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Availability and size class distribution of the most popular Indigenous fruits trees and implications for sustainable harvest around the Ivindo National Park, Gabon

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A study was carried out in "the often" and "the rarely" harvested locations of the Ivindo National Park (Gabon) to determine the availability, height and Diameter at breast height (DBH) size class distributions of *Coula edulis, Dacriodes buettneri* and *Irvingia gabonensis,* the three most popular Indigenous fruits (IFs) used by local people for meeting their livelihoods needs around the Ivindo National Park (INP), Gabon. In total 18 sample plots measuring each 20 × 10 m (six), 2 × 2 m (six) and 1 × 1 m (six) were purposely centered around identified mature trees, sapling and seedling individuals following a northeast direction, with three in each harvested location. DBH of mature trees and sapling individuals of the three species were determined and seedling height measured. These tree species were the most abundant in "the often" and "the rarely" accessed locations of the forests and *D. buettneri* was the least abundant in those locations. The poor population structures of seedling, sapling and mature tree species indicate an unhealthy population exposed to disturbances. Since few mature trees have a Fixed Felling Minimum Diameter (FFMD), bigger than DBH size class of (8) (70.0 - 79.9 cm) for *D. buettneri* and DBH size class of (5) (40.0 - 49.9 cm) for each of *C. edulis* and *I. gabonensis* means that the number of mature trees that can be cut off and produce seeds are limited. On-farm tree planting by local people should be encouraged to supply valued fruit trees species and reduce pressure on the protected forests.

Key words: Abundance, size-class distributions, Indigenous Fruits Trees, Sustainable harvest, Ivindo National Park, Gabon.

INTRODUCTION

The importance of forest resources such as indigenous fruit tree species for sustaining the livelihoods of people living nearby national parks is widely acknowledged in many regions of Africa. In the Southern Africa for example, indigenous fruit trees (IFTs) are important forest resources that contribute to improve the livelihoods of many rural people in the Miombo woodlands areas (Packham, 1993; Maghembe et al., 1994; Mateke et al., 1995; Ngulube et al.,

1995; Maghembe et al., 1998; Leakey, 1999; Muok et al., 2001; Saka et al., 2004; Tiisekwa et al., 2004; Akinnifesi et al., 2004; Kadzere et al., 2004; Mithofer et al., 2006; Akinnifesi et al., 2008) as alternative source of nutrition, cash income and food.

In the Congo Basin for example, the second largest tropical forest after the Amazon Basin, many populations living near natural parks make use of indigenous fruit tree species to fulfil their various sustenance's needs (Brandon and Wells, 1992; Leakey and Tomich, 1999; Cernea and Schmidt-Soltau, 2006; Eyog Matig, 2006; Falconer and Arnold, 1988; Mialoundama, 1993; Belcher and Schreckenberg, 2003; Evans, 1993; Ruiz-Pérez et al., 2000; Belcher and Schreckenberg, 2007). However, due to restriction measures for conservation purposes, local populations have often limited livelihood opportunities to meet their households' needs through forest products gathering from the wild (Ghimire, 1994).

This is also true in the case of Gabon, located in Central Africa, wherein most local people living nearby national parks tend to depend on forest products that are important traditional resources including timber and Non Timber Forest Products (NTFPs) bearing fruits also known as Indigenous Fruit Trees (IFTs). These forest products are one of the important traditional resources and represent major sources of food, income generation and healthcare for many rural people in the country (Walker and Sillans 1961; Bourobou-Bourobou, 1994; Bourobou-Bourobou and Posso, 1995; Pineau, 1995; Viano, 2005; Corblin, 2006; Lescuyer, 2006; Sassen and Wan, 2006).

Despite local people livelihoods' dependence on national park resources, the Gabonese government has established a network of thirteen (13) national parks throughout the country covering nearly 2.9 million (11%) ha of total land area (AFDB, 2011) with some of them representing extensions of the previous biosphere reserves. Protection of natural resources, representing one of the commonly adopted approach by the state to manage its natural resources, has started since colonial period with Lopé reserve establishment in 1946 followed by the Ipassa Makokou Biosphere Reserve in 1979. In that approach, rules and regulations exist under the decree on Customary Rights Law of 2004, Forest Code of 2001, and the National Parks Law of 2007 (Gabonese Republic, 2001, 2004, 2007). However, access and use of resources are strictly prohibited in the core area by the National Park Law of 2007, regulated in the buffer zone and let free of use "open access" in the transition area (Gabonese Republic, 2001, 2004, 2007).

Although subsistence harvesting has low negative ecological impacts on the forests (Hall and Bawa, 1993; Arnold and Pérez, 2001; Ticktin, 2004; Belcher and Schreckenberg; 2007), however illegal tree cutting and large-scale commercial trade of valued timber issued from preferred slow growing tree species which are also of multiple uses are not without any negative ecological impacts (Hall and Bawa, 1993; Ticktin, 2004). In Gabon, there is a lack of information on the status of NTFPs throughout the country and that available laws and regulations on protected forest of national parks have not fully considered the livelihoods of rural people even though most park areas used to be utilized by them. Thus, restriction measures that local people face may have negative impacts on their livelihood as other countries have experienced (Brandon and Wells, 1992; Ghimire, 1994; Nepal and Weber, 1995; Neumann, 1997; Kaimowitz, 2003; Adhikari et al., 2004). In addition, illegal practices currently observed may continue to threaten local people livelihood if left unchecked.

Although, industrial logging has been recently banned from all national parks, however illegal tree cutting and increasing collection of fruits, nuts and seeds by local people and the lack of valuable information appeared to be sources of concerns, especially the population's structure and supplies of the tree species directed to meet people livelihoods' needs as well as the ecology of the natural forests where these preferred resources are being harvested.

Several of these tree species highly valued for their fruits and nuts by rural people living adjacent to the forests make the trees vulnerable to depletion. *Baillonella toxisperma* (Moabi) is acknowledged as vulnerable in the IUCN Red List of Threatened species as a result of habitat loss (agriculture), selective logging activities and harvesting and trade of fruits and nuts containing oil) (IUCN, 2014; Sassen and Wan, 2006). One of the key concerns of local people and park managers is the increasing scarcity of these preferred multiple uses species from the wild. Thus, there is an urgent need to address such concerns by carrying out quantitative analyses to assess the effects of "illegal" tree cutting, fruits and nuts harvesting on natural populations viability instead of strict biodiversity conservation.

Without such analyses, it is quite impossible to design appropriate conservation and management strategies of the protected forests (Hall and Bawa, 1993; Peters, 1996a, b; Bruna and Ribeiro, 2005), especially in absence of information on species biology and ecological demographic data on growth rate (Condit et al., 1998), and pattern of use and harvest (Bitariho and McNeilage, 2007; Gaoue and Tictin, 2007). Consequently, it is crucial to estimate the population structure of these preferred tree species as a first step for developing sustainable use and management strategies (Hall and Bawa, 1993;

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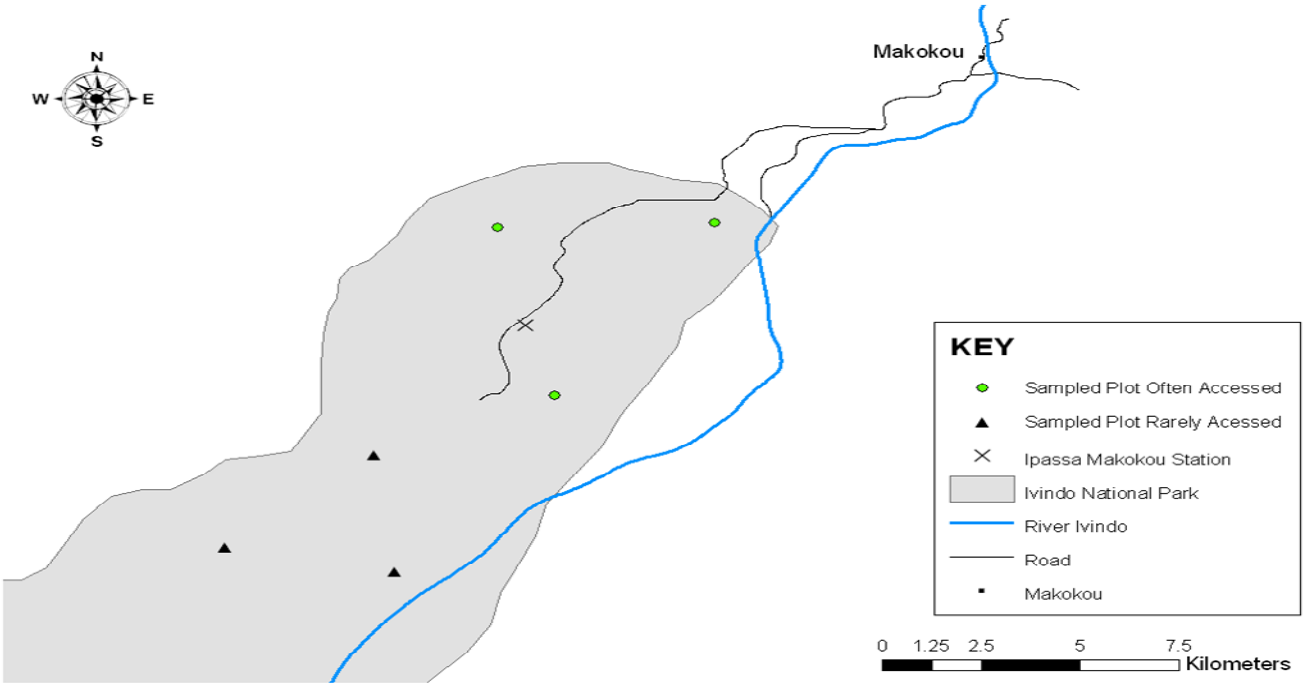

Figure 1. Localization of the study site in and around the Ivindo National Park.

Peters, 1996a,b). In addition, knowledge of the population structure of the target tree species provides useful insight into the availability, survival and habitat characteristics of the species used by local people (Hall and Bawa, 1993; Peters, 1996a,b; Bruna and Ribeiro, 2005) from different locations of forests of the INP that have been exposed to various levels of harvesting.

As a result, this study represents a supportive research that will complement the previous households and market surveys that were already conducted. As overall objective, it is aimed at gathering scientific information on: (i) the possibility of conserving and managing the three fruits tree species used by local people for livelihoods sustenance including *Coula edulis, Dacriodes buettneri* and *Irvingia gabonensis,* and (ii) monitoring changes in the population structure of the target tree species in their natural forests. Specifically, a reconnaissance survey followed by a forest inventory are carried out to : (i) determine the availability and population structure of the three preferred fruit tree species commonly harvested by local people in and around forests of the INP, and (ii) suggest appropriate implications for their sustainable harvest of these target species.

MATERIALS AND METHODS

Study area

The study was carried out in forested areas in and around the Ivindo National Park (INP) in the province of Ogooué-Ivindo, north-eastern Gabon, about 620 Km from Libreville, main capital city of Gabon. The INP is located in central African region (0° 23'-0° 33'N, 0° 42'-12° 49E) (Figure 1). The INP is one of the 13 national parks that was established in 2002 by a presidential decree. The climate of the region is an equatorial climate hot and humid, characterized by two raining and dry seasons (big and small each) and of a dense and humid vegetation type (Vande Weghe, 2006).

Timber and NTFPs (Indigenous Fruit Trees) are particularly abundant including *Desbordesia glaucescens, Dacryodes buettneri; Coula edulis, Irvingia gabonensis, Baillonella toxisperma, Gambeya lacourtiana and Trichoscypha abut*. Most of these forest resources have multiple purposes and used sources of food, timber, cash incomes, medicine and other uses by local people (Okouyi-Okouyi, 2006; Lescuyer, 2006; Sassen and Wan, 2006; Corblin, 2006; Viano, 2005). The INP covering an area of 30,000 ha represents an extension of the previous Natural Integral Reserve of Ipassa of 10,000ha that was established by Man and Biosphere of UNESCO in 1979 for strict protection biodiversity conservation (Vande Weghe, 2006).

The INP covers an area of 30,000 ha and represents an extension of the previous Natural Integral Reserve of Ipassa of 10,000 ha that was established by Man and Biosphere of UNESCO in 1979 (Vande Weghe, 2006). Access and use of forest resources are strictly prohibited in the core area, regulated in buffer zone while let free of use outside of the park by the National Park Law of 2007. Past policies and regulations on forests resources have been initially strengthened the previous views by both Forest Code of 2001 and the Customary Rights Law of 2004. However, policy makers have directed little attention towards setting up rules for accessing and making use of forest resources actually located inside of the newly established national parks, despite the fact that these forest resources used to be utilized by them for meeting various livelihood needs (Okouyi-Okouyi, 2006; Lescuyer, 2006; Sassen and Wan, 2006; Corblin, 2006; Viano, 2005). This poor consideration is source of concerns.

Local people's growing needs of protected resources has led them to illegally accessing and using of the resources, habitat destruction (agriculture), logging operations and uncontrolled trees cutting and trade of fruits and seeds are of the preferred wild species (Lescuyer, 2006; Sassen and Wan, 2006; Viano, 2005). As

a result, resources decline has been observed in the area. Forest species such as Baillonella toxisperma, one of most preferred wild species by local people, is already acknowledged as vulnerable and listed in the IUCN Red List of Threatened species driven by human disturbances (IUCN, 2014). Strict protection of forest resources has therefore not fully contributed to safeguard forest resources of the INP since issue of species decline and mismanagement of the resources have been often reported in some parts of the park (Lescuyer, 2006; Sassen and Wan, 2006). Thus, there is a need to seek for new approaches to keep balance between protection and resource utilization by rural people for their livelihoods' needs. This new approach passes through assessing the current status of these valuable traditional resources including nuts and fruits from indigenous trees in terms of availability, size-class distribution and population structure.

Three wild indigenous fruit were selected for this study including *Irvingia gabonensis* (Andock), *Dacriodes buettneri* (Ozigo) and *Coula edulis* (Noisettes). The selection of these wild forest products was based on the consumption and commercial values for local households. The importance of these wild forest products were initially identified during the previous households and market surveys in terms of usages, market values and selling price.

Sampling plot design

Reconnaissance survey and discussions with key informants have contributed to identify "the often" and "the rarely" accessed locations based on harvesting frequencies by local people in locations. "The often" accessed locations, characterized by open access are located close by people's homes and located around the Ivindo National Park (INP) while "the rarely" accessed locations, characterized by prohibited accessed and use of resources are found far away of their homes and inside of the park. Data on availability and population structure of the harvested resources on those sites are very important for management purpose of forest resources of the park.

In total 18 sample plots measuring each 20 × 10 m (six), 2 × 2 m (six) and 1 × 1m (six) were purposely centered around identified mature trees, sapling and seedling individuals following a northeast direction, with three each in "the often" and "rarely harvested locations. Firstly, mother trees of *I. gabonensis, D. buettneri,* and *C. edulis* were identified in "the often" and "the rarely" accessed locations based on local people's knowledge on the area. In total six sample plots measuring each 20 × 10 m (with three in each selected location) were centered following a northeast direction around each mature trees that were identified. All identified adult trees with circumference bigger than 30 cm at breast height were counted and measured using a surveyor's tape at 1.3 m above the forest ground. The circumference at breast height were converted into diameter at breast height (dbh) by dividing (Pi = 3.14159 (π)).

Secondly, six sub-plots of 2 × 2 m each were nested within each of the selected location (with three in "the often" and "the rarely" accessed locations). All sapling individuals with circumference smaller than 30 cm at breast height were counted and measured by using a surveyor's tape. Six smaller plots of 1m × 1m each were also laid down in "the often" (3) and "the rarely" (3) accessed locations to count the number of seedling individuals (that is trees with height small than 1 m) and measure their height with a pole. For mapping the area, geographical coordinates were taken in the field by using a Garmin Geographical Positioning System (GPS).

Data analysis

Data collected were presented using descriptive statistics such as mean and percentage (%). Frequencies distributions of the dbh and height class-size distributions of the woody, sapling and seedling Individuals were plotted into graphs. The DBH and height class's limits of woody, sapling and seedling individuals were categorized into ten, five and 11 size classes.

RESULTS

Availability of seedling and sapling individuals by harvesting locations of the park

In all harvested locations of the forests, the number of seedling individuals of *I. gabonensis* (71, 44%) and *C. edulis* (66, 41%) were the most abundant and *D. buettneri* (24, 15%) the least abundant in terms of number and ratio. In "the often" accessed locations, *I. gabonensis* had the highest density of 40 stems of individuals (for a total area of 3 m^2) with height less than 1 m, thus accounting for 48% of the stems of the tree species used for fruits and seeds collection. The densities of others trees in "the often" accessed locations were: *C. edulis* 31 (37%) and *D. buettneri* 13 (15%). Tree species densities in "the rarely" accessed were relatively the same except for *Coula edulis* 35 (45%) and this for the same total area (Table 1). Overall, 161 seedling individuals of *I. gabonensis, C. edulis* and *D. buettneri* were recorded in the both locations. The majority (84, 52%) was recorded in "the often" accessed and (77, 48%) in "the rarely" accessed locations. In "the often" accessed, means height of seedling individuals range from 22 to 30 cm and from 19 to 24 cm in "the rarely" accessed locations.

The number of sapling individuals of *I. gabonensis* was the most abundant and *C. edulis* the least abundant in all harvested locations of the forests (Table 2). In "the often" accessed locations, only one stem of *C. edulis* was encountered of DBH smaller than 30 cm (for a total area of 12 m^2) representing therefore 33% of the tree species used for fruits and seeds collection in all harvested locations the forests. In "the rarely" accessed locations, only two stems of *I. gabonensis* species were recorded (for a total area of 12 m^2) accounting for 67% of the tree species and this for the same total area. Means DBH of sapling individuals range from 0 to 28 cm in "the often" accessed and from 0 to 19 cm in "the rarely" accessed locations.

Regarding mature trees, the number of woody individuals of *C. edulis* (5, 36%) and *I. gabonensis* (5, 36%) were the most abundant and *D. buettneri* (4, 28%) the least abundant in all harvested locations of the forests. In "the often" accessed locations, all the three harvested tree species had the same density of species of 2 stems of individuals with DBH greater than 30 cm (for a total area of 600 m^2) representing therefore 43% of the tree species used for fruits and seeds' collection in all harvested locations the forests. In "the rarely" accessed, tree species densities were relatively different with the highest recorded for *C. edulis* and *I. gabonensis* (for the same total area) accounting for 3 stems each while *D. buettneri* had only 2 stems around sampled locations.

Table 1. Availability of seedling individuals by harvesting locations.

Locations	Scientific names			
	Coula edulis	***Dacriodes buettneri***	***Irvingia gabonensis***	**Total**
Often accessed	31 (37%)	13 (15%)	40 (48%)	
Mean (Height in cm)	22	30	23	84 (52%)
SE	12	13	9	
Rarely accessed	35 (45%)	11 (14%)	31 (40%)	
Mean (Height in cm)	19	21	24	77 (48%)
SE	10	8	11	
Total	66 (41%)	24 (15%)	71 (44%)	161 (100%)

Percentages of stems of the target tree species around sampled plots are in brackets.

Table 2. Availability of sapling individuals by harvesting locations

Locations	Scientific names			
	Coula edulis	*Dacriodes buettneri*	*Irvingia gabonensis*	Total
Often accessed	1 (100%)	0 (0%)	0 (0%)	
Mean (Height in cm)	28	0	0	1 (33%)
SE	0	0	0	
Rarely accessed	0 (0%)	0 (0%)	2 (100%)	
Mean (Height in cm)	0	0	19	2 (67%)
SE	0	0	2	
Total	1 (33%)	0 (0%)	2 (67%)	3 (100%)

Means DBH of mature individuals range from 161 to 212 cm in “the often” accessed and from 136 to 187 cm in “the rarely” accessed locations.

Population structure of seedling, sapling and woody individuals by harvesting locations and implication for sustainable harvest

Figure 1 shows the proportion of seedlings population in each DBH size-class in both “the often” and “the rarely” accessed locations of the forests around the park and this for each of the three target species. For all the target species, there is a lower seedlings’ population in small height size class (1-2) and the absence of individuals in the upper height size classes (8-11) compared to seedlings’ population encountered in the intermediate height size classes ranging from (3-7). The poor proportion of seedling’s individuals in small (1-2) and their absence in upper height size classes (8-11) may be an indication of a poor healthy population.

There is an increasing absence of sapling individuals in almost all DBH size classes of the three target species (Figure 2). No individual of *D. buettneri* was recorded in both harvesting locations. In rare cases, just one in individual of *C. edulis* was recorded in “the often” accessed location and none in “the rarely” harvested locations. On the contrary, two individual of *I. gabonensis* were recorded in “the rarely” harvested locations and none in “the often” accessed location. These trends are characteristics of a poor health of sapling population of all the three target species.

Figure 3 shows woody population’s structures of each of the three target species in “the often” and “the rarely” accessed locations of the park. Woody population’s structures of each of these species are not so different and there is a marked absence of individuals in some DBH size classes. For *C. edulis* and *I. gabonensis,* no individuals were encountered in the lower (1-4) and upper (8-10) DBH size classes, except in the intermediate DBH size classes (4-8). On the contrary, no individuals of *D. buettneri* were encountered in the intermediate DBH size classes (4-6), except at lower (2-3) and upper (7-9) DBH size classes. All these results are also characteristics of a poor health population of all the matured three tree species in the study.

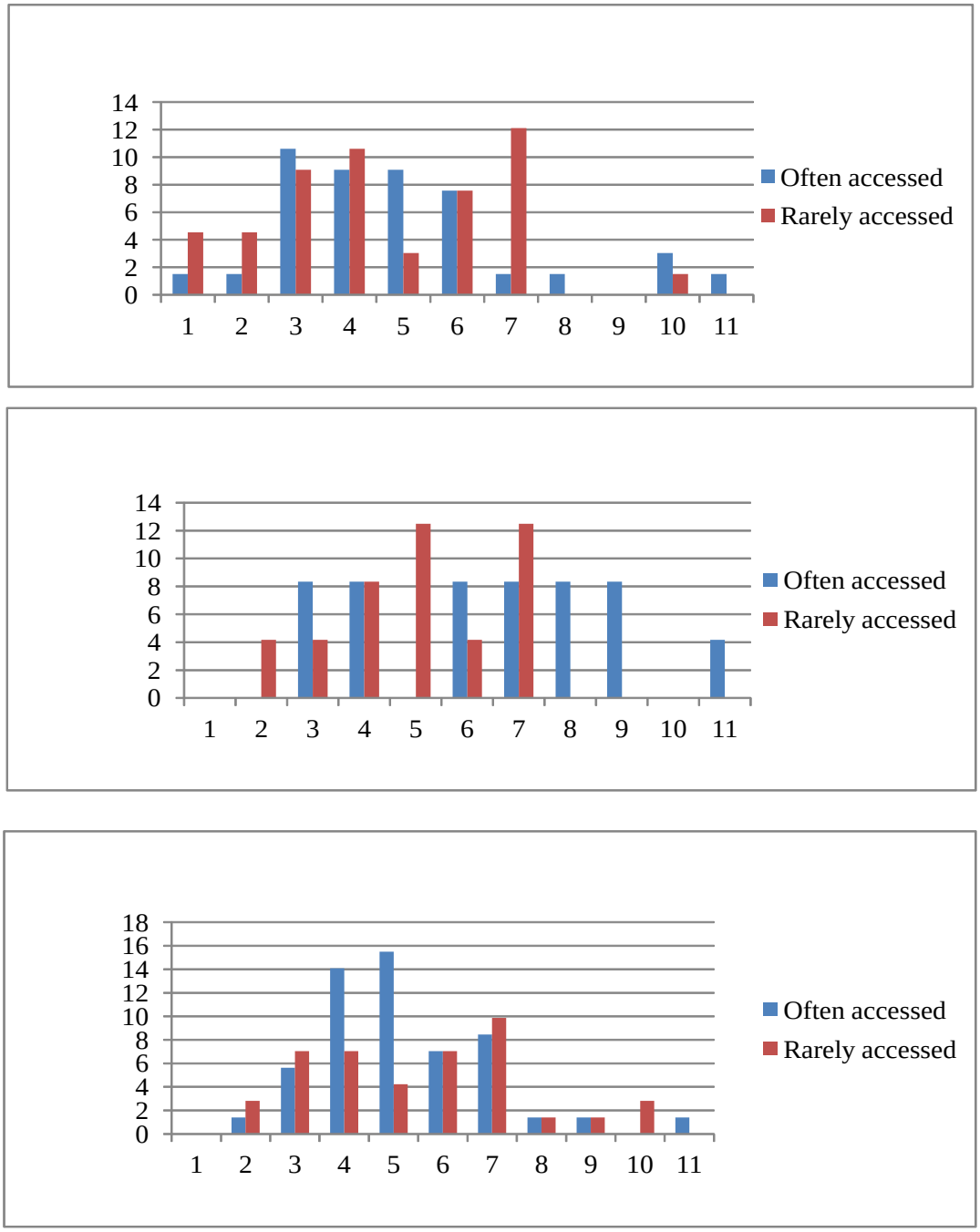

Figure 2. Seedling population structure by harvesting location.

Regarding the optimum DBH of each of the target tree species of 70 cm for *D. buettneri* and 40 cm for each of the *C. edulis* and *I. gabonensis* (See Decree n° 1285 /PR/MEFPE, of the 27 September 1993) that is legally known as Fixed Felling Minimum Diameter (FFMD) by the Forest code, it can be predict that there are few mature trees that have a FFMD, bigger than DBH size class of (8) (70.0 - 79.9 cm) for *D. buettneri,* size class of (5) (40.0 - 49.9 cm) for *C. edulis* and *I. gabonensis.*

DISCUSSION

Availability of seedling, sapling and woody individuals by harvesting locations

Although there were relatively more seedling and woody individuals of *C. edulis* and *I. gabonensis* than *D. buettneri* “the often” harvested locations comparatively to “the rarely” harvested locations, however, the proportion

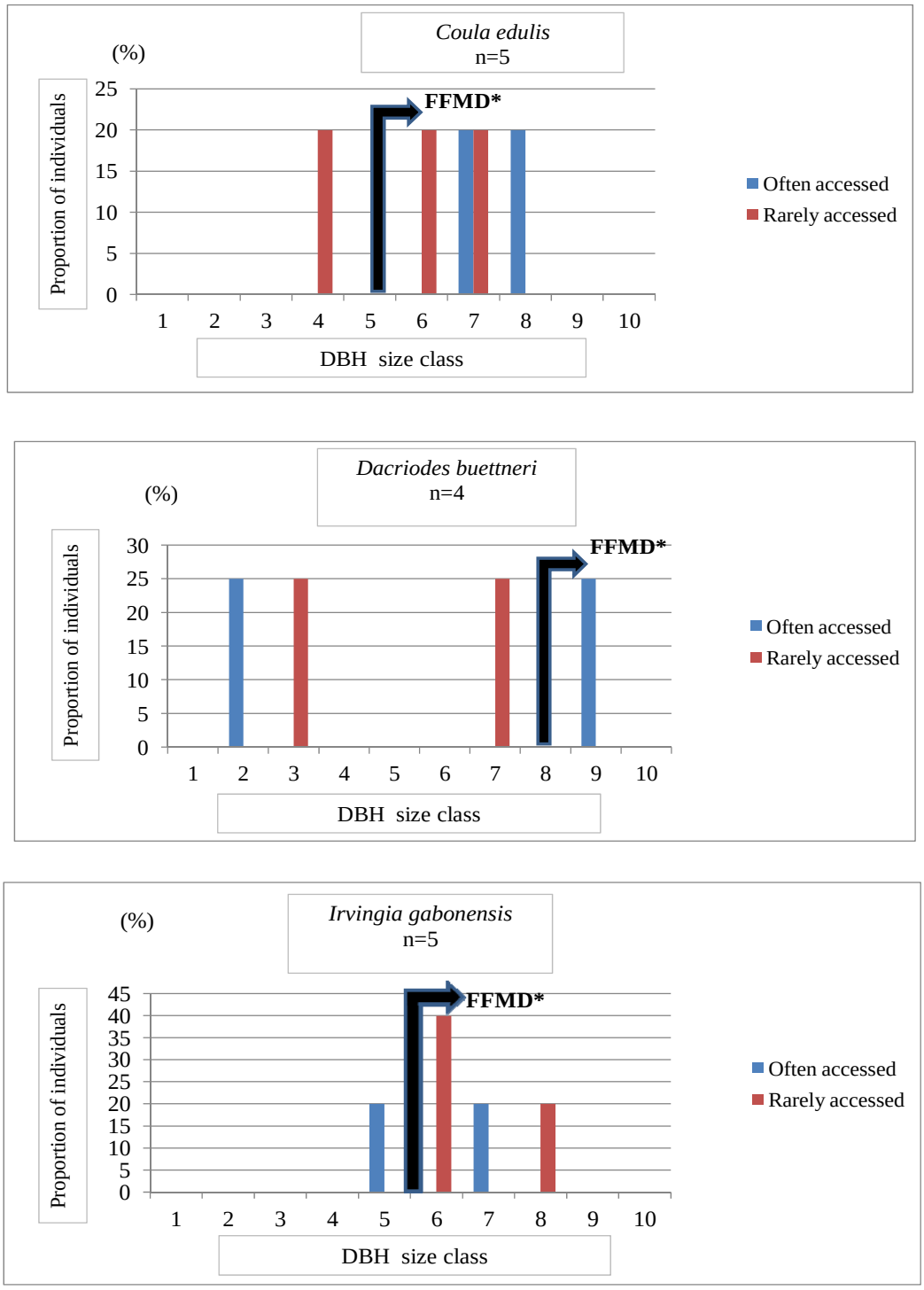

Figure 3. Woody population structure by harvesting location. FFMD*, Fixed Felling Minimum Diameter at breast height acknowledged by the decret n0 1285 /PR/MEFPE , of the 27 september 1993 in Gabon.

of seedling recorded were quite low in both locations (Table 3). This was probably due to past illegal access and uncontrolled tree cutting and other selective timber harvesting activities that have occurred inside and outside of the protected forests. Uncontrolled harvesting and selective logging often destroys mature and young trees (Whitmore and Sayer, 1992; Chapman and Chapman, 1997; Adekunle and Olagoke, 2010). The impact of timber harvesting may also has a negative impact on forest structure, composition and its regeneration's ability

Table 3. Availability of woody individuals by harvesting locations

Locations	Scientific names			
	Coula edulis	***Dacriodes buettneri***	***Irvingia gabonensis***	**Total**
Often accessed	2 (33%)	2 (33%)	2 (33%)	
Mean (DBH in cm)	212	161	163	6 (43%)
SE	17	149	52	
Rarely accessed	3 (38%)	2 (25%)	3 (38%)	
Mean (DBH in cm)	164	136	187	8 (57%)
SE	57	89	38	
Total	1 (33%)	4 (28%)	5 (36%)	14 (100%)

(He et al., 2010). This negative impact has certainly to do with the fact that logging operations tend to be concentrated around most valuable commercial trees species in the forest as further stressed by (He et al., 2010). Consequently, unsustainable management of timber resources tends to be a common trend in many tropical forests (Putz and Redford, 2010). In the study area, past land uses based on uncontrolled harvesting and selective logging may have influenced the density or availability of sapling and woody individuals since locations “often” and “rarely” accessed were subjected to human pressures in the past. A part of forests of the Ivindo National Park (INP) has been allocated to logging companies before it was gazetted in 2002 and the current location where the park has been established used to be utilized by local people to meet their various livelihoods needs (Corbin, 2006; Viano, 2005; Sassen and Wan, 2006; Lescuyer, 2006). The study carried out by Sapkota and Odén (2009) has stressed out that gap creation after tree felling has a potential to influence not only tree regeneration but also the growth of young seedling individuals. In the case of this study, gap formation after trees have been logged out and its influence on the growth of light demanding species (seedling and sapling individuals) might have caused the current decline of the valued timber species from the wild.

In addition, the differences in stem densities observed could have resulted from the varying levels of disturbances that the area has experienced over the years since few sapling individuals (DBH< 30 cm) of *C. edulis* (one) and *I. gabonensis* (two) were recorded in both harvesting locations. However, no sapling individual of *D. buettneri* (DBH < 30 cm) was recorded in both harvesting locations because probably of intensive tree harvesting (Table 2). Timber and Non-timber species harvesting are not always impacting negatively to the forest stand since the destruction of plants and impacts tend to depend on specie and the parts of the resources used (Peters, 1996a,b; Ticktin, 2004). On the contrary, forest resources harvesting may contribute to open excessive canopy gaps that often stimulate growth of seedling species and their survival (Beckage and Clark, 2003). For this study, the issue of forest resource decline may persist in these locations into the future (even though logging operations have been definitely prohibited in all national parks by the Gabonese government) since illegal access and uncontrolled trees cutting inside and outside of national parks are not being successfully addressed yet. Achieving this may call for setting up a proper regulations’ mechanisms in collaboration with people who depend on the resources base (Laird et al., 2010).

Considering that there is no on-farm planting of any of the target species around the study area and throughout of the country where similar cases occurred on one hand and that community forestry initiatives are still at their early stages on the other hand therefore, it is logical to suggest that parks managers and forest department should combined efforts to contain the harvesting of these species around forested areas inside and outside of the park in collaboration with local people knowing that top-down type of resources management often yields issue of resources decline (Ostrom, 2008).

Consequently, participatory involvement of local people in decision-making affecting their lives is crucial for implementing an effective regulatory mechanism over resource access and use (Ostrom, 2008), especially in Gabon where top-down approach based forest management seems to persist. It will be also crucial to grant and securing traditional rights (traditional property rights) over access and use of the resources (Clarke and Jupiter, 2010, Stahl, 2010). In Gabon, past traditional regulatory and institutional arrangements regulating access and use of forest resources have been abolished by the state and the only available legal regulatory and institutional arrangements designed to regulate access and use of forest resources are the ones dictated by the state. Thus, the state has an exclusive property rights over forests and land while local people have just been granted use fruits rights (Gabonese Republic, 2001, 2007). This means that local people are more exposed to rights alienation to some extent. Overcoming issue of property rights over resources access and use passes through a careful and an effective collaboration between legal and traditional regulatory and institutional

arrangements. Failing to achieve such successful synergy between legal and traditional customary resource tenure may more likely yield improper management of the resources and raise conflicts among resource users and state authorities as further highlighted by Clarke and Jupiter (2010).

In the case of this study, going back to such institutional synergy might be a non-negligible solution to address issue of unsustainable management of forest resources. It appears that the implementation of an effective participatory involvement of local communities in forest resources management (FRM) initiatives and trees planting represents a crucial mechanism that will more likely contribute to control and/ or regulate tree cutting and harvesting of fruits and seeds in the area given that the state alone seems to be failing to successfully managing the resources. Achieving the latter would require to implement a proper coordination and monitoring systems as well as training provision to the community followed by the formulation of clear and supportive by-laws by the state (Laird et al., 2010).

Population structure of seedling, sapling and woody individuals by harvesting locations and implication for sustainable harvest

Although population structures of seedling, sapling and woody individuals vary according to harvesting locations however, such trends indicate unhealthy population in each forest location. Past timber logging activities, illegal access and uncontrolled tree cutting could have influenced seed dispersal mechanisms, fruiting, germination and regeneration of each of the species while creating gap formation in stand forest. The absence of taller seedling individuals in the upper height size classes [8-11] compared to seedlings' population in the intermediate height size classes of [3-7] may be an indication of a poor natural regeneration (Figure 1). This means that seed sources were certainly depleted through strong harvesting of mother trees that have negatively impact of seeds and gene's ability to disperse as evidenced by Moran (2010). Overturning such poor trends may call for enrichment by tree planting that could more likely increase the population of the three target species on one hand and reduce pressure on resources base on the other hand around the study area.

The marked absence of sapling individuals in almost all DBH size classes of the three target species is also an indication of unhealthy population in the forests due to the fact that there are not enough sapling individuals in the forest undergrowth (Figure 2). Thus, the target tree species have certainly a poor sprouting ability meaning certainly that the current species population is less likely to increase and grow into more mature stems. There is also a paucity of some mature individuals in the lower [1-4] and upper [8-10] DBH size classes for both *C. edulis* and *I. gabonensis* and at [4-6] for *D. buettneri* suggesting that the recruitment process of those species may have been affected by a combination of factors including the history of logging operations and human disturbances in the area (Figure 3). Thus, past timber logging activities and illegal access and uncontrolled tree cutting of reproductively mature trees have certainly reduced the population of the target species and affected their seeds production.

Tree production's ability is strongly correlated to tree Fixed Felling Minimum Diameter (FFMD) also known as Minimum Cutting Diameter or Optimum Tree Felling Diameter. Thus, timber species under the minimum cutting diameter are not sufficiently fecund since they are unable to produce enough seed to maintain the regeneration of the forest stand (Gullison et al. 1996). Sustainable management of timber species therefore calls for a strict of respect of the legally determined cutting diameter by the state (SNOOK, 1996; Sist et al., 2003; Zimmerman and Kormos, 2012). The results of this study showed that there are few mature trees that have their Minimum Cutting Diameter bigger than DBH size class of (8) [70.0 - 79.9 cm] for D. buettneri and DBH size class of (5) [40.0 - 49.9 cm] for each of C. edulis and I. gabonensis. This means that the small numbers of mature trees that can produce seeds are limited and that they are not mature enough to produce seeds. Completely stopping all use of wood stems and fruits for resources sustainability and livelihood purposes of the local people might not be a viable solution to overcome the issue of resource decline in the area.

On the contrary, one of the feasible solutions might be directed towards implementing a proper regulation mechanism that would both aim at controlling and/ or regulating tree cutting and fruits harvesting in those forests locations given that these valued timber species appeared not to be able to recover from the further impacts related to tree cutting and intensive fruits and nuts harvesting. Thus, regulating tree cutting and fruits harvesting by allowing sustainable harvest calls for developing an appropriate management system for NTFPs (Peters, 1996b; Hall and Bangor, 2004; Vermeulen, 2009). The fact that trees cutting and fruits collection are limited to small size classes has probably to do with the fact that there is already scarcity of the "larger" preferred species in both "the often" and "the rarely" accessed locations of the park since those locations have experienced almost similar levels of harvesting pressures over the years (Figure 4). Past and current harvesting practices and other timber harvesting activities have certainly contributed to the decline of larger trees from the wild. This implies that strict forest protection type policy that is implemented by eco-guards and parks managers has not fully contributed to keep the forest "less disturbed" including inside of the park. Thus, uncontrolled harvesting of trees have certainly driven resources decline through destruction of mature and young trees (Whitmore and Sayer, 1992; Chapman and

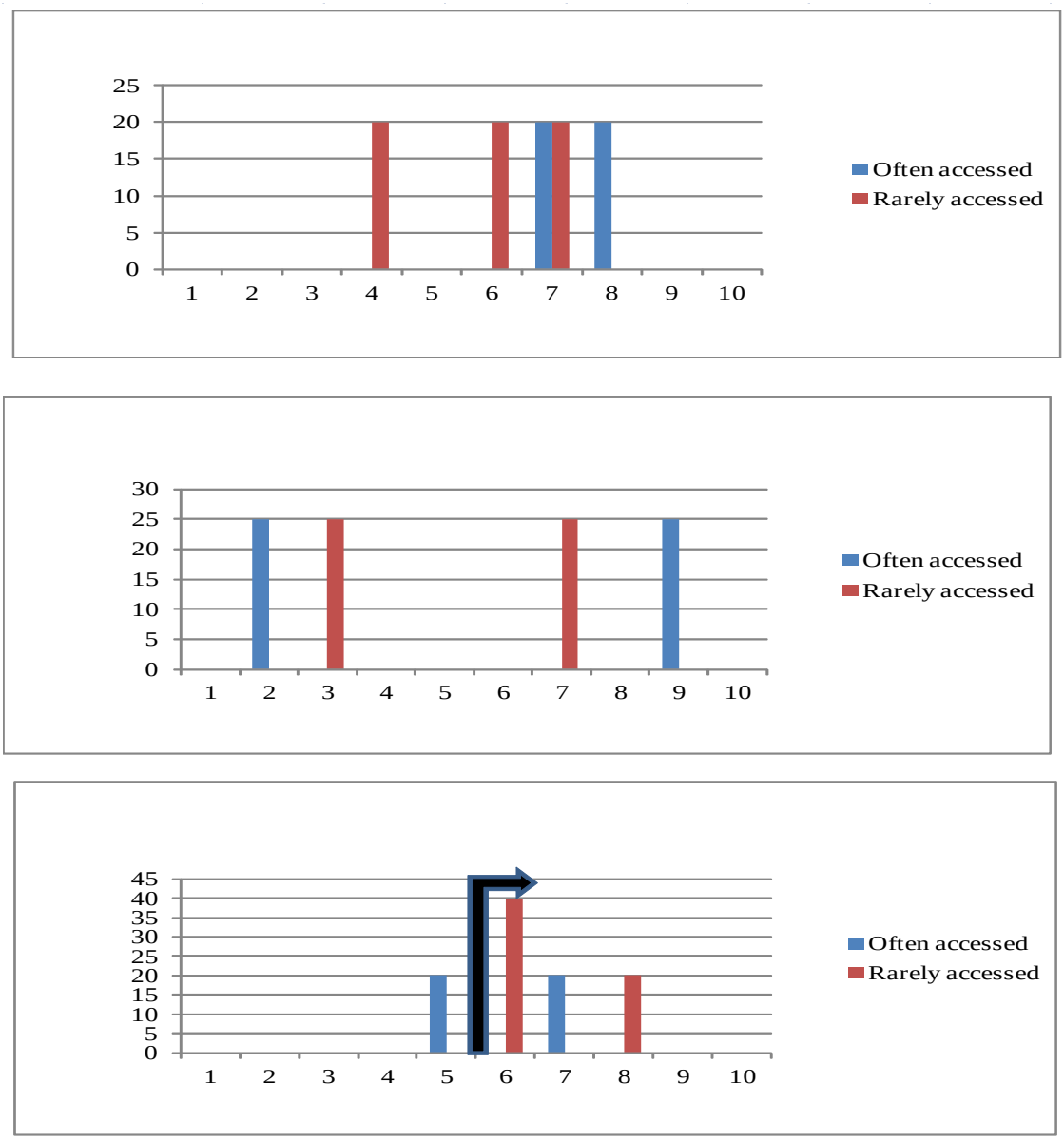

Figure 4. Woody population structure by harvesting location.

Chapman, 1997, Adekunle and Olagoke, 2010). Reversing such issue of forest resources decline is highly needed for both livelihood sustainability of local people and forest stand as a whole.

Conclusion

The study on the "Availability and size class distribution of the most popular Indigenous Fruits Trees and implications for sustainable harvest around of the Ivindo National Park, Gabon" is necessary and significant to the local community. The lower availability of seedling, sapling and woody of *D. buettneri, C. edulis* and *I. gabonensis* in "the often" and "the rarely" accessed locations and their poor population structures are an indication of unhealthy population. Thus, it would be important to focus on the protection and management strategies of the above target tree species to prevent further depletion. Among management strategies include limiting the number of trees cut per season (for forest recovery purpose) or encouraging resources users to turn towards other timber species (less valuable but with similar importance) as an alternative to generate the current stocks of the species. In the meanwhile, it would be also important to carry out monitoring operations on species growth rate for sustainable use's purpose. The current community forestry initiative in the country should also focus on on-farm cultivation of these valued timber species inside and outside

of the protected forests otherwise trees would not be available to local people in the near future, knowing that they are slow growing and take long to mature.

Recommendations

i. The current national parks policy based on the prohibition of logging operations and livelihoods activities inside of the parks) has not been as effective in conserving and managing resources since forests depletion has been observed. Therefore proper controls over tree cutting and fruit harvesting are needed to allow adequate regeneration strategies of target species. Achieving this would require proper planning and takes into account the current financial and human resources.
ii. There is a need to raise awareness of the local communities living around the protected forests about the declining status of the natural resource stocks from the wild.
iii. Regarding the scarcity of the three target species, on farms tree planting by local community living around these forests is need to be implemented and encouraged to supply the logs and fruits, nuts and seeds from different locations of the park via the tree domestication program of ICRAF for example.
iv. Further studies have to assess the regeneration capacity and regeneration strategies of the target fruit species to understand their recovery ability if appropriate management strategies have to be implemented by the state (Seydack, 1991; Everard et al., 1995).

Conflict of Interests

The author(s) have not declared any conflict of interests.

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