LUND UNIVERSITY
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HIV/AIDS and Agricultural Production in Sub-Saharan Africa

The impact of HIV/AIDS on Cassava Production in Tanzania and Nigeria (1990-2021)

By

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Abstract

This research paper analyses the impact of HIV/AIDS on cassava production on a panel of two countries from Sub-Saharan Africa: Tanzania and Nigeria. It covers the 1990-2021 time period. In addition, it provides a zoomed-in investigation on each country using time and country fixed effects, covering the same timeframe. This work contributes to the literature in three dimensions. First, it investigates the direct relationship between HIV/AIDS and cassava production. Second, it provides a more in-depth understanding of the study by focusing on two specific countries in East and West Africa. Third, it uses an empirical strategy with quantitative tools to determine the effect of HIV/AIDS on cassava production in Tanzania and Nigeria. Using several estimation methods, results show that HIV/AIDS significantly affects cassava production in both countries. In particular, HIV prevalence and HIV incidence have a negative effect on cassava production which confirms the two hypotheses. Nevertheless, the comparison within each country shows that HIV prevalence does not significantly impact cassava production in Tanzania and Nigeria. In contrast, HIV incidence appeared positively significant for Nigeria only. Finally, the paper also discusses interventions against the spread of the HIV/AIDS disease.

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1. Introduction

In recent decades, the world has become increasingly vulnerable to the outbreak and spread of new infectious diseases. This heightened global vulnerability is particularly seen with the case of Human Immunodeficiency Virus (HIV) and the Acquired Immune Deficiency Syndrome (AIDS), both of which are among the most significant global challenges, particularly in SubSaharan Africa. Living with AIDS can have a significant impact on human life, including an individual's physical health, mental well-being, social relationships, individual socioeconomic status and in extension a country's overall socioeconomic status via the interruption of the workforce as a result of the debilitating nature and the mortality of HIV/AIDS. Regrettably, no vaccine or cure for the disease has been discovered and this drives mortality rates up (Ndimbwa et al., 2013). The number of people receiving HIV treatment in Africa grew at a slower place in 2021, reaching only 1.47 million compared to 2 million seen in previous years. This represents the smallest increase since 2009, according to UNAIDS (2022). Notably, the largest increase in HIV treatment was seen in Western and Central Africa, while Eastern and Southern Africa experienced a much lower rate of increase compared to previous years. Despite the fact that approximately three-quarters of all people living with HIV have access to antiretroviral treatment, it is concerning that around 10 million people still do not. This decrease in access to treatment is said to have been triggered by the COVID-19 pandemic along with economic and humanitarian crises around the world. Therefore, the disruption of health services in lieu of the COVID-19 pandemic has led to a now global chronic issue of delayed diagnosis and treatment, in the case of HIV and AIDS, the lack of HIV diagnoses and access to treatment has led to an increase of individuals with AIDS (UNAIDS, 2022).

As the impact of the HIV/AIDS epidemic continues to significantly affect both individuals and society, it is crucial to recognize the profound consequences it has on a building block of life, food and agriculture. The cost HIV/AIDS has on the agricultural labor force can lead to a significant decrease in quantity and quality of agricultural output, which in turn risks an increase in food insecurity plus a strain on local and national economies. This study aims to examine the effects that the HIV/AIDS epidemic has on agricultural production in African countries that have high incidences of HIV/AIDS. Focus is given to the agricultural crop of cassava. Cassava is a vital staple food providing a source of income for the population and plays a key role in food security or poverty alleviation in Africa. It is well-suited to the continent's diverse agroecological conditions since it is climate resilient. Cassava is droughttolerant, does not require high soil fertility and is resistant to high temperatures. In Sub-Saharan Africa, the implementation of new policies reduced the profitability of crops such as maize and this triggered an increase in cassava production. The HIV/AIDS disease has led to a dramatic rise in mortality. With this in mind, farmers have started to rely on less labor-intensive crops like cassava. With this increase in production comes an increase in reliance on cassava. The nature of this crop (being less labor-intensive) attracts and suits a more female-based workforce. However, as a result of a rise in HIV/AIDS in females there is a risk that cassava production is affected. Agriculture is the principal source of livelihood for millions of people on the African continent and is seen as a key contributor to economic growth and development. Scholars have analyzed the relationship between HIV/AIDS and agriculture in Africa. Existing studies focus on agricultural crops such as cereal, banana, cotton or tea. They use a qualitative or quantitative approach but mostly focus on Sub-Saharan Africa in general or on the national level in specific countries of the region. Nevertheless, there is little research examining the effect of HIV/AIDS on cassava production even though it is an important crop in Africa (Pipitpukdee et al. 2020).

This paper examines the impact of HIV/AIDS on agricultural production in two important countries of Sub-Saharan Africa: Tanzania and Nigeria. More specifically, it answers the following research question: *What is the impact of HIV/AIDS on cassava production in Tanzania and Nigeria between 1990 and 2021?*

West Africa sees advanced cassava commercialization, with Nigeria being the world's largest cassava producer and marketing over 75% of its cassava harvest. In the country, half of its production is sold as urban convenience food. In comparison, cassava production has only emerged recently in Eastern Africa. According to Haggblade et al., (2012), this spillover of cassava production opens up important opportunities in the region. While cassava commercialization has been driven by urban demand for processed convenience foods in cassava-belt cities in West Africa, the Eastern part of the continent like in Tanzania has centered on fresh cassava markets. Additionally, rapid urbanization suggests that urban demand for convenience foods and high-value processed foods will increasingly dominate food markets. Therefore, examining the relationship between HIV/AIDS and cassava production in Sub-Saharan Africa is crucial.

Tanzania and Nigeria exist as two countries with a high prevalence of HIV/AIDS and both Tanzania and Nigeria are countries that play a major role in cassava production in Africa. While Nigeria is the world's largest cassava producer, Tanzania is also one of the largest cassavaproducing countries on the continent. Both countries experienced the HIV/AIDS epidemic that had severe socio-economic consequences. In particular, their agricultural sector was heavily touched since it represents the backbone of their economies. However, cassava production dramatically decreased in Tanzania between 1990 and 2008 at the same time as HIV/AIDS rose. In contrast, in Nigeria cassava production increased at the same time. This opposite relationship is interesting to analyze and will help to assess whether there is a direct link between HIV/AIDS and cassava production in Tanzania and Nigeria.

The current study contributes to the existing literature in three ways. First, it looks at the relationship between HIV/AIDS and cassava production. To the best of my knowledge, no existent studies analyzed the direct link between HIV/AIDS and cassava production. Focusing on this relationship is essential to understand the extent to which HIV/AIDS influences cassava production. This will help the design and implementation of effective strategies aiming at improving people's life and agricultural production. Second, this paper examines two specific countries in East and West Africa: Tanzania and Nigeria. Focusing on only two countries allows for a more in-depth understanding of the study. Third, it uses an empirical strategy with quantitative tools to determine the effect of HIV/AIDS on cassava production in Tanzania and

Nigeria. This research includes a longitudinal panel data analysis with a multiple regression model. It allows for an examination of changes, trends and patterns of different variables over time.

This thesis is structured as follows. First, the paper introduces the context of the spread of HIV/AIDS in Sub-Saharan Africa, Tanzania and Nigeria. Second, it gives a literature review on the impact of HIV/AIDS on economic development and more precisely on agricultural production in the region. Third, it describes the role of HIV/AIDS in gender and the importance of cassava in Sub-Saharan Africa, Tanzania and Nigeria. Fourth, it analyzes the link between HIV and cassava production in both countries. Fifth, it depicts gender roles in cassava production in Africa. Sixth, it presents the methodology and the empirical results of the study. Finally, the paper concludes with a discussion.

2. Hypotheses

The paper presents two a priori hypotheses about the impact of HIV/AIDS on cassava production:

H1: There is a significantly negative effect of HIV/AIDS prevalence on Cassava Fresh production in Tonnes

H2: There is a significantly negative effect of HIV/AIDS incidence on Cassava Fresh production in Tonnes

3. Context

3.1. The spread of HIV/AIDS in Sub-Saharan Africa, Tanzania and Nigeria

3.1.1. The spread of HIV/AIDS in Sub-Saharan Africa

Sub-Saharan Africa is a part of the world that has been hit the hardest by the HIV/AIDS pandemic. With just over 10% of the world's population, the continent had almost two-thirds of the world's HIV/AIDS cases which made it the epicenter of the disease in 2006 (Inungu&Karl, 2006). Lately, the region continues to be the most affected with 25.6 million people living with HIV in 2022. However, progress has been made over the past decade and this reduced new infections by 44% and AIDS-related deaths by 55% (WHO, 2022).

Setel et al. (1999) argued that to understand the spread of HIV/AIDS, looking at the year of discovery of the first case of the disease in Sub-Saharan Africa is not relevant. The authors state that it is more appropriate to examine the continent's past and history to truly grasp the disease's spread. They explain that colonialism had a huge impact on the propagation of HIV/AIDS, although a direct relationship cannot be claimed, the disruption of social structures and the increase of labor migration and mobility have been suggested to have increased the spread of HIV/AIDS. For example, colonization facilitated labor migration and led to workers (married and unmarried) traveling to new places for work. This increase in mobility and exposure to new settings away from family and support networks is said to have contributed to the spread of HIV via risky sexual behavior (Inungu&Karl, 2006).

Historically, the African continent was prone to the development of HIV/AIDS because of many reasons. Sub-Saharan Africa saw the development of socio-economic flux, political disruption, exploitation and bad government, which facilitated the spread of the disease. The presence of income inequality, the lack of social cohesion and unfair international trade practices impoverished the continent and triggered its vulnerability to infectious diseases such as HIV/AIDS (Lau&Muula, 2004). In Sub-Saharan Africa, the largest contributor to HIV/AIDS is heterosexual intercourse, which makes sexual behaviors the main way of infection. Those sexual behaviors are usually affected by socioeconomic and cultural factors such as impoverishment, a decline of social services, women's subordinate position in society, or even rapid urbanization and modernization (Lau&Muula, 2004). Particularly, urbanization plays a key role in the spread of HIV/AIDS in Sub-Saharan Africa. When people move from rural to urban areas, traditional and cultural values enforcing sexual discipline are lost and often this leads to having multiple sexual partners. Individuals are no longer under the traditions and sanctions of the rural environment and start adopting individualistic lifestyles (Setel et al., 1999). Moreover, urban areas have a higher number of people compared to rural areas and this gives the incentive to become involved in extramarital or multiple sexual relations

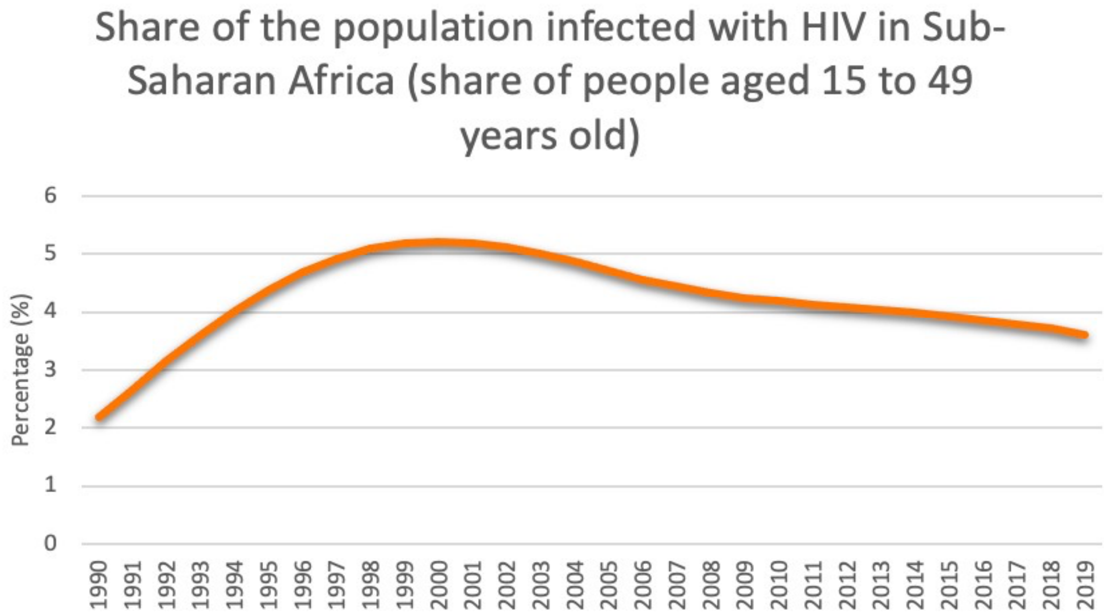
(Lau&Muula, 2004). Lastly, Tibaijuka (1997) argued that the polygamous culture in Africa helped spread the HIV/AIDS disease by having multiple sexual partners. In this context, SubSaharan Africa saw a quick propagation of HIV/AIDS over time that continues until today even though less dominant.

According to UNAIDS (2022), 54% (20.6 million) of all people living with HIV can be found in Eastern Africa. Women and girls are disproportionately affected by the disease with 63% of the region's new HIV infections in 2021. The United Republic of Tanzania illustrates the current HIV/AIDS epidemic in Eastern Africa. In 2021, 54,000 new HIV infections were detected among all ages and 28,000 infections were among women. Moreover, the HIV incidence per 1000 population was of 0.96% and AIDS-related deaths of all ages were up to 29,000 in the country that year (UNAIDS, 2022). Compared to other countries in Eastern Africa, Tanzania's HIV incidence is much higher. Ethiopia had an HIV incidence of 0.12% in 2021 and AIDS-related deaths of all ages of 12,000 the same year. Moreover, HIV incidence in Rwanda was of 0.34% in 2021 while AIDS-related deaths of all ages were 2,400 that year.

In contrast, Western Africa has the third highest burden of people living with HIV in the world, with 5 million people at the end of 2021. Again, the incidence rate is over three times higher among women compared to men of the same age. Nevertheless, there was a decline in new infections since 2010 which was much faster among men (56%) than women (39%) in the region. Nigeria is one of the most affected countries with the HIV/AIDS disease in the region. In 2021, there were 74000 new infections of all ages with 31000 being infected women. The HIV incidence per 1000 population was 0.34% and 51000 deaths of all ages were observed in the country (UNAIDS, 2022). In other Western countries in Africa, the numbers are much lower. Burkina Faso shows a HIV incidence per 1000 population of 0.08% and AIDS-related deaths of all ages of 2000 in the year 2021. Côte D'Ivoire has lower numbers with a HIV incidence of 0.21% and AIDS-related deaths of 8800 both in 2021.

Figure 1 illustrates the spread of HIV/AIDS in Sub-Saharan Africa from 1990 to 2019, as a share of the population aged 15 to 49 years old infected with HIV. From 1990 to 2000, there was a dramatic increase in HIV infections with 2% to a bit more than 5% respectively. Afterward, HIV infections started to decrease slowly in the 2000s and went down to less than 4% by 2019.

Figure 1. Spread of HIV/AIDS in Sub-Saharan Africa between 1990 and 2019, as a share of the population aged 15 to 49 years old infected with HIV (as a percentage).



Source: Own creation, data from Our World in Data (2023).

3.1.2. The spread of HIV/AIDS in Tanzania

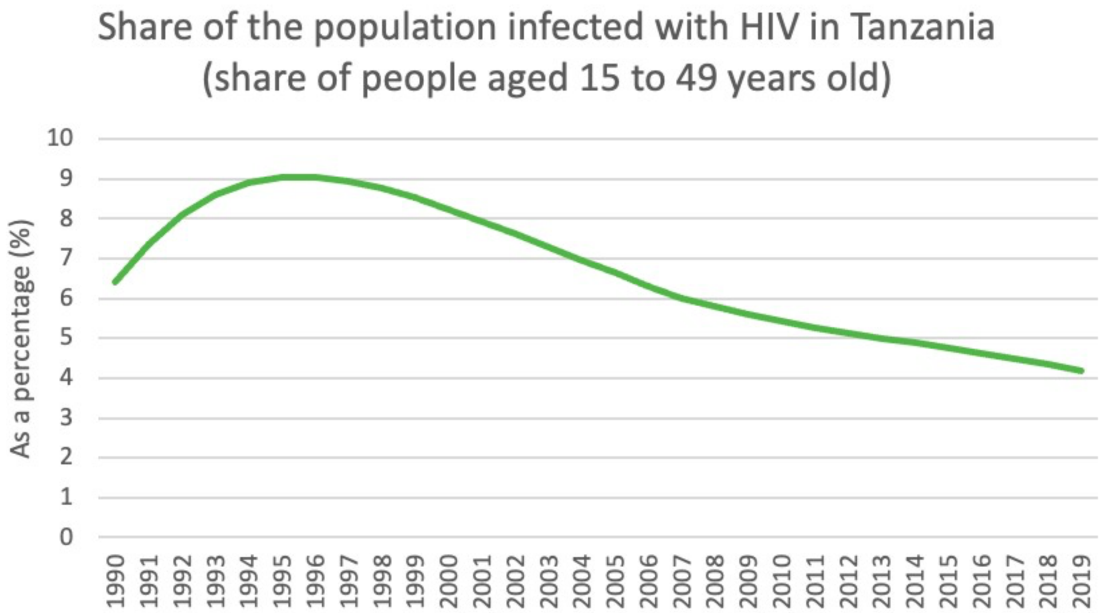
The first contamination of the HIV/AIDS disease in Tanzania was identified in a homosexual male in 1982 (Pokrovskiĭ et al., 1992). Afterward, the first cases of HIV/AIDS in the country were reported in 1983, in the region of Kagera. By 1987, all regions of Tanzania were touched by the disease and its prevalence was 9.6% by 2002. UNAIDS (2022) estimated that 1.6 million of Tanzanians lived with HIV/AIDS by 2003, with 1.5 million being adults and among those 56% percent were women (Garbus, 2004). Today, 63% of the eastern region's new HIV infections are among women and girls (UNAIDS, 2022).

Currently, Tanzania is one of the most affected countries with HIV/AIDS in Sub-Saharan Africa. Even though its HIV prevalence between 15 and 49 years old decreased to 4.5% in 2021, people living with HIV of all ages increased to 1.7 million in the same year (UNAIDS, 2022). The main way of HIV/AIDS transmission in the country is through heterosexual sex accounting for around 80% of the infections. However, HIV/AIDS prevalence in Tanzania is heterogeneous across age, gender, socioeconomic status, or geographic location (National Health Control Programme, 2023). Githinji (2008) argued that the cultural and social tolerance of having multiple sexual partners contributed to the spread of the disease in the country. The author found that although HIV/AIDS is caused by a biological pathogen, socio-economic factors enabled the virus and its syndrome to pervasively spread throughout Tanzania. One major factor was the political instability that Tanzania faced due to the war with Uganda between 1978-1979, which left long-lasting socio-economic consequences in the country. While it is difficult to measure the scale of HIV/AIDS, estimates from the UNAIDS (2022) show that AIDS-related deaths of all ages were 29000 in 2021 in Tanzania. In Sub-Saharan Africa, 20.6 million people are living with the disease especially in the eastern region.

Moreover, HIV/AIDS has been affecting both rural and urban areas in Tanzania ever since the first infection. Even though the major cause of the disease is sexual interaction, poverty also plays an important role in the transmission of the disease. It has forced women to go into commercial sex in exchange for material benefits and money. This is one of the reasons explaining the high HIV/AIDS infections among women (Ndimbwa et al., 2013). Women are more infected than men with a 6.3% prevalence, compared to 3.9% for men (National Health Control Programme, 2023).

Figure 2 depicts the spread of HIV/AIDS in Tanzania between 1990 and 2019, as a share of the population aged 15 to 49 years old infected with HIV. In 1990, HIV infections were about 6% and went up to more than 8% by 1995. This was followed by a huge decline over the next years, representing a drop in half of HIV infections (4%) by 2019.

Figure 2. Spread of HIV/AIDS in Tanzania between 1990 and 2019, as a share of the population aged 15 to 49 years old infected with HIV (as a percentage).



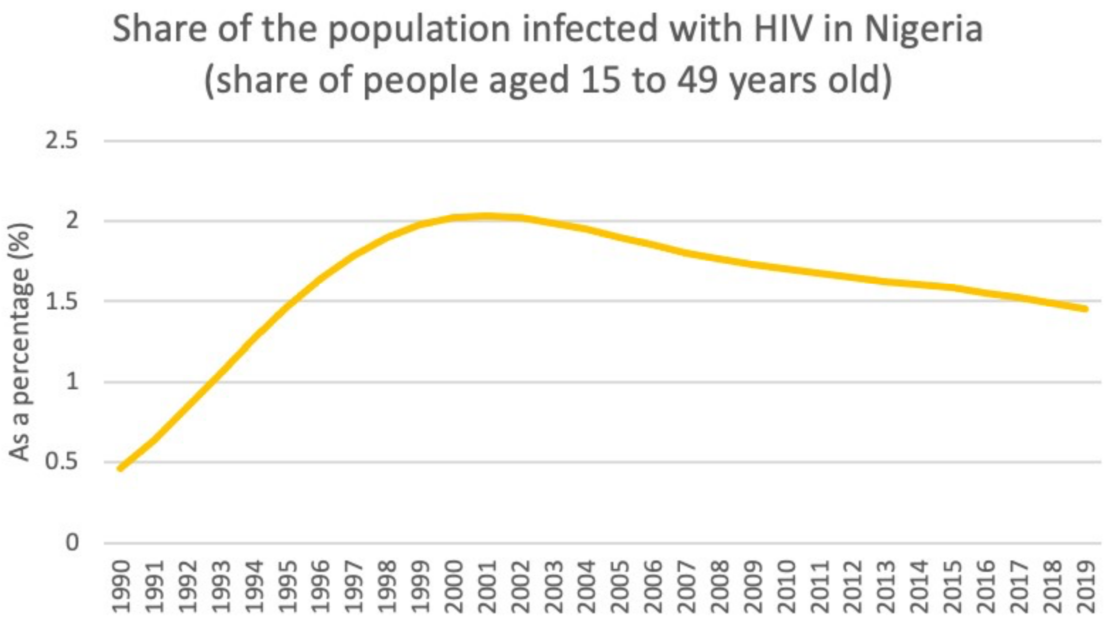
Source: Own creation, data from Our World in Data (2023).

3.1.3. The spread of HIV/AIDS in Nigeria

In Nigeria, the first AIDS case was diagnosed in 1985 on a young female sex worker aged 13 years. Since then, a total of 2200000 new HIV infections have been reported in 2014, mostly among adults over 15 years old. Nigeria is a large country with a very high number of people living with HIV, despite a relatively low HIV prevalence. When accounting for all people living with HIV globally, 9% of them lived in Nigeria in 2014 (Awofala&Ogundele, 2018). The country ranks third among countries with the highest burden of HIV infections in the world. In 1991, Nigeria had a 1.8% of reported HIV prevalence. This was followed by a 3.8% in 1993, 4.5% in 1996 and a peak with 5.8% in 2001 (Awofala&Ogundele, 2018). In 2018, 1.9 million people were living with HIV/AIDS and the country had a national HIV prevalence of 1.4% among adults aged 15-49 years in the same year (UNAIDS, 2019).

Furthermore, Nigerian women are more than twice as likely to be living with HIV compared to men, with 1.9% and 0.9% respectively. Also, the epidemic has a greater impact in certain areas of the country such as the South zone which has a prevalence of 3.1% among adults aged 15-49 years. This prevalence is also high in the North Central zone (2%) and in the Southeast zone with 1.9% (UNAIDS, 2019). Overall, heterosexual intercourse is the major factor for HIV transmission in Nigeria, accounting for over 80% of infections ((Awofala&Ogundele, 2018). Figure 3 represents the share of the population aged 15 to 49 years old infected with HIV in Nigeria. From 1990 to 2000, there was an increase in HIV infections going from 0.5% to 2% respectively. From the 2000s onwards, HIV infections started declining slowly to 1.5% by 2019.

Figure 3. Spread of HIV/AIDS in Nigeria between 1990 and 2019, as a share of the population aged 15 to 49 years old infected with HIV (as a percentage).



Source: Own creation, data from Our World in Data (2023).

4. Literature review

4.1. The impact of HIV/AIDS on economic development in Africa

The spread of HIV/AIDS in Africa has had serious socio-economic consequences on the continent (Rabbow, 2001). First, it has impacted the family structure. With sick parents, the family income decreases due to a lack of productivity and employment loss. Also, sick people must be cared for by others, who divert their attention from their own job. In addition, treatment and transport costs for the sick are high and thus family expenses increase. Second, the health system is very much impacted. Health services are already suffering from a shortage of staff and finances in Africa and dealing with the demand of HIV/AIDS patients becomes complicated. Particularly, health workers are a high-risk group for HIV/AIDS infections. Third, the national economy of the country suffers due to the loss of the labor force. This has a great impact on productivity and on the consumption of goods in the country.

To understand the spread of the disease and its consequences on Africa's economic development, Tibaijuka (1997) used a framework developed by Barnett and Blackie in 1989. This framework enables to look at the loss of labor and food production on the continent. The author analyzed the difference in income and capita as well as the increase of a dependency burden due to orphans and an old population. He found that farm incomes fell due to a decrease in production with labor shortage, in turn declining workers' productivity. This worsened nutritional status and accelerated mortality rates in Africa. Furthermore, the author found that women are the most affected since they are the main food producers, take care of the children and elderly people at home.

In this context, HIV/AIDS reduces life expectancy and population size but also increases mortality in Africa. The disease leads to welfare losses, which in turn affect the Gross Domestic Product (GDP) of African countries. Lastly, it imposes a burden on the health care system and households living with HIV/AIDS see their incomes decrease, while their health expenditures increase (Garbus, 2004).

4.2. The impact of HIV/AIDS on agricultural production in Africa

The impact of HIV/AIDS on agricultural production in Africa has been widely analyzed by scholars in recent decades. Existing studies do indicate that HIV/AIDS has a measurably adverse impact on agricultural production in Africa (Murphy et al., 2005). Nevertheless, analyzing agricultural outputs in general is beyond the scope of this study. For this reason, focus will be given to a singular crop that is cassava. There is little empirical evidence on whether HIV/AIDS affects cassava production in Africa. Therefore, this study tests the previously mentioned hypotheses.

In Sub-Saharan Africa, the largest share of the labor force works in agriculture. Hence, agriculture is the area that suffers the most from the HIV/AIDS epidemic in the region. The disease lowered the value of agricultural production to 2.4% in 2010 and has continued to do so in the following years (Nguthi, 2007). However, the existing literature usually measures the impact of the disease in the short run, which leads to an underestimation of its effect. Studying HIV/AIDS requires a dynamic analysis on the understanding of household behaviors and welfare change over time. Therefore, research focusing on the short-term effects fail to detect intergenerational effects from parents to children.

In Africa, HIV/AIDS is not only a health issue but also affects the agricultural sector with its structure, cropping systems or factors of production (Gillespie, 2006). The disease affects the quality of the workforce of both skilled labor and those pursuing education. The impacts of HIV/AIDS on one's ability to work risks a depletion of the workforce faster than it can be replenished. Thus, this depletion plus rising labor costs present a problem to sectors such as agriculture. Beegle (2003) studied the Kagera District of Tanzania using longitudinal data between 1991-1994 and only found temporary effects of HIV/AIDS mortality on household’s agricultural activities in the country. The results show that households affected by the disease maintain their supply of labor by drawing back new members to the farm. Similarly, Gillespie (2006) found that in Tanzania, there was only a short run effect of HIV/AIDS related mortality on household’s agricultural activities in the early 1990s. In the short run, individuals staying in other households supply labor to households with a prime-age death. Whereas in the long run, households might acquire new members to be able to increase their stock of labor.

Moreover, Larson et al. (2004) analyzed the effect of adult mortality due to HIV/AIDS on smallholder agriculture in cotton and maize in Zambia, using cross-sectional household survey data. Their findings show that afflicted households experienced a decline in their crop output of about 15 percent. Nevertheless, they concluded that the annual impact on agricultural production across all the households was less than one percent. Yamano&Jayne (2004) argued that HIV/AIDS has an adverse impact on agricultural production in Kenya, using a Differencein-Differences estimation at the household level. They found that rural Kenyan households suffering from HIV/AIDS deaths between 1997 and 2000 saw a decline in their agricultural production. However, the authors argued that this decline depends on the household’s sex and initial level of wealth. Results show that the death of an adult female caused a decline in the cereal area cultivated in the country. Thus, the relatively high HIV prevalence rate among women is problematic knowing that women provide up to 75% of the agricultural labor (Spring, 2000). Nevertheless, their findings only show a significant and severe result among the male head-of-household death in families in the bottom half of the wealth distribution. In this case, it strongly impacted their agricultural output with a 68% reduction in its value.

Furthermore, Githinji (2008) examined the effect of HIV/AIDS on banana production in Buhaya, a small village in Tanzania. The author found that the onset of HIV/AIDS coincided with an already declining agricultural system but its impact led to a further decline. Since households got infected, the agricultural labor input declined exponentially. When a household member becomes sick, his labor and the labor of the person taking care of the sick one is lost. Thus, the spread of the HIV/AIDS disease enhances people to seek off-farm activities. As an economic alternative, women start prostitution which triggers the increase of HIV/AIDS (Githinji, 2008). In addition, Fox et al. (2004) found that there is a significant decline in labor productivity among tea pluckers who contracted HIV/AIDS in Kenya. They analyzed the period 1997-2002 using longitudinal regression and their results showed that HIV positive workers plucked less tea and earn 16% less than farmers that do not have the disease.

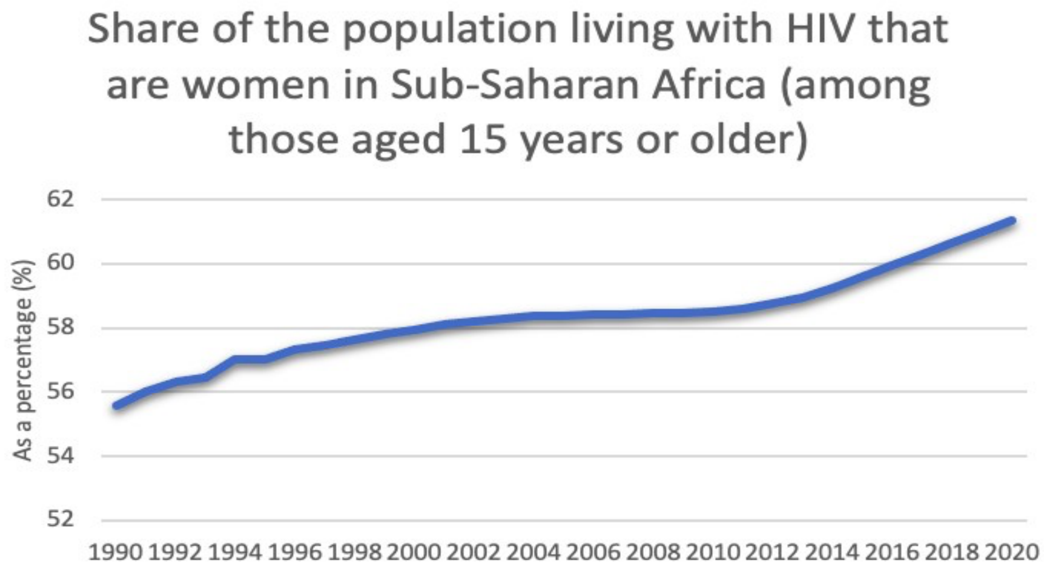
Additionally, Negin (2005) stated that HIV/AIDS brought important changes in the farming systems and behavior of the affected households. He found that the death of households who contracted the disease affects the amount of land cultivated and the type of crops farmed. After the death of a male head of household, the production of cash crops is reduced and replaced by more traditional female-produced crops such as cassava. Similarly, Yajima (2010) stated that HIV/AIDS stimulated cassava production in Malawi. The author explained that the cultivation of cassava demands less labor and its production is not really affected by the propagation of the disease. Therefore, farmers slowly started to cultivate cassava more compared to other crops that are heavily affected by HIV/AIDS. Likewise, Gillespie (2006) explains that the shift to less labor-intensive crops like cassava (Manihot esculenta) is becoming more and more common. The production devoted to cassava in Africa has risen dramatically in recent years, contributing to a shift from high-nutritive crops to less nutritive crops. One reason for this can be attributed to the HIV/AIDS disease but other factors such as policy changes reduced the profitability of other crop production like maize. Particularly, countries in Eastern Africa implemented state-led maize promotion policies with major investments in buying smallholder farming areas. Those policies reduced the profitability of growing maize in the more remote areas and shifted cropping incentives towards other food crops such as cassava. Overall, the author found that areas where cassava production increased appear to be those where the profitability of maize production declined, rather than areas having high HIV prevalence. Equivalently, Jayne et al. (2005) argued that cassava production increased in Zambia in recent years whereas maize production declined. The authors also explained that this is the result of the implementation of state-led maize policies in many Southern countries in Africa. Moreover, since cassava is a relatively unresponsive crop to fertilizer application, its adoption increased among African farmers. Undoubtedly, the HIV/AIDS epidemic also affected the cassava production subsector, which is a major agricultural livelihood activity of Sub-Saharan Africa. Therefore, the link between HIV/AIDS and cassava production is crucial to analyze for the understanding of the impact of the disease in Sub-Saharan Africa in recent years.

4.3. HIV/AIDS and gender in Sub-Saharan Africa

Gender inequality is an important determining factor on the impacts of the HIV/AIDS epidemic in Africa (Nguthi, 2007). First, women are biologically more susceptible to get infected by HIV compared to men. Second, the social and economic inequalities that women face such as the lack of employment opportunities and poor access to education make them more vulnerable to the disease than men. Estimations show that 60 to 80 percent of African women with HIV were infected because of not being in a position to negotiate safe sex or prevent their partners from having additional sexual contacts. According to Nguthi (2007), in rural areas women tend to be disadvantaged compared to men since they have a lower access to resources such as land or credit. Also, the HIV/AIDS disease adds to women's workload since they take care of the sick people in the household. Those additional duties accentuate the negative impact of HIV/AIDS on agriculture since women have less time for farming activities. Evidence from Kenya shows that women farmers have access to agricultural information only in the presence of a man (Nguthi, 2007). Therefore, there are inequalities in women's access to land, credit information or education. This leads to the failure of women to realize their full economic potential and consequently independence from men. Therefore, African women continue to live in situations at risk of contracting HIV/AIDS because they are dependent on men.

Figure 4 depicts the share of the population living with HIV in Sub-Saharan Africa that are women, among those aged 15 years and older, from 1990 to 2020. It shows that women infected with HIV represent more than 50% of the population in the region. The trend remained constant but slightly increased over the years, reaching 60% in 2020.

Figure 4. Share of the population living with HIV in Sub-Saharan Africa that are women (as a percentage), among those aged 15 years and older, from 1990 to 2020.



Source: Own creation, data from Our World in Data (2023).

5. The importance of Cassava in Sub-Saharan Africa, Tanzania and Nigeria

5.1. The importance of Cassava in Sub-Saharan Africa

Originally, cassava comes from South America and globally became an important staple food for over 800 million people in Africa. It provides a basic diet for the population in several countries of the continent, especially in the Sub-Saharan Africa region (Pipitpukdee et al. 2020). Cassava is a tropical crop that is mainly cultivated by small-scale farmers in Africa (Kizito et al, 2007). Farmers grow it for its starchy tuberous roots and its leaves that can also be used as vegetables. Overall, the cassava plant gives yields in soils with low nutrient content and does not need high management costs compared to other food crops. Hence, it is a perfect crop to grow in a region where farmers have poor resources such as Sub-Saharan Africa. Cassava is considered the second largest source of food calories in Sub-Saharan Africa. It is a key food security crop since it has a drought-tolerant perennial rootcrop and offers a low-cost vegetative propagation. Moreover, it has a flexible harvesting calendar and can be stored inground over several years, accentuating its importance against famine (Haggblade et al. 2012).

Haggblade et al. (2012) argued that cassava production became important in Southeastern Africa at the beginning of the 1990s. Cassava costs 60% to 70% of the cereal's costs such as maize and wheat, which enables profitable opportunities for the commercialization of cassavabased foods. Nevertheless, its commercialization in Southeastern Africa is still limited with about 30% of the production marketed. In the region, the production is centered on fresh cassava and low value-added cassava flour. Therefore, there is a need for strategic investments to help shape the cassava industry in Southeast Africa (Haggblade et al. 2012).

5.2. The importance of Cassava in Tanzania

Tanzania depends on small-scale agriculture which accounts for 25 percent of the GDP and more than 80 percent of the workforce in the sector. The country ranks seventh for cassava among African countries with an annual production of 4750160 tonnes (Reincke et al., 2018). Cassava is the second most produced agricultural commodity in Tanzania after maize and accounts for 8.5 percent of total calories in the population diet. More specifically, cassava is cultivated and produced in all regions of the country but is of bigger importance in the semiarid areas of Tanzania. It is mainly grown by low-income or smallholder farmers and does not need mechanization for production. Tanzania has been experiencing population growth and thus this triggered an increased demand for cassava food products in urban markets (Reincke et al, 2018). Therefore, the cultivation of cassava crops plays a key role in the country's food security and provides opportunities to extend the labor use (Kapinga et al., 2015).

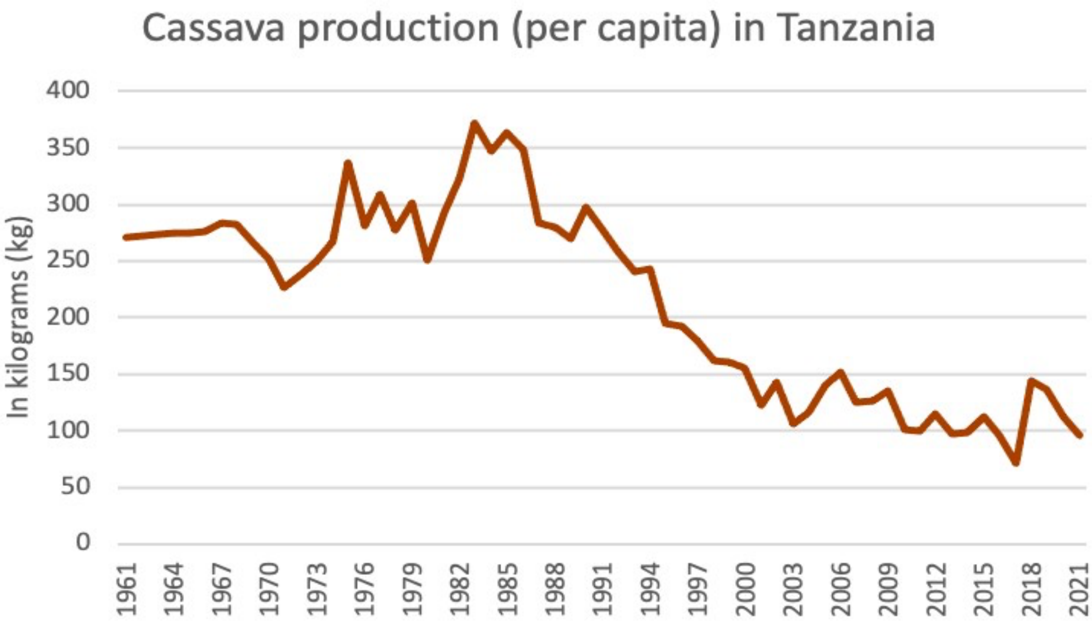
Particularly, 84 percent of the total production of cassava in the country is used as human food, while the rest is for livestock feed and export. In most villages, cassava is used in flour and in alcoholic beverages. Cassava roots used for alcohol beverages was found in 35 percent of staple land area. Overall, those two cassava products are made for sale and not for home consumption. Lastly, the growing of cassava on 50 percent of the staple land in peri-urban areas enables the supply of cities with fresh cassava roots (Kapinga et al., 2015).

Figure 5 below illustrates the cassava production per capita in Tanzania between 1961 and 2021. It shows that there was a huge decline in cassava production between 1990 and 2021. The early 1990s decline can be explained by the lack of a reliable market for cassava. The market was monopolized with the implementation of the National Milling Cooperation (NMC) and regional district cooperative societies during the 1980s. This limited the potential for cassava production in Tanzania (Lazaro et al., 2017). Moreover, the liberalization of markets for agricultural products in the same years left cassava in the hands of private traders. This change negatively affected the dried cassava market since the traders faced little or no competition and thus offered low prices, which led to low returns. Between 1992 and 1994, there was a decline in consumption in Tanzania which led to a decrease in production. It is because in 1990 NMC was dissolved, limiting the amount of cassava marketed and reducing its consumption (Lazaro et al., 2017). Lastly, cassava is planted in marginal or infertile areas and receives poor management practices leading to low productivity of the crops.

Moreover, Lazaro et al., (2017) argued that cassava production declined because of the green mite. This arthropod pest of the cassava plant was widespread and discouraged farmers to expand cassava production. Indeed, cassava varieties have low genetic potential in yield and poor resistance to pests and other diseases. Also, the other food crops did not resist the disease of the cassava plants therefore farmers stopped to cultivate cassava. Additionally, there was a constraint to the cassava production expansion since cassava's long growth cycle farmers were not able to grow the crop under continuous cultivation as much as they were able to do so with other crops. Usually, cassava was used to close a rotation cycle where the crop was stored in remote area fields with low demographic or market pressure (Lazaro et al., 2017). Furthermore, cassava is in farmland areas where farmers had access to market or improved postharvest facilities. Therefore, cassava quickly became a non-convenient food product not able to compete effectively with food grains in the market, not having as many market opportunities as other crops.

Overall, cassava production declined in Tanzania since it was not positively linked with the market, infrastructure was inadequate and the range of cassava food products was narrow. Thus, farmers had no incentives to adopt better management practices or expand land areas for cassava in the country.

Figure 5. Cassava Production (per capita) in Tanzania, between 1961 and 2021.



Source: Own creation, data from Our World in Data (2023).

5.3. The importance of Cassava in Nigeria

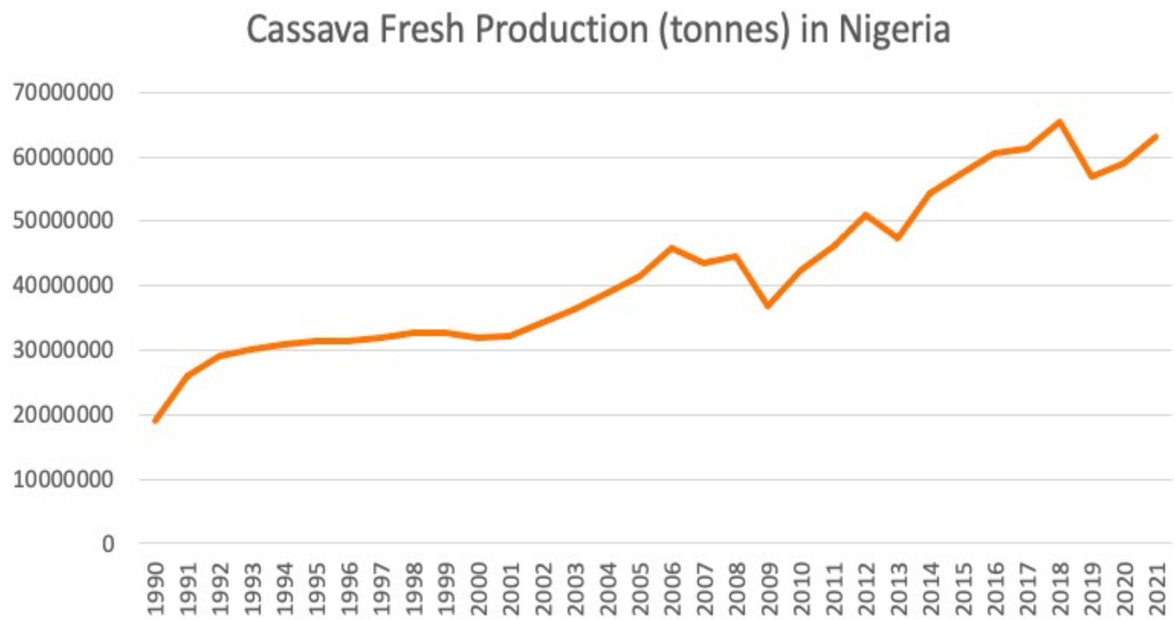
Cassava was introduced in Nigeria's southern part during the period of slave trade proliferated by Portuguese explorers and colonizers in the 16th century. In the late 19th century, its importance was boosted in the country when more slaves returned to their homeland and introduced processing techniques (Eguono, 2015). Nigeria is the largest producer of cassava in the world with more than 90% of the cassava produced in the country that are consumed locally. Estimations show that more than 90% of cassava production in Nigeria is processed into food while the rest is used for industrial production (Otekunrin&Sawicka, 2019). In 1999, the country produced 33 million tonnes and a decade later it went up to around 45 million tonnes representing almost 19% of the production in the world (Eguono, 2015). Also, cassava experienced a consistent growth in Africa with a total production of about 170 million tonnes in 2018. Particularly, Nigeria produced about 60 million tonnes of cassava in the same year (FAOSTAT, 2019). The increasing importance of cassava crops in Nigeria is due to its increasing demand but also its development as a food security crop. With more than 60% of the Nigerian population in agriculture, cassava became a reliable alternative against hunger and sustained the rural economy of the country. Indeed, the local processing of cassava created jobs for many Nigerian rural women (Ikuemonisan et al., 2020). However, it is considered a food for the poor and has been criticized for its propensity to deplete soil nutrients and open the farmland to erosion. Therefore, cassava crops are usually grown on marginal lands where there is no competition since no other crops are cultivated on this land (Ikuemonisan et al., 2020).

Additionally, studies show that 7 in every 10 Nigerians consume at least a cassava product derived from cassava roots once a day. Nevertheless, the trend in yield performance (production per hectare) remains low in the country. This can be explained by ineffective

agronomic practices and inefficient management of production resources (Ikuemonisan et al., 2020). Despite its increasing value at the global market, land tenure systems are discouraging factors for cassava production investments in Nigeria. Ikuemonisan et al. (2020) argued that Nigeria has a land tenure system featuring varieties of traditional rights, duties and restrictions concerning the use and control of lands. Under this system, land is not held by individuals but by the families, village or by the traditional ruler who acts as a trustee for the group under his authority. Having the right to use land is based on a usufruct system, where land belongs to a community member as long as it is being used. However, once it is not used anymore it goes back to the community and can be used by someone else. Therefore, this system does not allow community members to sell the land to foreigners. Nevertheless, individual title to land has become a quest using land speculation in Nigeria (Ikuemonisan et al., 2020). In this context, a group of individuals who have no intention to put a piece of land into any productive use, acquire it by outright purchase. They hold on to it for a long time so that its commercial value increases. This strategy is growing in the peri-urban and rural communities of the country, denying farmers from cultivating the lands.
Overall, the lack of or inadequate land policies contributed to the rise of land speculation in Nigeria. In turn, land became a major constraint to agricultural development and discouraged investments in cassava production in the country (Ikuemonisan et al., 2020). Therefore, land policies consisting of governmental actions should be put in place to design and modify the existing land tenure institution for greater equity and justice. Moreover, cassava production in Nigeria does not allow for large farm holdings suitable for mechanization since the plant is cultivated on small farm areas not conducive for mechanization. However, without the introduction of mechanization the cassava production is not sufficiently boosted in the country (Ikuemonisan et al., 2020).

Figure 6 shows that the production in Tonnes of Cassava Fresh in Nigeria slowly increased from 1990 to 2008. In 1995, Nigeria was prevalently infested with cassava diseases such as the cassava bacterial blight or the cassava green mite. Nevertheless, it is noticeable that the cassava production remained constant despite the diseases' surge thanks to the expanded area of cultivation of the crop. Moreover, the National Co-Ordinated Research Programme was approved in 1996 and this helped the elimination of the diseases and thus the conservation of cassava production in the country (Ikuemonisan et al. 2020). In 2008, the cassava production went up to almost 45 million tonnes. However, it started dropping after 2008 due to the global economic shock which affected food prices and production (Ikuemonisan et al. 2020). By 2010, the cassava production slowly increased again.

Figure 6. Production of Cassava Fresh (in tonnes) in Nigeria between 1990 and 2021.



Source: Own creation, data from FAOSTAT (2023).

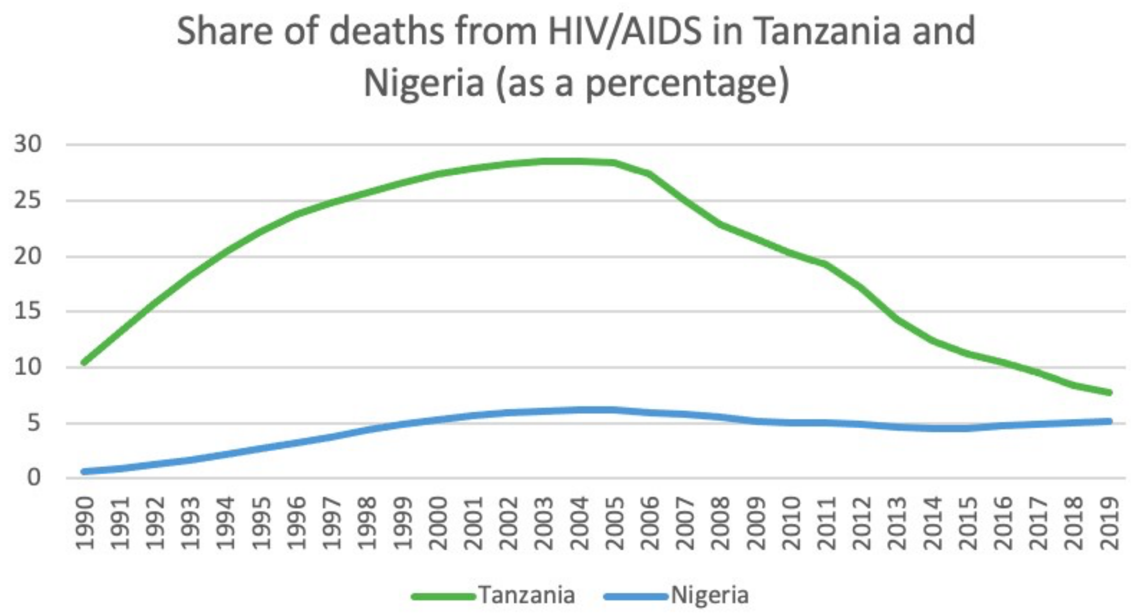
6. HIV/AIDS and cassava production in Tanzania and Nigeria

Figure 7 depicts the HIV/AIDS trends in Tanzania and Nigeria between 1990-2019, as a share of deaths from HIV/AIDS in percentage. Between 1990 and 2005, both countries experienced a dramatic increase in their share of HIV/AIDS deaths. However, this increase was more important in Tanzania. In 1990, the country's share of death due to HIV/AIDS was 10% and went up to more than 25% in 2005. In contrast, Nigeria saw an increase from 0% to around 5% during the same years. Moreover, the Tanzanian HIV/AIDS share of deaths started declining from 2005 onwards and reached less than 10% by 2019. For Nigeria, it remained more or less constant with around 5% of HIV/AIDS death share until 2019.

When comparing those results with the previous Figure 5 and 6 on cassava production in Tanzania and Nigeria respectively, the two countries do not show the same relationship on HIV/AIDS and cassava production. In Tanzania, there seems to be a negative relationship between HIV/AIDS and cassava production after the 1990s while this relationship looks positive for Nigeria. According to Lazaro et al. (2017), the negative relationship for Tanzania can be explained by several constraints on cassava production not related to the spread of HIV/AIDS. First, the prevalence of devastating pests or diseases decreased cassava plantation in the country. The Cassava Green Mite (COM), an arthropod pest of the cassava plant, contributed to killing cassava leaf cells and reduced the photosynthesis process. Thus, this triggered a decline in cassava production. Second, the production of the crop was influenced by a shortage of planting materials. Third, there was a low level of utilization of cassava and poor harvest handing techniques at the farm level. Fourth, cassava is less competitive than other crops due to its limited number of convenient products especially in urban areas. Fifth, compared to other countries in Africa, there is poor infrastructures and processing machines. In contrast, Githinji (2008) defended that HIV/AIDS' onset coincided with an already declining agricultural system in Tanzania and that its impact further accelerated this decline. When households become affected by the disease, their overall agricultural labor input decrease exponentially. Indeed, if one household member becomes too sick to farm his labor and the labor of the person taking care of the ill member will be lost.

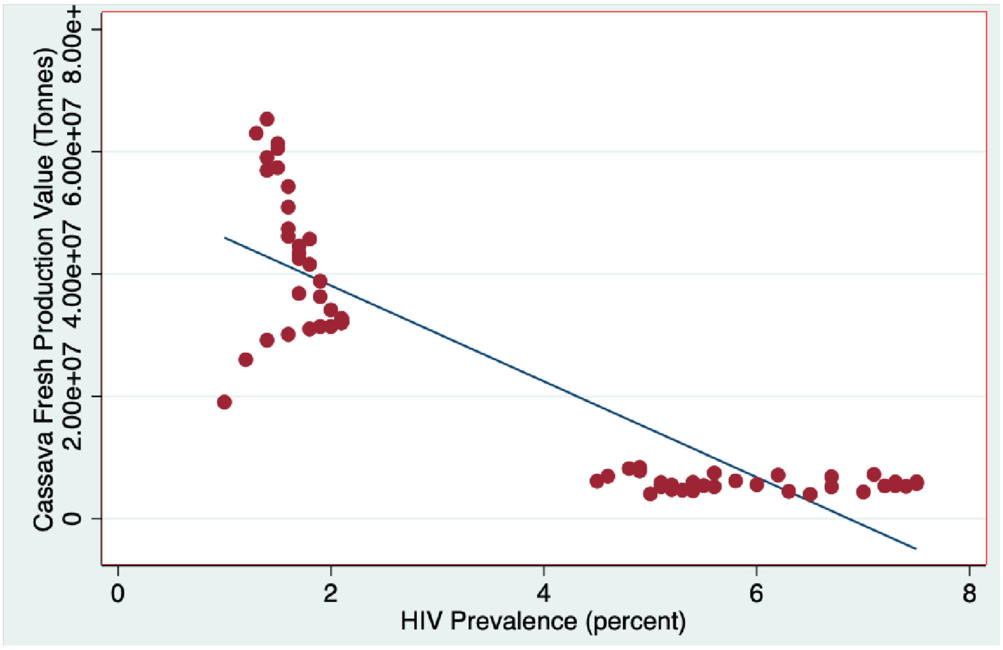
Furthermore, Figure 8 illustrates a negative and linear correlation between HIV prevalence as a percentage and Cassava Fresh production in Tonnes. Nevertheless, this correlation is not easily determined by this simple relationship and might be a pure coincidence since the decline is not per se related to HIV/AIDS as seen with Lazaro et al. (2017) findings. Therefore, an econometric analysis is necessary to explore the link between HIV/AIDS and cassava production in both countries more accurately. This thesis provides an in-depth analysis of this relationship using an empirical approach. The outcomes of this analysis are expected to be different for both countries.

Figure 7. Share of deaths from HIV/AIDS (as a percentage) in Tanzania and Nigeria between 1990 and 2019.



Source: Own creation, data from Our World in Data (2023).

Figure 8. Scatter plot of Cassava Fresh production (in Tonnes) by HIV prevalence (in percentage) including both Tanzania and Nigeria, showing a negative and linear correlation



7. Gender roles in cassava production in Africa

According to Tibaijuka (1994), men work less than women in the farming sector in SubSaharan Africa. Thus, changes should be fostered for men to work at least as much as women in the aforementioned sector. This requires the implementation of policies and education campaigns to improve returns from women's crops. Liberalizing gender roles would lead to more employment opportunities for men on the farm and increase the agricultural output. A study by Andersson et al. (2016) analyzed the structure and gender dynamics of the cassava leaves value chain in a district of Tanzania. Using semi-structured interviews, they found that two-thirds of the sampled farmers market cassava leaves. The value chain is dominated by women but the participation in different nodes and the benefit distribution is not equal between genders. Moreover, the authors argue that cassava commercialization involves the participation of more men and does not stay only a women's crop.

Masamha et al., (2019) findings suggest that men and women carry out different kinds of farm work with different levels of access to resources. Usually, women have less access to resources than men and lower incomes. Numbers show that over 45% of the farms were male-owned farms while only 24.8% were female-owned in 2017. Also, only 3.6% of women were able to cultivate cassava with 2.25 acres compared to 18.2% for men in the same year. According to

Kapinga et al. (2015), land preparation for cassava is done by both women and men using hand hoes except for ox-ploughing. They found that about 75 percent of arable cassava fields are owned by men, 15 percent by women and only 10 percent by families. However, the authors defended that planting and harvesting are mostly carried out by women whereas weeding is done by both genders but there is more labor input from female workers. Women provide more of the labor for the cassava staple crops and their major responsibilities are food processing, preservation and storage. In contrast, men take care of the decisions regarding the sale of cassava products, while women are in charge of small cassava sales and use the money obtained for necessities such as soap, matches or salt. Similarly, Shayo&Martin (2019) show that cassava processing is mostly done by women. Usually, men are responsible for land clearing while activities such as weeding and planting are carried out by women. Furthermore, David (2015) argued that cassava crops in Nigeria are mainly produced and controlled by women. They usually do the planting, weeding and harvesting of the cassava plant. Cassava's low labor requirement makes it an important source of income for women mainly since they make up to 50% of the labor force in Sub-Saharan Africa. Likewise, Masamha et al., (2019) found that cassava production and processing are dominated by women in Tanzania, while men take care of the marketing, income and control the resources. About 80% of land preparation for cultivating cassava is done by men within a household and they are involved in the transportation of cassava to different markets. Women are active in preparing cassava cuttings, (80%), planting (75%) and weeding (90%). Therefore, women perform the major roles in cassava cultivation but men are responsible for cassava cultivation decisions at the household level.

Overall, the cassava value chain in Sub-Saharan Africa includes more men than women wholesalers. However, the cassava production in the region is still dominated by women as argued above. Women dominate the farm which is the least profitable nodes of the cassava value chain (David, 2015). Nevertheless, women's labor input and post-harvest handling is of a big importance, which adds to the other responsibilities they have to fulfil in the domestic chores. Therefore, appropriate technologies should be put in place to reduce women's workload in Africa (Kapinga et al., 2015).

8. Methodology and Model

To examine the hypotheses, a longitudinal panel data analysis with a multiple regression model is used. Using a longitudinal panel data offers several advantages (Allison, 2009). First, it allows for an examination of changes, trends and patterns of different variables over time. Second, it assesses cause-and-effect relationships and controls for time-varying factors. Third, this method shows within-individual variations and their impacts on outcomes. Fourth, it accounts for unobserved heterogeneity and causality that may influence the relationship between variables. Therefore, the model in this paper controls for fixed effects and numerous covariates to deal with those issues. More precisely, it considers country and time-specific fixed effects. Fixed effects control for unobserved heterogeneity and remove omitted variable bias related to non-observable but country-specific properties by measuring changes across time with the introduction of dummy variables. Although, this might be at the expense of more noise and over-dampening in the model. Fifth, longitudinal panel data have greater statistical power compared to other kind of studies such as cross-sectional. Hence, it detects smaller effects and increases the precision of the estimates (Allison, 2009). The data are retrieved from The World Development Indicators (2023) and The Food and Agriculture Organization of the United Nations FAOSTAT (2023). The sample consists of two countries: Tanzania and Nigeria. Data covers the period 1990-2021 in both countries. Having a small sample size offers several advantages. Firstly, a small sample size facilitates in-depth exploration and understanding of the conducted study (Palinkas et al., 2015). Secondly, employing a small sample size behaves as a pilot study. Such studies assess the feasibility, design and methodology of a larger-scale research. It is usually used to identify relationships between variables or test data before conducting a larger study (Leon et al., 2011). Thirdly, when analyzing niche populations such as people infected with HIV/AIDS the use of a small sample size is quite inevitable. It gives insights on the specific population without having it generalized to larger populations. Lastly, a small sample size with two countries like in this paper allows for a comparative analysis. It can help pointing out unique factors and differences in outcomes without the complexity of having too many variables (Allison, 2009).

The following illustrates the main multiple regression model in this analysis:

$$lnCassavaProduction_{it} = \beta 1 HIVPrevalence_{it} + \beta 2 lnHIVIncidence_{it} + \beta 3 (lnHIVIncidence)^{2} + X_{it}\beta + d_{i} + t_{t} \in_{it}$$

Where:

d_{i}=country fixed effect t_{t}=time

fixed effect

$X_{it}\beta$ =other control variables

$\in_{it}$=error term

9. The variables

9.1. The dependent variable

The main dependent variable used to represent the agricultural production of cassava in both Tanzania and Nigeria is Cassava Fresh production in Tonnes between 1990-2021, from the Food and Agriculture Organization of The United Nations Database (FAOSTAT, 2023). Since the variable of cassava production is skewed to the right, it is transformed to its log form to be able to have a normal distribution and thus better results.

9.2. The independent variables

The first independent variable used for HIV/AIDS is the prevalence of HIV as a percentage of the total population infected by HIV between 15 and 49 years old in Tanzania and Nigeria for the period 1990-2021, retrieved from The World Bank Indicators (2023). It represents the prevalence rates of HIV infection in the Tanzanian and Nigerian populations. Most infections occur in young adults with especially young women being the most vulnerable (The World Bank Indicators, 2023). Data are collected from the Joint United Nations Programme on HIV/AIDS (UNAIDS). It considers the reduced infectivity among people receiving antiretroviral therapy, which has a large impact on HIV prevalence. Also, it allows for urbanization changes over time in generalized epidemics and includes plausibility bounds that reflect the certainty associated with the estimates (The World Bank Indicators, 2023). This variable has a normal distribution and thus will be used as it is.

The second independent variable in the model is the incidence of HIV in Tanzania and Nigeria per 1000 uninfected population, retrieved from The World Bank Indicators (2023). It represents the number of new HIV infections among uninfected populations expressed per 1000 uninfected population in the year before the period. This variable provides the incidence rate as a measure of progress toward preventing HIV transmission. Identifying newly infected persons helps for interventions to reduce the risk of disease transmission. Data are taken from surveys of the general population, antenatal clinic attendees and populations at increased risk of contracting HIV such as sex workers, men to men sex or drug users. This variable is relevant to include because it considers the number of people receiving antiretroviral therapy. This is important since this increases the prevalence of the disease because people living with HIV survive longer (The World Bank Indicators, 2023). Furthermore, using incidence data would be of more value for tracking the progress of the epidemic compared to the prevalence data. Prevalence data are of relatively limited value in evaluating changes during the epidemic since prevalence reflects infections acquired over many years. The log form for HIV incidence is used for more accurate results since its distribution is skewed to the right.

9.3. Marginal effect

A marginal effect model is included as an interaction to investigate how the dependent variable cassava production changes when a specific independent variable changes, assuming that the other covariates remain constant.

The model with interaction is as follows:

$$y = b1 * x + b2 * z + b3 * (xz)$$

The marginal effect x, at different level of z is evaluated:

$$d(y)/d(x) = b1 + b3 * z$$

A check is performed on whether the marginal effect of Cereal yield (x) is dependent on the level of HIV Prevalence (z). Appendix F illustrates that more HIV prevalence leads to less cassava production. However, there is a moderation effect since the effect of Cereal yield is different between countries as it will be seen in the results part.

9.4. Control variables

Self-evidently, many factors next to HIV/AIDS influence agricultural production in SubSaharan Africa. Several of those factors that are standard in the literature studying agricultural production in Africa were included as covariates for the years 1990 to 2021, to control for their impact.

First, the variable urban population as a percentage of the total population is retrieved from The World Bank Indicators (2023). It is defined by the national statistical offices and data is collected by the United Nations Population Division. This variable is included since numerous studies find a relationship between agricultural production and urbanization. Globally, the growth of cities illustrates a demographic transition from rural to urban areas and this is associated with a shift from an agricultural economy to mass industry, technology and service. Urbanization displaces agricultural production through the expansion of urban areas onto agricultural land, so that less land is available for farming (Stage et al., 2010). There is a shift in employment within the food system with fewer people working in agriculture and more working in transport or retailing. This change triggers a decrease in labor in farms and thus leads to less agricultural production (Satterthwaite et al., 2010). In contrast, Li&Li (2019) argued that the proportion of agricultural output value increases because of the process of rapid urbanization. High technical and capital investment improved agricultural production efficiency and increased farmer's incomes. Ikuemonisan et al., (2020) found that in Nigeria, this rapid rate of urbanization reduces the agricultural land availability at a time when demand for cassava products is increasing Nigeria's rate of performance for yield and production became very low with 10.6% in 2019, while other countries such as Ghana and Benin reached 14.8% and 12.9% respectively. This relatively poor performance shows that Nigeria is still struggling to increase its share in the world's cassava market. As agricultural land and farm labor decrease as a result of industrial expansion, the growing input could be further jeopardized. In comparison, Mlingi&Ndunguru (2007) found that urbanization in cassavaproducing countries such as Tanzania offers the opportunity to produce cassava for a larger consuming population. In West and East Africa, the increasing urbanization and improved production triggered cassava in becoming a cash crop that is now used industrially for the production of other products such as cassava flake or flour (Yeboah et al., 2016). Furthermore, urbanization is associated with the "nutrition transition", giving rise to a shift in diets or the prevalence of malnutrition in Africa (Cockx et al., 2019). People moving out of agriculture and relocating to urban areas experience a decrease in their basic food consumption, especially with cassava that is a home-produced food staple. Cockx et al. (2019) also defended that in Tanzania when people migrate from rural to urban areas, their consumption patterns change considerably. They experience a decrease in their consumption of basic staple foods such as cassava. In the country, the authors found that rural-urban migration decreased the cassava kilocalories intake of the population by 6.8 percentage points. This is because such food is typically home-produced in rural areas and thus their consumption decreases when people move out of agriculture. Another reason for this is that those products become more expensive in urban areas.

Second, the temperature change on land measured by meteorological year with Celcius degrees is used as another control variable for cassava production and is retrieved from the FAOSTAT (2023). It represents statistics of mean surface temperature change for the annual mean temperature anomalies, including annual updates. Data are based on the GISTEMP data, the Global Surface Temperature Change data by the National Aeronautics and Space Administration Goddard Institute for Space Studies (FAOSTAT, 2023). This variable was chosen because it might influence the production of cassava in Africa. The literature on the relationship between cassava production and climate change is mixed. Mupakati&Tanyanyiwa (2017) found that when it comes to climate change, cassava is the least affected crop compared to other major staples such as maize and is not affected by changes in weather patterns. The authors defend that cassava benefits from climate change and that its production will increase by 1.1% by 2030. Moreover, Amelework et al. (2021) argue that cassava can grow in a wider range of climatic conditions than other tropical staple crops. It provides reasonable yield in areas where environmental conditions are declining and makes it a perfect food security crop. Cassava is highly adaptable to changes in climate and is the least sensitive crop to climate conditions since it is drought resistant and is not easily destroyed by heavy rains (UNDP, 2017). On the contrary, Souza et al. (2023) argue that climate change strongly influences agricultural production in Africa, especially for cassava. They explain that agriculture is the most climatedependent of all human activities and that cassava yield decreases by about 5% when there is an increase in air temperature and a decrease in rainfall. Since casava normally grows in rainfed systems, temperature changes and precipitation are the most limiting factors of its production. Pipitpukdee et al. (2020) found an inverted U-shape relationship between cassava yield and temperature. They revealed that climate variability and extreme events statistically influenced cassava yields. Harvested area and yields of cassava reduce by 16.05% and 6.22% in 2020 and cassava production declines by around 21% from the baseline in the same year.

Third, the variable cereal yield kilograms per hectare of harvested land is used from The World Bank Indicators (2023). It includes wheat, rice, maize, barley, oats, rye, millet, sorghum, buckwheat and other mixed grains. The production data on cereals relate to crops harvested for dry grain only and cereal crops harvested for hay or grazing are excluded. The production data is allocated to the calendar year in which the bulk of the harvest took place. Data are collected through annual questionnaires from official national sources by the FAO and are supplemented with information from official secondary data sources. Those sources cover official country data from national ministries, national publications and international organizations. As mentioned earlier, Gillespie (2006) argued that the profitability of cereal crops such as maize declined due to policy changes, and this led to a huge increase in cassava production. He found that areas where cassava production increased appear to be those where the profitability of maize production declined, rather than areas having high HIV prevalence. Moreover, Jayne et al. (2005) found an increase in cassava production in recent years in Zambia, while maize production declined in the country. They explained this with policy changes on maize production, which decreased its financial profitability and thus production. Therefore, the inclusion of this variable as a control is relevant for this study since it might affect cassava production in Africa.

Fourth, the analysis includes the variable Population ages 65 and above as a percentage of the total population in Tanzania and Nigeria. Data is retrieved from The World Bank Indicators (2023) and includes Zanzibar. Age structure in the estimates is based on the age structure in the United Nations Population Division’s World Population Prospects and the values are midyear estimates. The definition of population is based on the de facto definition, counting all residents regardless of legal status or citizenship. Overall, high fertility rates and the decline of mortality rates affect the larger share of the 65 and older population. One limitation is that the five-year age group is the cohort unit and five-year period data are used in The United Nations Population Divison’s World Population Prospects. Thus, obtaining annual data or single age structure may not reflect age composition. The inclusion of this variable is relevant to this study since age is found to influence cassava production in Africa. Tafesse et al. (2021) found that age significantly and positively determines the allocative inefficiency of smallholder farmers in cassava production. Their results show that an increase in age by 1 year increases the allocative inefficiency of the production. Thus, older farmers are less efficient than younger ones. This can be because older farmers have fewer management skills to be able to effectively minimize costs in farming for instance. Similarly, Adeyemo et al. (2010) found that age is significantly and positively related to technical inefficiency in cassava production in Nigeria. Older farmers do not easily adopt improved technologies that can boost their efficiency. Moreover, Ogundari&Ojo (2007) also argued that the age of cassava farmers is significantly and positively related to cassava production inefficiency in Nigeria. The authors found that as cassava farmers become older, cassava output decreases. The baseline used in their paper is in conformity with the mean age of about 60 years recorded in the area of the country. This implies that older farmers were with no vigor to accomplish the task associated with cassava production.

Fifth, the variable School enrollment of primary education is included as a percentage of the gross enrollment ratio. Data are from The World Bank Indicators (2023) and based on the UNESCO Institute for Statistics with annual education survey. It is calculated by dividing the number of students enrolled in primary education regardless of age by the population of the age group corresponding to primary education and multiplying by 100. However, a high ratio may reflect several overage children enrolled in each grade because of repetition or late entry rather than a successful education system. Primary education provides the basics for reading, writing, mathematics skills, history, geography, natural science, social science, art and music. Nevertheless, enrollment indicators do not necessarily reflect actual attendance or dropout rates during the year. Age at enrollment may not be estimated accurately in communities where registration of births is not strictly enforced. Numerous studies found a relationship between education and cassava production in Africa. Tafesse et al. (2021) argued that there is a significant and positive link between education and economic inefficiency in cassava production in Ethiopia. Their results show that an increase by 1 year of education increases technical and economic inefficiency for cassava. This indicates that less-educated farmers are more technically and economically efficient than more-educated farmers. This can be explained by the increased probability that more educated farmers participate in other livelihood options. Thus, the time and knowledge put into cassava farming decline. Similarly, Wollie et al. (2018) and Ettah and Kuye (2017) concluded that cassava farmer's level of education positively contributes to cassava production inefficiency in Ethiopia and Nigeria. Nevertheless, Adeyemo et al. (2010) and Isitor et al. (2017) argued the opposite and showed that education negatively determines cassava production inefficiency in Nigeria. This means that the level of education enhances technical efficiency in the country. Their results show that cassava production becomes profitable and farmers are able to operate with maximum efficiency given the implementation of new cassava production technology.

10. Descriptive statistics and correlations

In advance to performing the regression analysis, it is useful to examine the correlations between the variables. Appendix A displays the descriptive statistics for each of the variables and Table 1 illustrates the Pearson Correlations between them. Importantly, multicollinearity is quite avoided in general, meaning that no independent variables are correlated with one another above the 0.8 level, the most common threshold (Vatcheva et al., 2016). However, there are few variables that are correlated slightly beyond this threshold: HIVPrevalence and lnHIVIncidence, Urban Pop and PopAge, UrbanPop and lnCassavaProduction and finally PopAge and lnCassavaProduction. Variables that are too multicollinear are effectively counted twice, making at least one of the multicollinear variables redundant. To see the magnitude of this problem, the Variance Inflation Factor (VIF) is used. It measures the degree of multicollinearity between the variables, which artificially inflates the R2 of the model. When the indicator is higher than 10, the reliability of the model would be affected by the relationship between the explanatory variables (O'Brien, 2007). The results of the indicator show that the variables Temperature, CerealYield, and SchoolEnrollment have a VIF value below 10 (Appendix B). Therefore, those variables do not have a severe enough correlation that requires attention. However, the other variables have values that exceed 10. Hence, their coefficient estimates and p-values in the regression outputs are likely to be unreliable. This is one limitation for this study that will be discussed later in this paper. In the case of the variable lnHIVIncidence, there is no cause of concern since it is in a special logarithm form. According to O'Brien (2007), the best thing to do in this case is to ignore multicollinearity since it can be due to a lot of different things next to the VIF such as a small sample size, which is the case in this study. He argues that strong conclusions can still be drawn from regression analyses and therefore this paper will proceed as such.

Table 1. Matrix of correlations between study variables.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) HIVPrevalence	1.000							
(2) UrbanPop	-0.819	1.000						
(3) TemperatureChange	-0.314	0.619	1.000					
(4) CerealYield	0.088	0.277	0.322	1.000				
(5) PopAge	-0.915	**0.873**	0.307	-0.001	1.000			

(6) SchoolEnrollment	-0.286	0.265	0.390	-0.094	0.106	1.000		
(7) -0.931	**0.826**	0.236	-0.046	**0.983**	0.093	1.000	lnCassavaProduction	
(8) lnHIVIncidence	**0.851**	-0.984	-0.628	-0.246	-0.849	-0.357	-0.808	1.000

The correlations provided in Table 1 suggest that in line with H1, there is a negative correlation between HIV prevalence as a percentage and cassava production in Tonnes (*r*=-0.872). This relationship is significant since the correlation coefficient (r) is different from zero. This means that higher levels of HIV prevalence as a percentage are associated with a significantly lower level of cassava production in Tonnes. Moreover, a negative correlation between HIVIncidence and cassava production can also be seen (*r*=-0.689), which aligns with H2. Nevertheless, those correlation results are not enough to draw conclusions and thus the use of an econometric analysis is necessary.

11. Analysis and results

To explore the link between HIV/AIDS and cassava production in both Tanzania and Nigeria, several pooled OLS (POLS) regressions were performed with different combinations of control variables. The results are depicted in Table 2 below. Overall, the R-squared in all of the models is quite high (>0.80), which is preferred. This reflects the strength of the relationship between the model and the dependent variable. For instance, Model 1 explains 86.7% of the variation in the dependent variable.

Model 1 includes the basic variables with the main dependent and independent variables. It shows that there is a significantly negative effect of HIV prevalence as a percentage of the total population infected by HIV between 15 and 49 years old on cassava fresh production in Tonnes (r=-0.398), at the 1% level. Specifically, one unit increase in HIV prevalence leads to 39.8% decrease in cassava production in Tanzania and Nigeria. Therefore, when both countries have more HIV prevalence their cassava production decreases. Hence, H1 is confirmed. This aligns with the findings of Githinji (2008) and Yamano&Jayne (2004) who defend that HIV/AIDS further accelerated a decline in agricultural production. Moreover, lnHIVIncidence has a negative effect on cassava production, even though insignificant. This means that higher HIV incidence suggests a higher likelihood of new HIV infections within the uninfected population, indicating greater vulnerability to HIV transmissions. The negativity of the coefficient's sign aligns with the literature saying that without strong interventions to prevent HIV infections, HIV incidence does not decrease (UNAIDS, 2022). Thus, uninfected people are getting infected by the disease and this triggers a decrease in cassava production.

Model 2 illustrates the situation when one other important variable representing urbanization is included. Results show that there is a positive and significant effect of the Urban population as a percentage of the total population on Cassava Fresh production in Tonnes (r=0.160), at the 1% level. Hence, if the urban population increases by one unit, then the cassava production will increase by 16%. This aligns with the literature of Li&Li (2019), arguing that rapid urbanization increases the value of agricultural output thanks to improved agricultural production efficiency. Moreover, Mlingi&Ndunguru (2007) suggested that urbanization in cassava-producing countries increases population's consumption and in turn, cassava production experiences an increase. Similarly, Yeboah et al., (2016) defended that increasing urbanization leads to cassava becoming a cash crop in West and East Africa which will boost its production. Furthermore, Drechsel&Dongus (2010) show that with urbanization expansion half of Africa's population will be urban by 2030. Thus, as a response to food demand there is a slow increase in urban farming. In West Africa, urban farming is a practiced phenomenon involving more than 20 million people. Therefore, this helps to increase agricultural production such as cassava in the presence of urbanization.

Furthermore, the coefficient of lnHIVincidence becomes significant and positive when controlling for urbanization. This means that higher HIV incidence leads to an increase in cassava production. This contradicts the literature suggesting that an increase in HIV incidence should decrease cassava production (UNAIDS, 2022). The expansion of HIV prevention and treatment is crucial to the reduction of HIV transmissions. Thus, identifying newly infected people among the uninfected population helps reducing the risk of disease transmission and hence HIV incidence. Therefore, a decline in HIV incidence reflects successful efforts in preventing new infections among the uninfected population and is seen as progress towards controlling the HIV/AIDS epidemic. Our result goes against this logic.

Model 3 exhibits the results when adding the School Enrollment variable next to the main independent variables HIVPrevalence and lnHIVIncidence. There is a significantly negative effect of School enrollment of primary education as a percentage of the gross enrollment ratio on Cassava Fresh production in Tonnes (r=-0.0179), at the 1% level. Thus, a one unit increase in School enrollment leads to a 1.79% decrease in cassava fresh production in Tonnes. This confirms the literature by Tafesse et al., (2021) explaining that when people get more education, their participation in other livelihood options increased and the time and knowledge put into cassava farming declines. In turn, this decreases cassava production. Moreover, this result is also validated by Wollie et al. (2018) and Ettah&Kuye (2017) who concluded that cassava farmer's level of education positively impacts cassava production inefficiency, leading to a decline in cassava production. Lastly, the coefficient of HIV incidence becomes significantly negative when controlling for school enrollment. This confirms the literature mentioned in the above model 2 and H2 can be accepted.

Model 4 includes two new variables on the Temperature change on land and the Cereal yield. There is a significant and negative impact of the temperature change on land in Celcius degrees on Cassava Fresh production in Tonnes (r=-0.475), at the 5% level. This means that if temperature change increases by one unit, the cassava fresh production decreases by 47.5%. Some literature supports this result by saying that cassava yield decreases when there is an increase in air temperature (Souza et al., 2023). Climate change strongly influences agricultural production since agriculture is the most climate-dependent of all human activities. Therefore, temperature changes and precipitation are the most limiting factors of cassava production. Similarly, Pipitpukdee et al. (2020) found that climate variability such as temperature has a statistically negative impact on cassava yields and thus on its production. Moreover, there is a positive but non-significant effect of Cereal yields kilograms per hectare of harvested land on Cassava Fresh production in Tonnes. The positivity of the sign contradicts the literature mentioned earlier saying that cassava production increased because of a decline in cereal crop production due to policy changes (Jayne et al., 2005). Lastly, it is noticeable that the coefficient HIVPrevalence decreases a bit and is still significant.

Model 5 includes the full set of control variables and adds the Population age. The most important variable HIVPrevalence stays significant and negative. Results show that the Population ages 65 and above as a percentage of the total population has a significant and positive impact on Cassava Fresh production in Tonnes (r=3.42), at the 1% level. This means that a one unit increase in the Population ages 65 and above as a percentage of the total population leads to a 0.0000342% increase in Cassava Fresh production in Tonnes. Despite this coefficient being very small, it does contradict the most common literature. Tafesse et al. (2021) argue that the age of the cassava farmers is positively related to cassava production inefficiency. They explain that older farmers are less efficient than younger ones and this triggers a decline in cassava output. This inefficiency might come from older farmers having fewer management skills to be able to effectively minimize costs in cassava farming. Adeyemo et al. (2010) also validated this argument. The authors explain that older farmers do not easily adopt improved technologies that can boost their efficiency on cassava production. Furthermore, Ogundari&Ojo (2007) argument that as cassava farmers become older, cassava output decreases. They suggest that this is due to older farmers having no vigor anymore to accomplish the task associated with cassava production. Lastly, it can be noticed that the HIV prevalence coefficient decreases even more in the presence of all the control variables, even though still significantly negative.

Table 2. POLS regressions on the relationship between HIV/AIDS and Cassava production.

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5
HIVPrevalence	-0.398***	-0.443***	-0.392***	-0.337***	-0.146***
	(0.0401)	(0.0284)	(0.0344)	(0.0557)	(0.0331)
lnHIVIncidence	-0.0757	1.913***	-0.184*	-0.365*	0.331
	(0.113)	(0.256)	(0.0996)	(0.188)	(0.216)
UrbanPop		0.160***			0.0143
		(0.0196)			(0.0184)
SchoolEnrollment			-0.0179***		-0.00104
			(0.00372)		(0.00221)
TemperatureChange				-0.475**	-0.0867
				(0.184)	(0.0819)
CerealYield				2.89e-05	8.15e-05
				(0.000238)	(0.000105)
PopAge					3.42e-07***
					(3.52e-08)
Constant	18.09***	11.82***	19.72***	18.35***	15.70***
	(0.114)	(0.770)	(0.351)	(0.333)	(0.701)
Observations	64	64	64	64	64
R-squared	0.867	0.937	0.904	0.881	0.981

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

To choose between using the Random (RE) or Fixed effects (FE) model, a Hausman test was carried out. This test is able to detect endogenous regressors in a regression model. The null hypothesis (H0) is assumed to be: RE model is appropriate. The results of the test show that Hausman rejects the null hypothesis since the p-value is statistically significant (pvalue=0.0182). Therefore, a FE model is preferred to a RE model since the latter is biased.

Table 3. Econometric models comparison between POLS and FE on the effect of HIV/AIDS and cassava production.

VARIABLES	(1) POLS	(2) FE
HIVPrevalence	-0.146***	-0.0936**
	(0.0331)	(0.0413)
lnHIVIncidence	0.331	0.601**
	(0.216)	(0.249)
UrbanPop	0.0143	0.0514**
	(0.0184)	(0.0255)
SchoolEnrollment	-0.00104	-0.000681
	(0.00221)	(0.00216)
TemperatureChange	-0.0867	-0.0807
	(0.0819)	(0.0798)
CerealYield	8.15e-05	8.91e-05
	(0.000105)	(0.000102)
PopAge	3.42e-07***	1.91e-07**
	(3.52e-08)	(8.20e-08)
Constant	15.70***	14.41***
	(0.701)	(0.931)
Observations	64	64
R-squared	0.981	2

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

When comparing the POLS with the FE model, a substantial difference can be seen (Table 3). The coefficient of HIVPrevalence becomes smaller in the FE model (*r*=-0.0936) compared to the POLS model (*r*=-0.146), while still negatively significant. This still confirms H1. Hence, the result of the POLS is largely coming from the cross-country differences in HIV/AIDS. However, FE shows that within the country the increase of HIVprevalence leads to a decrease in cassava production although the magnitude is not as large as the POLS result suggests. The FE method is applicable to a small number of countries and avoids the country-level omitted variable bias by controlling for country-level heterogeneity (Moring, 2012). Moreover, the coefficient of lnHIVIncidence is bigger and significant in the FE model (*r*=0.601) compared to being non-significant in the POLS model (*r*=0.331). Therefore, HIV incidence increases cassava production within the country, and this contradicts H2. The other variables behave largely the same in both models.

As seen with the regression analyses, HIV/AIDS' impact on cassava production seems to be different within and across countries. Thus, running another FE regression for Tanzania and

Nigeria separately is interesting to see their differences. Results can be found in the following Table 4.

Table 4. Fixed effect models comparison within each country: Tanzania and Nigeria

	(1)	(2)
VARIABLES	Tanzania	Nigeria
HIVPrevalence	0.148	0.0499
	(0.113)	(0.0693)
lnHIVIncidence	-0.622	0.532**
	(0.523)	(0.223)
UrbanPop	-0.133*	0.145*
	(0.0686)	(0.0728)
SchoolEnrollment	0.0144*	0.00252
	(0.00718)	(0.00246)
TemperatureChange	-0.0732	-0.0415
	(0.152)	(0.0595)
CerealYield	0.000145	0.000153
	(0.000134)	(0.000183)
PopAge	3.513***	-5.12e-07
	(1.204)	(4.75e-07)
Constant	7.240*	13.52***
	(3.688)	(0.825)
Observations	32	32
R-squared	0.468	0.949

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Results show several differences between the two countries (Table 4). Although HIVPrevalence does not significantly impact cassava production within each country, the coefficient is bigger for Tanzania. One potential explanation might be that the number of people on HIV treatment increased more in Western Africa such as in Nigeria, compared to Eastern Africa (UNAIDS, 2022). Thus, higher HIV prevalence is seen in Tanzania compared to Nigeria which in turn affects the country's cassava production as suggested earlier by the literature. Besides, the coefficient of HIVIncidence is significant and positive for Nigeria but it is non-significant and negative for Tanzania. The former observation is not supported by the literature saying that higher HIV incidence would lead to less cassava production. Indeed, HIV incidence rates remain unacceptably high in Nigeria (Kharsany&Karim, 2016). Daniel (2018) found that people's perception of fear of stigmatization on HIV infections in Nigeria prevents them from testing themselves to the HIV/AIDS disease. This enhances the spread of the virus among uninfected people and increases HIV-related deaths. Thus, less labor is available for farming and cassava production decreases. Nevertheless, a justification of the result could be that Nigeria experiences a higher number of people under HIV treatment, reducing mortality and prolonging infected people's life in the country (UNAIDS, 2022). Therefore, infected people continue to farm and this increases cassava production in Nigeria. Also, Nigeria has a high level of awareness among farmers on the existence and mode of transmission of the HIV/AIDS disease (Nkeme et al., 2022). Hence, this helps the reduction of HIV infections and supposingly the labor force in cassava production is kept and this enhances its increase in the long run. Even though insignificant, the coefficient sign of HIV incidence for Tanzania is supported by the literature. Despite the efforts in reducing HIV incidence in Tanzania, it still remains quite high in all age groups (Mosha et al., 2022). This indicates that there are still new infections emerging in the country despite the availability of multiple services and treatments against the HIV/AIDS disease. This is explained by the Tanzanian population having a low awareness on HIV/AIDS transmissions, especially along nomadic youths. Those nomadic communities constantly change locations, and it is difficult to ensure their accessibility to HIV services (Ngadaya et al., 2021). Therefore, this pattern does not allow the reduction of HIV/AIDS related mortality and negatively influences the agricultural labor force. Hence, cassava production in the country decreases.

Moreover, the coefficient of Urban population is significant in both countries at the 10% level. However, it is negative for Tanzania and positive for Nigeria. This implies that urbanization decreases cassava production in Tanzania but increases it in Nigeria. In the case of Tanzania, studies have shown that urbanization decreases the land available for farming due to the expansion of urban areas onto agricultural land (Stage et al. 2010). Therefore, there are fewer people working in agriculture and this leads to less cassava production in Africa (Satterthwaite et al., 2010). Moreover, Cockx et al., (2019) argued that people's consumption of basic staple foods such as cassava decreases when people migrate from rural to urban areas in Tanzania. This is explained by cassava being typically home-produced in rural areas and thus its consumption decreases when people move out of agriculture. In addition, the emergence of urban farming practices in Tanzania should increase cassava production in the country. However, Kiduanga&Shomari (2017) explained that urban farming is practiced poorly in Tanzania, especially in Dar es Salaam. This is because of land administration practices creating impediment to its expansion in the city. No place or zone have been designated yet for the practice of urban farming and there are many restrictions at the local level. Thus, farmers do not know what is allowed or not and problems emerge related to allocating or retaining lands. Similarly, Katera (2021) argued that in Dar Es Salaam the practice of urban farming is largely unregulated and faces institutional problems. Limited attention is given by urban authorities on the supervision of urban farming in the city. Also, national strategies in promoting agriculture have hardly considered urban farming and this turned its practice into a unreliable activity. Therefore, urban farming cannot contribute to the increase of cassava production in Tanzania. In contrast, the results for Nigeria show that with a process of rapid urbanization, cassava production increases. Li&Li (2019) argue that this is due to high capital investment, improving cassava production efficiency and increasing farmer's incomes in the country. Moreover, in East Africa the increasing urbanization and improved production triggered cassava in becoming a cash crop that is now used industrially for the production of other products such as cassava flake or flour (Yeboah et al., 2016). Furthermore, the emergence of urban farming systems in Nigeria influences the increase in cassava production through urbanization. In the country, urban farming takes the form of home gardening and surrounding farming with livestock production such as cassava. It guarantees food supply, employment and income generation. Therefore, even if the population moves into urban areas there is still an increase in cassava production in the country (Adebowale, 2017). Overall, those factors contribute to the rise of cassava production in Nigeria in the presence of urbanization.

Furthermore, School enrollment has a significantly positive impact on cassava production in Tanzania while it is insignificant for Nigeria. The results align with the literature defending that education negatively determines cassava production inefficiency in Africa. This means that higher education leads to less cassava production inefficiency and thus an increase in cassava production on the continent (Adeyemo et al., 2010). Another study by (Bakum, 2014) showed that with the growing importance of cassava as a critical crop for food and cash security, many African schools started implementing special programmes on cassava plantation in recent years. African students started to learn advanced cassava breeding skills at school, and this increased cassava production. More specifically, Tanzanian schools have been implementing agricultural training on cassava plantation. This contributes to children learning more about cassava and being able to use their skills at home, increasing cassava production in the country (IITA, 2022). Overall, education has been found to influence the adoption of agricultural technologies like with cassava. It creates a favourable mental attitude for the acceptance of new practices, especially information and management intensive practices (Mutuku et al., 2013).

Additionally, the coefficient for Temperature change is insignificant for both countries. However, the negative signs of both coefficients confirm the literature by Souza et al. (2023). The authors argued that cassava yield decreases when there is an increase in air temperature. Therefore, temperature change is a limiting factors of cassava production in Africa. In the case of Nigeria, Pipitpukdee et al. (2020) defended that temperature negatively affects cassava yield in the humid forest agro-ecological zone of Nigeria.

Lastly, the Cereal yield coefficient is insignificant in both countries. The positive signs of both coefficients do not confirm the studies by Gillespie (2006) and Jayne et al. (2005) arguing for a negative relationship between cereal yield and cassava production. They explain that when cereal production like maize decreased, there is a rise in cassava production. Additionally, Population age is significantly positive for Tanzania but it is insignificant and negative for Nigeria. For Tanzania, the result does not support the most common literature on the negative relationship between farmer's age and cassava production by Tafesse et al. (2021) and Ogundari&Ojo (2007). However, one explanation of this result is illustrated by Nyanda (2015). The author found that farmers' age has a significantly positive effect on cassava production in Tanzania. The adoption of new technologies became a determinant of cassava production in recent years. Thus, the government started to educate farmers with trainings on how to use cassava production technologies. More specifically, older farmers also got involved in learning the use of those new technologies. In turn, this helps to increase cassava production in the country. In the case of Nigeria, even if there is insignificance the negative relationship between population age and cassava production fits the existing literature. Adeyemo et al. (2010) support that older farmers do not easily adopt improved technologies that can boost their efficiency and thus this decreases cassava production in the country. Similarly, Ogundari&Ojo (2007) found that in Nigeria as cassava farmers become older, cassava output decreases. They explain that older farmers are not able to accomplish the task associated with cassava production anymore. Hence, cassava production starts to decline.

It is interesting to see whether cereal yield after interacting with other variables is influencing cassava production. Thus, analyzing the interaction between cereal yield and HIV prevalence is relevant. An interaction effect means that two or more variables combined have a significantly larger effect on the dependent variable as compared to the sum of the individual variables alone. Hence, this effect is important the understand in regression while trying to study the effect of several variables on a single response variable (Khot, 2020). As the previous literature illustrates, having high levels of HIV prevalence decreases cassava production. Moreover, having a lot of cereal yield also decreases cassava production. This can be explained by the presence of agricultural policies in favor of cereal production. Governments encourage domestic production of cereals such as maize to try to stop the growth of grain exports (Delgado, 1989).

The result depicted in Table 5 below shows a significant and negative interaction between HIV prevalence and cereal yield, aligning with the aforementioned literature. Therefore, Cereal yield alone is not significant (see Table 3 and 4) but its interaction with HIV prevalence proves to be very important for the prediction of cassava production (Table 5).

Table 5. Interaction between HIV prevalence and Cereal yield and its impact on cassava production

VARIABLES	(1) Interaction
HIVPrevalence	0.125
	(0.0955)
CerealYield	0.000973***
	(0.000364)
c.HIVPrevalence#c.CerealYield	**-0.000150**** (5.96e-05)
lnHIVIncidence	0.485**
	(0.242)
UrbanPop	0.0402
	(0.0248)
SchoolEnrollment	-0.000127
	(0.00208)
TemperatureChange	-0.148*
	(0.0807)
PopAge	1.23e-07
	(8.27e-08)
Constant	13.74***
	(0.928)
Observations	64
Number of country1	2
R-squared	0.737

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Static models which were conducted analyze a long-run impact and may provide spurious findings. Thus, as a robustness check a dynamic panel data is conducted to capture the dynamic relationship of the data in the short run. It permits to look at the differences within countries over-time process by which an equilibrium is achieved and controls for endogeneity. The model includes one lagged dependent variable (lnCassavaProduction), which enters as an explanatory variable (Table 6).

Besides, a White test is performed to test the presence of heteroskedasticity. The p-value is significant at the 1% level and thus the hypothesis that errors are heteroskedastic is confirmed (Appendix C). Hence, the use of robust standard errors to account for heteroskedasticity is essential.

Using a one-step difference Generalized Method of Moments (GMM) estimator model with robust VCE is the best type of estimator available, since heteroscedasticity is present in the data.

<u>The model takes the following form:</u>

$y_{it} = \delta y_{i,t-1} + x'_{it}\beta + c_i + u_{it}$

$\boldsymbol{c_i}$= usual individual-specific effects

$\boldsymbol{u_{it}}$=usual disturbance

<u>Assumptions:</u>

c_i and u_{it} are independent of each other

$u'_{it}s$= not correlated among themselves

Evidence from Table 6 below indicates that the coefficient of lagged lnCassavaProduction (L.lnCassavaProduction) is positive and statistically significant at the 10% level. Thus, this confirms the intuition that cassava production follows a dynamic adjustment process. L.lnCassavaProduction seems useful to estimate the current change in cassava production. Indeed, an increase in one percent of L.lnCassavaProduction would increase cassava production by 21.1%. This suggests that current cassava productions depend on the past values of cassava production. Therefore, cassava production in the past positively influenced the current cassava production.

Table 6. Dynamic model capturing the relationship of the data in the short run.

VARIABLES	(1) Dynamic
L.lnCassavaProduction	**0.211***
	(0.127)
HIVPrevalence	0.0927***
	(0.0208)
lnHIVIncidence	0.251***
	(0.0560)
UrbanPop	0.216***
	(0.0726)
SchoolEnrollment	0.00738***
	(0.00246)
TemperatureChange	-0.0224
	(0.0386)
CerealYield	8.39e-05***
	(1.80e-05)
PopAge	-2.21e-07**
	(9.17e-08)
year	-0.108***
	(0.0380)
Constant	222.1***
	(75.84)
Observations	60
Number of country1	2

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Nevertheless, the GMM approach is confronted with two issues. First, there can be autocorrelation because of the inclusion of a lagged dependent variable. Thus, testing whether the instruments are valid in the sense that they are uncorrelated with u is crucial. Second, the GMM estimation does not consider indicators such as R-squared to measure how good the model fits the data. Hence, additional tests need to be done.

Robust tests for serial correlation with the Arelano-Bond test are available (Appendix D). The output does not present strong evidence against the null hypothesis of zero autocorrelation in the first-differenced errors at order 1. This means that errors are not correlated over time as the model predicts. Thus, this does not support the use of a dynamic model to fit the data. Therefore, our analysis using POLS and FE is reliable. Moreover, the test for second-order autocorrelation presents no significant evidence of model misspecification. Therefore, HO cannot be rejected and errors are not correlated.

Furthermore, the Sargan statistic test of overidentifying restrictions is calculated without the robust VCE (Appendix E). The output does not present strong evidence against HO that the overidentifying restrictions are valid. Thus, not rejecting HO implies that it is not necessary to reconsider the model or the instruments.

12. Discussion

Despite little research that has been done on examining the effect of HIV/AIDS on cassava production in Africa, results from the existing theoretical and empirical literature differ largely on the topic. This study contributes to the existing literature by emphasizing the impact of HIV/AIDS on cassava production in Sub-Saharan Africa and more specifically on two countries: Tanzania and Nigeria. The analysis was made on a panel data of the two countries, covering the 1990-2021 period. The research question was: *What is the impact of HIV/AIDS on cassava production in Tanzania and Nigeria?* As expected, results showed that HIV/AIDS leads to less cassava production in both countries. Particularly, HIV prevalence and HIV incidence have a significantly negative effect on cassava production. Moreover, the two hypotheses H1 and H2 are confirmed. However, the comparison within each country shows that HIV prevalence does not significantly impact cassava production in Tanzania and Nigeria. In contrast, HIV incidence appeared positively significant for Nigeria only. The present findings were justified by the literature accordingly.

In Africa, the implementation of interventions has reduced the risk level of the incidence of new infections among the population (UNAIDS, 2022). The African government introduced a number of measures in response to the HIV epidemic including raising awareness, promoting reductions in risky behaviors, encouraging the use of condoms or providing AIDS care. According to UNAIDS (2022), in Tanzania a large randomized trial of sexually transmitted disease control resulted in a 42% decline in HIV incidence in the country. Moreover, to mitigate the effect of HIV/AIDS infection the National AIDS and Sexually Transmitted Disease Control Programme (NASCP) was established in 1988 in Nigeria (Nkeme et al., 2022). The government also set up a National Action Committee on AIDS (NACA) in 2001 that helped each state to establish their own actions between rural and urban areas. In general, adequate sensitization campaigns should be carried out in Africa to strengthen the misconception and causes of the HIV/AIDS disease among the African population. Particularly, farmers should be educated to ensure their incentive to do HIV tests regularly (Nkeme et al., 2022). Overall, many interventions have been put in place in Tanzania and Nigeria to reduce the spread of the HIV/AIDS disease and thus its impact on cassava production. However, there is no one-fits-all solution to the reduction of HIV/AIDS and thus solutions should be adapted to each country's policies or population's culture.

This study presents some limitations. Even though the study zooms on Tanzania and Nigeria specifically to see the impact of the HIV/AIDS disease on their cassava production, the use of a data panel only on those two countries excludes a generalizability on Sub-Saharan Africa in general. The findings are usually not representative of other countries or populations. Moreover, having a smaller sample size might give unreliable results. It might lack statistical power and increase sample biased. Therefore, results should be taken with caution and studies involving a larger sample size are needed to reach more reliable conclusions. Hence, future research might want to focus on the whole Sub-Saharan Africa region and look at the differences between countries inside this region. Alternatively, a focus on national data inside each country would have been interesting to analyze to see which areas of the country are the most touched by the impact of HIV/AIDS. Lastly, several variables exceeded a VIF of 10 (Appendix B). This can provide unreliable results when looking at their coefficient estimates and p-values in the regression outputs. Future studies should combine the concerned independent variables into a single index to avoid multicollinearity or use ridge regressions to analyze data suffering from this problem, as suggested by O'Brien (2007).

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Appendix A

Descriptive statistics for each of the variables.

VARIABLES	N	mean	SD	min	max
CassavaProduction	64	2.393e+07	2.027e+07	3.962e+06	6.535e+07
HIVPrevalence	64	3.809	2.253	1	7.500
HIVIncidence	64	2.384	1.893	0.340	6.910
UrbanPop	64	33.11	9.512	18.88	52.75
TemperatureChange	64	0.778	0.384	-0.232	1.559
CerealYield	64	1,419	247.1	858.1	2,044
PopAge	64	2.262e+06	2.391e+06	2.763	6.363e+06
SchoolEnrollment	64	88.56	11.72	66.58	112.4
lnCassavaProduction	64	16.53	1.019	15.19	18.00
lnHIVIncidence	64	0.566	0.798	-1.079	1.933

Appendix B

Variance Inflation Factor (VIF). Measuring the degree of multicollinearity between the variables.

Variable	VIF	1/VIF
UrbanPop	84.40	0.011848
lnHIVIncid~e	82.20	0.012166
PopAge	19.56	0.051113
HIVPrevale~e	15.37	0.065071
Temperatur~e	2.75	0.364059
CerealYield	1.87	0.535604
SchoolEnro~t	1.86	0.536236
Mean VIF	29.72	

Appendix C

White test for heteroskedasticity.

```
White's test
H0: Homoskedasticity
Ha: Unrestricted heteroskedasticity

   chi2(35) =  58.04
Prob > chi2 = 0.0085
```

Appendix D

Robust tests for serial correlation with the ArelanoBond test.

Arellano-Bond test for zero autocorrelation in first-differenced errors
H0: No autocorrelation

Order	z	Prob > z
1	**-1.3189**	**0.1872**
2	**-.90389**	**0.3661**

Appendix E

Sargan statistic test of overidentifying restrictions.

```
Sargan test of overidentifying restrictions
H0: Overidentifying restrictions are valid

        chi2(51)     =   47.2394
        Prob > chi2  =    0.6238
```

Appendix F

Marginal effect of Cereal Yield and HIV prevalence.