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VEGETATION DYNAMICS PATTERNS, BIODIVERSITY CONSERVATION AND STRUCTURE OF FOREST ECOSYSTEMS IN THE WILDLIFE RESERVE OF TOGODO IN TOGO, WEST AFRICA

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INTRODUCTION

The importance of protected areas in providing ecosystem services and biodiversity conservation is recognised all over the world by numerous authors (Morales-Hidalgo *et al.*, 2015; Scolozzi *et al.*, 2014; Boucher *et al.*, 2013). However, the information gathered on the flora and fauna, as well as on the ecological and economic importance of protected areas in Togo, are very weak (Adjonou *et al.*, 2013). Considering the current trend of a general decrease in the structural complexity and extent, or the complete disappearance, of the protected areas in Togo, in West Africa (Kokou *et al.*, 1999), such

information is crucial for decision-making (Geldmann *et al.*, 2015; Nagendra *et al.*, 2015; Romagosa *et al.*, 2015). The main threats of the reduction in protected areas in Togo are human population invasion for shifting cultivation, livestock grazing, selective cutting of valuable or rare tree species, and over-exploitation of non-timber forest products to satisfy the basic needs of rural communities (Masumbuko, 2013). In Togo, one of the valuable and priority protected areas is the Wildlife Reserve of Togodo (WRT) in the South-East of the country (Adjonou *et al.*, 2013). This reserve is the only protected area located in the Guinean zone and is the main site the country

currently has on the list of wetlands of International Importance (Ramsar Sites). It is in this protected area that the most important remnants of forest of the coastal area of Togo are found (Kokou & Caballé, 2000). Therefore the vegetation of this reserve, especially the forest remnants, constitutes a rare ecosystem in Togo and a very important representative of forest relics in the ecoregion at the level of the discontinuity in the West African rain forest block, the so-called Dahomey Gap (Salzmann & Hoelzmann, 2005). It preserves many endangered animal and plant species and many natural habitats, as well as the processes and services that generate and maintain the biodiversity (Abuzinada, 2003; Guénaou, 2006). The control of the current degradation trend in the WRT is a challenge for conservation. Nowadays, the scientific knowledge on the WRT is partial or insufficient to achieve appropriate planning and conservation initiatives, such as tracking progress toward goals like the AICHI Biodiversity Targets. To minimize this knowledge gap, this study was conducted to (i) establish a diagnosis of the dynamics of the land use types in the protected area, (ii) assess the state of the plant diversity conservation and (iii) analyse the structure of the forest ecosystems still preserved in the wildlife reserve of Togodo.

Therefore, we performed an analysis of the vegetation dynamics in the last 27 years and carried out a survey to determine vegetation distribution, plant diversity and forest structure. The study was developed in the context of the ClimAfrica project on adaptation to climate change of Sub-Saharan Africa (project FP7-ENV-2009-1-244240, European Union VII Framework Programme), within which the Togodo reserve was included as one of the seven Case Studies in Africa. The results will contribute in the decision-making regarding a more efficient management of this priority protected area in Togo. This study also provides a reflection framework for the Togolese Government on the need of creating synergy between the agricultural policy around this forest reserve and the management of the forest resources. Finally, the study provides a reference state on the biological environment of the WRT, to the extent that, on the one hand, in the framework of the redevelopment policy of the priority protected areas in Togo, the WRT can achieve nearly a status of National Park. On the other hand, the construction of the hydroelectric dam of Adjarala on the Mono River, right at the level of the park, is a reality and the opening of the dam will have an impact and disrupt the entire ecosystem of this protected area.

MATERIALS AND METHODS

Description of the study site

The WRT is located between 6°23' and 7° Northern latitude, and between 1°23' and 1°34' Western longitude (Figure 1). The WRT is bounded by either natural or artificial boundaries and is composed of two entities including the classified forest of South Togodo (18 000 ha) and the classified forest of North Togodo (13 000 ha), that is, a total area of 31000 ha. According to the Order No. 003 MERF/CAB dated May 3, 2005, the southern part (classified forest of South Togodo) will be transformed in a National Park and will be assigned the following functions: protection of the relict forests of the protected area for spiritual, scientific, educational, recreational and tourism purposes;

- sustainability of the ecological, geomorphologic, sacred and aesthetic components under the natural conditions;
- provision of stability and a local economic diversity.

The entire area lays on a large gently rolling plain (maximum altitude 90 m above sea level). The only noticeable land form is a hill which rises to 228 m. The river system in its whole is part of the sedimentary basin of the Mono river, including the tributaries of the right bank crossing the perimeter where they originate from. The area has a sub-equatorial climate, with a long rainy season from March to July and a short rainy season from September to November. These two rainy seasons are interrupted by a long dry season and a short dry season, giving therefore a bimodal rainfall pattern including two maxima and two minima which are unequally high. The average annual rainfall ranges from 1000 to 1200 mm and is distributed over 70-80 days. The relative humidity is about 75% in average. The annual average temperature is around 27°C.

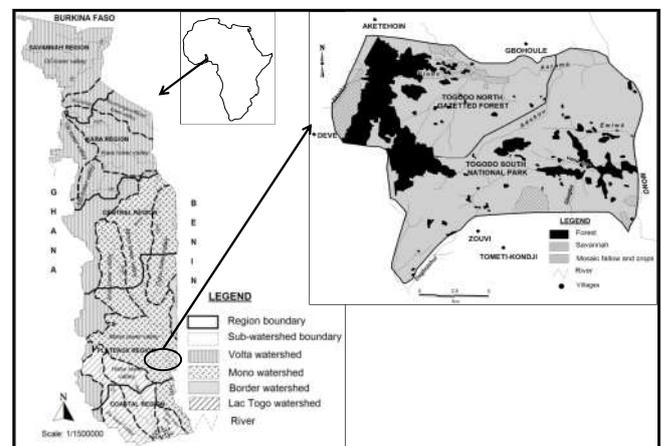


Figure 1. Location of the wildlife reserve of Togodo

Long-term vegetation dynamics

In order to determine land use changes in the last 27 years in the Togodo study area, we compared satellite images at three dates with a resolution of 30 m including Landsat 7 (January 1986) and Landsat 8 (December 2003 and December 2013). We also used the 1/200000 topographic map of the "Institut Géographique National (IGN)" 1980 of the maritime region and the plateau region. These data were supplemented by the geographic coordinates from the checkpoints on the ground in order to properly characterize the land use units.

Field survey

Floristic inventory

The conservation state of the plant diversity in the wildlife reserve of Togo was assessed through the floristic inventory of the area. To do this, 182 samples of 50 m x 10 m (500 m²) plots were established inside the study area. The plots were arranged on a continuous base along a transect. The transects had a length ranging from 500 m to 2 km. The location of these transects was determined beforehand according to the accessibility and the contrast of the occupation on the satellite image unit. From the 182 sampled plots, 83 plots were distributed in the semi-deciduous forests, 43 plots in the thickets, which are old fallows, and 56 plots in the wooded savanna; that is, overall an area of 9.1 ha was sampled, representing a sampling rate approximately 0.03%.

In each plot, presence/absence of all vascular plants (trees, shrubs, grasses) were noted. The species not identified on the field were collected and determined in the herbarium of the University of Lome. The nomenclature followed is that of the *Angiosperm Phylogeny Group III* (Chase & Reveal, 2009).

Forest inventory

A forest inventory was carried out in two forest ecosystems present in the region, the semi-deciduous dry forest and the woodland savanna. The structure of these two forest ecosystems was analysed through the forest inventory data. To this end, dendrometric measurements were conducted in 25 x 25 m (625 m²) plots (105 plots, including 55 plots in semi-deciduous forest and 50 plots in woodland savanna).

In these plots, tree species were identified and the diameter and height of all the trees and shrubs with a dbh \geq 10 cm were measured.

Data analysis and processing

Analysis of vegetation dynamics

The assessment of vegetation dynamics in the WRT mainly relied on the interpretation of three satellite images (Landsat 7 and 8). The mapping and assessment of the percentage of the vegetation covers were made using the QGIS and OTB software (Orfeo Toolbox). The various categories were digitized to produce the canopy map. The proportions of the various vegetation categories were assessed. The area occupied by each thematic unit of canopy is calculated as QGIS software after the classification of Landsat 7 and 8 images.

Vegetation and plant diversity analysis

The floristic survey yielded a total of 485 species recorded in the 182 plots. A Non-Metric Multidimensional Scaling (NMDS) was performed on the presence/absence of the recorded species in each plot to reveal the main vegetation patterns in the Togodo region. In order to analyse plant diversity, we classified the 182 samples of 50 m x 10 m plots into three categories: forest, thicket and savanna. The flora diversity of the various vegetation units identified was assessed by calculating the flora diversity indexes of each ecosystem. The flora diversity was determined by means of several indexes (Daget, 1980):

- N_0 = total number of the species recorded in the 5 ha plots;
- Index of Shannon ($I_{SH} = \sum_{i=1}^n pi \log(pi)$ where n = the

number of species recorded and pi = probability that a species i is present in a reading. In practice, $pi = qi/Q$ where qi is the number of readings where the species i was recorded and $Q = \sum_{i=1}^n qi$;

- Evenness ($E_q = \frac{I_{SH}}{\log_2 N_0}$) which is the ratio of the estimated Shannon diversity index and the possible maximum diversity given the number of species N_0 .

In addition, the status of key species was clarified, in particular with respect of the rare, exclusive species, that is to say, species only specific to the forest patches of this region in Togo, and new to the flora in Togo. To do this, a rarity index of the species (Rarity-weighted Richness Index) was calculated according to the equation of Géhu & Géhu (1980):

$$RI = \left[1 - \left(\frac{n_i}{N} \right) \right] \times 100$$

where RI: the rarity index, n_i : the number

of readings in which the species i is present and N : the total number of readings. According to this equation, the species with $RI < 80\%$ are considered as preferential species, very common in the studied forests.

Those with $RI > 80\%$ are rare.

Structural analysis

Based on the dendrometric data collected, density, total height and average diameter were calculated. The trees density calculation per hectare, the distribution of the density and the basal areas per diameter category were analysed.

RESULTS

Temporal dynamics of the vegetation in the wildlife reserve of Togodo

Through the analysis of the satellite images of the three dates, three main plant communities were identified. These include forests, woodland/shrubland savanna and crops/fallow areas. The examination of the maps drawn for the WRT and its peripheral zone showed important change in the forest area with time (Figure 2). Indeed, in 1986, the forests covered a total area estimated at 8473.2 ha (27.3% of the reserve). These forests were concentrated in the Western part of the reserve. In addition to these forest plant communities, there was a large proportion of the reserve which consists of savanna (48.4% of the reserve). At that moment, the crop/fallow areas occupied only 24.3% of WRT. In 2003, the land use units of the canopy observed are the same as those recorded in 1986, but in different proportions. Over a period of 17 years (1986 to 2003), the forest plant communities occupied a surface area of 20.4% of WRT. This variation area indicated the decline of the forest to less than 10% in 2003 compared to the situation in 1986. This decline was mainly observed in the Northwest part of the WRT where the forest block was greatly reduced and fragmented. The coverage of 1986 revealed intact forest complexes including the northern and southern parts of the WRT. Other forest patches and forests galleries along the rivers distributed around in the protected area in 1986 completely disappeared on the 2003 image. They represent 16.2% of WRT.

Contrary to what was observed for the forest surface, namely a decline, the area of savanna increased over this period from 48.4% (1986) to 56.9% (2003), that is, an increase of 8.5%. In 2013, the savanna areas represented 62.8%. This increase of the savanna area can be explained by the conversion of the degraded forest areas that were being developed progressively into savanna. At the same time, there is a decline in crop/fallow areas, the areas of which increased respectively from 24.3% in 1986 to 22.7% in 2003 (about 1.6% between 1986 and 2003) and to 21.0% in 2013. This decline could be explained by the conversion of these crop/fallow areas abandoned covered with thickets.

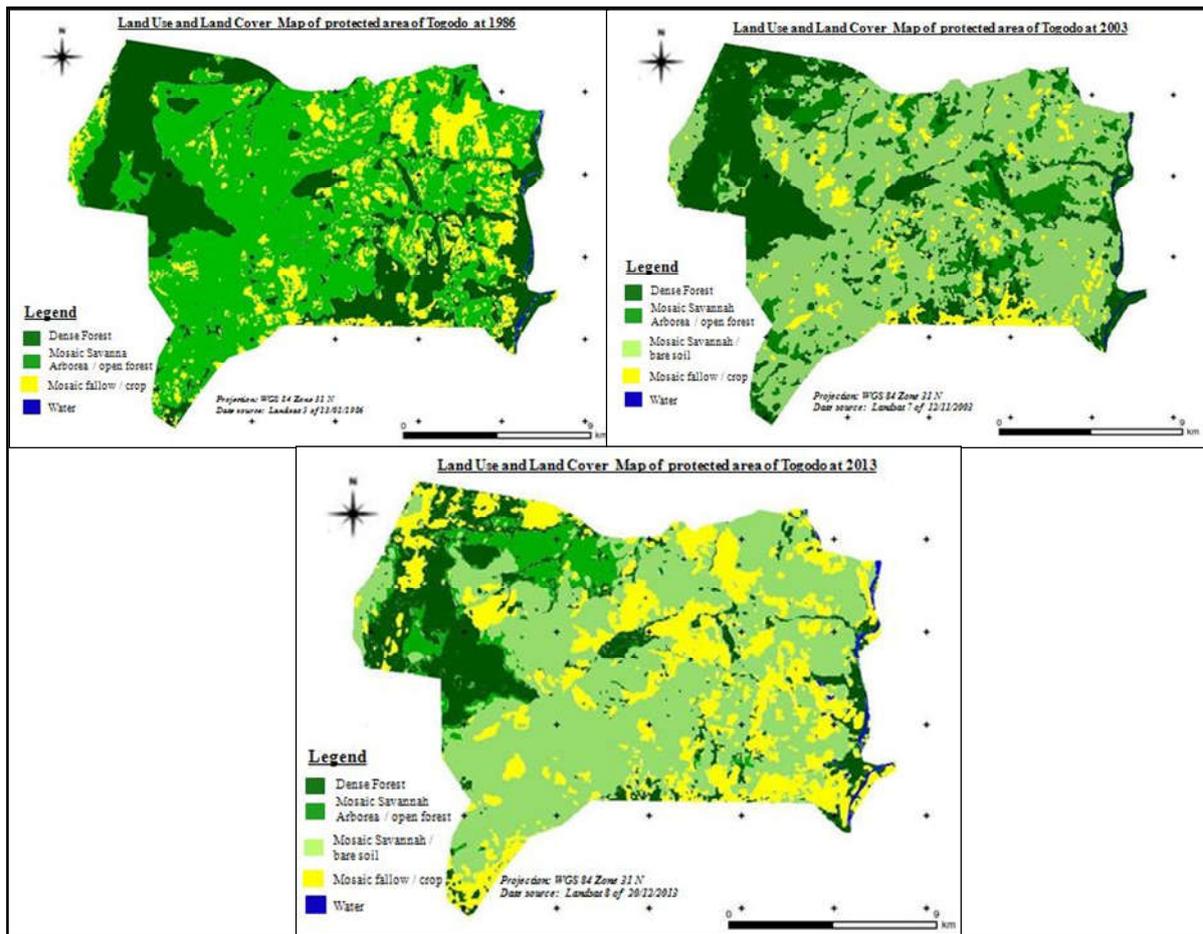


Figure 2. Progress of the vegetation in the wildlife reserve of Togodo

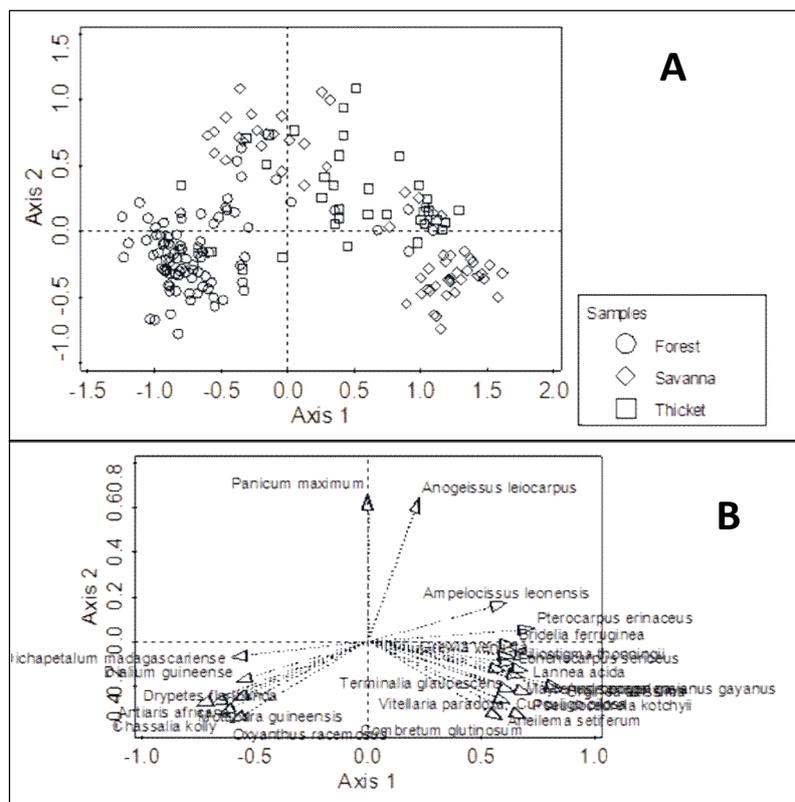


Figure 3: Distribution of plant communities of the Wildlife Reserve of Togodo on axes 1 and 2 of the NMDS (A: Samples distribution; B: Species distribution)

Current state of the vegetation and the flora

Habitats diversity

The Non-Metric Multidimensional Scaling (NMDS) analysis allows identifying groups of plant communities (Figures 3A and 3B). This discrimination is best expressed through the first two axes (Axis 1 and Axis 2) of the NMDS, reflecting the maturity gradient of these plant communities. Axis 1 separates the forests plots from those sampled in savanna. Axis 2 discriminates the tickets from the forest ecosystems and savanna.

The NMDS analysis shows that the forest fragments are fairly homogeneous in the WRT. These forest fragments are semi-deciduous forest on granite-gneissic bedrock and the characteristic trees are *Antiaris africana*, *Ceiba pentandra*, *Drypetes floribunda*. Only a few hygrophilous species (*Pterocarpus santalinoides*, *Cola laurifolia*, *Phyllanthus reticulatus*...) related to river banks and species related to edges (*Terminalia glaucescens*, *Hexallobus monopetalus*, *Bridelia ferruginea*...) were separated from the rest of the species by the NMDS. Axis 2 of the NMDS discriminated flora thickets or regrowth. This axis also expressed the sense of the thickets maturation.

Table 1: Flora diversity indexes in the wildlife reserve of Togodo

Diversity Indexes	Average diversity throughout the reserve	Forest fragments	Thickets	Savanna	F	P
N ₀ /ha	183 ± 38	205 ± 34	154 ± 21	129 ± 19	F _{28,3} =8.70	10 ⁻³
I _{sh}	6.97 ± 0.32	7.14±0.20	6.71 ± 0.24	6.33 ± 0.30	F _{28,3} =11.02	10 ⁻³
Eq	0.93 ± 0.01	0.93±0.00	0.92 ± 0.01	0.91 ± 0.01	F _{28,3} =13.37	10 ⁻³

NB: N₀: Flora diversity (total number of species); I_{sh}: Index of Shannon and Eq: Evenness

Table 2. Conservation status of plant species of the wildlife reserve of Togodo

Species	Family	RI (%)	Status
<i>Capparis viminea</i>	Capparaceae	99.45	VU
<i>Monanthes parviflora</i>	Annonaceae	99.45	EN
<i>Phyllanthus bellei</i>	Euphorbiaceae	99.45	CR
<i>Strychnos usambarensis</i>	Loganiaceae	99.45	NE ^{EX}
<i>Lannea welwitchii</i>	Anacardiaceae	98.90	EN
<i>Lasiodiscus mildbraedii</i>	Rhamnaceae	98.90	EN
<i>Pycnocomia angustifolia</i>	Euphorbiaceae	98.90	CR
<i>Oxyanthus subpunctatus</i>	Rubiaceae	98.35	EN
<i>Ventilago diffusa</i>	Rhamnaceae	98.35	CR
<i>Dovyalis afzelii</i>	Flacourtiaceae	97.80	CR
<i>Balanites wilsoniana</i>	Zygophyllaceae	97.25	NE ^{EX}
<i>Hymenostegia afzelii</i>	Fabaceae	96.70	EN
<i>Schrebera arborea</i>	Oleaceae	95.05	NE ^{EX}
<i>Gongronema angolense</i>	Apocynaceae	91.21	EN
<i>Croton nigritanus</i>	Euphorbiaceae	90.66	NE ^{EX}
<i>Ritchiea duchesnei</i>	Capparaceae	85.71	EN
<i>Chaetacme aristata</i>	Ulmaceae	78.02	VU
<i>Dennettia tripetala</i>	Annonaceae	76.92	EN

EX: Exclusive species of the wildlife reserve of Togodo and therefore critically endangered; EN: Endangered; CR: Critically Endangered; NE: Non evaluated, VU: Vulnerable

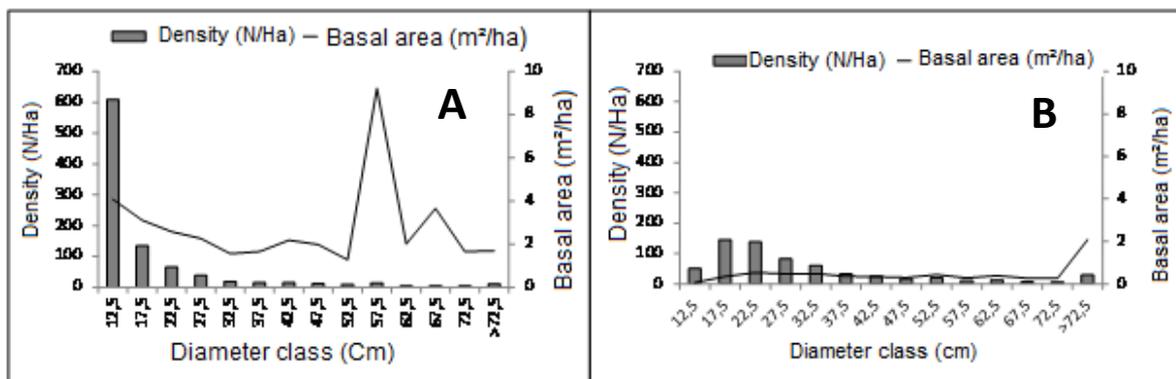


Figure 4: Distribution of trees and basal area in diameter classes (A: Semi-deciduous forest; B: Woodland savanna)

This discrimination of the plots is related to the specialization of 350 species peculiar to the forest habitats, 225 species recorded both in the tickets coming from abandoned farms or thicket on termite mounds scattered in savanna, then 206 species recorded in the savanna out of which 132 are peculiar to this ecosystem. Common species (158 taxa) can be found in the three ecosystems (forest fragments, tickets and savanna).

As in the case of the forest fragments, some savanna species are more relevant edge effects (*Annona senegalensis*, *Maytenus senegalensis*, *Pseudocedrela kotschyii*...). At the level of the savanna, the sampling of such plots allowed differentiating the best represented key species in the tree layer, namely *Anogeissus leiocarpus*, *Combretum collinum* and *Pterocarpus erinaceus*.

Flora diversity

A total of 485 species were recorded in the WRT, classified into 83 families and 317 genera. For the whole reserve, the best represented families of Angiosperms are the Fabaceae (61 species), Rubiaceae (35 species) and Euphorbiaceae (27 species). The flora encountered in the semi-deciduous forest patches includes 350 species classified into 75 families and 251 genera with the same families that dominate the global flora of the wildlife reserve of Togodo. In the forest regrowth, the species recorded are divided into 59 families and 169 genera. The species recorded in the savanna are divided into 57 families and 160 genera. As indicated by the above results, the forest fragments in the WRT seem to be the center of an important local plant diversity. Indeed, the diversity indexes show that the calculated values, especially the species richness (N_0) and the index of Shannon (I_{sh}) are higher than the average values over the entire site. Only the savanna has an average evenness significantly lower, showing that the forest species are also better distributed in the forest regrowth. The increased savanna of the WRT vegetation is a loss of the local forest biodiversity because the forest fragments retain more flora diversity (Table 1).

Conservation status of plant species of the wildlife reserve of Togodo

The analysis of flora data revealed the existence in this protected area of key species which are very rare, that is to say, $IR > 80\%$ (Table 2). These species include *Capparis viminea* (Capparaceae, $RI=99.45\%$), *Monanthotaxis parviflora* (Annonaceae, $RI=99.45\%$), *Phyllanthus bellei* (Euphorbiaceae, $RI=99.45\%$) and *Strychnos ambarensis* (Loganiaceae, $RI=99.45\%$) *Lannea welwitschii* (Anacardiaceae, $RI=98.90\%$), *Balanites wilsoniana* (Zygophyllaceae, $IR=97.25\%$), among others. Of these species with high rarity index, some (*Strychnos ambarensis*, *Balanites wilsoniana*, *Croton nigrifolius* and *Schrebera arborea*) are specific to these forest patches (found only in this forest in Togo). They are also species with rarity index higher than 80%, that is to say, critically endangered species for which the forests of Togodo are the last refuges in Togo. To these species with special conservation status stored in the wildlife reserve of Togodo, there is a need to add 18 taxa new to the flora of Togo, identified as a result of the surveys in these semi-deciduous forests patches.

Structural characteristics of the forest ecosystems

Dendrometric features

In the fragments of the semi-deciduous forests, tree density is 203 stems/ha. The most abundant species are those of the shrub layer (<7m height) including *Drypetes parviflora* (36 stems/ha) and *D. floribunda* (22 stems/ha) or still small trees that are a little higher than shrubs (*Millettia thonningii*, 18 stems/ha and *Hymenostegia afzelii*, 15 stems/ha). The best represented tree is *Ricinodendron heudelotii* (13 stems/ha), a pioneer species of disturbed forest. Among the high trees (7-25 m high or more) the best represented are *Ceiba pentandra* (10 stems/ha) and *Antiaris africana* (9 stems/ha). In the Savanna, tree density is 955 trees/ha. The most abundant species are *Grewia venusta* (91 trees/ha), *Anogeissus leiocarpus* (90 trees/ha), *Combretum collinum* (90 trees/ha). Woodland savanna has the highest tree density per hectare and the average value obtained for the basal area also reflects this trend.

Demographic structure: trees diameter distribution

The distribution in tree diameter classes in both main types of vegetation presents an asymmetrical left distribution, showing a L-shaped curve (Figures 4A and 4B). This distribution indicates the predominance of small stems (diameter between 10 and 30 cm for the semi-deciduous forests and diameter between 10 and 15cm for woodland savanna). It also shows a regular dynamics of individuals constituting these forest communities. Three diameter classes occupy the largest part of the total basal area in semi deciduous forests, that is, 43.57%. In those areas, diameter ranges between 10-15 cm (10.48% of the total basal area), 55-60 cm (23.72% of the basal area) and 65-70 cm (9.39% of the basal area) (figure 4A). In woodland savanna, these are trees of larger diameter classes mainly the classes >75 cm which occupies the maximum basal area, that is, 31.58% (Figure 4B).

DISCUSSION

Land use dynamics and forest fragmentation

The analysis of the satellite images of three different dates (1986, 2003 and 2013) with 27 years provided important information on the change of the plant community dynamics in this protected area. This study shows that the decline of the fragmented forests in Togo is real and is observed on the field or by satellite images analysis. The analysis of the trend of land-use dynamics observed in the WRT over the period 1986-2013 indicates an area decline of forest ecosystems of about 7% between 1986 and 2003 and about 4.2% between 2003 and 2013. This deterioration trend of the forest observed in this study is consistent with the indicated values for the general degradation of the forests observed throughout the Togolese territory through a study conducted by FAO in 2010 which highlighted that the forest area has declined by 14% over two decades (FAO, 2010). The decline results particularly in the loss of forest fragments and the fragmentation of the forest complexes which were intact particularly in the northern and southern part of the wildlife area. Unlike the forest, the savanna area experienced a net increase, that is, 14.4% between 1986 and 2013.

This fragmentation of habitats in general and the Togolese forest in particular were identified by many authors as one of the major threats to biodiversity preservation at the national, sub-regional and even global level (Wilcox & Murphy, 1985; Quinn & Harrison, 1988; Lande, 1993; Gibbs, 1998; Huxel & Hastings, 1999). It occurs when the intact and continuous habitat blocks are subdivided to provide habitat fragments the size of which is reduced in favor of their increasing isolation in the space. As described by Yeo *et al.* (2013), this process can result into serious malfunctions in the ecosystem, for example (1) *reduction of the species diversity of ecological communities and the population size, increasing therefore the risk of local extinction* (Donovan & Flather, 2002; Fahrig, 2002), (2) *disruption of significant ecological processes such as the pollination and the seed dispersal* (Barbosa & Marquet, 2002), (3) *changes in the structure of communities and invasion by the exotic species* (Laurance & Wasconcelos, 2004). The worsening of this forest fragmentation process could reduce the survival probability of certain species or result in the decrease in population size and even increase the extinction risk of vulnerable species.

For the particular case of Togo, the main causes that can explain the decline and fragmentation phenomenon of the forest formations are among others the deforestation and agriculture. Indeed, the species of marketable timber and located in semi-deciduous forests of the wildlife reserve of Togodo are highly sought by the loggers and the resident population around the reserve. Therefore, the red wood species such as *Milicia excelsa* and *Azelia africana* were systematically logged. Currently *Antiaris africana* and *Triplochiton scleroxylon* (respectively 9 trees/ha and 4 stems/ha) are highly sought as white woods across the country. Very often, several very close trees are cut resulting in significant and destabilizing gaps. These repeated logging have resulted in the change in species composition and forest structure (Kokou *et al.*, 2000). Otherwise, the opening of the dam on Mono river is expected to cause fragmentation of the forest located to the west of the reserve from the upwelling through the important drainage network. This fragmentation is a major threat to biodiversity conservation in these forest relics (habitat loss, loss of plant and animal taxa). The loss of plant diversity in forest and savanna patches are likely to be particularly disastrous if no action is taken regarding the exclusive, scarce and threatened species. The disappearance of ecologically important species would disqualify the WRT compared to its current status as "National Park" and "natural resources management area" because not only the extinction of these species would reduce the plant species populations but also especially cause an ecological crisis considering the United Nations Convention on Biological Diversity. The exclusive species of the classified forest of Togodo such as *Balanites wilsoniana* and *Schrebera arborea* may be extinct and will disappear from Togo definitely because these forest patches are their last refuge (Adjonou *et al.*, 2013).

Ecological indicators for the development of the wildlife reserve of Togodo

The major concern of the colonial rule at the time of the creation of the protected areas was the preservation of an important part of the biodiversity of the concerned countries. This study shows that in the countries with low forest cover such as Togo, the forest ecosystems and endangered species are still in perfect condition in the protected areas. This is the example of the semi deciduous forest fragments of Togodo as the remnants of an ancient forests. These vestiges are different in terms of structure, configuration compared to the semi-deciduous forests of the south-western Togo and the rainforests located on either side of the corridor of Dahomey. Adomou (2005) reported that it is about the semi-deciduous forests with *Triplochiton scleroxylon* - *Celtis zenkeri* that would have occupied the south of Togo and Benin to the current limit of the Guinea-Sudan savanna (Salzmann & Hoelzmann, 2005). In terms of floristic diversity, the 485 species recorded in the wildlife reserve of Togodo account for about 15% of the flora of Togo (Brunel *et al.*, 1984; Akpagana, 1992; Akpagana & Guelly, 1994). Among these ones, the 18 species new to the flora of Togo and mainly the "exclusive" species are vulnerable and could disappear from the territory if the forest fragments containing those come to disappear. These species deserve to be placed on the Red List, in the category of endangered species (IUCN, 2001). It should also be noted that the 18 taxa are new (Table 2), because they are neither yet reported in the flora of Togo (Brunel *et al.*, 1984) nor in the development following its edition (Akpagana, 1992; Akpagana & Guelly, 1994).

The rarity of these species makes them vulnerable; they could disappear from the territory in case of disappearance of the biodiversity sanctuaries. They deserve to be recorded on the Red List, in the category of endangered species. Furthermore, the analysis of the structural characteristics makes available the necessary indicators for the identification of the appropriate management options to maximize the contribution of forest resources and improve the socio-economic conditions of the population. As a result, the demographic structure reveals a decreasing exponential distribution trend ("L" shaped curve). This distribution reflects the predominance of small diameter individuals. It is about positively skewed distributions, typical to the forest stands with a predominance of young individuals or small diameter (Pascal, 2003). This distribution appears to be similar to that described in the forest types of the sub-region by other authors (Awokou *et al.*, 2009; Natta, 2003). This observation explains that the studied ecosystems (semi-deciduous forest and woodland) have a regular dynamics of the individuals constituting these stands with a constant regeneration in time and the woody individuals coexisting (Rasatatsihoarana, 2007; Fongnzossie *et al.*, 2008). Rubin *et al.* (2006) reported that this type of distribution can be regarded as an indicator of the balance of the forest structure mainly at the stand level. It also provides information on forest growth model (Hitimana *et al.*, 2004) and helps to understand the history of past management of the forest stand and its dynamics (Lisa & Faber-Langendoen, 2007; Wulder *et al.*, 2009). All the structural parameters considered in this study, including woody stand density, average tree height, the basal area and the diameter distribution were described by some authors as being the preliminary technical basis for the definition of the development objectives (Gehring, 2006). These elements are very important ecological indicators for the monitoring of these forest ecosystems, silviculture and logging (Adjonou *et al.*, 2013), helping to assess the state of the ecosystems degradation and to understand the past management history of these forest stands and their dynamics (Merino *et al.*, 2007; Nadkarni, 2008; Wulder *et al.*, 2009) in order to identify the types of development to be implemented (Hitimana *et al.*, 2004). For the studied forest (semi-deciduous forest patches and woodland savanna), these parameters provide the managers with significant scientific information on the biodiversity conservation status and stage of maturation and the utilization of these ecosystems so that they can guide adequately in the management options of this protected area.

Conclusion

This study provides important information on the decline of the forests in the protected area of Togodo of about 11.1% over a period of nearly 30 years and an increase in area of the savanna between 1986 and 2013 (14.4% increase for nearly two decades). The main causes that account for forest regression and fragmentation are among others deforestation and agriculture. In addition to these two causes, there is the threat of the Adjarala dam construction on the Mono River in the East of the wildlife reserve of Togodo. The entire dam infrastructure will cause losses of plant community. The loss of plant diversity due to the dam construction may be particularly disastrous if no action is taken regarding the "exclusive, rare and threatened" species. The depletion of the important ecological value species would disqualify the wildlife reserve of Togodo compared to its current status as "National Park" and "natural resources management zone" because not only would the extinction of these species diminish the plant species populations but also would

especially cause an ecological crisis in relation to the United Nations Convention on Biological Diversity.

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