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Trade-offs and synergies of climate adaptation strategies within the agriculture value chain in Africa

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Abstract
Climate change poses serious threats to trade globally, with a severe impact on developing African economies. This is problematic as African economies seek to leverage on the African Continental Free Trade Area (AfCFTA) and drive socioeconomic growth and development on the continent. Minimizing the effect of climate change on trade in general and the AfCFTA, in particular, requires the implementation of robust climate-induced strategies that can reduce the impact of climate change while building the capacity of economies and people to respond to the effect of climate change. Nevertheless, such strategies while addressing climate change may indirectly increase vulnerability, particularly in smallholder agriculture communities. This study adopts a systematic literature review to examine the synergies and trade-offs in climate adaptation strategies that are geared towards promoting trade in Africa. Using the agriculture value chain as a case study, the results show that adaptation strategies are largely concentrated within the production value chain where smallholder farmers are highly engaged. The existing adaptation strategies while increasing crop and livestock productivity for intra-African trade equally exert a negative impact on humans and the environment. Understanding the synergies and trade-offs associated with climate-induced strategies is essential to guide policymakers in the implementation of policies and strategies that both reduce vulnerability and enhance adaptive capacity in Africa.

Keywords
Intra-African trade; climate-smart agriculture; synergies; trade-offs; sustainable development; Africa;

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1. Introduction

The African Continental Free Trade Area (AfCFTA) has been described as a game changer for Africa's socioeconomic growth and development (African Union Commission, 2015). Signed by the African Heads of State and Government in 2018 and implemented in 2021, the AfCFTA has the greatest potential to transform intra-African trade, and trade with the rest of the world. Currently, intra-African trade remains relatively low (about 15&) compared to other regions of the world (Asia 59%, Europe 69% and 31% in North America) even though about 16% of the world population live in Africa (Songwe, 2019). The AfCFTA therefore, offers a great opportunity to increase trade among African countries, thereby boosting industrialization, robust and sustainable socioeconomic and structural transformation, and integration (African Union Commission, 2015; UNECA 2017).

The AfCFTA is reported to make Africa the biggest free trade area globally due to its current population of about $1.3 billion consumers. Economically, Africa is projected to attract about $3 trillion in the gross domestic product (GDP) from the AfCFTA in the long run (Songwe, 2019). In the short run, a projection of about $34.6 billion has been reported as a result of about a 52% rise in intra-African trade (UNECA, 2018). The benefits from the AfCFTA will also include spillover effects on job creation and its associated impact on employment and income, as well as improvement in food security, health, community development and wellbeing, particularly in smallholder agriculture communities (Elitcha, 2019).

Agriculture, being the backbone of African economies contributes substantially to growth and development on the continent. The agriculture sector in Africa is the major source of employment, foreign exchange, livelihood and food security strategies while sustaining industrialization due to its provision of raw materials for industries(AGRA, 2018; Oxford Business Group, 2021). As such, the implementation of the AfCFTA and its associated drive for industrialization on the continent makes agriculture a strategic sector for the progress of the free trade agreement. However, can Africa's agricultural systems drive industrialization and intra-African trade given that it is highly susceptible to the adverse effects of climate change?

Climate change and extreme weather such as high temperatures, poor and erratic rainfall patterns, floods, droughts and the associated pests and diseases, are prominent in Africa (IPCC, 2022), resulting in a drastic reduction in crops and animal yields, income from agriculture and household food security as well as worsening poverty (Asare-Nuamah, 2021; Sultan & Gaetani, 2016). Climate change has equally intensified the invasion of cereals and grains by fall armyworms, leading to about $3 billion in loss of maize annually on the continent (African Union, 2017). Indeed, climate change has serious implications on the contribution of agriculture to trade and industrialization under the AfCFTA (Glauber, 2022).

Nevertheless, climate change adaptation, which constitutes an adjustment in human systems to minimize the effects of current and future climate change and explore beneficial opportunities (IPCC, 2022), has the potential to boost the significant role of agriculture in trade. Adaptation may be planned (systematic), autonomous (incremental) or transformational and may be implemented by different agents across differential spatial scales (Fedele et al., 2019). Climate-induced adaptation strategies for trade are relevant across the entire agriculture value chain due to the trio benefits of improving productivity, adaptive capacity and mitigation (FAO, 2021). On-farm adaptation strategies such as the application of agrochemicals and improved crop varieties, irrigation and mechanized farming have been reported to significantly reduce the effects of climate change on agriculture by boosting yields and productivity (Asare-Nuamah, et al., 2021; Asare-Nuamah & Mandaza, 2020), which is essential for the sustainability of intra-African agricultural trade. Similarly, value addition and processing will be essential to increasing the competitive and absolute advantage of African countries' trading in agricultural goods (Glauber, 2022).

Climate change adaptation, however, results in trade-offs and synergies (FAO, 2021), which are inherently rooted in the adaptation decision-making process (Morrison-Saunders & Pope, 2013). Indeed, synergies and trade-offs may be recognized, neglected or overlooked during the adaptation decision-making process. For instance, smallholder farmers may overlook the health and ecosystem implications of the application of chemical fertilizer while prioritizing its use for improved crop productivity and the associated economic gains (Asare-Nuamah et al., 2021). Trade-off refers to a situation where the implementation of a particular adaptation strategy results in the achievement of a particular goal while limiting or hindering the achievement of another or other goals (s) (FAO, 2021).

According to Zhao et al., (2018), trade-off constitutes the opportunity cost of achieving a particular adaptation goal while Morrison-Saunders and Pope (2013) consider trade-off as the negative impact resulting from the implementation of a particular adaptation strategy. Inversely, synergy constitutes the situation where the implementation of a particular adaptation strategy results in the achievement of another or other goal(s) (FAO, 2021). Thus, synergy occurs when the aggregate or cumulative effect of combining two or more adaptation strategies is greater than the sum of each if implemented separately. According to Roy et al., (2022), synergy may not only be restricted to positive impact but co-benefits that may emerge from the implementation of adaptation strategies.

Trade-off and synergy is gaining significant attention in recent times in the climate change adaptation literature (Akinyi et al., 2021). This is necessary as a better understanding of the trade-offs and synergies associated with climate change adaptation helps to make an informed decision, particularly in a resource-constrained African environment. Roy et al. (2022) explored the synergies and trade-offs associated with global adaptation strategies in multiple ecosystems and their relation to gender and the achievement of sustainable development goal 5. Akinyi et al., (2021) equally assessed adaptation strategies employed in smallholder African agriculture systems and reported how they result in trade-offs and synergies. Given the relevance of the knowledge of climate change adaptation trade-offs and synergies in informed decision-making, however, climate change adaptation trade-offs and synergies within the framework of the AfCFTA have not received attention in the literature. Guided by the research question 'What are the trade-offs and synergies associated with climate-induced adaptation strategies within the agriculture value chain for intra-African trade? this study examines how climate change adaptation strategies within the agriculture value chain for intra-African trade can result in synergies and trade-offs.

The relevance of this study lies in its contribution to literature and policy by enhancing an improved knowledge of intra-African agricultural trade and the agriculture systems' resilience to shocks and stressors. Also, unlike previous studies (Akinyi et al., 2021; Roy et al., 2022), this study focuses on the agriculture value chain from production to transportation/distribution and storage. The rest of the paper is arranged as follows: research methods, results and discussion, and conclusion.

2. Research Methods

This study applied a systematic literature review approach and focused on the agriculture value chain comprising production, value addition, transportation/distribution and storage. The emphasis on the agriculture value chain is due to its relevance to trade in agricultural goods under the AfCFTA and the attainment of Africa's food security.

The systematic literature review was appropriate for this study due to the fragmentation of scientific documents and articles relating to the subject matter and the need to have a convergence and synthesis of the state of knowledge on the subject matter.

The systematic literature review is appropriate when a study seeks to evaluate the current state of knowledge on a particular subject matter or topic (Williams et al., 2018). As such, the systematic literature review approach has gained significant attention and application in recent times in many fields of research including climate change adaptation (McDowell et al., 2016). The structured and rigorous approach adopted in systematic literature review has enhanced its application among scholars. The approach begins with a systematic identification, selection and examination of scientific documents and articles about the subject matter studied, thereby enhancing the current state of knowledge as well as identifying gaps in the literature and directions for future research (Delaney et al., 2014; Tánago et al., 2016).

The search for documents and articles for a systematic literature review takes place in research databases and this study used Google Scholar and JSTOR databases. Limited access to other equally important databases informed the choice of Google Scholar and JSTOR. Key terms were developed and merged using the 'OR' and 'AND' Boolean operators to enhance the retrieval of all relevant documents related to the focus of the study. The literature search focused on documents or articles published between 2018 and 2022. The lower boundary was because the AfCFTA was signed in 2018, which may have influenced climate change interventions on the continent. The upper boundary was necessary to ensure that the latest knowledge on the subject matter was retrieved and included in the study.

The key terms for the retrieval of literature included "climate adaptation" OR "climate innovation" OR "synergies" OR "trade-offs" OR "co-benefit" OR "maladaptation" OR "agriculture" OR "intra-African trade" OR "AfCFTA" OR "Africa" OR "sub-Saharan Africa" OR "adaptation AND agriculture" OR "synergies AND trade-off" OR "adaptation AND trade". The inclusion criteria for the literature search included: journal articles published from 2018 to 2022 within the fields of agricultural, social, environmental and biological sciences as well as climate change, and focused exclusively on Africa.

About 1092 articles were retrieved from the databases and screened for eligibility following the systematic literature review process presented in Figure 1. The retrieved articles were screened for duplication and duplicate articles were removed. This was followed by a careful review of the titles of the articles to examine their suitability for the study. Titles that did not contain any of the key terms or those that contained some of the key terms but whose focus area was not on the subject matter or the geographic context (Africa) were excluded. The next stage of the review process involved the evaluation or screening of abstracts to identify their suitability for inclusion in the final articles to be reviewed. Afterwards, the included articles from the abstract screening stage were fully perused for eligibility, leading to the inclusion of 37 articles for final review in this study. Thematic qualitative analysis and descriptive quantitative analysis were employed. Articles with common or similar themes on synergies and trade-offs of adaptation strategies were grouped. Geographic categorization of the articles was also performed as well as the categorization of the articles into literature review studies and empirical research articles. Another categorization also focused on which part of the agriculture value chain an article belonged to or focused on.

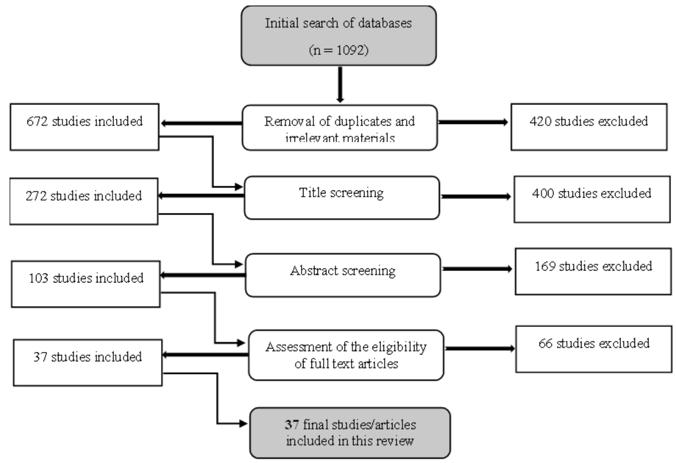

Figure 1. Schematic Representation of the systematic literature review adopted in this Study

3. Results and Discussion

3.1 Articles Characteristics

The majority of the articles were field-based research articles (54%) while the remaining were review articles. In terms of geography, Ethiopia, Ghana, Kenya, Burkina Faso, South Africa and Mali were the countries with the most articles (59%) on adaptation and its associated synergies and trade-offs. About one-third of the remaining articles focused on sub-Saharan Africa in general or a specific region such as Western, Eastern or Southern Africa. The majority of the articles (75%) also focused on adaptation strategies within the production value chain. The adaptation strategies adopted within the production value chain included the application of improved crop and livestock varieties, agrochemical application, irrigation farming, mulching, crop rotation and diversification, as well as intercropping, agroforestry, conservation agriculture, water harvesting and storage, and agricultural expansion.

3.2 Trade-offs and Synergies in Climate Change Adaptation for Intra-African Trade

3.2.1 Production Value Chain

This section presents climate change adaptation strategies that are employed to aid in agricultural production, which is necessary for intra-African trade, particularly trade in agricultural goods. The identified adaptation strategies include the application of improved crop and livestock varieties, agrochemical application, irrigation farming, mulching, crop rotation and diversification, as well as intercropping, agroforestry, conservation agriculture, water harvesting and storage, and agricultural expansion. Production adaptation strategies are applied on farms to boost crop and livestock yields (Swinnen et al., 2022), which is important for intra-African trade while improving households' income and food security among vulnerable farmers.

The impact of climate change on crops has significantly affected the ability of local crops to thrive, thereby resulting in the production, dissemination and application of improved crop varieties including drought-tolerant crops, less water consumption crops, pest and disease-tolerant crops, and early maturing crops, among others (Akinyi et al., 2021; Asare-Nuamah, et al., 2021; Rattunde et al., 2021). Farmers' preference for improved crop varieties is largely due to their ability to increase yields and income while improving the resilience of smallholder agriculture systems (Loboguerrero et al., 2019). This has the potential to boost the adaptive capacity and food security of vulnerable and poor households that depend mainly on agriculture as their livelihood strategy (Antwi-Agyei et al., 2018; Asare-Nuamah, et al., 2021; Hansen et al., 2019; vom Brocke et al., 2020). Specific to intra-African trade, improved varieties is essential to increasing a country's trade volumes, leading to higher returns. However, the application of improved crop varieties increases the financial burden of farmers due to their associated costs (Asare-Nuamah, et al., 2021; Maredia et al., 2019). Similarly, to reap the high-yielding potential of improved crops varieties, farmers combine improved crop varieties with agrochemicals, which poses risk to the environment and ecosystem systems such as microorganisms, water and aquatic lives as well as the health of humans (Akinyi et al., 2021; Antwi-Agyei et al., 2021).

Agrochemical application has gained attention in the literature as an agriculture intensification strategy to minimize the effects of climate change on crops (Antwi-Agyei et al., 2021; Kurgat et al., 2018). Agrochemicals - fertilizers, weedicides, and pesticides among others, have been intensively applied by smallholder farmers in Africa to increase yields (Antwi-Agyei, Dougill, et al., 2021), which is critical for the AfCFTA. Fertilizer in particular has been reported to increase soil fertility and crop productivity while weedicides and pesticides minimize the effects of invasive weeds and pests, respectively (Akinyi et al., 2021; Asare-Nuamah, 2022; Kurgat et al., 2020). The potential of agrochemicals to contribute indirectly to household food security and income has been highlighted (Kurgat et al., 2018).

Contrarily, agrochemicals have negative effects on the environment as their application increases carbon emissions, particularly nitrogen-content agrochemicals (Lopez-Ridaura et al., 2018; Tongwane & Moeletsi, 2018). Their chemical components are also toxic to soil organisms, human health and ecosystem services. Excessive and improper application of agrochemicals also exposes food crops to poisons which may affect human health when consumed (Asare-Nuamah et al., 2021).

Another adaptation strategy that has the potential to facilitate intra-African trade through improved crop productivity is irrigation farming (Kumasi et al., 2019). While not commonly practised among many smallholder farmers, irrigation farming increases access to water for crops and improves crop growth, thereby enhancing the quality of yields and productivity (Kurgat et al., 2020; Njoroge et al., 2018). Irrigation also enhances the resilience of vulnerable farming systems, particularly in arid regions (Lopez-Ridaura et al., 2018; Suckall et al., 2018). However, not all irrigation systems are environmentally friendly (Oremo et al., 2019). For instance, micro-irrigation such as sub-surface and drip irrigation is efficient in terms of water use and energy compared to macro-irrigation (Akinyi et al., 2021). Fossil fuel-dependent irrigation systems increase greenhouse gas emissions which has necessitated the adoption of solar-powered irrigation systems that are energy-efficient and environmentally friendly (Oremo et al., 2019). Irrigation is also capital intensive and therefore increases farmers' operational cost (Lopez-Ridaura et al., 2018). As such, collaborative irrigation projects facilitated by governments and cooperative is essential to minimizing the financial burden that comes with irrigation farming. Irrigation also competes with humans and livestock for water use, which is a source of conflict in certain parts of the continents, especially in dryland regions (Asare-Nuamah et al., 2021).

Crop rotation and diversification are traditional farming practices employed by smallholder farmers to increase yields and income while boosting households food security (Antwi-Agyei & Nyantakyi-Frimpong, 2021). With climate variability and change, farmers have intensified crop rotation and diversification to minimize the overall effects of climate change on crops (Asare-Nuamah & Mandaza, 2020). Crop rotation and diversification are combined with intercropping with legumes to increase their cumulative benefits such as improved soil fertility through nitrogen fixation from legumes, and an increase in soil water holding capacity and organic matter, which are important for crop productivity and yields (Asmare et al., 2019; Fadina & Barjolle, 2018). Similarly, these practices reduce erosion and soil depletion as well minimizing the emission of N2O and enhance nutrient recycling and carbon sequestration (Hansen et al., 2019). Through crop rotation and diversification as well as intercropping with legumes, livestock farmers increase their access to biomass to feed livestock (Peter, 2018). The trade-offs associated with intercropping with legumes, crop rotation and crop diversification include increasing the activities of pests and diseases as the cover crops create a micro-climate for the survival of pests and diseases; creating labour-intensive farming systems leading to the competition for labour by other sectors; and rising farm operational cost due to the demand for labour (Asare-Nuamah et al., 2021; Nassary et al., 2019).

Crop rotation, intercropping with legumes and crop diversification supplement mulching, which is an important soil and water management strategy adopted by farmers to increase crop yields and productivity. Mulching constitutes covering the upper layer of the soil with crop residues. Crop residues are applied to the surface of the soil for multiple reasons: increasing soil fertility through the decay of residues; reducing soil erosion; minimizing soil evaporation and conserving soil water; impeding the growth of weeds, providing a conducive environment for metabolism and microbial activities, which are essential for improving the stability and structure of soil (Asare-Nuamah, et al., 2021; Nyahunda & Tirivangasi, 2019; Peter, 2018). Mulching is practised in combination with minimal or zero tillage and intercropping with legumes as conservation agriculture, which enhances the structure of the soil, improves soil fertility and water-holding capacity, as well as minimizes erosion, and intensifies the absorption of carbon in the soil (Brown et al., 2018). In spite of the potential of mulching to increase crop productivity for intra-African trade, the practice increases the financial burden of farmers due to its labour-intensive nature (Brown et al., 2018). Similarly, in an intensive livestock environment, mulching results in competition and conflicts between crop and livestock farmers. Poor access to residue or biomass for livestock negatively affects livestock quality, reproduction in livestock and the production of meat and milk, especially during the dry season (Akinyi et al., 2021).

Agroforestry, which constitutes the cultivation of tree species such as oil palm, shrubs, mango, shea and cashew among others, on farmlands solely or in combination with crops and animals, has gained attention among farmers and governments in recent times. Agroforestry serves threefold purpose of increasing the supply of food crops, building farmers' and community adaptive capacity through income from agroforestry, and mitigating climate change (Loboguerrero et al., 2019). In many African countries, agroforestry has been intensified by governments as a carbon sequestration strategy (Teklewold et al., 2020). Kurgat et al. (2020) indicate that agroforestry increases soil nutrients and fertility through the recycling ability of trees. Again, agroforestry is instrumental to biodiversity and ecosystems as trees provide habitats and a conducive environment for species, and also reduce direct sun rays from reaching the soil, thereby enhancing the micro-climate for organisms (Williams et al., 2021). Nevertheless, agroforestry suppresses the survival and productivity of smaller crops as larger trees compete with smaller crops for nutrients, sunlight and water, which are all essential for plant growth and productivity (Lankoski et al., 2018). In smallholder food crop systems, farmers may resist agroforestry as the practice affects their access to and ownership of land. Water is an important ingredient for agriculture. However, climate change poses serious threats to farmers' access to water for agricultural purposes. Consequently, water harvesting and storage techniques have gained centre stage in climate change adaptation strategies, particularly in smallholder agriculture systems where farmers depend mainly on rainfall as the main source of water for agriculture (Asare-Nuamah et al., 2022). Farmers have constructed and installed open earth dams, ponds, water tanks and boreholes to harvest and store water for crops and other agricultural activities, especially during dry seasons. Water harvesting and storage practices are essential to boosting crop growth and productivity (Oremo et al., 2019). Similarly, water harvesting techniques help to minimize the direct impact of rainfall on loose topsoil, and reduce run-off and erosion. Inversely, water harvesting and storage have trade-offs including the cost involved in the construction and installation of storage facilities (Oremo et al., 2021). In extremely dry conditions, farmers bear more cost for transporting water from distant sources to their farms (Asare-Nuamah et al., 2022).

In an attempt to minimize the effects of climate change on agriculture, agricultural expansion or extensification has been reported among farmers in Africa. Agriculture extensification helps to reduce the overall effects of climate change on crops. For instance, farmers practice agriculture expansion to alleviate the impact of pests and diseases on crops, thereby maintaining yields, income and household food security (Antwi-Agyei et al., 2018; Asare-Nuamah, et al., 2021). Nevertheless, agricultural expansion is not environmentally friendly as the practice reduces cover crops and increases deforestation (Antwi-Agyei et al., 2018; Asare-Nuamah, et al., 2021). Agricultural extensification is equally counterproductive to mitigation as the removal of trees increases greenhouse gas emissions. For instance, the removal of trees meant for carbon sequestration leads to the release of absorbed carbon from trees into the atmosphere. In vulnerable farming communities, farm expansion also increases costs to farmers through increased labour to work on farms. Farmers practising extensification are also likely to apply more agrochemicals to increase yields, thereby further increasing farming costs (Asare-Nuamah et al., 2021). Nitrogen-rich agrochemicals also increase greenhouse gas emissions into the atmosphere (Antwi-Agyei et al., 2018). Furthermore, farm expansion results in competition for land for other use while creating conflicts in land ownership and access, particularly in the resource scare environment.

3.2.2 Value Addition

Traditionally, trade in raw agricultural goods is integral part of Africa's trade with the rest of the world. However, given that many African countries produce the same or similar agricultural goods, countries that prioritize value addition can significantly enhance their competitive and absolute advantage in trading under the AfCFTA. Value addition refers to increasing the value of an agricultural commodity by processing the good from its raw state to a finished state, which gives the particular good an improvement in its look, value, nutrition and usage.

Industrialization is key to increasing the value addition of agricultural goods. To take advantage of the AfCFTA, many governments in Africa are spearheading industrialization drive among small, medium and large enterprises. This is necessary to ensure that countries trade in goods with enhanced value and quality, and increase their gross domestic products and foreign exchange. Industries turn raw agricultural goods into finished products, increase the nutritional content of goods and enhance the look and attractiveness of finished products. Through value addition, the life span of raw agricultural commodities can be enhanced. Value addition also helps to improve efficient storage techniques of finished products. Thus, value addition to agricultural goods can immensely improve Africa's food security and nutrition-related challenges (Glauber, 2022). However, value addition is associated with trade-offs. For instance, toxins and harmful substances can be introduced into processed agricultural products, which exposes consumers to health-related challenges and diseases including salmonella (Glauber, 2022). There is also the likelihood of increased junk food on the African market due to the processing of some agricultural commodities. The consumption of junk foods has been associated with health conditions such as obesity and high cholesterol (Ruel & Fanzo, 2022). Processing plants also require a huge amount of water which may compete with domestic and other water use. In the absence of efficient and renewable energy use in industries, plants and machines used in processing industries increase carbon and other greenhouse gas emissions into the atmosphere (de Brauw & Pacillo, 2022). Industrialisation is also capital-intensive and in scarce resources, COVID-19 hit and climate extreme environment such as Africa, setting up industries puts pressure on government budgets. Public-private partnership is highly recommended for African countries in an attempt to industrialise and take advantage of the AfCFTA.

3.2.3 Transportation, Distribution and Storage

Transportation, distribution and storage are essential to the sustainability of intra-African trade as they facilitate the movement and exchange of goods and services across borders and communities. According to the African Development Bank, Africa currently has an infrastructure gap of about $100 billion annually and would require annual financing of $170 billion by 2025 (Kato, 2021). Poor and deficient infrastructure on the continent reduces Africa's output by 2% annually (African Development Bank, 2020). To enhance trade access and facilitation under the AfCFTA, sustainable transportation networks including roads, and warehouses, are essential. Transportation network is important for the transportation and distribution of agricultural goods. Similarly, warehouses ensure that producers and suppliers can store their goods and products, and improve access to commodities among consumers.

However, such infrastructure while facilitating and boosting intra-African trade also increases the carbon footprint of African countries (de Brauw & Pacillo, 2022). For instance, fumes from transportation contribute significantly to carbon and other greenhouse gas emissions (United Nations Environment Programme, 2022). Low adoption of environmentally-friendly electronic vehicles and green transportation in Africa means that many African countries are likely to depend more on fossil fuel combustions for the transportation and distribution of goods under the AfCFTA, which will increase the overall carbon footprint on the continent, thereby threatening efforts towards mitigating climate change. Similarly, air pollution from transportation also exposes African citizens to health challenges including lung and other respiratory diseases (United Nations Environment Programme, 2022). Promoting green transportation is therefore imperative to sustainable development in Africa and AfCFTA.

3.3 Conclusion and Policy Recommendations

This study adopted a systematic literature review to examine the synergies and trade-offs associated with climate change adaptation in the agriculture system and value chain and the implications on intra-African trade in agricultural goods. Although this study used only JSTOR and Google Scholar databases, which limited access to some relevant articles, the study, however, provides significant insights that are imperative to sustainable climate change adaptation and intra-African trade. Indeed, climate change adaptation strategies are strategic to the promotion of intra-African trade through an increase in agricultural production. Similarly, industrialisation could facilitate the value addition of agricultural goods and improve food security on the continent while infrastructural development for transportation and storage of agricultural commodities would significantly boost cross-border and intra-African trade.

However, adaptation strategies threaten the ability of African countries to drive sustainable development as many of the existing adaptation strategies increase environmental, biodiversity, ecosystem and human challenges. The vulnerability of smallholder farmers can be worsened through the trade-offs associated with some adaptation strategies, thereby weakening vulnerable and poor farmers' adaptive capacities. While recognizing the synergistic relationship between climate change adaptation and intra-African trade, the associated trade-offs call for the urgent need for policymakers to scale up the adoption and implementation of environmentally-friendly adaptation strategies such as renewable energy, green transportation, and subsidisation of improved crop varieties among others. The huge cost associated with sustainable adaptation strategies along the agriculture value chain must be tackled through cross-country and regional collaborations among governments and financial institutions. Similarly, public-private partnerships should be central to facilitating the implementation of sustainable adaptation strategies for intra-African trade on the continent.

Furthermore, educating smallholder farmers on the negative effects of adaptation strategies should be strengthened across the continent. Again, African governments must also intensify socioeconomic resources and social policies for vulnerable farmers to enable them to adapt effectively and sustainably to climate change. Further studies should explore mechanisms for scaling up the adoption of environmentally friendly adaptation strategies. It is also important for further studies to understand how behavioural change can drive sustainable agricultural practices.

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