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Deforestation, biodiversity and biomass losses in Kribi deep sea port area (Cameroon): Some mitigating measures

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This study is part of the environmental impact assessment realised in the deep sea port area of Kribi. Floristic inventory and diversity assessments were necessary to understand the species composition and diversity status of forests, trees biomass and investigate the potential impact of the project. Floristic analysis shows a high Shannon diversity index (5.3), indicating a rich and diverse flora composed of 83 species, 73 genera and 29 families among which one endanger species (*Diospyros crassiflora*), two lower risk/near threatened species (*Dialium bipendense, Irvingia gabonensis*) and vulnerable species mostly wood with high marketing value (*Afzelia bipindensis, Entandrophragma angolensis, Entandrophragma utile, Khaya ivorensis, Lovoa trichilioïdes, Pterygota macrocarpa*). The mean basal area (28 to 50 m²/ha) reflects the presence of patches of disturbed and non disturbed forest with high frequency of small size trees and few canopy trees with large buttresses. Tree biomass is estimated at 2840 Mg (379 Mg/ha) and carbon stock 189.31 MgC/ha. Ecological impact can be mitigating by a management plan which includes a sustainable choice of urbanization and an emphasis on the protection of biodiversity in the remaining forest especially Campo Ma'an national park known as hot spot of biodiversity and where all the censored species can be found.

Key words: Cameroon-Kribi, deep sea port, deforestation, biomass, mitigating measures.

INTRODUCTION

Biodiversity losses and species extinctions over the next century are expected to be high, driven largely by climate change and land use changes that convert natural vegetation to agricultural and urban uses (Brooks et al., 2002; Dirzo and Raven, 2003). The biodiversity is actually considered as a major driving force behind efforts to reform land management and development practices worldwide and to establish a more harmonious

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relationship between people and nature (Noss and Cooperrider, 1994). The construction of development infrastructures are among human activities that pose the highest threat to the conservation of biodiversity. Such projects represent artificial elements that cut through the landscape and interfere with the natural habitat conditions (Geneletti, 2002). The Kribi deep sea port is the linch pin of vision 2035, the projected year for the socio- economic emergence of Cameroon. The port will be a hub of trade for the entire central African countries and will significantly contribute to the wealth and sustainable development of Cameroon and the sub region. The sea port and the accompanying industrial and urban area will cover 26,000 ha. The residential area is expected to welcome approximately 300,000 inhabitants in 2040. If it is known that the deep sea port will boost the economy of Cameroon, it is also important to note that the project will cause an environmental degradation and the depletion of natural forest. The project needs to be sustainable in economical, social, spatial and environmental sense. Such concerns made evident the necessity for the planning authorities to get information about the possible environmental consequences of development actions. Therefore, Environmental Impact Assessment (EIA) is one of the appropriate tools available to satisfy this need and usually employed during the authorisation process to provide decision-makers with useful information for taking a decision. EIA is now applied worldwide, its potential role in attaining sustainable development objectives was recognised during the Earth Summit held in Rio de Janeiro in 1992 and take into consideration by Cameroonian laws n° 94/01 of 20 January 1994 on forestry, wildlife and fisheries as well as the decree n° 96/12 of August 1996 which recommends for large projects the development of Environmental and Social Impact Assessment (ESIA) to prevent risks and anticipate mitigation solutions. Our interest was to assess floristic diversity and tree biomass and investigate the potential impact of the project on the biodiversity. These informations are usefull to reduce and minimize habitat loss, habitat degradation, and fragmentation and promote landscape linkages which can help to mitigate the effects of the project on species extinctions and biodiversity loss (Von Haaren and Christian, 2011; Roel and Paul, 2013).

MATERIALS AND METHODS

Baseline study

The baseline study consists of the description of the area which will be affected by the project. It requires the collection and the processing of various types of data such as maps, record of floristic and environmental parameters. Some data are obtained from scientific literature and other from field surveys and interpretation of data. These informations serve to set a reference for the subsequent impact analysis. Moreover, it helps decision-makers to become familiar with the environmental features and the needs of the study area (Geneletti, 2002).

Geographic localisation of Kribi deep sea port

The Kribi deep sea port is based in south region of Cameroon, Ocean division and is extend on about 30 km along the coast line from Kribi 1 subdivision to Lolabé 3. The eastern border is the river Lobé which flows in the Ocean close to Kribi. The western border is the coastal line of the Atlantic Ocean. The entire project area is covered with a tropical forest which is part of the biafran rain forest belt (Figure 1).

Aspect of the vegetation in the deep sea port area and nearest forests

The forest consists of evergreen trees forming a fairly continuous canopy with emergent trees. This forest type is characterized by its dominance by Caesalpinioïdeae and Humiriaceae with many species that occur gregariously. Many emergent and canopy trees have large buttress (up to 6 m) and large diameter (greater than 2 to 3 m above buttress). The literature (Gonmadje et al., 2011; Jonkers and Van Leersum, 2000; Ngueguim, 2013; Onana and Cheek, 2011; Tchouto, 2004) indicates that the area has many species of high conservation priorities. The conservation value of the Campo Ma'an national park which is clooser of the site is high at local, national, regional and global levels. The area is recognized to be an important site within the Guineo-Congolian regional centre of endemism. The Campo Ma'an area and nearest forest contain about 2297 species of vascular plants comprise of 114 endemic plant species, 29 species restricted to the area, 29 species occuring just in the south western part of Cameroon such as in the Campo Ma'an national park and Ngovayang's lowland forests. A total of 17 plant species strictly endemic to the area and not found in the park, are threatened since their habitats are fragmented and disturbed as a result of past and present land conversion for people subsistance and industrial plantation (Tchouto, 2004). According to the Red data book of the flowering plants of Cameroon, IUCN global assessments, the south region of Cameroon, among which the Campo Ma'an national park and its surroundings belong to the meso hotspots of 50 to 100 threatened species (IUCN, 2004; Onana and Cheek, 2011). Kribi-Campo is part of the low Guinean forest, and has been recognized as the richness phytochoria endemic and rare plant species in Cameroon (Onana, 2013).

This high endemism and richness may be due to the fact that the site is close (Maley, 1987) or part (Sosef, 1994) of a series of postulated rain forest refuge areas in Central and West Africa. Despite this great biological importance, these forest ecosystems suffered from high human pressure which leads to the degradation of most of the forest along the coast and the lowland forest around settlements. The main conservation effort has been the creation of a technical operational unit (TOU) in August 1999 and one year later, the Campo Ma'an National Park within the TOU.

Tract selection and distribution

Floristic inventory and diversity studies are used to understand the species composition and diversity status of the forests (Phillips et al., 2003). A line transect approach was chosen to sample forest diversity; a total of 19 transects set up over 7.5 ha in the various vegetation types were surveyed. The transect line have 20 m wide and different length (150 to 200 m). All trees with diameter at breast height (dbh) greater than 10 cm were recorded, identified, measured with a diameter tape. Tree species with dbh greater than 10 cm are assumed to reflect the floristic composition and physical structure of the forest. Trees were identified up to species level, and in some cases just up to genus level. For unknown species, voucher specimens were collected for further identifications at the National Herbarium of Cameroon. The measured trees provided

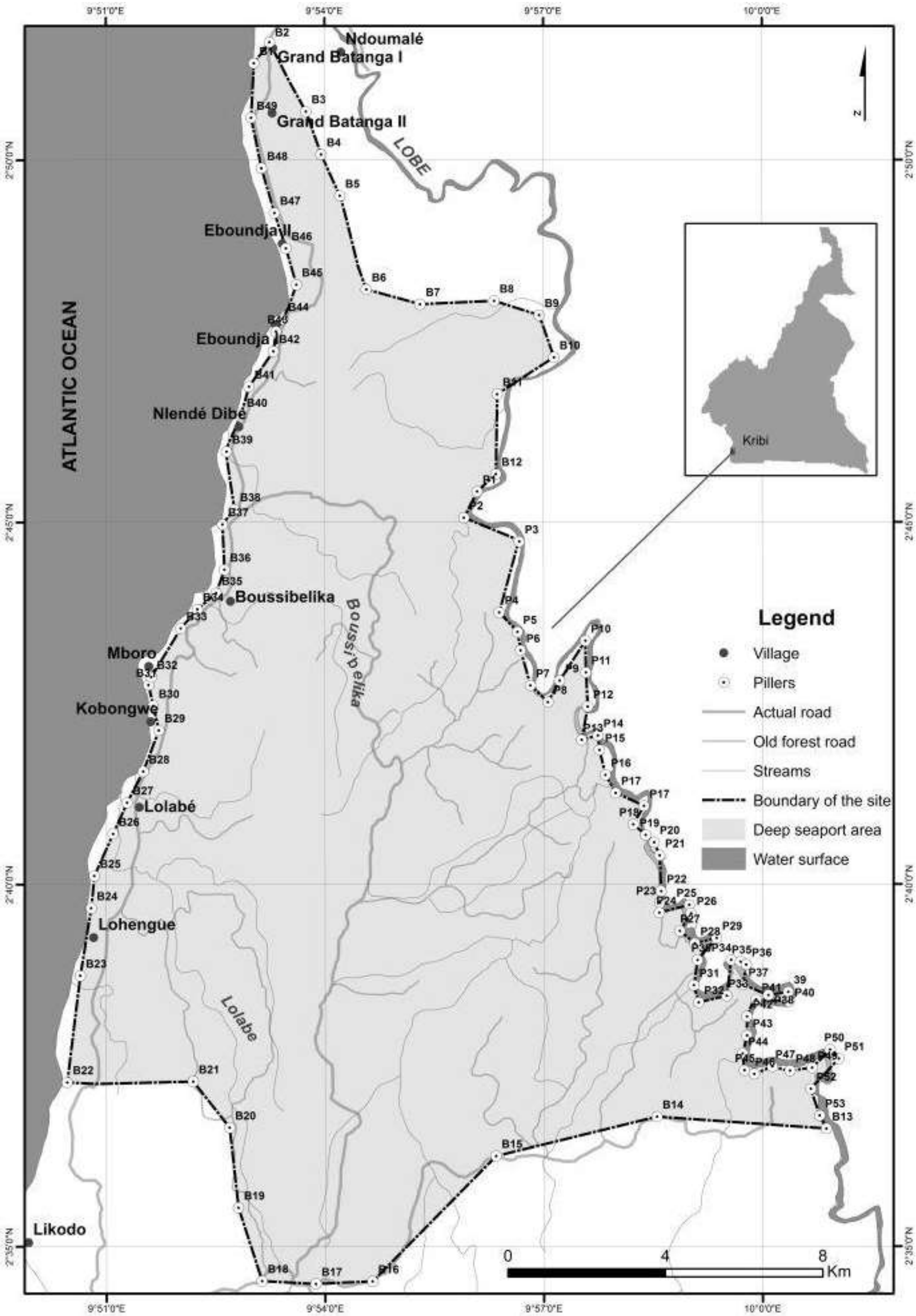

Figure 1. Map of the Kribi deep sea port area.

Table 1. Diversity index of periodically flooded forests (PFF) and terra firm forests (TFF). BA: basal area; N: tree density; RS: species richness; H': Shannon's index.

Types of forests	BA (m²/ha)	N (trees/ha)	RS	H'
Periodically flooded forest (PFF)	8.5	72	43	4.7
Terra firm forest (TFF)	50	453	81	5.3
Total in the KHP forest	28	249	83	5.3

quantitative information on the stand structure and floristic composition of the forest, while qualitative information on species richness was provided by qualitative samples.

Data analysis

Dendrometric parameters

All surveyed data were entered into Excel software. Phytosociological parameters such as basal area, relative density, dominance and frequency, important value index, and Shannon diversity index (H') were used to describe the forest structure and composition, and to measure the species richness and diversity of the various vegetation types.

$$Basal\ area = \frac{\sum \P\, D^2}{4}$$

$$Density\ of\ trees = \frac{\text{Total number of trees}}{\text{area}}$$

$$Relative\ abundance = \frac{\text{Number of individual of the species}}{\text{Total number of individual}} \text{ x } 100$$

$$Relative\ dominance = \frac{\text{Total basal area of species}}{\text{Total basal area of all species}} \text{ x } 100$$

Important value Index (IVI) = Relative abundance + Relative dominance

Shannon diversity index (H') = $\sum p_i \ln p_i$ where $p_i = n_i /N$

where n_i = number of individual of species, N = total number of individuals, and ln = log $base_n$

Biomass estimation

Biomass was estimated using allometric regression models to convert trees diameter measurements from the inventory data to an estimate of Above Ground Biomass (AGB). The moist forest equation delivered by Chave et al. (2005) was used:

$$AGB = \varphi .\ \exp\ [-1.499 + 2.148\ \ln(D) + 0{,}207(\ln(D))^2 - 0{,}0281\ (\ln(D))^3]$$

where D = dbh and φ = wood mass density compiled from the wood density database (http:// worldagroforestry.org/sea /Products/ AFDbases/WD/ Index.htm). In case of the lack of information on the wood density of some species, the average wood mass densitity recorded by Brown (1997) for FAO data concerning tropical Africa species was used (0.58 g/cm^3). The carbon stock was calculated by dividing the AGB values by two.

The species observed from the inventory has been assessed using the IUCN criteria and categories at the global level (IUCN, 2001 ver.3.1). The Hierarchical Ascendant Classification (HAC) will help to constitute floristic groups with different characteristics.

RESULTS

Forest diversity, abundance and guild composition

In total, 1871 trees, shrubs and other vascular plants were recorded, they belonged to 83 species, 73 genus and 29 families. All the records were identified at the species level. Overall, the most diversify and abundant families are Fabaceae (24 species and 23% of the relative abundance, where Caesalpinioïdeae has 17 species (22%)) and Sterculiaceae (6 species, 9%)). The most abundant species are *Uapaca guinensis* Müll.Arg. (10%), *Dialium zenkeri* Harms (7%), *Didelotia africana* Baill., *Diospyros crassiflora* Hiern, *Mammea africana* Sabine, *Coelocaryon preussii* Warb. (5% each), *Gilbertiodendron dewevri* (De Wild.) J. Lénoard., and *Coula edulis* Baill. (4% each).

The mean number of stems/ha for all vascular plants varies from 72 (286 stems) in periodically flooded forest (PFF = 4 ha) to 453 (1585 stems) in terra firms forests (TFF = 3.5 ha). For the entire forest, the tree density is estimated at 1871 trees (249 stems/ha). The mean basal area/ha varies from 8.5 m²/ha in PFF to 50 m²/ha in TFF. In general, the area is characterized by low mean basal area (28 m²/ha) due to the high frequency of small size trees and few canopy trees with large buttresses. The PFF is species poor and less diversify (43 species) than the TFF (81 species). The forest is characterized by a rich and diverse flora as indicated by the value of Shannon diversity index (H') which is relatively high and varied from 4.7 in PFF to 5.3 in the TFF (Table 1).

Table 2 shows dendrometric parameters of the most important species and families. One can notice that *Sacoglottis gabonensis* is the most important specie; its importance is due to the large size of trees (showing by the high value of basal area), while at the second and third rank *D. zenkeri*, *U. guinensis* have many stems composed by small size trees. The most important families are Fabacea followed by Myristicaceae and Humiriaceae. Fabaceae are the most important families in the various vegetation type, the ranks of the other most important species differed among forest type and with the index used (relative stem density or relative basal area). Based on their IVI, *S. gabonensis, D. zenkeri, U.*

Table 2. Summary of the number of trees (N), basal area (BA) and Important Value Index (IVI) of the various type of vegetation for all plants with Dbh ≥ 10 cm recorded.

Espèces	**N**	**BA**	**IVI**
Sacoglottis gabonensis	52	39	21
Dialium Zenkeri	138	18	16
Uapaca guinensis	183	13	16
Coelocaryon preussii	88	11	10
Didelotia africana	102	9	10
Gilbertiodendron dewevri	77	9	9
Pycnanthus angolensis	26	14	8
Diospyros crassiflora	100	4	7
Mammea africa	98	4	7
Coula edulis	67	4	6
Family	**N**	**G**	**IVI**
Fabaceae	425	59	51
Myristicaceae	172	29	23
Humiriaceae	52	39	21
Euphorbiaceae	214	14	18
Irvingiaceae	148	15	15
Sterculiaceae	160	9	13
Clusiaceae	121	6	9
Olacaceae	94	7	8
Ebenaceae	100	4	7
Burseraceae	63	6	6

guinensis and *D. africana* Baill. had the most important contribution in the PFF, while *S. gabonensis, U. guinensis* and *D. zenkeri* were among the most important species in TFF.

Red data taxa of Kribi – Campo area

The 83 recorded species composed of one endanger (EN) species (*D. crassiflora*) with a relative abundance estimated at 5.34% of the tree population; others are vulnerable (VU) species (2.03%) mostly comprising of wood species with high marketing value (*Afzelia bipindensis, Brachystegia kennedyi, Entandrophragma angolensis, Entandrophragma utile, Guarea cedrata, Khaya ivorensis* A. Chev.*, Lophira alata, Lovoa trichilioïdes, Pterygota macrocarpa* K. Schum.*,* and *Scorodophloeus zenkeri* Harms). About 89.47% of the recorded species do not have a particular status of protection. A survey at large scale (14.7 ha) done by Tchouto (2004) in the area indicate the presence of 11 critically endager (CR) species, 8 EN species and 56 VU species.

Multivariate analyses

The Hierarchical Ascendant Classification (HAC) based on tree biological parameters (Diameter, basal area, IVI, density) shows 3 groups. Inside the groups, one can notice the individualization of some plots (Figure 2). Trees are more or less arranged in three strata. In Group 1, we have large emergent and upper canopy tree species (about 30 to 50 m tall) such as *Piptadeniastrum africanum* (Hook.f.) Brenan*, S. gabonensis, P. angolensis,* and *G. dewevri.* The Group 2 is composed of trees of the intermediate storey with about 20 to 30 m high among which *Desbordesia glaucescens* Engl. Tiegl*, Klainedoxa gabonensis* Pierre*, Ongokea gore* (Hua) Pierre*, D. zenkeri* Harms*,* and *K. ivorensis*; while Group 3 represents the understorey with trees with less than 10 m high, discontinuous and consist of immature trees of upper strata and other small trees and shrubs. This group includes species like: *C. preussii, D. crassiflora, Musanga cecropioïdes* and *D. africana*. In general, the sea port forest is an old secondary forest characterised by a poor density of small trees in the undergrowth, high number of large trees and less pioneer species usually found along roads, logging paths and forest gap.

Forest structure and biomass estimation

The diameter distribution pattern of the stems were almost similar among the various types of vegetation and most of the transects were characterized by a high

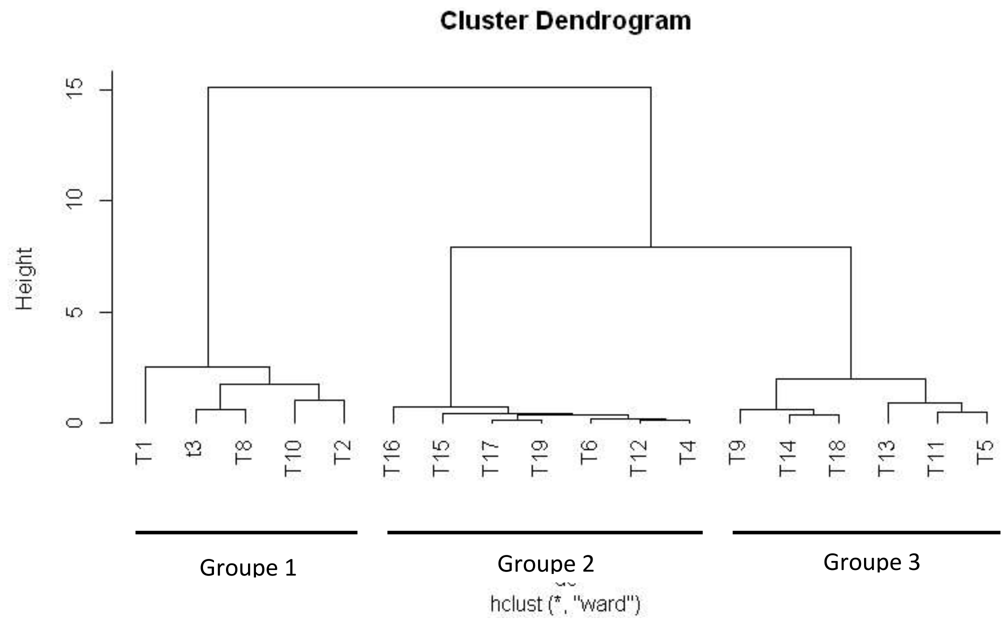

Figure 2. Hierarchical Ascendant Classification (HAC) of 83 species of vascular plants with Dbh greater than 10 cm recorded in 19 transects with different length and 20 cm size, based on tree biological parameters.

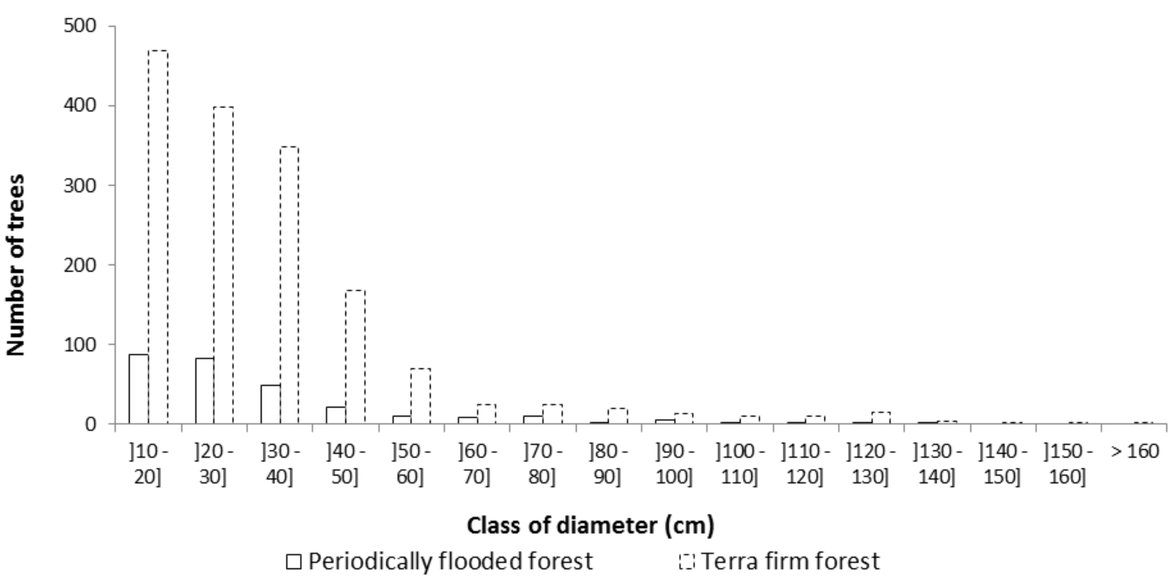

Figure 3. Variation of the density of trees with diameter class (cm) in the different type of forest.

density of stems (10 ≤ Dbh ≤ 30 cm) and a paucity of trees above 50 cm Dbh with a tendancy of large canopy trees in non disturb area especially in the hill and swamps (Figure 3). The stems are more abundant in terra firm forest in all the size class. The high number of trees in the first diameter class indicates a vigorous regeneration, while the presence of large trees with high diameter value shows that we are in an old forest. The sea port forest is constituted by patches of disturbed and non disturbed forest.

The total biomass estimate for the forest is 2840 Mg equivalent to 379 Mg/ha. These values varied significantly between the types of forest, respectively estimated at 117 Mg/ha for PFF and 677 Mg/ha in TFF. Most Above Ground Biomass (AGB) was found in trees with large diameters in the two types of forest. Individuals

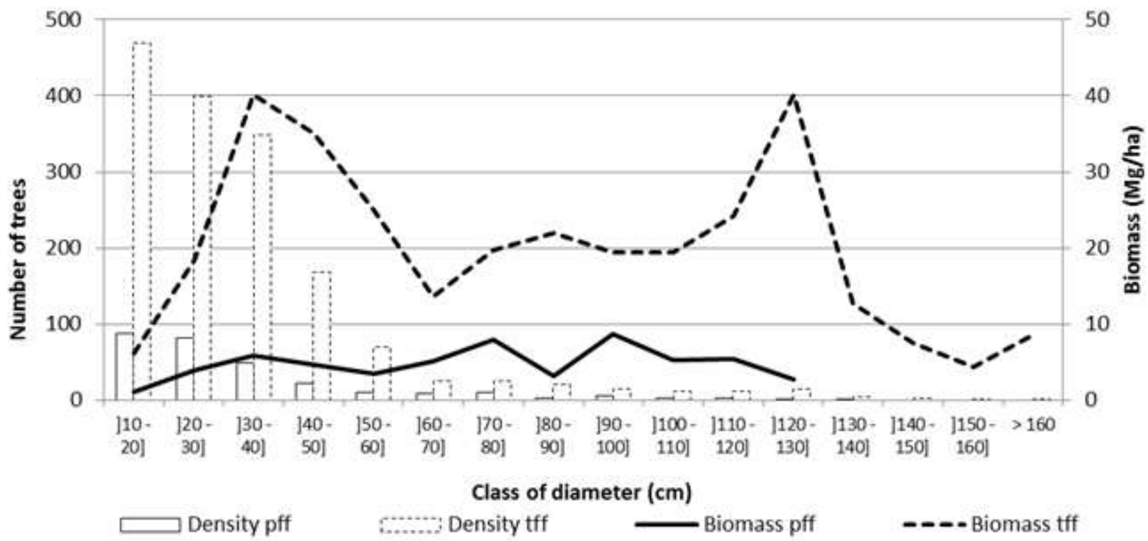

Figure 4. Variation of density and biomass depending on diameter classes in the different types of forests.

Table 3. Ten top species with the highest value of Above Ground Biomass in the deep sea port forest.

Species	N	Mean diameter (cm)	Standard deviation (cm)	AGB (Mg/ha)	AGB (%)
Sacoglottis gabonensis	52	91.92	32	87.86	23.20
Pycnanthus angolensis	26	76.35	36	32.14	8.49
Dialium Zenkeri	138	35.17	20	31.10	8.22
Coelocaryon preussii	88	36.36	18	19.27	5.09
Uapaca guinensis	183	26.91	12	18.35	4.85
Gilbertiodendron dewevri	77	33.44	21	16.68	4.40
Didelotia africana	102	28.57	17	14.64	3.87
Piptadeniastrum africanum	4	90.75	97	11.70	3.09
Klainedoxa gabonensis	21	52.64	26	11.24	2.97
Pachyelasma tessmanii	9	59.44	41	7.76	2.05
Total	700	53.16	32	250.73	66.22

with diameter greater than 50 cm accounted for 76% of the biomass in PFF and 68% in TFF. Variation in the abundance of trees with large diameter was the main reason for these differences (Figure 4).

Tree biomass allocation by different families and species

Few dominant species made the greatest contribution to the AGB. The top five species with the most important AGB contributed, in the entire site for 53.85% of the total biomass, with mean diameter of the stems of the group estimated at 53.34 ± 23.60 cm and a total stems 487 individuals which represent 26% of the trees population (Table 3).

The top five families contributed to 78.25% of the total biomass, with mean diameter of the stems of the group estimated at 46.24 ± 26 cm and a total stems 1011 individuals which represent respectively 54% of the trees population. The most important family according to their AGB are Fabaceae (28.42% where Caesalpiniaceae represent 24%) and Humiriaceae (23.18%) (Table 4).

DISCUSSION

Comparison of the floristic richness of Kribi deep sea port forest with other tropical forest

This study shows that the deep sea port area has a rich and diverse forest, rich in Caesalpinioïdeae, mixed

Table 4. Ten top families with the highest value of Above Ground Biomass in the deep sea port forest.

Species	N	Mean diameter (cm)	Standard deviation (cm)	AGB (Mg/ha)	AGB (%)
Fabaceae	425	44.93	40.43	107.72	28.42
Humiriaceae	52	91.92	32.24	87.86	23.18
Myristicaceae	172	37.68	26.62	55.59	14.67
Irvingiaceae	148	30.34	18.33	24.76	6.53
Euphorbiaceae	214	26.35	12.19	20.64	5.45
Sterculiaceae	160	24.91	10.36	12.59	3.32
Rubiaceae	56	30.93	19.53	10.15	2.68
Olacaceae	94	27.87	11.37	9.66	2.55
Clusiaceae	121	21.32	13.22	8.86	2.34
Burseraceae	63	32.55	11.04	8.83	2.33
Total	1505	36.88	19.53	346.66	91.47

evergreen and semi deciduous forest, periodically flooded, swamp forest, riparian vegetation, and secondary forest. Considering the Important Value Index (IVI), Caesalpinioïdeae was the dominant subfamily while *S. gabonensis* was the dominant species. The species of Caesalpinioïdeae subfamily were codominant and their abundance varied with the type of vegetation. Some of them were gregarious with a high regeneration capacity and many juvenile trees.

The specific richness of the forest is also important like those observed in other tropical forest as indicated by the low value of the report number of species over number of genus (E/G) and the high value of Shannon diversity index (H’). The high value of H’ corresponds to the good condition of the environment which favours regeneration of many species which composed of few numbers of individuals. This tendances of high diversity associated to low density of each species is always observed in tropical forest (Swaine et al., 1988; Peters, 1997). The site has a low basal area (28 to 50 m²/ha) like that of some disturbed forest of southern Cameroon (Ngovayang’s lowland forest: 29 to 42 m²/ha) compared to that of less disturbed forest such as Campo Ma’an national park (87 m²/ha) and Bawangling a Chinese natural reserve (54 m²/ha) (Table 5).

Impact assessment: Forest clearing and their influences on rural community survival, biodiversity conservation and environment

Habitat lossess

The clear cutting of the forest in the project area has many impacts such as the direct loss of ecosystems and the fragmentation of ecosystems. The project affected the floristic composition notably species density, abundance, distribution and their ecological importance. Disturbance of wet habitats like swamps can also contribute to loss of wetland biodiversity. In the context of disturbance and deforestation, species with low dispersal capability will be the first one affected. In case low dispersal, capability is combined with low possibility to survive during critical periods, the extinction risk increases. Various researches indicated that the probability of extinction increases dramatically when less than 10 to 30% of the original habitat area remains (Andrén, 1994). This is not the case for the censured species which can be found in the Campo Ma’an national park and in various other area of cameroonian dense humi forest where the beneficiate for a suitable and protected habitats (Raulund et al., 2011).

Long term disturbance

The kribi deep sea port area is mostly composed of people that rely on the sea and forest for their livelihood and have fishing and forest product gatherers as their main occupation. The clearing of the forest will seriously affect their life. The project will quickly contribute to increase the density of the population. Some people will be employed in the port and accompanying industries, others will be obliged to develop private activities to meet up with their basic needs. This can have some ecological impacts on the environment.

Deforestation due to agriculture practices/agro industries

Clearing of the natural vegetation to provide land for industries and agroindustries, subsistance agriculture and the port infrastructures are the biggest threats to the forest. Few years ago, large scale agro-industrial plantations destroyed about 7.5% of the forest covered in this area, this rate will significantly increase in the future. An analysis of Onana and Cheek (2011) in anonymous (2014:5) indicates that one of the main causes of the impoverishment of biological diversity for the threatened species is due to the degradation of the habitat which

Table 5. Comparison of tree density, specific richness, generic richness, specific quotient (E/G), Shannon diversity index and basal area of deep sea port forest to that of some tropical forests [1. Ngueguim (2013); 2. Sonké (2004); 3. Djuikouo et al. (2010); 4. Tchouto (2004); 5. Gonmadje et al. (2011); 6. Nshimba (2008); 7. Ukizintambara et al. (2007); 8. Scotto Di Vettimo (2010); 9. Naing et al. (2011)].

Sites	Code	Stations forestières	Density	Species	Genera	Species/Genus	H'	Basal area
		Deep sea port forest	249	83	73	1.14	4.7 - 5.3	28
	1	Mangombé	708	91	78	1.16	5.52	49
	1	Bidou	538	88	80	1.10	5.41	54
	1	Campo	569	75	68	1.10	5.40	87
Cameroun	2	Reserve de biosphère du Dja	352 - 460.4	281 - 372	215	1.44	5.62	29 - 37.5
	3	Parc National de Campo *		1116	421	2.65	/	58 - 89
	4	Ngovayang's lowland forests (South Cameroon)	532 ± 75	293	170	1.72	4.12	29 - 42
	5	Ile Mbiye, RDC*	-	470	297	1.58	/	
	6	Gabon - Lopé	742 - 932	251	/	/	/	19.5 - 58
Asie	7	Chine, natural reserve of Bawangling	755 ± 170	305	134	2.3	4.75	54
	8	Parc de Popa, Myanmar (Asie du sud Est)	604 ± 39	38 - 68	32 - 54	0.84 - 0.79	/	17 - 38

contributes for 76.6% of the decline of population according to the generations. When a species has a very low number of known individuals and is confined in a small number of localities, the rate of losses is estimate at 8.8% of the population through a generation (Anonymous, 2014). Slash and burn agriculture mostly practices in the area represents one of the major causes of degradation and deforestation around settlements since it involves land conversion from forest to permanent agricultural land, reducing the soil fertility and the natural vegetation covered. These practices can potentially eliminate or severely deplete the population of any localized endemic or threatened species of herb, shrups, liana or small tree. The presence of such important species might be unknown by the farmers (Onana and Cheek, 2011).

Legal and illegal logging

Timber exploitation is one of the main economic activities in the area. Logging concession represents about 31.4% of the area. The main wood species with high marketing value observed during the survey is estimated at 19 species, equivalent to 16.30% of the tree population. Tchouto (2004) estimated about 112 wood species in the Campo-Kribi area among which only 60 are exploited. According to the literature, the coastal zone has been selectively logged at least twice during the past 50 years. Less than one tree/ha is felled and logging is limited to about 60 trees species (Jonkers and Van Leersum, 2000). Any degree of damage represents a capital loss in terms of trees and deterioration of the biotic and physical environment. Logging creates skid trails that allow easy access for poachers and encourage settlers to establish forest camps, villages and farms. Furthermore, logging damage includes breakage of samplings and residual sterms and hinders the growth of seedlings by discarded crowns of felled trees (Parren, 2003).

The specific composition of the forest shows that the vegetation is actually strongly influenced by human activities. The presence of secondary species like *L. alata* and *Pycnanthus angolensis* characterize mature secondary forest. It is also important to notice that the replacement of forest in the coastal area of Cameroon into land use types began centuries ago, and results in the degradation of vegetation (Maley, 2002; Oslisly, 2001). Archeological exploration shows the presence of village along the coast in Lolabé (village in the port area) dated 3000 to 2500 BP (Ossa Mvondo, 1998) indicating that coastal forest may have undergone some changes in the past.

Non timber forest product (NTFP)

Southern forest offers about 250 Non Timber Forests Products (NTFPs), these forest products form an integral part of the rural economy and contributes to all aspects of rural life, providing food, fuel, employment, building materials,

Table 6. Comparison of the biomass and carbon uptake of the Kribi deep sea port with those of some tropical forests. [1. Kira (1971); 2. Chave et al. (2001); 3. Djuikouo et al. (2010); 4. Mugnier et al. (2009); 5. Zapfack et al. (2013); 6. Ngueguim (2013)].

No.	Sites	Biomass (Mg/ha)	Carbon (MgC/ha)
	Deep sea port forest	378.62	189.31
1	Tropical forests	148 - 669	74 - 334.5
2	French Guiana (Nouragues)	309	154.5
	French Guiana (Piste de Saint-Elie)	260	130
3	Dja Biosphere Reserve (Cameroon)	383.14 - 596.1	191.57 - 298
4	Congo Basin	324 - 300	162 - 150
5	Primary forest Lobeké national park Cameroon	247.52 ± 68.64	123.76 ± 34.32
	Secondary forest Lobeké national park Cameroon	237.20 ± 73.24	118.60 ± 36.62
	Bidou (10 km from port, south Cameroon)	738	369
6	Campo Ma'an national park (south Cameroon)	1277	638.5
	Mangombe (littoral region of Cameroon)	611	305.5

medecine, craft material, household items, ornamental and horticultural plants. The harvesting of NTFP is mostly done in the area for local consumption, but very few of the local people rely on it as source of income. So far, the gathering of NTFPs has little effect on the forest ecosystems and the biodiversity.

A total of 19 species known as NTFPs were recorded, they are estimated at 22.66% of the total number of stems. The most abundant are *Mammea africana, Irvingia gabonensis, C. edulis* and *Cola acuminata*. In the Kribi - Campo area, Tchouto (2004) indicate the presence of 249 species of NTFPs. The clear cutting of the forest can reduce the stock of some species like *Enantia chloranta*, the bark is harvested and used to cure malaria and fever. *C. edulis*, the fruits are consumed or sold in the local market. *Pausinystalia johimbe* the bark is used to perform genital organs while the fruit of *I. gabonensis* are eaten as spices, the marketing chain of this species extend to Gabon, Nigeria and some Europeans country (France, Italia, Germany).

Losses of forest biomass and carbon uptake

A precise knowledge of the biomass is crucial for harvesting assessments (Vanclay, 1995) and, at a much larger scale, for the study of greenhouse warming scenarios (Houghton et al., 2000). Atmospheric carbon uptake by the vegetation is believed to play a major role in the global climate changes of the century to come. An estimated 37% of the world's living terrestrial carbon pool is stored in tropical forests. Table 6 indicates that the value of biomass (378.62 Mg/ha) and carbon stock (189.31 MgC/ha) in the deep sea port forest is higher than that obtained in some tropical forests such as French Guiana where the trees biomass is estimated at 260 to 309 Mg/ha and the carbon uptake (130 to 154.5 MgC/ha) and lower than the value observed in Bidou (site distance from 10 km of the port) (738 Mg/ha biomass and 369 MgC/ha).

How to attenuate and mitigate some potential impacts of the deep sea port project?

The proposed solutions to attenuate and mitigate impacts of the project follow some of the five approaches recommended by George (2000). They will come together to reduce, restore and compensate impacts of the project such as to the following.

Improve ecological sustainable agriculture

Shifting cultivation is among the most destructive uses of the forest since it involves large amount of land conversion from natural forest to farms and fallow. In order to prevent further encroachment into the remaining lowland and coastal forests, farmers need to intensify their agriculture production systems. Crop production need to be increased in the existing agricultural land to feed the growing population. This need the professionalization of agriculture for food supply, to modernize agriculture practices through an adequate training of farmers on nursing, planting, maintenance, harvesting, storage, and marketing techniques in order to stabilized farms, stopped shifting cultivation and improve food production.

Implication for biodiversity conservation

The survey indicates that all the recorded species are present in the Campo Ma'an National Park (not far from the project area), where they benefit from an integral protection. In a short term, the population density in the area will considerably increase, and this will represent a serious threat for the ressource in the park. In such a situation the measures taken to protect the park, needs to be reinforce.

The rate of forest degradation is likely to accelerate in the near future, as the present trends in the land use patterns of exploitation will persist. Conservation needs are exceptionally urgent in Kribi, Campo area since plant species of great scientific interest are under severe threat. There is an urgent need for the developement of a separate management plan strategy in order to ensure the protection of the biodiversity hotspot and their endemic species. For example we can encourage other forms of land use such as community and communal forest recognized by Cameroonian forest law and compatible with the conservation of biodiversity, since their management is not only focused on nature conservation but also takes into consideration community interests. In each of these forms of forest, the beneficiary most identify biodiversity hotspot as the core conservation area surrounded by a buffer zone in which the sustainable management of non timber forest products and hunting are developed. Nowadays, as the forest loss increase, a careful sustainable land use strategy in the buffer zone surrounding the national park of Campo Ma'an and other identified core biodiversity hotspots is neccesary for their long term survival and the protection of the species of high conservation priority.

Conservation and environmental education

The biodiversity conservation is a new concept that needs to be mastered and understood by the local communities. This mis-understanding usually results to permanent conflict between conservation initiatives and the needs of the stakeholders (communities, logging industries, agro-industries). This necessites the reinforcement of environmental education progams in the area at all levels within different target groups such as traditional leaders, elite, farmers, timber exploiters, agroindustrials, and local administive authorities.

Afforestation and recreational value

The project will need a best and sustainable choice of urbanization of the Kribi-Campo area and implementation of urban forestry which will consist of plant trees and install garden and green space in some appropriate points of the town. The uses of teledetection and high-resolution satellite image can help to survey along the years evolution of landscape and vegetation around the project area.

Conclusion

The sea port forest is constituted by patches of disturbed and non disturbed forest. The disturbed area is reduce and generally covered with pioneer vegetation and has a low conservation value while the patches of natural forest have been weakly disturbed. However, the disturbed forest still has some ecological value. There are several habitat types, the most common are: riverine forest, swamp forest, few Raphia forest, old and mature forest. The evaluation of conservation potential of the 83 recorded species shows one endemic species (*Dialium bipendense* Harms), one endanger species (*D. crassiflora*) and 10 vulnerable species (2.03%) most composed of wood species (*A. bipindensis, B. kennedyi, E. angolensis, E. utile, G. cedrata, K. ivorensis, L. alata, Lovoa trichilioides, P. macrocarpa,* and *S. zenkeri*). A large majority of plant species identified within the project are used as food, medicine and construction materials. All the recorded plant species can be found in the Campo Ma'an National Park where they benefit from protection according to Cameroonian forest law. Few dominant species made the greatest contribution to the AGB in the studied forest.

Installation of the port and the accompanying industries will lead to the clearing of many hectares of forest and losses of biodiversity and their socioeconomic and ecologic services. Associated to this, the increasing number of inhabitants within a short term in this area will also contribute to disturb the remaining forest for subsistence and economic activities such as illegal logging, shifting agriculture, and urbanization. To mitigate the environmental impacts it would be better to: (i) create a sustainable choice of urbanization of the Kribi Campo area; (ii) manage the entire coastal zone; (iii) improve ecological sustainable agriculture; (iv) reinforce the protection and management of the Campo Ma'an national park and the buffer zone, (v) promote the conservation and environmental education and (vi) develop urban forestry.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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