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CARBON CREDITS: A PANACEA FOR MITIGATING CLIMATE CHANGE EFFECTS AND PROMOTING SUSTAINABLE AGRICULTURAL DEVELOPMENT AMONG ROOT AND TUBER CROPS FARMERS IN NIGERIA

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ABSTRACT

Climate change poses significant challenges to agricultural sustainability, particularly in regions like Nigeria where rural communities depend heavily on root and tuber crops for livelihoods and food security. This paper explores the potential of carbon credits as a solution to mitigate the adverse effects of climate change while fostering sustainable agricultural development among root and tuber crops farmers in Nigeria. The study examines the current climate change scenario in Nigeria, highlighting its impacts on agriculture, especially on root and tuber crops which constitute a significant portion of the country's agricultural output. It discusses the vulnerability of rural farmers to climate variability and the need for adaptive strategies to ensure food security and livelihood sustainability. Furthermore, the paper delves into the concept of carbon credits and their role in incentivizing climate-friendly agricultural practices among rural farmers. It explores the mechanisms through which farmers can participate in carbon credit programs, such as adopting climate-smart agricultural techniques, implementing agroforestry practices, and reducing deforestation and land degradation. Drawing upon existing literature and case studies, the abstract evaluates the potential benefits and challenges of integrating carbon credit schemes into rural agricultural systems in Nigeria. It discusses the economic, environmental, and social implications of such initiatives, including income generation for farmers, carbon sequestration, biodiversity conservation, and community resilience to climate change impacts. This paper highlights the importance of policy support and institutional frameworks in facilitating the adoption of carbon credit mechanisms by rural farmers. It emphasizes the need for capacity building, access to finance, and technical assistance to enhance the participation of smallholder farmers in carbon market initiatives.

Keywords**:** Carbon credit, climate change, sustainable agriculture, root and tuber crops farmers

Introduction

Climate change poses a formidable challenge to agricultural systems worldwide, intensifying vulnerabilities and threatening food security, particularly in regions heavily reliant on root and tuber crops (Intergovernmental Panel on Climate Change 2019). Among these regions, Nigeria stands out as a focal point, where rural communities depend significantly on crops such as cassava, yams, and sweet potatoes for sustenance and primary source of income for millions of smallholder farmers for livelihoods. Root and tuber crops possess several characteristics that make them suitable for carbon sequestration. Their extensive root systems enhance soil structure and organic matter content, which improves soil health and increases its carbon-holding capacity (Lal, 2020). Some studies have shown that the cultivation of these crops

can lead to substantial carbon storage in soils, helping to offset emissions from other agricultural activities (Smith *et al.,* 2008). Additionally, these crops are often grown in regions where sustainable farming practices can have a profound impact on both local ecosystems and global carbon cycles (FAO, 2017, World Bank 2019). These crops are not only essential for food security but also have a notable potential to sequester carbon in the soil, contributing to the reduction of green house gas emissions. However, the agriculture sector, including root and tuber crop farming, faces significant challenges due to climate change, which threatens yields and farmer livelihoods. In recent years, carbon credit schemes have emerged as a promising tool for promoting climate-friendly agricultural practices while generating additional income for farmers (United Nations Framework Convention on Climate change 2020), (Kiptot *et al* 2019). Carbon credits represent a tradable commodity that allows entities to offset their carbon dioxide CO_2 emissions by investing in projects that reduce or sequester greenhouse gases (GHGs) from the atmosphere. These carbon credits can be traded or sold to others who might find it harder to reduce their emissions, so in essence it's a system that encourage everyone to work towards a cleaner environment, whether is a company, a farmer or an individual, by participating in projects that cut down on greenhouse gas emissions, they can earn these credits and contribute to fight against climate change (FAO, 2017, Lobell *et al* 2010). While carbon credit schemes have been predominantly associated with industrial and energy sectors, their application in agriculture, particularly among smallholder root and tuber crop farmers, holds significant promise for climate change mitigation and sustainable development. The integration of carbon credit schemes into agricultural practices offers a unique opportunity to address multiple challenges simultaneously. By adopting climate-smart agricultural techniques, such as agroforestry, conservation agriculture, and improved crop management practices, smallholder farmers cannot only reduce their carbon footprint but also enhance soil fertility, conserve water resources, and improve crop yields (Okonkwo *et al* 2017, FAO 2013). These practices contribute to climate change mitigation by sequestering carbon in soils and biomass, thus offsetting emissions while promoting sustainable agricultural intensification. Carbon credits represent one innovative approach to addressing climate change impacts in agriculture while simultaneously providing economic incentives for farmers to adopt sustainable practices. By sequestering carbon in soil and vegetation, farmers can earn carbon credits, which can then be sold on carbon markets .This not only helps mitigate climate change by reducing greenhouse gas emissions but also provides an additional income stream for farmers, contributing to their resilience and food security (Akinnifesi *et al* 2019, Olawuyi *et al* 2020).

The implementation of carbon credit systems in the cultivation of root and tuber crops offers farmers economic incentives to adopt and maintain sustainable agricultural practices. By engaging in carbon credit markets, farmers can earn revenue from the carbon they sequester, which can then be reinvested into further sustainable practices or other aspects of their operations (Gattinger *et al.*, 2012,Kiptot et al. (2019)). This not only enhances the economic viability of their farming practices but also promotes environmental stewardship. More so several studies also highlighted the potential of carbon credit schemes to empower smallholder farmers and enhance their resilience to climate change impacts. For instance, research by (Kiptot *et al* 2019, Rockström *et al* 2010, Gattinger *et al.*, 2012,) demonstrates that

participating in carbon credit programs can substantially increase farmers' income and improve their livelihoods, particularly in resource-constrained rural settings. Similarly, findings from the study by (Molua *et al* 2017, Gebrehiwot *et al* 2020) highlight the positive socio-economic and environmental outcomes of integrating carbon credit schemes into smallholder agriculture, including poverty reduction, enhanced food security, and ecosystem restoration. Moreover, the role of carbon credits extends beyond financial incentives, encompassing broader socio-economic and environmental co-benefits. By promoting sustainable land management practices and forest conservation, carbon credit schemes contribute to biodiversity conservation, watershed protection, and ecosystem resilience, thereby safeguarding vital ecosystem services upon which rural communities depend (Antle *et al* 2008, FAO, 2017). Additionally, by diversifying income sources and enhancing access to markets, carbon credit schemes can help smallholder farmers cope with climate-related risks and market uncertainties, fostering greater socio-economic stability and empowerment. In the quest for sustainable agriculture, carbon credits have emerged as a vital tool for mitigating climate change while promoting environmentally friendly farming practices. Moreover, the potential for carbon credits in root and tuber crops aligns with broader sustainability goals. The integration of carbon sequestration efforts with crop production supports the United Nations Sustainable Development Goals (SDGs), particularly those related to climate action (SDG 13), life on land (SDG 15), and zero hunger (SDG 2) (FAO, 2019). By fostering sustainable agricultural practices, carbon credits contribute to the resilience of food systems, enhance biodiversity, and improve livelihoods in rural communities (Pretty *et al.*, 2018). Research also indicates that sustainable management practices, such as reduced tillage, cover cropping, and organic amendments, can significantly enhance the carbon sequestration potential of root and tuber crops (Michael, 2014, Poeplau & Don, 2015). These practices not only increase carbon storage but also improve soil fertility and crop yields, creating a positive feedback loop that further promotes sustainable agriculture (Tilman *et al.*, 2011). Carbon credits for root and tuber crops represent a promising avenue for advancing agricultural sustainability. These crops' inherent ability to sequester carbon, combined with economic incentives for farmers, creates a powerful synergy that can drive both environmental and socio-economic benefits. As the global community continues to seek effective strategies for combating climate change, integrating carbon credit systems into the cultivation of root and tuber crops offers a viable and impactful solution.

Potentials of Carbon Credits to Mitigate the Effects of Climate Change on Root and Tuber Crops Farmers in Nigeria

Carbon credits play a pivotal role in empowering farmers by providing them with financial incentives to adopt sustainable agricultural practices that mitigate climate change. Here, we delve into the multifaceted role of carbon credits for farmers:

***Promotion of Sustainable Practices*:** Carbon credit programs incentivize root and tuber crops in the adoption of climate-smart agricultural practices that reduce greenhouse gas emissions and enhance carbon sequestration in soils. Practices such as conservation agriculture, agroforestry, cover cropping, and crop rotation improve soil health, water retention, and biodiversity, while also reducing emissions of methane and

nitrous oxide from agricultural activities (Lipper *et al*., 2014; Smith *et al*., 2007). These practices not only enhance soil fertility and productivity but also contribute to environmental sustainability (Nkonya *et al.*, 2016).

***Financial Incentives*:** Participation in carbon credit schemes provides root and tuber crop farmers with additional income streams. By implementing sustainable practices, farmers earn carbon credits, which can be sold on the carbon market. Studies have shown the economic benefits of carbon credit programs for smallholder farmers in Africa, indicating their potential to alleviate poverty and improve livelihoods (Swallow *et al*., 2017). Carbon credit programs offer farmers an opportunity to generate additional income by participating in activities that reduce greenhouse gas emissions or sequester carbon. By implementing climate-smart agricultural practices such as agroforestry, conservation tillage, cover cropping, and improved livestock management, farmers can earn carbon credits, which can be sold on carbon markets. These financial incentives provide farmers with a new revenue stream, diversifying their income sources and improving their economic resilience.

***Access to Markets*:** Participation in carbon credit programs can provide root and tuber crop farmers in Nigeria with access to new markets for their produce. Buyers interested in supporting sustainable agriculture may be willing to pay premium prices for crops grown using environmentally friendly practices. Many consumers and businesses are increasingly seeking products certified as being produced sustainably or with low carbon footprints. By participating in carbon credit programs, farmers can differentiate their products in the market and attract environmentally-conscious consumers, thereby enhancing market opportunities and profitability. Enhancing market access can contribute to increased incomes and economic resilience for farmers (Liverpool-Tasie *et al*., 2019).

***Adoption of Climate-Smart Agricultural Practices*:** Carbon credit programs incentivize the adoption of climate-smart agricultural practices that reduce greenhouse gas emissions and enhance carbon sequestration in soils. Practices such as conservation agriculture, agroforestry, cover cropping, and crop rotation improve soil health, water retention, and biodiversity, while also reducing emissions of methane and nitrous oxide from agricultural activities (Lipper *et al*., 2014; Smith *et al.*, 2007).

***Climate Change Mitigation*:** The adoption of sustainable agricultural practices supported by carbon credit programs contributes to mitigating climate change by reducing emissions of greenhouse gases such as carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O). For instance, practices like afforestation and reforestation sequester carbon from the atmosphere, while soil conservation measures enhance carbon storage in agricultural soils. By actively participating in carbon credit schemes, farmers become key stakeholders in global efforts to combat climate change (Akinnifesi, *et al* 2019).

***Improved Soil Health and Productivity*:** Many of the practices incentivized through carbon credit programs not only reduce emissions but also improve soil health and agricultural productivity. For example, practices like conservation agriculture, agroforestry, and organic farming enhance soil fertility, water retention, and biodiversity, leading to increased crop yields and resilience to climate

variability. By adopting these practices, farmers can achieve sustainable increases in productivity while mitigating climate risks (Jose, 2009). Implementing sustainable land management practices, such as cover cropping, crop rotation, and mulching, can further enhance carbon sequestration and soil health in root and tuber crop farming systems. These practices improve soil structure, increase organic matter content, and reduce erosion, leading to long-term carbon storage in the soil.

***Policy Support and Institutional Development*:** Carbon credit programs require supportive policy frameworks and institutional structures to function effectively. Governments can play a crucial role in providing regulatory support, establishing monitoring and verification systems, and facilitating market access for carbon credits. Moreover, capacity-building initiatives aimed at farmers, extension workers, and other stakeholders can strengthen the implementation of sustainable practices and enhance the success of carbon credit programs (Place *et al*., 2012).

Community Development and Resilience: Carbon credit projects often involve community-based initiatives that promote social cohesion, capacity building, and sustainable development in rural areas. By empowering farmers to adopt sustainable practices and diversify their income sources, carbon credit programs contribute to poverty alleviation, food security, and community resilience to climate change impacts. Moreover, by conserving natural resources and ecosystem services, these initiatives safeguard the long-term well-being of farming communities. (Bäckstrand *et al*., 2017).

***Climate Resilience*:** Sustainable agricultural practices promoted by carbon credit programs enhance the resilience of root and tuber crop farming systems to climate change. Diversified cropping systems, improved water management, and soil conservation contribute to increased resilience against climate variability and extreme weather events (Jose 2009, Ouedraogo *et al.,* 2018). Beyond the economic benefits, carbon credit programs also contribute to climate resilience in root and tuber crop farming systems. Practices that enhance carbon sequestration and soil health improve the resilience of crops to climate variability and extreme weather events, such as droughts and floods. This resilience is crucial for maintaining stable yields and ensuring food security in the face of changing climatic conditions.

Enhanced Food Security and Livelihoods: Sustainable agricultural development supported by carbon credit programs contributes to food security and poverty alleviation in rural communities. By adopting practices that improve soil fertility, water efficiency, and crop yields, farmers can increase food production while reducing their vulnerability to climate-related risks (Thornton *et al.*, 2010; Lipper *et al*., 2014).

***Encouraging Emission Reductions*:** Carbon credit programs create financial incentives for industries, businesses, and individuals to reduce their greenhouse gas emissions. By establishing a price for carbon emissions through the trading of carbon credits, these programs encourage entities to invest in cleaner technologies, improve energy efficiency, and adopt sustainable practices. This leads to a decrease in overall emissions, helping to mitigate climate change by reducing the concentration of green house gases in the atmosphere (Jose, 2009).

***Carbon Sequestration in Soils*:** Sustainable agricultural practices promoted through carbon credit programs facilitate the sequestration of carbon in agricultural soils. Practices like conservation tillage, organic farming, and agroforestry increase soil organic matter, enhancing carbon storage capacity and contributing to climate change mitigation (Antle & Stoorvogel, 2008; Lal, 2004).

***Promoting Renewable Energy*:** Carbon credits support the development and deployment of renewable energy projects such as wind farms, solar installations, and hydropower plants. These projects generate clean energy without emitting greenhouse gases, displacing the need for fossil fuel-based energy sources. By providing financial incentives and market certainty, carbon credits make renewable energy investments more attractive and financially viable, accelerating the transition to a low-carbon economy.

***Improved Resilience to Climate Change*:** By adopting climate-smart agricultural practices, farmers enhance the resilience of agricultural systems to climate change impacts such as droughts, floods, and temperature extremes. Practices that improve soil health and water management, supported by carbon credit programs, help farmers adapt to changing climatic conditions while maintaining or increasing agricultural productivity (Lipper *et al.,* 2014; Thornton *et al*., 2010).

***Enhanced Food Security and Livelihoods*:** Sustainable agricultural development supported by carbon credit programs contributes to food security and poverty alleviation in rural communities. By adopting practices that improve soil fertility, water efficiency, and crop yields, farmers can increase food production while reducing their vulnerability to climate-related risks (Thornton *et al.,* 2010; Lipper *et al.,* 2014).

***Market Opportunities for Sustainable Products*:** Carbon credit programs create market opportunities for sustainably produced agricultural products. Consumers and businesses increasingly demand products with low carbon footprints and environmental certifications. By participating in carbon credit schemes, farmers can differentiate their products in the market, command premium prices, and access niche markets focused on sustainability (Lipper *et al.,* 2014;Molua & Lambi, 2007).

***Supporting Afforestation and Reforestation*:** Carbon credit programs incentivize afforestation (planting trees on land that has not been forested in recent history) and reforestation (replanting trees in areas that were previously deforested). Trees act as natural carbon sinks, absorbing carbon dioxide from the atmosphere through photosynthesis and storing it in biomass and soils. By promoting afforestation and reforestation projects, carbon credits help to sequester carbon, mitigating climate change while also providing additional environmental benefits such as biodiversity conservation and watershed protection (Okonkwo, *et al* 2017)

***Fostering Sustainable Agriculture*:** Carbon credits support sustainable agricultural practices that reduce greenhouse gas emissions from farming activities and enhance carbon sequestration in soils. Practices such as conservation tillage, cover cropping, agroforestry, and improved livestock management can help reduce emissions of methane and nitrous oxide, two potent greenhouse gases associated with agriculture. Additionally, these practices improve soil health and increase carbon storage in

agricultural soils, further contributing to climate change mitigation.

***Encouraging Carbon Capture and Storage (CCS)*:** Carbon credit programs incentivize the implementation of carbon capture and storage (CCS) technologies, which capture CO2 emissions from industrial processes or power plants and store them underground or in geological formations. CCS technologies play a crucial role in reducing emissions from industries with high carbon intensity, such as cement production, steel manufacturing, and fossil fuel power generation. By providing financial incentives for CCS projects, carbon credits help accelerate the deployment of this technology, contributing to climate change mitigation efforts (Smith *et al.,* 2014; Paustian *et al*., 2016).

***Facilitating International Cooperation*:** Carbon credit programs enable international cooperation and collaboration in addressing climate change. Through mechanisms such as the Clean Development Mechanism (CDM) and international carbon markets, developed countries can finance emission reduction projects in developing countries, where mitigation opportunities may be more cost-effective. This not only helps developing countries reduce emissions but also supports sustainable development by providing additional investment and technology transfer. (Ouedraogo, *et al* 2018)

Capacity Building: Carbon credit programs often include capacity-building initiatives aimed at educating farmers about sustainable practices and carbon sequestration techniques. These initiatives enhance farmers' knowledge and skills, empowering them to implement effective strategies for reducing emissions and improving soil health. Research by Place *et al*. (2012) underscores the importance of farmer training and extension services in promoting sustainable agriculture in Nigeria.

Adaptation Strategies for Carbon Credit Programs among Root and Tuber Crops Farmers

Farmers can adapt to climate variability while participating in carbon credit schemes by implementing a range of climate-smart agricultural practices that not only sequester carbon but also enhance resilience and productivity. Here's how farmers can adapt to climate variability under carbon credit programs:

***Agroforestry Systems*:** Farmers can integrate trees into their agricultural landscapes through agroforestry systems. Agroforestry not only sequesters carbon in trees and soil but also provides multiple benefits such as shade, windbreaks, and improved soil fertility. Farmers can earn carbon credits by establishing and maintaining agroforestry systems, which also help mitigate the impacts of climate variability by improving water retention and reducing soil erosion. : (Akinnifesi *et al* 2019).

***Conservation Agriculture*:** Conservation agriculture involves minimizing soil disturbance, maintaining crop residues on the soil surface, and practicing crop rotation to improve soil health and moisture retention. By adopting conservation agriculture practices, farmers can enhance their resilience to climate variability by reducing the risk of soil erosion, conserving water, and improving crop yields. Carbon credits can be earned through practices such as zero-tillage and cover cropping, which sequester carbon in soil organic matter. Lal, R. (2015).

***Improved Crop Varieties*:** Farmers can adapt to climate variability by selecting and planting crop varieties that are more tolerant to heat, drought, and other climatic stresses. Breeding and adopting climate-resilient crop varieties can help farmers maintain productivity even in the face of changing weather patterns. Participating in carbon credit programs can provide incentives for farmers to adopt improved crop varieties that sequester carbon and contribute to climate change mitigation. (Lobell, *et al* 2010)

***Water Management*:** Efficient water management is crucial for adapting to climate variability, particularly in regions prone to droughts and irregular rainfall. Farmers can invest in water harvesting techniques, such as rainwater harvesting and small-scale irrigation systems, to ensure reliable access to water for irrigation during dry periods. By using water more efficiently and effectively, farmers can mitigate the impacts of climate variability on crop production and qualify for carbon credits through improved water management practices. (Rockström,*et al* 2010)

***Livestock Management*:** Livestock management practices can also contribute to climate change adaptation and mitigation. Farmers can adopt sustainable livestock management practices, such as rotational grazing and improved feed management, to reduce greenhouse gas emissions from livestock production while enhancing resilience to climate variability. Carbon credits can be earned through practices that reduce methane emissions from livestock and enhance carbon sequestration in grassland sand soil. (Conant,*et al* 2017)

***Soil Conservation and Rehabilitation*:** Soil conservation and rehabilitation practices, such as agroforestry, cover cropping, and terracing, can help farmers adapt to climate variability by improving soil structure, fertility, and moisture retention. By implementing soil conservation practices, farmers can reduce the risk of soil erosion, enhance carbon sequestration in soil organic matter, and qualify for carbon credits under carbon credit programs (Lal, R. (2015).

***Capacity Building and Extension Services*:** To effectively adapt to climate variability and participate in carbon credit programs, farmers require access to training, information, and extension services. Governments, NGOs, and other stakeholders can provide capacity building support to farmers through training programs, demonstration plots, and extension services focused on climate-smart agricultural practices. By building the capacity of farmers to adopt climate-resilient and carbon-sequestering practices, carbon credit programs can help enhance the adaptive capacity of rural communities to climate variability (FAO, 2019)

Challenges of Carbon Credit to Farmers

While carbon credits offer significant potential for mitigating climate change and promoting sustainable agricultural development, several challenges need to be addressed to realize their full benefits. Here are some of the key challenges associated with carbon credits

***Complexity and High Transaction Costs*:** The process of participating in carbon credit programs can be complex and bureaucratic, involving significant transaction costs for project development, verification, and certification. Smallholder farmers, who often lack technical expertise and financial resources, may find it difficult to navigate these complexities, limiting their ability to access carbon credit markets (Phalan et al., 2009; Wollenberg *et al.*, 2008).

***Lack of Access to Finance and Resources*:** Many smallholder farmers face challenges in accessing the financial resources and technical assistance needed to implement carbon credit projects. Limited access to credit, inadequate infrastructure, and insufficient extension services can hinder farmers' capacity to adopt climate-smart agricultural practices and participate in carbon credit schemes (Bryan *et al*.,2010; Minang *et al.*, 2007).

***Land Tenure and Ownership Issues*:** Insecure land tenure and unclear land ownership rights present barriers to implementing carbon credit projects, particularly in developing countries. Uncertainty over land tenure can deter investment in long-term carbon sequestration activities such as afforestation and reforestation, limiting the potential for carbon credits in mitigating climate change (Larson *et al.*, 2013; Robinson *et al.*,2015).

Risk and Uncertainty: Carbon credit projects are subject to various risks and uncertainties, including fluctuations in carbon prices, policy and regulatory changes, and climate-related risks such as droughts or pest outbreaks. These uncertainties can undermine the financial viability of carbon credit projects and discourage investment, particularly in regions with high climate variability (Challinor *et al*., 2014; Daigneault *et al,*; 2012).

***Measurement and Monitoring Challenges*:** Accurately measuring and monitoring carbon sequestration and emissions reductions from agricultural activities pose significant challenges. Methods for quantifying carbon stocks and emissions in agricultural landscapes are often complex and require sophisticated monitoring technologies, which may not be readily available or affordable for smallholder farmers (Minang *et al*., 2007; Bryan *et al.*,2010).

***Market Volatility and Lack of Price Stability*:** Carbon markets can be volatile, with fluctuating carbon prices influenced by factors such as policy changes, economic conditions, and market speculation. Lack of price stability and predictability can deter investment in carbon credit projects and undermine their effectiveness in incentivizing emission reductions and sustainable agricultural practices (Chen *et al.*, 2018; Schneider *et al*.,2016).

Addressing these challenges requires coordinated efforts from governments, development organizations, and the private sector to design supportive policies, provide financial and technical assistance, strengthen land tenure systems, improve measurement and monitoring capabilities, and enhance market mechanisms for carbon credits. By overcoming these challenges, carbon credits can play a more effective role in mitigating climate change and promoting sustainable agricultural development.

Way Forward

Moving forward, addressing the challenges associated with carbon credits in mitigating climate change for sustainable agricultural development requires a concerted effort from policymakers, development organizations, researchers, and stakeholders.

***Policy Support and Institutional Strengthening*:** Governments should enact supportive policies and regulatory frameworks to facilitate the participation of farmers in carbon credit programs. This includes establishing clear land tenure systems, providing incentives for sustainable agriculture, and creating mechanisms for

monitoring and reporting emissions reductions (Phalan *et al*., 2009; Robinson *et al.*, 2015).

***Financial and Technical Assistance*:** Development organizations and financial institutions should provide financial and technical assistance to help farmers overcome barriers to participation in carbon credit schemes. This includes funding for capacity building, technology transfer, and infrastructure development, as well as access to credit and insurance (Bryan *et al.*, 2010; Minang *et al.*, 2007).

***Community Engagement and Empowerment*:** Stakeholder engagement and community participation are essential for the success of carbon credit projects. Farmers should be involved in decision-making processes, project design, and implementation to ensure that initiatives are tailored to local needs and priorities (Larson et al., 2013; Schneider et al., 2016).

***Enhanced Measurement and Monitoring*:** Efforts should be made to improve measurement and monitoring capabilities for carbon sequestration and emissions reductions in agricultural landscapes. This includes investing in remote sensing technologies, developing standardized methodologies, and building local capacity for data collection and analysis (Chen *et al.*, 2018; Daigneault *et al.*,2012).

***Market Mechanism Reform*:** Carbon markets need to be reformed to enhance price stability, transparency, and liquidity. This includes measures to reduce market volatility, increase demand for carbon credits, and streamline trading processes. Governments can play a role in establishing carbon pricing mechanisms and promoting the integration of carbon markets at the regional and international levels (Challinor *et al*., 2014;Wollenberg et al.,2008).

***Research and Innovation*:** Continued research and innovation are essential for advancing the effectiveness and scalability of carbon credit schemes in agriculture. This includes research on sustainable agricultural practices, climate-smart technologies, and ecosystem-based approaches to carbon sequestration. Innovation in monitoring and verification technologies can also improve the accuracy and reliability of carbon credit projects (Lipper *et al.*, 2014; Thornton *et al*., 2010).

By addressing these key areas, stakeholders can overcome the challenges associated with carbon credits in mitigating climate change for sustainable agricultural development, unlocking the full potential of these schemes to promote resilience, prosperity, and environmental stewardship in farming communities.

Conclusion

Carbon credits offer a promising avenue to support root and tuber crop farmers in adopting sustainable practices, enhancing their resilience to climate change, and improving their economic stability. By aligning agricultural practices with environmental goals, carbon credits can play a pivotal role in promoting a sustainable and food-secure future. However, addressing issues such as policy support, financial access, community engagement, measurement and monitoring, market reform, and research and innovation, stakeholders can unlock the full potential of carbon credit schemes to promote resilience, prosperity, and environmental stewardship in farming communities. Collaborative efforts among stakeholders at all levels are necessary to create an enabling environment and unlock

the full potential of carbon credit schemes to promote resilience, prosperity, where farmers can thrive both economically and environmentally.

Moving forward, it is essential to prioritize inclusive and participatory approaches that empower farmers, especially smallholders, to actively engage in carbon credit programs. This requires building local capacity, strengthening institutional arrangements, and fostering collaboration between governments, development organizations, research institutions, and the private sector. Furthermore, recognizing the interconnectedness of climate change, agriculture, and sustainable development is crucial for designing holistic solutions that address multiple challenges simultaneously. Integrating climate-smart agricultural practices, ecosystem-based approaches, and innovative financing mechanisms can enhance the effectiveness and scalability of carbon credit schemes, leading to more resilient and sustainable agricultural systems.

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