Direct contributions of dry forests to nutrition: a review

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SUMMARY

Globally, micronutrient deficiencies are more prevalent than calorie and protein deficiencies. In order to address global micronutrient deficiencies, increasing attention is being paid to the nutritional quality of people's diets. While conventional agriculture is key for ensuring adequate calories, dietary quality depends on the consumption of a diverse range of micronutrient rich foods. Many wild foods are rich in micronutrients, particularly fruits, vegetables, and animal source food. As a result there has been increasing interest in the value of wild foods to meeting nutritional requirements.

We review literature on the consumption of wild foods in dry forest areas to assess the current state of knowledge as to how dry forests may contribute to nutrition. We focus on papers that quantify consumption of wild forest foods. Although there is a great deal of literature that lends weight to the notion that dry forests are important for food security and nutrition, we find surprisingly little evidence of direct contributions to diets. Of 2514 articles identified by our search, only four quantify the consumption of wild foods from dry forests, and only one of these puts this consumption in the context of the entire diet. There is a need for research on the nutritional importance of dry forest foods which combines methodologies from nutrition science with an understanding and appreciation of the ecological, social, cultural and economic context.

Keywords: nutrition, dry forests, micronutrient, wild foods, bushmeat

Contribution directe des forêts sèches à la nutrition: une analyse

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Les carences en micro-substances nutritives sont globalement plus présentes aujourd'hui que les carences en calories et protéines. Pour faire face à ces carences globales en micro-substances nutritives, une attention croissante est accordée à la qualité nutritionnelle des régimes personnels. Alors que l'agriculture traditionnelle est essentielle pour assurer l'octroi de calories adéquates, la qualité des régimes dépend de la consommation d'un éventail varié d'aliments riches en micro-substances nutritives, tels que les fruits, les légumes et les aliments à base animale. Il en résulte un intérêt croissant porté à la valeur des aliments sauvages pour assouvir les besoins en micro-substances nutritives.

Nous étudions la littérature sur la consommation des aliments sauvages dans les zones de forêts sèches pour évaluer l'état actuel de la connaissance de la manière dont les écosystèmes forestiers secs peuvent contribuer à la nutrition. Nous nous concentrons exclusivement sur les contributions directes aux régimes dans les situations où les aliments sauvages en provenance des forêts sèches ont été quantifiés. Bien qu'il existe une large quantité de littérature appuyant la notion que les forêts sèches sont importantes pour sécuriser les aliments et la sécurité nutritionnelle, nous trouvons une surprenante faible quantité de preuves d'une contribution directe aux régimes. Sur les 2514 articles identifiés dans notre recherche, seuls quatre quantifient la consommation d'aliments sauvages provenant des forêts sèches, et un seul d'entre eux place cette consommation dans le contexte d'un régime complet.

Nous recommandons un focus renouvelé sur l'importance nutritionnelle des aliments des forêts sèches, combinant la méthodologie des sciences nutritionnelles avec une compréhension et une appréciation des contextes écologiques, sociaux, culturels et économiques.

Las contribuciones directas del bosque seco a la nutrición: una revisión

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En la actualidad, las deficiencias de micronutrientes son más frecuentes a nivel mundial que las deficiencias calóricas y proteínicas. Con el fin de abordar las deficiencias mundiales de micronutrientes, se está prestando cada vez más atención a la calidad nutricional de las dietas de las personas. Mientras que la agricultura convencional es clave para asegurar las calorías necesarias, la calidad de la dieta depende del consumo de una amplia gama de alimentos ricos en micronutrientes. Muchos alimentos silvestres, como las frutas, las verduras y los alimentos de origen animal, son ricos en micronutrientes. Como resultado, se ha observado un interés creciente en el valor de los alimentos silvestres para alcanzar los requisitos nutricionales.

Se revisa la literatura sobre el consumo de alimentos silvestres en zonas de bosque seco para evaluar el estado actual del conocimiento en cuanto al modo en que los ecosistemas de bosque seco pueden contribuir a la nutrición. Nos centramos exclusivamente en aquellas contribuciones directas a las dietas en las que se ha sido cuantificado el consumo de alimentos silvestres procedentes del bosque seco.

Aunque existe una gran cantidad de literatura que apoya la idea de que el bosque seco es importante para la seguridad alimentaria y la nutrición, sorprendentemente encontramos pocas pruebas de contribuciones directas a las dietas. De los 2 514 artículos identificados mediante nuestra búsqueda, sólo cuatro cuantifican el consumo de alimentos silvestres del bosque seco, y sólo uno de estos enmarca este consumo dentro del contexto de la dieta total.

Recomendamos la renovación del planteamiento sobre la importancia nutricional de los alimentos del bosque seco, mediante la combinación de metodologías de las ciencias de la nutrición con una comprensión y apreciación del contexto ecológico, social, cultural y económico.

INTRODUCTION

The forest and conservation literatures have tended to focus on the indirect contributions of forests to food security through their contribution to income as well as their safety-net functions (Arnold 2008, Wunder *et al.* 2014, Angelsen *et al.* 2014). A small but growing body of research, however, is highlighting the important nutritional contributions of forest foods (Arnold *et al.* 2011, Sunderland *et al.* 2013, Powell *et al.* 2013, Ickowitz *et al.* 2014). Foods from trees and forests such as fruits, vegetables and bushmeat are rich in micronutrients (Arnold *et al.* 2011) and can often be acquired cheaply and easily without the need for significant capital investment. As a result, in many areas they can constitute an essential source of nutritious foods for poor and remote populations, unable to access market sources of food either due to poor infrastructure of lack of purchasing power (Sunderlin *et al.* 2008, Colfer 2008).

Food security policy is also increasingly focused on nutritional quality in addition to energy adequacy (FAO 2012), reflecting research showing that energy deficiency is not the leading cause of malnutrition. Ensuring access to nutritionally important foods such as fruits, vegetables and animal source foods is particularly important for preventing micronutrient deficiencies (FAO 2012, Black *et al.* 2013). Agricultural intensification, expansion, and rising household incomes are unlikely on their own to yield sufficient improvements to dietary quality (Graham 2008, DeClerck *et al.* 2011, Ruel and Alderman 2013, Subramanyam *et al.* 2011). As a result, the contributions biodiversity makes to nutritional intake are receiving increased attention.

Recent reviews have demonstrated widespread usage of wild foods but have focused primarily on knowledge, use and nutritional composition of wild foods, and not on contributions to human nutrition (Penafiel *et al.* 2011, Bharucha and Pretty 2010). Given the growing evidence of associations between tree cover and improved dietary intake (Ickowitz *et al.* 2014, Johnson *et al.* 2013), and the lack of studies measuring consumption or intake of forest foods and their contribution to nutrition, we have sought to review the evidence of how dry forests contribute to nutrition through the consumption of wild foods. This review examines the contribution of wild foods to nutrition within one type of forested landscape. We focus solely on the contribution to nutrition of wild foods from dry forests where direct links between the collection of wild forest foods and consumption have been established.

We focus on dry forests for several reasons. First, dry forests are extremely under-researched relative to humid forests. Despite dry forests accounting for nearly half of the world's tropical and sub-tropical forests, a very small proportion of studies conducted in forests are conducted in dry forest regions (Murphy and Lugo 1986). Secondly, there is reason to suspect that dry forests play a key role in diets and nutrition. Not only are population densities and NTFP usage typically high in dry forests (Murphy and Lugo 1986), these populations are also amongst the most vulnerable and least food secure people in the world (Wunder 2001). Thirdly, these populations are likely to experience some of the severest effects of climate change (Parry *et al.* 2004, IPCC 1997) including crop failures and water-shortages (Wheeler and von Braun 2013, WWC and AWC 2009). Dry forests therefore may be of critical importance in enhancing the adaptive capacity of people to cope with current and future crises (Shackleton and Shackleton 2012, Pramova *et al.* 2012, Fischer *et al.* 2008).

METHODS

An initial literature search was carried out in April 2013 using Google Scholar and ISI Web of Knowledge, with a second search carried out in September 2014 to catch newly published articles. Further studies were identified through references from previous publications and reviews.

Search terms were divided into two parts: a dry forest term and a food security term. Dry forests terms covered words used to describe dry forests in the existing literature as well as local names for dry forest types. These terms were combined with those found in nutrition and food security literature as well as more general terms such as "food" in order to pick up non-specialist literature that might meet inclusion criteria. The search string used was ("dry forest*" OR "dipterocarp forest*" OR "semi-deciduous forest*" OR "monsoon forest*" OR "semi-desert" OR "miombo" OR "Chaco" OR "forest* savannah" OR "wood* savannah") AND ("food$" OR "wild food$" OR "nutrition*" OR "bushmeat" OR "vegetable$" OR "fruit$" OR "food security" OR "diet*"). We included only English-language, primary field studies undertaken in dry forests areas in our review. Peer-reviewed studies as well as grey literature from respected organizations were included. We used the definition of dry forests established by Mooney *et al.* (1995) of an area with >10% tree cover that experiences severe or absolute drought for several months in the year. Studies with mixed landscapes that included dry forest areas were included in the review if the analysis distinguished between land use types.

All articles in our search were assessed according to two criteria (see Table 1). The compulsory requirement for inclusion (level 1) requires that the study must be a primary research study quantifying (by weight, number or frequency) the consumption of wild foods from dry forests. All articles were additionally assessed against a second level of additional criteria (level 2) based on whether they show the impact of the consumption of these foods on either a) the overall diet; or b) the nutritional status of individuals. In order to show an impact on overall diet, there needs to be a comparison between forest and non-forest foods or some reference to the importance of forest foods relative to other sources of foods. In order to show a contribution of dry forest foods towards an individual's nutritional status, a study needs to report anthropometric measurements (e.g. height for age, weight for age etc) or biochemical tests of nutritional status.

A study was deemed to meet level 2 inclusion criteria if is met all of the requirements under level 1 and at least one of the three additional requirements.

RESULTS

Our search string returned 2,501 results in ISI Web of Knowledge and an additional 13 articles were identified from other sources. Of these, 1050 articles were considered sufficiently relevant to review and were screened by title and abstract leaving 45 articles assessed against the inclusion criteria. No additional studies were identified from Google Scholar that were not found in the Web of Knowledge search.

Overall, four studies met the minimum inclusion criteria of which, one study only met any of the additional inclusion criteria. Figure 1 shows the sequential review process although each article included was assessed against all criteria. Overall, of the 43 articles included in the review, the most frequent reason for non-inclusion in the review was the lack of quantitative data on the consumption of wild foods (n=34) followed by lack of evidence that forest foods were consumed (n=20) and unclear or unstated information regarding the source of the food (n=16). Of studies that documented the consumption of wild foods in dry forest areas, 22% of articles (n=5) did not specify clearly that wild foods were from forest areas or did not disaggregate foods by source (such as scrubland, hedgerows, ditches, weeds or between agricultural fields).

Of the four studies that met our inclusion criteria (see Table 2), two studies documented the consumption of bushmeat (Santos-Fita *et al.* 2012, Altrichter 2006), one the consumption of wild edible plants (Delang 2006) and one study documented the consumption of wild fruits (Campbell 1987). No studies were identified which attempted to quantify all forest-source wild foods consumed. Two studies used some form of dietary recall methodology (Campbell 1987, Delang 2006) whilst the other two estimated per capita or per household consumption. Differences were also found in the units of quantification used. Two studies quantified the consumption of wild foods in kilograms per year, either at the individual or the household level (Santos-Fita *et al.* 2012, Delang 2006), one by the frequency of consumption (Altrichter 2006) and one by the number of plants consumed (Campbell 1987). The quantities of wild forest products consumed ranged from none (Campbell 1987) to approximately one third of all meat consumed (Altrichter 2006).

Description of included studies

Campbell (1987) surveyed 225 households in the Condo region of Zimbabwe. Food consumption data were collected using 24-hour recall methods. Although 95% of respondents reported that their family regularly consume wild fruits, no consumption of wild fruits was found in the 24-hour recall survey.

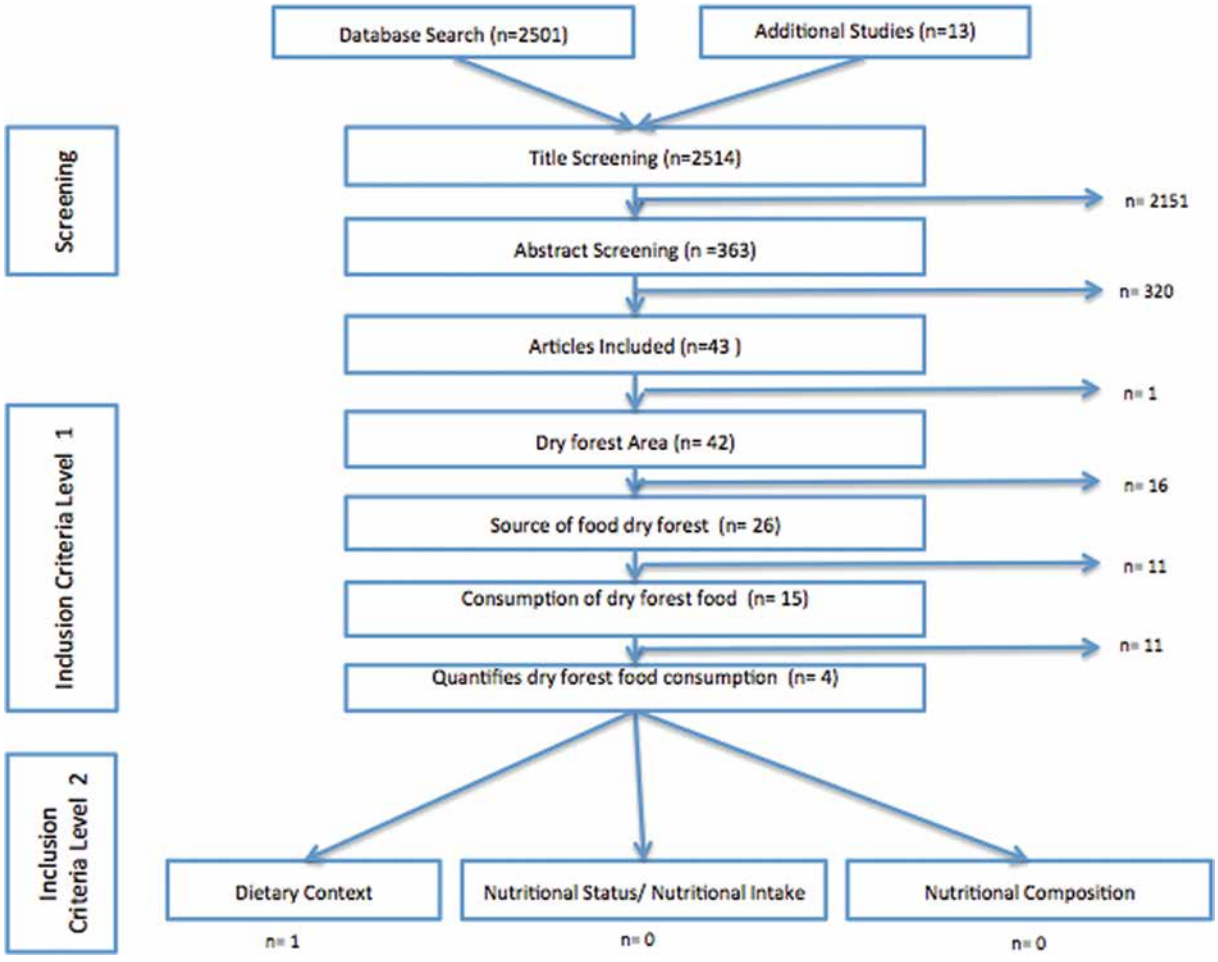
In Thailand, Delang (2006) used a 12-month recall survey with forest-dwelling Karen in western Thailand. Overall, 134 species of wild edible plants were identified by informants, consisting of leaves, stems, roots, fruits, flowers and shoots.

TABLE 1 *Inclusion Criteria*

Inclusion Criteria	**Compulsory Requirement (Level 1)**	**Additional requirement (Level 2)**
Primary field study	✓	✓
Dry forest area or self-reported dry forest	✓	✓
Source of food dry forest	✓	✓
Consumption of dry forest food documented	✓	✓
Consumption of dry forest food quantified (amount and/or frequency)	✓	✓
Contribution of dry forest food to diet in context of overall diet		✓*
Contribution of dry forest food to dietary adequacy		✓*
Assessment of nutritional status		✓*

* Either or

FIGURE 1 *Review Process*



An estimated 176 kg of leaves, 115 kg of stems and 133kg of fruit was consumed per household per year, but no details were given as to the significance of this in diets of the Karen.

Altricher (2006) used a combination of interviews and records collected by households to study the dietary and economic importance of wildlife in the Argentine Chaco and provided information not only on the quantity of bushmeat consumed, but also the contribution it makes to diets relative to other sources of meat. In rural households, wild meat was consumed on average 7.7 days per month contributing to 27.5% of days where meat was consumed, a comparable proportion to beef (29.7%) and goat (27.8%) and significantly more than chicken (13.2%) and pork (1.8%). The consumption of wild meat and domestic meat were negatively correlated with wild meat consumed during the hotter months due to the difficulty of storing meat.

Santos-Fita *et al.* (2012) quantified both the collection and consumption of bushmeat, estimating that 10,190 kgs of bushmeat were collected annually, with local people consuming an average of 4.65 kg person^{-1} year^{-1}, in rural areas of the Yucatan Peninsula. Data were collected via hunting records, participant observation, conversations and interviews.

TABLE 2 *Studies included in the review*

Study	Study Area	Food	Focus of Study	Research Method
Altrichter (2006)	Argentina	Bushmeat	Dietary and Economic importance of wildlife	Interviews and Records
Campbell (1987)	Zimbabwe	Wild Fruits	Importance of wild fruits to food security	24-hr recall
Delang (2006)	Thailand	Wild Edible Plants	Economic rational for consumption of wild food plants	12 Month Recall
Santos-Fita *et al.* (2012)	Mexico	Bushmeat	Importance of wildlife for subsistence	Interviews

DISCUSSION

Studies meeting inclusion criteria

Our inclusion criteria are much stricter than previous reviews on wild foods and nutrition (e.g. Penafiel *et al.* 2011, Bharucha & Pretty 2010) as we limited our review to one type of forested landscape as well as requiring studies to quantify consumption of forest foods.

To understand the direct contribution of forests to nutrition, the consumption of forest foods must be placed within the context of the overall diet. In places where diets are lacking in quality or quantity, a relatively small amount of forest foods can make a substantial contribution to peoples' diets; conversely, where people have ready access to a diverse range of food, even a moderate amount of forest food might not make a large contribution to overall diets. Only one study met any of the additional inclusion criteria by putting the consumption of wild forest foods into context by comparing their contribution against other sources of foods. For example, despite wild meat providing roughly one third of the total meat consumed in some areas of the Argentine Chaco, meat consumption in the area is generally high, even among those who did not consume bushmeat, and there was a ready availability of meat for purchase from livestock and from markets. Future research featuring a comparison of people who eat wild meat to those who do not in terms of prevalence of micronutrient deficiencies would improve our understanding of the nutritional importance of wild meat.

In some cases were the quantity of forest foods consumed is reported by weight it is possible to calculate post hoc, the contribution towards dietary guidelines. For example, the 79 kg of plant food consumed on average per person per year by the Karen in Thailand (Delang 2006) equates to roughly 54% of 400 g per person per day guidelines for fruits and vegetables as recommended by the World Health Organisation and the Food and Agriculture Organisation (WHO/FAO 2003). Likewise, although there are not internationally recognised minimum guidelines for intake of animal source foods, some context can be added to the figures though comparisons with maximum recommendations and randomized control trials trials. For example, the 4.65 kg of bushmeat consumed per person per year in the Yucatan Penisula, Mexico as reported by Santos-Fita *et al.* (2012) equates to roughly 18% of the maximum meat consumption guidelines recommended by World Cancer Research Fund (WCRF 2007), and 21% of the meat intake proven in randomized controlled trials to improve nutrition and cognition in malnourished children (Neumann *et al*. 2007). Such calculations highlight the importance of researchers reporting the consumption of wild foods in standardized units. Future research directly quantifying forest source foods and non-forest source foods should clarify the significance of such quantities within the context of within the context of dietary guidelines.

Several methodological challenges emerged from the review that deserve closer examination. Survey tools used to examine the contribution of wild foods in dry forest areas should reflect the highly seasonal nature of the landscape. Whilst the gold-standard for nutritional surveys is the 24-hour recall method (Thompson and Byers. 1994, Jonnalagadda *et al.* 2000), the only study included in our review that used this method (Campbell 1987) reported zero consumption of wild fruits. This finding was surprising given that 95% of the sample stated that their family regularly consumed wild forest foods. Within the context of highly seasonal environments such as dry forests, consisting of periods of heavy rain and seasons of serious drought, one-off recall surveys, as in the case of Campbell (1987), are likely to miss important periods of forest food dependence when forest foods are used as a safety net in times of shortage. At the other end of the scale, 12 month recall surveys are prone to significant recall bias as, the ability to recall events, and to provide quantitative estimates, diminishes rapidly with time (Delang 2006, Bernard *et al.* 1984). Two of the included studies used records kept by household members (either food diaries or hunting records) and corroborated information by cross-checking through participant observation, randomized interviews and conversations (Santos-Fita, Naranjo, and Rangel-Salazar 2012, Altrichter 2006). This approach proved to provide very good "overall picture" of food consumption patterns though lack the depth required for detailed nutrition analysis. Where possible, a combination of methods utilizing 24-hour recall surveys at multiple times of the year, combined with interviews, discussions and participant observation should be used for future research.

Studies not meeting inclusion criteria

Of the papers identified using our search terms, only four met the inclusion criteria we set for providing information needed to assess the contribution dry forests make to nutrition. Our inclusion criteria were deliberately stricter than inclusion criteria used in previous reviews of wild foods and nutrition (e.g. Penafiel *et al.* 2011, Bharucha & Pretty 2010) to identify studies which could definitively show direct contributions to nutrition. The small number of studies meeting the criteria clearly shows the need for more focused research showing the *extent* to which forest foods contribute to nutrition. The wide range of studies not included do however contribute significantly to our understanding of food security in dry forested landscapes through examining other pathways to food security.

The most frequent reason for not meeting our inclusion criteria was the non-reporting of quantified consumption data. Some such studies are however useful to understand the scale patterns of forest food use. For example, Kalaba *et al.* (2009) conducted household surveys among communities in the Miombo woodlands of Zambia, revealing that 97% of households collected wild fruits, and 46% of households consumed

[1] Based on the combined quantities of leaves, stems and fruits consumed for a an average household size of 5.3 individuals per person (as reported in Delang 2006).

these fruits in the form of juices or porridges. Similarly, Martin *et al.* (2012) quantified the proportion of households consuming bushmeat, showing that over 80% of respondents had consumed bushmeat within the 12 months Tanzania.

Another frequent reason for non-inclusion was unclear or unstated sources of wild foods. The non-reporting of specific sources of food is understandable. For many researchers, the focus of interest is the consumption of "wild foods" or "off-farm" foods and the general contribution that biodiversity makes to income and food consumption. Such research is of importance because traditional economic, agricultural and food security studies often neglect this important dimension of household income and food security (Scoones *et al.* 1992, Angelsen *et al.* 2014). Such research has wide implications for conservation management and food security policies, but more specifics about the diverse types of habitats from which foods are collected need to be included in landscape level planning for conservation and food security.

Research on wild foods and nutrition is spread over a wide range of disciplines including anthropology, economics, geography, food science and nutrition, each with its own specific research focus. Understandably therefore, research often touches different pathways to food security. Ethno-botanical research dominates the literature of wild edible plants, much of which takes the form of lists of species given by respondents along with botanical identification, sometimes including rankings of usefulness for various purposes, including food[2]. The perceived usefulness of a wild food, is a good indicator of its importance to a community as a food source but does not necessarily reflect its nutritional importance.

Many studies that did not meet our criteria, took an economic approach to understanding the importance of wild forest foods either to local livelihoods and incomes or national economies[3]. Some studies also examined the trade of wild forest foods and the contributions they make to food security beyond the communities doing the harvesting[4]. There is a substantial literature on the contribution of non-timber forest products, including food, to income (Sunderlin *et al.* 2005, Angelsen *et al.* 2014), However, whilst income is an essential component of food security, the relationship between income and the consumption of nutritious foods is complex and does not necessarily lead to better nutritional status (Subramanyam *et al.* 2011, Banerjee and Duflo 2007, Jensen and Miller 2011). Indirect pathways to food security such as income are outside the scope of this review.

Nutrient composition analyses of wild foods were also commonly identified by our search terms[5] though no such studies that we reviewed also quantified their consumption. The nutritional composition of wild foods is undoubtedly important, but without knowledge of whether and *how much* of these foods are being consumed, their contribution towards dietary adequacy and nutritional status is impossible to determine. Often nutrient composition analysis was combined with ethno-botanical research on famine foods, showing their nutritional suitability to tide over periods of shortage (e.g. Do Nascimento *et al.* 2012). Other studies reported correlations between periods of food shortages and increased consumption of wild forest foods, suggesting an important role of forest foods as famine foods, but did not quantify their consumption (e.g. Humphry *et al.* 1993).

CONCLUSION

Although the contribution of dry forests to food security and nutrition is frequently cited, there is startlingly limited empirical evidence that actually documents the extent of this contribution. Only one study that quantified the consumption of wild foods from dry forests also compared with the consumption of non-forest source foods (Altrichter 2006). No studies were found that quantified the contribution of wild foods from dry forests to meeting dietary adequacy or the effects of eating wild foods upon nutritional status. Four studies did however quantify the consumption of forest foods. Studies which quantified the consumption of dry forest foods varied dramatically in the level of contribution from zero consumption (Campbell 1987) to making up over a third of meat intake (Altrichter 2006). In reality, the contributions of dry forests are likely to vary greatly between communities and seasons as well as the local ecological, economic, social and cultural context. Even low consumption levels of micro-nutrient rich foods can have significant impacts on the nutritional status of individuals when diets are generally lacking in nutritional quality. However, without knowledge of the dietary context of the consumption of wild foods such contributions are impossible to judge.

We identify three issues in the existing literature which make it difficult for us to reach definitive conclusions about the contributions of dry forests to nutrition. First, there is a general failure in the literature to report the quantity or frequency of consumption of wild foods. This means that the contributions that wild foods make to the diets of people living near dry forests are impossible to estimate. Second, there is a lack of detail in the site descriptions included in many of the papers, making it difficult to establish the nature of the study site or the source of the foods. Many studies do not identify the location as dry forest and/or do not provide sufficient details on the forest type and climate of the study region to infer the presence of dry forest (such information is

[2] For good examples see (Camou-Guerrero *et al.* 2007, Suárez *et al.* 2011, Kala 2009, Somnasang *et al.* 1998, Somnasanc *et al.* 2000).
[3] See (Blessings *et al.* 2006, Cavendish 2000, Tibuhwa 2013, Schulte-Herbrüggen *et al.* 2013).
[4] See (Ndabikunze and Masambu 2010, Moreno-black and Price 1993, Moreno-black *et al.* 1996, Tibuhwa 2013).
[5] See (Do Nascimento *et al.* 2012, do Nascimento *et al.* 2013, Smith *et al.* 1996, Saka and Msonthi 1994, Murray *et al.* 2001, Ndabikunze and Masambu 2010, Scarpa 2009, Carvalho *et al.* 2011, Nordeide *et al.* 1996).

absent from virtually all standard nutrition publications). Finally, much of the research relevant to food security is being conducted through the lens of ethno-botany/ethno-biology, economic studies on NTFPs, and social science studies on knowledge and preferences. There is a need for focused studies that apply standard food security and nutrition methodologies such as dietary intake measurement (through 24-hour recalls, food frequency questionnaires, and weighted records), anthropometric measurements of stunting and wasting, and biochemical markers of nutrition. This needs to be complemented by an awareness of ecological context and explicit investigation of sources of food. In order to be able to address food insecurity and malnutrition, we need to first understand what it is that poor communities are eating and where these foods come from.

In summary, while it is likely that dry forests provide an important contribution to food security through multiple pathways, there is little evidence that quantifies the direct contribution to diets and nutrition, even at local scales. It is clear that many communities all over the world depend on the provision of wild dry forest foods but evidence is too scant to meaningfully comment on the number of communities or the scale of their dependence on forest foods. Due to our strict inclusion criteria, the evidence provided herein may paint a more conservative picture of the actual relationships between dry forests and food security. Evidence of the importance of wild foods from dry forests comes from a number of disciplines, each adding important perspectives and insights. Future research should be multi-disciplinary in nature, place greater emphasis on human nutrition, and take into account the ecological and cultural contexts of diets.

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