the dynamics in the area and the main disturbances leading to land cover changes. Homogeneous areas on satellite images and in the field were selected. Within these areas, samples (900 m^2) based on the Braun-Blanquet (Westhoff and van der Maarel, 1978) phytosociology concept were used to record information on land cover features such as type of vegetation and plant species, environmental attributes and anthropogenic disturbances.

The 160 sample sites used for this phytosociological investigation were used to assess the accuracy of vegetation type classification. These GPS (Garmin, GPSMAP® 60CS) records were set according to the Universal Transverse Mercator with a WGS84 datum coordinate system.

2.2.3 Land covers types definition

Land cover definitions were based on the previous vegetation classes defined by Afidegnon *et al.* (2003). The following land cover types were used: riparian forest (RF), flooded vegetation (FV), wooded savanna and dry forest (WS/DF), mosaic savanna (MS), fallows and parkland (FP), cropland and parkland (CP) and water (W).

2.2.4 Data analysis and interpretation

2.2.4.1 RGB-NDVI analysis of three Landsat image

The RGB-NDVI method (Sader and Winne, 1992) was used for change detection, as this method has been found to be more accurate and efficient for analyses of Landsat multi-temporal TM imagery than principal component analysis and images differencing (Hayes and Sader, 2001; Wilson and Sader, 2002). Several steps were necessary for this method.
After data acquisition, the bands of each scene were stacked. The three Landsat raw scenes were subjected to geometric calibration verification to georeference the images. A haze reduction algorithm, from Erdas imagine 9.2, was applied to the three scenes (TM_1987, ETM+_2000 and ETM+_2007) to reduce the effect of atmospheric scattering on the data. Haze correction algorithms are recommended when calculating band ratios or when comparing data from different dates (Chavez and MacKinnon, 1994), (Chavez, 1996) and (Andy and Dhari, 1996).
The normalized difference vegetation index (NDVI) (Rouse *et al.*, 1973; Tucker, 1979) was then calculated for each image using the following equation:

$$NDVI = \frac{NIR - R}{NIR + R}$$

(*NIR*: near-infrared; *R*: red)

Generally, NDVI separates green vegetation from other surfaces because the chlorophyll of green vegetation absorbs red light for photosynthesis while it reflects the near-infrared wavelengths owing to scattering caused by internal leaf structure (Tucker, 1979). NDVI values are represented as a ratio ranging in value from -1 to 1. Extreme negative values represent W; values close to zero refer to barren areas of rock, sand, or snow while low and high positive values indicate leaf biomass, such as grassland, shrubland or temperate and tropical rainforest (Sellers, 1985; Wilson and Sader, 2002).

The three NDVI images obtained (NDVI_87, NDVI_00 and NDVI_07) were stacked to get a new image of the three layers. This new image was formed from a red, a green and a blue layer, which corresponded to the NDVI_87, NDVI_00 and NDVI_07 images, respectively.

Among the several different unsupervised classification algorithms commonly used in remote sensing, the ISODATA (*Iterative Self-Organizing Data Analysis Technique*) clustering algorithm was chosen for this study because of its additional refinements in terms of splitting and merging clusters (Jensen, 2005). The NDVI image obtained by stacking the layers for different years (RGB_NDVI_870107) was subjected to unsupervised classification using the ISODATA algorithm (Lillesand *et al*., 2008; Tou and Gonzalez, 1974).

Finally, the image was post-classified. The standard (Ola, 2008) post-classification process includes class recoding, filtering, class identification and class area computation.

2.2.4.2 Supervised classification of 2007 ETM+ using Maximum Likelihood Classification technique

A systematic method was used for supervised classification. First, unsupervised classification was applied (ISO-DATA Algorithm) to the ETM+ 2007 image. The classification provided a synoptic view of the spectral signatures, which helped to define the types and extent of ground cover prior to field work (Folega *et al*., 2011).

One hundred ground check points were then chosen from the image according to the 10 land cover classes defined by the previous classification. After field surveys of the ground check points during the rainy season (August 2009) and dry season (March 2011), seven vegetation classes (RF, FV, WS/DF, MS, FW, CP and W, see above) were defined and used as training sites.

Subsequent to this, supervised classification was applied to the image based upon the training sites representing the seven vegetation classes. To increase the accuracy of the classification, a maximum likelihood classification technique was applied to the ETM+2007 image. The maximum likelihood classification tool considers both the variances and covariances of the class signatures when assigning each cell to one of the classes represented in the signature file. The algorithm used by the maximum likelihood classification combines cell assignments to classes in multidimensional space and Bayes' theorem (1763) of decision-making.

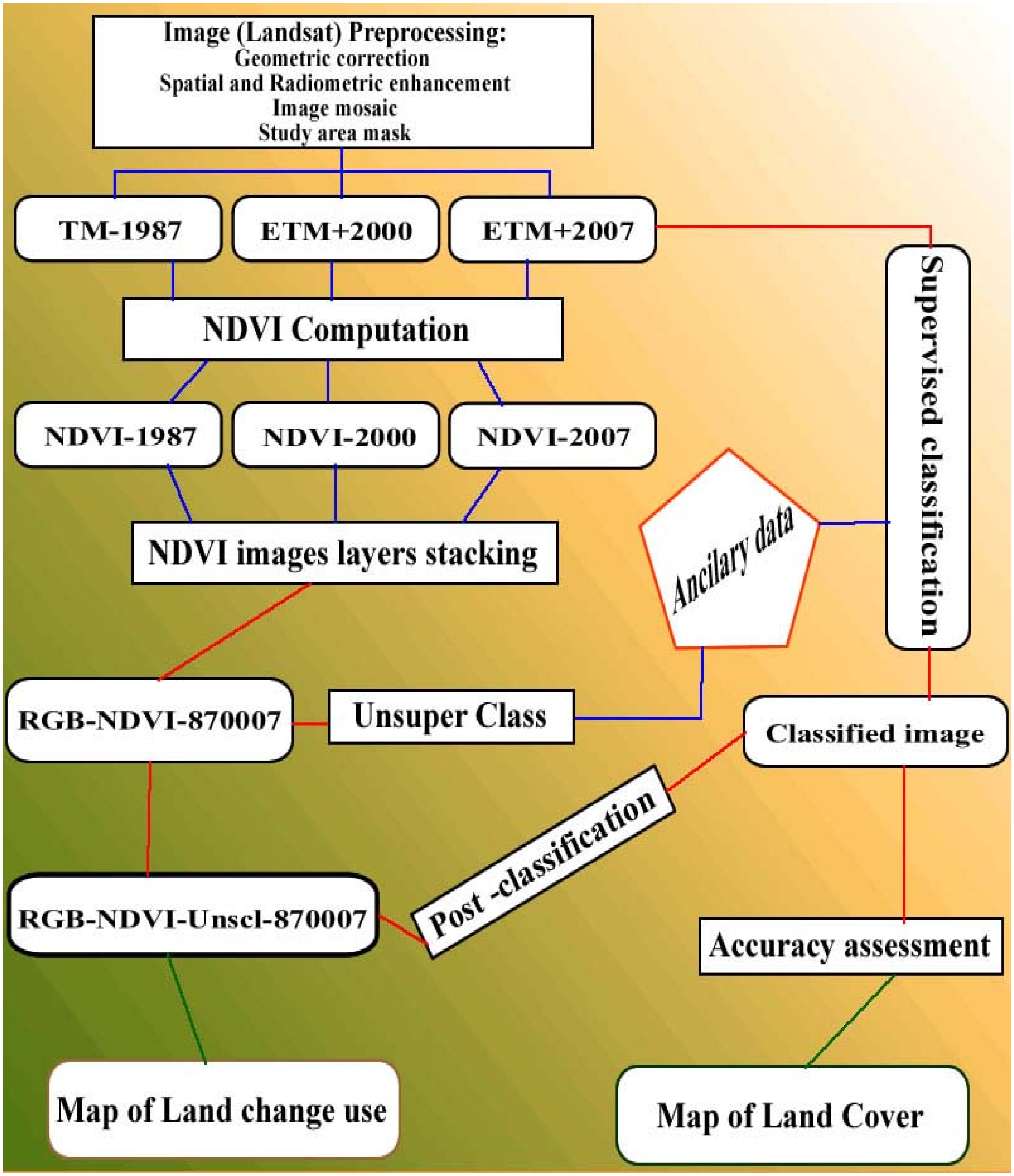
Accuracy assessment was performed on the 2007 land cover maps. The number of reference pixels in this process is an important factor, determining accuracy. In total 160 reference pixels were selected for the land cover maps. The overall accuracy and Kappa analysis were used to determine classification accuracy based on error matrix analysis (Congalton and Green, 1999). The overall accuracy was calculated by summing the number of pixels classified correctly and dividing them by the total number of pixels. Kappa analysis is a discrete multivariate technique used in accuracy assessment (Foody, 2002; Ye and Xu, 2008; Sun *et al.*, 2009). The Kappa coefficient of agreement (K_{hat}) is a measure of accuracy between the classified image and the reference data (Congalton, 1991). It is computed using the following equation:

$$K_{hat} = \frac{N^2 \sum_{i=1}^{k} x_{ii} - \sum_{i=1}^{k}(x_{i+} \times x_{+i})}{N^2 - \sum_{i=1}^{k}(x_{i+} \times x_{+i})}$$

Where *k* is the number of rows in the matrix, *xii* is the number of observations in row i and column i, *xi+* and *x+i* are the marginal totals for row i and column *i*, respectively, and *N* is the total number of pixels.

K_{hat} values ≥0.81 represent almost perfect accuracy between the classification map and the reference information. K_{hat} values between 0.80 and 0.61 represent substantial agreement. K_{hat} values between 0.60 and 0.41 represent moderate agreement. Values between 0.40 and 0.21 represent fair agreement. K_{hat} values between 0.20 and 0.01 represent slight agreement, while values ≤ 0.01 represent less than chance agreement (Anthony *et al*., 2005).

2.2.4.3 Experience scheme



2.2.4.4 Photo showing the main land cover type

- ***Land covers aspect in dry season (March 2011)***

11-Riparian forest

12- Water

13-Wooded savanna and Dry forest

14-Mosaic savanna and fallows

15- Croplands and Parkland

16-Flooded vegetation

- ***Land covers aspect in rain season (August 2009)***

17-Riparian forest

18- Water

19-Wooded savanna and Dry forest

20-Mosaic savanna and fallows

21- Croplands and Parkland

22- Flooded vegetation

2.3 RESULTS

2.3.1 Land Cover and Land Use change dynamic: the analysis of NDVI composition Map

The results for Land Cover and Land Use dynamics of the three protected areas are clearly shown in Table 2-2 and 2-3; and Figure 2-1. The different colors displayed in Figure 2-1 visually represent the level of change in NDVI values, while Table 2-2 and 2-3 shows the changes in NDVI values, in terms of the nine colors from which the RGB_NDVI image is composed, and in vegetation cover over twenty years.

Table 2-2: Interpretation of additive color resulted of the RGB-NDVI composition map

Images	Layer color	Change of NDVI values (''H'' and ''L'' indicate relatively high and low mean)								
NDVI_1987	Red	H	H	L	H	L	L	H	L	L
NDVI_2000	Green	L	H	H	L	L	H	H	L	L
NDVI_2007	Blue	L	L	L	H	H	H	H	L	L
Additive color		Red	Yellow	Green	Magenta	Blue	Cyan	White	Dark-gray	Black

Table 2-3: Analysis of the vegetation change base on additive color after post-classification

Class color	Class dynamic over the time	Class area (ha)	Class area (%)
Red	Vegetation lost (87-00)	30220.14	15.02
Cyan	Vegetation: lost before 87 and regeneration between 87-07	25237.19	12.54
Yellow	Vegetation: lost between 00-07	11659.55	5.79
Blue	Vegetation: lost before 87 and regeneration between 00-07	33514.79	16.66
Magenta	Vegetation: lost between 87-00 ,regrowth between 00-07	40924.87	20.34
Green	Vegetation: lost before 87, regrowth between 87-00 and lost between 00-07	29992.73	14.91
Black	No change :Barren areas, urban area or water	8604.57	4.27
Dark gray	No change :Stable vegetation (Low biomass)	11947.25	5.94
White	No change :Stable vegetation (High biomass)	9026.45	4.48
Total		201127.56	100

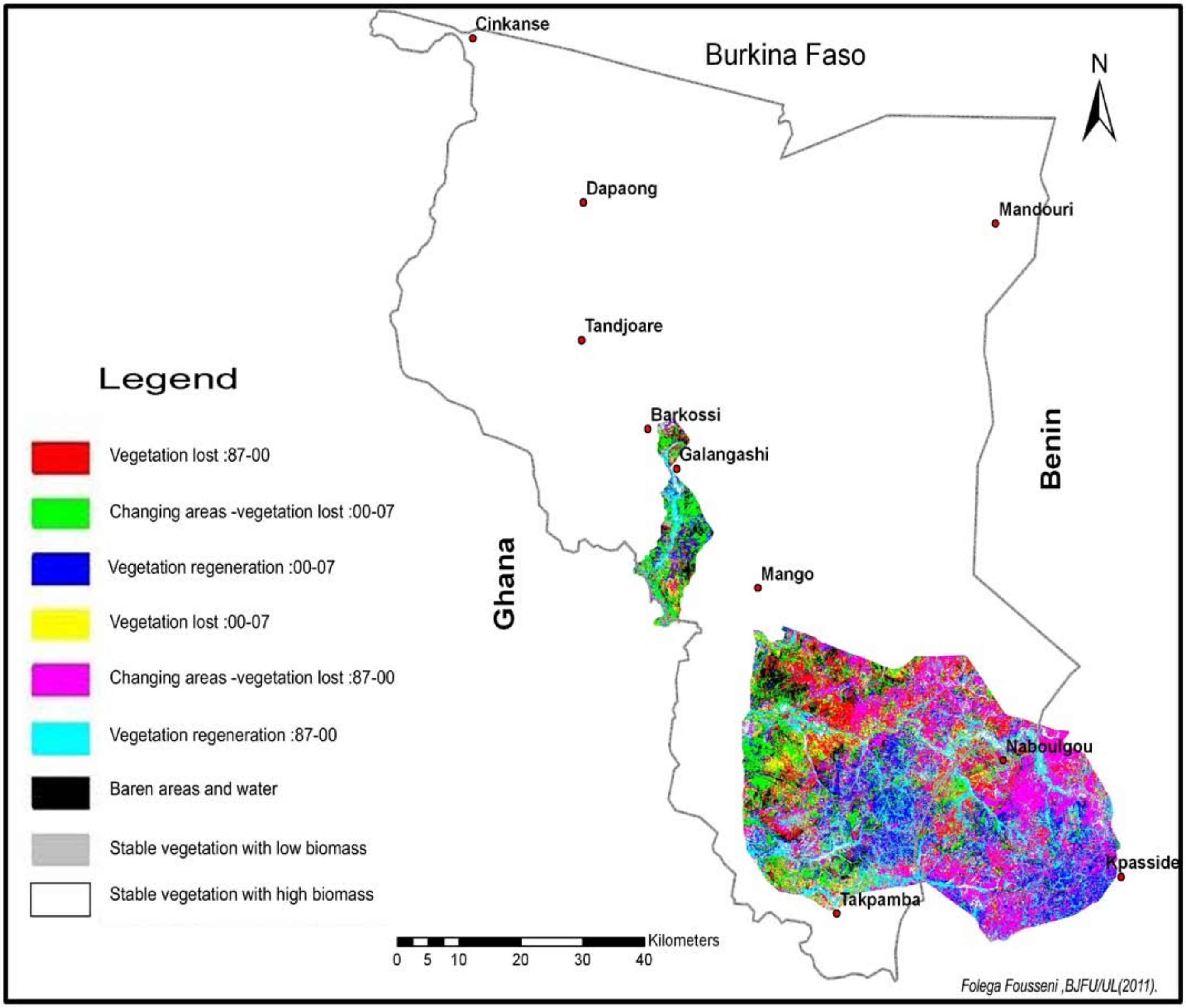


Figure 2-1: RGB-NDVI classified map showing the dynamic in Land Cover change

2.3.2 Major Land Cover types map analysis

Based on the digital image processing and visual interpretation of the imagery, seven classes of land cover were identified from differences in spectral wavelength.

These seven land cover type covered 194903.6625 ha (Table 2-5). Analysis and image classification accuracy are shown in Table 2-4. This shows the level of precision for each class and the main areas of confusion. The overall accuracy (72.51%) and Kappa statistic index (0.67) computed from the contingency matrix were significant. The Kappa statistic was calculated using the results of the land cover classification with the seven land cover classes shown in the confusion table (Table 2-4). The distribution of the seven class of land cover is shown through the Figure 2-2.

Table 2-4: Confusion Matrix and Kappa Index

	CP	FP	MS	WS/DF	RF	FV	W	Total	Producer's Accuracy (%)	User's Accuracy (%)
CP	**14**	4			1	1		20	73.68	70
FP		**13**	4					17	76.47	76.47
MS	2		**18**	2	2	1		25	78.26	72
WS/DF			1	**11**	7			19	61.11	57.89
RF	3			5	**34**			42	68	80.95
FV					1	**14**		15	66.66	93.33
W					5	5	**12**	22	100	54.45
Total	19	17	23	18	50	21	12		**160**	
Overall Accuracy									**72.51%**	
Overall Kappa statistics									**0.67**	

NB: CP: Cropland and Parkland; FP: Fallows and Parkland; MS: Mosaic Savanna; WS/DF: Wooded Savanna and Dry Forest; RF: Riparian Forest; FV: Flooded Vegetation and W: Water.

Table 2-5: Summary of the seven thematic classes

Class names	Color	Areas (ha)	(%)
Flooded Savanna		16837.83	8.63
Croplands and Parklands		11620.19	5.96
Mosaic Savanna		57688.58	29.59
Fallows and Parklands		26410.70	13.55
Riparian Forest		32611.11	16.73
Wooded Savanna and Dry Forest		44825.62	22.99
Water		4909.61	2.51
Total		194903.66	100

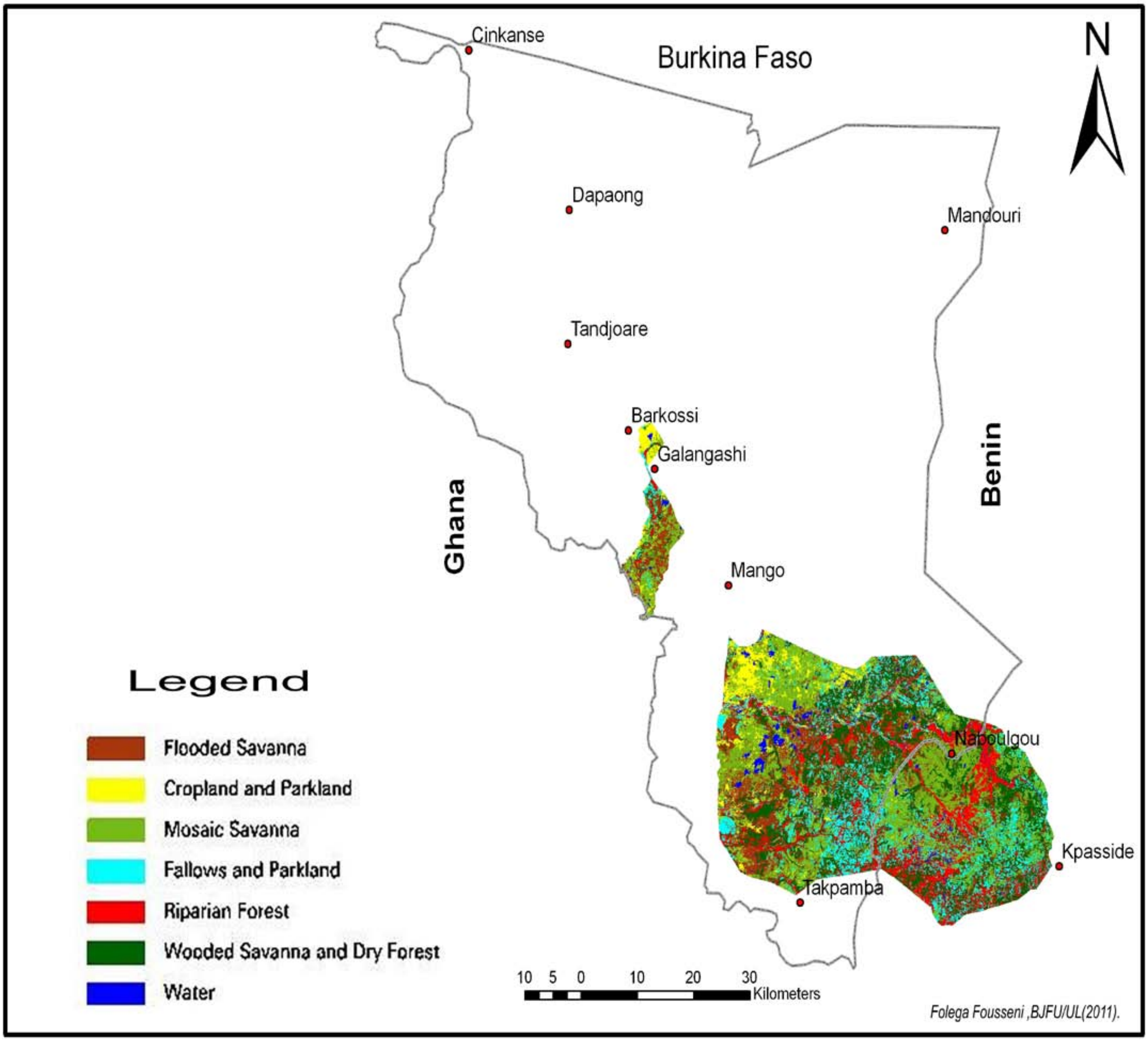


Figure 2-2: Land cover map from 2007 ETM+ image

The main areas of confusion encountered during this classification process for the ETM+_2007 image related to the spatial configuration of mixed croplands, parklands, fallows and the different stages of secondary succession of savanna.

2.4 DISCUSSION

2.4.1 Change in Land Use of the three protected areas

Fig. 2 clearly shows and quantifies major decreases or increases in green biomass associated with forest harvest or regrowth. Red and yellow areas represent a decrease in NDVI values (see also Table 1). These colors indicate vegetation loss, usually due to the harvest of plant resources. Vegetation loss between 1987 and 2000 was estimated to be 30220.1403 ha, while between 2000 and 2007 it was 11659.5526 ha (Table 1). Vegetation loss between 1987 and 2000 was probably the result of social, economic and political disorder from 1990. From observations made in the field, this vegetation loss has continued after 2000 until the present day, and this may be due to the lack of or insufficient monitoring and protection in these areas.

Zones with minor or no change in vegetation (Fig. 2, Table 1) are represented by black, gray and white colors on the map. Here the dynamics in vegetation are stable. However, negative NDVI values in black zones indicate Water, barren soil and villages. In gray and white areas, there is biomass. In gray areas, biomass is low, but in white areas it is very high. These few white areas correspond in particular to Riparian Forest and to Wooded Savanna. Clearing of Riparian Forest and neighboring Wooded Savanna such as dry forest is clearly seen in the western part of the Oti-Keran protected area along the Koumongou River. Barren land and flooded areas (characterized by black) increase in this part of the reserve. From Table 1, the small extent of Riparian Forest and undisturbed vegetation is apparent.

Cyan, blue, green and magenta areas represent zones showing dynamic fluctuation (Fig. 2). Interpretation of areas of these colors allows the analysis of vegetation clearing, no-change, and regrowth classes in a time series (Hayes & Sader, 2002; Sader *et al.*, 2003). Based on the semi-military management of the protected areas in Togo (Folega *et al*., 2011b) before 1990 and the loss of vegetation apparent before that date, it is likely that much more vegetation harvesting occurred after 1990.

Among the anthropogenic disturbances observed in the field in this study, farming was the most common, followed by tree cutting and burning (Photos 23 and 24). The high pressure of these unceasing and increasing disturbances between 1990 and 2000, corroborate well with the high levels of vegetation loss during the same period.

Photo 23: (A) Farming and bark harvest in Barkoissi Protected Area, (B) Cutting and carbonization in Oti-Keran PA, (C) Agriculture fire and cutting in Oti-Keran PA

Photo 24: (A) Burning, (B) Fire wood from cutting in Galangashi PA and (C) Fire wood stock inside Galangashi PA

The Barkoissi protected area illustrates this loss of vegetation well. Based on the results of ethno-botanical research (Pereki *et al*., 2010), the people on the borders of the protected area invaded the area over a period of nineteen years for farming and harvesting. In this traditional system of land exploitation (Folega *et al*., 2011b; Kperkouma *et al*., 2005), local residents deliberately preserved perennial, multipurpose, woody plants in association with their crops and breeding in a dispersed spatial arrangement. Today, this reserve appears more like an enormous range of parkland than a protected forest area.

However, estimation of loss and regrowth of vegetation is difficult in these fluctuating areas. Plant species regeneration in these protected areas has been higher than vegetation loss since the consensual rehabilitation of protected areas project was established (UICN/PACO, 2008). The Galangashi protected area provides better information on regrowth. Field studies here found that old fallow areas showed a progressive succession into shrubby and tree savanna.

The RGB-NDVI classification provided distinct change/no-change cluster classes and was a simple, fast and effective change detection technique. It should be a useful accessory for ecological monitoring programs.

2.4.2 Land covers types in the three protected area

Based on the digital image processing and visual interpretation of the imagery, seven classes of land cover were identified from differences in spectral wavelength. These seven land cover type covered 194903.66 ha, which was greater than the area mentioned in the literature (UICN/PACO, 2008).

A Kappa value of 0.67 represents a probable 67 percent better accuracy than if the classification resulted from a random unsupervised classification, according to the agreement criteria for the Kappa statistic defined by Antony *et al*. (2005). Thus, the classification can be considered as very good or substantial.

The overall accuracy is considered acceptable for this study. This is because in remote sensing projects, pixel classification can be an arbitrary measure dependent on the level of classification used, as well as the spatial resolution of the imagery utilized in the analysis.

However, there was some confusion between the seven classes from the error matrix. The confusion between Cropland and Parkland and, Mosaic Savanna can be explained by the composite nature of some croplands and parklands previously in a fallow stage. Confusion between Cropland and Parkland and, Fallows and Parkland was highly related to the agroforestry nature of these two classes; agroforestry practices are very recurrent in this region. The class for Woodes Savanna/Dry Forest was close to that for Riparian Forest, but in the field Riparian Forest growing along the meandering and temporary branches of the main rivers were easily confused with dry forests of *Anogeissus leiocarpus* (DC) Guill. & Perril and *Cissus populnea* Guill. & Perril. The heterogeneity of croplands and parklands were also responsible for the few confusions observed between this thematic class and Riparian Forest or Flooded Vegetation. Confusion between Flooded Vegetation and Water can be linked to seasonality, since an area may be a pond in the rainy season (field observation in 2009), but only just wet during the dry season. Overall, most confusion occurred owing to similarities in plant cover patterns due to the logging of large trees by harvesters.

Previous research in these areas, investigating biodiversity and generating plant community inventories (Folega *et al*., 2010; Dimobe, 2009) has demonstrated the impact of anthropogenic disturbances on landscape features (Pan and Liu, 2008). The consequences of these disturbances are clearly visible in the Barkoissi protected area where Cropland and Parkland is the most important thematic class (Fig. 3). The removal and degradation of plant resources are also notably visible in the north, west and south of the Oti-Keran protected area. However, these disturbances are also present in the Galangashi protected area, but this reserve is the best conserved and has suffered less from human disturbance.

2.5 CONCLUSIONS

A simple, fast and effective land cover change detection technique was employed using RGB_NDVI classification on remote sensed data. The accuracy of the supervised classification makes this technique useful for ecological monitoring. Estimates of changes in land cover over time at the scale of management practices could be useful for policy-makers with respect to conservation programs. However, this method could not explain land cover dynamics fully in heterogeneous areas. Thus, further research is needed in this area. Within these drought areas of Togo, quantification of biomass and water stress are still required.

CHAPTER 3 - DRY NORTHERN TOGO PROTECTED AREAS VEGETATIONS:

Ecological and Numerical Analysis of Plants Resources

3.1 INTRODUCTION

By ratifying all the agreements of the international conferences sponsored by the United Nations (UN), in particular that of Rio in 1992. Togo recognized the sustainable management of protected areas like an economic, social and eco-environmental stake. The protected areas through diversity which they contained, especially plant diversity provide partially the bases of our needs.

The sustainable management of the protected areas requires by a systematic inventory and knowledge of the floristic and faunistic resources available in these ecosystems while taking account of the orientations to assign it.

The flora remains a major component in the landscape of an area (Natta, 2003) and is the result of a long process of natural selection in relation with climatic, edaphic and anthropogenic factors (Braun-Blanquet, 1972). It was studied via phytosociological methods as competing as complementary (François, 2000; Gimaret-Carpentier, 1999) for recognizing and defining plant communities.

In Africa, particularly in its Western part the physiognomical and phytosociological study of the vegetation (Ouedraogo, 2006; Wala, 2004; Natta, 2003; Sopkon, 1995; Sinsin, 1993; Akpagana, 1989; Guinko, 1984) made it possible to define the sets under regional vegetation with Braun-Blanquet (Westhoff and van der Maarel, 1978) phytosociological approach. These studies of regional level were applied successfully in Togo (Drouma, 2008; Woegan, 2007; Kokou, 1998; Guelly, 1994; Akpagana, 1989; Brunel *et al*., 1984; Ern, 1979; Ake, 1971) within the framework of the typification of its vegetation.

Today sustainable management term of ecosystems became a significant subject in the international political agenda since the last two decade (Gareau, 2004; Maini, 1994); those because of the permanent pressure that the last sanctuary of diversity are subject (deforestation, poaching, and anarchistic exploitation of resources).

Since the classification of protected areas in Togo, especially that of Barkoissi, Galangashi and Oti-Keran, few studies of phytosociological (Kangni, 2000) on their sustainable management were done. This lack of data constitutes a major handicap for conservation approach of the diversity which is associated to these areas.

The principal objective assigned to this research remains a floristic and phytosociological study of the of these protected areas flora, in seen to have synoptic view of vegetation in this area. It aims at establishing the environmental factors which determine the distribution of the flora and at comparing the specific richness, on the one hand between the indices of diversities within the areas of study and, on the other hand, between the various plant communities which will be identified.

3.2 MATERIALS AND METHODS

3.2.1 Study area

The survey area covers the protected areas of Barkoissi, Galangashi and Oti-Keran. The study area is mainly localizing in the region des Savanes (North Togo). Both; they were respectively gazette as protected areas in 01/01/1954, 14/09/1954 and 28/09/1950. The area concerned the limit of the years of their classification (Sournia *et al.*, 1998) and covered 2000 ha for Barkoissi, 7500 ha for Galangashi and 163640 ha for Oti-Keran.

These protected areas are situated in eco-floristic zone 1 or northern plain (Ern, 1979) .They are located between 11° and 10° of northern latitude and between 0° and 1° of eastern longitude (Figure 1-1 to 1-11). The main relief of the investigation area is formed by a vast plain, which is dominated by tropical leached ferruginous soils covering a cuirass. The study area is drained by two famous rivers, Oti and Koumongou. The region has a Sudanese tropical climate marked by the alternation of a long dry season (Yema *et al.*, 1981). Heavy rains occur in August (Moussa, 2008) .The rainfall oscillates around 1058.9 mm per year. Temperatures vary between 20°C and 35°C while the annual average is 28.5°C for Mango meteorological station (Moussa, 2008).

The region faced to a strong anthropogenic influence on vegetation. The major human activities around the protected areas are agriculture, firewood collection and initiation of bush fires during the dry season. These activities are well present in the protected areas and denote their level of disturbance. The main crops species are millet, sorghum, groundnuts, maize, cowpeas, and yams. Livestock include caprine, sheep, and poultries. The zone is also face to the transhumance which implied it availability to produce more bovine. On national plan the region is the first provider in term animal protein.

The principal ethnic groups living in and around the study area include the following: Ngamgam, Tchokossi, Tamberma, Lamba, Moba, Gnande, Mossi, and Fulani.

3.2.2 Data collection

The phytosociological data collection was made from north to south starting with Barkoissi reserve to Oti-Keran via Galangashi. Both the transect and plot sampling techniques were employed in data collection.

3.2.3 Choice of the transects

Before identifying the location and the orientation of transect, Landsat ETM+ image (Enhanced Thematic Mapper Plus) of the three protected areas were subjected to an unsupervised classification.

This classification was achieved by using the algorithm ISODATA (*Interactive Self-Organizing Data Analysis Technology Algorithm*) (Tou and Gonzalez, 1974). The classification provided a synoptic view of various spectral signatures which helped in deducing the aspect of the land cover and occupation. Transects were oriented in such a way that they can cross and recut all spectral signatures defined by the previous classification. In total, 14 transects were defined on the images, 5 for Oti-Keran and, 9 for the Barkoissi-Galangashi complex.

3.2.4 Phytosociological samples

The technique of sampling adopted is based on the Braun-Blanquet (Westhoff and van der Maarel, 1978) phytosociological concepts .The floristic plots of 30m×30 spaced at least by 100m are placed along the transects previously defined, but the linear structure of plants formations along the rivers led us to place 50m×10 quadrats (Natta, 2003) to take into account more diversity. The choice of 900m ^{2} and 500m ^{2} as minimal areas is marked by the fact that they were used successfully in Togo (Drouma, 2008; Woegan, 2007; Wala, 2004; Kokou, 1998; Guelly, 1994) and in subregion (Ouoba, 2006; Natta, 2003; Masens, 1997; Sinsin, 1993); during various works relating to Sudano- Guinean tropical areas.

For each sample the species met were recorded and named by using the nomenclature of Hutchinson and Dalziel (1954-1972), then a coefficient of abundance/dominance according to

Braun-Blanquet scale was affected to the species: r = an individual, + = unimportant covering, 1 = less than 5 %, 2 = 5 -25 %, 3 = 25 - 50 %, 4 = 50- 75 %, 5 = more than 75 % (Westhoff and van der Maarel, 1978).

For qualitative ecological characterization; topographic attributes (plateau, slope, versant, valley and bank), edaphic variables (structure and texture of the soil), and disturbance level (e.g. fire, cutting and pasture) were noted along with the geographic coordinates.

Climatological data (rainfall, humidity, temperature) for any period were obtained from databases of nearest meteorological stations, in particular those of Barkoissi, Mango, and Takpamba.

In total, 170 samples have been installed in the three protected areas, among which 110 were placed in Oti-Keran reserve and 60 samples in the Barkoissi-Galangashi complex reserve.

3.2.5 Data processing and Analyzes

The general list of species composing the floristic procession of the three protected surfaces was drawn up, after the digital processing of the 170 samples.

On the basis of reference documents such as: Kokou (1998), Guinko (1984), Ake Assi (1984), Hutchinson and Dalziel (1954-1972), White (1986) and Aubreville (1950) these species were classified according to their phytogeographical types. The nomenclature retained for this classification is that of the authors above:

AA: Afro–American, AM: Afro-Malgash, AT: Afro-Tropical, G: Guinean, GC: Guineo-Congolian, I: undetermined, Pal: Paleo-Tropical, Pan: Pan-Tropical, PRA: Pluri -Regional in Africa, S: Sudanian, SG: Sudano-Guinean, SZ: Sudano-Zambezian.

Then on Raunchier work of (1934) together with that of Ake Assi (1984) were used to classify the species according to their form and biological type. The Following life forms types were selected:

Ph: Phanerophytes, Ch: Chamephytes, Hc: Hemicryptophytes, G: Geophytes, Th: Therophytes. The lianous forms (Lmph, Lnph, LmPh, LnPh and LGb) were also distinguished. The phanerophytes were distributed as below:

- ❖ MPh: mega-phanerophytes: trees of more than 30 m in height
- ❖ mPh: meso-phanerophytes: trees of 10-30 m in height
- ❖ mph: micro-phanerophytes: trees of 2-10 m in height
- ❖ nph: nano-phanerophytes: trees of 0,4-2 m in height

For each grouping the indices of diversity alpha (α) were calculated to find out some information on species spatial distribution. From the multitude of indices developed, the following were used in this work: specific richness, indices of Shannon (1948), Pielou (1975), (Margalef, 1958 and1968; Margurran, 1988 and 2004; Krebs, 1994). These indices are formulated as follows:

- ❖ Shannon diversity index (H'):

$$H' = -\sum_{i=1}^{s} (Ni / N) \times \log_2 (Ni / N)$$

- ❖ Pielou' S evenness index (E):

$$E = \frac{H'}{H'\max} = -\frac{\sum_{i=1}^{s} (Ni / N) \times \log_2 (Ni / N)}{\log_2 (s)}$$

(Ni: number of samples in which the species I is present, N: total number of samples, S = number of species).

At least, two matrices made of (170 relevés×282 species) corresponding to that of Presence/absence and of abundance/dominance were subjected to 4 analyses. The first analysis was an ordination of the relevés in indirect gradient: the DCA (Detrended Correspondence Analysis) to discriminate the plants groupings and to deduce which environmental factor influenced the distribution of the flora (Hill 1979b; Li *et al.*, 2008). From the 5 groupings identified the grouping three (G3) presents a mosaic character.

So the 90 samples which constitute the grouping three (G3) were subjected to a hierarchical classification (clustering) according to Ward method (1963) on the basis of Jaccard similarity.

After the ordination and the clustering, the species characterizing the groups of samples formed were given with the method of *INDVA*L or Indicator Value (Dufrene and Legendre, 1997). This method was preferred than TWINSPAN (Two Indicator Species Analysis) of Hill (1979a) because the characteristic species can be deduced from a hierarchical classification or not and their indicating values is the product of their fidelity and their abundance compared to other species in their grouping. The last analysis consisted in ordering all the relevés in direct gradient by the means of the CCA (Canonical Correspondence Analysis) to link directly the distribution of the samples to the environmental factors observed during the field work (ter Braak, 1985 and 1986; ter Braak and Smilauer, 1998; Zhang *et al.*, 2008).

To finish this part, the diversity beta (β) which reflects the modification of diversity alpha when we move from one ecosystem to another in a site; or quite simply, the rate of replacement of the species in a habitat in a given area will be calculates for these various groupings. The index of similarity or dissimilarity of Jaccard (1901) is retained and calculated as follows:

$$J = 100 \times \frac{c}{a + b - c}$$

(a = number of species in community A, b = number of species in community B, c = number of species common to both communities)

It will be used to determine the degree of resemblance between the plants communities. The matrix of similarity will also make it possible to build the dendrogram of all plants communities in order to have a synthetic sight of the floristic. A smaller index indicates less similarity in species composition between various habitats (Scientia, 1997; Condit *et al*., 2002; Yang *et al.*, 2008).

The following software were used to analyze the data CAP ® 2.15 (Community Analysis Package), Canoco ® 4.5, SPSS 18.0.

3.3 RESULTS

3.3.1 Floristic Analysis

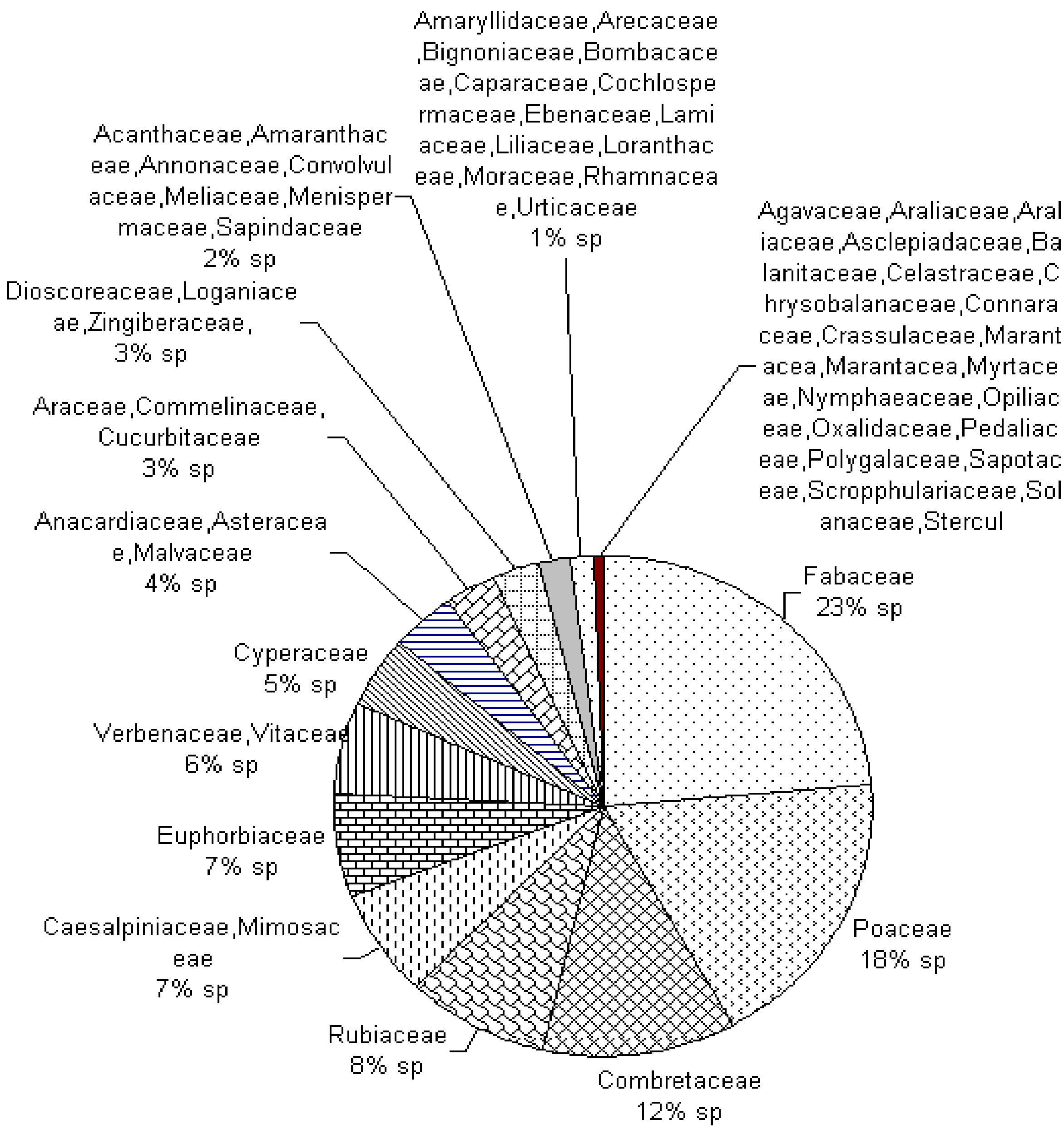


Figure 3-1: Specific spectra of families

From the various processing of floristic samples, 274 plants species were listed during this investigation. This floristic procession is distributed between 247 genera and 63 families. On the taxonomic level 211 species, 201 genera and 50 families belonging to the dicotyledonous class, on the other hand 63 monocotyledonous species, 46 genera and 13 families (Figure 3-2). The floristic composition differs from one protected area to another. The three protected areas have in common 70 species; however that of Galangashi and Oti-Keran have 108 species.

Six families are represented by more than 10 plants species: Fabaceae (36 sp), Poaceae (28 sp), Combretaceae (18 sp), Rubiaceae (14 sp), Caesalpiniaceae (11 sp), Mimosaceae (11 sp) and Euphorbiaceae (10 sp) (Figure 3-1). The third of families comprise one species each.

For all plant species recorded. One is new to Togo flora. This new specie concern *Strelizia reginae* Banks ex Aiton which was introduced in Togo (Folega *et al*., 2011).

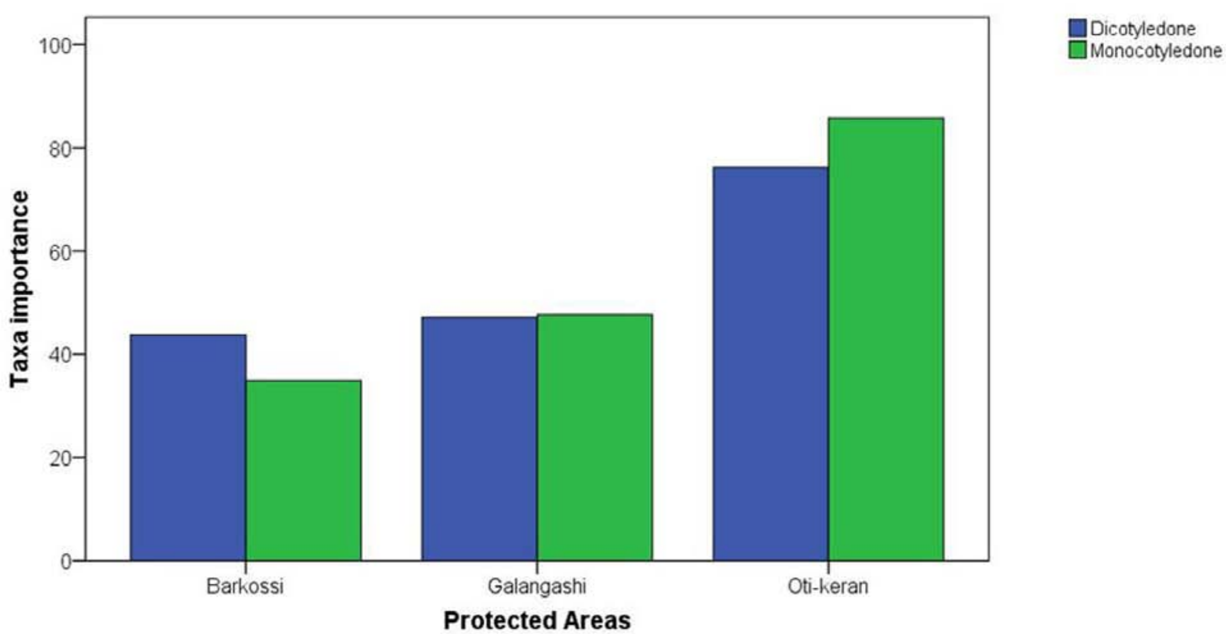


Figure 3-2: Taxon balance in the three protected areas

3.3.2 Frequency and Abundance Analysis

The Figure 3-3 shows the relation that exists between two qualitative variables (relative frequency and relative abundance) of species. *Andropogon tectorum, Combretum glutinosum, Sclerocarya birrea, Anogeisus leiocarpus, Detarium microcarpum* and *Pilliostigma thoningii* are species which are very frequent and very abundant in the landscape at the same time. Particularly for these species whose values of the frequencies and abundances are appreciably equal.

The most frequent species are *Andropogon tectorum, Combretum glutinosum, Terminalia laxiflora, Spermacoce ruelliae, Acacia polyacantha, Sticnos spinosa, Piliostigma thonningii, Anogeissus leiocarpus, Pteleopsis suberosa, Pterocarpus erinaceus, Vitellaria paradoxa* (Figure 3-4).

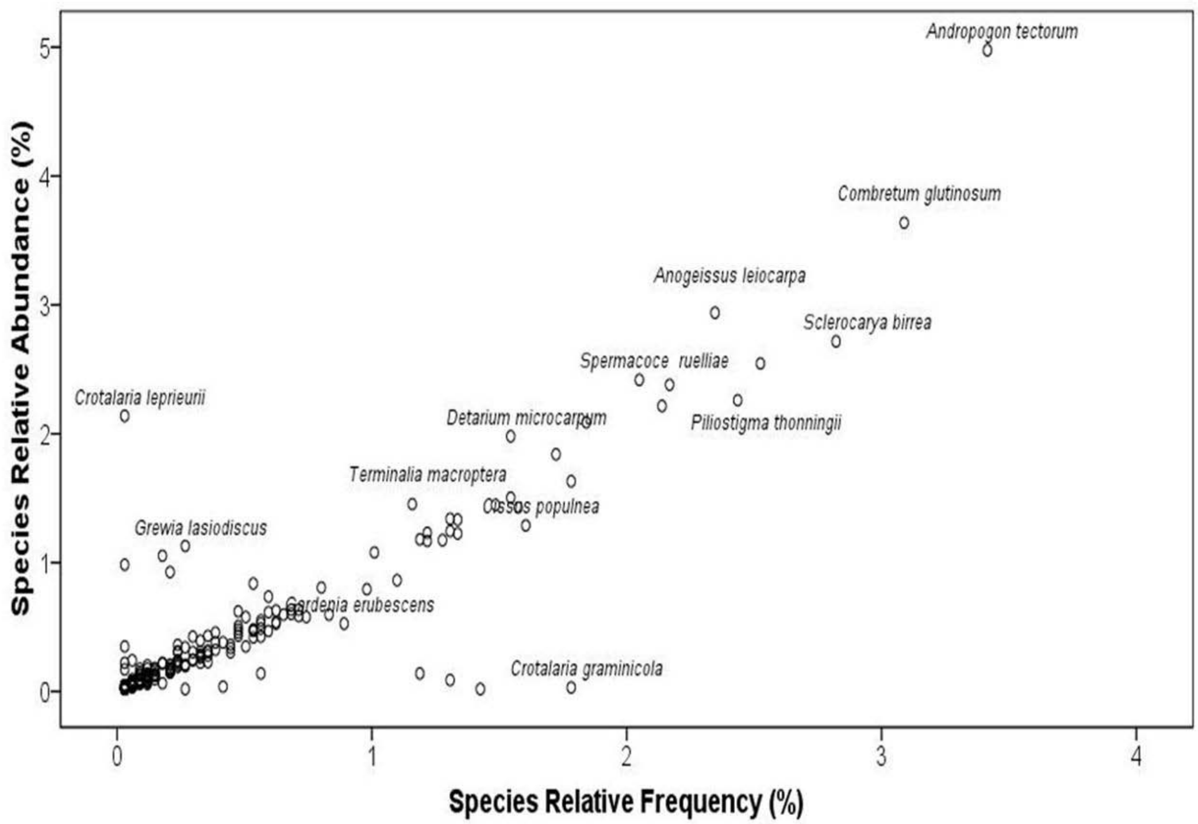


Figure 3-3: Relationship between frequencies and specific abundances

3.3.3 Biological life forms distrubution

In the three protected areas the prevalence of life forms is as follows: micro-phanerophytes (19.85%), nano-phanerophytes (17.275), Therophytes (15.07%).The lianas, Hemicryptophytes and the meso-phanerophytes fairly represented, have respectively 12.50%, 11.39% and 9.92% of total species (Figure 3-5). The hydrophytes and the parasites are underrepresented in this area.

The lianas which determine the degree of closing of vegetation are poorly diversified in the investigation zone. The following lianas forms were noted: meso-phanerophytes lianas (66.66%), nano-phanerophytes lianas (30.30%), and geophytes bulbiferous lianas (3.03%) (Figure 3-6).

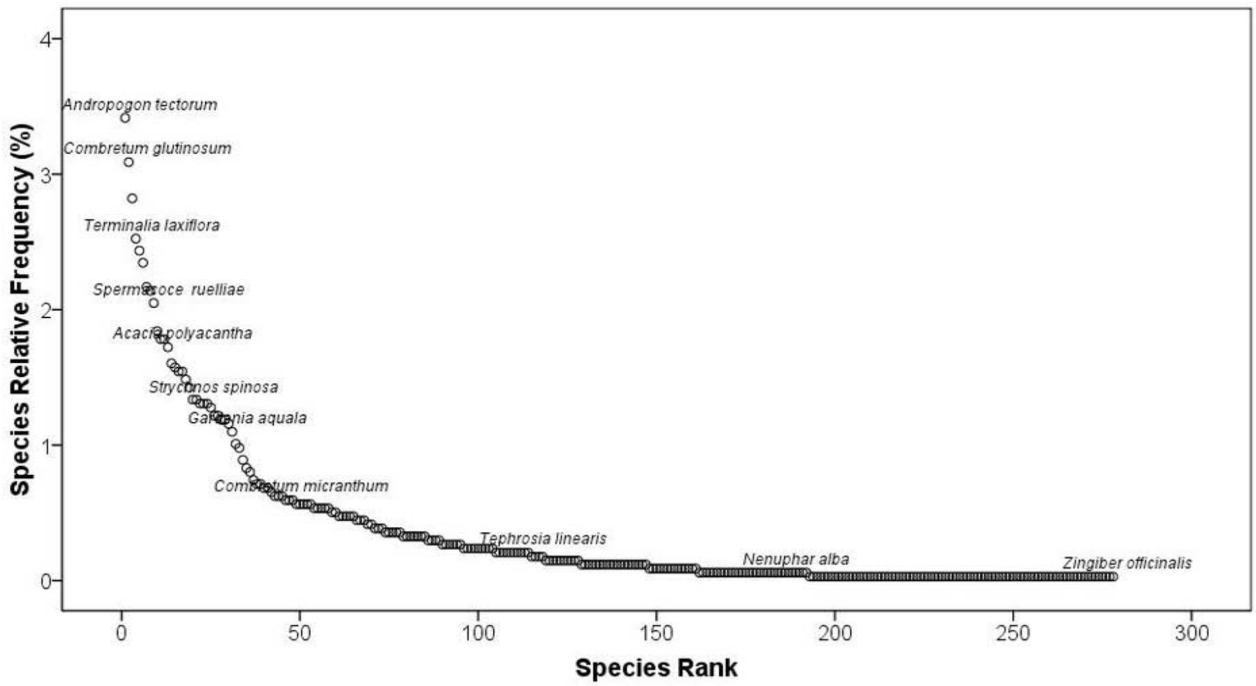


Figure 3-4: Curve rank - species frequency.

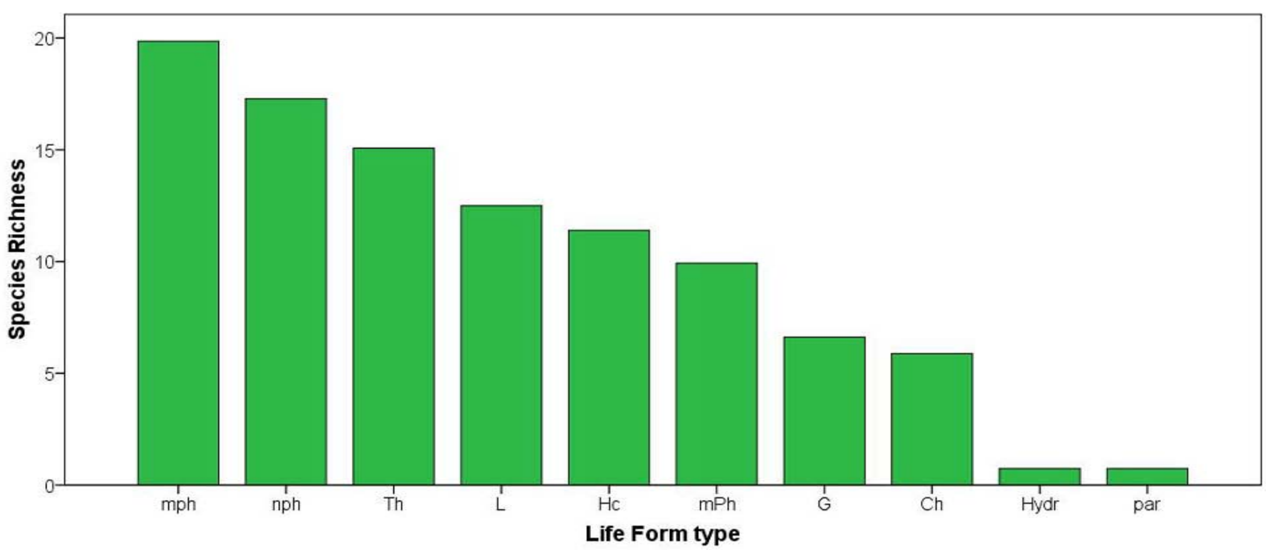


Figure 3-5: Life forms type frequency distribution in the three protected areas (mph: micro-phanerophytes, nph: nano-phanerophytes, Th: Therophytes, L: Lianas, Hc:

Hemicryptophytes, mPh: meso-phanerophytes, G: Geophytes, CH: Chamephytes, par: Parasite and Hydr: Hydrophytes).

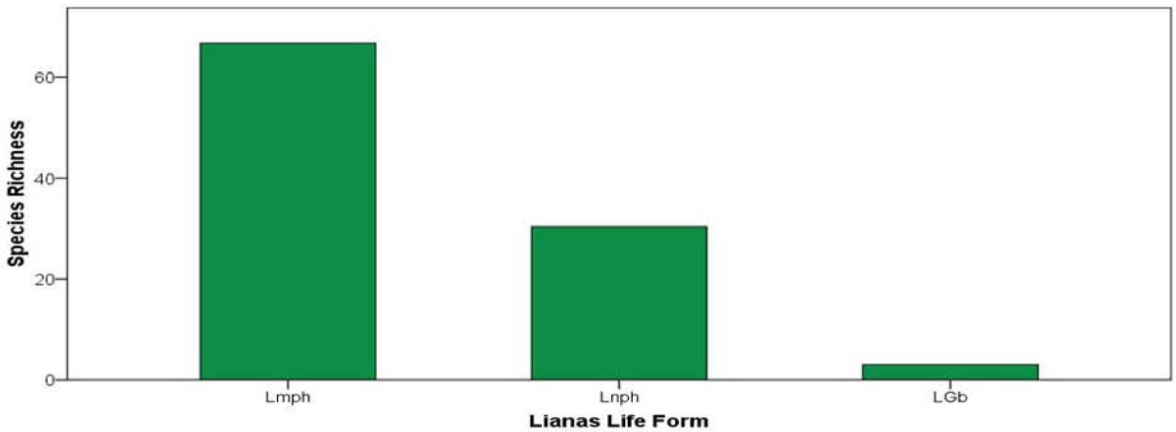


Figure 3-6: Lianas life form types frequencies distribution in the three protected areas (Lmph: meso-phanerophytes lianas, Lnph: nano-phanerophytes, LGb: Geophytes bulb)

3.3.4 Chorogical types distribution

On phytogeographical aspect the most frequent species in this zone are Sudano-zambezians (23.35%) followed by Pan-Tropicals (16.78%), Guineo–Congolians (15.32%) and Sudano-Guineans (11.67%). All the chorological types which have a relationship with the Sudanian climatic zone represented 44.52% of species listed, while those having the bonds with the Guinean climatic areas represent 30.29% of species. The species having a broad geographical distribution are well represented in this area: Pan-Tropical (16.78%). However the Afro-American species and Afro-Malgash are weak represented (Figure 3-7).

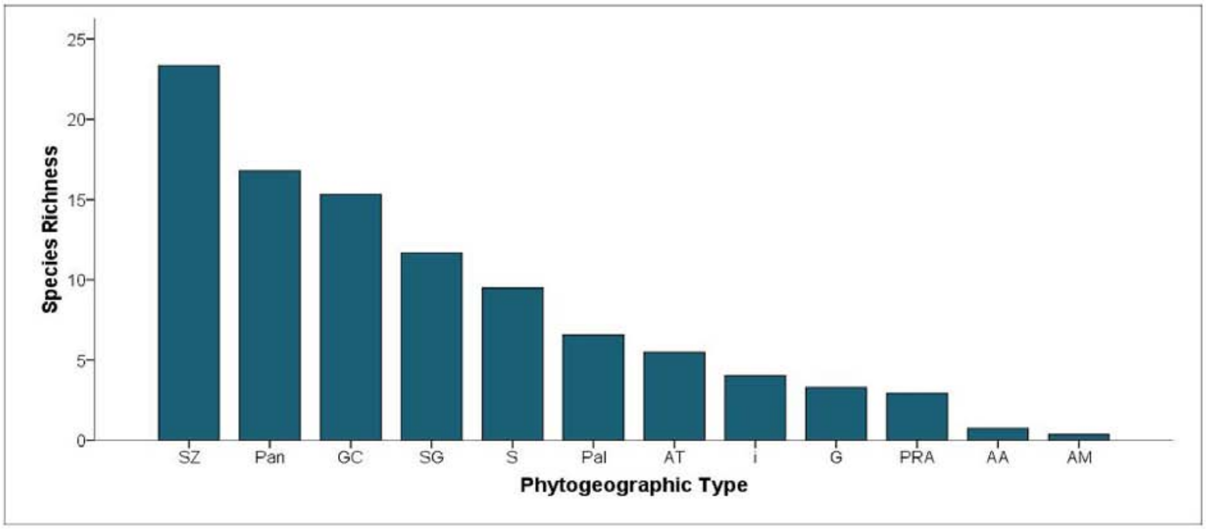


Figure 3-7: Phytogeographic types frequency distribution in the three protected areas.(SZ :Sudano-zambesian, Pan :Pan-Tropical, GC :Guineo-Congolian, SG :Sudano-Guinean, S :Sudanian, Pal :Paleo-Tropcal, AT : Afro-Tropical, i: undefined, G: Guinean, PRA : Pluri Regional in Africa, AA: Afro-American, AM :Afro-Malgash).

3.3.5 Particularity of the three protected areas

3.3.5.1 Barkossi

The processing of Barkoissi reserve samples made it possible to list 114 plants species. These species can be distributed into 91 genera and 43 families. The 114 species are divided into 92 dicotyledonous and 22 monocotyledons. *Terminalia macroptera* (4.75%), *Sclerocarya birrea* (4.29%), *Annona glauca* (4.07%), *Combretum glutinosum* (4.07%), *Crotalaria graminicola* (4.07%), *Detarium microcarpum* (3.39%), *Vitellaria paradoxa* (3.16%), *Andropogon tectorum* (2.94%), *Pteleopsis suberosa* (2.94%) and *Spermacoce ruelliae* (2.94%) represent the most frequent species .The life forms dominating in this protected area are micro-phanerophytes (23.68 %), meso-phanerophytes (15.78%), nano-phanerophytes (15.78%) and Therophytes (14.91 %) (Figure 3-9).The Sudano-zambezians (27.19%), Sudanians (14.91%), Pan-Tropical (14.03%) and Sudano-Guineans (11.40%) dominate the flora of Barkoissi reserve (Figure 3-8).

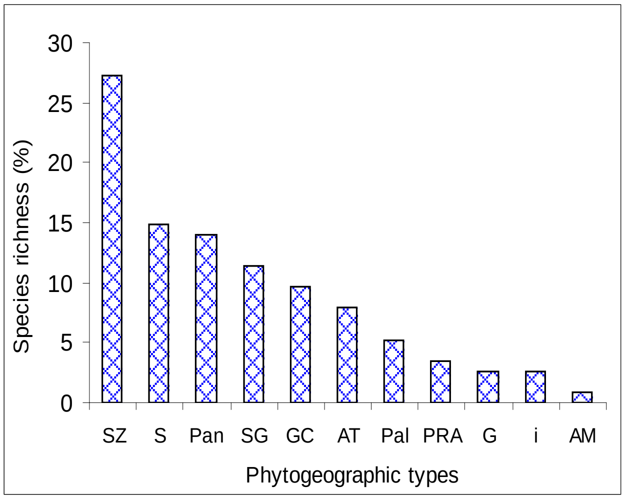


Figure 3-8: Phytogeographic types frequency distribution in Barkoissi protected area

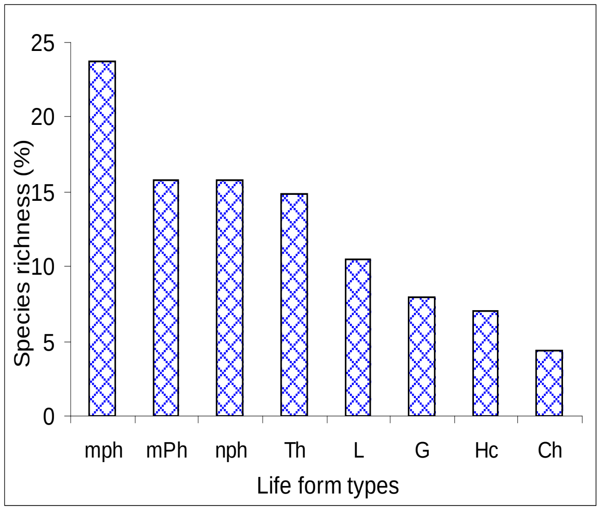


Figure 3-9: Life form types frequency distribution in Barkoissi protected area

3.3.5.2 Galangashi

With regard to Galangashi reserve, 129 species were recorded. All these species are distributed into 99 dicotyledonous, 30 monocotyledons, 43 families and 100 genera. The ten most frequent species are: *Andropogon tectorum* (4.10 %), *Terminalia macroptera* (3.37 %), *Sclerocarya birrea* (3.22 %), *Combretum glutinosum* (2.93 %), *Pteleopsis suberosa* (2.93 %), *Vitellaria paradoxa* (2.93 %), *Anogeissus leiocarpus* (2.78 %), *Spermacoce ruelliae* (2.78 %), *Ampelocissus bombycina (*2.63 %), and *Piliostigma thonningii* (2.49 %).

On phytogeographical level, the Sudano-zambezians species (25.78%), Pan-Tropical (12.50%), Sudano-Guineans (11.71%) and Sudanians (11.71%) are dominant (Figure 3-10). The most life forms met are the micro-phanerophytes (21.09 %), the nano -phanerophytes (16.04%) and the meso-phanerophytes (14.84%) (Figure 3-11).

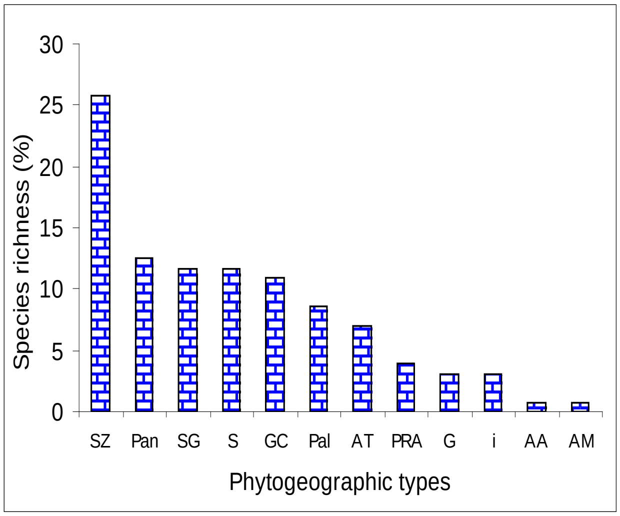


Figure 3-10: Phytogeographic types frequency distribution in Galangashi protected area

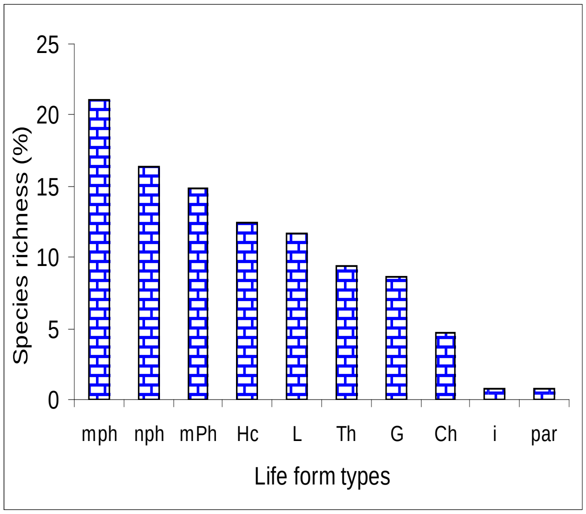


Figure 3-11: Life form types frequency distribution in Galangashi protected area

3.3.5.3 Oti-Keran

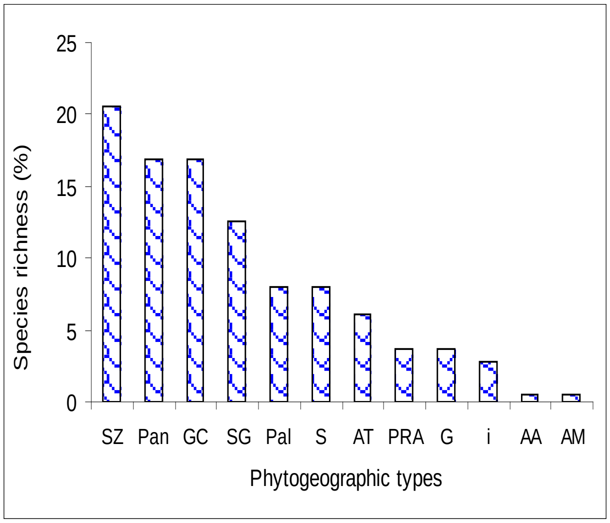


Figure 3.12: Phytogeographic types frequency distribution in Oti-Keran protected area

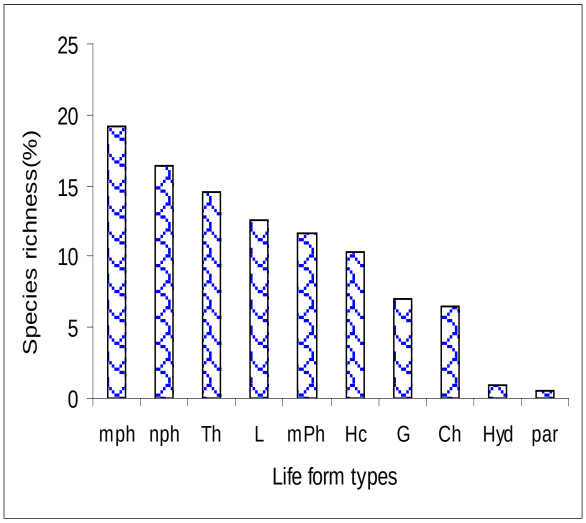


Figure 3.13: Life form types frequency distribution in Oti-Keran protected area

This reserve comprises 214 plants species, or two thirds of the total species. These species are distributed into 160 dicotyledonous and 54 monocotyledous. This flora can be subdivided into 152 genera and 61 families. *Andropogon tectorum* (3.34%), *Combretum glutinosum* (2.98%), *Piliostigma thonningii* (2.75 %), *Pterocarpus erinaceus* (2.70%), *Terminalia laxiflora* (2.66%), *Sclerocarya birrea* (2.43 %), *Anogeissus leiocarpus* (2.38%), *Pteleopsis suberosa* (1.83%), *Cissus populnea*, (1.78 %) and *Nauclea latifolia* (1.78%) are the ten most frequent species.

The species Sudano-zambezians (20.56 %), Side-Tropical (16.82%), Guineo-Congolians (16.82%) and Sudano-Guineans (12.61%) are dominant in this protected area (Figure 3-12). The micro-phanerophytes (19.15 %), the nano-phanerophytes (16.35%), Therophytes (14.48 %) and the Lianas (12.61%) are the species which were most met in this protected areas (Figure 3-13).

3.3.6 Ordination and determinations of plants communities

3.3.6.1 DCA (Detrended Correspondance Analysis)

Ordination in indirect gradient of the matrix of 170 samples×282 species of the vegetation of the three zones made it possible to discriminate five groupings. Four of the five are homogeneous but the grouping G3 is a mosaic constituted of wooded savannas and dry forest. The first four (4) axes of the DCA express 9.2 % of the original variance and 12.87% of total inertia. The standard deviation of the axis 1 (3.74) is inferior to 4 which highlights a non-unimodal distribution of the samples on this axis. The distribution of the statements presents an ecological significance in the factorial plan design by the axes 1 and 2.

The axis 1 of DCA expresses the gradient of ground moisture and present the following types of vegetation from the left towarding the right: shrubby Savannas (G1 and G2), a mixture of woody savannas and dry forests (G3), dense Forest dry (G4) and the riparian forest (G5). This axis opposed the formations less hygrophilous more hygrophilous one. Axis 2 however would express that the anthropogenic gradient was bound to the ground moisture. The top of this axis is occupied by formations in which almost all the human activities are listed (agriculture, pasture, cut, hunting, charcoal, bush fires and transhumance) while at bottom positions plant formations are less disturbed (Figure 3-14).

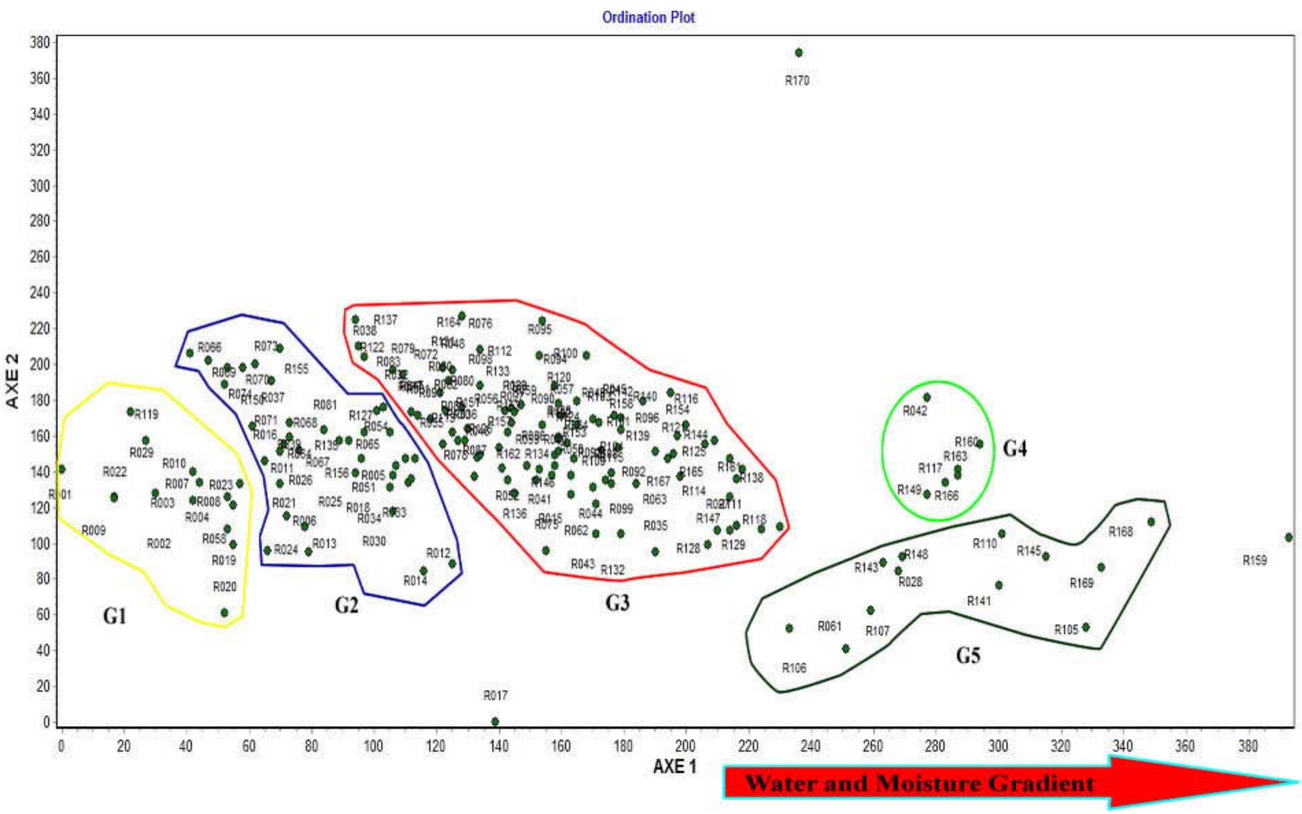


Figure 3-14: DCA ordination of 170 samples and 282 plant species showing five clusters

3.3.6.2 Hierarchical clustering of samples

The hierarchical classification of the 90 samples according to the method of Ward based on the similarity of Jaccard clustered these relevés in three plants communities largely dominated by the following physiognomical types: tree savannas (G31), wooded savannas (G32) and of tree Savannas (G33) (Figure 3-15).

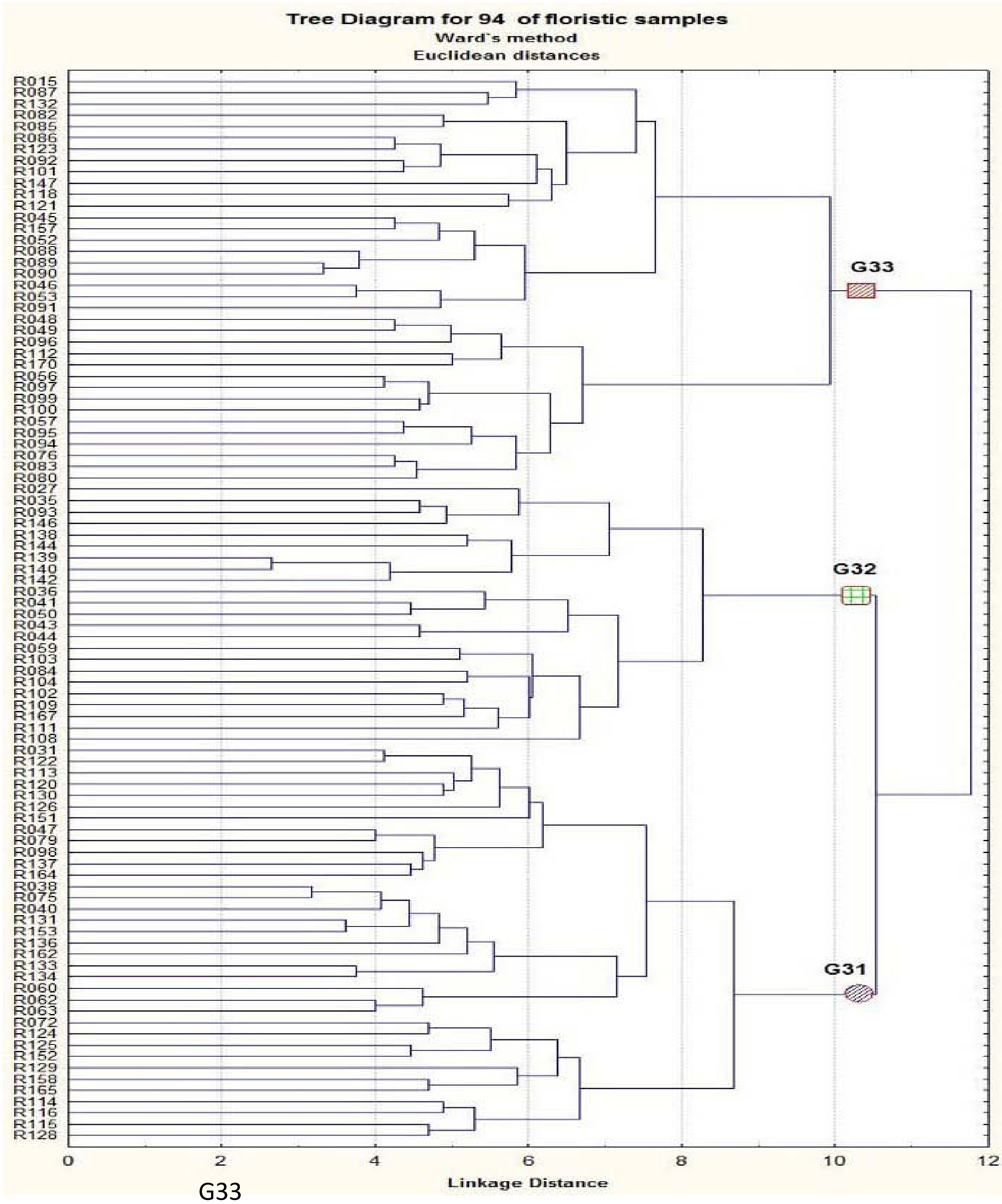


Figure 3-15: Dendrogram of 90 samples of G3 area showing 3 plant communities

3.3.6.3 Discriminated plants communities

The 170 floristic samples and the 282 plants species are grouped in 7 plant groupings after ordination and classification. The 7 groupings are presented below:

- **Shrubby savannas**

Crotalaria graminicola Taub. ex Bak.f. and *Terminalia macroptera* Guill. & Perr. *(*G1)

Crotalaria graminicola Taub. ex Bak.f. and *Terminalia laxiflora* Engl. & Diels (G2)

- **Tree savannas**

Vitellaria paradoxa C.F.Gaertn. and *Combretum micranthum* G.Don. (G31)

Terminalia laxiflora Engl. & Diels and *Pterocarpus erinaceus* Poir (G33)

- **Wooded savannas**

Terminalia laxiflora Engl. & Diels and *Securinega virosa* (Roxb. ex Willd.) Baill. (G32)

- **Dry and clear forests**

Ziziphus mucronata Willd. and *Terminalia laxiflora* Engl. & Diels (G4)

- **Riparians forests**

Vitex madiensis Oliv. and *Ampelocissus bombycina Planch*. *(*G5)

3.3.7 Diversity beta: degree of similarity between plants communities

The table 3-1 below shows the degree of similarity which exist between the 7 plant groupings identified. The index Jaccard of similarity (1901) varies between 0 and 100%. Two groupings are considered similar when the value is superior or equal to 50%. Considering the results consigned in Table 1 the grouping G1 and G2 are floristically very similar. A similarity is observed between the groupings G31, G32 and G33 however less than those of G1 and G2.

Table 3-1: Matrix of similarity between groupings based on species composition using the index of Jaccard

Groups	G1	G2	G31	G32	G33	G4	G5
G1							
G2	**100**						
G31	30.26	30.26					
G32	26.29	26.29	**53.45**				
G33	27.62	27.62	**57.39**	**57.89**			
G4	15	15	34.31	27.78			
G5	22.98	22.98	42.69	41.27	42.78	34.31	

3.3.8 Descriptions of plants communities

- ***Crotalaria graminicola* Taub. ex Bak.f. and *Terminalia macroptera* Guill. & Perr. (G1).**

This grouping consists of 15 samples among which 12 belong to Barkoissi reserve. 35 families, 59 genera and 76 species are present in this grouping. The indices of diversities of Shannon and Pielou are respectively, equal to 5.59± 0.0026bits and 0.89± 0.0004.

The grouping G1 is a shrubby savanna which developed on tropical hydromorphic ferruginous soil less evolved with clayey-sandy nature in a flat landscape. The drainage of water is weak which explains the ground immersion in rainy season. This grouping is strongly anthropogenic.

Crotalaria graminicola, Terminalia macroptera, Vitellaria paradoxa, Acacia polyacantha, Acacia gourmaensis, Terminalia laxiflora, Combretum micranthum are the species characteristic of G1. The arborescent layer is dominated by *Terminalia macroptera, Detarium microcarpum, Vitellaria paradoxa*, *Pteleopsis suberosa.*

The shrubby layer is dominated by Terminalia *macroptera*, Detarium *microcarpum*, *Acacia polyacantha*, Gardenia *erubescens*, *Terminalia laxiflora,* Combretum *glutinosum*, *Annona glauca, Pteleopsis suberosa*, *Strychnos spinosa.*

The low layer is characterized by herbaceous species like *Crotalaria graminicola*, *Andropogon tectorum, Spermacoce ruelliae, Pennisetum subangustum, Indigofera dendroïdes, Ampelocissus bombycina*, *Hibiscus asper*. Vitaceae family with the three following species: *Cissus populnea, Ampelocissus bombycina* and *Caryatia delicatula* correspond to the lianas share in this grouping.

The plant community is dominated by the phanerophytes such as micro-phanerophytes (20.73%), meso-phanerophytes (17.07%) followed by Therophytes (15.85%) and nano-phanerophytes (14.63%) (Figure 3-16).

The G1 remains dominated by species enfeoffed to Sudanese area such as Sudano-zambezians (22.98%), Sudanians (18.98%) and Sudano-Guineans (12.65%) (Figure 3-17).

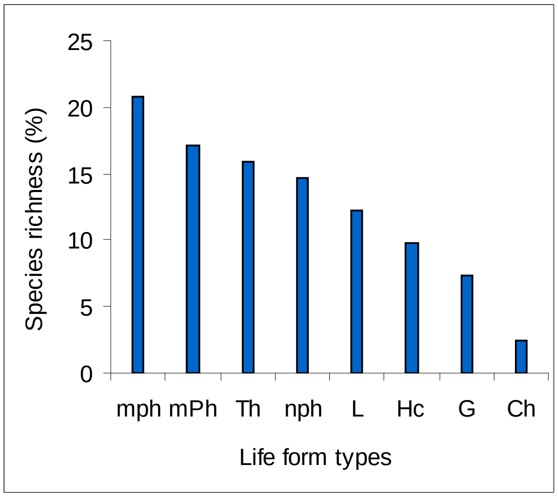


Figure 3-16: Life forms distribution in G1

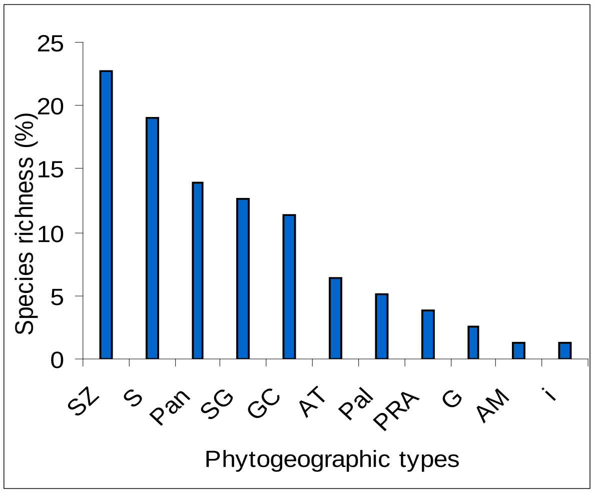


Figure 3-17: Phytogeographical types distribution in G1

❖ ***Crotalaria graminicola* Taub. ex Bak.f. and *Terminalia laxiflora* Engl. & Diels (G2)**

The grouping G2 formed by 40 relevés, is also a shrubby savanna. It develops on leached and hydromorphic tropical ferruginous grounds in most of cases. 75% of the samples of the plant community are found on flat ground; however the remainders are located on summits and slopes of rare hills.

This grouping is composed of 153 species, 111 genera and 47 families. The nonparametric diversity indices of Shannon and equitability are respectively, 6.31± 0.0022 bits and 0.86± 0.0003.

The species characterizing this grouping are: *Crotalaria graminicola, Terminalia laxiflora, Vitellaria paradoxa, Terminalia macroptera, Acacia polyacantha, Acacia gourmaensis, Securinega virosa, Pteleopsis suberosa, Combretum micranthum*. The arborescent layer is dominated by *Terminalia laxiflora, Pseudocedrela kotschyi, Acacia polyacantha, Anogeissus leiocarpus, Detarium microcarpum, Sclerocarya birrea, Entada abyssinica*. The dominant shrubs are: *Terminalia laxiflora, Terminalia macroptera, Detarium microcarpum, Combretum glutinosum, Pseudocedrela kotschyi, Pteleopsis suberosa, Anogeissus leiocarpus, and Securidaca longepedunculata*.

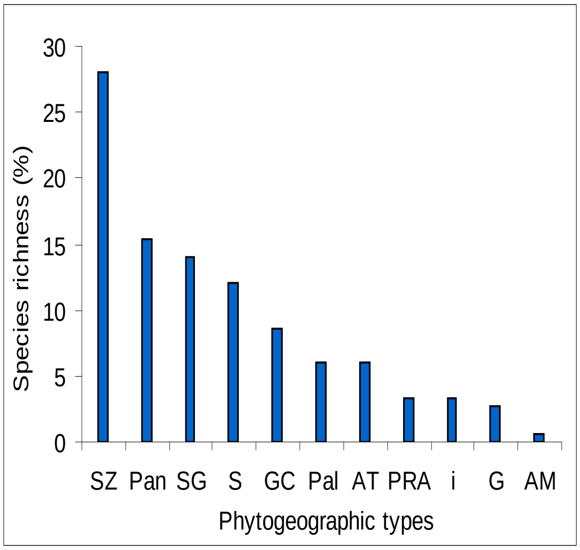


Figure 3-18: Phytogeographical types distribution in G2

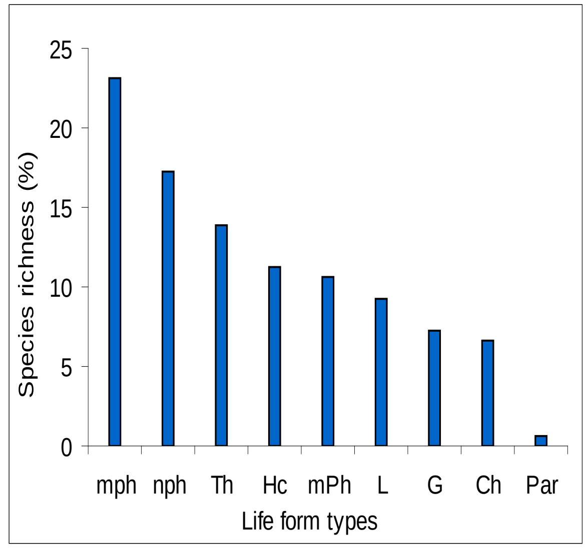


Figure 3-19: Life forms distribution in G2

The herbaceous layer is dominated by: *Crotalaria graminicola, Andropogon tectorum, Andropogon bisquamulatus, Digiteria diagonalis, Brachiaria deflexa, Tephrosia purpurea, Cochlospermum planchonii, Schizachyrium sanguineum, Gardenia aquala, Setaria megaphylla.*
The rough spectrum of chorological types is largely dominated by Sudano-zambezians species (28%) followed by Sudano-Guineans (14%) and Sudanians (12%). Species of large geographical distribution such as Pan-Tropicals, Paleo-Tropical, Afro-Tropicals and Pluri-Regional in Africa have rates which vary between 15% and 3.33% species (Figure 3-18). The major life forms in this grouping are the micro-phanerophytes (23.17%), nano-phanerophytes (17.21%) followed by Therophytes (13.98%). The lianas (9.27%) are dominated by the Vitaceae, the geophytes (7.28%) and the parasites are also met in this plant community (Figure 3-19).

- ***Vitellaria paradoxa* C.F.Gaertn. and *Combretum micranthum* G.Don. (G31)**

The plant community G31 is dominated by wooded savannas, however it had met dry forest, dry dense forest (raised 90, 92, and 94) and some savanna shrubby. This plant formation evolves on a tropical ferruginous substrate of clayey- sandy nature. An immersion of the ground is observed in the rainy season and in some place the soil is more hydromorphic. The essential of the samples of this grouping are located in the reserve of Oti-Keran.

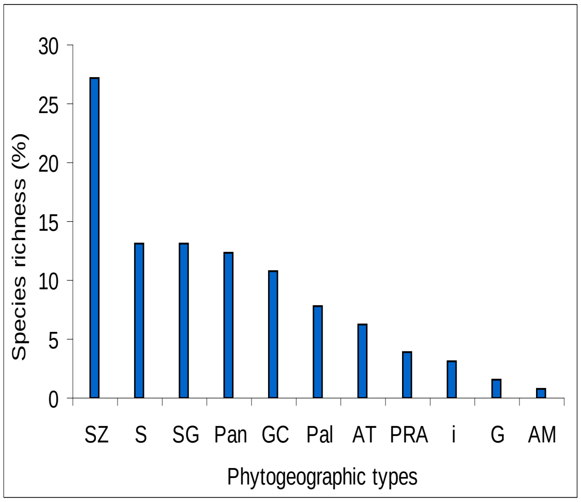


Figure 3-20: Phytogeographical types distribution in G31

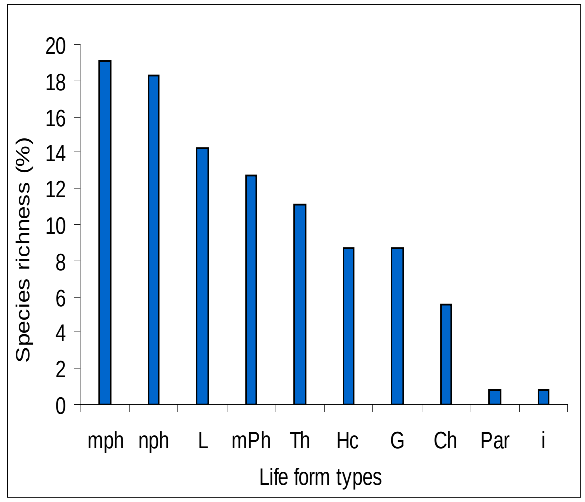


Figure 3-21: Life forms distribution in G31

36 families and 89 genera were recorded in the 25 relevés of the grouping. Its specific richness is 122 species while the Shannon and Pielou diversity index are respectively, equal to 6.14± 0.0023 bits and 0.88± 0.0003.The species characterizing this grouping are *Vitellaria paradoxa, Combretum micranthum, Acacia polyacantha, Combretum molle, Acacia gourmaensis, Tephrosia purpurea, Anogeissus leiocarpus, Pterocarpus erinaceus, Sporobolus pyramidalis, Andropogon tectorum.*

The taxa which dominate the high layer are composed of *Anogeissus leiocarpus, Acacia polyacantha, Sclerocarya birrea, Pterocarpus erinaceus, Combretum glutinosum, Mitragyna inermis, Vitellaria paradoxa, Daniellia oliveri,* and *Mayetenus senegalensis.*

The shrubby layer is made by *Combretum micranthum, Combretum glutinosum, Combretum molle, Acacia polyacantha, Vitellaria paradoxa, Anogeissus leiocarpus, Vitex madiensis, Strychnos barteri, Ipomoea mauritiana, Grewia venusta*. The low layer is dominated by *Andropogon tectorum, Hyparrhenia breviseta, Schizachyrium sanguineum, Crotalaria* *graminicola, Tephrosia villosa, Indigofera dendroïdes, Panicum maximum, Tephrosia purpurea, Vitellaria paradoxa, Desmodium ramosissimum, Acacia dudgeoni, Commelina erecta, Cissus populnea*.

From a chorological point of view the Sudano- zambezians (27.13%), Sudanians (13.17%) and Sudano-Guineans (13.17%) species dominate in G31, however put aside the Afro-Malgash and Guineans species which have less than three species, the restof the phytogeographical types is well represented in the grouping (Figure 3-20). The remarkable life forms are the micro-phanerophytes (19.04%) and nano-phanerophytes (18.25%). Lianas and the meso-phanerophytes, have 12.69% of the species, each. The same situation is observed for the geophytes and Hemicryptophytes which have 8.73% of the species, each (Figure 3-21).

- ***Terminalia laxiflora*** **Engl. & Diels and** ***Securinega virosa*** **(Roxb. ex Willd.) Baill. (G32)**

The G32 grouping is dominated by the tree savannas associated to dry forest. Some wooded savannas are met also. The 29 samples of the plant community have a specific richness of 143 species, 102 genera and 44 families. 6.38± 0.0022 bits and 0.88±0.0003 represent the Shannon and the evenness diversity index, respectively.

The G32 evolves in a relatively plane topographic landscape, on clayey-sandy soil which tropical ferruginous hydromorphic ground. The grouping is found along the axes of drainage. The species characterizing this plant community are: *Terminalia laxiflora, Securinega virosa, Vitellaria paradoxa, Anogeissus leiocarpus, Tephrosia purpurea, Prosopis africana, Setaria sphacelata, Pteleopsis suberosa.*

The arborescent layer is occupied by the following species: *Anogeissus leiocarpus, Pterocarpus erinaceus, Mitragyna inermis, Terminalia laxiflora, Parkia biglobosa, Vitellaria paradoxa, and Terminalia glaucescens.* The shrubby layer is dominated by *Combretum glutinosum, Nauclea latifolia, Terminalia laxiflora, Pteleopsis suberosa, Bombax costatum, Crossopteryx febrifuga, Securidaca longepedunculata, Mitragyna inermis, Gardenia erubescens* and *Grewia carpinifolia*. The dominant herbaceous species of the grouping are: *Securinega virosa, Andropogon tectorum, Andropogon bisquamulatus, Tephrosia purpurea, Cochlospermum planchonii, Crotalaria* *graminicola, Schizachyrium sanguineum, Setaria sphacelata, Sporobolus pyramidalis, Rottboellia exaltata, Panicum maximum.*

The Sudano-zambezians species (26.06%) strongly dominate in this grouping while Sudano-Guineans, Sudanians, Guineo-Congolians and Pan-Tropicals have almost the same rate (11.97%) (Figure 3-22). From the biological point of view the micro-phanerophytes (22.53%), nano-phanerophytes (14. 78%) and meso-phanerophytes (12.67%) correspond to the dominant life forms. The lianas, the Therophytes and the geophytes are present as well (Figure 3-23).

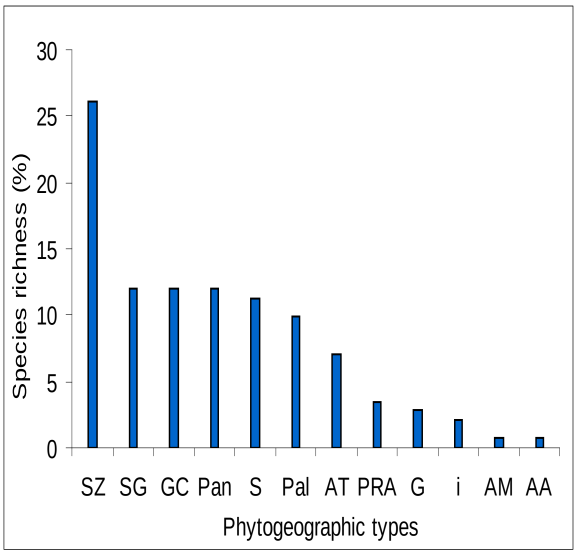


Figure 3-22: Phytogeographical types distribution in G32

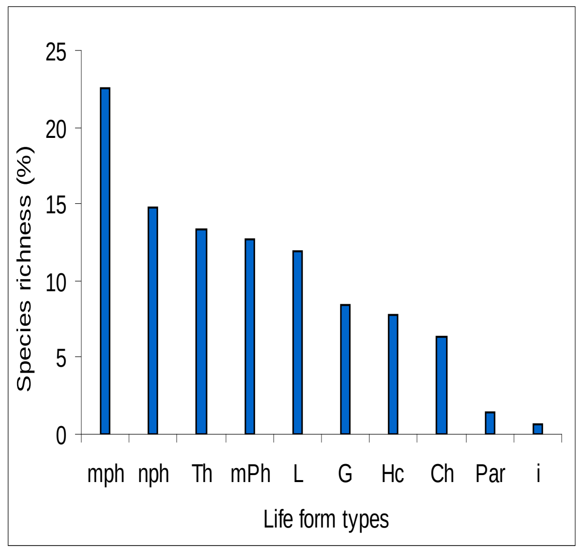


Figure 3-23: Life forms distribution in G32

❖ ***Terminalia laxiflora* Engl. & Diels and *Pterocarpus erinaceus* Poir (G33)**

The grouping G33 is also dominated by tree savannas. It has 42 relevés comprising 155 species distributed in109 genera and 44 families. The diversity alpha within the plant community is 6.37± 0.0022 bits for Shannon index and 0.87± 0.0003 for Pielou evenness.

The grouping develops on tropical ferruginous hydromorphic substrate of clayey-sandy to clayey-muddy nature. It is positioned along the drainages axes or at bottoms of the slopes. In general the drainage it is weak in this grouping.

The species characterizing this grouping are *Terminalia laxiflora*, *Pterocarpus erinaceus, Acacia polyacantha, Prosopis africana, Gardenia ternifolia, Pteleopsis suberosa, Securinega virosa, Crotalaria graminicola, Tephrosia villosa, Combretum micranthum*, *Terminalia macroptera* and *Sporobolus pyramidalis.*

The arborescent layer is dominated by the following species: *Pterocarpus erinaceus, Daniellia oliveri, Pteleopsis suberosa, Sclerocarya birrea, Terminalia macroptera, Crossopteryx febrifuga, Terminalia laxiflora, Lannea kerstingii, Entada abyssinica, Vitellaria paradoxa* and *Tamarindus indica.*

The dominant shrubs of this plant community consist *of Acacia polyacantha, Detarium microcarpum, Terminalia macroptera, Combretum glutinosum, Annona senegalensis, Gardenia aquala, Nauclea latifolia, Vitellaria paradoxa, Trema orientalis, Pteleopsis suberosa, Gardenia ternifolia, Grewia venusta* and *Mitragyna inermis.* However the low layer is dominated by *Andropogon tectorum, Rottboellia cochenesinensis, Schizachyrium sanguineum, Spermacoce ruelliae, Strychnos spinosa, Tephrosia purpurea, Fadogia agrestis, Aeschynomene schimperi, Pennisetum subangustum*, *Sporobolus pyramidalis*, *Tephrosia villosa*, *Eragrostis atrovirens, Tephrosia purpurea*, *Crotalaria graminicola*, *Tephrosia elegans*, *Microchloa indica*, *Panicum maximum* and *Crotalaria polygaloides.*

The life forms dominating in this grouping are the phanerophytes (49.66%). The nano-phanerophytes (18.54%) is followed micro-phanerophytes (17.88%) and meso-phanerophytes (13.24%) (Figure 3-24). The Therophytes (12.58%), the lianas (12.58%) and Hemicryptophytes (11.25%) are as well represented in this grouping. On the chorological level, the Sudano-zambezians species (21.79%) are followed of Sudano-Guineans (14.56%), of Guineo-Congolians (12.58%), Pan-Tropicals (17.21%) and Sudanians (11.25%) (Figure 3-25).

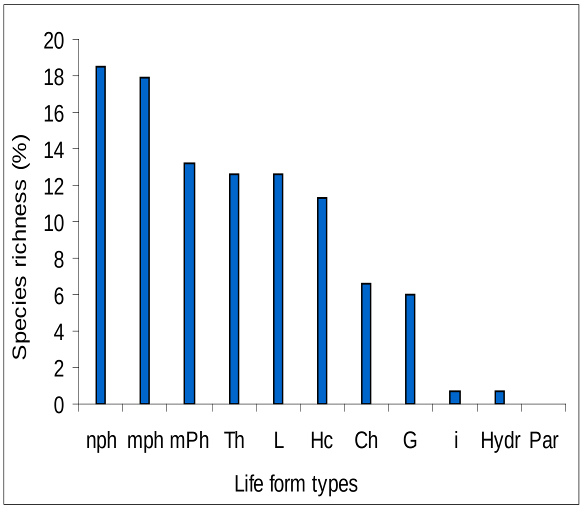


Figure 3-24: Life forms distribution in G33

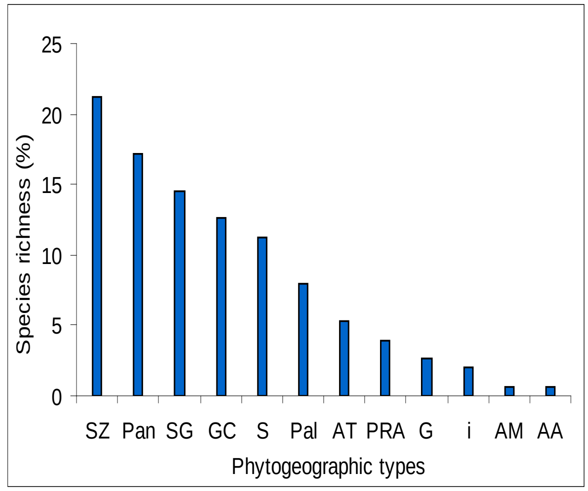


Figure 3-25: Phytogeographical types distribution in G33

❖ ***Ziziphus mucronata*** **Willd. and** ***Terminalia laxiflora*** **Engl. & Diels (G4)**

It is a grouping of dry and clear forests which develops on tropical ferruginous grounds of clayey –sandy. The grounds are evolved and less drained. 6 samples constitute this grouping. The 61 plants species listed are distributed into 52 genera and 28 families. The indices of Shannon and of Pielou diversity are respectively equal to 5.55± 0.0026 bits and 0.93± 0.0004.

The species characterizing this grouping are: *Ziziphus mucronata, Terminalia laxiflora, Anogeissus leiocarpus, Pterocarpus erinaceus, Prosopis africana, Vitex simplicifolia, Wissadula amplissima, Trema orientalis* and *Combretum micranthum.*

The higher layer is occupied by *Anogeissus leiocarpus, Daniellia oliveri, Pterocarpus erinaceus, Terminalia laxiflora, Cissus populnea* and *Ampelocissus bombycina.* However the middle layer is dominated by *Anogeissus leiocarpus, Combretum micranthum, Acacia polyacantha, Combretum glutinosum, Mitragyna inermis, Nauclea latifolia* and *Ampelocissus bombycina.*

The low layer is occupied by *Desmodium tortuosum, Rottboellia cochenesinensis, Anogeissus leiocarpus, Andropogon gayanus, Indigofera dendroïdes, Triumfetta rhomboidea, Wissadula amplissima, Desmodium gangeticum, Dioscorea dumetorum, Ziziphus mucronata* and *Cissus populnea.*

The Sudano-zambezians species (32.78%) represent the recurrent phytogeographical type in this grouping, it is followed by Pan-Tropicals (19 67%). The distribution is identical for Guineo-Congolians, Paleo-Tropicals and Afro-Tropicals species (8.19%) (Figure 3-26). The biological types are significantly represented by the micro-phanerophytes (22.95%), nano-phanerophytes (18.03%), meso-phanerophytes (18.03%) and the lianas (13.11%) (Figure 3-27).

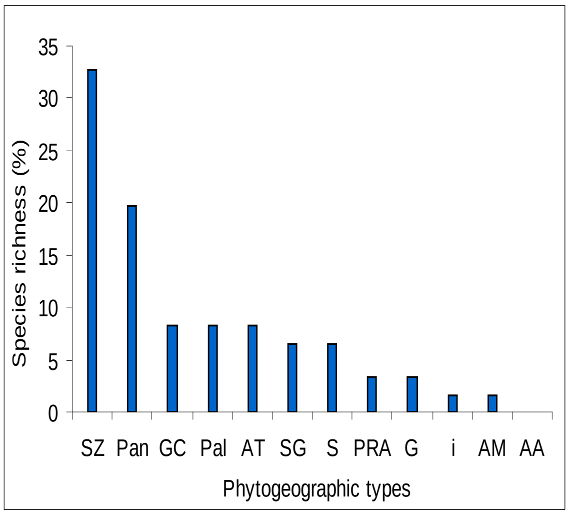


Figure 3-26: Phytogeographical types distribution in G4

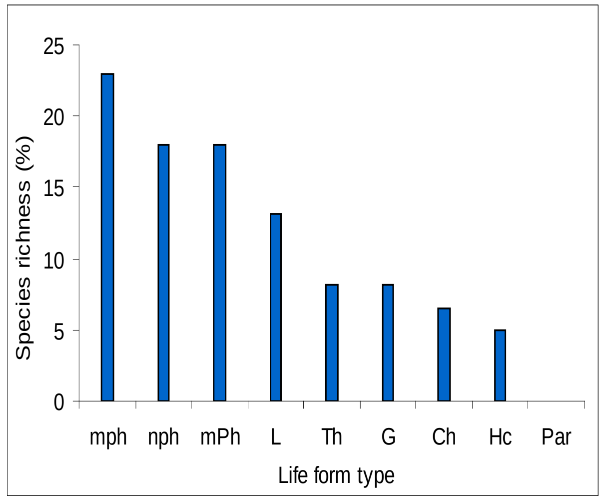


Figure 3-27: Life forms distribution in G4

❖ ***Vitex madiensis* Oliv. and *Ampelocissus bombycina Planch.* (G5)**

The *Vitex madiensis* and *Ampelocissus bombycina* plant community is made of riparian forests. Its develops on the banks of small meandrous rivers of savanna. The grounds are tropical ferruginous hydromorphic of muddy-clayey–sandy nature. The grouping counts 13 samples which conceal in all 122 species, 99 genera and 47 families. The diversity alpha is significant and corresponds to 6.40± 0.0021 bits for the Shannon index and 0.92± 0.0003 for Pielou evenness.

The species characteristic of this grouping are *Vitex madiensis, Ampelocissus bombycina, Quisqualis indica, Acacia polyacantha, Paullinia pinnata, Vitex doniana, Vitex simplicifolia,* *Ziziphus mucronata, Terminalia laxiflora, Terminalia glaucescens, Dioscorea dumetorum, Dioscorea togoensis, Mitragyna inermis, Anubias gigantean, Ipomoea mauritiana* and *Khaya senegalensis.*

The higher layer remains dominated by *Anogeissus leiocarpus, Sclerocarya birrea, Vitex madiensis, Acacia polyacantha, Lannea microcarpa, Acacia polyacantha, Terminalia glaucescens, Crataeva adansonii, Nauclea latifolia, Ficus sycomorus, Cissampelos mucronata, Vitex simplicifolia, Lannea kerstingii.* The shrubs consist of *Anogeissus leiocarpus, Crataeva adansonii, Combretum paniculatum, Vitex simplicifolia, Eugenia kerstingii, Nauclea latifolia, and Mitragyna inermis.*

The species occupying the low layer consist of *Vitex simplicifolia, Paullinia pinnata, Setaria barbata, Andropogon gayanus, Nenuphar alba, Sporobolus pyramidalis, Ampelocissus bombycina, Tacca leontopetaloides, Triumfetta rhomboidea, Rottboellia exaltata, Dioscorea alata, Dioscorea togoensis, Sapium ellipticum.*

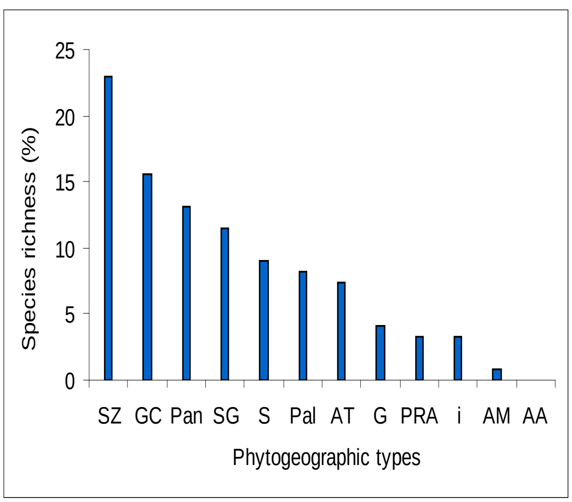


Figure 3-28: Phytogeographical types distribution in G5

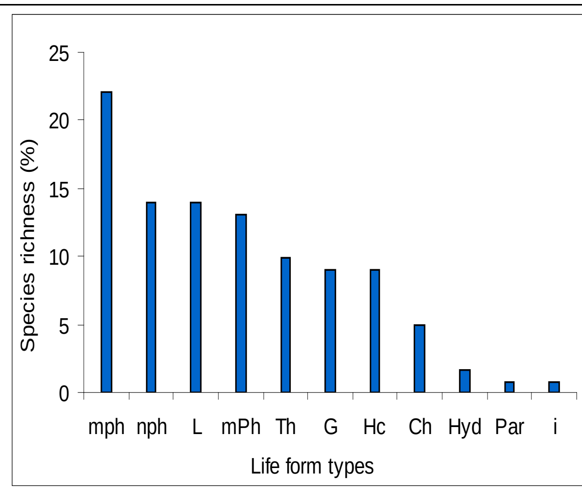


Figure 3-29: Life forms distribution in G5

On the chorological basis the Sudano-zambezians species (22.95%) followed Guineo-Congolians (15.57%), Sudano-Guineans (11.47%) dominate in this grouping (Figure 3-28). The micro-phanerophytes (22.13%), the nano-phanerophytes (13.97%), the lianas (13.97%) and the meso-phanerophytes (13.11%) are the remarkable life form types of this grouping. A weak presence of Hydrophytes (0.81%) is noted (Figure 3-29).

3.3.9 Environmental factors actions on species distribution: Canonical Correspondence Analysis (CCA)

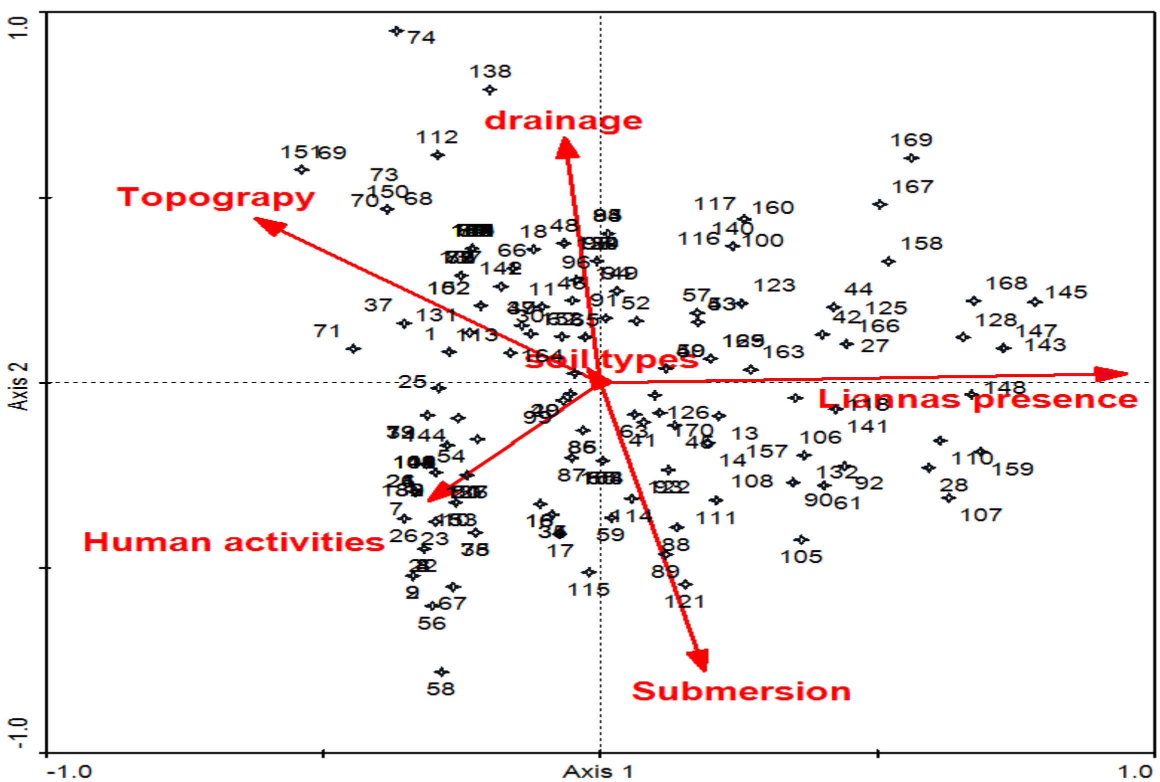


Figure 3-30: CCA ordination of 170 relevés in factorial axes 1 and 2.

For the six ecological variables taken into account, the floristic samples present a significant distribution in the factorial plan formed by axis 1 and 2 of the CCA (Figure 3-30). The four canonical axes express alone 78.1% of the original cumulated variance between the species and the variables. The total variance expressed for the floristic data is 12.87. The variations observed are explained by the second axis (2.8%) against 2% for the first; however the two axes make it possible to explain 4.8% of the original variance (Table 3-2). The Mont Carlo test for 999 permutations of the eigenvalues of the four axes is significant is (*p=0.0010*). It is the same for the correlation between the environmental species and variables for the six ecological factors retained for the CCA.

Table 3-2: Statistical synthesis of ordination in indirect gradient of the 170 samples

Axes	1	2	3	4	Total inertia
Eigenvalues	0.252	0.111	0.105	0.086	12.878
Species-environment correlations	0.857	0.762	0.755	0.709	
Cumulative percentage variance sp data	2.0	2.8	3.6	4.3	
Cumulative percentage variance sp-env.	35.4	51.1	65.9	78.1	

It is noted that the first axis is strongly correlated with the presence of the lianas while the second is correlated with the drainage and the submersion. Axis 1 highlights the degree of closing of the vegetation. In the canonical direction of the variable lianas presence is occupied by riparian forests, dry forest and wooded savannas, while in the opposite direction there is an open formation like shrubby savannas. The axis two expresses better the ground moisture and topographic gradient by discriminating the samples carried out on the banks, the depressions, low slopes and along of drainages axes, to those of on summits, slopes and flat grounds. The human activity canonical axis is strongly correlated to the relevés of shrubby savannas in the topographic, edaphic and moisture conditions, favorable to agriculture practice. These samples contain all of the listed human activities (cut, pastures, transhumances, bush fires). The Moisture in this most dry area of the country remains the convincing factor which influences the distribution of the species in space, topography also will intervenes but to lesser extent.

3.4 DISCUSSION

3.4.1 Floristic diversity

3.4.1.1 Floristic assessment

Through this floristic investigation a total of 274 plant species were recorded for the three protected areas, which represented the double of species identified by Dimobe (2009) in the fauna reserve of Oti-Mandouri in the same sector. This important difference could be explained by the seasonal mutation given the fact that the first was carried out in the rainy season while the later was conducted in the dry season. Smaller than that found in the sacred forests of Ouatchi area in the southern east of Togo by Kokou *et al*. (2005), the number of listed species is twice lower than that of those identified, on the one hand, in the Fazao-Malfakassa national park and the fauna reserve of Aledjo (central part of the chain of Atakora) (617 species) described by Woegan (2007) and, on the other hand, in the septentrional part of the same chain (Benin) (663 species) investigated by Wala (2004). This huge variation might have been due to a climatic determinism. The Protected Areas of Barkoissi, Galangashi and Oti-Keran located in the Sudanian climate zone would have less diversity compared to those located in the Guinean climatic zone. Although more species were listed in Niangoloko forest (Burkina Faso) (Ouoba, 2006) than in this study, Fabaceae and Poaceae are the most represented families in these two areas. These two families aside, Rubiaceae and Combretaceae are also well represented in the studies conclusions of the above-mentioned authors. The Combretaceae with 18 species and 11 for Mimosaceae are considered as characteristic families of this region (Aubreville, 1950). They would testify the existence of dry tropical climate (White, 1986).The high rate of graminaceous is essentially due to the fact the study area is dominated by savanna landscape. The Rubiaceae would highlight the existence of favorable forest conditions (White, 1986). The Rubiaceae and Fabaceae would be all the more abundant in the reserve of Oti-Keran which having a climatic and ecological conditions less favorable compared to the other two reserves.

Similar studies conducted in the Ecological and Cultural Site of Koro (Kadeba, 2009) presents similar results if the Fabaceae are taken in their set. (Herbaceous and ligneous). Unlike for this study, Kadeba (2009) has subdivided the floral procession of Koro into ligneous and herbaceous.

In general the flora of this region is also dominated by Fabaceae and Poaceae. All the floral studies carried out in the western Africa sudanian tropical zone present almost similar results, this similarity can be observed through the results obtained by Natta (2003) whose work covered Benin gallery forests.

3.4.1.2 Biological spectrum

The phanerophytes (47%) represent the most frequent life form. They would testify a low level of afforestation in the study zone (Woegan, 2007). According to Mangenot (1955) the tropical dense forest formations conceal 80 to 90% of phanerophytes, of which micro-phanerophytes (19.85%) and nano-phanerophytes (17.27%) have higher rates, in contrast to the meso-phanerophytes (9.92%). The predominance of phanerophytes (47%) and Therophytes (15%) is typical to savannas of the sudanian tropical zone (Natta, 2003). In a specific way, the same tendency is observed in Burkina Faso in the hippo pond protected area (Belem and Guinko 1998). The Therophytes with 15% of species would be related to the dominance of shrublands and to anthropogenic activities to which they are subject (Wala, 2004). The parasites, represented in this study by *Tapinanthus sp.*, are very negligible, which is similar to what Kokou and Guy (2000) described in the small forest islands of southern Togo.

The ligneous lianas as herbaceous represent an intrinsic component of the tropical forest (Kokou *et al*., 2002).12.50% of the species of this flora is represented by lianas, which is considerable for vegetation which emerges under less arid climate conditions. This rate would show the degree of reconstitution of the wooded formations (Kouame and Traore, 2001), on one hand, and the fragmentation state of this vegetation, on the other hand.

3.4.1.3 Phytogeographical spectrum

The endemic species of sudanian geographical zone represent 44.45% of the total species. The Sudano-Zambezians species (23.35%) are the dominant chorological types of this region. The same tendency was observed by most of the authors who realized similar studies in the Sudanese climatic zone (Dimobe, 2009; Ouoba, 2006; Ouedraogo, 2006; Wala, 2004). This predominance was also announced by Woegan (2007) in the central part of the chains of Atakora where prevail a semi-wet tropical climate. The rather significant share of the Guineo-Congolians (15.32%) and

Guineans species (3.28%) would be related to the hydrographic network, around which the hygrometrical conditions allowed the development of these species. The species of large distribution represent 27.37 % of the total number of species, among which the Pan-Tropicals and Paleo-Tropicals occupy respectively; 16.78% and 6.56%. Alimasi (1991and1999) and Nyakabwa (1982) noted high rates of Pan-Tropicals species in their research. This high rate of broad distribution spectrum species would indicate a strongly disturbed areas and secondary character of plant formations (Kaboyi, 2004). Sinsin (2001) found few of these species in the areas not very prone to the disturbances.

3.4.2 Diversity and conservation in the three protected areas

The three protected areas show diversity indices which varies from one to other. These variations are undoubtedly having some connection with the surface of the protected areas, with the number of floristic samples carried out and in lesser extent with their latitudinal position.

The reserve of Barkoissi with its 2000 ha is most subjected to human activities and presents the aspect of mega agroforestery parkland (Pereki *et al*., 2010), however the number of genera which it contained is slightly inferior to those identified in Galangashi. The fact that reserve of Galangashi is less subjected to anthropogenic disturbances would explain its diversity state (129 species, 100 genera and 43 families). On the basis of chorological types, the percentage of the species of broad distribution such as Pan-Tropicals (12.50%) is low compared to both other protected areas.

Oti-Keran and Barkoissi protected areas are strongly anthropized. This situation can be observed through the availability of large geographical distribution species which are 26.31% and 32.24% respectively for Barkoissi and Oti-Keran. On the other hand the reserve of Galangashi (10.93% of Guineo-Congolians) and Oti-Keran (16.82% of Guineo-Congolians) appearing to be wetter and having ecological conditions favorable to forest species growth.

The life forms spectrum of the three protected areas is dominated by the micro-phanerophytes, the nano-phanerophytes and the Therophytes. The hydrophytes and the parasites are underrepresented. This rough spectrum of the three protected areas of northern Togo compared to those of Fazao-Malfakassa and Aledjo (Woegan, 2007) presents different proportions between the life forms. Except Therophytes (15.07%) and the geophytes (6.61%) which show proportions raised against respectively (6.53%) and (5.44%). The other life forms types present a significant regression compared to those determined by Woegan (2007). The problematic of the biodiversity conservation needs to be elucidated because these reserves are all located in the sudanian climatic zone. In this situation the ecological conditions would explain these differences. Moisture factor would be determining in this diagram. The three protected areas of northern Togo in addition to being in a zone where the annual rainfall is around 1100 mm/year, they are on the way of a dry wind named harmattan which blows towards south west after the rainy season. However the two others (Aledjo and Fazao–Malfakassa) are localized in an area where the annual rainfall is 1400 mm/year and less subject to the harmattan effects. Beside the climatic determinism, the anthropogenic disturbances may also explain this difference. The recurring influence of the populations on the natural wooded formations in seen to create agroforestery parkland in a region dominated by shrubby savannas would explain the abundance of the Therophytes. The geophytes as for them would indicate an area subjected to the bush fires.

3.4.3 Plants communities' diversity

Seven plant groupings were identified after the numerical analyses. Some of them are similar to those determined in Togo and in under sudanian region.

All of the discriminated groupings present the similar indices of diversities; these indices turn around 6 bits for Shannon index and 9 for Pielou evenness. These diversity indices indicate a high specific richness of these plants communities, but for Mc.Cune and Grace (2002) a low values would indicate vegetation less diversified and dominated by one specie. For Zoungrana (2008) the Shannon index higher than 4.5bits would indicate groupings less subjected to anthropogenic factors in Sudanian region. That is contrary with our reports, in spite of Shannon index was higher than the 4.5 bits obtained in the classified forest Boulon and Koflande (Burkina Faso) the agricultural activities practiced by the bordering people is unceasingly increasing in these protected areas.

The groupings G1 and G2 which correspond to shrubby savannas are specific to tropical sudano-sahelian zone. The predominance and the frequency of *Crotalaria graminicola* in these groupings confirms the high presence of shrubby savannas usually burnt, which extends from Togo to Cameroun (Burkill, 1985). In Burkina Faso this species is found as well as in savannas and in opens forests. The ecological conditions in which the *Terminalia laxiflora* and *Terminalia macroptera* groupings are evolved in the classified forest of Niagoloko in Burkina Faso (Ouoba, 2006) are similar those of the groupings G1 and G2.

The G31 grouping which developed on clayey-sandy grounds is also similar to that identified by Christophe *et al*. (2005) in Ségou region (Mali), but the latter can be also found on argillaceous, muddy and sandy substrates. These same authors distinguished a grouping of *Combretum micranthum* but associated to the following species *Feretia canthioides, Diospyros mespiliformis, Acacia seyal* and Acacia *macrostachya.*

The G32 grouping in *Terminalia laxiflora* and *Securinega virosa* which develops on hydromorphic grounds would be closer to that defined in the classified forest of Niagoloko (Ouoba 2006), however that identified by Kadeba (2009) in the Ecological et Cultural Site of Koro (province de houet/Burkina Faso) presents a preference for the plateau with outcrop of bed rock. But for Thiombiano (2005) the plant formations with *Terminalia laxiflora* are ubiquists to all the wet edaphic substrates.

Grouping with *Ziziphus mucronata* and *Terminalia laxiflora* develops on lesser drained soils. The two species indicate more or less wet areas. The presence of *Terminalia laxiflora* in this grouping may suggest that the grounds of this plant community are temporarily flooded (Thiombiano, 2005); *Ziziphus mucronata* according to Christophe *et al*. (2005) indicates temporarily wet areas such as river edges. For White (1986) the groupings with *Ziziphus mucronata* would belong to clear forest of sudanian transitions zone formerly extended. The group 5 was considered as belonging to gallery forests of Sudanian areas. In North-Togo vegetation it is regarded as a formation which develops on the meandering rivers that run through Oti plain. The same grouping was identified by Woegan (2007) in central Togo; the latter are the filled on evolve on grounds not very deep.

The chorological types of various plant groupings also allow understanding also the state of the vegetation in this ecosystem. Savannas show high rates of Sudano-zambezians, Sudanians and Sudano–Guineans species. This is interesting because the study zone is localized in the Sudanian Endemism Regional Center defined by White (1986). The shrubby savannas of this zone show high rates of Pan-Tropicals species then indicating the degree of disturbance of anthropogenic origin. The high proportions of the Guineo-Congolians species suggest wet edaphic conditions and favorable to forest species growth, however the high value of Pan-Tropical in the groupings G33 and G4 confirms that the wooded and closed formations would not spared to human action. The high value of the Guineo-Congolians species of G5 grouping would confirms its forest character. The groupings having high percentages of Guineo-Congolians species present affinities for the ecosystems of Guineo-Congolian/Zambezians regional transition zone (White, 1986). Their remarkable presence in the sudanian zone is supported by the meandrous hydrographic network.

The life forms show the predominance phanerophytes in both groupings which indicates once again the wooded nature of the plant formation in this area. Therophytes are well presented in savannas groupings (G1, G2 and G32), but are very limited in wooded savannas, dry forests and forests galleries.

The prevalence of the phanerophytes in closed groupings such as wooded savannas, the dry forests and gallery forests is undoubtedly dependent on moisture and grounds nature. The high proportion of the lianas in wooded savannas, forests and certain trees savannas would indicate disturbed areas in reconstitution.

3.5 CONCLUSION

Present studies made it possible to have a synoptic view of diversity and plant groupings of Northern-Togo protected areas in particular those of Barkoissi, Galangashi and Oti-Keran. The phytodiversity of the investigated area is in accordance with the results obtained in previous studies, with the predominance of families such as Fabaceae, Poaceae, Combretaceae, Rubiaceae, Caesalpiniaceae and Mimosaceae which are characteristic of sudanian zones. In addition the plant groupings reflect the observations carried out during samplings. The biological and phytogeographical types allowed deducing, on the one hand, that the sampled vegetation is wooded in reconstitution, on the other hand, that it evolves under a dry tropical climate. All these considerations require that measurements are taken to limit the disturbances on these areas.

CHAPTER 4 - NORTHERN TOGO PROTECTED AREAS WOODED VEGETATION: Ecological, Numerical and Structure of Plants Communities

4.1 INTRODUCTION

The woody plant formations have an impact on environmental quality. Their woody and perennial components contribute a lot to the management of the natural resources in zones where they occur.

Unlikely, today, the majority of the wooded ecosystems of the world (FAO, 2007), especially those within the tropical and subtropical ares, are either few or managed without taking into account the forest principles adopted during the United Nations Conference on the environment and the development which took place in Rio in 1992 (CNUED, 1992).

These insufficiencies or lack in the woody resources management are responsible for the erosion of woodland diversity. According to FAO (2001), one of the main causes of this erosion is the anarchistic human pressure in its various forms (pasture, agriculture, lumber collection, wood energies, and forest nonwoody products). To this main cause is added the variations of the interannual rainfall (Catinot, 1988) observed in these sector. In Africa, particularly in the Western Africa these various pressures have a negative impact on the structure, floristic composition and dynamics of the natural wooded formations (Dourma, 2008; Lykke *et al.*, 2002; Tente and Sinsin, 2002; Lykke, 2000; Sonko, 2000; Tchamie and Bouraïma, 1997). Dis-forestation which is the lead cause of ecosystems destruction was estimated to be 25.5 to 30.2 million hectares since 1900 for West Africa (Fairhead and Leach, 1998). At present this rate is over 12 million hectares (FAOb, 2001).

In Togo, the situation is even more alarming in spite of the government efforts to classify certain ecosystems. For instance, out of the 43 protected areas selected in the context of consensual rehabilitation project of protected areas, only a few of them like Aboudoulaye Wildlife Reserve, Classified Forest of Tchorogo, National Park of Fazao-Malfakassa, Alédjo Wildlife Reserve and the Oti-Mandouri Wildlife Reserve had scientific data which can be used for their eventual management (DFC, 2003; Atato, 2002; Woegan, 2007; Dimobe, 2009). In Northern Togo the essential of arborescent vegetation lies in the protected areas which are even found in unfavorable climatic conditions. Forestry harvesters and local communities invade not only the villager’s domain but also the protected areas (Dourma, 2008; Woegan, 2007; Borozi, 2007; Tabe, 2007) in search of natural resources.

Vegetation provide to local communities basic subsistence and economic resources Nonetheless, it often faces absence or failure of the sustainable management policies of the woody plant communities in the protected areas. There is a great need to do an investigation of the existing woody resources and to explore various forms of human pressures in the protected areas in order to update the existing database for eventual management use. The part of this study was a contribution and had the aims to carry out a floristic and phytosociological survey as well as a demographic structure analysis of wooded plant communities of Northern Togo protected area.

4.2 MATERIALS, METHODS AND DATA PROCESSING

4.2.1 Study area

The survey area covers the protected areas of Barkoissi, Galangashi and Oti-Keran. The study area is mainly localizing in the region des Savanes (North Togo). Both; they were respectively gazette as protected areas in 01/01/1954, 14/09/1954 and 28/09/1950. The area concerned the limit of the years of their classification (Sournia *et al.*, 1998) and covered 2000 ha for Barkoissi, 7500 ha for Galangashi and 163640 ha for Oti-Keran.

These protected areas are situated in eco-floristic zone 1 or northern plain (Ern, 1979) .They are located between 11° and 10° of northern latitude and between 0° and 1° of eastern longitude (Figure 1-1 to 1-11). The main relief of the investigation area is formed by a vast plain, which is dominated by tropical leached ferruginous soils covering a cuirass. The study area is drained by two famous rivers, Oti and Koumongou. The region has a Sudanese tropical climate marked by the alternation of a long dry season (Yema *et al.*, 1981). Heavy rains occur in August (Moussa, 2008) .The rainfall oscillates around 1058.9 mm per year. Temperatures vary between 20°C and 35°C while the annual average is 28.5°C for Mango meteorological station (Moussa, 2008).

The region faced to a strong anthropogenic influence on vegetation. The major human activities around the protected areas are agriculture, firewood collection and initiation of bush fires during the dry season. These activities are well present in the protected areas and denote their level of disturbance. The main crops species are millet, sorghum, groundnuts, maize, cowpeas, and yams. Livestock include caprine, sheep, and poultries. The zone is also face to the transhumance which implied it availability to produce more bovine. On national plan the region is the first provider in term animal protein.

The principal ethnic groups living in and around the study area include the following: Ngamgam, Tchokossi, Tamberma, Lamba, Moba, Gnande, Mossi, and Fulani.

4.2.2 Data collection

The phytosociological data collection was made from north to south starting with Barkoissi reserve to Oti-Keran via Galangashi. Both, the transect and sampling techniques were employed in data collection.

4.2.3 Choice of transect

Before identifying the location and the orientation of transect, Landsat ETM+ image (Enhanced Thematic Mapper Plus) of the three protected areas were subjected to an unsupervised classification.

This classification was achieved by using the algorithm ISODATA (*Interactive Self-Organizing Data Analysis Technology Algorithm*) (Tou and Gonzalez, 1974). The classification provided a synoptic view of various spectral signatures which helped in deducing the aspect of the land cover and occupation. Transects were oriented in such a way that they can cross and recut all spectral signatures defined by the previous classification. In total, 14 transects were defined on the images, 5 for Oti-Keran and, 9 for the Barkoissi-Galangashi complex.

4.2.4 Phytosociological samples.

The technique of sampling adopted is based on the Braun-Blanquet (Westhoff and van der Maarel, 1978) phytosociological concepts .The floristic plots of 30m×30 spaced at least by 100m are placed along the transects previously defined, but the linear structure of plants formations along the rivers led us to place 50m×10 quadrats (Natta, 2003) to take into account more diversity. The choice of 900m ^{2} and 500m ^{2} as minimal areas is marked by the fact that they were used successfully in Togo (Drouma, 2008; Woegan, 2007; Wala, 2004; Kokou, 1998; Guelly,

1994) and in subregion (Ouoba, 2006; Natta, 2003; Masens, 1997; Sinsin, 1993); during various works relating to Sudano- Guinean tropical areas.

To collect the structural data of woody formations of these protected areas, a tree inventory was carried out inside the floristic samples. Structural features such as DBH $\geq$ 10 cm at 1.3 m above ground, height, crown diameter, number of individuals by species and the scientific names (Hutchinson and Dalziel, 1958-1972) of all the woody plant species were recorded. The height of the individual tree was estimated while the DBH was measured using the ribbon *pi*.

For qualitative ecological characterization; topographic attributes (plateau, slope, versant, valley and bank), edaphic variables (structure and texture of the soil), and disturbance level (e.g. fire, cutting and pasture) were noted along with the geographic coordinates.

Climatological data (rainfall, humidity, temperature) for any period were obtained from databases of nearest meteorological stations, in particular those of Barkoissi, Mango, and Takpamba.

In total, 170 samples have been installed in the three protected areas, among which 110 were placed in Oti-Keran reserve and 60 samples in the Barkoissi-Galangashi complex reserve.

4.2.5 Data processing

Upon completing the digital processing of 170 samples, a general list of all species procession recorded from the three protected areas was established. Based on: Aubreville (1950), Hutchinson and Dalziel (1954-1972), Aké Assi (1984) and Guinko (1984), these species were classified into phytogeographical types while their life form classification was based on Raunkier definition (1934).

For each sample the indices of diversity: specific richness, Shannon index and Pielou evenness (Magurran, 1988; Kent and Coker, 1992) were calculated to obtain synthetic information's on the distribution of the species. The following formulas were used to calculate these indices.

Shannon diversity index (H'): $$H' = -\sum_{i=1}^{s} (Ni / N) \times \log_2 (Ni / N)$$

Pielou's evenness index (E): $$E = \frac{H'}{H'\max} = -\frac{\sum_{i=1}^{s} (Ni / N) \times \log_2 (Ni / N)}{\log_2 (s)}$$

Where *Ni* is the number of relevés in which the species *i* is present; N is total number of relevés and *S* is the number of species.

Before proceedings to data analysis two matrices (samples×species) were realized for each reserve for the floristic analysis. The first matrix took into account the presence/absence of the species in a given sample. The second matrix took into account the coefficients of specific abundances. The third matrix (samples× ecological descriptors) was established for the entire zone of study. The matrices obtained were then subjected to 3 multivariate analyses.

The first consisted of hierarchically classified (clustered) phytosociological relevés according to the method of Ward using the Euclidean distance to discriminate plant communities (Huang *et al.,* 2006).

Then the species characterizing the clustering-derived groups of samples were obtained by *INDVAL* method or Indicator Value (Pierre L. and Louis L., 1998). This analysis was preferred to TWINSPAN (Two Indicator Species Analysis) of Hill (1979a) because the indicator species can be easily deduced from a hierarchical clustering or non hierarchical clustering with indicators values being the product of species frequency and their abundance, compared to the other species of their grouping. The indicator value was computed from the formula below for each plant community.

$$INDVAL = Ar \times Fr \times 100$$

$$Ar = ai / a$$

Where *Ar*: is relative abundance, *ai* a number of individuals of the species and *a* a total number of individuals of the plant community.

$$Fr = ni / n$$

Where *Fr*: is a relative frequency, *ni* the number of relevés where the species occurs and *n* the total number of relevés

The third phytosociological analysis was focused on ordering the samples in direct gradient via the CCA (Canonical Correspondance Analysis) (ter Braak and Smilauer, 1998) to link directly the distribution of samples to environmental factors observed during the field work.

The data processing and the first two analyses were made by using CAP® 2.15 (Community Analysis Package), third with PC-ORD® 4 and the fourth with CANOCO ®4.5. The choice of these multivariate analyses is guided by their ecological interpretability and significance (Hill and Gauch, 1980; Hill, 1979b).

To analyze the demographic structure of the defined community, the structural and dendrometric features such as the average heights (Hm), the average diameters (Dm), the density of the stems at hectare (D_{10}) and the basal area (G) were computed according to the formulas below:

- Density of the stems (D_{10}): $$D10 = N / S$$

Where D_{10} is density (*ni/ha*), N the total number of stems with DBH >10cm at 1.3m of the ground and S: surface (ha).

- Basal area (G): $$G = \sum \pi \frac{D^2}{4}$$

Where *G* is the basal area (m²/ha), D the diameter (m) at 1.3m of the ground.

The distribution of age classes by community has been used as a predictive tool in synecology (Michael *et al*., 1980) knowing the demographic variables.

The classes of stem diameter, although they do not define the age, are strongly correlated with the age. According to Dajoz (1974) and to Frontier and Pichod-Viale (1991) the classes of diameter are likened to age class. Thus to have the demographic structure of the plant community, the histograms of the stems by classes of diameters were built.

To complete all the analyses the mean values of the features indicating the diversity and the structure of the plant communities were compared. To achieve it, the analysis of variance ANOVA coupled with post hoc test of Newman-Keuls was applied using the software Statistica7.0.

4.3 RESULTS

4.3.1 Floristic, biological and phytogeographical Characteristic

4.3.1.1 Floristic and specific diversity

Out of 170 phytosociological samples, 68 woody species (DBH ≥ 10cm) were identified. They are distributed among 47 genera and 25 families, of which Combretaceae (11 species), Mimosaceae (8 species), Rubiaceae (8 species), Anacardiaceae (5 species) and Caesalpiniaceae (5 species) represents (Figure 4-1) the most common families with a procession of at least 5 species. The Oti-Keran and Galangashi reserve presents the same specific richness: 62 species (Table 4-1) while that of Barkoissi areas present 35 species.

A total of 5960 individual were identified and measured. The frequency and specific abundances are unevenly distributed and vary from one species to another. Thus the linear regression between the two variables is less significant (r^2 = 0.476) and shows as a whole that the most frequent species are the least abundant (Figure 4.2). The concerned species are: *C. glutinosum, P. erinaceus*, *Sclerocarya birrea* and *V. paradoxa.* At 5% level of significance for the relative and abundances frequencies, *A. leiocarpus* is the most frequent and most abundant species followed by *C. glutinosum*.

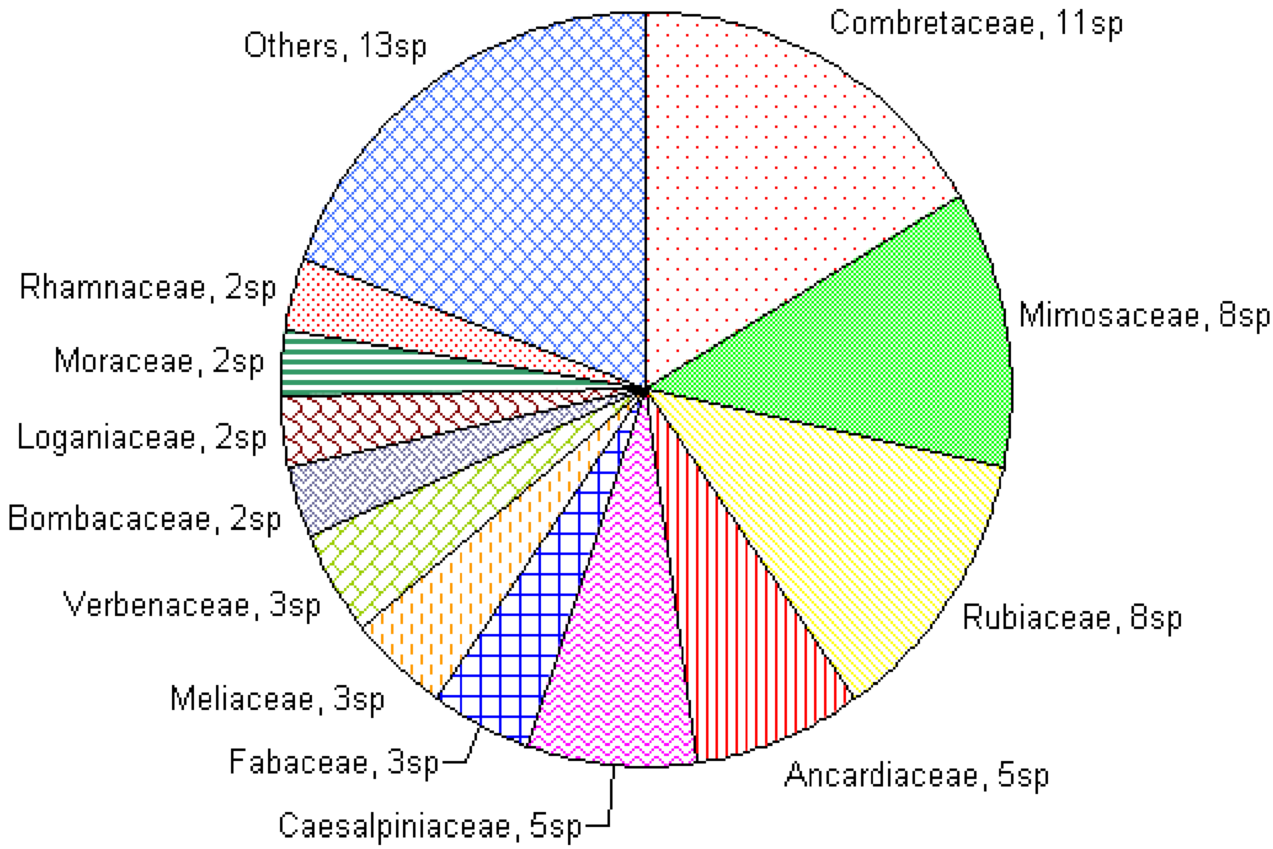


Figure 4-1: Specific spectra of families

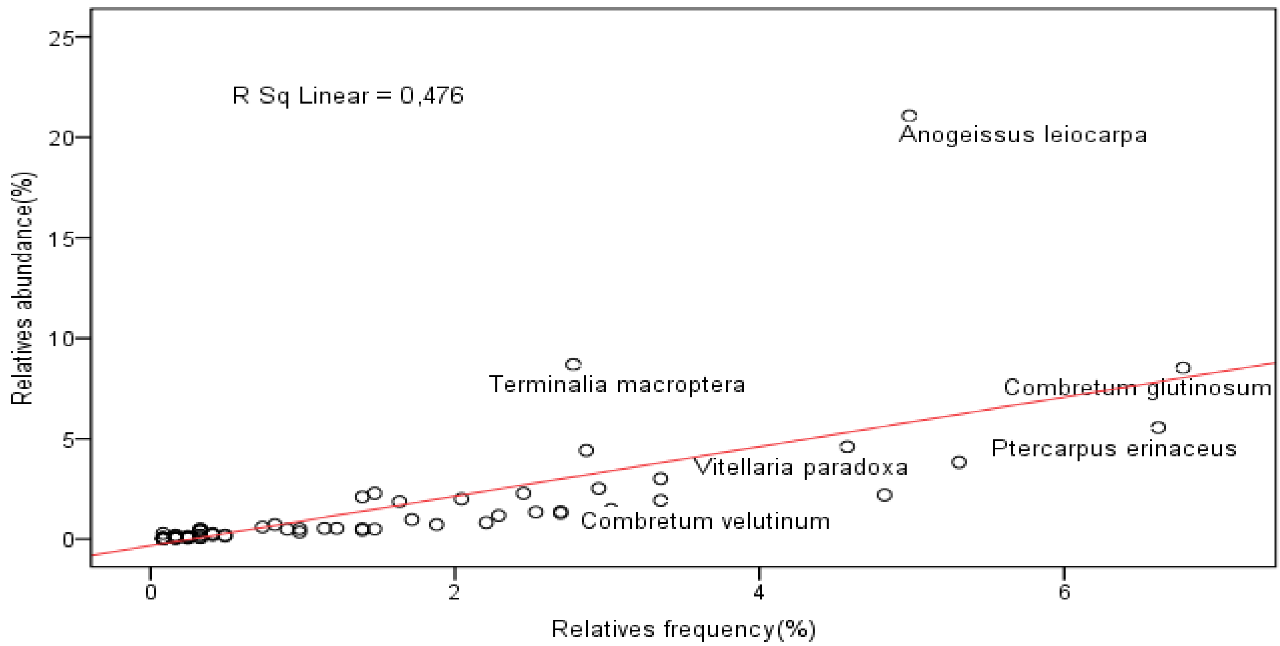


Figure 4-2: Relationship between frequencies and specific abundances

Table 4-1: Floristic balance of the three protected areas

	Family	Genera	Species
Barkossi	15	28	35
Galangashi	24	44	62
Oti-Kéran	25	43	62

4.3.1.2 Phytogeographical affinity and life forms

The Sudano-Zambezian (41.79%), Sudanian (16.41%), Afro-Tropical (10.44%) and Pluri-regional in Africa (10.44%) species are the dominant species types in the wooded community (Figure 4-3). The Sudano-Guinean (5.97%), Guineo-Congolian (4.47%), Paleo-tropical (4.47%) and Pantropical (4.47%) species have a similar distribution. As a whole 91.05% of species have an affinity for the African zone.

The trees species in the landscape is dominated by micro-phanerophytes (48.52%) followed by the meso-phanerophytes (32.35%) and nano-phanerophytes (19.11%). The lack of mega-phanerophytes was observed (Figure 4-4). The predominance of shrub and tree savannas explains the high rates of micro-phanerophytes whose heights in the field ranged between 2 and

10m. The absence of the mega-phanerophytes is due to the insufficiency of the ecological conditions which enables them to thrive.

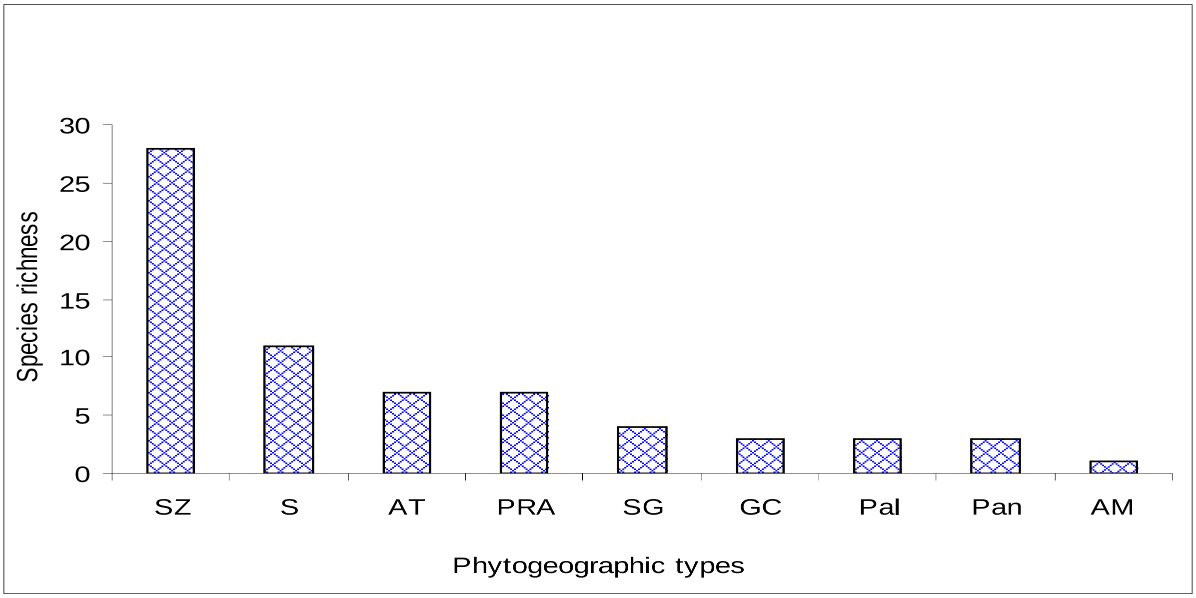


Figure 4-3: Overall frequency distribution of phytogeographic types of the wooded vegetation.(SZ :Sudano-Zambezian :Sudanian, AT : Afro-Tropical, PRA : Pluri Regional in Africa, SG :Sudano-Guinean,GC :Guineo-Congolian, Pal :Paleo-Tropical, Pan :Pantropical and AM :Afro-Malgash).

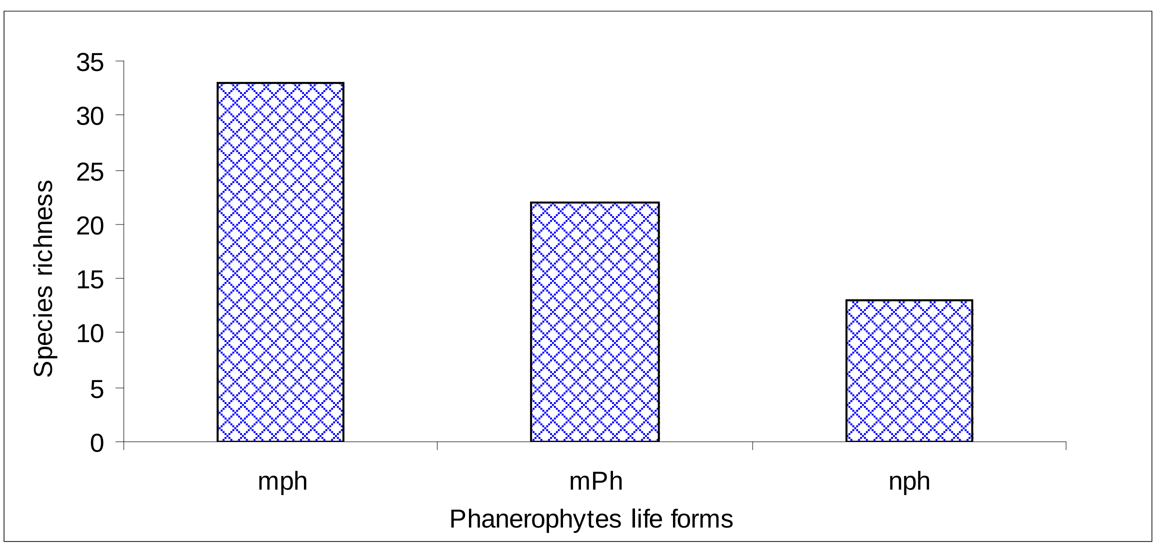


Figure 4-4: Frequency distribution of phanerophytes life forms of wooded vegetation (mph: micro-phanerophytes, mPh: meso-phanerophytes, nph: nano-phanerophytes).

4.3.2 Ordination of the samples in direct gradients.

In the factorial plan formed by axis 1 and 3 (Figure 4-5) the canonical axis of the ecological variables are represented in red. The first four canonical axis express 83.9% of the variance of the relation between the species and the environmental factors (Table 4-2). The test of Mont Carlo for 999 permutations of the Eigenvalues for the four axis is significant (F = 4.77; p = 0.001).

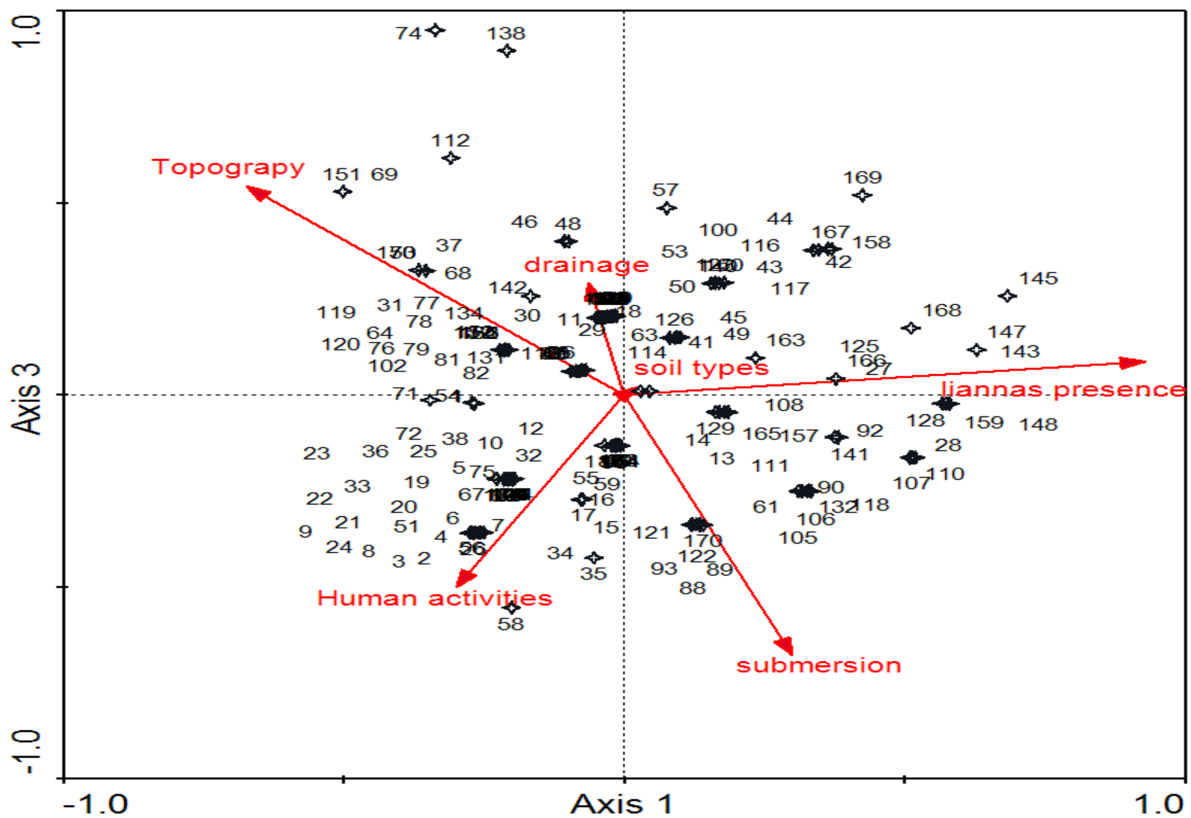


Figure 4-5: CCA ordination of 170 samples in factorial axis 1 and 3

Table 4-2: Statistical synthesis of ordination in direct gradient of the 170 samples

Axes	1	2	3	4	Total inertia
Eigenvalues	0.235	0.099	0.091	0.073	8.266
Species-environment (sp-env) correlations	0.761	0.691	0.653	0.632	
Cumulative % variance sp-env.	39.6	56.3	71.6	83.9	

The anthropogenous activities and submersion are strongly correlated with the ordination axis 1 which expressed the ground gradient. The canonical axis of these two variables are opposed in the factorial plan because the nature of the soils in the region used for agricultural practices is dregs to its submersion state. Along the axis 1 the samples are distributed from the most disturbed and opened to the closest one (Figure 4-5). The first half of this axis is occupied essentially by shrubby savanna and the second by dry forest and riparian forest which is confirmed by the high correlation of lianas presence. The canonical axis presence of the vine is correlated to that of topography. Therefore the abundance of the lianas depends on this environmental variable. The formations rich in vine species are located at low topographic state and become impoverished in those plants as topography is high.

The axis 3 expressed the gradient of ground moisture where the canonical axis of drainage and submersion are opposed but those of human activities and topography are well correlated. This axis discriminated the samples with good conditions of drainage and fewer used for croplands in the top. The bottom is occupied by more humid samples with good edaphic conditions that confirm the orientation of human activities canonical axis. Soil type variable is very lees correlated and showed that, the region under dry climate the moisture remain the factor which determines plant distribution in the landscape.

4.3.3 Individualization and description of plant communities in protected areas.

The hierarchical clustering of the 24 samples of Barkoissi PA allows differentiation of in 3 plant communities (Figure 4-6). In these 3 groupings the species *V. paradoxa* appears to be the indicator species of second order and shows the anthropic character of this reserve in which agroforestry practices are recurrent. That of the 36 samples of the protected area of Galangashi also allows discrimination of 3 plant communities (Figure 4-7). Unlike the Barkossi PA, it contains almost no shrubby savanna. This protected area contains much closed formation and its western part near Ghana is dominated by flooded plant formations. For the Oti-Keran PA the clustering shows 6 woody plant communities (Figure 4-8). These communities are mosaic and are presented by principal vegetation types of tropical area. The Table 4-3 summaries all of the plant communities discriminated with their characteristic parameters.

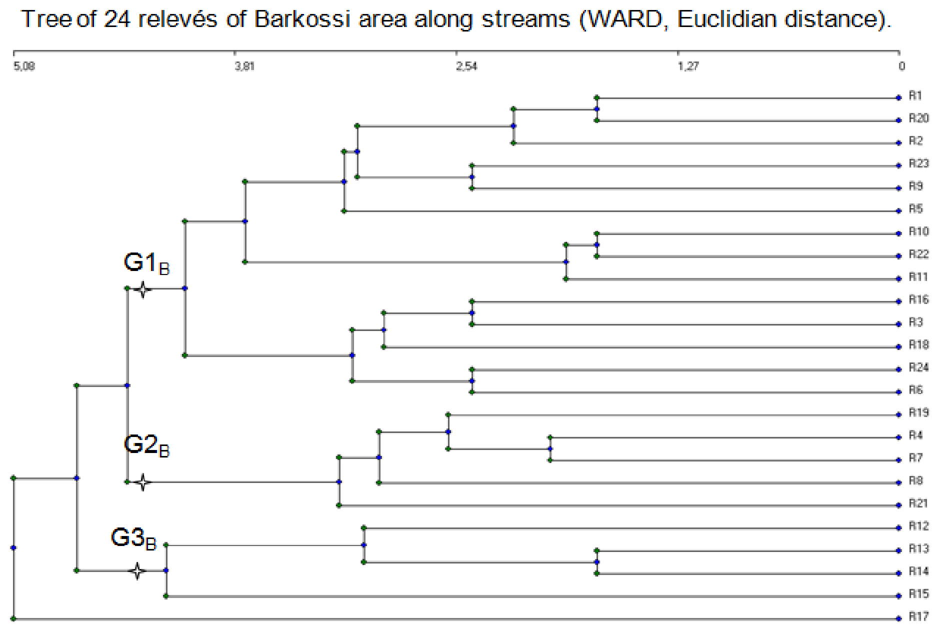


Figure 4-6: Dendrogram of 24 samples of Barkoissi area showing 3 plant communities (G1$_B$: *Terminalia macroptera* and *Vitellaria paradoxa*, G2$_B$: *Detarium microcarpum* and *Vitellaria paradoxa*, G3$_B$: *Anogeissus leiocarpus* and *Vitellaria paradoxa*)

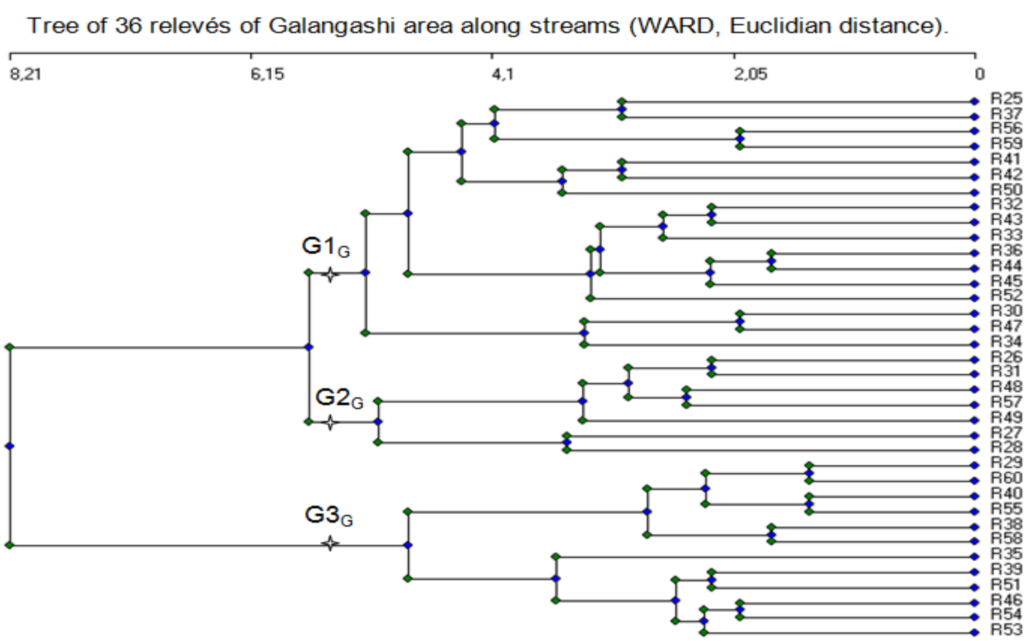


Figure 4-7: Dendrogram of 36 samples of Galangashi area showing 3 plant communities (G1$_G$: *Anogeissus leiocarpus* and *Vitellaria paradoxa*, G2$_G$: *Anogeissus leiocarpus* and *Pterocarpus erinaceus*, G3$_G$: *Pseudocedrela kotschyi* and *Gardenia ternifolia*).

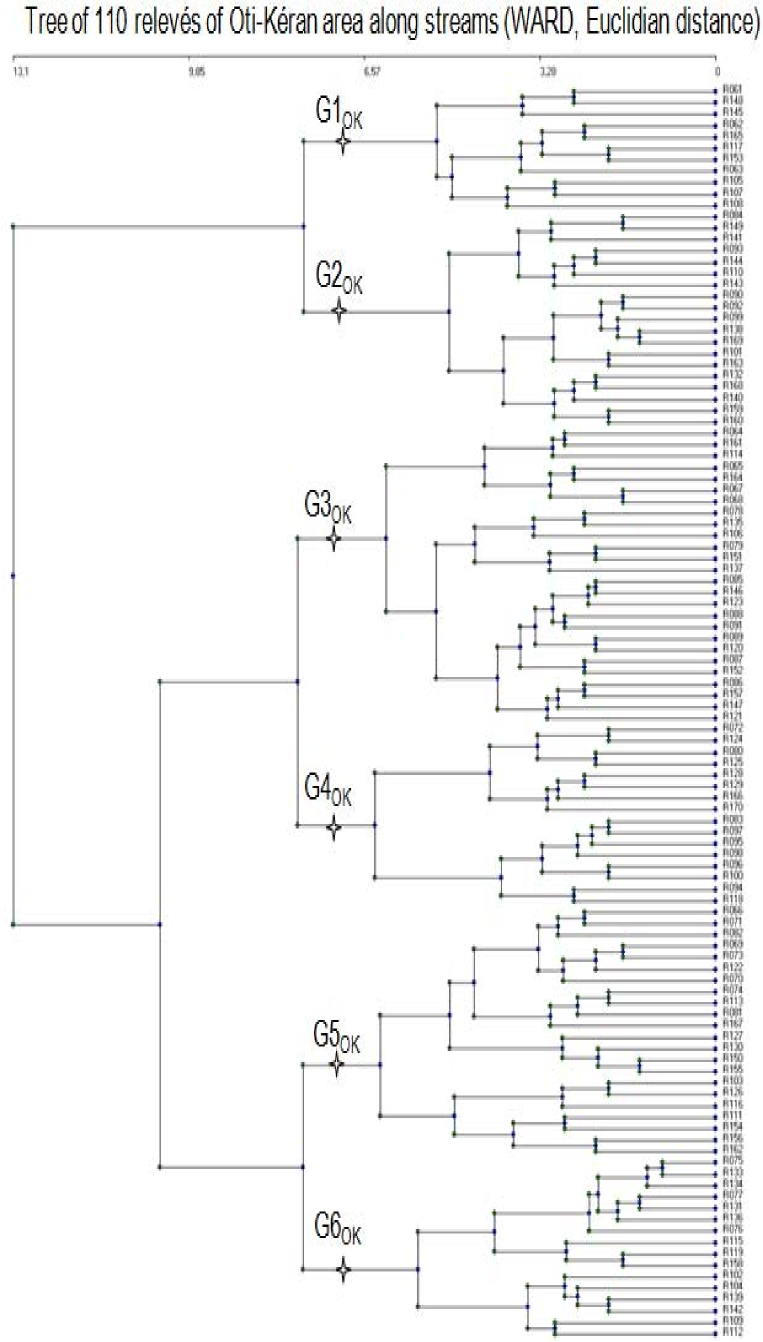


Figure 4-8: Dendrogram of 110 samples of Oti-Keran area showing 6 plant communities ($G1_{OK}$: *Terminalia macroptera* and *Mitragyna inermis,* $G2_{OK}$: *Anogeissus leiocarpus* and *Pterocarpus erinaceus,* $G3_{OK}$: *Combretum glutinosum* and *Sclerocarya birrea,* $G4_{OK}$: *Pterocarpus erinaceus* and *Anogeissus leiocarpus,* $G5_{OK}$: *Combretum glutinosum* and *Detarium microcarpum*, $G6_{OK}$: *Combretum glutinosum* and *Terminalia macroptera*).

Table 4-3: Synoptic views of synthetic and analytic results of the overall plants communities

PC	S	H ‘	E	Hm	Dm	G	D_{10}	AS
$G1_B$	26	3.01±0.08	0.64±0.003	2.97±0.092	8.50±0.28	2.96±0.0004	347.62±4.84	*Terminalia macroptera, Vitellaria paradoxa, Piliostigma thoningii*
$G2_B$	19	3.03±0.02	0.71±0.005	3.14±0.11	9.83±0.38	5.81±0.0004	553.33±6.04	*Detarium microcarpum, V. paradoxa, Terminalia macroptera, S. birrea*
$G3_B$	27	3.81±0.019	0.80±0.004	6.54±0.30	14.93±0.73	9.40±0.0027	382.22±3.32	*Anogeissus leiocarpus, Vitellaria paradoxa, S. birrea, G. erubescens*
$G1_G$	39	2.49±0.011	0.49±0.002	9.42±0.15	20.62±0.37	27.01±0.003	661.44±8.63	*A. leiocarpus, V.paradoxa, P. thonningii, C. glutinosum, T. laxiflora*
$G2_G$	30	3.98±0.01	0.81±0.003	6.24±0.26	16.85±0.83	12.22±0.003	353.97±2.12	*A. leiocarpus, Pterocarpus erinaceus, V. paradoxa, Strychnos spinosa*
$G3_G$	18	3.36±0.01	0.80±0.004	5.28±0.15	14.89±0.56	11.27±0.002	398.15±2.67	*Pseudocedrela kotschyi, G. ternifolia, T. laxiflora, C. glutinosum*
$G1_{OK}$	34	4.40±0.01	0.86±0.002	7.07±0.32	22.64±1.75	53.08±0.025	395.96±1.40	*T. macroptera, Mitragyna inermis, P. erinaceus, Vitex doniana*
$G2_{OK}$	29	2.76±0.01	0.56±0.002	7.77±0.38	17.30±0.53	21.50±0.16	513.67±4.38	*A.leiocarpus, P. erinaceus, M. inermis, N. latifolia, Daniellia oliveri*
$G3_{OK}$	40	4.46±0.011	0.83±0.002	6.22±0.20	13.82±0.41	18.75±0.13	328.20±1.16	*C. glutinosum, S. birrea, P. erinaceus, Acacia gourmaensis*
$G4_{OK}$	31	3.87±0.012	0.78±0.002	6.94±0.29	14.75±0.50	11.68±0.21	325.56±1.56	*P. erinaceus, A. leiocarpus, V. paradoxa, C. glutinosum*
$G5_{OK}$	38	4.39±0.001	0.83±0.002	4.21±0.22	10.11±0.36	6.12±0.0019	262.12±0.99	*C. glutinosum, D. microcarpum, P. suberosa, G. ternifolia*
$G6_{OK}$	28	3.40±0.013	0.70±0.002	3.75±0.18	8.88±0.36	8.37±0.14	477.77±2.72	*C. glutinosum. T.laxiflora, T.macroptera, A.leiocarpus*

PC: Plants Communities, S: Species richness, H’: Index of Shannon (*bits*), E: Evenness of Pielou, Hm: average height (*m*), Dm (for DBH≥10 *cm*): average diameter (*Cm*), G: basal area (m^2/ha), D_{10}: density (*Ni/ha*), AS: Abundant Species

Table 4-4: Homogeneous groups established using the Newman Keuls test at 5%.

	Homogeneous groups				
Plant community	Specific richness (S)	Density (D10)	Tree height (Hm)	Tree diameter (Dm)	Basal areas (G)
$G1_B$	B	B	A	A	A
$G2_B$	A	C	A	A	A
$G3_B$	B	B	B	B	A
$G1_G$	C	D	C	C	C
$G2_G$	B	B	B	C	B
$G3_G$	A	B	B	B	B
$G1_{OK}$	B	B	B	C	D
$G2_{OK}$	B	C	B	C	C
$G3_{OK}$	B	B	B	B	B
$G4_{OK}$	B	B	B	B	B
$G5_{OK}$	C	A	A	A	A
$G6_{OK}$	B	C	A	A	B

Nb: Groups with the same letter have no significant difference.

4.3.4 Demographic structure of the plant community present in the three protected areas

The comparison of the structural features' means of the discriminated plant communities (Table 4-3) is very significant. The variance analyses ANOVA associated with the post-hoc test of Newman Keuls at 5% to the threshold made it possible to establish a similarity between the groupings (Table 4-4).The *F* of Fisher calculated and *p* the alpha error of the various structural parameters obtained after the analyses are (F = 35.53; p = 54.10^{-5}) for the diameters, (F = 55.57; p = 11.10^{-5}) for the basal area, (F = 36.58; p = 48.10^{-5}) for the height and, (F = 42.18; p = 30.10^{-5}) for the densities (Figure 4-9, 4-10, 4-11 and, 4-12).

The bars charts (Figure 4-13 a, b, c and, d) show that the diametric structure of the trees species differs from one grouping to another. Apart from woody community ($G2_{OK}$), all the others present relative high numbers of individuals within the lower diameter classes. The high proportion of juvenile individuals indicates a dynamic balance in the natural regeneration of these woody plant communities. This structure in <L> is a proof of their stability and constant regeneration over the time.

The distribution of individuals per diameter classes obeys the law of exponential, logarithmic and polynomial functions. All the diametric structure in <L> obeys and assimilates to the exponential and logarithmic functions. However the grouping $G1_G$ in it structure obey to polynomial function of order 3 and to a distribution in bell. The groups $G1_G$, $G2_G$, $G3_G$ $G2_{OK}$ and $G4_{OK}$ have a significant number of individuals within intermediate diameter classes and the higher classes. These groupings correspond to wooded savanna and to forest plant formations. Their instability may be due to human illegal activities such as agriculture and pasture. The small proportion of the lower diameter individuals may be due to selective removal by farmers to avoid invasion of the fields by the young individuals. The few individuals with high diameter values (60-70 and 90-100 cm) met in $G1_{OK}$ may reflect the contribution of favorable edaphic conditions associated with moisture conditions.

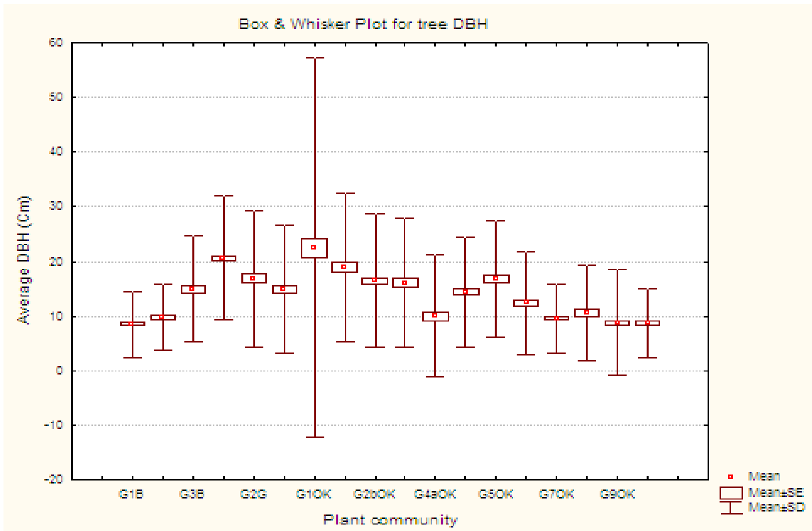


Figure 4-9: Distribution of tree DBH per plant community

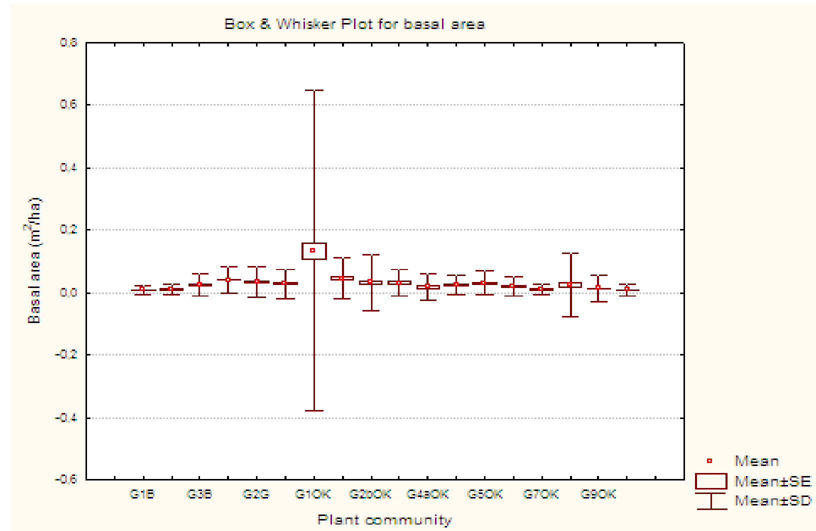


Figure 4-10: Distribution of tree basal area per plant community

Figure 4-11: Distribution of tree height per plant community

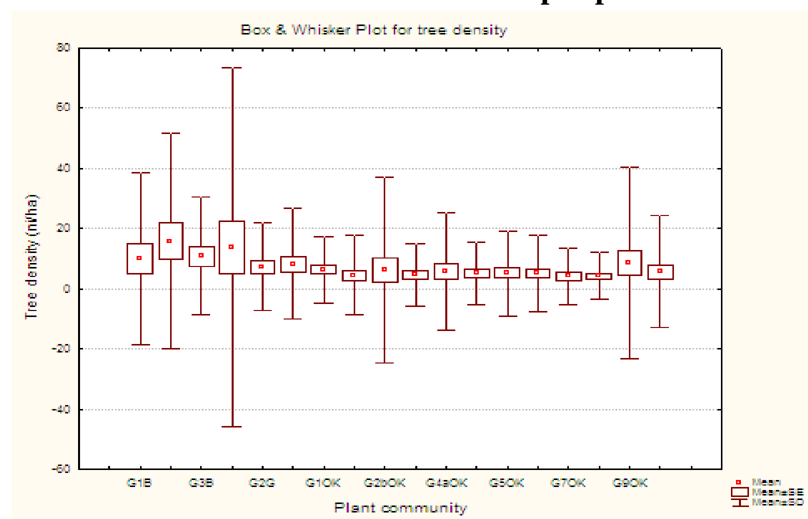
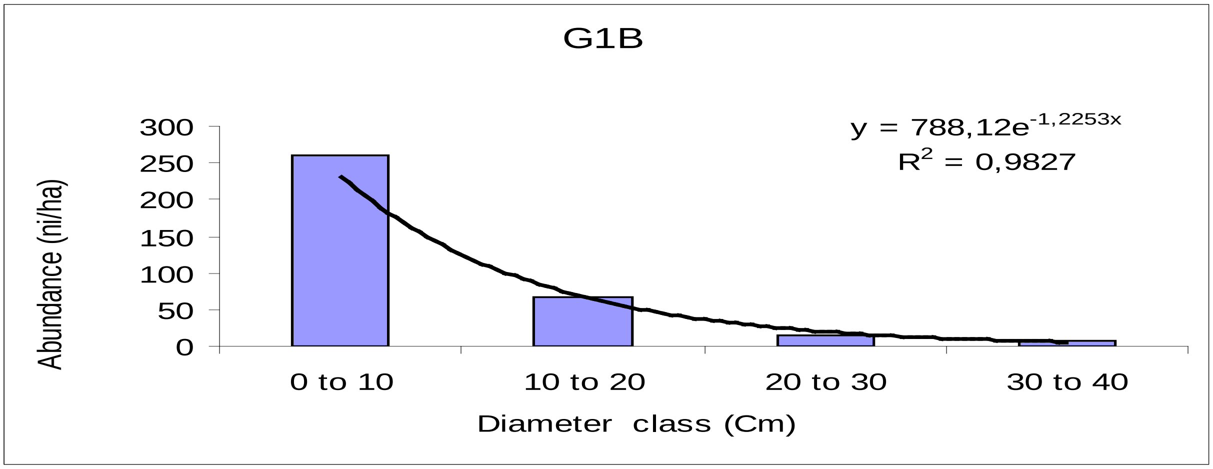
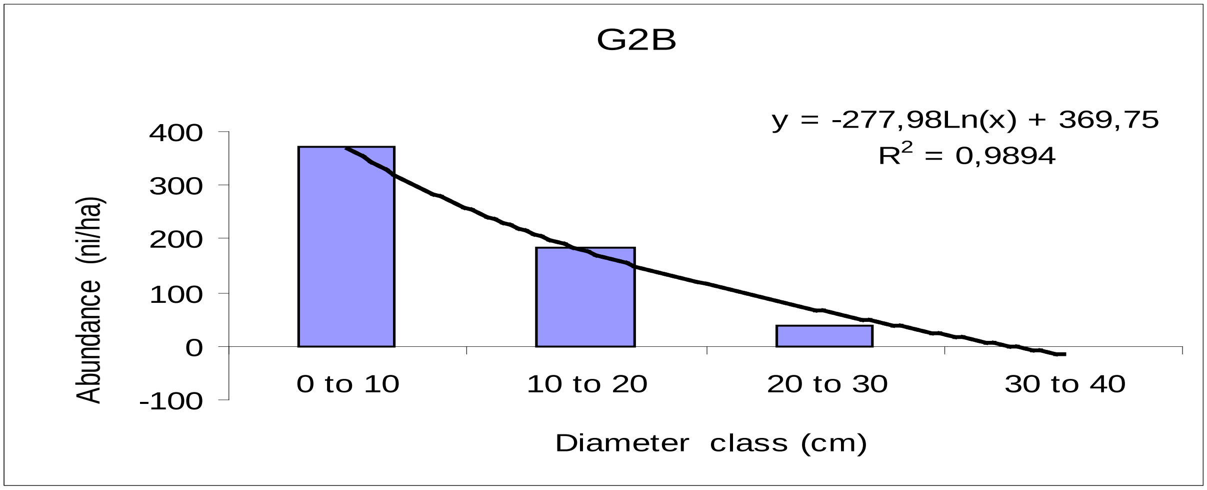


Figure 4-12: Distribution of tree density per plant community





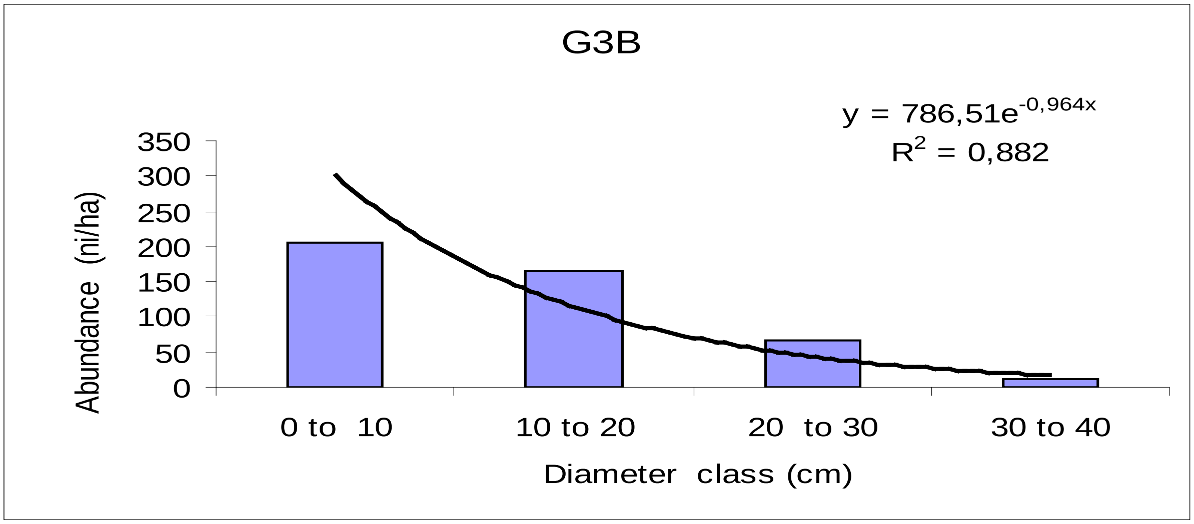
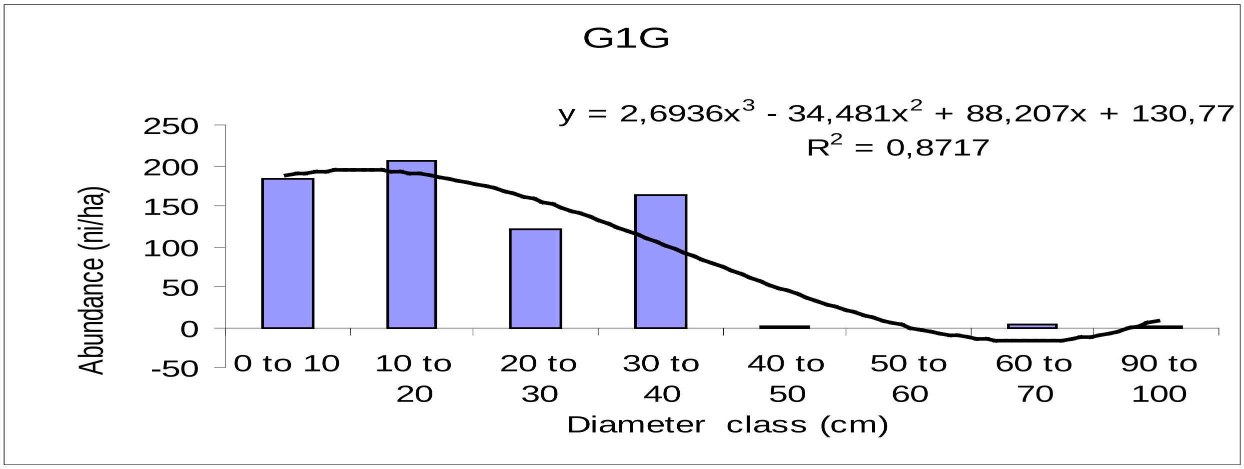
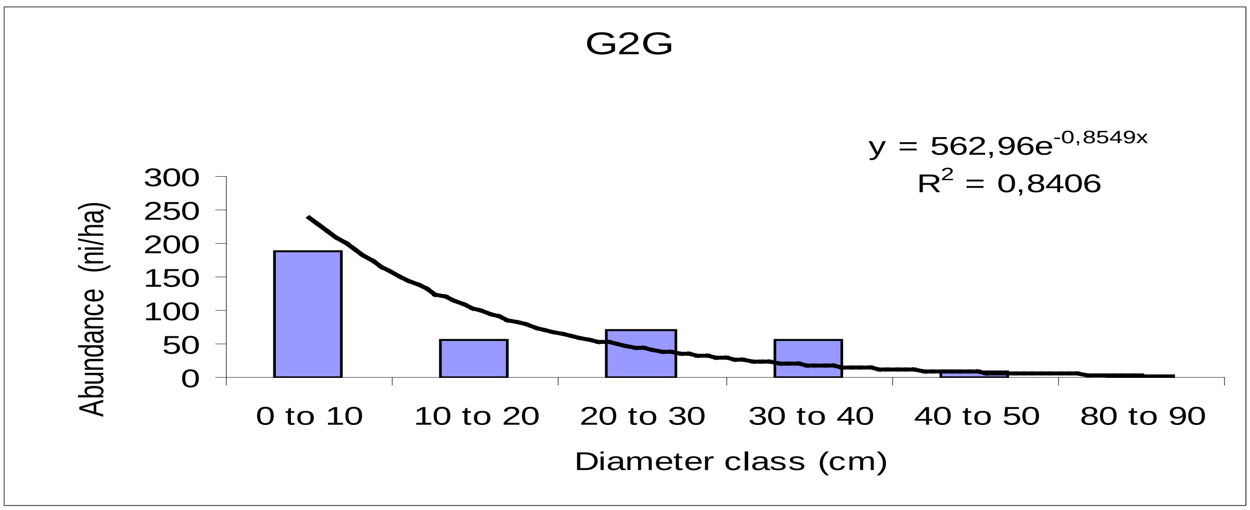


Figure 4-13a: Diameter structure of the overall plant community





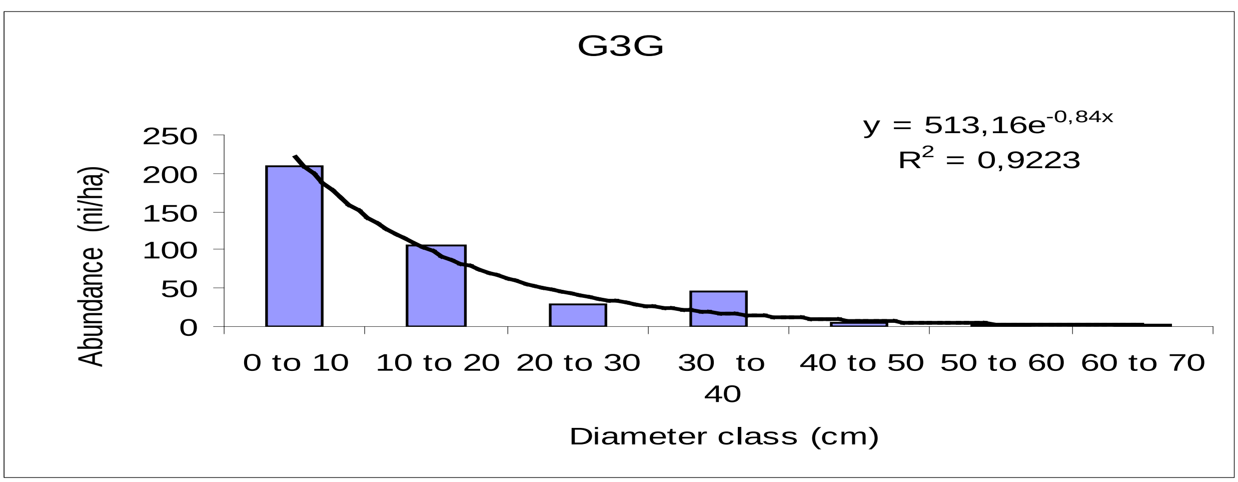
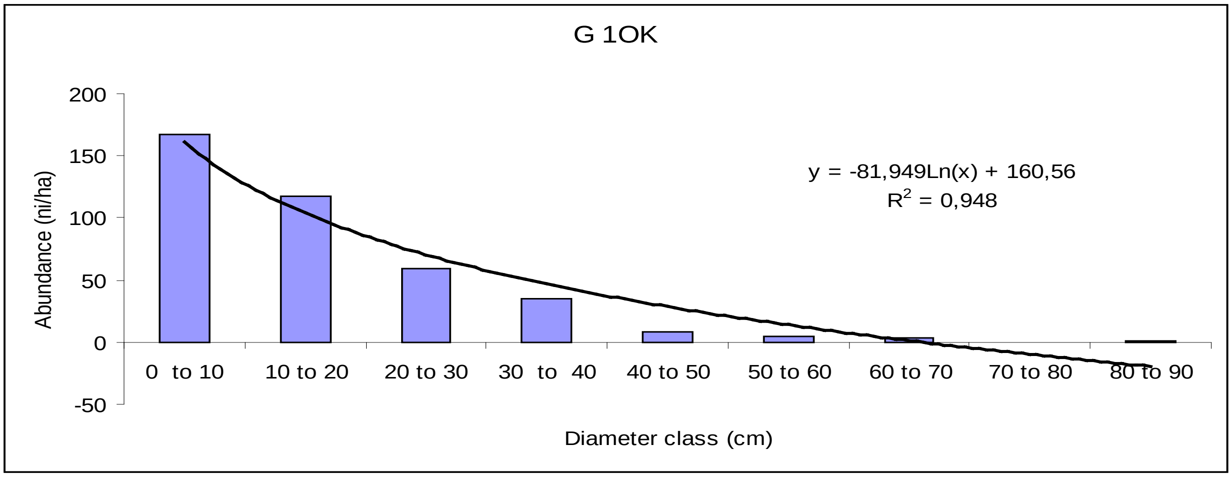
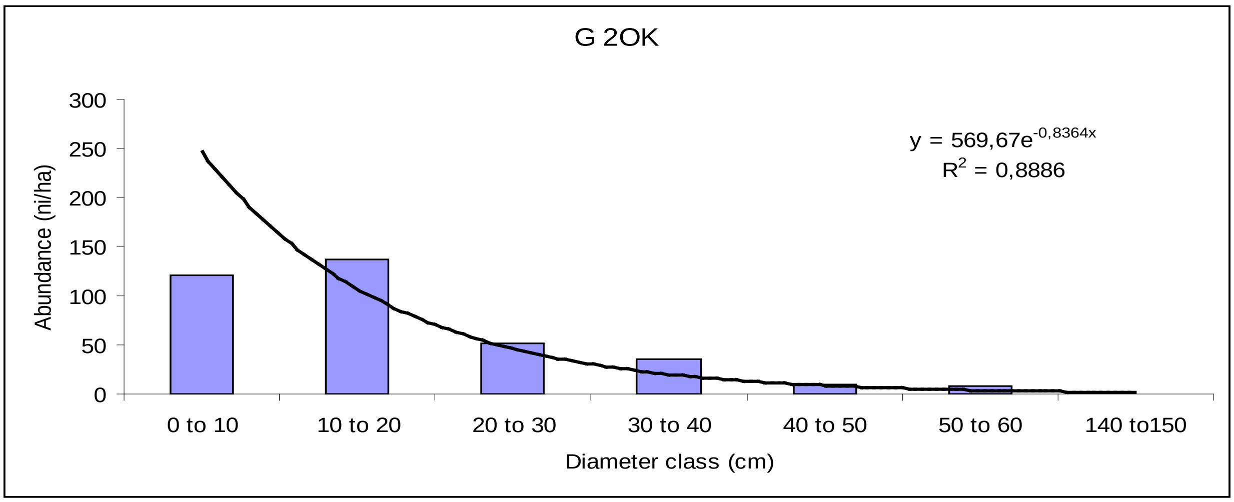


Figure 4-13b: Diameter structure of the overall plant community





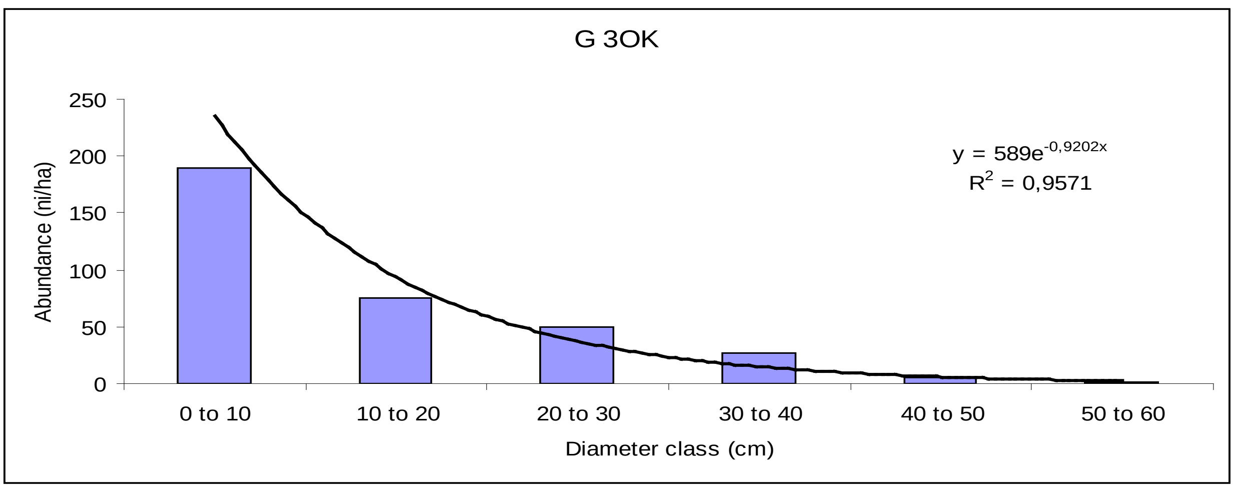
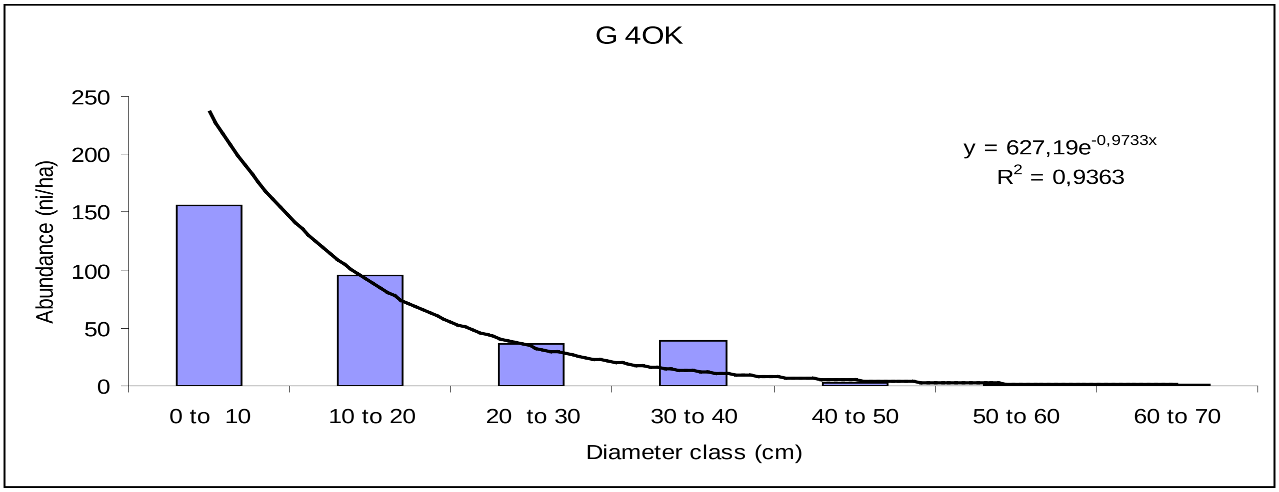
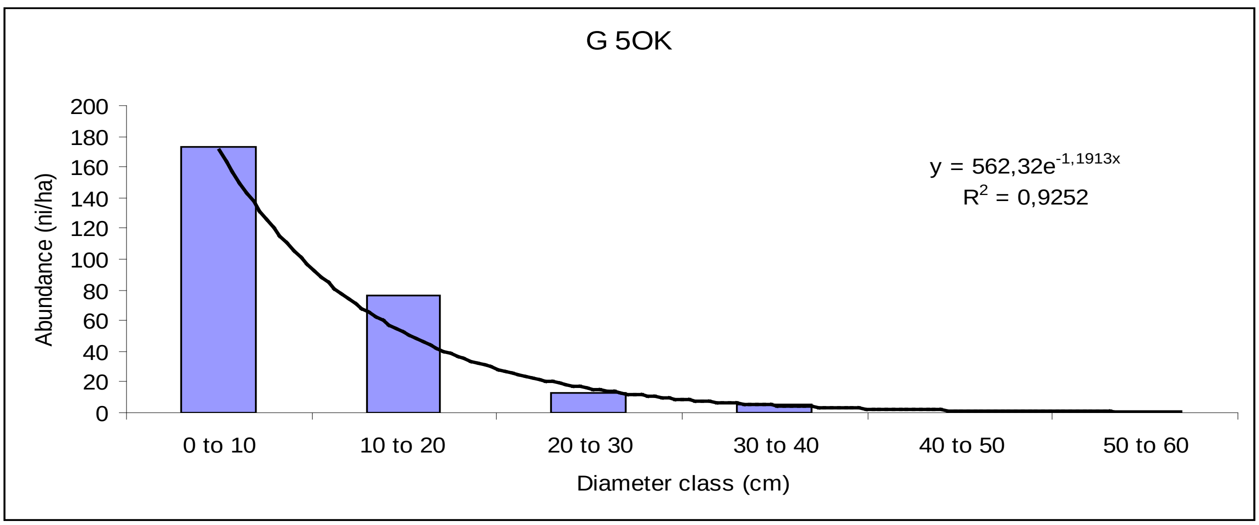


Figure 4-13c: Diameter structure of the overall plant community





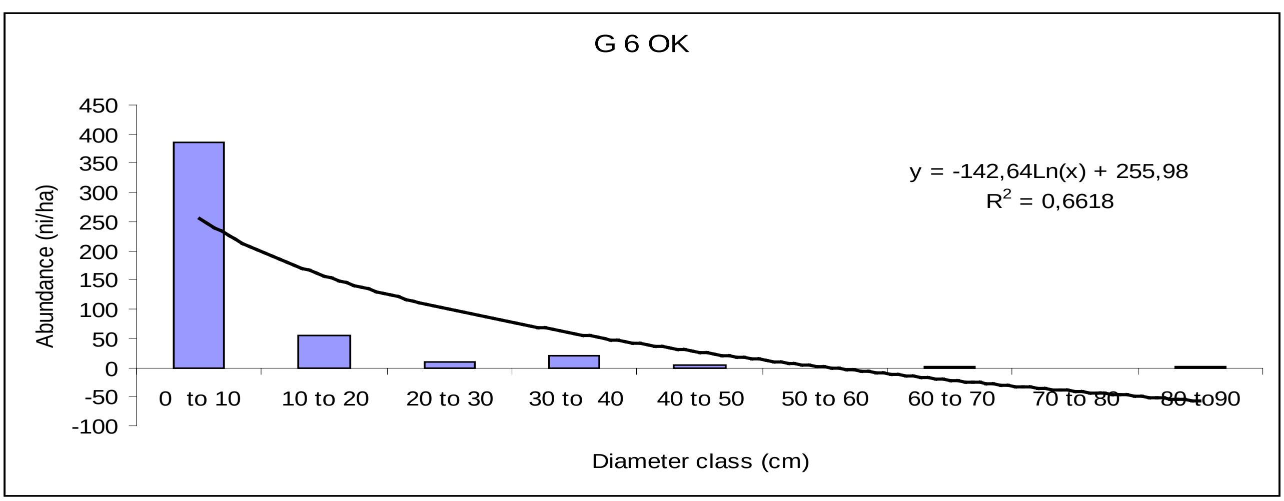


Figure 4-13d: Diameter structure of the overall plant community

4.4 DISCUSSION

4.4.1 Floristic, diversity and the phytogeographic types of the three protected areas

The three protected areas contain a total of 68 woody species. Its corresponds to 1.65% of species listed in the flora of Togo. This number is very small probably because the study only focused on the ligneous species with a circumference≥ 10cm. Moreover the sampling techniques placed a great emphasis on the anthropogenic pressures to which these protected areas are subjected. The protected area of Oti-Keran from its surface, its latitudinal position and its hydrographic network should be richer than the two others in term of species composition. But it presents the same number of species with Galangashi PA. Barkoissi and Galangashi PA have the same specific composition due to their proximity. These findings highlight the effects of human disturbances factors in the study area. Barkoissi and Oti-Keran PA are notably greatly occupied by old fallows with shrubby features and *V. paradoxa, S. birrea* fruit trees often preserved by peasants. With 62 tree species and 44 genera (Table 4.1), Galangashi PA is more diversified from a floristic point of view because, it has been redemarcated and as such it is less influenced by human action.

The investigation area is dominated by Combretaceae, Mimosaceae and Rubiaceae families. The first two are typical of woodland which grows under tropical Sudanian climate (Wala, 2004; Gondard, 1964). The significant proportion of Rubiaceae in the study zone emphasizes the existence of the forest ecological conditions because according to Aubreville (1950) Rubiaceae trees and shrub species are rainforest bio-indicators. The importance of Combretaceae and Mimosaceae indicates the existence of a drought climate (Aubreville, 1950). In this part of Togo the most frequent tree and shrub species are: *A. leiocarpus, P. erinaceus, V. paradoxa, D. microcarpum, T. laxiflora, C. glutinosum* and *E. abyssinica;* which are bio-indicators of tropical Sudanese climate (Dourma, 2008; Ouedraogo, 2006; Ouoba, 2006; Wala, 2004; White, 1986).

The three protected areas, taken individually or collectively are dominated by species characteristic of the Sudano-Zambezian and Sudanese chorological type. Similar trends were observed in the Oti-Mandouri PA (Dimobe, 2008) and in Burkina Faso (Ouedraogo, 2006).

4.4.2 Plants communities and ecological gradients

Although the floristic composition determines the clustering of plant groupings, it is deeply influenced by climatic conditions and stationary ecological factors (Guo *et al.*, 2005; Hu *et al.*, 2005; Wala, 2004; Toutain, 1999). In general, soils humidity is the main gradient factor along which plant formations are discriminated. Except the impact of the climate in the determinism of the plant community, it is also necessary to underline the effect of human selective practices on species composition. This selection of species which bring about a new aspect of vegetation is strongly related to the recurrent agroforestry practices in this region. In the Barkoissi PA *V. paradoxa* which is one of the two indicator species suggests that the agroforestry might have taken place in this protected area in the aftermath of the socio-political crisis in the 1990s. In overall the significant differences between the plants groupings evolving under the same climate are strongly correlated to the stationary ecological conditions (Ouedraogo, 2006; Wala, 2004; Thiombiano, 1996; Ozenda, 1982) such as topographic, edaphic, gradients.

The discriminated wooded formations in this research are almost similar to those found in the classified forest of Niangoloko in Burkina Faso (Ouoba, 2006). Nonetheless contrary to Ouoba's (2006) findings, plant groupings of the three protected areas can be grouped into shrubby and tree savannas as well as wooded savannas and dry forest. The groupings of *T. macroptera, D. microcarpum* and *C. glutinosum* correspond to the first grouping while the groups with *A. leiocarpus, P. erinaceus,* and *T. macroptera* correspond to the second. These plant communities also grow on similar conditions.

4.4.3 Structure of the plant groupings

The groupings of the wooded formations are all of a mosaic texture due to their specific richness in ligneous species. These differences in specific composition make up a structure which varies from one grouping to another. The horizontal and vertical structure showed by these plant formations is far from being only a consequence of the specific composition. It is worth noting that the average heights and diameters of these formations vary respectively between 3 and 9.5m; and between 9 and 23 cm. The ecological factors coupled with human activities play a role in the occurrence of these various structures (Dourma, 2008; Ojeda *et al*., 2000). Particularly in the study region, the human disturbances factors determine the vegetation structures caused to the sociological value attached to agroforestry practices. These practices eliminate species considered to be of less economic value by cutting and burning their juvenile and mature individuals when creating space for crops. Although species with socio-economic value like *V. paradoxa, P. biglobosa, L. microcarpum, L. acida* (Georges *et al*., 2005) are preserved, they have the lowest regeneration capacity (Georges *et al*., 2005). Agroforestry practices is common around protected areas, but it can also be observed inside the PA along with the illegal logging of high diameter class species for firewood and charcoal production. The low value of the structural and dendrometric parameters of these plant formations in particular that of shrubby and tree savannas can be related to these anthropogenic disturbances that are unceasingly increasing.

The relatively flat topography character with an average elevation of 200 m makes the study area very accessible. This easy access promotes more illegal activities (collecting and cutting wood energy, farm work, hunting), practiced by the local residents.

In addition to these activities practiced by the rural populations, it is also necessary to emphasize the effect of grazing through the transhumance activity. All these factors results in the bulk of the biodiversity being found around the hydrographic network, in the depressions where the grounds hydrous potential is important. The consisted plant formations are the groupings (Table 4.3) *A. leiocarpus*, *P. erinaceus*, *P. kotschyi* and *T. macroptera*. Their specific richness, Shannon index and Pielou evenness varied respectively between 26 and 34 species, 3.7 and, 4.4 bits; and 0.76 and 0.86. These qualitative variables show that these groups are well diversified (Wala, 2004). However, some groups like ($G1_G$), despite having a high specific richness (39 species) have the lowest alpha diversity index (2.49 bits 0.47).

The plant communities in their set shows natural characteristics (Rollet, 1974; Wala, 2004) through the decreasing distribution in function of diameter classes. According to Swaine *et al*., (1987), Wala (2004) and Dourma (2008) this distribution indicates a stability of these communities because of their strong juvenile potential.

By considering the ligneous flora of the three protected areas per vegetation type, the dry forests and wooded savannas which represent the least disturbed formations present an average of 8 species per sample ($900m^2$) with 3.36 bits and 0.70 as their respective average of Shannon and Pielou diversity indices, different to those found by Wala (2004) in the dry forests of the septentrional part of Atacora chain in Benin. The basal areas and the densities of these luxuriant

plant communities are 17 m^2/ha and 405 ni/ha, respectively which have the tendency to reflect the environments where moisture is high. These results are lower than those carried out by Biaou and Sokpon (2003) in the dry forest of Benin which are 120-500 ni/ha and 18 m^2/ha, respectively. This difference is related to the climatic and edaphic variables conditions (White, 1986). It should be noted that the dry forests of the area are dominated by *A. leiocarpus* and *P. erinaceus*.
The tree and shrubby savannas are less diversified and present low structural features. They are mainly dominated by shrubs interspersed with high tree diameter class. The diversity index and the structural characteristics within the tree savannas are superior to those of shrubby savannas. Nevertheless, certain shrubby savannas which had been fallowed have significant index of alpha diversity.

4.5 CONCLUSION

The protected areas of north Togo still remain the refuge of the biodiversity in spite of the tough ecological conditions and rough anthropogenic action they face and experience. Their plant community preserve the appearance and the structure of the formations occurring in the Sudanian climate area. The floristic and structural characteristics of the vegetation reflect the impact of bordering populations. The anthropogenic gradient decreases from the edge of the reserves towards the inner core, the rivers and the marshy zones. The major factor determining the diversity and trees structure is moisture. The higher this gradient is, the more closed vegetation structure shows. The phytogeographical types dominating these ecosystems are the Sudano-Zambezian and Sudanian species and these ligneous species accomplish multiple function. Today the agents of nature conservations try to reduce, through multiple actions, the human originated disturbances. The land crisis due to population growth has led the authorities to negotiate with the bordering populations to redesign the boundaries of the PA. This participative approach must take into account, on one hand, the need to safeguard and restore diversity, on the other hand, the incentives to encourage the population, to take part in the protection and conservation of these last sanctuaries of diversity.

CHAPTER 5 - ASSESSMENT AND IMPACT OF ANTHROPOGENOUS DISTURBANCES FACTOR IN NORTHERN TOGO PROTECTED AREAS

5.1 INTRODUCTION

Most of the ecosystems, terrestrial as marine of the world are faced to disturbances, which caused serious damage and change in their landscape (Breininger *et al*., 2010). The disturbances almost establish the vegetation patterns and the spatial patterns of many ecosystems (Turner, 2010); certain of them have the possibility to maintain landscape ecology (Odion and Sarr, 2007). These disturbances involve not only the natural one but also the anthropogenic perturbation too.

Today, forest and savanna ecosystems under the Sudanian tropical climate are much subjected to anthropogenous disturbances. The droughts of the last decade also increase the pressures of people on natural and preserve ecosystems (Yvon-Carmen, 2008; Breman and Kessler, 1995; Collins, 1990).

However, Togo is far to be a forest country as Ghana, Cote d'Ivoire and Guinea in West Africa sub region (White, 1986); its natural forest area include protected areas decrease about 26% since the forest biomass area (2 550 000 ha) was estimated in 1979 (Sessi, 2001). The following factor was previously listed to the cause of this reduction, itinerant farming on slash burn, pasture and transhumance, bush fire, protected areas invasion (Nacoulma *et al.*, 2011; Pare *et al.*, 2010). Outward the above mentioned disturbance, poaching, over exploitation of rivers fishery resources, trees cutting, plant organ harvest and fruit collect also disturb the integrity of these ecosystem especially, the protected areas of the most drought part of Togo (Folega *et al*., 2011).

Actually, the protection and the restoration of the protected areas which are perpetually subjected to the anthropogenous activities become the preoccupation of the planer. This preoccupation was clearly expressed by the decree N° 2003-237/PR of September 26, 2003 and the decree 005/MERF/CAB/SG/DFC of May 21, 2004 respectively about the establishment of standard framework for protected area management and, the requalification and redemarcation of protected areas (IUCN/PACO, 2008).

The achievement of these legal dispositions cannot be a success even some objective scientific research was not done in order to collect data about fauna and flora diversity, ecology community, landscape ecology and the assessment of disturbances, particularly those caused by local and bordering people of the protected areas.

This paper is a part of the research focus on Togo Northern protected areas. Its aims to assess the main anthropogenous activities present in these protected areas. It's also has the purpose to determine the relation between the disturbances and their drought environment.

5.2 MATERIALS AND METHODS

5.2.1 Study area

The survey area covers the protected areas of Barkoissi, Galangashi and Oti-Keran. The study area is mainly localizing in the region des Savanes (North Togo). Both; they were respectively gazette as protected areas in 01/01/1954, 14/09/1954 and 28/09/1950. The area concerned the limit of the years of their classification (Sournia *et al*., 1998) and covered 2000 ha for Barkoissi, 7500 ha for Galangashi and 163640 ha for Oti-Keran.

These protected areas are situated in eco-floristic zone 1 or northern plain (Ern, 1979) .They are located between 11° and 10° of northern latitude and between 0° and 1° of eastern longitude (Figure 1-1 to 1-11). The main relief of the investigation area is formed by a vast plain, which is dominated by tropical leached ferruginous soils covering a cuirass. The study area is drained by two famous rivers, Oti and Koumongou. The region has a Sudanese tropical climate marked by the alternation of a long dry season (Yema *et al*., 1981). Heavy rains occur in August (Moussa, 2008) .The rainfall oscillates around 1058.9 mm per year. Temperatures vary between 20°C and 35°C while the annual average is 28.5°C for Mango meteorological station (Moussa, 2008).

The region faced to a strong anthropogenic influence on vegetation. The major human activities around the protected areas are agriculture, firewood collection and initiation of bush fires during the dry season. These activities are well present in the protected areas and denote their level of disturbance. The main crops species are millet, sorghum, groundnuts, maize, cowpeas, and yams. Livestock include caprine, sheep, and poultries. The zone is also face to the transhumance which implied it availability to produce more bovine. On national plan the region is the first provider in term animal protein.

The principal ethnic groups living in and around the study area include the following: Ngamgam, Tchokossi, Tamberma, Lamba, Moba, Gnande, Mossi, and Fulani.

5.2.2 Disturbance factor data collection and analysis

The disturbance factors, mainly those from anthropogenous activities were collected through the sampling method. Before the field work, the potential areas to be much disturbed were identified on Landsat ETM+ 2007 image and on Google earth online resources. The investigations were more oriented on shrubby savanna and old fallows presented in these protected areas. The sampling method was base on phytosociology one. The samples of 900m^2 were placed at every 100m along the transects previously defined for floristic data investigation. The data collection was more qualitatively and was bound on field observations. In that regards the following disturbances were recorded in presence/absence in each sample: plant cutting, pasture, bush fire, charcoal production, plant organs harvest, transhumance, farming, hunting and honey harvest.

In order to understand well the presence of a kind disturbance in a given sample, it ecological features was also recorded. Among these, edaphic variables (structure and texture of the soil); topographic attributes (plateau, slope, versant, valley and bank), soil submersion /immersion were retained. In addition the vegetation type and the frequent plant species in the samples were also noted without their GPS position and photographs.

In whole, the anthropogenous disturbances factors were collected via 170 samples installed during rainy season (2009) and the 50 samples installed during the dry season (2011) in the three protected areas.

To complete the assessment of these factors questionary about the main activities practices, the opinion about the protected areas was subjected to bordering people met in the study areas. No particular criteria on sex, age, was defined to oriented this investigation but discussion in group of individual was much preferred than questioning an individual. Totally 85 persons were met and questioned in the study areas and at it edge. Among them, questionary was mainly held in focus group. In whole two individuals and eight focuses group were subjected to the investigation.

The data analysis and processing was almost numerical. In that regard a matrix consist of seven disturbances factors and 220 samples was created. From this matrix several analysis were done in order to determine the relation between factors and the environment in which they were found. Among them, the disturbances frequency of appearance, their descriptive statistics and factor analysis were used. To achieve these analyses the Statistica 7 software was use in all stage.

5.3 RESULTS

5.3.1 Anthropogenous disturbance factor evaluation

Among the eight variables identified to be disturbances factors, three of them represent more than 90% of the disturbances. The pasture dominated by the transhumance representing 31.88%, is followed by plants cutting (30.35%), and bush fire (30.13%) (Figure 5-1).

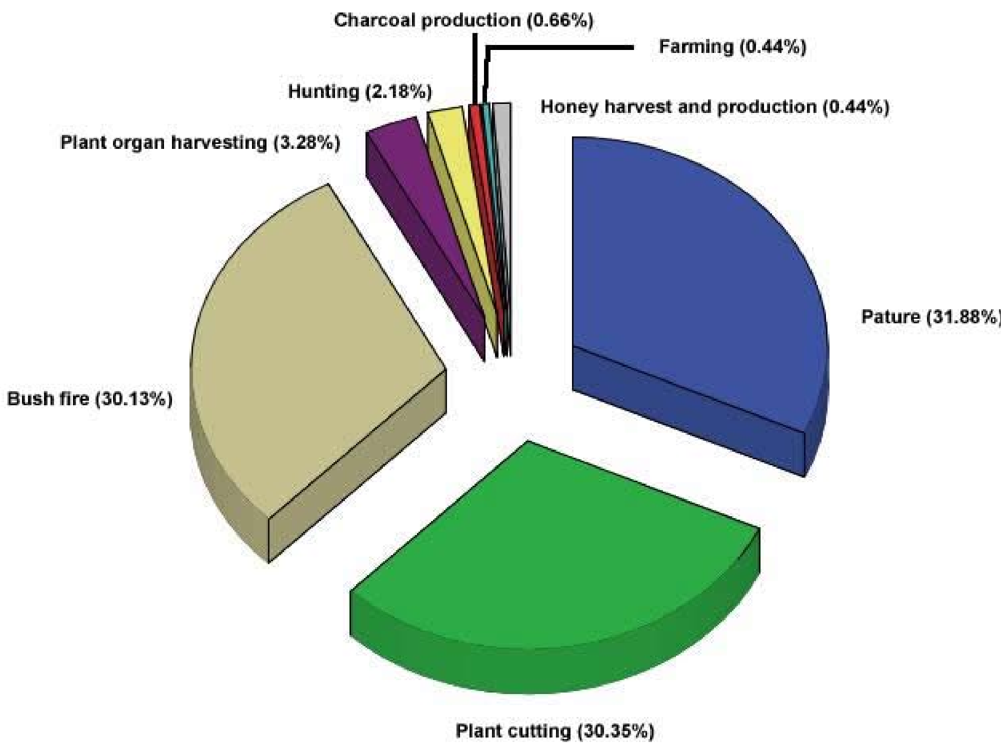


Figure 5-1: Disturbances frequencies distribution

The remains factors represent less than 9% of their distribution frequency.

Through the t-test graph (Figure 5-2), it is possible to get the central tendency of each factor of disturbance. Form the median position of bush fire, plants cutting and pasture factor that is possible to denote a symmetric distribution of the three variables. In the same way the length of their standard deviation express well a regular dispersion around the means. However, the plants organs harvesting and hunting standard deviation are also well symmetric and well disperse around their means, their parameters are lesser than those of bush fire, plants cutting and pasture; but higher than those of charcoal production and farming.

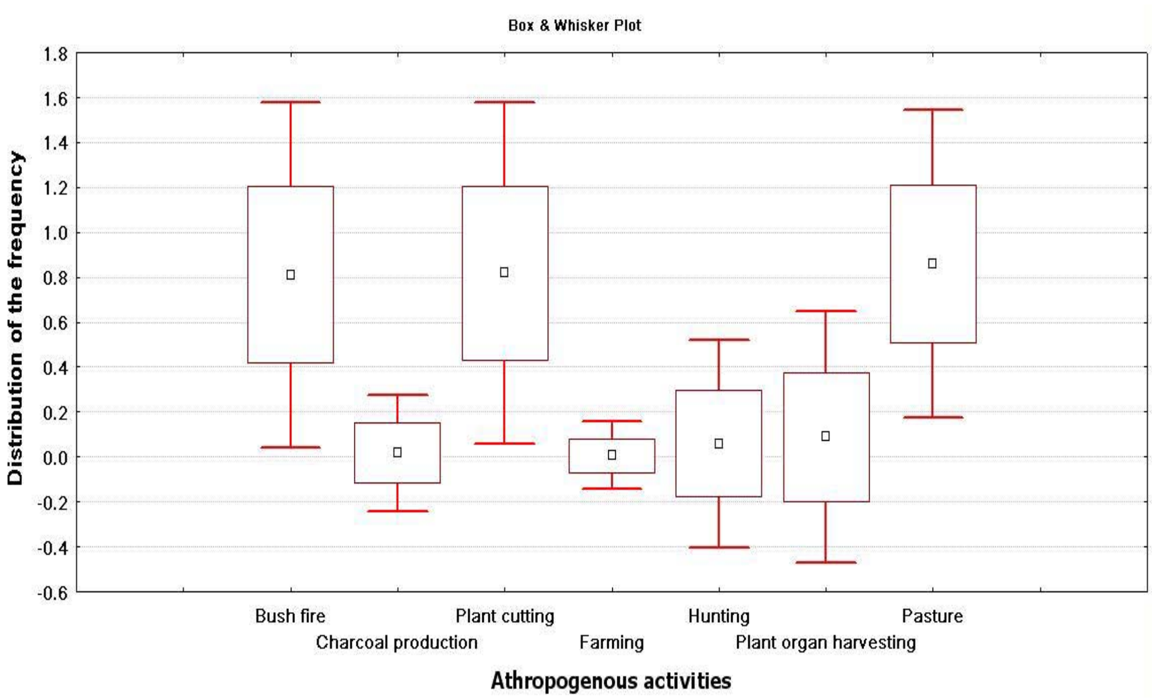


Figure 5-2: Comparison of the disturbance factors means

The Figure 5-3 shows the distribution of the disturbances per ecosystem. Among the ecosystem investigated, the shrubby savannas followed by the wooded savanna are very disturbed. In these two areas both of the disturbance factors were presented, but bush fire, plants cutting and pasture are the most frequent ones which cause more the destabilization of the ecology landscape. The dry and riparian forest are also disturbed, but in few dimension. The frequent disturbance factor met pasture, plant cutting, charcoal production and plant organ harvesting. The hunting is more visible in the shrubby and wooded savanna while the fishing is remarked along the rivers of the riparian plant formations (Photo 8 and 9).

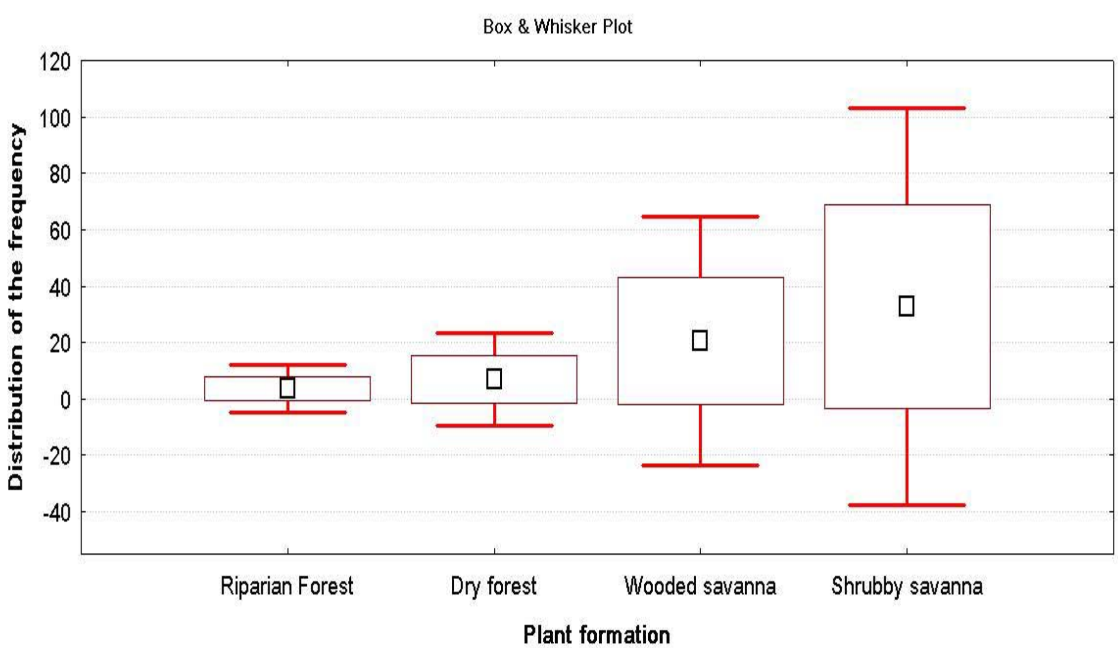


Figure 5-3: Distribution of major anthropogenous disturbances per plant formation

The Figure 5-4 shows the relationships and the variability among the disturbances factors. The Kaiser-Meyer-Olkin (KMO) measure is equal to 0.64. It indicates the adequacy of sampling and the appropriateness of factor analysis. Base on Kaiser Criterion (1960) and screen test, three factors present an initial eigenvalue ≥1 .The value is 2.21 for the first factor; however, it is respectively equal to 1.34 and 1.00 for the second and the third factor. The first two factors which explained 50.84 % of total variance is quietly sufficient to compare the seven variables distribution in the study area and their impact on it. Few variables are correlate to the factor 1, these variables concern farming (-0.046) and hunting (0.079). This factor axe is lesser correlate to the seven variables than the second factor axe (Figure 5-4). Most of the variables are correlated to factor 2, among them bush fire (0.00092), plant cutting (0.06218) and pasture (-0.15284) the higher ones. The cluster of these three variables along the factor 2 may be due to their presence in most of the samples. The plant organ harvesting and the charcoal production are much link to plant cutting and in few rates to bush fire; that also explain also, why they are correlate to the factor 2 axe. Once again the fire, grazing and cutting seem to be the important and recurrent disturbance in this drought area.

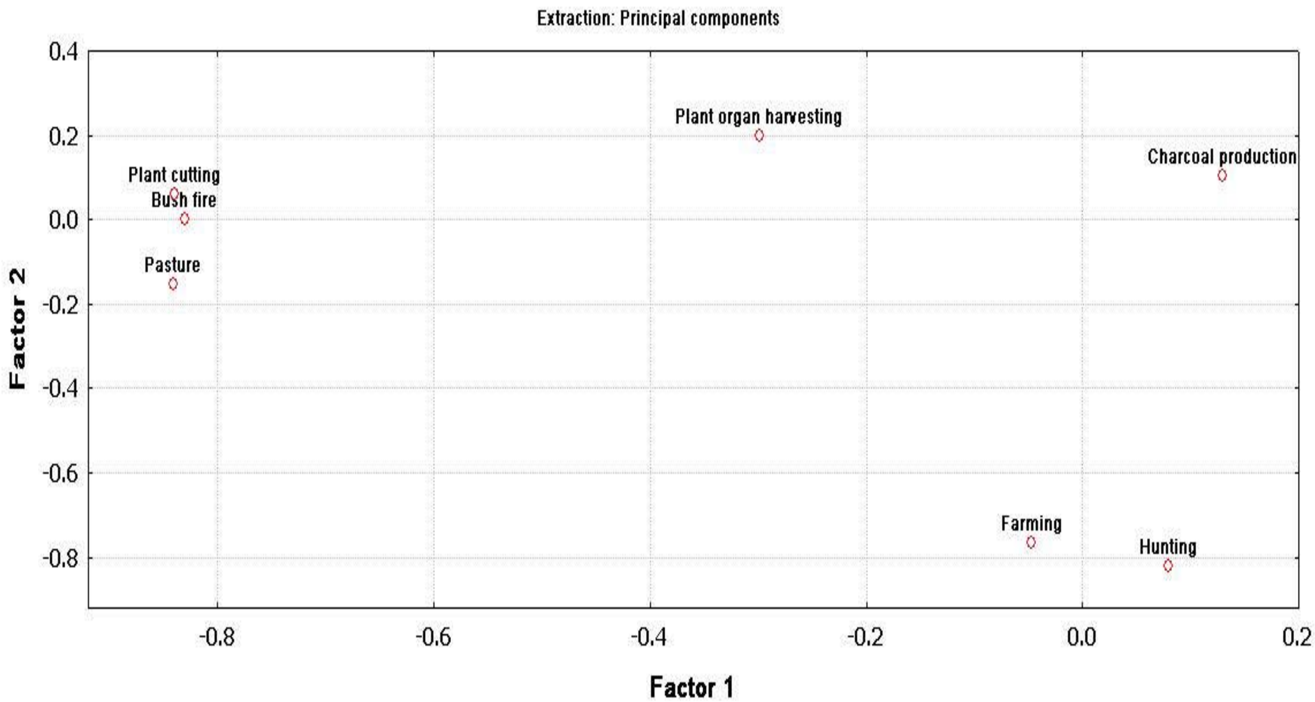


Figure 5-4: Factor analysis of the seven main disturbance factors

5.3.2 Bordering population opinion assessment

The bordering people investigations about the activities they often operate in the protected areas confirm much the observation done in the field. Most of the people met, recognized that more people invaded the study area for many purposes. These purposes include fuel wood collection, pasture, transhumance, plant organ harvesting, hunting, fishing, farming, forest none wood product harvest. For the bush fire practices both of the farmers reject the responsibility on pastors, who regularly burn the savanna in order to make fresh grass available for their animals. The part of plant harvest (98%) was used in pharmacopeia ways. 90% of the person surveyed seem to have a confusion about the practices tolerate or prohibit in the protected areas. In spite of the presence of Forest safeguard agent bordering people still invade the ecosystem for the reasons mentioned above. That suppose to think that the income of those people are linked to the activities they practice in the protected areas. The plant species which are constantly exploited by people concern the forest agroforestry trees. The plant common cited by surveyed include *Vitellaria paradoxa, Daniella oliveri, Parkia biglobassa, Pterocarpus erinaceus, Entada abyssinica, Anogeissus leiocarpus, Terminalia macroptera, T. laxiflora.*

Photo 25: Grazing during the rainy season

Photo 26: Grazing during the dry season

Photo 27: Bush and forest fire

Photo 28: Tree cutting

Photo 29: Dry forest clearing

Photo 30: Fuel wood market

Photo 31: Fuel wood market

Photo 32: Tree cutting (*Borassus aethiopum*)

Photo 33: Plant organ harvesting (*Vitellaria paradoxa*)

Photo 34: Plant organ harvesting *(Vitellaria paradoxa)*

Photo 35: Charcoal prodction at reserve edge

Photo 36: Charcoal prodction inside the reserve

Photo 37: Charcoal ready for selling

Photo 38: Seasonal farming along the Koumongou river

Photo 39: Water pumping fom Koumongou river

Photo 40: Fishing net

Photo 41: canoe and trap on Koukombou river

Photo 42: Traditional hive

Photo43: Honey harvest

Photo 44: Fulani camp

5.4 DISCUSSION

Through this investigation, seven major anthropogenous activities were found to be disturbances for the protected areas ecosystem integrity. Three of them appear to be recurrent and destroying for plant communities. Bush fire, pasture includes transhumance and plant cutting are very common in African savanna; and also participate to it maintaining. The previous research, in other protected areas close to the study areas have indexed fire, transhumance and forest harvest like the current perturbation (Kossi *et al*., 2009; Dimobe, 2009; Borozi, 2007). The same observations were made in tropical sudanian areas during it vegetation and landscape ecology studies (Noëllie, 2010; Yvon-Carmen, 2008; Ouoba, 2006). Certain of the disturbance factor are interdependent, but their actions almost are determined by stakeholders who use the protected areas resources.

The impact of listed anthropogenous activities vary from one ecosystem to another. The shrubby savanna and wooded savanna are the most disturbed ecosystems. The high rate of bush fire and pasture is highly bound to these ecosystem natures. The continued presence of gramineous tapie in this plant formation, important for grazing development explains the transhumance and pastoralism activities. However, those perpetually economic practices depend on the availability of grass, the fire contribute to its stability and often caused by pastor. The dry forest and riparian forest are less disturbed by the three main factors. The pastoralism which is the first cause of their destructuration, often takes place in these two areas during the dry season for water supplying and shadow generated by tree which is a suitable place for the cattle, to reduce the transpiration. The lacks of wood in shrubby savanna lead people to invade dry forest and riparian forest for selective plant cutting, for charcoal production (photo 35, 36 and 37). In spite of the ban to hold farming activity, it is not uncommon to find the forest cleared for planting crops and irrigated farming inside the protected area and particularly along the rivers (photo 29, 33, 38 and 39). According to the observation recorded during the two field work, it is important to notice that shrubby and wooded savanna anytime are almost subjected to anthropogenous activities, while the forest seem to be more disturb in dry season .

Nowadays, prescribed burning is a widely recognized and essential ecological tool for managing African grassland and savanna ecosystems (Winston and Lynne, 2004). The fire with its effect, favor the development of grassland and open savannas and vice versa (Winston and Lynne, 2002). In this sudanian area of Togo, the planers most of times allow early fire, and intend their self to manage it at the end of rainy season. This initiative is guided by the objective to increase the rate of ligneous species in the areas by reducing the competition between trees and herbaceous component (Lisa and Isabelle, 2001). The abundance of Combretaceae taxa (Folega *et al*., 2011) in this drought area, confirms the importance of anthropogenous activities (Jean-Louis and Anne, 1998), but the effective and importance presence of *Crotalaria graminicola* denotes an ecosystem which was often burned (Burkill, 1985). The later bush fire prohibited is commonly done by the stockbreeders in the middle and/or at the end of dry season, for the essential reason to activate the growth of fresh grass for the cattle. This interdependence between bush fire and pastoralism is the main cause of savanna landscape maintaining and its shrub control (Spottiswoode *et al*., 2009). The protected areas still populated by the wilds mammals, the availability of the grassland is necessary for their growing and development in spite of the absence or rarity of big feline. The fire in that regards is essential to provide and to ensure short and tender grass rich in protein. Although, the bush fires reduce in smoke and ash any vegetation which they consume. The bush fires have anyway a direct and positive impact on the ground through the phenomenon of organic matters mineralization, which enhance the fertility of the alluvia of the rivers and lowlands (Mahesh *et al*., 2008) in the landscape.

The unceasing demand of wood fuel and wood drift combustible by the cities; and the need to improve their income. The rural people do not hesitate to sell off the law and invade the protected areas for cutting. Almost the stems of cutting trees are used to product charcoal while the branches are used as wood fuel. In shrubby savanna the stems are directly used for wood combustible. Galangashi village is known to be the great place for wood fuel commercialization, around the study area (photo 30 and 31). Through the bordering people opinions assessment the plant species which are often used for fuel purposes include: *Anogeissus leiocarpus, Prosopis africana, Pterocarpus erinaceus, Terminalia macroptera, Terminalia laxiflora, Daniella oliveri, Detarium microcarpum.* The areas gradually cleared, at last is used as park and cropland.

The plant organ harvesting enters in pharmacopeia and nutrition uses of the people. Several plant species are used to treat diseases however the fruit participate to enrich the food palette of rural population. This kind pressure is high on the following species *Nauclea latifolia, Balanites aegyptiaca, Vitellaria paradoxa, Tamarindus indica, Parkia biglobosa, Sclerocarya birrea, Lannea kerstingii, Lannea microcarpa, Vitex doniana* and *Adansonia digitata;* but these species still benefited some conservation measures from the peasants agroforestry practices (Folega *et al*., 2011). Although the natural regeneration of the last seven species is quasi inexistent in the field because of the high rate fruits harvest; the mature one fruits production yield decrease gradually with the time (Photo 45-54).

Hunting and bush meat utilization are integral parts of the sociocultural traditions of many rural communities living around the forest and protected areas (Ofori and Attuquayefio, 2010). In spite of the nature of this part of Togo to be the great breeding meat provider, its protected ecosystems are faced to poaching and illegal fishing. This alarming situation is responsible of the migration of fauna from protected areas to neighboring countries through the natural corridors (IUCN, 2008; MERF, 2003).

However bordering people beginning install the hives in the protected areas particularly on *Vitellaria paradoxa, Parkia biglobosa* trees; they still employed the old manners which consist to harvest the honey directly from natural hives in the night by using fire to force bees leave the hive, but this action is harmful for the bees, which are often exterminated by this process.

Both the anthropogenous activities seem to disturb separately the ecosystem, but their actions and impacts on ecosystem integrity are interdependent.

Photo 45: Fruits of *Parkia biglobosa*

Photo 46: Fruits of *Tamarindius indica*

Photo 47: Fruits of *Detarium senegalensis*

Photo 48: Fruits of *Vitellaria paradoxa*

Photo 49: Fruits of *Ziziphus abyssinica*

Photo 50: Fruits of *Gardenia erubescens*

Photo 51: Fruits of *Adansonia digitata*

Photo 52: Fruits of *Lannea acida*

Photo 53: Fruits of *Balanites aegyptiaca*

Photo 54: Fruits of *Hyphaene thebaica*

5.5 CONCLUSION

The study enables to understand the main important human activities, held as well as inside and around the protected areas by bordering people. Among the disturbances, bush fire, pasture and forest harvesting are recurrent. However they are responsible of wooded and forest destructuration via fragmentation, reduction of ligneous biomass and migration of fauna; they participate to maintain and to increase the savanna area in this drought environment; in other term perennialized the pastoralism and transhumance. Even if some of the disturbance is consider being an integrant part of socio-economic activities, there is still a great need to monitor them in West Africa sub region context, because of the free movement of people and goods which prevail between its countries.

CHAPTER 6 - GENERAL DISCUSSIONS AND CONCLUSION

6.1 Land use and Land cover changes as powerful tool in vegetation monitoring

Through the two fields observations missions and the results obtained from the remote sensed data analysis and interpretation general information about the land use and land cover of the protected areas have been constituted. Although these results seem to be more descriptive and qualitative, it remains important for future land assessment in a region where the land conservation via the vegetation component protection becoming a great concern.

The land use change study shows the areas commonly invade by harvesters for many purposes .It also indicates the zone well conserved or lesser subject to harvesting and has just focus on the areas lost or gain in term of vegetation cover.

The dynamic of areas under the high anthropogenous pressure is going fast; in that regard it was widely complex to define the land cover type to setup the actual land cover map. The main difficulties were the confusion between dry forest and wooded savanna mostly dominated by *A. leiocarpus* and *P. erinaceus*. But the for establishment of the land covers types definition seven land cover types were retained base on the previous works and fields observations.

The quantification and the estimation of biomass of the region much covered by the savanna through the remote sensing would be helpful to determine the implication of this ecosystem in the global warming reduction, the carbon seeking and the sustained management the resources available.

6.2 Plant diversity and major plant community pattern

The floristic sampling of the vegetation of this sudanian tropical climate area let to generate a check list of 274 plants species belonging to 247 genera and to 63 families.

The Legumunosea follow by the Graminea, Combretaceae, Rubiaceae and Euphorbiaceae are the representative families in the three protected areas. These families are representing at least by less than ten species.

From the chorological point of view 44.52% are belong to Sudanian area while 30% belong to Guinean climatic zone. The species which to be link to human activities represent more than 20%. The woody nature of the area is confirmed by the rate of phanerophytes (49%). The lianas represent by 15% of species and expressing the reconstitution of areas previously disturbed.

Water availability expressed by the rainfall, the length and the intensity of the dry season, and the air humidity turns out to be the major factor determining the vegetation gradient. The ordination in indirect gradient associated to the cluster analysis let the discrimination of seven plant grouping. Those plants communities present high diversity index but few of them are similar. Actually the relationship between plant grouping, species spatial distribution range types and moisture availability indicates that plant species and communities are sensitive to climate change, but human disturbance must not neglected too.

6.3 Woody plant species pattern a major component for soils and water conservation

The wooded plant formations have an impact on environmental quality. Their woody and perennial components contribute a lot to the management of the environment in which they occur.68 woody species check list was generated after floristic processing. The 68 ligneous species constitute of 5960 individual are belonging to 47 genera and 25 families. In the same case the families mostly present in Sudanian area are predominant. The high rates of micro-phanerophytes (48.52%) and the lack of Mega-phanerophytes could be explained by the predominance of shrub and tree savannas.

The woody species distribution and the pattern spatial disposition obey more to moisture gradient which is determined by any kind of water available in the environment.

This area is more subjected to human disturbance such as farming, grazing, and cutting; these disturbances associated to the seasonality variability may also influence also to plant communities' patterns redesigning in the landscape. The twelve plant communities were identified, present good diversity index which show the constant reconstitution of the areas but the basal area, the height and the diameter are little low and well in line with it savanna nature. The diameter distribution has confirmed more the area is in potential regeneration stage with more juvenile individual than mature one.

6.4 The knowledge of the main human disturbances for a better management of resource use

It is well know that the disturbances almost establish the vegetation patterns and the spatial patterns of many ecosystems. Some of them have the power to maintain certain ecosystem. The protection and the restoration of vegetation which are perpetually subjected to the anthropogenous activities become the preoccupation of the planer. Knowing the disturbances, a framework for the management of land resource can be easily setup. The itinerant farming on slash burn, pasture and transhumance, bush fire is the main factors which affect highly the integrity of the ecosystem.

However the human disturbances are responsible of wooded and forest destructuration through the fragmentation, reduction of ligneous biomass and the migration of fauna; they also participate to maintain and to increase the savanna area in drought environment; in other term perennialized the pastoralism and transhumance.

6.5 Recommendation and suggestion

Through the results and the information's derived from this study; at local scale it can help to sustaining the management of the protected areas and planed or programmed well the activities in these areas under high pressure. To achieve the project of consensual rehabilitation of protected areas particularly those of Northern Togo it seem very important to take in account the suggestions below in the vast framework program hold by the planners.

- ❖ Setup a master and management plan based on the various scientific research done in the areas.
- ❖ Assess and remote the transhumance and the pasture activities via the establishment of permanent corridors.
- ❖ Take into account the need of pastor mostly bind to water availability by surrended where access to water is easy without violate the law.
- ❖ Encourage agroforestry practice by preserving not only the frequent quote agroforestry species but also those neglected by the peasants.
- ❖ Promote the afforestations of barren land in the village around the protected areas for the immediate need in fuel wood for villagers.
- ❖ Promote the use of gas in town in order to reduce the production of charcoal and wood fuel.
- ❖ Promote the valorization of forest none ligneous product and the domestication of certain species which present high values for the peasants.
- ❖ Try to setup framework ecological tourism which imply both of the stakeholders in the management of the protected areas.

- Increase the number of park managers and improve their work condition by giving them the adequate materials to monitor the parks.

REFERENCES

[1] Affaton P., 1975. Etude structurale du nord-ouest du Dahomey, du nord-Togo et du sud-est de la Haute–Volta [M]. Thèse géol. Aix Marseille III(France). 1975 :201.

[2] Affaton P., Rahaman M.A. Trompette R., and Sougy J. The Dahomeyide orogan: tectonothermal evolution and relationships with the Volta bassin [M]. *In* Dallmayer and Lécorché (Edit.): the Est-african Orogan and Circum Atlantic Correlatives. Projet 233, ICGP, IUGS, UNESCO.1990 : 107-122.

[3] Afidegnon D. Les mangroves et les formations associées au sud-est du Togo : analyse éco-floristique et cartographie par télédétection spatiale [M]. Thèse Doct., Univ. Bénin, (Togo). 1999 :237.

[4] Afidegnon D., Caryon J.L., Fromard F., Lakaze D., Guelly K. A., Kokou K., Woegan A.Y. and Batawila K. 2003. Carte de la végétation du Togo : notice explicative [M].UMR 5552/Université de Paul Sabatier, Faculté des Sciences /Université de Lome.2003 :55

[5] Ake Assi L.Flore de la Côte d'Ivoire : études descriptive et biogéographique, avec quelques notes ethnobotaniques [M]. Thèse de doctorat, Université d'Abidjan, Tomes I, II, et III.1984 :1067.

[6] Akpagana K. Recherche sur les forêts denses humides du Togo [M]. Doctorat de l'Université de Bordeaux III, III, Spécialité : sciences naturelles .Paris, France.1989 :181.

[7] Alimasi M. Contribution à l'étude floristique de la contrée de Lwiro (Kabare, Sud-Kivu, R.D.Congo) [M]. Mémoire inédit, UNIKIS (RDC).1999: 95.

[8] Andy Y. K. and Dhari A. A. Using Landsat Thematic Mapper Data to Detect and Map Vegetation Changes in Kuwait [J]. International Archives of Photogrammetry and Remote Sensing .1996. XXXI (Part B7):398-405.

[9] Anonyme [PNAE-TOGO].Monographie nationale sur la biodiversité [M]. Rapport intégral, PENA/MERF (Togo).2002:171.

[10] Anthony J., Viera M.D. and Joanne M. Understanding Interobserver Agreement: Th e Kappa Statistic [J]. Fam Med. 2005, 37(5):360-363.

[11] Attanda M.I., Cossi J. H., Thomas G. and Karl S. Land Use/Cover Map and its Accuracy in the Oueme Basin of Benin (West Africa) [J]. Conference on International Agricultural Research for Development. Tropentag, University of Bonn.2006.4p.

[12] Aubreville A. Flore forestière soudano-guinéenne: A.O.F. Cameroun A.E.F [M]. Sociétés d'Editions Géographiques, Maritimes et Coloniales, Paris.1950:523.

[13] Baldyga T. J., Miller S. N., Driese K. L., and Maina G. C. Land cover change assessment within Kenya's Mau forest region using remotely sensed data [J]. African Journal of Ecology.2007, 10(1111):1365-2028.

[14] Bayes T. An Essay toward Solving a Problem in the Doctrine of Chances [J] .Philosophical Transactions of the Royal Society of London .1763, (53): 370-418.

[15] Belém O. M. and Guinko S. La biodiversité des galeries forestières du Burkina Faso : cas de la réserve de la biosphère de la mare aux hippopotames [J]. In : Ba A.T., Madsen J.E. and Sambou B (eds), Atelier sur la flore, végétation et Biodiversité au Sahel. Aarhus University Press Aarhus Denmark, AAU Reports.1998, (39):75-88.

[16] Bernard T., Marie-Noel V. and Dominique D. Pastoralisme et aires protégées : Coexistence ou concurrence ? Leçons tirées d'études de cas en Afrique de l'Ouest [J]. World Park Congres .2003, (1) :5

[17] Biaou H.S. and Sokpon N. Aménagement des forets sèches du nord Benin : Bases techniques pour une gestion durable [J]. In Sokpon N., Sinsin B. et Eyog-Matig (eds).2003,(1) :XXX.

[18] Borozi W. Contribution à la gestion durable de la réserve de faune d'Alédjo, structure de la végétation, pression humaine et système de gestion [M]. Mémoire de DEA, Univ. Lomé (Togo). 2007:42.

[19] Braun-Blanquet J. Plant sociology: The study of plant communities [M]. (Facsimile of the edition of 1932, translated by Fuller G.D. and Conard H.S.) Hafner Publishing Company, New York .1972:439.

[20] Breininger D.R., Nichols J.D., Duncan B.W., Stolen E.D., Carter G.M., Hunt D.K. and Drese J.H. Multistate modeling of habitat dynamics: factors affecting Florida scrub transition probabilities [J]. Ecology. 2010, 91(11):3354-64.

[21] Breman H. and Kessler J.J. Woody plants in agro-ecosystems of semi-arid regions - with an emphasis on the Sahelian countries [M]. Advanced Series in Agricultural Science 23, Springer, Berlin, Heidelberg, 1995:340.

[22] Brunel J.F. Hiepko P. and Scholz H. 1984. Flore analytique du Togo: Phanérogames

[M].GTZ éd., Eschbom, 1984 :751.

[23] Burkill H.M. The useful plants of west tropical Africa [J].Plant jstor.1985, (3):xx http://plants.jstor.org/action/doSearch?type=advanced&searchText=Crotalaria+graminicola&submit=View+Results&sa=api&sa=lapi

[24] Catinot R. Projet National de semences forestières [M]. Document du Cameroun (Draft). Document interne, IUFRO & FAO. Rome.1988: XXX.

[25] Celia A. H., Oliver K., Robin C., Bruce G.F., Bryan F., Daniel M.G., Miguel M-R., Helda M., Ronald N., Lorena S-P., Michiel V.B., and Mark W. Integrating Agricultural Landscapes with Biodiversity Conservation in the Mesoamerican Hotspot [J]. Conservation and Policy.2008, 22(1):1-8.

[26] Chavez S. P. and MacKinnon J. D. Automatic detection of vegetation changes in the Southwestern United States using remotely sensed images [J]. Photogrammetric Engineering and Remote Sensing.1994, (60):571– 583.

[27] Chavez P. S. Image-based atmospheric corrections—revisited and revised [J]. Photogrammetric Engineering and Remote Sensing.1996, 62(9): 1025-1036.

[28] Christophe R., Julien B., Amadou N., Bocary K., and Nicole S. Biodiversité spécifique ligneuse et terroirs : quelles relations ? Le cas de trois villages de la région de Ségou (Mali) [J]. Bois et forêts des tropiques. 2005, 283 (1) :33-49

[29] Collins M. Die letzten Regenwälder [M]. RV Reise- und Verkehrsverlag, Berlin, Gütersloh, München, Stuttgart, 1990:199.

[30] Conférence des Nations Unies sur l'environnement et le développement (CNUED) .1992 : XXX.

[31] Congalton R.G. A review of assessing the accuracy of classifications of remotely sensed data [J]. Remote Sens Environ.1991, (37):35–46.

[32] Congalton R. G. and Green K. Assessing the accuracy of remotely sensed data: principles and practices [J].Boca Raton, Florida: CRC Press. 1999, 45–48pp.

[33] Dajoz R. Dynamique des populations [M]. Masson et Cie.1974 :306.

[34] Dimobe K. Analyse de la dynamique spatiale des différentes formes de pressions anthropiques dans la réserve de l'Oti-Mandouri [M]. Mem.DEA Biol .Veg. Appli. Univ. Lomé (Togo).2009 :61.

[35] Direction Générale de la Statistique et de la Comptabilité Nationale-Togo(DGSCN).Lome. 2011.

[36] Direction Générale de la Statistique et de la Comptabilité Nationale-Togo(DGSCN).Lome. 2006.

[37] Donatien N. Mapping deforestation in the Congo basin forest using multi-temporal spot-vgt imagery from 2000 to 2004[J]. EARSeL eProceedings.2008, 7.

[38] Dourma M. Les forêts à *Isoberlinia doka* Craib & Stapf et *Isoberlinia tomentosa* (Harms) Craib & Stapf en zone soudanienne du Togo: Ecologie, Régénération naturelle et Activités humaines [M]. Thèse de Doctorat, Université de Lomé(Togo).2008 : 181.

[39] Dufrene M. and Legendre P. Species assemblages and Indicator Species: The Need for flexible Asymmetrical Approach –Ecol.Monogr.1997, 67 (3):345-366.

[40] Ern H.Die Vegetation Togo[J]. Gliederrung, Gefährdung, Erhaltung. Willdenowia.1979, (9): 295-312.

[41] FAO. Promotion de la gestion durable des forêts et des terres boisées [M]. Fao.Rome.2007 : XXX.

[42] FAO. La Situation des forets et de la faune sauvage de en Afrique [M]. Commission régionale de la FAO pour l'Afrique. Rome, Italie.2001b:XXX.

[43] Folega F., Zhao X.H, Zhang C.Y., Kperkouma W. and Koffi A. Ecological and numerical analyses of plant communities of the most conserved protected area in North-Togo [J].International Journal of Biodiversity and Conservation .2010, 2(11): 359-369.

[44] Folega F., Zhang C.Y., Kperkouma W., Zhao X. H and Koffi A. Wooded vegetation of protected areas in Northern Togo. Case of Barkoissi, Galangashi and Oti-Keran: Ecological and Structure Analysis of Plant Communities [J]. Forestry Studies in China .2011, 13(1):23-35.

[45] Folega F., Zhang C.Y., Zhao X.H. Wala K., and Akpagana K. Floristic diversity in most dry and environmentally disturbed areas of Northern Togo [J] .Energy Procedia.2011,(11):2127–2132.

[46] Folega F., Zhang C.Y., Batawila K., Zhao X.H. and Akpagana K. Plant communities' pattern in most environmentally disturbed areas in most septentrional part of Togo [J]. Energy Procedia.2011,(11):2433-2441.

[47] Folega F., Zhang C.Y., Samake G., Kperkouma W., Batawila K., Zhao X.H. and Akpagana K. Evaluation of agroforestry species in potential fallows of areas gazetted as protected areas in north-Togo [J]. African Journal of Agricultural Research.2011, 6(12): 2828 - 2834.

[48] Foody G.M. Status of land covers classification accuracy assessment [J]. Remote Sensing of Environment. 2002, 80: 185-201.

[49] François G. La phytosociologie synusale intégrée, guide méthodologique [M].4eme ed. Université de Neuchâtel .2000:68.

[50] Frontier S. and Pichod-Viale D. Ecosystèmes structure, fonctionnement et évolution [M]. Masson. Collection écologie.1991 :392.

[51] Fairhead J. and Leach M. Réexamen de l'étendue de la déforestation en Afrique de l'Ouest au XXe siècle [J]. revue Unasylva. 1998, (192) : XXX. http://www.fao.org/docrep/w7126f/w7126f06.htm.

[52] Gareau P. Analyse organisationnelle d'une expérience de gestion intégrée de l'eau et de participation publique : le programme Zones d'intervention prioritaire (ZIP) [M]. Mémoire de maîtrise, Montréal, Université du Québec à Montréal.2000 :129.

[53] Georges Y., Barthélemy Y., Dossahoua T. Pratique et perception paysannes dans la création de parc agroforestier dans le terroir de Vipalogo (Burkina Faso) [J]. Biotechnol. Agron. Soc. Environ. 2005, 9 (4) :241–248.

[54] Gimaret C. Analyse de la biodiversité à partir d'une liste d'occurrences d'especes : nouvelles méthode d'ordination appliquées à l'étude de l'endémisme dans le gaths occidentaux [M]. Thèse de doct, Université Claude Bernard –Lyon 1, France .1999 :234.

[55] Grondard A. La végétation forestière du Tchad [J]. Bois et Foret des tropiques.1964, 93 :15-34 .

[56] Guelly K.A.Les savanes de la zone forestière subhumide du Togo [M]. Thèse de doct. Univ. Pierre et Marie-Curie, Paris VI.1994 :163.

[57] Guinko S. Végétation de la Haute-Volta [M]. Thèse d'Etat ès-sciences naturelles, Bordeaux III(France). 1984 :394.

[58] Guo D.G. and Guan T.L. Quantitative Classification and Ordination of Plant Communities in Midpiece of Zhongtiao Mountains (中條山中段植物群落數量分類與

排序研究) [J]. JOURNAL OF WUHAN BOTANICAL RESEARCH, 2005, 23(5):444-448.

[59] Hayes D.J. and. Sader S.A. Analyzing a forest conversion history database to explore the spatial and temporal characteristics of forest change [J]. Landscape Ecology.2002, (17):299-314.

[60] Hill M.O. Twinspan A FORTAN program for arranging multivariate data in an ordered two way table by classification of individual and attributes [M]. Cornell University, Ithaca, N.Y.1979a:90.

[61] Hill M.O.DECORNA A FORTAN program for Detrended correspondence analysis and reciprocal averaging [M]. Ecology and Systematics. Cornell University, Ithaca, N.Y. 1979b:52.

[62] Hill M.O. and Gauch H.G. Detrended Correspondance analysis: an improved ordination technique [J]. Vegetation.1980, (42):47-58.

[63] Hu L.L., Mao Z.H., Zhu J.J., Liu Z.G., Chen G.H. and Zhang L.J. Classification and ordination of secondary forests in montane zone of eastern Liaoning Province (遼東山區天然次生林的數量分類) [J]. ACTA ECOLOGICA SINICA, 2005, 25(11):2849-2854.

[64] Huang Y.Y., Huang L.M., Li J.L., Li H. and Wu Y.H. Vegetation Community Structure in Different Functional Areas of Nanning City, Guangxi Province (南寧市幾個功能區的植被群落結構特征分析) [J]. J OURNAL OF TROPICAL AND SUBTROPICAL BOTANY, 2006, 14(6):494-498.

[65] Hutchinson J. and Dalziel J.M.Flora of West Tropical Africa [M]. Crown Agents for Overseas Governments and Administrations, Londres. 1958, 1963, 1968, 1972: (1) tomes 1 and 2:828, (2):544, (3): tomes 1 and 2:852.

[66] Hutchinson J. and Dalziel J.M. Flora of West Tropical Africa [M]. 2nd ed. Crown Agents for Overseas, London. 1954:264-81.

[67] IGN. Carte du Togo au 1/500 000 [M]. IGN-Paris. 1991.

[68] ITTO. Status of tropical forest management .Yokohama, Japan. 2011:420(135-142). http://www.itto.int/news_releases/id=2663

[69] Jean-Louis D. and Anne F. Écologie d'une savane africaine .Synthèse provisoire

des résultats acquis [M]. ORSTOM / ERMES(France).1998 :77.

[70] Jaccard P. Distribution de la flore alpine dans le basin des Dranes et dans quelques régions voisines [J]. Bull. Soc. Vaudoises Sci. Nat. 1901, (37): 241-272.

[71] Jensen J.R. Introductory Digital Image Processing: A Remote Sensing Perspective [M]. 3rd Edition, Upper Saddle River: Prentice-Hall, 2005:526.

[72] Julien A. and Catherine M. Cartographie par télédétection des changements de la couverture végétale sur la bande littorale ouest-africaine : exemple des rivières du sud du delta du Saloum (Sénégal) au rio Gêba (Guinée-Bissau) [J]. Revue Télédétection, 2008, 8 (2) : 93-118.

[73] Kaboyi N. Etude floristique d'une végétation naturelle en milieu anthropisé: cas de la formation arbustive xérophile de Cabinda, au nord de Bukavu [M]. Mémoire de licence, Université de Kisangani, Centre Universitaire Extension de Bukavu (RDC).2004 :94.

[74] Kadeba A. Flore et végétation du site écologique et culturel de Koro (province du Houet/Burkina Faso) [M]. Mem.DEA Bot et Phytoécologie., Univ. Ouagadougou (Burkina Faso) .2009:71.

[75] Kaiser H. F. The application of electronic computers to factor analysis [J]. Educational and Psychological Measurement.1960, (20): 141-151.

[76] Kangni M.A. Ressources forestières naturelles et plantations au Togo [M]. FAO Rome.2000:30.

[77] Kent M. and Coker P. Vegetation description and analysis: a practical approach [M]. John Wiley & Sons, England. 1992:363.

[78] Kokou K., Adjossou K. and Hamberger K. Les forêts sacrées de l'aire Ouatchi au sud-est du Togo et les contraintes actuelles des modes de gestion locale des ressources forestières [J]. VertigO- la revue électronique en sciences de l'environnement.2005, 6 (3): XXX. URL : http://vertigo.revues.org/2456 ; DOI : 10.4000/vertigo.2456.

[79] Kokou K., Couteron P., Martin A. and Caballe G. Taxonomic diversity of lianas and wines in forests fragments of southern Togo [J] .Revue d'Ecologie (Terre Vie) .2002, (57):3-17.

[80] Kokou K. and Guy C. Ilots forestiers de la plaine côtière du Togolaise [J]. Bois et Foret des tropiques.2000, (263):39-51.

[81] Kokou K. Les mosaïques forestières au sud du Togo : biodiversité, dynamique et activités humaines [M]. Th. Doct. Univ. Montpellier II(France).1998 :140.

[82] Kossi A., Ronald B. and Kouami K. Les forets claires du Parc national Oti-Keran au Nord-Togo: structure, dynamique et impacts des modifications climatiques récentes [J]. Sécheresse.2009, 20 (1e): e1-e10.

[83] Kouame F. N. and Traore D. Exploitation Forestière et les lianes de forêts dense tropicale humide : cas de la forêt classée du Haut Sassandra [J]. .*In Rapport d'activité* 1999-2000 du Centre Suisse de Recherche Scientifique en Cote d'Ivoire (CRRS).Abidjan, Cote d'Ivoire .2001 :20-21.

[84] Kperkouma W., Brice S., Kudzo A. G., Kouami K. and Koffi A. Typologie et structure des parcs agroforestiers dans la préfecture de Doufelgou (Togo) [J]. Sécheresse. 2005, 16 (3):209-16.

[85] Krebs C.J. Ecology: The experimental analysis of distribution and abundance [M]. Harper Collins: NY.1994: XXX.

[86] Li R., Zhang K.B., Liu Y.F., Wang B.T., Yang X.H. and Hou R.P. Plant community spatial distribution pattern of wetland ecosystem in a semi-arid region of northwestern China (西北半干旱區濕地生態系統植物群落空間分布特征研究) [J]. Journal of Beijing Forestry University, 2008, 30(1):6-13.

[87] Lillesand T. Kiefer R. and Chipman J. Remote Sensing and Image Interpretation [M]. 6th edition. John Wiley & Sons, NY. 2008:756.

[88] Lisa K.M.G. and Isabelle D. The influence of fire on the demography of a dominant grass species of West African savannas, *Hyparrhenia diplandra* [J] .Journal of Ecology .2001 ,89:200–208.

[89] Luca C. Protected areas and landscape conservation in the Lombardy plain (northern Italy): an appraisal [J]. Landscape and Urban Planning .2006, 74:102–109.

[90] Lykke A.M. Local perception of vegetation change and priorities for conservation of woody savanna vegetation in Senegal [J]. Journal of Environmental Management.2000, (59): 107-120.

[91] Lykke A.M., Sambou B. and Goudiaby A. Dynamique des espèces ligneuses dans une savane soumise aux feux dans le parc national du Delta du Saloum, Sénégal [J]. Ann.

Bot. Afr. Ouest.2002, (02): 53-66.

[92] Magurran A.E. Ecological diversity and its measurement [M]. Princeton University Press, Princeton, New Jersey.1998:179.

[93] Magurran A.E. Measuring biological diversity [M]. Blackwell Publishing Company, United Kingdom. 2004:256.

[94] Maini J.S. Boreal and Temperate Forests: Their Significance and Sustainable Development [J]. Écodécision.1994, (13):24-27.

[95] Mahesh S, Jayashree R. and Niall H. Woody cover in African savannas: the role of resources, fire and herbivory [J]. Global Ecology and Biogeography.2008, (17) : 236–245.

[96] Mangenot G. Etude sur les forêts des plaines et plateau de la Cote d'Ivoire [J] .Etude Eburnéennes IFAN.1995, (4):5-61.

[97] Margalef R. Information theory in ecology [J]. Gen. Syst.1958, (3):36-71.

[98] Margalef R. Perspectives in Ecological Theory [M]. Chicago Series in Biology. University of Chicago Press. 1968:111.

[99] Masens D.Y.Etude phytosociologique de la région de Kikwit (Bandundu, Rép. Dém. du Congo) [M]. Th. doct. Univ. Libre de Bruxelles (Belgique) .1997 :398.

[100] Mc Cune B. and Grace J. B. 2002 .Analysis of ecological communities [M] .MJM software design, Gleneden Beach.2002:300.

[101] MERF. Stratégie pour conservation des populations d'éléphants au Togo [M]. MERF Togo.2003:40.

[102] MERF. Monographie nationale sur la diversité biologique [M]. Rapport intégral. MERF Togo: 2002:172.

[103] Michael L. M. Urbanization, Biodiversity and Conservation [J]. BioScience. 2002, 52(10):883-890.

[104] Michael G., Jack H. and Wanna D. Terrestrial Plant Ecology [M]. The benjamin/Cumming Publishing, Mento Park–California (USA).1980:604.

[105] Moussa A. Classification des climats en fonction de la végétation, des pluies et de la température (Togo) [M]. Mem de Maitrise Géographie, Université de Lomé (Togo).2008 :30.

[106] Nacoulma I.M.B., Schumann K., Traore S., Bernhardt-Romermann M., Hahn K., Wittig R. and Thiombiano A. Impacts of land-use on West African savanna vegetation: a comparison between protected and communal area in Burkina Faso [J]. Biodivers Conserv, 2011, (20):3341–3362.

[107] Natta A.K. Ecological assessment of riparian forests in Benin: phytodiversity, phytosociology and spatial distribution of tree species [M]. Ph.D. Thesis Wageningen University (Netherlands). 2003:222.

[108] Noëllie A.Y. Mapping Bushfire Distribution and Burn Severity in West Africa Using Remote Sensing Observations [M] .Doctorat dissertation. University of Julius-Maximilians (Germany).2010:137.

[109] Nyakabwa M. Phytocénose de l'écosystème urbain de Kisangani [M]. Thèse de doctorat, Inédite, Fac. Sc, UNIKIS (RDC). 1982:418.

[110] Oba G., Post E. and Stenseth N. C. Sub-saharan desertification and productivity are linked to hemispheric climate variability [J]. Global Change Biology.2001, (7): 241–246.

[111] Odion D. C. and Sarr D. A. Managing disturbance regimes to maintain biodiversity in forested ecosystems of the Pacific Northwest [J]. Forest Ecology and Management .2007,(246):57–65

[112] Ofori B.Y. and Attuquayefio D.K. Hunting Intensity in the Suhuma Forest Reserve in the Sefwi Wiawso District of the Western Region of Ghana: A Threatto Biodiversity Conservation [J]. West African Journal of Applied Ecology.2010,(17):135-142

[113] Ojeda F., Maranon T. and Arroyo J. Plant diversity patterns in the Aljibe Mountains (S. Spain): a comprehensive account [J]. Biodiversity and Conservation.2000, (9):1323-1343.

[114] Ola A. Extending post-classification change detection using semantic similarity metric to overcome class heterogeneity: A study of 1992 and 2001 US National Land Cover Databases changes [J]. Remote Sens .Environ.2008, (112):1226-1241.

[115] Ouedraogo A. Diversité et dynamique de la végétation ligneuse de la partie orientale du Burkina Faso [M]. Thèse de doctorat, Univ. Ouagadougou (Burkina Faso).

2006:195.

[116] Ouoba P. Flore et végétation de la forêt classée de Niangoloko, sud-ouest du Burkina Faso [M]. Thèse de Doctorat, Université de Ouagadougou (Burkina Faso) .2006:140.

[117] Ozenda P. Les végétaux dans la biosphère [M] .Dion Editeurs, Paris, France.1982 :431.

[118] Pan J.H and Liu P.X. An analysis of temporal - spatial features of land use and landscape pattern in the low er reaches of the Hei He river (黑河下游土地利用与景观格局时空特征分析) [J]. REMOTE SENSING FOR LAND and RESOURCES, 2008, 2:87-98.

[119] Pare S., Savadogo P., Tigabu M., Ouadba J.M. and Oden P.C. Consumptive values and local perception of dry forest decline in Burkina Faso, West Africa[J].Environ Dev Sustain ,2010, (12):277–295.

[120] Pereki H., Folega F., Batawila K., Wala K. and Akpagana K. Reserve of Barkoissi conversion in agroforestery parklands [J]. Int. For. Rev. 2010, 12 (5):193.

[121] Pielou E.C. Ecological diversity [M] .John Wiley and Sons, New York. Viii+ .1975:165. (209, 215, 238, 239, 244, 245).

[122] Pierre L. and Louis L. Numerical Ecology [M] .Second English edition: Elsevier Science B.V., Amsterdam. 1998:853.

[123] Pierre S., Oscar E-M. and consultants nationaux. Situation des ressources génétiques forestières de la zone Sahélienne et Nord Soudanienne et plan d'action sous-régional pour leur conservation et utilisation durable [M]. FAO .Roma.2001 : XXX

[124] Raunkier C. The life forms of plants and statistical plant geography [M]. Oxford University Press, London, 1934:632.

[125] Roland P. Etude morphopédologique du nord du Togo a 1/500000 [M]. ORSTOM, Paris (France).1996 :145.

[126] Rollet B. L'architecture des forets denses humides sempervirentes des plaines [M]. CTFT. Paris (France) .1974:298.

[127] Rouse J. W., Haas R. H., Schell J. A., and Deering D. W. Monitoring vegetation systems in the Great Plains with ERTS [J]. Third ERTS Symposium, NASA .1973, SP-351 (I):309-317.

[128] Sader S.A. and Winne J.C. RGB-NDVI colour composites for visualizing forest change dynamics [J]. International Journal of Remote Sensing.1992, 13(16):3055-3067.

[129] Sader S.A., Bertrand M. and Wilson E.H. Satellite change detection of forest harvest patterns on an industrial forest landscape [J].Forest Scienc.2003, 49(3):341-353.

[130] Scientia Silvica, 1997. – Plant diversity in Old-Growth and Second-Growth stand in the coastal Rainforests of British Columbia Extension Series, Number 3.

[131] Sellers P. J. Canopy reflectance, photosynthesis, and transpiration [J]. International Journal of Remote Sensing.1985, (6):1335–1372.

[132] Shannon C.E.A mathematical theory of communication [J] .Bell System Technical Journal.1948, (27):379-423.

[133] Simpara N. Etude géologique et structurale des unités externes de la chaîne panafricaine (600MA), des Dahomeyides dans la région de Bassar (Togo) [M]. Thèse Univ. Marseille (France). 1978 :164.

[134] Sinsin B. Formes de vie et diversité spécifique des associations de forets claires du Nord du Bénin [J]. In: E. Robbrecht et al., 2001. Systematics and Geography of plants. National Botanic Garden (Belgium).2001, (1) :873-887.

[135] Sinsin B. Phytosociologie, écologie, valeur pastorale, production et capacité de charge des pâturages du périmètre Nikki-Kalalé au nord-Benin [M]. Thèse de doctorat, Université Libre de Bruxelles (Belgique) .1993 :350.

[136] Sonko I. Etude des effets de différents régimes de feux sur la dynamique de la flore et de la végétation ligneuse des plateaux du Parc National du Niokolo-Koba (Sud-est du Sénégal). Thèse de doctorat, Universié de Dakar (Senegal).2000 :126.

[137] Sournia G., Alassoum O., Belemsobgo U., Djeri-Alassani B., Lartiges A., Sinsin B. and Thomassey J. (1998). Les aires protégées d'Afrique francophone [M]. Ed. ACCT/ Jean–Pierre de Monza.1998 :272**.**

[138] Spottiswoode C.N., Wondafrash M., Gabremichael M.N., Dellelegn A.Y., Mwangi M.A.K., Collar N.J. and Dolman P.M. Rangeland degradation is poised to cause Africa's first recorded avian extinction [J]. Animal Conservation. 2009, 1(9):1469-1795.

[139] Sun Z.Y., Ma R. and Wang Y.X. Using Landsat data to determine land use changes in Datong basin, China [J]. Environ Geo.2009, (57):1825–1837.

[140] Swaine M.D., Hall J.B. and Alexandrer I.J. Tree population dynamics at Kade, Ghana (1968-1982) [J]. Journal of Tropical Ecology.1987, (3): 331-345.

[141] Tabe N. Contribution à l'étude de la structure des peuplements à Isoberlinia de la réserve de faune d'Alédjo [M]. Mémoire de DEA, Université de Lomé (Togo).2007 :63.

[142] Tchamie T. Lessons from the hostility of local people in respect of protected areas in Togo [J].Unasylva.1994, 176.

[143] Tchamie T. and Bouraïma M. Les formations végétales du plateau Soudou-Dako dans la chaîne de l'Atakora et leur évolution récente [J]. J. Bot. Soc. Bot. Fr.1997, (3): 83-97.

[144] Tente B. and Sinsin B. Diversité et structure des formations arborescentes du secteur Perma-Toucountouna dans la chaîne de l'Atacora (Bénin) [J]. Etude Flor. Vég., Burkina Faso.2002, (6): 31-42.

[145] Ter Braak C.J.F. and Similauer P. CANOCO reference manual and user's guide to Canoco for Windows. Software for canonical community ordination [M]. Center of Biometry Wageningen, CPRO-DLO. Wageningen (the Netherlands).1998:352.

[146] Thiombiano A. Contribution à l'étude des Combretaceae dans la région EST du Burkina Faso [M]. Thèse de Doctorat, Université d'Ouagadougou (Burkina Faso).1996 :220.

[147] Thiombiano A. and Millogo R. J. Initiation à la phytocoenologie, éléments de T.D et T.P. [M].Universite de Ouagadougou (Burkina Faso). 2005 :38.

[148] Thomassey J.P.Les aires protégées d'Afrique francophone [M]. Ed. ACCT/ Jean – Pierre de Monza.1998 :272.

[149] Tou J.T. and Gonzalez R.C. Pattern recognition principles [M]. Addison-Wesley, London.1974: XXXX.

[150] Toutain B. Dynamique de la végétation et évolution des écosystèmes pâturés au sahel [J]. The sahel.in: Lykke A.M., Reenberg A. and Nielsen I. (Eds).SEREN occasional papers.1999, (10):1-11.

[151] Treu M.C., Magoni M., Steiner F., Palazzo D. Sustainable landscape planning for Cremona, Italy [J]. Lands Urban Plan. 2000, (47):79–98.

[152] Tucker C. J. Red and photographic infrared linear combinations for monitoring vegetation [J]. Remote Sens. Environ.1979, (8):127-150.

[153] Turner M.G. Disturbance and landscape dynamics in a changing world [J]. Ecology. 2010, 91(10):2833-49.

[154] UICN/PACO. Evaluation de l'efficacité de la gestion des aires protégées: aires protégées du Togo [M]. IUCN, Burkina Faso.2008:44p.www.papaco.org

[155] Virginia H. D., Linda A. J., Steve M., Ronald P. N., Matthew P.A., Michael D. F., Paul J. H., Lloyd C. I., Ariel E. L., Chris J. P., Daniel S., Frederick J. S., Brian J. S., and Michael B. W. Climate Change and Forest Disturbances [J]. BioScience. 2001, 51(9):723-734.

[156] Wala K. La végétation de la chaîne de l'Atakora au Bénin : diversité floristique, Phytosociologie et impact humain [M]. Thèse de Doctorat, Université de Lomé(Togo).2004 :138.

[157] Wang S.Y.，Zhang Z.Y., Zhou Q.B. and Wang C.Y. Study on Spatial-Temporal Feature of Land Use / LandCover Change Based on Technologies of RS an d GIS (**基于遥感与 GIS 技术的土地利用时空特征研究**) [J]. Journal of Remote Sensing, 2002, 6(3):223-229.

[158] Ward J. Hierarchical grouping to optimize an objective function [J]. J. Am. Statist. Assoc. 1963, (58):236-244.

[159] Watts K., Ray D., Quine C.P., Humphrey J.W. and Griffiths M. Evaluating Biodiversity in Fragmented Landscapes: Applications of Landscape Ecology Tools [J]. Forest research**,** Edinburgh.2007: 8. www.forestresearch.gov.uk/landscapeecology.

[160] Westhoff V. and van der Maarel E. (1978). The Braun-Blanquet Approach, 2nd ed. In: R.H. Whittaker (ed). Classification of Plant Communities [M]. Junk, The Hague.1978: 287-399.

[161] Winston S.W. T. and Lynne A. T. Prescribed burning in African grasslands and savannas for wildlife management [J]. Fire Ecology.2004, (55). http://www.turf.arizona.edu/OALS/ALN/aln55/trollope.html

[162] Winston S.W.T. and Lynne A.T. Fire behaviour a key factor in the fire ecology of African grasslands and savannas [M]. Forest Fire Research & Wildland Fire Safety, Viegas (ed.) © 2002 Millpress, Rotterdam.2002:15.

[163] White F. La végétation d'Afrique. Mémoire, carte de la végétation d'Afrique [M].

UNESCO/AETFA/UNSO.1986:383.

[164] Wilson E.F. and Sader S.A. Detection of forest type using multiple dates of Landsat TM imagery [J]. Remote Sensing of Environment .2002, (80):385-396.

[165] Woegan Y.A. Diversité des formations végétales ligneuses du parc national de Fazao-Malfakassa et de la réserve de faune d'Aledjo (Togo) [M]. Thèse de Doctorat, Université de Lomé (Togo).2007 :142.

[166] Yang X.L., Cui G.F., Ren Q.S., Wang J.S. and Huang Y. Plant diversity pattern and stability of the timberline community on Sejila Mountain in Tibet, western China (西藏色季拉山林線植物群落多樣性格局及林線的穩定性) [J]. Journal of Beijing Forestry University, 2008, 30(1):14-20.

[167] Ye L. and Xu H.Remote Sensing of Spatio-temporal Land Use Dynamics in Fuzhou District during the Last 20 Years (近 **20** 年来福市土地利用时空变化的遥感分析) [J]. GEO—INFORMATION SCIENCE, 2008, 10(1): 80-87.

[168] Yema E., Georges L. and Association des géographes togolais .Atlas du Togo [M]. (Les Atlas Jeune Afrique), Éditions J.A. Paris (France).1981 :64(58-59).

[169] Yvon-Carmen H.H.Dynamique environnementale en zones sahélienne et soudanienne de l'Afrique de l'Ouest: Analyse des modifications et évaluation de la dégradation du couvert végétal [M]. Thèse de doctorat. Université de Liege, (Belgique) .2008 :153.

[170] Zhang J.T., Meng D.P. and Xi Y.X. Ordination of self-organizing feature map neural network and its application in the study of plant communities (自組織神經影射網絡排序及其在植物群落分析中的應用) [J]. Journal of Beijing Forestry University, 30(1):1-5.

[171] Zoungrana M. Diversité floristique et potentialités de la vegetation ligneuse des forêts classées de Boulon et de Koflande, Province de la Comoé, Burkina Faso [M]. Mémoire d'ingénieur eau et forêt, Université polytechnique de Bobo–Dioulasso (Burkina Faso).2008 :105.

ANNEX

Annex 1: Plant species checklist of the study areas

Dicotyledone

Familly	**Species**	**PT**	**LF**
Acanthaceae	*Asystasia calycina* Benth.	G	Th
	Lepidagadis anobrya Nees	SZ	Hc
	Lepidagathis collina (Endl.)Milne-Redh.	SZ	Hc
Amaranthaceae	*Pandiaka angustifolia* (Vahl) Hepper.	Pan	Th
	Pandiaka involucrata (Moq.)B.D.Jackson	S	Ch
	Philoxerus vermicularis (L.) P. Beauv.	GC	Ch
Anacardiaceae	*Anacardium occidentale* L.	Pan	mph
	Lannea acida A.Rich.	PRA	mPh
	Lannea kerstingii Engl. & K.Krause	SZ	mPh
	Lannea microcarpa Engl. & K.Krause	SZ	mPh
	Ozoroa pulcherima (Schweinf.) R. & A. Fernandes	SZ	nph
	Sclerocarya birrea (A.Rich.)Hochst.)	AT	mph
Annonaceae	*Annona glauca* Schum. & Thonn.	SZ	nph
	Annona senegalensis Pers.	SZ	nph
	Monanthotaxis parvifolia (Oliv.) Verc.	G	Lnph
Araliaceae	*Cussonia kirkii* Seem.	SZ	mPh
Asclepiadaceae	*Leptadenia hastata* (Pers.) Decne.	SZ	Ch
Asteraceae	*Aspilia bussei* (Schum. & Thonn.)Oliv. & Hiern	SG	Th
	Aspilia helianthoides (Schum. & Thonn.) Oliv. & Hiern	SZ	Th
	Chrysanthellum senegalensis DC.	Pan	Th
	Echinops longifolius A. Rich.	SZ	nph
	Synedrella nodiflora (L.) Gaertn.	Pan	Th
	Tridax procumbens L.	Pan	Th
Balanitaceae	*Balanites aegyptiaca* (L.)Del.	SZ	mph
Bignoniaceae	*Crescentia cujete* L.	i	mph
	Spatodea campanulata P.Beauv.	GC	mph
Bombacaceae	*Adansonia digitata* L.	SZ	mPh
	Bombax costatum Pellegr. & Vuill.	SZ	mph
Caesalpiniaceae	*Afzelia africana* Smith ex Pers.	S	mPh
	Cassia mimosoides L.	Pan	nph
	Cassia occidentale L.	Pan	nph
	Cassia sieberiana DC.	S	mPh
	Cassia tora L.	Pan	nph
	Daniellia oliveri (Rolfe) Hutch. & Dalziel	SZ	mPh
	Detarium microcarpum Harms	S	mph
	Dialium guineensis Willd.	GC	mPh
	Erythrophleum suaveolens (Guill. & Perr.) Brenan	SG	mPh
	Piliostigma thonningii (Schumach.)Milne-Redh.	S	mph
	Tamarindus indica L.	Pan	mPh

Caparaceae	*Cleome viscosa* L.	SG	Th
	Crataeva adansonii DC. subsp. Adansonii	Pal	mph
Celastraceae	*Maytenus senegalensis* (Lam.) Exell	SZ	nph
Chrysobalanaceae	*Maranthes polyandra* (Benth.) Prance	S	mph
Cochlospermaceae	*Cochlospermum planchonii* Hook.f.	SG	nph
	Cochlospermum tinctorium Perr. ex A.Rich.	S	nph
Combretaceae	*Anogeissus leiocarpa* (DC.)Guill. & Perr.	PRA	mPh
	Combretum acutum Laws	S	Lmph
	Combretum aculeatum Vent.	S	Lmph
	Combretum collinum Fresen.	SG	mPh
	Combretum fragrans F. Hoffm.	SZ	mph
	Combretum glutinosum Perr. ex DC.	SZ	mph
	Combretum micranthum G.Don.	S	mph
	combretum molle R.Br. ex G.Don	AT	mph
	Combretum nigricans Lepr. ex Guill. & Perr. var. elliotii (Engl.&Diels) Aubrév.	S	mph
	Combretum paniculatum Vent.	AT	mph
	Guiera senegalensis J.F.Gmel.	S	nph
	Pteleopsis suberosa Engl. & Diels	PRA	mph
	Quisqualis indica L.	Pal	Lmph
	Terminalia avicennioides Guill. & Perr.	S	mph
	Terminalia glaucescens Planch. ex Benth.	SG	mph
	Terminalia laxiflora Engl. & Diels	S	mph
	Terminalia macroptera Guill. & Perr.	S	mph
	Terminalia mollis M. A. Lawson	SZ	mph
Connaraceae	*Cnestis ferruginea* Vahl ex DC.	GC	nph
Convolvulaceae	*Ipomoea aquatica* (L.)Ker Gawl	GC	lnph
	Ipomoea argentaurata Forssk.	S	Gr
	Ipomoea mauritiana Hall.f.	Pan	Lmph
Crassulaceae	*Bryophyllum* pinnatum (Lam.) Oken	GC	nph
Cucurbitaceae	*Citrullus colocynthis* (L.)Schrad	I	Th
	Colocynthis citrullus (L.) O.Ktze	AT	Th
	Cucumis melo L. subsp.agrestis (Naudin) Pangalo	Pan	Lnph
	Luffa aegytiaca Mill.	Pan	Lnph
	Zeheria hallii C.Jeffrey	SG	Lnph
Ebenaceae	*Diospyros abyssinica* (Hiern)F.White	GC	mPh
	Diospyros mespiliformis Hochst. ex A.DC.	SZ	mPh
Euphorbiaceae	*Alchornea cordifolia* (Schum. & Thonn.)Müll. Arg	GC	mph
	Bridelia ferruginea Benth.	PRA	mph
	Croton lobatus L.	Pan	Th
	Euphorbia convolvuloides Hochst. ex Benth	S	Th
	Malotus oppositifollus (Geisel.)Müell.Arg.	Pal	nph
	Phyllanthus muellerianus (O.Ktze.)Exell	SG	Lmph

	Sapium ellipticum (Hochst. ex Krauss) Pax	AT	mph
	Sapium grahamii (Stapf) Prain	SZ	nph
	Securinega virosa (Roxb. ex Willd.) Baill.	Pan	nph
	Tragia benthamii Bak.	GC	Lnph
Fabaceae	*Aeschynomene afraspera* J. Léonard	PRA	Ch
	Aeschynomene schimperi Hoscht. Ex A. Rich.	i	i
	Alysicarpus ovalifolius (Schum. & Thonn.) J. Léonard	Pal	Th
	Alysicarpus vaginalis (L.) DC.	Pan	Th
	Baphia pubescens Hook. f.	GC	mph
	Cajanus kerstingii Harms	i	nph
	Centrosema pubescens Benth.	GC	Lmph
	Crotalaria graminicola Taub. ex Bak.f.	S	Th
	Crotalaria leprieurii Guill. & Perr.	SZ	nph
	Crotalaria pallida Aiton var. obvata (G. Don) Polhill	Pan	Ch
	Crotalaria polygaloides welw. ex Bak	Pan	nph
	Crotalaria retusa L.	Pan	Ch
	Desmodium gangeticum (L.)DC.	Pal	nph
	Desmodium linearifolium G. Don	i	Ch
	Desmodium ramosissimum G. Don	Pal	Th
	Desmodium tortuosum (Sw.) DC.	Pan	nph
	Desmodium triflorum (L.) DC.	Pan	lnph
	Desmodium velutinum (Willd.)DC.	Pal	Ch
	Eriosema pulcherrimum Taub.	SZ	nph
	Erythrina senegalensis A. DC.	SG	mph
	Indigofera dendroides Jacq.	SZ	Th
	Indigofera spicata Forssk. var. spicata	GC	nph
	Indigofera trichopoda Lepr. ex Guill. & Perr.	SZ	Th
	Lonchocarpus sericeus (Poir.)Kunth	PRA	mPh
	Millettia thonningii (Schum. & Thonn.)Baker	GC	mph
	Pericopsis laxiflora (Benth.) Van. Meeuwen	SG	mph
	Pterocarpus erinaceus Poir	SZ	mPh
	Ptreocarpus santaloïdes DC.	PRA	mPh
	Rhynchosia minima (L.) DC. var. minima	GC	Lmph
	Tephrosia *bracteolata* Guill. & Perr.	SG	Ch
	Tephrosia elegans Schumach.	SG	Ch
	Tephrosia linearis (Willd.)Pers.	SG	Th
	Tephrosia purpurea (L.)Pers. subsp. Purpurea	Pal	Ch
	Tephrosia villosa (L.)Pers.	Pan	Ch
	Uraria picta (Jacq.) DC.	Pal	nph
	Zornia glochidiata Rchb. ex DC.	SG	Th
Lamiaceae	*Cymbopogon citratus* (DC.) Stapf	i	Hc
	Hyptis suaveolens Poit.	Pan	Th
Loganiaceae	*Spigelia anthelmia* L.	AA	Th

	Strychnos barteri Soler.	GC	LmPh
	Strychnos nigritana Baker	GC	LmPh
	Strychnos spinosa Lam.	AM	mph
Loranthaceae	*Tapinanthus dodoneifolius* (DC.) Danser	SZ	Par
	Tapinanthus pentagonia (DC.) van Tiegh.	SZ	Par
Malvaceae	*Hibiscus articulatus* Hoscht. Ex A. Rich. var glabrescens Hochr.	SZ	Hc
	Hibiscus asper Hook.f.	SG	nph
	Sida acuta Burm.f. subsp. Acuta	Pan	Ch
	Sida rhombifolia L.	GC	nph
	Urena lobata Benth.	G	nph
	Wissadula amplissima (L.)R.E.Fries	SZ	Th
Meliaceae	*Azadirachta indica* A.Juss.	Pal	mPh
	Khaya senegalensis (Desr.)A.Juss.	SZ	mPh
	Pseudocedrela kotschyi (Schweinf.)Harms.	SZ	mph
Menispermaceae	*Cissampelos mucronata* A. Rich.	SZ	Lnph
	Tiliacora funifera (Miers) Oliv.	GC	Lmph
	Triclisia subcordata Oliv.	G	Lnph
Mimosaceae	*Acacia albida* Del.	SZ	mph
	Acacia dudgeoni Craib ex Holland	SZ	mph
	Acacia gourmaensis A.Chev.	S	mph
	Acacia polyacantha Willd.	SZ	mPh
	Acacia sieberiana DC. var. sieberiana	SZ	mph
	Dichrostachys cinerea (L.)Wight & Arn	SG	nph
	Entada abyssinica Steud. ex A.Rich.	AT	mPh
	Entada africana Guill. & Perr.	SZ	mph
	Mimosa pigra L.	Pan	nph
	Parkia biglobosa (Jacq.)R.Br. ex G.Don f.	Pal	mPh
	Prosopis africana (Guill. & Perr.)Taub.	SZ	mPh
Moraceae	*Ficus sycomorus* Linn. Subsp. gnaphalocarpa (Miq.) C.C. Berg	SZ	mph
	Ficus vallis-choudae Delile	SZ	mph
Myrtaceae	*Eugenia kerstingii* Engl. & Brehm.	GC	mph
Nymphaeaceae	*Nymphea lotus* L.	Pan	Hydr
Opiliaceae	*Opilia amantaceae* Roxb.	SZ	Lmph
Oxalidaceae	*Biophytum petersianum* Klotzsch.	Pan	Th
Pedaliaceae	*Sesamum radiatum* Schum. & Thonn.	GC	nph
Polygalaceae	*Securidaca longepedunculata* Fres.	AT	nph
Rhamnaceae	*Ziziphus abyssinica* Hochst. ex A.Rich.	SZ	mph
	Ziziphus mucronata Willd.	PRA	mph
Rubiaceae	*Argocoffoepsis rupestris* (Hiern) Robbr.	SG	mph
	Canthium multiflorum (Schum. & Thonn.) Hiern	SZ	nph
	Crossopteryx febrifuga (G. Don) Benth.	SZ	mph
	Fadogia agrestis Schweinf. ex Hiern	S	Ch

	Feretia apodanthera Delile Ssp. apodanthera	SZ	nph
	Gardenia aquala Stapf & Hutch.	SZ	nph
	Gardenia erubescens Stapf & Hutch.	SG	nph
	Gardenia ternifolia Schum. & Thonn. Syn G. triacantha DC.	Pal	nph
	Mitragyna inermis (Willd.)O.Kuntze	SZ	mPh
	Morinda lucida Benth.	Pan	mph
	Nauclea latifolia Smith	AT	mph
	Oldenlandia corymbosa L.	Pan	Th
	Spermacoce ruelliae DC.	SG	Th
Sapindaceae	*Allophylus africanus* P.Beauv.	Pan	mph
	Blighia unijugata Bakker.	GC	mph
	Paullinia pinnata L.	AT	Lmph
Sapotaceae	*Vitellaria paradoxa* C.F.Gaertn.	S	mPh
Scropphulariaceae	*Striga hermonthica* (Delile) Benth.	Pal	Th
Solanaceae	*Physalis angulata* L.	Pan	Th
Sterculiaceae	*Sterculia setigera* Del.	SZ	mph
Strelitziaceae	*Strelizia* reginae Banks ex Aiton	i	Hc
Thymelaeaceae	*Waltheria indica* L.	Pan	nph
Tiliaceae	*Grewia carpinifolia* Juss.	GC	mph
	Grewia cissoides Hutch. & Dalziel	S	nph
	Grewia lasiodiscus K.Schum.	SZ	mph
	Grewia venusta Fresen. Syn. G. mollis Auct.	S	nph
	Triumfetta rhomboidea Jacq. var. rhomboidea	Pan	nph
Ulmaceae	*Trema orientalis* (L.)Blume	Pan	mph
Urticaceae	*Laportea aestuans* (L.) Chew.	GC	Th
	Laportea ovalifolia (Schum. & Thonn.) Chew	GC	nph
Verbenaceae	*Clerodendrum capitatum* (Willd.)Schum. & Thonn.	GC	Lmph
	Lantana camara L.	SG	Lmph
	Lippia multiflorum Moldenke	SG	nph
	Premna quadrifolia Schumach.& Thonn.	G	nph
	Stachystarfeta indica (L.) Vahl	AA	Th
	Tectona grandis L. F.	Pal	mPh
	Vitex doniana Sweet	AT	mPh
	Vitex madiensis Oliv.	SZ	nph
	Vitex simplicifolia Oliv.	SZ	nph
Vitaceae	*Ampelocissus bombycina* Planch.	GC	Lmph
	Caryatia delicatula (Willems) Descoings	GC	Lmph
	Cissus araliodes (Welw. ex Baker) Planch.	SG	Lnph
	Cissus lageniflorum (Gilg & Brandt) Descoings	SZ	Lmph
	Cissus populnea Guill. & Perr. var. populnea	S	Lmph
	Cissus quadrangularis L.	SZ	Lmph
	Cissus vogelii Hook.f.	G	mph
	Cyphostemma griseo-rubrum (Gilg &Brandt) Descoings	Pan	Lmph

	Cyphostemma sokodense (Gilg & Brandt) Descoings	G	Lmph

Monocotyledone

Agavaceae	*Sansevieria liberica* Gérôme & Labory	GC	Gr
Amaryllidaceae	*Crinum ornantum* (Alt.) Bury	SG	Ge
	Crinum jagus (Thomp.) Dandy	GC	Ge
Araceae	*Amorphophallus flavovirens* N.E.Br.	G	Gt
	Anchomanes difformis (Blume)Engl.	GC	Gt
	Anubias gigantea A. Chev. Ex Hutch.	GC	Hyd
	Stylochiton hypogaeus Lepr	S	Gt
	Stylochiton lancifolius Kotschy &Peyr.	S	Gr
Arecaceae	*Borassus aethiopum* Mart.	SZ	mph
	Elaesis guineensis Jacq.	GC	mph
Commelinaceae	*Aneilema beniniense* (P. Beauv.)Kunth	GC	Hc
	Aneilema lanceolatum Benth.	SZ	Th
	Commelina erecta L.	AT	Ch
	Cyanotis longifolia Benth.	SG	Hc
	Murdannia simplex (Vahl) Brenan	AT	Hc
Cyperaceae	*Afrotrilepis pilosa* (Boeck.)J.Raynal	SG	Hc
	Bulbostylis abortiva (Steud.)C.B.Clarke	Pan	Hc
	Cyperus alternifolius L.	i	Gr
	Cyperus pilchellus R. Br.	SZ	Hc
	Cyperus tenuiculmis var. schweinfurthii	SG	Hc
	Fimbristylis dichotoma (L.) Vahl. subsp. Dichotoma	Pan	Hc
	Kyllinga appendiculata K. Schum.	Pan	Gr
Dioscoreaceae	*Dioscorea alata* L.	i	G
	Dioscorea dumetorum (Kunth)Pax	SZ	Gt
	Dioscorea similacifolia De Wild.	GC	Gt
	Dioscorea togoensis Kunth	GC	Gt
Liliaceae	*Asparagus warneckei* (Engl.) Hutch.	G	Lmph
	Gloriosa superba L. Syn. G. simplex L.	GC	LGb
Marantacea	*Marantocloa purpurea* (Ridl.) Milne-Redh.	GC	nph
Poaceae	*Andropogon gayanus* Kunth var. bisquamulatus (Hochst.) Hack.	SG	Hc
	Andropogon gayanus Kunth var. gayanus DC.	SG	Hc
	Andropogon macrophyllus Stapf.	GC	Hc
	Andropogon tectorum Schum. & Thonn.	SG	Hc
	Brachiaria deflexa (Schumach.)Robyns	Pal	Th
	Brachiaria lata (Schumach.) C.E. Hubbard.	Pal	Th
	Cymbopogon nardus (L.) Rendl	i	Hc
	Cynodon dactylon (L.) Pers.	Pan	Ch
	Digitaria sangiuneum	SZ	Th
	Digiteria diagonalis (Nees)Stapf	SG	Hc

	Echinochloa colona (L.) Link	Pan	Th
	Eragrostis atrovirens (Desf) Trin. Ex Steud (Hochst. ex A. Rich.) Maire & Weiler	Pal	Hc
	Hyparrhenia involucrata var. breviseta W.D. Clayton	SZ	Th
	Loudetia simplex (Nees) C.E.Hubb.	SG	Hc
	Loudetiopsis ambiens (K. Schum.) Conert	AT	Hc
	Microchloa *indica* (L.f.) P.Beauv.	Pan	Th
	Oryza longistamina A. Chev. & Roehr	Pan	Hc
	Panicum maximum Jacq.	GC	Hc
	Paspalum distichum L. syn P. vaginatum SW.	GC	Hc
	Pennisetum purpureum Schumach.	Pan	Hc
	Pennisetum subangustum (Schumach.) Stapf & C.E. Hubb.	SG	Th
	Rottboellia cochenesinensis (Lour.) W. D. Clayton	Pan	Th
	Schizachyrium sanguineum (Retz.)Alston	Pan	Hc
	Setaria sphacelata (Schumach.) Moss var. sphacelata	AT	Hc
	Setaria barbata (Lam.)Kunth	Pan	Th
	Setaria megaphylla (Steud.) Dur. & Schinz.	GC	Hc
	Sporobolus pyramidalis P. Beauv.	SZ	Hc
	Vitiveria nigritana (Benth.) Stpf	SZ	Hc
Taccaceae	*Tacca leontopetaloides* (L.)O.Kuntze	Pal	G
Tiliaceae	*Corchorus aetuans* L.	Pan	Th
Zingiberaceae	*Aframomum alboviolaceum* (Ridley) K.Schum.	SZ	Gr
	Aframomum angustifolium (Sonnerat) K. Schum	GC	nph
	Costus afer Ker-Gawl.	AT	Gr
	Zingiber officinalis Rosc.	i	Gr

Phytogeographic types

SZ: Sudano-zambesian, Pan: Pan-Tropical, GC: Guineo-Congolian, SG: Sudano-Guinean, S: Sudanian, Pal: Paleo-Tropcal, AT: Afro-Tropical, i: undefined, G: Guinean, PRA: Pluri Regional in Africa, AA: Afro-American, AM: Afro-Malgash

Life forms types

mph: micro-phanerophytes, nph: nano-phanerophytes, Th: Therophytes, L: Lianas (Lmph: meso-phanerophytes lianas, Lnph: nano-phanerophytes, LGb: Geophytes bulb), Hc: Hemicryptophytes, mPh: meso-phanerophytes, G: Geophytes, CH: Chamephytes, par: Parasite and Hydr: Hydrophytes

Annex 2: Plant species checklist present in each protected area

Species	**Bar**	**Gal**	**O-K**
Acacia albida Del.	1		
Acacia dudgeoni Craib ex Holland	1	1	1
Acacia gourmaensis A.Chev.	1	1	1
Acacia polyacantha Willd.	1	1	1
Acacia sieberiana DC. var. sieberiana	1		
Adansonia digitata L.		1	1
Aeschynomene afraspera J. Léonard			1
Aeschynomene schimperi Hoscht. Ex A. Rich.		1	1
Aframomum alboviolaceum (Ridley) K.Schum.			1
Aframomum angustifolium (Sonnerat) K. Schum	1		1
Afrotrilepis pilosa (Boeck.)J.Raynal			1
Alchornea cordifolia (Schum. & Thonn.)Müll. Arg			1
Allophylus africanus P.Beauv.	1	1	1
Alysicarpus ovalifolius (Schum. & Thonn.) J. Léonard	1	1	1
Alysicarpus vaginalis (L.) DC.			1
Amorphophallus flavovirens N.E.Br.		1	1
Ampelocissus bombycina Planch.	1	1	1
Anacardium occidentale L.	1		
Anchomanes difformis (Blume)Engl.	1	1	1
Andropogon gayanus Kunth var. bisquamulatus (Hochst.) Hack.			1
Andropogon gayanus Kunth var. gayanus DC.		1	1
Andropogon macrophyllus Stapf.			1
Andropogon tectorum Schum. & Thonn.	1	1	1
Aneilema beniniense (P. Beauv.)Kunth			1
Aneilema lanceolatum Benth.			1
Annona glauca Schum. & Thonn.	1	1	1
Annona senegalensis Pers.			1
Anogeissus leiocarpa (DC.)Guill. & Perr.	1	1	1
Anubias gigantea A. Chev. Ex Hutch.			1
Argocoffoepsis rupestris (Hiern) Robbr.		1	1
Asparagus warneckei (Engl.) Hutch.	1	1	1
Aspilia bussei (Schum. & Thonn.)Oliv. & Hiern			1
Aspilia helianthoides (Schum. & Thonn.) Oliv. & Hiern	1		
Asystasia calycina Benth.			1
Azadirachta indica A.Juss.		1	1
Balanites aegyptiaca (L.)Del.	1		1
Baphia pubescens Hook. f.			1
Biophytum petersianum Klotzsch.			1
Blighia unijugata Bakker.			1
Bombax costatum Pellegr. & Vuill.	1	1	1
Borassus aethiopum Mart.	1	1	

Brachiaria deflexa (Schumach.)Robyns	1		1
Brachiaria lata (Schumach.) C.E. Hubbard.			1
Bridelia ferruginea Benth.		1	1
Bryophyllum pinnatum (Lam.) Oken		1	
Bulbostylis abortiva (Steud.)C.B.Clarke	1	1	1
Cajanus kerstingii Harms			1
Canthium multiflorum (Schum.& Thonn.) Hiern	1		1
Caryatia delicatula (Willems) Descoings	1		
Cassia mimosoides L.	1	1	1
Cassia occidentale L.			1
Cassia sieberiana DC.	1		
Cassia tora L.			1
Centrosema pubescens Benth.			1
Chrysanthellum senegalensis DC.	1		
Cissampelos mucronata A. Rich.		1	1
Cissus araliodes (Welw. ex Baker) Planch.	1	1	1
Cissus lageniflorum (Gilg & Brandt) Descoings	1		1
Cissus populnea Guill. & Perr. var. populnea	1	1	1
Cissus quadrangularis L.			1
Cissus vogelii Hook.f.			1
Citrullus colocynthis (L.)Schrad	1		1
Cleome viscosa L.	1		
Clerodendrum capitatum (Willd.)Schum. & Thonn.			1
Cnestis ferruginea Vahl ex DC.			1
Cochlospermum planchonii Hook.f.	1	1	1
Cochlospermum tinctorium Perr. ex A.Rich.			1
Colocynthis citrullus (L.) O.Ktze	1		
Combretum acutum Laws	1		
Combretum aculeatum Vent.		1	
Combretum collinum Fresen.		1	1
Combretum fragrans F. Hoffm.			1
Combretum glutinosum Perr. ex DC.	1	1	1
Combretum micranthum G.Don.	1	1	1
combretum molle R.Br. ex G.Don	1	1	1
Combretum nigricans Lepr. ex Guill. & Perr. var. elliotii	1		
Combretum paniculatum Vent.			1
Commelina erecta L.	1	1	1
Corchorus aetuans L.	1		1
Costus afer Ker-Gawl.	1		1
Crataeva adansonii DC. subsp. Adansonii			1
Crescentia cujete L.	1		
Crinum ornantum (Alt.) Bury	1	1	1
Crinum jagus (Thomp.) Dandy		1	1
Crossopteryx febrifuga (G. Don) Benth.		1	1
Crotalaria graminicola Taub. ex Bak.f.	1	1	1

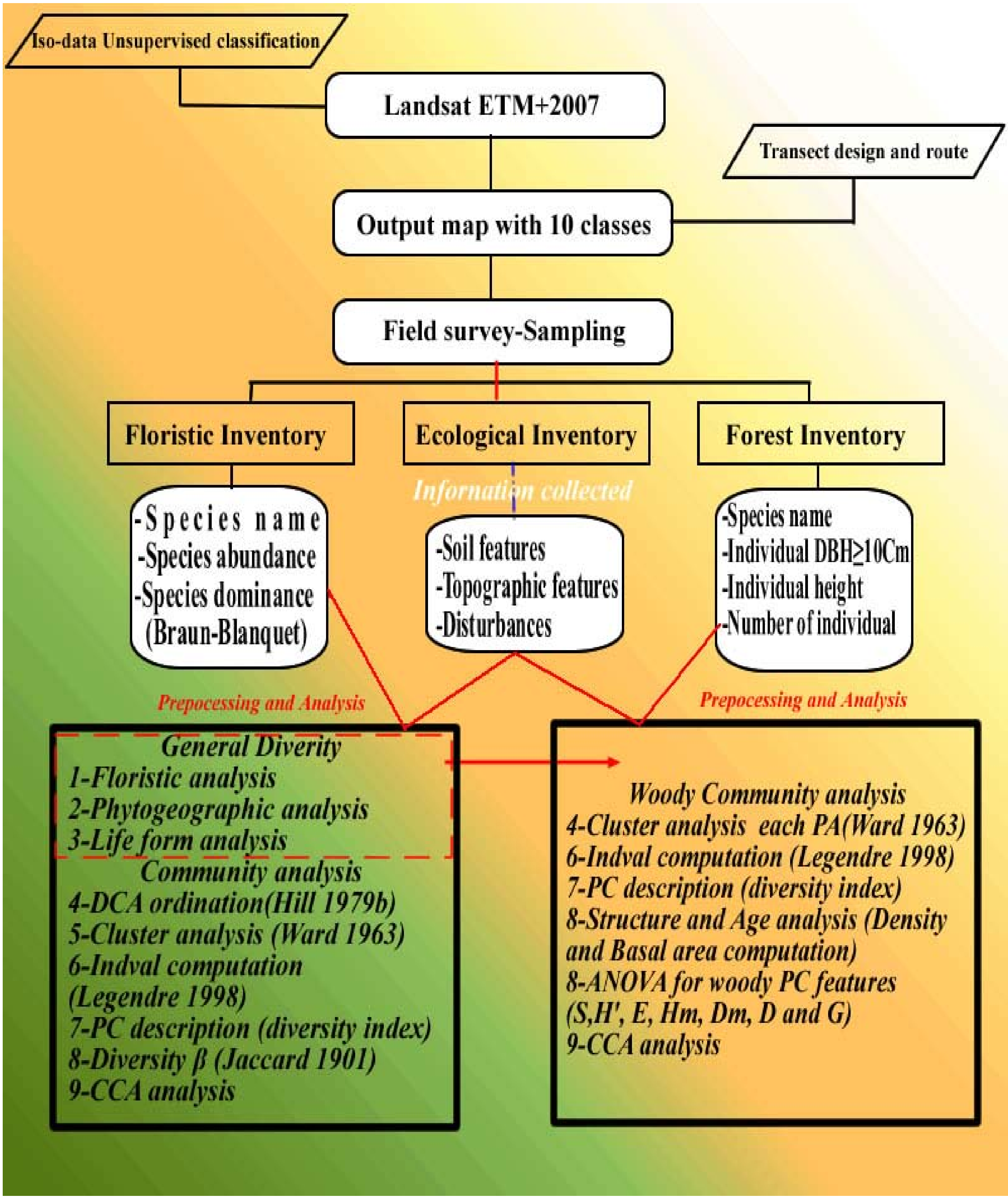
Crotalaria leprieurii Guill. & Perr.		1	
Crotalaria pallida Aiton var. obvata (G. Don) Polhill			1
Crotalaria polygaloides welw. ex Bak			1
Crotalaria retusa L.	1	1	1
Croton lobatus L.		1	
Cucumis melo L. subsp.agrestis (Naudin) Pangalo	1		
Cussonia kirkii Seem.	1	1	1
Cyanotis longifolia Benth.	1	1	1
*Cymbopogon nardus (*L.) Rendl		1	1
Cynodon dactylon (L.) Pers.			1
Cyperus alternifolius L.			1
Cyphostemma griseo-rubrum (Gilg &Brandt) Descoings			1
Cyphostemma sokodense (Gilg & Brandt) Descoings	1	1	1
Daniellia oliveri (Rolfe) Hutch. & Dalziel	1		1
Desmodium gangeticum (L.)DC.	1	1	1
Desmodium ramosissimum G. Don		1	1
Desmodium tortuosum (Sw.) DC.			1
Desmodium triflorum (L.) DC.	1	1	1
Desmodium velutinum (Willd.)DC.			1
Detarium microcarpum Harms	1	1	1
Dialium guineensis Willd.			1
Digitaria sangiuneum			1
Digiteria diagonalis (Nees)Stapf			1
Dioscorea alata L.		1	1
Dioscorea dumetorum (Kunth)Pax	1	1	1
Dioscorea similacifolia De Wild.			1
Dioscorea togoensis Kunth		1	1
Diospyros abyssinica (Hiern)F.White	1		
Diospyros mespiliformis Hochst. ex A.DC.	1	1	1
Echinochloa colona (L.) Link		1	1
Echinops longifolius A. Rich.		1	
Elaesis guineensis Jacq.			1
Entada abyssinica Steud. ex A.Rich.	1	1	1
Eragrostis atrovirens (Desf) Trin. Ex Steud		1	1
Eriosema pulcherrimum Taub.	1		
Erythrina senegalensis A . DC.		1	1
Erythrophleum suaveolens (Guill. & Perr.) Brenan			1
Eugenia kerstingii Engl. & Brehm.			1
Euphorbia convolvuloides Hochst. ex Benth	1		
Fadogia agrestis Schweinf. ex Hiern			1
Feretia apodanthera Delile Ssp. apodanthera	1	1	
Ficus sycomorus Linn. subsp. gnaphalocarpa (Miq.) C.C. Berg		1	1
Ficus vallis-choudae Delile			1
Fimbristylis dichotoma (L.) Vahl. subsp. Dichotoma		1	

Gardenia aquala Stapf & Hutch.		1	1
Gardenia erubescens Stapf & Hutch.	1	1	1
Gardenia ternifolia Schum. & Thonn. Syn G. triacantha DC.	1	1	1
Gloriosa superba L. Syn. G. simplex L.	1	1	1
Grewia carpinifolia Juss.			1
Grewia cissoides Hutch. & Dalziel	1	1	
Grewia lasiodiscus K.Schum.	1		
Grewia venusta Fresen. Syn. G. mollis Auct.	1	1	1
Hibiscus articulatus Hoscht. Ex A. Rich. var glabrescens Hochr.		1	1
Hibiscus asper Hook.f.	1	1	1
Hyparrhenia involucrata var. breviseta W.D. Clayton		1	1
Hyptis suaveolens Poit.	1		1
Indigofera dendroides Jacq.	1	1	1
Indigofera spicata Forssk. var. spicata	1	1	1
Indigofera trichopoda Lepr. ex Guill. & Perr.			1
Ipomoea aquatica (L.)Ker Gawl		1	1
Ipomoea argentaurata Forssk.	1	1	1
Ipomoea mauritiana Hall.f.		1	1
Khaya senegalensis (Desr.)A.Juss.		1	1
Kyllinga appendiculata K. Schum.		1	
Lannea acida A.Rich.			1
Lannea kerstingii Engl. & K.Krause	1	1	1
Lannea microcarpa Engl. & K.Krause	1	1	1
Lantana camara L.		1	1
Laportea aestuans (L.) Chew.			1
Laportea ovalifolia (Schum. & Thonn.) Chew			1
Lepidagadis anobrya Nees	1		
Lepidagathis collina (Endl.)Milne-Redh.	1		
Leptadenia hastata (Pers.)Decne.	1		1
Lippia multiflorum Moldenke			1
Lonchocarpus sericeus (Poir.)Kunth	1	1	1
Loudetia simplex (Nees)C.E.Hubb.	1		
Loudetiopsis ambiens (K. Schum .) Conert			1
Luffa aegytiaca Mill.			1
Malotus oppositifollus (Geisel.)Müell.Arg.		1	
Maranthes polyandra (Benth.) Prance		1	1
Marantocloa purpurea (Ridl.) Milne-Redh.			1
Maytenus senegalensis (Lam.) Exell	1	1	1
Microchloa indica (L.f.) P.Beauv.			1
Millettia thonningii (Schum. & Thonn.)Baker			1
Mimosa pigra L.			1
Mitragyna inermis (Willd.)O.Kuntze	1	1	1
Monanthotaxis parvifolia (Oliv.) Verc.			1
Morinda lucida Benth.			1
Murdannia simplex (Vahl) Brenan		1	1

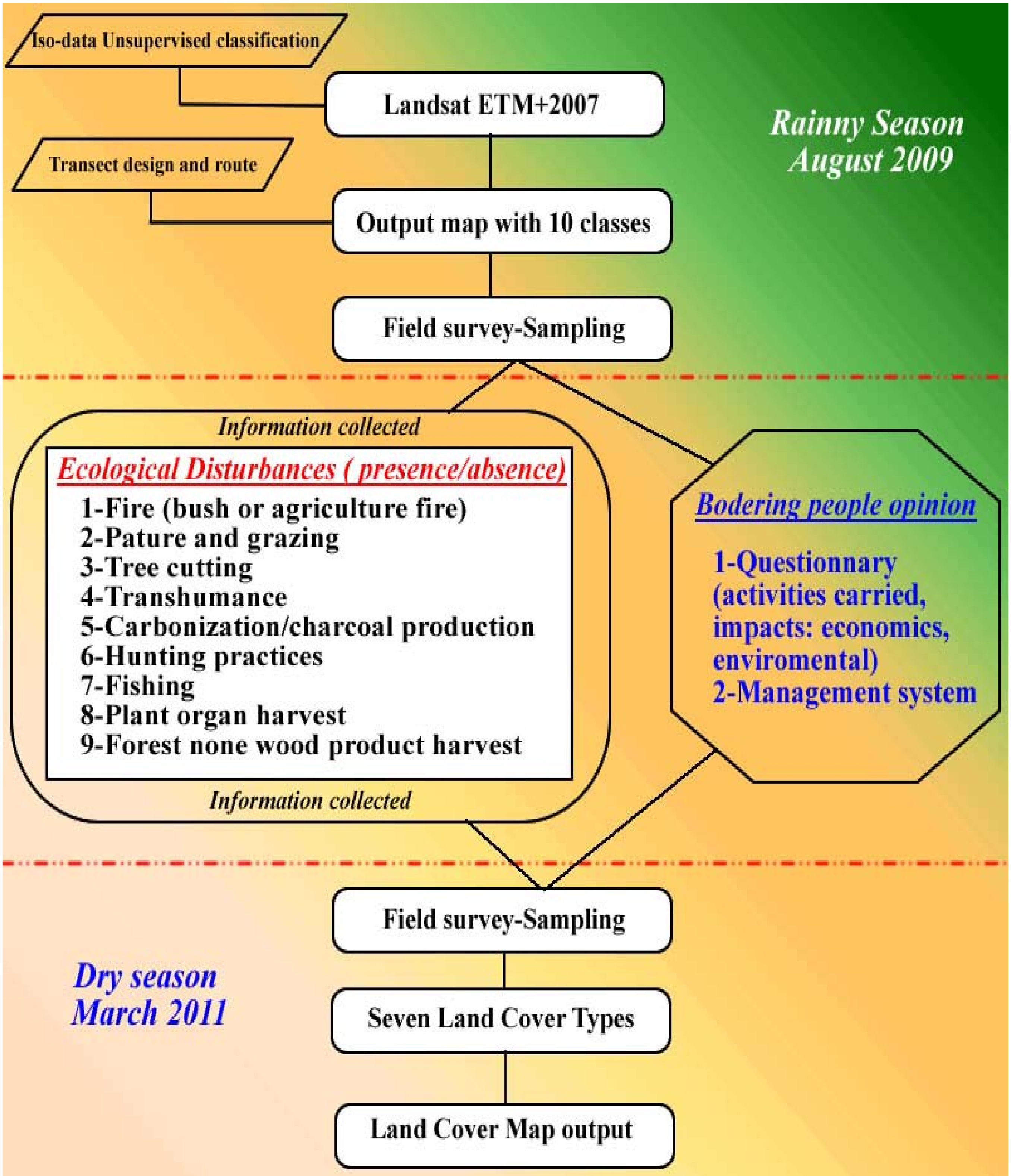
Nauclea latifolia Smith	1	1	1
Nymphea lotus L.			1
Oldenlandia corymbosa L.	1		
Oryza longistamina A. Chev. & Roehr			1
Ozoroa pulcherima (Schweinf.) R. & A. Fernandes	1		
P. *distichum* L. syn P. vaginatum SW.	1	1	1
Pandiaka angustifolia (Vahl) Hepper.		1	
Pandiaka involucrata (Moq.)B.D.Jackson			1
Panicum maximum Jacq.	1	1	1
Parkia biglobosa (Jacq.)R.Br. ex G.Don f.	1	1	1
Paullinia pinnata L.			1
Pennisetum purpureum Schumach.		1	
Pennisetum subangustum (Schumach.) Stapf & C.E. Hubb.	1		1
Pericopsis laxiflora (Benth.) Van. Meeuwen	1		
Philoxerus vermicularis (L.) P. Beauv.		1	
Phyllanthus muellerianus (O.Ktze.)Exell			1
Physalis angulata L.	1		
Piliostigma thonningii (Schumach.)Milne-Redh.	1	1	1
Premna quadrifolia Schumach.& Thonn.			1
Prosopis africana (Guill. & Perr.)Taub.	1	1	1
Pseudocedrela kotschyi (Schweinf.)Harms.		1	1
Pteleopsis suberosa Engl. & Diels	1	1	1
Pterocarpus erinaceus Poir	1	1	1
Ptreocarpus santaloïdes DC.			1
Quisqualis indica L.		1	1
Rhynchosia minima (L.) DC. var. minima		1	1
Rottboellia cochenesinensis (Lour.) W. D. Clayton			1
Sansevieria liberica Gérôme & Labory	1		
Sapium ellipticum (Hochst. ex Krauss) Pax	1	1	
Schizachyrium sanguineum (Retz.)Alston		1	1
Sclerocarya birrea (A.Rich.)Hochst.)	1	1	1
Securidaca longepedunculata Fres.		1	1
Securinega virosa (Roxb. ex Willd.) Baill.	1	1	1
Sesamum radiatum Schum.& Thonn.			1
Setaria sphacelata (Schumach.) Moss var. sphacelata			1
Setaria barbata (Lam.)Kunth			1
Setaria megaphylla (Steud.) Dur. & Schinz.		1	1
Sida acuta Burm.f. subsp. Acuta	1		1
Sida rhombifolia L.			1
Spatodea campanulata P.Beauv.			1
Spermacoce ruelliae DC.	1	1	1
Spigelia anthelmia L.		1	1
Sporobolus pyramidalis P. Beauv.		1	1
Sterculia setigera Del.	1	1	1

Strelizia reginae Banks ex Aiton		1	
Striga hermonthica (Delile) Benth.		1	1
Strychnos barteri Soler.			1
Strychnos spinosa Lam.	1	1	1
Stylochiton hypogaeus Lepr	1	1	1
Stylochiton lancifolius Kotschy &Peyr.			1
Synedrella nodiflora (L.) Gaertn.			1
Tacca leontopetaloides (L.)O.Kuntze	1	1	1
Tamarindus indica L.	1	1	1
Tapinanthus dodoneifolius (DC.) Danser		1	
Tapinanthus pentagonia (DC.) van Tiegh.			1
Tectona grandis L. F.			1
Tephrosia bracteolata Guill. & Perr.			1
Tephrosia elegans Schumach.	1	1	1
Tephrosia linearis (Willd.)Pers.			1
Tephrosia purpurea (L.)Pers. subsp. Purpurea		1	1
Tephrosia villosa (L.)Pers.		1	1
Terminalia glaucescens Planch. ex Benth.			1
Terminalia laxiflora Engl. & Diels	1	1	1
Terminalia macroptera Guill. & Perr.	1	1	1
Terminalia mollis M. A. Lawson		1	
Tiliacora funifera (Miers)Oliv.			1
Tragia benthamii Bak.	1	1	1
Trema orientalis (L.)Blume			1
Triclisia subcordata Oliv.			1
Tridax procumbens L.	1		1
Triumfetta rhomboidea Jacq. var. rhomboidea			1
Uraria picta (Jacq.) DC.			1
Urena lobata Benth.	1	1	
Vitellaria paradoxa C.F.Gaertn.	1	1	1
Vitex doniana Sweet	1	1	1
Vitex madiensis Oliv.		1	1
Vitex simplicifolia Oliv.			1
Vitiveria nigritana (Benth.) Stpf			1
Waltheria indica L.			1
Wissadula amplissima (L.)R.E.Fries			1
Zeheria hallii C.Jeffrey			1
Zingiber officinalis Rosc.	1		
Ziziphus mucronata Willd.	1	1	1
Zornia glochidiata Rchb. ex DC.		1	1

Annex 3 Floristic and forest data inventory design



Annex 4 Anthropogenous disturbances assessment design



ACKNOWLEDGEMENTS

First of all I would like to thank Allah for the grace He provides for me during this study.

I would like to express my gratitude to Chinese Government and Togolese Government who gave me a great opportunity through the scholarship to achieve the Ph.D degree.

This gratitude goes also to Beijing Forestry University, who accepted enroll me to his Ph.D program, to the Key Laboratory for Silviculture and Conservation of Ministry of Education (Beijing Forestry University Beijing) and to Laboratory of Botany and Applied Plant Ecology (Faculty of Sciences) of University of Lomé for full support during all the process of this thesis.

Hope the ministry of Forest Resources and Environment finds here our thanks for their technical assistance during the field works investigation.

Our sincere gratitude goes to International Student Office Staff (Mrs Wang, Mrs Diao and Mrs Xu) and his Director Prof. Ph.D Jun Chang Liu for effective management during the five years I stay in Beijing.

My special thanks and gratitude are directed to my Mentor Prof. Ph.D. Zhao Xiu Hai and Prof. Dr. Akpagana Koffi; and co-promotor Prof. Ph.D. Huang Hua Guo, Prof .Dr. Kokou Kouami, Prof. Dr. Guelly Atsu, Prof. Dr Batawila Komlan and Dr. Wala Kperkouma who have guided this thesis and whose useful support, comments and fruitful suggestions improved the work considerably.

I sincerely thank Prof. Ph.D. Zhao for his open mind, supportive kindness and excellent guidance. It is difficult to sufficiently express my gratitude to him who provided continuous personal support in all stages this thesis achievement.

I gratefully acknowledge Ph.D candidate Bawa Anissou, Dimobe Kangbeni and Pereki Hodabalo for their patience, motivation and assistance during the several fieldworks. I also thank Mr. Kaman for sharing his botanical knowledge with me and helping for species determination.

I would like to express my gratitude to the Director of the Direction des Ressources Forêts et l'Environnement/Region des Savanes (DRFE/Savanes) and his staff for granting me permission and technical assistance to work in the protected areas in Northern Togo. I remain very grateful for the representants of water and forest protection of Barkoissi, Galangashi and Mango. I would like Mr. Eugene, Harahore and Atounde find here again my gratitude for his fruitful contribution.

I am most grateful my Mentor assistants, particularly Ph.D. Zhang Chun-Yu, Ph.D. Xia Fu-Cai, Ph.D. Her Djan and Ph.D. Gao Lu-Shuang. With them, I had fructuous discussions about forest new techniques of inventories and management, without forget their advice in the conception of the research.

I would like Dr. Gbobgo, Dr. Woegan, Dr. Dourma, Dr. Akpavi, Dr. Kanda, and Dr. Atato found here my thank for their moral assistance each time I stay in Lome for field research.

My sincere gratitude goes to Mr. Jin and his family, the facilities he brought to me to let my stay to be very funny.

Hope Prof Gadow von Klaus found here my sincere gratitude for the advices， he shared with me each time of his stays in Beijing.

Many friends contributed to make my stay in Beijing pleasant and successful. I also grateful Chinese classmate especially my Mentor students Zhang Yun ,Wang Jin Song, Rui Qiang, Liu Wei Guo, He Jun, Lian Da Shuang, Liu Bao Xing, Pan Chun Fang, Wang Xiao Ming, Dong Dian. With them, I learn more about china and his culture during my stay.

Many people provided moral assistance at all stages of this thesis. Without attempting to be complete, I wish to cite Ph.D. Samake Gabriel, Chen K. Sarah, Ph.D. Camara Moussa, Ph.D. Konate Djibril, Ph.D. Nassrelddin Mohamed Zei Ahmed, Ph.D. Toure Saoudatou, Ph.D. Mokgolodi Neo, Ph.D. Morgnya Phillip, Jean L. Seburanga, Kampungu Gerson, Rene, Toure Ange-Mariette, Mendosa D. Claudino.

My sincere gratitude goes to my countrymates, Ph.D. Gnoufougou Douoman (多曼) and his wife Nourata, Lamboni Sébastien, Ph.D. Alfa-Sika Mande Seyfe-laye, Ph.D. Anani Koffi Ayelle, Ayeva Afifa, Kolani illa, Ouro-Djobo Bilamakazo Sadicou, Nakpapere Bante (大卫), Gnoufougou Yedoutie, Teteh Tedokou (特德库), Abdoulaye Mohamed (古德), Sabour Bonfoh (伊索),Kabiya Passa (贝莎).

I sincerely thank El Hadj Abdoulaye Watara, who still gives me any kind of support since I reach the university.

I would like my uncle Kondian Kandjeb Yacoubou common name “GK”, His adorable wife Konlani Midaghob Pascaline and their children Nadege and Bertrand found here a complete grateful for everything they did and still do for me, during my stay in Lomé and in Beijing.

To my brothers Abdoul-Razak (佛里佳尔), Abdel-Akim and my sister Cherifa for placing their confidence, hope they can find in this work the breath to evolve more high than their elder can.

Sincerely, I would like my partner KOMBONGOU Yenduman found here my gratitude for her constant support, patience and love.

Finally but importantly, I am grateful to my parents FOLEGA F. Naba and KOLANI Lampougue Catherine, who have supported me in various ways throughout my studies.

CURRICULUM VITAE

PERSONAL CV

My graduate study programme at Beijing Forestry University, my modest experience in teaching and research, and active commitment, and participation in the World Scout Association has greatly improved my leadership and communication skills as well as the ability to work in a team environment. I am fluent in both spoken and written English and French. I can work anywhere in mainland China, since I am also able to speak and write Mandarin very well which I have been studying since September 2007.

FOLEGA FOUSSENI (**佛里佳)** was born on 03 Jun 1982 in Dapaong prefecture de Tone, Togo. He obtained his Baccalauréat D in 2002 and joined the Faculty of Sciences (FDS), of the actual University of Lome (Togo). He obtained his BSc degree in Natural Sciences in 2005 and continues his postgraduate studies in Plant Biology in the same University. He obtained his "Maîtrise es Sciences" in 2006, He has been working as Research Assistant in the Department of Botany and Plant Ecology (FDS) in 2007 and as high school biology teacher at College JJ-Rousseau (Lome) of the same year. During the 2007 he was granted a PhD fellowship within the framework of bilateral cooperation between Chinese and Togolese Government. He was enrolled in PhD degree programme in Forest Ecology at Beijing Forestry University in the College of Forestry. His PhD research was focused on protected areas sustainable management through their ecological, land use changes and land cover studies. He is specialized in remote sensing, Geographic Information System, plant ecology, phytosociology and biodiversity conservation. From 2009 to 2012 he taught Sciences of Life and Earth (SVT) to the students of Consular Secondary School of Republic of Congo (Beijing). Amator of computer and software, He also had training in web design and in landscape design.

Contact

Email: ffolegamez@live.fr/ ffolega@yahoo.fr/ ffolegamez@gmail.com/ 954693447@qq.com
QQ: 954693447
Skype: ffolega2000

SUPERVISOR CV

ZHAO Xiu Hai was born on December 1962. His qualification include Prof. Ph.D position in College of Forestry at Beijing Forestry University, Ph.D candidate Mentor, member of young talent Ph.D forum at Ministry of Education, Director of National Forest Administration (Department of Shanxi Tai Yue Mountain Ecosystem).

He is a project manager in chief of several projects at National level. Among them Project of National Sciences Funding, Project of National "15" and "1015" technical, Project 948 of National Forestry Bureau. In 2009, He was awared as first price of National Forestry Bureau respectively in Forestry technics and in field works activities assessments. He authored and co-authored more than 100 publications.

LIST OF PUBLICATIONS

FIRST AUTHORS

Folega F, Zhang CY, Samake G, Kperkouma W, Batawila K, Zhao XH, and Akpagana K (2011). Evaluation of agroforestery species in potential fallows of areas gazette as protected areas. *African Journal of Agricultural Research*, 6(12):2828-2834.

Folega F, Zhang CY, Zhao XH Wala K, and Akpagana K (2011). Floristic diversity in most dry and environmentally disturbed areas of Northern Togo. *Energy Procedia*, 11: 2127–2132.

Folega F, Zhang CY, Batawila K, Zhao XH and Akpagana K (2011). Plant communities' pattern in most environmentally disturbed areas in most septentrional part of Togo. *Energy Procedia* ,11: 2433–2441.

Folega F, Jean LS, Huang HG, Zhao XH and Alfa-Sika M S-L (2011). Urban area vegetation changing assessment over the last 20 years based on NDVI**.** *Energy Procedia*, 11: 2449–2454.

Folega F, Zhao XH, Zhang CY, Huang HG, Kangbeni D, Hodabalo P, Anissou B, Kperkouma W, Komlan B and Koffi A (2012). Land use change and numerical assessment of plant communities of Oti prefecture protected areas (North Togo*). African Journal of Agricultural Research*, 7(6):1011-1022.

Folega F, Kperkouma W, Komlan B, Zhang CY, Huaguo HG, Zhao XH and Koffi A (2012). Use of 3S Technology as a Tool for Endangered Vegetation Area Assessment in Togo. (Accepted for publication in *African Journal of Microbiology Research*).

Folega F, Zhao XH, Zhang CY, Wala K and Akpagana K (2010). Ecological and numerical analyses of plant communities of the most conserved protected area in North-Togo. *International Journal of Biodiversity and Conservation*, 2(11):359-369.

Folega F, Zhang CY, Wala K, Zhao XH and Akpagana K (2011). Wooded vegetation of protected areas in Northern Togo. Case of Barkoissi, Galangashi and Oti-Keran: Ecological and Structure Analysis of Plant Communities. *Forestry Studies in China*, 13(1):23-35.

Folega F, Zhang CY, Zhao XH, Kperkouma W, Komlan B and Akpagana K (2012). Assessment and impact of anthropogenous disturbances factor in northern Togo protected areas. (Accepted for publication in *Forestry Studies in China*)

Folega F, Hodabalo P, Zhang CY, Kperkouma W, Komlan B, Zhao XH and Koffi A (2012). Baseline research for Future eventual ecological restoration of drought areas on sandstone hill (infra-tilitic group) of Dapaong. (Accepted for publication in *Forestry Studies in China*)

Folega F, Zhao XH, Komlan B, Zhang CY, Kperkouma W and Koffi A (2012). Basic Overview about Riparian Forest in Savannah Ecosystem: case of Togo. (Under review AJB)

Folega F, Zhao XH, Zhang CY, Huang HG, Wala K, Batawila K and Akpagana K (2012). Land Uses Change in Northern Togo Protected Areas. (Under review JFR)

Folega F, Zhang CY, Zhao XH, Kperkouma W, Marra D, Agbélessessi W, Komlan B and Koffi A (2012). Ecological and structure analysis of forest ecosystem in Togo. (Under review JTFS)

CO-AUTHOR

Pereki H., Folega F., Batawila K., Wala K., Akpagana K.(2010).Reserve Barkoissi conversion in agroforestery parklands. *Int. For. Rev.*, 12 (5):193.

Seyf-Laye Alfa-Sika Mande, Mingzhu Liu, Fousseni Folega, Fei Liu and Honghan Chen (2011). A Comparative Study of Adsorption of Cr (VI) from Water by Commercial Absorbent and by Activated Carbons Prepared from Agriculture Waste. *Energy Procedia*, 11: 2587–2593.

Gabriel SAMAKE, Fousseni FOLEGA, Ali KANSAYE, and Hua-Fang WANG.2011.*In Vitro* Regeneration of *Acacia nilotica* on Wood Plant Versus B5 Media. *Journal of Agriculture, Biotechnology & Ecology*, 4(2): 64-75.

SAMAKE Gabriel, FOLEGA Fousseni, TRAORE Bakary M., SENOU Hamidou and WANG Hua-Fang (2011). *In vitro* regeneration of *Acacia nilotica* (L.) Willd. ex Del from nodes on B5 medium. *Journal of Agricultural Biotechnology and Sustainable Development*, 3(5):85-89.

XIA Fucai1, PAN Chunfang, FOLEGA Fousseni, ZHAO Xiuhai, HE Huaijiang (2012)The effect of over-story on the seasonal variability of under-story herbs in primary broad-leaved Korean pine forest of Changbai Mountain. (Under review AJAB)