SUN - Sustainable use of natural vegetation in West Africa

Project No. INCO 031685

SUN

Tools for management and Sustainable Use of Natural vegetation in West Africa

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Project coordinator name: Anne Mette Lykke

Project coordinator organisation name: Aarhus University Version 1.

SUN - Sustainable use of natural vegetation in West Africa

Executive summary

Natural vegetation of arid and semi-arid West Africa is of immense value to local people’s daily subsistence and nutrition, economic benefits, and survival in hunger periods. Nonetheless, poor management and unsustainable use deteriorate the vegetation at a high rate. Much scientific information and local knowledge is needed for improving management strategies. Some already exist, but it must be organised, analysed, targeted and made available to decision makers and local communities. New research must be targeted to fill important gaps in this knowledge. One of Africa’s major development challenges is to establish a link between global initiatives and local management actions. SUN will broaden the role of scientists as mediators between the world of scientific information, global conventions and the African realities where practical actions are wanting. SUN will develop new, practical management tools and concrete management actions for improved sustainable use of natural vegetation by combining scientific vegetation data, remote sensing and socio-economic information with local people’s knowledge and needs. SUN combines three types of activities: 1) Interdisciplinary research on vegetation dynamics, causal factors and economic instruments and policies to enhance sustainable economic growth. 2) Development of new decision support tools for improved natural resource management – by organising scientific data. 3) New low-budget management and restoration actions - in collaboration between scientists and local people. SUN includes West African and European scientists within vegetation-ecology, socio-economy, ethnoecology and remote sensing, all with experience in applied research - 17 African PhD students will be educated within the project. SUN will function as a knowledge- and technology-based platform for vegetation management in West Africa by gathering the major expertise, by novel use of scientific data and by improved interaction between scientists and stakeholders.

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Contractors

The 10 partner institutions are listed below:

Participant no	Participant organisation name	Short name
1 coordinator	Aarhus University, Denmark	AARHUS
2	Danish Institute of Agricultural Sciences, Denmark	DIAS
3	University of Cheikh Anta Diop of Dakar, Senegal	DAKAR
4	Johan Wolfgang Goethe University, Germany	FRANKFURT
5	Senckenberg Research Institute, Germany	SENCKENBERG
6	University of Ouagadougou, Burkina Faso	OUAGADOUGOU
7	University of Bobo Dioulasso, Burkina Faso	BOBO DIOULASSO
8	University of Abomey-Calavi of Cotonou, Benin	COTONOU
9	Joint Research Center of Ispra, Italy	JRC
10	University of Abdou Moumouni of Niamey, Niger	NIAMEY

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Section 1 – Project objectives and major achievements during the reporting period

Project objectives

SUN will develop new, practical management tools and concrete management actions for improved sustainable use of natural vegetation by combining scientific vegetation data, remote sensing and socio-economic information with local people's knowledge and needs.

State of art

The natural vegetation is of immense value for subsistence and nutrition, marketing and economic income and survival during famine periods. People in West Africa have developed livelihood strategies that are based on diversification and risk avoidance by extracting from the wild and by integrating wild plants into agricultural systems, but the natural resources have come under increasing pressure, and local people increasingly feel the shortage of traditional products.

Degradation of natural resources is often a consequence of poor management resulting from failures of traditional management systems to meet changed social, climatic and demographic structures or resulting from inappropriate management actions that have been imposed top-down. The natural resource-supply can, therefore, be enhanced considerably by improved management strategies based on local knowledge, needs and preferences. It is generally recognized that a major challenge in developing countries is to combine sustainable use of natural resources with continuous economic growth over the long term.

One of Africa's major problems is its great lack of credible institutions for ecosystem management. Civil society organisations tend to be small and isolated and they remain unable to link the abstract language of the global-level institutions to the field realities of poverty, resource use conflicts, land degradation and biodiversity loss. Many West African institutions and civil society organization are not even aware of the global opportunities, and if they are, they usually lack the infrastructure and the expertise to connect their knowledge to the abstract and complicated world of international organizations. This means a great loss of opportunities for authentic poverty alleviation, land rehabilitation and ecosystem protection. The energies of the civil society organisations remain untapped, because global funds and knowledge have difficulties in finding their way to Africa's own organisations and to field realities.

One of Africa's major development challenges is, therefore, to establish a link between global initiatives and local management practices. This link is not always easy, but African scientists with interest in applied research can play a crucial role as an important link between the two extremes. They can extract relevant information from conventions and scientific literature and bring it to the local society, and they are in close contact with local people to formulate management plans that meet local people's needs and preferences, but also take more broad-scale ecological problems into consideration.

Main achievements

Workpackage 1
Maps of vegetation patterns and land use units have been prepared for the project core areas. Extensive vegetation inventories from land use areas and protected areas have been conducted and data are stored in a vegetation database (WP4) and used for modelling of phytodiversity patterns in relation to human impact. Population dynamics of several highly valued species show declining tendencies in land use areas compared to protected areas. An improved understanding of vegetation dynamics and their causal factors will be used to identify and protect vulnerable areas and habitats (WP5).

Workpackage 2
Five indices that measure changes in phenology have been developed and evaluated to verify that these indices measure; 1) Changes in the peakedness of the growing season, 2) Changes in the average annual greenness, 3) Shifts in the time of the peak of the season, 4) Changes in the length of the season and 5) Changes in the shape of the phenological profile. These indices have been used to derive maps depicting the changes in phenology that have taken place over the period of the time series used (1982 – 2008) and to analyse the correlations between these changes and changes in the key climate parameters of precipitation and temperature. Changes in vegetation phenology are significantly correlated with changes in rainfall over much of Africa and, occasionally, with changes in temperature.

Workpackage 3
Local preferences and needs in relation to vegetation use have been identified and analysed within all the core areas. Economic instruments, such as subsidies, taxation, quotas or property right institutions, have been identified and analysed according to political feasibility as tools for improved management. Cultural and socio-economic impediments to sustainable use of the vegetation are also identified and ways to redress them are explored.

Workpackage 4
An online vegetation database (West African Vegetation, URL http://www.westafricanvegetation.org/) has been developed, which allows entry of all major plot types and maximises user acceptance by a flexible access rights approach. The online database concept has the advantage of common standards, facilitated exchange, good visibility of available data and high data security. The synchronization feature makes it possible to use a local offline version of our database directly in the field and under slow internet conditions. The database has a digitization record of 360028 single observations and 10743 plots.

Workpackage 5
Indicators of sustainable use were analysed and identified at different scales (landscape, habitat, species). For identification of vulnerable habitats and species, the Climate Change Severity Index was derived, and the population pressure on the core areas was assessed. Vegetation data were prepared for comparison of land use and protected areas, and data on highly valued species in relation to the nearest settlements were used to identify the use impact on the species. A list of indicator species is in preparation.

Workpackage 6
Biophysic data and socioeconomic data have been gathered and compiled for the SUN Map Server that stores spatial information about the four SUN core areas, the participating countries in SUN and Westafrica in general. All of the data and their respective metadata can be downloaded in vector or raster format. The SUN Map Server can be accessed under: http://mapserver.uni-frankfurt.de (login:sun, password: sun:maps). The Map Server is a tool that aims to facilitate spatial information about the region and the SUN areas that can be used for further processing in Geographic Information Systems (GIS). Data structure of the Sun Map Server is as follows: Core Areas (W National Park, Tamou Reserve, Boulon-Koflandé Forest, Patako Forest). Participating Countries (Burkina Faso, Benin, Niger, Senegal). Region (Westafrica). The information about the core areas consists in data about boundaries, infrastructure,

villages, fire frequency (from JRC: http://bioval.jrc.ec.europa.eu/APAAT/), soils and geology. For W National Park a NDVI image and two satellite image mosaics of the area are online.
The SUN countries folders contain data about cities and villages, administrative borders, infrastructure, rivers, vegetation types, landuse, topography, geology and soils. For Arli National Park (folder: Burkina Faso) and Pendjari National Park (folder: Benin) Landsat classifications are available.
The data for Westafrica is composed by spatial information about infrastructure, political administrative boundaries, elevation, vegetation (major vegetation types according to White 1983, WWF terrestrial ecoregions, protected area system, ESA Globcover, JRC Global Landcover), population (1960-2000) and hydrology. Besides the common zoom and (length and area) measurement functions the SUN Map Server has an identify function to display information of a selected feature on the screen. The download function is implemented as an icon for each data layer. The Sun Map Server will be updated regularly and data collected and compiled during the UNDESERT project will be integrated to make the Map Server more complete and thereby more useful for the users.

Workpackage 7
A participatory management plan is being prepared for each core area on the basis of vegetation, satellite and socio-economic data. Management of natural resources is being improved by increasing local populations' awareness of new possibilities for sustainable use of forest resources and by integrating local knowledge in the management plans. The management plans are being prepared in close collaboration between researchers and local communities. presently, after the project finished, several activities in relation to nurcery establishment and treeplanting are ongoing.

Workpackage 8
Restoration activities are carried out in different ecological sites of Benin, Burkina Faso and Niger. A total of 10 ha were reforested using low-cost budget (traditional) techniques and deep ploughing. In total, 2500 saplings of value species were planted. In the Sahelian conditions, *Acacia senegal* and *Faidherbia albida* are the best species, and in the Sudanian zones, *Combretum micranthum*, *Jatropha curcas, Bauhinia rufescens* and *Faidherbia albida* are able to grow on degraded soils. The best low-budget techniques are half-moon, zaï and stone walls. More expensive techniques like deep ploughing present more effect on soil restoration and biodiversity conservation.

Workpackage 9Dissemination is an important part of all research activities, and all PhD students focus on disseminating of research results. The dissemination is carried out on various levels: information to international institutions, local governments, natural resource management organisations, NGOs and local communities. The scientific results are published in international journals and in brochures in a simplified form. Publications are listed at the end of this report.

Problems and corrective actions

The major problem has been a delay in money transfer, as we still in April 2010 were waiting for the third money transfer, which was expected in July 2009 or, at the latest, in October 2009. This delay has meant that the fieldwork has been stopped for a period and project activities were severely delayed.

Many changes in EU contact persons have caused a lot of administrative problems, as each contact person has requested different things, and some of the administrative reports have been revised several times.

Another problem is that four of the PhD students have stopped their projects because of illness or other personal reasons. This has caused some delay in the work, but the work has been conducted anyway, in one case by employing another PhD student and in other cases by researchers taking over the work in collaboration with Master Students.

Section 2 – Workpackage progress of the period

WP1 Local scale vegetation dynamics

Dr. Karen Hahn-Hajdali, Partner 4

Participants: P3 Dakar, P4 Frankfurt, P5 Senckenberg, P6 Ouagadougou, P8 Cotonou, P9 JRC, P10 Niamey, P7 Bobo

WP objectives:
The overall objective of this workpackage is to obtain a detailed understanding of vegetation dynamics under varying degrees of human impact at a local scale as a basis for improved ecosystem management.

The specific objectives are:
To map spatial vegetation patterns and model phytodiversity in relation to human impact.
To assess and analyze population dynamics of highly valued species.
To analyze indicators of sustainable use at landscape, habitat and species scale.
To analyze temporal vegetation changes in relation to human impact and climatic changes.
To assess habitats and species vulnerability

Deliverables

D1.1 Maps of vegetation patterns and models of phytodiversity in relation to human impact

For all core areas, maps of spatial vegetation patterns are provided. Refinement of maps and modelling of diversity patterns have been finalised.

For the core area W-National Park in Burkina Faso, high resolution ASTER images from 2006 and 2007 with a spatial resolution of 15 m are being classified in a supervised manner. These data were used for cross-linking with vegetation data for specific objective 1.5 (Assess habitats and species vulnerability). Phytosociogical vegetation data were collected for two layers, the herbaceous layer (sample size 100 m²) and the woody layer (sample size l900 m²). A total of 311 relevés comprising 440 species (264 genera from 80 families) were performed in the park area. The most represented families are *Poaceae* (15,45%) and *Fabaceae* (11%) followed by *Cyperaceae* (7%), *Rubiaceae* (5%), *Combretaceae* (4%), *Mimosaceae* (4%), *Caesalpiniaceae* (3%), *Euphorbiaceae* (3%), *Acanthaceae* (3%) and *Liliaceae* (3%). Dominant life forms are therophyta (36%), microphanerophyta (14%), geophyta (11%), hemicryptophyta (10%), mesophanerophyta (8%), nanophanerophyta (7%).
Soil samples for analysis of various soil parameters were taken from representative vegetation types inside the park and in the adjacent land use areas.

Data analysis of the phytosociological relevés showed a total of five vegetation types which were determined using k-means-clustering and indicator species analysis. These are: *Anogeissus leiocarpa_Wissadula rostrata*-type, *Strychnos spinosa*, *Andropogon gayanus*-type, *Loudetia togoensis_Digitaria horizontalis*-type; *Terminalia macroptera_Scleria sphaerocarpa*-type (Fig. 1.1). All of them were found in the protected area as well as in the communal area. The results on these vegetation patterns will be published soon (Titel: *Comparison of vegetation patterns and phytodiversity in and adjacent to the W National Park, Burkina Faso*).

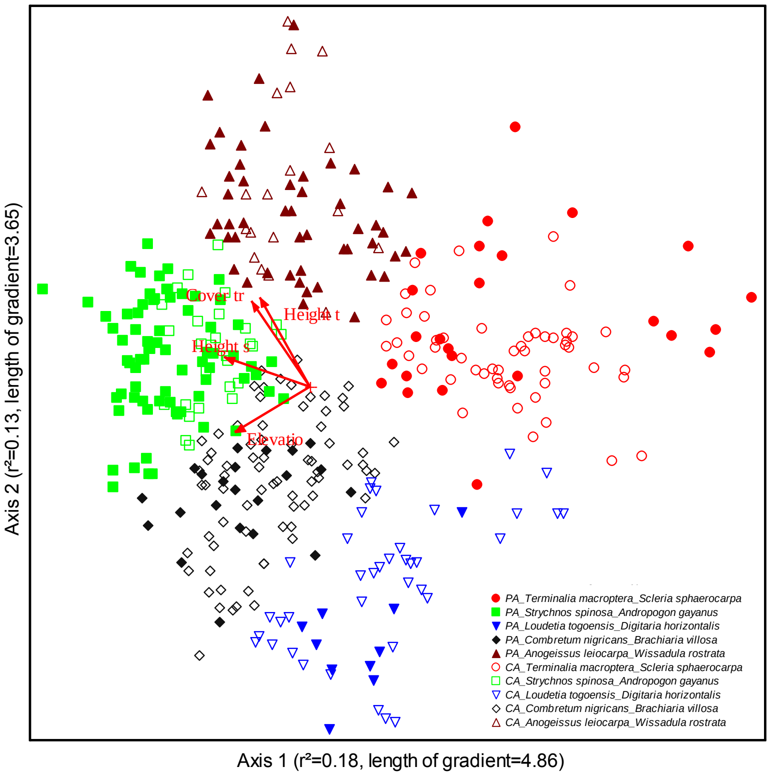

Figure 1.1: Ordination-diagram of the vegetation of the protected and communal area based on the species cover

According to the ordination, the plots of the five vegetation types were located along an elevation and water availability of the habitat gradient (r^2=18.4, length of gradient=4.86) and a physiognomic gradient (axe 1: r^2=13.33, length of gradient=3.65). The first axis of the ordination showed a gradient from up and dry lands to low and wet lands (depressions). The gradient of the second axis was defined by the physiognomic type with a gradual turnover from dense vegetation to less dense vegetation in herb savannas.

The phytodiversity map of W National Park (Burkina Faso) has been processed. The potential distribution of the 100 most frequent woody species of W-National Park in Burkina Faso and its surrounding communal area was modeled based on an ecological niche modeling approach. As environmental parameters, the ASTER Digital Elevation Model was processed and seven indices were derived from a set of three 30 m multispectral ASTER images (11^{th} of October 2006). These indices were namely: Colour Index, MSAVI, NDVI, Texture Index and Tasseled Cap 1, 2 and 3. After running a correlation analysis, several test runs were conducted in Maxent with different sets of uncorrelated environmental variables. Statistical tests to determine the omission rates and the area under the receiver operating characteristics curve (AUC) were used to analyze the performance of Maxent. The combination of the ASTER DEM, Tasseled Cap 2 (Vegetation Index) and Tasseled Cap 3 (Wetness Index) was finally selected as the best uncorrelated variable set to explain the information in the data. The tests were undertaken with indices derived from the original 30 m ASTER image and also with indices derived from a re-sampled 60 m resolution. To avoid changes in the original pixel values, the 30 m resolution was maintained. 40 woody species entered finally in the ecological niche modeling process. For each of the target species, more than 20 occurrence points had been captured in the study area. The AUC value of each modeled potential distribution was over 0.7. After having calculated 40 distribution maps, binary presence (1) and absence (0) data files were calculated using the respective “Equal Test Sensitivity and Specificity Logistic Threshold” for each of the 40 woody plant species. The 40 binary files were summed up to generate a phytodiversity map (Figure 1.2).

The predicted woody species richness was higher in the communal area than in the protected area. This result coincides with the field data analysis. The highest values of woody species richness were found in old fallows and in the buffer zone of the communal area. In contrast, the lowest values were found in the southern part of the protected area. The higher woody species richness in the communal area compared to the protected area might be the effect of human activities (e.g. agriculture, livestock grazing and trampling, preservation of highly valued tree species). Human disturbances may lead to an increased patchiness in the environment, which provides many different microhabitats for recruitment of woody species. Lower woody species richness in the protected area can be the consequence of disturbed recruitment of several woody species due to competition of the two to three meter tall grass species and intensive fires, as grass biomass is high. Intensive fire affects seed survival and leads to a negative effect on woody plant density. However, individual woody species response to these disturbances has to be considered. Some of the woody species (e.g. *Bombax costatum*, *Xeroderris stuhlmannii*, *Figure 1.3*) are regularly distributed in the protected area, while other woody species, mostly shrubs, show a more regular occurrence in the communal area (e.g. *Combretum collinum*, *Guiera senegalensis*, *Figure 1.4*). Rare woody species were not represented in the modelling, as only species with at least 20 occurrence points were included in the analysis. In fact, more rare woody species occurred in the protected area than in the communal area, suggesting that rare woody species are most severely affected by decline in the communal area.

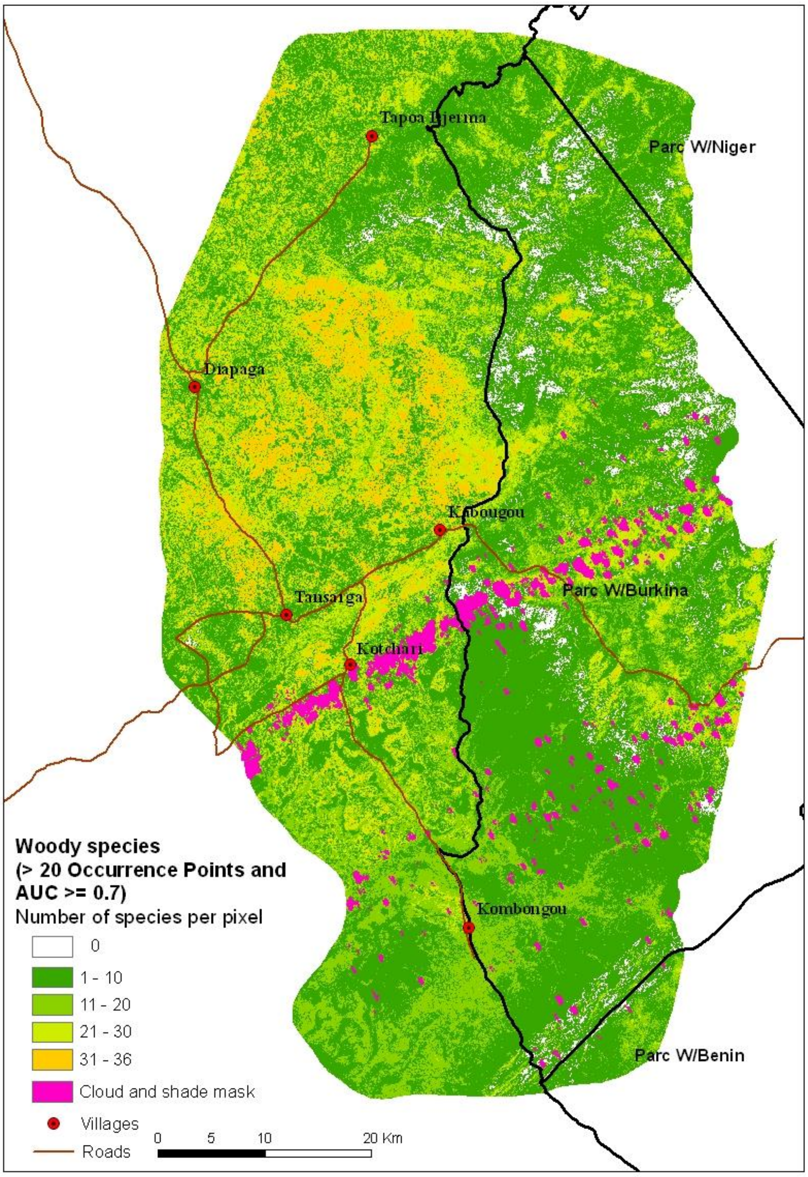

Figure 1.2: Predicted woody species richness in the western part of W-National Park and the adjacent communal area

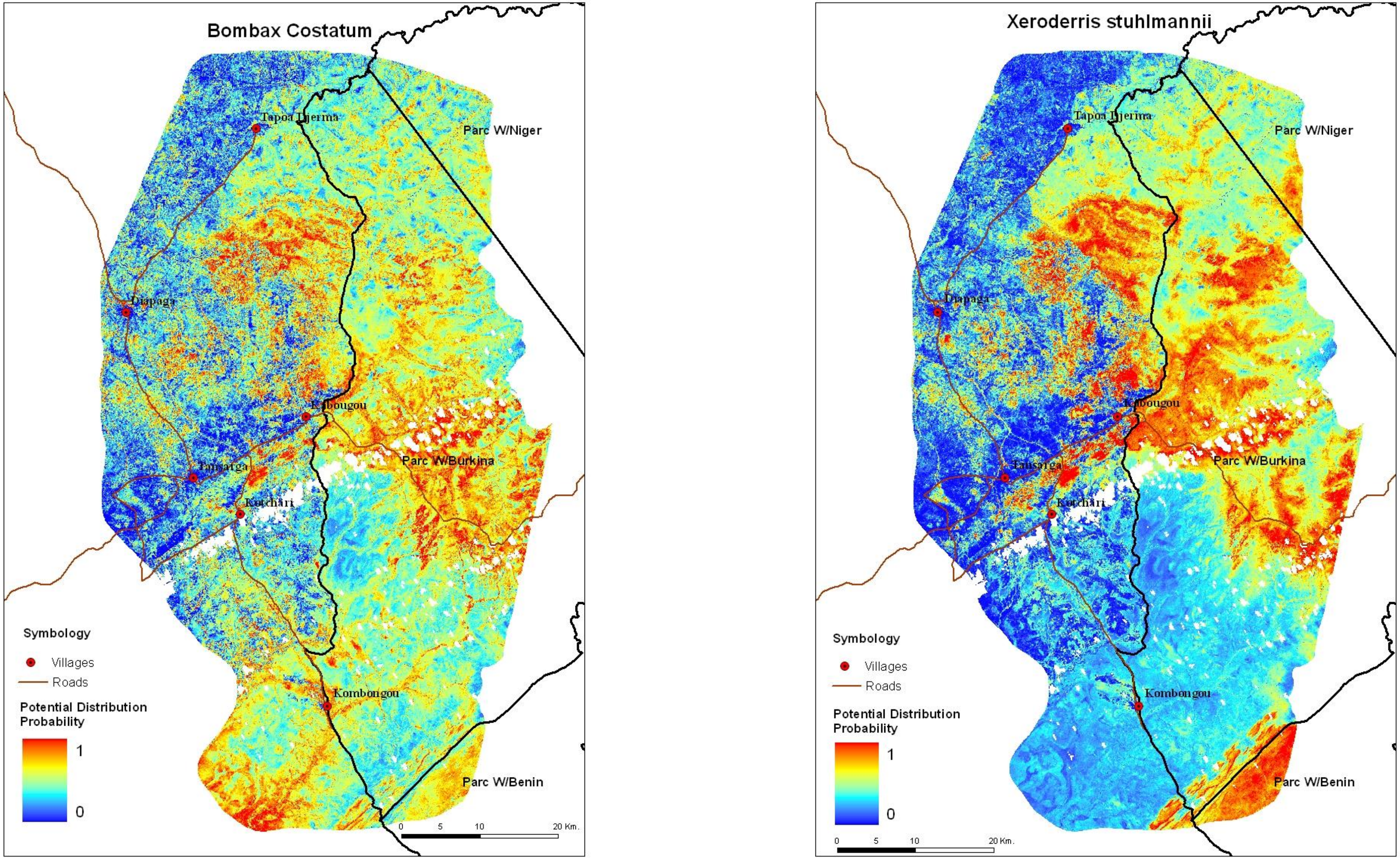

Figure 1.3: Potential distribution probability for *Bombax costatum* and *Xeroderris stuhlmannii* in the western part of W-National Park and the adjacent communal area under the applied environmental parameters: elevation, vegetation index and wetness index. The dark blue colours represent a low probability of finding appropriate conditions for the species. The probability rises from light blue to yellow and orange, until finally the highest probabilities for potential distribution are displayed in red colours.

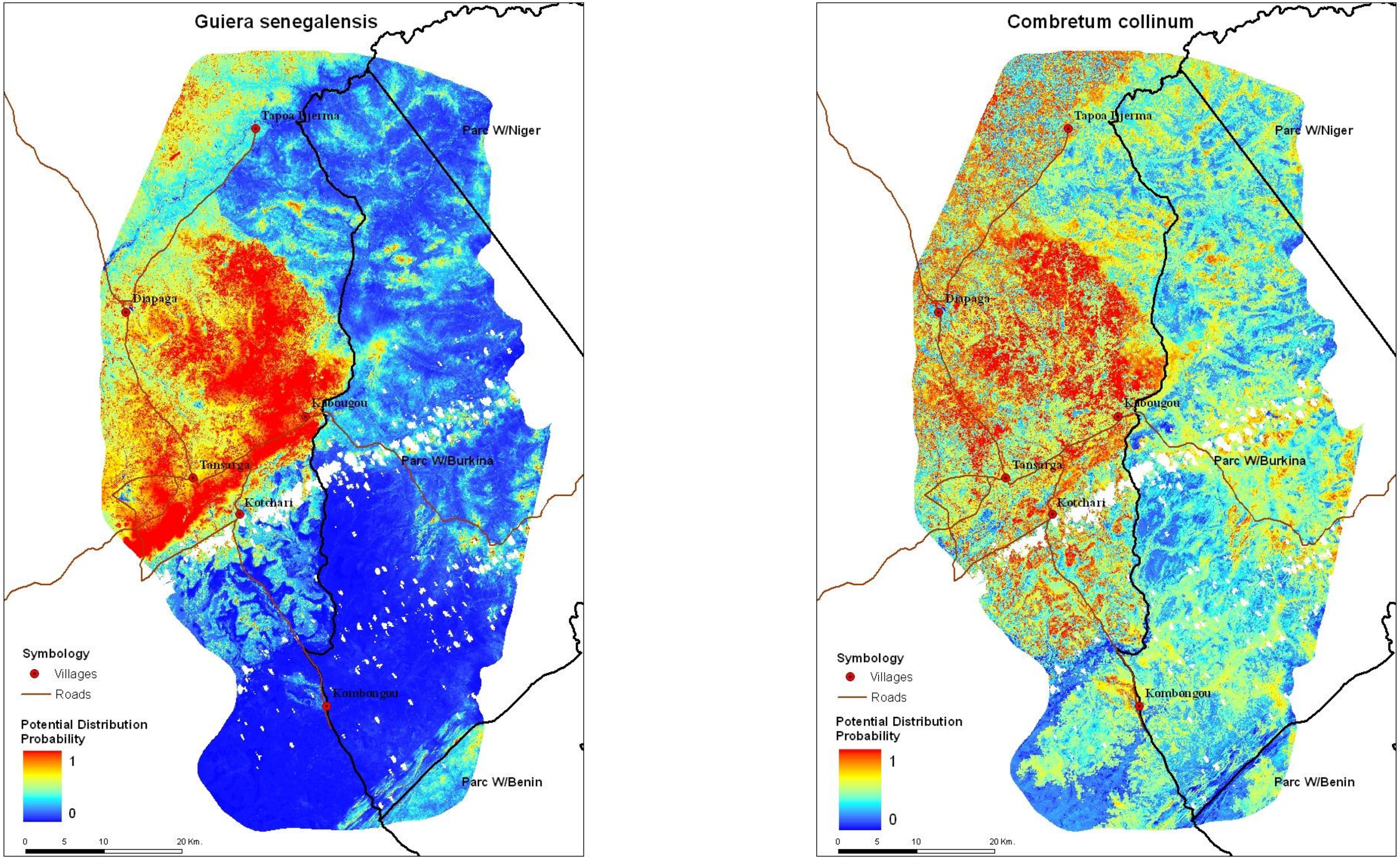

Figure 1.4: Potential distribution probability for *Guiera senegalensis* and *Combretum collinum* in the western part of W-National Park and the adjacent communal area under the applied environmental parameters: elevation, vegetation index and wetness index. The dark blue colours represent a low probability of finding appropriate conditions for the species. The probability rises from light blue to yellow and orange, until finally the highest probabilities for potential distribution are displayed in red colours.

Around the W National Park of Benin, the distribution pattern of *Sclerocarya birrea*, a highly valued indigenous fruit tree species, was assessed. This species has a limited distribution and is located only in the Northern part. We used the climate envelope modeling techniques implemented in Maxent to predict the current potential and future distribution of the species under various climate scenarios. 447 species occurrence points were recorded through its distribution range in Northern Benin. In order to take into account a more comprehensive distribution range of the species for more predictive accuracy, we obtained complementary occurrence points (100 records) of the species from the highest occurrence latitudes (more drier areas from Burkina Faso and Niger). For identifying the current suitable area of the species, we used the WorldClim database environmental layers derived from ≈1950-2009 climate data; Version 1.4 (release 3). For climate variables under future conditions, we used the average projections of three GCMs (CCCMA, HADCM3 and CSIRO) for the year 2050 under the A2 emission scenario. Climatic data were used at a resolution of 2.5 arc min (ca 5x5 Km^2 grids). We used value of monthly minimal and maximal temperature and rainfall to derive nineteen (19) bioclimatic variables. A random test percentage of 25% of records was used to validate the model. All duplicate points in the 5x5 km^2 grid were removed. The model showed a good predictive ability with AUC > 0.90. Results showed that the most suitable current potential distribution range of the species remain mainly restricted to the sudano-sahelian zone of the country encompassing the two main protected areas. Under the projected climate scenario, the probability of the potential distribution increases and high probability values are displayed in the southern part of the country. A fraction of the projected suitable habitat for the species will still be encompassed by W-National Park and Pendjari National Park (Fig. 1.6). However, the species might face a conservation challenge without proper management measures, as the high population growth rate will increase the agricultural pressure in open areas. If land use changes and soil parameters could be included in the ecological niche modeling of *Sclerocarya birrea,* a more complete picture of the species' future potential distribution area pattern could be given. Further analysis revealed that applying a threshold (0.1) for the determination of absence or presence of the species the suitable area will decrease, and only Pendjari National Park will encompass a suitable habitat in the future.

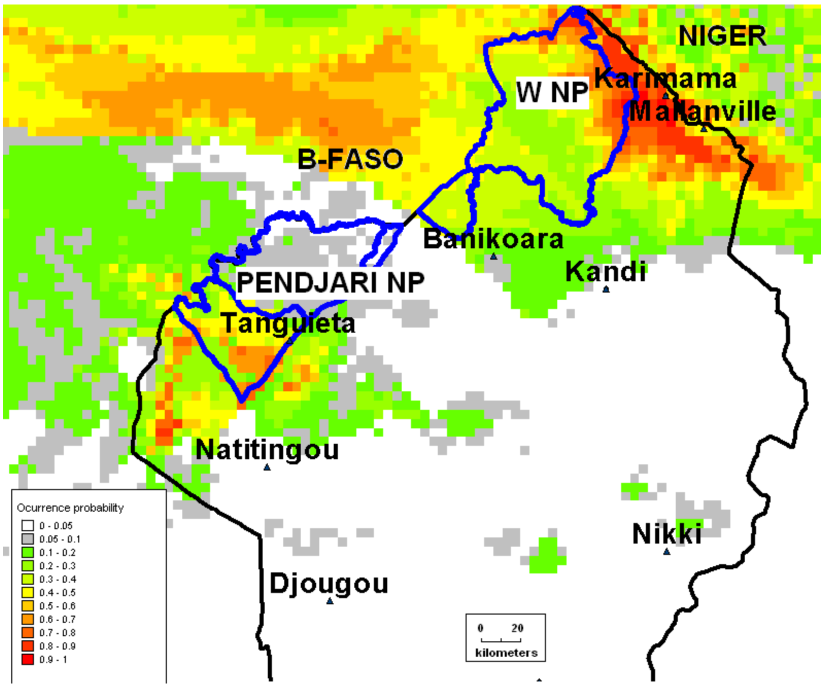

Figure 1.5: Current potential distribution for *Sclerocarya birrea* subsp. birrea in Benin

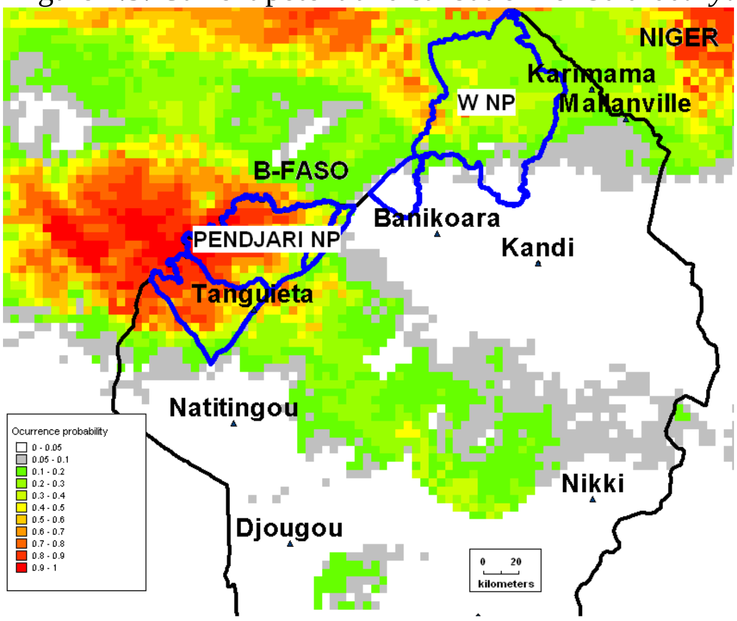

Figure 1.6: Predicted potential distribution for *Sclerocarya birrea* under CO_2 emission scenarios (detailed in the text).

For the northern part of the W-Park (Niger), Landsat TM scenes from 2005 were used for a detailed vegetation classification. The classification was validated with ground truth data from phytosociological releves (see below). A total of 19 vegetation types/land use units were defined with savanna, patchy bush vegetation and vegetation on outcrops being most widespread covering 41%, 19% and 17%, respectively. The vegetation map resulting from this study will be used as support for working out an efficient program for sustainable management of this protected area (WP7). It will also be used as a reference for future assessment of vegetation dynamics.

To assess and analyze in detail plant community patterns and floristic diversity of woodland vegetation (forêt claire), phytosociological data were recorded. Hierarchical classification was applied based on Sorensen's similarity index using the Multi-Variate Statistical Package (MVSP 3.1). A Principal Component Analysis (PCA) using PCORD 5 was performed on floristic data. Indicator Species Analysis (ISA) was used to identify the indicator value of species. Four plant communities of woodland were identified for this part of the W National Park. A total of 179 species were identified belonging to 115 genera in 45 families. The most important families in species richness were *Fabaceae* (13%), *Poaceae* (8%), *Caesalpiniaceae* (7%), and *Combretaceae* (6%). The study revealed that phanerophytes and therophytes were the dominant life forms and Sudano-Zambesian and Sudanian species were represented with 26% and 24%, respectively.

For the Forêt de Patako in Senegal, a time series of vegetation maps (1972, 1988, 2002) based on Landsat image interpretation were completed. The maps show a rapid degradation of the vegetation cover which is essentially due to agricultural impacts (see also D1.4).

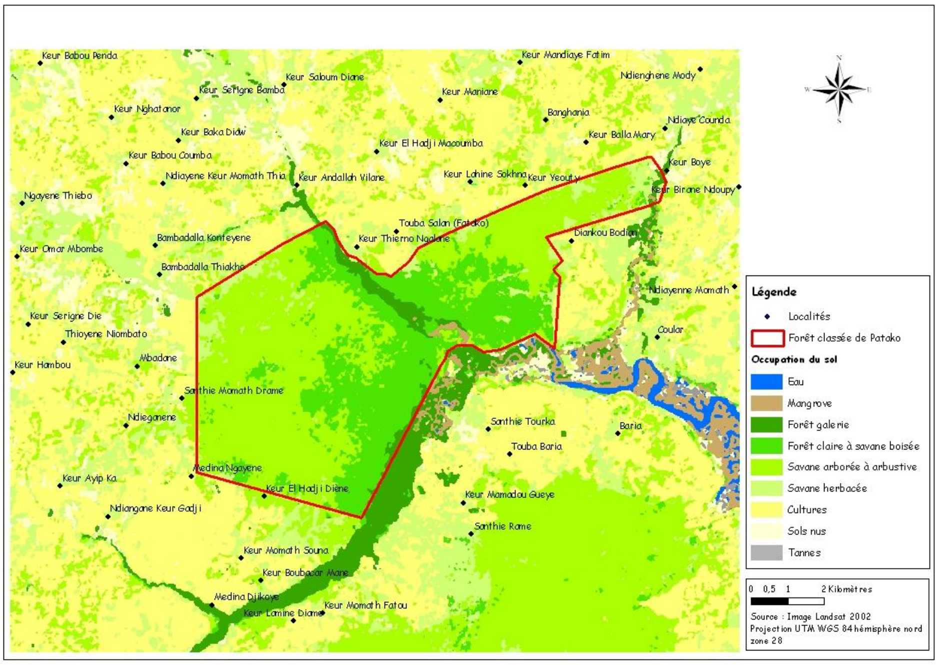

Figure1.7: Land cover map of Patako area in 2002

An allometric model was developed for biomass estimation and carbon sequestration. Carbon stock and dynamics of carbon of the woody biomass were assessed (thesis of Cheikh Mbow).

For the core area Boulon-Koflandé, dendrometric inventories were completed on 160 plots. Herbaceous diversity was documented and biomass was measured. Analysis of diameter classes shows a reversed J-shaped curve for the population structure, which indicates stable populations inside the park area.

All vegetation data from phytosociological relevés and dendrometric inventories are compiled in the vegetation database VegDa (see WP4) for cross-linking and further analysis of data, for modelling of phytodiversity and to obtain the specific objectives 4 (time series analysis) and 5 (vulnerable habitats and species). The data are being made available to public services via the web-version (see WP4).

D1.2 Description of population dynamics of highly valued species in relation to human impact

In regard to population dynamics of highly valued species in relation to human impact, information was completed for all core areas. Moreover, the population dynamics of the most important species were investigated in detail in several core areas.

For the Patako area, the highly valued species are: *Pterocarpus erinaceus, Cordyla pinnata, Parkia biglobosa, Adansonia digitata, Tamarindus indica, Ficus iteophylla, Combretum glutinosum, Detarium senegalense, Saba senegalensis, Rhizophora mangle, Avicennia africana, Bombax costatum, Elaeis guineensis.*
Besides *Combretum glutinosum*, all species populations are declining due to rain fall decline and over exploitation of the populations.

Human driving forces and triggers were determined for each of the species:

- Wood extraction: *Cordyla pinnata, Pterocarpus erinaceus, Khaya senegalensis, Terminalia macroptera, Afzelia africana, Rhizophora mangle, Avicennia africana, Bombax costatum, Prosopis africana, Pericopsis laxiflora*
- Fuel wood extraction: *Combretum glutionsum, Combretum nigricans, Cordyla pinnata, Terminalia macroptera, Guiera senegalensis, Rhizophora mangle, Avicennia africana*
- Non wood forest extraction: fruits of *Detarium senegalense, Saba senegalensis, Neocarya macrophylla, Cordyla pinnata, Parkia biglobosa, Cola cordifolia, Ficus sycomorus* ; bark and sap of *Daniellia oliveri, Elaeis guineensis*
- Plants for medical use: *Ficus iteophylla, Swartzia madagascariensis, Pterocarpus erinaceus, Vitex madiensis, Detarium microcarpum, Cassia siberiana, Kigelia africana*

Other driving forces and triggers for these species are forest land conversion into agricultural land, vegetation fragmentation, fire, climate variability, soil erosion and soil salinisation, as well as spreading of invasive species.

In the Western part of the W-Park and the adjacent land use areas (Burkina Faso), detailed studies were carried out for *Adansonia digitata, Anogeissus leiocarpa, Afzelia africana, Pterocarpus erinaceus* and *Isoberlinia doka*. By comparing species populations inside and outside the protected area, the impact of land use on species structure and spatial distribution was quantified. Occurrence points of individuals (for *Adansonia digitata*) as well as plot based data (900 m²) for all the other species were mapped in different land use units (fallows, croplands and villages) and the protected area (PA). Dbh and height was measured for all individuals and human impact (e.g. pruning, debarking) was documented. Data on the reproductive performances (fruit production) were recorded for *A. digitata*. In addition, a total of 120 plots (1ha-size) were installed to assess the species abundance of *A. digitata* and *Anogeissus leiocarpa*.

A clear difference in the population structure and abundance between the protected area and the land use units was found for *A. digitata*: a reverse J-shaped curve for the PA populations indicates good rejuvenation, while populations in fallows, croplands and villages showed a bell shaped curve, indicating a lack of recruitment and declining populations. The number of adult trees was almost similar in villages and parks, whereas it was lower in fallows and fields. The difference of the abundance and population structure between the park and the three land use units might be partly due to different harvesting impact. Harvesting rates (% of leave and bark harvest per tree) attain about 100% in the land use units and about 50% in the Park. Higher harvesting rates may result in lower growth rates and lower reproductive performance of *A. digitata* trees. However, only pruning decreased fruit production and growth of *A. digitata*, while debarking or combined debarking and pruning had no significant effects.

The number of seedlings was highest in villages, which might be due to high fruit consumption and dispersal of seeds with garbage. The mortality rate was high as well, probably because of livestock browsing and trampling. The lower number of seedlings in fallows and croplands may also be due to fire and clearing for fields. However, the current distribution and abundance of *A. digitata* indicates that this species is not declining severely yet in these land use units. This might be a consequence of traditional protection practices, as baobabs are excluded from chopping when fallows are cleared for fields. We assume that current moderate pruning practices of medium and large trees are sustainable, since fruit production is secured, and even enhanced by low pruning.

The population structure of *Anogeissus leiocarpa* also differed between different land use units. Size-class distribution slopes were negative for all units. However, they differed in the steepness of the slopes. Fallow populations had the steepest slope, indicating high numbers of individuals in the lowest diameter classes, mainly seedlings and a gradual decline in the middle and larger diameter classes. This steep slope exhibited a reverse-J shaped curve and a healthy regeneration pattern. Croplands also had a negative slope, but it was less steep. SCD was far from having a reverse-J shaped occurrence, but rather showed a bimodal curve. This indicates a high number of seedlings, but a lack of saplings. Park populations had the smoothest slopes, indicating low recruitment. In fact, Park populations showed a bell-shaped curve, which is characterised by under-representation of the smallest size-classes. The abundance of regeneration (0-5 cm dbh) and of adults (> 5 cm dbh) was highest in fallows. Similar abundance of regeneration was found in the Park and cropland, while the number of adult trees was higher in the Park than in croplands.

Our results reveal that land use has an impact on the population structure of *A. leiocarpa*. The difference of the structure and the abundance between the three land use units suggests that fallows present better conditions for *A. leiocarpa* than the Park and croplands. This difference is unlikely due to different harvesting impact, because harvesting rates (% of individuals pruned and/or debarked) were much higher in fallows and croplands (80-100% o) than in the Park (5%). The lack of regeneration in the Park may be explained by the higher fire intensities in the Park. *A. leiocarpa* is a fire-sensitive species, as its germination is inhibited by heat and smoke. Fire damage was most severe in the Park (62% of the individuals were damaged by fire), but negligible in fallows (4%) and croplands (20%).

For *Afzelia africana* and *Pterocarpus erinaceus,* results show a large difference between land use regimes. The species are under severe human pressure in anthropogenic areas, where more than 80% of their individuals are pruned or debarked. Tree densities of *A. africana* and *P. erinaceus* were highest in the protected area and three times lower in anthropogenic areas. Population patterns of both species differ according to land use regimes. The species showed lower densities of seedlings and adults, and a total lack of saplings in the anthropogenic areas compared to the protected area (Table 1.1). For *Isoberlina doka* there was no significant difference for saplings within the two sites. This could be explained by high proportions of suckers after cutting of trees in the fields and fallows (Figure 1.8).

Also, species population structures were stable in the protected area compared to a decline indicating structure in the anthropogenic areas. In addition, 95.51 ± 2.21% of *A. africana* and 96.34 ± 2.09% of *P. erinaceus* trees in the anthropogenic areas were severely pruned or debarked. The harvesting was not diameter size-related. These results could be explained by the land use intensity which increased the pressure on these species. We conclude that harvesting combined with agricultural practices in the anthropogenic areas strongly impact negatively *A. africana* and *P. erinaceus* population dynamics.

Table 1.1: Comparison of seedling, sapling and tree densities (mean individuals/ha ± SE) of species in protected and anthropogenic areas

Specie	Age class diameter (cm)	Protected area	Anthropogenic area	Statistical parameters
	Seedlings (0-5)	2466,67 ± 369,62	4,44 ± 4,44	U = 94, p = 0.000
A. africana	Saplings (5-10)	3,46 ± 1,05	0	U = 765, p = 0.000
	Trees (>10)	52,10 ± 4,16	21,48 ± 1,95	U = 269.5, p = 0.000
	Seedlings (0-5)	244,44 ± 101,98	6,67 ± 6,67	U = 764, p = 0.001
P. erinaceus	Saplings (5-10)	3,95 ± 1,28	0	U = 765, p = 0.000
	Trees (>10)	43,46 ± 3,70	20,25 ± 1,94	U = 370, p = 0.000
	Seedlings (0-5)	48,82 ± 4,45	84,82 ± 3,41	U = 4551,5, p = 0.000
I. doka	Saplings (5-10)	1,31 ± 0,32	0,99 ± 0,30	U = 6907, p = 0.468
	Trees (>10)	4,37 ± 0,48	0,69 ± 0,26	U = 4756,5, p = 0.000

Figure 1.8: Suckers of *I. doka* in the field (A) and in the fallow (B) after cutting the mother tree

For assessing the impact of harvesting (pruning & debarking) on the reproductive performance of *Afzelia Africana*, 91 trees (30 in the park and 61 in land use areas) were surveyed. In land use areas, three levels of harvesting (weak, severe and very severe) were recorded. Results show significant differences between the number of fruits, seeds produced and their weight (or mass in kg) among the levels of harvesting. The weak levels of pressure (pruning and debarking) had no effect, neither on the number of fruits or seeds produced per tree nor on the mass of the fruit or seeds. However, at the severe levels, there was no fruit production ($p<0.0001$) and, consequently, no seeds. In conclusion, severe harvesting practices for medicinal and fodder purposes negatively impact *Afzelia africana* reproductive performance in the unprotected areas.

In order to assess the status of natural regeneration of *Afzelia Africana*, seven permanent plots were established in three sites inside the park. Regeneration of *A. africana* was monitored during the wet season (September to October) and the dry season (May to June) from 2008 to

2010. Preliminary data analyses showed that a significant difference exists in the two periods ($p<0.027$). Higher proportions of seedlings were found in the rainy season (42±6.93 per 25m²) compared to the dry season (17.86±3.85 per 25m²). This could be explained by the climatic effect, mainly by the rainfall variation between these two seasons.

In regard to population dynamics in the Beninian part of the W-Park, the diameter class distribution was used as a tool for a quick assessment. For three highly valued fodder tree species *Lonchocarpus laxiflorus, Pterocarpus erinaceus* and *Stereospermum kunthianum,* diameter size-class-distributions were analysed in different vegetation units. Fore none of the species, the typical reverse J-shaped curve was found. Some diameter classes were missing, mainly the class from 5 to 10cm. The curve was not declining in a typical manner up to the bigger size classes, but showed a saturation trend in the size classes over 10cm in diameter.

Also, the conservation status of five locally valued tree species (*Sclerocarya birrea, Prosopis africana, Parkia biglobosa, Afzelia africana and Daniellia oliveri)* was assessed in agroforestry systems and non protected areas around the W National Park in Northern Benin. We particularly focused on *Sclerocarya birrea* by investigating the population ecology, ethnobotany and productivity of the species. Adult density was about nine times higher in the protected area ($p < 0.001$) compared to agroforestry systems (agro-systems). Seedling occurrence was similar in both land use types, even though seed germination was most favoured in agro-systems. Saplings and adults with 5 - 20 cm dbh were almost absent in agro-systems. The mean diameter in agro-systems systems was about two times higher than in the protected area. Although a log-linear analysis showed a difference in the size class distributions between land use types ($p < 0.0001$), they were all positively skewed. Green's index showed a clumped distribution in the protected area (0.48) compared to agro-systems (0.05). Population structure variation could mainly be explained by agricultural pressure. Sapling conservation is required in agro-systems to ensure sustainable use. Regarding folk perception of sexual dimorphism, sex ratio and spatial repartition among male and female individuals, a field survey showed that 55% of interviewees were aware of sex separation in the species. Some local people used bark appearance to make distinction between sexes, but this morphological criterion was not consistent with statistical results. The sex ratio did not deviate significantly from 0.5 in any of the districts or land use types, taking into account the whole populations surveyed. However, there was some bias toward female or male individuals in some subpopulations, and this can be an indicator of local anthropogenic actions. Bivariate spatial analysis with pair correlation function revealed no spatial association between male and female individuals. Moreover, a strict spatial segregation of sexes was not observed, even though some individuals of the same sex could sometimes be encountered together. These results brought some arguments in favor of the functional dioecism of the species and showed that the species did not display any apparent sex specific dimorphism outside the reproduction period or any apparent sex specific requirement for environment conditions. A monitoring of 30 female trees of various diameters (15.3 -101.7 cm) in agroforestry systems during the fruiting season showed that fruit production varied greatly from tree to tree, with an average of 5839 ± 1334 (Mean± SE; CV = 114%) in the season. The level of fruit production was positively, but weakly, correlated with diameter at breast height ($R^2 = 0.11$). Forty-two (42) female trees of various diameters in agroforestry parklands from two climatic zones around the W National Park and Pendjari National Park were also used to assess variations in fruits. Fruits were partitioned into peel, fresh juice/flesh and pit (shell + kernel). Each fruit was labelled, and its components were measured and weighted keeping the identity through the series of assessments. The overall mean fruit mass was 18.58 ± 0.24 g (mean ± SE), but fruits from drier zone populations were significantly greater (19.90 ± 0.37g vs 17.02 ± 0.24g). There was a high correlation between fruit and component traits in general ($P < 0.05$). However, tree diameter was very weakly correlated with fruits and component traits. There was a high correlation within and between population variation in fruits and components traits. The within population variation represented the most important part (67 to 100%) of the total variation in traits. The mating system would partly explain the high within population variation which depicted a high selection opportunity for the species. Although its population is not severely threatened, anthropogenic pressure remain the main causes of its decline in farmlands. An understanding of the mating pattern is necessary for the selection of desirable traits for further domestication program in the perspective of actual valorisation of the species.

D1.3. List of local scale indicators of sustainable use

Indicators of sustainable use were identified at different scales (landscape, habitat, species). For the Patako area, biomass was estimated and the ecosystem vulnerability was focused on by integrating the parameter bush fires, land cover change, invasive plants, soils salinisation, weed development and erosion. These degradation factors were evaluated in their evolution over time.

For all core areas, fire density and the fire specificity index were determined, which are two indicators of ecological peculiarity and environmental trend at the landscape and habitats level.

Fires are central in the ecology of African tropical savannas and are commonly used as a tool for managing the tree-grass balance in protected areas. Because of their impacts on the habitats, fires are also used for conservation purposes. We have monitored the fire activity in the 5 core sites (protected areas PAs) of the SUN project (Patako forest in Senegal, Boulon forest in Burkina Faso, Park-W-Burkina, Park-W-Benin and Park-W-Niger) considering the number of fire events, detected by Earth observation techniques, from 2004 to 2009. In addition to the five PAs of the SUN network, eleven protected areas have been considered in the analysis (Figure 1.9): four faunal reserves and seven national parks. This additional set of PAs was selected to enlarge the range of ecological domains considered in the analysis, more particularly the guineo-congolian and guineo-congolia/Sudanian ecoregions.

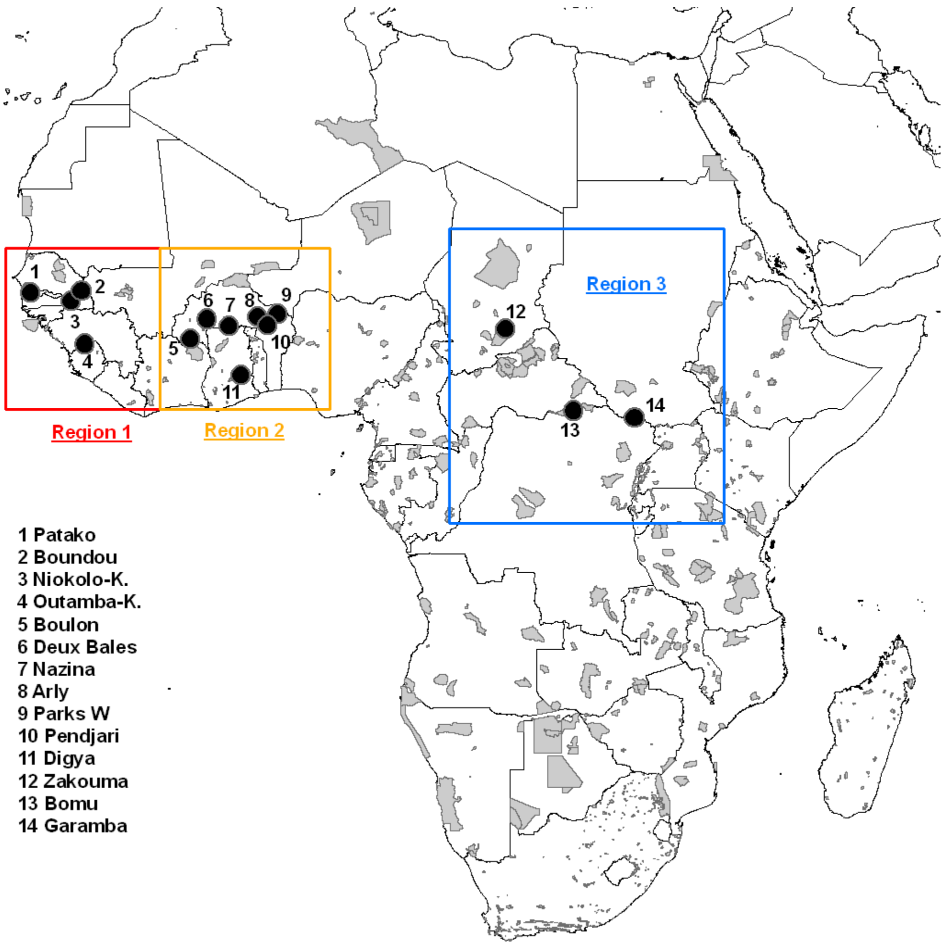

Figure 1.9. Location of the three regional windows and of the protected areas (black circles) considered in the analysis.

Three variables have been used to characterize the temporal patterns of burning activity: i) the number of fires detected during each week of the potential burning season ii) the time expressed in number of weeks, since the start of the potential burning season needed to reach 25% and 50% of the total number of fires detected over the season iii) the length of the core burning season, which is expressed as the number of weeks between the first quartile (25% of the total) and the fourth quartile (75% of the total).

In addition to the three variables used to characterize the temporal patterns of fire activity, two other variables have been defined for assessing the overall level of burning activity: i) the number of fires per 1000 ha detected over a given period of time; called fire density, which allows comparisons between sites ii) the ratio between the fire density observed inside a given site and the one observed in a 25 km buffer zone around the area. Called Specificity Index, this ratio helps assess how specific an area is in terms of land cover conditions, compared to its surroundings. It is an indicator of its ecological peculiarity. In fact, the fire density in the sudanian and guineo-sudanian regions is largely driven by the quantity and the spatial distribution of the fuel available for burning, essentially the grass layer. The quantity of grass biomass is much higher in the natural savannas or woodlands found in the protected areas, such as the SUN core sites, than in the surrounding area where croplands and pastures are the dominant land cover types. Moreover, numerous fire breaks prevent the development of fire events in this peripheral domain.

If one compares the fire densities observed inside the PAs of the SUN network with those of the other PAs in a similar ecoregion, their relative situations do not change much over the 2004–2009 period (Figure 1.10). The Patako classified forest (Senegal) is always in the lower part of the distribution (low fire densities), while the Boulon classified forest (Burkina Faso) stands towards the high values of fire density; the Park W components tend to be in the average values.

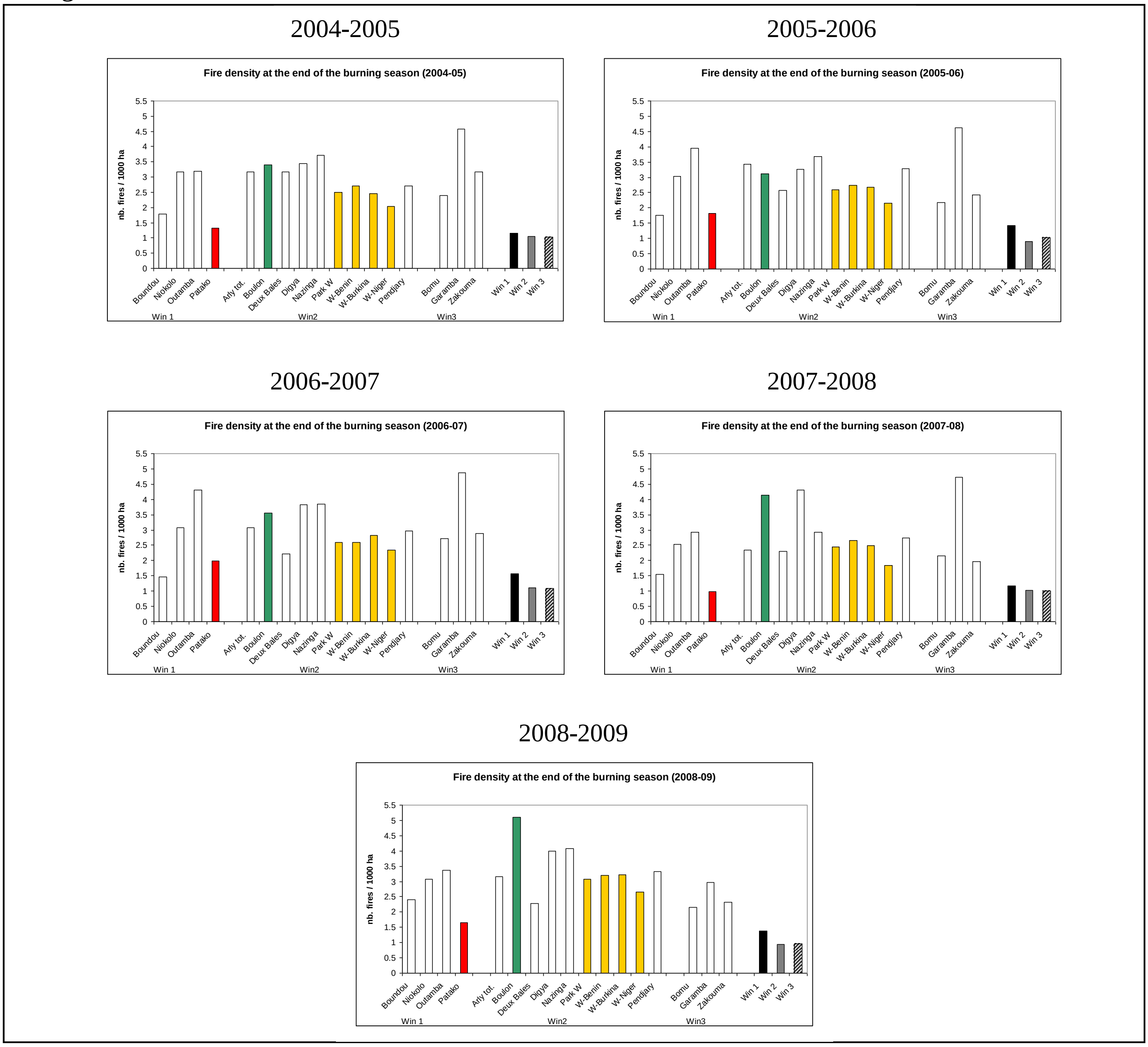

Figure 1.10: Fire density (nb. fire pixels/1000 ha) in Patako (red), Boulon (green), Park W (orange) and other 11 protected areas of West and Central Africa from 2004 to 2009. Fire density in the regional windows: window 1 (black), 2 (grey) and 3 (striped).

If, instead, one considers the ratio between the fire density inside and in the 25 km buffer zone (Specificity Index), the situation for the SUN PAs appears quite different (Figure 1.11). They are clearly among the PAs for which there is a high contrast between the fire activity inside and outside the PA. The extreme situation being observed for the Patako classified forest and for the ParkW-Niger, with a Specificity Index always above 5, which means that the fire activity is 5 times higher in these PAs than in their surroundings. In fact, the average fire density in the buffer zones of Patako and of ParkW-Niger over the five year period has been extremely low: 0.2 and 0.1 for Patako and ParkW-Niger, respectively. We hypothesize that this situation is largely due to the predominance of agriculture lands around the PA, with a low level of fuel and numerous fire breaks which would not allow the development of an intense fire activity. The GLC2000 land cover map was used to assess the extent of agricultural land around the PAs. For Patako and ParkW-Niger, the GLC2000 land cover class ‘Cropland (>50% agriculture)” occupies 69% and 60% of the 25 km buffer zone; while it occupies 21%, 18% and 0% for ParkW-Benin, ParkW-Burkina and Boulon, respectively. These results, although based on satellite data acquired during the year 2000, while the fire information covers the period 2004–2009, seem to confirm that the fire activity around the PAs relates to the level of agricultural activity: increasing agriculture leads to a decrease of fire activity.

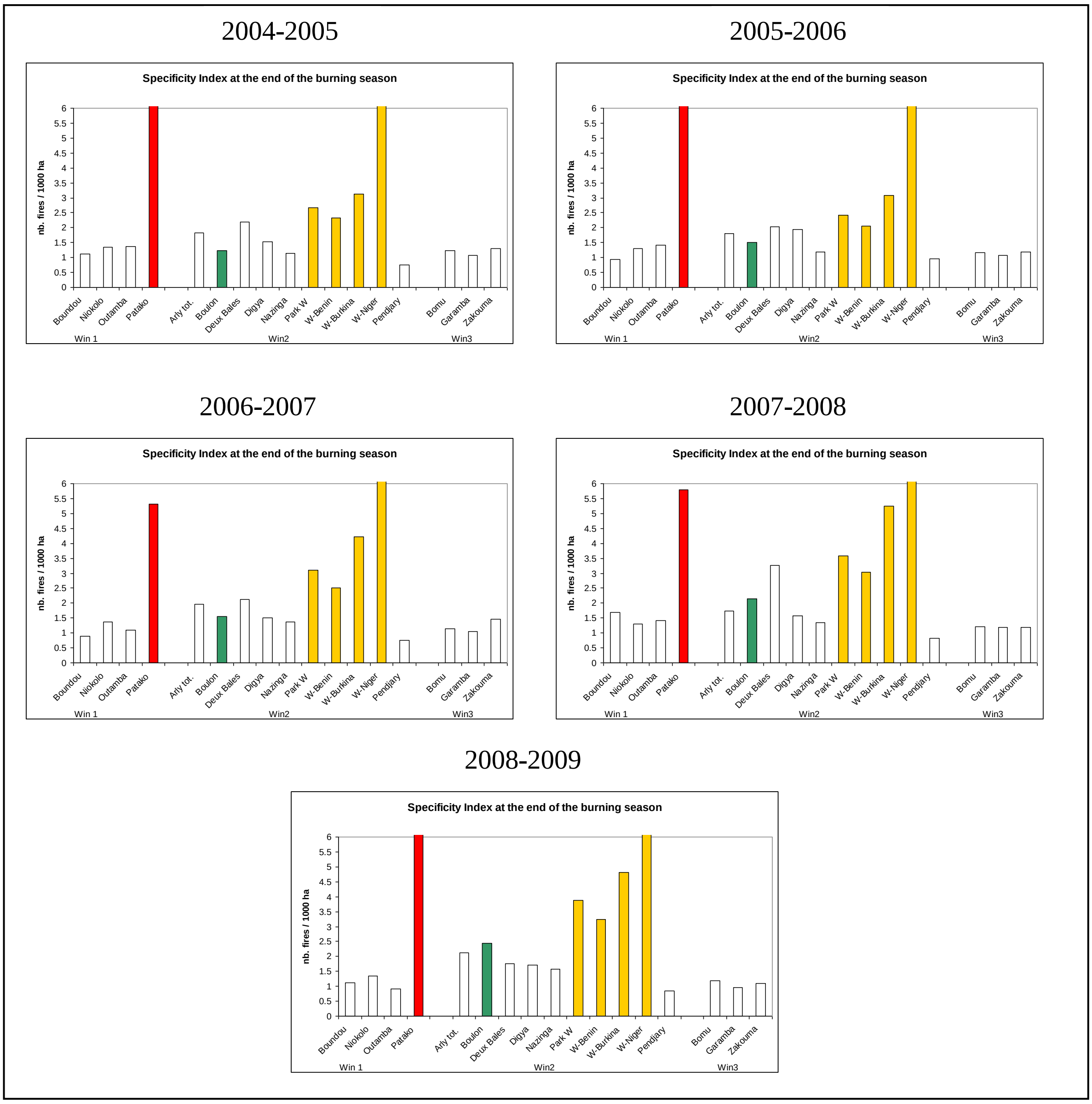

Figure 1.11: Specificity Index in the Patako (red), Boulon (green), Park W (orange) and other 11 protected areas of West and Central Africa from 2004 to 2009.

The evolution of the Boulon classified forest must be noted: its Specificity Index increases from 1.2, in 2004–05, to 2.5, in 2008–09. This means that the level of fire activity was more or less the same inside and outside the PA during the 2004–05 season, while five years later, it is more than two times higher in the PA than in the surrounding buffer zone. In fact, the fire density has increased in the PA, from 3.4 to 5.1 over the five years, while it has decreased in the buffer zone, from 2.8 to 2.1. Here again, this change of the Specificity Index might be indicative of a progressive extension of the area dedicated to agriculture, at the expenses of the natural savannas, around the classified forest and, consequently, a progressive isolation of the Boulon protected area. A similar trend, although less pronounced, is observed for the Burkina and Benin components of Park W. If confirmed by additional observations in the coming years, this trend would be a clear indicator that these PAs are progressively loosing their capacity to conserve biodiversity. In fact, the conversion process around the PAs usually affects the structure and dynamics of the species populations inside the PAs.

In summary, for the PAs of the SUN network, we might conclude that an ecological isolation is ongoing for the Boulon forest and, to a minor extent, for the ParkW-Benin and ParkW-Burkina. For the Patako forest and ParkW-Niger, the ecological isolation is already quite high due to the extended agricultural land around these two PAs.

D1.4 Maps of temporal vegetation changes

Temporal vegetation change analysis was done for the core area Patako forest on two series of data from 1972 to 2002. Maps of land cover change have been performed. MODIS data are being explored to track NDVI trends over the core area of Patako.

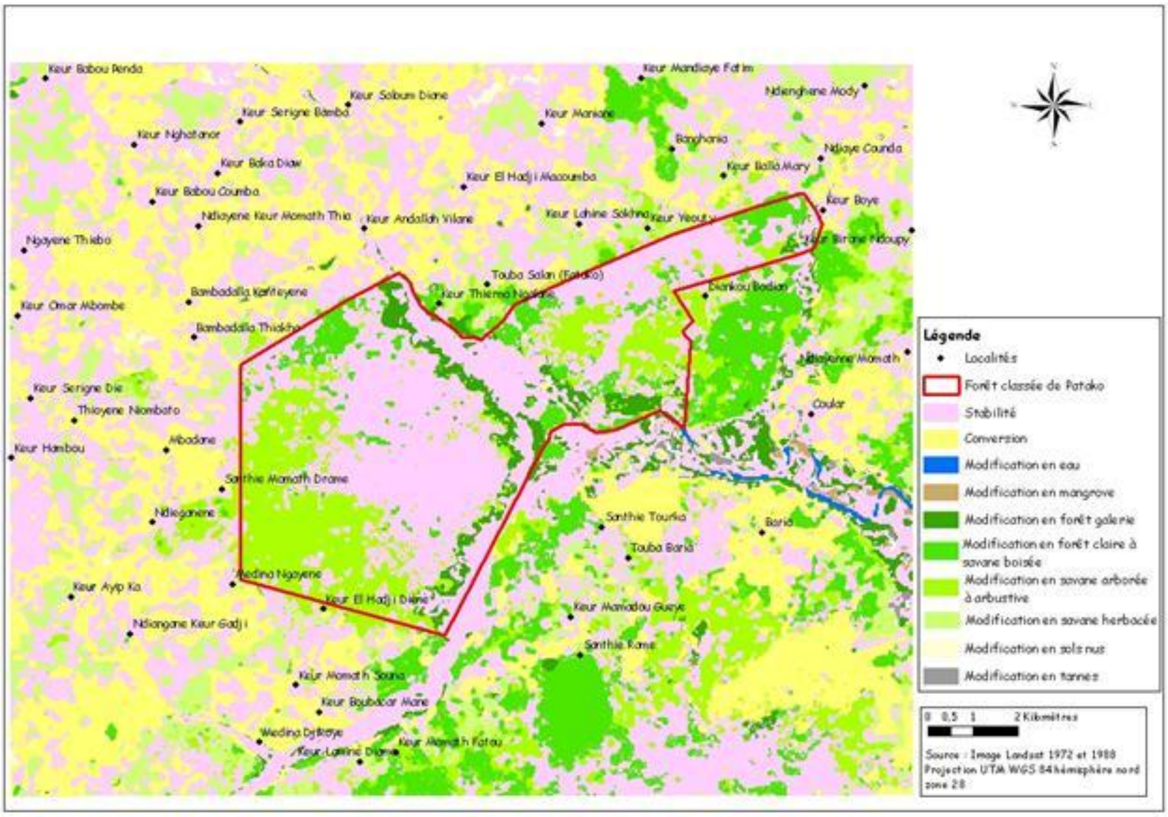

Figure 1.12: Temporal vegetation change in Patako forest from 1972 to 1988

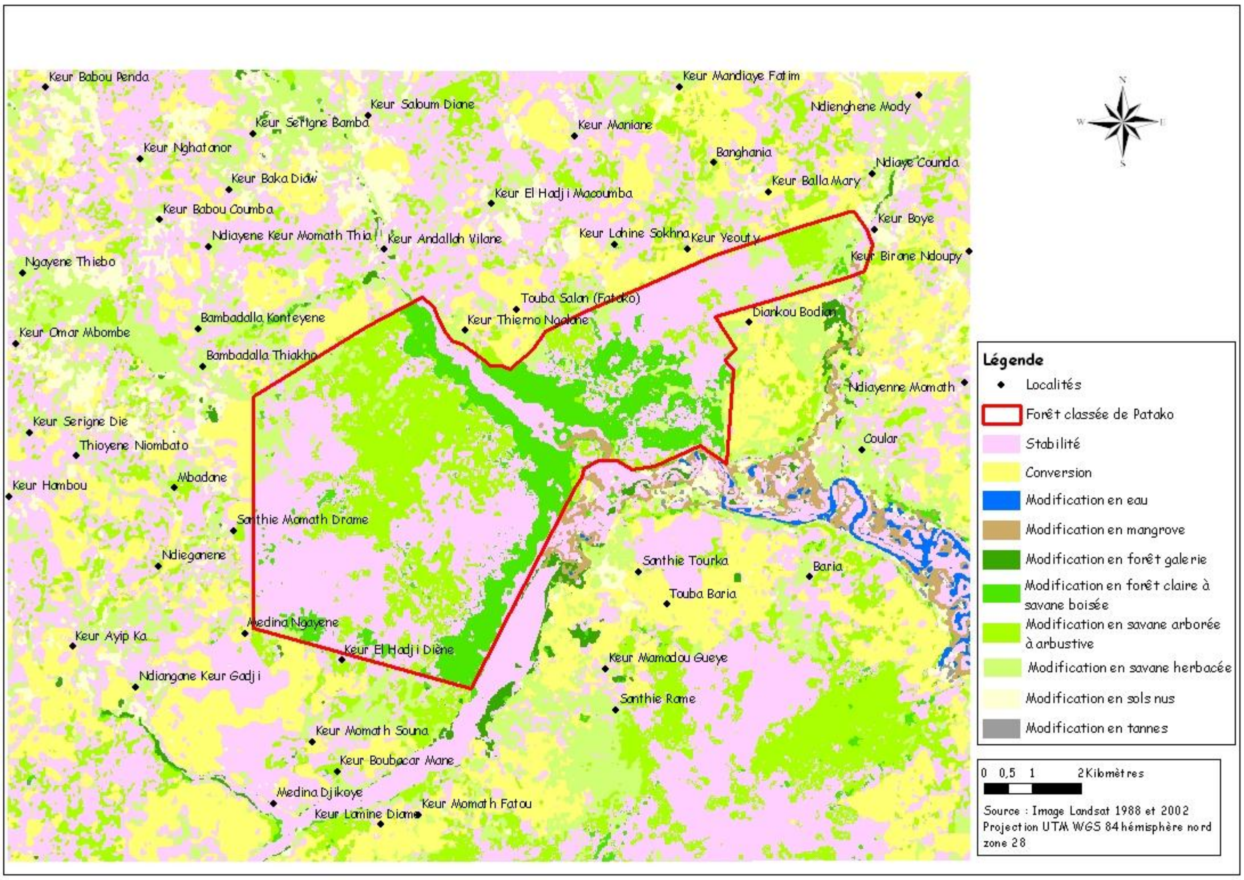

Figure 1.13: Temporal vegetation change in Patako forest from 1988 to 2002

Temporal vegetation change in the W-National Park is assessed by the Normalized Difference Vegetation Index (NDVI) on a series of Landsat images of 1986, 1998 and 2002 (all from November). A fourth scene of a more recent date was not integrated due to the failure of the Scan Line Corrector (SLC) of the ETM+ instrument on May 31, 2003. Landsat images are only available with interpolated data for the missing lines. We are currently analysing whether the differences of the NDVI values between the three images can be explained by true changes of the vegetation patterns in the landscape or if they were produced by perturbing factors during image capture.

For the analysis of small scale temporal vegetation changes, 40 monitoring sites were recorded in the core area Benin for the third and fourth time. Data on population structure for all woody plant species within the distinguished vegetation units were completed. Due to individual based monitoring for every woody plant species in the permanent plots, the demographic fate can be modeled. Preliminary analysis for one selected highly valued species, *Detarium microcarpum* (mainly for firewood), was done. In total, 370 individuals were monitored from May 2008 to May 2010 on 39 permanent sites. About 35% of them could be relocated at every date of monitoring and tended to re-sprout early after the dry season. About 31% of the individuals were not located at the first date in May, 2008, but in September 2008. They tended to be present in the population, but re-sprouted later. Thus, about 66% of the population of *D. microcarpum* stayed alive during the monitoring period. Only 8.3% of the whole population died back.

Soil samples were taken and grazing observations for cattle and small ruminants were carried out to quantify their influence on the monitoring plots, particularly on the regeneration of woody species. The determination of grain size distribution, pH-value, exchangeable cation concentration for Na+, K+, Ca2+ and Mg2+, organic content (Corg) and total nitrogen concentration (N) for C/N-ratio and available phosphate (P2O5) were done for all 80 soil samples. Data are processed and results will be available at the end of 2010. Grazing observations served also to evaluate the value of fodder species in different seasons. While in the dry season, cattle mainly consume twigs and leaves cut by the herders, grasses and herbs are most important in the rainy season.

D1.5 Descriptions of vulnerable habitats and species under threat

The Climate Change Severity Index (CCSI, Anderson 2008) was calculated for West Africa from UK Meteorological Office's Hadley Centre Climate Data (HadCM3) with 1km^2 spatial resolution for 2000-2050 under the two scenarios a2a (business as usual) and b2a (environmentally conscious, sustainable economies). The CCSI is constructed of baseline climate data and monthly anomaly data and is derived from a Temperature Change Severity Index (CCSIt) and a Precipitation Change Severity Index (CCSIp). The CCSI measures the climate change that a particular location on earth may undergo, compared to the natural climatic variation that the location has been exposed to historically (here called: "comfort zone"). The CCSI measures whether the location will stay in its comfort zone, or how far it will be placed outside in future. The values of the CCSI are grouped in six climate change severity classes starting with a "Low Severity" level and ending with the "Far Outside Comfort Zone" level. In Fig 1.14 and Fig. 1.15, the results for the CCSI are displayed for the two scenarios a2a and b2a and are overlaid by the SUN core sites and the biomes of the AEFTAT vegetation map of Africa (White, Frank; 1983; Vegetation of Africa - a descriptive memoir to accompany the Unesco/AETFAT/UNSO vegetation map of Africa; Natural Resources Research Report XX; U. N. Educational, Scientific and Cultural Organization; Paris/France). According to both scenarios, the southern parts of the Sudanian zone, the entire Guinea-Congolian zone and the transition zone between both zones are projected by 2050 to undergo medium to severe climatic changes displayed by the Classes 4-6 of the CCSI. The projected changes of the CCSI are directly related to the high values for the Temperature Change Severity Index (CCSIt) and a projected increase of 3˚C mean annual temperature (a2a, 2050) in combination with the high results for the Precipitation Change Severity Index (CCSIp). The values for the CCSIp vary between class 4 and 6 for the Guinea-Congolian zone due to the projected increases for the annual sums of precipitation for 2050. According to the projected climatic conditions by HadCM3, the ecosystems of the three SUN core areas will be situated in the transition zone between Class 2, "Approaching significant changes" and Class 3, "Significant changes vary during the year" in 2050 in both scenarios.

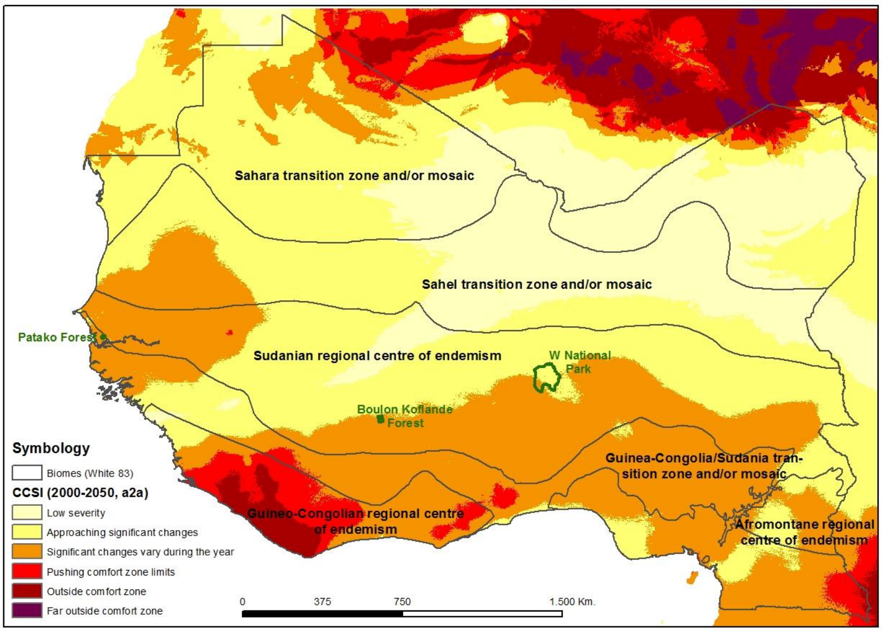

Fig. 1.14: CCSI for Westafrica with biomes (White 1983) and SUN Core Areas (2000-2050, scenario a2a, HADCM3)

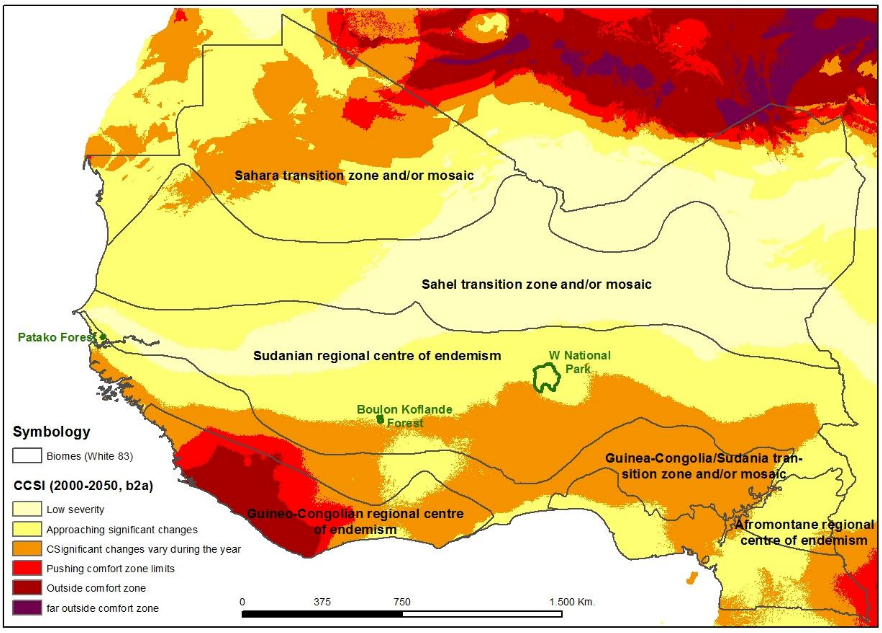

Fig. 1.15: CCSI for Westafrica with biomes (White 1983) and SUN Core Areas (2000-2050, scenario b2a, HADCM3)

Actual population numbers and historical population data were assessed for the SUN core areas with the LandScan 2008 Global Population Database at a resolution of 1km^2. Fig 1.16 presents the population data for 2008 in the three SUN core areas (Oak Ridge National Laboratory, Landscan 2008). Population data for the surroundings of the W-National Park and Boulon Koflandé Forest display low to medium density (< 51 persons/km^2, Classes 1-4) in the buffer zones in 2008, with the highest concentrations along the roads (> 50 persons/km^2, Classes 5-7). W-Park/Niger and W-Park Burkina Faso display higher population numbers in the buffer zone than W-Park/Benin.

Around the Patako Forest, a densely populated pattern with more than 50 persons/km^2 existed in 2008. There is no linear structure notable at high concentrations. In the near future, population pressure could be a serious obstacle for the conservation of the Patako Forest.

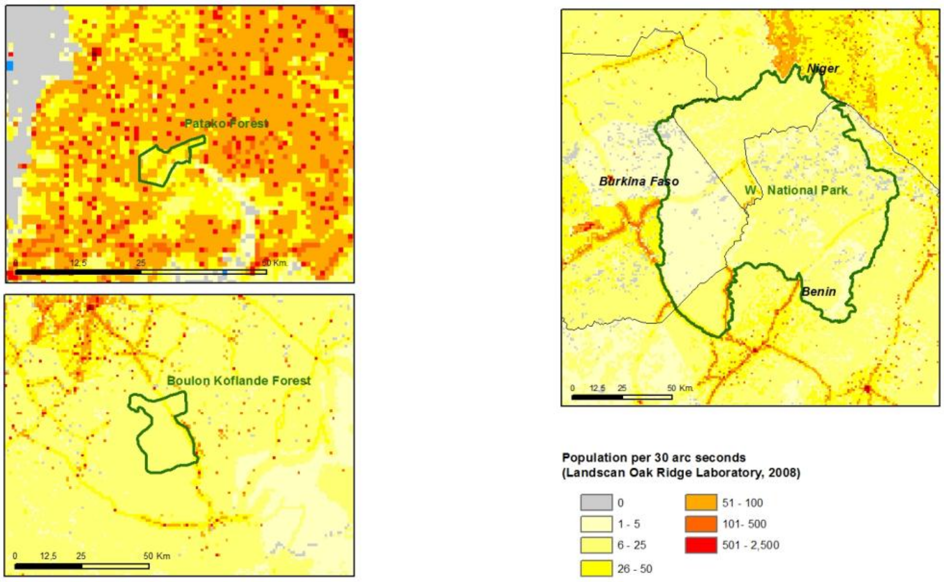

Fig. 1.16: Population/1km^2 in SUN Core Areas in 2008 (Oak Ridge National Laboratory, Landscan 2008)

The development of the population growth in the SUN core areas was calculated from UNEP Gridded Population Database for the time frame from 1960 to 2000 (Fig. 1.17). The current high population numbers around the Patako Forest are based on a significant population growth between 1960 and 2000. In 50% of the buffer zone of the Patako Forest, the number of persons/km^2 increased by 50-100 persons/km^2 between 1960 and 2000. The other 50% of the buffer zone was submitted to increases of 1-50 persons/km^2. A similar increase rate per km^2 could be found around the W National Park and Boulon- Koflandé Forest for the same period. The surroundings of the Boulon-Koflandé Forest have been affected less by population growth during 1960-2000 than the other two areas.

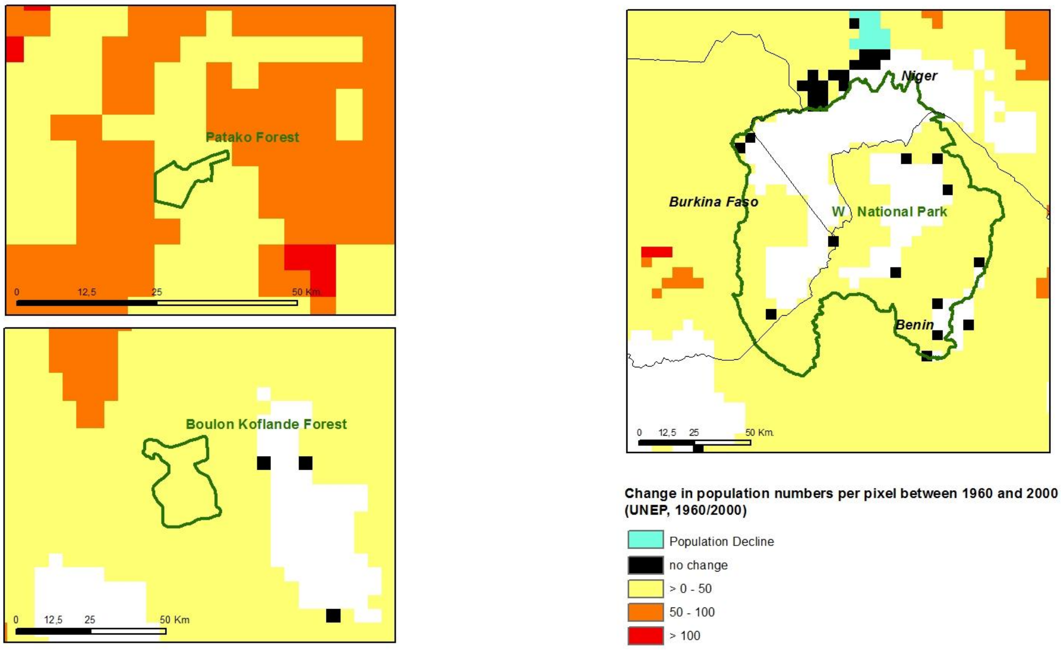

Fig. 1.17: Population growth per km^2 between 1960 and 2000 in and around the SUN Core Areas (UNEP, Gridded Population Database)

For analysis of the vulnerability of two highly valued species in the western periphery of the W- National Park (*Adansonia digitata*, 837 sample points and *Anogeissus leiocarpa*, 104 sample points), the distances between each sample point and the nearest village/nearest road were calculated (ESRI®ArcGISTM 9.3) to study whether there is a statistical correlation between the presence of human settlements/access with the intensity of use of the two selected species.

In the core area W-Park (Benin), an assessment of the population structure in relation to different habitats was carried out for the highly useful species *Prosopis africana, Daniellia oliveri, Parkia biglobosa and Afzelia africana* around W National Park. Three types of habitats (farmland, fallow, hills) were considered outside the protected area on three sites: the southern part (Sampeto village), central part (Alphakoara and Goungoun) and the northern part (Karimama district) of the park representing a gradient in the rainfall and in consequence in aridity. We used the line transect method to estimate adult plant species abundance. Additionally, some subplots were established in 1ha-plots plots laid out in the occurring populations of the species to assess and estimate regenerations. A preliminary analysis of the results showed that *A. africana* was threatened in all types of habitats globally on the three sites inventoried. While the species found refuge on hills in the southern part, it is almost absent in the northern part of the protected area (driest site). Generally, the farmland was found to be a vulnerable habitat for all species, while the hills are still serving as refuge for *Prosopis Africana,* which is scarce in other types of land use. The more humid areas, mainly gallery forests crossing the farmland in the southern part of the park, were more suitable for *Daniellia oliveri,* which showed weak abundance in other land uses types. *Parkia biglobosa* was found to be present in croplands and fallows (albeit more abundant in the southern part), while it is quite absent on hills.

In northern Benin, the spatial repartition of dongas (erosion formations) was also studied in the W National Park of Benin and its periphery in order to study the impact of erosion and the donga phenomenon on plant communities. The occurrence points of those vulnerable habitats have been collected in Karimama and Banikoara in the W National Park and its land use area for mapping. Dongas are recorded on different soil types in which the more favourable soils are (i) leached ferruginous tropical soil with low clay, washed into sexquioxydes (52% dongas), (ii) hydromorphic unevolved soil (35% dongas) and (iii) the poorly evolved hydromorphic soil (7 % of dongas). Dongas also exist in small numbers on other types of soils. Phytosociological data were collected in "donga" and the "plateau" to characterize plant communities of "donga" and "plateau". Six plant communities were discriminated along an edaphic gradient and human impact. Thus, the plant communities G1 with *Grewia barteri* and *Pandiaka angustifolia*, G2 with *Acacia Senegal* and *Caralluma dalzielii* and G3 with *Acacia hockii* and *Cochlospermum planchonii* of the W National Park were dissociated to G4 with *Schoenefeldia gracilis* and *Mitracarpus villosus,* G5 with *Sterculia setigera* and *Ipomoea vagans* and G6 with *Hibiscus acetosella* and *Spermacoce filifolia* of land use area. Data were collected to evaluate which sand quantity has been lost annually and annual run-off in those vulnerable habitats.

All relevant data regarding the Patako forest were collected. Currently, the integration of various sources of data (including hot spots of erosion area, weed plants development, invasive species, fire frequencies, logging activities, salinity outcrops, population density and pressure, remote sensing and GIS data) is performed to derive habitat sensitivity. The analysis will be finalized this year.

Milestones

Initial maps of vegetation and land use patterns (month 12).
This milestone is achieved for all core areas except Boulon-Koflandé.

Initial results on valued species, indicators, temporal vegetation change and vulnerability analysis (month 21).
Initial results are achieved for valued species, indicators and temporal vegetation changes. The vulnerability analysis is also achieved for several core areas.

Expected result
The expected result is an improved understanding of vegetation dynamics and their causal factors.
This result is fully achieved.

WP2 Regional Scale Vegetation Dynamics

Partner 2

Participants: P1: AARHUS, P2: AARHUS, P3: DAKAR, P5 – SENCKENBERG, P7 – BOBO DIOULASSO, P8: COTONOU, P9: JRC, P10: NIAMEY

WP objectives:
The overall objective of this workpackage is to increase the effectiveness of remote sensing for ecosystem management in arid and semi-arid areas by mapping vegetation and investigating the relationship between remote sensing and actual plant community distributions and the spatial and temporal changes due to climate and the activities of man.

The specific objectives are:
To map the spatial pattern of plant communities in relation to the activities of man and variations in climate at the regional scale.
To map the temporal trends in plant community distribution and status and relate this to the activities of man and climate.
To clarify the relationship between remotely sensed data, plant communities and their drivers.
To predict the effects on the distribution and status of the plant communities of changes in climate and the activities of man in order to identify vulnerable areas and management needs.

Deliverables

D2.1 Maps of and articles on the distribution of the plant communities and their status on a regional scale

The JRC has produced estimates on land cover change over the tropics for the years 1990-2000-(2005)-2010 derived from high resolution Landsat-type satellite imagery. The method is based on a systematic sampling approach where at each intersection of the 1 degree lines of latitude and longitude a sample will be located. The standard sample size is taken as 20*20 km around each intersection of the 1 degree lines of latitude and longitude. Object-oriented image segmentation has been used in order to obtain polygons of homogenous pixels. Image classification and change statistics have been applied on the following land cover classes: Tree cover, tree cover mosaic, shrub cover, other vegetation cover (including natural grasslands, pastures and agriculture), bare and artificial, burnt (temporal class) and water. Results of the change assessment will be published in 2011.

A joint field mission has been organized by JRC and LERG-UCAD in the framework of the SUN project. 10 sample sites were identified and visited for detailed field studies. The aim of the field visits was to ground truth the satellite images and their respective classifications. Vegetation species assessment and systematic field photos representing all the different land cover types of the samples visited have been taken and linked with GPS data in order to obtain geo-tagged photos. The satellite image classifications of the samples have been directly compared with the current situation in the field. During the field trip (A. Brink, P. Mayaux and C. Bodart for JRC, Cheikh Mbow and Assane Goudiaby for LERG-UCAD), about 2400 km were covered by car to reach the 10 sampling sites, of which two were located in Protected Areas. The visited protected area was Niokolo-Koba and partly Ferlo-Nord. In addition, also the Boundou community based reserve were visited. Contacts have been made with the Park Managers and/or Park Scientists from the Niokolo-Koba park and the coordinator of the Boundou community based reserve project. Species lists have been compiled from the field work.

Distribution of African Acacia has been used for modelling species for plant distributions and their status on a regional scale. Currently, the database is still being assembled. Data had been obtained through collaboration with several people, and herbarium visits to Kew (K), Coimbra (COI) and Lisbon (LISC). Some data have also been obtained from observational data, such as the data that has been recorded in the West African Vegetation Database and is openly available. Also, preliminary maps of West African species were created and shown at the final SUN workshop, where botanists of the various countries of the region commented on the distribution maps, pointing out mistakes and areas where data was potentially missing (Figure 2.1).

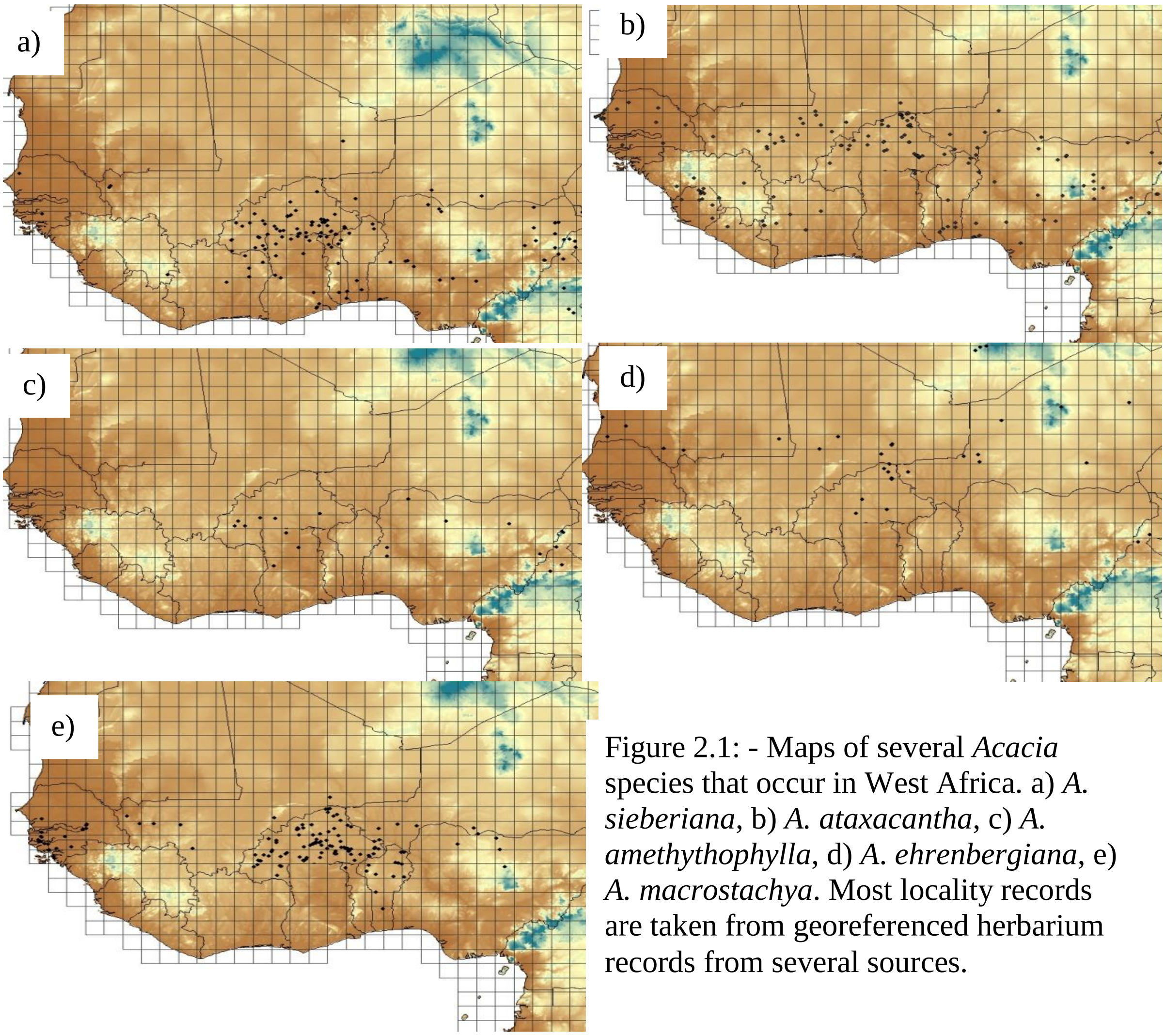

Figure 2.1: - Maps of several *Acacia* species that occur in West Africa. a) *A. sieberiana*, b) *A. ataxacantha*, c) *A. amethythophylla*, d) *A. ehrenbergiana*, e) *A. macrostachya*. Most locality records are taken from georeferenced herbarium records from several sources.

This work will continue after the SUN project has stopped, as the PhD student in charge of the work will be paid to finalise the work form Aarhus University.

D2.2 Maps of and articles on trends in plant community distribution on a regional scale.

Trends in regional plant community distribution have been analysed using a suite of five indices developed for this purpose based on time series image data (1982 – 2008) (McCloy, 2010) and from this derived maps depicting how the plant phenology and, hence, community mix has changed over this time period. This work has resulted in several symposium articles and two submitted journal articles.

These five indices measure the way that the vegetation phenology has changed in accordance with the theoretical basis for the indices that starts with consideration of the ways that plants can respond to climate change. This consideration has led to the hypothesis that the integrated phenological curve as detected from remotely sensed image data can change in a combination of the five ways depicted in Figure 2.2.

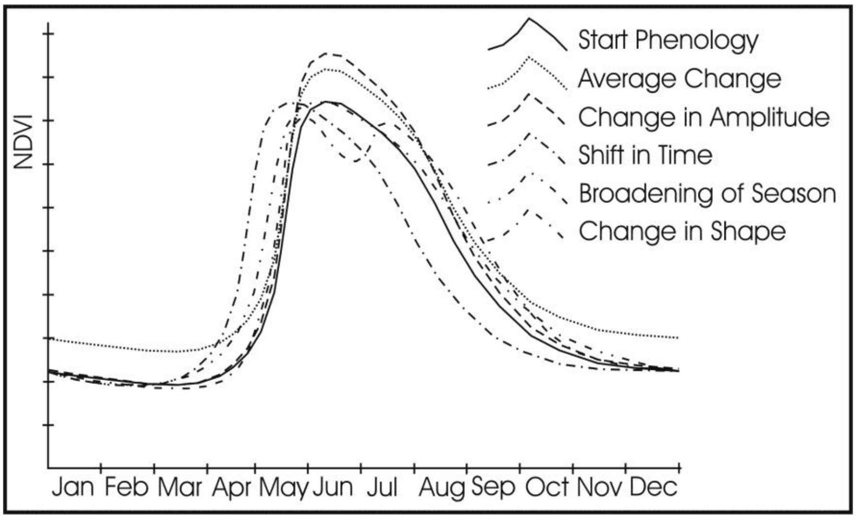

Figure 2.2. The five ways that the phenological profiles as recorded in image data can change over time.

These five ways are;

1 **A change in the peakedness of the growing season (Gain Index)**. For example in areas that are moisture constrained in the growing season, increased rainfall in the growing season may result in more green growth. Another explanation could be that plant communities with stronger vegetation index response, such as grasses compared with most forests, invade the area (Figure 2.4).

2 **An average change in greenness throughout the year (Offset Index)**, as for example the replacement of deciduous by evergreen species or replacement of needle leafed with broad leafed species(Figure 2.5).

3 **A shift in the time of the peak (Shift Index)** of the growing season as can occur when, for example, annual species are affected by changes in the temperature and/or rainfall regimes, leading to shifts in the phenophases associated with growth, maturation and death in these annual species(Figure 2.6).

4 **A broadening of the growing season (Broad and Length Indices)** as can occur for example in areas that are temperature constrained (Figures 2.7 and 2.8)., and

5 **A change in the shape of the Phenological Curve (CofD Index)**, for example by the emergence of multiple peaks in the growing season caused by the invasion of species with different growth cycles, or due to changes in the rainfall regime (Figure 2.9).

In addition to these indices, the residuals from the fitting can be used to improve our understanding of the potential causes of the changes that are detected by the Phenological Change Indices (PCI's).

These indices have been evaluated to verify that they mimic the ways that the vegetation phenology can change, and maps (Figures 2.4 – 2.9) have been produced that show how the vegetation has changed over the period of the time series used to derive the indices (1982 – 2008). These maps show that the phenology has a decreasing peakedeness and increasing average annual greenness in the south where the shape is changing most dramatically, suggesting greater affects due to man due to changes in land use, whilst in the north the peakedness is increasing and the average annual greenness is decreasing. In the north, the shape of the phenology is not changing significantly in the Soudainian zone, but it is in the Sahelian and semi-desert fringe, suggesting that these areas are experiencing significant changes in cover conditions. The Broad and Length indices show that the length of the season is increasing in the Soudainian and Guinea zones, agreeing with results found by other workers.