

Review

Evaluation of Wild Foods for Responsible Human Consumption and Sustainable Use of Natural Resources

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Abstract: Traditional consumption of plants, fungi and wild animals constitutes a reality for the feeding of diverse human groups in different tropical territories of the world. In this regard, there are two views within the academic community: (1) those who defend the importance of the traditional consumption for family food security in rural areas, especially in tropical countries with emerging development; and (2) those who affirm their inconvenience as they are considered vectors of rapidly spreading diseases worldwide. A systematic literature review and an Analytic Hierarchy Process (AHP) with experts were carried out to identify the contributing criteria and dimensions in Science, Technology and Innovation (STI) that help evaluate the potential of wild foods for responsible consumption in terms of human health and nature conservation. Four dimensions were identified. The first three are: (1) importance of food for the community that consumes it ($w = 0.31$); (2) nutritional value and risks for human health ($w = 0.28$) and (3) sustainability of the local use of wild food model ($w = 0.27$). These three obtained similar integrated relative weights, which suggests the possible balanced importance in the formulation of multidisciplinary methods for estimating the potential of wild foods. The fourth identified dimension is: (4) transformation techniques for turning wild foods into products with commercial potential, obtained an integrated relative weight of 0.14, which, although is lower than the other three, still contributes to the potential of this type of food. The study found ten assessment criteria to evaluate the identified dimensions, constituting a starting point to estimate the potential of this type of food.

Keywords: assessment of wild food; dimensions in science; technology and innovation (STI); estimation of potential; food security; tropical forest areas

1. Introduction

Wild biological diversity as a source of food resources, contributes to family food security through ancestral practices of exploitation of fungi, plants and animals, especially in tropical forest areas [1]. These contributions are reflected at different levels of importance regarding their use. In many rural areas they are the main option for the consumption of animal protein, cereals, tubers, vegetables and fruits. In urban areas they constitute an alternative that complements the supply of non-wild and commercial food within the usual family basket of the territory [2–9]. Wild foods also

contribute to the family economy through the generation of income from activities such as hunting, gathering, planting or raising plants, fungi and animals. Usually, the generation of economic income is derived from the occasional or regular sale of said products and the economic resources obtained are used for family subsistence [1].

The consumption of wild food is thus a reality for populations in different tropical territories of the world. This reality deserves a deep analysis, as there are currently different studies that attribute to zoonosis the origin of rapidly spreading diseases worldwide [10–13], and at the same time recognize the contributions of wild foods to the family food security of these territories [1]. One way of solving this dilemma is to generate empirical studies and arguments that enable responsible consumption of this type of food, understanding the processes of manipulation and ingestion of wild foods as responsible consumption that minimizes the risks to human health or biological and/or ecosystem conservation.

These studies are especially necessary in tropical areas that currently occupy some 4 billion hectares and account for about 31% of the world's land surface [14]. Some 800 million people live in these areas [15,16] of whom 38% are undernourished [17]. Tropical forests are distributed in countries in Africa, Asia and Latin America and the Caribbean.

The academic community has been making efforts in Science, Technology and Innovation (STI) to address this need. Disciplinary studies define ethnobiological aspects to describe the wild species of plants, fungi or animals consumed, the frequency and forms of this consumption, as well as the social groups that consume them. This knowledge base serves to analyze the importance of these wild foods in the food security of families living in specific territories [2,8,18–22]. This type of analysis evaluates the nutritional value and risks to human health from the consumption of certain foods (bromatological studies); evaluates possible techniques to develop different products with more commercial potential [23–36]; and describes and/or enhances ancestral planting or breeding practices [37–42]. All this information allows us to understand the importance of wild foods for family food security in tropical areas. Even so, a knowledge gap continues to exist that enables identification of wild foods that can be consumed and/or manipulated without risks to human health or the conservation of natural resources. Furthermore, there is no known theoretical approach that allows the multidisciplinary estimation of the potential of wild foods from its advances in STI.

Therefore, the present study sought to contribute to the identification and definition of evaluation alternatives of those dimensions in STI that define the potential of wild foods for responsible consumption in territories associated with tropical forests. Once the dimensions are identified, a methodological process is developed to weigh and rank them according to their importance in explaining the potential of wild food. Prioritizing the dimensions according to their importance could help define a logical order in evaluating the potential of a wild food. By evaluating the most important dimension first, the non-positive results might indicate that the evaluation is not worth continuing, unless these results can be reversed through STI processes. Finally, criteria are defined to guide the practical measurement of each dimension. In order to meet these objectives, the following research questions were addressed: (1) what are the dimensions in STI that define the potential of wild foods for responsible consumption in tropical forest territories? (2) what is the relative importance of these dimensions in defining the potential of a wild food? and (3) what evaluation criteria could be defined to measure the identified dimensions?

The results generated in the present study—dimensions and evaluation criteria—will contribute to the formulation of multidisciplinary methods that allow estimating the potential of wild foods; an estimate that allows these foods to be analyzed as alternatives in planning food and nutrition security in tropical forest areas where their traditional consumption is a reality today.

2. Methods

The methodological process conducted in the present study was developed under three stages (see Figure 1). In the first stage, a systematic literature review was carried out, through which the main dimensions in STI that define the potential of wild foods for responsible consumption in tropical forest areas were identified. The second stage involved prioritizing these dimensions according to

their importance in determining the potential of these foods. For the development of this stage, 15 experts were consulted. Experts were from different knowledge areas related to the use of wild foods by human populations in tropical forest areas. One of the most frequent methods applied in participatory processes in sustainable forest management [43–50] is the Analytic Hierarchy Process (AHP). This method is the most popular multiple criteria decision method used in public participation processes regarding nature resources management. In fact, according to Esmail and Geneletti [51] and Díaz-Balteiro and Romero [52] over 98 applications of this tool have been recorded in nature conservation and forest management. We applied this method to rank the dimensions in STI identified. AHP is based on pairwise comparisons between criteria and alternatives, which are compiled into square matrices whose coefficients are numerical values assigned to the preferences indicated by the participants. Finally, in the third stage the evaluation criteria were defined as a proposal to value wild foods in each of the identified dimensions.

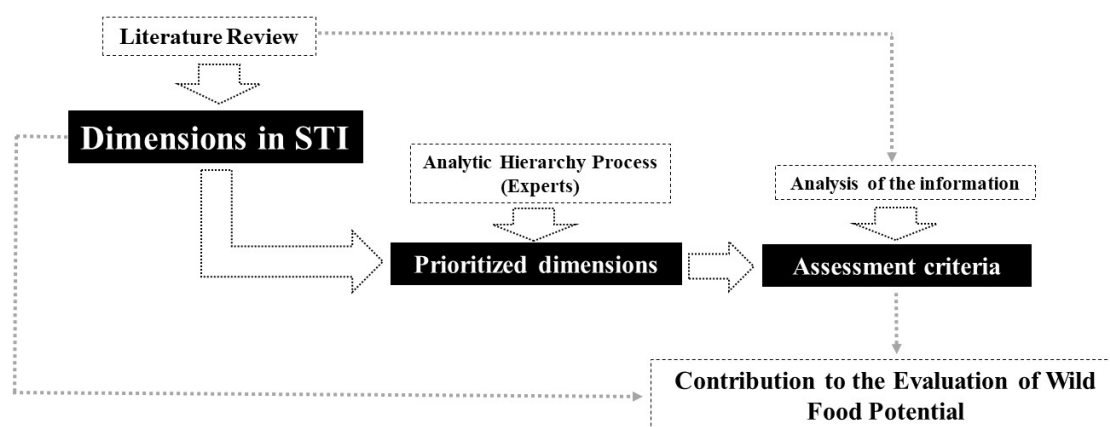


Figure 1. Methodological steps of the study.

2.1. Identify the Dimensions (Literature Review)

To identify the dimensions, it was necessary to previously recognize the importance of this type of food for people who use it in communities associated with tropical forests as well as the main challenges and needs in STI for responsible consumption. The recognition of the importance of wild foods and their main challenges and needs in STI was carried out through a systematic literature review, for which a methodological process of three stages was developed. That process includes: (a) identifying and obtaining documents; (b) reviewing and selecting the most relevant documents and (c) analyzing the information and structuring the results [53,54].

2.1.1. Identification and Retrieval of Documents

A total of 182 documents were identified among books, book chapters and scientific papers. To obtain these documents, consultations were made on scientific websites: Web of ScienceTM Core Collection, BIOSIS Citation IndexSM, BIOSIS Previews[®], Current Contents Connect[®], Derwent Innovations IndexSM, Inspec[®], MEDLINE[®] and SciELO Citation Index (all linked to WEB OF SCIENCE), as well as queries on Google Academic. Searches were conducted in English and Spanish using keywords in the document titles and were guided by the terms: wild foods, wild vegetables, indigenous vegetables, wild edible plants, wild meat, edible wild fruit and bushmeat. Each of the words was also searched in combination with the terms of food security and challenge. No language restrictions, years of publication, or area of knowledge were programmed.

2.1.2. Review and Selection of Documents

Only documents published in peer-reviewed journals or books published by renowned publishers were included. For the inclusion of a document, in addition to the above characteristics, it was verified that its content contributed to answering the research questions raised in the present

study and its area of study corresponded to tropical forest areas. After the review and analysis process of the 182 identified documents, only 45 met the defined criteria and were included (8 books and 37 scientific articles). These 45 documents are cited in the reference section of this article and the 137 documents discarded are listed in Table A1.

2.1.3. Analysis of Information

Through a detailed review of the collected documents, the importance of wild foods for family food security in tropical forest areas and the main challenges and needs in STI were identified, so that this type of food could be responsibly consumed in these territories. During the analysis process for the identification of these elements, and when necessary, contributions were made to the results based on empirical experiences of the authors and/or knowledge generated during technical discussions in regular meetings.

Finally, the identification of the dimensions of technological and/or scientific knowledge that define the potential of wild foods was carried out through analyzing the main challenges and needs in STI so that this type of food could be considered as a viable alternative in food and nutritional security planning. The main arguments for the recognition of each dimension were the identification of its contribution to understanding the importance of the food for the communities that consume it or its possible contributions to the solution of the challenges and/or needs in STI.

2.2. Prioritize the Dimensions (Analytic Hierarchy Process)

To identify the preferences of each expert, the multicriteria decision making method Analytic Hierarchy Process (AHP) was used [55] during the last three months of 2018. According to Saaty [56]: “The purpose of the method is to enable the decision maker to structure a multi-criteria problem by building a hierarchical model”. In this case the structure had two levels: objective and criteria. The objective of the model in our study was: ordering dimensions according to their capacity to define the suitability of wild food to be consumed in tropical forest areas, broken down into four criteria corresponding to the identified dimensions. The schema of this methodology is shown in Figure 2.

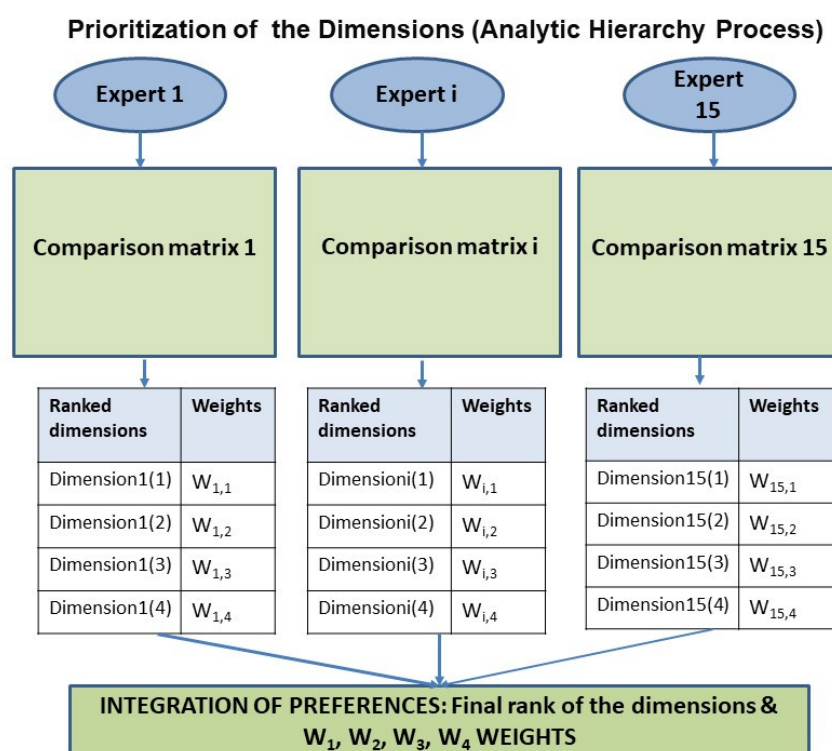


Figure 2. Structure of the dimension prioritization process.

Pairwise comparisons were then performed between the dimensions. A pairwise comparison matrix allows subjective assessments to be converted into relatively important global scores or weights. The comparisons are done by asking the following question: How important is the C_i criterion (dimension i) in relation to the C_j criterion (dimension j)?

A comparison matrix, $C_{4 \times 4}$, is built for every participant. Every entry C_{ij} is a number representing the comparison between criteria i and j , according to the scale used. A comparison matrix, C , has three basic properties, namely positivity ($C_{ij} > 0$, for all i, j); homogeneity ($C_{ij} = 1$, if criteria i and j are considered equally important: specifically $C_{ii} = 1$ for each i) and reciprocity ($C_{ji} = 1/C_{ij}$ for all i, j). From this perspective, only $1/2m(m - 1)$ comparisons need to be made in the comparison matrix.

The AHP pairwise comparison scale was adopted from Saaty [57]:

1 = Both criteria equally important.

3 = Very slight importance of one criterion over the other.

5 = Moderate importance of one criterion over the other.

7 = Demonstrated importance of one criterion over the other.

9 = Extreme of absolute importance of one criterion over the other.

Values express intermediate preference between the two contiguous odd values.

Once all the participants' matrices were obtained, we applied the eigenvector method proposed by Saaty [57] to obtain the weights of the criteria from each matrix. As a measure of consistency of the preference (if A is preferable or indifferent to B , and B is preferable or indifferent to C , then A is preferable or indifferent to C) reflected in every matrix. We applied the Consistency Ratio $CR = CI/RI$, to measure this transitivity, where CI , the Consistency Index is $CI = (Imax - n)/(n - 1)$ and RI , the Random Index, is $RI = 1.98(n - 2)/n$, $Imax$ is the maximum eigenvalue of the matrix and n the number of rows of the matrix. If CR is less than 0.1, then the preference is consistent and the estimate is accepted.

The comparisons were done individually by 15 research experts from different tropical countries with training profiles and/or research experience in different areas of knowledge. These areas include: (1) ethnobiology, (2) food and nutritional security, (3) agronomy and/or zootechnics, (4) biology and/or ecology, (5) agricultural and/or natural resources economics and (6) agroindustry. The quality requirements defined for the selection of the experts were: Doctor's degree (PhD) with scientific publications in high-quality indexed journals and having participated in research projects in their area of knowledge.

The results obtained by each expert were averaged to obtain the final relative weight of each dimension by the area of knowledge (see Figure 2). For each area of knowledge, the dimensions were ordered by their importance and a hierarchy of importance was drawn that defined the potential of wild foods for responsible consumption in territories associated with tropical forests.

In addition, three analyses of variance were carried out to see the relationship among the factors "Area of knowledge" and "Dimension", and the quantitative variable "Weight" obtained with the AHP method. These three analyses were: (1) analysis of the influence of the "Area of knowledge" on the average behavior of the variable "Weight" of the expert; (2) analysis of the influence of the "Dimension" on the average behavior of the variable "Weight" of the expert and (3) if the factor "Dimension" influenced the integrated value of the "Weights by area of knowledge".

2.3. Define the Criteria

Once the dimensions were obtained and prioritized, a set of evaluation criteria was defined based on the needs identified in STI during the literature review. The evaluation criteria were obtained from a rigorous analysis process on the STI needs related to each of the identified dimensions. From this perspective, a matrix was built in which each evaluation criterion responds to a mechanism to solve a need in STI. The evaluation criteria constitute the minimum conditions a wild food must meet for responsible consumption or for being considered as a viable alternative in the planning of food and nutritional security for tropical forest territories. Based on the results, a set of

dimensions and their respective evaluation criteria is proposed to check the minimum conditions of wild food with respect to its advances in STI.

3. Results

3.1. Key Challenges in STI of Wild Foods

Two main challenges in STI were identified in the literature review. They are the challenges for wild food to be consumed in a responsible way or considered as a viable alternative in the planning of food and nutrition security in tropical forest areas. They are related to (1) the negative effects on biodiversity conservation as a result of unplanned extractive harvesting practices and (2) the possible risks to human health due to the lack of assessment of their nutritional and health quality.

With regard to the first challenge, some studies conducted in different areas of tropical forest in Africa and Latin America show concerns about the frequent and extractive use of wild plants, fungi and animals. The most negative effects in the medium and long term are the reduction of populations of vulnerable species, local extinction and habitat fragmentation, with consequences on the functioning of ecosystems and people's lives [1,9,58–62].

Concerning the second challenge, food products whose nutrition has not been studied, can generate food imbalances for individuals who consume them instead of providing nutrients. This would be counterproductive for food security [2,5,63,64]. In addition, more than 35 new infectious diseases have emerged in humans [53] in recent decades, many of which are attributed to the handling and consumption of plants, fungi or jungle animals [2,5,11–13,63–67]. Nevertheless, the consumption of plants, fungi and wild animals in tropical forest areas as food is not commonly related to government food security policies. On the contrary, this consumption is related to the ancestral traditions and socio-cultural customs of local communities.

On a higher-detailed scale, these challenges could be expressed through the following needs and dimensions in STI identified in the literature review.

3.2. Needs and Dimensions in STI That Define the Potential of Wild Foods

Ten needs in STI were identified in the literature review. They were analyzed and conceptualized in four technological and/or scientific knowledge dimensions. These dimensions in STI constitute the structural axes for estimating the potential of wild foods for responsible consumption as an alternative resource in the planning of interventions in favor of food and nutrition security for tropical forest territories. These dimensions are: (a) importance of food for the community that consumes it; (b) sustainability of the local model of wild food use; (c) nutritional value and risks to human health and (d) processing techniques into products with commercial potential. By its nature, the understanding of these dimensions must be addressed from a multidisciplinary approach since knowledge is required from different disciplines for the study such as sociology, anthropology, biology, ecology, economics, agronomy, zootechnics, veterinary sciences and laws, among others. Each dimension and its respective needs in STI are detailed below.

3.2.1. Importance of Food for the Community That Consumes It

This dimension defines the importance of wild foods based on traditional uses and other aspects that shape the use of a food in a specific community. The food whose pattern of use (obtained through scientific research) demonstrates the importance of this edible food's usage for the territory will have greater potential. Below are the needs for advances in STI related to the dimension: (1) recognition and documentation of the traditional use of wild species in the feeding of communities living in tropical forest territories to include lists of species used as food and studies with different types of use where food is included, etc.; (2) recognition of the pattern of use of wildlife in the feeding of communities in tropical forest areas, with special emphasis on the species/culture/territory relationship and parts of the plant, fungus or animal used, ways of use, frequency of use, economic assessment of the contribution of these products to food and nutritional security, etc., and (3) identification of drivers for the consumption of wild foods including preferences between wild and

non-wild foods, limitations to obtaining other alternatives, effects of culture on the consumption of wild foods, etc.

3.2.2. Sustainability of the Local Model of Wild Food Use

This dimension is based on the sustainability of the source from which wild food could be obtained for family consumption and contribution to food and nutritional security in the territory. The wild food will have greater potential if it has at least a sustainable harvesting mechanism tested in the territory. The needs for advances in STI related to the dimension are: (1) recognition of supply sources of the wild food in the territory whether extractive and/or non-extractive use; (2) generation of technological and/or scientific knowledge on mechanisms for the sustainable use of wild food and (3) cost/benefit analysis of such mechanisms.

3.2.3. Nutritional Value and Risks to Human Health

This dimension is based on technological and/or scientific knowledge about the nutritional value of wild food products and the assessment of possible risks to human health due to their intake. The wild food with known nutritional value whose result is similar or better than commercial non-wild foods belonging to the same group (fruit vs. fruit, meat vs. meat, vegetables vs. vegetables, etc.) will have greater potential. Food with studies showing that its consumption does not create risks to human health will also have greater potential. Below are the needs for advances in STI related to this dimension: (1) identification of the nutritional value of wild food products being consumed by human populations in the territory studied; (2) identification of the biological assimilation of these wild food products and (3) assessment of food quality with regard to risks to human health due to its consumption.

3.2.4. Processing Techniques into Products with Commercial Potential

This dimension values the technological and/or scientific knowledge advances about the transformation of wild foods into products with potential economic importance for human communities. Food with advances in technological developments that allow transformation into products with commercial potential will have greater overall potential. There is one need for advances in STI related to this dimension and that is: the generation of scientific knowledge, experimental developments and/or technological developments for the transformation of raw materials into products with commercial potential.

3.3. *Sorting of the Dimensions According to Experts' Preferences*

Once the dimensions were identified, each expert using the AHP method arranged them in order. The results of this consultation with the fifteen experts and the application of the AHP method can be found in Table 1.

As a result of the application of the AHP method by each expert, the importance of each dimension for each expert was obtained. This importance was expressed by the weights shown in Table 1. These were the weights obtained for each expert who was using the AHP process for each dimension. In Table 1, the experts were grouped according to their knowledge area to make it easier to compare results.

Table 1 also shows that the consistency of preference for all experts was acceptable since no CR value had exceeded the limit value of 0.1 [57].

Table 1. Analytic Hierarchy Process (AHP) weights for each expert E_i of each knowledge area, for each dimension and Consistency Ratio (CR).

Dimensions/Knowledge Area	Agronomy and/or Zootechnics			Agroindustry		Biology and/or Ecology			Natural Resources Economics		Ethnobiology		Food and Nutritional Security		
	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15
Importance of food for the community that consumes it	0.15	0.43	0.25	0.59	0.61	0.43	0.28	0.04	0.31	0.22	0.14	0.23	0.20	0.09	0.33
Sustainability of the local model of wild food use	0.64	0.04	0.25	0.12	0.05	0.09	0.57	0.10	0.56	0.15	0.14	0.29	0.59	0.25	0.49
Nutritional value and risks to human health	0.15	0.42	0.25	0.20	0.09	0.05	0.10	0.60	0.08	0.47	0.48	0.37	0.12	0.63	0.13
Processing techniques into products with commercial potential.	0.05	0.11	0.25	0.09	0.25	0.43	0.04	0.25	0.05	0.15	0.23	0.10	0.09	0.04	0.05
Consistency Rate (CR)	0.04	0.09	0	0.07	0.07	0.02	0.08	0.03	0.04	0	0	0	0.04	0	0.08

Once the results from the AHP method were obtained, they were analyzed using an ANOVA if the knowledge area to which each expert belonged influenced the AHP results. The p -value of this test was 1, so we could not reject that the knowledge area did not influence the average behavior of the variable AHP-weight. The residuals met the requirements of normality, (p -value of the Kolmogorov–Smirnov test = 0.084217), homoscedasticity (Levene’s test p -value = 0.4972), independence (autocorrelation coefficient for lag = 1 was -0.23514 , which did not belong to the 95% Confidence Interval $(-0.250031; 0.253031)$), and the residuals average was 0.

These findings allowed us to analyze the AHP weights as a whole and not by the knowledge area. We ranked for every expert the dimensions from the most preferred to the least according to their AHP weight value and also integrated the AHP weights of the experts calculating the geometric mean. Table 2 shows the global results of this ranking.

Table 2. Global preference order of the dimensions according to the experts’ individual rankings.

Dimension	First Place	Second Place	Third Place	Fourth Place	Total	Weight Integrated Value	Standard Deviation	Final Ranking
Importance of food for the community that consumes it	5	6	3	1	15	0.31	0.17	1
Sustainability of the local model of wild food use	6	2	4	3	15	0.27	0.22	3
Nutritional value and risks to human health	6	3	5	1	15	0.28	0.2	2
Processing techniques into products with commercial potential	1	4	2	8	15	0.14	0.11	4

The first columns of Table 2 show how many times each dimension has been chosen from first place to the last one for the 15 experts together. These data have been obtained from Table 1 by ordering the dimensions from the most preferred to the last for each expert and then counting how many times each dimension is ranked in first, second, third or fourth place. The dimensions appear in the table in order of preference. The result from the consultation with experts strictly analyzed by the relative weight values suggest the dimension “Importance of food for the community that consumes it” as the most important in defining the potential of wild foods for responsible consumption. A total of 11 experts out of 15 considered it as the first or second most important

dimension. The following dimensions in order of importance would be: “Nutritional value and risks to human health” and “Sustainability of the local model of wild food use” with practically equal integrated weights: 0.28 and 0.27 respectively. The number of experts who consider them as the most important dimension is the same, and they are the dimensions in which the standard deviation has been highest. Finally, the dimension considered to be in the 4th position, by more than 50% of the experts, was “Processing techniques into products with commercial potential”.

3.4. Criteria for Assessing the Potential of Wild Foods

Based on the literature review, ten assessment criteria are proposed according to the needs in STI identified in each dimension. These criteria include the minimum conditions that a wild food must meet to be responsibly considered for its consumption in territories associated with tropical forests. Figure 3 shows the assessment criteria for each of the dimensions.

Dimensions in STI		Assessment criteria
Potential of wild foods	Importance of food for the community that consumes it	<ul style="list-style-type: none"> • Food is regularly consumed in the territory. • The pattern of use of the wild food in the territory is known: forms of use (raw food or in some kind of preparation), parts or by-products used as food, description of culinary preparation (when applicable), frequency of family consumption in the territory, etc. • The consumption preference of this food has been technically demonstrated with respect to at least one non-wild food of the same group within the family basket of the territory.
	Sustainability of the local model of wild food use	<ul style="list-style-type: none"> • The traditional sources for obtaining the food for family consumption in the territory are known. • There are proven mechanisms for sustainable use of the wild food in the territory. These mechanisms ensure the availability of the food without risking the conservation of the wild species from which it is obtained or for any other species that coexist in its environment. The mechanisms are in line with the applicable wildlife protection laws of the respective country. • Positive cost/benefit analysis of the mechanisms for sustainable use of the wild food tested in the territory.
	Nutritional value and risks to human health	<ul style="list-style-type: none"> • Wild food having a nutritional value with similar or higher quality (in at least one bromatological characteristic) with respect to a non-wild food of the same group. The results should be obtained through samples of the wild food obtained in the territory. • Wild food with positive results in biological assimilation studies carried out in the territory. • Wild food with studies in the territory showing that its consumption does not entail risks to human health.
	Processing techniques into products with commercial potential	<ul style="list-style-type: none"> • Wild food with at least one experimental development and/or technological development (carried out in the territory) that allows its transformation into products with commercial potential.

Figure 3. Evaluation criteria for each of the Science, Technology and Innovation (STI) dimensions that define the potential of wild foods.

4. Discussion and Conclusions

The dimensions identified in this study were related to the approach of Arenas and Scarpa [68] where it is stated that the recognition of the potential for human consumption of wild fruits depends on three aspects: cultural acceptance, the abundance of the species in their natural environment and fruit quality. The present research built upon this and proposed four dimensions in STI that define the potential of wild foods as an alternative resource in the planning of food and nutritional security for tropical forest territories. These dimensions are: (a) importance of the food for the community that consumes it; (b) sustainability of the utilization model, (c) nutritional value and risks to human health and (d) processing techniques into products with commercial potential.

The integration of the opinion of the experts has allowed ordering the dimensions by their importance. The consistency of the results makes this ordering applicable in the decision-making process. The results of AHP indicate the unanimity when considering the dimension “Importance of food for the community that consumes it” the most important one. A diet should not be imposed if there is no local tradition in its consumption. It is assumed that initiatives concerning food and

nutritional security that include traditional food in the territory could be more relevant and sustainable.

The AHP results also show that the nutritional quality of food consumed by the population should be explored and considered first, as well as the management of sustainable use mechanisms, before considering the processing of wild food and its exploitation for sale in local markets or other places. On the other hand, the differences between the integrated weights of the first three dimensions (a, b and c) vary between 8 and 10%, lower than the variability of the weights of these dimensions (see Table 2). This indicates, for practical purposes, the need to consider the dimensions with equal demand when deciding whether a food should be incorporated into the diet of a population or not.

Knowing the “Importance of food for the community that consumes it”, (a) how often it is consumed and what people in the community consume it, is decisive in managing the foods, since cultural preferences and traditional practices tend to maintain them and their modification is difficult [69]. Failure to apply sustainable wild food management (b) can lead to over-exploitation of these species. In the case of forest species there is frequently multiple use of these items as food, firewood, construction or fencing [69]. The dimension of “Nutritional value and risks to human health” (c) will allow measuring whether the wild food consumed by a community meets the requirements of an adequate diet for the population, as demonstrated by the work of Fungo et al. [70] in Nigeria, Gabon and Congo, where, due to wild berries, they are able to get an adequate diet. Knowing the nutritional value of food determines its safety for the health of the community. The lack of studies on the risks consumption entails for human health can cause serious stomach problems, pains in the chest or even the death in these tropical areas [71]; or complex problems such as the COVID-19 pandemic [11–13], which is attributed by some experts to the unplanned management and consumption of wildlife.

The results of the fourth dimension on processing techniques (d) also show their contribution to estimating the potential of wild foods, but the other three dimensions should be addressed as a priority and are considered by experts to be more important.

The ten criteria defined for the evaluation of the four dimensions form the basis to create mechanism that allow the formulation of multidisciplinary methods (qualitative and/or quantitative) for estimating the potential of wild foods for responsible consumption or as an feasible alternative in planning food and nutrition security for territories associated with tropical forests.

The dimensions and criteria presented are not intended to be suggested as absolute variables for evaluating the potential of wild foods for responsible consumption in tropical forest areas. On the contrary, this study seeks to contribute to discussions on methods for multidisciplinary estimation of the potential of this type of food that, although not officially included in the planning of food security policies, does constitute a reality for the food of various human groups in different tropical territories on this planet.

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Appendix A

Table A1. Documents discarded in the literature review and not listed in the reference section.

Geographical Area	Journal Name	Document Type	Document Title	Language	Year of Publication
Africa	Energy Policy	Paper	Biofuels and food security: Micro-evidence from Ethiopia	English	2013
Africa	Energy Policy	Paper	Potential impacts of biofuel development on food security in Botswana: A contribution to energy policy	English	2012
Africa	African Affairs	Paper	Biofuels, food security, and Africa	English	2010
Africa	International Food and Agribusiness Management Review	Paper	The Impact of biofuel production on food security: A briefing paper with a particular emphasis on maize-to-ethanol production	English	2008
Africa	Economics-The Open Access Open-Assessment E-Journal	Paper	South African food security and climate change: Agriculture futures	English	2013
Africa	Review of Development Economics	Paper	Climate change, agriculture and food security in Tanzania	English	2012
Africa	Climate and Development	Paper	Climate variability, yield instability and global recession: The multi-stressor to food security in Botswana	English	2012
Africa	Climatic Change	Paper	East African food security as influenced by future climate change and land use change at local to regional scales	English	2012
Africa	International Journal of Pest Management	Paper	Food security, politics and perceptions of wildlife damage in Western Ethiopia	English	2012
Africa	International Journal of Climate Change Strategies and Management	Paper	Gendered response and risk-coping capacity to climate variability for sustained food security in Northern Cameroon	English	2012
Africa	Environment Development and Sustainability	Review paper	Climate change and variability in Sub-Saharan Africa: A review of current and future trends and impacts on agriculture and food security	English	2011
Africa	American Journal of Agricultural Economics	Paper	Does adaptation to climate change provide food security? A micro-perspective from Ethiopia	English	2011
Africa	Mitigation and Adaptation Strategies for Global Change	Paper	Food security and climate change in drought-sensitive savanna zones of Ghana	English	2011
Africa	Area	Paper	Farming flexibility and food security under climatic uncertainty: Manang, Nepal Himalaya	English	2010
Africa	Sustainability Science	Paper	Food security and seasonal climate information: Kenyan challenges	English	2010
Africa	Journal of Human Ecology	Paper	Climate variability, environment change and food security nexus in Nigeria	English	2009
Africa	Environmental Science and Technology	Paper	Markets, climate change, and food security in West Africa	English	2009
Africa	Erdkunde	Paper	Climate change and food security in tropical West	English	2008

			Africa—A dynamic-statistical modeling approach		
Africa	Journal of Energy in Southern Africa	Paper	The impacts of climate change on food security and health in Southern Africa	English	2008
Africa	Proceedings of the National Academy of Sciences of the United States of America	Paper	Warming of the Indian Ocean threatens eastern and southern African food security but could be mitigated by agricultural development	English	2008
Africa	Climatic Change	Paper	The economic and food security implications of climate change in Mali	English	2005
Africa	Philosophical Transactions of the Royal Society B-biological Sciences	Paper	Weather patterns, food security and humanitarian response in sub-Saharan Africa	English	2005
Africa	Agricultural Water Management	Paper	Adaptation to climate change to enhance food security and preserve environmental quality: example for southern Sri Lanka	English	2004
Africa	Food and Nutrition Bulletin	Paper	Food security indicators after humanitarian interventions including food aid in Zimbabwe	English	2010
Africa	Agrekon	Paper	The status of household food security targets in South Africa	English	2009
Africa	Disasters	Paper	Measuring populations' vulnerabilities for famine and food security interventions: the case of Ethiopia's Chronic Vulnerability Index	English	2008
Africa	Disasters	Paper	The underutilization of street markets as a source of food security indicators in Famine Early Warning Systems: a case study of Ethiopia	English	2008
Africa	Food Culture and Society	Paper	Toward improved understanding of food security a methodological examination based in rural South Africa	English	2013
Africa	Systems Research and Behavioral Science	Paper	Designing sustainable food security policies in sub-Saharan African countries: How social dynamics over-ride utility evaluations for good and bad	English	2012
North America	Economics-The Open Access Open-Assessment E-Journal	Paper	US food security and climate change: Agricultural futures	English	2013
North America	Ecohealth	Paper	Adapting to the impacts of climate change on food security among Inuit in the Western Canadian Arctic	English	2010
North America	International Journal of Circumpolar Health	Paper	Local observations of climate change and impacts on traditional food security in two northern Aboriginal communities	English	2006
North America	Ambio	Paper	A call for urgent monitoring of food and water security based on relevant indicators for the Arctic	English	2013
North America	Journal of Nutrition	Paper	Food security of older adults requesting older Americans act nutrition program in Georgia can be validly measured using a short form of the U.S. household food security survey module	English	2011

North America	Public Health Nutrition	Paper	The assessment of food security in homeless individuals: a comparison of the Food Security Survey Module and the Household Food Insecurity Access Scale	English	2011
North America	Public Health Nutrition	Paper	Does interview mode matter for food security measurement? Telephone versus in-person interviews in the current population survey food security supplement	English	2007
North America	Journal of Nutrition	Paper	Recent advances provide improved tools for measuring children's food security	English	2007
Arctic	International Journal of Circumpolar Health	Paper	Indicators of food and water security in an Arctic health context—results from an international workshop discussion	English	2013
Asia	Renewable and Sustainable Energy Reviews	Review paper	Biofuel and food security in China and Japan	English	2013
Asia	Mountain Research and Development	Paper	Solar greenhouse technology for food security: A case study from Humla District, NW Nepal	English	2012
Asia	Renewable Energy	Paper	Will the development of bioenergy in China create a food security problem? Modeling with fuel ethanol as an example	English	2012
Asia	Journal of Environmental Quality	Paper	Biofuel development, food security and the use of marginal land in China	English	2011
Asia	Energy for Sustainable Development	Paper	Bioenergy and food security: Indian context	English	2009
Asia	Philippine Agricultural Scientist	Paper	Sugar as a biofuel: Implications for Philippine agriculture and food security	English	2008
Asia	Agronomy for Sustainable Development	Paper	Climate change impact on China food security in 2050	English	2013
Asia	Journal of Food Agriculture and Environment	Paper	Climate change, agriculture and food security issues: Malaysian perspective	English	2013
Asia	Sustainability	Paper	Impact of climate and land use changes on water and food security in Jordan: Implications for transcending "The tragedy of the commons"	English	2013
Asia	Environmental Modeling and Assessment	Paper	Modeling of ecological footprint and climate change impacts on food security of the hill tracts of Chittagong in Bangladesh	English	2013
Asia	Chinese Geographical Science	Paper	Soil degradation and food security coupled with global climate change in northeastern China	English	2013
Asia	Ambio	Review paper	Climate change and population growth in Timor Leste: Implications for food security	English	2012
Asia	Food Security	Paper	Adaptation to climate change for food security in the lower Mekong Basin	English	2011
Asia	Journal of Developments in Sustainable Agriculture	Paper	Enhancing food security in the context of climate change and the role of higher education institutions in the Philippines	English	2010

Asia	Asia Pacific Journal of Clinical Nutrition	Review paper	Climate change and food security in East Asia	English	2009
Asia	Food Security	Paper	Climate change, flooding and food security in south Asia	English	2009
Asia	Climatic Change	Paper	Climate change, land use change, and China's food security in the twenty-first century: An integrated perspective	English	2009
Asia	Asia Pacific Journal of Clinical Nutrition	Review paper	Food security in the Asia-Pacific: Climate change, phosphorus, ozone and other environmental challenges	English	2009
Asia	Environmental Management	Paper	Food security in the face of climate change, population growth, and resource constraints: Implications for Bangladesh	English	2004
Asia	Bulletin of Indonesian Economic Studies	Paper	Using climate models to improve Indonesian food security	English	2004
Asia	The Journal of Nutrition	Journal Article	Development and validation of an Arab family food security scale	English	2014
Asia	Advanced Materials Research	Paper	Established the evaluation index system of food security in state farms of Heilongjiang province	English	2011
Asia	Public Health Nutrition	Paper	An empirical study of Taiwan's food security index	English	2010
Asia	Journal of Preventive Medicine and Public Health = Yebang Uihakhoe Chi	Review paper	The concept and measurement of food security	Korean	2008
Asia	Asia Pacific Journal of Clinical Nutrition	Paper	Household food security status measured by the US-household food security/hunger survey module (US-FSSM) is in line with coping strategy indicators found in urban and rural Indonesia	English	2007
Asia	Food Security	Paper	How disaggregated should information be for a sound food security policy?	English	2013
Europe	Food Policy	Paper	Disentangling the consensus frame of food security: The case of the EU common agricultural policy reform debate	English	2014
Europe	Renewable and Sustainable Energy Reviews	Review paper	Biomass energy in Vojvodina: Market conditions, environment and food security	English	2010
Europe	Economics-The Open Access Open-Assessment E-Journal	Paper	Russia's food security and climate change: Looking into the future	English	2013
Europe	Applied Artificial Intelligence	Paper	Food security risk level assessment: a fuzzy logic-based approach	English	2013
Europe	Cybernetics and Systems Analysis	Paper	Integrated modeling of food security management in Ukraine. I. Model for management of the economic availability of food	English	2013
Global	Food Policy	Paper	Policy coherence and food security: The effects of OECD countries' agricultural policies	English	2014
Global	Pastos y Forrajes	Paper	Producción de agroenergía a partir de biomasa en sistemas	Spanish	2010

			agroforestales integrados: una alternativa para lograr la seguridad alimentaria y la protección ambiental		
Global	Revista de Salud Pública (Bogota, Colombia)	Paper	Biocombustibles, seguridad alimentaria y cultivos transgenicos.	Spanish	2009
Global	California Agriculture	Paper	Biofuel policy must evaluate environmental, food security and energy goals to maximize net benefits	English	2009
Global	Renewable and Sustainable Energy Reviews	Review paper	Biofuels: Environment, technology and food security	English	2009
Global	Chemical Engineering Research and Design	Paper	Relation of biofuel to bioelectricity and agriculture: Food security, fuel security, and reducing greenhouse emissions	English	2009
Global	Biofuels Biofuels Bioproducts and Biorefining-Biofpr	Paper	Is the expansion of biofuels at odds with the food security of developing countries?	English	2007
Global	Environment	Paper	The ripple effect: Biofuels, food security and the environment	English	2007
Global	Berichte Über Landwirtschaft	Paper	Challenges of global change for agricultural development and world food security	German	2013
Global	Current History	Paper	Climate change and food security	English	2013
Global	Science	Review paper	Climate change impacts on global food security	English	2013
Global	Journal of Crop Improvement	Paper	Declining agricultural productivity and global food security	English	2013
Global	Ecohydrology and Hydrobiology	Paper	Food security in a changing climate	English	2013
Global	Global Change Biology	Review paper	How much land-based greenhouse gas mitigation can be achieved without compromising food security and environmental goals?	English	2013
Global	Journal of Renewable and Sustainable Energy	Paper	Achieving food security while switching to low carbon agriculture	English	2012
Global	Bulgarian Journal of Agricultural Science	Paper	Agricultural research in 21st century: Challenges facing the food security under the impacts of climate change	English	2012
Global	Environmental Health Perspectives	Review paper	Climate change and food security: Health impacts in developed countries	English	2012
Global	Current Opinion in Environmental Sustainability	Paper	Climate change, agriculture and food security: A global partnership to link research and action for low-income agricultural producers and consumers	English	2012
Global	Irrigation and Drainage	Paper	Deltas: The new challenges to food security under climate change	English	2012
Global	Global Environmental Change-Human and Policy Dimensions	Paper	Farmers and perverse outcomes: The quest for food and energy security, emissions reduction and climate adaptation	English	2012
Global	Proceedings of the Royal Society B-Biological Sciences	Review paper	Food security and climate change: On the potential to adapt global crop production by	English	2012

			active selection to rising atmospheric carbon dioxide		
Global	Isle-Interdisciplinary Studies in Literature and Environment	Paper	Framing Emerson's "farming": Climate change, peak oil, and the rhetoric of food security in the twenty-first century	English	2012
Global	Environmental Science and Policy	Review paper	Options for support to agriculture and food security under climate change	English	2012
Global	Euphytica	Review paper	Implications of climate change for diseases, crop yields and food security	English	2011
Global	Journal Fur Verbraucherschutz Und Lebensmittelsicherheit (Journal of Consumer Protection and Food Safety)	Paper	Threat of the "food security" by the effects of climate change	German	2011
Global	Wiley Interdisciplinary Reviews-Climate Change	Review paper	Adapting to climate change to sustain food security	English	2010
Global	Food Security	Paper	Beyond Copenhagen: Mitigating climate change and achieving food security through soil carbon sequestration	English	2010
Global	Food Policy	Paper	Global water crisis and future food security in an era of climate change	English	2010
Global	Progress in Natural Science-Materials International	Review paper	Climate change impacts on crop yield, crop water productivity and food security—a review	English	2009
Global	Food Security	Paper	Declining global per capita agricultural production and warming oceans threaten food security	English	2009
Global	Science	Paper	Prioritizing climate change adaptation needs for food security in 2030	English	2008
Global	Proceedings of the National Academy of Sciences of the United States of America	Paper	Global food security under climate change	English	2007
Global	Climate Change and Global Food Security	Paper	Assessing the consequences of climate change for food security: A view from the intergovernmental panel on climate change	English	2005
Global	Philosophical Transactions of the Royal Society B-Biological Sciences	Paper	Climate change and food security	English	2005
Global	Climate Change and Global Food Security	Paper	Climate change and tropical agriculture: Implications for social vulnerability and food security	English	2005
Global	Climate Change and Global Food Security	Paper	Greenhouse gases and food security in low-income countries	English	2005
Global	Ids Bulletin-Institute of Development Studies	Paper	Climate change and food security	English	2004
Global	Proceedings of the National Academy of Sciences of the United States of America	Paper	A systems science perspective and transdisciplinary models for food and nutrition security	English	2012
Global	Grey Systems: Theory and Application	Paper	Grey prediction model-based food security early warning prediction	English	2012
Global	Food Security	Paper	A food systems approach to researching food security and its interactions with global environmental change	English	2011

Global	Ciencia and Saude Coletiva	Paper	Conceptualizing and measuring food and nutrition security	Portuguese	2011
Global	Nutrition	Review paper	Food security measurement in cultural pluralism: Missing the point or conceptual misunderstanding?	English	2010
Global	Food Security	Paper	Food security: Definition and measurement	English	2009
Global	Journal of Physical Therapy Science	Review paper	Measuring household food security: The global experience	English	2008
Global	Journal of Tsinghua University (Science and Technology)	Paper	Optical immuno-sensors chip for environmental monitoring and food security detection	Chinese	2007
Global	Applied Geography	Paper	A city and national metric measuring isolation from the global market for food security assessment	English	2013
Global	Chinese Journal of Chromatography	Paper	Development of sample pretreatment techniques-rapid detection coupling methods for food security analysis	Chinese	2013
Global	Food Security	Paper	Rethinking the measurement of food security: From first principles to best practice	English	2013
Global	Advances in Nutrition	Review paper	What are we assessing when we measure food security? A compendium and review of current metrics	English	2013
Global	Environmental Science and Policy	Paper	A framework to assess national level vulnerability from the perspective of food security: The case of coral reef fisheries	English	2012
Latin America and the Caribbean	Energy for Sustainable Development	Paper	Bioenergy and sustainable development: The dilemma of food security and climate change in the Brazilian savannah	English	2010
Latin America and the Caribbean	China Agricultural Economic Review	Paper	Biofuels, food security and compensatory subsidies	English	2010
Latin America and the Caribbean	Mitigation and Adaptation Strategies for Global Change	Paper	Implications of a changing climate on food security and smallholders' livelihoods in Bogota, Colombia	English	2014
Latin America and the Caribbean	Climatic Change	Paper	Climate change and critical thresholds in China's food security	English	2007
Latin America and the Caribbean	Ciencia and Saude Coletiva	Paper	Metodos de analise em programas de seguranca alimentar e nutricional: Uma experiencia no Brasil.	Portuguese	2013
Latin America and the Caribbean	Revista Chilena de Nutrición	Paper	Escalas para medir la seguridad alimentaria en Colombia: ¿Son válidas?	Spanish	2012
Latin America and the Caribbean	Revista Chilena de Nutrición	Paper	Seguridad alimentaria en Colombia y modelo rasch	Spanish	2012
Latin America and the Caribbean	Revista de Salud Pública (Bogota, Colombia)	Paper	Seguridad alimentaria: Un método alterno frente a uno clásico	Spanish	2010
Latin America and the Caribbean	Revista Chilena de Nutrición	Paper	Validéz factorial, consistencia interna y reproductibilidad de la escala de seguridad alimentaria en hogares de Bucaramanga, Colombia	Spanish	2009

Latin America and the Caribbean	Bmc Public Health	Paper	Internal validity of a household food security scale is consistent among diverse populations participating in a food supplement program in Colombia	English	2008
Latin America and the Caribbean	European Journal of Clinical Nutrition	Paper	Psychometric properties of a modified US-household food security survey module in Campinas, Brazil	English	2008
Latin America and the Caribbean	Revista de Nutrição	Paper	Segurança alimentar e nutricional: Desenvolvimento de indicadores e experimentação em um município da Bahia, Brasil	Portuguese	2008
Latin America and the Caribbean	Bmc Public Health	Paper	The 18 household Food Security Survey items provide valid food security classifications for adults and children in the Caribbean	English	2006
Latin America and the Caribbean	Public Health Nutrition	Paper	Self-administration of a food security scale by adolescents: Item functioning, socio-economic position and food intakes	English	2005
Latin America and the Caribbean	Cadernos de Saude Publica	Paper	Validación de escalas de seguridad alimentaria y de apoyo social en una población afro-colombiana: Aplicación en el estudio de prevalencia del estado nutricional en niños de 6 a 18 meses.	Spanish	2005
Latin America and the Caribbean	Archivos Latinoamericanos de Nutrición	Paper	Valoración de informadores clave sobre el plan de acción de las políticas de seguridad alimentaria en Colombia.	Spanish	2005
Oceania	Food Policy	Paper	Impact of water scarcity in Australia on global food security in an era of climate change	English	2013
Oceania	Regional Environmental Change	Paper	Dangerous climate change in the Pacific Islands: Food production and food security	English	2011

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