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PLANT DIVERSITY AND CARBON STOCK IN SACRED GROVES OF SEMI-ARID AREAS OF CAMEROON: CASE STUDY OF MANDARA MOUNTAINS

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Abstract

The Mandara Mountain eco-region is one of the most important mountain areas of Cameroon. It is often considered as a refuge for several plant and wildlife species. This area is fragile and vulnerable, and faces severe threats from land use change, unsustainable exploitation of natural resources, desertification and climate change. Recent studies in sacred groves portrayed these land use types as indigenous strategies which can help to address these environmental problems. Understanding the plant diversity and carbon storage of these land use types in Mandara Mountain can be a good step towards their sustainable management for the delivery of diverse ecosystem services. In this perspective, we established a total of 10 nested circular plots of 1257 m^2 each, in the sacred grove of the Mouhour village in Mandara Mountain, and all trees and shrubs with average diameter at breast height (dbh) ≥ 2.5 cm were counted. Tree biomass was estimated on the basis of DBH and understory biomass using destructive method. A total of 182 woody plants were measured, belonging to 21 species, 18 genera and 12 families. The richest family is Combretaceae with 5 species, followed by Caesalpiniaceae and Mimosaceae (3 species each). The analysis of species diversity indexes shows a relative important biodiversity and the vegetation structure showed a high occurrence of small-diameter of plant species. Mean aboveground carbon stock of 31.13 ± 10.8 tC/ha was obtained in the study area. *Isoberlinia doka* showed the greatest carbon stock (5.7 tC/ha) followed by *Boswellia dalzielii* (3.9 tC/ha), *Acacia senegal* (3.5 tC/ha), *Anogeissus leiocarpus* (3.3 tC/ha) and *Terminalia laxiflora* (3.1 tC/ha). These results suggest that the sacred groves of Cameroon dry lands need to be taken into account in national environment protection policies as an alternative to respond to international agreements related to biodiversity conservation, combatting desertification and climate change.

Key words: Sacred groves; Mandara Mountain; biodiversity, climate change; desertification

Introduction

The Far North Region of Cameroon is the driest zone and contains most of the important ecological zone of the country. The area is part of the Sahel band of Africa with five main Eco-region including Sahelian Acacia savannah, East sudanian savanna, Mandara Plateau mosaic, Lake Afrotropic and Lake Chad flooded savannah (Olson *et al.*, 2001).

Some scientific research in these eco-regions reveal a rich biological diversity with more than 30 large mammal species such as Lion (*Panthera leo*), African Elephant (*Loxodonta africana africana*), Buffalo (*Syncerus caffer nanus*), Giraffe (*Giraffa camelopardalis*), Cheetah (*Acinonyx jubatus*), Roan Antelope (*Hippotragus equines*), Hartebeest (*Alcephalus busephalus*), 379 species of avifauna and more than 36 reptiles species (Stuart *et al.*, 1990). This biodiversity is mainly conserved in five major conservation areas including Waza, Kalamaloue, Mzogo-Gokoro and Ma Mbed Mbed national parks, Kalfou, Mayo Louti forest reserves, and also in sacred groves (Delpierre and Vivien, 1992; Froumsia *et al.*, 2012; Fotsing, 2009; Ntoupka, 1999).

The Mandara Mountain is part of Mandara Plateau mosaic eco-region and is one of the most important mountain areas of Cameroon. It is often considered as a refuge for several plant and wildlife species with East African mountain affinities (WWF, 2001). The region has three known endemic reptile species, Mount Lefo chameleon (*Chamaeleo wiedersheimi*), Mabuya langheldi (*Trachylepis* sp.) and African wall gecko (*Tarentola ephippiata*) (Stuart *et al.*, 1990). However, this area is fragile and vulnerable, and faces severe threats from land use change, unsustainable exploitation of natural resources, extensive grazing and burning for clearing of new land, desertification and climate change (WWF, 2001; Campbell and Riddell, 1984; Stuart *et al.*, 1990). Natural ecosystems of Mandara Mountain are among the most degraded in this geographic zone. Hoekstra *et al.* (2010) estimated the rate of habitat loss from land conversion between 60 and 90 % in 2009. Since several decades, some ethnic groups conserve patches of forest, considered as sacred. These community-protected forests are often associated with traditional regulations or rules such as taboos, totems and myths that deter human exploitation within the groves (Nganso *et al.*, 2012).

Recent studies in sacred groves in Africa and worldwide highlighted their key role in conservation of cultural heritage (Savadogo *et al.*, 2011). In addition, these areas provide some ecosystem services such as clean environment i.e., air, soil and water conservation, flora and fauna conservation, carbon sequestration and temperature control (Kokou and Kokutse, 2007; Kokou and Sopkon, 2008; Kandar *et al.*, 2014)). Sacred grove is one of the important components of the National Biodiversity Strategy and Action Plan of Cameroon (Republic of Cameroon, 2012). A total of 1361 sacred groves, covering an area of 46920 ha, have been inventoried in Cameroon, with 95 in semi-arid area of Cameroon (MEM, 2010).

In some degraded landscape as Mandara Mountains, sacred groves could also provide other co-benefice such as prevention of soil erosion and degradation in addition of biodiversity conservation. Despite this importance, benefits provided by sacred grooves have long been poorly studied in the area. The current work is designed to characterize the sacred groves of Mandara Mountains from a biodiversity and carbon storage perspective. It is a to promote the importance contribution of sacred groves in addressing of environmental problems including climate change, desertification and loss of biodiversity.

Materials and methods

Presentation of the study area

The Mandara Mountains extend from the North latitudes of 10° to 11°15’ and 13°30’ to 14° 30’ East longitude (Fig. 1) within the Sudano-Sahelian belt. In Cameroon, this region located within three main Divisions including Diamare, Mayo Tsanaga and Mayo Sava. The climate of the region is characterized by a five-month rainy season (May through September) and a seven-month dry season (October through April) with rainfall between 850 and 1100 mm per year (L’Hote, 1998). The Mandara Mountains rise to 1500 m above sea level, with most of the massif between 1000 and 1200 m. Vegetation is thorn-bush steppe to savanna dominated throughout by *Acacia* species but with variations depending upon groundwater supply. Continuous vegetative cover is largely restricted to the margins of watercourses (Boutrais, 1984). Data were collected in one sacred grove of village of Mouhour located at 1 km in south of Mokolo.

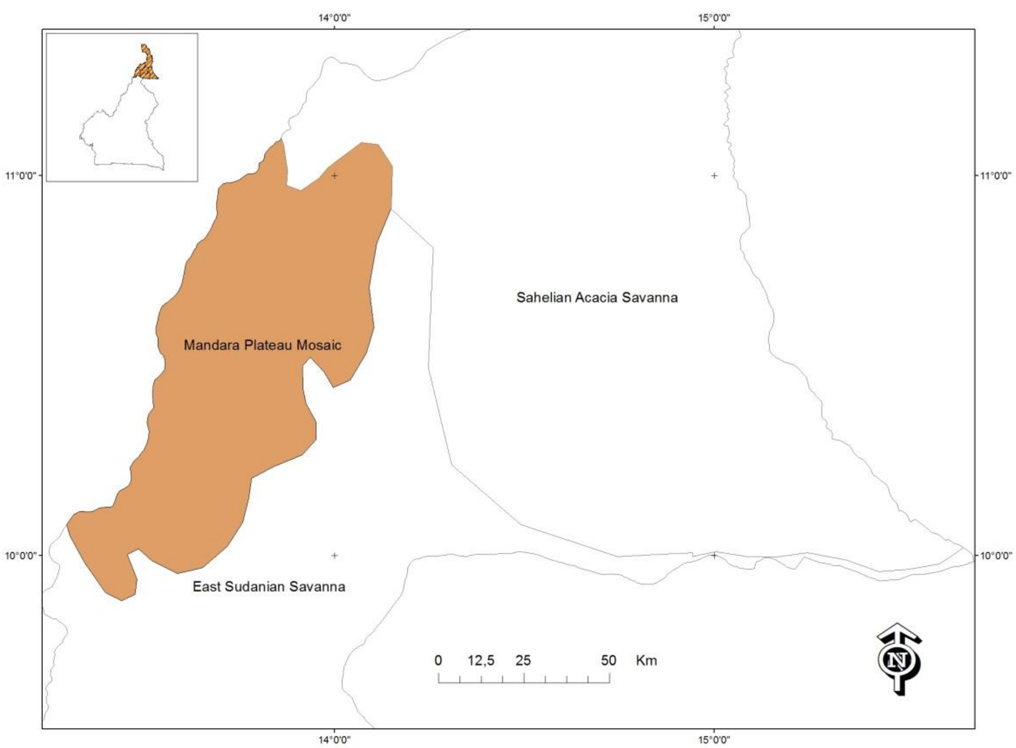

Fig. 1: Map of location of the Mandara Mountains in Cameroon

Data collection

The nested plot method was used for the sampling of the above ground vegetation. It is one of the most commonly used for all kind of vegetation sampling. The method is applicable to baseline as well as project scenario. In this sacred grove 10 nested circular plots of 1257 m^2, 616 m^2 and 50 m^2 were established randomly. The diameter of woody plant species were measured at 30 cm in each circular plot. To estimate tree biomass and understory biomass, non-destructive and destructive methods were respectively used. The understory carbon pool includes the aboveground biomass of all trees less than 2.5 cm DBH along with all non-tree vegetation. The biomass of tree was estimated on the basis of DBH. For understory biomass, fresh and dry weights were measured. Biomass values were then multiplied by an expansion factor to scale them to a one hectare area.

Data analysis

Species richness, Shannon-wiener index (H), Simpson index (D') and Hill index were used to calculate the species diversity (Shannon and Wiener, 1963).

$H = - \sum Pi \log_2 Pi$, Where $Pi = ni /N$, ni is the number of individuals of the species and N is the total number of individuals of all species. $D' = 1-\sum Pi^2$

Hill = $(1/\lambda)/e^H$, where $1/\lambda$: is the reciprocal of the Simpson index; e^H ': This is the exponential of the Shannon index.

Rarity-weighted Richness Index (RWRI) was also calculated using equation formula of Géhu and Géhu (1980). RWRI = [1-(ni/N)] x100. RWI index is high when the sample is composed only of rare species and low when there are few rare species in the sample. In this study, we assume that when RWRI is higher than 80 % the species is considered as rare.

The quantitative analysis of frequency, density and abundance was done by using the standard expressions. The importance value index (IVI) was determined as the sum of relative frequency, relative density and relative dominance (Curtis, 1959). IVI determines vegetation status and importance of component species in a stratum stand.

The above ground biomass was calculated using allometric equation of Chave *et al.* (2005) of dry forest.

Results

Taxonomic composition

A total of 182 woody plants were measured, belonging to 21 species, 18 genera and 12 families. The richest families include the *Combretaceae* with 5 species, followed by *Caesalpiniaceae* and *Mimosaceae* (3 species each) and *Anacardiaceae* (2 species). Height plant families are monospecifics (table 1). The richest genera are *Combretum* and *Acacia* with respectively 3 and 2 species (table 2).

Table 1: Recorded families and their number of species

Family	Species richness
Combretaceae	5
Caesalpiniaceae, Mimosaceae	3
Anacardiaceae	2
Bignoniaceae, Burseraceae, Celastraceae, Ebenaceae, Meliaceae,	1

Rhamnaceae, Rubiaceae, Sterculiaceae	
Genera	**Species richness**
Combretum	3
Acacia	2
Ekebergia, Isoberlinia, Strychnos, Boswellia, Stereospermum, Lannea, Sterculia, Haematostaphis, Senna, Terminalia, Diospyros, Piliostigma, Anogeissus, Parkia, Ziziphus, Maytenus	1

Table 2: [Species characteristics in study area]

Parameter	Value
Total density of woody plants (trees/ha)	900.7
Species Richness (Total number of species)	21
Shannon's Index (bit)	3.64
Simpson diversity index (D')	0.89
1-Hill diversity index	0.76

Species richness, diversity and abundance

The Shannon Weiner diversity index is 3.64 bits. The high value of Simpson diversity index (D'= 0.89) show a relatively high species diversity in this sacred grove in term of plant species. This result was confirmed by 1-Hill index which is closed to 1 (0.76).

The most abundant species include *Isoberlinia doka* (19.8 % of all trees inventoried), *Acacia senegal* (17.0 %), *Anogeissus leiocarpus* (9.3 %), *Piliostigma thonningii* and *Terminalia laxiflora* (8.8 % each).

The most dominant species include *Boswellia dalzielii* (40.9 %), *Isoberlinia doka* (15.4 %), *Anogeissus leiocarpus* (8.4 %), *Piliostigma thonningii* (5.7 %) and *Parkia biglobosa* (5.4 %).

Basis on values of rarity weighted index, 52 % of inventoried species can be considered as rare (RWRI upper or equal to 80 %). These species include *Acacia hockii, Combretum adenogonium, C. molle, Diospyros mespiliformis, Ekebergia senegalensis, Haematostaphis barteri, Maytenus senegalensis, Senna singueana, Sterculia setigera, Stereospermum kunthianum* and *Strychnos spinosa.*

The average density of woody plants is around 900.7 trees/ha. The top ten plant species with high density include *Acacia senegal*, *Isoberlinia doka*, *Terminalia laxiflora*, *Piliostigma thonningii*, *Lannea fruticosa, Combretum collinum, Anogeissus leiocarpus, Maytenus senegalensis, Strychnos spinosa* and *Ziziphus mauritiana* (Table 3).

Table 3: Quantitative analysis of vegetation

Species	Tree densities (trees/ha)	Relative abundance (%)	Relative dominance (%)	IVI	Rarity-weighted Index (%)
Acacia hockii	19.9	0.5	0.01	12.2	**90**

Species	Tree densities (trees/ha)	Relative abundance (%)	Relative dominance (%)	IVI	Rarity-weighted Index (%)
Acacia senegal	271.8	17.0	3.8	103.9	30
Anogeissus leiocarpus	45.2	9.3	8.4	53.5	60
Boswellia dalzielii	9.6	6.6	40.9	82.0	60
Combretum adenogonium	0.8	0.5	1.5	11.6	**90**
Combretum collinum	50.5	3.3	0.5	36.1	70
Combretum molle	13.2	2.7	1.3	22.7	**80**
Diospyros mespiliformis	20.7	1.6	0.6	22.9	**80**
Ekebergia senegalensis	21.5	2.2	1.3	23.7	**80**
Haematostaphis barteri	1.62	0.5	0.3	10.5	**90**
Isoberlinia doka	127.7	19.8	15.4	69.6	60
Lannea fruticosa	51.3	3.8	1.3	57.0	50
Maytenus senegalensis	40.6	2.7	0.8	15.3	**90**
Parkia biglobosa	16.0	4.4	5.4	47.2	60
Piliostigma thonningii	58.6	8.8	5.7	72.2	40
Senna singueana	1.6	0.5	0.5	10.7	**90**
Sterculia setigera	0.8	0.5	2.0	12.1	**90**
Stereospermum kunthianum	0.8	0.5	0.9	11.0	**90**
Strychnos spinosa	39.8	1.1	0.3	14.8	**90**
Terminalia laxiflora	74.8	8.8	5.2	53.5	60
Ziziphus mauritiana	33.9	4.4	3.6	57.3	50

Ecological importance of plant species

The most important tree species based on IVI score are. *Acacia senegal* (103.9), *Boswellia dalzielii* (82.0), *Piliostigma thonningii* (72.2), *Isoberlinia doka* (69.6) and *Lannea fruticosa* (57.0) (table 2).

Structure of woody vegetation

The distribution of DBH classes conformed to ‘L’ shape curve, with 52 % of individuals having DBH lower than 10 cm (Fig. 2). Diameter structure of sacred groves presents a high tree density within the lower diameter classes which decreases with increasing diameter. The high proportion of young individuals could suggest a dominance of small diameter trees in these sacred groves, or a dynamic balance in the natural regeneration of these groups.

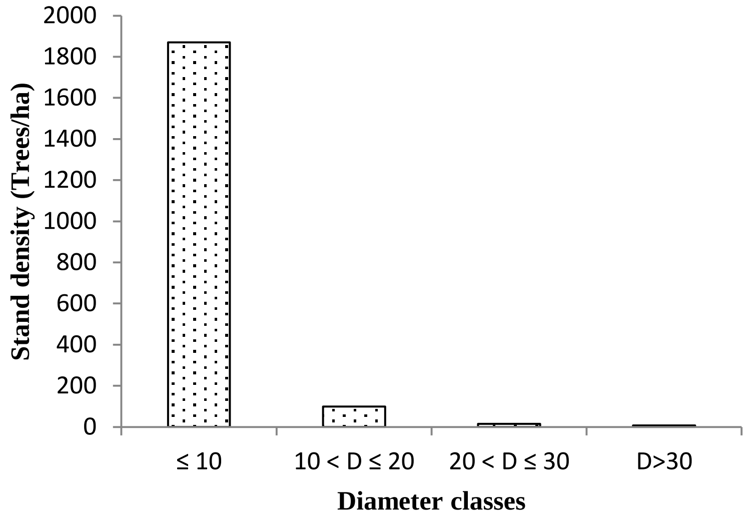

Fig. 2: Stand structure of trees based on diameter classes

Carbon stock in sacred grove of Mandara Mountain

Mean aboveground carbon stock of 31.1± 10.8 tC/ha was obtain in the study area with mean diameter between 2.5 and 36.5 cm (table 4). The average carbon stock of live trees is 29.8 when understory carbon stock is around 1.3 tC/ha

Isoberlinia doka showed the greatest carbon stock (5.7 tC/ha) followed by *Boswellia dalzielii* (3.9 tC/ha), *Acacia senegal* (3.5 tC/ha), *Anogeissus leiocarpus* (3.3 tC/ha) and *Terminalia laxiflora* (3.1 tC/ha). These top five plant species represent 66 % (19.6 tC/ha) of the total standing live tree carbon stock. Lowest stock was observed with *Acacia hockii* (0.02 tC/ha), *Haematostaphis barteri* and *Stereospermum kunthianum* (0.08 tC/ha each), *Senna singueana* and *Sterculia setigera* (0.10 tC/ha) and *Combretum adenogonium* (0.15 tC/ha).

Table 4: [Standing live carbon stock]

Species	DBH (cm)			Basal area (m^2/ha)	Carbon stock (t/ha)
	Min	Mean	Max		
Acacia hockii	2.5	2,5	2.5	0.1	0.02
Acacia senegal	3	6,6	14.6	15.8	3.49
Anogeissus leiocarpus	5.7	13,7	23.9	9.6	3.32
Boswellia dalzielii	20.1	36,3	66.2	11.3	3.92
Combretum adenogonium	25.8	25,8	25.8	0.4	0.15
Combretum collinum	2.8	5,3	10.3	1.8	0.36
Combretum molle	6.4	10,3	12.7	1.3	0.40
Diospyros mespiliformis	6.1	8,9	13.4	1.6	0.73
Ekebergia senegalensis	6.1	11,2	18.0	2.6	0.62
Haematostaphis barteri	12.1	12,1	12.1	0.2	0.08
Isoberlinia doka	3.2	11,8	30.3	20.3	5.75
Lannea fruticosa	3.4	8,6	13.1	4.4	1.40
Maytenus senegalensis	4.4	8,0	13.0	3.3	0.96
Parkia biglobosa	5.1	15,6	28.7	3.7	1.25

Species	DBH (cm)			Basal area (m^2/ha)	Carbon stock (t/ha)
	Min	Mean	Max		
Piliostigma thonningii	6.4	12,2	17.0	8.7	2.16
Senna singueana	15.0	15,0	15.0	0.3	0.10
Sterculia setigera	29.9	29,9	29.9	0.6	0.10
Stereospermum kunthianum	20.3	20,3	20.3	0.3	0.08
Strychnos spinosa	7.6	8,6	9.6	2.3	0.61
Terminalia laxiflora	4	10,3	22.9	9.6	3.10
Ziziphus mauritiana	5.4	13,1	17.7	4.1	1.24

Discussion

Plant diversity conservation in sacred grove of Mandara Mountain

Plant diversity conservation in sacred grove of Mandara Mountain is significant though the parameter of plant diversity obtained in this study was low compared to those of non-protected natural vegetation in the same study area (Fanaka Ngolei, 2006; Thorgang, 2001). This low value can be explained by the low sampling effort (1.2 ha). The species-area curve (fig. 3) confirms this observation. However Sawadogo *et al*. (2011) obtain similar value of Shannon diversity index in Mossi sacred grove in Burkina Faso. With the continuous high rate of conversion of natural ecosystem in Mandara Mountain (Hoekstra *et al*., 2010), sacred grove in this area could serve in the future as refuge of several native plant species.

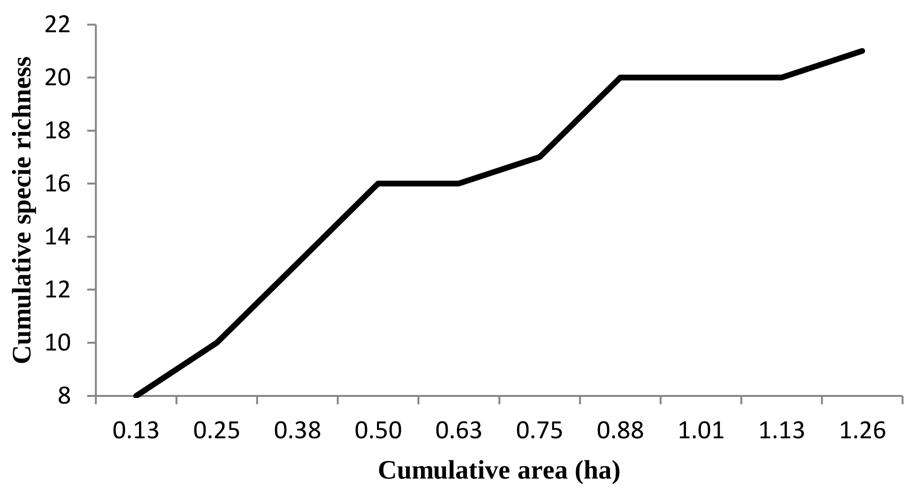

Fig. 3: Species-area curve

The structure of woody vegetation with high rate of individuals with diameter less than 10 cm could suggest either a good regeneration of individual tree species in this milieu, or that these sacred groves are dominated by small diameter tree species. Fanaka Ngolei (2006) obtains the same structure in the study area. Nevertheless, soil texture from gravels to silt in this area could constitute one of the limiting factors for height growth of tree. Thus, the shortage of plant with high diameter could be not necessarily considered as negative consequence of human activities in sacred grove. In addition, total basal area obtained in our study area is higher than values generally observed in Sudanian warm dry forests of western Africa that range between 3.6 to 10.1m 2 per hectare (Timberlake *et al.*, 2010).

Sacred grove and climate change mitigation in Mandara Mountain

According to Brown and Adger (1994) conservation of forests, including those under the control of local communities in developing countries, is an important component of a comprehensive climate mitigation strategy. This study identified sacred grove of Mandara Mountain as an important carbon sink due to the relative high diversity of plant species which significantly contribute to reduce atmospheric carbon. The quantity of carbon stock obtained during field investigation range between 20 – 150 $tC.ha^{-1}$, values generally found in semi-arid natural ecosystems (Allen-Diaz et al., 1996; Tiessen et al., 1998).

Acacia senegal, the most represented species in this sacred grove in terms of individuals had been reported by several studies to have a good regeneration (Diallo *et al.*, 2012; Obeid and Din, 1970). The protection of this area from bush fire could help to avoid their destruction and therefore improve its capacity to mitigate climate change.

The presence of three (03) Leguminosae species among the top five most ecological important plants is an indicator for the role of these land uses in atmospheric nitrogen reduction.

Sacred grove as approach to combat desertification in Mandara Mountain

The direct causes of desertification and land degradation come mostly from severe reduction or destruction of the perennial plant cover and simplification of the vegetation structure (Le Houérou, 1968; 1976). Conservation of native vegetation is therefore primordial to combat desertification and avoid soil erosion. In some African countries, sacred groves are considered as major participatory approaches for dry land management and combat desertification (Annorbah-Sarpei *et al.*, 1993). Although the total basal area of woody plant species remains low in sacred grove of Mandara Mountain (12.2 m^2 per hectare), the wide coverage of herbaceous plant species enables it to ensure its soil protection function.

Conclusion

Mandara Mountain ecosystems are among the most vulnerable in the semi-arid area of Cameron because of its high rate of land conversion. In this context, the current study highlights the key role of sacred groves of this zone in addressing some environmental problems including biodiversity loss, climate change and desertification. The main results obtained include relative high value of diversity indexes, carbon stock and woody basal area. These results suggest that the sacred groves of Cameroon dry lands need to be taken into account in national environment protection policies as an alternative to respond to international agreements related to biodiversity conservation, combatting desertification and climate change.

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