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Can the production of wild forest foods be sustained in timber concessions? Logging and the availability of edible caterpillars hosted by sapelli (*Entandrophragma cylindricum)* and tali (*Erythrophleum suaveolens*) trees in the Democratic Republic of Congo

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ABSTRACT

Sapelli (*Entandrophragma cylindricum*) and tali (*Erythrophleum suaveolens*) are among the most important timber species harvested from Congo Basin forests. They also host edible caterpillars, *Imbrasia oyemensis* and *Cirina forda,* respectively, which are important to the nutrition and income of rural and urban populations. This study evaluated the density of these tree species within a 10 km radius around each of 4 villages and in the 2012 annual cutting areas of two timber concessions in the region of Kisangani (DRC). Sapelli and tali trees ≥ 20 cm dbh and their stumps were identified and measured on 21 five ha plots around each village and 20 five ha plots on each concession. Around villages and on concessions, sapelli trees occurred at densities of 0.048 ± 0.008 harvestable trees (≥ 80 cm dbh) ha^{-1} and 0.135 ± 0.019 precommercial trees ha^{-1}. Harvestable tali trees (≥ 60 cm dbh) were seven times more abundant at 0.347 ± 0.032 ha^{-1}, while precommercial tali trees occurred at densities of 0.329 ± 0.033 trees ha^{-1}. Between 25% and 40% of the harvestable sapelli trees had been logged as compared to < 3% of the harvestable tali trees. Production per tree, derived from another study, was extrapolated to estimate caterpillar yields on a half circle of 15,700 ha within 10 km of villages, using these estimates of tree densities. Depending on the village, yields were estimated as 11.6–34.5 Mg $year^{-1}$ of *I. oyemensis* from sapelli trees, and 65.8–80.9 Mg $year^{-1}$ of *C. forda* from tali trees, an average of 0.74–2.2 kg ha^{-1} year and 4.2–5.2 kg ha^{-1} year, fresh weight, respectively (0.23–0.68 kg ha^{-1} $year^{-1}$ and 1.3–1.6 kg ha^{-1} $year^{-1}$, dry weight, respectively). Harvestable trees yielded more caterpillars, providing most of the *C. forda* caterpillars. However, because harvestable sapelli trees occurred at low densities, the bulk of *I. oyemensis* caterpillar production would be hosted on precommercial trees. Logging practices that reject poorly formed or hollow trees and guidelines that call for high minimum diameter limits and retention of seed trees or prohibit logging on slopes or riparian zones, safeguard edible caterpillar production. Multiple resource management for multiple stakeholders would require more deliberate planning and management approaches based on negotiations with local communities and approaches like setting aside collection zones or collection trees that would be protected from logging.

1. Introduction

More than 1.7 million km^2 of the Congo Basin were covered in dense humid forest in 2012 (Potapov et al., 2011 in Marquant et al., 2015), 99% of them primary or naturally regenerated (Megevand et al., 2013). The Democratic Republic of the Congo (DRC) has 101.8 million ha of dense tropical forests (Bayol et al., 2012), of which 12.2 million ha are currently allocated to 80 timber concessions (Bayol et al., 2012; Karsenty and Ferron, 2017). Between 1991 and 2009, DRC produced an average of 228,000 m^3 of logs/year (Bayol et al., 2012). The Federation of Forest Industries in DRC has documented an increase in timber exports, of which the value in 2002 was estimated at €6.9 million but reached €35.3 million in 2005 (Eba'a Atyi and Bayol, 2009).

In Central Africa, forests provide food and other subsistence products to the approximately 60 million people who live within and near them (De Wasseige et al., 2014 in Marquant et al., 2015), as well as contributing to the nutrition of another 40 million people who live in urban areas near the forest estate (Nasi et al., 2011 in Marquant et al., 2015). In the DRC, seventy percent of the country's population, about 40 million people, live in rural areas and depend on these forests (Vundu, 2007).

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They obtain both income and food from non-timber forest products (NTFP), particularly during the so-called hunger periods, after one year's agricultural production has been consumed and before the next is harvested. These products also add diversity to local diets, providing proteins, vitamins and minerals not provided by their crops.

Forest inventories in three provinces of the DRC documented 709 potential timber species (DIAF, 2009), of which 53 were being exploited. The annual harvest potential of commercial species is estimated at 1–3 $m^3 ha^{-1}$ (Malele, 2005). Many of the species harvested also produce NTFP that are important to the economies and food security of populations living within and around the forest areas (Cunningham, 1996; Tabuna, 1999; Liengola, 2002; Ndoye and Tieguhong, 2004; Kahindo, 2007; Ingram et al., 2012; Rist et al. 2012; Eckebil et al., 2017). The 2002 DRC forest code adopted through Law No. 11/2002 to encourage sustainable management and socioeconomic benefits, was complemented with guidelines requiring that concessionaires submit management plans and sign an agreement with local communities. The code recognized the traditional user rights of communities to resources in production forests, including ownership of trees around their villages (Lescuyer et al., 2014). Typically, local users are not impeded from gathering or collecting NTFPs within concessions, for subsistence use (Cerutti et al., 2017). However, to date, forest management has rarely taken into account these non-timber resources and benefits (Ndoye and Tieguhong, 2004; Bikoue et al., 2007; Karsenty and Vermeulen, 2016; Eckebil et al., 2017).

Among the important foods obtained from forests are edible caterpillars ('mbinzo', in Lingala), which are both consumed and sold, contributing to food security and income of the rural and urban populations around Kisangani (Malaisse, 1997; Tabuna, 1999; Mbétid-Bessane, 2005; Toirambe, 2007; Latham, 2008; Hopkins, 2007; Amon et al., 2009; Lisingo et al., 2012). Caterpillars are high in proteins and rich in micronutrients, providing magnesium and iron that are essential for the nutrition of pregnant women and babies (FAO, 2013), as well as important vitamins and fatty acids, notably linoleic and linolenic acids (Malaisse, 1997; Amon et al., 2009). Flour made from the caterpillar *Imbrasia oyemensis* contains 58% protein and 24% fats (Amon et al., 2009) as well as potassium, calcium and phosphorus (Foua Bi et al., 2015 in Eckebil et al., 2017). *Cirina forda* contains 14% protein, a proportion similar to beef. As a result, edible caterpillars are important to preventing malnutrition and represent a crucial complement to the diets of young children, essential for their physical and cognitive development (Vantomme et al., 2004).

These edible caterpillars feed on the leaves of several tree species that are harvested for timber, notably African mahogany, or sapelli (*Entandrophragma cylindricum*), which hosts the larvae of *I. oyemensis;* and tali (*Erythropheum suaveolens*), which hosts the larvae of *C. forda.* Of the 53 timber species harvested in the DRC, sapelli is the most important, contributing 19.6% of the national production. In 2007, sapelli was the species with the highest production volume among the timber industries in the DRC (60,910 m^3 out of a total of 310,130 m^3, Eba'a Atyi and Bayol, 2009). Sapelli bark is also used in traditional medicine (Kemeuze, 2008 in Eckebil et al., 2017). Tali ranks fourth in volume among timber species harvested in the Congo Basin (Bayol et al., 2012). Tali also produces bark and roots that are high in alkaloids and are used in traditional medicine and as fish poison (Okeyo, 2006).

Harvesting of these timber species reduces the amount of foliage available to feed the caterpillars and could therefore affect their abundance and availability (Mate, 2002; Lisingo et al., 2012; Eckebil et al., 2017). This represents a potential conflict of use between a one-time harvest of timber and an annual harvest of edible caterpillars over decades. A reduction in the availability of these caterpillars could have long term effects on the well-being of local populations, particularly those rural people who are most vulnerable. For this reason, timber harvesting could represent a conflict between the interests of timber concessions and those of local people. Approaches to forest management that consider resources used by local people as well as industrial timber could minimize the potential conflicts between logging and the needs of local populations that consume these wild foods (Guariguata et al., 2010; Ingram et al., 2012; Rist et al., 2012; Herrero-Jauregui et al., 2013; Karsenty and Vermeulen, 2016). To move forward towards multiple resource management requires information about the yields of edible caterpillars on timber trees and how logging affects their availability (Hopkins, 2007; Eckebil et al., 2017).

This study was carried out to address these information needs by quantifying the density of sapelli and tali trees of different size classes around villages and within concessions; and the number logged. In addition, it extrapolates the quantity of caterpillars yielded annually on these host trees and evaluates the ways forest management affects the potential to sustain these two types of resource. It is hoped that the results will contribute to the development of management approaches to sustain the production of both timber and non-timber resources for multiple stakeholders in these forests

2. Study area

The study was carried out in two logging concessions in the vicinity of Kisangani, in Eastern DRC. One, referred to as Alibuku, is managed by the Compagnie de Transport et Exploitation Forestière (COTREFOR, abbreviated as CR), and extends over 275,000 ha, centered on 00°44.92′N, 25°17.84′E, at 433 m elevation. The other is referred to as the Kayete concession, managed by the Compagnie Forestière de Transformation (CFT, abbreviated as CT), with an extension of 190,000 ha, centered on 00°08.92′N, 25°37.07′E, at 457 m elevation (Fig. 1). Monthly mean temperature in this area ranges from 22.4 °C to 29.3 °C, with an annual mean of 25 °C; and annual rainfall ranges from 1500 mm and 2000 mm, averaging 1750 mm/year (MONUSCO, 2014). COTREFOR began operations their concession in 2005 while CFT has been exploiting theirs since 2010. Both are carrying out harvests under their first 25 year cutting cycle. However, timber was harvested from both concession areas by other companies prior to these two. Parallel studies were carried out in two villages within or adjacent to each of these concessions: Nyonga ('Na'), and Agbokanga ('Aa') within concession CR; and Babongena ('Ba') and Kayete ('Ke') adjacent to or within concession CT (Fig. 1). The villages were selected on the basis of their proximity to or inclusion within the concession and their potential dependence on the concession forest.

3. Methods

3.1. Data collection

3.1.1. Density of trees on concessions

To determine the density of the selected timber species within the concessions and the impact of logging, sampling was carried out one year after log extraction in the cutting areas of 2012: 9098 ha on the CR concession and 3833 ha on the CT concession. A total of 20 five ha sample plots (100 m × 500 m), were distributed according to a stratified random sampling scheme. Five 25 ha inventory plots were selected at random within each of four quadrants of each cutting area, and within each of the twenty selected inventory plots a 5 ha sample plot was laid out. Within each five ha plot, individuals of sapelli and tali ≥ 20 cm dbh were identified and their diameters measured with a tape at 1.3 m, except for trees with buttress roots at 1.3 m, in which case diameter was measured 20 cm above the buttresses. Stumps of these species were also identified and measured at stump height, which varied from one to another.

3.1.2. Density of trees around the villages

Around the sample villages associated with each concession, densities of sapelli and tali trees were estimated by sampling an area of a half circle of 10 km radius towards the central part of the concession from the village. The sampling scheme consisted of 3 transects 10 km long, laid out at 45° angles one from the other, towards the concession. Each