Preliminary Reflections on the Nexus between Food Systems and Climate Change Responses in Central Africa

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Abstract

This study analyses the importance of understanding the nexus between food systems and climate change responses in Central Africa. Despite the diversity of agriculture in the region, climate-related challenges such as changing rainfall patterns and increasing natural disasters significantly impact food production and distribution. Climate change responses in the region have focused on improving food systems, including developing climate-resilient crops and agricultural practices, as well as local food storage and distribution systems. These efforts are essential to increasing the resilience of Central African food systems and addressing broader climate change mitigation and adaptation goals. However, significant challenges exist in ensuring that such responses are effectively implemented. These challenges include broader systemic issues related to governance, infrastructure, and trade. Additionally, it is crucial to ensure that climate change responses consider the unique perspectives of different groups within society, such as female farmers and indigenous peoples. Warning systems for food security and basic climate information services are still at an early stage. This study aims to address these challenges by synthesising and analysing the existing literature. Ultimately, the goal is to better understand and address the nexus between food systems and climate change responses in Central Africa.

Keywords: Central Africa, Congo Basin, climate change, adaptation to climate change, climate change mitigation, food system, food security

1. Introduction

The IPCC (Intergovernmental Panel on Climate Change) Special Report on Land highlights the importance of the global food system to global climate change. Food systems are estimated to be responsible for one-third of global anthropogenic greenhouse gases (GHG) emissions (Crippa *et al*. 2021). Therefore, it is crucial to incorporate this into response efforts focused on reducing global emissions. In addition, the food system is particularly vulnerable to the effects of climate change, including decreased and unstable crop yields. For instance, Anwar *et al*. (2013) found that climate variability is strongly associated with maize yield variations in sub-Saharan Africa's agricultural areas with large mean farm sizes. Given the close link between the food system and climate, understanding their intersection has become a critical aspect of the global environmental agenda.

The food system is a complex and diverse industry that varies across geographical regions and even within the same country, depending on different factors. This system is similar to other sectors in that it involves labour division, where certain regions are highly specialised in producing agricultural inputs, while others excel in producing specific agricultural products. The recent crisis in Ukraine exemplifies how the production and consumption of food occurs in different locations, making food a vital global industry. Not all parts of the world share the same reality regarding food security. Africa continues to struggle with the challenge of achieving food security, having missed out on its green revolution, in contrast to Asia and South America.

While the Horn of Africa has highly publicised hunger issues, other regions on the continent are also facing food insecurity due to low development indicators. Central African countries, specifically those in tropical rainforest zones (the focus of this study), are currently facing agricultural constraints, including limited availability of agricultural inputs, pests, diseases, and inadequate breeding materials. These challenges are further compounded by climate change and the need to increase agricultural productivity while preserving natural ecosystems, such as the Congo Basin, and its ecological services. Additionally, Central African countries rely heavily on inputs from countries outside the continent, highlighting the dependence of their food security on both national conditions and the functioning of international relations and agendas.

Several countries in Central Africa are currently working to develop climate change responses within the United Nations Framework Convention on Climate Change (UNFCCC). These responses include policies such as National Determined Contributions (NDCs), National Plans for Adaptation (PANs), REDD+ strategies, and efforts to conserve biodiversity through the Convention on Biodiversity (CBD). However, these responses have not adequately addressed the issue of food security. It often seems to certain stakeholders that the objectives of climate change responses are pursued at the expense of food security in Central Africa. Little consideration has been given to the vulnerability of food systems to climate change. Thus, food security in Central Africa needs to be addressed by considering the other crises (wars, poverty,

pressure on natural resources, etc.) faced by the region (Jones and Franks 2015). Therefore, this study aims to better understand the link between the food system and climate change, as well as the current responses implemented in Central Africa.

Considering the unique context and realities of each location, it is vital to contextualise the implications of food systems and incorporate them into climate change responses. This study analyses (1) the contribution of the food system to ecological fragility and (2) how food security related to forest management plays a crucial role in both adaptation and mitigation responses to climate change.

2. Food systems

Food systems are a complex and multifaceted concept that encompass various aspects of food production, management, and consumption. They go beyond agricultural practices and food processing that bring food from the farm to the table, to the cultural, economic, and political systems that shape how food is distributed and consumed (Rosenzweig *et al*. 2021). The food systems approach theoretically considers all the components, interactions, and related effects in the food system. This holistic approach moves beyond focusing on single sectors, sub-systems, or disciplines, thereby widening the framing and analysis of a particular issue, resulting from a complex web of interwoven activities and feedback (Crippa *et al*. 2021).

Food security is one of the key concepts in the study of food systems, which refers to the ability of individuals and communities to access safe, nutritious, and culturally appropriate foods (Tendall *et al*. 2015). Nonetheless, achieving food security requires addressing issues such as poverty, inequality, and food deserts as well as balancing economic and environmental sustainability. Another related concept is food sovereignty, which emphasises local control over food production and distribution. This approach aims to promote community self-sufficiency and resilience, while also addressing cultural and ecological considerations (Van der Ploeg 2014).

Food justice is an important aspect of food systems. It addresses the unequal distribution of and access to food based on factors such as race, class, and geographic location. This concept aims to address issues such as food deserts, which are locations where residents have limited access to healthy and affordable food, and food insecurity, which refers to the lack of consistent access to food (Meenar and Hoover 2012). This approach to food systems also considers the social and cultural dimensions of food and seeks to promote equitable access to food that is nourishing and culturally appropriate.

Analysing the environmental impacts of food production and consumption is crucial when studying food systems. This includes an examination of the impact of food production on soil health, water resources, and climate. This approach seeks to promote agroecological solutions, such as regenerative agriculture, that prioritise soil health, biodiversity, and ecosystem services (Gosnell *et al*. 2019). Additionally, the economic and political structures that shape food systems at local, national, and global levels must be considered. These include issues such as land ownership, labour rights, and international trade policies.

Hence, food systems are an amalgamation of various endeavours, including the interactions and connections among individuals that exist within a community to convert raw materials into end products and their subsequent utilisation and elimination (Tubiello *et al*. 2021). By understanding these interrelated factors, food systems research can promote food sovereignty, security, justice, environmental sustainability, and economic viability. In theory, within the framework of systems theory, a food system can be seen as an intricate network (Mesarovic and Takahara 2006), as each of its components can be categorised as a subsystem. The study of a food system involves examining the connections and interdependence of individuals and organisations throughout the system to (1) ascertain system effectiveness, (2) measure external effects, (3) comprehend human behaviours, (4) understand the development of food systems, (5) evaluate the impact of changes (such as policies, interventions, or shocks), and (6) identify areas of high risk and points for intervention. Unfortunately, in Central Africa, with its socio-economic and environmental complexities, few studies have conducted a thorough analysis of how the food system is affected by global, regional, and national socio-economic and environmental dynamics.

3. Food system in Central Africa

3.1. Food systems components

Food systems in Central Africa face a range of challenges including climate change, political instability, and limited resources. In some countries such as the Central African Republic and the Democratic Republic of the Congo (DRC), conflict and violence have disrupted food production and distribution systems, leaving many communities with limited access to food. In other countries such as Cameroon and Chad, climate change and desertification have had a significant impact on agricultural production, leading to reduced yields and increased food insecurity. Despite these challenges, a range of initiatives and programs aimed at improving food systems in the region have been introduced. These include efforts to promote sustainable agriculture, build resilience to climate change, and improve access to markets and financing for small-scale farmers.

Food systems are complex and multifaceted systems that include a range of components involved in production, processing, distribution, and consumption. Different countries in Central Africa have different food systems that reflect their unique cultures, landscapes, and histories. For example, in Cameroon, cassava is a staple crop that is used to produce a range of food products, including fufu and garri. In Chad, millet and sorghum are important crops used to make a range of dishes, including couscous and porridge. There is also significant transboundary food circulation in Central Africa (Nkendah 2013). Beef meat sold in Gabon originates from Cameroon and Chad. Additionally, Cameroon exports food to Congo Brazzaville. As a result, urban cities in Central Africa are familiar with food from neighbouring countries. In these cities, which attract populations from rural areas, traditional food systems (consisting of local/traditional knowledge passed down through generations as part of intangible heritage) coexist with imported food

components and practices. The food system in Central Africa is constantly evolving, reflecting the region's migration patterns and increasing globalisation. In many countries, traditional food systems have come under pressure from changing diets and the availability of processed foods. Efforts are being made to promote traditional foods, improve nutrition, and reduce the dependence on imported food products. These efforts involve a range of stakeholders, including governments, civil society organisations, and international development agencies (Sneyd *et al*. 2015).

In addition to efforts aimed at improving food production and distribution, there is growing recognition of the importance of addressing the broader social and economic factors that influence food systems in Central Africa. For example, poverty, inequality, and inadequate infrastructure can all limit access to food and contribute to food insecurity in the region. These issues are particularly acute in rural areas, where most agriculture occurs and opportunities for employment and economic development are often limited. Addressing these challenges requires a multifaceted approach that includes increasing investments in rural infrastructure, improving access to financing and markets for small-scale farmers, and promoting policies supporting sustainable agriculture and small business development.

Another important aspect of food systems in Central Africa is the role of women. Women play a critical role in the food systems across the region, from farming and processing to distribution and preparation. However, they often face significant barriers to participating in these activities, including limited access to resources, discriminatory social norms and practices, and limited access to education and training. For example, farms managed by women are cultivated much less intensively than male-managed farms because of the limited ability of women to acquire technological input in the DRC, Rwanda, and Burundi (Ochieng *et al*. 2017). Women have less access to rural credit, extension services, and social capital than men. Efforts to promote gender equality and empower women in food systems can help improve productivity and sustainability, reduce poverty and hunger, and promote social and economic development. These efforts include measures to enhance women's access to land, technology, and financial resources as well as to promote more equitable gender relations within households and communities.

Non-timber forest products (NTFPs) are an important component of food systems in Central African countries, providing a range of products such as fruits, nuts, and medicinal plants. Non-timber forest products represent many goods and services with multiple uses that are beneficial for the well-being of populations that are dependent on them (Ngansop *et al*. 2019). Although NTFPs are often harvested from natural forests, they can also be grown in agroforestry systems, providing an important source of income and nutrition for small-scale farmers. However, trade in NTFPs is often informal and unregulated, leading to poor prices for producers and unsustainable exploitation of natural resources. A range of initiatives have been aimed at promoting the sustainable harvesting and trade of NTFPs, including the development of certification schemes and the establishment of community-based forest management programs (FAO and

UNEP 2020). These efforts can help ensure that NTFPs continue to provide benefits to local communities and contribute to the broader goals of poverty reduction and sustainable development in Central Africa.

In Central Africa, 86 million people living in or near forests depend on natural resources for a significant part of their diet (Eba'a Atyi *et al*. 2009). Among NTFPs, the most collected are Marantaceae leaves, *Gnetum* spp. (Eru or Fumbua), *Dacryodes edulis*, caterpillars, mushrooms, fish (smoked and fresh), and bush meat (Nkem *et al*. 2010). Their use varies according to cultural and dietary habits. According to Pagezy (1993), the Ntomba society in the DRC rely on 74 uncultivated plants, which encompasses 26 types of mushrooms for sustenance. In addition, they consume 118 different animals and an assortment of fish. Bahuchet (1985) documented a diverse range of nourishment in the Central African Republic, consisting of nine types of tubers, nine varieties of foliage, 19 types of seeds, 14 species of fruits, and 22 types of mushrooms. In the southern region of Cameroon (van Dijk and Wiersum 1999), nearly 200 animals and 500 plant species are used in 1200 ways as NTFPs. This diversity of products and uses reflects the role of NTFPs in people's diets and can be used as a means of subsistence by the local population, thus contributing to the fight against food insecurity. Sundriyal and Sundriyal (2001) highlighted that wild edible foods are rich in vitamins, protein, fat, sugars, and minerals, and depending upon their availability, can be used in different seasons throughout the year. Year-round availability allows people to have access to food sources, especially during seasons of low agricultural production. De Merode *et al*. (2004) reported that during the lean season, in DRC consumption of agricultural produce declined by nearly 50%, whereas that of wild plants increased by 200%, bushmeat by 75%, and fish by 475%. Although NTFPs are a source of income for people, they are also a source of food and nutrients, and thus, a livelihood that can contribute to the fight against food insecurity. Managed sustainably, they can serve as a framework for climate change responses.

3.2. Status of the food system trend in Central Africa

The food system in Central Africa has undergone a rapid transformation over the past few decades. With a population of over 150 million people, the region has experienced significant urbanisation, economic growth, and changes in dietary patterns. Despite these changes, many challenges remain for the food system, including food insecurity, malnutrition, and limited access to markets, particularly in rural areas (FAO and UNEP, 2020). One of the key trends in the food system in Central Africa is the growth of urban areas and the concomitant rise in the demand for processed and convenient foods. This trend has been shaped by a range of factors including changes in lifestyle and work patterns, increased income levels, and the availability of imported goods. However, it has also contributed to the decline of traditional food systems and the erosion of local food cultures as consumers turn to more convenient and readily available options (United Nations Development Programme(UNDP) and United Nations Research Institute for Social Development (UNRISD) 2017).

Another trend in the food system is a growing awareness of the need for sustainable and equitable food production and consumption. This is reflected in a range of initiatives aimed at promoting sustainable agriculture, reducing food waste, and improving nutrition. According to the Food and Agricultural Organization (FAO 2019), there is a growing emphasis on the role of small-scale farmers and agroecology in addressing food security and poverty reduction in the region. However, despite these efforts, many challenges remain in the food industry. Climate change is one of the most pressing issues threatening to disrupt food production and exacerbate food insecurity in the region (Sonwa *et al*. 2014). Moreover, political instability and conflict continue to undermine food systems in countries such as the DRC and the Central African Republic, leading to the displacement of farmers and the disruption of food markets (Sneyd *et al*. 2015, Enenkel *et al*. 2015).

In response to these challenges, a range of initiatives have been introduced, aimed at promoting sustainable food systems and improving food security in Central Africa (Sneyd *et al*. 2015, Ndjouenkeu *et al*. 2010). These include efforts to promote agroecology and sustainable agricultural practices, strengthen local food systems, and improve access to markets and financing for small-scale farmers. In addition, there is growing attention to the need for policies that support equitable and sustainable food systems, such as food labelling and certification schemes, and measures to promote inter-sectoral collaboration and resource sharing. Although the food system in Central Africa has undergone significant transformation in recent years, challenges remain. Climate change, political instability, and economic inequality pose significant threats to regional food security and sustainability. However, there are also opportunities to promote sustainable and inclusive food systems that support small-scale farmers, preserve local food culture, and promote nutrition and health. Addressing these challenges requires a multi-sectoral approach that involves the government, civil society, private sector, and research institutions.

4. Food production and ecological consideration in Central Africa

4.1. Food crops and biodiversity

Central Africa is renowned for its rich biodiversity, making it one of the most important regions on the continent in terms of ecological abundance (Eba'a Atyi *et al*. 2008). The Congo Basin is notable for its high biodiversity, encompassing a wide range of ecosystems, from coastal to mountainous regions. These include plains, plateaus, inland waters, peatlands, mangroves, savannahs, steps, and semi-dry and humid areas. Numerous species thrive in these habitats, some of which are exclusive to the region. In recognition of Central Africa's diverse agrobiodiversity, several protected areas have been established to safeguard it. However, it is important to note that not all biodiversity in the region is confined to these protected areas. Biodiversity is common in rural landscapes and coexists with areas suitable for food production. The Congo Basin forests are under significant pressure for their biodiversity and biological resources, resulting in forest degradation and deforestation. There are a multitude of causes for deforestation, including logging for

timber, fuel, cooking, and agriculture at both large and small scales. Large-scale commercial and local subsistence agriculture accounted for 40 and 30 % of tropical deforestation between 2000 and 2010, respectively (FAO and UNEP 2020). According to International Union for Conservation of Nature (IUCN) data, agriculture is a major cause of global endangerment and is responsible for the loss of approximately 60% of amphibians and birds and 20% of plants worldwide (Muluneh 2021). In the Congo Basin, an estimated 84% of the forest disturbance areas are due to small-scale, non-mechanised forest clearing for agriculture (Tyukavina *et al*. 2018) and unmonitored forest loss and fragmentation in the region have a direct effect on the habitats of valuable plants (Mbile *et al*. 2006). It has been clearly established that agricultural expansion contributes not only to deforestation and degradation but also to biodiversity loss, notably through the higher use of fertilisers and pesticides.

However, the effects of biodiversity loss vary, depending on the food crop system used. Slash and burn agriculture practiced by local populations has a significant impact on biodiversity that could lead to the extinction of some species, the weakening of ecosystems through weak system resilience to diseases (both animal and plant) and invasive species. Large-scale agriculture has more a noticeable impact. Monoculture systems reduce aerial and underground biodiversity and cause genetic erosion and low food diversity. Palm oil concession areas in the DRC and road infrastructure increased by 34% in the three years between 2011 and 2013 (Yingheng and Wigglesworth 2017). In 2017, palm oil plantations comprised at least half of the area of disturbed forests in all parts of the Littoral Region of Cameroon (Mahmoud *et al*. 2019).

Some studies have reported palm oil plantations to negatively affect the abundance and occurrence of a wide range of taxa, including birds, invertebrates, and mammals (Fitzherbert *et al*. 2008, Yue *et al*. 2015). Indeed, the expansion of agriculture contributes to the loss of biodiversity through the loss of flora which constitute habitats and food sources for wildlife. The fact that the expansion and intensification of agriculture have been major drivers of past biodiversity loss and global ecosystem degradation is beyond dispute (Norris 2008). The food crop system is not only a cause of biodiversity loss but could also be considered a refuge for insects that contribute to the pollination system. Additionally, depending on the type of crop cultivated, agricultural landscapes provide either a source of food for animals (mostly non-tree crops), opportunities for shelter (non-edible tree crops), or both. Although agriculture is a source of many goods and services, it is essential to develop new approaches that would allow farmers to settle while increasing their yield and preserving biodiversity.

4.2. Food and carbon emission

Food system activities, including food production, transportation, and storage of wasted food in landfills, produce GHG emissions that contribute to climate change. Climate change is one of the greatest challenges of our era. This escalating issue poses a mounting danger to food systems as its consequences become increasingly apparent. Surges in temperature, alterations in rainfall patterns, and occurrences of severe

weather events, along with other ramifications, are presently diminishing agricultural production and causing disruptions in food distribution. It is projected that by 2050, climate change will jeopardise the well-being of millions of people, subjecting them to hunger, malnutrition, and poverty.

There is a great deal of ambition in food systems. Global conferences in 2021 emphasised the crucial importance of transforming food systems to combat climate change and achieve various development objectives. Efforts to tackle climate change are already in progress; however, they must be expedited by accelerating innovation, revamping policies, adjusting market incentives, and enhancing financial support. Climate change affects food systems and plays a significant role in their development. Recent calculations suggest that food systems are responsible for over one-third of GHG emissions that lead to climate change, underscoring the importance of reducing these emissions as part of any effort to mitigate climate change. Additionally, the agricultural, forestry, and land-use sectors are currently the sole sectors with significant potential to act as net emission sinks, removing more GHGs from the atmosphere than is released by establishing and safeguarding carbon sinks in forests, oceans, and soils. The significance of food systems in global climate discussions and solutions was acknowledged at the UN Food Systems Summit and UNFCCC COP26 meetings in 2021. This recognition signifies a crucial change in prioritising food systems in global conversations regarding the impacts and resolutions of climate change. However, the crisis remains unaddressed because of an inadequate focus on and financial support towards agriculture and food systems.

Food systems have been identified as responsible for one-third of GHG emissions from human activity, consequently putting agricultural yields at risk due to climate change impacts (Dinesh *et al*. 2021). Transforming forests into agricultural land increases GHG emissions. For example, a hectare of forest, which originally stored 308 tons of carbon per hectare lost 220 when transformed into agricultural land in Cameroon (Kotto-Same *et al.* 1997). In a forest of Yangambi landscape in the DRC, 99% of its aboveground biomass is transformed when transitioning to the cropping system(Mangaza et al. 2022). Food systems account for up to 34 percent of the overall GHG emissions derived from farming and land utilisation, preservation, transportation, packaging, manufacturing, retail, and consumption. This negatively impacts global food security levels and Central Africa in particular. Recent calls have increased the need to transform global food systems in response to various challenges, including climate change. This highlights the need for a change in the use of the food system to reduce global GHG emissions. Greenhouse gas emissions are significantly influenced by food systems, and it is crucial to contribute to mitigation efforts by implementing alterations in agricultural practices and land utilisation. Additionally, more effective value chains and decreased food loss and waste are essential. Agriculture plays an important role in climate change mitigation, as mentioned in the NDC documents of Central African countries.

4.3. Food and climate change vulnerability

A primary issue in the twenty-first century is reducing the dangers posed by climate change on food systems. The effects of climate change on crop yield are already evident in observable data (Lobell and Gourdji 2012). Central Africa is not a highly polluted region; however, it is vulnerable to the effects of climate change (Sonwa *et al*. 2014, Sonwa and Nkem 2014). The food sector in Central Africa is fully dependent on rain fed agriculture which makes it highly vulnerable to climate change (Molua *et al*. 2023). The repercussions and outcomes of climate change on agriculture are particularly harsh for nations with elevated initial temperatures, regions with limited or already deteriorated lands, and lower levels of development that possess minimal capacity for adaptation (Ngaiwi *et al*. 2023). Climate change has caused vulnerability not only to forest ecosystems, but also to forest-dependent communities (Molua *et al*. 2023). The food system is a collection of dynamic interactions that occur among various components. Food production, processing, distribution, preparation, and consumption occur within the biogeophysical and human ecosystems (Gregory *et al*. 2005). These encompass aspects of food supply (manufacturing, dissemination, and trade), food entry (affordability, distribution, and choice), and food utilization (nutrient content, societal importance, and food security (Meliko *et al*. 2023). Each stage of the system is continuously exposed to climate change.

Non-climate stressors such as population and income expansion, as well as the demand for animal-based products, exert pressure on the food system in addition to climate change. Both climate- and non-climate-related pressures affect four fundamental aspects of food security: availability, access, utilisation, and stability (Mbow *et al*. 2019). The profound impact of climate variability and alteration on food systems is particularly severe and poses a direct and palpable threat to livelihoods worldwide (Loboguerrero *et al*. 2020). The observed alteration in climate has already impacted food security through rising temperatures, altered patterns of rainfall, and a higher occurrence of certain extreme events (high confidence) (Mbow *et al*. 2019). The effects of climate change on food security have global and regional consequences. All nations, whether they are exporters or importers or rely on subsistence farming, will be impacted by climate change's influence on agricultural food systems. Variations in average rainfall and temperature, along with an increase in extreme weather events, have repercussions on farming, livestock production, forestry, and fishing. Numerous consequences such as heightened land degradation and soil erosion, alterations in water availability, loss of biodiversity, more frequent and severe pests, disease outbreaks, and disasters must be addressed across various sectors (FAO 2008). In Central Africa, recent IPCC reports and others have revealed the fragility of the food system under future climate change (Sonwa *et al*. 2014).

5. Food and climate change responses

5.1. Food and adaptation to climate change

Discussions on adaptation are taking place, particularly in Africa, because food systems are already affected by anthropogenic greenhouse gases and aerosols emitted in the past, with continued emissions exacerbating

these effects (Le Quéré *et al.* 2020). Sub-Saharan Africa, particularly Central Africa, is still on the absorptive end, focusing primarily on adaptation measures. Food systems play a pivotal role in implementing climate change adaptation policies (Molua 2022). Prominent choices for climate change adaptation in food systems have been outlined and rely on proof and familiarity, particularly in Africa. These choices encompass governmental policies and motivating resolutions, the food supply chain, and means of subsistence as well as on-farm and fruitful terrain resolutions. Within this array of choices, the primary areas for governmental investment in Africa can be categorised into five aspects: research and expansion, water administration, infrastructure, sustainable land administration, and climate information services (Ba 2016).

The need for climate change adaptation is pressing yet attainable for food systems. The methods of food production, distribution, and consumption must be modified in response to climate change to enhance rural livelihoods and ensure nutritious diets for everyone, despite the rising demand for food due to population and income growth (Swinnen *et al*. 2022). A 3°C trajectory will cause catastrophic disruption to African food systems within the next 30 years. A trajectory of 1.5°C offers additional possibilities for the adjustment of African food systems yet necessitates immediate measures. The enhancement of African farmers' resilience heavily relies on the crucial involvement of small-scale producers in adaptation investments. Consequently, it is imperative to amplify and direct financial resources towards these farmers, livestock caretakers, fishermen, and small enterprises (Pequeno *et al*. 2021). In nations where the food system not only supplies nutrition but also stimulates the rural economy, it is crucial to contemplate the consequences of transitioning towards nutritious eating habits in relation to the sustenance of small-scale farmers and the impoverished rural population. In such instances, it is essential to handle the adverse effects on earnings and livelihoods with caution as food systems evolve to provide accessible whole diets (FAO *et al.* 2020).

Ensuring access to sufficient food must be seen as a primary factor in determining the success of adaptation efforts at both national and local levels. It is crucial to incorporate food security considerations explicitly into the adaptation strategies of the agricultural, forestry, and fishery sectors in response to climate change and variability. This can be accomplished by increasing the awareness of policymakers, offering incentives, and advocating the implementation of resilient food production systems. In addition, it is essential to prevent or eliminate maladaptive practices when adapting to climate change. Maladaptation refers to measures that inadvertently increase vulnerability instead of reducing it (FAO 2008).

5.2. Food and climate change mitigation

Since the adoption of the Paris Agreement at the 2015 United Nations Climate Change Conference (COP 21), there has been a global embrace of more robust efforts to mitigate and stabilise the effects of global warming. Numerous countries have revisited their plans to enhance efficacy or explore alternative solutions. While emission reductions from energy, transportation, and other industrial sectors have received significant attention in GHG emission mitigation policies, the same cannot be said for emissions stemming from food

production. As a result, agriculture has the potential to become the primary contributor to global GHG emissions by the middle of this century. Consequently, it is imperative that the agricultural sector plays its part in addressing climate change if we are to achieve the targets set forth in the Paris Agreement, which aim to limit global temperature increases to 1.5°C or well below 2°C.

Food systems contribute significantly to the release of greenhouse gases and should be involved in efforts to reduce them. This can be achieved by altering agricultural methods and land utilisation, establishing more effective supply chains, and minimising food loss and waste (Swinnen *et al*. 2022). Mitigation options for reducing methane and nitrous oxide emissions from rice and other crops include alterations to irrigation, cropping, and fertilisation. Similarly, changes in manure management, feed conversion, and feed additives can be used to decrease enteric fermentation in livestock. According to the latest report from the IPCC on climate change, there is a comprehensive analysis of GHG emissions in relation to climate mitigation and food security. The report concluded that there are significant opportunities to achieve both objectives simultaneously by adopting diets that align with health-based dietary recommendations, as stated by the FAO (IPCC 2019, FAO *et al*. 2020).

Numerous encouraging advancements and strategies have the potential to address climate change in food systems, enhance productivity and diets, and promote the inclusion of vulnerable groups. These include novel plant types, renewable energy sources, and digital innovations, as well as modifications to trade policies, landscape management, and social protection initiatives. To achieve these goals, it is necessary to substantially increase funding for research and development, as well as other investments in sustainable food system transformation. To stimulate and expedite climate action, it is crucial to implement food system policies that establish improved market incentives, reinforce regulations and institutions, and allocate funds for the research and development of climate-resilient technologies and practices.

The adoption of nutritious and sustainable diets offers significant opportunities for decreasing GHG emissions from food systems and enhancing health outcomes. Examples of such diets include those rich in whole grains, legumes, fruits, vegetables, nuts, and seeds but low in energy-intensive animal-based products and discretionary foods (such as sugary drinks). Additionally, these diets adhere to carbohydrate limits. It is estimated that by 2050, the overall technical potential for mitigating emissions through dietary changes could range from 0.7 to 8.0 GtCO2-eq yr–1[1]. This estimation considers reductions in emissions from livestock and the sequestration of carbon in the soil on spared land. However, the potential health co-benefits were not considered in this study. The actual mitigation potential of dietary changes may be even higher, but its large-scale realisation depends on the choices and preferences of consumers, which are influenced by social, cultural, environmental, and traditional factors, as well as income growth. Plant-based meat substitutes, lab-grown meat, and edible insects have the potential to facilitate a shift towards healthier and

[1] GtCO2-eq yr–1 means gigatons per carbon dioxide equivalent per year. This is a standard unit used in estimating greenhouse gas emissions.

more environmentally friendly eating patterns. However, their environmental impacts and levels of acceptance remain uncertain (Mbow *et al*. 2019).

Addressing the obstacles posed by climate change requires a complete overhaul of our food systems. This calls for significant policy changes, considerable funding, and a supportive atmosphere that encourages and welcomes innovation. The IPCC report highlights six key policy areas that primarily target developing nations that are projected to endure the harshest consequences of climate change but lack the resources to facilitate adaptation and the establishment of sustainable food systems. These policy priorities include investments in research and development to foster innovation, promote healthier diets and more sustainable production methods, strengthen value chains, and implement climate-smart financial strategies.

Food systems have the potential to achieve significant reductions in emissions and carbon sequestration by establishing and safeguarding carbon sinks like forests. In Central Africa, it is crucial to prioritise the promotion of agricultural practices that enhance productivity and reduce emissions in the region. Notably, substantial greenhouse gas mitigation can be accomplished by decreasing nitrous oxide emissions from fertilisers, methane emissions from paddy rice, and enteric fermentation (resulting from the digestion of cattle and other ruminants). Additionally, reducing emission intensity within sustainable production systems and minimising food loss and waste are effective strategies. On the demand side, shifting towards healthy diets has been proven to contribute significantly to emissions reduction. By combining these efforts, we can work towards achieving net zero emissions globally.

6. Geopolitics implications on food systems and climate change

Zero Hunger is the second goal of the United Nations 2030 Agenda for Sustainable Development Goals. It seeks to 'End hunger, achieve food security and improved nutrition and promote sustainable agriculture' by 2030. However, since 2015, the percentage of undernourished people increased to 690 million in 2019, up by almost 60 million since 2014 (Laborde *et al*. 2020). This estimate has been aggravated in recent years by the COVID 19 crises, climate change, and, most recently, the war in Ukraine. In total, 130 million people are at risk of hunger (World Food Programe(WFP), 2020). Currently, countries deploy multiple diplomatic strategies to negotiate commodities such as wheat, rapeseed, and sunflowers. Trade is necessary to ensure global food security. Thus, climate change interacts with resource security, health, trade, and armed conflict in its various effects on food security. In the domain of climate variability, strategies can include irrigation techniques, tree domestication, the adoption of techniques and innovation to reduce yield variability, and adjusting crops to new seasonal calendars (Finger *et al*. 2011, Claessens *et al*. 2012).

Seo *et al*. (2008) found that farmers shift the crops they plant to match the climate they face. Indigenous knowledge must be considered, and in this vein, Nyong *et al*. (2007) concluded that the inclusion of indigenous knowledge, which are abundant in regional substances, can enhance the creation of sustainable strategies for mitigating and adapting to climate change. The incorporation of indigenous knowledge adds

value to the development of such strategies. In Cameroon, Tingem and Rivington (2009) argued that adaptation policies might mitigate some of this vulnerability. Maize, sorghum, and Bambara groundnut showed good adaptive capacity, and new cultivars of other crops in the northern region were more suitable.

In Sud-Kivu, the DRC, farmers have shown a willingness to use other practices, such as integrated soil fertility management, to overcome changes (Pypers *et al*. 2011). Moreover, they have been an innovative approach for overcoming food scarcity due to climate variability (Alinovi *et al*. 2007). The National Program of Adaptation (PANA) initiative has brought more hope through the provision of climate information at some pilot sites in the DRC. Deressa *et al*. (2009) argued that the level of education, gender, age, and wealth of the household head could affect adaptation. Access to extension services and credit as well as information on climate, social capital, agroecological settings, and temperature can also play a role in adaptation. Farmers have proven highly adaptable to short- and long-term variations in climate and their environment; they also have a high awareness of climate issues (Mertz *et al*. 2009).

Regarding the food system of Central Africa through a geopolitical lens, a main issue is the apparent tension between the conservation of the Congo Basin Forest and peatland carbon stocks and biodiversity versus the growth of small/big agricultural farming systems. Although the ecological services provided by this forest are useful to humanity, the farming system is viewed as useful by smallholders and the national economy. It generally appears as if the global community wants to achieve ecological goals at the expense of small rural livelihoods and national economies of Central Africa. At the sub-Saharan level, regional water cycling pumped by this forest allows rain beyond the Central African region, leading to climate connections between several countries. While some agricultural products (mainly perennial crops) are exported from the continent, the main imports (fertilisers, pesticides, etc.) are from outside Africa and thus contribute to linking the food system of Central Africa to the global world.

Central Africa experiences geopolitical tensions related to natural resources, particularly in terms of food production. Examples include conflicts between pastoralists and farmers as well as tensions between fishers and pastoralists in the Lac Chad watershed. Additionally, the region is home to several countries, including Chad, the Central African Republic, the DRC, and more recently Cameroon, which are prone to conflict. These conflicts often result in population displacement and hinder the utilisation of arable land for food production. Displaced populations are not only vulnerable to the effects of wars and tensions but also the effects of climate change in their new environments. Furthermore, the abandonment of rural areas and their food production potential in new areas exacerbate socio-economic and environmental pressures on host communities and villages. These emerging pressures must be considered when planning responses to climate change. It is essential to consider climate change in humanitarian responses when addressing the food security of displaced people. Similarly, when framing responses to climate change, it is important to consider the implications for food, and the conflicting nature of certain parts of Central Africa.

7. Conclusion

Climate change poses significant challenges to food systems in Central Africa, and climate change responses that focus on improving these food systems are essential for increasing resilience in the face of such challenges. However, implementing effective responses requires addressing systemic issues related to governance, infrastructure, and trade, while ensuring that responses consider the unique perspectives of different groups within society. This study aims to contribute to these efforts by conducting a preliminary analysis of the existing literature to better understand the nexus between food systems and climate change responses in Central Africa. Finally, this study seeks to support efforts to develop and implement effective responses to climate change in this region. This preliminary work needs to be complemented by other studies from the perspective of structuring a climate-smart food system that is useful to both people and nature.

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References

Alinovi, L., G. Hemrich, and L. Russo 2007. *Addressing Food Insecurity in Fragile States: Case Studies from the Democratic Republic of the Congo, Somalia and Sudan*. ESA Working Paper 07-21. FAO.

Anwar, M.R., D.L. Liu, I. Macadam, and G. Kelly 2013. 'Adapting Agriculture to Climate Change: A Review'. *Theoretical and Applied Climatology* 113 (1-2): 225-245.

Ba, M.N. 2016. 'Strategic Agricultural Commodity Value Chains in Africa for Increased Food: The Regional Approach for Food Security'. *Agricultural Sciences* 7(9). doi: 10.4236/as.2016.79055.

Bahuchet, S. 1985. *Les pygmées Aka et la forêt Centrafricaine: Ethnologie écologique*. Paris: SELAF.

Claessens, L., J.M. Antle, J.J. Stoorvogel, R.O. Valdivia, P.K. Thornton, and M. Herrero 2012. 'A Method for Evaluating Climate Change Adaptation Strategies for Small-Scale Farmers Using Survey, Experimental and Modeled Data'. *Agricultural Systems* 111：85-95.

Crippa, M., E. Solazzo, D. Guizzardi, F. Monforti-Ferrario, F.N. Tubiello, and A. Leip 2021. 'Food Systems Are Responsible for a Third of Global Anthropogenic GHG Emissions'. *Nature Food* 2(3)：198-209.

De Merode, E., K. Homewood, and G. Cowlishaw 2004. 'The Value of Bushmeat and Other Wild Foods to Rural Households Living in Extreme Poverty in Democratic Republic of Congo'. *Biological Conservation* 118: 573-581.

Deressa, T.T., R.M. Hassan, C. Ringler, T. Alemu, and M. Yesuf 2009. 'Determinants of Farmers' Choice of Adaptation Methods to Climate Change in the Nile Basin of Ethiopia'. *Global environmental change* 19(2): 248-255.

Dinesh, D., D.L. Hegger, L. Klerkx, J. Vervoort, B.M. Campbell, and P.P. Driessen 2021. 'Enacting Theories of Change for Food Systems Transformation under Climate Change'. *Global Food Security* 31: 100583.

Eba'a Atyi, R., D. Devers, C. de Wasseige, and F. Maisels 2008. 'State of the Forests of Central Africa: Regional Synthesis'. In *The Forests of the Congo Basin - State of the Forests*. Eds. C. de Wasseige, D. Devers, P. de Marcken, R. Eba'a Atyi, R. Nasi, and P. Mayaux, Luxembourg: Publications Office of the European Union, 15-41.

—— 2009. 'État des forêts d'Afrique centrale: synthèse sous-régionale'. In *Les forêts du Bassin du Congo: État des forêts*. Eds. C. de Wasseige, D. Devers, P. de Marcken, R. Eba'a Atyi, R. Nasi, and P. Mayaux, Luxembourg: Office des Publications de l'Union européenne, 17-44.

Enenkel, M., L. See, M. Karner, M. Álvarez, E. Rogenhofer, C. Baraldès-Vallverdú, C. Lanusse, and N. Salse 2015. 'Food Security Monitoring via Mobile Data Collection and Remote Sensing: Results from the Central African Republic'. *PloS ONE.* doi: 10.1371/journal.pone.0142030.

FAO 2008. *Climate Change Adaptation and Mitigation in the Food and Agriculture Sector*: Technical Background Document from the Expert Consultation Held on, 5 to 7 March 2008. FAO.

—— 2019. *The State of Food and Agriculture 2019: Moving Forward on Food Loss and Waste Reduction*. FAO.

FAO, IFAD, UNICEF, WFP, and WHO 2020. *The State of Food Security and Nutrition in the World : Transforming Food Systems for Affordable Healthy Diets*. Rome, FAO. <https://www.fao.org/publications/card/en/c/CA9692EN, Accessed on 9 September 2023>

FAO and UNEP 2020. *The State of the World's Forests, Forests, Biodiversity and People*. FAO, UN Environmental Program.

Finger, R., W. Hediger, and S. Schmid 2011. 'Irrigation as Adaptation Strategy to Climate Change: A Biophysical and Economic Appraisal for Swiss Maize Production'. *Climatic Change* 105(3-4): 509-528.

Fitzherbert, E.B., M.J. Struebig, A. Morel, F. Danielsen, C.A. Brühl, P.F. Donald, and B. Phalan 2008. 'How will Oil Palm Expansion Affect Biodiversity?'. *Trends in Ecology & Evolution* 23(10): 538-545.

Gosnell, H., N. Gill, and M. Voyer 2019. 'Transformational Adaptation on the Farm: Processes of Change and Persistence in Transitions to "Climate-Smart" Regenerative Agriculture'. *Global Environmental Change* 59: 101965.

Gregory, P.J., J.S.I. Ingram, and M. Brklacich 2005. 'Climate Change and Food Security. Philosophical Transactions of the Royal Society B'. *Biological Sciences* 360(1463): 2139-2148. doi: 10.1098/rstb.2005.1745.

IPCC 2019. *Climate Change and Land: an IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*. IPCC.

Jones, X.H. and P. Franks 2015. 'Food vs Forests in Sub-Saharan Africa: A Challenge for the SDGs'. *IIED Briefing Papers*. London: The International Institute for Environment and Development (IIED).

Kotto-Same, J., P.L. Woomer, A. Moukam, and L. Zapfack 1997. 'Carbon Dynamics in Slash-and-Burn Agriculture and Land Use Alternatives of the Humid Forest Zone in Cameroon'. *Agriculture, Ecosystems & Environment* 65(3): 245-256.

Laborde, D., S. Murphy, J. Porciello, and C. Smaller 2020. *Ending Hunger Sustainably*: *Biodiversity*. The International Institute for Sustainable Development.

Le Quéré, C., R.B. Jackson, M.W. Jones, A.J.P. Smith, S. Abernethy, R.M. Andrew, A.J. De-Gol, D.R. Willis, Y. Shan, J.G. Canadell, P. Friedlingstein, F. Creutzig, and G.P. Peters 2020. 'Temporary Reduction in Daily Global CO2 Emissions During the COVID-19 Forced Confinement'. *Nature Climate Change* 10(7): 647-653. doi: 10.1038/s41558-020-0797-x.

Lobell, D.B. and S.M. Gourdji, 2012. 'The Influence of Climate Change on Global Crop Productivity'. *Journal of Plant Physiology* 160(4): 1686-1697.

Loboguerrero, A.M., P. Thornton, J. Wadsworth, B.M. Campbell, M. Herrero, D. Mason-D'Croz, D. Dinesh, S. Huyer, A. Jarvis, A. Millan, E. Wollenberg, and S. Zebiak 2020. 'Perspective Article: Actions to Reconfigure Food Systems'. *Global Food Security* 26：100432.
doi: 10.1016/j.gfs.2020.100432

Mahmoud, M.I., M.J. Campbell, S. Sloan, M. Alamgir, and W.F. Laurance 2019. 'Land-Cover Change Threatens Tropical Forests and Biodiversity in the Littoral Region, Cameroon'. *Oryx* 54(6): 882-891. doi:10.1017/S0030605318000881.

Mangaza, L., J.R. Makana, W. Hubau, D. Sonwa, G. Batsi, and A. Fayolle 2022. 'Impacts du changement d'utilisation des terres sur la biomasse et la diversité dans le paysage forestier de la réserve de biosphère de Yangambi en République démocratique du Congo'. *Bois et Forêts des Tropiques* 353: 61-73.

Mbile, P., Z. Tchoundjeu, E. Asaah, A. Degrande, P. Anegbeh, C.C. Facheux, M.L. Mpeck, D. Foundjem-Tita, and C. Mbosso 2006. 'Rural Livelihoods: Conservation, Management and Use of Plant Biodiversity in West and Central Africa'. *Biodiversity* 7(3-4): 17-26. doi: 10.1080/14888386.2006.9712807.

Mbow, C., C. Rosenzweig, L.G. Barioni, T.G. Benton, M. Herrero, M. Krishnapillai, E. Liwenga, P. Pradhan, M.G. Rivera-Ferre, T. Sapkota, F.N. Tubiello, and Y. Xu 2019. 'Food Security'. In *Climate Change and Land: an IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*. Eds. P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D.C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J.

Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, and J. Malley, Intergovernmental Panel on Climate Change. 437-550.

Meenar, M.R. and B.M. Hoover 2012. 'Community Food Security via Urban Agriculture: Understanding People, Place, Economy, and Accessibility from a Food Justice Perspective'. *Journal of Agriculture, Food Systems, and Community Development* 3(1): 143-160. doi: 10.5304/jafscd.2012.031.013.

Meliko, M.O., E.R. Mossy, and M.E. Ngaiwi 2023. 'Food Accessibility Measurements Amongst Rural and Urban Informal Dwellers in Buea Municipality'. *Journal of Agriculture and Food Research* 12: 100606. doi: 10.1016/j.jafr.2023.100606.

Mertz, O., C. Mbow, A. Reenberg, and A. Diouf 2009. 'Farmers' Perceptions of Climate Change and Agricultural Adaptation Strategies in Rural Sahel'. *Environmental management* 43: 804-816.

Mesarovic, M.D. and Y. Takahara 2006. '*Complex Systems*'. In *Abstract Systems Theory. Lecture Notes in Control and Information Sciences.* Vol. 116. Eds. M.D. Mesarovic and Y. Takahara, Berlin, Heidelberg: Springer, 330-414. doi.org/10.1007/BFb0042469.

Molua, E.L. 2022. 'Private Farmland Autonomous Adaptation to Climate Variability and Change in Cameroon'. *Rural Society* 31(2): 115-135. doi:10.1080/10371656.2022.2086223.

Molua, E.L., D. Sonwa, Y. Bele, B. Foahom, J.P. Mate Mweru, S.M. Wa Bassa, M. Gapia, F. Ngana, A.E. Joe, and E.M Masumbuko 2023. 'Climate-Smart Conservation Agriculture, Farm Values and Tenure Security: Implications for Climate Change Adaptation and Mitigation in the Congo Basin'. *Tropical Conservation Science* 16(1). doi: /10.1177/19400829231169980.

Muluneh, M.G. 2021. 'Impact of Climate Change on Biodiversity and Food Security: A Global Perspective—A Review Article'. *Agriculture & Food Security* 10(1): 36. doi:10.1186/s40066-021-00318-5.

Ndjouenkeu, R., E.J.F. Nzossie, C. Kouebou, C. Njomaha, A.I. Grembombo, and K.M. Oudanan 2010. 'Le maïs et le niébé dans la sécurité alimentaire urbaine des savanes d'Afrique centrale'. ISDA 2010. Cirad-Inra-SupAgro.

Ngaiwi, M.E., E.L. Molua, D.J. Sonwa, M.O. Meliko, E.J. Bomdzele, J.E. Ayuk, A. Castro-Nunez, and M.M. Latala 2023. 'Do Farmers' Socioeconomic Status Determine the Adoption of Conservation Agriculture? An Empirical Evidence from Eastern and Southern Regions of Cameroon'. *Scientific African* 19: e01498. doi:10.1016/j.sciaf.2022.e01498.

Ngansop, T.M., D.J. Sonwa, F.E. Fongnzossie, H.B. Biyé, P.F. Forbi, T. Oishi, and B-A. Nkogmeneck, 2019. 'Identification of Main Non-Timber Forest Products and Related Stakeholders in its Value Chain in the Gribe village of Southeastern Cameroon'. *ASC-TUFS working papers 2018.* Tokyo University of Foreign Studies. 181-191.

Nkem, J., B.K. Fobissie, M. Idinoba, A.S. Olufunso, O. Ndoye, and A. Awono 2010. 'Shaping Forest Safety Nets with Markets: Adaptation to Climate Change under Changing Roles of Tropical Forests in Congo Basin'. *Environmental Science & Policy* 13(6): 498-508.

Nkendah, R. 2013. 'Estimating the Informal Cross-border Trade of Agricultural and Horticultural Commodities between Cameroon and its CEMAC Neighbours'. *Food Policy* 41: 133-144.

Norris, K. 2008. 'Agriculture and Biodiversity Conservation: Opportunity Knocks'. *Conservation Letters* 1(1): 2-11. doi: 10.1111/j.1755-263X.2008.00007.x.

Nyong, A., F. Adesina, and B. Osman Elasha 2007. 'The Value of Indigenous Knowledge in Climate Change Mitigation and Adaptation Strategies in the African Sahel'. *Mitigation and Adaptation Strategies for Global Change* 12: 787-797.

Ochieng, J., L. Kirimi, and J. Makau 2017. 'Adapting to Climate Variability and Change in Rural Kenya: Farmer Perceptions, Strategies and Climate Trends'. *Natural Resources Forum* 41(4): 195-208.

Pagezy, H. 1993. 'The Importance of Natural Resources in the Diet of the Young Child in a Flooded Tropical Forest in Zaire'. In *Tropical Forests, People and Food: Biocultural Interactions and Applications to Development* (Man and the Biosphere Series 13).UNESCO, 365-365.

Pequeno, D.N.L., I.M. Hernández-Ochoa, M. Reynolds, K. Sonder, A. MoleroMilan, R.D. Robertson, M.S. Lopes, W. Xiong, M. Kropff, and S. Asseng 2021. 'Climate Impact and Adaptation to Heat and Drought Stress of Regional and Global Wheat Production'. *Environmental Research Letters* 16(5): 054070. doi: 10.1088/1748-9326/abd970.

Pypers, P., J.M. Sanginga, B. Kasereka, M. Walangululu, and B. Vanlauwe 2011. 'Increased Productivity through Integrated Soil Fertility Management in Cassava–Legume Intercropping Systems in the Highlands of Sud-Kivu, DR Congo'. *Field Crops Research* 120(1)：76-85.

Rosenzweig, C., F.N. Tubiello, D. Sandalow, P. Benoit, and M.N. Hayek 2021. 'Finding and Fixing Food System Emissions: The Double Helix of Science and Policy'. *Environmental Research Letters* 16(6): 061002. doi:10.1088/1748-9326/ac0134.

Seo, N., R.O. Mendelsohn, P. Kurukulasuriya, A. Dinar, and R.M. Hassan 2008. *Differential Adaptation Strategies to Climate Change in African Cropland by Agro-Ecological Zones*. World Bank.

Sneyd, A., A.F. Legwegoh, and L.Q. Sneyd 2015. 'Food Politics: Perspectives on Food Security in Central Africa'. *Journal of Contemporary African Studies 33*(1): 141-161.

Sonwa, D.J., P. Scholte, W. Pokman, P. Schauerte, M. Tsalefac, C.B. Biona, C.P. Brown, A. Haensler, F. Ludwig, and F.K. Mkankam 2014. 'Climate Change and Adaptation in Centration Africa: Past, Scenarios and Options for the Future'. In *The Forests of the Congo Basin: State of the Forest 2013*. Eds. C. de Wasseige, J. Flynn, D. Louppe, F. Hiol Hiol, and Ph. Mayaux, The Congo Basin Forest Partnership (CBFP), 99-119.

Sonwa, D.J. and J. Ndi Nkem Eds. 2014. *Les forêts du Bassin du Congo et l'adaptation aux changements climatiques*. Paris: Karthala.

Sundriyal M. and R.C. Sundriyal 2001. 'Wild Edible Plants of the Sikkim Himalaya: Nutritive Values of Selected Species'. *Economic Botany* 55 (3): 377-390.

Swinnen, J., C. Arndt, and R. Vos 2022. 'Climate Change and Food Systems: Transforming Food Systems for Adaptation, Mitigation, and Resilience'. In *Global Food Policy Report*. Washington, D.C.: International Food Policy Research Institute (IFPRI), 6-15.

Tendall, D.M., J. Joerin, B. Kopainsky, P. Edwards, A. Shreck, Q.B. Le, P. Krütli, M. Grant, and J. Six 2015. 'Food System Resilience: Defining the Concept'. *Global Food Security 6*：17-23.

Tingem, M. and M. Rivington 2009. 'Adaptation for Crop Agriculture to Climate Change in Cameroon: Turning on the Heat'. *Mitigation and Adaptation Strategies for Global Change* 14(2): 153-168. doi: 10.1007/s11027-008-9156-3.

Tubiello, F.N., C. Rosenzweig, G. Conchedda, K. Karl, J. Gütschow, P. Xueyao, G. Obli-Laryea, N. Wanner, S.Y. Qiu, J.D. Barros, A. Flammini, E. Mencos-Contreras, L. Souza, R. Quadrelli, H.H. Heiðarsdóttir, P. Benoit, M. Hayek, and D. Sandalow 2021. 'Greenhouse Gas Emissions from Food Systems: Building the Evidence Base'. *Environmental Research Letters* 16(6): 065007. doi: 10.1088/1748-9326/ac018e.

Tyukavina, A., M.C. Hansen, P. Potapov, D. Parker, C. Okpa, S.V. Stehman, I. Kommareddy, and S. Turubanova 2018. 'Congo Basin Forest Loss Dominated by Increasing Smallholder Clearing'. *Science Advances* 4(11). eaat2993. doi: 10.1126/sciadv.aat2993.

United Nations Development Programme (UNDP) and the United Nations Research Institute for Social Development (UNRISD) 2017. *Global Trends: Challenges and Opportunities in the Implementation of the Sustainable Development Goals*. UNDP and UNRISD.

van der Ploeg, J.D. 2014. 'Peasant-Driven Agricultural Growth and Food Sovereignty'. *The Journal of Peasant Studies* 41(6): 999-1030.

van Dijk, H. and F. Wiersum 1999. 'NTFP Resource Management as an Option for Multiple-Use Forest Management in South Cameroon'. In *Seminar Proceedings NTFP Research in the Tropenbos Programme: Results and Perspectives, - Wageningen, 28 January 1999*. Ed. M.A.F. Ros-Tonen, Wageningen: Tropenbos Foundation, 115-122.

World Food Programme (WFP) 2020. 'COVID-19: Level 3 Emergency'. *External Situation Report no*. 10, (3 July 2020).

Yingheng C. and T. Wigglesworth 2017. *The Tropical Tree Crop Sector of Sub-Saharan Africa.* London: Hardman Research.

Yue, S., J.F. Brodie, E.F. Zipkin, and H. Bernard 2015. 'Oil Palm Plantations Fail to Support Mammal Diversity'. *Ecological Applications* 25(8): 2285-2292.