Chapter

Implications of Ethnoecological and Phytoecological Studies for the Sustainable Management of the Mozogo-Gokoro National Park (Cameroon)

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Abstract

Sustainable management planning of protected areas depends on data from their biophysical and human environment. Based on such a premise, and using established international and national standards, this chapter proposes to outline a range of measures that can be considered in this process, drawing on the results of ecological studies carried out in the Mozogo-Gokoro National Park, located in the Sudano-Sahelian dry zone in the Far North of Cameroon. Initially, determining attributes for conservation were identified, notably those relating to the richness of the flora and the structure of the vegetation, which are close to a reference ecosystem. Subsequently, recommendations for sustainable management were formulated and analyzed in turn, taking into account especially the destructive anthropization identified as a major threat to the stability of the park. These management orientations could also be applied to safeguard other ecosystems in the Sudano-Sahelian zone.

Keywords: Conservation, Ecological studies, Far North Cameroon, Management guidelines, Park, Valorization

1. Introduction

The extension of research results to the range of actors involved with natural resources is an essential operation for the sustainable management of plant formations. The concept of forest extension is described as a systematic process of exchanging ideas, knowledge and techniques that can change attitudes, practices, knowledge, values and behaviors for better forest and tree management [1, 2]. With the multiplicity of partnerships involved in sustainable forest management (local people, non-governmental organizations, private sector and government, scientists), there is a need for wider dissemination of forestry-related information and for flexible communication based on dialog, feedback and flexibility [3, 4]. Indeed, Kandzior and Rivas [4] consider forestry extension to be a minimum requirement

for any forestry program targeting rural people. Decision-makers are aware of the importance of research results in the day-to-day management of forest sites. However, they cite obstacles such as accessibility and insufficient skills for their exploitation [5, 6]. There is therefore a great interest in synthesizing and making accessible to different stakeholders, the diversity of data from research considering the complexity of sustainable forest management processes.

The sustainability-oriented forest management process involves six key concepts [7]: better management practices/reduction of the impact of logging, biodiversity conservation, forest protection, multi-scale planning, participatory forestry and maintaining forest production. This conception is in line with the paradigm of "systemic forestry" of Nocentini *et al.* [8], who further specify that the sustainable management of vegetation must integrate multisectoriality, an implementation oriented towards a dynamic resilience-seeking process, the multifunctionality of ecosystems including ecological, social and economic components, and the plurality of actors. With this divergence of approaches, goals and specific realities, forest management has recently evolved towards the concept of sustainable forest management [9, 10]. The sustainable management of protected areas has its own particularities and is even more essential because of the major interest in *in situ* biodiversity conservation [10, 11], or the importance of the ecosystem goods and services it promotes, especially for the benefit of riparian communities [12, 13]. This observation justifies the multiple strategies put in place by organizations working in the fields of biodiversity conservation for greater efficiency in the management of these natural sites. They are working to permanently reduce, generally through guidelines, the lack of ownership of research results in forest governance.

Many steps in sustainable management planning for protected areas are supposed to be based on the results of prior studies [11, 14]. In reality, however, this governance is sometimes based on empirical considerations [5, 15], as has long been the case in Mozogo-Gokoro National Park, located in a semi-arid sudano-sahelian region in the Far North of Cameroon. In a context marked by strong edapho-climatic and anthropogenic constraints, this management is sometimes considered effective in the MGNP, due to its resilience [16]. With multiple publications describing this protected area [17–25], this chapter aims to be part of a process of sustainable management that respects international and national standards. Considering the complexity and uncertainty recognized in the study of natural environments [8, 26, 27], it is not intended to recommend rigorous actions on a scientific basis. Instead, with the identification of governance deficiencies, threats, pressures and valuation assets, sustainable management guidelines can be formulated based on reference documents [7, 8, 11, 14, 28–33].

In this chapter, the specific objectives set are, among others, to state the characteristics for the valorization of the MGNP, to determine the managerial insufficiencies, the pressures and the threats to its conservation, to identify and comment on the major axes of intervention in relation to the management objectives, all of this in confrontation with the principles or experiences known in the literature.

2. General information on the MGNP

The MGNP is located in a dry zone in the far north of Cameroon (10°56′ and 10°57′ North latitude and 13°54′ and 13°58′ East longitude.), Mayo-Tsanaga Department, Mayo Moskota Arrondissement (**Figure 1**). This site was created as a forest and fauna reserve by decree No. 165 of 12 June 1932 of the High Commissioner of the French Republic in Cameroon, and then set up as a national park by decree No. 120 of 5 December 1968 of the Secretariat for Development of

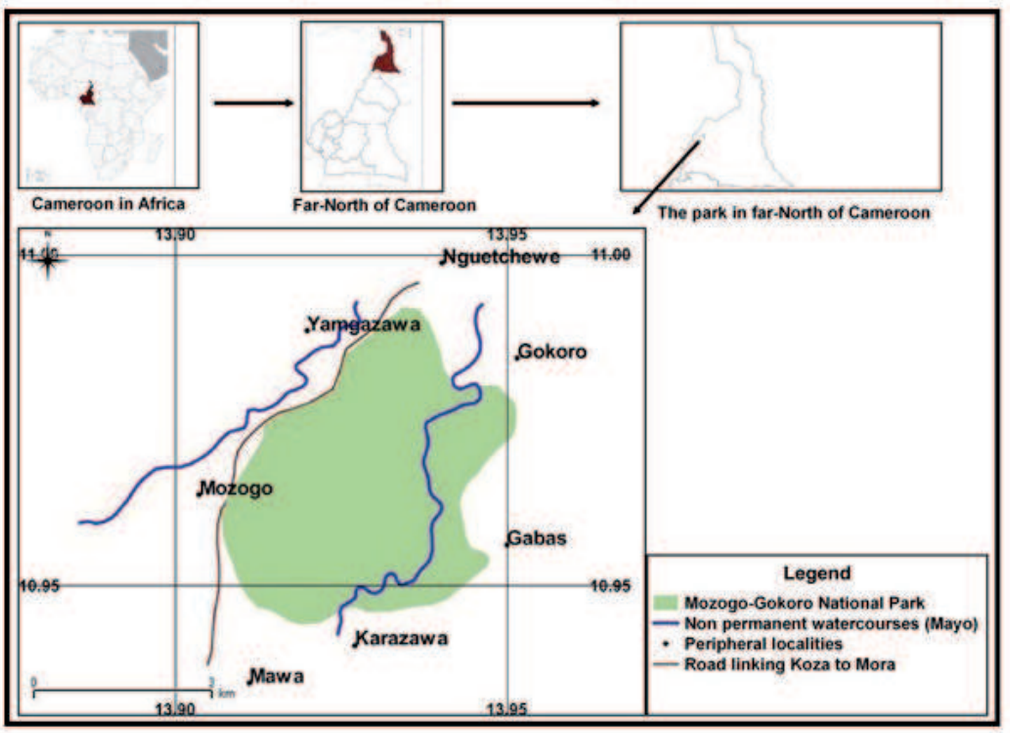

Figure 1.
Location of Mozogo-Gokoro National Park.

the State of Cameroon. Its governance is essentially state-owned, notably with the Cameroonian government's Order No. 911/MINEF of 12 April 1994, which guides its management through its designation as a 3rd category Technical Operational Unit, based on its surface area of 1400 ha (50,000 ha being the lower limit of the 2nd category). In Olson *et al.*'s [34] classification, it corresponds marginally to the Mandara Plateau mosaic ecoregion. However, in reality, its biodiversity is closer to the savannah ecosystems of eastern Sudan or the Sahelian savannahs with *Acacia* spp. The MGNP also belongs to the Ramsar site of the Waza-Logone floodplains, representing the 10% of wetlands in the West African sahel [35]. Its designation as a park is theoretically assimilated to category II of the IUCN classification, but it does not have a management plan in line with this status.

This protected area has been demarcated without cadastral reference [25]. Its boundaries can therefore be moved by the population according to their interests. In addition, the park lacks a buffer zone as provided for by the regulations. Difficulties in water supply constitute a factor degrading the habitat of the medium-sized fauna it contains, corresponding to mammals (patas monkeys, olive baboons, gray duikers, mongooses, burrowing squirrels, porcupines, Thomson's Gazelles, ...), birds (114 species), reptiles (monitor lizards, canine pythons and other snakes), and several batrachians and invertebrates [20]. As a solution to this problem, the forestry administration built two artificial ponds in 2009 (one of which is mostly dry) and a solar-powered pumping trough (currently non-functional). The administration has also worked to build twenty kilometers of tracks within the park, but these are often not maintained.

Three vegetation zones have been distinguished as Field Data Collection Units or (CU) in some of the work done in this protected area [16, 23]. These are CU1: Mosaic of gallery forests, dense dry forests and shrub thickets (392.73 ha), CU2: Mosaic of dense dry to clear forests and shrub thickets (836.33 ha), and CU3: Mosaic of clear dry forest to wooded savannahs and shrub thickets, (95.91 ha). The climate is megathermal with mean annual temperatures ranging from 26–28°C [16].

Rainfall variability (with the observation of intense episodes of drought with sometimes less than 800 mm of annual rainfall), or even climate change, and anthropisation supported by a population density of more than 300 inhabitants/km^2 [25], have not significantly impacted the vegetation of the park [22]. These are nevertheless real pressure factors, which although they have affected the vegetation (with several signs of degradation noted especially in CU3); have certainly not led to a loss of resilience [16]. Illegal resource harvesting [20], has led to the creation of several trails into the park. It is an ecoregion whose soils are mainly classified as Oxisols, Vertisols and Fluvisols [36]. Their fertility certainly justifies the strong land pressure in the riparian zone of the park, with the existence of multiple crop fields [25]. Evidence of grazing and human constructions are also observed at the edge of the park.

3. Methodological approach

The methodological approach initially involved assessing a range of available information on the MGNP, mainly publications describing the biophysical and human environments [16–25], and secondarily recent administrative reports. At the same time, it was necessary to draw on international guidance documents, national texts, and scientific literature on the sustainable management of natural ecosystems, in order to draw from this initial assessment, highlights and proposals for measures applicable in such a process to the MGNP.

The salient points arising from the analysis of the work carried out in the MGNP were defined in accordance with Cameroonian regulations and the guidelines presented by several authors [11, 28, 29, 31, 37–41]. The aim was to distinguish the elements of value for conservation, and then to identify the shortcomings in the management of the park, as well as the pressures and threats to its stability. In the end, management objectives were formulated based mainly on the same reference documents, and measures to conserve values and limit pressures and threats were proposed. **Figure 2** outlines the organization the methodological approach.

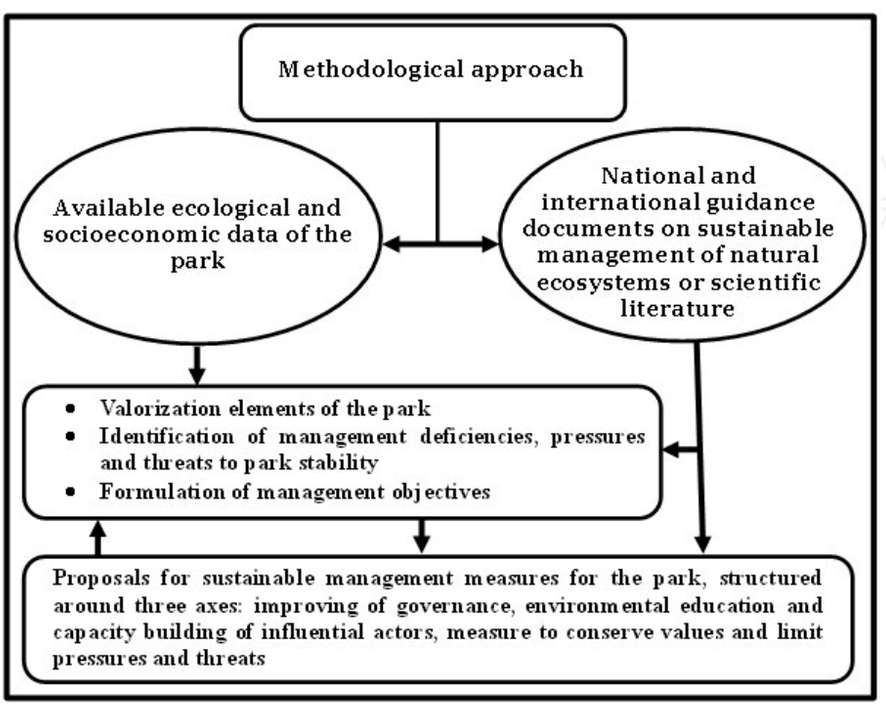

Figure 2.
Structuring of the methodological approach.

4. Valorization elements for a sustainable conservation of the park

4.1 Attributes of a reference ecosystem in the Sudano-Sahelian zone

A set of characteristics gathered from the present study of the MGNP constitute particular assets for this protected area. This analysis could lead to greater appreciation and a positive impact on the conservation of the park if an effective management approach were applied by the local communities and decision-makers.

The work carried out in the MGNP shows a structural vegetation dynamic with increasing density and size of individuals, and major socio-economic and ecosystem roles, as perceived by various stakeholders in the management process [25]. Phases of reforestation are observable from the analysis of its diachronic evolution by remote sensing [19, 25]. The other major indicators identified for the development of the MGNP are mainly related to the diversity of its flora and its structure, which is considered sufficiently stable [16–19, 23, 24]. This predominantly exuberant vegetation is illustrated by the two images in **Figure 3**. The anthropisation indices noted are certainly inherent to its functioning, and justify the characterization of its resilience. Its compositional diversity is particularly high, with a very rich flora constituting a gene bank (110 species of woody plants, Shannon-Weaver index evaluated at 4.54 bits and Simpson's index at 0.90). Several species that are rare in the natural environments surrounding the park and even vulnerable or threatened at the global level are found there (*Afzelia africana*, *Khaya senegalensis*, *Dalbergia melanoxylon*...). The importance value index (IVI) of families and species shows its great heterogeneity (floristic groups of ligneous plants with more than 25 species with a high IVI and 30 families). The density and basal area of individuals are also high (2694.16 stems/ha and 43.88 m^2/ha), indicating a low impact of the various environmental constraints. Its high woody phytomass indicates high production (331.73 tMS/ha on average for each CU). There is also a strong presence of specific Sudanian or Guinean elements, indicating adaptability to the quality of the soil and favorable climatic conditions. The specificities of the Oxisols, which are widespread in the region, are generally preserved. The high proportion of sarmentous and lianascious individuals sometimes makes the undergrowth impenetrable, and mechanisms of self-destruction or natural mortality indicate that this ecosystem has followed a trajectory towards quasi-typical Sudano-Sahelian vegetation without major disturbances. Remote sensing data show that savannization is certainly underway, especially in CU3, but to a limited extent.

With the implementation of an effective management system, these ecosystemic and scientifically beneficial values of the MGNP could make it eligible as

Figure 3.
Characteristics of exceptional vegetation in the Sudano-Sahelian zone: (a) Regreening of the mosaic of dense dry forest and shrub thickets in the rainy season; (b) image of a dense to open dry forest in the same season.

a UNESCO World Heritage Site. The MGNP presents itself as close to a natural habitat model for *in situ* conservation of biological diversity, representative of the ecological and biological processes involved in the evolution and development of ecosystems in this geographical area of Cameroon. Leaving aside the smallness of its area, this is also a feature in line with criterion C of the IUCN definition of key biodiversity areas [42]. Other plant formations in the Sudano-Sahelian zone can benefit from the sustainable conservation of the values identified in the MGNP.

4.2 Implications for the sustainable management of Sudano-Sahelian ecosystems

The assessment of the explanatory mechanisms of vegetation evolution in MGNP via remote sensing [22], did not reveal highly significant correlations between the characteristics of the park's flora on the one hand and rainfall and demographic factors on the other. Circumstances related to the inaccessibility of the flora, as well as the dangers of entering the park due to popular belief, would have sufficiently reduced anthropic pressures. This low anthropisation, combined with the irrefutable climatic variability in this region, has nevertheless resulted to increasing of savannization noticeable in CU3 [16].

In view of the floristic assets of the MGNP, there would therefore be a great benefit in respecting conservation measures, or even in implementing management plans for ecosystems in the Sudano-Sahelian zone, which give an important place to the safeguarding of the flora, with the hope of obtaining a regeneration of the vegetation similar to that of the MGNP. To confirm this hypothesis, the work carried out by Donfack [43] showed phytoecological characteristics of 30-year-old fallows that were quite similar to the vegetation of the MGNP. Ecological restoration and rehabilitation projects for Sudano-Sahelian ecosystems in the area could thus be based on the compositional and structural foundations of the MGNP.

5. Managerial shortcomings, pressures and threats to the conservation of values

The identification of multiple threats and pressures to the stability of the park, and the numerous arguments demonstrating inadequacies in management, represent risks of regression in values. **Table 1** presents these obstacles to the process of sustainable management of the park, ranked according to importance in terms of their recurrence in the analysis of various works on the park.

In the event of their persistence or accentuation, a rapid depreciation to the level of UNESCO's natural heritage in danger is conceivable, or even a reclassification in the permanent forest domain of the Cameroonian state. Also, it is necessary to point out a limitation of the valuing consideration of the MGNP, which is not based on the effectiveness of its management system and its governance system, particularly according to the principles of the IUCN green list [44, 45]. Despite the managerial shortcomings noted, the reference ecosystem values of the MGNP can be used for its sustainable management, given the official non-existence at the time of writing of a park management plan that complies with the texts in force in Cameroon.

6. Proposed management objectives

The use of information on the MGNP and the analysis of the management experiences of protected areas in Africa and in Cameroon in particular [35, 46–48],

Main elements of managerial shortcomings, pressures and threats to the stability of the park	Evaluation of importance*
• Lack of formal participatory and integrated sustainable management planning	Very important
• Poor governance of state actors, corruption and degradation of public morals	Important
• Lack of a framework for the conjunction of actions of the different actors	Less important
• Lack of a buffer zone, smallness and lack of ecological connectivity	Less important
• Perception of a regressive trend in animal and plant biodiversity	Important
• Land pressure from agro-pastoral practices, risk of encroachment and intrusion	Important
• Droughts, rapid population growth and large influx of refugees and displaced persons	Very important
• Illegal harvesting of resources (fuelwood, service wood, non-timber forest products), grazing and bush fires on the periphery of the park	Very important
• Removal techniques for woody plants often do not favor easy regeneration	Important
• Degradation of wildlife habitat, especially due to lack of water	Very important
• Indications of sahelisation, savannization, proliferation of thickets and regression of gallery forests	Important
• Presence of an exotic species such as *Azadirachta indica* within the vegetation	Less important
• Indices of soil fragility and degradation	Less important
• Ecological imbalance and significant rarity indices for several woody species	Less important
• Insufficient knowledge of wildlife resources	Important
• Insecurity and lack of ecotourism activities	Important

**Importance of elements of managerial inadequacy, threats and pressures assessed according to their recurrence in the analysis of available data on the park.*

Table 1.
Managerial shortcomings, pressures and threats to the stability of the park.

revealed shortcomings that led to the recommendation of the three main management objectives below:

- improve the governance of the protected area;
- educate and build the capacity of influential actors in park management;
- design strategies and actions to conserve values and limit pressures and threats.

The management measures and strategies attached to each of these objectives are applicable at different scales in this process, from the central state to local populations. The aim is to comply with the requirements of donors and international institutions in charge of biodiversity conservation programs, which support natural resource management based on participatory approaches [49, 50].

7. Areas of intervention for sustainable management of the MGNP

7.1 Improving governance

In the MGNP, in order to promote the effectiveness of integrated and participatory management that respects the norms, the State, which holds the property

rights, must set up a consultation framework involving the various stakeholders. Forest administration actors are also invited to promote it, for its true recognition as a reference for plant conservation in the Sudano-Sahelian zone, and to work for the provision of financial resources, within the framework of the carbon market. In this process, they should establish the necessary partnerships, ensure the involvement of scientific and technical expertise, exploit the available data on the park, and gather all the necessary means for appropriate management. Wicander [46] believes that state governance in sub-Saharan Africa has indeed the potential to achieve effective biodiversity conservation. He adds that with the requirement for greater transparency and accountability, it can be more effective, increasing social inclusion for greater societal legitimacy, to reduce conflicts and inequities, maximize resources, capacities and skills for the benefit of stakeholders.

However, in a context of state governance of protected areas, distrustful attitudes and bureaucratic red tape often hinder the involvement of some stakeholders in the management process [51]. Evaluations of management effectiveness should therefore be regular exercises, integrated into the management and planning cycles of protected area administrations [40].

Considering the many constraints to compliance in protected area management, some authors do not exclude the use of alternative and palliative measures, essentially contributing to the maintenance of resilience [8]. Other studies recognize the importance of non-scientific sources of knowledge in forest management practices [52, 53]. Thus, the authorities involved in forest management should invest as much as possible in maintaining a rigorous protection of the park, minimizing the negative impact of humans on its entire extent, especially with the activities of the terrorist sect "Boko Haram", which have led to a massive influx of displaced people and refugees in the area. The aim here is simply to apply the law, which prohibits encroachment or access to the park for the purpose of collecting any products whatsoever. The use of Geographic Information Systems and other innovative technological tools, could improve governance, even in the face of insufficient staff. Ecotourism promotion is also essential in this management. However, in practice, it must be recognized that it is very difficult to apply strict restriction measures on intrusions into the park, with the multiple existing paths or tracks. It would therefore seem more appropriate to manage the park sustainably, based on less restrictive or dissuasive initiatives, including above all a good awareness-raising of all influential actors.

Furthermore, for a long-term improvement of governance, it is not unrealistic to recommend the design and implementation of legal texts that would focus attention on the particularities of dryland ecosystem management and give more value to the conservation of natural resources in this area. Gautier *et al*. [51] have argued for a reform of forest governance applied in semi-arid zones. In order to address the lack of joint action in favor of the park, the creation of an agency dedicated specifically to the management of protected areas could be envisaged at the national level, with regional branches.

The lack of a buffer zone is a legal loophole, constituting one of the major threats to the sustainable conservation of the biodiversity of the MGNP. The currently known limits, which correspond to the edge of the vegetation, cannot constitute a brake on the poaching and destructive intentions of the population in the vicinity. This contiguity with the riparian population is very pronounced in some places, with the establishment of social infrastructures (schools, health centers, and roads), dwellings and crop fields in almost its entire border (**Figure 4**), with the exception of a degraded zone separating the villages of Karazawa and Gabas.

As information from farmers indicates that animals may move between the park and the surrounding mountains, an extension of the park into such a corridor

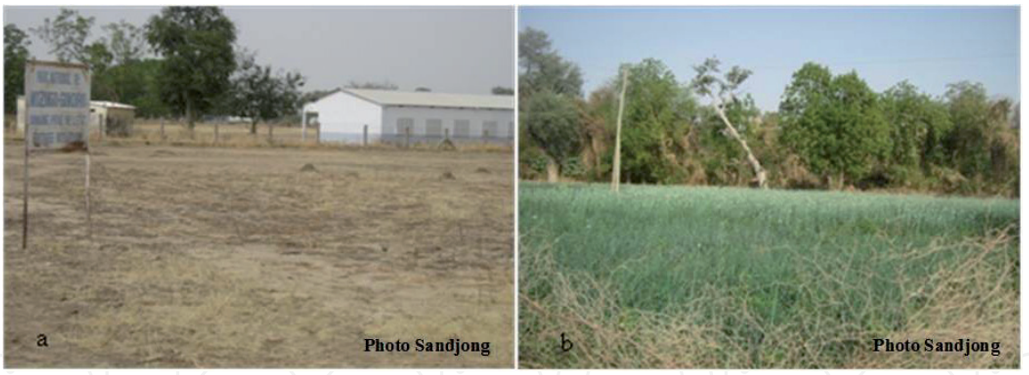

Figure 4.
School (a) and cultivated area (b) at the periphery of the park.

may be suggested. In this area and other peripheral spaces, degraded land will be restored and agro-sylvo-pastoral practices will be implemented, favoring the resources desired by the farmers. Such actions must be carried out according to an agro-ecological approach. It aims to reconcile, in the long term, the productivity of agricultural systems and the preservation of natural resources [54]. According to Lausche [33], the emergence of climate change requires the extension of existing protected areas, the creation of new ones and the strengthening of environmental connectivity. Regarding the planting of woody species in the buffer zone, minimum interspecific spacing of 4.5 m, or intraspecific spacing of 3 m, have been suggested in the Sudanian zone [55]. In his book on the reconfiguration of protected areas in Africa, Chardonnet [48] advocated the establishment of an alternative to buffer zones called peripheral areas or conservancies, contributing more effectively as a transition zone to both the maintenance of values and the development of local communities.

There is therefore a possibility to create this transition zone, in accordance with the principle of ecological connectivity in such a space [56, 57], with real adhesion of the population, while respecting prior consultations and compensation measures concerning all expropriated persons. However, this is a solution that, although favorable to the MGNP, is limited by the high land pressure, already very visible in this densely populated area. The establishment of a dense natural protection barrier, such as a hedgerow, is another option to be considered in places where such an extension is not feasible.

7.2 Organization of environmental education of the stakeholders of influence of the park

Awareness raising, education and capacity building are important principles in sustainable forest management in sub-Saharan Africa [31]. Environmental education, having a major contribution in the extension process**,** is an essential activity for the effectiveness of protected area management. It will be necessary to integrate in its organization, the diversity of actors without discrimination (activities, gender, ethnicity, religion). Chalabi and Mahamadou [58] make this an important issue for the conservation of protected areas in the Sudano-Sahelian zones.

To make people understand the ideal of conservation, the approach to be recommended in raising awareness among the population results from their perception of species that are disappearing, decreasing or increasing. It should emphasize on the responsibility of man in the evolution of vegetation, as well as non-destructive use rights in relation to forestry legislation. The organization of meetings and discussions in influential groups are ways of spreading awareness messages.

Also, with formal education, young people can be influenced by ways of thinking, a new understanding of nature, and a more concrete perception of environmental preservation [25]. Education also involves the media and new technologies, which, through the play of permanent messages, can lead people to adhere to the ideal of biodiversity conservation. In the end, a good compromise is needed between the development of the local population and the preservation of the environment.

Significant knowledge of regeneration patterns is essential. For example, managers need to be aware of interventions that can enhance the potential for regeneration by sexual (viable seed stocks) or vegetative means. The importance of vegetative regeneration (adventitious or proventive stump sprouts, suckers) is noted in the area compared to Guinean regions [28, 59]. Bellefontaine *et al*. [60] thus advocate the inseparability of sexual reproduction and vegetative propagation (asexual reproduction) for a true enrichment in woody plants. He encourages the practice of regeneration techniques that are more accessible to populations, at lower cost, notably suckering and terrestrial layering. Such techniques must

Figure 5.
Base cutting of a Balanites aegyptiaca stem (left) and extensive debarking of Ziziphus spina-christi (right).

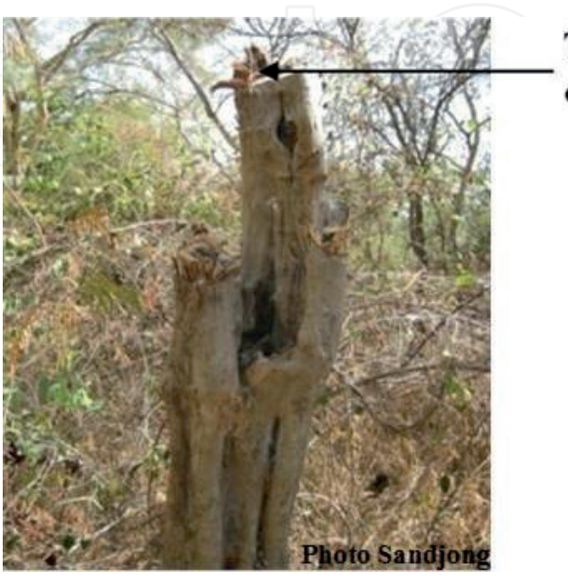

Figure 6.
Tadpole cutting of one individual of Dalbergia melanoxylon.

be popularized for the successful establishment of an agro-sylvo-pastoral zone, integrating agro-ecological practices, in the park's surroundings.

With the observation that totally destructive logging is sometimes practised, in the removal of ligneous and NTFPs (**Figures 5** and **6**), it would be essential to teach logging or cutting techniques that facilitate easy regeneration [60], in particular the so-called improved cuts that preserve rare species and individuals with small diameters. In the area, cutting and protection regimes (**Table 2**), including minimum exploitable diameter, duration of cutting rotation have been proposed by Catinot [59], Nouvellet [61], Peltier *et al*. [62], Ntoupka [63], Sokpon *et al*. [65], Faye *et al*. [64] and clearly, more species-specific cutting rotations are recommended for better stand recovery.

Managers must also become familiar with assisted natural regeneration techniques. Fire and grazing practices in a less degrading form, maintaining the fragile balance of the ecosystems, must also be known by the populations. These pressure factors have been reported to the MGNP [25]. **Figures 7** and **8**, show that these practices are present in the park. Several authors [66, 67] propose early annual fires as a possible solution, rather than late fires, as well as moderate grazing outside the rainy season.

Minimum diameters (Ø) or heights of cuts and species concerned found in the MGNP	**Indication of the duration of the cutting rotation or protective measures**	**Authors**
Between 8 and 15 cm Ø (simple coppicing) No species details	• Short rotation (7 years ±2 years) fuel-wood, fodder and miscellaneous uses • Average rotation (14 years ±2 years) timber and service wood	Nouvellet [61]
Coppice (cut to a sufficient diameter) No species details	• –7-8 years old without selection • 14 to 16 years old selection in clumps and service wood stems	Catinot [54]
• 6 cm Ø at the base for *Guiera senegalensis, Combretum micranthum* • 8 cm Ø at the base for *Combretum nigricans and C. glutinosum*	Can be cut to an ankle size (approximately 8 cm) or wrist size (approximately 6 cm)	Peltier *et al* [62], Ntoupka [63]
• 20 cm in height for *Combretum glutinosum and Guiera senegalensis*	//	Faye *et al.* [64]
• No operation recommended • *Anogeissus leiocarpa* and many other timber and service species	At least 6 years	Ntoupka [63]
• No operation recommended • NTFPs (fruit trees): *Tamarindus indica, Sclerocarya birrea, Senegalia senagal*	Protection until standing dead	Ntoupka [63]
• More than 2 m high • *B.aegyptiaca*, *Senegalia. nilotica*, *Stereospermum kunthianum*, *Ficus* sp., *Khaya senegalensis*	No flush cutting until standing dead, pruning or trimming tolerated	Ntoupka [63]
• 45 cm Ø for *A. leiocarpa,* 35 cm Ø for *D. mespiliformis* and *Pterocarous erinaceus*, 55 cm Ø for *P. kotschyi*	Between 15 and 30 years for the main exploitable species (Sudanese open forests in the north of Benin)	Sokpon *et al*. [65]

Table 2.
Examples of cutting regimes in the Sudanian or Sahelian zone.

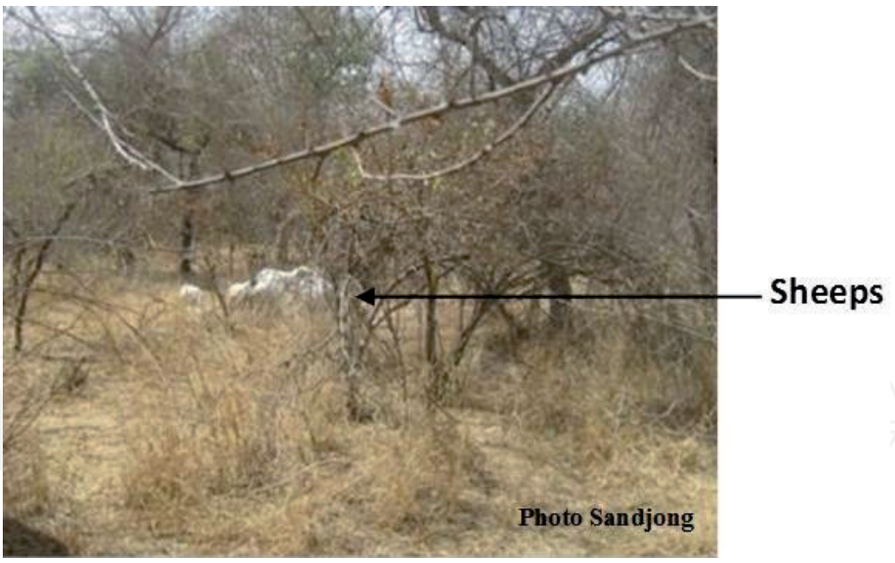

Figure 7.
Evidence of grazing in the park.

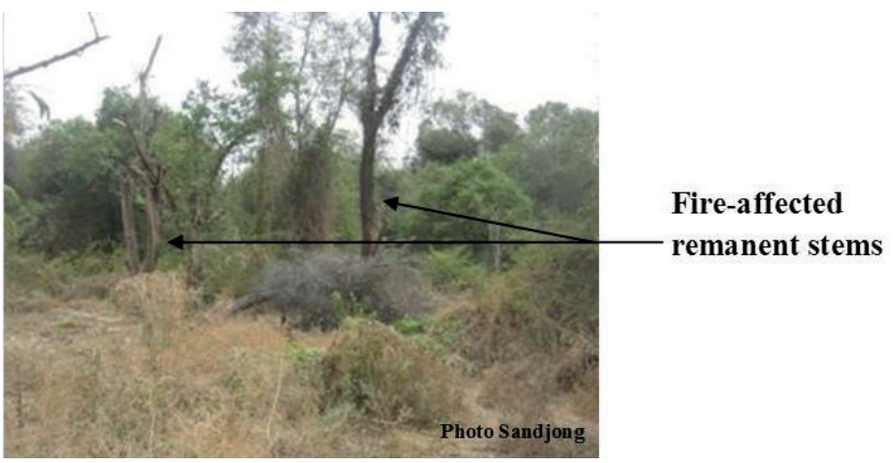

Figure 8.
Area attacked by a late fire caused by carelessness one year earlier.

In addition, people need to be informed about the decline in quantity of several gallery forest species (Mayo-specific vegetation), so that they can take a greater interest in their conservation.

7.3 Measures to conserve values and limit pressures and threats

7.3.1 Special protection measures for some rare and coveted species

A number of species recorded are rare in the park (50.91% of the woody species recorded), and others are known from the IUCN red list. It would be important to draw up a national or even regional directory of these species, with images to facilitate their identification. This measure will help raise awareness among the various stakeholders of the need to preserve them. It is also a recommendation of the IUCN [68] to evaluate the risk of extinction of species and publish it in the red list for defined geographical areas.

On the other hand, the expression of the needs accorded to certain plant resources may favor the implementation of special measures for their valorization in the sense of the urgency of their conservation or more important restrictive measures if, in addition, they are rare or threatened. Among the species cited for

their usefulness, some have been quantified with a certain rarity or even considered more or less endangered by the IUCN (*Dalbergia melanoxylon*, *Prosopis africana, Afzelia africana, Khaya senegalensis ...)*. It would therefore be important to apply measures aimed at multiplying them, within the vegetation or in a buffer zone that can be delimited from the eastern periphery (selective thinning, enrichment with protection of seedlings, assisted natural regeneration). It will also be necessary to raise the awareness of the local population and even of all the actors involved in the management of these trees about their fragility, the risk of seeing them disappear, and to train them for their planting.

7.3.2 Special measures concerning invasive species

In exceptional cases, selective cutting, stump removal or girdling should be authorized to destroy invasive exotic species, which are known to induce an imbalance in phytocenoses. This is the case of *Azadirachta indica* (**Figure 9**), which could impoverish the native dry forest flora through its propensity to invade [69]. Triplet and Howard [70] argue that any exotic species should be managed as if it were potentially invasive until there is convincing evidence that it poses no threat. Invasive non-native species displace local fauna and flora, and in many cases affect ecosystem function [71].

7.3.3 Enrichment of gaps or windfalls

Beyond assisted natural regeneration, enrichment of gaps of vegetation can only be planned if there is evidence of significant extension. If the soil quality and nature of the bedrock allow it, it is preferable to opt for rare species in the park, or those whose regeneration has been analyzed as weak, slowed or disturbed [22]. This would be an exception to the legally prescribed restrictions on trespassing in this type of protected area. It is not out of the question to consider soil restoration in these areas, if real difficulties arise.

7.3.4 Improving the quality of wildlife habitat

Limitations in water supply, with a man-made pond drying up completely for 6–7 months a year (**Figure 10**), limited ecological connectivity and reduced surface area all act as barriers to animal flourishing in the MGNP. A drastic

Figure 9.
Proliferation of several stems of Azachdirata indica in the undergrowth.

Figure 10.
Pond without water in dry season in CU2.

decrease in the vertebrate community is a consequence of habitat degradation and habitat fragmentation [72]. Ponds constructed in the recent past have not achieved the desired objectives of permanent water conservation for wildlife, due to poorly conducted works. It is imperative to correct these shortcomings in the long term, at the risk of seeing a large part of the park's animal population perish in the near future. Also, the reduction of excessive overgrowth caused by the extension of thickets must be considered, notably by selective cutting of the species most concerned, which hinders the movement of certain animal species: *Senegalia ataxacantha*.

7.3.5 Proposed ecological monitoring indicators and parameters to be monitored

The essential values of the MGNP are linked to the exceptional vegetation cover in the Sudano-Sahelian zone, constituting a forest relic or an exemplary *in-situ* conservation area for the flora. In addition, it is a suitable habitat for several fauna species (avifauna, reptiles, and mammals) of varying degrees of rarity. According to the IUCN guidelines [32], ecological monitoring strategies should be oriented towards safeguarding these values for the well-being of present and future generations, but also towards limiting pressures and threats. A partnership with scientists is very often necessary for their implementation.

Therefore, for ecological monitoring of vegetation, it is more appropriate to proceed by permanent monitoring of its evolution based on remote sensing work. Information on the rate of progression of degraded forest or savannah and vegetation indices can be obtained to reflect the effectiveness of management actions. During the various patrols, it would also be important to identify and quantify the species taken in order to ensure the protection of rare and vulnerable species. With regard to fauna, beyond the need for more in-depth knowledge, regular inventories can help to control the park's animal populations in order to maintain them in balance with their habitat.

7.3.6 Ecological restoration of areas of advanced degradation in the park and its periphery

Ecological restoration makes it possible to recover ecological integrity, including the conservation of biodiversity with ecosystem goods and services [73].

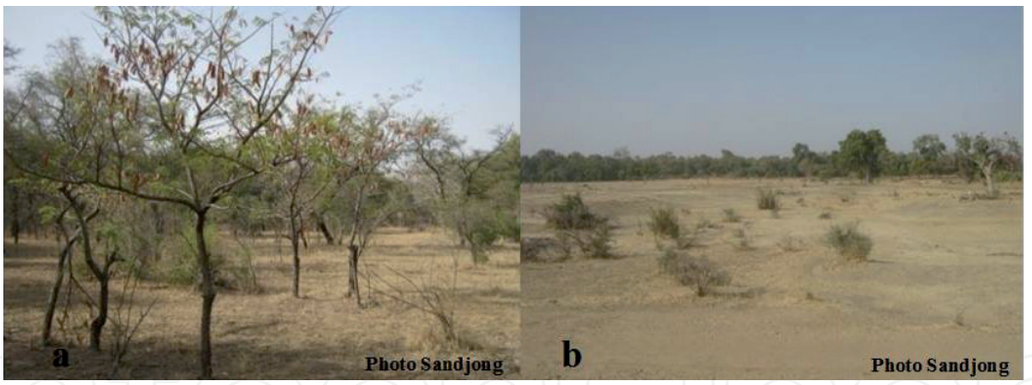

Figure 11.
Areas of advanced degradation: (a) in MGNP, (b) in the periphery.

In MGNP, particularly in CU3 and its periphery, where there is evidence of degradation linked to savannization, and sometimes soil denudation (**Figure 11**), ecological restoration can take the various forms proposed by Keenleyside *et al.* [74], including the re-establishment of locally extinct or rare species, the deliberate removal of invasive non-native species, the reduction of certain pressures, enrichment interventions such as plantations, and the improvement of the physico-chemical properties of the soil. The periphery should also be addressed. Biodiversity conservation in protected areas located within human-dominated landscapes and ecological connectivity should be improved, through the restoration of these forest landscapes or small areas around these protected areas [75, 76]. Restoration actions should also respect the principles of effectiveness, efficiency and commitment [74].

With regard to CU3 in particular, anti-erosion management is recommended. Several approaches exist, but as a priority it will be necessary to find techniques adapted to tropical conditions and involving the population in their implementation. Roose [77] has mentioned the duration of these types of management (5 to 10 years), their dependence on the farmers' will and socio-economic contingencies. It may simply be proposed, as Ntoupka [63] did, to lay down branches in order to limit runoff, trap organic matter, increase water storage, and attract termites and earthworms. This technique increases microporosity, and in the medium term favors vegetation recovery. Roose *et al*. [78] conclude that in a favorable socio-economic context, with an improvement in the level of income of the populations and a limitation of land tenure problems, six rules should be respected to restore degraded soils and improve their biodiversity: adequate management of surface water (stone barriers, hedges, basins, etc.); reopening and reuse of land (e.g. by means of an irrigation system); and a reduction in the number of trees and shrubs. These include: adequate management of surface water (stone barriers, hedges, basins, etc.); reopening and stabilization of macroporosity (tillage and burial of organic matter); revitalisation of the surface horizon by adding humified organic matter; improvement of soil pH; plant nutrition; and a choice of locally adapted but non-invasive plants.

The re-greening process of certain degraded areas could be based on local plant species with favorable effects on soil fertility, mainly belonging to the Fabaceae family [79], or playing a role in soil protection and regeneration, such as *Leptadenia hastata* [80]. In the same vein, previous soil rehabilitation experiments in the North and Far North of Cameroon, which have proved to be conclusive, can be put into practice, notably surface development by reforestation [79] or by improving the water regime [81, 82]; planting techniques [83], or water saving and tillage techniques [84]. Some farming techniques that are sometimes considered beneficial

(earth dams, tillage with plow or hoe, application of organic matter, integration of farming techniques such as fallow, crop association and rotation) cannot be overlooked, but could be improved with expert input [85].

7.3.7 Measures to improve monitoring and limit illegal resource extraction

The organization of surveillance patrols, not systematic and above all improvised, and sometimes at night in the dry season, is strongly recommended. No peripheral or internal area of the park should be excluded within the limits of accessibility. The use of civilian aerial drones, which are of great interest in forest management [86], would make a significant contribution to this surveillance, especially at the edges (entrances, fire pockets). In the absence of legal reform, this measure takes into account the legal prohibition in parks on flying aircraft below 200 m altitude [38]. In the event of infringements, the sanctions provided for by the regulations in force must be applied. However, these repressive actions are generally a last resort.

Indeed, other so-called palliative strategies favor the use of alternative sources of animal protein [87]. Development involving farmers would make it possible to reconcile the production of firewood, a scarce resource, with the sustainability of tree parks [88]. Bergonzini [89] proposes ways of reducing pressure on wood and fodder resources, such as improving the energy efficiency of stoves, using alternative energy sources, reducing the number of herds and controlling grazing and fire management techniques.

The collection of firewood is a constant concern of the farmers. The law does not allow this practice in the protected area, as the entire ecosystem balance must be preserved. Such a measure, as well as selective cutting of invasive bush species, could only be tolerated around tracks set up to facilitate travel during recreational visits. It is known that the fallen stems and branches of living or dead woody plants represent micro-habitats for micro-organisms in the more or less long term, which contribute to the enrichment of soil organic matter. In the Oti-Ke'ran National Park in North Togo, the sale of collected deadwood and the allocation of income to local people are proposed to managers to facilitate participatory management [90].

Most accounts did not mention the major destructive action of fires in the core of the vegetation. Culverwell [91] stated that the MGNP had not burned for at least 40 years. Nevertheless, a recent observation at the edge of an area of about 2000 m^2 consumed by a farmer's accidental fire confirmed the effectiveness of this threat. The protected area is not particularly fireproof and as its degradation intensifies, the hygrometry that limits the spread of bushfires will be reduced. This could lead to a total burning of the vegetation. It is therefore imperative to control and prevent early dry season fires and to enrich the edge of the forest with fire-breaking hedgerow species, also constituting a protective barrier. This natural protective barrier, using a few natural non-invasive plant species, can be put in place by involving the riparian population, especially in easily accessible areas, with human constructions or crop fields at the edge. It will also be necessary to monitor their proliferation on a permanent basis.

7.3.8 Guidelines for the implementation of a geographic information system (GIS)

With the obtaining of important spatial data of the park and its periphery, the implementation of a GIS could be done by exploiting the identification of land occupation units over the years. This multiple mapping will allow multi-date cross-referencing, with a view to detecting changes in land cover and carrying out simulations. The geo-referencing of spatial information, in the large vegetation

units concerning climate, plant composition and structure, pedological data, anthropisation parameters, and remote sensing indices could favor ecological monitoring. These data should be renewed periodically, taking into account the resources available, in order to gauge the effectiveness of management measures, and thus guide new decision-making. The data collection points are integrated into the GIS. Thus conceived, this GIS would be part of a sustainable management dynamic for the MGNP.

8. Conclusion

In conclusion, this chapter has essentially allowed measures to be proposed in order to promote sustainable management of the MGNP. On the basis of information gathered from its physical and human environment, a number of values were identified, as well as management shortcomings, threats and pressures, with a view to formulating a number of management guidelines favorable to its sustainable conservation. The aim was to contribute to the popularization of the results of the research work on this park, presented in the form of guidelines applicable to the diversity of actors likely to interact with the resources or to be involved in its management. Other specialists in the field of natural resource management are therefore called upon, particularly in support of the design of better awareness-raising strategies, for the full appropriation and effective application of the proposed management measures. It is obvious that adherence to the results of this work will have to face certain reprehensible resistances. Indeed, these behaviors are in contradiction with the United Nations' vision of sustainable development, in favor of sharing benefits, goods and ecosystem services between present and future generations. These obstacles call for a real consideration of socioeconomic, sociocultural, psycho-affective (sensitivity to environmental issues), political and economic factors in the realization and operationalization of management plans for protected areas in general, and for the MGNP in particular.

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