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BIODIVERSITY – FOOD SYSTEMS NEXUS: UNPACKING LINKAGES BETWEEN BIODIVERSITY, DIETS AND NUTRITION IN BURKINA FASO AND NIGER

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ABSTRACT

A growing body of evidence shows the strong linkages between biodiversity and food and nutrition security. However, there is a gap in knowledge on such linkages in developing countries, which are more affected by food insecurity and malnutrition. Moreover, it is not clear what are the implications of the ongoing biodiversity loss for food security and nutrition. In this context, the present review analyses the state of research on the nexus between biodiversity, diets and nutrition security in Burkina Faso and Niger. It draws upon a search of scholarly literature indexed in the Web of Science. The review suggests that there is a huge gap in research on this topic in both countries. In general, the literature shows a positive association between biodiversity and dietary diversity, nutrition and food security. Indeed, dietary diversity is affected by the variety of farm crops and animals, as well as foraged wild plants and trees. The pathways linking biodiversity and diets are context-specific. The effects of cropland expansion on dietary diversity are mixed and depend on farming systems diversity. The contribution of agrobiodiversity to nutrition is affected by the nutritional quality of products. Moreover, traditional knowledge plays a central role as an interface between biodiversity and dietary/food diversity. This review suggests that biodiversity is necessary for dietary diversity and nutrition security. Although still small, the existing body of evidence supports investments in agrobiodiversity to address food insecurity and malnutrition in Burkina Faso and Niger.

Keywords: *agrobiodiversity, crop diversity, animal diversity, dietary diversity, food security, nutrition, West Africa, Sahel.*

INTRODUCTION

According to the Convention on Biological Diversity (UNEP 1992), biodiversity (i.e. biological diversity) refers to "*the variability among living organisms from all*

sources, including, inter alia, terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems" (p. 27). Biodiversity refers to diversity at different scales of biological organization (genes, populations, species, and ecosystems) and multiple geographic scales (local, regional, or global) (Millennium Ecosystem Assessment 2005). Biodiversity is the foundation of ecosystems, which provide different services that are fundamental for human well-being. These include provisioning services (e.g. food, fibre, fuel, water), regulating services (e.g. climate, diseases, water quality), supporting services (e.g. nutrient cycling, soil formation, photosynthesis) and cultural services (e.g. aesthetic enjoyment, recreation, spiritual fulfilment) (Millennium Ecosystem Assessment 2005). The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) introduced recently a new concept, viz. Nature's Contributions to People (NCP) (Díaz et al. 2018), which is closely related to the ecosystem services concept. Food provisioning is one of the most important services delivered by ecosystems. Therefore, biodiversity loss can have high economic and social costs and increase poverty and hunger (Millennium Ecosystem Assessment 2005). In this context, agricultural biodiversity has always played a crucial role in sustaining and strengthening food security, nutrition, and livelihood security (Toledo and Burlingame 2006). However, the genetic diversity of food crops and animal breeds is diminishing rapidly (Millstone and Lang 2008).

Biodiversity loss is one of the most pressing challenges facing humanity. This explains why biodiversity conservation is addressed in many Sustainable Development Goals (SDGs) such as SDG 2 "Zero Hunger" and SDG 15 "Life on Land" (United Nations 2015). Humans rely on an increasingly limited number of plant and animal species for their nutrition. Indeed, only 30 crops provide 90% of dietary needs, with only three crops (viz. wheat, rice and corn) providing about half of the food consumed worldwide (FAO 2010). Likewise, fewer than 14 species (e.g. cattle, goats, sheep, chicken) account for about 90% of the global trade in animal products (Secretariat of the Convention on Biological Diversity 2008). The most important drivers of biodiversity erosion and loss are overexploitation (e.g. over-hunting, over-fishing), habitat change (e.g. land-use changes), climate change, pollution (nitrogen, phosphorus), and invasive alien species (Millennium Ecosystem Assessment 2005).

A growing body of literature links biodiversity to food and nutrition security (Burlingame et al. 2009; Fanzo et al. 2013; Foresight 2011; Toledo and Burlingame 2006). Indeed, agricultural biodiversity results instrumental to diversify diets and improve nutrition and health (Fanzo et al. 2013). This is particularly important to address the issue of micronutrient malnutrition (i.e. hidden hunger), which affects approximately 2 billion people worldwide (FAO et al. 2017). Diets simplification and the erosion of agro-biodiversity are responsible for nutrient deficiencies in many parts of the world (Johns and Eyzaguirre 2006). The strong linkage between biodiversity and nutrition is also acknowledged in the definition of sustainable diets (FAO 2011). However, it seems that the relationship between biodiversity and

dietary diversity, i.e. number of food items or food groups consumed over a given period of time (Ruel 2003), is not straightforward. For instance, El Bilali et al. (2017), in their analysis of the relationship between biodiversity and dietary diversity in the Mediterranean, found that despite a general decline in agricultural biodiversity, dietary diversity increased over recent decades, possibly reflecting greater affluence and the effects of globalization and agri-food trade.

However, it is assumed that the relationship between domestic biodiversity and diversity of diets changes from one country to another. Moreover, it can be posited that it is stronger in developing countries, especially landlocked countries that are less exposed to international agri-food trade. This makes the examples of Burkina Faso and Niger particularly interesting.

Burkina Faso and Niger are two landlocked West African and Sahelian countries. They have low human development (UNDP 2019), are affected by multiple forms of malnutrition (FAO et al. 2018; USAID 2018a, 2018b), and have a gap in terms of sustainable development (Sachs et al. 2017). Agriculture is a leading sector for the economies of Niger and Burkina Faso, with a significant contribution to the gross domestic product (GDP) and employment (World Bank 2019a). However, agriculture is extensive, poorly mechanized and almost entirely reliant on the variable summer rainfall, making it vulnerable to climate change. Staple dryland crops include cereals (e.g. sorghum, millet, maize) and legumes (e.g. cowpea), while major cash crops are cotton and groundnut (USAID 2017). Natural resources are deteriorating in a context of changing climate and recurrent droughts (USAID 2017). Climate change represents a challenge for agriculture (Mainardi 2011; Sultan et al. 2005; USAID 2017) and is also an important driver of poverty and livelihoods vulnerability. The prevalence of undernourishment is high (FAO et al. 2018), while deficiencies of micronutrients (e.g. iron, vitamin A, iodine) continue to affect the health and well-being of a wide share of the population in both countries (Institut National de la Statistique and ICF International 2013; USAID 2018a, 2018b).

In this context, the present review analyses the state of research on the nexus between biodiversity, diets and nutrition security in Burkina Faso and Niger.

METHODS

The present systematic review follows the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (Moher et al. 2009). It draws upon a search of all documents indexed in the Web of Science (WoS) carried out in May 2021 using the following Title-Abs-Key search query: *(biodiversity OR "species diversity" OR "genetic diversity") AND (diet OR consumption OR consumer OR nutrition OR intake OR nutrient) AND (Burkina OR Niger OR "West* Africa" OR Sahel).* The search on WoS yielded 147 documents. The selection of the documents to include in the systematic review was informed by the methodology suggested by El Bilali (2021; 2020). In particular, three eligibility criteria were considered: geographical coverage (viz. the document deals with Burkina Faso and/or Niger); thematic focus (viz. the document deals with

both biodiversity and diets); and document type (viz. only research articles, chapters or conference papers were selected; letters to editors, commentaries, notes as well as reviews were discarded). Only the documents that meet all the eligibility criteria were included in the systematic review. Table 1 describes the selection steps and process.

Table 1. Articles selection process.

Selection step	Number of selected documents	Number of documents excluded and exclusion reasons
Search on WoS	147	--
Screening of documents based on titles	147	45 documents excluded because they deal with other countries than Burkina Faso and Niger viz. Argentina, Benin, Botswana, Brazil, Cape Verde, Chile, China, Congo, Cote d'Ivoire, Ethiopia, Germany, Ghana, Guinea, Guinea-Bissau, India, Madagascar, Mali, Mauritania, Nigeria, Sao Tome, Saudi Arabia, Senegal, Switzerland, Togo, and UK.
Screening of documents based on abstracts	81	81 documents excluded: 35 documents do not deal with Burkina Faso and/or Niger; 5 documents do not address biodiversity; 41 documents do not deal with diets or nutrition.
Scrutiny of full-texts	22	6 documents excluded: 3 documents not addressing Burkina Faso and/or Niger; 1 document not addressing diets or nutrition; 2 reviews.
Inclusion in the systematic review	15	--

First, 45 documents were excluded following the screening of titles, as they do not refer to Burkina Faso and/or Niger; documents covering wider geographical areas (e.g. West Africa, Sahel, Sub-Saharan Africa,) or those where the geographical scope is not reported in the title were kept for further scrutiny. Second, 81 documents were excluded following the scrutiny of abstracts as they do not meet the eligibility criteria. Finally, 6 documents were discarded following the analysis of full-texts, including 2 reviews. Consequently, only 15 documents were included in the systematic review (Table 2).

Table 2. List of the eligible documents included in the systematic review.

Year	References
2021	Lourme-Ruiz et al. (2021)
2020	Morgan and Moseley (2020)
2019	Baudron et al. (2019)
2018	Félix et al. (2018); Sandwidi et al. (2018)
2017	Sunderland et al. (2017); Gaisberger et al. (2017)
2016	Poole et al. (2016); Agúndez Leal et al. (2016)
2015	Taylor et al. (2015)

Year	References
2021	Lourme-Ruiz et al. (2021)
2020	Morgan and Moseley (2020)
2019	Baudron et al. (2019)
2013	Stadlmayr et al. (2013); Barnaud et al. (2013)
2010	Garrity et al. (2010)
2009	Belem et al. (2009)
2003	Wahlqvist (2003)

RESULTS AND DISCUSSION

The low number of the selected documents suggests a huge gap in research on the relations between biodiversity, diets and nutrition in Burkina Faso, Niger and West Africa at large.

Many articles analyse the relationship between biodiversity in general, and agrobiodiversity in particular, and dietary diversity (Baudron et al. 2019; Lourme-Ruiz et al. 2021; Morgan and Moseley 2020). Indeed, the literature shows that the diversity of diets is affected by the diversity of farm crops and animals, as well as wild plants, forest trees and wild animals that households have access to and can use. Lourme-Ruiz et al. (2021) found that WDDS-10 (a women's dietary diversity score based on ten food groups) is positively associated with production diversity score (PDS) and the number of agroforestry trees species in farms of the Hauts-Bassins (western Burkina Faso). Therefore, the dietary diversity of women in farming households depends on the diversity of on-farm production (Lourme-Ruiz et al. 2021). Local farm management and crop associations provide opportunities to collect diverse nutrition-rich species year-round thus sustaining household nutrition in semiarid West Africa (Félix et al. 2018). Baudron et al. (2019) highlight that three pathways may link forests to diet diversity viz. direct pathway (forest products consumption), income pathway (forest-related income used to purchase food), and agro-ecological pathway (forests and farm trees sustaining on-farm food production). They found that the agro-ecological pathway was more plausible in Burkina Faso as greater forest cover in the landscape improved crop and livestock production. They conclude that the different pathways are not straightforward and context-specific (Baudron et al. 2019). Likewise, as highlighted by Lourme-Ruiz et al. (2021), the results of the assessment of the relationships between dietary diversity and agro-biodiversity depend on how agricultural biodiversity is evaluated i.e. indicators and metrics used.

In this context, particular attention is paid to foraging as a source of nutrient-rich wild plants (Belem et al. 2009; Morgan and Moseley 2020). Foraging can concern a wide range of wild plants such as herbaceous plants (Belem et al. 2009) and woody species (Agúndez Leal et al. 2016; Belem et al. 2009; Gaisberger et al. 2017). Belem et al. (2009) found that 43 tree, shrub, and annual herbaceous plant species are foraged in the community of Seguenega, northern Burkina Faso. In their analysis of the use of biodiversity by smallholder farmers in semi-arid West

Africa, Félix et al. (2018) put that "*Wild plants (i.e. grasses, shrubs, vines, and trees) collected from surrounding landscape play an important role in sustaining micro-nutrient accessibility at the household level*" (p. 83). Morgan and Moseley (2020) found that foraging represents an important source of micronutrients and dietary diversity for female farmers in Burkina Faso. However, foraging may lead to the overexploitation of food plants and trees thus their genetic erosion and loss (Belem et al. 2009; Gaisberger et al. 2017). Belem et al. (2009) point out that leafy wild food species are threatened by over-harvesting, animal browsing, cutting, and bushfires in Northern Burkina Faso. The use of the meat of wild animals (i.e. bushmeat) (Taylor et al. 2015) results particularly problematic; it certainly contributes to the food security of riparian communities, but represents a threat to wildlife.

The literature also addresses the effects of cropland expansion, especially mono-cropping, on agro-biodiversity and consequently dietary diversity. Morgan and Moseley (2020) suggest that rice New Green Revolution projects do not affect foraging in Burkina Faso. However, Sunderland et al. (2017) argue that the transition from a forested landscape to a more agrarian system might have unintended consequences such as the loss of dietary diversity and ecosystem services/forest products. Gaisberger et al. (2017) found that overexploitation and cotton production represent the most serious short-term threats to food tree species in Burkina Faso. Lourme-Ruiz et al. (2021) show that the relationship between cotton production and dietary diversity of women depends on the type of management; it was positively associated with WDDS-10 when managed by women but not when men managed cotton production (Lourme-Ruiz et al. 2021). However, changes in land use can also have positive impacts on biodiversity and food security. For instance, some land management approaches such as Evergreen Agriculture (Garrity et al. 2010) have allowed restoring exhausted and degraded soils, thus increasing food crop yields and improving household food security, in several Sub-Saharan Africa countries such as Burkina Faso (cf. pit technology, zai, along with farmer-managed regeneration of trees) and Niger (cf. *Faidherbia albida* agroforests in sorghum and millet fields).

The contribution of agro-biodiversity to nutrition is affected by the quality of agri-food products, especially their nutritional quality. In this context, food composition tables become fundamental to have precise data about the nutrient content of foods, including orphan crops and underutilized cultivars/varieties (Stadlmayr et al. 2013). Lourme-Ruiz et al. (2021) call for paying more attention to the nutritional quality of agri-food products in agriculture policy in Burkina Faso by providing support to the production of nutrient-dense crops (e.g. vegetables, fruits, beans), instead of focusing only on mass production of cotton and maize.

Some documents analyse the role of biodiversity in food security (Belem et al. 2009; Garrity et al. 2010; Poole et al. 2016). This relates to food availability and utilisation as well as food access. In fact, the use of biodiversity plays a crucial role in the livelihoods of many rural communities, especially those living close to forests and other biodiverse ecosystems. Agúndez Leal et al. (2016) suggest that

woody food species complement the diets of rural populations in Niger in times of food scarcity. Scholars also analyse different approaches that are supposed to reconcile the divergent objectives of food security, climate change mitigation/adaptation and biodiversity conservation such as Evergreen Agriculture (Garrity et al. 2010), an agroforestry system consisting in the integration of tree species into annual food crop systems. However, Baudron et al. (2019) warn that the positive contribution of forest ecosystems to rural livelihoods and food access/security cannot be generalized and change from one context to another.

Further documents highlight the central role of traditional knowledge (cf. culture, traditions) as an interface between biodiversity and dietary/food diversity (Sandwidi et al. 2018; Wahlqvist 2003). In fact, traditional, local knowledge and culture determine the way local biodiversity is used, especially in local cuisine (Wahlqvist 2003). This, in turn, determines the level of resource use sustainability. Women play an important role in the conservation and dissemination of knowledge on local agrobiodiversity and its use, especially that relating to neglected and underutilised species such as baobab (*Adansonia digitata*), nere (*Parkia biglobosa*) and shea (*Vitellaria paradoxa*) in Burkina Faso (Poole et al. 2016).

Other articles address the implications of the linkages between biodiversity and nutrition for breeding of different relevant crops in West Africa such as fonio (Barnaud et al. 2013). In particular, participatory breeding processes ensure that nutritional traits valued by local communities are taken into consideration by breeders (Sandwidi et al. 2018). The participation of local communities is also paramount for the conservation of local diversity of cultivated and wild food species (Belem et al. 2009; Sandwidi et al. 2018).

CONCLUSIONS

This review provides a comprehensive analysis of how the nexus between biodiversity, diets and nutrition in Burkina Faso and Niger is addressed in the scholarly literature. The low number of documents addressing this topic suggests a huge gap in the research field and the need for more attention and investments. In general, the literature shows that dietary diversity and nutrition are affected by the diversity of farm crops and animals, as well as wild plants, forest trees and wild animals to which households have access through foraging. However, there are different, complementary pathways linking biodiversity and diets, and they are context-specific. These include a direct pathway, involving consumption of foraged products, or an income pathway, implying selling them to buy food. However, foraging may lead to the overexploitation of food plants and trees. The relationship between dietary diversity and agro-biodiversity depends on how they are evaluated. Moreover, the effects of cropland expansion on dietary diversity are mixed and depend on the diversity of farming systems. The contribution of agro-biodiversity to nutrition is affected by the quality of agri-food products, especially their nutritional quality. Biodiversity is also associated with food security; wild food products complement the diets of rural communities in times of food deficit. Traditional knowledge (cf. culture, traditions) plays a central role as an interface

between biodiversity and dietary/food diversity. In this context, the participation of local communities in breeding and conservation endeavours becomes paramount for their success.

Biodiversity, diets, and food and nutrition security are strongly interlinked. Enhancing agro-biodiversity could be an effective strategy to address food insecurity and malnutrition in Burkina Faso and Niger. Research is highly needed to strengthen the body of evidence on the interlinkages between biodiversity and nutrition, point out the potential solutions to optimise synergies between biodiversity and nutrition while minimising trade-offs, inform policy to adopt appropriate approaches by the governments and other stakeholders to address present and future challenges in Burkina Faso and Niger. Research is also needed to examine further the relationships between (agro)biodiversity and nutrition security from different angles, at different levels and in different contexts, also concerning increasing socio-economic affluence and regional agri-food trade. Further research should also explore the associations between biodiversity, dietary diversity, and health and nutritional well-being outcomes.

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