Journal of Business and Environmental Management (JBEM)

Volume 2, Number 1, 2023, Pages 1 – 23

Journal Home Page

https://journals.airsd.org/index.php/jbem

Non-Timber Forest Products (NTFPs) as Climate Actions in West Africa Sahel: A review

Moussa Soumaila Abdoul Rachid[1], Sani Iddi Hannatou[1], Moussa Soulé[2]

[1]West African Center for Sustainable Rural Transformation (WAC-SRT), Faculty of Sciences and Techniques, University Abdou Moumouni of Niamey, Niger
[2]Department of Biology, Faculty of Sciences and Techniques, University Dan Dicko Dankoulodo of Maradi (UDDM), BP: 465 Maradi, Niger

ARTICLE INFO

Article History:

Received:	January	1, 2023
Revised:	January	20,2023
Accepted:	February	5,2023
Available Online:	March	10,2023

Keywords:

NTFPs, adaptations, mitigation, climate change, West African Sahel, Biodiversity

ABSTRACT

Climate change posed a significant challenge in the West African Sahel, a region identified as one of the most vulnerable to climate change globally. Despite this vulnerability, the role of Non-Timber Forest Products (NTFPs) in addressing climate change impacts has been underexplored. This study aimed to compile and analyze existing research highlighting the contribution of NTFPs in addressing climate change effects in the West African Sahel. The methodology employed in this study involved a systematic review of available data, drawing from various sources such as Google Scholar, Google, Z-library, Mendeley, and ResearchGate, covering the period from 2010 to 2023. The analysis revealed two primary categories of NTFPs based on their composition and societal utility: NTFPs of plant origin and NTFPs of animal origin. NTFPs made up approximately 3% of West Africa's GDP, with a significant impact on rural areas. They served as a crucial source of income for rural households in the Sahel, with some families earning up to USD 200 per month, constituting a substantial portion of their total income. The study identified various NTFPs and their roles in climate action in the West African Sahel. Examples included the leaves of baobab (Adansonia digitata), gum from Acacia senegal, Vitellaria paradoxa, and honey. These NTFPs enhanced community resilience by promoting food and nutrition security, income generation, and land conservation. Moreover, the study underscored the vital socio-economic role of NTFPs in strengthening community resilience and their significant contributions to carbon sequestration and biodiversity conservation. Consequently, this review paper recommended the inclusion of NTFPs in the climate change policies and programs of the West African Sahel.

Corresponding Author's Email: a.rachid.ms@gmail.com

INTRODUCTION

Climate change is causing significant and dangerous disruptions to nature and affecting the lives of billions of people around the world. People and ecosystems suffer the most. Rising

temperatures, droughts, and floods are already exceeding the tolerance thresholds of plants and animals, leading to mass mortalities in species such as trees (GIEC, 2022). These extreme weather events have exposed millions of people to acute food and water insecurity, particularly in Africa, Asia, Central, and South America, small islands, and the Arctic (GIEC, 2022). The West African Sahel region would be particularly affected by the risks posed by climate change in terms of food security. Several studies carried out across the region have highlighted the impact of current and future climate change on crops and food security (Bouda Maja Chardi et al., 2022; Sanou et al., 2022).

In addition, over the past few years, there has been a succession of interventions reiterating the commitment of political actors to development actions in the fight against poverty and hunger. Thus, on an international scale, consideration was given to the importance of plant diversity, in particular, the usefulness of forest products other than ligneous matter, qualified as non-ligneous forest products (NTFPs) in the improvement of human well-being (BA, 2020; USAID et al., 2014**).** Non-timber forest products are natural resources other than timber extracted from wild species from natural, modified or managed forest landscapes and other forest lands (Sardeshpande & Shackleton, 2019; Sills et al., 2011)**.** People recognize the benefits of NTFPs. But the importance of NTFPs and their contribution to food security and poverty reduction is generally underestimated because most of them are not included in national economic statistics. Furthermore, the NTFP sector operates in an informal setting. An adequate organizational, institutional and legal framework is lacking and the sector is underestimated (BA, 2020)**.**

Historically marginalized in favor of wood, NTFPs are receiving special attention because of their contribution to improving the living conditions of many people in developing countries. providing a combination of income, food, and therapeutic (BA, 2020)**.** However, the region is facing a gradual decline in forest resources, driven by factors such as demographic pressure, increased sown areas, charcoal production, and erratic rainfall patterns, leading to disastrous cycles of drought (USAID et al., 2014)**.** Consequently, this decline has resulted in lower agricultural yields, heightened food insecurity, and rural poverty, prompting communities to increasingly rely on NTFPs as a vital adaptation strategy. The West African Sahel region has experienced a significant decline in forest cover by 15% over the past decade due to deforestation and climate-induced stress on forests has further worsened the situation, exacerbating food insecurity and adding pressure on vulnerable populations (Lézine et al., 2023) .

Amidst climate change challenges, the West African Sahel region is witnessing ongoing efforts to promote the sustainable management and conservation of NTFPs (Coulibaly-Lingani et al., 2011; Tigabu et al., 2019). These initiatives aim to harness the potential of NTFPs to improve food security, alleviate poverty, and enhance the resilience of local communities. Community-Based Forest Management programs empower communities in Mali, Niger, and Burkina Faso to preserve traditional NTFP knowledge and adopt sustainable harvesting practices (B. Belcher et al., 2005). Forest and Landscape Restoration efforts integrate NTFP conservation, and Capacity Building and Training programs enhance skills related to sustainable NTFP harvesting, processing, and marketing (Endamana et al., 2016). Research efforts inform evidence-based policies for NTFP management (Tieminie et al., 2021), while Policy and Legal Reforms support the integration of NTFPs into national forest management plans. Market Access and Value Chain Development initiatives strengthen NTFP value chains, and Cross-Border Collaboration fosters knowledge exchange and best practices sharing (Essougong et al., 2019). These combined efforts highlight the growing recognition of NTFPs' significance in climate change adaptation and sustainable

development, contributing to community well-being, biodiversity conservation, and ecosystem resilience in the region.

Thus, to adapt to the changing context linked to the emergence of climatic and socio-economic disasters that affect populations, West African countries must significantly improve decision-making tools, governance and intervention schemes (Moussa et al., 2022)**.** This requires knowledge adapted to the local environmental, social, economic and technical context. In addition, scientific research should take into account climate actions in the mapping of resilience needs. This study falls within this perspective. It aims to demonstrate the contribution of NTFPs in the fight against the various impacts of climate change in the West African Sahel.

I. Material and methods

1.1. Presentation of the study area

The study covers all the Sahel countries of West Africa (Niger, Burkina Faso, Mali, Mauritania, Senegal, Guinea-Bissau, Guinea and Gambia). West African populations live mainly from agriculture (Hachigonta et al., 2013)**.** The agricultural sector is particularly vulnerable to climate change in West Africa. Regional cereal production has been estimated at around 66-74 million tonnes over the past five years (CILSS & USAID, 2016). However, this production represents only 3% of global production (FAO, 2018b). Unlike agricultural production, statistics on fruit production are very poorly controlled in the region. With more than 32% of arid zones unfavorable to rain-fed agricultural production, livestock farming constitutes the second economic activity of most Sahelian countries (CSAO-OCDE, CDAO, 2008)**.**

The Sahel and West Africa zone is very diverse in agro-climatic terms. Rainfall patterns vary from tropical climates in the south (Nigeria to Guinea), where bimodal rainy seasons are characterized by annual rainfall accumulations significantly greater than 2.5 m of rain in 8 to 10 months, to the Sahara Desert (from Mauritania to Chad), where not a single drop of rain is recorded all year round. Rainfall is the main production factor in the region given the low proportion of irrigated crops. Indeed, rainfed crops, which represent more than 95% of agricultural production in the region (CILSS & USAID, 2016).

The relationships between climate change and natural disasters are inherently complex and West Africa is no exception. Disasters vary greatly in intensity, spatial scale, slowness or speed, and frequency. The impact on populations, according to their degree of vulnerability, their capacity to respond to changes and disasters and to react also varies over time, in space and according to their socio-economic characteristics (Gautier et al., 2016)**.**

From the arid zone in the north to the humid tropical zone in the south, West Africa is facing various environmental changes. Moreover, the effects of global warming constitute a serious obstacle to development, contributing to food insecurity and aggravating health problems. In situations where natural resources are the basis of livelihoods and food security, environmental degradation has complex effects on human vulnerability and resilience (Gemenne et al., 2017).

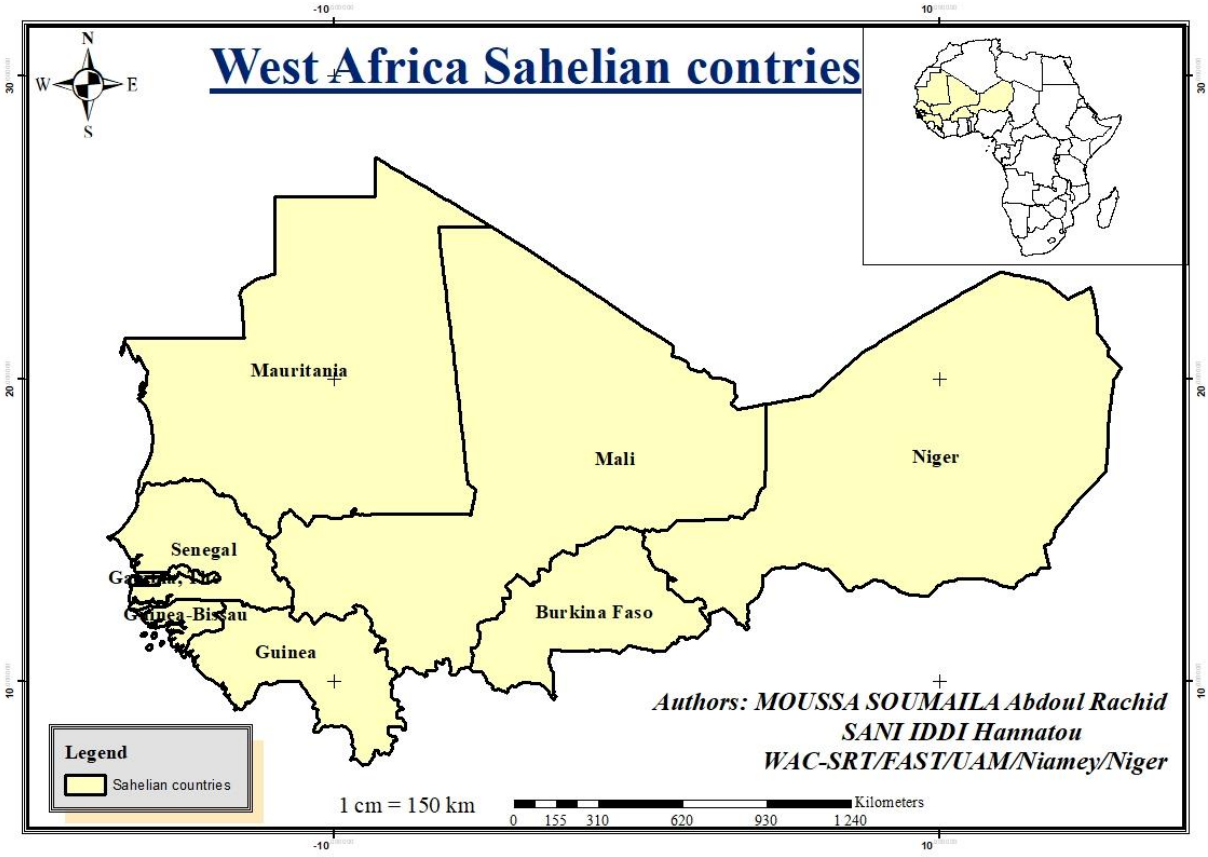

Figure 1: *Location map of the study area*

RESEARCH METHODOLOGY

As part of our article, we began by carrying out a review of the literature in order to define the concepts and to develop a theoretical framework on which we could rely to carry out our analyses. During this stage, it is a matter of collecting as much information as possible through the previous works having an interest for our study and thus to create a database. Emphasis was placed on data of different kinds (reports, scientific articles, books, field notes and other documents already published). Key words such as non-timber forest products, typology, adaptation, resilience, and biodiversity were used in search engines (Google, Google scholar, Researchgate, Mendeley, and Z-Library) for document collection. To better enrich our documentation, we have organized the search using the keywords: Boolean operators (and, or); proximity operators (adj, near); truncation and mask (*, $); parentheses, mask quotes and hypertext links.

The research was organized as follows: research into the types of non-timber forest products found in the West African Sahel; research into the contribution of non-timber forest products in adapting to and mitigating the effects of climate change and finally their contribution to the conservation of biodiversity. We performed the search specifying the period from 2010 to 2022.

It is from this database that we carried out most of our analyses. Our analysis strategy was divided into three stages. First, we familiarized ourselves with the data collected. In a second step, we reorganized the data and we cleaned them (pruning the variables deemed irrelevant). Finally, we manipulate its data in order to produce necessary information.

Figure 2 provides an overview of the methodology used.

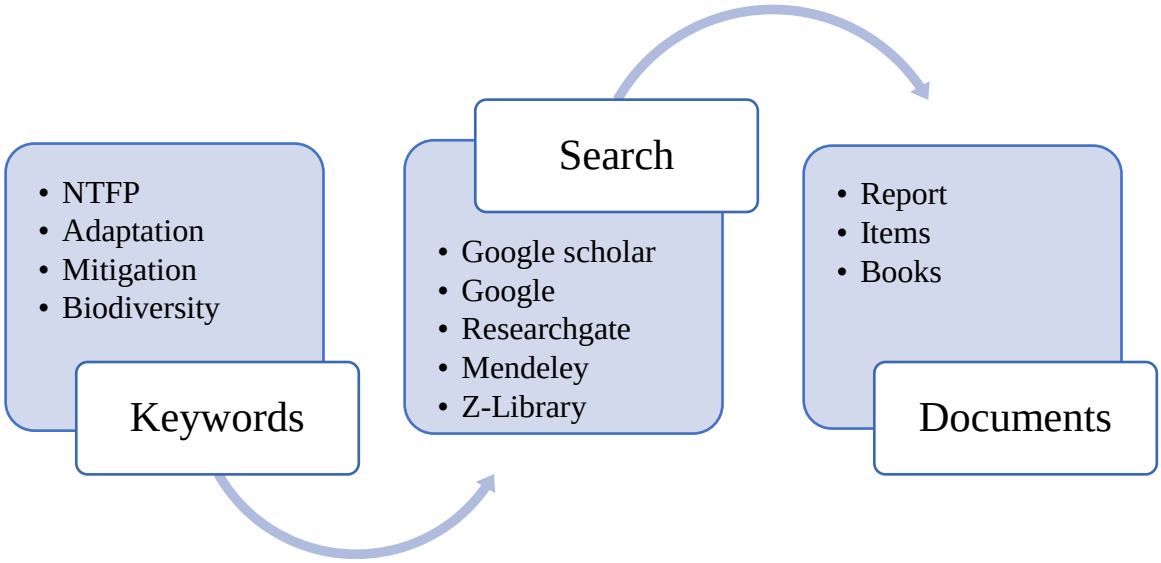

Figure 2: *Methodology used,Source: Authors*

Typology of non-timber forest products

RESULTS

Typology of non-timber forest products

The FAO Forest Service divides NTFPs into two main categories based on their lack of lignin in their anatomical composition and their use as a service to society (FAO, 1999; Kouakou, 2019)Tables I and II present the classification of NTFPs according to FAO (2002). Thus, a distinction is made between NTFPs of plant origin **(Tab 1)** and NTFPs of animal origin **(Tab 2).**

Tab 1: *Description of the main categories of non-timber forest products of plant origin*

Categories	Descriptions
Food	Foods and drinks from fruits, nuts, seeds, roots, etc.
Forages	Food for animals and bees from leaves, fruits, etc.
Medications	Medicinal plants used in traditional medicine and/or for pharmaceutical industries.
Perfumes and cosmetics	Aromatic plants providing essential (volatile) oils and other products used for cosmetics.
Dyes and tannins	Plant material (bark and leaves) providing tannins (mainly leaves and fruits) used as dyes.
Utensils, handicrafts and building materials	Heterogeneous group of products including thatch, bamboo, rattan, wrappings with leaves, fibers.
Ornamentation	Plants or parts of plants used for ornamental purposes.
Exudates	Gums (water soluble), resins (insoluble in water) and latex (milky or clear juice), extracted from plants by exudation.

Source: (FAO, 1999; Kouakou, 2019)

Tab 2: *Description of the main categories of non-timber forest products of animal origin*

Categories	Descriptions
Living animals	Vertebrates (mammals, birds, reptiles, etc.) raised or sold as pets.
honey, beeswax	Products supplied by bees.
Game meat	Meat from vertebrates, mainly mammals.
Other edible animal products	Edible invertebrates (caterpillars, snails, etc.) and other secondary animal products (eggs and nests).
Hides and skins, for hunting trophies	Hides and skins of animals used.
Medicine	Animals or parts of animals used for medicinal purposes.
Dyes	Animals or parts of animals used as dyes.
Other inedible animal products	Bones used as tools.

Source: (FAO, 1999; Kouakou, 2019)

Non-timber forest products and adaptations to climate change

In sub-Saharan Africa, many woody species provide non-timber forest products (NTFPs) that contribute significantly to food and nutrition security and improved living conditions for local people (Lykke & Padonou, 2019). According to an FAO study, NTFPs account for about 3% of West Africa's GDP, with a significant contribution in rural areas (FAO, 2011)**.** NTFPs are an important source of income for rural households in the West African Sahel region which is key to build climate resilience. For instance, the income generated from the NTFPs chain values are used by the farmers to buy drought tolerant crop species, to labor the croplands and even pay the school fees of their children. According to a USAID study, households that harvest and market NTFPs can earn up to US$200 per month, which can represent up to 50% of their total income (USAID, 2017)**.** A study conducted by the United Nations Development Programme (UNDP) examined the effects of gum Arabic marketing on food security and livelihoods of rural households in Niger. The results showed that the commercialization of gum Arabic can help reduce the vulnerability of rural households to economic and environmental shocks by providing them with additional income to invest in agriculture (UNDP, 2014).

Another study, conducted by the Food and Agriculture Organization of the United Nations (FAO), has shown that the use of improved seeds and fertilizers can help increase the production of gum Arabic and improve the quality of gum produced. Using revenues from the sale of gum Arabic to purchase agricultural inputs can be an effective approach to strengthening the resilience of rural communities to climate change in Niger (FAO, 2018a).

The exploitation of NTFPs generates income that contributes to improving the socio-economic situation of rural households and to the development of national economies (Assogbadjo et al., 2012; Vodouhê et al., 2009). In recent decades, semi-arid areas have experienced an accelerated deterioration of environmental conditions, which has weakened the balance of natural ecosystems (Guimbo et al., 2016).These pressures lead to accelerated degradation of natural plant formations, leading to the decline and disappearance of many woody species used by local populations (Ganamé et al., 2019; Traoré et al., 2019). However, the promotion of green jobs through the sustainable management and use of natural resources, such as non-timber forest products (NTFPs), can provide alternative income sources for rural populations, while also contributing to the restoration of degraded ecosystems. In this context, the conservation and sustainable use of NTFPs can play a crucial role in promoting both environmental sustainability and poverty reduction in the Sahel region.

Agroforestry with multifunctional tree species is an essential adaptation measure. Farmers sow cultivated woody species or promote natural regeneration. This provides a variety of ecosystem services that reduce the impacts of climate change on agricultural production and enable farmers to harvest non-timber forest products. The sale or domestic consumption of these NTFPshelps people cope with household food shortages during drought years (Lawali et al., 2018; Sendzimir et al., 2011). Farmers harvest flowers, fruits, fibers, fodder and medicine from a wide variety of trees for both domestic and commercial purposes. During the rainy season, farmers also harvest wild herbaceous species such as *Ceratotheca sesamoides*, *Cleome gynandra* and *Corchorus tridens*, on their farms for household food and sale, and some store them until the dry season. Some farmers have even domesticated certain wild plants for food and commercial purposes (Soulé et al., 2017) in Niger. This constitutes one of the major sources of income generating activities of the farmers in Niger which a climate change adaptation measure.

A large part of the population has no recourse but to collect and exploit the forest resources of plants and fauna to meet their daily needs. The new decentralized local and regional authorities could therefore be able to respond to their strategies of adaptation and management of the resources at their disposal, adopt management measures and regulations that risk compromising traditional and cultural practices (free access to certain resources, for example) of local populations at present, the exploitation and marketing of certain NTFPs in particular are not subject to any form of legislation. We are indeed witnessing a rebirth of interest in these species (Soulé et al., 2017).

In addition to the mentioned benefits, it is crucial to emphasize the significance of green jobs in West Africa. These green jobs can help retain youth in rural areas by providing sustainable economic opportunities. For instance, the income generated from the exploitation of non-timber forest products (NTFPs) can be used by women to purchase livestock, contributing to income diversification and household economic resilience. This approach also empowers women in rural regions(UN, 2021). It is important to note that the growth of green jobs can contribute to reducing the climate vulnerability of local populations. For example, the commercialization of products like gum Arabic can not only provide an additional income to rural households but also contribute to the preservation of local ecosystems. Moreover, using income from the sale of these products to invest in agricultural inputs, such as improved seeds and fertilizers, can strengthen rural communities' resilience to climate change challenges (ILO, 2023; UN, 2021). Consequently, the sustainable exploitation and management of NTFPs can play a pivotal role in promoting environmental sustainability and poverty reduction in the Sahel region. However, it is worth mentioning that the establishment of new decentralized local and regional authorities may require appropriate measures and regulations to preserve traditional and cultural practices, including free access to certain resources. For instance, certain activities related to the exploitation and marketing of NTFPs are currently not subject to any form of legislation, which necessitates special attention to ensure sustainable management while respecting the needs of local populations (ILO, 2023).

As we delve deeper into the realm of non-timber forest products (NTFPs) and their role in climate change adaptation, it becomes evident that edible insects deserve our attention as a sustainable dietary option. In certain cases, edible insects outshine conventional animal sources in terms of nutritional value. For instance, consider the iron content of beef, which typically averages around 6 mg per 100 g of dry weight. In contrast, various species of locusts exhibit iron contents ranging from 8 mg to 20 mg per 100 g of dry weight, contingent on the locust species and their specific diet. This revelation opens the door to the potential of

locusts as a nutritious alternative to beef, particularly in addressing iron deficiency among children, a condition that can impede their development and result in anemia (Mojisola, 2018).

Moreover, the consumption of edible insects generates income for rural populations in sahel west Africa. This not only enhances their economic resilience but also promotes sustainable livelihoods. Edible insects are a rich source of beneficial fats and oils, many of which contain polyunsaturated fatty acids and are naturally devoid of cholesterol. These qualities offer advantages not only for children but also for the prevention of heart diseases in adults. In addition to these nutritional merits, insects are low in calories. Thus, incorporating them into our diets alongside vegetables and fruits could play a pivotal role in reducing the risk of obesity, especially in the context of climate change adaptation (Mojisola, 2018).

Figure 2: *Grasshoppers, Source: (Usman & Yusuf, 2021)*

In the context of non-timber forest products (NTFPs) and their vital role in climate change adaptation, it is imperative to underscore the substantial contribution of these forest resources to the resilience of rural populations in the West African Sahel. One remarkable illustration is the impact of *Leptadenia hastata*, a plant that stands out for its versatility and economic importance. This plant, commonly known as 'yadiya' in Niger, plays a crucial role in adapting to the climatic challenges that affect the Sahel. A survey conducted in Burkina Faso in 1999 on food preferences for 14 herbaceous vegetables ranked *Leptadenia hastata* as the third most preferred wild vegetable. This popularity is attributed to its delightful taste and exceptional ability to withstand drought, pests, and poor-quality soils (Kimba & Patrick, 2017).

Leptadenia hastata is a concrete example of how non-timber forest resources contribute to climate change adaptation. During periods of drought or food scarcity, this plant serves as a valuable source of food, thereby enhancing food security for rural communities. Moreover, even in normal times, disadvantaged populations rely on this plant for their daily sustenance. Furthermore, *Leptadenia hastata* makes a significant contribution to diversifying income sources in these arid regions. Women, in particular, earn a substantial income from collecting

and selling the leaves, young shoots, and flowers of this plant. These economic activities, often carried out on-site, empower women financially and contribute to the improvement of livelihoods within Sahel's rural communities (Kimba & Patrick, 2017; UN, 2021). *Leptadenia hastata* is a tangible example of how non-timber forest products can play a pivotal role in adapting to the effects of climate change in the West African Sahel. This versatile plant contributes to food security, income diversification, and the improvement of living conditions for local populations, while enhancing their resilience to the region's climate challenges (Kimba & Patrick, 2017).

Figure 3: *Leptadenia hastata,* Source: (Tela Botanica, 2014)

The table 4 illustrating the diverse applications of gums, particularly gum Arabic, underscores the pivotal role of non-timber forest products (NTFPs) in climate change adaptation within the Sahel region of West Africa. These extensive uses of gums showcase their versatility and impact on the socio-economic development and resilience of local communities. The involvement of gums in the food industry, pharmaceutical sector, and various other domains not only fosters income generation but also bolsters food security, a critical consideration in the face of climate-related food shortages. Furthermore, their contributions to creating "green jobs" and supporting economic resilience, especially for rural populations and women, are noteworthy. The sustainable management of NTFPs, including gums, aligns with conservation efforts and aids in ecosystem restoration, enhancing both environmental and community resilience. It is imperative that in this process, cultural and traditional practices are preserved, and the introduction of regulations is done thoughtfully to ensure sustainability. In sum, the multi-faceted applications of gums exemplify their significance in mitigating the complex challenges of climate change in the Sahel while promoting environmental sustainability, economic growth, and cultural respect.

Tab 3: *Utilization Sectors and Key Applications of Gums in Burkina Faso*

Sector	Primary Applications
Food Industry	- Confectionery: Used in pastillation, dragee production, chewing gum, etc. - Beverage Aromatics: Stabilizes foams in soda, syrup, and other beverages. - Flavoring Products: Found in powdered flavors, clouding agents, and instant beverages. - Oenology: Used for tannin suspension and wine stabilization. - Food Products: Employed in coating dried fruits, sauces, condiments, icing for biscuits, cakes, desserts, and more.
Pharmaceutical Sector	- Pharmacy: Utilized in cough pastes, powdered vitamins, coated pills, syrups, and more.
Various sectors	- Lithography and Offset Printing: Serves as a plate protectant, offset printing solution, anti-setoff, and roller dampener. - Adhesives: Used in office glue, stamps, envelopes, and gummed paper. - Cosmetics: Found in liquid soaps and lotions. - Miscellaneous: Applications in foundry, ceramics, pyrotechnics, explosives, insecticides, pesticides, textile industry, and more.

Source: (Zida & Tiveau, 2009)

Figure 4: *Gum Arabic in Burkina Faso, Source: (Zida & Tiveau, 2009)*

In the realm of non-timber forest products (NTFPs) and their pivotal role in climate change adaptation, the table highlighting the contributions of *Balanites aegyptiaca* in Niger provides compelling insights. This species, known for its diverse utility, significantly bolsters the resilience of Sahelian communities in the face of climate challenges. Its multifaceted uses encompass food, medicine, and various services, showcasing its adaptability to meet a spectrum of needs. Furthermore, its prevalence in the northern regions presents a promising source of climate-resilient resources in areas marked by scarcity. The species' adaptability shines through in its varied utilization across different ethnic groups, contributing to diversified adaptive strategies. Traditional medicine benefits from *Balanites aegyptiaca*, as all its parts are employed to treat a range of human and animal ailments, underpinning local

health resilience. Additionally, the positive interactions between *Balanites aegyptiaca* and crops enhance food security and livelihoods for local communities, emphasizing its vital role in climate-resilient agricultural practices. In the context of climate change adaptation, *Balanites aegyptiaca* exemplifies the broader significance of NTFPs in addressing the intricate challenges faced by the Sahel region, reinforcing their crucial role in fostering resilience and sustainability. These findings add depth and nuance to the discussion of NTFPs' contributions to climate adaptation in the Sahel, enriching our understanding of the vital role these resources play in the region's efforts to combat climate change.

Tab 4: Contributions of *Balanites aegyptiaca* to Climate Change Adaptation in Niger

Aspect	Contribution
Diverse Uses of *Balanites aegyptiaca*	Provides a wide range of products for food, medicine, and other services, enhancing the resilience of Sahelian populations.
Agro-Ecological Variation	The species' abundance in the northern region offers potential climate-resilient resources in areas facing scarcity.
Ethnic Variability	Different ethnic groups have varying utilization patterns, contributing to diversified adaptive strategies.
Traditional Pharmacopoeia	All parts of *Balanites aegyptiaca* are used in traditional medicine to treat various human and animal illnesses, supporting local health resilience.
Positive Interaction with Crops	Beneficial interactions between *Balanites aegyptiaca* and crops enhance food security and livelihoods for local communities.

Source: (Ousmane et al., 2023)

The baobab fruit pulp in Mali is gaining recognition for its high nutritional value, particularly with regard to its rich content of procyanidins and flavonol glycosides, with tiliroside as the major component. The chemical analysis of both commercial baobab fruits and leaves reveals their potential as valuable sources of bioactive compounds. Notably, the similarity in phenolic profiles between baobab leaves and fruits suggests that the entire baobab tree can be utilized. These findings are essential in the context of climate change adaptation, as baobab fruit pulp extracts have displayed significant antioxidant activity, with the highest observed in specific fruits. Additionally, these extracts exhibit the potential to inhibit α-glucosidase, indicating their role in managing blood sugar levels and potential health benefits. Overall, the nutritional richness and diverse chemical composition of baobab contribute to its significance in climate change adaptation in Mali.

Tab 5: *Contributions of Baobab Fruit Pulp to Climate Change Adaptation in Mali*

Aspect	**Contribution**
Nutritional Value of Baobab Fruit Pulp	Baobab fruit pulp in Mali is gaining attention due to its high nutritional value, especially with regards to its fruit pulp.
Chemical Profiles of Baobab Fruits and Leaves	Chemical profiles of commercial baobab fruits and leaves have been analyzed, with a focus on phenolic content.
Rich in Procyanidins and Flavonol Glycosides	Baobab fruit pulps in Mali are rich in procyanidins and flavonol glycosides, with tiliroside identified as the major constituent.
Similar Phenolic Profiles in Leaves and Fruits	Baobab leaves in Mali exhibit a phenolic profile similar to that of the fruits, but with a higher number of detected phenolic compounds.
Antioxidant Activity of Baobab Fruit Pulps	Extracts from baobab fruit pulps have demonstrated antioxidant activity.
Extracts from baobab fruit pulps have demonstrated antioxidant activity, with the highest activity observed for Fruit.	Baobab fruit pulp extracts exhibit higher α-glucosidase inhibition compared to the standard acarbose, indicating potential health benefits.

Source: (Braca et al., 2018)

The following table provides a concise overview of the multifaceted contributions of non-timber forest products (NTFPs) to climate change adaptation in the Sahel region of West Africa. These contributions encompass a wide range of aspects, from enhancing food security and income to promoting green jobs, sustainable NTFPs management. This table serves as a visual summary of the significant role that NTFPs play in addressing the complex challenges of climate change in the Sahel, showcasing their diverse impacts on local communities and ecosystems.

Tab 6: *Contributions of NTFPs to Climate Change Adaptation in the Sahel West Africa*

Aspect	Contribution	Source
NTFPs' Role in Food Security and Income	NTFPs significantly enhance food security, income, and living conditions for local populations in the Sahel.	Lykke & Padonou, 2019; FAO, 2011; USAID, 2017; UNDP, 2014; Assogbadjo et al., 2012; Vodouhê et al., 2009
Promoting Green Jobs	Green jobs generated by NTFPs contribute to economic resilience, youth retention, and climate adaptation.	UN, 2021; ILO, 2023
Sustainable NTFPs Management	Sustainable NTFPs management plays a key role in forest conservation and climate change adaptation.	Nadkarni & Kuehl, 2013; Sardeshpande & Shackleton, 2019

The figure 5 below succinctly portrays the substantial contribution of non-timber forest products (NTFPs) in the West African Sahel to climate change adaptation. The two intersecting circles represent "Income (Promoting Green Jobs)" and "Sustainable NTFPs Management." The convergence of these aspects epitomizes the essence of NTFPs in adaptation. NTFPs not only create sustainable income opportunities, particularly through green jobs, bolstering local economies, retaining rural youth, and enhancing climate resilience, but also underscore the importance of sustainable resource management to ensure continued availability amid climatic challenges. The synergy between income generation and sustainable management empowers communities to adapt to mounting environmental pressures, fostering food security, sustainable employment, resilience, and the preservation of local ecosystems.

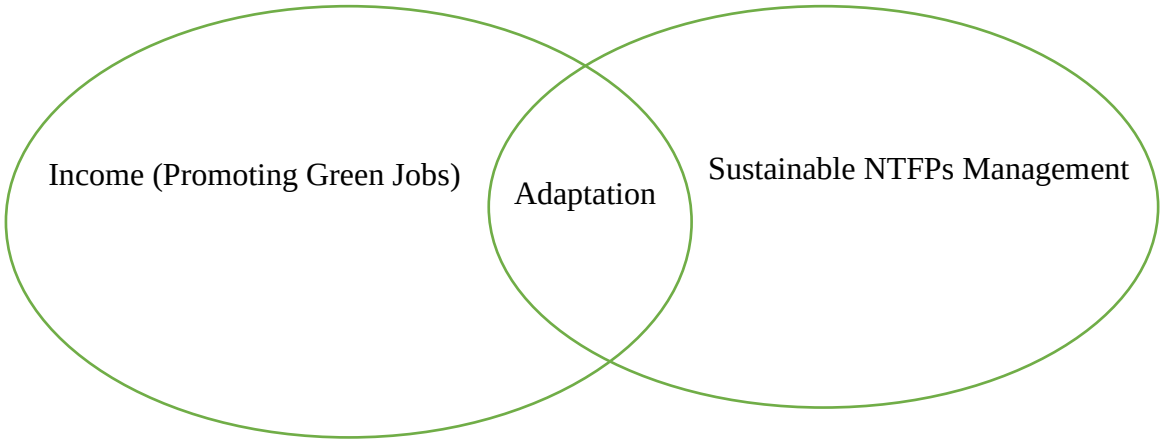

Figure 5: *contribution of NTFPs to climate change adaptation in Sahel West Africa Source: Authors*

Non-timber forest products and climate change mitigation

In the Sahel, NTFPs can contribute directly or indirectly to reducing emissions. NTFP production helps store and sequester carbon in forest systems. In addition, by providing income and livelihoods, NTFPs help reduce deforestation. This is of course interesting for REDD+. For these concepts to work effectively, the relationship between NTFPs and carbon sequestration in Sahelian forests must be studied to quantify each relationship (Nadkarni & Kuehl, 2013; Sardeshpande & Shackleton, 2019).

When considering the role of NTFPs in carbon sequestration, the issue of extraction (removal of biomass from forests) must be considered. Many initiatives aim to protect forests by prohibiting logging or restricting access. However, NTFPs often have to be extracted, removed or used to provide incentives for livelihoods or forest conservation. The life cycle of NTFPs can be very different from that of trees, potentially allowing sustainable logging at much shorter intervals. This indicates that NTFPs may need to be treated differently in forest policy in the Sahel in order to realize their potential for forest conservation and carbon sequestration. In addition, research on the sustainable extraction of NTFPs should be carried out (Nadkarni & Kuehl, 2013; Sardeshpande & Shackleton, 2019).

The management of NTFPs is key to forest sustainable forest management. For instance, it has been reported that the woody species which provide many services to the local people may be more protected for the sake for its values. Many forests have created based on the NTFPs such as *Acacia senegal* forest in Niger during many programmes. *Acacia senegal* forests have been established in Niger as part of various programs focused on restoring degraded land and promoting sustainable land use practices. These forests are often established through community-based initiatives that aim to provide economic opportunities for local communities through the sustainable harvest and sale of gum arabic, a valuable non-timber forest product (NTFP) derived from the tree's sap.

In the context of the Sahel, bees play a pivotal role in supporting the health and vitality of local ecosystems. Their activities, including pollination, significantly contribute to the reproduction and regeneration of various tree species. This, in turn, enhances the overall ecosystem productivity and resilience, making it essential for the sustainable management of forest resources. Moreover, bees' pollination activities promote increased photosynthetic rates in trees, facilitating carbon dioxide (CO2) uptake from the atmosphere. Bees' involvement in these activities can be particularly beneficial in semi-arid regions like the Sahel, where the impact of climate change is pronounced (Galea et al., 2016). The role of bees in carbon sequestration and the reduction of CO2 levels deserves attention. Bees, through their pollination services, facilitate the production of more fruits and seeds in trees and plants. The increased fruit and seed production, which are rich in carbon, essentially acts as a carbon sink. It enables the capture and storage of atmospheric CO2 in the form of organic matter, a process that contributes to reducing CO2 levels in the atmosphere. As such, bees indirectly aid in mitigating climate change by supporting the removal of CO2, a greenhouse gas, from the environment (Galea et al., 2016; Tscharntke et al., 2011).

The interplay between NTFPs, carbon sequestration, and bees highlights the intricate relationships within the Sahel's ecosystems.

According to a report by the United Nations Development Program (UNDP), as of 2019, over 5 million hectares of degraded land in Niger had been restored through initiatives such as the African Forest Landscape Restoration Initiative (AFR100), the Great Green Wall Initiative, and the Sustainable Land and Water Management Project (SLWMP). These initiatives have helped to establish thousands of hectares of *Acacia senegal* forests, which serve as a source

of income for rural communities while also providing ecosystem services such as carbon sequestration.

In order to summarize the key points regarding non-timber forest products (NTFPs) and their role in mitigating the effects of climate change, we have created a synthesis table. This table (Tab 4) provides a concise overview of the essential aspects, significant contributions, and relevant reference sources to gain a better understanding of this complex relationship. Explore the details of this table for an overview of the benefits of NTFPs and their sustainable management practices in the context of climate change in West Africa's Sahel region.

Tab 7: *Contributions of NTFPs and Sustainable Practices to Climate Mitigation in the Sahel*

Aspect	Contribution	Source
NTFPs in Emissions Reduction	Contribute to emissions reduction in the Sahel	Nadkarni & Kuehl, 2013; Sardeshpande & Shackleton, 2019
NTFPs in Carbon Storage and Sequestration	Aid in carbon storage and sequestration	Nadkarni & Kuehl, 2013; Sardeshpande & Shackleton, 2019
NTFPs in Income Generation and Deforestation Reduction	Provide income and reduce deforestation	Nadkarni & Kuehl, 2013; Sardeshpande & Shackleton, 2019
Bees' Role in Ecosystem Health	Play a vital role in supporting ecosystem health	Galea et al., 2016
Bees' Enhancement of Photosynthesis	Enhance photosynthetic activity in trees	Galea et al., 2016; Tscharntke et al., 2011
Bees' Contribution to CO2 Reduction	Contribute to the reduction of CO2 levels	Galea et al., 2016; Tscharntke et al., 2011
***Acacia senegal* Forests in Niger**	Established as a result of NTFPs programs	United Nations Development Program (UNDP)
Degraded Land Restoration Initiatives	Helped establish *Acacia senegal* forests	United Nations Development Program (UNDP)

Non-timber forest products and biodiversity conservation

The economy of the countries of the Sahel is based mainly on the primary sector, especially the rural sector. However, productive activities are severely affected by recurrent droughts, desertification, climatic hazards, demographic pressure and high levels of demographic poverty. These phenomena, while aggravating climatic drought, accelerate the degradation of natural resources in general and forests in particular (Dramé & Berti, 2008). Nevertheless, despite the limited potential, forest resources, especially those that provide non-timber forest products (NTFPs) play a strategic role for the populations who obtain a food supplement, medicines, and fodder for the livestock. Even under threat, these NTFPs contribute to the preservation of biodiversity. However, in the absence of a clearly defined policy for the promotion of non-timber forest products in the Sahel, all of these forest resources providing NTFPs will be threatened with extinction. The natural formations are in an advanced state of degradation due to excessive removal of wood linked to an ever-increasing population growth (Dramé & Berti, 2008). The scarcity or even the disappearance of natural resources leads to the advance of the desert, to the reduction of soil fertility, to the decline of agricultural productivity, thus causing food insecurity. In this context, the protection of natural resources, especially plant species, is becoming increasingly important in agricultural practices.

Several studies on local woody plant plantations in projects such as the Great Green Wall, show the ecological benefits, economic and social impacts of local timber plantations in

projects such as the Great Green Wall in West Africa, in particular with regard to the restoration of degraded land, the protection of biodiversity and poverty reduction. A study conducted by Gadzama (2017) examined the potential ecological and economic benefits of the Great Green Wall in Africa. The results showed that the project could contribute to the restoration of ecosystems and the protection of biodiversity (Gadzama, 2017). Another erude conducted by Goffner et all (2019) examined the effects of large-scale plantations on local vegetation as part of the Great Green Wall in Senegal. The results showed that plantations increased the diversity of plant species and promoted the regeneration of natural vegetation, thus contributing to the conservation of biodiversity (Goffner et al., 2019). One of the main coping strategies is to combine crops with livestock and forestry. This use of agroforestry pastoral land improves soil fertility, reduces poverty and leads to the preservation of biodiversity, which further builds resilience (Ministère de L'Agriculture du Niger, 2019).
The value of including non-timber forest products (NTFPs) in forest management has been established by various international conventions and national forestry programs as the best way to balance conservation and development (Vantomme & (Vantomme & Gazza, 2010). These measures were based on the principle that NTFPs are easily accessible products for the poor while providing them with additional income. Furthermore, it was assumed that the harvesting, processing and marketing of these did not require any investment or skill on the part of the exploiters (Belcher & Vantomme, 2003). As a result, NTFPs have been seen as a tool to improve people's livelihoods while encouraging them to conserve natural resources (Kusters et al., 2005). In order to test this hypothesis, several scientists have contributed to the study of NTFP trade and production (Kusters et al., 2006; Tynsong et al., 2013). Most of the research results have shown that despite the support provided in terms of valuing NTFPs, reconciling conservation and development remains a challenge (Jensen & Meilby, 2008). Proved that the commercialization of NTFPs could lead to the depletion of exploited resources and an unequal distribution of added value. It is therefore not possible to establish a general policy for the management of NTFPs, nor to identify the overall effects of their exploitation.

The free collection of NTFPs generally leads to overexploitation of the resource, which leads to its depletion (Tchatat & Ndoye, 2006). This situation is mainly facilitated by an increased demand for the target NTFP in the market or by an increase in the value of the product (Peltier et al., 2008). With regard to controlled harvesting, this generally has a positive impact on the conservation of the species. Nevertheless, silvicultural practices aimed at promoting the production of the target NTFP can lead to the elimination of certain species (Vennetier, 2014). This can lead to a change in the structure of the habitat. Combining intercropping strategies with specialty crops also has positive conservation effects. However, there is a risk of transformation of forests into agricultural plantations (Vantomme & Gazza, 2010).

Reconciliation between development and conservation could be achieved through the adoption of controlled harvesting or a specialized agricultural strategy (Kusters et al., 2005). However, the products for which a given country or region has the most comparative advantage should be prioritized.

Fruit picking contributes to the conservation of the tree and the species, provided that the practice of picking does not involve felling the tree. However, the harvesting of stems, bark, resin or latex has a negative impact on the regeneration and growth of the individual (Tchatat & Ndoye, 2006). This could lead to resource depletion, causing habitat disturbance and threatening biodiversity conservation. Regarding the collection of leaves or fruits for the extraction of essential oil, it can be the source of a massive consumption of wood energy (Cavalcanti et al., 2015).

In the Sahel region, where climate challenges and the need for biodiversity conservation intersect, it is crucial to comprehend the dynamics of non-timber forest products (NTFPs). The following Table 5 provides a condensed overview of these connections. It distills the intricate relationship between NTFPs and biodiversity conservation in the Sahel, emphasizing the importance of sustainable practices and the need for a harmonious balance between resource utilization and preservation.

Tab 5: *NTFPs and Biodiversity Conservation*

Aspect	Contribution	Source
Importance of NTFPs in Sahelian economies	Essential for food security, livelihoods, and climate resilience	(Dramé & Berti, 2008)
The role of the Great Green Wall in biodiversity conservation	Shows ecological and economic benefits, including land restoration and biodiversity protection	(Gadzama, 2017; Goffner et al., 2019)
Agroforestry as a resilience strategy	Enhances soil fertility, poverty reduction, and biodiversity preservation	(Ministry of Agriculture of Niger, 2019)
NTFPs in forest management and conservation	Vital for balancing conservation and development; face challenges like resource depletion	(Vantomme & Gazza, 2010; Kusters et al., 2006)
Impact of resource collection methods	Controlled harvesting positively impacts biodiversity; free collection may lead to overexploitation and habitat disruption	(Tchatat & Ndoye, 2006; Vennetier, 2014)
Prioritizing products based on comparative advantage	Prioritization of NTFPs is crucial for sustainable resource management, balancing development and conservation	(Kusters et al., 2005)
Sustainable harvesting and the impact on tree health	Sustainable practices benefit tree and species conservation; unsustainable practices may negatively affect regeneration and growth	(Tchatat & Ndoye, 2006; Cavalcanti et al., 2015)

DISCUSSION

Non-Timber Forest Products (NTFPs) have been recognized as an important climate action in West Africa Sahel due to their potential to mitigate climate change, promote adaptation and reduce poverty. NTFPs are products obtained from forests other than timber, including fruits, nuts, medicinal plants, and non-wood fibers. The utilization of NTFPs promotes sustainable forest management, reduces deforestation and forest degradation, and provides economic benefits for local communities.

In West Africa Sahel, where the impacts of climate change are particularly severe, the promotion of NTFPs can contribute to enhancing the resilience of ecosystems and communities. For example, the cultivation and use of drought-resistant crops, such as baobab and jujube, can improve food security and provide income for rural households, while also reducing the pressure on natural resources.

Several studies have highlighted the potential of NTFPs as climate actions in West Africa Sahel. For instance, a study by Koffi et al. (2017) examined the contribution of shea butter production to climate change mitigation and adaptation in Burkina Faso. The study found that shea butter production reduces the need for firewood and charcoal, thus reducing

deforestation and associated greenhouse gas emissions, while also providing income for women and enhancing their adaptive capacity (Koffi et al., 2017)**.**

Another study by Miyake & Kohsaka (2022) assessed the potential of NTFPs to promote adaptation to climate change in the Sahel region. The study found that NTFPs, particularly medicinal plants and wild fruits, have the potential to improve food security, promote health, and enhance the resilience of rural communities (Miyake & Kohsaka, 2022)**.**

However, their full utilization and potential are hindered by several challenges. One significant challenge is limited market access. Many rural communities rely on local markets, which may not offer competitive prices or reach a wide customer base. Improving market linkages, supporting value chain development, and exploring opportunities for NTFP trade at national and international levels can help overcome this challenge (Cavendish, 2018; Ingram et al., 2019).

Another critical challenge is climate vulnerability. While NTFPs can contribute to climate adaptation, they are also susceptible to the impacts of climate change, such as shifting rainfall patterns and extreme weather events. Building climate resilience in NTFP-dependent livelihoods through agroforestry practices, diversification of income sources, and community-based adaptation strategies is crucial (Pokorny et al., 2019; Rasmussen et al., 2020).

Unsustainable harvesting of NTFPs is another pressing concern. Uncontrolled harvesting can lead to overexploitation and threaten the long-term availability of these resources. Implementing sustainable harvesting guidelines, monitoring systems, and involving local communities in resource management can promote responsible NTFP use (Nasi et al., 2018; Paudel et al., 2021).

To unlock the full potential of NTFPs in the region, appropriate policies and interventions are needed. This includes developing supportive policy frameworks that recognize and integrate NTFPs into broader climate action and sustainable development strategies (Börner et al., 2019; Kusters et al., 2021). Additionally, capacity building and training programs for local communities on sustainable NTFP harvesting, processing, and value addition can improve the efficiency and quality of NTFP-based products (Russo et al., 2021; Shackleton et al., 2017) Inclusive stakeholder engagement involving local communities, government agencies, NGOs, and private sectors is essential to ensure a holistic approach and ownership of NTFP initiatives (Cunningham et al., 2020; Schreckenberg et al., 2019). Furthermore, investment in infrastructure, such as processing facilities and transportation networks, can enhance the value chain for NTFPs and improve market access (Russo et al., 2021; Shackleton et al., 2017).

By addressing these challenges and implementing these recommendations, the West African Sahel region can fully leverage NTFPs as essential measures to address climate change and promote sustainable and equitable development for local communities. Overall, NTFPs offer significant potential as climate actions in West Africa Sahel, providing multiple benefits for both the environment and local communities. However, their full potential can only be realized through policies and interventions that promote sustainable forest management and support the development of value chains for NTFPs.

CONCLUSION

Non-Timber Forest Products (NTFPs) represent a valuable opportunity for effective climate actions and biodiversity conservation in the West Africa Sahel region. By providing alternative sources of income and livelihood for local communities, NTFPs can help reduce reliance on unsustainable practices like overgrazing and deforestation. Moreover, the sustainable use of NTFPs contributes to the preservation of the region's rich biodiversity by promoting the conservation of forests and other natural habitats. Embracing policies and programs that encourage the sustainable utilization of NTFPs holds the potential to yield positive environmental, economic, and social outcomes in the West Africa Sahel region. As a result, it is imperative for governments, policymakers, and stakeholders to prioritize the promotion and conservation of NTFPs to foster sustainable development in the region.

To strengthen these efforts, specific recommendations and action plans can be implemented to support the sustainable management and market development of NTFPs. Firstly, promoting community-based management of NTFPs and empowering local communities in decision-making processes can enhance their ownership and ensure responsible resource use. Secondly, investing in capacity-building initiatives to train local communities in sustainable harvesting, processing, and value addition of NTFPs will improve the quality of products and access to higher-value markets. Additionally, fostering partnerships between governments, NGOs, and the private sector can facilitate the development of strong value chains for NTFPs, enabling fairer and more competitive market access for local producers. Moreover, integrating NTFPs into climate change adaptation and mitigation strategies at the regional and national levels can raise awareness of their significance and secure financial support for their conservation and sustainable use.

While NTFPs offer significant potential for sustainable development, it is essential to acknowledge and address existing challenges and limitations in their utilization. Ensuring equitable distribution of benefits and promoting gender-inclusive approaches can enhance the social impact of NTFP initiatives. Combining traditional ecological knowledge with scientific research can foster innovation and best practices in NTFP management. Addressing climate change vulnerabilities and building resilience in NTFP-dependent livelihoods require adaptive and context-specific strategies that take into account local ecological and socio-economic dynamics.

Overall, NTFPs have emerged as valuable allies in addressing climate change and fostering biodiversity conservation in the West Africa Sahel region. By embracing their potential and addressing challenges, the region can embark on a path towards a more sustainable and resilient future. Specific action plans and policy measures are pivotal to fully harness the benefits of NTFPs, ensuring their positive impact on both the environment and local communities. Acknowledging the importance of NTFPs and devising targeted solutions will contribute to a more practical and impactful approach to achieving sustainable development in the region.

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