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The Cost of Gathering Among the Baka Forager-Horticulturalists From Southeastern Cameroon

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What present-day foragers do for their living and what they eat have long been privileged areas for exploring human behavior, global health, and human evolution. While many studies have focused on hunting and meat acquisition, less attention has been given to gathering and plant foods. Despite evidence of variation in both nutritional quality and energetic costs of gathering different plants, the overall effort spent on gathering in relation to other subsistence tasks is still under explored. In the current context of economic, climate, and social changes, many forager societies also rely on other subsistence strategies, including agriculture and wage labor. In this study, we aim to explore the place of gathering in the livelihood of a mixed economy society, the Baka forager-horticulturalists of southeastern Cameroon, by comparing the involvement and the costs of activities related to food acquisition. From a pool of 153 adult participants (97 women and 56 men), we collected 246 daily records using a GPS (Global Positioning System) tracker combined with heart rate monitor and time allocation recalls. We compared the duration, distance traveled, and the intensity of work, measured by calculating the metabolic equivalent of task (MET), of subsistence activities related to food acquisition. Results from this work show that gathering activities, performed by both women and men, are energetically costly, with higher MET values than hunting and fishing activities. Furthermore, the MET values vary depending on the targeted plant foods. We discuss these insights in the overall framework of subsistence patterns, merging them with the socio-cultural and environmental factors that might explain Baka livelihood and subsistence strategy.

Keywords: food choice, wild edible plants, energy expenditure, MET, hunter-gatherers

INTRODUCTION

The livelihood and subsistence patterns of human groups have been studied from a variety of viewpoints, often with the goal of finding universal patterns or drivers of behavior. Insights from such research are used to build economic theories, to explain global health patterns, and even to create models of human evolution (Cordain et al., 2005; Hawkes et al., 2017; Widlok, 2017; Veile, 2018). Hunter-gatherer groups are of particular interest, as foraging subsistence patterns are thought to define 99% of human history (Crittenden and Schnorr, 2017). Subsistence behaviors, and the related social structures such as the gendered and age-related division of labor, egalitarianism and the high rate of sharing seen among hunter-gatherers (Hewlett, 2014), are often considered

to represent fundamental human patterns (Marlowe, 2007; Codding and Kramer, 2016). However, there is a great deal of variation both between and within foraging societies in how subsistence tasks are performed (e.g., Kelly, 1995). Men tend to spend more time and energy on hunting and women on gathering (Gurven and Hill, 2009) and men cover greater distances than women for acquiring food (Pontzer and Wood, 2021; Wood et al., 2021). Subsistence activities also vary across age categories, with children and adults focusing on different resources (Gallois, 2017), and elders dedicating more time to activities other than food acquisition, such as childcare and knowledge transmission (Kaplan et al., 2000).

Most research on subsistence has focused primarily on the acquisition of meat, with less attention given to gathering and plant foods (e.g., Lee and DeVore, 1973; Cordain et al., 2002; Sillitoe, 2002). This bias is due in part to the emphasis on animal foods both assumed by the researcher and expressed by certain forager groups. Economic models such as optimal foraging theory emphasize the higher caloric returns of meat over other foods (Hawkes et al., 1982), and some hunter-gatherer groups, such as the Hadza of Tanzania, the Ache of Paraguay, and the Hiwi of Venezuela, rely heavily on animal foods (Kaplan et al., 2000). Moreover, socio-cultural investigations reflect the stated importance and preferences for animal foods (Motte-Florac et al., 1996) and prestige signaling opportunities (show-off behavior) associated with hunting (Gurven and von Rueden, 2006). In contrast, gathering as a fundamental human pattern is still underexplored, even if it might be a predominant activity among several hunter-gatherer societies (Dahlberg, 1981; Kelly, 1995). Furthermore, wild plants play a major role in providing micronutrients and ensuring food security (Pontzer and Wood, 2021). Evidence indicates great differences in nutritional quality and energetic costs for gathering diverse plant foods (Hladik, 1996; Paine et al., 2019). Their abundance and distribution across the landscape also differ, which contributes to varying travel distances and therefore time and energy spent while foraging (Wood et al., 2021). Despite this variation among gathered resources, “gathering” is often considered only as a single, homogenous category (e.g., Hurtado et al., 1985; Gurven and Kaplan, 2006). Therefore, carefully quantifying the costs of gathering compared to other subsistence tasks such as hunting, fishing and farming, and exploring the intrinsic variability in costs among different wild resources might provide us with relevant insights on an understudied component of human foraging behaviors.

Worldwide, hunter-gatherer societies are increasingly faced with challenges to their culture and livelihood through processes such as market integration, influence of the “mainstream” culture, and local environment degradation. These influences lead many to adopt other subsistence strategies, such as agriculture and wage labor (Codding and Kramer, 2016; Reyes-García and Pyhälä, 2017). Such changes have also led to a process of dietary transitions with a decrease in the consumption of wild foods and greater use of processed foods (Kuhnlein, 2015; Reyes-García et al., 2019), which has consequences for the health of these societies (Kuhnlein, 2015). This transition is not a single unidirectional process, and several societies maintain hunting

and gathering while relying on other subsistence activities (Codding and Kramer, 2016). It remains unclear, however, how these dietary changes might alter gathering practices.

With this study, we aimed to fill these gaps by exploring the role of gathering wild foods in the livelihood of a hunter-gatherer society exposed to socio-ecological changes. We worked with the Baka, a group of forager-horticulturalists from southeastern Cameroon, who combine hunting and gathering with growing a small number of crops, and working for the neighboring Bantu-speaking farmers. To explore the role of gathering among the Baka, we posed the following research questions: (1) How do the Baka engage in the different activities related to food acquisition and how is their time allocation in subsistence activities related to the gender and the age of the individuals, and to their settlement (village vs. forest camp)? (2) Do the different subsistence activities vary in terms of intensity of effort, duration of work, and distance traveled? Are the variations in intensity, duration, and distance of these activities driven by the gender, the age or the settlement of the individuals? (3) Is gathering a uniform subsistence type, or do the intensity, duration and distance vary depending on the types of food gathered?

THE BAKA

The Baka live in the tropical forest of the Congo Basin across the Republic of Congo, Gabon, Central African Republic, and Cameroon, with a population of about 30,000 individuals (Leclerc, 2012). They were formerly a nomadic society, mostly living on hunting, gathering, fishing, and bartering products with their neighbors, sedentary Bantu-speaking farmers. Since the 1950s the Baka in Cameroon have shifted from a hunter-gatherer to a more forager-farmer livelihood through a process of sedentarization along the logging roads and adoption of agriculture (Leclerc, 2012). These permanent settlements, usually close to those of their farming neighbors, have provided them increased access to schools and health services, and a broader market, due to the presence of shops and the visits of merchants and traders of forest products. In addition, ecological changes due to deforestation and land degradation, the increasing arrival of external actors (loggers, traders of bushmeat and forest products), and also the establishment of conservation areas have reduced Baka's access to land and to natural resources as they do not have any land tenure.

Today the Baka engage not only in subsistence activities including hunting, gathering, fishing, and cultivating crops in agricultural fields (either their own or those of the Bantu), but also in economic activities such as selling forest products and wage labor for logging companies, Bantu-speaking farmers, or other outside groups coming from other areas in Cameroon. Most of the food consumed by the Baka, particularly the staples such as cassava (*Manihot esculenta*) and plantain (*Musa x paradisiaca*), come from the agricultural fields (Reyes-García et al., 2019; Gallois et al., 2020). However, a variety of key nutrients come from forest foods, including protein from wild game and fish, fat from nuts, and other important non-caloric nutrients from a large number of wild plants (Gallois et al., 2020).

The Baka use a variety of forest foods in their meal: wild tubers (mostly from *Dioscorea* spp.) are often the main source of carbohydrates, leaves and mushrooms are added to the main dish, and oils from nuts, particularly palm nuts and *Irvingia* spp. are used for cooking and providing fat. Other products are consumed separately from the main meal, including palm wine made from the pith of *Raphia* spp. and honey produced by a variety of different bees, including *Apis mellifera*, and several species of stingless bees from the Meliponini tribe.

The Baka have a high level of expert knowledge about forest resources that they use for food, medicine, and shelter (i.e., house building and maintenance) (Bahuchet, 1992; Dounias, 2001; Hattori, 2006). More than 100 different wild edible plants are known and used by the Baka (Gallois et al., 2020), and the wild yams (*Dioscorea* spp., see Gallois et al., 2020 for the IDs) are the best-studied examples of Baka's plant knowledge (Dounias, 2001). Despite their challenging nature – they are difficult to find and dig up (Sato et al., 2012) – the Baka have developed sophisticated techniques to make use of these key starchy resources, including harvesting methods that encourage regrowth (Dounias, 2001), and even transplanting them in their own fields. Beyond nutrition, these plants also appear as key elements of their cosmology and relationship to both the forest and the elephant (Dounias, 2001).

The Baka's relationship with their food resources is changing, however, due to sedentarization, dietary transitions, and the increasing consumption of drugs and alcohol, all of which have considerable impacts on Baka culture, social cohesion and health (Dounias and Froment, 2006; Gallois et al., 2020). Settlements that are close to market towns show stronger effects of such influences (Carson et al., 2019), including considerable changes in how they acquire their food. For example, Baka living in communities closer to the market town purchase all of their sweets from the market (e.g., candy), while people living in more isolated villages gather all of their sweets from the wild (i.e., honey; Reyes-García et al., 2019).

Given the Baka's reliance on a mix of forest resources, crops, and purchased foods, the Baka represent an ideal group to explore the activity costs compared between gathering and other subsistence activities, such as hunting, farming, and fishing, and further to investigate how gathering costs might vary among different food items. Based on what has been previously published about the division of labor by age and gender among Central African hunter-gatherer groups (Hewlett, 2014), and our own previous experiences among the Baka, we are able to make several hypotheses about patterns of subsistence activities among the Baka. First, we expect Baka women to engage more in gathering activities than men, and that involvement in foraging activities will decrease with age. In line with the grandmother theory and cultural transmission (Hewlett, 2014), we expect elders to devote more time in activities different from food acquisition such as child care taking, resting or socializing. We also expect that the intensity of work will differ among activities given that they require different techniques and levels of physical engagement (e.g., Gurven et al., 2013; Meehan et al., 2013). Furthermore, we expect that this intensity should decrease with age, as physical strength often decreases after about 45 years

old (as summarized in Walker et al., 2002), and roles and activities within the community change. In addition, we expect that the duration and distance traveled will also vary among activities, given that resources are located in different areas. In particular, we anticipate that hunting will require greater travel distances and more time than other subsistence activities (Wood et al., 2021). Because each settlement is located in a specific ecological landscape, with different distances to fields, hunting grounds, and other resources, we also anticipate that the kind of settlement would influence the duration of particular activities, such as crop harvesting. We also expect that individuals from settlements with higher market integration, for example, located closer to a market town and to the Bantu villages, would engage more in wage labor and other non-subsistence activities, and less in foraging activities, especially in gathering wild plants, than more isolated settlements such as forest camps. Finally, we expect a large variation in intensity of work, duration, and distance traveled within “gathering” activities given the diversity of products gathered and the different techniques needed to access them (Gallois et al., 2020).

METHODOLOGICAL APPROACH

This study took place in four Baka settlements in the Lomie and Messok district of the Haut Nyong division in southeastern Cameroon. The primary Bantu-speaking group in this region is the Nzime. Because the availability of food and the time allocation of the Baka vary considerably throughout the year, the data were collected during three fieldwork periods of 7 weeks during three different seasons: the major dry season (January–February 2018), the major rainy season (October–November 2018), and the minor rainy season (April–May 2019).

Before the onset of the study, we obtained Free Prior and Informed Consent (FPIC) from every individual taking part in this research. This study adhered to the Code of Ethics of the International Society of Ethnobiology, and received the approval of both the ethics committee of Leipzig University (196-16/ek) and the Ethical Committee from the Ministry of Health of Cameroon (n°2018/06/1049/CE/CNERSH/SP). All data were collected within the context of immersion into Baka life, with the first author living directly in the settlements and participating in domestic work. The interviews were conducted directly by the first author who had previously learned the Baka language and with the help of a local research assistant who spoke the Baka language.

Data Collection

In the four studied villages, we collected socio-demographic data at the individual level regarding the gender and age of the participant, and established the kinship chart among all participants in each village. As the Baka do not have any birth records, we estimated their age by using kinship information and the previously established estimates for age of first birth (18 years old) and birth interval (2.5 years old) (Ramirez Rozzi et al., 2015). We also estimated the level of market integration of the settlement by collecting data on the number of inhabitants, the

proximity to the market town, and the presence of shops, schools, and health services (Table 1).

We assessed how the Baka spent their time and energy while performing subsistence activities by combining GPS (Global Positioning System) and heart rate records during their daily activities with self-reported time allocation recalls. Specifically, we invited the participants to wear an activity monitor that included a GPS device and a chest-worn heart rate monitor (Garmin fenix® 3/HR) during their daily tasks. They were asked to wear the activity monitor during the whole active period, from early in the morning (between 6 a.m. and 8 a.m.) to the end of their day, when they were back in the village and had ended their activities (between 5 p.m. and 7 p.m.). In addition to these records, we interviewed each participant when they returned the activity monitors, asking them to report all of the activities they had performed and the products they had gathered while wearing the GPS device (time allocation recall). We also calculated an approximate duration of the activities using mostly solar references, which has been recently shown to be a good predictor for hunter-gatherers living in rainforest environments (Jang et al., 2019). We included all individuals willing to participate in this study with the aim of getting a sample that was balanced in terms of age categories and genders. A total of 246 daily GPS tracks and heart rate records were collected (156 among women, 90 among men) among 153 individuals (97 women, 56 men). Seventy-nine individuals were interviewed once, 55 twice, and 19 three times (Supplementary Material 1).

We also collected contextual information related to how the Baka spent their time on subsistence tasks and additional ethnographic data by conducting informal interviews with men and women separately in order to ensure both genders were equally heard. We asked questions about perceived effort (e.g., “what is the most difficult activity that you do?”), seasonal calendar, group composition (e.g., “with whom do you usually perform [subsistence activity]?”), food sharing practices, and other aspects of their livelihood. Moreover, the previous long

period of fieldwork spent by the first author – more than 30 months in total – living directly in Baka settlements provided us additional information that has been used for further contextualizing our results.

Variable Constructions

We first extracted the data from the activity monitor, namely the GPS position, the heart rate, the speed, and time. These data were recorded every second throughout the day, and data for each second is called an epoch. Commercial activity monitors such as we used are known for occasionally recording epochs with biologically unrealistic speeds (<0 or >8 m/s) (Pontzer, 2015) and missing or unrealistic heart-rate values ($>208 - 0.7 \times \text{age}$) (Tanaka et al., 2001). We cleaned the data to remove these errors by removing these epochs from the daily record. After cleaning, the records were on average 38,056 s long (about 10 h 34 min). Combining the self-reported time allocations and the tracks recovered from the GPS locations, we identified on the individual daily records: (a) the time spent outside and inside the settlement, and (b) the different activities performed. We also calculated the duration, distance traveled, and energy expenditure for both the actual performance of the activities. Each activity record included the travel to reach and leave from the place where the activity took place (for example, the travel to the forest spot, the actual moment of hunting, and the travel back to their settlement).

For assessing energy expenditure while performing their daily activities, we used the formulae proposed by Keytel et al. (2007), which provide an estimate of energy in kJ per minute based on heart rate in beats per minute. For men, this formula was: $-55.0969 + 0.6309 \times \text{Heart rate (in beats per minutes)} + 0.1988 \times \text{Weight (in kg)} + 0.2017 \times \text{Age (in years)}$; and for women: $-20.4022 + 0.4472 \times \text{Heart rate} + 0.1263 \times \text{Weight} + 0.074 \times \text{Age}$. Every second, the activity monitor estimated the average heart rate in beats per minute. We applied these formulae to calculate energy expenditure from heart rate value every epoch. This provided estimates of energy

TABLE 1 | Description of the four Baka settlements included in this study.

Settlements	Type of settlement	Approximate number of inhabitants	Proximity to the market town (km)	Number of shops	Schools and health services	Other relevant characteristics
Le Bosquet	Village along logging road	800	26	4	1 private school and health center (missionaries)	Big settlement built by missionaries and long visited by foreigners (missionaries and researchers).
Mombokola	Village along logging road	500	12	3 (in the Nzime village)	1 public school – no health service	At the crossing of several logging roads. Base of one logging company. In continuation of the Nzime village.
Elonda	Village along logging road	400	33	1	1 private school – no health service	2 km from the Nzime village.
Kungu	Forest camp	200	11 (including 4 km in the forest, 1.5 h of walking)	0	1 public school in the Nzime village (1.5 h away) – no health service	Settlement in the forest where people live occasionally. Residents of the forest camp also have a house in a village along the logging road that is a continuation of a Nzime village, about 1.5 h walk away.

consumption in kJ per minute for each epoch, so we therefore divided this value by 60 to have the energy expenditure in kJ per second for each epoch. We summed these kJ per second values over the entire set of seconds in order to obtain the total energy expenditure for each activity.

For the resting basal metabolic rate (BMR), we used the New Oxford formulae proposed by Henry (2005), which account for variation in BMR due to weight, gender, and age. These were: for men between 18 and 30 years-old: $0.0669 \times \text{Weight (in kg)} + 2.28$; men between 30 and 60 years-old: $0.0592 \times \text{Weight} + 2.48$; men 60 + years old: $0.0563 \times \text{Weight} + 2.15$; For women between 18 and 30 years old: $0.0546 \times \text{Weight} + 2.33$; women between 30 and 60 years old: $0.0407 \times \text{Weight} + 2.90$; women 60 + years old: $0.0424 \times \text{Weight} + 2.38$. In all cases, these formulae provide BMR in MJ per day, so we then converted the resulting values to kJ per minute.

For every self-reported activity, we calculated the metabolic equivalent of task (hereafter, MET) following Ainsworth et al. (2011) as the ratio of the average energy expenditure spent in kJ/min during each activity to the average energy expenditure spent in kJ/min by that individual when resting. Using MET instead of summed kJ spent per activity allows us to account for differences in BMR among individuals. It also averages out potentially unrealistically high or low energy values (in kJ/min) that might be the result of errors in the measurements taken by the activity monitors. While we were not able to directly assess unrealistically high or low energy values, we did explore the potential variation in heart rate values within and among a subsample of the recorded activities (**Supplementary Material 2**) in order to assess if the MET values provide a realistic estimate of the overall intensity of the task. With the exception of water carrying, which demonstrated a pattern of low or/moderate heart rate followed by high heart rate values, there were no distinct patterns of heart rates among activities. Within each activity, some individuals had a moderate and steady heart rate throughout the activity, while others showed a lower heart rate with punctuated episodes of higher heart rate. Overall, MET values appear to accurately reflect the average intensity of a task. A final advantage of using MET is that it provides a unit-less indication of the effort put into an individual task, or, in other words, the intensity of the work.

We then used these data in a number of different analyses to investigate: (1) daily time allocation, (2) duration, distance traveled, and intensity of work among the different activities, and (3) detailed exploration of gathering activities. We specifically compare between genders (men and women), among villages, and among age categories. We chose the four villages explicitly given their different levels of market integration, distance to market towns, distance to agricultural plots and proximity to Nzime villages. We divided the participants into three age categories: under 30, 30–60, and older than 60. Hunter-gatherers reach their highest foraging productivity at 30 years old (Koster et al., 2020), so we used this age as the division between young and middle-aged individuals, while 60 is considered the start of senior years in many demographic studies.

Data Analysis

Daily Time Allocation

First, we explored how the Baka spent their time among various subsistence activities. In each daily record, we calculated the percentage of time that the Baka spent outside the settlement. We then compared the time spent outside the village among villages, between genders, and among age categories. As we were primarily interested in food acquisition activities, we then focused on those that took place outside of the camp. We classified each self-reported activity into one of eight different categories: (1) gathering, (2) hunting, (3) fishing, (4) agricultural work (e.g., field maintenance, weeding, etc.), (5) crop harvesting (e.g., acquisition of food items for consumption or sale), (6) firewood collection, (7) water fetching, and (8) others. This latter category includes the following activities: gathering building material, logging, other wage jobs, traveling to other villages, and visiting other villages. We observed 531 activities. If one individual reported that they performed the same activity on separate trips in the same daily records, we counted this as one observation in order to avoid inflated data per activity, which reduced the total analyzed activities to 513. We compared how the participation in the various activities varied between genders, across age categories and among villages.

Energy Spent on Activities

Second, we explored the effort spent by the Baka among activities. We measured effort by looking at the duration, the distance traveled, and the MET across activities, and explored whether these varied between genders, among villages and among age categories. For these analyses we had to use a reduced dataset that included only those records in which a single activity was reported. As we discuss in detail below, many of our participants reported performing multiple activities in the same trip outside the settlement (e.g., crop harvesting and fuel collecting). We could not separate the time and energy spent on these activities in our records. Therefore, our reduced dataset included only 258 activities, from 202 individual daily records in which the participant reported performing “single” activities. We first examined the relationship between distance and duration by performing two power correlation tests. Based on the results (in detail below) we opted to proceed further with only the duration of the activities. We specifically predicted that the intensity of effort (as measured by MET), and the duration of the task (time in minutes) should vary among activities between men and women (e.g., women spend effort and/or more time on gathering than do men). We also predicted that the work might vary among activities between villages (individuals in forest camp might spend more effort and/or more time on gathering than those in Le Bosquet). Finally, we predicted that the energy spent should vary among activities between age categories (older individuals might spend less effort and/or time on gathering).

These predictions led to us building two general linear mixed models (GLMMs) which tested the effects of these interactions, one on duration of the activity, and the other on MET as a measure of intensity of effort. In both models, activity, age, gender, and village were included as fixed effects, with interactions between gender and activity, age category and

activity, and village and activity. Because we were explicitly testing the effect of the interactions of activity and the other factors, we had to remove activities that were incompletely nested. In our observations, only women went fishing, so we removed this activity from the data set. Furthermore, we did not observe water carrying among individuals in our oldest age category. We therefore also removed this activity from the data set. Finally, because the “other” category included a variety of different activities, we would not expect a coherent pattern in either the duration or the intensity for this activity. We therefore removed it from the data set. This left us with a dataset of 216 observations of five activities (gathering, crop harvesting, hunting, firewood collection, and agricultural work).

Given that we observed some of the same individuals multiple times, and that our observations were spread out over several different days, we included the subject number and date of observation as random effects. Furthermore, we noted that different activity monitors could provide differing but internally consistent measurements, so we also included the number of the activity monitor as a random effect.

Prior to running the analyses, we log transformed and then z-transformed to a mean of zero and standard deviation of one both duration and MET values in order to improve model fitting. The models were fitted using the function `lmer` of the R package `lme4` (Bates et al., 2015), with a Gaussian error distribution and identity link function, using maximum likelihood (REML = FALSE) to make it possible to compare among models with different random effects structures.

As a last exploration of energy expenditure, we estimated the total energy spent on the various activities across all of the records in our single-activity data set. Given the potentially unrealistically high values recorded by the activity monitors, we chose not to use the total kJ values. Instead, we multiplied the MET value (average intensity) by the duration of the activity per record. We then averaged this calculated energy value across all observations of the activity, then multiplied this average MET by the frequency of occurrence of that activity to get a sense of the energy budget per activity and per activity between genders.

Gathering

Third, we more closely explored gathering activities themselves, with the goal to see if gathering varied among the different wild products that were collected. From the 106 gathering events recorded, we could extract the duration and MET values for 51 gathering activities: 36 among women and 15 among men. We then compared the duration, distance traveled, and MET among the different wild foods that were collected. We finally estimated the total energy spent while gathering the various food items as a proportion of the total energy budget, by multiplying the average MET by the average duration per food item, and then multiplying this by the frequency of gathering that food item within the total number of activities.

Our data were analyzed using a combination of Stata 11.1 and R version 3.6.3 (2020-02-29) – “Holding the Windsock” (R Core Team, 2020).

Limitations

We recognize that there may be inaccuracies in the self-reporting and the data provided by the activity monitors. However, we chose to use interviews and activity monitors instead of other methods for assessing energy expenditure such as focal follows and oxygen monitors, because these allowed us to maximize the number of participants and to interfere the least with their habitual behaviors. We were also interested in separating out daily activities, so methods such as doubly labeled water were not appropriate for this analysis. A further caveat is that the “MET” value for each activity that we derived from calculations based on heart rates does not necessarily match those published elsewhere (Ainsworth et al., 2011) and may therefore not be broadly applicable for comparisons of activities beyond the scope of this article. However, as the aim of this research is to compare the effort between the different activities within a single community and using one method set, by standardizing our activities by the individual’s BMR, we can compare the MET between the different activities and individuals.

RESULTS

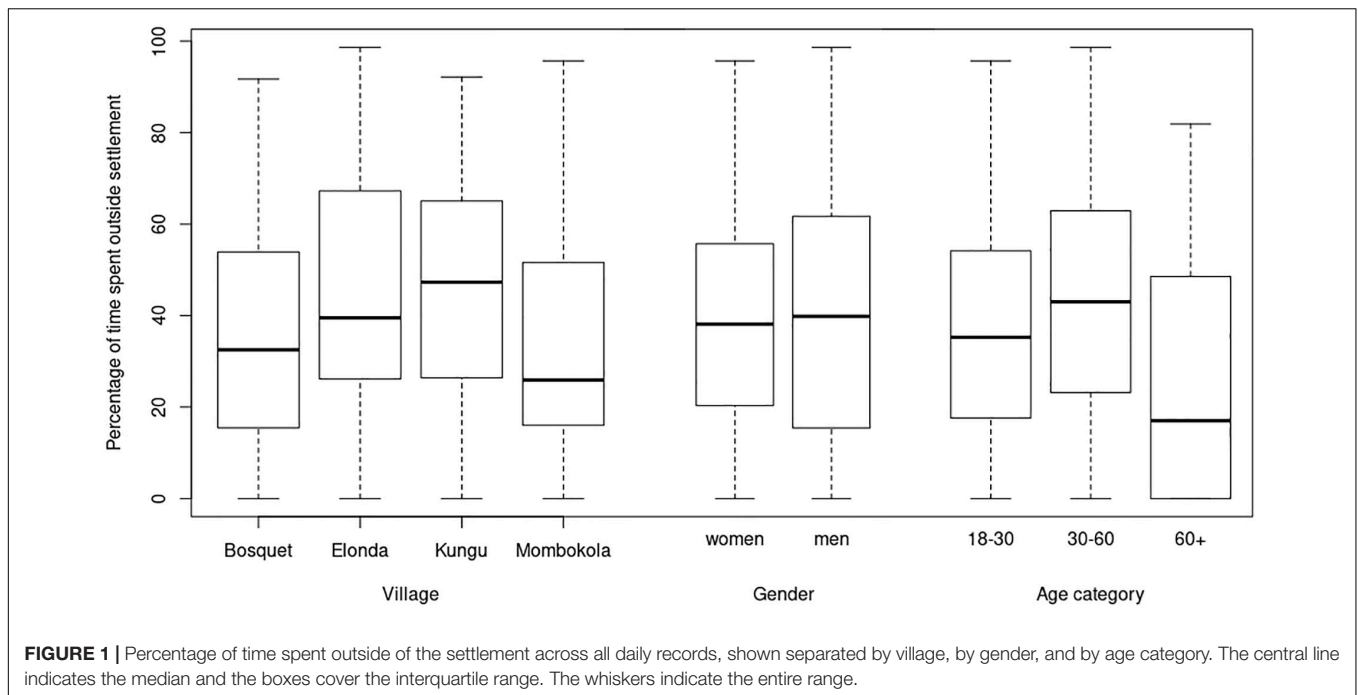
Daily Time Allocation Outside the Settlement

The Baka regularly leave the settlement: Of the 246 individual daily records, only 17 recorded staying in the settlement the entire day either for performing activities such as house maintenance, handicraft, socializing, or for resting. Overall, individuals traveled an average of 15 km (SD = 5.2), with no significant difference between men and women (men: 16.1 km ± 6.4; women: 14.8 km ± 4.3; Wilcoxon signed rank tests: $z = -1.44$, $p = 0.15$). Individuals who left the settlement spent an average of 260 min, or 4 h 20 min, away (SD = 164 min). Compared to the total time recorded, about 39% of the day was spent outside of the settlement.

Plotting the percentage of time spent outside revealed interesting patterns (Figure 1). While there was no difference between men and women, we did observe differences among age categories: individuals above 60 years old spent less time outside of the settlements than the other two age categories. The amount of time spent outside also varied among settlements, with individuals living in Le Bosquet and Mombokola – the two larger settlements – spending less of their time outside than those in Elonda and Kungu.

Involvement in Food Acquisition Activities

While away from settlement, the Baka reported a total of 531 different activities that they conducted in 419 different trips. Note that here we distinguish between a trip outside the village and a daily record – in 1 day an individual might make one or more trips. In some cases, the Baka performed multiple activities in the same trip, for example, leaving the settlement to work in the agricultural plots, and also gathering wild plants and collecting firewood at the plot or along the way. We found that 49% of the activities ($n = 207$) were reported as combined activities, meaning



that the participants left the settlement and conducted different activities in a single trip before going back to the settlement.

On average, the Baka engaged most frequently in agricultural work (51.2% of the out of the camp activities), and gathering (41.1%), followed by crop harvesting (29.7%), and firewood collecting (27.6%). In contrast, hunting and fishing were the least frequently performed (14.6 and 4.5%, respectively) (**Figure 2**). Men and women engage differently in their daily activities outside of the settlement. Women tend to engage more frequently than men in crop harvesting, firewood collecting, fishing, and water fetching. Men are more frequently involved in hunting than women (**Figure 2**).

The occurrence of the different activities also varies among age categories and villages. The youngest individuals more frequently conducted water fetching and fishing than the two older age categories. Individuals in the middle age category more frequently engaged in agriculture than both other age categories (**Figure 2**). Inhabitants of Elonda, a village of about 400 individuals settled along the logging road, reported less gathering than the others. Individuals from both Elonda and Mombokola reported agricultural work and crop harvesting more frequently, but fishing less often than in both other villages (Kungu and Le Bosquet). Individuals from Kungu, the forest camp, performed hunting more frequently than those in all other settlements (**Figure 2**).

Duration, Distance, and Metabolic Equivalent of Task of the Food Acquisition Activities

Duration and Distance Traveled

Among the reduced data set of “single” activities, there was significant variation in the duration of the activities, from 45 min

to more than 5 h (Kruskal–Wallis test: $X^2 = 100.46$, $p = 0.0001$) and distance traveled from 1.61 to 17.23 km ($X^2 = 96.86$, $p = 0.0001$). Specifically, fishing and hunting required more time and the furthest travel (**Table 2**). In contrast, gathering did not require a similar investment in travel (7.7 km, 169 min), and the shortest distances were traveled while collecting firewood and fetching water (**Table 2** and **Figure 3** for the distance where took place the main activities, by settlement).

Distance and duration were correlated, according to the results of two series of power correlation tests ($p < 0.000$), one taking all recorded activities together (Pearson’s correlation coefficient = 0.923) and the other by category of activities (coefficients = gathering: 0.97; hunting: 0.961; fishing: 0.985; agriculture: 0.906; crop harvesting: 0.958; water fetching: coef = 0.878; fire collecting: 0.879; and others: 0.958). Therefore, to simplify our results, we used only the duration of the activities in our further analyses.

In the GLMM exploring the influence of our main factors and their interaction on the duration of the activities, we discovered that the full model with all three random effects (subject number, date, and activity monitor number) provided a singular fit. Given that date and activity monitor number had no effect on the MET (see below), and that we anticipated that these potential influences should have even less effect on duration than on MET, we therefore retained only subject ID as the random effect in our further analysis. We checked whether the assumptions of normally distributed and homogeneous residuals were fulfilled by visually inspecting a qqplot and the residuals plotted against fitted values. Both indicated no obvious deviations from these assumptions. We checked for model stability by excluding data points one by one from the data and comparing the estimates and fitted values derived with those obtained from the model based on all data. These indicated some potentially influential

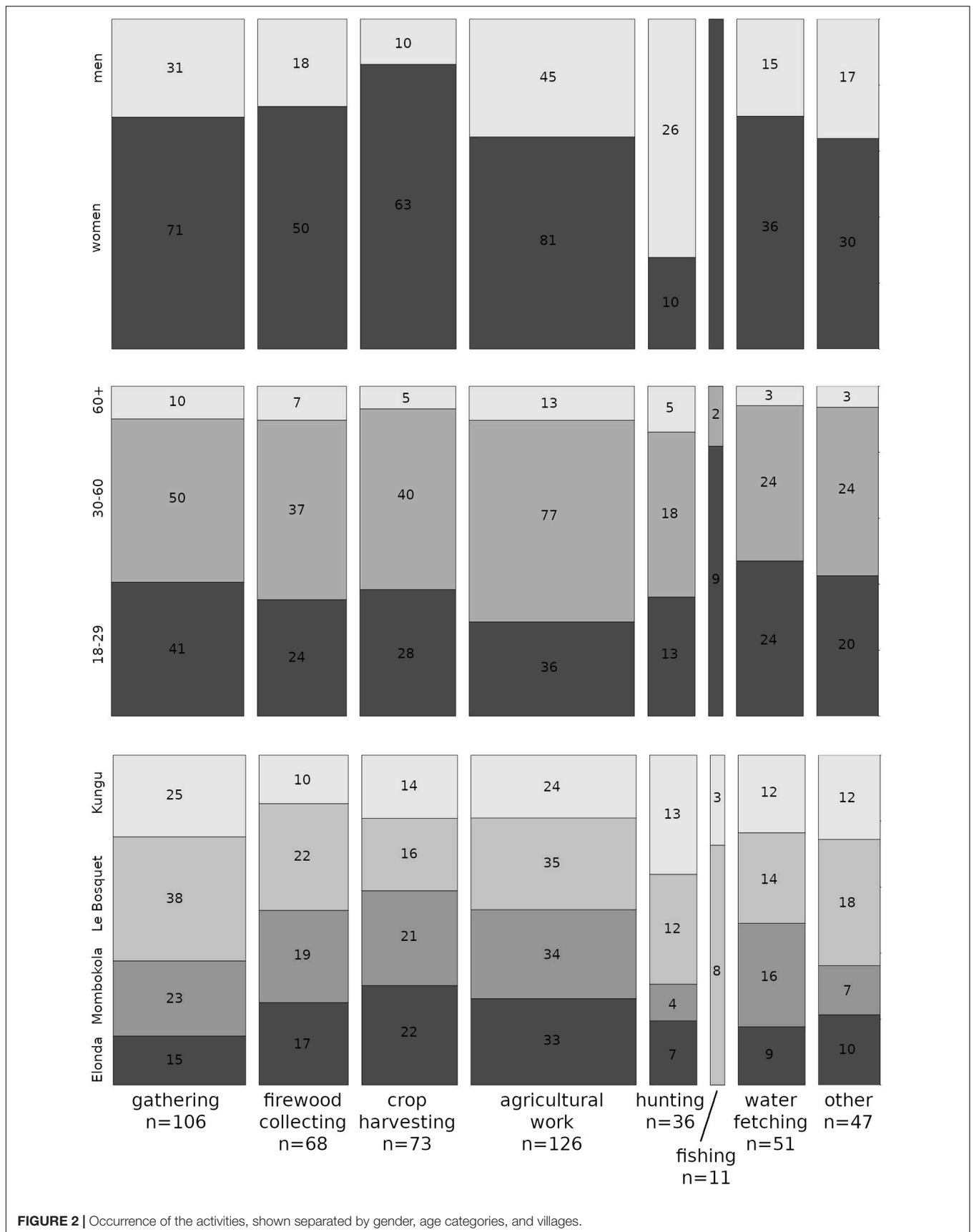


FIGURE 2 | Occurrence of the activities, shown separated by gender, age categories, and villages.

TABLE 2 | Average MET, time spent, and distance traveled among subsistence activities observed in 202 records from 135 individuals (90 women and 45 men).

	Recorded single activities			MET						Duration (in minutes)						Distance in km					
	Total		Men	Total		Women	Men		Total		Women	Men		Total		Women	Men				
	Average	SD	Average	SD	Average	SD	Average	SD	Average	SD	Average	SD	Average	SD	Average	SD	Average	SD			
Crop harvesting	28	26	8.26	1.82	8.30	1.89	7.82	0.69	121.76	144.26	121.80	149.53	121.25	54.08	4.91	6.60	4.93	6.83	3.11		
Water fetching	22	15	7.28	1.68	7.99	1.45	5.75	0.83	37.70	20.73	37.39	18.26	38.36	26.94	1.82	0.97	1.81	1.00	0.99		
Firewood collecting	27	22	6.94	1.74	7.15	1.41	5.98	2.80	45.35	24.01	44.03	23.43	51.12	28.57	1.61	1.02	1.55	0.89	1.56		
Agricultural work	94	61	6.92	2.17	6.86	2.01	7.06	2.48	232.05	134.41	228.32	131.35	238.95	141.72	8.15	4.90	7.71	4.28	5.86		
Gathering	51	36	6.82	2.76	7.11	2.89	6.14	2.38	169.32	143.54	146.39	123.07	224.35	176.41	7.7	7.27	6.49	5.84	10.61		
Others	13	9	6.66	2.62	6.44	1.95	7.17	4.1	192.23	158.77	153.0	152.5	280.49	232.89	9.18	8.64	6.09	5.73	16.36		
Fishing	7	7	6.4	1.37	6.4	1.37			334.34	172.17	334.34	172.17			17.23	8.54	17.23	8.54			
Hunting	16	4	6.33	2.43	7.74	1.58	5.86	2.53	239.72	153.04	91.99	35.70	291.18	141.54	11.74	8.47	3.63	1.63	15.45		
Snares	3	1	6.98	2.27	8.97		5.98	2.08	276.56	148.76	123		353.33	94.28	15.73	11.24	5.4		20.9		
Unearthing	6	1	5.53	2.54	7.04		5.23	2.72	278.96	187.83	50.02		324.75	168.45	12.52	9.34	2.1		14.6		
Other (spear, shotguns)	7	2	6.74	2.56	7.47	2.31	6.44	2.85	190.3	129.27	84.13	33.99	232.76	129.96	9.37	7.02	3.5	1.56	11.72		

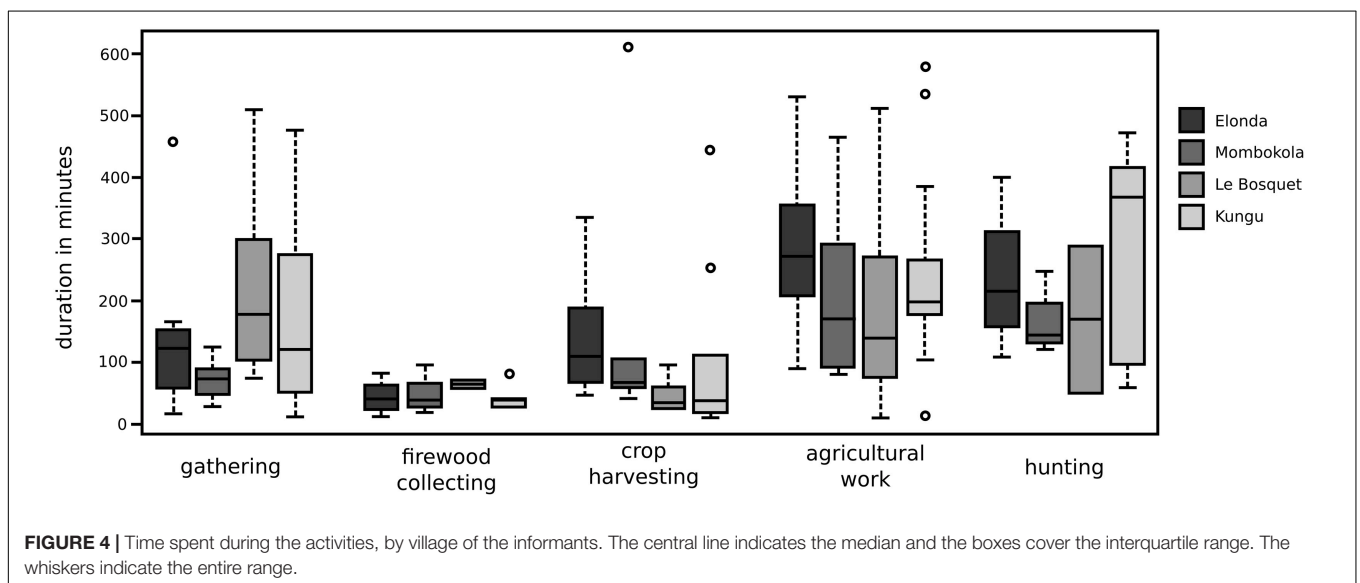
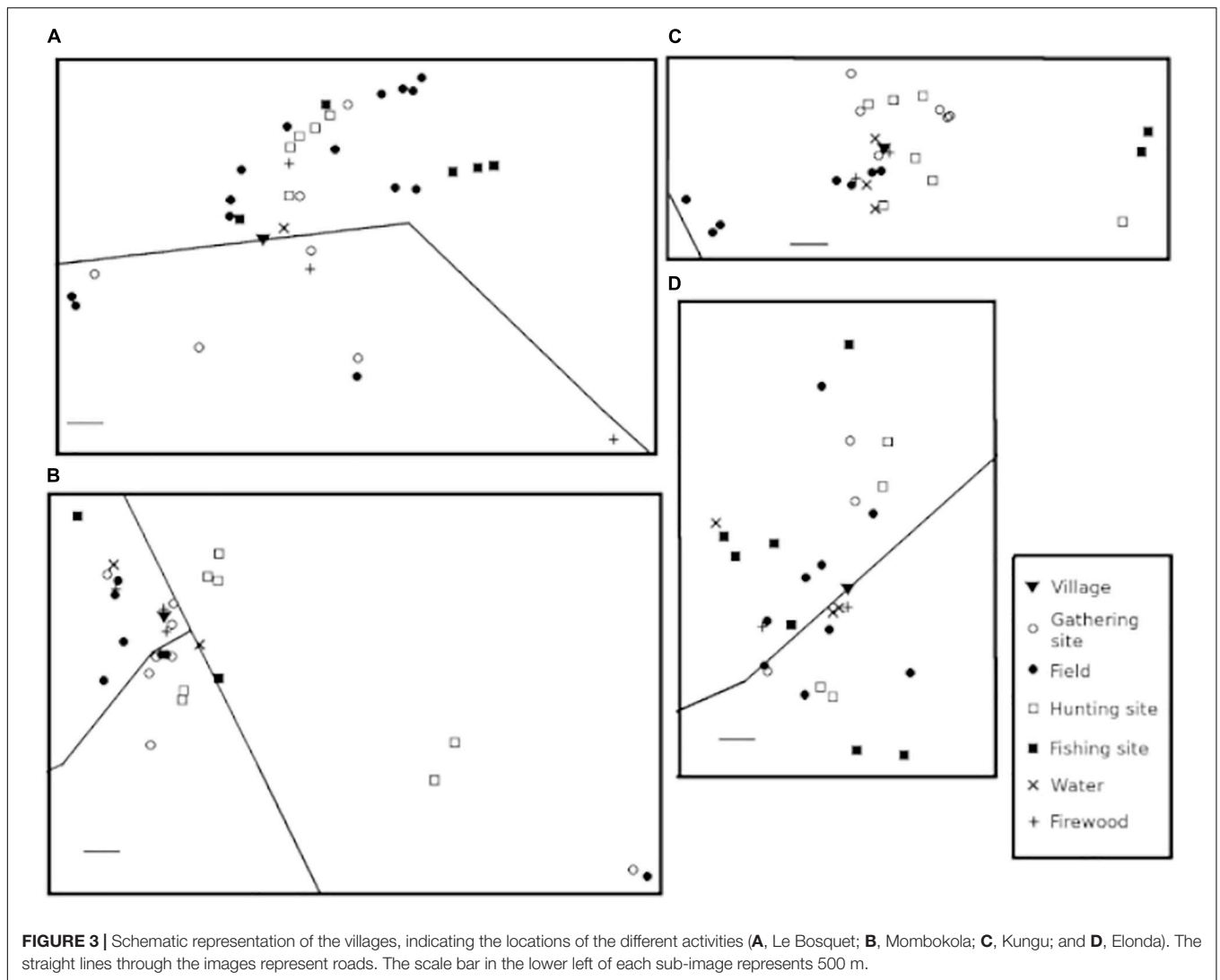
cases. Examination of the data revealed that in the 60+ age category, there were only two individuals who collected firewood, only two who harvested crops, and only two who hunted. We chose not to exclude any of these cases from the model because doing so would have resulted in an incompletely nested structure. Variance Inflation Factors (ViF) were derived using the function `vif` of the package `car` (Fox and Weisberg, 2011) applied to a linear model excluding the random effects. These values were all below 2.5 suggesting no problems. The full model was significant as compared to the null model which comprised only subject ID as the random effect (likelihood ratio test using the ANOVA function with the test set to “Chisq” $\chi^2 = 123.21$, $df = 34$, $p < 0.001$). *p*-Values for the fixed effects and interactions were based on the function ANOVA of the package `lmerTest` (type II analysis of variance with Satterthwaite’s method, Kuznetsova et al., 2017).

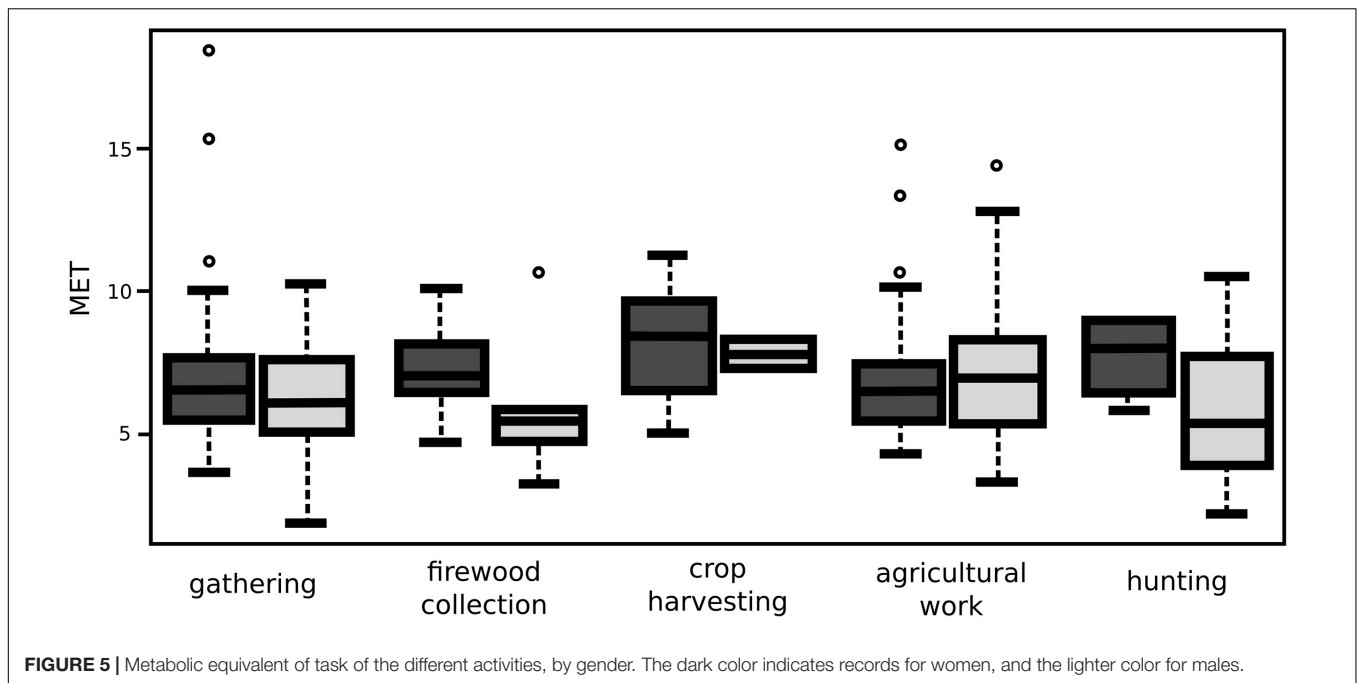
As we expected, the amount of time spent varied significantly among the activities. Crucially, the amount of time spent on a task was significantly influenced by the interaction of activity and village, with individuals in le Bosquet spending significantly less time on both crop harvesting ($df = 196.90918$, $t = -4.098$, $p < 0.001$) and on agriculture ($df = 202.15752$, $t = -3.129$, $p = 0.002$) than any other activity and village combination (Figure 4 and Supplementary Material 3).

Metabolic Equivalent of Task

Metabolic equivalent of task values allowed us to compare the average cost of individual activities regardless of the time spent. We first explored whether MET values correlate with duration and distance, both considering all activities together or individually. Pairwise correlation tests showed no correlation between duration and MET (coefficient = -0.0651 , $p = 0.30$) or between distance and MET (coefficient = -0.0239 , $p = 0.702$). We explore whether the average MET values varied according to the activity performed, the gender, the age category, and the village of the informants (Table 2). The most energy demanding activities are crop harvesting (8.26), water fetching (7.28), and agricultural work (6.94). Interestingly, the MET of gathering – 6.82 – is higher than those of fishing (6.4) and hunting (6.33) (Table 2).

For the GLMM in which we tested whether MET was significantly influenced by activity, age, gender, village, and the interactions among age and activity, gender and activity, and village and activity, we first tested whether our random effects (subject ID, date, and activity monitor number) significantly improved the model fit. We therefore removed each one individually and compared to the full model. These tests indicated that the model that removed the date did not significantly differ from the full model (likelihood ratio test using the ANOVA function with the test set to “Chisq”: $\chi^2 = 0.9144$, $df = 1$, $p = 0.339$). The model that removed the activity monitor number also did not significantly differ from the full model ($\chi^2 = 0.2104$, $df = 1$, $p = 0.646$). We therefore removed both of the random effects from further analyses. However, removing the random effect of the subject number was highly significant, ($\chi^2 = 21.324$, $df = 1$, $p < 0.001$) so we retained this in our further analysis. All tests for model assumptions, model stability and ViF were completed as described above. As above there were indications





for influential cases in the 60+ age category due to a limited number of records, but we chose not to exclude these. The other tests revealed no other significant problems. The significance of the full model as compared to the null model (comprising only the random effect) was established using a likelihood ratio test ($\chi^2 = 60.26$, $df = 34$, $p = 0.004$). p -Values for the fixed effects and interactions were based on the function ANOVA of the package lmerTest.

All of our individual predictors were combined in interactions, therefore we cannot individually assess their effect on the model. Of the three interactions, only the interaction of activity and gender was significant ($df = 4$, $dendf = 173.10$, $F = 4.7841$, $p = 0.001$). Men had significantly higher MET values than women when performing agricultural tasks ($df = 163.765183$, $t = 3.320$, $p = 0.001$). Men also showed slightly lower MET values for hunting, but this was not significant. The model also revealed that while age and gender overall might have an influence on intensity as measured by MET, these effects did not differ among activities (in other words, the interaction was insignificant) (Figure 5 and Supplementary Material 3).

Finally, we aimed to get an overall descriptive overview of the total amount of energy dedicated to each of the activities within our data set, we multiplied the average MET per activity by the average duration, and then multiplied this by the frequency of that activity within our dataset. Given their high MET values, moderate duration times, and high frequency of occurrence, agricultural work and gathering are the two most energetically expensive activities, and constitute respectively about 36 and about 20% of the total energy spent outside the settlement for the whole sample, and for women respectively 39 and 20% and for men 34 and 23% (Table 3). The next most costly activities varied between the genders, with women spending about 19% of their energy in crop harvesting, while men engage a similar amount of

energy in hunting, and also in performing activities outside the settlement other than for food acquisition, as for instance cutting and collecting wood for house building or visiting other villages for social reasons.

Detailed Exploration of Gathering Activities

To assess how the costs of gathering can vary across food items, we compared the characteristics (MET, duration, and distance) of gathering among individual wild products.

Of the 51 gathering events analyzed, most of them were for gathering *koko* leaves (*Gnetum africanum*). There were in total 27 *koko*-gathering trips, including three events during which other wild edibles were also collected (in the “Various” category, Table 4). The second most frequently gathered products were the tubers of wild yams (*Dioscorea* spp.), conducted in eight records, including two trips during which other wild edibles were collected. Both men and women gather leaves, mushrooms, and yams, but only men gather honey and cut palm trees for gathering their sap and making palm wine. In our sample, only women gathered the fatty fruits from *Elaeis guineensis*, but this might be due to the small number of records, as both men and women reported to us that men regularly engage in gathering these fruits.

While all of these activities fall under the general heading “gathering,” there are considerable differences in the distance traveled and time spent for acquiring each food type (Table 4). Honey gathering requires the furthest distance. Gathering trips targeting more than one product require considerable distance to cover, as does collecting yams (Table 4). In contrast, palm wine gathering takes the shortest distance traveled, because the palms are usually close to the settlement or to their fields.

TABLE 3 | Amount of energy dedicated to each of the activities, estimated by multiplying the average energy spent in the activity by the average duration of the activity, and then by the frequency of occurrence of the activity across all of the daily records (258 activities from 202 individual daily records).

Activities	Whole sample				Women				Men			
	Number of records	Total energy estimated	SD	Relative proportion	Number of records	Total energy estimated	SD	Relative proportion	Number of records	Total energy estimated	SD	Relative proportion
Agricultural work	94	802.79	538.67	0.36	61	767.47	473.78	0.39	33	868.08	644.7	0.34
Gathering	51	447.11	431.03	0.20	36	392.54	312.64	0.20	15	578.07	626.99	0.23
Fire collecting	27	85.98	53.82	0.04	22	88.38	57.69	0.04	5	75.4	34.42	0.03
Crop harvesting	28	304.68	408.37	0.14	26	306.06	423.3	0.15	2	286.81	150.21	0.11
Hunting	16	199.12	141.34	0.09	4	95.42	44.98	0.05	12	233.68	146.54	0.09
Fishing	7	91.03	51.97	0.04	7	91.03	51.97	0.05	0			0.00
Water fetching	22	57.42	34.69	0.03	15	63.35	35.47	0.03	7	44.73	31.63	0.02
Others	13	267.4	309.32	0.12	9	178.89	190.49	0.09	4	466.57	547.76	0.18
Total	258	2255.53		1.00	180	1983.14		1.00	78	2553.34		1.00

Similarly, the intensity of work needed during collecting these different foods varied (Table 4). The MET values of gathering varied the most among all of other subsistence activities (SD = 2.76; Table 2), suggesting that this category in fact subsumes a wide number of tasks that differ energetically. While the leaves of *G. africanum* are the most frequently gathered product, they require the lowest intensity. The gathering of the oil-rich nuts and seeds, including **kana** (*Panda oleosa*), **bokoko** (*Klainedoxa trillesii*), **mbila** (*E. guineensis*), and **payo** (*Irvingia spp.*) requires the greatest intensity. These nuts often have very thick shells, so the Baka crack the shell to open the fruits and gather the seeds (except for *E. guineensis*). The gathering of yams is also high intensity work, because they grow quite deep in the ground, up to 3 m deep (Dounias, 2001) and the Baka have to dig them up. This activity is more energetically demanding than honey gathering, partly because during our field seasons the Baka collected only the honey of bees who nest in fallen trees.

When considering the products individually, it is noteworthy that the MET of gathering nuts is higher than that of crop harvesting (9.52 vs. 8.26, respectively). Likewise, the gathering of yams and of honey have MET values just between those of crop harvesting and water fetching. The collection of these products is therefore among the most energy demanding subsistence activities performed by the Baka. Finally, regarding the amount of energy dedicated to each of the gathering activities we see the gathering of koko leaves and various wild edibles were the two most energetically expensive gathering activities, and constitute respectively about 36 and about 24% of the total energy spent for gathering for the whole sample, and for women respectively 43 and 24% and for men 31 and 39% (Table 5).

DISCUSSION

Food Acquisition Activities in a Mixed Subsistence Society

Our data reveal that agricultural tasks (including working in the field and harvesting crops), are the main activities undertaken by the Baka on a daily basis, followed by gathering wild resources. This first overview confirms that the Baka from this area in

southeastern Cameroon rely on a farming-foraging livelihood, not only hunting and gathering. Agriculture is highly valued (Gallois, 2017), and the Baka tend to prefer domesticated crops above most other foods (Gallois et al., 2020). These preferences may be due in part to: (1) multiple and ongoing political and developmental campaigns that promote agriculture in Cameroon, (2) perceptions of a higher social status that may be associated with having agricultural fields (Gallois, 2017), or (3) personal taste preferences for crop foods. The way the Baka engage in their subsistence activities is not homogenous in the studied area, with slight differences among the settlements. While people from the forest camp tend to conduct hunting more frequently than in the other settlements, gathering was reported more frequently in a village settled along the logging road (Elonda). Baka living in the forest camp were not isolated from agriculture or from wage labor opportunities, likely because this forest camp was quite close to the village (about 1.5 h walking), which made it possible to travel there and back from the closest Nzime village within 1 day. Furthermore, variability exists between the villages settled along the logging road, likely due to their individual social and ecological contexts. Elonda and Mombokola seemed to be more orientated toward agriculture than Le Bosquet, for which the frequency and duration of agricultural tasks were lower than both other settlements. Mombokola and Elonda are closer to Nzime villages than is Le Bosquet, which might increase the frequency and duration devoted to agriculture because the Baka more frequently engage in wage labor by working in Nzime fields. Inhabitants of the two largest villages (Le Bosquet and Mombokola), spent less time outside the settlement, possibly due to more opportunities for subsistence activities within the settlement (e.g., selling products and wage labor). To further develop our understanding of drivers of time allocation, future work is needed to better quantify the different social, ecological, and economic factors of each village, but equally as importantly, to explore the factors affecting household and individual decisions of time allocation.

As has been previously seen in other studies, our data also showed that both women and men tend to engage in similar activities. Even if fishing and hunting are more frequently performed by one gender, there is not any apparent restriction

TABLE 4 | Metabolic equivalent of task, duration, and distance traveled in gathering activities, by wild edible products, by the whole sample and by gender.

Wild edibles	Number of records			MET						Duration in minutes						Distance in km					
	Total	Women		Men	Total	Women		Men	Total	Women		Men	Total	Women		Men					
		Average	SD			Average	SD			Average	SD			Average	SD		Average	SD	Average	SD	
Nuts	5	4	1	9.52	5.09	10.46	5.36	5.76	116.07	90.67	114.58	104.63	122.02	6.9	4.65	7.23	5.31	5.6			
Yams	6	5	1	8.21	4.83	9.47	4.15	1.89	239.14	196.07	231.92	218.32	275.28	11	9.93	10.62	11.05	12.9			
Honey	4	0	4	8.08	2.10	8.08	2.10	8.08	417.48	97.45	417.48	97.45	417.48	21.78	3.95	3.95	3.95	3.95			
Mushrooms	5	3	2	7.15	0.98	7.08	0.82	7.24	100.03	100.94	126.42	128.89	60.43	47.99	4.85	5.9	6.12	2.1			
Palm wine	2	0	2	7.15	2.29	7.15	2.29	7.15	46.49	50.17	172.47	69.63	46.49	1.71	1.69	8.93	3.91	1.71			
Various*	5	4	1	6.7	1.18	7.06	0.99	5.24	222.38	126.84	172.47	102.5	422	11.78	7.23	8.93	4.21	23.2			
Koko	24	20	4	5.64	1.41	5.87	1.26	4.53	127.55	101.81	126.17	102.5	134.47	5.04	4.50	4.9	4.21	5.7			

*The category "various" includes activities in which several products were gathered during the same event (e.g., koko and fruits, mushrooms and yams, or various fruits).

against the other gender engaging in either activity, but rather a difference in techniques and prey (Reyes-García et al., 2020). This low division of labor is a characteristic of hunter-gatherer societies (Marlowe, 2007), which the Baka appear to retain despite the adoption of a more farming-based lifestyle. That said, women do invest more than men in providing and especially preparing food, particularly the staple foods and daily meal, as also seen among the nearby Aka (Kitanishi, 2000). Although we were unable to directly measure the time and energy spent on food processing because it usually took place in camp, and was impossible to separate out from other in-camp activities in our records, we rarely observed men engaging in preparing food, except for processing nuts or when going on hunting expeditions. Moreover, women engage more frequently than men in high intensity activities such as crop harvesting, water fetching, and firewood collecting, differences that have also recently been shown among the Bayaka foragers (Sarma et al., 2020). Even if the involvement in intense activities might not relate to the overall energy spent over the day (Sarma et al., 2020), further study should explore gender differences in the energetic cost of food acquisition and preparation in relation with health among the Baka. As the Baka are currently experiencing nutritional transition (Reyes-García et al., 2019), and Baka women seem to play a key role as food providers, they might be more exposed to food insecurity, especially the older and post-reproductive women, as seen among the Aka (Robinson and Remis, 2016).

As we expected, the engagement of individuals of different ages in food acquisition activities varied. The individuals older than 60 spent less time than others in acquiring food. Instead, they spent a considerable amount of time in the settlement, resting, socializing with each other, conducting domestic chores, and especially caring for children while their parents were out of the settlement (unpublished data). Baka elders, and particularly grandmothers, play an important role in reducing the energy expenditure of their daughters, as also observed among the Aka (Meehan et al., 2013). More generally, the older cohort performs tasks that allow other age category to focus on subsistence activities, in line with what has been largely explored under the "grandmother hypothesis" (Hawkes, 2003).

Effort Required Among Food Acquisition Activities

The intensity (MET) and duration of work differed among subsistence activities. The Baka access their foods on foot, meaning that walking constitutes a large part of their daily effort and thus a large part of the time devoted to the activity, which is also seen among other societies (Christopher et al., 2019). The kilometers traveled during their activities depend on the location of the food and the total distance traveled while performing the activities itself.

The accessibility of subsistence resources varied among different activities, with firewood and water – indispensable elements for preparing food – being collected closest to the settlements. Firewood is often picked close to or in the agricultural field or the settlement, while water is fetched either in the settlement, when a water pump is present, or in the

TABLE 5 | Amount of energy dedicated to each of the gathering activities, estimated by multiplying the average energy spent in gathering a food item by the average duration of the gathering that food item (from **Table 4**), and then by the frequency of occurrence of the gathering that food item calculated by dividing the numbers in column 1 (total number of reported gathering events per food type) by the total number of observed activities (246 daily records, from **Table 3**).

	Whole sample					Women			Men				
	Total number of reported gathering events	Number of records with MET values	Total Energy estimated	SD	Relative proportion	Number of records	Total energy estimated	SD	Relative proportion	Number of records	Total energy estimated	SD	Relative proportion
Nuts	6	5	22.98	15.65	0.05	4	24.44	17.67	0.07	1	17.14	–	0.04
Yams	11	6	61.36	46.73	0.15	5	68.97	47.91	0.19	1	23.3	–	0.06
Honey	4	4	56.14	22.5	0.13	0	–	–	0.00	4	56.14	22.5	0.14
Mushrooms	9	5	25.25	22.7	0.06	3	30.49	28.21	0.08	2	17.4	16.21	0.04
Palm wine	4	2	4.47	4.1	0.01	0	–	–	0.00	2	4.47	4.1	0.01
Various*	17	5	99.5	47.31	0.24	4	86.17	42.42	0.24	1	152.85	–	0.39
Koko	50	24	149.55	135.81	0.36	20	155.34	140.9	0.43	4	120.59	119.66	0.31
Total	101	51	419.25	–	–	36	365.41	–	–	15	391.89	–	–

*The category “various” includes activities in which several products were gathered during the same event (e.g., **koko** and fruits, mushrooms and yams, or various fruits).

river close to the settlement. In contrast, accessing fishing or hunting locations required much longer distance trips. While gathering activities often required walking long distances to access particular resources, agricultural activities also required a lot of movement over long distances. While the fields might be only 1 or 2 km from the settlement, they might reach 1500 square meters in size (unpublished data). Thus, when working on their field, the Baka travel considerable distances moving back and forth within the field itself, greatly adding to the total distance required for the activity. The distance traveled in performing such activities highly depends on the environmental landscape of the settlement, which affects the time allocation pattern. For example, in other Baka settlements from Cameroon located along the Dja river, the Baka are much more involved in fishing (Oishi, 2006) than what we observed. Even in the same area, the local environment of each settlement shapes the time allocation pattern. In this study, we saw that agricultural tasks involved the lowest durations in Le Bosquet, in part due to the limited distance people from this settlement had to travel to their fields (an average of 6.4 km). Agricultural tasks took more time in other villages, where people either had their field further from their settlement, or worked more often in distant Nzime fields (Elonda 10.3 km, Kungu 8.4 km, and Mombokola 7.22 km).

Given the relatively long distances traveled for subsistence activities, it is not surprising that the Baka combine different tasks in one trip. Either planned or opportunistic, these combined activities might be an effective way to optimize their energy use. Moreover, many subsistence activities also provide benefits not directly related to nutrition, such as social sharing (sharing of stories or daily worries), transmission of traditional knowledge, and development of sexual identity and gender roles (Gallois and Duda, 2016), which are key aspects for the social cohesion of the communities (Joiris, 1992) and the cultural evolution among humans (Gurven and Kaplan, 2006).

The actual intensity of work needed for acquiring food varies, as shown by the variability of the MET according to the activity performed (**Table 2**). Some emic and ethnographic insights might explain why some activities are more effort demanding than others. When we asked the Baka which activity was the most difficult, they reported cutting trees. This occurs on several

different occasions: when opening new fields, gathering firewood, and collecting honey. The Baka customarily burn and cut some of the large living trees when opening a new field. As it occurs mostly during both dry seasons, periods in which we collected some of the data, this may contribute to the high MET value recorded for agricultural work. Also, they occasionally cut standing dead wood as it is considered to be better fuel than fallen wood. This might contribute to the large costs seen in firewood gathering. Lastly, they often cut down trees in which bees are nesting instead of climbing the tree. While this activity would have increased the average energy spent on gathering activities, all of the honey collected during our study period was from bees that nest in already-fallen trunks, so no trees were cut down. We also suppose that the high MET values of crop harvesting, water fetching and firewood collection relate to the heavy loads the Baka transport, in baskets carried on their heads that can reach about 20–30 kg (unpublished data). Further studies should explore in detail the relative effort demanded for the different tasks conducted in these activities. Using both heart rate monitors and focal follows might be a useful method for better understanding the drivers of the effort demanded within the different food acquisition activities.

Crucially, we found that hunting has a lower MET than does gathering. While hunting requires complex skills and knowledge (Gurven and Kaplan, 2006; Duda et al., 2017), the techniques used by the Baka in our records do not require as high intensity of work, as measured by MET, as other activities, especially gathering. When comparing hunting techniques, we do note that pursuing game with either spears or guns had a lower MET than when using snares (**Table 2**). However, because we have relatively few records of hunting, these results may not be representative. Some hunting expeditions, especially those taking place at night, might be longer than those we measured. An average of 8 h has been recently reported in other Baka settings (Martin et al., 2020). Longer hunting trips would increase the overall energy spent, but the average intensity of work might not be much higher, as most of the time is spent walking. The hunting of large mammals, which might imply periods of high level of effort, is nowadays almost never performed by the Baka (Duda et al., 2017). Therefore, the low average MET we report

might nevertheless be representative of the Baka's present-day hunting techniques.

Finally, most of the energy seems to be devoted to agriculture and gathering. This mixed strategy may help provide better nutrition (Milton, 2000; Yamauchi et al., 2000) and allow forager societies to be less at risk of famine than their neighboring farmers (Berbesque et al., 2014). However, the engagement in this mix of farming and foraging activities varies according to the settlements, which have diverse socio-economic and ecological contexts. This includes the accessibility of the resources, as discussed earlier, and also the proximity to Bantu villages, their market integration, the exposure to outsiders, etc. While the performance of agriculture seems to be a general pattern, the subsistence strategy is a local decision made within a particular socio-ecological context. Livelihood strategies among former foragers in a changing context depend on several interrelated ecological, social, and economic factors, and also on individual and familial decisions. In the same village, some households might focus more heavily on foraging, others on farming, others on wage labor, while some seem to mix all kinds of activities (Reyes-García et al., 2017). Thus, as these groups might demonstrate “*astute awareness of changing opportunities and often develop ways to take advantages of novel resources, technologies and interactions with non-foraging neighbors*” (Codding and Kramer, 2016, p. 40), it is necessary to take a multivariable approach when looking at changes in local livelihood and culture in this global context. This kind of approach may help explain the variable and non-linear patterns of the adoption of agriculture observed in other places and times in human history (Codding and Kramer, 2016).

Specificities and Characteristics of Gathering Activities

Gathering was one of the most frequent activities within Baka daily life, and was performed by both men and women. Men regularly engage in gathering not only high risk foods such as honey (Marlowe et al., 2014) or high energy foods like nuts (Sillitoe, 2002), but also in foraging for leaves, mushrooms, and other foods such as palm wine and caterpillars. In line with studies among different hunter-gatherer societies showing that men considerably invest in gathering (Panter-Brick, 2002; Bird et al., 2012), and that men target the same or similar foods as women do (Lee and DeVore, 1973), our results further confirm the involvement of both genders in gathering.

Overall, gathering implies considerable intensity of work, as the average MET for gathering activities was higher than those of both hunting and fishing. Moreover, it is not a homogeneous task, with a higher variability in MET values than any other activity, and with significant differences in MET among food items (Table 4). Gathering subsumes a large number of different techniques, amounts of time spent, and effort expended. This variability might be explained regarding the diverse products and their related gathering techniques.

Some wild foods, such as **koko** leaves, mushrooms, and fallen fruits and seeds require the gatherer to only collect the edible parts, while other products need more tools and processes. Notably, gathering activities of two most energetically dense foods consumed by the Baka, fat-rich nuts and starch yams,

have the highest MET values among all subsistence activities measured. For the fat-rich seeds, the gatherer also has to extract the kernel, which involves significant time and intensity of work. This is the case for 10 different species, including *P. oleosa*, *Irvingia* spp., *Klainedoxa* spp., *Baillonella toxisperma*, *Poga oleosa*, and *Pentaclethra macrophylla*. The gathering of yams (about ten different species of *Dioscorea*) requires deep digging to access the edible tubers, often with specialized tools and knowledge (Dounias, 2001). Therefore, the effort of the gathering activities directly depends on the resources targeted within the large range of available foods.

To more fully understand the relationship of gathering effort among different food types, future research should focus on the caloric and nutrient returns from gathering expeditions. While the nutritional values of some plants have been described (see for instance Hladik, 1996), most of the plants from the Baka region are understudied. This lack of detailed nutritional information is unfortunately still a problem for most wild plants eaten by hunter-gatherer groups (Pontzer and Wood, 2021). Furthermore, the studies that have been carried out indicate that there is a high degree of nutritional variability even within a single taxon, such as within **koko** (Ali et al., 2011). Such variability suggests that highly detailed nutritional studies need to be coupled with foraging return rates in order to accurately explore the place of wild food in Baka diet and more generally on forager-horticulturalist foraging behavior and diet.

Beyond their nutritional benefits, plant foods and gathering also have value in a cultural and social context. Studying socio-cultural elements might provide insights on the reasons that the Baka gather different wild plants. The collection and consumption of some plants might relate to local perceptions toward food (De Garine, 1996), which then drive subsistence strategies. For example, the frequently consumed **koko** leaves were listed as both a preferred food and a “prestigious” food (i.e., a food that the Baka would prepare when receiving an important guest), while no other wild leaf was mentioned as such (Gallois et al., 2020). The yams also play an important role in the Baka cosmology (Dounias, 2001), which may contribute to their continued use of these foods despite access to potentially more-energy-dense domesticated tubers. For the Baka, the fatty nuts foster a feeling of abundance and satiety, which is intimately related to their concept of “well-eating” (Joiris, 1996). However, the gathering of these nuts is also driven by economic considerations such as opportunities to earn money because they are often targeted by traders (Gallois et al., 2020). Therefore, a higher integration to the market does not necessarily imply a decrease of gathering activities, as also reported elsewhere (Codding and Kramer, 2016). Due to the different potential factors driving both the collection and the consumption of wild plants, it seems crucial to settle any study, whether focused on energetics, nutrition, socio-cultural effects, or ecology, in the overall complex context in which the society has developed. Considering the general pressures influencing local societies and environments, the cost of gathering is not only spent for providing food to the local communities but also as a part of the global market, with the potential consequences of overexploitation of natural resources.

CONCLUSION

While gathering is often characterized as an easy activity, we found that it requires considerable effort in comparison with other subsistence activities, and that the costs vary depending on the food targeted. Studies that work with contemporary societies in order to understand universal patterns of human behavior should consider exploring the variability of techniques and related effort within each subsistence activity. Finally, socio-cultural contexts and individual decisions are crucial elements for understanding how foraging societies are adapting their livelihood and culture in this era of rapid global changes.

AUTHOR'S NOTE

Sandrine Gallois (Ph.D. in Environmental Science and Eco-Anthropology, 2016) is a post-doctoral research fellow at Leiden University, the Netherlands. Her research focuses mostly on human environment relations including the acquisition of local ecological knowledge in a context of global change. Taking an interdisciplinary approach, her areas of interest are biocultural diversity, cultural transmission, childhood, ethnobotany, social-ecological systems, and science-policy interface.

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DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by this study adheres to the Code of Ethics of the International Society of Ethnobiology, and received the

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approval of both the Ethics Committee of Leipzig University (196-16/ek) and the Ethical Committee from the Ministry of Health of Cameroon (n°2018/06/1049/CE/CNERSH/SP). Before the onset of the study, we obtained Free Prior and Informed Consent (FPIC) from every individual taking part of this research. Explanation of the project and individual consent was audio recorded, since many of the participants were illiterate. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

Both authors designed this study and wrote the final manuscript. SG collected, processed, and analyzed the data from all field seasons. AH collected data in the first field season, performed the GLM analyses, and contributed to other analyses of the data.

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SUPPLEMENTARY MATERIAL

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