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Full Length Research Paper

Interface of biodiversity and ecosystem services: Does soil organic carbon correlate with the diversity of carabid beetles (Coleoptera: Carabidae) in the Uzungwa Scarp Nature Reserve, Tanzania?

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Tropical forest soils have potential to mitigate climate change and support biodiversity. Human activities in these forests threaten biodiversity and alter the ability of the soil to sequester carbon. Many tropical countries experience rampant anthropogenic activities in the forests, yet the extent to which these activities affect biodiversity and soil organic carbon and the relationship between the two is not well studied. In this study, the correlation of soil organic carbon (SOC) and ground beetles was assessed in both control and disturbed sites in Uzungwa Scarp Nature Reserve (USNR). Disturbance activities included logging for timber, tool handles and building poles; fire, hunting, footpaths, collection of fuel wood, and clearing for agriculture. Pitfall trapping, active searching during the day, and active night searching were methods used to collect the ground beetles. Soil samples were collected at three depths 0-15, 15-30 and 30-45 cm in twelve plots: six in disturbed and six in control sites. A total of 890 ground beetles comprising 30 species were collected. The species richness of carabid beetles was high in the control sites (26 species) and low in disturbed site (16 species), with the respective Shannon-Wiener being H'= 2.103 and H' = 1.327. The difference in species diversity was statistically significant. Abundance of carabid beetles was also significantly higher in control sites compared to disturbed sites. Mean SOC was low in disturbed sites and high in control sites at all three depths. In disturbed sites, the correlation between SOC and species richness was weakly negative but not significant, and positively correlated with abundance, though it was not statistically significant. In control sites, there was a significant positive correlation between SOC and carabid abundance, but not with species richness of carabid beetles. To conclude, protection of natural forests is prerequisite for biodiversity and ecosystem services. We recommend that management improvement is urgently required, because ongoing human activities seem to contribute to diminished SOC stock.

Key words: Soil organic carbon, disturbance, ground beetles, correlation.

INTRODUCTION

Soil is an important carbon pool in tropical areas, storing about 30% of the carbon in the world (Batjes, 1996; Scharlemann et al., 2014). Comparatively, the amount of carbon stored in soil is greater than the total amount of carbon stored in the atmosphere and the living biomass when combined (Ciais et al., 2013). Soil organic carbon (SOC) is among the five carbon pools recognised by the Intergovernmental Panel on Climate Change (IPCC), other pools include above ground, below ground, dead wood and litter (IPCC, 2006).

Healthier and functioning tropical forests and their diversity are known to enhance productivity, and soil carbon storage, among other ecosystem services (Sheil et al., 2016; Chen et al., 2018). Thus, on-going widespread destructive anthropogenic activities in the tropical forests as a result of human activities such as encroachment for farming, logging, hunting mining, and fire, among other factors, greatly causes loss of biodiversity and affects ability of soil to sequester carbon (Houghton, 2007; Sheil et al., 2016)

In recent years, studies are emerging to assess the correlation between ecosystem carbon stock and biological diversity of different groups of taxa (Strassburg et al., 2010; Kessler et al., 2012; Gilroy et al., 2014; Basham et al., 2016; De Beenhouwer et al., 2016). Some report that carbon stock can have a positive influence on the biodiversity of tropical forests (Strassburg et al., 2010; Venter, 2014). Most of current studies, however, deal with either above-ground carbon stock (Gilroy et al., 2014; Basham et al., 2016) and/or total carbon stock, including SOC (Kessler et al., 2012; De Beenhouwer et al., 2016). Few studies have specifically reported how soil carbon relates with biological diversity of soil dwelling invertebrates, especially ground beetles in agroforestry systems (Kessler et al., 2012; De Beenhouwer et al., 2016).

Existing studies on ground beetles and carbon are based in agroforestry systems and are contradictory, with some reporting that there is a relationship (Kessler et al., 2012), while others report no relationship (De Beenhouwer et al., 2016). However for other taxa, according to (Venter, 2014), a higher carbon stock correlates with higher biodiversity. Likewise, Gilroy et al. (2014) reported that in a secondary forest, both birds and dung beetles were favoured by an increase in non-soil carbon stock. A similar trend was observed in a regenerating secondary forest in tropical Andes (Basham et al., 2016) with regard to amphibian species richness and abundance; also Strassburg et al. (2010) reported correlation between above-ground carbon and selected vertebrates. However, the opposite trend has also been observed (Beaudrot et al., 2016).

More research, therefore, is still needed to understand the relationship between SOC and ground beetles in natural forest settings. Similar to other tropical forests in the world, USNR in Tanzania has been facing disturbances from several anthropogenic activities such as unsustainable farming activities, fire, honey harvesting, collection of fuel wood, building materials, timber, tool handles, forest encroachment for agriculture, illegal hunting and trespassing (Zilihona et al., 1998; Topp-Jørgensen et al., 2009; Rovero et al., 2012).

These activities are among some of the immediate drivers of habitat degradation in developing countries, including Tanzania (URT, 2010; Kissinger et al., 2012); however, to what extent they affect SOC and invertebrates specifically ground beetles in USNR is not very well studied. Some of the known research in the USNR include studies on vertebrates (Fjeldså, 1999; Menegon and Salvidio, 2005; Stanley and Hutterer, 2007; Rovero et al., 2012) and those on invertebrates only confined at the Kihansi waterfall (Zilihona and Nummelin, 2000; Zilihona et al., 2004). Other studies on invertebrates include Scharf (1992) and Sorensen et al. (2004) but did not address the impact of ongoing disturbances on ground beetles. Thus, little is known about the impact of the ongoing human activities on soil carbon stock and ground beetle diversity in the USFR.

Studies of carabid beetles in Tanzania have been recorded by surveys carried out in the Uluguru Mountains by Basilewsky (1962, 1976), these were museum collections, and do not provide ecological information. Other available research include Zilihona and Nummelin (2000) and Zilihona et al. (2004) that address the impact of Kihansi gorge construction in USNR, and Nyundo and Yarro (2007) on designing inventory methods, as well as Belousov and Nyundo (2013) on taxonomy of some new species in Udzungwa Mountain National Park. Therefore, there is limited information on the impact of ongoing activities on ground beetles in USNR.

Ground beetles have been chosen for this study for several reasons: (a) they can be sampled using simple methods (McGeoch, 1998; Rainio and Niemela, 2003), b) they are abundant in most ecosystems and they are good indicators of habitat disturbance, c) they occur with species that possess strong habitat preferences, d) most of the ground beetle species show association with specific microclimate conditions, e) they show a rapid response to changes in vegetation and overall landscape ecology, and f) they have a high functional importance (Rosenberg et al., 1986; McGeoch, 1998; Rainio and Niemela, 2003).

The present study aimed to enhance understanding of the impact of anthropogenic disturbances on biodiversity and ecosystem services in USFR, which is an area with high endemism (Myers et al., 2000; Rovero and Menegon, 2005), and has a possible high rate of species extinction and rampant anthropogenic activities (Fjeldså, 1999; Menegon and Salvidio, 2005; Stanley and Hutterer, 2007; Rovero et al., 2012).

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Specifically, the study aimed at: a) evaluating the effect of anthropogenic disturbances on ground beetle diversity, b) assessing the impact of anthropogenic disturbances on SOC, and c) examining the relationship between ground beetle diversity and SOC. Since management and conservation of forest embraces both ecosystem services and biodiversity, this study may provide insight on the relationship that exists between SOC and ground beetles. Detailed information about carbon and biodiversity patterns can help in the formulation of policy objectives such as reducing emissions from deforestation and forest degradation (REDD+). Moreover, the impact of forest disturbance leading to degradation is less well known in Tanzania (Burgess et al., 2010); hence, this study will provide an understanding on how forest disturbance impacts SOC. This may help in developing mitigation measures at both local and international level.

MATERIALS AND METHODS

Study site

The study was carried out in the USNR, an area of about 207 km^2 located in the Udzungwa Mountains within the Eastern Arc Mountains (EAM) of Tanzania and Kenya (Myer et al., 2007). The USNR lies between latitudes 35° 50' and 36° 05' E and longitude 8°10' and 8° 37' S in southern central Tanzania within Morogoro and Iringa Regions (Figure 1). Its altitude ranges from 300 to 2,068 m a.s.l. (MNRT, 2010). The area has an estimated average temperature between 20°C maximum in December and 15°C minimum in July; while in lowland areas, temperatures reach a maximum of 27°C in December and a minimum of in 19°C in July. Annual rainfall varies from 1,350 to 2,000 mm and sometimes exceeds 3000 mm in wetter areas (MNRT, 2010).

Study sites were selected based on presence/absence of signs of human activities such as log stumps, snares for trapping animals, footpaths, presence of abandoned human habitats, collected fuel wood and tool handles, and pit sawing sites. A site was considered as disturbed if five or more recent (<2-year) activities mentioned earlier were encountered within the plot or within 50 m outside the plot perimeter. Study sites were located between 466 and 740 m. a. s. l. (Table 1).

Data collection

A total of twelve plots, each 1 ha in size (100 m × 100 m), were established at each site. Each site was characterized as either disturbed or control, based on the intensity of human activities. Within a 1 ha plot, sampling for both carabid beetles and soil was done. Sampling took place in November and December 2016 and July and August 2018; these periods mark the end of dry and end of wet season, respectively.

Data on Carabid beetles

Carabid beetles were sampled using three methods: pitfall traps, active searching (day), and active searching (night) (Greenslade, 1964; Nyundo and Yarro, 2009). Geographical position and altitude of each site were recorded using Garmin GPS 60 (Table 1).

Forty pitfall traps made of plastic containers (12 cm top width, 15 cm depth, 1 L capacity) sunken in the ground and half filled with a preservative (propylene glycol), were set at a distance of 10 m apart around the perimeter of the 1-ha plot. Traps were checked after one week. Each trap constituted a “sample”. Ground beetles from pitfall traps were sieved and collected using forceps.

Within the same plots, active searching for 1 h constituted a sample. Active searching was done both day (for three hours) and night (for three hours) at each site. The activity involved searching for ground beetles under logs, rotting logs and in leaf litter. Leaf litter was scooped onto a 1-m^2 white cloth; and carabid beetles were collected by hand or using a pooter collection device. Specimens were kept in labelled plastic bags containing 75% alcohol and transported to the University of Dar es Salaam (UDSM) for sorting and identification.

Data on soil samples

Soil samples were collected in 1-m^2 quadrats established at three points within each plot boundaries using a soil auger. Soil samples were collected at three depths 0-15, 15-30 and 30-45 cm for determination of SOC. The soil was mixed according to their specific layers to form composite. A sub-sample mixture from each layer was kept in sealed polythene bags with labels. Using a cylinder steel core, soil was sampled for determination of bulk density; the known volume of core cylinder was used. While being careful, without disturbing the top layer, the soil samples were collected and kept in polythene plastic bags with labels for further laboratory analysis at the UDSM. For bulk density analysis, samples were oven dried at 105°C for 24 h then weighed for sample dry weight. Volume of the core cylinder and weight of the dry sample were used to calculate the soil bulk density. Soil organic carbon content was determined using Walkley and Black’s potassium dichromate method as described in Nelson and Sommers (1982). Soil organic carbon in tonnes per hectare (t/ha) was calculated using Equation 1 (Bross and Baldock, 2008).

$$\text{Soil organic carbon (t/ha)} = \text{depth (cm)} \times \text{bulk density (g/cm}^3\text{)} \times \%\ \text{organic carbon} \quad (1)$$

Carabid beetle identification was carried out by use of identification keys (Basilewsky, 1953) and specimens available in the collections of Zoology and Wildlife Department of the UDSM. Identification considered all external visible features excluding genitalia. Identification was made to species level whenever possible; whenever there were difficulties to identify species level, we identified genus or subfamily.

Data analysis

Diversity of ground beetles was computed using the Shannon-Wiener Index and compared using a special diversity t-test. The Shannon-Wiener diversity index takes into consideration the number of individuals (abundance) and the number of taxa (species richness) (Magurran, 1988). The difference in abundance between disturbed and control sites was assessed using a Mann-Whitney test.

SOC (t/ha) estimated from the three sampling points for each depth was averaged to get the estimate of SOC per site. Not all data were normally distributed; therefore data were logarithmic-transformed. Carbon stock between disturbed and control sites, and at three depths, was analysed using parametric tests; namely, two-sample t-test and ANOVA, respectively.

The relationship between carbon and carabid beetle diversity was assessed using a Pearson linear correlation (r). Simple linear regression was performed using Reduced Major Axis (RMA) for coefficient of determination (R^2). Total SOC for each site was regressed against ground beetles. Finally, PAST software Version

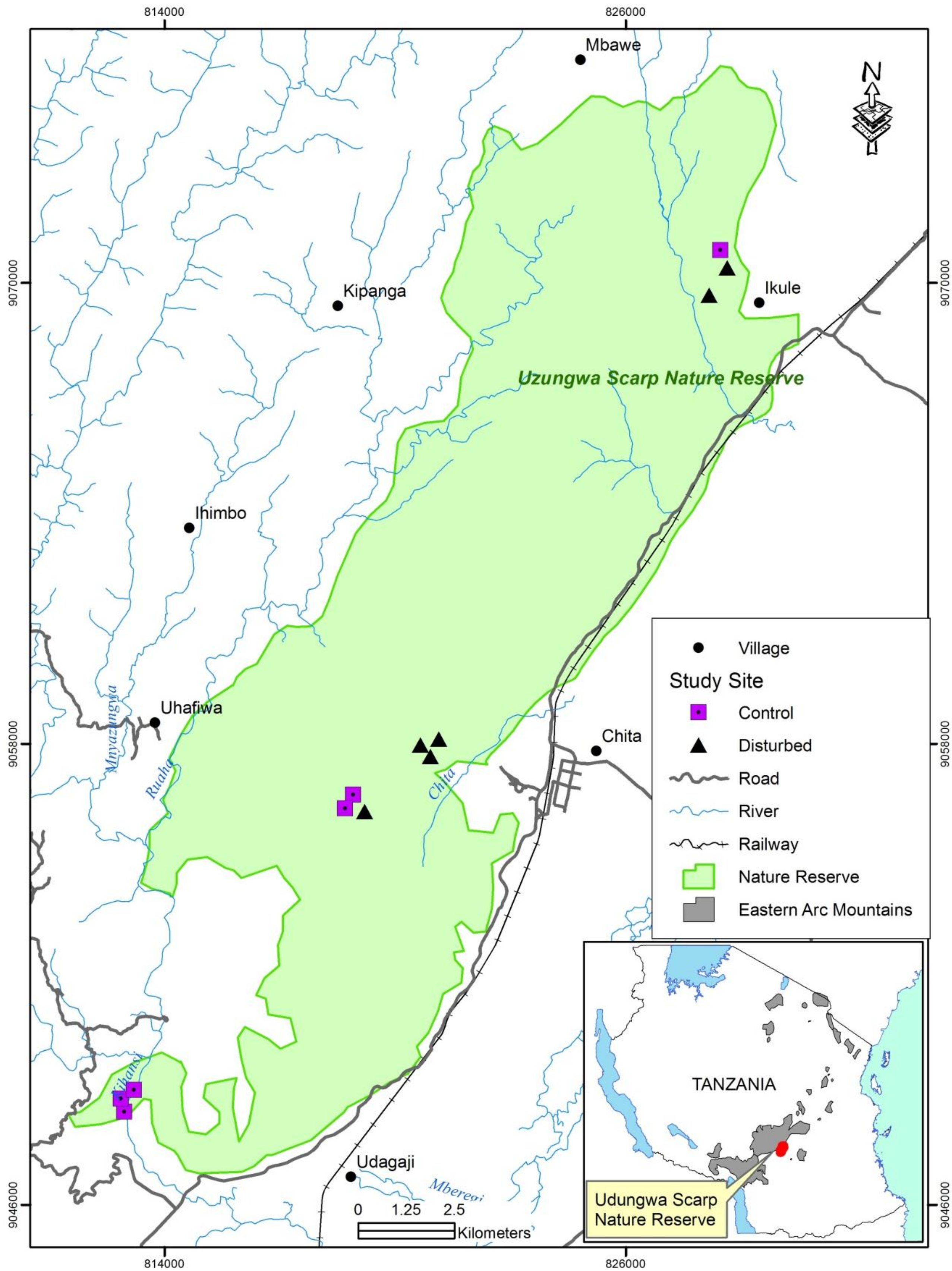

Figure 1. Sampling sites for carabid beetles and Soil in the USNR.

Table 1. Enumeration and description of the sampling sites

Site Code	Location	GPS Coordinates	Elevation (m asl)	Description
S1 (Control)	Adjacent to Chita Village	UTM 36L 818876 9056470	725	Forest with tall emergent trees, including: *Tabernaemontana stapfiana*, *Newtonia buchananii*, *Tricalysia pallens*, *Englerophytum natalense*.
S2 (Disturbed)	Adjacent to Chita Village	UTM 36L 819213 9056241	619	Disturbed site with few emergent trees including *T. stapfiana* and *Drypetes gerrardii*
S3 (Control)	Adjacent to Chita Village	UTM 36L 818704 9056316	740	Forest with tall emergent trees including *T. pallens T. stapfiana*, *E. natalense*, *Parinari excelsa*
S4 (Disturbed)	Close to Chita Secondary School	UTM 36L 820826 9058001	547	Disturbed site with few emergent trees including, *T. stapfiana*, *Treculia africana*, *Synsepalum brevipes,*
S5 (Disturbed)	Close to Chita Secondary School	UTM 36L 820832 9058090	504	Disturbed site with few emergent trees including *T. stapfiana*, *Synsepalum brevipes*,
S6 (Disturbed)	Close to Chita Secondary School	UTM 36L 820915 9057808	466	Disturbed site with few emergent trees including *T. stapfiana*, *Synsepalum brevipes*,
S7 (Disturbed)	Adjacent Ikule Village	UTM 36L 830152 9070463	568	Disturbed site with few emergent trees including *Strombosia scheffleri*, *Milicia excelsa*, *T. stapfiana*
S8 (Disturbed)	Adjacent Ikule Village	UTM 36L 830221 9069844	647	Disturbed site with few emergent trees including *T. stapfiana*, *N.buchananii*, *S. brevipes*
S9 (Control)	Adjacent Ikule Village	UTM 36L 830211 9070552	706	Forest with tall emergent trees including *Macaranga capensis*, *Bombax rhodognaphalon*, *Lettowianthus stellatus*, *N. buchananii*, patchstella, *T. stapfiana, E. natalense*

Table 1. Contd.

S10 (Control)	Kihansi	UTM 36L 812960 9048424	580	Forest with tall emergent trees including *T. africana*, *Synsepalum brevipes, T. pallens*, *T. stapfiana, N. buchananii*
S11 (Control)	Kihansi	UTM 36L 812973 9048731	588	Forest with tall emergent trees including *T. africana*, *Synsepallum brevipes, T. pallens, Sorindeia madagascariensis*, *Celtis gomphophylla*, *N. buchananii*
S12 (Control)	Kihansi	UTM 36L 813142 9048852	558	Forest with tall emergent trees including *Allanblackia stuhlmannii*, *Cephalosphaera usambarensis*, *Garcinia semseii, Trema orientalis*

3.20 (Hammer, 2018) was used for all statistical tests and graphs generation.

RESULTS

Abundance and diversity of carabid beetles in control and disturbed sites

Overall, carabid beetle abundance was high in control sites with 596 individuals and low in disturbed sites with 294 individuals. In control sites, the minimum number of carabid beetles per sample was 0 while the maximum was 18, while in disturbed sites, the minimum and maximum number of carabid beetles per sample was 0 and 9, respectively. The mean number of carabid beetles was 0.725 ± 0.065 in control sites and 0.356 ± 0.038 in disturbed sites. A Mann-Whitney test showed that the difference in abundance between control and disturbed sites was not statistically significant ($p > 0.05$).

Overall, a total of 890 carabid beetles represented by 30 species of carabid beetles were collected. The species richness of carabid beetles was high in control sites (26 species) and low in disturbed site (16 species). Some species appeared only in disturbed sites, while others were strictly in control sites; and others were found in both disturbed and control sites in a varying composition. Shannon-Wiener diversity index (H') revealed that species diversity was high in control sites (H' = 2.082) and low in disturbed sites (H' = 1.260). Carabid beetle species diversity differed significantly between disturbed and control sites ($p = 1.807$ E-14).

Comparison of the amount of soil organic carbon between disturbed and control sites

Overall results show that, at all three depths, disturbed sites contained a lower amount of soil organic carbon when compared with control sites (Figure 2). Also, there was a significant difference in SOC between disturbed and control sites for 15-30 and 30-45 cm depth, but not for 0-15 cm. The respective mean SOC was 46.93 and 60.38 t C/Ha (Table 1). The two sample T-test revealed that the difference was statistically significant ($p = 0.008$). Testing the level of significance by depth, within control sites, there was no significant difference in SOC stock (Table 3), while in disturbed sites, carbon differed significantly with depth (Table 4).

Correlation between SOC and carabid beetle diversity

In examining the relationship between ecosystem service (soil organic carbon) and biodiversity of the carabid beetles at the sampling sites, a mixed pattern of associations was found, some aspects showing positive while others showing a negative relationship.

Species richness was positively correlated to SOC for control sites, while in disturbed sites it was negatively correlated, however not significant ($r = 0.318$, $p = 0.538$ and $r = -0.256$, $p = 0.625$, respectively) (Figure 2a and b). The coefficient of determination was $R^2 = 0.102$ for control sites. Abundance was positively correlated to SOC in both disturbed and control sites ($r = 0.322$, $p = 0.534$, and $r = 0.829$, $p = 0.041$, respectively) (Figure 2c and d). The coefficients of determination were $R^2 = 0.072$ and 0.687, respectively.

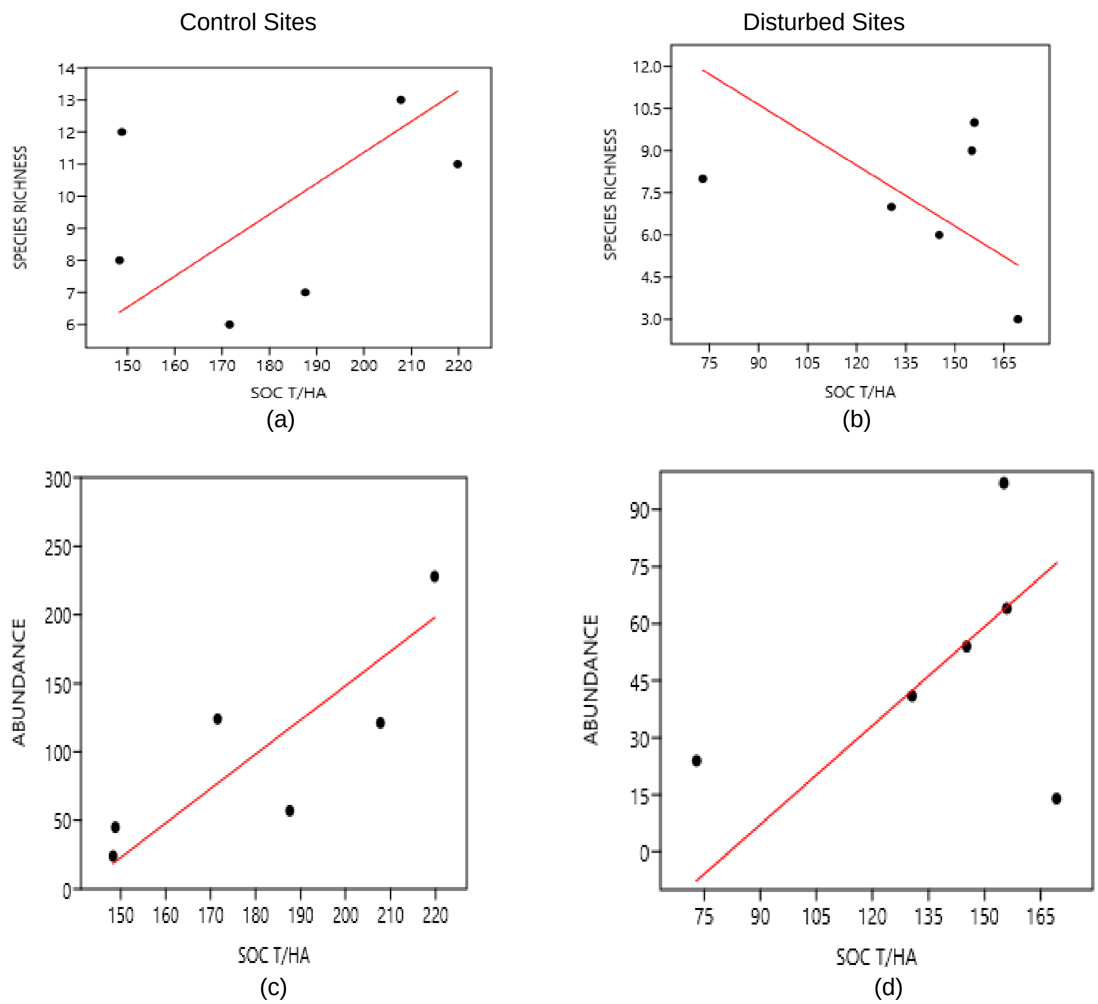

Figure 2. (a-d) The relationship between SOC and carabid beetles species richness (a, b) and abundance (c, d) at control sites and disturbed sites.

DISCUSSION

The mean soil organic carbon estimated in the present study for 0-15 and 15-30 cm is lower than the values reported by Munishi and Shear (2004) from the Uluguru and Usambara Mountains. Historical records of threats in the reserve date back to the 1990s (Hunter, 1992; Shangali et al., 1998). Also studies by Rovero et al. (2005) and Rovero (2012) show that human activities are wide spread in the reserve. Therefore, both historical and ongoing anthropogenic activities in the USNR might have contributed to depletion of the stock.

The present results show that soil organic carbon was higher in control sites and lower in disturbed sites at all three soil depth (Table 2), providing evidence that on-going human activities in the reserve reduce the capacity of soil to sequester carbon. Similar observations were reported by Chiti et al. (2018) when comparing natural and degraded forest in Kenya and also Kessler et al. (2012) when comparing natural forest and agroforest systems. Despite the fact that little is known on the effect of forest degradation on SOC (Berenguer et al., 2014), the present study establishes evidence that upper layer soils 0-45 cm are very sensitive to forest degradation.

The results reveal that soil organic carbon stock decreases from the upper depth (0-15 cm) to the lower depth (30-45 cm). This trend of higher SOC in the top layer might be attributed by higher rate of litter decomposition and might be suggesting that the upper layer is associated with other biological activities (Alamgir and Al-Amin, 2008; Dinakaran and Krishnayya, 2008; Sheikh et al., 2009). A similar decreasing trend was also noted in Uluguru and Usambara Mountains (Munishi and Shear, 2004) for 0-15 and 15-30 cm depth. When depth-wise comparison was considered, it was revealed that for the upper depth the difference in soil organic carbon stock was not significantly different between control and disturbed sites; this was contrary to the middle and lower depth which showed significant differences in soil organic carbon stock (Table 1). Also, the amount of SOC stored

Table 2. Depth-wise comparison of differences in carbon stock between control and disturbed sites.

Depth (cm)	Disturbed C (t/ha)	Control C (t/ha)	p-value (2 sample t-test)	Remarks
0-15	62.46	66.06	0.4	Not significant
15-30	48.13	60.69	0.03	Significant
30-45	30.20	54.39	0.003	Significant
Overall mean	46.93 (± 3.83)	60.38 (± 3.31)	0.008	Significant

Table 3. ANOVA depth-wise analysis for SOC in control sites.

Parameter	Sum of squares	df	Mean square	F	P (same)
Between groups	0.16765	2	0.083825	2.676	0.07851
Within groups	1.59768	51	0.031327	-	-
Total	1.76533	53	-	-	-

Table 4. ANOVA depth-wise analysis for SOC in disturbed sites.

Parameter	Sum of squares	df	Mean square	F	P (same)
Between groups	1.75957	2	0.879784	12.39	0.00004
Within groups	3.6217	51	0.071014	-	-
Total	5.38127	53	-	-	-

among different depths differed significantly in disturbed sites (Table 4) when compared with control sites (Table 3). This might be suggesting that in disturbed sites, there is less input in the upper depth (0-15cm), thus lower SOC is moving down. The present findings are in agreement with Dinakaran and Krishnayya (2008).

Disturbed sites hold a lower amount of SOC when compared with control sites. There may be several possible explanations. First, the altered tree species composition in disturbed sites as a result of disturbance might have altered the quality of litter input. Moreover, the different tree species may increase the quality of litter production and increase rate of decomposition processes, which adds carbon to the soil. Review studies on litter decomposition (Hättenschwiler, 2005; Hättenschwiler et al., 2005), have revealed that decomposition rate of litter from species-rich plant communities are higher than the rate of decomposition of a single species litter. Furthermore, the presence of plant communities with high species richness usually supports and enhances abundance of primary herbivores and numerous microbial activities associated with them. This in turn, will act on litter and hasten decomposition rates adding SOC to the soil. This was also reported by several authors (Fornara and Tilman, 2008; De Deyn et al., 2011; Lange et al., 2015). The second reason for lower SOC in disturbed sites might be associated with the number of stems; disturbed sites had few stems when compared with control sites. This situation leaves the soil bare and prone to mineralization, erosion and decomposition. This may lead to carbon losses (De Beenhouwer et al., 2016). Several studies concur with the present study (Omoro et al., 2013; De Beenhouwer et al., 2016).

Contrary to the present study, Kessler et al. (2012) reported no variation in soil organic carbon stock when comparing an agroforestry and natural forest system. These results might have been attributed by the fact that agroforestry systems do not involve total removal of trees and for this reason the soils are neither left bare nor exposed to severe erosion. The remaining trees prevent soil erosion and mineralization processes and enhance retention of SOC (Sepúlveda and Carrillo, 2015). Also, Dawoe et al. (2013) reported high soil organic carbon in areas with increased management intensification, which involved slashing and burning.

Carabid beetle species diversity, abundance and species richness was high in control sites and lower in disturbed sites. The difference in the diversity of ground beetles between disturbed and control sites is an indication that on-going human activities affect ground beetles' diversity in USFR. Disturbance might have created habitats suitable for only a few generalist species, because it contained few and less tree stands when compared with control sites (pers. observ.), which could create a more homogeneous microclimate and alter soil moisture content by increasing temperature and lowering the moisture content of the soil; this condition might have had an effect on carabid beetles species richness and diversity as suggested by Ings and Hartley (1999). Also, increase in soil temperature and low moisture content have negative effects on SOC (Chen et al., 2018). On the other hand, increase in tree species in control sites may influence creation of diverse habitats and food resources, because increase in vegetation diversity supports an increase in primary productivity (Hooper et al., 2005); this would support herbivore arthropods, and as a consequence the biomass of consumers will increase (Borer et al., 2012). This situation may affect the diversity of ground beetles positively. This observation was also supported by several prior studies for insects (Winter and Möller, 2008; Axmacher et al., 2009; Schuldt et al., 2010).

High carabid species diversity in control sites is supported by the “Enemies hypothesis” (Root, 1973), which postulates that plant communities with diverse tree species will support more predators than simple plant communities with few species; thus, high plant diversity increases the ability of predator to catch prey (Russell, 1989). The present findings are also in agreement with Andow (1991). Likewise, high species diversity in sites with high plant species diversity is in agreement with species-energy ecological theory by Wright (1983). Moreover, the control sites had an undisturbed layer of leaf litter, which would provide habitat for cryptic carabid beetles. The situation may support diverse species to co-occur when compared with disturbed sites where habitats are unsuitable and too few food resources are available to support diverse species.

Contrary to the present study, other investigators (De Beenhouwer et al., 2016; Latty et al., 2006) report no variation in carabid beetle abundances in forests with different management types. In the current study, abundance of carabid beetles and SOC for control sites showed highly positive significant correlation with high values of coefficient of determination. In disturbed sites, the correlation was positive but not significant and coefficient of determination was low. These results suggest that, in absence of human disturbance, SOC is a better predictor of the abundance of ground beetles compared to a disturbed one. It is likely that disturbance is altering SOC, and this changes other conditions, such as soil temperature and moisture content, which directly affect carabid beetles. A recent study by Chen et al. (2018) reported that SOC is negatively correlated with high temperature and low moisture.

Species richness showed a positive correlation with SOC, but not significant for control sites; while disturbed sites showed only a marginal negative correlation, however not significant. It seems that disturbance may be affecting SOC and other factors that are important for different species of ground beetles. Several other factors are important for existence of ground beetles, factors such as specific microclimate condition, food resources that are crucial; and these factors may have been changed as a result of disturbance and changes in carbon. The findings suggest that in disturbed sites, apart from carbon, there might be other environmental parameters that are affected in a similar way to carbon, and likely have influenced the relationship between SOC and carabid beetles.

Similar to the present study, Kessler et al. (2012) reported a positive correlation between carbon and carabids species richness, when only forest species and total (below and above ground) carbon in natural forest was considered; and a negative correlation in agroforestry systems. Other studies examining other taxa are in agreement with the present study; however they used non-soil carbon (Basham et al., 2016) for amphibians, and Gilroy et al. (2014) for dung beetles and birds, and at a global scale (Strassburg et al., 2010) for selected vertebrates. Conversely to the present study, De Beenhouwer et al. (2016) reported no relationship between total carbon and carabid beetles.

CONCLUSION AND RECOMMENDATION

Overall, the present study showed that ongoing human activities in the USNR affect both biodiversity (carabid beetles) and ecosystem serviced (soil organic carbon). These activities should not be overlooked when updating management plans. Therefore in USFR, forest degradation should be kept minimal or halted completely. The positive correlation noted in control sites provides information that maintaining a natural forest can embrace biodiversity and climate mitigation, thus initiatives such as REDD+ activities may serve both biodiversity and climate mitigation. Further research should also include carbon pools such as leaf litter and dead wood in relation to carabid beetles.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Effect of construction of natural reserve on the livelihoods and income of local residents around Conkouati-Doulinational Park, Republic Of Congo

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This study was conducted in Conkouati-Douli National Park (CDNP) to analyze the effect of CDNP construction on local residents' livelihoods and income. A survey of questionnaires of 100 households was carried in four villages: Tandou-Ngoma, Nzambi, Ngoumbi and Mpela. Focused groups discussions, field observations and secondary data from different sources were used to collect information. The data were analyzed using SPSS (version 19), Excel and simple descriptive statistics. Local communities livelihoods were assessed using the sustainable livelihood framework; the households' average monthly income at the village scale was also calculated. The results showed that before the establishment of the CDNP, 45,18,16,10 and 4% of households depend on crop farming, fishing, hunting, trading and formal-employment respectively, while 7% of households were unemployed. After the establishment of the CDNP, 33, 19, 14, 5 and 1% of households depend on fishing, trading, agriculture, formal-employment and hunting respectively, while 19% of households were unemployed. The households' average monthly income before and after the establishment of the CDNP was 227.81 USD and 104.97 USD, respectively, with a change rate of -53.69%. The findings also revealed that incomes were distributed unequally over all households and estimated to be 54.61%; this corresponds to a Gini coefficient of 0.54.

Key words: National Park, Conkouati-Douli, livelihoods, households' incomes, human-wildlife conflicts.

INTRODUCTION

A natural reserve is a protected area of importance for wildlife, flora, fauna or features of geological or other special interest that is reserved and managed for conservation. It also provides special opportunities for study or research. According to scientists at IUCN's (International Union for the Conservation of Nature), World Conservation Monitoring Center (WCMC), and UNEP (United Nations Environment Program), there are 209.429 protected areas today, covering a total area of 32,868,673 km^2 - an area larger than the African continent. In total, 3.41% of marine areas and 14% of terrestrial areas of the world are currently protected (Deguignet et al., 2014). About 65% of the world's protected area network sites are located in the European region. However, these sites represent only about 12% of the total area covered by protected areas. Conversely,

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the African and South American regions are characterized by a relatively small number of protected areas (respectively 3.32 and 1.62% of the total), but these sites are generally very large and cover about 15% protected area (UNEP-WCMC, 2014). Today The Republic of Congo has 15 protected areas, covering an area of 3,990,000 hectares. In total, 11.7% of the national territory (Doumenge et al., 2015), including 4 national parks covering an area of 2,706,464 ha and 4 wildlife reserves covering an area of 323,700 ha. It also includes 3 sanctuaries covering an area of 322,298 ha, one community reserve covering an area of 438,960 ha, one biosphere reserve covering an area of 136,000 ha and one hunting area covering an area of 65,000 ha (DGSD, 2014).

The CDNP is a site that brings together a wide variety of habitats including lagoons and lakes with brackish and mild water, dense forest of dry land, dense marshy forest, grassy and shrubby savannas, mangroves, maritime fringe and sea. This diversity of habitats justifies the diversity of animal and plant species. However, several threats weigh on this site. Indeed, the Conkouati forest is subject to logging, mining and several oil explorations. The existence of the national road, the high human density in the Park and the poaching are other threats to the site. In addition, the proximity of Pointe-Noire to this site favors the illegal trade in bush meat. Another phenomenon is to report, trawlers causing huge damage to turtles. The main objective of this study is to analyze the impact the construction of the Conkouati-Douli National Park on local residents' livelihoods and income as well the influencing factors.

MATERIALS AND METHODS

Study area

This study was conducted in Conkouati-Douli which is a national park located in the south-east of Congo in Central Africa (Figure 1) The Conkouati-Douli National Park was created in 1980 by Order 4432 / MEF / DEFRN / BC-17-01 of May 20, 1980, and the Decree 99/136 bis of August 11, 1999 (Boukoulou, 2016). In 2012, about 7,000 people live in 28 villages that surround the national park, which included approximately 3,500 in the 14 coastal villages of the District of Nzambi and 3,150 in the 14 forest villages of the District of Madingo-Kayes (IUCN/CWAP, 2012). The coastal people are of Vili ethnic origin and they settled in the area in the 13th Century; however, people from villages along the forest road come from various forest ethnic origins. More than 50% of the populations are less than 18 years old, while 80% of the people between the ages of 18 and 45 are unemployed. Local populations, mostly of Vili ethnic origin, make up about 2,500 inhabitants who have remained deeply attached to traditional values and practices related to their natural environment. The dominant activities remaining here such as farming, hunting, and fishing have seized the strong dependence of the populations towards the local natural resources.

CDNP covers a total area of 504,950 ha, the currently known Congo floristic diversity amounts to just over 5,100 species but could reach 6,000 to 6,500 species (DGDD, 2014). It extends between 3° 23- 4° 18 and 11° 06 - 11° 43 E and bounded on the north by the border with Gabon, on the east by Cotovindo savannas, on west by the Atlantic Ocean and on south by Conkouati Lagoon and Ngongo River (Vheiye et al., 2011). The CDNP has two rainfall trends: from October to December and from March to May, with rainfall ranging between 1,200 and 1,700 mm, interspersed with two dry seasons from mid-December to mid-March and from June to September. The CDNP is also characterized by a daytime overcast, a relative humidity of about 85%, a net solar radiation of 70 W / m^2, and low temperatures: 19-21°C compared to the national average temperatures: 24 - 27°C (Vheiye et al., 2011). Mean annual temperatures, moderate, are around 25°C (extreme: 26 - 32°C).

Vegetation is composed of a mosaic of ecosystems as follows. There are semi-deciduous dense rainforests containing *Aucoumea klaineana*, *Terminalia superba*, and *Dacryodes* spp. In the northern part, there are sublittoral forests with a semi-deciduous trend; and transitional and contact formations with *Hyparrhenia* spp. in savannas; clear shrub strata with *Cyperus papyrus* in marsh formations; mangroves with *Rhizophora racemosa* and *Phoenix reclinata*; and bush-like thickets along the coast. These biotopes are home to the classic fauna of Congolese forests and savannas, and a wide variety of seasonal or permanent birdlife, with 48 mammal species, 400 bird species and 41 reptile species (Vheiye et al., 2011).

Sampling

The study was carried out in January-February 2017 in four different villages: Tandou-Ngoma, Nzambi, Ngoumbi, and Mpela. One hundred people responded to the questionnaire submitted, wherein several teams were developed around the CDNP to collect these data. The study took the form of a field survey based on selected households and key informants. The primary data were collected through a random sampling method of open and closed-ended questionnaires. The questionnaire had three sections with information on demographic and socio-economic profile, perceptions of wildlife cost, benefits and attitudes and perceptions of wildlife conservation. The questions were asked to generate answers concerning the characteristics, the professional situation, and the economic situation of the respondents as well as the factors of influence. In addition, personal interviews were conducted in crop field areas. The Kitouba, Vili and French languages were used as a means of communication. Key informants included local leaders (chief, assistant chief). Secondary data were obtained from annual project reports and from the department responsible for social relations in CDNP. The information collected was compared with the findings of the current study on how the community perceives conservation projects. The responses to the structured questionnaires were supplemented with information from key informants.

The survey data was analyzed using the Statistical Package for Social Sciences (SPSS) Version 19 and Excel. Regarding the distribution of household livelihoods, they were classified by categories while taking into account the respective villages on SPSS. Talking about households' income, households' average monthly income at the village level was calculated, a Gini's coefficient (GC) was calculated using Excel to show households' income repartition. The current income of 1979 has been converted to the current price of 2017 according to the exchange rate at the time and the annual average inflation rate of the US dollar.. According to the exchange rate between the US dollar and the franc at that time, the average annual inflation rate of the US dollar used was 3.49% (Data source: www.InflationData.com).This PA was selected because the CDNP is a special case; it practically covers all the natural habitats that can be found on the Congolese territory (rivers, lakes, lagoons, swamp forests, dry land forests, savannas, bush savannas, mangrove swamps, sea coast, etc.). It could be said that CDNP can be redefined as the Congo in

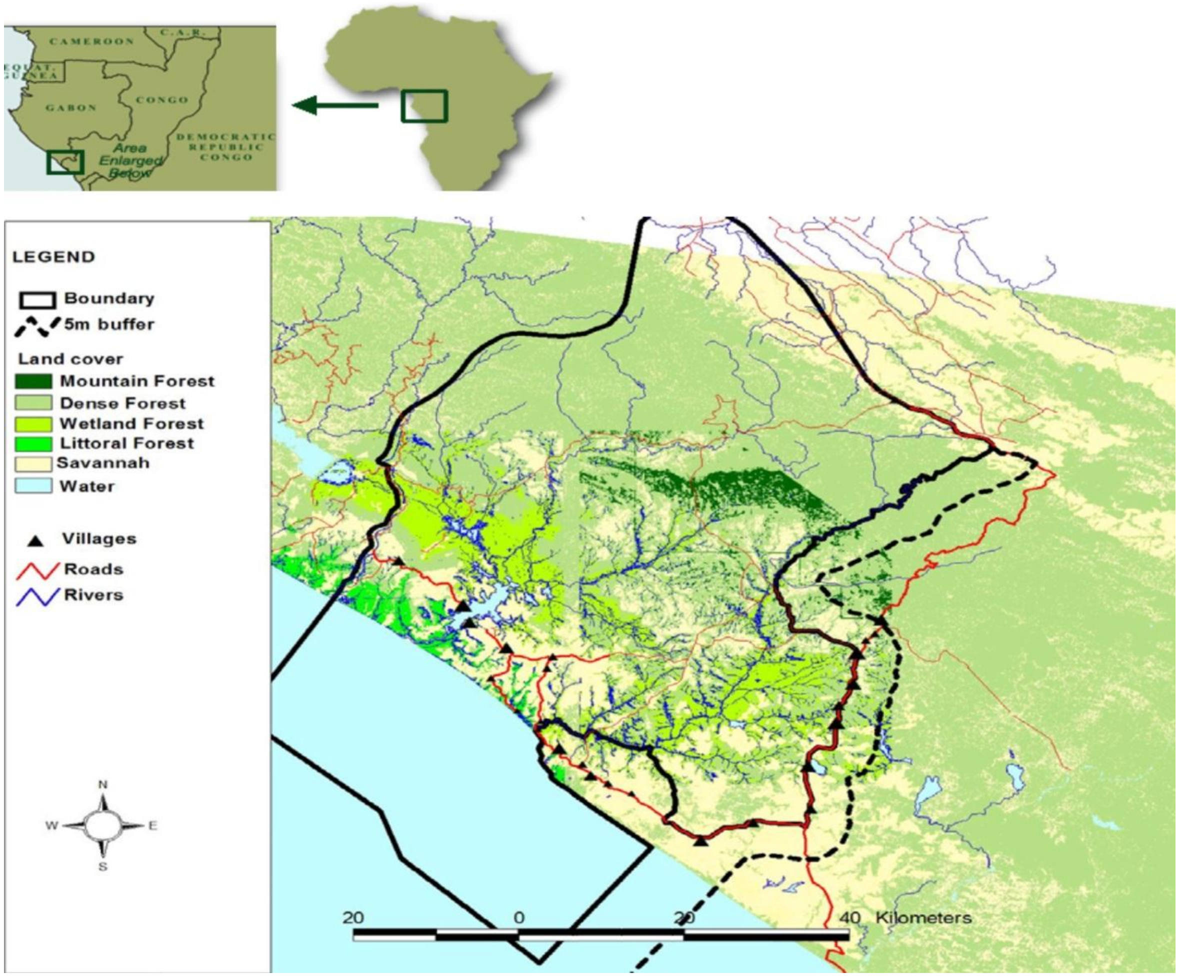

Figure 1. Study area: Conkouati-Douli National Park (CDNP).

miniature in terms of ecosystems because everything that can be found in Congo is in the CDNP. The researchers were able to communicate easily with local people because they also mastered one of the languages, the Kitouba language, spoken in the region.

The CDNP is one of the largest parks in the country. Originally, it covered only a few hectares. Subsequently, the Government of the Republic of Congo decided to enlarge its area by Decree Ministerial to increase its extent to several thousand hectares. This extension encompassed a number of villages that were not included within the Park at the time of its creation. On the other hand, the villages of Tandou-Ngoma, Nzambi, Ngoumbi and Mpela have been inside the Park since its creation. The latter have therefore known all the stages of the evolution of the Park to this day. This particularly motivated the focus of study on these villages to know the point of view of the inhabitants before, during and after the creation of the reserve. The results of this study are detailed in this manuscript.

RESULTS

Characteristics of household samples

Table 1 present our households' characteristics. One hundred respondents were interviewed. Fifty-three of those interviewed were men and 57 were women 38 households were selected in the village of Tandou-Ngoma including 26 men and 12 women. In the village of Nzambi, 29 households were selected 12 men and 17 women. Twenty households were selected in the village of Ngoumbi, including 11 and nine 9, and in the village of Mpela, 13 households were selected, including 4 men and 9 women. Regarding the ages of the respondents, reluctance was observed because most female members were unwilling to tell us their age. Results showed that 75% of the respondents have never been to school, 18% of respondents attained a primary level, while 5% of respondents have attained secondary level of education. Only 1% of the respondents have attained tertiary level and only 1% of the respondents have attained college level of education. Regarding religious beliefs, results revealed that 24% of respondents called themselves Christians, 4% were Catholic, and 72% were practicing ancestral traditions. Results also showed that 87% of the respondents were natives of the region, 13% of the

Table 1. Respondent characteristics across 100 households interviewed.

		Households samples			
		Tandou-Ngoma	Nzambi	Ngoumbi	Mpela
Genre of households	Male	26	12	11	4
	Female	12	17	9	9
Education of households	None	29	22	13	11
	Primary	6	5	5	2
	Secondary	1	2	2	0
	Tertiary	1	0	0	0
	College	1	0	0	0
Religion of households	Christianity	7	9	5	3
	Catholicism	3	1	0	0
	Others	28	19	15	10
Migration of households	Born	34	25	17	11
	Moved	4	4	3	2

Source: a household survey in 2017.

respondents came from neighboring regions.

The change of household samples' income

Table 2 presents the change of household samples' income per village. Before the establishment of CDNP, results have revealed that sixty-one (45%) of the respondents depend on crop farming including 20 and 41 women; 67.2% of farmers were women against 32.8% of male farmers. Twenty-four of the respondents (18%) were fisherman, all of which were men. Twenty-two (16%) of the respondents depend on hunting, all of which were also men. Thirteen (10%) of the respondents were traders including 3 and 10 women. Six (4%) of the respondents were employees, and nine (7%) of the respondents were unemployed. It is important to mention that a respondent could have two or more livelihoods at a time. After the establishment of CDNP, the first finding is the number of unemployed households had increased reaching 28% against 7% before the establishment of CDNP. Only one hunter among the 22 hunters was interviewed before CDNP. The number of farmers also dropped by more than half, from sixty-one farmers (45%) before CDNP to fifteen farmers (14%) after CDNP. There are more fishermen (35, 33%) after CDNP than before CDNP (24, 18%). There are also more traders after CDNP that before CDNP, their numbers increased by 20 (19%). The number of employees after CDNP is 5 (5%).

Here, shows the change in households' livelihoods structure, their income structure and their income variation rate before and after CDNP's establishment, this section is classified into five parts. Table 3 presents the households who have no changes in the livelihoods and decrease of the income before and after the establishment of CDNP. The findings have shown that after the creation of CDNP, 9 crop farmers, 7 fishermen, 5 traders and a household engaged in hunting, fishing and crop farming at the same time, got their livelihoods being the same, but have seen their monthly income decreased 92.21%, 93.27%, and 91.70%, respectively. respectively. The annual income of 2017 was converted to the current price of 2017 based on the exchange rate and the annual average inflation rate of the US dollar. The calculated US dollar income in 1979 was based on the income of the year 1979. According to the exchange rate between the US dollar and the franc at that time, the average annual inflation rate of the US dollar from 1979 to 2017 was 3.49% (Data source: www.InflationData.com).

Table 4 presents the group of households who have changed their livelihoods and increased their income before and after CDNP. The results have revealed that after the creation of CDNP, a group of three households engaged in hunting, fishing and crop farming before CDNP, ended up fishing only after the CDNP, and their incomes have increased by 6.26%. Results also revealed that a group of two households engaged in crop farming and trading before the CDNP, ended up farming only after the CDNP, and their income have increased by 154.24%. Finally, a household engaged in formal-employment and fishing after the CDNP turned into crop farming after the CDNP with an income increase of 28.80%. Table 5 presents the group of households who have changed their livelihoods and decreased their income after CDNP. Table 6 presents the households

Table 2. Livelihoods Change of 100 households samples before and after the establishment of CDNP unit: households.

Villages	Hunting		Fishing		Crop Farming		Trading		Formal-Employment		Unemployed	
	Before	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**after**
Tandou-Ngoma	10	1	18	19	20	8	4	4	1	3	3	8
Nzambi	4	0	4	5	19	6	4	7	4	2	3	10
Ngoumbi	5	0	2	8	13	1	2	5	1	0	2	6
Mpela	3	0	0	3	9	0	3	4	0	0	1	6
Total	22	0	24	35	61	15	13	20	6	5	9	30

Source data: household survey in 2017.

Table 3. Livelihoods diversification and income of households' samples (no changes in the livelihoods and decrease of the income after CDNP).

Livelihoods	Samples	Income USD	Variation rate	Livelihoods
		Before (1979)	**After (2017)**	**%**
Crop Farming→ Crop Farming	9	1494	1108	-25.84
Fishing →Fishing	7	1252	802	-35.94
Trading →Trading	5	912	721	-20.94
Hunting/Fishing/ Crop Farming→Hunting/Fishing/ Crop Farming	1	179	179	0.00

Data Source: household survey in 2017.

who moved from livelihoods after the CDNP to unemployed situation after the CDNP. The findings have revealed that 19 households engaged in crop farming before the CDNP ended up unemployed after the CDNP. Three households engaged in hunting before the CDNP ended up unemployed after the CDNP. A group of 2 households engaged in hunting and fishing at the same time before the CDNP, ended up unemployed after the CDNP. A household engaged in formal-employment, another household engaged in crop farming and formal-employment and another one engaged in fishing, crop farming and formal-employment before the CDNP, all ended up unemployed after the CDNP. Table 7 present the households who moved from unemployed situation before the CDNP to livelihoods after the CDNP. The results have shown that six unemployed households before the CDNP ended up engaging in fishing, trading and formal-employment. To determine households' total income, the average household cash income in one month from all sources of income in each village were calculated. This study classified income sources into hunting income, fishing income, agricultural income, trading income and formal employment income. Income generating activities contribute variably to the total household income. The households' average monthly income before and after the establishment of the Conkouati-Douli National Park was 227.81 USD and 104.97 USD, respectively, a rate of change of -53.69%. The results also revealed that before the establishment of the Conkouati-Douli National Park, the minimum and maximum income was 35USD and 2680 USD respectively, and after the establishment of the Conkouati-Douli National Park, the minimum and maximum income was estimated to 18 USD and 711 USD respectively. The households' average monthly income at the village level was distributed in the following way: before and after the establishment of the Conkouati-Douli National Park, the households' average monthly income in the village of Tandou-Ngoma was estimated to be 282.81 USD and 139.49 USD, a rate of change of -50,68. In the village of Nzambi, the households' average monthly income before and after the

Table 4. Livelihoods diversification and income of households' samples (Change in the livelihoods and decrease of the income before and after CDNP).

Livelihoods	Samples	Income USD	Variation rate	Livelihoods
		Before (1979)	After (2017)	%
Hunting → Fishing	5	1377	546	-60.35
Crop Farming → Trading	7	1519	728	-52.07
Crop Farming → Fishing	4	482	381	-20.95
Hunting → Fishing	5	1377	546	-60.35
Crop Farming → Trading	7	1519	728	-52.07
Fishing / Crop Farming → Fishing	3	1228	954	-22.31
Fishing / Crop Farming → Formal Employment	2	1049	404	-61.49
Fishing / Crop Farming → Fishing / Crop Farming	1	143	41	-71.33
Crop Farming / Trading →Trading	4	1454	420	-71.11
Hunting / Crop Farming → Fishing	3	984	537	-45.43
Hunting / Fishing →Fishing	2	804	447	-44.40
Fishing / Trading → Fishing / Trading	1	536	426	-20.52
Formal Employment →Fishing / Crop Farming	1	245	89	-63.67
Fishing / Formal Employment →Fishing	1	268	179	-33.21
Hunting/Crop Farming →Formal Employment	1	536	91	-83.02

Data Source: household survey in 2017.

Table 5. Livelihoods diversification and income of households' samples (from livelihoods to no livelihoods before and after CDNP).

Livelihoods	Samples	Income USD	Variation rate	Livelihoods
		Before (1979)	After (2017)	%
Hunting / Fishing → Unemployment	2	447	0	-100.00
Crop Farming→ Unemployed	19	2589	0	-100.00
Hunting → Unemployed	3	3073	0	-100.00
Formal Employment → Unemployed	1	143	0	-100.00
Crop Farming / Formal Employment → Unemployed	1	245	0	-100.00
Fishing / Crop Farming / Formal Employment → Unemployed	1	179	0	-100.00

Data Source: household survey in 2017.

establishment of the Conkouati-Douli National Park was estimated to be 170.55 USD and 94.96 USD respectively, a change rate of -44.32. The households' average monthly income before and after the establishment of the Conkouati-Douli National Park in the village of Ngoumbi was estimated to be 181.1 USD and 80.8 USD respectively, a rate of change of -56.35. Finally, in the village of Mpela, the households' average

Table 6. Livelihoods diversification and income of households' samples (from no livelihoods to livelihoods before and after CDNP).

Livelihoods	Samples	Income USD		Variation rate
		Before (1979)	After (2017)	%
Unemployed → Fishing	2	0	268	268.00
Unemployed → Trading	2	0	223	223.00
Unemployed → Formal Employed	2	0	449	449.00

Data Source: household survey in 2017.

Table 7. Contribution of different income-generating activities to households' average monthly income before and after the establishment of CDNP in village level.

Village	Households' average monthly income in village level USD		Variation rate
	Before	After	
Tandou-Ngoma	282.81	139.49	-50.68
Nzambi	170.55	94.96	-44.32
Ngoumbi	185.1	80.8	-56.35
Mpela	210.38	61.84	-70.61

Source data: household survey in 2017.

monthly income before and after the establishment of the Conkouati-Douli National Park was estimated to be 210.38 USD and 61.84 USD respectively, a change rate of -70.61.

Factors affecting households' livelihood and income

These changes are influenced by several factors mentioned above. Laws prohibiting hunting on the economic scale, damages caused by wild animals in farmers' crops subsequently are not compensated for the most part by the authorities. Conflicts between local people and CDNP's staff added to the lack of hiring in the villages and the lack of markets in which the prices of the products could be well fixed by the local populations. Not all these factors are unrelated to inequalities in the income of local populations.

Loss of access to land forest products

The findings have revealed that there is significant association between restrictions on access to resources and loss of economic opportunities from hunting $\chi 2$ = 39.984 (df = 1, N = 100) P < 0.05. The results also showed that there is significant association between restrictions on access to resources and loss of economic opportunities from agriculture $\chi 2$ = 10.633 (df = 1, N = 100) P < 0.05.

Wildlife depredations on croplands

Several Pearson independence tests were conducted using SPSS (version 19) to show a significant association between wildlife damages and households' livelihoods and income. The results have revealed that there were significant associations between wildlife damages and households' livelihoods $\chi 2$ = 17.667 (df = 2, N = 100) P < 0.05. The results also showed that there is a significant relationship between wildlife damages and the decline in the number of farmers after the establishment of CDNP, $\chi 2$ = 23.087 (df = 2, N = 100) P < 0.05. The findings also showed that there is a significant relationship between wildlife damages and unemployed households after the establishment of Conkouati-Douli Natural Park. $\chi 2$ = 17.667 (df = 2, N = 100) P < 0.05. The results also showed that there is a significant association between damages caused by wildlife and loss of agriculture's opportunities,

Table 8. Gini coefficient of the households' total income before and after CDNP.

Livelihoods	Gini-coefficient	
	Before	After
Total	0.45	0.54
Tandou-Ngoma	0.50	0.52
Nzambi	0.50	0.55
Ngoumbi	0.32	0.47
Mpela	0.26	0.58

Source: household survey in 2017.

Table 9. Gini coefficient of households' income by livelihoods before and after CDNP.

Livelihoods	Gini-coefficient	
	Before	After
Hunting	0.52	1
Fishery	0.39	0.40
Agriculture	0.31	0.25
Trading	0.27	0.30
Formal-Employment	0.20	0.27

Source: household survey in 2017

$\chi 2$ = 13.465 (df = 2, N = 100) $P < 0.05$. The people living in and around the Conkouati Douli Park are the first to oppose this, denouncing its disastrous consequences on the economy and agriculture. The villages of Tandou-Ngoma and Nzambi are most affected by the ban. Situated near the border of Gabon, they are often the target of elephant raids. In this case, 66% of households claimed to have had experienced this impact by elephants, most of them were women. The households listed many crop-raiding species including antelopes buffaloes, monkeys, wild pigs, most frequently listed species were elephants (95% of farmers have been victims of the damage caused by elephants), and they were ranked the most problematic. The household survey also indicate that banana fields, maize, and cassava (essential staple food of communities), are often consumed and trampled by elephants.

Income inequality of household samples

The Gini's coefficient was used to measure the distribution of income in this study population before and after the establishment of the Conkouati-Douli National Park. Table 8 presents households' income inequality per village. Before and after the establishment of the National Park of Conkouati-Douli, households' total income respectively shows a Gini's coefficient 0.45 and 0.54, which means before CDNP, there was 45.85% of inequality in the total income distribution, and 54.61% of inequality in the total income distribution after the establishment of the CDNP. Regarding the villages before the CDNP, results respectively show 50.19, 50.07, 32.70 and 26.07% of inequality in the total income distribution in the villages of Tandou-Ngoma, Nzambi, Ngoumbi, and Mpela. After the CDNP, the findings respectively show 52.16, 55.09, 47.71 and 58.15% of inequality in the total income distribution in the villages of Tandou-Ngoma, Nzambi, Ngoumbi, and Mpela. From these results, it was discovered that the inequality rate in the total income distribution has decreased in the villages of Tandou-Ngoma and Nzambi and has increased in the last two villages.

Table 9 presents households' income inequality per livelihoods. Results showed 52.22 and 100% of inequality in total hunting's incomes distribution before and after the CDNP respectively. The same results showed respectively 39.57 and 40.78% of inequality in total fishing's incomes distribution before and after the CDNP. Regarding Agriculture, the findings showed respectively 31.64 and 25.61% of inequality in total incomes distribution before and after the CDNP. Regarding Trading, results showed respectively 27.68 and 30.14% of inequality in total incomes distribution before and after the CDNP, and finally, results showed respectively 20.90 and 27.84% of inequality in total formal employment incomes distribution before and after the CDNP.

DISCUSSION

This study is based on a comparison of the economic situation (livelihoods and incomes) of local communities before and after the creation of the park.

Effects of CDNP on community livelihood

Effects of CDNP on local livelihoods can be from two main points of view: 1) loss of access to land and forest product due to the policy changes; and 2) Human-Wildlife conflicts. According to the Human Development Index (HDI), about 90% of the world's poor depend on the forest (Rich, 2014). In Africa, about 600 million people have been estimated to rely directly on forests for their livelihoods (Bauer et al., 2015). Many authors have highlighted the flaws in the establishment and implementation of conservation policies in PAs that impact local communities' livelihoods and their lands user rights (Ayari, 2017; Rainforest Foundation UK, 2014). Previous studies have examined the issue of the environmental impacts of protected areas, yet one of the most difficult issues in conservation science and policy concerns the impact of protected areas on the well-being of local communities. In this case study, several factors are the cause of the restriction of access to forest resources such as Conflicts with PA's staff, land use rights that are not respected by the government and PA's staff, policy changes on the conservation of PAs. Bennet (2016) made the same observation by conducting a study on Community perceptions of marine protected area livelihood impacts, governance and management in Thailand." A similar study was conducted in Congo and the observation was the same, local communities no longer have access to forest resources, their rights are flouted (Ayari, 2017).

Human-Wildlife conflicts can be classified into two categories: damage to croplands and threats to human life by wild animal from the CDNP. In the case of CDNP, the challenge is crop-raiding mainly by elephants, which especially destroy banana, cassava and maize croplands. Nature studies of the forest elephant's diet reveal that it consumes a variety of food dominated by leaves (Blake, 2002). Boukoulou et al., (2012) made the same observation about feeding behavior by conducting a study on “Human/Elephants conflicts in Miélékouka village north of Odzala Kokoua National Park (Congo) and came to the conclusion that Elephants are much more involved in destruction of banana, cassava and maize crops. It can be assumed that their preference for banana, cassava and maize is due to the abundance and availability of these crops in the croplands. Crop raiding by elephants is considered as major impact, since rural incomes often depend on small-scale farming and raids are rarely compensated. Similar conflicts involving elephants were reported in Africa (Mwakatobe et al., 2014; Mc Guinness et al., 2014; Nyirenda et al., 2013) and in Asia (Redpath et al., 2015; Karanth et al., 2013). Elephants sometimes cause infrastructural and physical damage (Wilson et al., 2015; Hoare, 2015; Redpath et al., 2013; Gubbi et al., 2014).

The need to effectively resolve human-wildlife conflicts inside and outside protected areas is becoming increasingly important. In this case, suggestions were made to minimize human-elephant conflict in the CDNP such as: 1) Propose elephant eviction techniques based on scaring combined with fire and chili spraying. These devices will be installed in and out of the fields. 2) Vigilance methods that aim to alert farmers to the presence of approaching wildlife. 3) Training community members on Human-Wildlife Conflicts (HWC) and Animal Control Strategies by non-governmental organizations and Parks Authority. Some of these methods have been observed and recorded as being used in different countries (Boukoulou et al., 2012; Barua et al., 2013; Redpath et al., 2015).

Conclusion

This particular study aimed to assess the livelihoods of communities living in and around and their local expansions on the construction of the Conkouati-Douli National Park. It also assessed the impact on household monthly incomes before and after the establishment of the National Park of Conkouati-Douli. Finally, it analyses the main problems caused by the park and the recommendations made by local populations in order to solve the problems they encounter. After this study, it can be concluded that the creation of the CDNP does have a negative impact on local people's incomes and livelihoods. The findings have showed crop farming was the main activity before the CDNP (61 before the CDNP to 15 after the CDNP), and after the establishment of the CDNP, fishing became the main activity inside and out of the PA (24 before the CDNP to 35 after the CDNP).

The households' average monthly income before and after the establishment of the CDNP, was 227.81 USD and 104.97 USD, respectively, a rate of change of -53.69%. The findings have also shown a strong unequal distribution of total income after the establishment of the National Park of Conkouati-Douli with a Gini's coefficient of 0.54 against a Gini's coefficient of 0.45 before the establishment of the CDNP. Regarding the villages, results have shown an unequal distribution of income in the villages of Tandou-Ngoma and Nzambi with respectively a Gini's coefficient of 0.50 and 0.50 before the CDNP. The villages of Ngoumbi and Mpela showed respectively a Gini's coefficient of 0.32 and 0.26. After the establishment of the CDNP, the four villages show an unequal distribution of income with Gini's coefficient of 0.52, 0.55, 0.47 and 0.58, respectively. Gini's coefficients of households' income by livelihoods also show an unequal distribution of income.

This research argues that it is important for authorities to understand how to achieve conservation objectives in protected areas. It would be important to take into account the perceptions of local people, in order to find a good balance between ecosystem management and improving the living conditions of local communities. Conservation programs usually imply restrictions to land use and access, and changes in land use habits that are rarely beneficial to communities. For that reason, it would be necessary for the Government to respect the rights of local people, to strengthen partnerships with local community organizations by providing them with sufficient resources through PA budgets to participate meaningfully. Also, the government is told to encourage and support local people to move towards non-farming activities.

In summary, this study was very productive and interesting. However, during this survey, data such as crops areas of farmers' fields including areas damaged by wildlife, the estimation of the total cost from crop damages by wildlife, the prices of the main crops, the prices of the main sales products from traders and prices of major fishery products were not collected. There was also some challenges with the time consumption to gather an interesting number of people. Lack of data on the households, the refusal of some to cooperate during the interrogations, and the lack of materials and technical support needed in the data analysis posed as challenges; these would have enabled a comprehensive work on the impact of protected areas on local populations. This study represents a relationship between local populations on protected areas and their impact in the socio-cultural and economic fields; also to make local populations aware of the importance of protected areas in the national territory.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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