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The sources and dynamics of technological change in cassava farming in Ghana

by

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Abstract: Farm size expansion in some countries in Sub-Saharan Africa, including in Ghana, is a recent phenomenon, and is indicative of the agricultural transformation process taking place in the region. Technology use and adoption level is an integral and complex part of this process, which is studied in relation to the expanding farm sizes and agricultural transformation in this study. It follows an explorative qualitative research design drawing on the 35 semi-structured interviews with cassava farmers and agricultural extension officers in Volta and Ashanti regions in Ghana. The research findings indicate that the farms are growing in size. They also suggest that technological change in cassava farming in Ghana is happening unevenly across time, space and sometimes farm sizes. The study finds that the farmers are increasingly adopting such labour-saving technologies as mechanical ploughing and weedicides, which serve as major enablers of the farm size expansion. While some progress can be observed in land-saving technologies such as improved cassava varieties, but the use of fertilisers is quite low. The farmers are also constrained by the changing rainfall patterns, absence of irrigation infrastructure and high input prices. Extension officers and formal ways of learning remain to be the major sources of knowledge and skills expansion for farmers, while cassava processing factories, farmer associations, vendors of agro-inputs shops, as well as NGOs and micro-finance organizations also contribute to a lesser extent.

Keywords: Ghana; cassava; technology adoption; agricultural transformation; farm size; agricultural extension service

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1 Introduction

Agriculture plays a key role in the economy of every country, starting from providing basic necessities such as food and employment to driving economic productivity and growth. According to some estimates, by 2050 the world population will grow from current 8 to 9.7 billion people and the agriculture sector will need to increase food production by 70% to meet the future demand (Despommier, 2010). This forecast is particularly concerning for Sub-Saharan Africa (SSA), which houses over one-third of the world's undernourished (Ayanlade & Radeny, 2020), and where the population is expected to increase 2.5-fold by 2050 (van Ittersum et al., 2016). Thus, there is an urgent need to transform the agri-food systems to ensure better nutrition, wellbeing and employment opportunities for the people in vulnerable parts of the region. For most of these countries, the answers lie in agricultural transformation, including better use of agricultural technologies.

The SSA countries have achieved the highest growth rates of agricultural production value since 2000, compared to any other region in the world, increasing by 4.3% a year as opposed to 2.7% of the world average. In most countries, growth of Gross Domestic Product (GDP) has strong correlation with growth rates of agricultural sector. Hence, many economists now agree that agriculture-based economic growth strategies are the best possible solutions for the development of most African countries. However, most of the growth rates (75%) were achieved by expanding the cropland, and only 25% stem from yield improvements (AGRA, 2021). This highlights the need for agricultural intensification and making more efficient use of the agricultural technologies in order to respond to rising domestic and global demand. In addition, the value added per worker in the sector seems to be lower than other sectors, and the lowest compared to other regions in the world (Gollin, 2021). Hence, the status report by AGRA (2021) (Alliance for a Green Revolution in Africa) emphasizes the importance of the within-sector productivity growth as a central feature of resilient food systems, which requires faster adoption rates of agricultural innovation and more efficient agricultural institutions.

Ghana is a good example of the country from SSA, that comprises the opportunities and challenges of the agriculture sector in the region. So far, the role of agriculture was significant in achieving sustained growth rates in Ghana, since close to one fifth of the country's GDP comes from the agriculture sector, which employs about 30% of the total workforce (World Bank, 2022). Although at quite good level compared to some other SSA countries, still these indicators are much lower than in other developed countries, e.g. 2-3% share of agriculture in GDP of the US or Australia (World Bank, n.d).

In economic history, the agricultural transformation process has coincided with the increase of the average farm sizes, as it happened along the economic development of some advanced economies, such as the US, the UK and some other European countries. Currently, of about 570 million farms around the world, most are small and family-owned and about 12% of the world's agricultural land is operated by small farms (less than 2 ha) (Lowder, Skoet & Raney, 2016). The average size of the farm in low and lower-middle income economies was decreasing over the period of 1960-2000, while at the same time it was increasing in middle-income and advanced economies (Lowder, Skoet & Raney, 2016). There are multiple possible explanations offered by the economists, including that bigger farms utilise labour, financial and land resources in a maximum efficient way compared to smallholder farms, for which it is burdensome to invest their little income into large fixed capital. It is believed that growing farm sizes also boost income generation by decreasing poverty rates, particularly in rural areas.

Recent empirical research indicates that the farm sizes are expanding in Ghana and some other leading African economies providing evidence for the ongoing agricultural transformation process. By analysing the survey data in a number of SSA countries, Jayne et al. (2016) found that the number of smallholder farms in Ghana are decreasing, while medium-sized farms (5-100 ha) are increasing and now occupy about 32% of total farmland. Another recent study by Yaro et al. (2021) also suggests that the share of the lower-medium-scale farms (4-20 ha) has more than doubled in Ghana in the period between 2000 and 2020. According to the authors, better use of technology, particularly of weedicides and mechanization, was one of the key enablers of the size expansion.

The agricultural transformation that happened in Southeast Asia around the 1970s, which was later termed as the "Green Revolution" was associated with much higher and efficient use of the new technologies. During that period, increasing productivity of staple food crops, such as rice, was essential in the agricultural transformation process in Southeast Asia (Byerlee, de Janvry & Sadoulet, 2009). Because Southeast Asia is also inherently made up of small farms, it is assumed that another Green Revolution could also happen in Africa if farmers had better access to machinery, improved varieties and other technological advancements, including efficient extension services. While some researchers find that the use of technologies has improved in recent years (Yaro et al., 2021), others state that African farmers have a long way to go to have access to and capabilities to use technologies at least at the same level as in Southeast Asia (Ruzzante, Labarta & Bilton, 2021).

1.1 Research problem

Farm size expansion in some SSA countries, including in Ghana, is a recent phenomenon and only little empirical evidence is available. However, the farm size increase could be an indication of the ongoing agricultural transformation process in Ghana, which might ignite even stronger economic growth for the country in the long run. Even less is known about the current transformation process happening in Ghana in relation to the use of technology by farmers. Hence, more insight on a farm level is needed to investigate this transformation process and the role of the technology in it, in order to identify the dynamics of the change process, as well as the challenges and prospects. Thus, this thesis fills this research gap by presenting and analysing the primary data collected in 4 districts of 2 regions in Ghana. It focuses on uncovering the relationship between the farm size change, taken as a proxy for the agricultural transformation process, and the technology adoption rates by farmers.

The thesis is narrowed down to study the above relationship based on one of the main staple crops in SSA and Ghana – cassava. Occupying the position of the 6th world's largest producer of cassava, according to some estimates, cassava production, trade and services contribute to about 22% of Ghana's agriculture (WorldAtlas, 2017). In Ghana, almost every farm household plants cassava, which accounts for about 30% of daily calory intake in the country (WorldAtlas, 2017), with an average per capita consumption of 153 kg/year (Adjei-Nsiah & Sakyi-Dawson, 2012).

Cassava serves as both subsistence and cash crop in much of Africa, as well as generating employment in rural areas (Anaglo, 2011). Cassava's wide applications make it a perfect food crop that, and if right policies and programmes applied, can help to industrialise the sector. Apart from human consumption, cassava has also wide industrial uses such as feed for animals, main component of starch and ethanol production, as well as uses in pharmaceuticals, bakery, confectionery, cardboard and wallpaper manufacturing, paper and textile industries, among many others (Mbanjo et al., 2021). For these reasons, the thesis sheds light on the technology adoption by farmers in Ghana in cassava farming.

1.2 Aim and Objectives

Given such importance of cassava and increasing demand for it, this thesis sets some objectives such as:

- exploring the type of technologies used in cassava production in Ghana and opportunities and challenges that farmers have in accessing them;
- investigating the ways farmers learn about and use the new technologies in cassava farming;
- discovering the early signs of the agricultural transformation process happening in Ghana, based on the evidence of increasing farm sizes.

Within this thesis, technology covers the aspects of cassava farming such as mechanization, new varieties of cassava, use of fertilisers, weedicides and herbicides, mobile phones, digital technology, farming practices but also knowledge and skills of farmers.

Considering all the above mentioned, this study aims to answer the following research question regarding the agricultural transformation process:

How does the use of technology change in cassava farming in Ghana in the process of agricultural transformation?

Even though there is enough previous research and various theories suggested to explain the technology adoption by farmers, this thesis fills the gap by shedding light on the topic in the context of growing farm sizes. The advantage of the thesis also lies in that it is based on the first-hand empirical data collected right after Ghana opened up its borders caused by the breakout of the pandemic in 2020. Hence, it reflects the current state of the art for both the availability and affordability of agricultural inputs, as well as how farmers are learning and adopting new technologies.

1.3 Outline of the thesis

This thesis is organized as follows. Introduction section establishes the research topic and helps to define the thesis' overall aim and research questions. Chapter two – the background section presents the justification for the choice of the country, location, crop and the aspect of economic development, i.e., agriculture and agricultural transformation. In chapter three, the conceptual framework is discussed in detail, and the justification is provided for why this particular framework and these theories are chosen for the analysis. The methodology section sheds light on why specifically qualitative research method was chosen, how the data was obtained, how the research design was developed, as well as case selection, limitations and ethics. Results and discussion sections are the main body of the thesis, and is based on the analysis of the interviews from the fieldwork, main findings and how they relate to the selected conceptual framework and also in comparison with literature review. The final chapter concludes the thesis and highlights the research areas to be studied in the future.

2 Background

2.1 Economic development of Ghana

After a relative stagnation since gaining independence in 1957, Ghana's economy increased by more than 11 times from 1990 to 2019, which allowed it to join the lower-middle income group of countries (World Bank, n.d.). Ghana's GDP grew about 1.5-2% more than the Sub-Saharan Africa average in the past decade (IMF, 2020). Gross National Income (GNI) per capita grew by more than 5.5 times since 1990 and significant reduction of poverty levels was achieved, mostly concentrated in rural areas (GLSS 7 – Ghana Living Standards Survey Round 7). Almost half of the population (49.8%) lived at less than $ 1.90 a day in 1991, which dropped to 13.3% in 2016 (World Bank, n.d).

2.2 Challenges of technological development in Sub-Saharan Africa

When the share of agriculture in employment is considerably larger than the share of agriculture in GDP, this indicates that labour productivity is low. Essentially, there are many households working in the sector which produce the smallest share of GDP and thus, have lower income compared to the other sectors of the economy. According to (Diao et al., 2019) between 1984 and 2011, only 25% of the total growth in labour productivity came from the structural change, while 75% was associated with within-sector productivity change. This was in line with the trends of many other SSA countries, and completely opposite to what happened in Asian countries in early development stages, where much of the productivity growth was achieved by labour moving to other sectors. This once again proves that in Ghana, as in other SSA countries, the services sector could not provide higher productivity than in traditional agriculture, but maybe even lower in some cases (Diao et al., 2019).

Despite the considerable progress in recent years, the pressure for Ghana to increase its agricultural Total Factor Productivity (which measures how much total input is used to produce total amount of output) even further is increasing. Rapidly growing population will result in demand-side pressure to provide affordable and nutritious food in the coming decades, since agricultural productivity growth so far was at the expense of land extension in most of the SSA countries (Suttie, 2019). Agricultural sector contributes significantly to the export and balance of payments of the country, hence the sector should be able to meet both domestic and international demand for food.

2.3 Technological development in agriculture in Ghana

So far, the growth in Ghana's agriculture has mostly relied on the land expansion practices, rather than the intensification of production. The expansion of cultivated land in Ghana is occurring mostly by clearing virgin forest, shortening fallow periods, and due to increasing use of labour-saving technologies and mechanization (Ecker, 2018). As a result, the land productivity did not increase as dramatically as labour-saving practices (Ecker, 2018). In other words, food production has not increased due to high productivity but instead higher land use. Land use and land use change is important to monitor from a for sustainable development.

Shortened fallow periods are resulting in deteriorating soil fertility, to which farmers are adapting by applying crop rotations, shifting to crop varieties tolerant to poor soil and changing rainfall patterns. Generally, farmers in Ghana have been managing well to adapt to declining soil fertility, changing availability of rural workforce and responding to market demands (International Food Policy Research Institute (IFPRI), 2018). Still a substantial difference is observed between the achievable yield levels and the actual yield harvested. The primary reason for this yield gap lies in the unsustainable cropping practices and low use of available technologies (Giller et al., 2021). One of the reasons the technological uptake was not as progressive as in other parts of the world, could be because smallholders are reluctant to invest in their small farms with modern farm inputs due to meagre returns, and have to look for non-farm income (Giller et al., 2021).

An interesting trend that is happening lately in Ghana is that the number of mid-size farms are increasing at the expense of small and large farms (Diao et al., 2019). (Jayne et al., 2016) note the decrease of the share of farms under 5 ha in Ghana from 92% in 1992 to 84% in 2012. This trend is happening mostly in the northern regions in Ghana, which is in contrast with the southern regions of forest and coastal zones, where the number of no-land households is increasing dramatically while the share of small farms with less than 2 ha has increased by 10% (Diao et al., 2019). Yaro et al. (2021) find that mechanization and increased availability of fertilisers and herbicides are the major driving factors of the agricultural transformation process in Ghana, when increased farm sizes are taken as a proxy.

Economists have for some time tried to answer the question of why the mechanization process was so slow in Africa compared to other regions. According to Pingali et al.'s (1987) estimates and research, the slow progress in development of farming systems is the main reason, and that mechanization would catch up when the long fallow periods become shorter and increase the need for ploughing against grassy weeds and hard soil. In line with Pingali et al.'s (1987) predictions, in Ghana, the demand for mechanization, including by smallholder farms has increased substantially in recent years (Diao et al., 2014). Ghana is an example of the country, which in its early years of industrialisation as in some Asian and African countries, the government tried to incentivise the mechanization. These incentives were carried out through such programmes as Agricultural Mechanisation Services Centres (AMSECs). The idea of these centres were to act as locations farmers come to hire tractor services. However, these programmes only worked for a couple of years, and eventually failed because the profit generated was only enough for sustaining the centres (Diao et al., 2014). The tractors, delivered through development grants where donor dictated the type of brand of machinery to import, still could not respond to the high demand during the ploughing season. Since the process was heavily controlled by the state, it also resulted in rent-seeking behaviour by the government (Diao et al., 2014). This government intervention slowed down the mechanization process in the country, resulting in distortions in machinery prices, thus meddling in the supply side of the equilibrium, as well as discouraging the development of the private sector.

Having cost the state budget enormous amounts, the programme seized out gradually (Diao et al., 2014). These days, the tractor services are provided by farmers of small and medium sizes, who provide ploughing services after they finish working their own land. Usually, the tractors they own are second-hand imported tractors. Diao et al., (2019), therefore, call for the government to allow the private sector to meet the demand needs, and indirectly incentivise the importers of second-hand tractors by private individuals or farmers. They also find that the least mechanized regions of Ghana are Central and Ashanti regions with less than 10% of farmers reporting to use machinery, while the most mechanized regions are the Northern and BrongAhafo. The latter two are located in the transition and savannah zones compared to the other 2 regions mentioned, which once again shows North-South divide in agricultural development. Reportedly, about 10,000 tractors are operational in Ghana these days (Diao et al., 2019). Although, the need for tractors for land preparation is now well recognised, there is still not enough attention to other forms of mechanisation in harvesting, harrowing, transportation, post-harvest processing, etc.

2.4 Role of technology in cassava farming in Ghana

After being introduced from South America by Portuguese traders in the 16th century, slowly cassava has become one of the major staple food crops in Africa, being widely integrated in varying cuisines across the continent in the form of fufu, garri, tapioca, cassava chips, etc. It is the main source of carbohydrates for low income households in most parts of Africa (Anaglo, 2011). Cassava is also highly regarded for its resilience to changing climatic conditions, as well as deteriorating soil quality (Kondo et al., 2020). Hence, the policies and investment directed at increasing cassava production might yield beneficial results in the future, and is less risky compared to other crops.

Sub-Saharan Africa accounted for over 60% of the world’s cassava production in 2020 (FAOSTAT, n.d.). Even though the yield level increased in recent years mainly due to land expansion, but it is still far below the average achieved by Asian countries – 21.5 tonnes per hectare as compared to 9.1 tonnes in Africa (Mbanjo et al., 2021). However, the yield level in Ghana was particularly high at 23 tonnes per hectare in 2020 (FAOSTAT, n.d.), which is still far below the levels achieved by some other South Asian countries at around 28 tonnes per hectare in 2018 (FAOSTAT, n.d.).

Particular attention to cassava in Ghana and attempts towards its industrialisation started in around the early 1990s with a number of initiatives, including by announcing 1994 as a year of cassava, which lead to National Cassava Task working groups and task forces being established later in 1995-96 (Anaglo, 2011). Acheampong, Owusu and Nurah (2013) studied the reasons for low adoption of improved cassava varieties released by the National Agricultural Research Systems and what the preferences of farmers were in choosing the varieties to plant. Their empirical results for 450 farm households in Ghana indicate that in-soil storage and disease resistance were the most important features of the varieties the farmers chose. The authors also find that farmers' age, gender, access to extension services and farming experience were among major factors creating the heterogeneity in productivity and choice of the variety.

Chemical inputs, such as fertilisers and weedicides are mainly supplied by the private sector in Ghana. However, the level of usage of these chemical inputs is still quite low, which is usually because of the high price and other supply-side issues. In light of the high cost of these inputs, combined with absence of irrigation systems, soil fertility and others, the purchase of fertilisers and weedicides are too risky for farmers (Diao et al., 2019). Farmers buying the inputs without much prior knowledge and soil testing presents another challenge. The irrigation system of Ghana has not been updated or invested in recent years, leaving a large gap in reaching the country's irrigation capacity. The majority of the famers rely solely on the rainfall during the rainy season, which has become quite erratic in recent years due to climate change.

Ministry of Food of Agriculture of Ghana (MOFA) provides extension services in each district throughout the country through Agricultural Extension Officers (AEOs). Serving as a link between the farmers and the agricultural researchers and MOFA, the role of AEOs is immeasurable in developing the agriculture sector in Ghana. The effectiveness of the extension services has evolved over time and has been assessed and researched quite widely. For example, Antwi-Agyei and Stringer (2021) have recently carried out extensive research on the preparedness of the extension services to address the above-mentioned challenges caused by climate change. Through mixed methods approach, where they have conducted expert interviews as well as surveys among farmers, the authors find a capacity gap between the officers' knowledge and the current demands for climate change adaptations needed for farmers and suggest a number of policy directions to improve it. Another research by Danso-Abbeam, Ehiakpor and Aidoo (2018) also highlight the importance of regular capacity building trainings for the AEOs, but find that generally the extension services provided to farmers in the Northern region in Ghana quite efficient. Their quantitative study using cross-sectional data for 200 farmers find correlation between the active participation of the farmers in extension services and the increased income from the farm. Communication and dissemination of the information about new technologies is an essential part of the extension services. Hence, some researchers also find that while AEOs are one of the main sources of information for farmers, the issues of time, cost and cultural barriers constrain the farmers to make full use of their services (Brobbey et al., 2018). Hence, more timely and structured communication would improve the extension services even further.

Recognising the challenges in the supply of agricultural inputs, infrastructure bottlenecks, inefficient extension services and weak market linages, the government of Ghana established a flagship "Planting for Food and Jobs" (PFJ) programme. With a focus on smallholder farmers, the programme aimed to provide better seed provision and fertilisers, improve the extension services, input and output markets, as well as digitising the monitoring system to ensure targeted and improved governance and impact (MoFA, 2017). Other programmes also being implemented alongside the PFJ programme, such as Planting for Export and Rural Development (PERD) target the cultivation of tree crops and mostly by medium and large farms. These programmes are slowly contributing towards the changes in land tenure, overall development of infrastructure, markets and improvement in access to inputs.

3 Conceptual framework

This chapter starts by discussing and analysing the existing literature in order to build the theoretical principles behind the conclusions. The conceptual framework also helps to analyse the data in a systematic way and contribute to the previous research on the topic of adoption of agricultural technologies. It attempts to capture the state or the link between the available technologies for cassava farmers in Ghana and how they learn new technologies during the state of the agricultural transformation. Increasing farm sizes are taken as a representative variable for the agricultural transformation, while learning and extension creates an institutional basis for technology adoption.

3.1 Agricultural transformation in Sub-Saharan Africa. Literature review

The trends and developments of the agriculture sector in SSA have always puzzled the economists. Despite the heavy reliance of the region on agriculture both for food and income, the agricultural productivity growth was much slower compared to other regions in the world. Around the same time the countries of Southeast Asia were experiencing the Green Revolution – the agricultural intensification and increased use of technology, most of the SSA countries went through a brief downturn of economic and agricultural growth around the 1980s. The scholars are still trying to understand how almost the entire continent suffered from sharp decline in both land and labour productivity between 1973 and 1984 (Timmer, 1988). However, the rates of development have sped up in most countries of the region since the turn of the century (Ecker, 2018; Yaro et al., 2021). The share of agriculture decreased in both GDP and employment, at the same time agricultural commercialization and intensification processes took off in the region owing to high population growth, increase in rural and urban incomes and thus increased domestic demand (Gollin, Jedwab & Vollrath, 2016).

Agricultural intensification means more frequent use of land and the use of inputs that help increase the yield, and thus achieving land productivity. The Green Revolution in East Asia was partly a response to the rapidly increasing number of population in these countries in light of the land scarcity, and hence there was a need for more efficient use of the available land. SSA is the only region in the world, where the rural population number continues to increase (Jayne et al., 2016). Often the agricultural intensification goes in parallel with the structural change within the economy, whereas the excess labour moves from agriculture to more productive sectors, such as industry and services.

However, many scholars agree that this structural change process will be more challenging for late developing countries, most of which are situated in SSA, than for the East Asia, owing to heavy take-off of the manufacturing sector due to the abundance of cheap and already available products from earlier developers and tough international trade competition, among others (Losch, Fréguin-Gresh & White, 2012). Amidst the unprecedented population growth in the region, the level of urbanization is increasing, adding on the food security and nutrition issues in many countries. This process, described as “urbanization without industrialization” is also coupled with high growth rates of the services sector (Gollin, Jedwab & Vollrath, 2016). Even though the services sector now makes up the most of the GDP of SSA countries, the labour productivity is not necessarily better than the traditional agriculture, due to high informality in the sector and labour-intensive activities (Ecker, 2018). Hence, the agriculture-led transformation process remains to be the most straightforward option of development path for most of the countries in SSA. This would require the transformation of subsistence-oriented traditional agriculture into a technologically advanced, commercialized sector with added value chains (Diao et al., 2019).

The relation of the farm sizes and the productivity, particularly in SSA, has generated a lot of discussion during the past couple of decades. Many economists agree (Giller et al., 2021; Tschirley et al., 2015) that one of the major obstacles of successful agricultural transformation in Africa is that most land is owned by very small farms. Generally, it is believed that larger farm sizes utilise resources in a more efficient way, and owing to the economies of scale, are able to generate more profit, and thus afford more and better quality farm inputs compared to the smallholder farms. Smallholder farms are often said to have difficulties with decision making for profit or subsistence, which results in the type of food crops and inputs they work with (Giller et al., 2021). Some estimates suggest that the vast majority of farms in SSA are smaller than 1 ha (Giller et al., 2021), which is smaller than the average farm size in Ghana, at less than 2 ha (Diao et al., 2019).

Empirical research into the recent agricultural transformation in SSA shed light on the patterns and dynamics happening in the region. Jayne et al. (2016) find evidence that in some African countries, including in Ghana, the number of medium-sized farms (which they classify as between 5 to 100 ha) has been increasing and showing some signs of the transformation process. The increase in medium-sized farms is happening simultaneously with the decrease in the number of small farms (less than 5ha), except in the case of Kenya. According to their estimates, medium-size farms occupy 20% of total farmland in Kenya, 32% in Ghana, 39% in Tanzania, and over 50% in Zambia. Although the changes in the farm sizes are not taking place uniformly across all the regions of Ghana (Molini & Paci, 2015), the agriculture sector overall across some SSA countries is enjoying technological advancements, increased agro-processing, commercialisation and market integration (Jayne et al., 2016). Another study (Chapoto, Mabiso & Bonsu, 2013), adds that most of this expansion, particularly in Ghana’s case, is not the result of foreign investment, but rather reinvestment by the local farmers.

Over the time, the views, policies and approaches both by academics and the states in the region have changed and evolved in relation to the agricultural extension services. Ever since the extension policies were supported for the first time in Kenya in 1981 by World Bank as a Training and Visit system (V&T), the topic has been generating heated discussions among the scholars (Venkatesan, 1997). In most SSA, the extension service was introduced by international donors through various complex programmes, which were then discontinued at some point. After the second World War, significant investments had been implemented to establish the extension services by the colonial authorities as part of the national programmes to improve food production. Starting of as recommendations, those later became rules for farmers, in order to avoid the punishment, and by mid-1950s, most farmers had been in contact with extension officers (Green, 2018). Most issues with extension service systems can be associated with 2 broad categories – systemic problems of the sector as a whole and implementation issues (Venkatesan, 1997). The extension by itself cannot be a solution if other systemic problems persist, such as high cost of input factors, credit challenges and top-down approach of the extension system.

In order to serve the farmers well, the extension system as a whole should be well disciplined and extension staff should receive continuous retraining. In addition, the service itself would not work if it is not connected to the ongoing research and technology development. Ugochukwu and Phillips (2018) provide an extensive systematic review of the extension service systems applied by the state in SSA. They find that recently, the evident trend is that the extension systems are evolving across the region, now also comprising non-profit and private sectors. Extension is undergoing a transformation in many countries through decentralization and adopting a pluralistic approach to delivery. For example, the authors find that Ethiopia and Uganda operate a large but inefficient and costly service. While privatization and commercialisation of the extension service is slowly taking off, in most places the private sector actors concentrate on specific commodities or value chain gains or assist commercial farmers, which again benefit mostly medium- and large-sized farmers, bypassing the smallholders (Nwafor, Nwafor & Ogundeji, 2020).

3.2 Agricultural transformation

Agriculture plays a crucial role in economic growth, particularly in developing countries for its roles in economic growth, poverty reduction, provision of equity, food security and environmental sustainability (Byerlee, de Janvry & Sadoulet, 2009). As a result, it is considered that the agricultural transformation process in the early stages of growth is a critical phase in which agricultural policies must be appropriately executed in order for other sectors to develop.

Agricultural transformation is the process in which the agri-food system shifts from subsistence-level production to a more productive and commercialized one (Timmer, 1988). In the advanced levels of agri-food systems, most of the value added of the sector happens off-farm, meaning that more processing of food production takes place. This process usually happens in sync with urbanization and structural transformation, whereas there is a wider diversification of the livelihoods and strong linkages of the agricultural sector with industry and services. Although, the role of the agricultural sector in the GDP of the country diminishes at the later stage of development, it is important to build a strong agri-food system for an economy to take off (Ranis & Fei, 1961).

According to Timmer (1988), the transformation process, which includes four phases, starts when the agricultural labour productivity increases. The surplus that is generated from the productivity is utilised to develop the non-agricultural sector through taxation and factor flow. In order for the factors to flow out of agriculture, the sector should be well integrated with other industries through infrastructure and market linkages, which occurs during the third phase (Timmer, 1988). In the last stage, the farm-gate price of the agricultural produce becomes considerably smaller because of added processing and marketing costs. In addition, the labour occupation level in the sector drops compared to other sectors, along with the proportion of food expenses in household consumption (Timmer, 1988).

The role of technology in increasing productivity is immense in the first phase of the development. According to Timmer (1988), re-investing some of the surplus revenue (in the form of direct and indirect taxes) back into the sector is important in the first stage of the transformation process. Some of these resources need to be directed to public investment in research, infrastructure and policies to support farmers to invest in new technologies. These technologies are then used to increase land and labour productivity in the sector. The next sub-section delves into the technological change in agricultural transformation process.

3.3 Technological change in agriculture

Figure 1. Author's interpretation of Timmer's (1988) four phases of Agricultural Transformation

Timmer (1988) emphasizes that "understanding the source, dynamics and impact" of technological change in agriculture is a major part of understanding the agricultural transformation". He believes that the complications of the technology adoption are multidimensional, including macro-level policies (investment in research and development, infrastructure), as well as micro-level decisions of farmers whether to adopt these innovations or not.

Placing the role of technology in agriculture, and generally in economic growth is seen from two different perspectives: technology as an endogenous or exogenous factor. In the "induced innovation model", Ruttan and Hayami (1984) see the technological change process as an endogenous phenomenon. The theory suggests technical innovations are spurred by the changing input prices, which in turn lead to innovations developed by private or public sector. For example, scarcity of labour or land leads to innovations in mechanization (e.g., in labour-scarce United States and Canada) or improved high yielding varieties of plants (in land-scarce Japan). Since then, Ruttan and Hayami's theory became one of the central tools in explaining the productivity differences among countries. Over the years, the authors developed the theory and included the institutional innovation, an example of which could be changes in property rights or tenure arrangements, which can lead to technological change (Ruttan & Hayami, 1997). In later revisions of their work, the authors tried to combine the institutional change theory with the changes in factor and cultural endowments to explain the endogenous nature of technological change. Since then, more academic literature focused on uncovering the relationship of institutional innovation and diffusion of new technologies by treating institutional change as an endogenous phenomenon and as “an economic response to changes in resource endowments and technical change” (Ruttan and Hayami, 1984).

Adoption of technologies by farmers is a complex social phenomenon and is researched from many different perspectives such as learning behaviours, institutional change, innovation diffusion, network analysis, risk aversion, etc. The most iconic work in the sphere of technology adoption in agriculture is that by Griliches (1957). He observed that not all farmers uniformly adopted the new hybrid varieties of maize in the US. Based on his observations, he suggested the first model of technology adoption based on the case of the diffusion of hybrid variety of corn among farmers in the US. Since then, a number of theoretical models and research have been suggested in an attempt to explain the factors that contribute to the decision of farmers, but the results are often contradictory. De Janvry, Macours and Sadoulet (2016) provide an overview of the models and theories exploring the technology adoption process by farmers, based on how information spreads in complete and incomplete social networks. They find that if the diffusion process is looked beyond just the spread of information as a binary variable, and analysed from the adoption perspective, the models tend to become complex. They also support some research conducted, which recognize the positive role of agricultural extension agents in spreading the information about the potential benefits of an innovation.

Review of both theoretical and empirical literature pretty much agrees on the important factors or variables that contribute to farmers adopting the new technology. Feder, Just and Zilberman (1985) define adoption as “the integration of new technology into farmer’s normal farming practices over a certain period of time”. Since adoption is a continuous process, the introduced innovation needs to be included in farmer’s routine farming activities for an extended period of time. In their theoretical survey, they identify the following factors, which limit the adoption of new technology by farmers:

- limited access to information – extension services and farmer training;
- inadequate farm size;
- limited supply of labour and the quality of human capital;
- restricting land tenure arrangements;
- absence of adequate farm equipment;
- capital constraints – access to credit;
- distorted supply of additional agricultural inputs;
- poor transport infrastructure.

The analysis and data collection within this thesis focused on researching some of these constraints, such as access to information and farm size. Diffusion of innovation has been mentioned as a policy challenge by Timmer (1988), because not all farmers have equal access to the knowledge to use the new technology (i.e., the need for education and extension services). He also mentions that financial resources limit even average size farmers to utilise some inputs because they are too lumpy and financially burdensome. Hence, with strategic policy choices, these differences can be smoothed out to some degree.

The questions of the interviews with farmers focused on these issues and specifically on how farmers learn new practices and technologies. Therefore, the core of the conceptual framework is based on this theory that if these constraints are studied and measures are taken to reduce or eliminate them, it will contribute to faster agricultural transformation. It has to be mentioned that during the data collection, other factors have also been mentioned by farmers, which contribute to understanding the wider context, but were not necessarily the focus of this study by design. The underlying assumption is that the farmers are rational agents, adopting or not adopting new technology based on the available information and make decision in favour of increasing their productivity. Like most studies presented below, we assume that the farmers' adoption process is based on Bayesian learning, where the agent continuously reassesses the decision following any new information that emerges.

3.3.1 Farm size and technology adoption

Generally, the relation between farm size and technology adoption level is a contested area. While some scholars believe that larger farms adopt technologies faster and utilise them more efficiently, others argue that the smallholder farms are as efficient as medium and large-sized farms. Interestingly, farm size can affect and be affected by other determinants of technology adoption.

Most often, the costs associated with new technologies, such as fertilisers and hybrid seeds are substantially higher. Therefore, where credit for small farms are not available or limited, the adoption rate of technologies by small farms are lower than large farms (Feder & O'Mara, 1981). In turn, financing large farms is less risky for credit institutions and promise to receive higher return to investment. A model by Feder and O'mara (1981) suggests that during the initial years of introduction of innovation, large farms allocate a portion of land for it, while medium and small farms do not attempt at all. The adoption level among the latter slowly increase as more information becomes available during the later years of the innovative product. The authors also argue that there is a critical level of the size of the farm, beyond which the farms will not adopt the new technologies even at later stages.

Another factor which works in favour of large farms is the access to information, both in terms of acquisition of information as well as resources to utilise that information and knowledge. Limited access to information is associated with the perceived level of risk a farmer is ready to accept. While credit constraint is an exogenous factor, risk tolerance level is endogenous, and therefore can be changed by increasing access to information. However, according to Feder and O'mara (1981), the above theory about risk-aversion is only valid if certain assumptions hold true. Otherwise, the adoption level by small farms in early years of introduction of new technology cannot be explained just with the perceived risk level.

Ali and Pernia (2003) assert that there is an inverse relationship between the size of the farm and poverty reduction potential, stemming from the diversity of their income. The authors classify the landless and marginal farmers as net buyers of food, and highly vulnerable to food price volatility. The smallholder-led transformation models are also criticised for resulting in high entry barriers to markets for small farmers, who cannot meet the quality and quantity of production demanded by processing companies and international markets (Bernstein & Oya, 2014). Therefore, Collier & Dercon (2014) propose that given the right technologies and infrastructure, the larger farms would be better suited to drive economic change and reduce poverty.

On the other hand, some studies show a negative relation between the farm size and the rate of the technological change. They find that the smallholder farms are better at adopting and utilising input-intensive technologies, such as labour-intensive and land-saving (Harper et al., 1990). Some other papers (Bonabana-Wabbi, 2002), however, found no substantial evidence on the effect of the size of the farm on adoption of certain technologies, such as pest management systems. Mwangi and Kariuki (2015), therefore, suggest that these authors could get a different result if they used not the total farm size, but the measurement of the crop area on which the innovation is being tested.

Many articles and policy papers, citing UN and FAO, indicate that the world's 70% of food is produced by smallholder farms, and therefore agricultural strategies and policies should be directed at them. However, more recent evaluations (Ricciardi et al., 2021) have found that the figure was not based on recent raw empirical data. Their models, therefore, suggest that smallholder farmers account for about 28-31% of total crop production and 30-34% of food supply. The study also emphasises that small farms tend to achieve higher yields occupying over 24% of agricultural land through high land productivity, but conclude that their labour productivity is much lower, and therefore, they are often poor and vulnerable.

3.3.2 Access to information and learning

A number of theoretical models and empirical evidence exist in the literature regarding the effect of farmer's education and generally access to information and learning. Most of them define farmer's education as one of the determining variables that is associated with technology adoption. Access to extension services and learning opportunities is often used as another variable in these studies, although in some others access to extension is taken to replace the education variable, so they are used interchangeably (Feder, Just & Zilberman, 1985). However, extension services and learning have also been developed as individual models, which is discussed in more detail in this subsection.

In the meta-analysis review of technology adoption, Ruzzante, Labarta and Bilton (2021) present 15 most commonly cited factors that affect the adoption of new technologies. The authors use a meta-regression method based on weighted least squares regressions of 367 models previously published in literature. They highlight that farmer's access to extension services is one of important external factors presented in most of these models.

A significant proportion of these models link farmer's risk management behaviour to the information availability, and thus extension services. For example, Hiebert (1974) finds that as the information about the new seeds and fertilisers become abundant, including through extension agents, the likelihood of adoption increases. Another study (Feder & O'Mara, 1981) complements this theory by presenting a Bayesian model of farmer's learning, whereas the decision on the adoption is consistently re-evaluated upon gaining access to new information about the seed or fertiliser. Additional information is updated through both on-farm and off-farm exposure to it, i.e., through farmer's own experimentation and network and extension services, whereas the latter one is presented in a more structured and formal manner.

One of the critiques of these models is that they include and measure only the availability of the extension services, rather than their efficiency. Another problem with these models which focus on extension only are endogeneity, which does not allow for causal inferences. This means that extension officers might approach farmers that are more likely to adopt the new technologies, or vice versa, early adopters can seek out extension agents as well (Ruzzante, Labarta & Bilton, 2021).

4 Methodology and Data

The method section of this study will focus on the methodological choices which were made to collect the data and analyse it afterwards. Specifically, this section of the thesis tries to answer such questions as, why specifically qualitative method was found fit for this study, explain the data collection process, what instruments were used to collect data and its analysis, the selection of the sample size and the cases. The section also includes other methodological aspects, such as ethics, data triangulation and limitations of this study.

4.1 Research Approach

As was discussed in the literature review section, despite the recent studies and evidence of the signs of the agricultural transformation that is happening in Ghana, the specific role of technological change remains unclear.

The chosen method – qualitative study was found suitable for this study for a number of reasons. First of all, as can be seen from the above research questions, the focus of this study has more of exploratory nature – it helps to investigate the given situation or change (Flick, 2018). Thus, the qualitative approach was defined by the nature of research questions, that describe the process – how a phenomenon develops or changes, including its causes and consequences. The author, therefore, had an aim to discover the state of the use of modern technologies in cassava farming in selected regions of Ghana by asking questions, observing and gathering new insights.

Second, the departure point of the study lies in trying to understand the context and the processes of the agricultural transformation in Ghana by studying the changing role of technologies in cassava farming. Hence, the purpose was to explore the change process, and then return to the reviewed literature, in order to adopt or refute the existing theories of transformation process. Hence, the grounded theory approach is used, with an idea that the theory might be developed based on the prior collected empirical data (Flick, 2018). The quantitative method, following the deductive process of thought, starts in opposite direction – studying the theories, deriving hypotheses and then testing them based on the quantifiable data.

This leads to the third reason - the study aimed to collect qualitative data, which would explain the change process in-depth, while trying to identify the factors behind the process. In the light of little available data about the process of the change in selected locations, building a comprehensive quantitative method, which allows to sift out the causal relationships is quite challenging. Qualitative method, however, can be more advantageous in this regard, because it gives the researcher a first-hand experience to see the context and collect relevant data through in-depth interviews. In order to be able to tell a full story of the technological change process, the interviews with farmers were also combined with the analysis of the in-depth interviews with agricultural extension officers as key actors of the change process and document analysis.

4.2 Research Design

The research design presents the means of achieving the goals of the research (Flick, 2018). The research adopts case study design, the aim of which is to obtain clear description or reconstruction of the cases (individuals, families, institutions, etc) under study. Each individual farmer-respondent is treated as a case or units of analysis (Flick, 2018). Using individuals as a case allows the researcher to provide general characteristics, easily define and explore the social relations (ed. Ritchie et al., 2014). In this particular research, both farmers and AEOs were taken as cases.

The advantage of the case study design over others is that it allows to capture the transformation process in a "very exact and detailed way" (Flick, 2018), which is the main purpose of this thesis. Another advantage of the case study approach is that it allows to research the topic within "… dynamically changing, real life context" (Yin, 2017). However, Flick (2018) also warns that this method might lead to bias in analysing the data through theoretical generalization of the cases if the number of cases is too little. This was dealt with by conducting a study of series of cases, which is why the interviews were held in two different regions of Ghana. This study is designed as a single static case study, i.e., the agricultural transformation was studied in one country and the cases (farmers) were interviewed only once. In addition, using multiple sources of information, including from interviews and document review are often applied in case study design (Carson et al., 2001).

4.3 Data Collection method

After identifying the method of research, it is important to define the types and ways of collecting the data. For this particular research, all three major types of data were used – verbal (interviews), non-verbal (observations) and existing data (documents). The data was collected during a two-months of fieldwork organized in Hodzo and Central Tongu districts of Volta region and Mampong and Sekyere Central districts of Ashanti region. The total number of interviews is 35 (29 with farmers, 5 with AEOs and 1 with processing factory representative). The interview guide comprised of about 32 questions for farmers and 20 for AEOs. Most of the interviews lasted between 30 and 45 minutes. Before visiting the regions for the interviews, an introductory 3-day visit was arranged in order to get familiarized with the locations and to identify the contact persons. The data collection instruments were first tested with the very first farmers interviewed in Volta region, and subsequently the interview guide was slightly amended. The researcher spent one week in each location. Due to language barriers, interpreters who can speak the local language were hired – Ewe speaking interpreter for Volta region, and Twi interpreter for Ashanti region.

The choice of locations was based on two intersectional criteria. The selected regions were supposed to be the largest cassava producing regions in Ghana and represent a higher percentage of medium size farms among these regions. In consultation with the representatives of the MOFA in these regions as well as GLSS7 and literature review, Volta and Ashanti regions were selected for the fieldwork. These resources and criteria were applied again in order to select the districts within each region. In order to avoid bias and to represent the region fairly, it was decided that two districts per region should be visited. Since the MOFA district office would engage with the same farmers within the district, it helped the author to avoid bias when questions about the access and efficiency of the AEOs are asked from the respondents in the same district. So, in total 38 interviews were held in four districts of two regions.

The sampling in case study design is often purposive, since the individual features of the cases are important, rather than statistical sampling, which focuses on just representing the overall wider population with no selection criteria. The farmers were selected for the interviews based on the scale of the farms, whether the farm transitioned from small to medium size, as well as geographic locations. Within this narrowed sample, the project benefited from combining the reviews of typical and critical cases in terms of the sizes of the farm. In qualitative study, the size of the sample is usually decided by the researcher depending on the research questions and topic (Ritchie et al., 2014). The number of cases to analyse is subject to debate and depends on many factor such as research questions and topic, the resourced, the process of later analysis, etc. Perry (1998) suggests to add cases until the theoretical saturation is achieved. Based on these factors, 23 interviews were conducted in two districts in Volta region. And 16 interviews were conducted in Ashanti region.

4.4 Data Analysis

Ritchie et al. (2014) suggest to divide up the data analysis process into six steps: familiarisation with the data, identifying the themes that come up often in data, indexing those themes, restructuring the themes, and then finally analysing and interpreting it. Data analysis was conducted by coding the interviews obtained from the field into various themes and issues as they emerged during the review process. The table below summarises the key themes and sub-themes or codes that came up during the read-through of the interviews, which then also helped to structure the results section.

Table 1. Key themes and sub-themes of data organisation

Themes	Sub-themes
Farm size	Change in farm size Land tenure arrangement Productivity change
Farmer characteristics	Education of a farmer Cooperative or association member Cassava farming experience

	Marketisation of produce
Technology	Planting process Machinery Variety Weedicides/herbicides Fertilisers Input sources and prices Mobile phones Any other technology
Training and extension	A farmer's interaction with AEO Formal training experience Other government support
Environment and sustainability	Sustainable farming practices Effects of climate change

The list of codes was then reorganized based on the selected conceptual framework. For this purpose, NVivo software was used, which also helped to compare and triangulate the data based on the previously coded literature review, observation notes and other decrees and policy documents. This helped to analyse the obtained data holistically and also by presenting a bigger picture to the answers given by respondents. Data was presented as both descriptive generalized analysis, as well as short and long quotes from the interviews.

4.5 Validity and reliability

The biases and misinterpretation of collected data can be overcome by putting a proper triangulation strategy in place, which will ensure the validity of the acquired information (Ritchie et al., 2014). Triangulation means combining different methods, study groups, theoretical perspectives, as well as other settings. This allows to test the researcher's biases and assumptions. Triangulation of this study was conducted on a few levels. First, the research is designed so that besides the interviews, the document review was also conducted to check the observations and findings from the verbal data. A document analysis helps the researcher to better understand the studied events about the research problem (Bowen, 2009; Merriam, 1988). It allows for a more structured procedure of assessing and analysing the existing documents and is often applied in qualitative case study research (Bowen, 2009; Yin, 2017). Together with the literature review, the document analysis was the basis for constructing the interview guidelines. For this purpose, government decrees, policy and programmes as well as previous reports of government, non-government and international organisations in support of the agricultural development in Ghana were considered. The findings from the text data (transcribed interviews) were also complemented and triangulated using the researchers' observations of the farms, rural neighbourhoods and markets. The findings from the interviews with farmers were also enriched and double-checked based on the interviews with AEOs.

4.6 Limitations

The major limitation was the language barrier. Although the interpreters were briefed about the research, the importance of direct and accurate translation, it cannot be guaranteed that the interpretation was not skewed towards the interpreters' own knowledge and capabilities to translate. The transcripts of the audio interviews were also prepared based on only the translations during the interview, mainly due to resource and time availability. Exactly due to this reason, the researcher had to discard one of the interviews (interview 25). During the transcription process, which done with a help from a native Twi speaker, it was revealed that the AEO, who was helping to interpret on the field, was misinterpreting the words of respondents. The AEO helped to interpret that interview because the interpreter that came to the fieldwork together with researchers was not available. Upon the consultation with a Twi speaker, the transcriptions were found to be completely unusable, because the AEO interpreted the answer of the respondent differently, kept interrupting the respondents, and when conveying the questions from the researcher to the respondent, already presented questions in a skewed way, so the respondent has nothing left but to agree.

Another source of bias might come from the snowballing method of finding respondents. Since this research is conducted in collaboration with the University of Ghana, at the initial stages, the researchers made use of the University's contacts and resources. Another concern was ending up interviewing respondents only recommended by the MOFA representatives, since they have been used as gatekeepers to the villages and farmers. The bias might come from ending up interviewing farmers with the same characteristics. Therefore, the researcher found other contacts, including through networking, in order to get access to respondents other than those recommended by the AEOs.

4.7 Ethics

Ethics of the research process is important and helps to avoid doing harm for interviewees, maintaining their confidentiality during the data analysis, as well as ensuring justice in analysing the data. The full anonymization process was done in order to ensure the confidentiality of participants. According to EU's General Data Protection Regulation and Lund University research ethics, the researcher was not allowed to collect or keep any information that does not directly contribute to the research. Ethics rules also dictate that only data that expands knowledge and contributes to science can be collected and processed for research purposes, because if these criteria are not met, the research findings can be disqualified. The digital data and interview recordings have been securely saved in the Lund University portal LU Box.

5 Results and analysis

5.1 General characteristics of the farms

The researcher visited 5 communities in 4 districts in Ghana and interviewed 29 farmers and 5 AEOs. The districts visited were located in Volta and Ashanti regions. Unless otherwise mentioned, the generalisations and summary of the data is presented for both regions. Where the differences of the results between the regions or communities are substantial, this is stated clearly in the analysis.

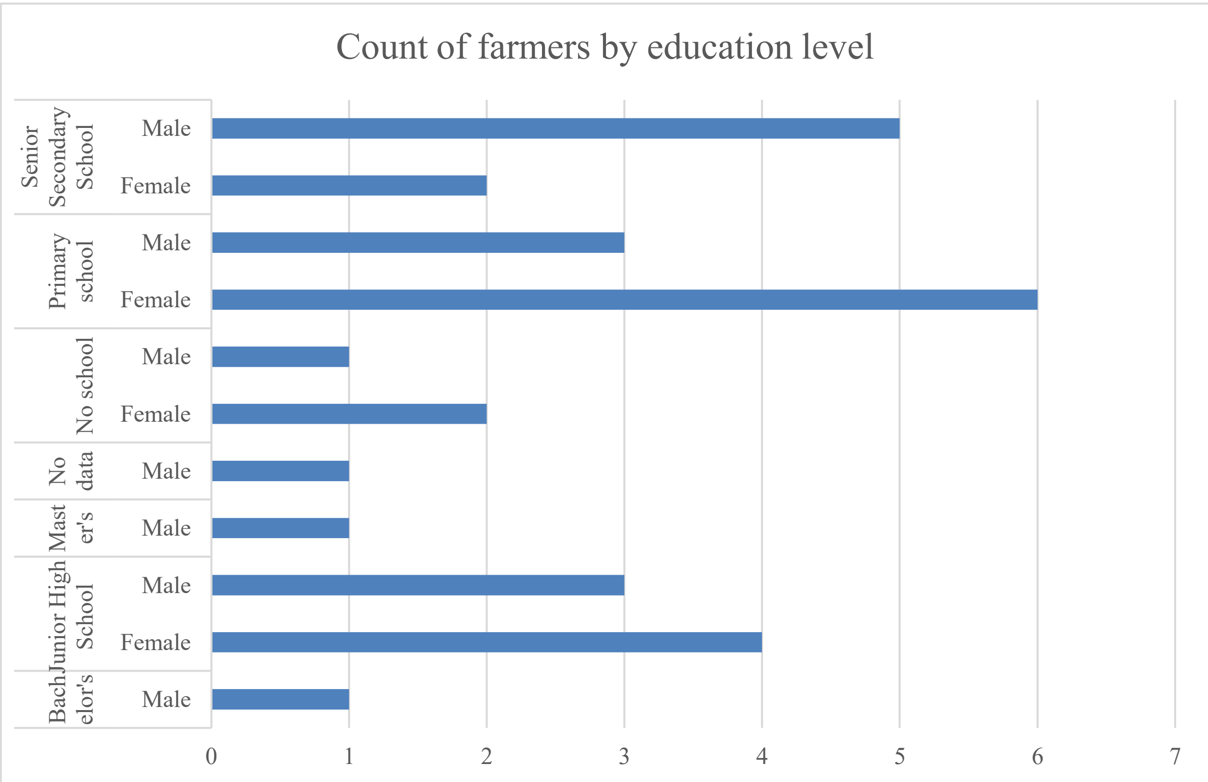

Figure 2. Last attained education level of farmers by gender among 29 interviewed farmers.

Talking about the characteristics of the farmers themselves, most were between the ages of 30-59, with 14 female and 15 male respondents. 9 farmers are primary school graduates, while 7 finished junior high school and 7 completed their education after senior secondary school (figure 2). Slightly over half of the respondents started planting cassava 10-15 years ago, while some others have been planting cassava since childhood (F09, F13, F18, F21). Few respondents mentioned that they have changed to cassava farming some time ago from planting cocoa (F26), tomatoes (F27) or cabbages (AEO05). They mentioned that they switched because of the limited availability of water for irrigation, particularly during the dry season, and the soil in that area supported cassava cultivation better.

5.1.1 Farm sizes and productivity change

The farm sizes varied considerably among the respondents. The majority were between 3-4 acres (1.2-1.6 ha) and 7 acres (2.8), even though there were some that would fall under lower medium scale of farm sizes and stood at 16, 25, 26, 50 and 100 acres (F04, F26, F19, F06, F01). In general, the farm sizes have increased from average 7.4 acres (2.9 ha) to 13.5 acres (5.4 ha). There was no noticeable difference in the size of the farms between the communities and the regions. However, despite the gendered balance among the respondents, the average farm size of female farmers (6,7 acres) is much lower than the male farmers (19,8 acres). Although, this is not enough to make conclusive arguments because of district differences of gender composition of respondents, still, this is in line with the general observations that usually women have less access to land, and men are more likely to inherit the family land (Byerlee, de Janvry & Sadoulet, 2009).

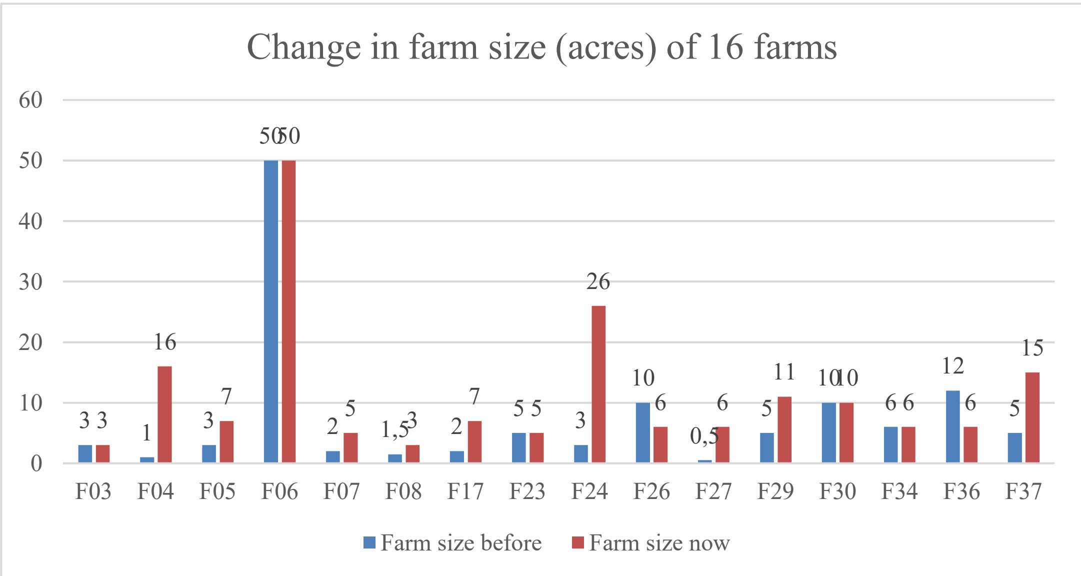

Figure 3. Farm size change (in acres) of 16 farms.

16 farmers could tell with precision on how big their farms were some time ago and now. Another important aspect worth mentioning is that while the increase in farm sizes is not uniform, the scale of the increase for most is considerable, for example from the initial 1-2 acres up to 10 acres. According to some farmers interviewed, there could be some reasons such as weather and rainfall patterns that could be limiting further expansion. For example, two respondents F16 and F38 said that they have the capacity to increase even further from current 10 and 15 acres to 20 and 25 acres of cassava respectively.

[interpreter]: "… because they are sure that if they farm, the rain will come and they will get enough harvest. That is why they were expanding, but recently the rainfall is erratic, you plough and you won't get rain, so that is why it seems they are stagnant around the 10 and 15 but they have the capacity to do to 20 and 25 acres".

Some respondents noted change in their farm size over a long period of time. Not all of them could remember or tell exactly how much their farms were 10 years or 5 years ago. Hence, the data collected on the change of the size of the farm is not uniform across all the cases presented here (figure 3). It can be seen from the data that for most family-owned farms, the land available for cultivation in the season depends on many factors, including on the resources available to start the cultivation process, such as money for labourers, to pay rent, hire a tractor, as well as some other personal factors such as age of the farmer, and the weather conditions and rainfall volume.

There are few respondents who noted a decrease in the size of the farm over long term. For example, having 100 acres of land, respondent F01 in Volta region said that he used to cultivate even bigger land, but due to his age, he does not have the capacity to cultivate bigger area. So was the answer of another farmer from Ashanti region (F21). A few other interviewees noted a temporary decrease of the current land under cultivation due to the land being left to fallow for some years. There was only one case (F28) in Ashanti region where the farmer had to scale down the production of cassava because there was not enough demand for the produce afterwards. So he had to reduce from 12 acres to 6 acres of cassava. As the interpreter said:

"He started with 12 acres, but he wasn't getting buyers for the cassava … so he had to discard about half of them [the land]".

About 5 farmers responded that they have not experienced any change in the size of the farm in the past 5 or 10 years. Most of these respondents had relied only on their family land, while renting land was also pretty common. In order to hire the land, in most places, but particularly in Ashanti region, the farmer needs to go to the chief of the community and ask for an empty lot of land to cultivate. Two types of rent arrangements were observed. The most common one is where the landlord charges from 100 to 300 Ghana Cedis per acre of land per year, depending on the location of the land and the quality of the soil. In another arrangement, the harvest is divided into three equal parts and the landlord is given one part, while the farmer keeps two parts (F25, F26, F05).

When asked if the yield the farmers get changed in the past couple of seasons compared to 5-10 years ago, the answers are mixed. When clarified further and explained that by "yield", the interviewer meant harvest per 1 acre of land under cassava, some farmers understood it as increasing the harvest overall, including through land expansion. That could also be indicative of the way farmers think of increasing the yield and the profit – the more land you work on, the more harvest you get. After the question was clarified, the answers were still mixed. One of the respondents (F01) who owns 100 acres of land said this:

"We don't have such particular details. We just know, well, you cultivate this place – if the yield is quite okay… we have not been too ordered to

find out whether this year increased or decreased, or go beyond what we cultivated previously. It depends on the size that you cultivate."

When asked about the yield, some farmers responded that they could not get much this year, because some part of their farm was under fallow (F26). This means that some farmers, instead of focusing on increasing the yield, they concentrate on land expansion in order to obtain more harvest and higher revenue.

Those who noted a positive change in the harvest they get from cassava connected it to different possible reasons, but mostly the new higher yielding varieties (F18, F05), tractors (F06, F07) and new planting techniques (F18, F27). Two respondents linked the increase of their harvest to applying fertiliser to their land after they have noticed signs of soil depletion (F15, F23).

Rainfall patterns have been mentioned quite often when asked about the changes in yield. From one side, it is beneficial when it rains more often for cassava to develop bigger and more tubers, but too much rain also creates waterlogs and spoils cassava (F10, F11). Hence, according to these people, the rainfall patterns heavily affect the yields and have been unfavourable during the past couple of years (F09, F19). Therefore, due to absence of irrigation infrastructure and dependence to rainwater, and erratic rainfall patterns, the farmers are sometimes reluctant to invest too much into farm inputs, fearing they will not be able to make enough profits to cover the costs (F29).

An important aspect worth mentioning is that a lot of farmers do not weigh their harvest, so some of them were not able to tell exactly how much harvest they get from an acre. Most common way of measuring the output was by bags of 50kg or 100kg, a full load of a tricycle or a full load of a tractor. That has implications for how farmers sell their produce as well.

5.1.2 Marketisation and processing

Marketisation of cassava harvest usually happens in one of two ways. First, farmers deliver their produce to the closest market or buyers come to buy from them on the spot. Another common way is also for the buyers to come and uproot the cassava themselves from the agreed plot of farmer's land. Sometimes the price for this arrangement is even negotiated in advance of uprooting.

Where there are small-scale processing associations exist, farmers try to process their cassava harvest into garri (granular flour), kokonte (fine flour texture) and cassava chips. 10 out of 29 interview respondents confirmed they belonged to an association for cassava farmers, although 6 of them were all part of the same association for small-scale cassava processors in the same community visited in Volta region (F12-17, while 3 were part of another association in Ashanti region (F19, F21, F22). The farmers see the benefit of processing cassava themselves before selling it in the market, because they can sell it at a higher prices (F19), thus creating a value added to their produce.

One more way farmers sell their cassava produce is to processing factories. There were middle scale processing companies in three locations visited. While first factory visited had lost trust among the farmers nearby by offering lower price than the market rate, the other two factories had active engagement with their outgrowers. Almost all factories had some of their own land where they cultivated cassava, and they provide tractor services or provide some of the inputs to their outgrowers. The cost of using their services is then later deducted from the price based on which the factory buys the produce from farmers.

Therefore, it is interesting to look at what technologies are available and how farmers are using them in cassava production, which is discussed in more detail in the next sub-section.

5.2 Availability of technology

Cassava can be planted any time during the rainy season, i.e. between March and October period, it can also be uprooted and used for consumption any time between 6-24 months depending on the variety. Planting is usually scheduled to have constant supply of cassava, particularly for domestic consumption of the farmer. Cassava planting process starts with preparing the land. If there are big tree stumps and thick grass, the land is usually burned to clear. After burning, if tractors are available around the area, then farmers do ploughing with tractors. Otherwise, they hire labourers to do manual tilling. Casual workers are hired again to do manual weeding. Sometimes weedicides and herbicides are sprayed on the cleared area before and sometimes right after the tillage. Often cassava is intercropped with other crops, such as cowpea, ground nuts, but mostly maize. After maize sprouted and somewhat grew off the ground, cassava stems are planted in between maize. Usually, fertiliser is not applied to cassava. However, fertiliser applied to maize also affects the cassava stems when intercropped. After cassava sprouts and between harvest, usually two more rounds of weedicides are applied, but sometimes just manual weeding is done when cassava plant is too young. Most of the uprooting of cassava is done manually, even on a commercial scale.

In the following sub-sections, more detailed discussion is presented on each type of technology used during the planting and harvesting process described above.

5.2.1 Mechanisation

Mechanisation and access to tractors was found to be the biggest challenge in cassava farming. Almost 100% of the interviewed farmers said they would like to have their land ploughed by tractor in preparation for planting if they had an opportunity. Only one community member in Ashanti region said that no one uses tractors in their community (F24), while another farmer from the same location said their land is fertile enough so they do not use mechanical tillage. Usually, the tractors can be found for hire by private individuals, who are often farmers themselves. They till their own land, and work during the season by providing tractor services to farmers around (F28). Several issues have been identified that limit the level of mechanisation in cassava farming.

For most of the farmers, hiring a tractor means convenience, and thus labour-saving, while few (F01) revealed that they also get more yield. In addition, using tractor also helps with weed control, since after mechanical tillage, the weeds take longer to come out again (F11). Respondent F19, who has 26 acres of cassava farm, told that they do manual tillage with hoe by hiring farm workers. He added that if they had any tractors nearby, they would even be able to extend their farm to 50-60 acres. However, even realising the apparent benefits of increased yield, if the tractors need to be sought out and hired from too far, the farmer decides not to attempt to do tillage by tractor, and does it manually. This decision is made due to added costs of bringing the tractor to the community (F01) or the tractors cannot even pass through to the farms on the roads (F11).

Another issue identified from the interviews in terms of access to mechanical tillage is the price. Depending on the demand and how clear and free from tree stumps the farm already is, the prices for hiring a tractor for ploughing in the beginning of the rainy season cost between 120 GHS to 260 GHS per one acre. For comparison, renting one acre of farm land also costs between 150-200 and rarely up to 300 GHS a year. Due to sharp increase of fuel prices in Ghana and around the world in early 2022, the tractor hiring services also increased in price. For example, the rates increased from 120 GHS last year to 170 GHS in 2022 as reported F29, or from 200 too 260 GHS this year in another place (F16). However, another related issue is the tree stumps on the farm. The interviews were conducted in southeast and southwest forest agroecological zones. Hence, clearing the land often involves removing the trees, but removing the tree stumps completely from the farm involves other machinery. However, tractors usually do not want to work on these farms because it damages the harrow attached to a tractor for tillage. Hence, the tractor owners either do not service those farms, or the service price is higher than average.

Limited number of machineries also affect the timing of planting and eventually the harvest. Even at places where there are a few tractors which can be found in neighbouring communities, farmers usually have to wait in long queues to hire a tractor (F012, F23). In one community in Volta region, where there were no tractors, but was situated close to the road, the farmers go on to the road during the ploughing season and wait for a tractor to pass by to ask them to come plough their land (F15) or they go out to the street when they hear one passing by (F13).

> *Interpreter: "They stand by the road and if the tractors are passing then they call them. But they also have their contacts so if they want to plough then they call them or go to the big town called Mafe-Kumase to go and get someone to plough their farm".*

A farmer from another community (F23) in Ashanti region said because there are only few people around the community, who have the tractors, the tractor owners also consider only people close to them, i.e., their friends and family first. That is why, sometimes they travel at night to talk to the tractor owner (F12), or have to go to the machine operator multiple times to convince them to come to the farm (F17). This has implications for when the farmer plants the crop if they keep waiting for a machinery turnaround, and the harvest time later on. This happens because the farmers need to find an optimal time during the early rainy season for cassava to get enough rain water before the dry season starts, and before the peak rainy time so that the land is soft enough to plough, but has not yet turned into mud from excessive rain water (F18).

5.2.2 Planting in rows

An aspect of cassava farming that was not considered in the initial interview guide, but that was mentioned quite often by the farmers was planting techniques, and specifically planting in rows. The farmers noticed considerable increases in yield when they shifted to planting in rows, which basically means sowing the plant in straight lines with a certain interval between each one. Previously, farmers were sowing the stems anyhow, not following any particular direction or pattern. A farmer from Kruwi community in Ashanti region (F27) said this new method helped him increase his yield, since instead of 100 stems, he can now sow up to 150-200 stems per acre. Another advantage of this method is that it allows each stem to develop fully and get harvest from each seed, because the air passes through the farm (F18). The farmers also benefit from this method in weeding and harvesting, since equal intervals between the stems allow enough room for a farmer to weed the farm (F19).

However, there is a noticeable regional difference in the time period the farmers learned the method of planting in rows. A farmer from Kruwi community in Ashanti region said he was taught planting in rows by AEOs *"last year [2021]"* (F25), while another farmer from the same location said she wishes to learn how to plant in rows (F24), when asked what kind of technologies she would like to have access to. In contrast, a farmer from Volta region said he was taught planting in rows about 6 years ago (F05).

5.2.3 Fertilisers

10 out of 29 farmers said they try to apply fertilisers for their cassava crops. The most common types of fertilisers used were NPK 15-15, Urea and Ammonia. Interestingly, most of those who were part of cassava producer's associations in Central Tongu district in Volta region and Sekyere Central district in Ashanti region used them specifically for cassava. And those who said they do not use it for cassava were from districts where there were no functioning cassava associations. According to respondent F13 at Central Tongu district, once they join the association, the agreement is that all members start using fertilisers. However, they still cannot apply them regularly because of high prices. Respondent F15, who belongs to the same association said:

> *"continuous cropping on the same land deplete the nutrient there, so by application of fertiliser, you make sure that you definitely get something [harvest]".*

11 respondents said they do not or have never used fertilisers on cassava (including those who intercrop with maize). Fertilisers are mostly used for maize and other crops. And particularly,

when intercropped with maize, they believe that cassava stems then pick up some benefits of fertilisers. The AEO of one of the districts also said they were encouraging the farmers not to use inorganic fertilisers and to shift to organic manure (AEO04). The author's observations and the interviews from that district clearly show lower level of fertiliser application. Respondent F23 from the same district confirmed the AEO's statement that they apply either store-bought fertilisers or organic manure on the farm, and that they see the difference in the yield.

The farmers gave multiple reasons why they do not apply fertilisers. The most common answer was that the land was fertile enough and they did not see the need for them (F01). One of the farmers in Ho municipality of Volta region said they applied fertilisers in a small amount 2 years ago when the price dropped due to the subsidy from the Ministry of Agriculture. He added that afterwards they were not able to get those or find fertilisers by themselves, so they stopped using them. Another farmer (F24) from Kruwi community in Ashanti region said he believed that the fertiliser application makes the cassava harvest rot underground even before harvesting. According to the AEOs (AEO02), price is the biggest deterrent for farmers to use the inputs such as fertilizers. Because a couple of years ago, the fertilisers were provided at reduced prices due to state subsidies, price for the NPK brand of the fertiliser jumped from GHS 55 (9.5 USD as of March 2021) in 2021 to GHS 200 (28 USD as of March 2022) in 2022 for a 25kg bag (AEO02). Although, the aftereffects of the COVID-19 and economic turmoil around February-March 2022 also have a play in it.

These examples are presented here not to argue in favour of or against fertiliser application for cassava, since the AEOs and farmers know better the soil quality and nutrient capacity of the land they work on. The purpose here is to show the diversity of the answers, and farmers' perceptions of fertilisers. An AEO from Volta region (AEO02) said they are not convinced about using fertilisers on cassava. It is a crop to be eaten, and since the tubers are dug up from the ground during the harvest, they believe the residue on the tubers will make it unsafe to eat the produce. Most AEOs said they believe their land is fertile enough, so there is no need for fertiliser use. In addition, a close correlation can be established about farmers' perception and the AEO suggestions, which varies from community to community.

5.2.4 Variety

The most popular varieties of cassava among the interviewed participants were Ankra, Osionka, Tek in Volta region, and Ampong, Sika, Tek, Isambankye in Ashanti region. In total, there are about 27 types of cassava varieties that the farmer group knows of in Sekyere Central district of Ashanti region (F19). According to the farmers, Osionka matures in 8 to 12 months, Ankra – 1 year or more (F11), some even take from 4-5 months to be ready for harvesting depending on the land (F11, 12, 17). Local old varieties of cassava used to mature from 1.5 to 2 years (F01). So faster time for reaching maturity was one of the important factors for farmers to adopt the new varieties.

It is already known, that the type of land and soil quality have substantial effect on the maturity and taste level of cassava (FAO, 1977). Cassava develops higher acidity level in drier areas, and the same variety can result in different taste (F12; FAO, 1977). Most often a farmer has different types of cassava on their farm at the same time. That is because the varieties for domestic consumption are different from those they sell to processing companies. Hence, the taste and purpose of use after harvest also made an impact on the choice of cassava to plant. Another factor that affected the decision to adopt was increased number and weight of tubers (F13, F15, F21). A farmer from Volta region said that the old ones used to give 3-4 tubers, while with the new varieties they can get up to 10-15 tubers (F18).

5.2.5 Weeding and weedicides/herbicides

Weeding is a more tedious part of cassava planting and farming in general, where farmers need to keep removing the weeds and herbs that come out in the farm naturally. If weeding is not done properly, it limits the growth of the crop, and harvesting becomes difficult as well. There are some ways that farmers can do for weed control. According to the respondent F01, the weeds come out slower in the area that has been left for fallow recently. Another farmer mentioned that when the ploughing is done mechanically, it also helps for weeds to grow slower (F11). Most often farmers also burn the land before ploughing. That is used to kill thicker grass and bushes (F19). But so far the most efficient way of weeding is applying weedicide and herbicide chemicals on the farm that limits the growth of weeds.

Farmers unanimously agree that applying weedicides is the most effective way, which helps farmers to extend their farm sizes, saves farmer’s time and cash to hire labourers to do weeding. On average, farmers started applying them about 4 to 6 years ago. Although, even by applying weedicides, depending on the location, manual weeding needs to be done between two to four times before harvesting the plot. When applying chemicals, if a farmer does not have the protective gear and the spraying machine (often in a form of a rucksack), they hire labourers who own those. Still, nearly all farmers agreed that it is more expensive to hire farm workers for weeding than buying chemicals, despite all of them mentioning about high prices for weedicides/herbicides.

Farmers in Ashanti region were slightly more sceptical of using chemicals, particularly after planting compared to those in Volta region. Some farmers from Kruwi community in Ashanti region believed that using chemicals to remove the weeds after cassava is already planted in the ground spoils the tubers. Therefore, they did only manual weeding after planting, and applied chemicals only once before or after ploughing the land (F24, F25, F26, F27). This belief seems to be supported by their local AEOs (F27). Another farmer from Woraso community (F29) of the same region said he prefers not to use weedicides.

> *“[Interpreter:] He said, what they realised is when they use the weedicides to weed under the cassava the leaves started folding and then the tubers sometimes is not good for consumption”.*

In contrast, the farmers in Volta region have mentioned that they only start applying chemicals when cassava has grown enough off the ground, usually allowing 2-4 weeks or even 6 months before applying the weedicides again (F01, F06, F07). They manually weed the farm up until that time.

5.3 Learning and access to information

The interviews identified several ways the farmers receive information and learn about new technologies and their applications. Farmers receive most of their new knowledge and skills through contact with AEOs, then to some lesser degree with processing companies, owners or vendors of agro-inputs shops, as well as NGOs and micro-finance institutions. There was no noticeable difference in technology adoption levels based on famer's gender.

5.3.1 Extension services

AEOs seem to play major role in how farmers learn new technologies and upgrade their knowledge. When asked about the types of agro-inputs and how farmers learned to use them, almost all of them mentioned the AEOs. There were only few farmers, who said they do not learn anything from anyone, and only rely on their own knowledge and experience (F08, F25). Most often farmers mentioned that they have learned about the weedicides and fertilisers, which type to use for which crop and how to apply them from AEOs, whether through one-to-one contact or trainings provided by the latter (F02, F03, F05, F06, F012, F14, F19, F22, F23, F26, F27, F28). That also sometimes included aspects of applying chemicals, such as to wear protective garment and how to dispose of the containers of chemicals (F06). Farmers also attribute their knowledge of the new varieties of cassava and planting in rows to trainings received from the AEOs (F06, F12, F13, F19, F21, F27, F28). The subsidised inputs and some cassava varieties are also distributed by AEOs sporadically and in some small quantities (F01, F19).

In most communities, close connection has been established between the AEOs and farmers and they turn to AEOs with issues that are even sometimes out of their scope of job responsibilities. For example, a farmer from Hodzoga community in Volta region said they also discuss other farming issues they have with their officer, such as their limited financial resources to extend their farm (F03). The AEOs not only provide advice on the production process, but also cassava processing aspect. For example, an AEO from Central Tongu district of the same region advised the farmers to add coconut and soya beans to fortify the gari they produce (F012). Respondent F16 said that the same AEO helps him to negotiate payment arrangements with owners of the agro-input shops.

> *[Interpreter]: "Sometimes, they don't get the money immediately to buy [fertilisers] but because the agric officers [AEOs] know the shop owners and those people, they are able to liaise with the shop owners. So, they will lease it on credit in time, so they use."*

5.3.2 From the perspective of the AEOs

According to the AEOs, they mostly face two major challenges in providing their services to the farmers – financial and transportation. Because a lot of the foreign funding reaches the actual field in May/June, e.g. based on the donor's start of the financial year, it might be too late in the rainy season to start planting some crops or supporting the farmers through various programmes (AEO02). Another challenge that was quite often mentioned was the difficult access to the farms, either because of the quality of the roads to some of the farms or the absence or limited availability of the modes of transport (AEO02, AEO03, AEO04, AEO05). Those staff that were given motorbikes (some received through Canadian funding (AEO02)), are only partly reimbursed for the fuel costs (AEO01, AEO03). However, it was surprising to see that the reimbursement amount for fuel costs varied drastically between the regions. An AEO in Volta region said he receives GHS 200 (approx. 28 USD as of March 2022) per month (AEO01), while the one in Ashanti region said he receives GHS 90 (approx. 12.5 USD as of March 2022), which would be enough for two days of work (AEO05). Another challenge they mentioned was the number of farms and farmers they need to service – between 1,000 and 2,000 farmers were mentioned. The average statistics for Ghana is about 1,500 farmers per officer and they had 5 officers in one of the districts in Ashanti region (AEO03). With the advancement of the communication technologies, it is also quite often when the farmers call the AEOs for particular advice, or send a picture of the disease on the farm by WhatsApp (AEO04). If the AEO does not know the disease, they visit the farm, try to study it, and sometimes send it to the regional offices for agronomists' inspection (AEO02). Radios were also found to be an efficient means of dissemination of information about the new technologies and agricultural policies (AEO02, AEO03).

In terms of the technology adoption by the farmers, the AEOs consider the prices of inputs as the biggest deterrents. Sometimes, even the subsidized fertilisers and weedicides are too expensive for the farmers. These policy and programmes are set up to lower the prices of inputs to encourage the farmers to try using the inputs and see the difference in order to integrate these into sustained practices. Another AEO (AEO02, AEO05) mentioned that traditional ways and risk-aversion major obstacles for farmers not to adopt the new technologies. They also fear that if they invest in expensive inputs at the beginning of the farming season, and they will not have enough rainfall that year, their harvest will be poor and instead of making profit, they actually go into debt. Often, the farmers are also hesitant to cultivate new varieties of cassava, fearing that it will be difficult for them to sell those compared to the old varieties that they already know will generate at least some demand after the harvest (AEO02, AEO03). AEOs (AEO03, AEO04) also complained that sometimes the farmers gain distrust to new technologies, because they do not apply them in correct proportions because of high prices and end up seeing no increase in the yield. In another community, AEO (AEO04) also said the farmers do not attend the trainings organised for them. All AEOs find the practical in-person demonstrations of the cultivation process and results to be the most effective and convincing way for farmers to adopt the new technologies.

The AEOs themselves go through trainings regularly – once a month at a district level (AEO01, AEO02), and once a quarter at a regional level (AEO03). Some extra trainings could also be organised if there is a new disease spreading around the farms (AEO04). However, in some other district, the AEO (AEO05) said the trainings are organised only at the beginning of every season.

5.3.3 Other learning and access to information

Other common way for farmers to learn about the new technologies were through processing companies. The farmers adopt the new varieties of cassava and start growing those varieties requested by the companies. For example, a popular Tek variety of cassava matures faster than older local varieties and was introduced by one of the leading factories producing ethanol from cassava. The processing companies also make contribution to cassava production by providing machinery, seeds and stems to plant, weedicides and fertilisers. The cassava processing companies often provide trainings for their contracted outgrowers on the new varieties of cassava and the use of fertilisers and weedicides on their farms (F06, F07, F11, F28, F29). Hence, one farmer can have several types of cassava at the same time depending on the purpose, e.g., for domestic consumption, processing into gari, processing for starch, etc. A farmer from Volta region says the training he received from the processing company was useful and he learnt not to mix different varieties of cassava on the same plot, but to have separate plots of land for each variety (F07).

Information on which type of weedicides and fertilisers to use and how to apply them and at which stage of cassava growth, was also provided by the shop owners. In fact, it was quite often mentioned by farmers that AEOs in particular districts were not satisfied that their advice was being ignored over the recommendations of the agro-shop vendors (AEO05). AEO05 also added that:

> *"The early adopters believe in extension officers and the late adopters rely on agro-chemical sellers for advice".*

The agro-input shops advise the farmers on the products they sell, and inform them how to apply, in what quantities, etc. (F03, F09, F11, F15, F16, F17, F23, F24, F27).

Surprisingly, very few people mentioned about learning from other farmers and community members. They mentioned that they had learned about the new varieties by talking to other farmers in the community (F01, F03, F04), by observing other's farms and how their cassava is growing (F11, F25), as well as through associations (F016, F19, F22). Only one person said he applies the chemicals by reading the instructions on the container (F25). Some farmers also mentioned that other members of their community come to them for advice because they have won the district or regional awards by MOFA on "Best cassava farmer of the year" (F19, F26).

Being a member of an association for cassava processing also affect positively the adoption of technologies. The learning process is extended by being in the group both by learning from other group members, as well as receiving trainings by AEOs and other organisations (F016, F19, F22). Some associations of cassava processors also make a requirement for their members to apply such technology as fertilisers on their farms (F013).

A farmer in Ashanti region (F28) mentioned he had received some training in cassava farming from a local bank "Opportunity Bank", which specializes in micro-financing in agricultural sector. The bank also provided some soft loans to the farmers. Other organisations briefly mentioned by farmers include Kwame Nkrumah Science and Technology Institute and Crop

Research Institute, both of which visited some farmers in Ashanti region, but there was no indication of trainings being provided by them (F29). AEO 20 also mentions that sometimes they cooperate private companies offering extension services, they introduce them to the farmers, and other times it is some chemical companies who come to promote their products and teach them how to use their products.

6 Discussion

This section will try to directly answer the main research question of this study *"How does the use of technology change on cassava farms in Ghana in the process of agricultural transformation?"*. To answer this question, we need to put all the pieces of the puzzle together, i.e., by bringing in the conclusions from the results section, conceptual framework, literature review and the earlier provided background for Ghana's economic development and agricultural technology.

6.1 Progress and challenges in technology adoption

Technological change in cassava farming in Ghana is happening unevenly across time, space and sometimes farm sizes. While some farmers have learnt planting in rows a couple of years ago, or even 5 years ago, there are still few farmers who said they wish to learn it. More progress has been achieved in labour-saving technologies, which can also be seen from the increased demand for tractors and weedicides. The weedicide application methods and frequencies were different among respondents in different districts and regions. Access to tractors and other machinery remains a huge challenge for farmers, and particularly for smallholders. Apart from costing farmers an arm and a leg, finding and hiring tractor services during the planting season is extremely challenging and burdensome. The farmers who are located close to cities and towns, even those close to the highways, have more advantage of getting their land ploughed mechanically, than those whose farms are located in remote villages.

Land expansion together with some policy interventions, urbanization and increased non-farm income opportunities were found to be some of the enablers of the mechanisation and adoption of some other technologies in Ghana (Diao et al., 2019). Mechanical ploughing helped some farmers to increase their farm sizes, while lack of access to it is inhibiting others from cultivating to their potential. Interview results find that most of the tractors owned by few farmers in the communities are imported second-hand tractors, as was also mentioned by Diao et al. (2019). The authors criticised the previous government programmes such as AMSEC for distorting the market, the results of which can still be seen in the supply-side issues in this mechanisation process. According to their estimates, Ashanti is one of the least mechanized regions with 10% of farmers reporting to use machinery. Based on the interviews, however, no noticeable differences in mechanization level was found between the Volta and Ashanti regions.

Other types of inputs such as fertilisers and weedicides are supplied by the private sector, but come at high prices for farmers, sometimes even after the government subsidies through targeted policy programmes. This decreases famer's willingness to try and adopt new technologies. Investment into irrigation and other large infrastructure objects are necessitated by the effects of climate change and decreasing rainfall volumes. This is another reason for why farmers' risk tolerance level is high when it comes to trying out costly technologies. If they buy costly fertilisers, and they don't get enough rain that year, their expenses will not be covered. In other words, financial barriers, even despite the governmental subsidies, decrease the attractiveness of production-enhancing technologies delivered by the private sector.

Although lately slow changes are happening in the power shift of land allocation from community chiefs to local authorities in much of SSA (Diao et al., 2019, p.227; Jayne et al., 2016), still land tenure system and security of property rights is another reason why farmers are not willing to invest into the land. Interview results show that most farmers have their land inherited from their parents, and when they need to expand they obtain some fallow land for 5-6 years with permission from the local chief. Change in land allocation system has started to move away from rights-based customary approach, thus creating land markets, where it "becomes a commodity for rent or sale" (Jayne et al., 2019). Other than cocoa industry, farmers cultivating other crops have little credit options, and often have to borrow from relatives and traders (Diao et al., 2019, p.224) or sometimes within their farmer associations.

One way the smallholder farms are responding to the technological challenges is by creating farmer-based associations for specific crops. In some of the communities visited, the farmers were part of the cassava processing associations, in which they both teach and learn from each other, but also utilise their collective bargaining rights by setting same farm-gate price. In one of the districts visited, women's farmer-based associations had received a grant from foreign aid to establish a small-scale cassava processing factory. This gave them an opportunity to process cassava into gari, kokonte and other products, and sell at higher prices at the market by creating a value added to their produce. High urbanization rates are expanding demand and creating market for post-harvest processed cassava products.

Processing companies were particularly impactful in terms of introducing and buying the new varieties of cassava. There is not much direct engagement of farmers with research institutions, unless it is through AEOs. This lack of interaction between the actors in the system can cause bottlenecks in the transformation process. The crop research institutions usually engage more with the processing factories, who then pass on the new varieties and other technologies to farmers as their outgrowers, thus creating backward linkages.

The technology adoption process is also affected by the changing global trends and farmers are vulnerable to recently distorted supply chains after the pandemic for the availability and affordability of inputs. Almost all agro-inputs increased by at least double of the amount from in 2022 compared to the previous year (fertilisers, weedicides), while fuel prices were also increasing sharply during the fieldwork and after, which would increase rates for tractor services.

6.2 Farm sizes and productivity increase

Diao et al. (2019) and Jayne et al. (2016) agree that the farms in Ghana have grown larger in size, while the small farms of less than 2ha still dominate. They assert that the share of middle-sized farms (2-20ha) has been increasing at the expense of small and large farm sizes at a national level. Though the regional divide is striking - in the north, medium size farms now account for over 60% of all farms, but in contrary, the proportion of medium-sized farms are decreasing in the north, while small farms are increasing (Diao et al., 2019). Jayne et al.'s (2016) findings give more of a national level picture. Of the data that the researcher was able to obtain through interviews with farmers, there is an indication that over the past 5-10 years the farm sizes have grown almost double from average 7.4 acres (2.9 ha) to 13.5 acres (5.4 ha). Although, now the average farm size – 5.4ha is right on the margin of being classified as middle size (5-100ha), still the trend shows growth in size.

Diao et al. (2019) find that the farmers in Ghana have been adept at responding to expanding market opportunities and shifting to market-oriented crops by expanding the operated farms, both by shorter fallow periods and acquiring more land even in distant communities. The interview results confirm that most of this land expansion was possible owing to the labour-saving technologies, such as tractors and the use of weedicides, which corresponds to the study by Yaro et al. (2021). Jayne et al. (2019) provide four main reasons for why the farm sizes are increasing in Africa: expanding land markets, increased global food prices, more efficient agricultural policies and increased voices of the farmer unions.

However, there is some difference in how different farm size owners are learning and getting access to new technologies. The owners of small farms are facing access issues in that they are at times being deprioritized when it comes to access to learning and technology, i.e., when the AEOs gather smaller groups for training activities, they select more commercialized bigger farms and who are better integrated into processing and the value chain production. Tractor owners also prefer to service the bigger farms for efficiency purposes, in order not to waste time moving in between the different farms, and also for more efficient use of fuel. For example, a recent study (Janulevičius et al., 2019) finds considerable fuel and time efficiency savings when larger farms are ploughed compared to smaller ones. They find that ploughing of fields with lengths of 200, 300, 500, 750, and 1000 m resulted in time efficiency values of 0.56, 0.67, 0.78, 0.84, and 0.88, respectively.

This study findings also indicate that there are advancements in labour-saving technology use, such as weedicides. However, there are evident challenges on the land productivity questions. This is in line with Ecker's (2018) research, who asserts that land productivity did not grow as much in Ghana, because increased production is occurring due to land expansion, by clearing virgin forest and shortening fallow periods. Interviews clearly show that farmers try to expand the land they cultivate the crop and prefer extensive farming, rather than increasing output from the existing land. That in turn increases their labour hiring costs and expenses to buy chemical inputs to cover larger area. Only few respondents linked their increased output to the use of fertilisers.

6.3 Learning and extension

Timmer (1988) asserts that truly profitable innovations can spread regardless of specific efforts, if there is right economic environment. Same can be observed in this study - the diffusion of the Tek variety of cassava, which matures much faster and yields more tubers, spread quite quickly and almost every farmer had Tek variety among others. However, government research and extension services are still required to adapt some location-specific innovations. This will help to make them less financially burdensome for farmers while ensuring more equal access to them. Hence, the governments' agricultural policies cannot be underestimated, both to drive productivity growth, but also to address poverty and marginalisation among smallholder farmers. If the diffusion of planting materials such as new varieties can spread more or less without intervention, however, more knowledge-intensive technologies, such as planting in rows still require training and extension. This means that productivity improvements per unit of land can be acquired from requiring both high (planting in rows) and low (planting new cassava varieties) interventions.

The literature review and background sections provide a number of recent studies, which find that the extension services in Ghana are quite efficient, which corresponds to the findings of this study. Interviews establish that AEOs' main responsibilities include dissemination of the information about the new technologies and new ways of farming, linking farmers with researchers, acting as a knot in the value chain, as well as implementing government agricultural policies and reporting back. Despite the systemic underfunding, the extension services are quite efficient in fulfilling their objectives. AEOs seem to play major role in how farmers learn new technologies and upgrade their knowledge on farming techniques. Almost all farmers mentioned they learned the new technologies from AEOs, and most are in regular contact with their AEOs. They themselves also face a number of challenges, including transportation issues and thus not being able to access the remote areas and farmers, which is also highlighted in the study of extension services in Northern Ghana by Antwi-Agyei and Stringer (2021). Higher penetration of mobile networks and internet, however, is helping both farmers and the extension agents. If farmers have any disease on their farm, they can just send a picture to their dedicated AEO for advice, and AEOs also find it easier to contact farmers by phone or messaging to invite to trainings or disseminate any news or information.

However, in the long-term there might be a need to reduce the influence of the extension officers as the first contact point for farmers and make room for farmer-market relationship to develop, i.e., food processing companies might want to directly engage with farmers to dictate the conditions for the varieties and standards of production. While privatization and commercialisation of the extension service is slowly taking off, in most places the private sector actors concentrate on specific commodities or value chain gains or assist commercial farmers, which again benefit mostly medium- and large-sized farmers, bypassing the smallholders (Nwafor, Nwafor & Ogundeji, 2020).

Other common way for farmers to learn about the new technologies were through processing companies. The cassava processing companies often provide trainings for their contracted outgrowers on the new varieties of cassava and the use of fertilisers and weedicides on their farms. Processing factories were particularly impactful in terms of introducing and buying the new varieties of cassava. The agro-input shops also advise the farmers on the products they sell, and inform them how to apply, in what quantities, etc. Although, sometimes their advice is discredited by the AEOs in some districts. Being a member of an association for cassava processing also affects positively the adoption of technologies. The learning process is extended by being in the group both by learning from other group members, as well as receiving trainings by AEOs and other organisations. Some associations of cassava processors also make a requirement for their members to apply such technology as fertilisers on their farms. Surprisingly, very few people mentioned about learning from other farmers and community members. Those few farmers mentioned that they had learned about the new varieties by talking to other farmers in the community, by observing other's farms and how their cassava is growing, as well as through associations.

6.4 Agricultural transformation and technological change in Ghana

What triggers the agricultural transformation process is more efficient use of land and labour resources in order to create linkage with other sectors of the economy, which ultimately results in the structural change. According to Timmer's (1988) four phases of agricultural transformation, after the labour productivity increases, the factor (e.g. labour) and raw materials start are supplied by agriculture to other manufacturing industries. We can see that in Ghana's example, there are some signs of increasing labour productivity and to some degree land productivity. However, there is still a huge potential for further increase. This study shows that the value added of the agricultural sector is slowly increasing with farmers realizing the potential benefits of own processing or engaging with processing industries.

Forward linkages are being created with the industry through processing cassava into other materials for manufacturing such as ethanol, glue, pharmaceuticals, bakery, confectionery, cardboard and wallpaper manufacturing, paper and textile industries, among many others (Mbanjo et al., 2021), thus expanding the markets and consumer products. This has implications for the overall economic growth in the country, which, according to the Modern Economic Growth theory, is defined by the increase in capacity to produce various economic goods for consumers. Additionally, the economic potential of cassava production is not limited to just food production, but is also increasing the resilience of the local economy as well as its sustainability through small-scale processing and commercialisation.

Timmer (1988) highlights the importance of the technological change during the transformation process to understand its source, dynamics and impact. In this regard, if we apply Ruttan and Hayami's (1973) induced innovation theory to the case of Ghana, we can see that because of land availability and increasing labour shortage labour-saving technologies are developing faster. Ruttan and Hayami's (1984) study into the differences between land and labour productivity changes in many developing countries in 1960-1980 clearly indicate that faster labour-productivity growth is expected. In Ghana's case, this is happening partly because more labour is moving into the urban areas, and the increase in the standard of living is making the labour cost for farmers more expensive. Diao et al. (2019), contend that induced innovation might be happening in specific urban areas in Ghana, but not overall at the national level. They add that keeping the induced innovation hypotheses in mind, urbanisation has not affected the agricultural intensification process as much other than influencing non-rural wages. However, this study findings indicate that urbanisation is also expanding the market for raw and processed cassava products.

6.5 Environment and sustainability

The intensification process should be well thought-through. The green revolution in East Asia resulted in multiple environmental problems, such as agrochemical pollution, mismanagement of water resources, deaths from pesticide poisoning and biodiversity loss and deforestation (Byerlee, de Janvry & Sadoulet, 2009). Based on the interviews, the farmers do not use fertilisers for cassava with belief that their land is fertile enough or the portion they used for maize will also be picked up by cassava since it is mixed cropped. However, recent literature (Diao et al., 2019; Giller et al., 2021; Jayne et al., 2016) all point towards declining soil quality for all crops due to shortened fallow and mono-cropping on commercial scale. Conservation tillage and other sustainable agricultural practices are being utilised more often now in some countries as India, Bangladesh and Nepal, yielding plausible results in improving the soil organic content.

However, these practices require extensive training of both extension agents and farmers, which cannot happen overnight. They are also considered to be knowledge-intensive, requiring in-depth research and development capacity by the government to study and adapt these practices and technologies to local agro-ecological conditions. These should consider the indigenous practices of maintaining soil fertility, such as rotation of specific crops in a particular area and mounding or ridging (e.g., when preparing cassava or yam plots) which can be an alternative to mechanical tillage. Otherwise, these conservation innovations might lose the trust of farmers in extension services and new technologies altogether. Hence, the study by Antwi-Agyei and Stringer (2021) identified multiple capacity building needs of extension agents, including the use of ICT and climate-smart technologies. Analysing the climate change discourse and actions of the government of Ghana within the agriculture sector Sarpong and Anyidoho (2012, p.10) suggest that the dominant narratives in this area focus on the hope for “triple wins” – to “reduce emissions, reduce vulnerability to climate change effects through adaptation, and promote economic growth and development”. The authors contend that while there are several initiatives and policy suggestions from the government, their implementation are challenged by the different interests of the stakeholders.

7 Conclusion

The present study provided some insight into the agricultural transformation process in Ghana by looking at the technological change process in cassava farming based on the primary data. The objectives of the research were to explore the type of technologies used in cassava farming, investigating how farmers learn new technologies in order to gain understanding of the agricultural transformation process which is happening in Ghana on a local level. The aim of this study was to answer the research question of "how does the use of technology change in cassava farming in Ghana during the process of agricultural transformation".

The conceptual framework of this study established the phases of the agricultural transformation and processes of the technology utilization and adoption with expanding farm sizes and a proxy for agricultural transformation and learning and extension as an institutional basis for adoption. Conceptual framework also highlighted some common challenges in technology utilization and specificities of the agricultural transformation processes happening in Sub-Saharan Africa, and in Ghana.

Using the exploratory qualitative research method and based on the interviews with 29 farmers, 5 AEOs and 1 factory representative, this study investigated which types of technologies do farmers use and what challenges and opportunities they have. New varieties of cassava, initially introduced by processing factories to outgrower farmers, made considerable impact on the productivity of the farmers, both in terms of production volume and decreased harvesting time. Increasing demand for mechanization and widespread use of the weedicides are major enablers of the increasing farm sizes. Learning to plant in rows also enabled the farmers to increase their productivity. The attitude and demand for fertilisers were varied among the respondents, however, over time this might change due to deteriorating soil quality and climate change. There are supply-side issues with responding to high demand for tractors, which is expensive to hire and get access for farmers. Farmers also face challenges in access to chemical inputs due to high prices and price volatility. Small-scale post-harvest processing of cassava is creating linkages with other sectors by providing food products to urban residents, as well as supplying cassava materials for manufacturing, such as ethanol, cassava flour, and others.

The data on the farm size changes is broadly consistent with recent literature, which indicated increasing farm sizes and rise of middle-size farms in Africa and Ghana. The results of this study (based on the available data) also confirm that farm sizes increased from 2.9 to 5.4ha in the locations visited. Most researchers agree that the within-sector productivity increase is happening owing to labour-saving technologies rather than land-saving ones. Hence, as per induced innovation theory, relative land-abundance compared to labour shortage has resulted in more demand for labour-saving technologies, such as mechanical ploughing and use of weedicides.

Several methods for farmers to get information and learn about new technologies and their applications were found during the interviews. Farmers gain most of their new knowledge and skills through AEOs, and to a smaller extent from processing enterprises, proprietors or sellers of agro-inputs stores, as well as NGOs and micro-finance organizations.

Technological change in the agricultural transformation process is being partly driven by several institutions, such as the extension service, (which has been fairly successful), farmer associations, as well as through direct and indirect cooperation of farmers with agro-processing activities. However, technological change process is also being constrained by the lack of macro-scale policy and climate change adjustment policies, such as creating access to irrigation systems for farmers. This could also help mitigate the effects of climate change in the long run, while providing the farmers with security and stability in their farm investments. Immediate implementation of sustainable farming practices are evident from the deteriorating soil quality.

The results are of direct practical relevance. According to Timmer (1988), the reason for differences in agricultural productivity among countries can lie in different resource endowments, use of technical inputs (such as fertilisers and mechanical power), human capital and technical knowledge, and different size of farms. Ghana is blessed with resource endowments in land and favourable agro-ecological climate. At the same time, Ghana's investment into human capital through general education and technical agricultural knowledge dissemination is yielding its early fruits in the form of early stages of agricultural transformation in the country. Addressing the access issues to some of the technologies, focusing on large infrastructural investments and integration of sustainable agricultural practices would ensure these growth gains will be sustainable in the long term. The future research in this area could address these challenges, as well as a production factor that could not have been considered in this research – credit and financial resources of farmers.

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Appendix A: List of participants

Interview reference	Respondent	Date	Location
Volta region			
F01	Farmer	21 Feb 2022	Ho municipality
F02	Farmer	21 Feb 2022	Ho municipality
F03	Farmer	22 Feb 2022	Ho municipality
F04	Farmer	22 Feb 2022	Ho municipality
F05	Farmer	22 Feb 2022	Ho municipality
F06	Farmer	22 Feb 2022	Ho municipality
F07	Farmer	22 Feb 2022	Ho municipality
F08	Farmer	23 Feb 2022	Ho municipality
F09	Farmer	23 Feb 2022	Ho municipality
F10	Farmer	23 Feb 2022	Ho municipality
F11	Farmer	23 Feb 2022	Ho municipality
AEO1	Agricultural extension officer	23 Feb 2022	Ho municipality
AEO2	Agricultural extension officer	23 Feb 2022	Ho town
F12	Farmer	24 Feb 2022	Central Tongu district
F13	Farmer	24 Feb 2022	Central Tongu district
F14	Farmer	24 Feb 2022	Central Tongu district
F15	Farmer	24 Feb 2022	Central Tongu district
F16	Farmer	24 Feb 2022	Central Tongu district

F17	Farmer	24 Feb 2022	Central Tongu district
AEO3	Agricultural extension officer	24 Feb 2022	Central Tongu district
F01	Factory representative	25 Feb 2022	Gborkpo-dorfor
F18, F38	Farmer	25 Feb 2022	Gborkpo-dorfor
Ashanti region			
F19	Farmer	9 Mar 2022	Sekyere Central district
~~F20~~	Farmer, Removed interview	~~9 Mar 2022~~	Sekyere Central district
F21	Farmer	9 Mar 2022	Sekyere Central district
F22	Farmer	9 Mar 2022	Sekyere Central district
AEO4	Agricultural extension officer	9 Mar 2022	Sekyere Central district
F23	Farmer	9 Mar 2022	Sekyere Central district
F24	Farmer	10 Mar 2022	Mampong district
F25	Farmer	10 Mar 2022	Mampong district
F26	Farmer	10 Mar 2022	Mampong district
F27	Farmer	10 Mar 2022	Mampong district
AEO5	Agricultural extension officer	10 Mar 2022	Mampong district
F28	Farmer	11 Mar 2022	Mampong district
F29	Farmer	11 Mar 2022	Mampong district

Appendix B: Interview guide for farmers

Date: 28 January 2022

Interview guide for farmers: agricultural transformation and technology adoption in Ghana

Personal information

1. What is your name?
2. How old are you?
3. What is your level of education? (primary, high-school, university, postgraduate, vocational, technical)

Description of the farm

4. How many ha/acres of land do you
    a. operate/manage:
    b. own:
    c. rent:
5. Has there been any change of your farm size in the last 10 years? If so, how big/small was it?
6. Is cassava your main income crop?
7. How long have you been engaged in cassava farming?
8. What other food crops do you grow?
9. What farming system do you practice? Describe it… (monocropping/ mixed cropping, intercropping)
10. Was there any change in the output from each crop within the past 3-5 harvest season? How much yield did you use to get from 1 acre of land in the past and now?
11. Are you part of any association or cooperative? If so, please describe.
12. Where do you sell your produce?
13. Do you sell your product to any agro-processing household/industry or a middleman reselling to agro-processing households/industries?
14. If yes, do you get any technological assistance from the agro-processing companies you work with?
15. Was there any change in the number of employees you hire? [e.g., how many you had 5 years ago and now]

Technology

16. Can you walk me through the whole process of production – from preparing the land to harvesting and processing, including the use of technologies in each stage?

17. What type of machinery, fertilizers, or knowledge (new varieties of seeds, planting/harvesting techniques, land preparation, etc) have you used to improve productivity in your farm in the past and now?
18. From whom and where do you get the necessary machinery and agrochemicals from? [e.g., AEO, NGOs, enterprises, etc]
19. How did you learn to use/operate them?
20. Did you know anyone who was using this technology before you started using? How many approximately?
21. Have you ever had any formal training/workshops/seminars about new technologies?
22. Do you have access to necessary machinery and fertilisers when you need them? If not, why?
23. How did the increased use of machinery and agrochemicals change your demand for other input factors:
    a. Land
    b. Labour
    c. Investment
    d. Any others?
24. Do you use any mobile application or the phone itself directly in your farming activities? [e.g., even just calling to suppliers, customers, etc.]
25. How do you think using all the above new technologies contributed to your overall output?
26. Is there any type of technology that you currently don't have access to? Why?
27. Is there any other aspect of technology adoption in cassava farming, which needs to be considered in order to increase productivity while ensuring sustainability?
    a) the roads to farmers;
    b) transporting machinery (tricycles);
    c) water/irrigation?
28. Have you ever thought of any new practices or innovations in cassava farming yourself?

General questions

29. Do you get assistance from AEO's? What type of assistance do you get?
30. Apart from AEOs, how does the government, NGOs, agro-processing companies support farmers with new technologies?
31. How would you describe the support you get from the Department of Agriculture? How do you think you can have better access to AEOs?
32. Do you have any questions to me?

Appendix C: Interview guide for agricultural extension officers

Date: 28 January 2022

Interview guide for agricultural extension officers: agricultural transformation and technology adoption in Ghana

1. Please, tell me your occupation and a short description of your responsibilities.
2. How much land do your responsibilities cover (in ha/acres)?
3. How many farms does that include?
4. What type of technologies do you provide/supply to farmers?
5. Why specifically these types of technologies?
6. Can you walk me through the process of providing them with technologies?
7. (If not already covered) Do they request specific technology or you recommend them yourself?
8. How efficiently do you think the farms currently use the technologies – from 1 to 10?
    a. list the technologies they mentioned earlier;
    b. machinery (tractors, combines, etc.);
    c. fertilisers;
    d. herbicides/weedicides;
    e. pesticides;
    f. new varieties of seeds;
    g. use of phones/mobile applications,
9. How do farmers learn how to use the new technologies – from each other, from master-classes/workshops, direct contact with extension officers, etc?
10. What are the biggest factors that contribute to farmers adopting new technology?
11. What challenges do farmers face in the way farmers learn and start using new technologies?
12. How can these challenges be overcome?
13. What opportunities are there for wider utilization of technologies
14. Do you think there are any differences in technology adoption by different farms, in terms of:
    - Size (smallholder, medium size, large);
    - Gender of the owner/manager of the farm;
    - Investment availability;
    - Labour structure.

    a. What challenges do AOEs face in helping to increase the use of technologies in cassava farming?
15. Are you aware of any technological innovations that would help cassava farmers, but is not available here?
16. Are you aware of any innovations made locally in cassava farming?
17. Is there any other aspect of technology adoption, that is important to consider?
18. Do you have any questions to me?

Appendix D: Informed consent form

Project “Agricultural transformation process in Ghana”

This interview is part of an ongoing research project called “Agricultural transformation in Ghana”. The project is funded by and carried out at Lund University, as part of the Master in MSc in Economic growth, population and development.

The project aims at understanding the agricultural transformation processes and its impact on the economic development. The project focuses on the changing labour structures, linkages to agro-processing industry and technological aspects of the transformation process.

The project is led by three student-researchers from Lund University and supervised by Lund University’s Economic History and Human Geography departments.

The project is supported by the Geography and Resource Development department of the University of Ghana.

Interview Consent form – individual interviews

The interview will be digitally recorded, and the interviewer will take notes. Both notes and recordings will remain confidential. We are aware that these interviews may include risks by discussing sensitive information. These risks will be mitigated by a strict protection of the data in a password protected software environment. Only the project leader and the researchers in the project will have access to the notes.

Your personal identity will remain anonymous. No views will be directly attributed to you in any document that may be produced from the interviews. The participation in the project is voluntary. You may also refuse to answer any specific questions you may feel uncomfortable with.

You name may however be known in the report unless you explicitly indicate otherwise.

The information gathered from this study will be used to contribute to the project. It may be presented in the form of a report, a paper to a colloquium and/or a published scientific paper. I waive any copyright and other intellectual property rights in my contribution to the project, and grant the researcher a non-exclusive, free, irrevocable, worldwide license to use my contribution for the purposes of this project.

Consent

I hereby agree to participate in research regarding “Agricultural transformation in Ghana“ on the conditions above.

I understand that if I decide to participate in this study, my participation is free and voluntary and I have the right to withdraw my consent to take part or to stop my participation at any time without penalty or negative consequences.

……………………………..

Signature of participant Date:…………………..

Name……………………………….

I hereby agree to the tape recording of my participation in the study

……………………………..

Signature of participant Date:…………………..

If you have any questions about your rights as a study participant, or are dissatisfied at any time with any aspect of the study, you may contact us at the phone and the emails on the business cards. In case you wish to raise an issue about this research with a person in authority, please contact the supervisor – Prof. Dr. Kwadwo Owusu kowusu@ug.edu.gh.