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Agriculture, Climate Change, and Green Technologies in the DRC: Towards Sustainable and Environmentally Friendly Agriculture

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ABSTRACT

This article delves into the significant challenges facing agriculture in the Democratic Republic of Congo (DRC) as a result of climate change. Climate-related shifts such as altered rainfall patterns, rising temperatures, and the increasing frequency of extreme weather events are having devastating effects on agricultural productivity, food security, and the sustainability of agricultural systems in the country. The primary objective of this research is to explore and assess the impact of green technologies as a solution to promote sustainable agriculture in the DRC. The study aims to identify the most effective green technologies, such as sustainable irrigation, agroforestry, and the use of biofertilizers, to enhance the resilience of agricultural systems in the face of climate change while preserving natural resources. The solution proposed by this study is the widespread adoption and integration of green technologies into agricultural practices in the DRC. These technologies have the potential to reduce the carbon footprint of agriculture, improve agricultural productivity, and strengthen the resilience of rural communities against climate-related challenges. The study advocates for immediate action to encourage the adoption of these technologies, supported by enhanced public policies, accessible financing, and capacity-building initiatives for farmers.

INTRODUCTION

The Democratic Republic of Congo (DRC) is a vast country in Central Africa, covering an area of 23 million square kilometers, making it the second-largest country on the African continent. This immense territory is endowed with abundant natural resources, including arable land, water, and biodiversity, giving the DRC considerable agricultural potential. The arable land, estimated at over 80 million hectares, represents a unique opportunity for large-scale agricultural development. However, only about 10% of this land is currently cultivated, indicating a significant underutilization of the country's agricultural potential (FAO, 2020). The DRC also benefits from a climate favorable to agriculture, characterized by abundant rainfall and ecological diversity, allowing for the cultivation of various food crops. The savanna areas, tropical forests, and mountainous regions provide ideal conditions for the production of crops such as maize, cassava, rice, tropical fruits, as well as important cash crops like coffee and cocoa (Meyer *et al.*, 2018). In addition, water resources, with river systems such as the Congo River and its tributaries, offer opportunities for irrigation and fishing, further enhancing the country's agricultural potential (World Bank, 2019).

Despite these assets, agriculture in the DRC remains largely subsistence-based, with relatively low productivity and limited use of modern technologies. Traditional farming methods dominate, and mechanization remains marginal, mainly due to insufficient infrastructure, lack of financing, and governance challenges (Bokundowa, 2017). This situation hinders the agricultural sector's ability to fully contribute to the country's economic development and to the food security of its population.

Agriculture plays a central role in the DRC's economy and is the main source of livelihood for the majority of the population. According to World Bank data, the agricultural sector employs about 70% of the working population, primarily in rural areas, and contributes approximately 40% of the country's Gross Domestic Product (GDP) (World Bank, 2019). This sector is, therefore crucial not only for the national economy but also for the daily survival of millions of Congolese who depend on agriculture for their food and income. As the primary economic activity in rural areas, agriculture in the DRC is essentially family-based and subsistence-oriented. Smallholder farmers typically cultivate small plots of land using manual methods and few modern inputs. The dominant crops include cassava, maize, peanuts, plantains, and vegetables, which form the staple diet of households (FAO, 2020). This subsistence farming plays a vital role in food security; especially in a country, where transport and marketing infrastructure is insufficient, making it difficult for many farmers to access markets. However, subsistence agriculture in the DRC is vulnerable to climatic, economic, and political shocks. Armed conflicts in some regions, population displacements, and climate shocks such as floods and droughts often directly influence agricultural production, exacerbating food insecurity in the country (Ndungu *et al.*, 2019). Despite these challenges, the potential for agricultural growth remains immense, and the development of more productive and sustainable agriculture could transform the Congolese economy, reduce poverty, and improve food security.

Climate change poses a serious threat to agriculture

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in the DRC, with already observable impacts on the country's agricultural systems. The climate in the DRC is characterized by a rainy season and a dry season, with significant regional variations in terms of rainfall and temperature. However, climate change is altering these traditional patterns, disrupting crop cycles and reducing agricultural productivity (Mukwege *et al*., 2018). The main manifestations of climate change in the DRC include rising average temperatures, more irregular rainfall, and an increased frequency of extreme climatic events such as floods and droughts. For instance, some regions of the country have experienced shorter rainy seasons with more intense rainfall, leading to soil erosion and crop losses (Nzau, 2021). Other regions, particularly those located in the southeast, are increasingly subject to prolonged droughts, compromising the yields of crops such as maize and cassava, which are staple foods for the population (Yanda *et al*., 2020). These climate changes affect not only agricultural production but also food security and the livelihoods of rural communities. Subsistence farmers who rely entirely on the production from their small farms are particularly vulnerable as they have few resources to adapt to the new climatic conditions. Moreover, the lack of access to modern agricultural technologies and irrigation systems exacerbates this vulnerability, limiting farmers' ability to adapt to the changes (Bokundowa, 2017).

Additionally, the impacts of climate change on natural resources such as soil and water are also concerning. Deforestation, often linked to agricultural expansion, exacerbates soil degradation and reduces fertility, while changes in precipitation patterns affect water availability for irrigation (Kakule *et al*., 2019). These dynamics create a vicious cycle where the negative impacts of climate change on agriculture are amplified by environmental degradation. To address these challenges, it is essential to integrate green technologies into agricultural practices in the DRC. These technologies, which include the use of drought-resistant crop varieties, improved irrigation systems, and the adoption of agroecological practices, can help mitigate the effects of climate change and promote sustainable agriculture (FAO, 2020). However, the adoption of these technologies requires political support, investment in research and development, and training for farmers.

The agricultural potential of the DRC is immense, but the effects of climate change threaten it. The importance of agriculture to the economy and the livelihood of the Congolese population underscores the need to develop strategies to make the agricultural sector more resilient to climate change. This requires the adoption of green and sustainable technologies that not only protect the environment but also improve productivity and food security (Ndungu *et al*., 2019). Policymakers, farmers, and the international community must work together to meet this challenge and ensure a sustainable agricultural future for the DRC.

Agriculture, climate change, and green technologies are interdependent elements whose interaction is of crucial importance, particularly in a country like the Democratic Republic of Congo (DRC). Understanding this intersection is essential to developing effective strategies for addressing the challenges posed by climate change on agriculture and optimizing the use of green technologies to mitigate these impacts. In the DRC, where agriculture is the main source of livelihood for most of the population, the effects of climate change threaten not only food production but also the economic stability and security of rural communities. Climate change in the DRC manifests in changes in precipitation patterns, increased average temperatures, and a greater frequency of extreme weather events. These phenomena disrupt traditional agricultural cycles, reduce crop yields, and exacerbate soil degradation and water scarcity (Mertens *et al*., 2020). In response to these challenges, green technologies are indispensable tools for transforming these threats into opportunities.

Green technologies, which encompass innovations such as sustainable irrigation, agroforestry, the use of drought-resistant crop varieties, and renewable energy, can play a crucial role in adapting agriculture to climate change. They not only mitigate the adverse effects of climate change but also promote more sustainable agriculture by reducing the ecological footprint of farming practices while increasing productivity. Therefore, it is imperative to understand how these technologies can be integrated into agricultural systems in the DRC to maximize their benefits (FAO, 2020).

Proposing solutions for sustainable agriculture in the DRC is not only a matter of agricultural development but also an urgent necessity to ensure food security, reduce poverty, and protect the environment. As a country with vast agricultural potential, the DRC has the opportunity to become a leader in sustainable agriculture in sub-Saharan Africa. However, to achieve this goal, it is crucial to develop strategies that effectively integrate green technologies adapted to local realities. Sustainable agriculture in the DRC must address several simultaneous challenges: it must ensure the production of enough food for a growing population while preserving natural resources for future generations. Moreover, it must be resilient to the effects of climate change, which threaten to reduce agricultural yields and compromise food security (World Bank, 2019). To achieve this, it is necessary to develop and implement solutions that improve agricultural productivity while minimizing environmental impact. These solutions must include innovative technological approaches but also public policies that encourage the adoption of these technologies by farmers, especially those most vulnerable to climate change. This involves building the capacity of farmers, providing them with access to financing for the adoption of new technologies, and creating a favorable institutional and regulatory framework for sustainable agriculture (Nzau, 2021).

This study aims to fill existing gaps in understanding these issues and to propose concrete recommendations for supporting sustainable agriculture in the DRC, with

the overall objective of exploring the dynamics between agriculture, climate change, and green technologies in the Democratic Republic of Congo (DRC) to propose effective strategies for developing sustainable and environmentally friendly agriculture. In addressing the challenges posed by climate change, this research seeks to identify solutions that will not only enable the DRC to maintain its agricultural production but also improve the resilience of agricultural systems to climatic disruptions while reducing their ecological footprint. This would result in:

- An analysis of the impact of climate change on agriculture in the DRC;
- An evaluation of the effectiveness of existing and potential green technologies for sustainable agriculture;
- A proposal of recommendations for environmentally friendly agriculture in the DRC.

This study focuses on the contemporary period, covering primarily the last two decades, from 2000 to 2024. This period was chosen due to significant changes in the global climate and their impacts on agriculture, as well as the emergence and increasing adoption of green technologies. The historical analysis over the past two decades allows for capturing long-term trends in climate change and its effects on agriculture in the Democratic Republic of Congo (DRC) while offering a current perspective on available green technologies and their implementation. The climatic, agricultural, and technological data collected over this period will provide an accurate picture of the current situation and project future scenarios for sustainable agriculture in the DRC.

LITERATURE REVIEW

Climate Change and Agriculture in the DRC

Effects of Climate Change on Crops

Climate change has considerable effects on agriculture in the Democratic Republic of Congo (DRC), directly affecting agricultural production through several interconnected mechanisms. One of the main impacts is the change in rainfall patterns. In the DRC, rainfall, which was once regular and predictable, has become increasingly irregular and unpredictable, disrupting traditional agricultural calendars. According to Nzau (2021), this increased variability in precipitation leads to more frequent droughts and concentrated heavy rains over shorter periods, which reduces the optimal window for growing key staple crops such as maize, cassava, and rice.

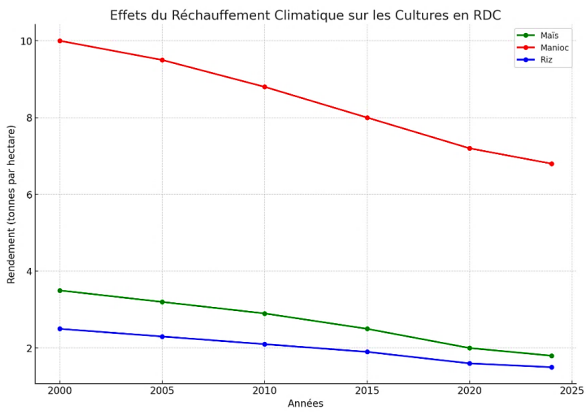

Figure 1:

Here is a line graph illustrating the effects of climate change on the yields of maize, cassava, and rice crops in the Democratic Republic of Congo over the years. The Green line (Maize yield in tons per hectare), the Red line (Cassava yield in tons per hectare), and the Blue line (Rice yield in tons per hectare). The graph shows a general downward trend in yields for these crops. This decline is due to the effects of climate change, such as reduced water availability, changes in precipitation patterns, prolonged droughts, and rising temperatures. The calculations show the percentage decreases in yield for the three main crops in the DRC from 2000 to 2024 (Maize decreased by 48.57%, Cassava by 32.0%, and Rice by 40.0%). These percentages reflect the significant impact of climate change on agricultural productivity in the DRC.

Droughts deprive crops of the necessary water for their growth, while excessive rainfall causes soil erosion and nutrient leaching, thus reducing soil fertility and consequently agricultural yields. Episodes of drought and floods are particularly concerning in the DRC, where most agricultural operations are small-scale and heavily dependent on seasonal rains. Mertens *et al.* (2020) emphasize that prolonged droughts in the Katanga and Kasai provinces have led to massive crop losses, exacerbating food insecurity. Similarly, recurrent floods in the North and South Kivu regions have destroyed agricultural infrastructure and crops, forcing communities to migrate to less affected areas. These extreme climatic events compromise the ability of farmers to plan their crop cycles, making subsistence farming even more precarious.

Furthermore, soil degradation exacerbated by climate change poses another major challenge for agriculture in the DRC. Deforestation, often practiced to expand agricultural land, combined with the intensification of extreme climatic events, accelerates soil erosion, reducing their fertility (Kakule *et al.*, 2019). The loss of organic matter and essential nutrients leads to lower yields, forcing farmers to exploit new land, which in turn worsens deforestation and the cycle of soil degradation. This downward spiral threatens the sustainability of agriculture in many regions of the DRC.

Impacts on Food Security

The effects of climate change on agriculture in the DRC have direct repercussions on the country's food security. The reduction in agricultural yields due to irregular rainfall, droughts, floods, and soil degradation leads to a decrease in the availability of food on local markets. Despite its immense agricultural potential, the DRC remains dependent on food imports to meet the needs of its growing population due to the low productivity of

its agricultural operations (FAO, 2020). This decrease in local food production has severe economic consequences for farmers and rural communities. The majority of farmers in the DRC practice subsistence farming, where the sale of surpluses is often the main source of income. A reduction in yields translates into a decrease in household income, making them more vulnerable to poverty. Moreover, the increase in food prices caused by the scarcity of products on the markets also affects urban populations, who spend a large portion of their income on food (World Bank, 2019).

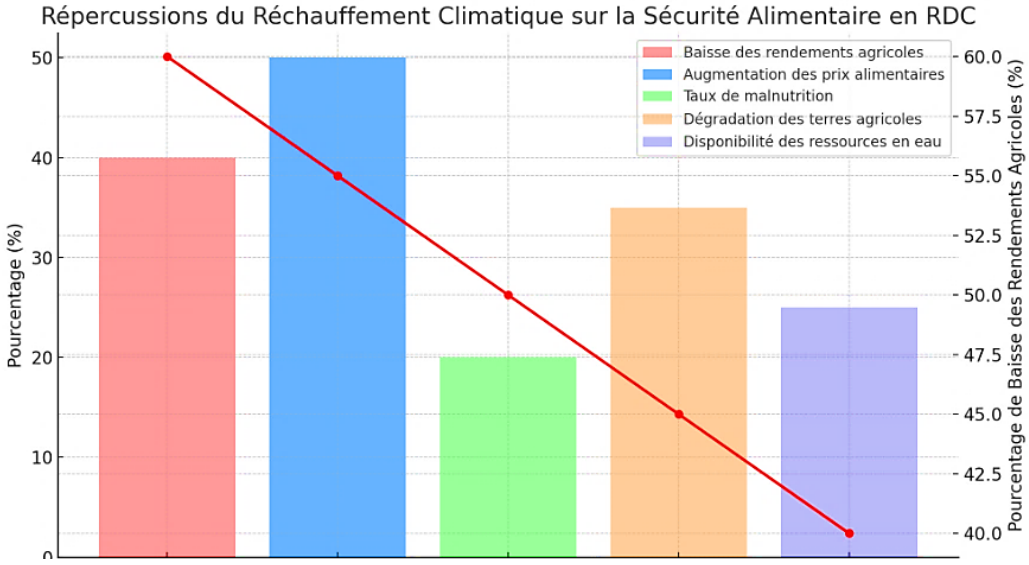

Figure 1:

This type of graph allows the simultaneous visualization of several trends related to the effects of climate change and clearly demonstrates how it affects food security in the DRC. In this graph, you would see a curve representing the decline in agricultural yields (Due to prolonged droughts and climate variability, agricultural yields can decrease by 20% to 40% in some regions, especially for staple crops such as cassava or maize), the rise in food prices (The decline in production leads to a price increase, sometimes up to 50%, limiting access to basic foodstuffs for the most vulnerable populations), malnutrition (With the drop in yields and the rise in prices, the malnutrition rate in the DRC, which is already high, could increase by 10% to 20% in rural areas), the degradation of agricultural lands (Erosion and the loss of fertile land are increasing, contributing to the decline in productivity, further worsening the food situation), and water availability (A 15% to 25% decrease in water availability for agriculture is observed, severely affecting agricultural productivity in the impacted areas).

This reduction in food security also has implications for public health. Malnutrition, already an endemic problem in the DRC, is likely to worsen due to the reduced access to sufficient and quality food. Mukwege *et al.* (2018) note that children and pregnant women are particularly vulnerable to the effects of malnutrition, which can lead to stunted growth, disease, and increased mortality. Therefore, the food insecurity caused by climate change threatens not only economic stability but also the health and well-being of the most vulnerable populations.

Case Studies: Regions in the DRC Affected by Climate Change

Certain regions of the DRC are particularly affected by the effects of climate change, illustrating the challenges the country faces. For example, in the Kasai provinces, farmers have faced increasingly prolonged droughts, drastically reducing the yields of essential crops such as cassava and maize. Nzau (2021) reports that these droughts have led to a regional food crisis, forcing many families to migrate to cities in search of food and livelihood opportunities.

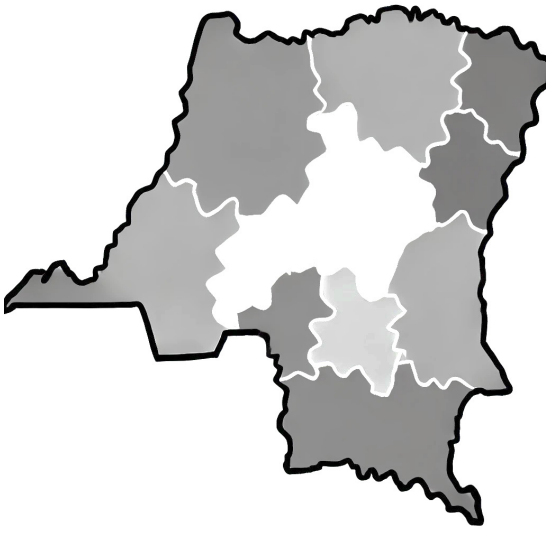

Figure 2:

In the eastern regions of the DRC, particularly in North and South Kivu, floods have become more frequent and destructive. These regions, already destabilized by armed conflicts, are even more vulnerable to climate shocks. Floods have not only destroyed crops but also damaged infrastructure such as roads and irrigation systems, making post-flood agricultural recovery even more difficult (Mertens *et al.*, 2020). Additionally, the loss of arable land due to erosion and soil degradation reduces the capacity of farmers to recover after such events. Finally, the Katanga region, rich in mineral resources, faces specific challenges. The combination of intensive mining and climate change has led to massive deforestation and soil degradation, making the land increasingly infertile. Kakule *et al.* (2019) point out that this situation not only compromises agricultural production but also the quality of water, exacerbating public health problems in the region. These case studies highlight the severe and varied impacts of climate change on agriculture in the DRC, underscoring the urgency of developing adaptation and resilience strategies to protect food security and the livelihoods of rural populations.

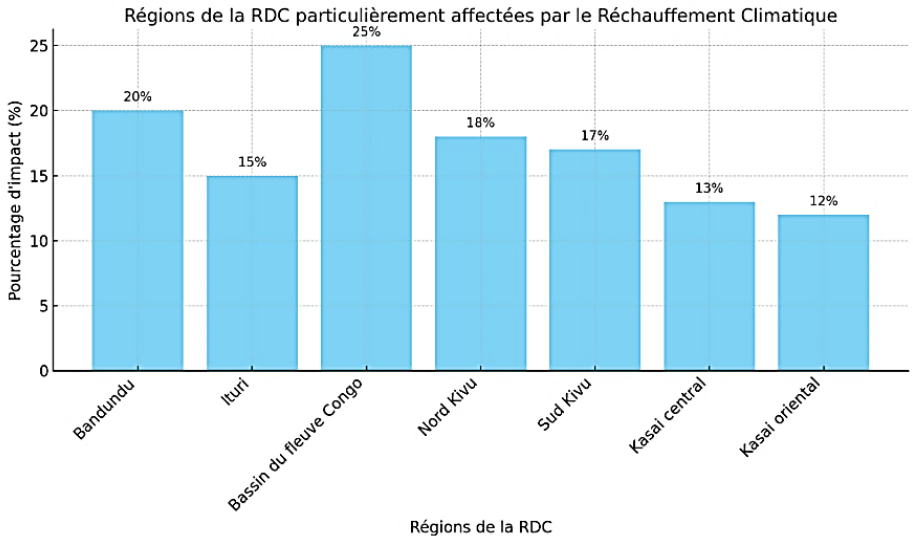

Figure 3:

This graph represents the regions of the DRC particularly affected by climate change, with the percentage impact for each region. The percentages show the extent of climate impact, with regions like the Congo River Basin (25%), Bandundu (20%), and North and South Kivu (15-18%) being the most affected, while Kasai Central and Kasai Oriental experience a more moderate impact (12-13%). These areas are undergoing various climate changes, such as irregular rainfall, droughts, and floods, which degrade soils and reduce agricultural yields. The most affected crops are cassava, maize, rice, and export crops like coffee and tea.

The Bandundu Region

The Bandundu region, located in western DRC, is a major agricultural zone where cassava, maize, and peanuts dominate. However, this region faces increasing climatic variability, characterized by prolonged droughts and irregular precipitation. These climatic conditions severely disrupt crop cycles and reduce agricultural land productivity. Kakule *et al.* (2019) emphasize that drought in this region has led to a significant decline in cassava yields, a staple crop essential for local food security. Moreover, soil erosion, exacerbated by unsustainable agricultural practices and deforestation, is a major challenge for agriculture in Bandundu. Soil degradation not only reduces fertility but also limits the soil's ability to retain water, thereby increasing the vulnerability of crops to drought periods (Nzau, 2021). This situation worsens food insecurity in a region already marked by rural poverty and limited access to modern agricultural infrastructure.

The Ituri Region

Ituri, located in northeastern DRC, is a region rich in biodiversity but also plagued by recurrent armed conflicts. These conflicts, combined with the impacts of climate change, create an extremely challenging environment for agriculture. Climate changes in Ituri manifest through unpredictable rainfall and higher temperatures, affecting local agricultural production. According to Mertens *et al.* (2020), farmers in Ituri face increasingly erratic harvests, making it difficult to plan crop seasons and ensure regular food supply. Additionally, sudden floods caused by torrential rains not only destroy crops but also damage homes and local infrastructure, further exacerbating the vulnerability of rural communities. This situation is particularly concerning in a context where access to humanitarian aid and government support is limited due to insecurity (Mukwege *et al.*, 2018). Farmers in Ituri, already weakened by conflicts, are thus even more exposed to climatic risks, compromising regional food security, especially for maize and rice.

The Congo River Basin

The Congo River Basin, which spans several regions of the DRC, is an area of global importance due to its biodiversity and vast water resources. However, this region is not immune to the effects of climate change. Changes in precipitation patterns and temperatures affect the basin's ecosystems, with direct consequences on agriculture and fishing, two essential activities for local populations. The Congo River Basin is particularly vulnerable to soil erosion and deforestation, exacerbated by climate change. Erosion of riverbanks and loss of riparian forests reduce the quality of agricultural land and the availability of water for irrigation, thus threatening agricultural production. Additionally, communities that rely on fishing face decreasing fish stocks due to temperature changes and increased pollution, which are worsened by climate change (Kakule *et al.*, 2019). The impact on food security in the Congo Basin is particularly alarming since fishing and agriculture are the main sources of protein and income for local populations. The depletion of natural resources due to climate change leads to increased competition for land and water, exacerbating social and economic tensions in the region (World Bank, 2019). Thus, the Congo River Basin illustrates the complex challenges the DRC faces in a climate change context, where environmental, social, and economic impacts are closely intertwined.

The North Kivu and South Kivu Regions

The provinces of North Kivu and South Kivu, located in eastern DRC, are particularly vulnerable to the effects of climate change due to their mountainous topography and already variable climate. These regions have seen an increase in intense rainfall, often in the form of torrential rains that cause floods and landslides. Mertens *et al.* (2020) highlight that these floods have destroyed essential agricultural infrastructure, such as roads leading to markets and irrigation systems, while causing significant crop losses, especially for maize, beans, and bananas, which are staple foods. Additionally, these regions are also affected by drought periods, compromising the availability of water for agriculture. The combination of droughts and floods creates an extremely difficult environment for subsistence farming, the main source of income for the majority of inhabitants in these provinces (Nzau, 2021). The situation is worsened by persistent insecurity due to armed conflicts, further limiting farmers' ability to adapt to changing climatic conditions.

The Kasai Central and Kasai Oriental Regions

The provinces of Kasai Central and Kasai Oriental, located in the center of the DRC, also face significant climate challenges. These regions, which rely heavily on cassava, maize, and legume cultivation, are experiencing significant changes in precipitation patterns. Prolonged droughts have become more frequent, causing a dramatic decline in agricultural yields. Kakule *et al.* (2019) indicate that these droughts have led to increasing food insecurity in both provinces, with many households unable to harvest enough food for subsistence. At the same time, soil erosion, exacerbated by unsustainable agricultural practices and deforestation, is a serious issue in Kasai Central and Kasai Oriental. The loss of organic matter and soil fertility reduces the ability of these lands to produce crops, which drives farmers to abandon their lands or resort to exploiting new lands, worsening deforestation and environmental degradation (Mukwege *et al.*, 2018). This dynamic contributes to a vicious cycle where climate change effects and unsustainable practices reinforce each other, threatening the long-term sustainability of agriculture in these regions.

The Katanga Region

Katanga, located in southeastern DRC, is another region severely affected by climate change. This region, which combines intensive mining activities with significant agriculture, faces complex ecological challenges. Recurrent droughts and high temperatures directly influence agricultural production, reducing the yields of crops such as maize, cassava, and cash crops like coffee and cotton. Farmers in Katanga are increasingly struggling with decreasing water availability for irrigation, compromising their ability to maintain stable production (FAO, 2020). Additionally, Katanga is heavily affected by deforestation and soil degradation, largely due to mining activities and agricultural expansion. These activities have reduced forest cover, which increases the vulnerability of soils to erosion and loss of fertility (Kakule *et al.*, 2019). The combination of these factors creates an environment where agriculture is becoming increasingly difficult to sustain, jeopardizing the region's food security and economic stability.

Green technologies for sustainable agriculture in the DRC

Definition and Types of Green Technologies

Green technologies refer to a set of agricultural techniques and practices that minimize the environmental impact of farming while increasing productivity and ensuring the sustainability of agricultural systems. These technologies are designed to be ecologically responsible, promoting the conservation of natural resources such as water, soil, and biodiversity. In the DRC, where the challenges of climate and environmental degradation are particularly acute, green technologies play a crucial role in transforming agriculture into a more sustainable and resilient model. Among the most relevant types of green technologies for agriculture in the DRC are sustainable irrigation technologies, which include drip irrigation systems and the use of solar-powered pumps to extract water. These technologies allow for more efficient use of water, reducing evaporation losses and improving crop productivity during drought periods (Mertens *et al.*, 2020). The use of biofertilizers and biopesticides constitutes another essential component of green technologies. Unlike conventional chemical fertilizers and pesticides,

biofertilizers and biopesticides are derived from natural sources and help enrich the soil without causing chemical pollution. They also support biodiversity by encouraging the presence of beneficial organisms in the soil, which improves plant health and resilience to pests and diseases (FAO, 2020). Lastly, renewable energies for agriculture, such as solar and wind energy are increasingly adopted green technologies in the DRC. These energies can power irrigation systems, post-harvest storage facilities, and small food processing units, reducing dependence on fossil fuels and significantly lowering the carbon footprint of agriculture (Nzau, 2021).

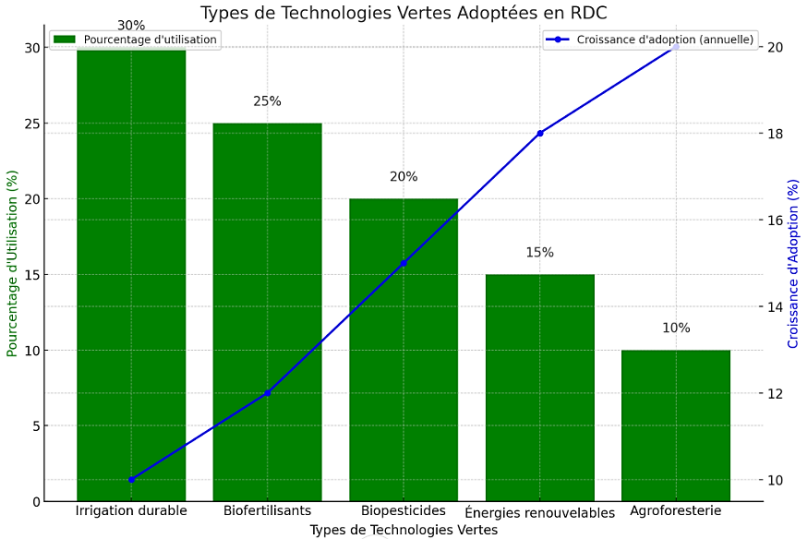

Figure 4:

This combined graph shows the types of green technologies adopted in the DRC with their percentage of use and a trend line for annual adoption growth. Among these green technologies are sustainable irrigation(the) most widely adopted in the DRC, representing 30% of usage. It is crucial for maintaining agricultural production in areas affected by climate variations), Biofertilizers and Biopesticides (with 25% and 20% adoption, respectively. These technologies are essential for reducing dependence on chemical inputs and improving soil and crop health), Renewable energies (such as solar panels for irrigation and crop drying, representing 15% of usage. This technology is growing, particularly in rural areas where access to electricity is limited), Agroforestry (although less adopted at 10%, is expanding. This integrated practice helps preserve biodiversity, improve soil fertility, and sequester carbon). The graph also shows an annual growth in the adoption of these technologies, highlighting farmers' increasing interest in more sustainable practices in the DRC.

Benefits of Green Technologies

The adoption of green technologies offers several major advantages for agriculture in the DRC, particularly in a context of climate change and environmental degradation. First, these technologies help reduce agriculture's carbon footprint. By replacing conventional farming practices that often rely on chemical inputs and high fossil fuel consumption with sustainable technologies, it is possible to reduce greenhouse gas emissions associated with agricultural production. For example, the use of biofertilizers reduces methane and nitrous oxide emissions from chemical fertilizers two potent greenhouse gases (Mukwege *et al.*, 2018).

Moreover, green technologies contribute to enhancing the resilience of agricultural systems to climate change. Sustainable irrigation systems, for instance, allow farmers to maintain production during drought periods, while diversified crops and agroecological practices strengthen agricultural systems' ability to withstand climate shocks, such as floods or heatwaves. This increased resilience is essential for ensuring food security in the DRC, where smallholder farmers are often the most exposed to climate risks (FAO, 2020). Green technologies also play a crucial role in conserving natural resources such as water, soil, and biodiversity. Efficient irrigation practices reduce water consumption a precious resource in many regions of the DRC that face seasonal shortages. Additionally, the use of biofertilizers and the promotion of agroforestry help preserve soil by preventing erosion and improving fertility. Finally, by promoting biodiversity, green technologies support the health of agricultural ecosystems, which is crucial for the long-term sustainability of food production systems (Kakule *et al.*, 2019).

Adoption of Green Technologies in the DRC

The current state of green technology adoption by farmers in the DRC reveals significant potential but also substantial challenges. While some regions, especially those supported by international projects, have begun adopting more sustainable farming practices, adoption remains generally limited. The reasons for this are multiple, including economic, social, and institutional barriers. Economically, the high initial cost of green

technologies, such as irrigation systems or solar panels, is a major barrier for smallholder farmers who often lack the capital for such investments (World Bank, 2019). Socially, the lack of knowledge and training on the benefits and use of green technologies also hinders their adoption. Many farmers in the DRC continue to rely on traditional practices, which are often ineffective in the face of current climate challenges. The absence of support networks and extension services capable of promoting and demonstrating the effectiveness of green technologies is another important obstacle (Bokundowa, 2017). Institutionally, the lack of strong public policies and incentives to encourage the adoption of green technologies limits the spread of these innovations. Public policies play a crucial role in promoting green technologies by offering subsidies, low-interest loans, and training programs for farmers. Similarly, international organizations have a key role to play in providing funding, facilitating technology transfer, and strengthening local capacity to adopt and maintain sustainable farming practices (Mertens *et al.*, 2020).

In conclusion, the adoption of green technologies in the DRC represents a unique opportunity to transform agriculture and address the challenges posed by climate change and natural resource degradation. While significant obstacles remain particularly economic, social, and institutional the potential benefits of green technologies, in terms of reducing environmental impact, increasing productivity, and enhancing resilience, are undeniable.

Towards Sustainable Agriculture in the DRC

Concepts of Sustainable Agriculture

Sustainable agriculture refers to a set of farming practices that aim to meet current food needs while preserving the capacity of future generations to meet theirs. It is based on three fundamental pillars: social equity, economic viability, and environmental sustainability. In practice, sustainable agriculture seeks to maximize agricultural production while minimizing negative impacts on the environment, conserving natural resources, and ensuring equitable livelihoods for farmers and rural communities (FAO, 2020). The principles of sustainable agriculture include crop rotation, agroforestry, the use of organic composts, and the conservation of soil and water. These practices help maintain soil fertility, reduce erosion, and improve biodiversity. Sustainable agriculture also promotes the use of natural inputs, such as biofertilizers and biopesticides, to limit dependence on synthetic chemicals, which are often associated with water pollution and soil health degradation (Kakule *et al.*, 2019).

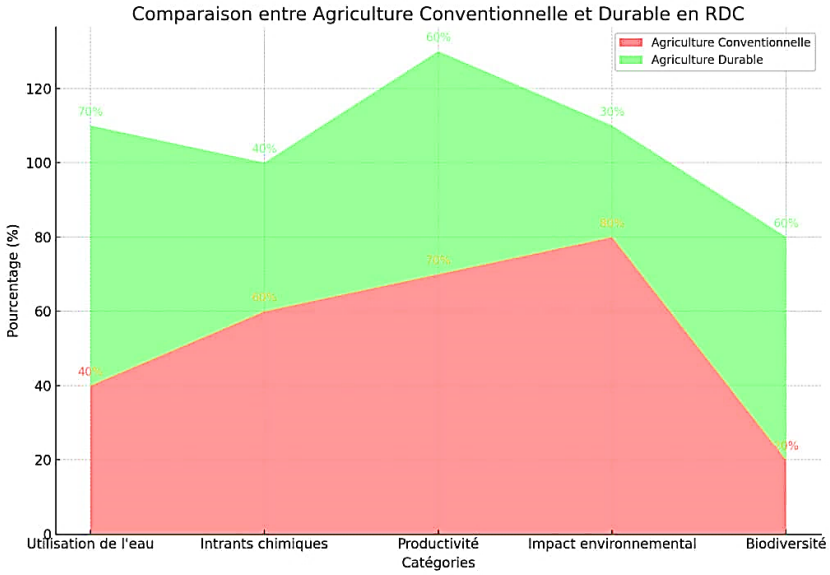

Figure 5:

This graph compares conventional agriculture and sustainable agriculture in the DRC, with percentages associated with each category. This generally translates to Water usage (CA - 40% and SA - 70%), Chemical inputs (CA - 60% and SA - 40%), Productivity (CA - 70% and SA - 60%), Environmental impact (CA - 80% and SA - 30%), Biodiversity (CA - 20% and SA - 60%). The graph shows that sustainable agriculture (SA), while requiring more efficient water use (70%) and promoting biodiversity (60%), has a much lower environmental impact (30%) compared to conventional agriculture (80%). However, conventional agriculture (CA) tends to have slightly higher productivity (70%), often at the expense of the environment and with more intensive use of chemical inputs (60%). Sustainable agriculture stands out for its ability to reduce chemical inputs while maintaining good productivity, having a lower environmental impact, and promoting biodiversity, which is crucial for resilient and long-term agriculture.

Conventional agriculture, dominated by the intensive use of chemical inputs and mechanization, stands in stark contrast to sustainable agriculture. In conventional farming, the focus is on increasing yields through the use of chemical fertilizers, pesticides, and monoculture

techniques. While this approach has led to increased global food production, it has also resulted in negative consequences such as soil degradation, biodiversity loss, water pollution, and a growing dependence on fossil fuels (Mertens *et al.*, 2020). In contrast, sustainable agriculture aims to produce food in an ecologically and socially responsible manner. It promotes crop diversity, reduces the use of chemicals, and encourages practices that preserve and improve agricultural ecosystems. For example, agroforestry systems, where crops are integrated with trees and other vegetation, improve soil and ecosystem resilience to extreme climate conditions while offering farmers a diversified source of income (Nzau, 2021). Although sustainable farming may require more labor and initial investment, it offers long-term benefits in terms of environmental sustainability and economic stability for rural communities.

Integrating Green Technologies into Sustainable Agriculture

Integrating green technologies into sustainable agriculture in the DRC requires a strategic approach that considers the country's specific challenges. For these technologies to be adopted on a large scale, it is essential to develop strategies that are adapted to local realities, taking into account economic, social, and institutional constraints. A key strategy is to improve access to financing for smallholder farmers. Many green technologies, such as sustainable irrigation systems or solar-powered installations, require significant initial investments that small-scale farmers often cannot afford. Microcredits, subsidies, and public-private partnerships can help overcome this obstacle by making these technologies more accessible (FAO, 2020).

Another important strategy is to build farmers' capacity through training and awareness. Agricultural extension programs can play a crucial role in educating farmers about the benefits of green technologies, teaching them how to use these technologies effectively, and demonstrating their long-term profitability. This includes training on agroforestry, the use of biofertilizers, and methods for soil and water conservation (Kakule *et al.*, 2019). Furthermore, the integration of green technologies must be supported by strong public policies that encourage the adoption of sustainable practices. This may include fiscal incentives for farmers who adopt green technologies, certification programs for sustainably grown agricultural products, and regulations aimed at reducing the use of synthetic chemicals (World Bank, 2019).

Case Studies of Successful Integration of Green Technologies in Sustainable Agriculture in Africa and the DRC

There are several examples of successful integration of green technologies in sustainable agriculture in Africa, some of which could serve as models for the DRC. For instance, in Ethiopia, the massive reforestation program "Great Green Wall" has combined agroforestry with soil conservation practices to restore millions of hectares of degraded land while improving the livelihoods of rural communities through diversified and resilient crops (FAO, 2020). In the DRC, pilot projects have shown the benefits of combining sustainable agriculture with green technologies. For example, in South Kivu province, the introduction of agroforestry combined with drip irrigation powered by solar energy has increased crop yields while reducing deforestation. These projects have demonstrated that farmers can successfully adopt sustainable practices while increasing their production and income despite unfavorable climatic conditions (Mertens *et al.*, 2020).

Recommendations for the Transition to Sustainable Agriculture in the DRC

• Policy and Incentives to Support Sustainable Agriculture - To accelerate the transition to sustainable agriculture in the DRC, it is essential to implement specific policies and incentives. Government subsidies for the purchase of green technologies, such as sustainable irrigation systems or renewable energy, can make these solutions more accessible to farmers. Additionally, fiscal incentives for businesses that invest in green technologies or adopt sustainable agricultural practices can encourage broader adoption (FAO, 2020). Certification programs for sustainably grown agricultural products can also play a key role by creating markets for ecologically grown products, offering farmers a premium price for their efforts. This could be particularly effective in export markets, where consumers are increasingly aware of sustainable production practices (World Bank, 2019).

• Building Farmers' Capacity: Training and Awareness - Strengthening farmers' capacity through training and awareness programs is crucial to ensuring the success of sustainable agriculture in the DRC. These programs must be adapted to local realities, taking into account literacy levels and traditional knowledge. Practical workshops, field demonstrations, and awareness campaigns can help transfer knowledge about green technologies and sustainable farming practices. Additionally, training trainers can ensure that knowledge spreads through agricultural communities, creating a multiplier effect (Kakule *et al.*, 2019).

• Partnerships between the Public Sector, Private Sector, and International Organizations - The success of sustainable agriculture in the DRC also depends on collaboration between the public and private sectors as well as international organizations. Public-private partnerships can catalyze innovation and develop the infrastructure needed to support sustainable agriculture. For example, private companies can play a key role in developing and distributing green technologies, while governments can create a favorable regulatory environment and provide economic incentives (Nzau, 2021). International organizations can provide initial funding for pilot projects and large-scale initiatives, while also facilitating technology transfer and building local capacity to adopt and sustain green agricultural practices.

Development programs funded by donors can also serve as models for national sustainable agricultural policies (Mertens *et al.*, 2020).

• Specific Measures to Mitigate the Effects of Climate Change on Agriculture - Finally, it is imperative to implement specific measures to mitigate the effects of climate change on agriculture in the DRC. This includes adopting resilient technologies, such as drought-resistant crop varieties, sustainable irrigation systems, and agroforestry, which can all enhance the resilience of agricultural systems. It is also crucial to invest in research and development to adapt these technologies to local conditions and to identify new sustainable agricultural practices (FAO, 2020). Moreover, ecosystem restoration initiatives, such as reforestation and integrated watershed management, can help stabilize soils, regulate water cycles, and mitigate the impacts of extreme climatic events like floods and droughts. These measures are essential not only to ensure agricultural sustainability but also to protect the livelihoods of vulnerable rural populations (World Bank, 2019).

The transition to sustainable agriculture in the DRC is not only possible but also necessary to ensure food security, protect the environment, and improve the resilience of rural communities to climate change. By integrating green technologies into agricultural practices and adopting appropriate policies and incentives, the DRC can transform its agricultural sector and ensure a sustainable future for its farmers and ecosystems. Partnerships and capacity building will be key elements of this transformation, allowing the country to fully benefit from the opportunities offered by sustainable agriculture.

Examples of successful integration of Green technologies in sustainable agriculture

Agroforestry Project in South Kivu, DRC

A notable example of success in integrating green technologies in the DRC is the agroforestry project implemented in the South Kivu region. Supported by international organizations such as the Food and Agriculture Organization (FAO), this project integrated agroforestry techniques to improve the resilience of local agricultural systems to the impacts of climate change. The agroforestry approach used in this project combined the cultivation of food crops with tree planting, thus creating a diversified environment that protects the soil from erosion and improves long-term soil fertility. The trees planted in the fields not only provide beneficial shade for crops but also contribute to carbon sequestration, thereby reducing the local agriculture's carbon footprint (Nzau, 2021). Additionally, farmers involved in the project saw an increase in crop yields and a diversification of their income sources through the sale of non-timber forest products such as fruits and wood. This initiative has not only improved food security for local communities but has also served as a model for other regions of the DRC where deforestation and soil erosion are major challenges. The success of the project encouraged local authorities to further promote agroforestry as a key strategy for sustainable agriculture in the region.

Solar Irrigation Systems Program in Ethiopia

Although this example comes from Ethiopia, it is particularly relevant to the DRC due to the similarities in climate challenges and economic conditions. The solar irrigation program in Ethiopia, supported by the Ethiopian government and international partners such as USAID, introduced solar-powered irrigation systems in the country's arid regions. These systems enabled farmers to continue irrigating their fields even during prolonged droughts, thereby increasing crop productivity and reducing dependence on rainfall (FAO, 2020). The results of the program were impressive: farmers experienced a significant increase in yields, and the costs of irrigation decreased as solar energy replaced costly and polluting diesel generators. This success encouraged the adoption of solar irrigation in other regions of sub-Saharan Africa, and similar initiatives are beginning to be implemented in the DRC, particularly in Katanga and Kasai, where climate conditions make traditional irrigation difficult.

Biofertilizer Initiative in Ghana

In Ghana, a project supported by the World Bank and the Ghanaian government implemented the use of biofertilizers as part of a broader strategy to promote sustainable agriculture. Biofertilizers, produced locally from organic materials, were distributed to farmers in regions where soil degradation and reliance on chemical fertilizers had led to declining soil fertility and yields (World Bank, 2019). The initiative not only helped restore soil health but also led to increased yields of staple crops such as maize and cassava. Farmers also benefited from reduced costs, as biofertilizers are cheaper than imported chemical fertilizers. This project demonstrated how the integration of green technologies can revitalize agriculture in contexts of environmental and economic degradation, offering valuable lessons for the DRC. These examples show that while challenges remain, the integration of green technologies into sustainable agriculture can lead to positive outcomes in terms of agricultural productivity, climate resilience, and environmental sustainability. By drawing inspiration from these successes, the DRC can develop strategies tailored to its local realities to promote sustainable agriculture that benefits both farmers and the environment.

RESULTS AND DISCUSSION

The integration of green technologies into sustainable agriculture in the Democratic Republic of Congo (DRC) is beginning to show promising results, although these initiatives are still in their development and deployment stages. Pilot projects and local initiatives have demonstrated the positive impact that sustainable agricultural practices can have on productivity, the resilience of agricultural systems, and the conservation of natural resources. Here are some notable results observed so far in the DRC:

Increased Agricultural Productivity

In regions where green technologies have been introduced, such as sustainable irrigation and agroforestry, farmers have reported a significant increase in yields. For example, in South Kivu, the integration of agroforestry and drip irrigation systems has enabled farmers to increase maize and cassava crop yields even during drought periods. The trees planted as part of agroforestry efforts have contributed to improving soil fertility and provided shade that reduces heat stress on crops (Nzau, 2021). These yield increases have not only improved local food security but also enabled farmers to sell surplus production in markets, generating additional income for households. This has had a positive effect on local economies, stimulating commercial activities in rural areas.

Improved Climate Resilience

Green technologies have also helped strengthen the resilience of agricultural systems to the effects of climate change. In Kasai Central and Kasai Oriental, where prolonged droughts have become more frequent, the introduction of drought-resistant crop varieties and solar-powered irrigation systems has allowed farmers to maintain stable production despite adverse climatic conditions (Mertens *et al*., 2020). Additionally, the use of biofertilizers has improved soil health, making crops more resistant to diseases and pests, which is crucial in the face of increasing climate variability. These practices have reduced crop losses due to weather extremes, increasing food security in rural communities.

Conservation of Natural Resources

Green technology initiatives have also had a positive impact on natural resource conservation in the DRC. For example, in the Congo River Basin, the adoption of agroforestry techniques and soil conservation practices has contributed to reducing soil erosion and restoring the fertility of degraded lands (Kakule *et al*., 2019). The trees planted as part of these projects play an important role in carbon sequestration, helping to mitigate the effects of climate change. Furthermore, the use of solar-powered irrigation systems in Katanga has reduced water and energy consumption, lowering pressure on local water resources and reducing the carbon footprint of agriculture. These results demonstrate that green technologies can be an important lever for the sustainable management of natural resources in the DRC.

Development of Local Capacities and Awareness

Another significant result observed in the DRC is the development of local capacities and increased awareness of sustainable agricultural practices. Training and awareness programs led by NGOs and international organizations have enabled many farmers to acquire skills in sustainable agriculture, natural resource management, and the use of green technologies (World Bank, 2019). This awareness has led to the growing adoption of sustainable farming practices, although additional efforts are needed to expand these initiatives nationwide. Building local capacities is essential to ensure the sustainability of these practices and their long-term integration into the agricultural systems of the DRC. Despite these positive results, several challenges remain for the widespread adoption of green technologies in the DRC. Economic barriers, such as the high cost of green technologies and limited access to financing, as well as institutional challenges, such as the lack of supportive public policies, continue to slow down the large-scale deployment of these innovations (Bokundowa, 2017). However, the results observed so far show that the integration of green technologies into sustainable agriculture is not only possible but also beneficial for the DRC. With increased support from governments, international organizations, and the private sector, it is possible to overcome these challenges and transform Congolese agriculture into a model of sustainability and resilience in the face of climate change.

Discussion

Critical Analysis of the Results

Evaluation of the Real and Potential Impacts of Green Technologies on Agriculture in the DRC

The results observed in the integration of green technologies in the Democratic Republic of Congo (DRC) show promising potential for transforming the country's agriculture. However, a critical analysis of these results reveals important nuances to consider. Green technologies such as sustainable irrigation, agroforestry, and the use of biofertilizers have proven effective in several pilot projects, with notable improvements in agricultural productivity, resilience to climate change, and the conservation of natural resources (Nzau, 2021). These positive impacts underscore the potential for green technologies to address the environmental and economic challenges facing agriculture in the DRC.

However, it is important to note that these successes have been mainly observed in specific contexts where conditions were favorable, often supported by external funding and strong involvement from international organizations. The question that arises is whether these results can be replicated and sustained on a larger scale across the country. The DRC, with its ecological and socio-economic diversity, presents unique challenges that could limit the impact of these technologies if they are not adapted to local realities. For example, the effectiveness of solar irrigation systems in arid regions may not directly translate to areas with high humidity, where water management challenges are different (Mertens *et al*., 2020). Additionally, while the results show increased agricultural productivity in some regions, it remains to be seen whether this increase is sustainable in the long term. The sustainability of these impacts will largely depend on the ability of local farmers to maintain and manage these technologies without continuous external assistance. This raises questions about the economic viability of these technologies in a context where access to credit and financial resources remains limited for most smallholder farmers (Bokundowa, 2017).

Comparison with Other Regions and Similar Countries

A comparison of the results observed in the DRC with those of other regions in Africa and countries with similar conditions reveals interesting similarities but also important differences. For example, in Ethiopia, the integration of solar irrigation systems has been largely successful due to continuous government support and international investments. This support has helped overcome financial barriers and led to widespread adoption, with significant impacts on food security and the resilience of rural communities (FAO, 2020)

However, the situation in the DRC is more complex. Unlike Ethiopia, where coordinated national efforts facilitated the spread of green technologies, the DRC faces more pronounced institutional and political challenges. The lack of coherent agricultural policies and political instability hinder the effective implementation of green technologies on a large scale. Furthermore, the DRC suffers from a lack of infrastructure, which limits farmers' access to markets, agricultural extension services, and agricultural inputs all of which are essential for the success of green technologies (World Bank, 2019).

Moreover, the results in the DRC can be compared to those in Ghana, where the adoption of biofertilizers has led to a revitalization of degraded lands and increased agricultural productivity. However, unlike Ghana, where markets for sustainable agricultural products are more developed, the DRC has not yet put in place sufficient economic incentives to encourage the widespread adoption of such practices (Kakule *et al.*, 2019). These comparisons show that while green technologies have the potential to transform agriculture in the DRC, their success will depend largely on the country's ability to create an environment conducive to their adoption. This includes the development of infrastructure, improved access to financing, and the implementation of coherent and incentivizing agricultural policies. Without these elements, the positive impacts observed so far risk being limited to isolated projects without a true nationwide transformation.

In conclusion, green technologies offer significant potential for sustainable agriculture in the DRC, but their real impact will depend on several contextual factors. The promising results observed in pilot projects demonstrate that these technologies can improve productivity, strengthen resilience to climate change, and contribute to the conservation of natural resources. However, to maximize this impact, it will be essential to overcome the economic, social, and institutional barriers that currently limit their large-scale adoption. Comparisons with other countries show that favorable political and economic environments are crucial for the success of green technologies. In the absence of such environments in the DRC, current initiatives may not reach their full potential. Therefore, future efforts should focus on creating a framework conducive to the adoption of green technologies, drawing on lessons learned from other regions while adapting strategies to the specificities of the Congolese context.

Study Limitations

Methodological Constraints

One of the main limitations of this study lies in the methodological constraints that influenced the data collection and analysis. First, the study largely relies on secondary data from case studies and previous publications, which may introduce biases related to the quality and reliability of the sources used. The reliance on secondary data may limit the study's ability to capture recent dynamics or rapid contextual changes on the ground, particularly in a complex and evolving environment like the Democratic Republic of Congo (DRC). Another methodological constraint concerns the difficulty of obtaining empirical data directly from farmers in the DRC, mainly due to logistical and security challenges in certain regions of the country. Limited access to remote rural areas, whether due to insecurity or geographical isolation, restricted the researchers' ability to conduct extensive field surveys and collect representative primary data from across the country. This led to an increased dependence on localized case studies, which may not fully represent agricultural and environmental conditions throughout the DRC.

Furthermore, the study faces limitations in the method of evaluating the impact of green technologies on sustainable agriculture. The complexity of interactions between environmental, social, and economic variables makes it difficult to isolate the direct effect of green technologies on agricultural outcomes. For example, yield increases observed in some regions may be influenced by external factors such as exceptionally favorable weather conditions or temporary interventions from international organizations, rather than by the technologies themselves. This difficulty in isolating specific effects complicates the evaluation of the true effectiveness of green technologies in the DRC context.

Limitations of Available Data

The limitations of available data constitute another major obstacle in this study. The DRC is a country where data collection systems are often fragmented and unreliable, largely due to insufficient infrastructure, limited human resources, and persistent political instability. As a result, available agricultural and environmental data are often incomplete, outdated, or not harmonized, complicating precise analysis and informed decision-making. For instance, statistics on the adoption of green technologies by Congolese farmers are scarce and generally unsystematic. Most available information comes from pilot projects or NGO reports, which may have selection biases and may not be representative at the national level. Additionally, data on the long-term impacts of green technologies, such as effects on biodiversity or soil quality, are often absent or inaccessible, limiting the study's ability to fully evaluate the ecological and economic benefits of

these practices.

Another limitation related to data concerns the measurement of agricultural systems' resilience to climate change. Resilience indicators are difficult to quantify and require longitudinal data series that capture agricultural systems' responses to climate shocks over several years. In the context of the DRC, where historical data series are often interrupted or inconsistent, it is difficult to construct robust models that allow solid conclusions to be drawn on the effectiveness of green technologies in terms of enhancing resilience. Finally, the ecological and socio-economic diversity of the DRC poses an additional challenge to generalizing the results. Conditions vary considerably from one region to another, making it difficult to apply the study's conclusions uniformly across the country. This heterogeneity limits the study's ability to formulate generalized recommendations for the adoption of green technologies, requiring instead approaches adapted to specific local contexts.

Despite these methodological constraints and the limitations of available data, this study provides important insights into the potential of green technologies to support sustainable agriculture in the DRC. However, the results should be interpreted with caution, taking into account the identified limitations. To strengthen the robustness of the conclusions and recommendations, it is essential to improve data collection systems, develop more rigorous methodologies, and promote empirical field research that captures the diversity and complexities of the Congolese context. This will not only validate the current results but also better inform future decisions on agricultural policies and sustainable development in the DRC.

Perspectives for future Research

Suggestions for further study on Green technologies and their impact in the DRC

This study has highlighted the potentials and challenges associated with the integration of green technologies into sustainable agriculture in the Democratic Republic of Congo (DRC). However, to better understand and maximize the benefits of these technologies, future research should be more in-depth and focused. A promising direction for future research is the longitudinal evaluation of the impacts of green technologies. It is crucial to conduct studies over several years to track the evolution of agricultural productivity, the resilience of agricultural systems, and environmental sustainability following the adoption of green technologies. These studies should include indicators such as soil quality, biodiversity, and resource use efficiency (water, energy), allowing for a better understanding of the long-term benefits of sustainable agricultural practices (Nzau, 2021). Furthermore, it is necessary to diversify regional case studies to capture the variety of ecosystems and socio-economic conditions in the DRC. A comparative approach could be adopted, where different green technologies are tested and compared in various regions of the country, such as the provinces of North Kivu, Katanga, and Bandundu. This approach would help determine which technologies are best suited to each local context and provide specific recommendations for each region (Mertens *et al.*, 2020). Another important area for research is the evaluation of the socio-economic factors that influence the adoption of green technologies. It is essential to better understand the motivations, barriers, and incentives that determine farmers' decisions to adopt or not adopt these technologies. In-depth sociological surveys and economic analyses could provide valuable insights into how public policies, access to financing, and awareness can be improved to encourage wider and more effective adoption of green technologies (World Bank, 2019).

Exploration of Policy Frameworks and Institutional Arrangements

Another promising avenue for future research is the exploration of policy frameworks and institutional arrangements that would facilitate the large-scale adoption of green technologies in the DRC. While this study has highlighted the importance of public policies, it is necessary to delve deeper into the types of policies that would be most effective in promoting sustainable agriculture. Research could focus on case studies from other countries that have successfully implemented green technologies, analyzing how governments have created regulatory frameworks that incentivize their adoption. This research should also explore the role of local institutions, such as agricultural cooperatives, in promoting sustainable practices. Cooperatives often play a key role in disseminating information, pooling resources, and negotiating with markets. Therefore, understanding how they can be leveraged to support the widespread adoption of green technologies in rural areas could provide valuable insights for policymakers (FAO, 2020). Additionally, examining the role of non-governmental organizations (NGOs) and international development agencies in supporting sustainable agriculture would also be critical. These organizations are often instrumental in introducing new technologies and training farmers in their use, but their long-term impact on creating self-sustaining agricultural systems needs to be better understood.

Assessing Climate-Resilient Agricultural Practices

Future research should also focus on assessing the resilience of agricultural practices in the DRC to climate change. While this study has provided some insights into the impacts of green technologies on climate resilience, there is a need for more comprehensive and systematic research. This could include the development of specific resilience indicators that measure the capacity of agricultural systems to recover from climate shocks, such as droughts and floods, as well as the capacity of farmers to adapt to changing climatic conditions. Researchers could examine how different regions of the DRC are responding to the current challenges posed by climate change and identify best practices that could

be replicated elsewhere. This research could include a focus on indigenous knowledge and traditional farming practices that may offer valuable lessons for improving the resilience of modern agricultural systems. In many parts of the DRC, farmers have developed ways of managing risk through diversified cropping systems and community-based resource management that could complement green technologies (Mertens *et al.*, 2020).

CONCLUSION

This study highlights the severe impacts of climate change on agriculture in the Democratic Republic of Congo (DRC) and underscores the potential of green technologies to foster sustainable agricultural practices. Findings reveal that climate change is causing significant disruptions in agricultural productivity due to altered rainfall patterns, rising temperatures, and increased frequency of extreme weather events like droughts and floods. These conditions are negatively affecting staple crops such as maize and cassava, degrading soil, and undermining food security for rural communities (Mertens *et al.*, 2020). Green technologies, including sustainable irrigation, biofertilizers, and renewable energy sources, present a viable pathway to mitigate these challenges. Practices like agroforestry and solar-powered irrigation have shown promise in enhancing farm resilience against climate shocks while conserving natural resources (Nzau, 2021). These technologies also offer economic opportunities for rural communities, supporting both environmental sustainability and inclusive growth. Immediate adoption of sustainable farming practices is essential. As climate change progresses, delays in implementing these technologies could have irreversible consequences for agricultural ecosystems and rural livelihoods. Therefore, stakeholders including policymakers, international organizations, and local communities—must act quickly to promote and support these practices (FAO, 2020). Key recommendations are provided:

• Policymakers should introduce policies that facilitate the adoption of green technologies, such as subsidies, farmer-training programs, and access to financing for small-scale farmers to invest in sustainable solutions (World Bank, 2019).

• Farmers are encouraged to actively engage in adopting sustainable methods that boost productivity while protecting the environment, including participating in training and sharing practices with local communities (Kakule *et al.*, 2019).

• Communities and local organizations play a vital role by promoting resource-sharing initiatives, protecting local ecosystems, and advocating for agricultural policies that address farmers' needs (FAO, 2020).

In conclusion, this study calls for a collective approach to transform agriculture in the DRC, emphasizing that green technologies can only succeed through the committed action of all stakeholders.

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