

Article

Perspectives on sustainable resource conservation in Community Nature Reserves: a case study from Senegal

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Abstract: The coalescing between development and conservation has given rise in the last years to community-based conservation. Under this framework, sustainable livelihood strategies are incorporated for the sake of conservation purposes, on the basis that the integration of local priorities into management guidelines benefits conservation. Along these lines is placed the approach of the Community Nature Reserve of Dindéfélo, in Kédougou, Senegal, to protect biodiversity without jeopardizing local people's reliance on natural resources. In this article we provide evidence that sustainable resource conservation is a very powerful mechanism to redirect labour and capital away from ecosystem-degrading activities. Three examples are here presented with the aim to illustrate different ways in which local people's management and sustainable use of natural resources can be beneficial in terms of biodiversity conservation.

Keywords: sustainable management; community conservation; Nature Reserve; forest resources; Senegal; ethnoecology; live fences; chimpanzees; washing facility.

1. The erosion of biodiversity: drivers and concerns

Biodiversity erosion is currently recognized as one of the burning topics of study in the recent scientific literature [1-3]. Since the 1970s, much research has addressed the issue with particular emphasis in attempting to estimate the fraction of the global biodiversity threatened with extinction [4-6]. The most commonly cited figure shows that up to 38% of the world's total number of species could be threatened with extinction [7], although it is widely recognized that this appraisal is a serious underestimate, taking into account that biodiversity in many parts of the world, especially in tropical latitudes, remains poorly studied and that the conservation status of only 2.7% of the world's described biodiversity is currently known [7,8].

Indeed, the goal of biodiversity conservation faces the complex tasks of: 1) identifying the existing information on the ecology of species; 2) evaluating their respective causes of endangerment and threats; and 3) establish a conservation framework to address their endangerment. Extensive biological research is required for the implementation of conservation strategies and the establishment of a protection framework for biodiversity. To date, most of the efforts to conserve biodiversity have come from conservationists aware of the current degradation rates of the world's ecosystems. However, in the last two decades some attempts have been made to try to account for local people's perspectives and perceptions towards biodiversity [9,10].

For most rural and indigenous people living in natural environments, forest resources are the basis of their livelihoods, providing a wide variety of products including food, medicine, timber or charcoal, and material for building and crafting, among others [11,12]. Moreover, according to the World Health Organization, up to 80% of the world's population relies to some extent on forest resources such as medicinal plants for curing various diseases [13], and, at the same time, they have an intangible spiritual value [14,15]. Numerous studies have also revealed the importance of wild vegetal species in human feeding -particularly in Africa [16-18]-, many of which might be endangered [19-21]. It is therefore crucial to ascertain local people's reliance on biodiversity as a first step towards sustainable resource conservation, on account of two assumptions: a) people's well-being in many parts of the world is highly dependent on wild resources; and b) local people have an important role in the success of biological conservation strategies.

2. Community Conservation and Sustainable Development

In general terms, there are two perceptions of the effects that local people's management and use of natural resources have in terms of biodiversity conservation. On one hand, some authors note that local people use of resources may lead to overexploitation, particularly in those cases in which there is a regime of commercialization [22-24]. This framework provides theoretical justification for the conservationist paradigm of strict natural protection (e.g. National Parks), where any prospection or use of natural resources is forbidden. On the other hand, many studies argue that local's people management actually enhances biodiversity [25-27], since local-knowledge based management strategies ensure a focus on the species that are most valuable to local communities. Under this framework, initiatives allowing people living in Community Nature Reserves to make a sustainable use of natural resources have been developed on the basis that the incorporation of local priorities into

management guidelines benefits conservation goals [28-30]. However, as many authors hold [31,32], both views are not strictly opposed, but rather complementary or even case specific.

The merging of development and conservation has given rise in the last years to community-based natural resource management. Community conservation attempts to create a link between development and conservation [33,34], so that both can be achieved simultaneously. In this context, sustainability emerges as a mechanism to: a) redirect labour and capital away from activities that degrade ecosystems; b) encourage commercial activities supplying ecosystem services as joint outputs; and c) raise incomes to reduce dependence on unsustainable resource extraction. In this sense, sustainable livelihood strategies are incorporated as substitutes to ecosystem-degrading activities [35], which might help to close the gap between conservation managers and local communities [36,37].

The purpose of this paper is to provide an empirical study to determine the effectiveness of such a community-based approach to conservation, using the case study of the Community Nature Reserve of Dindéfélo in Kédougou, Senegal. It also examines the different ways in which a coalescing between sustainable development and conservation can be achieved in Nature Reserves, and highlights substantial concerns on how to address local people's attitudes and perceptions towards conservation.

3. The Community Nature Reserve of Dindéfélo study case

3.1. Context, data and forest profile

Senegal represents an ideal country to address the questions arisen in previous sections. Although about 57.9% of Senegal's population live in rural areas where forest resources are central to their livelihood [38], conservation projects including local people in their design and implementation are still rare. So, for instance, we lack a clear understanding of local population resource use and attitudes, which is essential to the success of conservation projects aiming to promote sustainable development [39,40]. In terms of legal status, approximately only 11% of the total land of the country is under some form of protection [41]. These protection figures include natural areas managed under solely protection objectives, but also nature reserves managed by local communities, such as the Community Nature Reserve of Dindéfélo, the case study of the current article.

The Community Nature Reserve of Dindéfélo (*Réserve Naturelle Communautaire de Dindéfélo*, henceforth RNCD) was created by the Rural Council of Dindéfélo in 2010 and is located at the Kédougou Department, in the South-eastern extreme of Senegal (Fig. 1). It is home to a great diversity of flora and fauna, but also to a great cultural variety, with three ethnic groups (mainly *Peul*, but also *Bassari* and *Diakhanké*) spread in 10 villages and hamlets around the Reserve, with 6.951 inhabitants and 651 households. It covers an area of 13.300 ha –over a half of the total area of the Rural Community- and it is located at the edge of two different eco-regions: the Western Sudan savannah and the Guinean forested mosaic (eco-regions AT0707 and AT0722, respectively), according to the classification by [42]. Five types of vegetation predominate in the study area: a) woodland, shrub and herbaceous savannah; b) woodland; c) dense forest; d) gallery forest; and e) *bowé*, outcrops of laterite rock where trees and shrubs cannot grow and that are only covered by grass during the rainy season. Land uses in the RNCD as well as its percentages of representativeness are shown in Fig. 2 and Table 1.

Figure 1. (a) Situation of the Rural Community of Dindéfélo. (b) Situation of the Community Nature Reserve of Dindéfélo within the Rural Community

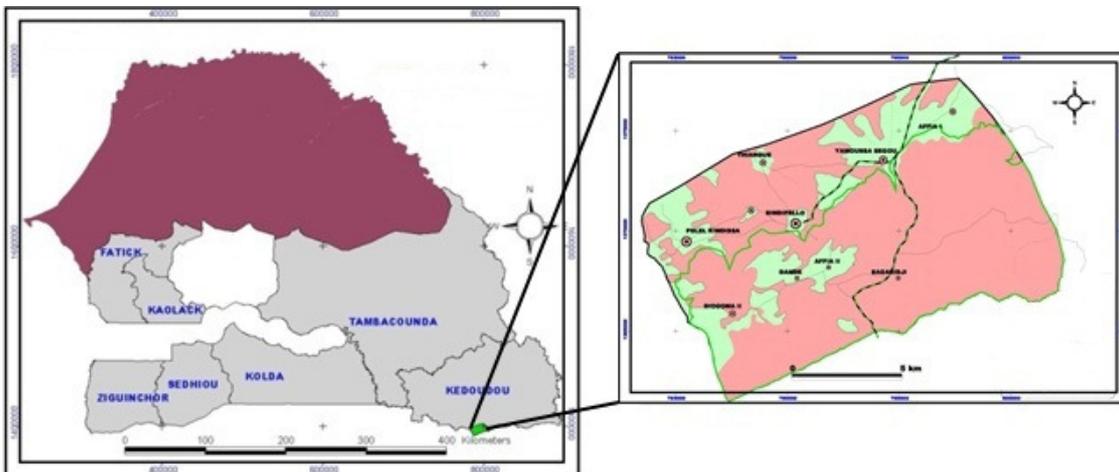
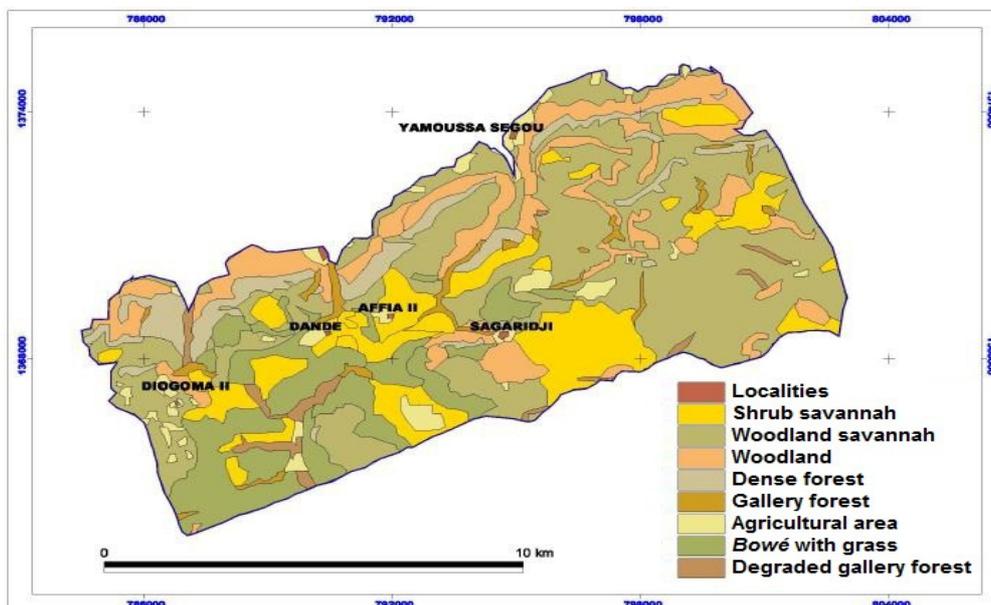


Table 1. Distribution of land use in the RNCD

Type of land use	Surface (in ha)	Percentage over the total
Woodland and herbaceous savannah	4.860	37%
Forests (<i>all types</i>)	3.197	24%
Shrub savannah	2.430	18%
<i>Bowé</i> and prairie grass	2.174	16%
Agricultural areas	512	4%
Others (houses, rocks...)	128	1%
TOTAL	13.301	100%

Figure 2. Land use in the RNCD



The RNCD was established with the aim of carrying out a community-based management of its natural resources, as well as protecting the last population of chimpanzee (*Pan troglodytes verus*) in Senegal, listed by the IUCN as an endangered species worldwide and with an estimate of only 500 individuals for all the country [43,44]. The presence of this species in the region represents the north-western limit of its geographical distribution and the reason why IUCN considers Dindéfélo as an important area in terms of conservation [45]. However, the conservation of chimpanzees at the Reserve faces the impacts of local people's activities, including timber harvesting, fire regimes for the creation of open pastures for cattle, or pollution of watercourses, as in other natural areas of Africa [46,47]. Natural resources in the region of Kédougou –considered one of the last bastions for wildlife in Senegal- suffer also a big impact due mostly to poaching and overexploitation beyond local people's use. For instance, uncontrolled clearing to address the reduction of land productivity and the absence of fallows take part in the erosion and degradation of biodiversity, substantially destroying some biotopes.

This collision of agendas generates a conflict of interests between local communities whose welfare depends on the forest goods and services, and conservationists aware of the degradation of the ecosystems. The current situation asks for an extensive assessment of the local ways of sustainable management of biodiversity, which is highly required for addressing the conservation challenges of this newly established Reserve and give answer to the several threats menacing its ecological integrity.

3.2. Examples of sustainable projects in Natural Protected Areas and future challenges

3.2.1. Nurseries as an alternative to the unsustainable exploitation of forest fruits

The increasing unsustainable exploitation of forest fruits in the RNCD is a source of degradation and fragmentation of the habitat. Furthermore, the diet of many animals, such as the highly endangered chimpanzee, relies in the same wild edibles collected by local communities [48]. Maybe the most relevant example is the case of the liana *Saba senegalensis* (Fig. 3), known also by its Wolof name *madd*, whose fruit is very appreciated by local people in South-eastern Senegal, often appearing in local markets in the dry season [49]. The increasing pressure over this fruit, and therefore the seeds contained on it, has led to a substantial decrease in the natural regeneration of the species, with negative effects on biodiversity, since, for instance, chimpanzee's diet depends mainly on this fruit in the dry season, acting as an endozoochorous seed dispersal agent [44].

In order to make compatible the use of this resource by local communities with its preservation in the forest and its availability for chimpanzees, the viability of several actions has been studied in the Reserve. On one hand, methods for collecting *S. senegalensis* fruits are usually destructive, so raising the population awareness about sustainable and non-destructive practices can be very effective. Also, the zonation of the RNCD has allowed the protection of certain areas of special importance for chimpanzees, such as the gallery forests, which are free from any exploitation of natural resources due to their vulnerability. However, these areas are very limited for the chimpanzees in terms of space, and that is the reason why an alternative have been proposed by the Jane Goodall Institute Spain: to substitute the exploitation of wild fruits of *S. senegalensis* in the Reserve through the implementation of nurseries in the communities.

Figure 3. (a) Fruit of *S. senegalensis*. (b) *S. senegalensis* fruit extraction at Dindéfélo.



Different experiences in Senegal have demonstrated the viability of the nurseries of *S. senegalensis*. The infrastructure requires only the installation of a supporting structure in which the liana grows. In addition to this, local people work through management committees, and only the creation of a group responsible for the task is needed. Perhaps the main limitation of this alternative is the time that it takes to the nurseries to be productive, since *S. senegalensis* begins to bear fruit around 3-4 years after its plantation [50]. Therefore, it is very important during this period to raise sensitization activities designed to promote sustainable harvesting practices.

However, the conflict over *S. senegalensis* is only an example, since chimps and humans share many more fruits from the forest. According to preliminary studies carried out on the diet of chimpanzees by the Jane Goodall Institute Spain, they share with local people at least 39 different types of forest species, which represents 43% of their diet [51]. Among these, 8 are likely to be sold both in local and national markets: *Lannea* sp., *Adansonia digitata*, *Detarium* sp., *Tamarindus indica*, *Parkia biglobosa*, *Ziziphus* sp., *Vitellaria paradoxa*, *Cola cordifolia* [52]. Therefore, there is an urgent need to work also on these species, either by reproducing them in nurseries, or if it is not possible (as for example in the case of *A. digitata*), by defining operational zones for a sustainable extraction and preserving some for wildlife.

3.2.2. Live Fencing: a strategy for sustainable resource conservation

A second sustainable project active within the RNCD is the extension of live fencing. For the purposes of this paper, live fences could be defined as “narrow linear strips of planted trees, generally consisting of a single row of a few densely planted species that are established and managed by farmers” [53]. Research has shown that live fencing is used throughout the world as a sustainable agriculture practice and yields numerous benefits for local populations and the environment [54-60]. Likewise, live fencing in the Nature Reserve contributes significantly to biodiversity and forest conservation while, at the same time, it has a positive financial impact in local people.

The primary implementer of live fencing technology within the Nature Reserve is a cooperative project between the NGO *Trees for the Future* and the *U.S. Peace Corps*. The aim of the project is to

extend agroforestry techniques to subsistence farmers in order to increase their food security and curb deforestation. Program staff members and volunteers provide technical training and aid in the financing of community tree nurseries, established and maintained by local farmers that produce saplings for the planting of live fences. Species currently being extended are *Jatropha curcas*, *Acacia nilotica*, *A. mellifera*, *Bauhinia rufescens* and *Ziziphus mauritiana*. These species were chosen because they are effective barriers and animal deterrents, their seed is available locally, they are fast growing, they produce income-generating by-products and also there is local demand for their use. There are currently four participating communities –Dindéfélo, Ségou, Tiabécaré and Yamoussa– within the Reserve, as well as one additional village, Thiangué, in the Rural Community of Dindéfélo. To date, over 50 program participants have planted approximately 20,000 trees in live fences, and plans are to extend to remaining communities in the Reserve within two years.

The form and function of today's live fencing in the Nature Reserve differs from its historic predecessors. Traditionally, live fencing at Dindéfélo used only *Jatropha* and had two primary functions: the cementing of land ownership claims and the controlling of human traffic in and out of a village for security. These practices have been documented in other areas of West Africa [58,61]. These traditional functions have largely fallen out of usage or been replaced by dead fences composed of woven bamboo, thorny branches and/or tree limb posts. Today, program participants cite three main reasons for the establishment of live fences: a) as an alternative to current fencing options for the protection of high-value and out of season agricultural products; b) to generate income directly through the sale of live fencing by-products; and c) for environmental conservation. An exploration of these reasons will elucidate the positive impacts of live fencing in the RNCD.

Livestock free grazing is widely practiced within the Nature Reserve and is only restricted during the period of cereal grain production, from late-June to December. However, there are a number of profitable agricultural products that contribute significantly to villager nutrition and dietary diversity, such as manioc and garden vegetables grown outside of this season and, therefore, jeopardized by free grazing. In order to protect these plants, farmers enclose them with either a dead fence or an industrial fabricated barrier such as chain link fencings, metal posts or barbed wire. While effective, both of these fencing options pose a number of problems that can be overcome by live fencing. Dead fences degrade within one to two planting seasons due to aggressive termites, are labour intensive and contribute to deforestation, since wood for their construction must be gathered from wild areas in the Reserve. Industrial fabricated barriers are financially out of reach to the majority of farmers and, being of questionable quality and subject to harsh environmental conditions, quickly rust and deteriorate. Alternatively, live fences, owing to the fact that they are composed of living plants, strengthen rather than deteriorate over time, are not subject to termite damage or rust, do not require the user to cut and gather wood, cost significantly less in terms of materials and labour than industrial barriers and are largely permanent once established. It is this longevity and elimination of the need for wood collection that makes live fencing both economically and environmentally sustainable.

An important incentive to establish a live fence is income generation from fencing by-products, specifically the sale of *Jatropha* seeds and seedlings for biofuel production and artisanal soaps and candles [62] and *Ziziphus* “jujube” fruit for consumption [63]. These extra financial incentives – absent with dead and industrial fencing– make *Jatropha* and *Ziziphus* the most popular live fencing species amongst participants and complement conservation. Thus, by providing villagers with

proximate sources of natural products, live fencing reduces the incentive to forage for these products within the Reserve, reducing both human traffic in wild spaces and human-wildlife competition for food sources.

Live fences replace dead fences and eliminate the need to enter into the Reserve and clear forest for fence construction. Widespread adoption of live fences has the potential to preserve hectares of forest and contribute significantly to biodiversity within the reserve. Research suggests that live fences provide important supplementary habitat for birds [64,65] and other groups [66,53] and may act as movement corridors across agricultural landscapes for a variety of species [67,53], including primates [68]. Live fences in the RNCD contribute to conservation not only in what they provide in terms of habitat and movement corridors, but also in what they prevent, namely deforestation, human traffic in wild areas and human-wildlife competition while positively benefiting villagers' economic situation in a sustainable way.

3.2.3. Construction of municipal washing facilities: an example of sustainable policy-making

The last sustainable project here explained is the construction of a municipal washing facility at the village of Dindéfélo. One of the most relevant conflicts between humans and chimpanzees throughout the RNCD concerns the confluence of these great apes, along with other fauna, with local villagers, mostly women and young teenagers, at the water points during the dry season [45,51]. Preliminary studies in the Reserve show that local people in 6 out of the 10 villages in the Natural Reserve appear to have constant conflicts with chimpanzees over the water resources [45]. These conflicts are not a fight over the water itself, but the encounter of people and animals at the same place and time, which are stressful and irritating for both sides [48].

Figure 4. Women washing clothes in the river stream of Dindéfélo



There are different sources of water in the Rural Community of Dindéfélo. In most of the rural areas, located in the plateau, they only have water holes as a source of water. These are often near the small villages, but in some cases they are as far as 2 kilometers away. Women often visit the water hole in the early morning or late evening to gather water and wash the clothes. That is also the time

when the chimpanzees and other fauna approach these points to drink [69]. If there is an adequate amount of water, the women are able to wash clothes. After washing the clothes they are let dry over branches. By doing that they will not be carrying as much weight on their heads once laundry is done [70]. Other water sources in the RNCD are the streams and rivers. They basically happen in the villages on the plain, such as Dindéfélo and Ségou. Those who live near one use them to bath in and wash clothes. Women typically visit the streams throughout the day because they are usually located in gallery forests and therefore sheltered from the sun [70,71]. They immerse the dirty clothes in the running water and use large rocks to assist in the scrubbing process (Fig. 4). Washing powders and bars are available as well as homemade soap to clean the clothes. After scrubbing the clothes, they wring them out and allow them to dry in the sun or drape them over bushes or branches as a surreal clothing line [70,71]. The last sources of water at Dindéfélo are the wells. Where these are installed, women pump the water into large buckets and carry it to their homes for household use. The clothes are washed in large basins filled with water. This last case rarely happens in the villages around the Reserve for there are very few wells and usually get waterless during the dry season.

These household activities, i.e. washing clothes, dishes and showering, summed up with the fact that the streams are also used to urinate and to defecate [72], have a direct impact on the water quality, which harms the riverside flora and pollutes the ground water (Fig. 5). Concretely, the use of water by local people alters the physical conditions of the riverside, the oxygen-consuming substances and the nutrient cycle, which entails an increase in the presence of pathogen substances for chimpanzees [48]. Apart from these factors, it is noteworthy that the plastic bags containing the powder are disposed anywhere, as well as wasted clothes, which hang from the trees or simply lay on the ground becoming a solid contaminating agent. During the dry months, when food is scarce, a small number of these inedible disposed clothes are consumed by hungry livestock and primates, causing them severe obstructions in their stomachs, with the result of death in many cases [45,48].

Figure 5. (a) Organic pollution in the washing area. (b) Clothes drying out on the bushes



The Jane Goodall Institute Spain, which accompanies the Rural Community of Dindéfélo for the consecution of a strategic plan for the Reserve, conceived the construction of a municipal washing facility in Dindéfélo (Fig. 6) to put an end to the increasing levels of water pollution around the washing points of the Reserve. The infrastructure was funded by the *Àrea Metropolitana de Barcelona* and was, since its outset, a collective idea with the consensus of local people, particularly with the

approval of local women. The election of the village of Dindéfélo as the benefactor of the installation was justified by two reasons: a) it is the most populated village in the Reserve, with more than 1600 people [45]; and b) the stream that they use to conduct their household activities, situated near the highest waterfall in Senegal, was already severely degraded by pollution. Women were the main benefactors of the project, but so were the chimpanzees and other fauna and flora relying on the water sources at the RNCD.

Figure 6. (a) Filter system and *Moringa* nursery bed. (b) Local women using the new washing facilities



The water quality in the streams of the Reserve has improved since the construction of the washing facility, due to the gray water waste control implemented, consisting on a filter system and *Moringa* nursery bed. This evacuating system is a very simple but effective one including different layers of filters such as carbon. After the filtering process, waters end up in a piece of land that has a plantation of *M. oleifera*. This species is used by local peoples for purifying ground water, through a phytoremediation process [50,73]. Its roots have an essential oil that can turn gray water into drinkable one. This plant it is also used for erosion control and live fencing, among others [73]. The installation of the washing facilities was also accompanied by a management plan for solid waste and plastic bags, as well as an environmental education program.

4. Concluding remarks

The conservation model of the RNCD began as an experiment to enhance the conservation of African chimpanzees from a community-based perspective. Since its creation, it has been proved that including local people's perspectives in the design and implementation of management plans of Nature Protected Areas gives conservation schemes a better chance of success. However, any management of natural resources in Community Nature Reserves must be carried out under the framework of sustainable development. The three different examples exposed in the current article illustrate different

paths in which conservation purposes can be complemented by a sustainable use of natural resources. In a continent like Africa, where both human development and conservation of natural areas are urgently needed, initiatives like the ones carried out in the RNCD emerge as a viable way towards sustainable resource conservation.

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Conflict of Interest

The authors declare no conflict of interest.

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