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Can wild forest foods contribute to food security and dietary diversity of rural populations adjoining forest concessions? Insights from Gabon, DR Congo and Cameroon

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HIGHLIGHTS

- A high diversity of forests foods for consumption exists in DR Congo, Cameroon and Gabon
- Despite a diverse pool of wild foods, more than 80% of households suffer from food insecurity.
- A significant inverse correlation exists between food insecurity and forest foods consumption meaning that forest foods play a role in ensuring food security and nutrition among populations near forest concessions.
- Age and business ownership are significant determinants of food security among forest communities.
- Investing in strategies to provide income outside unlicensed logging and practicing agriculture on logged land, can contribute to addressing health, nutrition and food security.

SUMMARY

The potential of forest foods to address malnutrition, food insecurity and poor dietary intake is increasingly being recognized. However, most existing data presents average results of proximate analysis, overlooking the opportunities to document how forest foods contribute to nutrition, food security and dietary intake. In this study, food security was estimated using the HFIAS score while dietary intake was estimated using FFQ recalls among 720 households in and around six logging concessions in Cameroon, DR Congo and Gabon. There was a high diversity of forests foods consumed, with DR Congo (FFCS=16.2) registering the highest number. Cameroon had the highest number of food groups (HDDS=12.5) while Gabon had the highest number of food varieties (FVS=24.5). Despite a highly diverse pool of wild foods in the region, households 87% of suffered from food insecurity. A significant inverse correlation was observed between the HFIAS score and the FFCS (r^2=−0.26, P=0.0002), revealing that forest foods can play a role in ensuring food security and nutrition among populations near forest concessions. The chi-square test revealed that age >46 years, and business ownership were associated with food security. Further work is required to document how wild forest foods can contribute to improved diets among these populations, including documenting the nutrient composition of more forest foods, integrating them into regional dietary guidelines and encouraging their domestication.

Keywords: forest-dwellers, forest concessions, biodiversity, dietary intake, forest foods

Les aliments sauvages peuvent-ils contribuer à la sécurité alimentaire et à la variété diététique des populations rurales jouxtant les concessions forestières? Découvertes provenant du Gabon, de la République Démocratique du Congo et du Cameroun

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Pour faire face à la malnutrition, à l'insécurité alimentaire et à un apport alimentaire appauvri, le potentiel des aliments forestiers est de plus en plus reconnu. Toutefois, la plupart des données existantes présentent des résultats moyens d'analyse approximative, faisant fi des opportunités de documenter la manière dont les produits forestiers peuvent contribuer à la nutrition, à la sécurité alimentaire et à l'apport alimentaire. Dans cette étude, la sécurité alimentaire a été estimée en utilisant le score HFAIS, alors que l'apport alimentaire était estimé en utilisant les rappels FFQ auprès de 720 foyers autour et au sein de six concessions de coupe au Cameroun, en République Démocratique du Congo et au Gabon. On trouva une haute diversité d'aliments forestiers consommés, la République Démocratique du Congo en enregistrant le plus grand nombre (FFCS=16.2). Le Cameroun comptait le plus grand nombre de groupes d'aliments (HDDS=12.5), alors que le Gabon pouvait se vanter de la plus grande variété d'aliments (FVS=24.5). Malgré la forte diversité d'aliments sauvages dans la région, la plupart des foyers (87%) souffrait d'insécurité alimentaire. Une corrélation inverse importante était observée entre le score HFIAS et le FFCS (r^2=–0.26, P=0.0002), révélant que les aliments forestiers peuvent jouer un rôle en assurant la sécurité alimentaire et la nutrition dans les populations vivant proches des concessions forestières. Le test chi-square révéla qu'un âge >46 ans et l'accès à des revenus provenant de commerce étaient associés à la sécurité alimentaire. Un travail supplémentaire est nécessaire pour documenter la manière dont les aliments sauvages forestiers peuvent contribuer à améliore les régimes dans ces populations, incluant la composition nutritive de davantage d'aliments forestiers, en les intégrant dans les lignes de conduite alimentaires régionales et en encourageant leur domestication.

¿Pueden los alimentos silvestres del bosque contribuir a la seguridad alimentaria y a la diversidad de la dieta de las poblaciones rurales adyacentes a las concesiones forestales? Perspectivas de Gabón, la República Democrática del Congo y el Camerún

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Cada vez se reconoce más el potencial de los alimentos del bosque para hacer frente a la malnutrición, la inseguridad alimentaria y una dieta deficiente. Sin embargo, la mayoría de los datos existentes presentan resultados promedio de análisis de constituyentes que pasan por alto las oportunidades de documentar la contribución de los alimentos del bosque a la nutrición, la seguridad alimentaria y la dieta. En este estudio, la seguridad alimentaria se estimó utilizando la puntuación de la HFIAS, mientras que la ingesta dietética se estimó utilizando cuestionarios de Frecuencia de Consumo de Alimentos (FCA) en 720 hogares dentro o alrededor de seis concesiones madereras en el Camerún, la República Democrática del Congo y el Gabón. Se observó una gran diversidad de Alimentos Forestales Consumidos (AFC=16,2), siendo la República Democrática del Congo la que registró el mayor número. Camerún mostró la mayor Diversidad Elevada de Dieta (HDDS=12,5) mientras que Gabón tuvo el mayor número de Variedades de Alimentos (VA=24,5). A pesar de la gran diversidad de alimentos silvestres de la región, la mayoría de los hogares (87%) sufren inseguridad alimentaria. Se observó una correlación inversa significativa entre la puntuación de la HFIAS y los AFC (r^2=–0,26, P=0,0002), lo que revela que los alimentos forestales pueden desempeñar un papel para garantizar la seguridad alimentaria y la nutrición de las poblaciones cercanas a las concesiones forestales. La prueba de chi-cuadrado reveló que la edad >46 años, y el acceso a ingresos procedentes de negocios o salarios, estaban asociados con la seguridad alimentaria. Es necesario igual trabajando en documentar la forma en que los alimentos silvestres del bosque pueden contribuir a mejorar la dieta de estas poblaciones, como la composición de nutrientes de un mayor número de alimentos del bosque, su integración en las directrices dietéticas regionales y el fomento de su domesticación.

BACKGROUND

The most recent global food security report revealed that severe or moderate food insecurity is rising among Central and West African countries, from 45.3% in 2014 to 53.6% in 2019 (FAO, IFAD, UNICEF, WFP and WHO, 2019). Food insecurity, undernutrition and micronutrient deficiencies undermine health, psychological wellbeing, work capacity and economic development (Mbhenyane 2017, Vollmer, *et al.* 2016). Reports elsewhere indicate that undernutrition and micronutrient deficiencies are a persisting public health challenge in Central Africa (Kamgaing *et al.* 2018), with Cameroon documented to have the highest stunting a measure of height-for-age (HAZ) for individuals, rates of (33%) and iron deficiency (45%). While DR Congo has the highest vitamin A deficiency (42%) among women in the region. For the purposes of this paper, food security refers to the ability of communities, households and individuals to have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (World Food Summit 1996).

Millions of people in Central Africa, including the Congo Basin, rely on forests for food and income (Pimentel *et al.* 1997, Laird 1999, Ndoye and Tieguhong 2004, Tieguhong

and Ndoye 2007, Fungo *et al.* 2016a). The economic growth attributable to forest sourced foods and their products ranges between 6 to 10% per annum (Sonwa *et al.* 2012). The World Bank additionally estimates that more than 50% of the Congo Basin forest population depends, to varying degrees, on forests for livelihoods, not just for food but also for fuel, livestock grazing and medicine (World Bank 2006). Angelsen *et al.* (2014) and Tata-Ngome *et al.* (2017) reported that wild foods obtained from tropical forests are as vital to the livelihoods of rural people in developing countries as agriculture. Forests contribute about 30.3% of household food worth (about $304), including fish, bush meat, fruits, vegetables and mushrooms all of them important sources of proteins, vitamins and essential minerals for the rural poor (Angelsen *et al.* 2014). The superiority of forest foods in contributing to essential nutrients and bioactive contents as compared to the processed and imported foods has been documented in several African countries (Onimawo *et al.* 2003, Blaney *et al.* 2009, Fungo *et al.* 2015, Fungo *et al.* 2019). For example, in Gabon and Cameroon, forest foods have been reported to address both macro and micronutrient deficiencies and non-communicable disease disorders related with inadequate intake of bioactive compounds (Fungo *et al.* 2019, Blaney *et al.* 2009, Fungo *et al.* 2005). In Gabon, forest fruits of *Poga oleosa, Panda oleosa, Gambeya lacourtiana* and *Afrostyrax lepidophyllus*, if consumed in adequate daily amounts by a non-lactating and non-pregnant woman, can provide their 100% daily nutrient requirements (DRI), for magnesium (1000 mg/day), iron (58.8 mg/day) and zinc (12 mg/day). Also, 100% DRI for vitamin E requirements of 0.4 mg/day for children and 19 mg/day for women can be met by consuming adequate amounts of fruits of *Poga oleosa, Panda oleosa and G. lacourtiana.* In neighbouring Cameroon, children aged between 1–3 years and women of reproductive age can get considerable amounts of vitamins C, A and E, selenium, calcium, iron and zinc from forest foods (Fungo *et al.* 2016). Tata *et al.* (2019), further revealed that forests can provide foods that are protective against anaemia in women and children. Bush meat and fish are major animal source foods providing significant amounts of digestible iron to address anaemia among communities residing near forest concessions (Nasi *et al.* 2011, Fa *et al.* 2015). Furthermore, in the last decade, studies have documented positive correlations between household dietary diversity presence of forests (Powell *et al.* 2012, Johnson *et al.* 2013, Ickowitz *et al.* 2014, Fungo *et al.* 2016a). Ickowitz *et al.* (2014), reported positive correlations between forest cover and dietary diversity among forest dependent communities in 21 African countries.

It has been reported that forests provide food and other subsistence products to approximately 60 million people who live within and near them (De Wasseige *et al.* 2014, 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). However, to date few dietary intake and food security assessment studies have documented how wild forest foods can be used to address food insecurity and improve dietary intake among populations residing near concessions. In particular, studies that combine assessment of forest food consumption scores with food insecurity assessment techniques and dietary assessment methods are limited. It consequently remains unclear how forest biodiversity contributes to food security and dietary intake for rural populations in Central Africa. Therefore, the overall objective of this study was to investigate the role of wild forest foods in diet and food security of villagers living in forest environments in Gabon, Cameroon and DR Congo. It describes the dietary indices of women, evaluates their food insecurity security categories and their coping mechanisms and documents the relationship between food consumption indices and food security indicators. Furthermore, the determinants of food insecurity among forest foods consumers were analysed.

METHODS

Study concessions

The study was carried out among communities residing in or around six purposefully selected forest concessions (Table 1), adjoining forests in Cameroon, Gabon and DR Congo. These three countries account for more than 80% of the forest cover of Central Africa (Tchatchou *et al.* 2015). Study concessions were selected based on: existence of trees of multiple use (timber/food value); ease of access to sites for the research team; the willingness of the forest concessionaires to allow the study to be implemented in or around concession villages; and the presence of village populations and various ethnic groups willing to participate in the study. To determine whether their logging activities were reducing access to forest foods for villagers, concessions that were actively logging were selected.

Concession, district, village and household selection

A four-stage cluster sampling technique involving two stages of purposeful selection and two stages of randomization were deployed during the selection of the study villages and households. The first stage involved selecting concessions, following the criteria outlined above. The second stage involved purposefully selecting districts within each concession on the basis of their accessibility, ethnicity and willingness of the community to participate in the study, and ongoing logging activities in the surrounding forests. The third stage involved selecting five villages randomly within the two chosen districts. With the assistance of the village authorities including village chiefs, study villages were mapped using village transect walks. Households and their occupants were listed in each village. The fourth stage involved selecting 24 households randomly within each village. This resulted in a total of 720 households (6 concessionaires*5 villages per district*24 households per village=720 households). The survey was simultaneously conducted in and around the six forest concessions.

TABLE 1 *Characteristics of the concessions in Cameroon, Gabon and DR Congo*

Country Concession	Cameroon		Gabon		DR Congo	
	Société Camerounaise de Transformation du Bois (SCTB)	**Fabrique Camerounaise de Parquet (FIPCAM)**	**Convention Provisional Planning operations and Transformation (CPAET) of Bayonne**	**Compagnie Equatoriale des Bois (CEB)**	**Congo Compagnie de Transport et d'Exploitation Forestière (COTREFOR)**	**Compagnie Forestière de Transformation (CFT)**
Longitude (degrees)	3.50 to 4.15 N	2.24 to 2.93 N	1.0 to 29.36S	13.00 to 320.68 E	25.20 to 26.00 E	25.3 to 26.00E
Latitude (degrees)	13.18 to 14.20 E	11.13 to 11.40 E	11.00 to 28.37 E	00.0 to 83.36N	0.65 to 1.25N	0.00 to 0.55N
Location (region)	East	South	South West	South East	North East	North East
Existence of management plan	No	Yes	No	Yes	No	Non
Ethnic groups	Bulu and Baka pygmies	Kako, Pol and Baka pygmies	Nzebi, Sira (Punu) and Mbete	Nzebi, Mbete and Sira (Punu)	Bamanga, Popoi, Boa, Lokele, Turumbu, Mbole, Kumu, Lendu, Wagenia, Rega, Topoke, Turumbu, Basoko and Alur	Bamanga, Boa, Lendu, Lokele, Turumbu, Mbole, Kumu, Wagenia, Rega, Topoke, Lokele, Turumbu, Basoko and Alur

The interviews

Structured questionnaire-based interviews were administered to collect data on socio-demographic characteristics, household food insecurity access scale (HFIAS) and food consumption from 720 non-pregnant and non-lactating women older than 18 years who were married or cohabiting. For polygamous households, one respondent among the wives of the household head was selected to respond on behalf of the rest of household members if the entire household (including her co-wives) was preparing one meal for the entire family. If wives were preparing food separately for their children and husband the respondent answered questions with reference only to those she took care of in her household. Women were interviewed because in rural African settings they are responsible for food collection and preparation and are custodians of knowledge on wild and forest foods, that is passed on from generation to generation (Maundu 1992, Becquey *et al.* 2009). Interviews took place in the respondents' homes, during the months of May-October 2012. The long rainy season in the region commences in May and ends in November (United Nations Environment Programme 1999). The questionnaires were pre-tested and translated into local languages for those that could not speak French by educated and locally recruited Field Assistants.

Household characteristics

Household characteristics documented included information on the age, gender, economic occupation, and education level of the head of household; source of water used in the household and length of residence in the study area.

Dietary diversity scores

Dietary diversity scores were obtained using a seven day recall food frequency questionnaire that was designed preceding the survey to capture information. A total of thirteen food groups were assessed including the twelve food groups specified in the FAO guidelines for measuring household and individual dietary intake, in addition to the food group for forest foods (Arimond *et al.* 2010, FAO 2011). The food groups were: (i) cereals and wheat products; (ii) roots and tubers; (iii) legumes and lentils; (iv) nuts; (v) dairy and fats; (vi) meat; (vii) poultry; (viii) fruits; (ix) fish and seafood; (x) vegetables; (xi) alcoholic drinks; (xii) non-alcoholic beverages; and (xiii) forest foods (including bush meat, honey, caterpillars, wild fruits, roots and vegetables). In the present study, forest foods were defined as foods of plant and animal origin, which were growing wild and collected from forests (Agbogidi 2010). The food items consumed were distributed among the thirteen food groups and the household dietary diversity score (HDDS) was calculated by summing the number of food groups consumed. The food variety score (FVS) was computed as the number of different food varieties or items consumed over the recall period of 7 days. The forest food consumption score (FFCS) was calculated by summing the occurrences and incidents of consuming of forest food items and varieties (FAO 2011).

Household food insecurity assessment

The Household Food Insecurity Access Scale (HFIAS) was assessed following the method described by Coates *et al.* (2007). A set of nine standard questions was posed to women, who responded on behalf of other household members. The HFIAS score is a continuous indicator ranging from 0 (food secure) to 27 (maximum food insecurity) (Coates *et al.* 2007), with the score categorized into four levels of household food insecurity: food secure (score=0), mildly food insecure (score=1–13), moderately food insecure (score=14–16) or severely food insecure (score=17–27). The household food insecurity access scale score (HFIAS Score) and the household food insecurity access prevalence categories (HFIAP categories) were calculated by country. The household food insecurity occurrence and coping mechanisms and food insecurity categories per concession were also calculated. The HFIAS score was calculated for each household by summing the codes for each frequency of occurrence question. The higher the HFIA score, the more food-insecure the household. The HFIAP categories per country and between consumers and non-consumers of forest foods were also computed by adding the occurrence of different categories of food insecurity.

Data analysis

All data were analysed using the statistical software package IBM SPSS Statistics Version 21.0 and statistical significance was set at $P < 0.05$ for all tests. The mean values were computed for continuous variables while proportions were computed for the categorical variables. Differences between means or proportions were considered statistically significant if $P < 0.05$. To assess how forest foods are related to food security, logistic regression analysis and Spearman's correlation analyses were performed. Chi-square tests were further performed to assess the determinants of food insecurity among forest food consumers. Respondents were dichotomized into food secure and food insecure, the latter including those who were suffering from mild, moderate and severe food insecurity.

RESULTS

Characteristics of study populations

A total of 720 households were surveyed. The mean age of the sampled female respondents was 46 years (SD = 10.4) with a range from 17 years in both DR Congo and Cameroon to 89 years in Gabon (Table 2). The majority of respondents interviewed were monogamously married with about 85% of these marriages registered in Cameroon, 58% in Gabon and 100% in DR Congo. In terms of household size, Gabon had the fewest household members (5) while DR Congo had the most (8). About a quarter of respondents in each country had no formal education while three quarters of the total respondents in both Cameroon and Gabon and 100% in DR Congo, did not have access to protected water sources. Despite living in forests, more than 90% of the respondents in each country were farmers who also practiced unlicensed logging. More than three quarters of the respondents in all the countries were natives of the study sites and 72% or more had lived there for more than 10 years.

Household dietary diversity, food variety and forest food consumption scores

Respondents' FVS for the seven days preceding the interview ranged from 11 to 23 in Cameroon, 16 to 28 in DR Congo and 17 to 30 in Gabon (Table 3). During the seven day recall period, each individual reported consuming from 11 to 23 food items in Cameroon; from 16 to 28 food items in DR Congo; and from 17 to 30 food items in Gabon. In Cameroon, the majority of the respondents (67%) consumed 15 to 19 different food items over the seven day period, while in DR Congo about 50% of the respondents consumed 17 food items, and in Gabon 67% of the respondents consumed 23 to 25 food items. In terms of food groups, about 50% and 60% of the respondents in DR Congo and Cameroon, respectively, ate items from all the thirteen food groups during the seven day recall period. In Gabon, respondents reported consuming from only 11 food groups. While 94% of respondents in Cameroon had DDS of 12–13 (consumed food items from thirteen food groups), with a mean of DDS 12.5±0.7 food groups, in Gabon 79% respondents had DDS of 9–10 (mean DDS 9.6±0.8 food groups) and in DR Congo 100% of respondents had consumed DDS of 11-13 (mean DDS 11.9±1.0 food groups).

As regards forest food consumption, the highest was registered in DR Congo with FFCS ranging from 15 to 18 forest foods consumed during the seven day recall period. Ninety-five percent of respondents in DR Congo had high forest food consumption (FFCS of 16-17), with a mean FFCS of 16.5±0.59 forest food varieties. In DR Congo animal source foods were the most consumed, including caterpillars (*Gonimbrasia belina*), snails (*Gastropoda*) and cat fish (*Siluriformes*). Wild mushrooms (fungi) were also commonly consumed forest foods. In Cameroon the FFCS ranged from one to eight, with the largest group (31%) reporting having eaten three forest food items (mean FFCS 3.97±1.6) during the seven day recall period. Most consumed forest foods in Cameron included *Irvinga gabonensis* (bush mango), a wild fruit used for cooking oil production and as a food thickening agent in soups and stews, and wild oranges (*Citrus spp)*. Other forest foods included wild growing yams (*Dioscorea spp.*) and forest-harvested Bambara groundnuts (*Vigna subterranea*). Among the forest vegetables, *Solanum nigrum* was a widely consumed green. Among the meats, porcupine and rats were the most commonly consumed in Cameroon. Gabon registered the fewest forest food varieties and items consumed, with FFCS ranging from one to three. In Gabon, taro (*Colocasia esculenta*), porcupine and wild birds were the most consumed. Seventy-three percent of the respondents interviewed did not consume any type of forest food.

TABLE 2 *Socio-demographic characteristics of households in Cameroon, Gabon and DRC*

Household characteristics	Cameroon	Gabon	DRC
	% of households (n=278)	% of households (n=241)	% of households (n=201)
Age			
Mean ± SE	44±3	55±9	38±2
Minimum	17	21	17
Maximum	82	89	65
Marital status			
Single	9	25	0
Married (monogamous)	85	58	100
Married polygamous	6	17	0
Household size			
Mean ± SE	6±3	5±3	8
Minimum	1	1	-
Maximum	14	17	-
Education			
No formal Education	26	31	22
Primary school completed	42	35	57
Secondary school	22	33	21
University	10	2	0
Source of water			
Unprotected	80	71	100
Protected	20	29	0
Occupation (%)			
Farming and unlicensed logging	97	89	100
Salaried employee	2	6	0
Business owner	1	3	0
Other		3	
Residence within the study area (%)			
<1 year	2	12	0
1–5 years	11	8	0
5–10 years	6	8	0
>10 years	81	72	100

Household food insecurity access and prevalences scales

According to the HFIAP categorization, nearly half (48%) of the respondents in Cameroon, and 100% and 88% of households in DR Congo and Gabon, respectively, were severely food insecure (Table 4). Cameroon had the highest number of food secure households (20%), followed by Gabon with only 4%. None of the households surveyed in DR Congo were registered as food secure. Categorizing all forms of food insecurity of HFIAS by forest concessions revealed that the average HFIAS scores were significantly different between the two forest concessions in both Gabon and Cameroon (Table 5). For instance, in Cameroon, the proportion of households that were food-insecure around SCTB concession without a forest management plan, was significantly higher (at $P \leq 0.0001$) than the proportion that were food-insecure in FIPCAM (74% vs. 5%, respectively). In Gabon, the average proportion of households that were food-insecure was significantly higher around CEB without a forest management plan, compared to those registered in Bayonne (96% vs. 89%, respectively) at $P \leq 0.03$. However, in DR Congo, the populations in and around both concessions were all (100%) food-insecure.

TABLE 3 *Food varieties consumed (FVS)[a], household dietary diversity score (HDDS)[b] and forest food consumption frequency (FFCS)[c] and mean dietary scores over a period of seven days in Cameroon, Gabon and DR Congo*

Cameroon		DR Congo		Gabon	
% of households (n=278)	**SD**	**% of households (n=241)**	**SD**	**% of households (n=201)**	**SD**
Food variety score (FVS)					
11	0.4	16	1	17	1
12	1	17	48	20	2
13	1	18	9	21	1
14	5	19	4	22	7
15	6	20	20	23	19
16	10	21	13	24	25
17	14	22	5	25	23
18	19	28	0.4	26	9
19	18			27	8
20	12			28	4
21	9			29	2
22	3			30	1
23	1				
Mean	**18**		**19**	**25**	**2**
Household dietary diversity score (HDDS)					
≤9	0.4	≤11	50	≤8	6
10	1	12	1	9	47
11	4	13	49	10	32
12	34			11	15
13	60				
Mean	**13**	**1**	**12**	**1**	**10**	**1**
Forest food consumption score (FFCS)					
0	2	15	3	0	73
1	3	16	47	1	20
2	9	17	48	2	5
3	31	18	3	3	2
4	19				
5	16				
6	14				
7	4				
8	1				
Mean	**4**	**2**	**17**	**1**	**0.4**	**1**

n:Number of households

[a]: FVS is food variety score, i.e. the number of food items/species consumed by the respondents

[b]: Dietary diversity score is the average sum of the number of food groups consumed

[c]: FFCS (forest food consumption score), is total number of forest food species consumed in a seven day period.

TABLE 4 *Household Food Insecurity Access Prevalence per category per country*

Household Food Insecurity Access Category	Cameroon	DR Congo	Gabon
	% of households (n=278)	% of households (n=241)	% of households (n=201)
Food Secure	20	0	4
Mildly Insecure	8	0	0
Moderately Insecure	25	0	9
Severely Insecure	48	100	88

TABLE 5 *Food Insecurity in all degrees, among the residents of the six concessions in the sample countries*

Country	Company	Food insecurity % (n)	P Value (Significance for difference between concessions)
Cameroon	SCTB	74 (99)	P=0.001
	FIPCAM	5 (2)	
DR Congo	COTREFOR	100 (121)	P=0.76
	CFT	100 (120)	
Gabon	Bayonne	89 (40)	P=0.04
	CEB	96 (125)	

*calculated using X^2-tests for factor variables; ANOVA for comparison of means, set at p=0.05

Occurrence and coping strategies for Household Food Insecurity Access

With regards to HFIAS occurrences, several coping strategies to address food insecurity were used in varying degrees by the respondents from the three countries. The respondents in Cameroon were the most food secure, thus fewer respondents employed the coping strategies listed under the HFIAS scale compared to the respondents in DR Congo and Gabon. For example, in Cameroon, during food-insecurity episodes, just over half of the households deployed three coping strategies including 53% who reported eating just a few kinds of foods, 62% who ate smaller meals and 54% who ate fewer meals in a day. On the other hand, in DR Congo, more than 80% of the households used seven coping strategies including: expressing anxiety and uncertainties about accessing food; eating few kinds of foods; eating foods they do not want to eat; eating a smaller meal; eating fewer meals per day; and not eating any kind of food. In Gabon all the nine strategies listed in HFIAS were used by more than 70% of the households interviewed.

Relationship between forest food consumption and food insecurity and dietary intake

Logistic regression analysis revealed that forest food consumers were 90% (OR=0.9; 95% CI 0.71, 4.01; p=0.001) more likely to be food secure compared with non-forest food consumers (Not in table). There was no significant difference in the proportion of consumers of forest foods who were food secure as compared to non-consumers (12% vs 11%, respectively; p=0.74) (Table 6). However, fewer consumers of forest food reported severe food insecurity (59% as compared

TABLE 6 *Food security/insecurity by category among consumers of forest food and non- consumers in sampled villages*

HFIAS [a]	Percentage among consumers of forest foods (n=567)[b]	Percentage among non-consumers of forest foods (n=153)[c]	P* value (significance of difference between the two groups)
Food secure (0)	12	11	P=0.74
Mildly insecure (1–13)	9	6	P=0.03
Moderately insecure (14–16)	20	14	P=0.0001
Severely insecure (17–27)	59	68	P=0.0001

[a]: Household Food Insecurity Access Scale. Numbers in parentheses represent the cut off of HFIAS for each food security category

[b]: Eating at least one forest food during the seven day recall period

[c]: Did not eat forest foods during the seven day recall period

*calculated using X^2-tests for factor variables; ANOVA for comparison of means, set at p=0.05

to 68%, p≤0.0001; Table 6). When the results were further subjected to Spearman's correlation analysis, it was observed that among forest food consumers, the mean HFIAS score was significantly and inversely correlated with the FFCS (r^2=−0.26, p=0.0001) (Table 7). This suggests that households that consumed more forest foods were less food insecure. Statistically significant positive correlations between the FFCS and the FVS (r^2=0.29, p=0.05) and between the FFCS and the HDDS (r^2=0.25, p=0.0001) further support the association between higher forest food consumption and reduced risk of food insecurity.

Socio-demographic factors affecting food security among consumers of forest foods

The chi square test analyses in the present study revealed that among forest food consumers, only a minority of food secure households (31%) had a younger household head (<46 yrs) while the majority of food insecure households (81%) had a younger household head. (Table 8). A higher proportion of respondents (~82 %) who were food insecure relied on unlicensed logging and subsistence farming on previously logged and abandoned land as compared to 65% of food-secure households. Twenty percent of those who were food-secure were business owners as compared to 8% of those that were food-insecure.

DISCUSSION

Contribution of forest foods to dietary indices

To the best of our knowledge, this is the first regional study in which the relationships between food insecurity and HDDS, FVS and FFCS have been assessed among forest dwelling populations in Central African countries of Cameroon, Gabon and DR Congo, considering all types of foods, both plant and animal. Although Tata-Ngome (2016) quantified food insecurity in Cameroon, he addressed only fruits. Furthermore, Tata-Ngome (2016) did not assess household dietary patterns and nutrient adequacy indicators of HDDS, FVS and FVS. Consuming a variety of foods (HDDS, FVS and FFCS), is considered a useful indicator of household food security (Mbhenyane 2017, Hoddinott and Yohannes 2002) and a key proxy of nutrient adequacy (Rathnayake *et al.* 2012), which is apparent in most dietary patterns across Africa. In the present study, a high consumption score for forest foods (FFCS) was registered in DR Congo and Cameroon, while in Gabon, a high food variety score (FVS) was registered. Previous studies in DR Congo (Termote *et al.* 2012) and Cameroon (Tata-Ngome 2015, Fungo *et al.* 2016b), documented how forest foods can mitigate food insecurity and health disorders related to inadequate intake of nutrients, if consumed in adequate amounts. In Benin, a higher diversity score and higher food security were documented among the population residing around the precincts of the government owned forest reserve in the North West of the country, than among the populations in urban centres of Parakou city. This was attributed to increased access to forest tree foods (Van Liere *et al.* 1995). In Benin, the government grants periodic permits to residents to collect forest foods from the forest reserve.

Household food insecurity and coping strategies

The most recent United Nations food security report revealed that more than half (54%) of the total population in the Congo Basin Region were food insecure (FAO, IFAD, UNICEF, WFP and WHO 2019). The present study found a much higher prevalence of food insecurity, with 78 % of the populations participating in this study being categorized as severely food insecure, 17% as moderately and 8% as mildly food-insecure. The high prevalence of food insecurity among the respondents in the present study may be due to the majority having low levels of education, to the high proportion of respondents relying on unlicensed logging and subsistence farming on previously logged and abandoned land in the three countries; and having a large number of household dependents. Previous studies in Cameroon (Fungo *et al.* 2016b, Tata-Ngome *et al.* 2017) and in DR Congo (Termote *et al.* 2012) have attributed high food insecurity among forest food consumers to low volumes of forest foods consumed, seasonal availability of forest foods and practicing agriculture on previously logged degraded land. This was corroborated in studies carried out by Levang *et al.* (2015), Tata-Ngome (2015) and Leakey (2019), who reported that the forest food and fruit gatherers who also practiced agriculture on logged land, suffered worse food

TABLE 7 *Spearman's correlation matrix of food security indicators for forest communities of the six concessions*

Household food security	Household dietary diversity score	Forest food consumption score	Food variety score	Household food insecurity access scale score
Household dietary diversity score[a]	1	0.25**	0.46**	-0.13*
Forest food consumption score[b]		1	0.29*	-0.26**
Food variety score			1	-0.11
Household food insecurity access scale score				1

*, **: Correlation is significant at 5% and 1% level respectively.

[a]: The maximum score includes 13 food groups

[b]: Only forest food species were included in the count group

TABLE 8 *Comparison per socio-demographic factor among food secure and food insecure consumers of forest foods consumers in sampled villages*

Characteristics	Forest food consumers (n=567)		
	Food secure % (n=69)	Food insecure (%) n=498	P* (Significance for difference between food secure and food insecure)
Age groups			
<46 years	31	81	P=0.03
>46 years	69	19	P=0.01
Marital status			
Single	3	5	P=0.89
Married (monogamous)	71	67	P=0.05
Married (Polygamous)	26	28	P=0.68
Education			
No formal Education	75	77	P=0.72
Primary school	17	13.7	P=0.54
Secondary school	6	6.4	P=0.79
University	1	2.6	P=0.75
Source of water			
Unprotected	92.8	90.8	P=0.15
Protected	7.2	9.2	P=0.09
Occupation			
Farming on previously logged land and unlicensed logging	65.2	82.1	P=0.04
Salaried employee	14.5	10.0	P=0.08
Business owner	20.3	7.9	P=0.03
Residence within the study area			
<1 year	4.3	0.2	P=0.02
1–5 years	8.7	10.2	P=0.24
5–10 years	5.8	4.2	P=0.38
>10 years	81.2	85.4	P=0.51

*calculated using X^2-tests for factor variables; ANOVA for comparison of means, set at p=0.05

insecurity than those practicing agriculture alone. This may reflect the fact that those who are short of food from abandoned formerly agriculture land rely on forest foods as a safety net (Shackleton and Shackleton 2004, Kuhnlein *et al.* 2007). Similar studies conducted among the forest communities of Benin (Boedecker *et al.* 2014) and Burkina Faso (Maisonneuve *et al.* 2014) revealed that despite the communities' having access to highly diverse forest diets, low dietary intake and high food insecurity were rampant among these communities. Food insecurity in Burkina Faso and Benin were attributed to the seasonality of forest foods, the annual and regional variations in food availability, and the small portion sizes of forest foods consumed.

Coping strategies are the methods used by households or individuals to meet their food and nutrient requirements, or survive when faced with food scarcity (Ellis 2000). In the present study, different coping strategies listed under the HFIAS scale (Coates *et al.* 2007) were adopted by food-insecure households. In Cameroon, among respondents who were the most food-secure, fewer employed the coping strategies, as compared to the respondents in Gabon and DR Congo, who were faced with more severe food scarcity. For instance, worrying about not having enough food in the household was experienced by fewer than 50 percent (43%) of the food insecure respondents in Cameroon, compared to 98% and 94% of DR Congo and Gabon respondents, respectively. Communities in DR Congo and Gabon who suffered from severe food insecurity deployed progressively more coping strategies as food insecurity levels increased in these two countries. For example, almost all (94% to 100%) of the

food-insecure respondents in DR Congo and Gabon employed four coping strategies: consumption of only a few kinds of foods, not eating preferred foods, eating a smaller meal and consuming foods that the respondents did not really want. In Cameroon, DR Congo and Gabon, about 30%, 40% and more than 70%, respectively, of the respondents that were food-insecure would go a whole day and night without eating and went to sleep hungry; some did not have any kind of food. Tata-Ngome (2016) reported 50% going to sleep hungry. Food insecurity results in decreased nutrient intake (Berman *et al.* 2014). This was confirmed in this study, with the majority of the food-insecure respondents from Cameroon (62%), DR Congo (~100%) and Gabon (96%) cutting portion sizes, and 54%, 99% and 95%, respectively, consuming fewer meals.

Relationship between food consumption indices and food security

Spearman's correlation analysis and regression modelling in the present study revealed that greater forest food consumption was significantly and positively associated with increased dietary diversity and food security among consumers of forest foods. The significant inverse correlation between FFCS and HFIAS, and the positive correlation between FFCS and HDDS and FVS, indicate that forest foods may be playing a significant role in household and community food security and nutrition. These findings are in agreement with findings among forest dependent women of reproductive age from Embolowa region and Bertoua region in the South and East, in Cameroon (Tata-Ngome 2017, Fungo *et al.* 2016b) and among children and women residing in Awajún forests of Peru (Roche *et al.* 2008) and among rural household farmers of northern Ethiopia (Maxwell *et al.* 2014). In Cameroon, Fungo *et al.* (2016a) and Tata *et al.* (2017) observed a positive relationship between the forest food consumption score and household dietary diversity score, food variety score and food security. Among the Awajún community of the Amazonian forests of Peru, Roche *et al.* (2008) reported a positive association between the traditional forest food diversity score and food security, with dietary intakes higher among the forest-dependent communities residing in the lower Cenepa River region of the Awajún community.

The majority of previous studies relating dietary diversity to household food insecurity focused on assessing household dietary diversity, individual or women's dietary diversity by measuring conventional food groups or individual food items over a fixed period of time (Ruel 2003). However, in the present study and the previous study reported by Fungo *et al.* (2016b) in Cameroon, the score of forest foods consumption (FFCS) was added to the list of commonly used dietary diversity indicators that assessed household food security. As a result of high biodiversity in the study areas in Cameroon, Gabon and DR Congo, and the high nutrient content of several forest foods (Kana-Sop *et al.* 2008, Djoulde *et al.* 2012, Fungo *et al.* 2015 and Fungo *et al.* 2019), inclusion of the FFCS indicator is a useful complementary measure for assessing dietary diversity and food security among forest-dependent communities.

Determinants of food insecurity among forest foods consumers

The proportion of respondents in the present study that prepared household meals using forest foods (79%) was considerably higher than what has been reported elsewhere in the Congo Basin countries of Cameroon (Fungo *et al.* 2016) and DR Congo (Termote *et al.* 2012). In the villages of Turumbu and Kisangani (DR Congo), 22% of the forest-dwelling population was reported to prepare meals with forest-sourced foods (Termote *et al.* 2012) while in the South and East regions of Cameroon, about 40% of the population prepared meals with forest foods (Fungo *et al.* 2016b). The higher consumption of forest foods documented in the present study may be attributed to the greater number of respondents (720) sampled from villages close to forest concessions, as compared to the 278 in Cameroon and 241 in DR Congo sampled from towns and cities by Termote *et al.* (2012). The chi-square test analysis in the present study revealed that food security of households consuming forest foods was higher when the head of household was aged 46 years and above. Previous studies have documented improved food security status among older household heads who consumed forest and wild foods (Pelto *et al.* 2004, Tata-Ngome *et al.* 2017, Fungo *et al.* 2016b). A study from eMantlaneni village in the East of South Africa, revealed that elderly household heads were not only more knowledgeable about wild foods but also these households were more food-secure than households with younger household heads (Dweba and Mearns 2011). Other studies revealed that older household heads experience more stable household food security (Egger and Dixon 2014) and associated this with their better access to land and capital, major factors of producing their own foods, than younger household heads (Egger and Dixon 2014, Tata-Ngome 2015). This study found, also, that households with income from salaried employment or business ownership, were more likely to be food-secure.

The high food insecurity recorded among the younger respondents in the present study may be attributed to rapid westernization of diets in Congo Basin forest countries, easier access to imported and processed foods than forest foods and associating consumption of forest or wild foods with poverty (Rensburg *et al.* 2007, Fungo *et al.* 2016a). The aggressive promotion of imported and processed food crops by industrialists, agricultural research centres and government extension officers have been documented as some of the bottlenecks hindering use of forest foods and traditional indigenous foods to address the high food insecurity in rural Africa (Dweba and Mearns 2011, Keller *et al.* 2006, Rensburg *et al.* 2007). This is associated with an inability of the older generation to successfully pass on their indigenous knowledge about African forest foods to the younger generation, exacerbating the substitution of forest foods with imported foods in Africa (Fungo *et al.* 2016a).

Studies elsewhere in Africa, including among rural communities in South Africa (Pelto *et al.* 2004), Cameroon (Fungo *et al.* 2016a, Tata-Ngome 2015) and Uganda (Tabuti

et al. 2004) have reported better food security among forest-dependent communities with little or no formal education. The findings in the present study corroborate previous findings in Cameroon, which revealed that the uneducated consume more of the wild forest foods than the educated (Fungo *et al.* 2016a). In contrast, the food-secure coastal Mediterranean populations of Europe, with higher nutritional knowledge, consume more nutrient-rich wild and forest foods than the less educated in Europe (Serra-Majem *et al.* 2007). Fungo *et al.* (2016a) further attributed the difference in the results between the Mediterranean study and the present African studies to socio economic status and health consciousness among the populations of the two continents. African elites with higher income have tended to move away from eating traditional forest foods with strong cultural identity, to consuming less nutritious western foods (Pingali 2007). In many such communities in central Africa, forest foods are increasingly being replaced by imported and refined foods that have high saturated fats and sugars (Frison *et al.* 2006). For instance, in Gabon, where forest foods are widely being replaced with refined imported diets, diet-related non-communicable diseases including obesity, type 2 diabetes and cardio-vascular diseases are on the rise, especially among the urban elite (Siawaya *et al.* 2015). Studies among forest populations of Central Africa have suggested that populations residing in or around forests that are designated as concessions for timber logging may be restricted from obtaining nutrient- rich forest sourced foods (Laird 1999, Blaney *et al.* 2009, Guariguata *et al.* 2010, Tata-Ngome *et al.* 2017). This restrictions can have an impact on the food security, health and welfare of these populations. In Cameroon and Gabon, about 50% of the forests are allocated to logging concessions, which are legislatively protected areas. It has been hypothesized that this may, or has, limited the surrounding populations' access to nutrient rich forest foods (Blaney *et al.* 2009, Rist *et al.* 2012, Tata-Ngome *et al.* 2017). For example, in the North of DR Congo, Hardin and Auzel (2001), reported how one logging company that employed about 650 workers, consumed 390 tons of bush meat (live animal weight), or close to 35 000 animals per year, depriving the surrounding communities of an important source of proteins and micro nutrients. Consumption of wild animals by logging company employees deprives communities of important sources of dietary fat and other energy sources, leading to severe food insecurity (Bailey and Peacock 1988). However, recent studies have found that the situation for other forest food resources is not so clear: for one thing, trees below the minimum cutting diameter provide both fruits and edible caterpillars, but are not cut by industrial loggers; for another, not all commercial-sized trees are removed in harvesting operations, as some have poor form and others are inaccessible; and thirdly, local people tend to gather forest foods within a limited radius of their villages (Noutcheu *et al.* 2016, Muvatsi *et al.* 2017, Taedoumg *et al.* 2018).

The potential of forest foods to address food insecurity has been neglected by governments, donors, non-governmental organizations and community-based initiatives for decades, yet it represents an opportunity worth exploring further (Fungo and Tieguhong 2019). Integration of forest foods into agro-forestry interventions and policies for better food and nutrition security coupled with sustainable use of forest biodiversity, could contribute to addressing food insecurity among rural populations in Central Africa (Leakey 2013, 2014, 2017). A limitation of this study is that it focuses on forest dependent communities residing around logging concessions. The results can thus not be generalized to all forest dependent communities. Furthermore, this was a cross-sectional study and no causal pathways between food insecurity and dietary diversity could be drawn. Although this study has revealed that some socio-demographic factors are associated with food and nutrition security among consumers of forest foods, the study does not provide the reasons for the rampant food insecurity in Central Africa. Longitudinal studies are thus recommended to further explore relationships. Finally, this study was carried out at during the peak of the rainy season within the region, which relates with the most food secure period of the year in Central Africa. Because the availability of forest foods varies by season, the same research could be repeated during the dry season to reveal additional insights.

CONCLUSION

This study points to a serious problem of household food insecurity, affecting about 90% of respondents, among communities residing adjacent to the forest concessions in Congo Basin. The results provide some of the first insights into the food insecurity status and dietary diversity measures among communities adjoining forest concessions. Across the region, a high food insecurity score was found among both those who consume forest foods, who were most frequent in DR Congo, and among those who did not, in Gabon. A high forest foods consumption score (FFCS) in DR Congo did not result in food security. However, fewer consumers of forest foods were severely food insecure than was the case for those who did not consume forest foods. Furthermore, an inverse relationship between FFCS and HFIAS and the positive correlation between FFCS and HDDS and FVS, implies that forest foods have the potential to contribute to addressing food insecurity in the Congo Basin. Given that access to income from sources other than agriculture on logged land and unlicensed logging was associated with higher food security, investing in alternative ways to provide income could contribute to addressing health, nutrition and food security. To sustainably address food insecurity in the three countries, urgent action is required to promote, domesticate and conserve nutrient-rich forest foods that are locally acceptable.

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