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A methodological approach for the non-monetary valuation of ecosystem services in three communities of the Colombian Amazon

Una aproximación metodológica para la valoración no monetaria de servicios ecosistémicos en tres comunidades de la Amazonia Colombiana

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ABSTRACT

To conduct a non-monetary valuation of ecosystem services, this study explored combining data on the use of ecosystem resources with measuring the effort expended on agricultural activities in three communities of the lower Caqueta, Colombian Amazon. By measuring the energy expended by people during their principal subsistence activities, a measure of well-being was also indirectly obtained. For the three communities, the most costly ecosystem service in terms of energy expended was land in forests, which is prepared for planting with felling and clearing, with a value of 1,353 kcal per workday. This was followed by bush meat from hunting at 811 kcal per workday, fish at 682 kcal, obtaining food from the *chagra* (small family farming plot) at 470 kcal, collecting fruits at 380 kcal, collecting firewood at 148 kcal, and fetching water at 29 kcal. The preparation of *casabe* (cassava flatbread) as a cultural service has an energy cost of 386 kcal, while preparing *mambe* (toasted pulverized coca leaves) has a much higher cost at 808 kcal.

Key words: Amazon River, indigenous peoples, traditional knowledge, natural resources, food security, energy expenditure.

RESUMEN

A fin de realizar una valoración no monetaria de servicios ecosistémicos este trabajo explora la combinación de datos de uso de los recursos del ecosistema y la actividad agrícola con la medición del esfuerzo dedicado a estas actividades en tres comunidades de la región del bajo Caquetá en la amazonia colombiana. Al medir el consumo energético de las personas en sus principales actividades de subsistencia, se está obteniendo indirectamente una medida de bienestar. Según los niveles de esfuerzo medidos en las tres comunidades el servicio ecosistémico de mayor costo energético es el suelo fértil para sembrar, representado por las actividades de tumba y roza, con un valor de 1,353 kcal por jornada. Seguido está el servicio de provisión de carne animal a través de la caza con 811 kcal por jornada, luego la provisión de peces con 682 kcal, y seguido la provisión de comida de la chagra con 470 kcal, recolección de frutos con 380 kcal y por ultimo están los servicios de provisión de leña con 148 kcal y agua con 29 kcal. La elaboración de casabe como servicio cultural tiene un costo energético de 386 kcal, mientras que la elaboración del mambe (polvo hecho con hojas de coca tostadas) tiene un costo mucho más alto con 808 kcal.

Palabras clave: Río Amazonas, población indígena, conocimiento tradicional, recursos naturales, seguridad alimentaria, gasto de energético.

Introduction

Benefits to humans from natural ecosystems, such as game animals, timber, fuel wood, water, fertile soil, inspiration and others described by de Groot *et al.* (2002), are defined as ecosystems services (ES) (Millennium Ecosystem Assessment, 2005).

To better conserve and understand the Amazon Region and its ES, the Project on Attaining Sustainable Services from Ecosystems through Trade-off Scenarios (ASSETS) selected a group of multiethnic indigenous communities of the Colombian Amazon. Our study, a non-monetary economic valuation of ES, was developed within the framework the ASSETS Project in the Corregimiento of La Pedrera, Department of Amazonas (http://espa-assets.org/).

De Groot *et al.* (2012) reviewed 320 studies on the economic monetary valuation of different biomasses, 96 of which were conducted in tropical forests. The average value produced was US$5264 per hectare per year. The authors recognized that the methodologies used, such as market prices, had distortions, for example, they did not include the cultural value in which people held ecosystems. However, when contingent valuation is used, ecosystems may be undervalued if studies are conducted in vulnerable

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or economically poor populations who cannot pay much for them. In Colombia, an official guide exists to develop economic valuations, but all of them focus on monetary values (MAVDT, 2003).

In contrast, ecological valuation has developed other methodologies, such as the emergy valuation or Emergy Assessment (EMA) (Brown *et al.*, 2009), and energy analysis (EA) (IFIAS, 1974, cited by Herendeen, 2004). In spite of this, the existence of different approaches to determine a monetary value, Chan *et al.* (2012) point out the gap in economic valuation and the possible discomfort with expressing cultural services in dollars; so they suggest applying nonmonetary valuation and using decision making for services such as spiritual values, cultural identity, social cohesion, and heritage values. Services absolutly important for indigenous communities and settlers in the Amazonia.

The interactions between Amazon communities and nature are highly complex, demanding valuations of ES that are not just monetary. According to Brondízio *et al.* (2010), as the complexity of a system and the value of plurality increase, the monetary valuations drop in scientific quality and gain doubtful relevance for policy-making.

In response, we took some elements of different methodologies to present another methodological approach. We propose human labour as an indicator of the value of ecosystem services. To make this assumption, we took into account the considerations of Odum: "the most energy-intensive item in embodied energy is human labor" (Kamp *et al.* (2016), and the authors cited therein). Also, subsistence activities do not use much technology or external resources, such as fuel or electricity to do them; instead, time, effort and traditional knowledge are the mean inputs to get benefits from nature.

To account for labor, Kamp *et al.* (2016, and the authors cited therein) suggested suggested the use of food metabolism calories as the correct unit to quantify the energy supporting a person and, consequently, to measure the energy expenditure.

Human labor, represented by effort, was selected in this study as the best symbol of value in Amazon communities, in contrast to the fact that no money is exchanged to get ecosystem services, but time and effort are.

Subsistence, well-being, and effort in Amazon communities

The communities in this study defined *well-being* according to different indicators, including availability of sufficient land for subsistence activities; skills in hunting, fishing, and agriculture (including the possession of tools for these activities); having access to state services such as health and education; and, to a lesser extent, but also necessary, economic income, however infrequent.

The conventional definition of *subsistence* is: that minimal standard for satisfying needs. Previously, it took into account only physical characteristics. Today, however, *subsistence* now refers to that minimal standard for satisfying the physical, mental, and productive efficiency needs of human beings (Sharif, 1986).

Currently, calorie intake is an energy indicator for tracking sustainability in developed countries (Singh *et al.*, 2009), so calorie expenditure is complementary information to know production system's efficiency and also sustainability.

According to Vargas *et al.* (2011), the total energy cost (TEC) of one person is the level of energy needed to maintain the balance between consumption and energy expenditure. The latter constitutes the sum of the basal metabolic rate (BMR), endogenous thermogenesis (ET), and physical activity (PA). In sedentary persons, about two-thirds of the TEC is used in basal metabolism, while only one-third is spent on PA. In highly active individuals, the TEC may be as high as double the BMR, or even higher in some athletes and in those who carry out heavy work.

This study aimed to demonstrate another methodological approach for valuation other than monetary. That is, to quantify the energy that communities invest to obtain not only natural resources, but also to maintain their way of life based on, for example, hunting, fishing, cultivating the *chagra* (small family farming plot), collecting wild fruits, and preparing *mambe* (toasted pulverized coca leaves) and *casabe* (cassava flatbread).

Materials and methods

Study area

The study was carried out in the rural zone of the Corregimiento of La Pedrera located on the banks of the River Caqueta, near the border with Brazil, a more detailed description of this town is in Ramirez-Gomez *et al.* (2014).

The research method used involved selecting three communities, the closest community was located in the Camaritagua Indigenous Reserve at coordinates 1°19'49" S and 69°35'13.7" W. Various ethnic groups have converged in this area, mostly the Mirañas, Tanimucas, and Yucunas.

It is a small community of about 13 families who live by cultivating *chagras*, fishing, hunting, and, to a lesser extent, obtaining paid work in La Pedrera.

The most distant community was Borikada, where the Curare-Los Ingleses Indigenous Reserve is located, at coordinates 1°20'55.4" S and 69°57'32" W. The community has 14 families of multiethnic origins, including the Cubeos, Yucunas, Boras, and Carijonas. The community's life strategies are cultivating the *chagra*, fishing, hunting, collecting wild fruits, and some casual (remunerated) work within the community itself.

The intermediate community corresponded to the Vereda La Madroño, located within a forest reserve protected by Colombian legislation. Its coordinates are 1°18'47" S and 69°32'44.8" W. As it is a mixed community of settlers and indigenous people, with a predominance of indigenous persons (SantoDomingo, 2011). Incomes are derived mostly from lumber, commercial fishing, and other remunerated casual work in La Pedrera. The community has 11 families of different origins, the principal ethnic groups found are the Matapís, Yucunas, Tanimucas, and Boras, but also there are a lot of Brazilians and settlers.

According to Van der Hammen (1992), SantoDomingo (2011) and Cardona (2015) communities in the lower Caqueta river Basin depend on subsistence, mainly natural resources from the forests and rivers by fishing, hunting and cultivating *chagra*, so a sample of three families (volunteers) in the three communities that participated was used to measure the value of invested effort in each activity (Tab. 1).

TABLE 1. Characteristics of the families in three communities of the Colombian Amazon.

Location	Family 1 M / W	Family 2 M / W	Family 3 M / W
Camaritagua	Age 32/31 Wt 61/54	Age 44/45 Wt 70/52	Age 20/18 Wt 57/50
Borikada	Age 49/49 Wt 65/53	Age 39/42 Wt 74/50	Age 39/15 Wt 52/52
Madroño	Age 40/29 Wt 82/56	Age 47/42 Wt 77/84	Age 45/26 Wt 70/67

Only man (M) and women (W) did the activities and took records, has the characteristics of them. Wt: weight (kg).

During the third season, two of the three families were changed in La Madroño, they could not continue in the project, so two new couples were selected. Also, for Camaritagua, two families were changed only during second season.

Identifying activities linked with ES

Table 2 provides a brief description of the recorded activities. Not all activities were carried out in the three recording periods, as these depended on the ecological calendar, which is very similar for the communities in the lower Caqueta.

TABLE 2. Recorded subsistence activities in three communities of the Colombian Amazon.

Activity/Epoch of the year	Data description	ES linked
Hunting/all year	Any hunting activity was recorded, whether in the jungle or on the *chagra*, or whether prey was captured or not	Bush meat
Fishing/all year	The recorded fishing was used for household consumption, not for commercial purposes	Fish
Clearing/all year but less in Sep.-Oct.	This activity was carried out mostly in stubble-lands in all epochs of the year. Between August and November, it was conducted in the jungle	Fertile soil
Felling/J-F and mainly Sep.-Oct.	The communities carried out felling in either stubble-lands or jungle	Fertile soil
Fruit collection/ Jan.-Feb. and June-July	This activity was recorded for both wild and backyard fruits	Fruits
Cultivating the *chagra*/all year	This set of activities included planting, weeding, and pulling up cassava and other previously planted crops	Crops such as casaba, plantain
Fetching water/ all year	This activity was recorded in those homes where family members had to leave to fetch water	Water
Preparing *mambe*/all year	This activity was recorded in two parts: first, collecting coca leaves from the *chagra*; and second, arriving back at the house and preparing *mambe*	Spiritual values, cultural identity
Preparing *casabe*/ all year	As for the previous activity, *casabe* preparation was recorded in two parts: first, collecting cassava from the *chagra*; second, collecting the starch, expressing out the liquid, kneading it into a type of *arepa* (tortilla), and cooking it (Fig. 1)	Cultural identity, social cohesion
Preparing *farina*/ all year	This activity was recorded only in La Madroño as the families there (e.g., settlers) had either lost or never had the custom of making *casabe*. Instead, they prepared *fariña*, which they ate regularly. This activity was also recorded in two parts, but few were recorded	Cultural identity, social cohesion

The measurement of effort

To measure effort, we used Polar® sports equipment. This recorded the intensity of physical activity as a percentage of the maximum cardiac frequency (CF_{max}) with which the activity could be carried out. The CF_{max} was used to estimate energy expenditure on the basis of the maximum number of beats per minute (bpm) during maximum physical effort. The CF_{max} was also useful for determining the intensity of an activity (Polar, 2013).

FIGURE 1. Woman preparing *casabe* (cassava flatbread). Photograph: Z. Duran.

The CF_{max} as measured by Polar® equipment was calculated, using Eq. 1.

$$CF_{max} = 220 - age \quad (1)$$

CF_{max} is in beats per minute (bpm) (Polar, 2013)

The equipment consisted of a cardiac frequency sensor that was placed on the chest of the test subject, using an elastic band, a speed sensor that was placed on the foot, and a training computer, RCX3, that was worn like a watch. The computer received data from the sensors and stored them for later downloading onto a Polar® online application. Also an initial setting is necessary according to the age, weight and gender´s user of the equipment.

Figure 2 shows a scene from one of the workshops held with the communities for training in using the equipment.

FIGURE 2. Using Polar® equipment, Camaritagua community in La Pedrera (Colombia). Photograph: Z. Duran.

To differentiate among the seasonal changes in the offer of natural resources and the ecological calendary, three sets of records were made in different epochs of year 2014, the three communities simultaneously. The first set was taken between January and February (Epoch of frog) when river levels of the Caqueta were low, few rains and communities celebrate Traditional "Doll Dance". The second set was taken in June and July (Epoch of fish shoal), months of high rainfall, and the river levels of the Caquetá were at their highest, with an abundance of fish and traditional "Feather Dances". Finally, the third set was taken in September and October (Epoch of Cicada), when the river levels had dropped again over the short summer, families start preparing new *chagras* and with the traditional "Pineapple Dance".

During 30 d for each epoch, the families had the equipment to take records and fill the formats. A facilitator in each community helped with the recordings, this person was training too. He or she visited the families every week to review the recordings made, also he or she completed a field diary with information that complemented each activity recorded by the families and change the initial information's settings of the equipment according who were going to take records. At the end of each period, the forms, field diary and equipment were collected, checked and contrasted.

Energy cost and efficiency calculation

Mean values of invested kilocalories were calculated for each activity in each community and each epoch; also, a frequency of those activities was asked, allowing for the calculation of a value of expended energy per day between the men and women through the different epochs of the year.

Following the methodology used by Harris (1971); Bayliss-Smith (1977) and Vickers (1989), the efficiency (T) for each activity was estimated as follows Eq. 2:

$$T_{Activity} = \frac{(kg\ of\ food) \times (kcal\ per\ kg)}{Kilocalories\ recorded\ for\ each\ activity} \quad (2)$$

The ratio between the energy expenditure and acquired energy through the natural resources (meal, fish, cassava, fruits), is measure of T.

For the statistical analysis, the data were analyzed using the statistical program SPAD v. 5.6 and, to determine the correlations for number of kilocalories, duration of each activity, and the product obtained for each activity in each community.

Results

Identifying ecosystem services

The ecosystem services (ES) used by the communities were classified according to The Economics of Ecosystems and Biodiversity (TEEB) (de Groot *et al.*, 2010), that is, in terms of the services of regulation, habitat, provisioning, and culture.

The ES described in Tab. 3 had a high social-cultural value (Scholte *et al.*, 2015). In spite the classification of ES, it is true that all of the ecosystem functions had a cultural importance for the Amazon communities, not only the cultural services. The activities of subsistence related to the provisioning services, such as hunting, fishing, wood collecting, and fetching water; even the supporting service as nutrient cycling related to clearing and felling, met spiritual and cultural beliefs and build the social life of the communities.

Each ES deserves a thorough analysis, but this was out of the scope of this study; Tab. 3 provides a brief description of the services valuated with the proposed methodology.

This study linked the indigenous traditional practice of slash and burn of the forests with many ecosystem functions, such as nutrient regulation. This kind of agriculture is known as shifting cultivation, the difference with the slash and burn agriculture is that the forest fallow period is longer than the resting period in the second system (Palm *et al.*, 2005).

Shifting cultivation has been accepted as a system with proven long term compatibility with tropical forests and biodiversity (Lavold, 2014); it also restores the soil physical properties, accumulates carbon and nutrients in the fallow biomass, eradicates weed populations and has no soil erosion risk (Palm *et al.*, 2005).

Valuating ecosystem services

A significant aspect to highlight was the high variability of the data recorded among the three communities due to externalities such as illness, unpremeditated trips or just because there wasn't the time to do it. The total number of records for each activity is shown in Tab. 4.

TABLE 4. Number of records taken per epoch and community in La Pedrera (Colombian Amazon).

Activity	Camaritagua			Borikada			La Madroño		
	E1	E2	E3	E1	E2	E3	E1	E2	E3
Hunting	5	2	8	8	6	8	1	4	2
Fishing	6	2	8	9	6	9	3	6	4
Felling	5	2	8	0	3	5	4	1	2
Clearing	4	7	0	7	6	0	2	0	0
Chagra cultivation	18	6	13	10	7	12	4	8	19
Firewood collection	9	10	13	11	10	12	6	8	3
Fetching water	-	6	8	-	7	11	-	7	7
Fruit collection	7	6	0	9	8	4	5	6	1
Preparation of *mambe*	-	7	3	-	6	6	-	-	1
Preparation of *casabe*	-	5	10	-	5	3	-	-	1

E1, E2, and E3: epochs of the year, where 1 is January-February; 2, June-July; 3, September-October.

TABLE 3. Ecosystem services in three communities of the Colombian Amazon.

Ecosystem function	Description
	Regulation
Nutrient regulation	Shifting cultivation for opening up *chagras* represents a significant supply of nutrients and organic matter for the soil, obviating the need for fertilizers. Fallowing allows soils to recuperate and stubble to regrow, so that, after 1 to 5 years, the soil recovers its functions of recycling nutrients and enabling natural seed regeneration
	Production
Food	Communities living on the banks of the Caquetá River depend on its supply of fish, especially during the months of rising water levels (June-July). Those species unprotected by the Conservation Agreements* are also extracted from lakes. The jungle provides food in the form of wild fauna and wild fruits.
Raw materials	Natural fibers and dyes are used for most things between housing and costumes for cultural celebrations. They are extracted from the rivers, forest, and soil.
Medicinal plants	Indigenous communities keep an inventory of more than 1600 medicinal plants as remedies for conditions such as diarrhea, vomiting, pinta, malaria, colds, toothaches, hernias, snake bites, and abortion
	Cultural services
Spiritual and historical information	In Amazon cultures, each animal, each river, each mountain, each plant has an origin, a history, and owner spirits. This knowledge can only be acquired and passed on between generations through meetings in the *malokas* (longhouses) during cultural celebrations and, to a lesser extent, in community schools

* These agreements prohíbit the extraction of arawanas (arowanas or bonytongues) and pirarucus (arapaimas, also called bonytongues) (CIC, 2015).

Despite this variability and to quantify the level of energy invested per activity, for each community, average values of energy expenditure were calculated for each activity per epoch, allowing us to see seasonal differences in the efforts invested by each family into their subsistence.

"*Epoch of the Frog*" January-February

For almost all of the activities, Camaritagua, the community closest to La Pedrera, had the highest energy expenditure in this epoch. Fishing, fruit collection, preparation of *mambe,* felling and hunting demanded more effort than the other communities, Camaritagua holds the Dance of the Doll in February, for which it must collect about 5 m^3 of peach-palm pulp and a lot of food for around 200 people, and this could influence the energy expenditure.

For Borikada, the community furthest from La Pedrera, the effort in maintenance of the *chagra* is less in January and February, firewood collection is almost equal to the other communities, as well as preparing *casabe* and chagra cultivation.

La Madroño invested more energy in clearing and chagra cultivation. Water collection does not appear in Fig. 3 as its values were too small to be observed.

"*Epoch of fish shoal*" June - July

For Borikada, the epoch of June-July received a major investment of energy in felling, fishing, fruit and firewood collection, more than the other communities. Chagra cultivation was also more energy demanding in Borikada and La Madroño, likely because they are river communities with island chagras.

For Camaritagua (Fig. 4), clearing, preparing *casabe* and *mambe* were highest. In Borikada, *mambe* preparation is done by men usually only until collecting coca leaves from the chagra and women then are whom toasted the leaves and prepare *mambe*, so records in Borikada are only for one part of the procedure of this activity.

"*Epoch of Cicada*" September-October

In Camaritagua the high expenditure that the families invest in felling and clearing is noticeable in September-October, in comparison to Borikada (Fig. 5).

Few people in La Madroño are hunters, one of them took records for September-October, in the other two epochs he wasn´t. The epoch in which most effort was invested in this activity was September, followed by June-July.

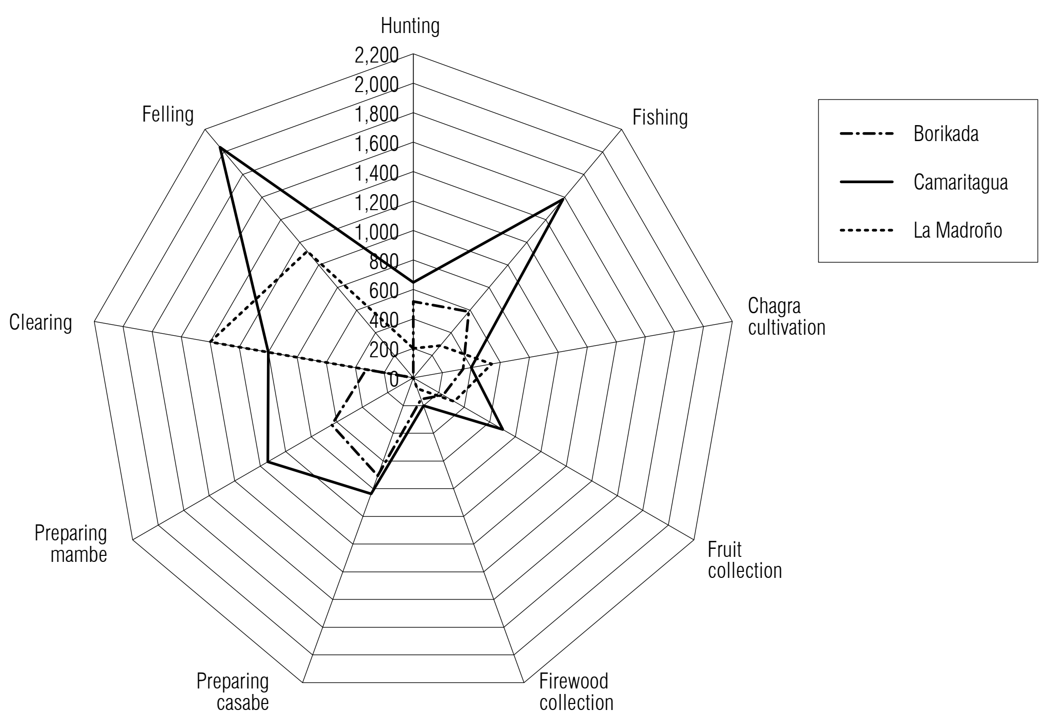

FIGURE 3. Energy expenditure (kcal) in the three epochs for Borikada community (La Pedrera, Colombian Amazon).

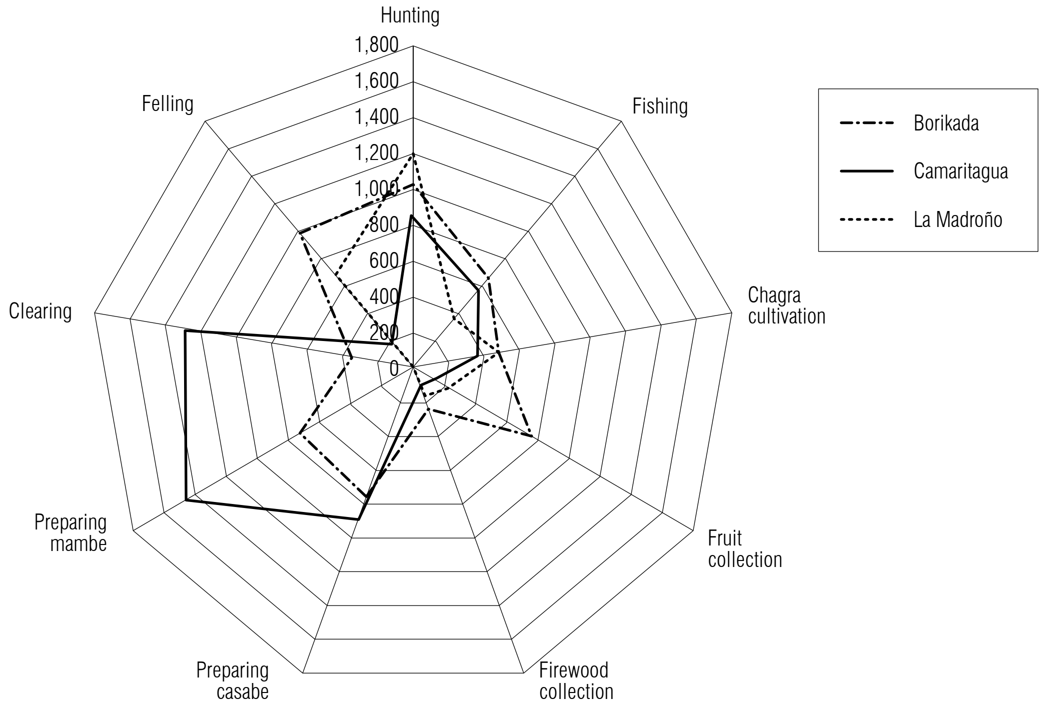

FIGURE 4. Energy expenditure (kcal) in the three epochs for Camaritagua community (La Pedrera, Colombian Amazon).

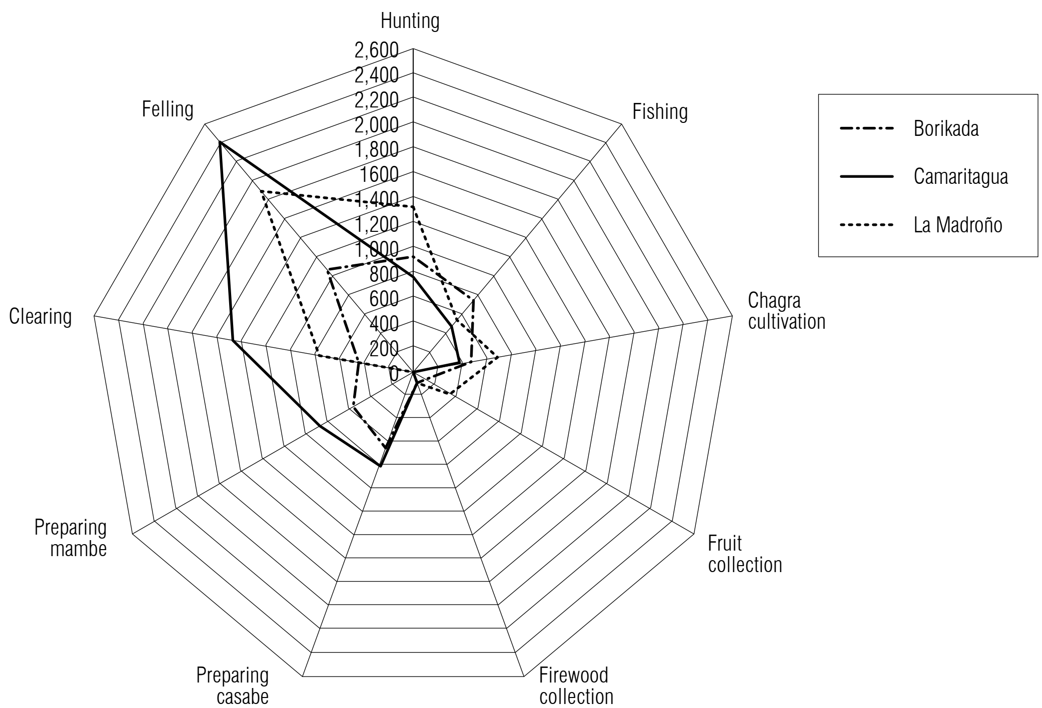

FIGURE 5. Energy expenditure (kcal) in the three epochs for La Madroño community (La Pedrera, Colombian Amazon).

La Madroño does not hold cultural celebrations but celebrates the Anniversary of the Board on 11 October. For this event, enough food must be brought together for all the participants, meaning that the most effort was expended for hunting and fishing in October.

Table 5 presents the results conducted in subsistence activities for the communities. Figure 6 compares the communities for the values of the approximate daily energy a family (man and woman, without children or elders) expends on the measured subsistence activities.

TABLE 5. Weekly frequency of subsistence activities in three communities of the Colombian Amazon.

Activity	Camaritagua			Borikada			La Madroño		
	E1	E2	E3	E1	E2	E3	E1	E2	E3
Hunting	3	0.5	1	3	2	2	0.25	1	0.25
Fishing	4	7	4	5	7	5	1	7	3
Felling[a]	0.08	0.08	0.2	0.08	0	0.26	0	0	0.75
Clearing[a]	0.2	0.2	0.5	0.2	0.2	0.5	0.08	0	0.2
Chagra cultivation	7	7	7	7	7	7	4	4	4
Firewood collection	14	2	3	7	7	7	7	7	7
Water collection	14	3	3	14	7	14	7	7	7
Fruit collection	1	3	3	1	3	0	2	1	2
Prep. *mambe*	2	2	2	2	2	2	–	–	–
Prep. *casabe*, part 1	3	3	3	2	2	2	–	–	–
Prep. *casabe*, part 2	14	14	14	14	14	14	–	–	–

E1, E2, and E3: epochs of the year, where 1 is January-February but extended to April; 2, June-July but extended between May to August; 3, September-October but extended to December.

[a] Calculations are made from known frequencies (answered by participants): felling, at day 1 in E1 and E2, and after 3 d in E3; clearing, after 2 d for E1 and E2, and after 6 d in E3.

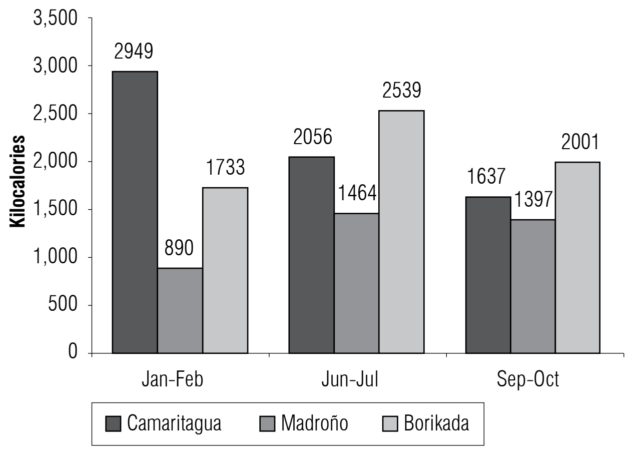

FIGURE 6. Daily energy expenditure for subsistence activities in three communities of the Colombian Amazon.

The values for energy expenditure in La Madroño were noticeably smaller than those of Camaritagua and Borikada, while Camaritagua had the highest energy expenditure in the first month of the years, and Borikada during rainy season in June and July and September-October.

Energy efficiency

Values of *T* were determined for each subsistence activity, using the average value between the three communities in each activity by season, also the field forms included data of the obtained product (Tab. 6).

Marvin Harris (referenced by Bayliss-Smith, 1977) estimated the average number of kilocalories produced for each kilocalorie expended in food production (*T*) for five

TABLE 6. Efficiency of subsistence activities in three communities of the Colombian Amazon.

Activity	Average obtained product per event (kg)			Kilocalories in each product			*T*		
	E1	E2	E3	E1	E2	E3	E1	E2	E3
Hunt[1]	2.1	19.2	8.7	2,550	22,793	10,379	4.7	21.6	12.1
Fish[2]	10.3	6.1	5.3	7,287	4,292	3,764	8.4	8.3	6.0
FC[3]	19.3	16.2	7.8	18,811	15,762	7,605	45.8	39.0	37.5
PC1[4]		32.1			-			-	
PC2[4]		6.5			22,295			17.7	

Hunt: hunting; Fish: fishing; FC: fruit collection; PC1: preparation of *casabe*, part 1; PC2: preparation of *casabe*, part 2.

[1] For hunting the waste could be 30% including the bones and animal's skin, for 100 g of meal the amount of kilocalories was assumed to be 170 kcal (Vickers, 1989).

[2] Fishing had the same assumptions as hunting, but the amount of kilocalories was 101 kcal/100 g.

[3] This activity included a wide range of fruits, so for counting *T*, we used an average of kilocalories amount in moriche palm, peach-palm pulp, pineapple and Açaí palm, mean fruits collected.

[4] Efficiency in preparation of *casabe* had in the amount of *casabe* processed in part 1 and the kilograms of tortillas cooked in the part 2, so at the end, *T* was calculated with the kilocalories given by *casabe*, according to ICBF 100 g of *casabe* have 343 kcal.

types of production system, two of them based on the same subsistence activities that the communities in this study, the results were 9.6 and 9.8 for hunters and gatherers in Kalahari and shifting cultivators and pig herders in New Guinea respectively, similar to the average for Amazon communities from this study was 12.8 for hunting and 7.6 for fishing.

Vickers (1989) found a value of *T* for hunting 9.33 and 2.99 for fishing, his study with Sionas and Secoyas in the Ecuadorian amazon did not measure the efficiency of preparation of *casabe*, but he pointed out that in terms of calorie production, hunting and fishing are not as generous as plant cultivation, only 20.7% of the calories come from animal products, however they give 80.9% of the protein consumed. The results in Tab. 3 confirm this affirmation, fruits were the mean and efficient source of calories, followed by casaba, then meal and finally fish.

To compare the indigenous traditional production system with the western industrialized system, Schramski *et al.* (2013) measured the efficiency in an organic vegetable production farm in Kentucky, USA, cuantifying all energy outputs and inputs, the value of *T* was 0.025, smaller than the Amazon community efficiency.

Discussion

Correlations between the variables

For Borikada community, a positive correlation (0.786) was found between the variables "time" and "kilocalories" for all of the recorded activities. In contrast, the correlation between time and product obtained per activity (e.g., kilograms of food or hectares worked) was less than 0.228; and between product and kilocalories was less than 0.154.

For Camaritagua, the correlation between kilocalories and time was 0.701, while the variable "product" did not correlate with either of the other variables.

For La Madroño, the variables time and kilocalories had a correlation of 0.739, while the correlation between variables kilocalories and product was negative at -0.29. Likewise, the correlation between product and time was negative at -0.367.

Comparison between the communities

Possible explanations of the results for La Madroño include, first, that the community members did not record many of the subsistence activities because they no longer performed them, such as hunting; second, they dedicated less time to the traditional work of their communities, particularly the men, who sought remunerated work in the town or neighboring communities; and third, the families who took records over the three epochs themselves had many changes.

Figure 6 also demonstrates that the epoch with the most investment of effort in Camaritagua was January, while for Borikada and La Madroño, it was June. This is logical because Borikada and La Madroño are river communities with island *chagras* that demanded increased effort in this epoch to harvest the *chagras* before flooding. In contrast, Camaritagua had most work in January because of hunting, fishing and fruit collection for the Dance of the Doll (FUCAI *et al.*, 2001) and they do not have island *chagras* because they are on the riversides.

Another reflection about La Madroño was the values for effort in the wild-fruit collection, they were very similar for September and January while, for June-July, the values were much smaller. Indigenous people know that September is not the month for harvesting wild fruit, while January is, and that June is the month for harvesting açaí palm nuts. However, in La Madroño, wild fruits from the forest are not usually collected, but instead fruits are collected from the backyards and *chagras*, places where fruits are always available.

Ecosystems service value

According to the levels of effort measured in the three communities, the ES demanding the highest energy investment was, without doubt, the land under the forests, which needs to be prepared for planting and maintaining soil fertility, the service identified as essential for agricultural activities (Ramirez-Gomez *et al.*, 2014), as represented by activities such as felling and clearing during September at a value of 1,353 kcal per workday.

The next most expensive service was bush meat represented by hunting at 811 kcal per workday, which could be sensible as people perceived a decrease in this resource in the last 20 years as Ramirez *et al.* (2014) mentioned.

Fish were the next resource with more than 682 kcal, food from the *chagra* at 470 kcal, fruit collection at 380 kcal, and lastly firewood collection at 148 kcal and water collection at 29 kcal.

The preparation of *casabe* as a cultural service has an energy cost of 386 kcal. The cost of preparing *mambe*, however, is higher at 808 kcal.

Some of this study's results are very similar to those reported by Dafour (1984) for Tukana women in the Department of Vaupés, Colombia. He found an average daily energy cost for women of 2,133 kcal. However, this cost did not include other activities, observed at least for La Pedrera, such as fishing, clearing, and toasting coca leaves.

To compare the same activities measured by Dafour, we totaled the values for energy expenditure for the following activities: *chagra* cultivation, firewood collection, water collection, and *casabe* preparation. We then double this value to find the value for the total energy cost. The result was an energy consumption of 2,150 kcal for Camaritagua and 2,009 kcal for Borikada.

Finally, we point out that the highest energy expenditure was recorded in Borikada and La Madroño during the rainy period (June-July). This finding is similar to those of Bleiberg *et al.* (1980), who compared the energy expenditure in agricultural activities of 15 women. They found heavier investment during the rainy months than in the dry season, with values at 2,890 and 2,320 kcal, respectively.

Food security implications for the indigenous communities

If the indigenous way of life is assumed to be active, that is, in no way sedentary, then the total daily energy expenditure may be double that spent in subsistence activities, measured as described above according to Vargas *et al.* (2011).

This indicates that a couple in Camaritagua, to maintain their indigenous way of life, must ingest 5,898 kcal daily during January-February, 4,112 kcal during June-July, and 3,224 kcal in those months with similar dynamics as those of September-October.

In Borikada, the total daily energy expenditure of a household formed by a man and woman would be 3,466 kcal/day for months such as January-February, 5,078 kcal/day for months such as June-July (the rainy period), and 4,022 kcal/day for months such as September-October.

In La Madroño, a similar couple would expend 1,780 kcal/day (between man and woman) to maintain their way of life during January-February, 2,928 kcal/day during the rainy season, and 2,764 kcal/day for September-October.

The daily energy requirements for women aged between 17 and 65 years old are 2,250 kcal, and for men of the same age range 3,000 kcal, according to the recommendations of the *Instituto Colombiano de Bienestar Familiar* (ICBF, 1999). That is, for a couple, the total daily requirements would be 5,250 kcal.

Based on the foregoing discussion, there would be insufficient food for supplying the needs of communities such as Camaritagua during January-February. In the same way, the energy obtained is barely enough to supply the needs of a community like Borikada in June-July, the months of most effort. In the other seasons, for these two communities, supplies are in excess of daily requirements by 1,000 to 2,500 kcal. For La Madroño, this relationship could not be made, as the men of the households performed fewer subsistence activities.

Conclusions

In terms of area, Borikada is located in the biggest Indigenous Reserve, while Camaritagua is in the smallest one; the mean effort in Camaritagua was 2,214 kcal per day (man and woman) and Borikada 2,090 kcal per day (man and woman), this data show that there could be a relationship between the available area and invested total effort for subsistence. However, single records in activities from the results presented here, we saw that this was not necessarily true. Although levels of effort were sometimes related to availability, as in the case of fish, increased effort could also depend on other variables such as the techniques used; the purpose of the resource, whether for household consumption or community celebration; or personal needs such as hunting for cash.

Energy expenditure in obtaining resources was much less for La Madroño. On understanding its context, these results could be interpreted as this community being less dependent on ES than the other two communities, where energy expenditure was almost double in some epochs although they fulfill their food needs with more market products from La Pedrera.

The methodology used allowed us to conduct a non-monetary valuation of ES identified in the study area. If the activities for provision were specifically separated from cultural activities, the indigenous way of life related directly with all the services that the Amazon Region provided, and with each of its ecosystems such as the *cananguchales* (stands of moriche palm), flooding zones, lakes, and the savanna. Thus, the energy expended in maintaining this way of life represents an indirect value of all other ES.

We found that products obtained in subsistence activities did not correlate strongly with either time or kilocalories consumed for each workday. On the contrary, a more reliable variable appeared to be the expertise of the person conducting the activity. Such expertise would include knowledge of the place, hour, and techniques for searching for prey or fish; and the strength and resilience in working on the *chagra*, including felling and clearing.

Amazon communities differ markedly in the physical activities that they develop throughout the year. Our study showed that energy expenditure can change considerably from epoch to epoch. A useful complementary study of this research would be to compare the kilocalorie intake in the same epochs, and, thus, adjust the recommendations for caloric intake made by institutions working on food security.

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Literature cited

Bayliss-Smith, T.P. 1977. Energy use and economic development in Pacific communities. pp. 317-359. In: Bayliss-Smith, T.P. and R.G. Feachem (eds.). Subsistence and survival: rural ecology in the Pacific. Academic Press, London.

Bleiberg, F.M., T.A. Brun, S. Goithman, and E. Gouba. 1980. Duration of activities and energy expenditure of female farmers in dry and rainy seasons in Upper-Volta. Br. J. Nutr. 43, 71-82. Doi: 10.1079/BJN19800065

Brondízio, E.S., F.W. Gatzweiler, C. Zografos, and M. Kumar. 2010. Socio-cultural context of ecosystem and biodiversity valuation. pp. 1-40. In: Martinez-Alier, J. (ed.). TEEB, the economics of ecosystems and biodiversity: the ecological and economic foundations. Routledge, London.

Brown, M.T., M.J. Cohen, and S. Sweeney. 2009. Predicting national sustainability: the convergence of energetic, economic and environmental realities. Ecol. Model. 220, 3424-3438. Doi: 10.1016/j.ecolmodel.2009.08.023

Cardona O., S.B. 2015. Aproximación al hábitat indígena, una propuesta desde la práctica estética del caminar, en Bajo Caquetá, Amazonía Colombiana. MSc thesis. Faculty of Engineering and Architecture, Universidad Nacional de Colombia, Manizales, Colombia.

Chan, K.M.A., A.D. Guerry, P. Balvanera, S. Klain, T. Satterfield, X. Basurto, A. Bostrom, R. Chuenpagdee, R. Gould, B.S. Halpern, N. Hannahs, J. Levine, B. Norton, M. Ruckelshaus, R. Russell, J. Tam, and U. Woodside. 2012. Where are *Cultural* and *Social* in ecosystem services? a framework for constructive engagement. BioScience 62, 744-756. Doi: 10.1525/bio.2012.62.8.7

CIC, Conservación Internacional Colombia. 2015. Monitoreo biológico comunitario de de pirarucú (*Arapaima gigas*) y arawana (*Osteoglossum bicirrhosum*) en los bajos ríos Caquetá y Apaporis. Programa Amazonia. La Pedrera, Colombia.

Dafour, D.L. 1984. The time and energy expenditure of indigenous women horticulturalists in the Northwest Amazon. Am. J. Phys. Anthropol. 65, 37-46. Doi: 10.1002/ajpa.1330650107

de Groot, R., B. Fisher, M. Christie, J. Aronson, L. Braat, J. Gowdy, R. Haines-Young, E. Maltby, A. Neuville, S. Polasky, R. Portela, and I. Ring. 2010. Integrating the ecological and economic dimensions in biodiversity and ecosystem service valuation. pp. 1-40. In: Kadekodi, G.K. (ed.). TEEB, the economics of ecosystems and biodiversity: the ecological and economic foundations. Routledge, London.

de Groot, R., L. Brander, S. Van der Ploeg, R. Costanza, F. Bernard, L. Braat, M. Christie, N. Crossman, A. Ghermandi, L. Hein, S. Hussain, P. Kumar, A. McVittie, R. Portela, L.C. Rodriguez, P. Ten Brink, and P. van Beukering. 2012. Global estimates of the value of ecosystems and their services in monetary units. Ecosyst. Serv. 1, 50-61. Doi: 10.1016/j.ecoser.2012.07.005

de Groot, R.S., M.A. Wilson, and R.M.J. Boumans. 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecol. Econ. 41, 393-408. Doi: 10.1016/S0921-8009(02)00089-7

FUCAI, Fundación Caminos de Identidad. 2001. La selva y su riqueza: Proyecto Educativo Comunitario (PEC). In: http://eduamaz.wikispaces.com/file/view/MirCalendario5.pdf: consulted: April, 2016.

Harris, M. 1971. Culture, man and nature: introduction to general anthropology. Crowell, New York, NY.

Herendeen, R.A. 2004. Energy analysis and EMERGY analysis: a comparison. Ecol. Model. 178, 227-237. Doi: 10.1016/j.ecolmodel.2003.12.017

ICBF, Instituto Colombiano de Bienestar Familiar. 1999. Guías alimentarias para la población colombiana mayor de dos años: bases técnicas. Bogota.

Kamp, A., F. Morandi, and H. Ostergard. 2016. Development of concepts for human labour accounting in emergy assessment and other environmental sustainability assessment methods. Ecol. Indic. 884-892. Doi: 10.1016/j.ecolind.2015.08.011

Lavold, L. 2014. Shifting cultivation and forest landscapes in the Amazon. In: Global Landscapes Forum. Peru.

MAVDT, Ministerio de Ambiente, Vivienda y Desarrollo Territorial. 2003. Metodologías para la valoración económica de los bienes, servicios ambientales y recursos naturales. Bogota.

Millennium Ecosystem Assessment. 2005. Ecosystems and human well-being: synthesis. Island Press, Washington DC.

Palm, C.A., S.A. Vosti, P.A. Sanchez, and P.J. Ericksen. 2005. Slash-and-burn agriculture: the search for alternatives. Columbia University, New York, NY.

Polar. 2013. Maual del usuario polar RCX3. Kempele, Finlandia.

Ramirez-Gomez, S.O., C.A. Torres-Vitolas, K. Schreckenberg, M. Honzák, G.S. Cruz-Garcia, S. Willcock, E. Palacios, E. Pérez-Miñana, P.A. Verweij, and G.M. Poppy. 2014. Analysis of ecosystem services provision in the Colombian Amazon using participatory research and mapping techniques. Ecosyst. Serv. 13, 93-107. Doi: 10.1016/j.ecoser.2014.12.009

SantoDomingo J., A.J. 2011. Sistema cultural y uso del territorio en la vereda multicultural el Madroño, bajo río Caquetá, Amazonas, Colombia. Undergraduate thesis. Facultad de Estudios Ambientales y Rurales (EAR), Pontificia Universidad Javeriana, Bogota.

Scholte, S.S.K., A.J.A. Teeffelen, and P.H. Verburg. 2015. Integrating socio-cultural perspectives into ecosystem service valuation: a review of concepts and methods. Ecol. Econ. 114, 67-78. Doi: 10.1016/j.ecolecon.2015.03.007

Schramski, J.R., K.L. Jacobsen, T.W. Smith, M.A. Williams, and T.M. Thompson. 2013. Energy as a potential systems-level indicator of sustainability in organic agriculture: case study model of a diversified, organic vegetable production system. Ecol. Model. 267, 102-114. Doi: 10.1016/j.ecolmodel.2013.07.022

Sharif, M. 1986. The concept and measurement of subsistence: a survey of the literature. World Develop. 14, 555-577. Doi: 10.1016/0305-750X(86)90124-5

Singh, R.K., H.R. Murty, S.K. Gupta, and A.K. Dikshit. 2009. An overview of sustainability assessment methodologies. Ecol. Indicat. 15, 181-299. Doi: 10.1016/j.ecolind.2011.01.007

Van der Hammen, M.C. 1992. El manejo del mundo: naturaleza y sociedad entre los Yukuna de la Amazonia colombiana. Serie Estudios en la Amazonia Colombiana. Vol. IV. Tropenbos International Colombia, Bogota.

Vargas Z., M., L. Lancheros P., and M.D. Barrera P. 2011. Gasto energético en reposo y composición corporal en adultos. Rev. Fac. Med. 59, 43-58.

Vickers, W.T. 1989. Los sionas y secoyas: su adaptación al ambiente amazónico. Ediciones ABYA-YALA; MLAL, Quito, Rome.