# The contributions of wild tree resources to food and nutrition security in sub-Saharan African drylands: a review of the pathways and beneficiaries[1]

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SUMMARY

Wild tree resources are known to play an important role in local stakeholders' livelihoods particularly in the food and nutrition security of people living in semi-arid sub-Saharan Africa. Based on a comprehensive review of the literature, this article examines the relative importance of the contributions of tree resources to food and nutrition security for rural households, while considering alternative causal pathways. The main conclusions of the review are that most studies provide useful evidence on specific contributions of tree products to food and nutritional security, and for whom. However, detailed data on the actual contribution of tree products are still lacking. In addition, we argue that the concept of access as a pillar of food security is not sophisticated enough to understand the landscape dynamics and the socio-economic relations at the nexus of food security and rights of access. Links are needed to better understand the underlying processes in the definition of each stakeholder's rights of access to tree resources in a context of rapidly changing landscapes, and how income generated by tree resources contributes to food and nutrition security. An approach to food security based on rights of access would advance our understanding of their use and tackle the root causes of food deficiency based on different social groups. In light of current patterns of access to tree food for different stakeholders, including women and children, an intersectional approach that accounts for age, gender, ethnicity and wealth would benefit food security research by a more targeted and discerning approach to existing rights of access and to the roles of different community members.

Keywords: wild tree food, dietary diversity, rights of access, gender, sub-Saharan African drylands

## La contribution des ressources arborées sauvages à la sécurité alimentaire et nutritionnelle dans les régions semi-arides d'Afrique sub-saharienne: une revue de littérature des chemins d'impact et des bénéficiaires

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Les ressources des arbres non cultivés interviennent de manière conséquente dans les moyens d'existence et plus particulièrement la sécurité alimentaire et nutritionnelle des habitants des régions semi-arides d'Afrique Sub-Saharienne. L'article s'appuie sur une revue de la littérature pour examiner l'importance relative de la contribution des produits des arbres à la sécurité alimentaire et nutritionnelle, ainsi que les différents canaux de causalité à l'œuvre. La revue fait ressortir deux résultats principaux. Un premier constat est que la plupart des études fournissent des éléments pertinents sur certaines modalités spécifiques de contribution des produits des arbres à la sécurité alimentaire et nutritionnelle, ainsi que sur les bénéficiaires. Cependant, il manque des données détaillées sur les niveaux de contribution effectifs. D'autre part, nous mettons en évidence que le concept d'accès, communément utilisé comme un des piliers de la sécurité alimentaire, est trop général pour comprendre les dynamiques paysagères et les relations socio-économiques qui sous-tendent le nexus entre droits d'accès aux ressources non cultivées et sécurité alimentaire. Un modèle relationnel plus élaboré est nécessaire pour mieux comprendre comment se définissent les droits d'accès aux ressources arborées pour différentes parties prenantes, dans un contexte de changement rapide des paysages, et comment, de l'exercice de ces droits d'accès, découlent des ressources alimentaires ou des revenus monétaires qui ont un impact sur la sécurité alimentaire et nutritionnelle des populations. Une approche de la sécurité alimentaire basée sur la théorie des droits d'accès permettrait de mieux comprendre la diversité des usages des ressources par différents groupes sociaux, et de trouver des solutions plus adaptées pour améliorer la sécurité alimentaire. Une approche intersectionnelle prenant en compte les différences d'accès aux ressources arborées non cultivées en fonction, entre autres, de l'âge, du genre, de l'ethnie et du niveau de richesse, permettrait d'approfondir les connaissances existantes sur la sécurité alimentaire et de développer des approches plus ciblées sur les rôles et les enjeux pour différentes parties prenantes, y compris les femmes et les enfants.

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## Las contribuciones de los recursos de árboles silvestres a la seguridad alimentaria y nutricional en las tierras secas del África subsahariana: examen de las vías de acceso y los beneficiarios

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Se sabe que los recursos arbóreos silvestres desempeñan un papel importante en los medios de subsistencia de las comunidades locales, en particular en la seguridad alimentaria y nutricional de las personas que viven en el África subsahariana semiárida. A partir de una revisión detallada de la literatura, este artículo examina la importancia relativa de las contribuciones de los recursos arbóreos a la seguridad alimentaria y nutricional de los hogares rurales, al tiempo que considera vías de acceso alternativas. Las principales conclusiones de la revisión son que la mayoría de los estudios proporcionan pruebas útiles sobre las contribuciones específicas de los productos arbóreos a la seguridad alimentaria y nutricional, y para quién. Sin embargo, todavía faltan datos detallados sobre la contribución real de los productos arbóreos. Además, se postula que el concepto de acceso como pilar de la seguridad alimentaria no es lo suficientemente sofisticado como para comprender la dinámica del paisaje y las relaciones socioeconómicas en el nexo entre la seguridad alimentaria y los derechos de acceso. Se necesitan vínculos que permitan comprender mejor los procesos subyacentes en la definición de los derechos de acceso de cada interesado a los recursos arbóreos en un contexto de paisajes que cambian rápidamente, y cómo los ingresos generados por los recursos arbóreos contribuyen a la seguridad alimentaria y nutricional. Un enfoque de la seguridad alimentaria basado en el derecho de acceso nos permitiría comprender mejor su utilización y abordar las causas más profundas de la carencia de alimentos en función de los diferentes grupos sociales. A la luz de las actuales pautas de acceso a los alimentos de los árboles por parte de las diferentes partes interesadas, como las mujeres y los niños, un enfoque intersectorial que tenga en cuenta la edad, el género, la etnia y la riqueza sería beneficioso para la investigación sobre la seguridad alimentaria, para un enfoque más específico y exigente de los derechos de acceso existentes y para las funciones de los diferentes miembros de la comunidad.

## INTRODUCTION

In 2018, more than 820 million people in the world went hungry and the number increases every year. Hunger is on the rise in almost all sub-regions of Africa, and the prevalence of undernourishment has reached levels of 22.8% in sub-Saharan Africa (SSA) versus 11% worldwide. The term 'food insecurity' not only covers undernourishment but also nutritional deficiencies that can severely impair both physical and cognitive development. Its prevalence is estimated to be approximately twice as high as undernourishment alone (Ickowitz *et al.* 2019). Six hundred million people (two people out of three) in sub-Saharan Africa experience moderate or severe food insecurity measured using the food insecurity experience scale (FIES) (FAO *et al.* 2019). As defined by the World Food Summit (1996), food security exists when people have at all times physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. Thus, the concept is broad, multi-dimensional and too complex to assess with a simple indicator. That is why four components, or pillars, have been developed to address the global concept in a more appropriate and functional way. The four pillars are (i) the availability of sufficient quantities of food of appropriate quality, including own production and foraging; (ii) access to adequate resources to acquire appropriate food, including income or right of access; (iii) the utilization of food as the socio-economic aspects related to the choice, preparation and knowledge of food. This pillar highlights the importance of non-food inputs in food security, such as the diversity of the diet and intra-household distribution of food; and (iv) stability as a cross cutting dimension that includes the fact that the three other pillars must be fulfilled at all times (figure 1).

Food security in SSA drylands may be challenged by the effect of climate variability on crop production (e.g. changes in rainfall leading to drought or flooding, or rainfall stopping during the rainy season, thereby reducing yields) (Challinor *et al.* 2007, Kotir 2011, Thornton *et al.* 2011). This effect affects all the components of food security (Gross *et al.* 2000): availability, accessibility, utilization (Thompson *et al.* 2010) and stability (Challinor *et al.* 2007, Sultan *et al.* 2013). Hence, it increases the risk of hunger and malnutrition in these regions. But food security is also challenged indirectly through land degradation, changes in markets, food prices and in the supply chain infrastructure (Gregory *et al.* 2005, Thompson *et al.* 2010).

SSA drylands including regions in western, eastern and southern Africa are understood here in relation to agrarian systems, and thus include cropping and herding. Some studies have examined food insecurity in SSA drylands in all its complexity combining the four pillars of food security. However, to date, the main focus has been on the availability and accessibility of food supplied by rain-fed agriculture (Cooper *et al.* 2008, Tittonell and Giller 2013) or mixed crop-livestock systems (Thornton and Herrero 2014), and to a lesser extent by irrigated crops (Cassman and Grassini 2013), produced either directly on the farm or obtained indirectly thanks to income (earned from on-farm or off-farm activities) and access to markets (Frelat *et al.* 2016).

Even though trees are omnipresent in the SSA dryland landscapes, both inside and outside cropped areas, their contribution to food security is often treated separately in the food security literature. Two explanations are possible.

First, trees have been associated with soil fertility in semi-arid SSA for decades. In agroforestry studies, the main link between trees and food security in SSA is seen as a way to reduce soil erosion, increase soil fertility and crop yields and hence food availability and accessibility (Sanchez 2002, Garrity *et al.* 2010, Akinnifesi *et al.* 2011, Mbow *et al.* 2014) as well as to provide people with a direct supply of food that grows on agroforestry trees (Jamnadass *et al.* 2011).

Second, another body of literature linking trees to food security has emerged since the mid-1990s (Pimentel *et al.* 1997, Vinceti *et al.* 2008) because certain researchers consider that agro-ecosystems are too frequently separated from other natural landscape ecosystems. They believe insufficient attention is paid to the way in which services can flow to and from the agro-ecosystem to surrounding ecosystems (Poppy *et al.* 2014). This body of literature has increased notably recently, calling for integrative approaches, for more attention to be paid to the role of wild trees in food security and nutrition in tropical countries and for further analysis of food security at the landscape level (Sunderland *et al.* 2013, Vinceti *et al.* 2013, Vira *et al.* 2015). However, this body of literature mainly considers the contribution of wild trees to dietary diversity, and the link with foraged tree products, whereas the quantity consumed and their contribution to ingested nutrients as components of the diet has rarely been discussed (Termote *et al.* 2014, Rowland *et al.* 2015). Still, the four pillars of food security (availability, access, stability and utilization) are not absent from this second corpus. The contribution of wild tree resources follows the same structure as the contribution of agriculture to food security and nutrition. Like agricultural products, tree products can be consumed or sold, require labor, contribute to empowerment or depend on prices, and in that way, follow the same agriculture-nutrition pathways (Haddad 2000, Pandey *et al.* 2016). That is why tree resources are progressively being more frequently included in the concept of agricultural biodiversity, which corresponds to the crops, animals and plants managed by farmers (Jones 2017). Wild tree and forests products can contribute to food security and nutrition in two main ways. When consumed, they can improve both the diet and dietary diversity. Nuts, fruits, leaves, roots of trees, and tubers on the one hand, and bushmeat, honey, mushrooms, and insects on the other, are crucial sources of micronutrients in many rural communities (Vinceti *et al.* 2008, Sunderland 2011, Kehlenbeck *et al.* 2013, Boedecker *et al.* 2014, Powell *et al.* 2015).

In addition, wild tree products also contribute to food security because they can be sold and provide cash income for households and individuals. Such sales play a key role in the case of the most vulnerable people for whom wild products may represent safety nets, as marketable goods to buy food (Angelsen and Wunder 2003, Shackleton and Shackleton 2004, Paumgarten 2005, Shackleton *et al.* 2011, Wunder *et al.* 2014, Koffi *et al.* 2016). Further, some evidence has been found for an indirect link between food security, gender and access to common resources, showing that access to common resources (woodlands and pastures) reduces the probability that female-headed households face food insecurity. This evidence confirms a safety net effect specific to female-headed households, although it is not specific to dry areas (Delvaux and Paloma 2018). These two main ways led to the food and nutrition security issue being taken into consideration at the landscape scale, in the living and daily activity spaces of rural people in semi-arid sub-Saharan Africa (Powell 2012, Padoch and Sunderland 2014, Powell *et al.* 2015).

In the broader sense, Gautier *et al*. (2006) defined a SSA dryland landscape as a repetitive combination of landscape elements including housing, *champs de case*, permanent and temporary fields, in which agroforestry parklands, barren fields, fallow land, dry forests or woodlands, that interact according to the agrarian system and to the pattern of the "terroir" concerned (Bassett *et al.* 2007). In this review, we focus on how wild tree resources provided by all the interacting landscape elements contribute to food security.

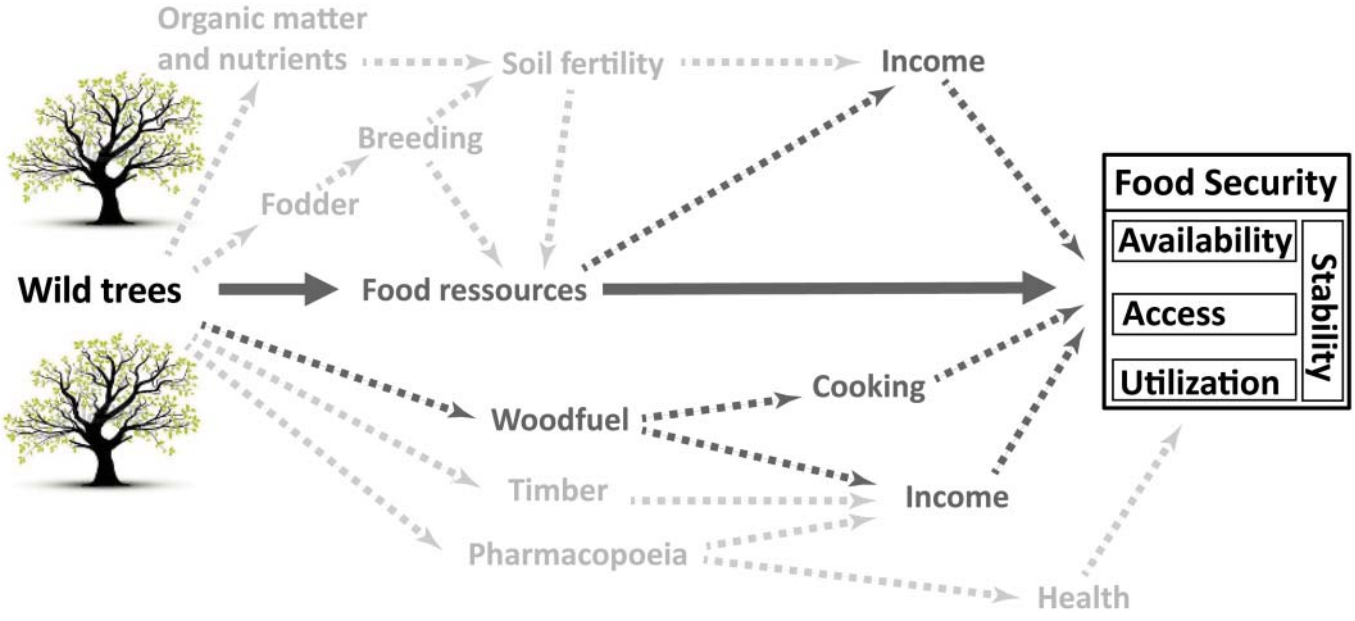
We assume that one of the most important causes of people's exposure to food insecurity in the rural areas of SSA drylands is increasing climate variability (Gregory *et al.* 2005, Mertz *et al.* 2009, Kotir 2011, Gautier *et al.* 2016) as it influences people's coping strategies and their use of tree resources in facing food insecurity. However, we also acknowledge that the food insecurity experienced by many farmers in SSA drylands is not necessarily due to a climatic event. People can experience food insecurity for many other reasons including not having produced enough or having sold too much of their food stocks before the new harvest season, and not having any other ways to access food, i.e. other agricultural or non-agricultural sources of income. On the other hand, they can cope with a bad climatic season or a small harvest thanks to their capacity to buy food when they have off-farm activities (selling their labor force, selling tree resources or livestock they have accumulated as a buffer against shocks and stress, etc.), social networks such as local mutual aid or remittances from migrant family members. Investigating the contribution of tree resources to food insecurity in SSA drylands also requires understanding the complex structures and causes of people's vulnerability and the social, economic and political power games at play (Watts and Bohle 1993, Bohle *et al.* 1994, Misselhorn 2005, Baro and Deubel 2006, Harragin 2006, Watts 2013) as well as the adaptive strategies available to cope with food insecurity (Liwenga 2003, Davies 2016).

In this paper, we investigate the contribution of trees to food security and nutrition in the SSA drylands as reported in the literature according to the four pillars of food security. We pay particular attention to the rights of access to tree resources in each landscape element that affects the outlook for food and nutrition security for particular social groups, including the poor, women, and children, and to the use of any income generated by tree resources to improve diet.

## METHOD

Our review focuses on papers that seek to demonstrate a direct link between wild tree products and food security in rural areas of sub-Saharan African drylands, whether by improving the quantity or the diversity of food, and regardless of whether the pathway is direct (tree products are included in people's diets) or circuitous through income generation (tree products are sold and the proceeds of the sales are used to purchase food). Other pathways are mentioned when useful, but without going into detail (Fig. 1).

FIGURE 1 *Pathways between wild trees and food and nutritional security (in dark gray the pathways that are the core of the review)*




Although some meta-analyses of this corpus are general, we focused our review on drylands in sub-Saharan Africa, and only case studies conducted in semi-arid and dry sub-humid zones are included. SSA drylands can be found in western, eastern and southern Africa, where woody vegetation is already well characterized as dry forests, woodlands or savannahs, depending on the region (Timberlake *et al.* 2010). Climate variations in the three regions display similarities but also differences (Hulme 1996) as reported by Salack *et al*. (2016) in West African drylands; Camberlin *et al.* (2009) in eastern Africa; and Crétat *et al*. (2012) in southern Africa. Broadly speaking, SSA drylands can be defined by an aridity index (AI = mean annual precipitation / mean annual potential evapotranspiration) ranging between 0.03 and 0.65 (Zomer *et al.* 2008). However, because neither hyper-arid zones (AI of < 0.03) nor arid zones (0.03 < AI < 0.20) can support crop and livestock production and are very sparsely populated by trees, these zones are not relevant for this particular study on food security. We consequently narrowed our investigations to an area characterized by an AI of between 0.2 and 0.65 covering semi-arid and dry sub-humid zones. This choice is not only ecologically coherent but is also linked to the issues of access to resources and food security.

Regardless of the region, climate anomalies can affect the cropping season and disrupt food production through fluctuations in seasonal temperatures and precipitation and the uncertainty of both the quantity and timing of water availability: low total rainfall, delayed onset of the rains, unexpected drought periods during the rainy season, drought at the end of the rainy season, but also floods. However, when it comes to food security issues, a distinction needs to be made between the 'lean season' or the 'food shortage period' that affects the most vulnerable people almost every year and a 'food crisis', which is often linked to a drought event, like in the Sahel (1972–73, 1983–84, 2008, 2011) and affects most people, although less frequently.

Our review was mainly based on the identification of relevant scientific papers using the search engine "Google Scholar". Many key words are used to describe tree resources associated with diet in drylands. They may be related to trees, e.g. savanna, woodlands, forest, but also to nature and the wild. We combined these key words with those found in the literature on food security and adaptation to climate change. The search string used was ("tree" OR "woodland" OR "parkland" OR "savanna" OR "miombo" OR "forest" OR "nature" OR "wild" " OR "NTFP") AND ("food security" OR "nutritional security" OR "dietary diversity" OR "dietary intake" OR "diet" OR "food" OR "fruits") AND ("coping strategies" OR "drought" OR "adaptive strategies" OR "vulnerability" OR "climate change" OR "climate variability" OR "food shortage" OR "famine" OR "safety net" OR "income" OR "market"). Based on these criteria, a total of 278 articles were downloaded and analyzed. We first ranked them by analyzing the title and the abstract of all 278 papers. We then selected 150 articles that specifically address the contribution of tree resources to food and nutrition security in SSA drylands. After reading these 150 papers, we selected 110 that were clearly focused on our review topic (Table 1).

In each of the 110 papers, we investigated: (i) the nature of the contribution of tree resources to people's diets according to the four pillars of food security (availability, utilization, stability, access) (table 2); (ii) the stakeholders concerned by the study; (iii) the landscape elements people used to gather tree resources for food consumption or to generate income to purchase food; (iv) the evidence provided and the evidence that would have been useful to better understand the coping strategies used to face food insecurity.

TABLE 1 *Distribution of the 110 selected papers according to the region of SSA*

| SSA regions | Number of relevant papers |
|---|---|
| Southern Africa | 41 |
| Eastern Africa | 35 |
| Western Africa | 26 |
| The SSA as a whole | 8 |

TABLE 2 *Distribution of the 110 selected papers according to the four pillars of food security (some papers deal with more than one pillar)*

| Food security pillars | Number of relevant papers |
|---|---|
| Availability | 31 |
| Utilization | 30 |
| Access | 39 |
| Stability | 30 |

We added other papers not identified by the Google search string but that we found useful: (1) scientific reviews focused on a more global geographical level than SSA drylands or a more global analysis of food security in SSA drylands than the contribution of trees; (2) papers on neighboring topics such ecosystem regulation services provided by trees; (3) papers highlighting some processes at play in the relationship between the wild tree resources and food and nutrition security, for example, power relationships in access to tree food resources.

## THE CONTRIBUTION OF TREE RESOURCES TO FOOD AND NUTRITION SECURITY: MAIN RESULTS AND TRENDS

### Tree resources contribute to food security by providing a supplement to staple food all year long (pillar: availability)

In SSA drylands, staple foods like cereals (maize, sorghum, millet, rice) and in rare cases, tubers, ensure the supply of essential energy to rural people, while wild tree resources, mainly fruits, seeds and leaves, together with cultivated legumes, fruits and vegetables, or livestock provide the ingredients for the sauces that accompany staple foods and snacks (Greffeuille and Mouquet Rivier 2010, Bricas and Akindès 2012).

Tree resources are significant sources of food as dietary supplements throughout the year, in addition to the other foods that make up the diet, rather than as substitutes for the diet (Zinyama *et al.* 1990, Johns and Kokwaro 1991, Lamien *et al.* 1996, Shava 1999, Mertz *et al.* 2001, Lykke *et al.* 2002, Shackleton *et al.* 2002, Cocks and Wiersum 2003, Twine *et al.* 2003, Mojeremane and Tshwenyane 2004, Msola 2007, Kalaba *et al.* 2008, Ekesa *et al.* 2009, Guigma *et al.* 2012, Pouliot 2012, Njana *et al.* 2013, Boedecker *et al.* 2014, Rowland *et al.* 2015). Most edible tree products are eaten as part of the normal diet, rather than because nothing else is available. Rural households use different tree resources to meet their daily food needs (Shackleton and Shackleton 2004), including leaves, roots, nuts, seeds and fruits. These resources are consumed either raw or cooked or are dried and stored for future consumption.

Dried or fresh leaves, fresh or processed fruits provide the basis for the sauces and condiments that accompany the staple foods, depending on the season. In the season when the trees produce fruits and leaves, the sauces may be more diverse than in the dry season (Savy *et al.* 2006). However throughout the year, combined with some vegetables that may also be dried such as gombo, *Corchorus spp*. or *Hibiscus spp*., a limited number of tree products are essential components of the sauce, like baobab leaves or *Parkia biglobosa* seeds for West Africa (Mertz *et al.* 2001), *Strychnos madagascariensis* and *Sclerocarya birrea* fruits in South Africa (Shackleton *et al.* 2000). In addition to their contribution to sauces and condiments, people eat tree products as snacks between their main meals, when walking between two places, collecting fuelwood, herding livestock (Njana *et al.* 2013), or children on their way to school (Ogle and Grivetti 1985).

When farmers spare standing trees in their fields in SSA drylands, in many cases, it is because they use the trees are a source of food (Faye *et al.* 2010, Okiror *et al.* 2012, Kehlenbeck *et al.* 2013). In Boulgou province in south-eastern Burkina Faso, wild vegetables (mainly provided by three trees) account for between 35% and 59% of total vegetable consumption (Mertz, Lykke, et Reenberg 2001). In this province of Burkina Faso, the main source of edible fats and oil is the fruit of the Shea tree (*Vitellaria paradoxa*) (Okafor 1980, Pouliot 2012). In Tanzania, although only 3% of food items consumed are wild foods obtained from the bush, 15% of items consumed are wild species, mostly foraged on farmland (Powell 2012). In rural Zimbabwe, tree resources are part of a basket of natural resources used to supplement staple food in periods of food shortage (Mithöfer and Waibel 2003).

As a result of the importance of some wild tree products in food security and nutrition in SSA drylands, the pressure on them is increasing despite some evidence for an increase in the woody cover in these regions (Hiernaux *et al.* 2009, Brandt *et al.* 2017). Except for baobab trees that are being increasingly planted in the *champs de case* so that their tenure is secure, rights of access and rights of use of agroforestry products are becoming more and more restricted, particularly in the agroforestry parkland areas in the western and eastern SSA drylands (Rocheleau and Edmunds 1997, Rousseau *et al.* 2016).

### Tree resources contribute to food security in periods of food shortage (pillar: stability)

In addition to the microclimatic effects of trees and the soil-tree-crop interactions that increase crop production in agroforestry parklands (Sileshi *et al.* 2007 for the Miombo eco-region; Asfaw *et al.* 2015 for Malawi; Bayala *et al.* 2015 for the West African Sahel; Sida *et al.* 2018 for the Central

Rift Valley in Ethiopia; Kuyah *et al.* 2019 for a meta-analysis on SSA), tree products contribute directly to food security in periods of food shortage (usually the end of the dry season and the wet season in the three SSA drylands. In these periods, tree food resources are generally abundant, with fresh fruits and leaves that serve as a buffer in difficult food conditions, such as in the case of crop failure (Harris and Mohammed 2003, Musinguzi *et al.* 2006). Tree food resources are all the more important for the diets of people living in SSA drylands because they are available in the lean season before people's granaries are filled with the yield of new crops (Campbell 1986, Vainio-Mattila 2000, Faye *et al.* 2010, Atato *et al.* 2011, Mwema *et al.* 2012, Powell 2012, Poole *et al.* 2016). During periods when rural households have limited or no stocks of food (Chileshe 2005, Lamien *et al.* 2005), tree resources play a significant role in food security particularly for the poor (Guinand and Lemessa 2000, Fentahun and Hager 2009, Feyssa *et al.* 2011, Chakona and Shackleton 2019).

In the lean season, tree food resources are generally only eaten as a supplement and as a source of food diversity, and not as a substitute for staple food. Among the 110 papers we examined, none clearly stated that tree food resources are consumed as substitutes for staple food crops during the annual lean season. Only two mentioned that households reported consuming resources from the dry forest as substitutes for crops during food shortage periods (Corkill 1949, Fisher *et al.* 2010) but the resources were wild yams, which is not a tree food resource, as also reported by Mortimore (1989: 74). In regions where food trees such as *Ficus spp.* are common in the cropping areas for cultural reasons, they can be used a substitute for staple foods in the case of famine. In northern Cameroon, Seignobos (1989) and Dury (1997) reported that *Ficus spp.* represented a reserve of fruits that were converted into porridge in lieu of cereals in periods of food shortage.

Otherwise, there is little evidence in the literature for the use of wild tree food as a substitute for regular food during periods of food shortage. Among the 110 papers analyzed, only four compared the consumption of wild food in the lean season with that in another season (Campbell 1987, Matiza *et al.* 1988, Powell *et al.* 2013, Maseko *et al.* 2017). In a village in the low-rainfall area of Zimbabwe, Matiza *et al*. (1988) investigated if wild food consumption differed in stress free periods and food shortage periods, and reported that less than one-third of the respondents said they increased their consumption of wild foods in food shortage periods. Again in Zimbabwe, Campbell (1987) found that people intentionally selected fruits in periods that are not particularly rich in fruit because they needed supplementary foods in periods of seasonal food shortages. In Tanzania, Powell *et al.* (2013) suggest that in both the wet and lean season, local people make greater use of wild resources (the percentage of wild foods from all sources and wild foods from the forest in the diet almost doubled), than in the rest of the year, when cash is more available and people are able to purchase more food items. In rural Malawi, during food insecure periods, some children relied to a great extent on wild food, such as insects or a mixed dish of wild vegetables as a meal (Maseko *et al.* 2017).

Tree food resources become "famine food" when the food shortage period becomes serious (Shackleton and Shackleton 2004). In rural Namibia, the more a household suffers from food insecurity, the more likely it becomes that its members will harvest wild fruits as food supplements (Musaba and Sheehama 2009). However, the consumption of tree products to face food shortage is usually part of a set of on-farm and off-farm coping strategies such as reducing the number of meals, spending savings and consuming less balanced meals (Agyei and Asumadu 2019, Aniah *et al.* 2019).

**Tree resources contribute to food security because they increase the dietary quality (pillar: utilization)**

Tree resources generally contribute to dietary quality and micronutrient intakes (Smith *et al.* 1996, Powell 2012, Boedecker *et al.* 2014). In the literature on linkages between dietary diversity and agricultural biodiversity, tree resources are sometimes taken into account when the trees grow in agroforestry parkland. Empirical studies (Herforth 2010 in Kenya and Tanzania; Powell 2012 in Tanzania; M'Kaibi *et al.* 2015 in Kenya; Bellon *et al.* 2016 in Benin) found a positive correlation between agricultural biodiversity and individual dietary diversity. However, these studies often combined crops, tree resources and wild/semi-wild plants in a single indicator, making it difficult to identify the contribution of tree resources to improving dietary diversity. In Burkina Faso, Lourme-Ruiz *et al.* (2016) considered agroforestry trees separately from crops and found a positive correlation between women's dietary diversity and their consumption of fruits and leafy vegetables in May and August when they are ready to be eaten.

In Tanzania, Powell (2012) observed that individuals had better dietary diversity and consumed more animal source foods and nutrient dense food when they collected food from the forest. However, Powell reported that forest foods and wild foods provided only a small proportion of nutrients in the diet because they are rarely consumed. However, when these foods are consumed, they represent a significant source of protein, vitamin A and C, iron or calcium. Individuals who used foods from SSA dry forest and other woody land had more nutrient dense diets. For example, households located in more forested areas have improved vitamin A intake compared to households in areas with less forest cover in Malawi (Johnson *et al.* 2013, Hall *et al.* 2019) and in Tanzania (Powell *et al.* 2011).

Indeed, several studies in SSA drylands showed that tree products increase dietary diversity and provide considerable quantities of nutrients to rural people. These include the fruits of *Lannea microcarpa* (Achaglinkame *et al.* 2019), *Uapaca kirkiana* (Chivandi *et al.* 2015), *Azanza garckeana*, *Parinari curatellifolia*, *Gardenia erubescens, Diospyros mespiliformis*, *Balanites aegyptiaca* (Achaglinkame *et al.* 2019), *Parkia biglobosa* (Bayala *et al.* 2014, Vinceti *et al.* 2018), *Lannea*

*microcarpa*, *Saba senegalensis* (Bayala *et al*. 2014), *Vitellaria paradoxa* (Bayala *et al.* 2014, Vinceti *et al.* 2018), *Borassus aethiopum, Ziziphus spp*., the leaves and fruits of *Adansonia digitata* (Bayala *et al.* 2014, Boedecker *et al.* 2014, Chivandi *et al.* 2015, Vinceti *et al.* 2018), and the flowers of *Bombax costatum*. This is particularly true of children (Shackleton *et al.* 2005) who often consume them as snacks (Corkill 1949) on their way to school (Ogle and Grivetti 1985) or when herding livestock (Njana *et al.* 2013). The consumption of tree food resources improve dietary diversity and supply nutrients (vitamin C and sugar among others) of rural people and is particularly important during food shortage periods (Vivero-Pol *et al.* 2002, Loki and Ndyomugyenyi 2016).

However, although there is evidence that wild fruits and wild vegetables in SSA drylands are nutritionally rich (Glew *et al.* 1997, Msuya *et al.* 2008), there is also sociological evidence that they are consumed mainly because they are sweet rather than for their nutritional value (Shava 2000, Lykke *et al.* 2002, Simitu 2011, Moombe *et al.* 2014), or as processed products such as juices and alcoholic beverages (Shackleton *et al.* 2005, Musinguzi *et al.* 2006). In general, rural people have limited knowledge of the nutrient content of the tree food resource (Musinguzi *et al.* 2006), even if some elders recognise that they kept them healthy and long-living (Shava 1999). However, in some cases, the nutritional values of tree resources appear to be recognized. For example, Campbell (1987) reported that in rural Zimbabwe, when people were asked why they ate wild fruits, the respondents mostly said for their nutritional value (61%) and/or because they taste good (52%).

In addition to increasing the quality of the diet, tree resources are also indispensable as fuel for cooking (Gazull and Gautier 2015, Vira *et al.* 2015, Sharma *et al.* 2016) and the availability of woodfuel is a crucial part of nutritional transformation (Koffi *et al.* 2018). Woodfuel shortages can have negative nutritional effects, since efforts to economize on the use of wood can lead to a shift to less nutritional foods that need less woodfuel to cook.

### Tree resources contribute to food security as a source of direct dietary improvement or as a source of income to purchase food (pillar: access)

In SSA drylands, almost all household members (men, women and children) and all types of households are involved in the collection, consumption and/or trading of tree resources to generate income and ensure food security. However, the social perception of collecting and processing tree resources is usually that these are activities for the poor and for women (Kiptot and Franzel 2012). Preparing the condiments to accompany the staple dish is also considered to be a women's responsibility. However, men also play an important role in the contribution of forest resources to rural livelihoods (Sunderland *et al.* 2014), which, in turn, helps buy staple food, improves the diet, particularly in the shortage period and for the poor for whom the shortage period can be longer than for other households. Some studies also highlighted sales of wild foods by children in Ethiopia (Balemie and Kebebew 2006) and South Africa (McGarry and Shackleton 2009), where it appears to be particularly significant for vulnerable children.

*Contribution to improving the diet*

When it comes to improving the household diet, the importance of collecting tree resources varies with gender, age and health status, as demonstrated by our review. In our experience, it is unusual for men of any age, even those who wish to emancipate themselves from the farm household, to be involved in gathering wild tree products for household consumption. As far as food is concerned, their responsibility is limited to procuring staple food (Gausset *et al.* 2005). They may be involved in gathering woodfuel, fodder, gum arabic, resins, but except in the case of serious famine, rarely in collecting tree food.

The fact that women collect and process tree resources for their own family diet is much better documented in the literature. Women usually collect tree resources as a contribution to diet mostly in agroforestry parklands, where they have secured access to trees and, to a lesser extent, in fallows (Powell *et al.* 2013, Rousseau *et al.* 2016). Women may happen to collect some tree resources in woodlands when gathering wood. The collection of wild resources is important for their family's food diversification when the wild food is included in the sauces, and even more so when the lean period is severe. But it is also important for their livelihoods, as demonstrated by their involvement in collecting wild fruits in SSA drylands: in Sudan, in Rashad locality, all collectors of *Ziziphus spina-christi* fruit are women (Adam and Pretzsch 2010); in rural Burkina Faso, women are still the only family members involved in collecting and trading *Vitellaria paradoxa* fruits despite the globalization of the shea nut trade (Pouliot 2012, Rousseau *et al.* 2016); in northern Benin, women are also the main collectors and sellers of shea nuts (Schreckenberg 2004); in northern Ghana, women are the main actors involved in shea and locust bean collection, processing and sale (Poudyal 2009); and in Zimbabwe, women collect and sell indigenous fruit tree products to purchase household goods (Mithöfer and Waibel 2003). The income obtained by collecting and processing tree resources helps women diversify the household diet through market purchases, but also engage in expenses for their children's education and health care. In some cases, they can use the income from these sources to buy some staple foods (normally done by men) when staples become scarce during the lean period (Koffi *et al.* 2016). In rural South Africa, tree resources were shown to contribute more to the total household income in households headed by women than those headed by men (Clarke *et al.* 1996, Shackleton *et al.* 2007).

Children often help women collect and trade tree products and wild foods in general, e.g. in rural Ethiopia (Guinand and Lemessa 2000, Feyssa *et al.* 2011, Worku *et al.* 2011), in northern Nigeria (Harris and Mohammed 2003), in Botswana (Legwaila *et al.* 2011), in rural Malawi (Maseko *et al.* 2017), in rural South Africa (Dovie *et al.* 2002, Cocks and Wiersum 2003), and in rural Zimbabwe (Campbell 1987, Maroyi 2011). Dovie *et al*. (2002) also confirmed that the more female adults

and children there are in a household, the greater the value of the woodland resource products, e.g. wild fruits, collected.

Finally, and even though not very well documented to date, our own field knowledge in the West African drylands leads us to consider that the household members who make the best use of tree resources by eating wild fruits or collecting and selling them are children on their way to school, on their way to the field or when herding. In so doing, they supplement their diets in proteins and vitamins (Shackleton *et al.* 2002). Only a few examples exist of the impact of this supplementation because it is complicated to survey children's food intake when there are outside their homes, to assess the quantity of wild food they have eaten and the diet supplementation their obtain in this way. Some evidence does however exist confirming schoolchildren's use of edible wild food while walking long distances from their home to their school as they pass through different landscape elements on their way (Ogle and Grivetti 1985). This "free access" to food by nutritionally vulnerable groups (McGarry and Shackleton 2009) is crucial to balance certain deficiencies, as dietary diversity was shown to increase significantly when children consumed wild food. The linkages between children's free access to wild food and its impact on their nutritional balance requires further food security research.

This free access of vulnerable groups to food during a growth stage or during a crisis is important and is generally tolerated and accepted by local social norms and rules in different parts of the landscape. However, it can be hindered by specific social and economic factors. For instance, in South Africa, the impact of HIV/AIDS on the use of wild foods is ambivalent. Some studies suggest that it leads to an increase of the use and/or trade, of wild foods because less labor is available to cultivate the fields (Shackleton *et al.* 2006, McGarry and Shackleton 2009, Ncube *et al.* 2016); others that it reduces the use of wild food due to labor shortages and social stigma (Kaschula 2008).

*Contribution to income generation from tree resources to purchase food*

Tree resources in SSA drylands contribute significantly to income generation by rural households. Trade in non-timber forest products (NTFPs) is profitable when the formal market value of the products is significantly higher than their direct use value (Sardeshpande and Shackleton 2019). For example, in the Eastern Cape, South Africa, Roland and Oyelana (2014) showed that about 50% of the people extracted products for the purpose of income generation. In SSA drylands, households that sell tree products may earn 10% to 40% of their income from these products (Shackleton and Shackleton 2006 in the Kat River In South Africa; Akinnifesi *et al.* 2007 in South Africa; Bwalya 2011 in Zambia; Mulenga *et al.* 2011 in Zambia; Walelign and Nielsen 2013 in Mozambique; Worku *et al.* 2014 in south-eastern Ethiopia; Suleiman *et al.* 2017 in northern Nigeria).

Richer households obtain relatively more money from the sale of forest products than poorer households. Richer households often target high-value forestry activities such as trade in hardwood timber, while poor households often specialize in labor intensive and low-value forest products involving gathering and selling wild fruits (Bwalya 2011 in Zambia; Ouedraogo and Ferrari 2015 in Burkina Faso).

However, it is now well established that tree resources help reduce poverty in SSA drylands especially among the poorest (Fisher 2004, Mamo *et al.* 2007, Shackleton *et al.* 2007, Tschakert 2007, Babulo *et al.* 2008, Shackleton *et al.* 2008, Yemiru *et al.* 2010, Worku *et al.* 2014, Djoudi *et al.* 2015). Poor households are the most dependent on income from tree resources (Cavendish 2000 in Zimbabwe; Hautdidier and Gautier 2005 in Mali; Shackleton and Shackleton 2006 in south Africa; Kamanga *et al.* 2009 in Malawi; Mulenga *et al.* 2012 in Zambia; Neudeck *et al.* 2012 in Botswana) and in some cases, tree resources may be their primary source of income, and up to 40% of their total income when they specialize in wood extraction and sale, charcoal making, fodder, etc.

Households in rural areas in SSA drylands generate income from tree resources in both times of plenty and periods of food shortage, but few authors provide evidence for a clear link between the income generated by tree resources and food purchases. In the Borana region in Ethiopia, Abdulla (2013) showed that cash income from tree resources mainly supports current food consumption. Income generated from the sale of marula – *Sclerocarya birrea* – fruits in rural South Africa (Shackleton and Shackleton 2005) and from the sale of *Adansonia digitata* fruits*, Ziziphus spina-christi* fruits or *Balanites aegyptia* fruits in the savanna zone in South Kordofan State in Sudan (Adam *et al.* 2013) is also used to purchase food items to supplement the household diet.

These studies are clearly linked to the household's wealth level or to gender. Indeed, women's interest in trees focuses on their use-value for the household, such as finding the ingredients for the sauce accompanying meals in addition to generating income to pay for the children's education, health care and the daily domestic tasks such as feeding the household. In some cases, their social marginalization makes it more difficult for them to sell tree resources to purchase commodities, including food (Hyder *et al.* 2005). In addition, the actual use of the income derived from the sale of tree products is not always specified, but there is a strong assumption that women use it to buy food items for the family (Adedayo *et al.* 2010). In rural Mali, women spent their income from parkland trees on food, clothing, and children's school fees, while men used their income to cover wedding expenses, purchase agricultural equipment, and repair or purchase means of transport (Faye *et al.* 2010).

Concerning the contribution of income generated by the sale of tree resources to food security, only one paper out of 110 evaluated the caloric needs of people and stated that those who collected and sold tree resources enjoyed more food security than those who did not (Ibrahim *et al.* 2015). Otherwise, we found no peer reviewed papers that clearly addressed this issue by considering the use of income from the sale of tree resources to improve dietary diversity and nutrition in a "regular" climate season. Although several studies in SSA drylands reported that income generated from the sale of tree resources was used to buy food items and to supplement diet, none listed the food items purchased.

More papers documented income generation from trees growing in SSA drylands to buy food as an adaptive strategy to cope with food insecurity and malnutrition during periods of food shortage. Trading tree resources does not usually require a financial commitment and is thus particularly appropriate for the poor. Tree resources like gum arabic, resin (Worku *et al*. 2011), wood as fuel (fuelwood and/or charcoal) (Mamo *et al.* 2007, Koffi *et al.* 2016, Amakye 2017), shea nuts (Koffi *et al.* 2016) are sold in food shortage periods to purchase food items. This strategy is most widespread among the poor. In rural Malawi, poor households with no opportunities for a short term labor contract are most likely to trade forest-based items to obtain cash to buy food in periods of food shortage (Fisher, Chaudhury, and McCusker 2010).

The availability of tree resources in the surrounding landscape and the rights of access to – and the use of – these resources determine the best strategy used to cope with food insecurity. According to Koffi *et al.* (2016), during the food shortage period in 2012 that followed the dramatic rainy season in 2011 in Burkina Faso, depending on the landscape surrounding their village, poor households either cut wood or collected shea nuts to sell them in the market and buy cereals for household consumption. Tree resources were their primary source of income and the income was significantly higher than the income they obtained from tree resources during stress-free periods.

Despite the key contribution of income from tree resources to the purchase of food during food shortage periods, comparisons between this income and the budget dedicated to food purchases are lacking. Whether this source of income can buy enough food and maintain household food security in terms of per capita daily caloric intake is also insufficiently documented. Among the 110 papers we analyzed, none demonstrated that the income from tree resources sales was sufficient to purchase the food required to cover rural people's food needs during food shortage periods, nor compared the food security level of households who sold tree resources to buy food with that of those who did not.

It is also worth mentioning that the coping strategy of selling tree resources to buy food during the food shortage period can also affect people negatively. In north-west Namibia for example, Galloway *et al.* (2016) demonstrated that some households spent their income from the sale of tree resources to buy modern foods that are rich in fats and sugars or highly processed. These food purchases may increase the risk of diabetes, high blood pressure and cardiovascular diseases. This coping strategy is closely linked to the dynamics of the surrounding landscape and the tree resources present in the landscape. What is more, it can be challenged by competition between stakeholders. In the context of globalization, some tree resources may be grabbed by people who take advantage of a valuable market for industrial enterprises to trade or to supply cities with woodfuel or food (Rousseau *et al.* 2019).

*Access rights, land tenure and tree tenure*

Considering the accessibility dimension of indigenous tree resources leads to the conclusion that local people benefit more from tree products if they have right of access to these products (Ribot 2003). This study highlights the importance of considering rights of access to and rights to the use of tree resources to ensure food and nutritional security in SSA drylands. To date, few studies account for the landscape dimension and related stakeholders' rights of access to landscape elements and access to and use of tree products for food in SSA drylands. The processes behind the definition of these rights of access according to the type of landscape element and the choice to use tree products for diet improvement are poorly documented.

Some tendencies are revealed in the literature. In both formal and customary law, rights to trees may not match rights to the land on which trees grow (Bruce and Fortmann 1989, Chambers and Leach 1989). Physical access to tree resources depends on the location of trees in the landscape (Lamien and Vognan 2001, Coulibaly-Lingani *et al.* 2009, Adedayo *et al.* 2010), gender (Lamien and Vognan 2001, Coulibaly-Lingani *et al.* 2009, Adedayo *et al.* 2010, Gautier *et al.* 2019), ethnicity (Coulibaly-Lingani *et al.* 2009) and wealth (Bwalya 2011, Ouedraogo and Ferrari 2015). The rules of access to tree resources do not favor the use of these resources by the households that most need to address food insecurity. Generally, these households are the poorest, both financially and in terms of asset ownership. The rules of access to tree resources partly depend on the nature of the ecosystem or related landscape element. They are generally not the same in fields, fallow, savannah and in State forests. In State forests, the law is supposed to be the same for all. In practice, men dominate the exploitation of tree resources in these State forests because they have more time and financial resources to obtain an exploitation permit than women (Adedayo *et al.* 2010). In the African savannas, access is generally considered to be free by local people and stakeholders can collect the dead wood and fruits (Heubach *et al.* 2011). In fallow, access is much less restrictive than in cultivated fields. However, when tree resources are scarce, access to fallow is often forbidden. For migrants whose fallow lands have been loaned to them by autochthons, the migrants often do not have the right to collect the fruits of some trees in their fields (Poudyal 2009). In fields where the most important trees are protected by the households, access is prohibited. Only the owner of the field has the right to use and dispose of the trees in the field (Schreckenberg 1999, Poudyal 2009). In SSA drylands, households with less arable land per capita produce less food and are more likely to face food insecurity due to climate variability. To cope with food insecurity, they sometimes circumvent the restriction on access to fields belong to others through theft. Some will wake up very early in the morning to try to obtain some tree products in the fields. But their practices often lead to conflicts with the holders of rights to the resource. At the household level, women do not always have secure access to the trees in their own households' fields (Adedayo *et al.* 2010) and men may retain exclusive control over some trees (Coulibaly-Lingani *et al.* 2009). As women play a central role in the use of tree products to address food insecurity, this is a constraint that needs to be tackled (Fortmann and Rocheleau 1985, Rocheleau and Edmunds 1997).

## CONCLUSION

In sub-Saharan African drylands, tree resources are important for household food security, more particularly for dietary diversity, for all the household members but particularly for children. In these regions, trees provide foods that contain important nutrients for direct consumption. They also provide products that can be sold to buy staple food or missing condiments. Gathering, processing and selling tree resources are among the adaptive strategies used to face food insecurity. Women and children are the most actively involved in the collection and sale of tree products and women are more likely to use the income they make from selling tree resources to purchase food items for their household. Under several ongoing global processes including (i) climate change; (ii) population growth with an associated increase in the demand for food for urban populations and for croplands; (iii) world demand for some key food resources like shea nuts, pressure on tree resources is increasing and the rights of access to them are changing. These rights of access to and use of tree resources increasingly depend on the social status and the socioeconomic characteristics of the households and on the status of women within the household. These rules often fail to benefit the poor, or migrants, who are generally the most dependent on wild tree resources for their food security, particularly in periods of shortage. As SSA dryland landscapes are becoming increasingly dominated by agroforestry parklands with more restricted rights of access to trees, it is important that future research focuses on: (i) how children compensate for the loss of wild fruits that have disappeared with the clearing of woodlands and scarcity of fallows in terms of nutrients; (ii) how women who have restricted access to agroforestry parklands manage to diversify their diet, particularly during the food shortage period; (iii) and how households use income from the sale of woodlands products (woodfuel, fodder or wild fruits) to buy food. To tackle these research goals, we argue that despite the complexity of rights of access to trees, the food access pillar has not been sufficiently studied to understand the socio-economic and power relations at play in a context of rapidly changing landscapes. A secured access to food trees for nutritionally vulnerable groups seems vital to offset certain deficiencies by increasing dietary diversity. An approach based on rights of access to food security would help to tackle the root causes of food deficiency in different social groups. Furthermore, in the light of existing patterns of access to tree food for different stakeholders, for instance children, an intersectional approach that takes age, sex, ethnicity and wealth into consideration would benefit food security research, through a more targeted and differentiating approach based on existing rights of access and the roles of different members of the community. This needs to be reflected also in the way different disciplines are interconnected in the food security research to better understand the underlying processes at run in the definition of each stakeholders' rights of access to tree resources and the way income generated by tree resources sale contributes to food and nutritional security. It means a relevant theoretical and empirical background that has the potential to insert social relations and dynamic in studies on food and nutritional security.

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Annex 1. *Distribution of the 110 papers selected for review according to the location of the study*

| SSA countries | Number of relevant papers | References |
|---|---|---|
| South Africa | 22 | Chakona *et al*. 2019; Clarke *et al*. 1996; Cocks and Wiersum 2003; Dovie *et al*. 2002; Kaschula *et al*. 2008; McGarry and Shackleton 2009; Mertz *et al*. 2001; Ncube *et al*. 2016; Ogle and Grivetti 1985; Paumgarten 2005; Roland *et al*. 2014; Shackleton and Shackleton 2004; Shackleton 2011; Shackleton and Shackleton 2005; Shackleton and Shackleton 2006; Shackleton *et al*. 2005; Shackleton *et al*. 2007; Shackleton *et al*. 2008; Shackleton *et al*. 2002; Shava 1999; Shava 2000; Twine *et al*. 2003 |
| Ethiopia | 10 | Abdulla (2013); Babulo *et al*. 2008; Fentahun and Hager 2009; Feyssa *et al*. 2011; Guinand and Lemessa 2000; Mamo *et al*. 2007; Vivero-Pol *et al*. 2002; Worku *et al*. 2014; Worku *et al*. 2011; Yemiru *et al*. 2010 |
| Tanzania | 8 | Cordeiro 2013; Msola 2007; Msuya *et al*. 2008; Njana *et al*. 2013; ; Powell *et al*. 2011; Powell 2012; Powell *et al*. 2013; Vainio-Mattila 2000 |
| Burkina Faso | 10 | Guigma *et al*. 2012; Koffi *et al*. 2016; Lamien *et al*. 1996; Lamien *et al*. 2011; Lykke *et al*. 2002; Ouédraogo *et al*. 2015; Poole *et al*. 2016; Vinceti *et al*. 2018; Rousseau *et al*. 2016; Savy *et al*. 2006 |
| Zimbabwe | 5 | Campbell 1987; Maroyi 2011; Matiza *et al*. 1988; Mithöfer and Waibel 2003; Zinyama *et al*. 1990 |
| Botswana | 4 | Campbell 1986; Legwaila *et al*. 2011; Mojeremane and Tshwenyane 2004; Neudeck *et al*. 2012 |
| Kenya | 5 | Ekesa *et al*. 2009; Johns and Kokwaro 1991; M'kaibi *et al*. 2015; Mwema *et al*. 2012; Simitu 2011 |
| Malawi | 7 | Asfaw *et al*. 2015; Fisher 2004; Fisher *et al*. 2010; Hall *et al*. 2019; Johnson *et al*. 2013; Kamanga *et al*. 2009; Maseko *et al*. 2017 |
| Sudan | 4 | Adam and Pretzsch 2010; Adam *et al*. 2013; Corkill 1949; Ibrahim *et al*. 2015 |
| Zambia | 6 | Bwalya *et al*. 2011; Kalaba *et al*. 2008; Kalaba *et al*. 2013; Moombe *et al*. 2014; Mulenga *et al*. 2012 |
| Ghana | 6 | Achaglinkame *et al*. 2019; Agyei *et al* 2019; Amakye 2017; Aniah *et al*. 2019; Glew *et al*. 1997; Poudyal 2009 |
| Nigeria | 4 | Adedayo *et al*. 2010; Harris and Mohammed 2003; Okafor 1980; Suleiman *et al*. 2017 |
| Benin | 3 | Boedecker *et al*. 2014; Schreckenberg 1999; Schreckenberg 2004 |
| Namibia | 2 | Galloway *et al*. 2016; Musaba and Sheehama 2009 |
| Uganda | 2 | Loki and Ndyomugyenyi 2016; Musinguzi *et al*. 2006 |
| Mali | 2 | Faye *et al*. 2010; Hiernaux *et al*. 2009 |
| Togo | 1 | Atato *et al*. 2011 |
| Mozambique | 1 | Walelign *et al*. 2013 |
| Literature review (1 in Sahel, 6 in SSA, 1 in dry forest) | 8 | Akinnifesi *et al*. 2007; Bayala *et al*. 2014; Bvenura and Sivakumar 2017; Chivandi *et al*. 2015; Hyder et 2005; Kehlenbeck *et al*. 2013; Rowland *et al*. 2015; Sardeshpande 2019 |

Annex 2. *Distribution of the 110 selected papers according to the pillars of food security*

| Pillars of Food Security | Number of relevant papers | References |
|---|---|---|
| Availability | 31 | Abdulla 2013 (Ethiopia); Aniah *et al*. 2019 (Ghana); Boedecker *et al*. 2014 (Benin); Cocks and Wiersum 2003 (South Africa); Ekesa *et al*. 2009 (Kenya); Faye *et al*. 2010 (Mali); Guigma *et al*. 2012 (Burkina Faso); Hiernaux *et al*. 2009 (Mali); Johns and Kokwaro 1991 (Kenya); Johnson *et al*. 2013 (Malawi); Kalaba *et al*. 2008 (Zambia); Kehlenbeck *et al*. 2013 (SSA); Lamien *et al*. 1996 (Burkina Faso); Lamien *et al*. 2001 (Burkina Faso); Lykke *et al*. 2002 (Burkina Faso); Mertz *et al*. 2001 (Burkina Faso); Mithöfer and Waibel 2003 (Zimbabwe); Mojeremane and Tshwenyane 2004 (Botswana); Msola 2007 (Tanzania); Njana *et al*. 2013 (Tanzania); Ogle and Grivetti 1985 (South Africa); Okafor 1980 (Nigeria); Powell *et al*. 2011 (Tanzania); Powell 2012 (Tanzania); Rowland *et al*. 2015 (Dry forest); Savy *et al*. 2006 (Burkina Faso); Shackleton *et al*. 2002 (South Africa); Shackleton and Shackleton 2004 (South Africa); Shava 1999 (South Africa); Twine *et al*. 2003 (South Africa); Zinyama *et al*. 1990 (Zimbabwe) |
| Utilization | 30 | Achaglinkame *et al*. 2019 (Ghana); Aniah *et al*. 2019 (Ghana); Bayala *et al*. 2014 (Sahel); Boedecker *et al*. 2014 (Benin); Bvenura and Sivakumar 2017 (SSA); Campbell 1987 (Zimbabwe); Chivandi *et al*. 2015 (SSA); Corkill 1949 (Sudan); Feyssa *et al*. 2011 (Ethiopia); Galloway *et al*. 2016 (Namibia); Glew *et al*. 1997 (Ghana); Hall *et al*. 2019 (Malawi); Ibrahim *et al*. 2015 (Sudan); Johnson *et al*. 2019 (Malawi); Loki and Ndyomugyenyi 2016 (Uganda); Lykke *et al*. 2002 (Burkina Faso); McGarry and Shackleton 2009 (South Africa); M'Kaibi *et al*. 2015 (Kenya); Moombe *et al*. 2014 (Zambia); Msuya *et al*. 2008 (Tanzania); Musinguzi *et al*. 2006 (Uganda); Ogle and Grivetti 1985 (South Africa); Powell *et al*. 2011 (Tanzania); Powell 2012 (Tanzania); Simitu 2011 (Kenya); Vivero-Pol *et al*. 2002 (Ethiopia); Shackleton *et al*. 2005 (South Africa); Shackleton *et al*. 2002 (Sout Africa); Shava 1999 (South Africa); Shava 2000 (South Africa); Vinceti *et al*. 2018 (Burkina Faso) |
| Access | 39 | Adam and Pretzsch 2010 (Sudan); Adam *et al*. 2013 (Sudan); Adedayo *et al*. 2010 (Nigeria); Akinnifesi *et al*. 2007 (SSA); Babulo *et al*. 2008 (Ethiopia); Bwalya *et al*. 2011 (Zambia); Clarke *et al*. 1996 (Zimbabwe); Cocks and Wiersum 2003 (South Africa); Dovie *et al*. 2002 (South Africa); Fisher 2004 (Malawi); Harris and Mohammed 2003 (Nigeria); Hyder *et al*. 2005 (SSA); Kamanga *et al*. 2009 (Malawi); Kaschula *et al*. 2008 (South Africa); Koffi *et al*.2016 (Burkina Faso); Lamien *et al*. 2001 (Burkina Faso); Legwaila *et al*. 2011 (Bostwana); Mamo *et al*. 2007 (Ethiopia); Maroyi 2011 (Zimbabwe); Mulenga *et al*. 2012 (Zambia); Ncube *et al*. 2016 (South Africa); Ouedraogo *et al*. 2015 (Burkina Faso); Powell *et al*. 2013 (Tanzania); Neudeck *et al*. 2012 (Botswana); Poudyal 2009 (Ghana); Roland *et al*. 2014 (South Africa); Rousseau *et al*. 2016 (Burkina Faso); Sardeshpande *et al*. 2019 (SSA); Schreckenberg 1999 (Benin); Schreckenberg 2004 (Benin); Shackleton and Shackleton 2005 (South Africa); Shackleton and Shackleton 2006 (South Africa); Shackleton *et al*. 2007 (South Africa); Shackleton *et al*. 2008 (South Africa); Suleiman *et al* 2017 (Nigeria); Walelign *et al*. 2013 (Mozambique); Worku *et al*. 2014 (Ethiopia); Worku *et al*. 2011 (Ethiopia); Yemiru *et al*. 2010 (Ethiopia) |
| Stability | 30 | Agyei *et al*. 2019 (Ghana); Amakye 2017 (Ghana); Aniah *et al*. 2019 (Ghana); Asfaw *et al*. 2015 (Malawi); Atato *et al*. 2011 (Togo); Campbell 1986 (Botswana); Chakona *et al*. 2019 (South Africa); Cordeiro 2013 (Tanzania); Corkill 1949 (Sudan); Faye *et al*. 2010 (Mali); Fentahun and Hager 2009 (Ethiopia); Feyssa *et al*. 2011 (Ethiopia); Fisher *et al*. 2010 (Malawi); Guinand and Lemessa 2000 (Ethiopia); Harris and Mohammed 2003 (Nigeria); Kalaba *et al*. 2013 (Zambia); Maseko *et al*. 2017 (Malawi); Matiza *et al*. 1988 (Zimbabwe); Msola 2007 (Tanzania); Musaba and Sheehama 2009 (Namibia); Musinguzi *et al*. 2006 (Uganda); Mwema *et al*. 2012 (Kenya); Paumgarten 2005 (South Africa); Poole *et al*. 2016 (Burkina Faso); Powell *et al*. 2011 (Tanzania); Powell 2012 (Tanzania); Powell *et al*. 2013 (Tanzania); Shackleton and Shackleton 2004 (South Africa); Shackleton 2011 (South Africa); Vainio-Mattila 2000 (Tanzania) |