**Journal of Agricultural and Crop Research**
**Vol. 10(1), pp. 1-13, April 2022**
**doi: 10.33495/jacr_v10i1.21.133**
**ISSN: 2384-731X**
**Research Paper**

# Sustainable management of edible insects of Yaounde rural area: Biodiversity, host plants and socio-economic impacts

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Accepted 25th December, 2021.

***Abstract.*** The objective of this work was to contribute to the safeguarding of the forest ecosystem of six villages in Yaoundé through the mastery of edible insects/host plants relationships and the sustainable exploitation of feeding trees larvae and caterpillars consumed and marketed. To achieve these goals, the insects were captured manually and with the use of a net on their host plants and preserved in 70% ethanol and curlpapers. The study found out that,insects consumed in Yaoundé belong to 4 orders of 6 families of 10 species associated with 8 families host trees of 10 genera and 10 species:Lepidoptera-Saturniidae with *Imbrasia* genus of 7 species living on Lecythidaceae, Euphorbiaceae, Meliaceae, Fabaceae, Anacardiaceae of 7 species;Polyphagous Orthoptera-Acrididae (*Acrida* sp.) and Pyrgomorphidae (*Zonocerus variegatus*); Blatodea-Termitidae (*Macrotermes falciger*); Coleoptera-Curculionidae (*Rhynchophorus phoenicis*). On the whole, 2110 host plants of edible insects were listed and were used locally as medicinal plants, food, coal trees, firewood and saw log. The most variously exploited species were *P. macrocarpus*, *E. cylindricum* and *R. heudelotii*. Among the causes blocking the durability and the productivity of these edible insects are slash-and-burn farming (37.78 %), saw down of the host plants during harvests (30%), the firewood (11.11%) and the coal industry (3.33%).The investigations on the field showed that the insects represent a running ingredient in the local preparation of dishes.They are mainly eaten as additional food by all the surveyed populations (100%).Top pruning of host trees would reduce their boles and thus facilitate harvesting.

**Keywords:** Biodiversity, edible insects, host plants, durable management, livelihoods, Cameroon.

## INTRODUCTION

In tropical regions in general, and particularly in sub-Saharan Africa, agriculture is recognized as the main factor of economic development, sometimes contributing more than 60% of gross domestic product (Suwadu and Ibrahima, 2020).Projections made in 2011 by the UN show a 36% increase in the world's population by 2050 (UN, 2011). The growth of the world's population is resulting in an increase in food needs. The satisfaction of demand for agricultural production, therefore, depends either on the increase in agricultural land or on the increase in yields (Phalan *et al*., 2011). Moreover, the meat crisis is prompting us to look for an alternative protein source, because since 1970 meat consumption has almost tripled and is expected to double by 2050 (FAO, 2014). Agricultural land resources will soon be depleted, as 70% of them are already reserved for livestock. In addition, industrial livestock production is responsible for at least 15% of greenhouse gases, which cause global warming. It is therefore essential to question our diets and eating habits and in particular our meat consumption (Malaisse *et al.*, 2017). Additionally, global interest in insects as a food for humans continues to grow. New initiatives are emerging, both in tropical and western countries, to explore their potential (FAO, 2014). In agricultural areas in particular, between protected forest areas (National Parks, Biological Reserves, Conservation Areas, and Biological Corridors), the expansion and intensification of agricultural activities cause the gradual fragmentation of forest habitats and a significant loss of biodiversity. The aim of the Nagoya (Japan) conference in 2010 was to define a new strategy after the 1992 Rio de Janeiro (Brazil) biodiversity strategy aimed at stemming the damage caused by human activities (MINEP, 2011). In Africa, despite the development of agricultural production, malnutrition and food insecurity persist, especially in rural areas. One of the major problems is the coverage of the need for animal protein, especially for young children, which remains one of the major economic concerns of the poor communities (Abdoul *et al.*, 2015). Edible insects, with their high energy and nutrient intake, help to cover much of these needs. They are an important element of food security and also a significant aspect of the economy of some rural areas (FAO, 2010). Trade in edible insects is done at the local level, but also from rural areas to cities. The large-scale use and trade of certain species in environments subject to significant land-use changes may threaten the sustainability of the resource (Lisingo *et al*., 2010). This is the case for caterpillars of the Saturniidae family, harvested in very large masses from host trees and whose density is decreasing due to the clearing of land for agricultural use and the trade of firewood and coal to urban centres (Mbetid-Bessane, 2005).

In Cameroon, despite efforts to increase food production, malnutrition persists mainly in rural areas.Thus, following the report of the workshop on the promotion of unconventional food resources held in Douala in 2002, it was recognized that unconventional food resources can help fight malnutrition (Mbetid-Bessane, 2005). Unconventional animal food resources identified in the country include fungi, snails and insects. Today, caterpillars are eaten both in rural and urban areas, which is explained by the population's appreciation of their flesh. However, edible insects are becoming increasingly rare, which could be attributed to the misuse of host trees. The transition from a harvesting system to an organized mode of production through mass breeding would be a way forward. For exports of agricultural and forest products in 1997, the exploitation of biodiversity contributed 40% of the gross domestic productin Cameroon. According to the 4$^{th}$ Cameroon Biodiversity Report (MINEP, 2009), globally there are 235 families, 1,179 genera, 8,500-10,000 species including 7,000 Poacees, 808 endemic species, 411 exotic species, 3,000 species of useful plants, 11 species of invasive plants in Cameroon. For animal biodiversity, the collection is protected and unprotected areas give 409 species of mammals (of which 11 are endemic and 40 are endangered), 230 species of reptiles, 150 species of snakes, 381 species of amphibians, 415 species of fish (including 57 endemic), 850 species of birds, 2084 species of insects (including 67 new species of termites), 25 species of molluscs, 3 kinds of crustaceans, 20 new species of rotifers (MINEP, 2009).

With approximately 1,500 species of edible insects inventoried to date, their diversity and food value are the subject of numerous studies(Malaisse, 2004). These insects belong to 107 different families in 14 orders (Malaisse, 2004). Foua *et al.* (2015) determined that *Imbrasia oyemensis* contained proteins, carbohydrates, minerals, essential amino acids, fats. Akpossan *et al.* (2015) showed that those fats were of saturated and unsaturated types. Regional and national estimates have also been made: Kelemu *et al.* (2015) showed that over 470 species of insects are eaten in Africa and the Central African region remains the most important hotspot of having a culture of entomophagy; Ramos (2005) rated 549 species in Mexico; Chen *et al.* (2009) have listed 170 species in China; Young and Viwatpanich (2005) recorded 164 species in the Lao People's Democratic Republic, Myanmar, Thailand and Vietnam; Paoletti and Dufour (2005) estimated that 428 species were consumed in the Amazon basin. The overall objective of this study is to contribute to the preservation of the forest ecosystem of six villages in the rural Yaounde area through the characterization of edible insect/host trees systems and the reasoned exploitation of feeding trees of consumed and marketed larvae and caterpillars.

## MATERIALS AND METHODS

### Choosing the study area

This work was carried out in the Central Region, Department of Mfoudi, in six villages of the Yaounde III sub-division (03-52'290" N and 11-25'420" E): Ntouessong, Nkol-Binguela, Mekoumbou, Afanoyoa, Nomayos and Nkol-Biyen (Figure 1). The choice of this study area was based on the availability of insects as a food source; the entomophagy character of the riparian populations; the presence of insect-feeding plants and increasing deforestation.

### Climate

Yaounde has an Equatorial Guinean climate with four seasons of uneven durations: a great dry season from November to mid-March; a small rainy season from mid-March to mid-June; a small dry season from mid-June to

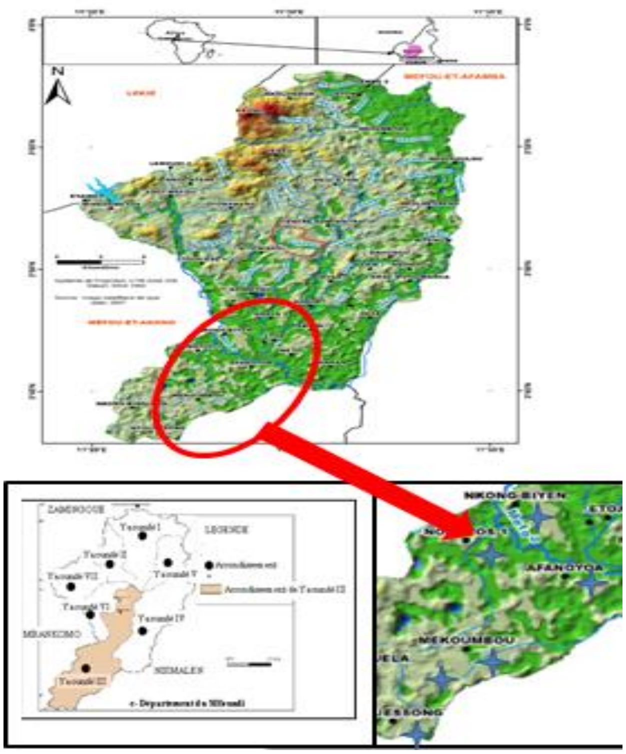

**Figure 1.** Location of Yaounde study area

mid-August; a big rainy season from mid-August to late October. The annual average rainfall is 1747 mm. The average annual temperature is 25°C with an average annual amplitude of 2.5°C. This climate promotes the conduct of 2 agricultural campaigns each year.

## Relief, soil and hydrography

The Yaounde region has a low rugged and varied terrain (presence of plains, hills and valleys) with slopes between 0 and 5% reflecting a low sensitivity to erosion. The average altitude is around 720 m above sea level. This hill site is divided into three topographical units inscribed in a precambrian gneiss bedrock: the inselberg barrier in the northwest dominated by the Mbam Minkom Mountains (1,295 m) and Mount Nkolodom (1,221 m) and in the southwest, Mount Eloumden (1,159 m); a set of hills of 600 to 700 m altitude and plateaus. Granite soils are either ferralitic or hydromorphic. Under the forest cover, these ferralitic soils are sometimes clay, porous, highly permeable and rich in humus. Hydromorphic soils are found mainly in swampy areas and around streams. The hydrographic system consists of rivers with permanent or seasonal regimes, the best known of which are Mfoundi, Ekozoa, Biyeme, Mefou, Yégué, Abouda, Akono, Mekongo, Djobo, Menyeng adzap, Ewong, Ebong Zogo, Etog ngosamba, Metubu, Mbawa. These streams serve as a place for laundry, fishing and sand collection (Neba, 1987).

## Flora and fauna

The vegetation of the region is characterized by secondary dense forests and marshy to raphial shoals. These plant formations are rich in marketable species and Non-Woody Forest Products (NWFP). The flora is very diverse and includes tree species, grassy species and a varied range of food, market garden and perennial crops. The fauna consists of goats, pigs and chickens. Traditional fishing offers Tilapia, snake fish, red tail fish and freshwater captains.

## Main economic activities

The main economic activities of the locality include agriculture, livestock, fishing, hunting, handicrafts, small trade and artisanal logging and sand.

## Artisanal exploitation of forest resources

We are witnessing a saw down of wood as a wood of energy and labour. The tree belongs to the owner of the plot who has the right on. Trees are generally sold on foot to informal farmers. The artisanal exploitation of sand takes place in continental quarries, along rivers and in marshy areas.

## Collection of edible insects and inventory of host plants

Edible insect species have been inventoried in the field in collaboration with local populations that consume them. For some species not encountered in the field during our investigations, the local population confirmed their presence at specific times of the year. Insects were captured manually or using entomological net. Then stored in empty bottles containing 70% ethanol. The specimens were identified at the Laboratory of Agricultural Zoology of the Phytopathology and Agricultural Zoology Research Unit (UR_PHYZA) at the University of Dschang using the identification keys of Delvare and Aberlenc (1989) and Borror *et al.* (1989). Host trees were filmed and a herbarium was made up and then identified at the Yaounde National Herbarium. On large farms, the installation of the squares (squares of 1600 $m^2$) is made for sampling all woody and tree species. In small areas, a systematic inventory of the floristic biodiversity of the host trees of edible insects was made. Discussions were being held with farmers about the availability and causes that hinder the production of insects in the locality during our investigations.

Shannon and Simpson's diversity indices and Pielou's equitability were used to highlight the specific diversity of woody hosts of edible insects.

The Shannon-Weaver Diversity Index (H) measures diversity by taking into account the specific richness, but also the proportion represented by each species within the community.

$$H = -\sum_{i=1}^{S} Pi\, log_2\, ni/N$$

With: H= Shannon Diversity Index; i= a species of the system studied; S= total number of species in the system studied; Pi ni /N= proportion of a species i in relation to the total number of species (S) in the study system; ni=number of individuals for species i; N= Total number of individuals of all species.

Simpson's diversity index measures the probability that two randomly selected individuals belong to the same species. It measures how individuals are distributed among species in a community.

$$Es = 1 - \sum_{i=1}^{S} {P_i}^2$$

With: Es=Simpson's Diversity Index; Pi ni /N= proportion of a species i in relation to the total number of species (S) in the study system; ni= number of individuals for species i; N= Total number of individuals of all species.

Pielou's fairness is the ratio of the diversity of a stand or sample and the number of species present in the plot. It expresses the equitable distribution of individuals within species. This index ranges from 0 to 1. When a species makes up the majority of the population, this index tends to be 0. And it tends to 1 when all species have the same abundance.

$$J = \sum_{i=1}^{S} H / log_2\, S$$

With J=Equitability or Pielou Index; H= Shannon's diversity index; S= total number of species in the system studied.

### Collecting dendrometric parameters

Various dendrometric measurements were found on trees, and host shrubs of insects. They were the diameter at chest height (dhp), the surface of the crown, the height of the tree.

### Land surface

The land surface tells us about the surface occupied by the sections of the barrels at 1.30 m from the ground. It is expressed in square metres ($m^2$) per hectare. The total land surface is the sum of all the land surfaces of the species on the surface inventoried. It is calculated by the following formula:

$S = (\sum \pi D_i^2) / 4$

With: S= land surface, D= diameter of the individual i measured in m.

### Product and service census

The focus group allowed us to make initial contact with the local population. Direct observations coupled with interviews with farmers through a pre-established questionnaire identified key ecosystem services in general, particularly procurement services.

### Socioeconomic survey

A focus group allowed a first contact with the riparian populations, then surveys were carried out in each village. Our direct observations, coupled with a pre-established questionnaire, helped to achieve the objective.

### Sample and data analysis

As part of this work, we used the simple random sampling technique. It involved working with farmers exploiting randomly selected forest resources in each of the six villages in the area, 30 individuals per village for a total of 180 individuals. The investigation itself took place from April 1 to May 5, 2019. A pre-survey was conducted from April 1 to 5, 2019 and involved testing the designed questionnaire sheet and a survey itself was conducted from April 5 to May 5, 2019. This included a set of questions to obtain information on how edible insects and host trees are exploited and managed.

## RESULTS AND DISCUSSION

### Biodiversity of edible insects in Yaounde

The insects encountered in Yaounde belong to 4 orders: Isoptera, Orthoptera, Coleoptera, Lepidoptera of 6 families: Termitidae, Acrididae, Pyrgomorphidae, Curculionidae, Notodontidae, Saturniidae (Table 1). The Saturniidae family is the richest with the genus *Imbrasia* of 7 species, of which 3 are formally identified (*Imbrasia epimethea*, *I. oyemensis*, *I. truncata*) (FAO, 2004). They are the most abundant and consumed in this community.

**Table 1.** Biodiversity of insects and host trees identified in Yaounde.

| Insects consumed | | | | | Host trees | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Scientific names** | **Orders & families** | **Local name** | **Consumed stage** | **Periods** | **Scientific names** | **Local name** | **Frequency** | | **Usages** |
| | | | | | | | **Feet** | **%** | |
| *Macrotermes falciger* | Blatodea-Termitidae | Cile | Adult | Jan-Fev, Aug-Sep | (Termite mound) | Asomen | / | / | / |
| *Acrida* sp. | Orthoptera-Acrididae | Mboul | Adult | Nov-Dec | Varied | / | / | / | Alimentary |
| *Zonocerus variegatus* | Orthoptera-Pygomorphidae | Mbassanin | Adult | Nov-Dec | Varied | / | / | / | Alimentary |
| *Rhynchophorus phoenicis* | Coleoptera-Curculionidae | Menyet, | Larva | year | *Elaeis guineensis*, *Raphia* sp. (Palmaceae) | Alenn | 754 | 35.73 | Medicinal, lumber |
| | | Pan | Adult | year | | Zam | 346 | 16.40 | |
| *Anaphe* sp. | Lepidoptera-Notodontidae | Meyos | Caterpillar | Aug-Sep | *Triplochiton scleroxylon* (Malvaceae) | Ayous | 52 | 2.46 | Lumber, charcoal, firewood |
| *Imbrasia epimethea* | | Mimbing | | | *Petersianthus macrocarpus* (Lecythidaceae) | Abing | 161 | 7.63 | Medicine, charcoal, lumber, firewood |
| *Imbrasia oyemensis* | | Byssoil | | | *Ricinodendron heudelotii* (Euphorbiaceae) | Essessang | 44 | 2.09 | Food, lumber, firewood |
| *Imbrasia truncata* | Lepidoptera- Saturniidae | Bngoimbe | Caterpillar | May-Jun, Aug-Sep | *Entandrophragma cylindricum* (Meliaceae) | Assié (Sapelli) | 11 | 0.52 | Lumber,charcoal and firewood |
| *Imbrasia* sp. 1 | | Bitom | | | *Erythrophleum ivorensis* (Fabaceae) | Elon | 38 | 1.80 | Lumber and firewood |
| *Imbrasia* sp. 2 | | Biwolo | | | *Funtumia africana* (Fabaceae) | Elé.ndamb a | 71 | 3.36 | Médicinal, firewood |
| *Imbrasia* sp. 3 | | Efok | | | *Mangifera indica* (Anacardiaceae) | Andok | 604 | 28.63 | Médicinal, firewood |
| *Imbrasia* sp. 4 | | Mikom | | | *Lovoa trichiloides* (Anacardiaceae) | Ewolo | 29 | 1.37 | / |

They are harvested from secondary forests, fallows and hut gardens. The order of Coleoptera with the Curculionidae family and the species *Rhynchophorus phoenicis* is encountered in the larval and adult stages. Larvae are taken from old dead palm trunks.The Orthoptera have two families: the Acrididae (*Acrida* sp.) and the Pyrgomorphidae (*Zonocerus variegatus*). They are found in fallows in a gregarious way. The Isoptera is represented by the family of Termitidae with the species *Macrotermes falciger*. These insects are consumed by riparian populations (Figure 2). Similar studies have been carried out in several African countries, for example, Tchibozo *et al.* (2016) identified 24 species of edible insects in Benin, 17 in Togo, 7 in Niger, 18 in Burkina Faso, 10 in Mali and 15 in Guinea Conakry. The 6 genera encountered in Yaounde are also found in the same works. But some insects consumed in Yaounde as part of this study are not in other West African countries according to Tchibozo *et al*. (2016). For instance, *Z. variegatus* is not consumed in Niger and Mali; *M. falciger* is consumed in 5 countries except Burkina Faso where *M. bellicosus* is consumed exclusively. *R. phoenicis* is consumed in Benin, Togo and Guinea Conakry; *Anaphe venata* and *Anaphe* sp. only in Guinea Conakry. Lepidoptera Saturniidae of the *Imbrasia* genusof 7 species was the most abundant.

According to Kelemu *et al.* (2015), the insects that are mostly eaten are dominated by Lepidoptera, Orthoptera and Coleoptera which is in agreement with our results. According to Tchibozo *et al*. (2016), the Saturniidae family includes 3 genera *Bunae alcinoe*, *Cirina butyrospermi*, and *Imbrasia*

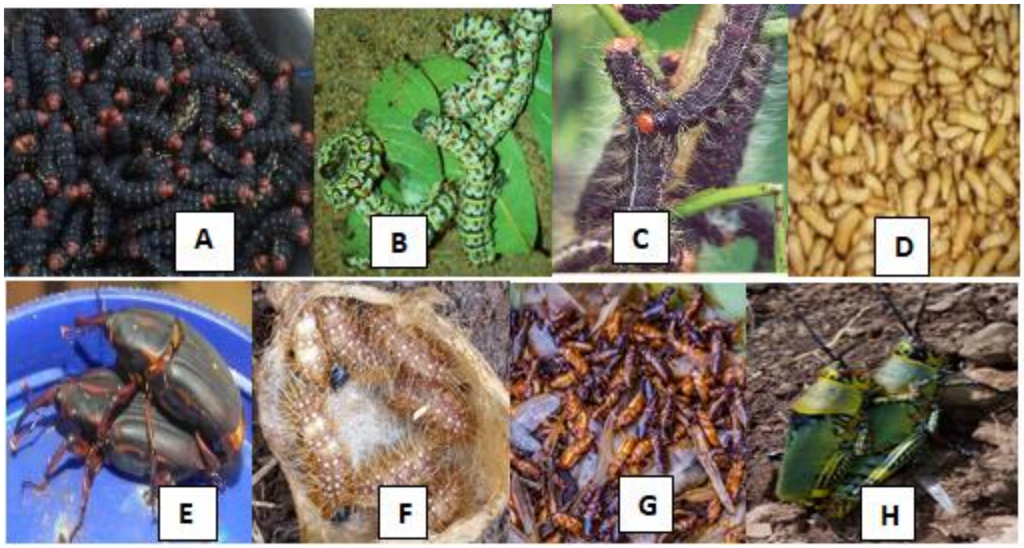


**Figure 2.** Some insects consumed in Yaounde. (A) *Imbrasia truncata*, (B) *Imbrasia oyemensis,* (C) *Imbrasia epimethea,* (D) Larvae and (E) Adult of *Rhynchophorus phoenicis*;(F) *Anaphe* sp.; (G) *Macrotermes falciger*; (H) *Zonocerus variegatus.* B and C source (FAO, 2004).

with 3 species (*I. alopia, I. epimethea, I. oyemensis*). *Rhynchophorus* sp. are consumed in Asia, Africa and Latin, and are used for food in Laos, Myanmar, Thailand and Vietnam. Some authors have focused on the consumption of Lepidoptera insects globally (Malaisse *et al*., 2016) as well as African (Malaisse and Lognay, 2003; Malaisse, 2005; Malaisse and Latham, 2014). These indicate that while there are relatively many publications on Lepidoptera consumption for Nigeria (at least 25 citations) and to a lesser extent for Cameroon (at least 10 citations), it was not until 2014 that an article was devoted to them for the countries concerned. Indeed, Badanaro *et al.* (2014) were interested in the *Cirina forda* marketing circuit among the Moba of North Togo.

The harvesting period of these insects varies from species to species; caterpillars of the genus *Imbrasia* have been observed twice a year (May to June, August to September) while the species *Anaphe* sp., *Z. variegatus*, *Acrida* sp. are univoltine. *Anaphe* sp. is observed between August-September and *Z. variegatus* and *Acrida* sp. November-December. In Yaounde, the heavy rains run from August to October. *R. phoenicis* is present all year round in Yaounde (Table 1). For Malaisse (1997), caterpillar harvesting is a seasonal activity, while the harvest of larvae is year-round. The collection period often takes place during the rainy season. The availability of caterpillars may vary between different agro-climatic zones due to different climatic conditions and the existence or not of host plants. In North Ubangui in DRCongo, the harvest period runs from June to September, the period of heavy rains that affects the foliage of host trees (Yabuda *et al*., 2019).Edible insects are subservient to 5 types of habitat. These are secondary forests, fallows, palm groves, hut gardens and termite mounds. In Congo, Lisingo *et al.* (2010) identified 4 types of edible caterpillar habitat: primary forest, secondary forest, fallow and surrounding the village. Depending on their host tree habitat, larvae are present in different forest types as well as in tree savannas and shrubs. N'gasse (2003) in his research on the abundance of *Nudaurelia oyemensis* on sapelli, found that, on average, a host tree was occupied by a weight corresponding to 3.3 kg (dry matter) in caterpillars. Other research indicates higher values, Latham (2001) reports a presence of 5 kg/ha (dry matter) for *Cirina forda* in the Province of Bas-Congo.

## Biodiversity of host trees

In our study area, 10 species of host trees of edible insects belonging to 10 genera of 8 families (Table 1) have been identified. Of these host trees, 4 species are the majority: *Elais guineensis* (754 individuals identified, 35.73%), *Mangifera indica* (604 individuals, 28.63%), *Raphia* sp. (346 individuals, 16.40%), *Petersiantus macrocarpus* (161 individuals, 7.63%). Other woody (5 species) are poorly represented: *Triplochiton scleroxylon* (52 individuals identified, 2.46%) (Figure 3), *Ricinodendron heudelotii* (44 individuals, 2.09%), *Erythrophleum ivorensis* (38 individuals, 1.80%), *Lovoa trichiloides* (29 individuals identified, 1.37%), and *Entandrophragma cylindricum* (11 individuals identified, 0.52%).

*Acrida* sp. and *Z. variegatus* live on several species of host plants. *Z. variegatus* live on several species of plants grown in our study area.The work of Lisingo *et al*. (2010) mentions 32 species of caterpillar host plants in the Kisangani and Tshopo districts of the Democratic Republic of Congo. Anvo *et al.* (2016) reported that


**Figure 3.** Some host trees and manner of harvesting edible insects. A: Young caterpillars in clusters on leaf of *Triplochiton scleroxylon*; B: Caterpillars colony on the trunk of *Petersiantus marcrocarpus*; C: Caterpillars on a cut-off branch; D: Caterpillars in the nest on the ground; E: Picking up white worms on a dead palm trunk; F: Termite mound in a fallow.

**Table 2.** Harvesting method and organoleptic preference of surveyed populations for edible insects.

| Genera and species | Harvest mode | Organoleptic preference | | Population surveyed | |
|---|---|---|---|---|---|
| | | Nutritional quality | Taste quality | Number of individuals | % |
| *Macrotermes falciger* | Picking up in termite mounds | ** | ++ | 5 | 2.79 |
| *Acrida* sp. | Pick-up in fallows | ** | ++ | 6 | 3.33 |
| *Zonocerus variegatus* | Pick-up in fallows | ** | ++ | 11 | 6.11 |
| *Rhynchophorus phoenicis* | Collection after slaughter of the host plant | *** | +++ | 22 | 12.22 |
| *Anaphe* sp. | | *** | +++ | 24 | 13.33 |
| *Imbrasia epimethea* | | *** | +++ | 31 | 17.22 |
| *Imbrasia oyemensis* | Picking up on the trunk, leaves and branches of the host plant | *** | +++ | 32 | 17.78 |
| *Imbrasia truncata* | | *** | +++ | 35 | 19.44 |
| *Imbrasia* spp. | | *** | +++ | 14 | 7.78 |
| Total population surveyed | | | | 180 | 100 |

***: Very good; **: Good; +++: Very rich; ++: Rich

*Vitellaria paradoxa* (Sapotaceae), is the nursery plant of *Cirina butyrospermi*, whose caterpillar is rich in protein (63%) lipids (14%). The flowers of this plant according to the same authors, are very visited by bees who willingly establish their nest in their fronds. In addition, with regard to the species of plant feeder of the beetles, Dounias (2003) noted that the palm-raffia and the oil palm are the larvae lodge of *R. phoenicis*. Their collection and breeding should be thoroughly studied in Cameroon.

## Crop management, organoleptic and nutritional qualities

People are fully aware of how to harvest and have preferences in times of resource abundance. Edible insect harvesting occurs in several ways in our study region (Table 2): the collection of caterpillars from trunks, branches and stems of cut or uncut host trees, in termite mounds, in nests on the ground and trunks of dead palm

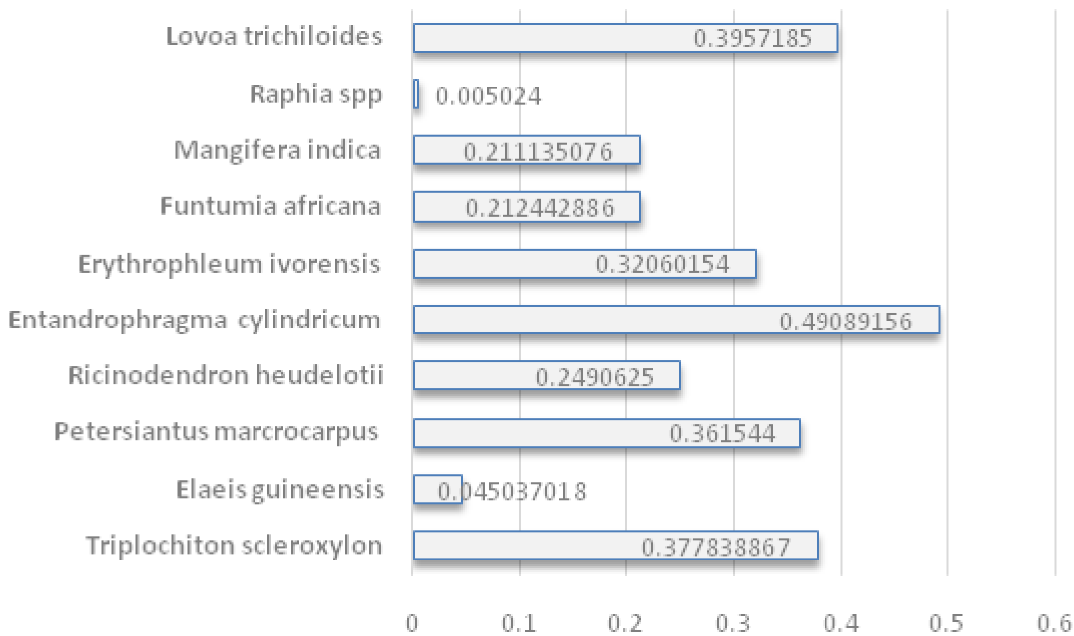


**Figure 4.** Land surface of edible insect trees in Yaounde (in $m^2$).

trees. Harvest is facilitated when caterpillars descend from trunks when they mature. Malaisse (2005) observed that in the Central African region, harvesting was either by manual collection on the ground, trunks, branches and leaves or by felling the host trees of caterpillars. According to the same author, people also cut whole branches to improve the harvest or to better conserve caterpillars and then sell them alive. For some species, such as *Imbrasia* sp., bowls are placed on the trunks at a relatively low height so that they fill up in five or six days. Some palm trees are attacked by *R. phoenicis*, then lose their leaves and die. Those palm trees are cut and split and the larvae are extracted alive (Figure 3E). Oil palms and Raphia cut for wine production provide larvae as a by-product.

Local populations appreciate the organoleptic qualities of all edible insects in the region with a preference over white worms and caterpillars of the genus *Imbrasia* and *Anaphe* (Table 2). In French-speaking West African countries, it is estimated that more than 15,000,000 people feed on insects.The nutritional composition of edible insects depends on the metamorphic stage, habitat and diet of the insect (Rumpold and Schüter, 2013).The species *Imbrasia oyemensis*, identified in Guinea Konakry, is dried and sold at the Adjamé market in Côte d'Ivoire, because it has a high nutritional value, with a raw protein level of 57.77%, as shown by the work of Akpossan *et al*. (2009). Apart from its food consumption, the authors consider its use in the pharmaceutical and cosmetic fields. Biochemical analysis of 100 g of boiled beef yields 22.3% raw protein compared to 61.1% for the same amount of locusts (Premalatha *et al.*, 2011). Igwe *et al*. (2011), in their conclusion on the chemical analysis of *M. nigeriensis*, revealed a very good source of nutrients, vitamins, minerals and unsaturated fatty acids, especially proteins and carbohydrates necessary for combating protein-energy malnutrition.

## Land surface

Observations show that the land surface of the edible caterpillars in our study area varies by species. It is higher in *E. cylindricum*, *L. trichiloides*, *T. scleroxylon* and *P. macrocarpus* and low in palmaceae such as *E. guineensis* and *Raphia* spp. (Figure 4).

## Structural features

### *Distribution of individuals by diameter class*

Figure 5 shows that there are more stem individuals in the centre class (100-110, or 9%), and their number decreases to the class (290-300). The average dhp is 107cm for a standard deviation of 56,049 with a 95% confidence interval ranging from 103.94 to 110.10. The curve of the diametric structure is better adjusted to irregular distribution because they are trees from natural forests. This erratic look is characteristic of typical heliophilic species. This would explain the dependence of

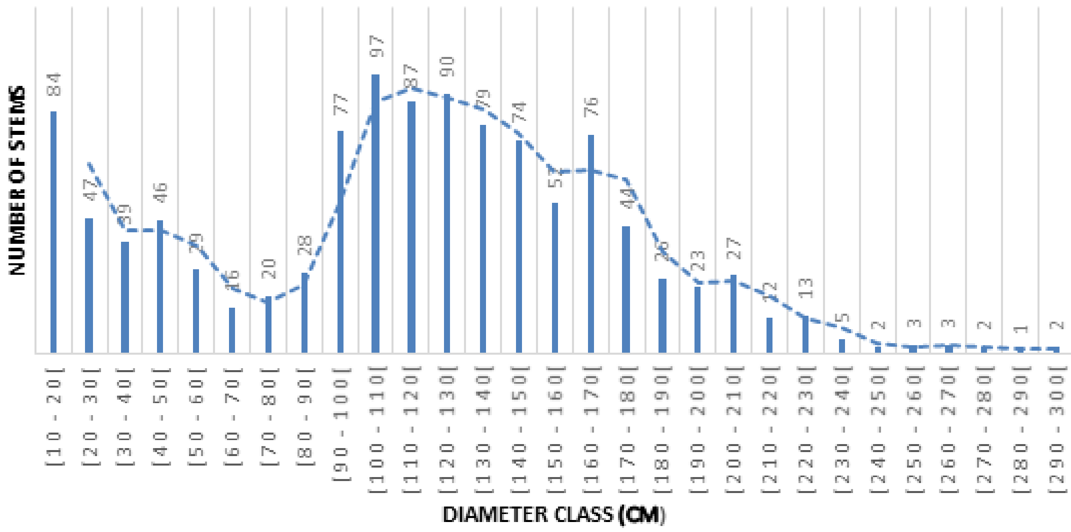


**Figure 5.** Distribution of the number of stems per diameter class to the dhp.

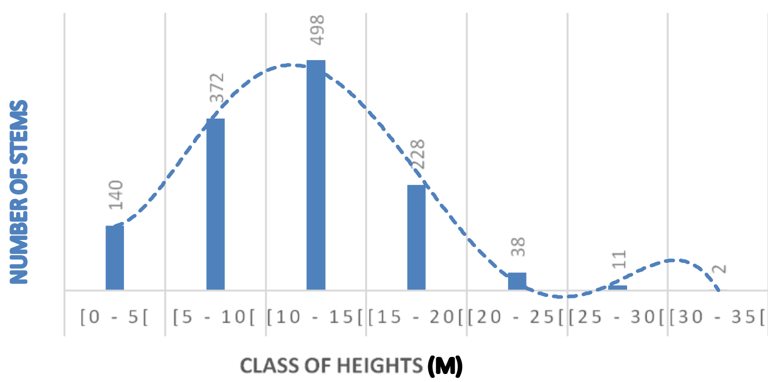


**Figure 6.** Distribution of individuals by class of total height.

woody hosts of edible insects in light for their regeneration and testifies to the relationship between diametric structure and the temperament of the species.Thus, the temperament of the species leads it to seek above all light for its development. For Martinez-Ramos *et al.* (1989), Clark and Clark (1999), the simple dichotomy acquired between heliophilic and shadow species (or pioneers) does not allow the reproduction of the diversity of species strategies in the rainforest, first because each species has a range of tolerance on either side of a physiological optimum and secondly because the temperament of a species evolves with the age of individuals. However, Hubbell (1980), Durrieu and Forni (1997) have shown that the structure of a species can vary at the station or distribution area level.

## Distribution of individuals by class of total height

The average height of caterpillar feeding trees is 11m (Figure 6). The dominant height varies between 10m and 12m. The minimum is 2m, the maximum is 31m with a standard deviation of 4,897 and the confidence interval at 95% is 10.6 ± 11.18. The curve is dissymmetrical to the left where the minimum number of individuals is in the center of class [30-35]. The middle-class numbers are the highest, with a maximum for the class [10-15]. In terms of height, the concentration of heights in total height classes remains constant in the class of 10 to 15, or 38% of the population individuals. The more stems there are, the more leaves will be available for the edible insects.

## Shannon, Simpson and Pielou diversity indices

We observed a low value of the Shannon Diversity Index (H -2.59); this could be due to the fact that a species of feeding tree dominates strongly in this area. This result is confirmed not only by the value of the Simpson Diversity Index, which shows that the probability that two randomly

**Table 3.** People's views on the causes of the decline in edible insect production.

| Causes | Number of people | % |
|---|---|---|
| Slaughter of host trees during harvests | 54 | 30 |
| Logging | 32 | 17.78 |
| Charcoal | 6 | 3.33 |
| Firewood | 20 | 11.11 |
| Slash-and-burn farming | 68 | 37.78 |
| Total | 180 | 100 |

selected individuals belong to the same species is high (0.64), the Pielou Equitability of 0.31, tending to 0, confirms the low diversity of species. This low diversity of wood species that host edible insects is believed to be due to the misuse of these resources, which could lead to their degradation. Dibong and Ndjouondo (2014) have shown that the more degraded the medium, the less diverse it is. For him, sociability associated with habitat preference influences the diversification of the environment.

## Socioeconomic interests of host plants

The host plants of caterpillars are mainly used by the population as medicinal plants, food, charcoal trees, timber and firewood. The most diversely exploited species are *P. macrocarpus*, *E. cylindricum* and *R. heudelotii*. At the same time, these species are the hosts of several species of caterpillars. According to FAO (2010), forests and other woodlands are recognized as resources that provide many services, essential to the survival of about 1.4 billion people. They are a huge reservoir of biological diversity and their ecological functions are essential for humanity. Forest formations play an important role in meeting many of the basic needs of local people. They provide wood and energy and contribute to the coverage of nutritional needs, especially for the most vulnerable social groups. They are also the main source of medicinal products in rural areas and contribute to local and national economies. In Assam (India), the work of Gogoi *et al.* (2019) on traditional knowledge of plants show that they are consumed (as vegetable or as firewood), serve as fences, ornamental and medicinal. In North-Ubangui province (RDC), Yabuda *et al.* (2019) note that the host plants of the caterpillars are mainly used by the population for timber, firewood, energy wood and the manufacture of canoes.

## Causes of production decline

Table 3 presents the views of the populations surveyed on the causes that lead to this decline in the production of edible insects. Note the following considerations: 37.78% of respondents identify slash-and-burn farming as the main cause of the decline in edible insect production in Yaounde, followed by the felling of host trees during harvest (30%), logging (17.78%), artisanal charcoal industry (3.33%), production of firewood (11.11%). Despite differing opinions, it is certain that all of these activities have a cumulative adverse effect on the production of edible insects. One of the solutions we recommend is the choice of small to medium-sized host trees, insect species that descend from mature host plants, cases of *Imbrasia epimethea* on *P. macrocarpus*. Salumu (2004) found that the majority of the rural population used charcoal primarily for cooking and that short-fallow slashing would limit the regeneration of caterpillar host tree species. According to Latham (1999), traditional systems of itinerant cultures include fallow periods of 7 to 14 years. This period of regeneration allows a large number of plants to regenerate, especially forest species, while at the same time providing new habitat for various species of caterpillars. Due to population growth, the land is often re-cultivated after two or three years, resulting in a gradual loss of biodiversity. Latham (1999) recommends assisting farmers to restore multiple uses of fallows.

## Socioeconomic importance of the sector

Investigations conducted at the rural market of Ahala II show that the Trade in Edible Insects is not organized, despite the importance of the market. In addition, the marketing circuit has many intermediaries between collectors and consumers. This uncontrolled activity provides wholesalers and retailers with a significant profit margin. Insect sales take place during the rainy season. *Imbrasia* caterpillars begin are seen at the market in May. The outbreak period is between the end of July and the August period. However, the beetles are observed from March until November, with periods of the outbreak between June and September. At the Ahala II market, 5 caterpillars of the genus *Imbrasia* and 4 *R. phoenicis* beetles are sold at 100 FCFA. Termites and locusts are sold in heaps of about 200g for 500 FCFA and 300 CFA francs, respectively. The sale of edible insects allows many poor households to diversify their economic income. But the harvesting and marketing of edible insects are still done in artisanal and informal conditions.

The remarkable increase in the number of stakeholders justifies the profitability of the business. In addition to cyclical problems, two main factors can strengthen the contribution of trade in edible insects to the fight against food insecurity and poverty reduction. The organization of the actors involved in the commercialisation by the consolidation of producers, transporters, wholesalers and retailers; the need to promote domestication of host trees as part of agroforestry to reduce the long distances travelled by collectors.

Field surveys have shown that insects are a common ingredient in local food preparation. They are mainly eaten as supplemental food by all the populations surveyed (100%). Caterpillars and beetles are the most popular and most consumed.To prepare fresh larvae, they should be washed and cooked, fried, or grilled in different ways. One of the possibilities is to prepare certain species in water or oil, or by adding different combinations of spices or other ingredients such as peanut paste. Often they are mixed with sauce, mushrooms, fish, meat and/or legumes, leaves of *Gnetum africanum* and *G. buchholzianum*. Nevertheless, these products are useful in food security. Indeed, according to Ngbolua *et al.* (2014), the consumption and trade of non-timber forest products can contribute to the population's food security and is an effective means of fighting poverty. Because of their high nutritional value, insects are often mixed with flour in the preparation of porridge to combat child malnutrition. The work of Foua *et al.* (2015) determined that *I. oyemensis* contained proteins, carbohydrates, minerals, essential amino acids and fats. These fats are saturated and unsaturated fatty acids (Akpossan *et al*., 2015). Species that are particularly rich in protein (*Imbrasia epimethea*, *I. dione*, *Antheua insignata*), calcium (*Tagoropsis flavinata*), or iron (*Cinabra hyperbius*) are given to anaemic people and pregnant women at their breakfast. Several other species play an important role in traditional medicine (Malaisse and Latham, 2014).In general, caterpillars are not considered relief food, but they contribute to the diet during certain seasons. Average caterpillar consumption data differs by region. N'gasse (2003) cites an anonymous survey of the Ngotto forest in the Central African Republic, which established a consumption of about 137 g of fresh insects per person/day, between mid-June and the end of September; compared to a consumption of 83 g of dried insects per person/day, once or twice a week during the season of abundance. Paulian (1963) cites 40 g of smoked insects per person/day, from November to January, in Brazzaville. According to Mapunzu (2002), 6.12 g of fresh insects per person/day are consumed, for the period of June March, in Kinshasa. Given the total quantities supplied by the provinces, he estimates that the annual consumption of caterpillars in Kinshasa is 9,600 tonnes.But insects are rich in nutrients and moisture, providing a favorable environment for microbial survival and growth (Klunder et al., 2012). Banjo *et al.* (2006) reported the presence of the pathogenic bacteria *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *Bacillus cereus* in edible rhinoceros beetle species in West Africa. Thus, harmonious management of edible insects requires the mastery of their ethology, the knowledge and the management of their host trees and their ecosystems.

## CONCLUSION

Edible insects add value to the well-being of riparian populations.These insects are consumed mainly as a dietary supplement in several forms. But the risks of loss of flora and fauna biodiversity are real in our study environment. This ecosystem is threatened by activities such as slash-and-burn agriculture, the felling of host trees during harvests and for timber. During reforestation, the choice of small to medium-sized host trees and those of mature insect species that leave leaves to soil should facilitate the harvesting of insects, as well as those with multiple uses. Overall, all initiatives that would allow sustainable management of host trees of edible insects are to be encouraged.

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