Rural Agricultural Markets: A Case Study in Ghana

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Abstract

In this report we describe the start of a pilot baseline study of the soon to be established Ghana commodity exchange. We begin by presenting a case study of agriculture in a relatively poor rural area in a fairly central location in Ghana. In the context of that case study, we indicate the existing data available and the data needed for a successful impact evaluation of the commodities exchange. Finally, we describe a number of mobile phone applications we have developed, which could be of assistance in collecting the baseline data for a nation-wide impact evaluation of the forthcoming exchange.

1. Introduction

The goal of this working paper is two-fold. On the one hand, we provide a brief case study of rural agricultural markets in sub-Saharan Africa. Second, we will discuss in the context of our case study the state of existing data and some mobile phone apps we have created to provide baseline data for the measurement of the impacts of policy innovations like the soon to arrive Ghanaian Commodities Exchange.

As African traditional agriculture is transformed it is important to obtain the data necessary to document the change, to measure it and to attempt to determine the winners and the losers from that change. This paper studies the potential impact of commodities exchanges in transforming African agriculture from the current loosely organized system into a modern regulated centralized system. The Government of Ghana has announced the imminent introduction of a commodities exchange, the Ghana Commodities Exchange or GCX. Before market players begin to adapt to this announcement it is important to obtain baseline information against which the impacts will be measured. But what is it that should be measured? What are the existing data sources and what are the new technologies which can be commandeered to help in obtaining the relevant measurements? This paper will provide some answers to these questions.

We begin with a case study in a region which is currently poor and which has fairly traditional methods of agriculture. Within the context of the case study some key variables will be identified as being critical to any impact evaluation on policy.

Our next section will then discuss the existing datasets available for that exercise. In the context of agriculture in poor nations and particularly in sub-Saharan Africa, we will see that there is relatively limited data which can be used in any study of impact of a new institution or

new policy. Cash strapped governments find it very hard to collect standard datasets in a regular fashion and even harder to obtain the data necessary for a rigorous evaluation or study of policy impacts.

There has recently been a lot of excitement about the importance of the mobile phone and its associated technologies. Even in very poor areas, poor illiterate farmers have access to mobile phones. This suggests that the mobile phone can be used as a device to aid in the important exercise of data collection. In last sections of this paper we describe work that has been done to this effect, primarily by the team of the author, NYU's Center for Technology and Economic Development (CTED). A number of mobile phone apps have been created by CTED to facilitate data collection in remote rural areas. This data will in turn enable the rigorous determination of the impact of the commodities exchange GCX over time.

In the conclusion of this paper, we will discuss our conjectures as to what we will expect in any meaningful impact evaluation of the introduction of a commodities exchange. The author and team are now engaging in the baseline data collection in the study area whose case study is presented here. It is hoped that these techniques will be used shortly for a nationwide effort at data collection for a national baseline study. We are also hoping that the techniques used here will be of use to others contemplating an evaluation of major policy changes in the Agricultural sector of rural sub-Saharan Africa.

2. Traditional African Agriculture – A Case Study

We will be interested in measuring the impact of commodity exchanges and other big national policy interventions. To do this, we need to begin with a description of the current state of the agricultural system. Rather than discuss this in abstract, we instead provide a particular case study in one particular area of Ghana.

We focus initially on three crops – Maize and Rice, which will be a part of the commodities exchange, as well as yams which will not be a part of the exchange. Each one of these three crops is important for Ghana. By having one crop outside of the exchange we will, in principle, be able to measure the differential effects on commodities caused by being in the exchange as opposed to outside of it. This is a "difference in differences technique" which will enable us to back out long term macro phenomena which could help all crops regardless of whether they are in the exchange or not (incomes, price inflation on commodities, technology, infrastructure, etc.).

We concentrate on a particular part of Ghana which is typical of the country in the sense of being rural, somewhat remote with little infrastructure and relatively poor in comparison to the rest of the country. Ghana is divided into about 230 political districts (parliamentary constituencies), each with its own Member of Parliament (MP). There are two political districts in our study area, Sekyere Kumawu and Sekyere Afram Plains, with tiny pieces of a few others. The political district of Sekyere Afram Plains, which is roughly 60% of our study region in terms of area, has currently no secondary school, did not have mobile phone access until last year or so, has no trained doctor in the few clinics in the district, and is only now getting on to the national electricity grid. The 2010 population of the study area was approximately 100,000

people. This is made up 65,402 people in the Sekyere Kumawu district and 28,535 in the Sekyere Afram Plains district and a small number outside those two districts[1].

As far as we could tell, there is also relatively limited NGO activity in the region which could disturb our measurements and introduce extraneous issues into the study. The study region is in the middle/southern part of the country (Eastern part of Ashanti) and is not in the northern and central regions of the country which get large amounts of attention from large foundations and NGO's like the USAID with its Feed The Future program, GTZ from Germany, etc. By many measures the Sekyere Afram Plains district is as poor as many of the other districts in the very North of the country, currently the focus of a lot of the development assistance from abroad.

As remarked above, our study area is what is referred to as the Kumawu Traditional Area. This is the area which is under the jurisdiction of a paramount chief (Omanhene), with its capital at Kumawu in the Ashanti region. The area is often referred to as an "Oman" or state – and the chief is the ruler of that state and is called the Omanhene which is the conjunction of the word State (Oman) and Chief (Ohene). The chief of the Kumawu Oman is therefore called the Omanhene. The Kumawu state or Oman is then referred to as Kumawuman ("Kumawuman"). As part of the larger Ashanti Kingdom, this Omanhene is in many but not all senses subservient to the chief of Ashanti (the Asantehene).

The area of our study region, which includes the Digya Forest reserve (which is in the Sene district), is 8396.77km^2, which is about 3.51% of Ghana's total landmass. Without the

[1] Our study area also includes very tiny portions of the Kwahu North, Asante-Akyem North Municipal and the Effiduase districts.

Digya reserve the landmass of the study area[2] is 5589.51 km^2. The location of our study area within Ghana is illustrated in figure 1 below.

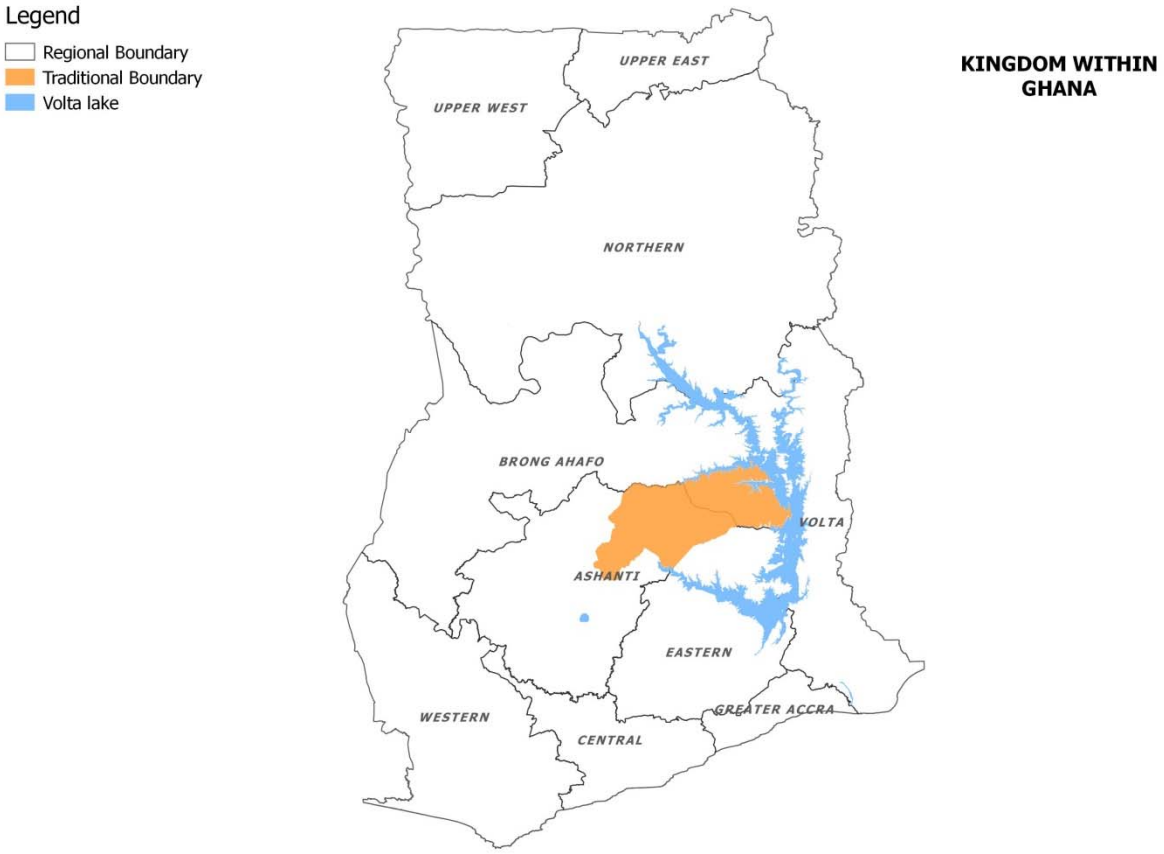


Figure 1: The Case Study Area.

[2] Author's computations from various public government shape (.shp) files.

Traditional Agriculture

The agricultural system in our study area remains what can be described as very traditional. Most farmers use no machinery or implements other than the cutlass, and there is little animal drawn ploughing. There is also very little irrigation. Foodstuff on the farms is carried by hand (or sometimes on the head in baskets) to the 'farm gate' or to the local market where traders, in relatively small quantities, transport the foodstuff in locally hired trucks and vans to the bigger towns and cities.

In our studies, we saw none of the corporate style distribution systems prevalent in say the US. The markets were very thinly regulated – the only regulations had to do with entry into the market and payment of some nominal fees. There was no control by government agencies on quality or sanitation in any of the markets we studied. There was no official or standard grading of commodities. There did seem to be some restrictions on entry into the market to sell goods – there were some "Market Queens" and other fees. However, there were no restrictions we could tell on buying goods. Other than the entry restrictions related to the existence of market queens, which we shall touch upon later, the markets seemed to be as free as could be imagined. The region is a relatively poor region, even by Ghanaian standards.

Despite the relatively low levels of activity of the area, or perhaps because of it, we are expecting major changes over the next few years. The introduction of the Ghana Commodities market, currently not on anyone's horizon in terms of anticipating the future, could really transform agriculture in this region. We found the staff at the local ministry of food and agriculture offices very impressive and extremely dedicated. The area has just installed a new traditional ruler ("Chief" or "Omanhene") who seems extremely committed to the economic development of the region.

This paper is an attempt to measure the current state of the agricultural system so as to have a benchmark to measure progress in the future. The paper is geared not so much as to provide a baseline study with numbers and data, but instead to discuss what will be needed in constructing such a baseline study. In other work being conducted by the author and field team members, this baseline study is being implemented and the data is being collected.

The Markets

The markets in our study area handle not only the produce grown in the area, but also serves as trans-shipment points for food traveling through our study area, with the principal movements being North-South. Our team went to the markets in and around our study area primarily during the fall of 2015 and conducted interviews of market participants.

Figure 2: Close-up of the Kumawu Traditional Council area and surrounding markets.

The capital of our study area – the capital of the kingdom (or traditional area) and the capital of the more populous political district in our study area – is Kumawu. It is also the location of our Center for Technology and Economic Development (CTED) research center in the region. The market which serves the capital Kumawu, is a town called Bodomase. That market is one of the smaller markets we studied. In some ways it serves as a "retail" market for the town of Kumawu and smaller towns around it.

There are other markets we study which border our study area. There markets are the Ejura, Atebubu, Mampong and Nsuta markets to the North and North-West; then there is the

Agogo market a little south; then the main city market of Kumasi further South and to the West. These markets differ in the types of trades that take place there. The Ejura and Atebubu markets are on the main road between the North and the South of the country. They are among of the largest markets we study. Mampong and Kumasi are two markets which are very interesting. Mampong is a market which is similar to Bodomase as it serves primarily as a consumer market for people living in Mampong and its environs, in a similar way that Bodomase serves the Kumawu area. Mampong is a much more affluent town than Kumawu so the market there is a step up form that of Bodomase. There is some trade from the Kumawu area into the Mampong area because of the large maize mill there.

Kumasi is the second largest city in Ghana and so the market there is, relatively speaking, the consumer market par excellence. One would expect that Kumasi would also play the role of an intermediary point for foodstuff going from the North to the South of the country. Our studies did not show that it played that role to the extent that we expected for the crops we were studying. A lot of the crops go from the North to the South bypassing Kumasi, often via Ejura.

Apart from the main market in Kumasi, most of the other markets we study meet once a week. The main market days for the markets in and around our study area are in the table below.

Bodomase (Friday)	Atebubu (Tuesday)
Mampong (Wednesday)	Techiman (Wednesday, Thursday and Friday)
Ejura (Monday)	Agogo (Friday)
Kumasi (Daily)	Nsuta (Thursday)

Table 1: Main Market Days

Maize, yam, cassava, plantains and rice are among the most important crops grown in our study area. The road infrastructure in the area is very bad. There are very few roads, and those roads are often untarred, with potholes and following windy paths. There are many farms which are not near roads, which require tractors to traverse hilly and muddy terrain to bring food from the farms to the roads for onward delivery to the markets. The lack of large numbers of tractors in the area results in large tracts of land going either unfarmed or farmed in a subsistence manner by locals who live close by.

The general flow of food is from North to South. However we have information suggesting that food (yam and maize in particular) come from the North to Atebubu and Ejura, then go South to Kumasi, and then come back up North to Bodomase.

As regards the traders, typically the trader is one woman. That woman will go to the farm to negotiate with the seller. The trader has a rented car or small truck with her and goes with the car to the market to sell the produce. Traders often trade in many goods rather than focusing on one particular good. For example, a yam trader will often also be in the maize or plantain business. In some cases the trader will not deal directly with the farmer, but with an intermediary between the farmer and the trader in the local market.

As we shall discuss later, with maize an important part of the food equation is poultry farmers (chicken in particular). Poultry farmers are a big part of the value chain and are significant in price formation as well as setting the price floor and are a big player in terms of volumes of maize being purchased in the markets and from the farms. The poultry farmers often bypass the traders and deal directly with the farmers, often offering them credit for their inputs in advance of receipt of the output of the farmers.

Ejura

Excluding the major cities where food is consumed, there are three major food markets in the country important for trans-shipment of foodstuff: Ejura, Techiman, and Tamale, each on major North-South roads running through the middle of the country, north of our Study area, with Ejura the closest, followed further north by Techiman then yet further north by Tamale. The Ejura market is of extreme importance for our study area, being the closest. It is also important because it is going to be one of the places which will be a warehouse depot or station for the new Ghana commodities exchange.

The Ejura market operates from Saturday evening to Monday afternoon. The district administration collects 1 *GH¢* about US $ 0.25 at existing exchange rates) for every bag of product entering the market and one cedi for every bag leaving the market.

Rice

More than half of the rice that comes to the Ejura market is from the Northern part of the country. Traders travel from the north and come south each week and sell in the rice market. The rice market is much less regulated and the right to sell rice is less exclusive than in other commodities and other markets. Many rice traders from the North come to Ejura rather than going all the way to the capital Accra because they do not have the business relationships in Accra. Traders will transport their bags of rice on trucks paying a per bag price for shipping and follow the load in a car or taxi to do the selling in the market. Many use a local rice milling plant to process the rice before sale. We were told of a "*rice trader who had brought her product from*

the Northern (Tamale) part of the country. She brought 50 bags of rice to Ejura market. According to her she bought one bag of rice at GH¢ 150 and sells to other traders at GH¢220."

Many rice traders go to the farm and buy directly, often committing in advance to a purchase a crop in the paddy on the farm. They then transport the rice to the rice mill in town, mill the rice and then send the rice to the market for sale. One rice seller told us she has *"a long standing multigenerational relationship with rice farmers in one community"* and that community forms the major part of her trading operation.

There were informal notions of grades of rice in the market, and the prices of rice would vary according to those grades. There also seemed to be some very new varieties of rice on display in the market.

In a sign of things to come in the future we observed one business, owned by a professional in the capital, having a vertically integrated operation where they farm, mill and market their own rice and brand it for sale locally and at some future for sale in Accra.

A lot of the rice in the country comes from imports, which the country spends large sums of scarce foreign exchange on. The value of these imports is of the order of US $1bn per year. This is potentially a big market for local rice manufacturers – i.e., replacing imported rice. Ultimately this could become one of the big impacts of the commodities exchange, if it enables the increase in the quantity of rice production in the country of a sufficiently high quality to successfully compete with imported rice.

Figure 3: Rice milling center at the Ejura Market.

Maize

The area around Ejura is a major maize growing area. There are two harvests per year – the major and the minor. The major season is February through to end of June. Currently, i.e., in 2016, there are climate change issues and the rains are in very late, and are not expected in full force until mid to end of March. This is causing no small amount of nervousness among maize

farmers in our study area. The minor season begins in August and the harvest is around November and December.

Maize has to be harvested when it is dry, otherwise some toxins may be introduced which can harm the maize and cause it to begin to rot. The harvesting at the end of the major season coincides with the rains the possible beginning of new rains, which means that there is a small window of about 3 weeks where the maize must be harvested. If harvested when the rains are in season, farmers may lose most of their maize. The second harvest is around November and December, just as the dry season is beginning. There is a lower chance of water related damage to crops during this season, with losses, according to some farmers, at around only 30% of the total relative to higher percentages at the end of the major season. For this reason, growing maize is very risky business in these areas.

The maize in this area has a color ranging from very white to yellow or greyish. Typically the white maize is associated with higher quality. Sometimes some modified varieties are used to make the maize yellow, which is preferred by the poultry industry. Maize is grown on farms often with crop rotation, with legume – white beans – used to replenish the soil.

Where does the Maize Come from?

The area around Ejura is a major maize growing area. There are relatively small amounts of maize which come from other areas – unlike say rice. All the "middlemen" we spoke with told us that they receive the maize from farmers around the villages of Ejura.

Around April, May and June, some traders go to Burkina Faso to purchase some maize, when the supply from the locality is on the low side. There is the perception among some that

the maize imported from Burkina Faso is not of the same quality as the locally produced varieties. We asked why they run out stock during the months of April, May and June and we were told that this is because there is a lack of proper storage facilities. There used to be a government run entity, Ejura Farms, which stored a lot of maize for farmers. That facility is not working that well at this time. Burkina Faso, and sometimes Togo, is able to provide maize when it is low in the Ejura area because those places have different seasons and also because they have land which is flat and consequently is more mechanized than in our study area and so a less weather dependent area.

Trading on farms

Many estimate that about one half of the maize trading in Ejura is maize sold directly off the farm and not at the Ejura market itself. Maize farmers sometimes bring their produce to the market, however they then usually prefer to sell maize to the wholesalers in the market. Many farmers have implicit agreements with these wholesalers to continue to purchase maize from them even in periods of glut. Some traders mentioned that it is dangerous to buy maize from the far away farms when going there alone. Many of the traders are women and all traders hold large amounts of cash, which can cause security problems. Some traders who used to go directly from Accra to the farmers' farms, now have agreements in place with the farmers or with farmer's associations so their physical presence is not essential. Traders employ local people to buy the maize, bag it, and then guide the traders transport trucks from farm to farm picking up enough bags of maize to fill a load. Mobile banking is making this much easier as the trader can easily get the cash to the agent in advance of the pickup.

Many told us that the farmers associations are necessary so that traders coming in from Accra do not cheat the farmers, or make promises they will not keep. Likewise, there are associations of traders and often trader associations, which have agreements with farmer associations to help in dispute resolution and protect individual market participants.

Some of the maize can be stored at homes. Sometimes it is left to dry on rooftops or on elevated tables and stored in various rooms in houses. Farmers often use storage of maize in their homes as a form of savings. They will sell their stored maize as and when they need cash for some expenses. We were told also of some storage sheds that are sometimes made available, often in connection to collateral on bank loans, and owned by the bank or with the collaboration of the banks.

Trading in the Market

The Ejura market is a bustling stereotypical Ghanaian or West African market. There are different sections of the market for different goods, and it is primarily an outdoor market. Around 20% of the market area is devoted to maize. There were many middlemen acting as intermediaries, taking maize from farmers and looking for traders to sell the maize to.

We heard about one particular middleman and were told that *"he receives the maize from the farmers, and as of Monday he had stocked 200 bags of maize in his shop. He further said he doesn't buy them from the farmers, but instead he only holds on to them and sells them for a commission on behalf of the farmer. He sells to traders at GH¢ 130 (white maize) and GH¢140 (Yellow maize)."* These middlemen hold onto and handle the maize until it is purchased to the traders. The traders are responsible for handling after the purchase logistics. They are required

to use labor supplied by the market maize association to move maize purchased and load trucks. This is a source of revenue for the association. We therefore see that there are three types of players in the market: the farmers, the middlemen and the traders.

Traders buying maize come from all the major markets and may not come to the market in person each week. Traders working with trusted middlemen may send trucks or vans to pick up purchased maize or arrange to have purchased maize sent by truck. The price to get a bag of maize from Ejura to Accra is *GH¢* 17. From north of the country to Ejura it costs *GH¢* 30. Cell phones and now mobile money is making it less necessary for traders to come to Ejura on every market day. Traders in Accra, for example, can now check prices in multiple markets and buy and arrange for delivery remotely.

Ejura farms

Ejura Farms is an interesting story of government initiatives gone bad. Ejura farms were started during the time in the late 60's to early 70's. It was supposed to produce maize on large farms, dry and process it, and then provide storage facilities for the maize. It had great ambitions when it was created, with hopes of becoming the breadbasket of the country. Currently only the drying operation is ongoing, and the large factory and silos are dusty leaving the entire place with a sleepy quiet look, occupied by a lot of the machinery idled and no longer working.

Poultry Farmers are the floor

Poultry feed dealer often buy directly from farmers and, we were told, are more likely to loan farmers money than other traders. They come from all the big towns: Kumasi, the Volta region, Accra, and elsewhere. The typical poultry farmer has some implicit grading in their minds to determine the price. They look at the maize's color and use that to infer its grade. We were told that the white maize is usually considered the best. If the maize goes from white to brown then that is taken as a sign that it has deteriorated in quality or it is bad. Some poultry farmers look for good quality higher priced grades of maize for their poultry while others are content with the lower priced inferior quality maize. The latter set the market in terms of the prices – some of them will often be the ones buying the cheapest maize. They are also the floor in a more literal sense – we observed some people picking up left over maize on the floor of the market, bagging them, and selling them, usually to some of these poultry farmers. Many poultry farmers own dryers to finish drying maize, so are willing to take from farmers maize which have not been completely dried.

Yam

Yam is traded in lots of 110 tubers. The lots are of size 110 because there are a variety of fees to different market participants and transportation people, which will eventually eat up 10 of the tubers. Many farmers are loaned inputs by middlemen with the agreement that they will bring their tubers to the trader to sell on "commission". Out of lot of 110 tubers, one yam is given to the Yam Market Queen and one is given to the Yam Chairman (a male). The "for sale" lots of 108 yams are stacked in a neat pattern to build a circular mound or "spire" of yams. They are not weighed but in the spire a large surface area of a good number of the tubers are exposed for

inspection. “Quality” is judged by size and variety. Some buyers (traders) prefer a large size because the volume is greater per tuber and others prefer a smaller, and presumably tastier, variety.

The middleman sells the lots of 108 tubers to traders who then bag the tubers for trucking. The middleman then deducts the loan input costs and deducts the commission, which might have been about 10%, and pays the farmer the rest. The middleman’s job involves cultivating relationships with the farmers, loaning them inputs, monitoring the progress of the crop, and ensuring the farmer brings the Yam’s to the market for sale and ultimately, repayment.

We met with a Yam Queen, elected by the middlemen. She is one of four Yam Queens who each control the activity in a set boundary of the Yam market. She was in her fifties. Her role is supervising and financing the traders. She will advance funds to the middlemen who then advance it to the farmers as a way of securing trading business. She will also loan money to the middlemen for day trading. These funds must be repaid at the end of the day. The Yam Queen also gets one tuber of yam for each 108 circular mound or spire of yam.

The Queen also often provides a floor to the market by taking responsibility for all yams left over at the end of the market. She has a shed for storage. If there is the chance of there being excess, she will call her contacts in Kumasi, Accra, and elsewhere to sell the leftover yams.

The Yam Queen works with the Yam Queens at the other markets to enforce the repayment of farmer loans. Farmers attempting to sell yams outside their home market to avoid repaying loans are reported by the Yam Queens and the sales are returned to the proper trader. This enforcement makes the system work and is taken very seriously.

The Yam Queen makes money through many channels: the return on capital to farmers for inputs, a share of commission sales from middlemen, her one tuber per spire, and selling leftover yams outside the market.

As with the rice market, we call the final buyers of yams in this market the traders. These traders buy from the middlemen and sell in other markets, usually in Accra, Kumasi or other big consumer markets. Traders do not have a hard time finding middlemen in the Ejura market in the above-mentioned system. On the other hand, traders trying to go outside this system may run into difficulties. There are farmers who are committed to selling to only farmer groups or who are tied to traders or middlemen via the loans for inputs. Traders working outside the Yam Queen system who deal directly with farmers will be asked for input funds and will then be at the risk of farmers selling to other traders who fail to repay their loans.

Similarly, farmers wishing to change traders for a better deal may be faced with prospective traders unwilling to take a farmer from a fellow trader. Changing traders before clearing debt with the previous trader will be very difficult. Farmers in debt to traders will have a hard time negotiating price, particularly with such a crop, which is in principle perishable.

The market seemed to function well, despite these obvious restrictions to free trade. Most market participants seemed to know the rules of the game. We noticed in our trips to the market that by the end of the day the yam lots were largely gone, sold to traders for onward journeys to consumer markets around the country.

Bodomase Market

The Bodomase market is a small, primarily retail market, very close to the main town Kumawu, where our research headquarters are situated. This market is much smaller than the Ejura market in terms of volume, and, as mentioned earlier, is more of a retail market while Ejura is more of a wholesale market. The market meets once every Friday. Most market participants interviewed said that it was fairly easy to sell in the Bodomase market although sellers need permission from the market authorities (the district assembly). Further, sellers are required to pay a fee to build a permanent booth. Goods leaving Bodomase require about a one cedi tax, which is paid to the district assembly.

Maize

In the maize market, many of the buyers are poultry producers or traders selling to poultry producers. There are also some small entrepreneurs buying for resale in small quantities. One market participant said: "*In the maize market you see the farmers who have brought their bags to sell to traders. The bad rains last night made transport very difficult and reduced the amount of maize in the market. There were maybe 150 bags total from 20 farmers (although there may have been some consolidation among farmers before heading to market). Trucking from Afram Plains to the market is 14 or 15 cedis*[3] *per bag plus the 10 cedi each way the farmer pays to move himself – with some farms sending more than one person.*"

Farmers do not have to sell in the market but instead could sell at the "farm gate," where they wait for traders (buyers) to come to the edge of their farm where they have stacked their produce for sale. The majority of maize in Afram Plains (our study area) is sold from the farm to traders

[3] At this time the dollar cedi exchange rate is a little less than 4 to 1, so 1 cedi is US $0.25.

with large trucks headed to Accra, Ejura, etc., or directly to poultry producers. They pay 100 cedi/bag on the farm.

We had conversations with several of the traders who buy at Bodomase market. These traders travel to multiple markets around Kumawu, including Bodomase, for the Kumasi market. One trader said *"the prices at Bodomase were high last week so I will try another market this week."* From what we could tell, these traders were not buying for their own retail business but rather were selling to retailers and/or may have some specific accounts like schools or restaurants.

Farmers also make decisions on when to go to the market. One farmer said *"I am coming to the market hoping to sell for 130 cedi, and after paying 15 cedi for transport, I will make 15 cedi over the farm gate price."* The farmers go to the market multiple times over the day and again over the weeks searching for good prices for their produce.

There is a lot of risk encountered by farmers and sellers. There is the issue of supply on the day of the market (variability in supply causes big fluctuations in the price). There are the usual problems with transporting goods to the market from their farms (disputes, getting stuck in the car, rain, etc). Some noted issues with traders demanding that they pay for their goods on credit. Then, there is the problem of finding themselves at the end of the once-a-week market with no buyer at a good price for their foodstuffs.

There are also non-farmer traders who are selling in the market. We learned in conversation with a market participant the story of one trader who was "*selling maize to poultry producers who had capital to buy 25 bags at 130 cedi. She would pay 5 cedi/bag to have the bags loaded and 10-15 cedi/bag to have them trucked, 1 cedi for [the] district assembly, possibly another 5 cedi/bag to have them unloaded, for the hope of selling the bags for 170-180 cedi for a profit of*

15 cedi/bag. From this, she will deduct her expenses including her personal travel and possibly interest on capital." We spoke to another market participant told us that "*another entrepreneur was buying maize to make maize dough for resale at a nearby market. She said business was good for her."* In another case, one small entrepreneur was "*buying four bags at 130 cedi to resell at small quantities from her house in a nearby town. She was also paying 5 cedi to get herself to and from the market, 5 cedi per bag to load and 5 cedi/bag to unload and 10 cedi/bag to transport."*

There are the poultry people who "set" the prices in the market. They are important players in terms of volume, but additionally they set the price floor on the maize prices. We observed a woman who sweeps off the floor the dropped pieces of maize. She will probably clean it and resell even though people walk past her and probably step on the maize on the footpaths. This maize goes to poultry farmers who are willing to buy the lowest "grades" of maize.

Figure 4: Different grades of maize.

Figure 5: Bodomase Market maize sales.

Yam

In some contrast to maize, the Yam Queen controls the yam market. There are many yam sellers (about 75) but they must buy from the Yam Queen. Farmers and traders who are selling sell to the Yam Queen. She then allocates the yams to the traders (mostly women) who sell in the market, usually at the retail size level. Farmers who want to sell their yams themselves in the retail market must "see the queen first." Apparently, the queen controls the price paid to the farmers and the price the market sellers pay to get yams, keeping the margin for herself. She is elected by an association of participants in the Yam trade business.

Figure 6: Yam sales at the Bodomase market.

Rice

There were very few transactions in terms of rice in the Bodomase market.

Storage

There is very little by way of storage facilities in the small Bodomase market and the farmers are at major risk because of this. They know that at the end of the day they will be “price takers” and may have to sell to a trader on unfavorable credit terms. We often saw market participants looking up at the sky nervously. This was the rainy season and the rain could mean the early termination of the market day, with consequent potential losses.

Regulation and Hygiene

An immediate observation is the lack of regulation on food quality and basic hygiene. Our case study observers witnessed people treading on maize to be sold. They saw some produce being sold very close to gutters, which carry sewage, and sometimes, in the case of plantains, were inside the gutter itself (although they were dry when visited).

Kumasi Market

Kumasi is the second biggest city in the country and the largest regional market close to our study area. Our research into this market was hampered by the fact that it had recently moved to a new area and it was not clear whether this would be the permanent or temporary space for market participants while construction work was going on at the old market site.

Maize

In Kumasi, the maize market was at Asawase and is known as Asawase market (opposite Odotobiri Rural Bank). The market was then moved to Nkontompo (Nkontopo market) near Asokore Mampong where they sell varieties of goods, however, maize, cola nuts and yam were the main commodities we found in the market. We were told the government is putting up a new structure for them.[4] There was a market chairman of the maize market, who described his role as a chairman and the nature of the market to us as follows: "*As a chairman, I make sure things are in order. I make sure there are peace and harmony among members and our customers. I also serve as a middleman (Agent) and sometimes give loans to farmers to farm. I mostly receive maize from people and redistribute to others*." The yam chairman was in an acting capacity as the principal maize chairman was not around.

[4] This research was conducted in August of 2015.

This market in Kumasi, unlike other smaller markets, operates daily. A lot of the maize from our study area (particularly Drobonso and its environs) is distributed in the Kumasi market.

As with other markets, there is a lack of storage facilities. Many indicated to us that it would be good if they had a dryer for the maize, which they do not. We were told that "*Kumasi was once more of a national maize market with maize being sold to Accra from Kumasi. This ended when the train stopped running. Now the maize coming to the Kumasi market is sold in the Kumasi market for consumption only.*"

Yams

There was a distinct place in the market for the trade in yams. We met the chairman for yam association at Nkontompo market. He indicated that most the yams come from Northern region. He stated, "*The yam market is really big and traders from all over the country come here to buy. There are agents who come around to buy from us and export them to USA.*"

There are about 25 yam traders working the market. They buy yam from the north, from the local neighboring region, and at Atebubu. The chairman and his trader brother claimed the best yam growers were from the north and as transplants were the best growers in the local region as well. He claimed that those farmers were skilled at storing yams. We also observed that most of the farmers were Muslim.

From our observations, we found that most of the traders have networks of agents who work directly with yam growers and they loan the growers capital for their inputs. In return, these borrowers must then let the trader sell their yams to recover the loans given to him or her.

Once the yams are trucked to the market, the trader sells the yams and then sends the money back to the yam grower minus a commission and loan repayment.

There is currently a very small export market for the yams. However, this export market is growing and is the major business for one person we interviewed. Yams are consumed abroad by Ghanaians living in those foreign countries – UK, Holland and the USA, in particular. Out of the different varieties of yam, the "puna," variety is the one exported when in season, with others used for export when puna is not in season. The trader then carefully stacks yams onto his large truck and transports them for movement to Accra (he does not use bags). In Accra, the capital city of Ghana, the trader washes the yams and puts them in crates with labels and ships them off to his customers in London, Holland, France and New York City (NYC). We were told the NYC market prefers larger yams to smaller ones. When asked, he confirmed that he has more demand than he is able to supply. Consequently, in order to meet supply he tries to ships yams every week and is limited more by supply of proper yams than by the demand for yams.

Figure 7: Kumasi market: Yams grown in the Northern region to be transported to Holland.

Rice

Kumasi also has a rice market in a small area called Akwetia. Traders go to farmers much further north of the Kumawu study area and buy unprocessed rice (with the husk still on). Other places were one could buy unprocessed rice are Yeiji, Agona and Tepa, which are further away from our study area. One trader told us that a lot of the rice came from the Mampong area.

There is a rice mill at the Kumasi market. Traders come here and mill their rice, partially explaining the attractiveness of that market. The rice market is organized around the milling operations. Traders will go into the "hinterlands" to buy from farmers, bring their loads to the mills to have it milled, and then sell it primarily to local buyers. When train services ran, they also sold to Accra, but this has ended when the train services stopped.

Most of the traders are small scale, but every now and then larger scale traders enter the market acquiring food for various boarding schools that have feeding programs.

One trader made the following observation, indicating the impact of mobile phones and researchers regarding information: "*The market is not good at all and I can say [that] the so called researchers who have caused it. Sometimes they come and ask questions to know every details of the business and then go and set up their own, making it more competitive. The introduction of the mobile phone is also another problem [because] farmers in the villages could call traders in the cities and get the prices of the rice."* Two other traders blamed cell phones for hurting their businesses. Now, farmers can call the market and get the prices and costs for milling so they can negotiate with the traders. Making life even harder for the traders, the millers are willing to work directly with farmers. They will mill for a farmer and then "assist" them in selling it. Thus, traders and farmers are working the market side by side.

One other trader mentioned concern that people pay more for imported rice and have a preference for imported rice relative to local rice.

Sanitation and Hygiene

As with the Bodomase market, we noticed the lack of many regulations and very unsanitary conditions. Often times, we saw rice on the floor, which was stepped on and later sold.

Mampong market

The Wednesday Mampong market is a very pleasant retail market serving a community that appears to be more prosperous than Kumawu. The market is in a dedicated area located off the main road with some permanent infrastructure. The various types of goods were generally co-located but not in a rigid manner. This gives the impression of less formal organization than other markets.

Many interviewees informed us that the area is best known for vegetables and some rice.

Yam

Our team met with the Yam Queen and her coterie. She is elected for life by the other traders. Additionally, this yam association is fairly weak. Anybody can sell yams including farmers. There are 75 members of the association but not everybody is active every week. Most of the yams come from the Atebubu market, north of Mampong on a major road. The larger traders travel together to Atebubu to buy yams and one man organizes the transport back. The Atebubu market day is Tuesday and the Mampong market day is Wednesday. The traders rarely make loans to local farmers in the vicinity and many traders told us that they generally consider the local farmer's production lower quality in comparison to those further north.

We did not find any traders buying yams from the Mampong market for sale elsewhere, a reflection of that market being a retail market. There were few large trucks present and most selling venues seemed to have six bags or fewer of yams. It costs about 10 cedis to transport a bag from Atebubu to Mampong.

Rice

Even though some rice is produced in the Mampong area there was little evidence of local rice in the market, just one unusual variety with a few bowls for sale. This is probably because the local rice moves to Kumasi for milling and is then sold there. The rice sold in the Mampong market comes from the north and is bought in Ejura. The Mampong rice sellers buy directly from the rice traders travelling from the north to Ejura. Each rice seller stated they tend to buy consistently from a trusted rice trader at Ejura. It costs about 10 cedis to move a bag from Ejura to Mampong.

There was no evident association for rice sellers and some rice booths also sold beans from Ejura.

Maize

There was very little maize sold at Mampong. We found one woman selling maize from a couple bags and she said she bought the maize locally.

3. Issues of Measurement

In this section, we will discuss the information required to describe the state of traditional agriculture as outlined in our brief case study of the previous section. This information is integral to macroeconomic planners in predicting inflation (via prediction of output). It is also important in the very definition of inflation, as one needs to account for quality in assessing prices – if the price of a good rises because its quality has risen, we are in a completely different situation than if the prices rise due to purely monetary causes unrelated to quality improvements.

Development economists need accurate food production and quality data to assess the effect of different types of policy interventions on the poor – and not only commodity exchanges. There are questions of food wastage on the farm and value losses along the value chain, often caused by lack of storage facilities, which need to be measured properly. Finally, there is the very important issue of determining the impact of climate change in African agriculture. All of these require accurate information on production levels and the quality of the output.

The goal of this section is to indicate the types of data that are currently being collected by government agencies and private companies. We shall indicate that there is a role for the use of mobile phone apps to collect and crowdsource information on production and quality levels. After making this case, we shall in the next section indicate our own work in creating mobile phone based apps for collecting this data.

The two initial commodities to be traded on Ghana Commodities Exchange (GCX) under current plans are maize and paddy rice. These will be of major importance in our research. We also look at yams as this constitutes a commodity that is very important in our study areas, and is not covered by the commodities exchange. A comparison of the evolution of maize and rice production on the one hand in comparison with yam (and possibly cassava and plantain) on the other hand could provide some information on the impact of the commodity exchange.

In our research, we have enjoyed a productive relationship with the Ghanaian Ministry of Food and Agriculture (MoFA) at two levels. The first is through the central data office (SRID). We have also been in touch with the local MoFA directorates in the towns and villages of our study area, which is our second source. Through these MoFA sources, we have obtained data on

food production and prices. We are also currently well-informed on the nature and the processes of that data collection.

We have production data available at the district level. However, this data is not complete and does not have the accuracy needed to detect fine changes in agricultural activity.[5] As will be discussed in later sections, the NYU CTED team has created a mobile phone app called AgricNotes, which has been tested with MoFA field agents.

Market Structure and Market Participants

There are no measurements of these variables as far as we can tell. In any evaluation of the commodities exchange, it will be necessary to measure the market participation. In our case studies, we have identified as market participants three types of players: the farmers, the middlemen and what we called the traders.

Production Data Sources for Ghana

The Ministry of Food and Agriculture (MOFA) collected agricultural production data using a Multi-Round Annual Crop and Livestock Survey starting in 1999. In 2011, two IFPRI working papers outlined deficiencies of MIRCLAV data collection and suggested a pilot study Ghana Agricultural Production Survey (GAPS) to improve data collection methods and, therefore, the quality of the data.[6]

The most important shortcomings of MRACLS survey are as follows:

[5] We currently have district level data from 2001 to 2010. MOFA supplies production data to FAO at country level, which is available from 1964 to 2014.
[6] Quinones, Munoz, and Ngelza (2011) and Munos (2011)

- Due to resource constraints, part of the survey is not administered at all and the other part is conducted with a significantly reduced sample size. For example, the field measurement sample size has been reduced from 20 to 10 per Enumerator Area (EA), and yield estimate has been reduced from 20 to 5 per EA (Quinones, Munoz, and Ngelza, 2011).
- Once statistics are being collected and processed for MOFA purposes, it is provided in aggregate and original data is hard to find, which makes it unsuitable to address many important questions.
- The data is collected only for the major seasons, which not only underestimates the total production, but also makes relative between-district production statistics significantly biased since the minor season is extremely important in the south, and less important in the north.

GAPS was conducted at least for two seasons: 2011/2012 and 2012/2013, for both minor and major seasons. During the major season, the data was collected on cropped areas and on yields of various crops. Minor season surveys focused on pre-harvest and post-harvest household activities. We were able to find two online reports both for minor seasons.[7,8] The data for the minor season of 2012/2013 is available online but requires an application. Unfortunately, we could not find indications that any other data is available on micro level; also, there is no information on continuation of Ghana Agricultural Production Surveys after the 2012/2013 season.

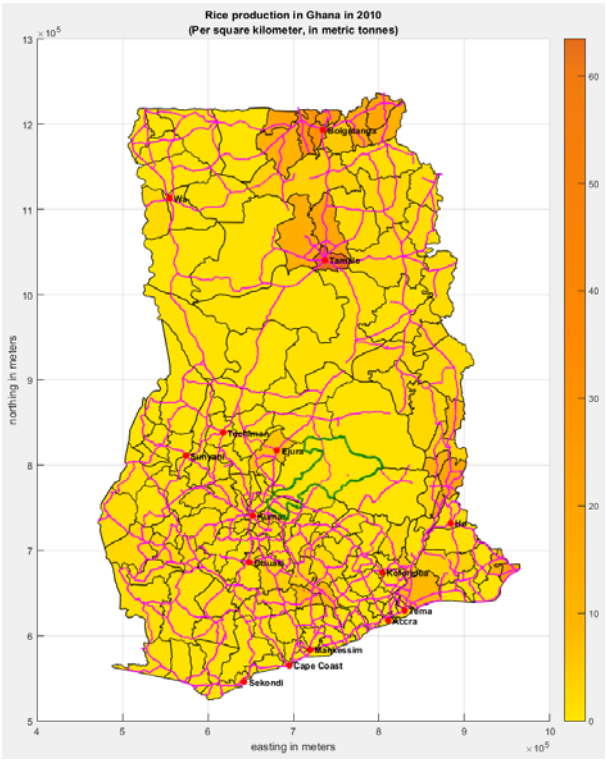
[7] Osei-Akoto, Horlu, Bonsu and Appliah-Kubi (2014)
[8] http://www.statsghana.gov.gh/nada/index.php/catalog/87/datacollection

District Production Data

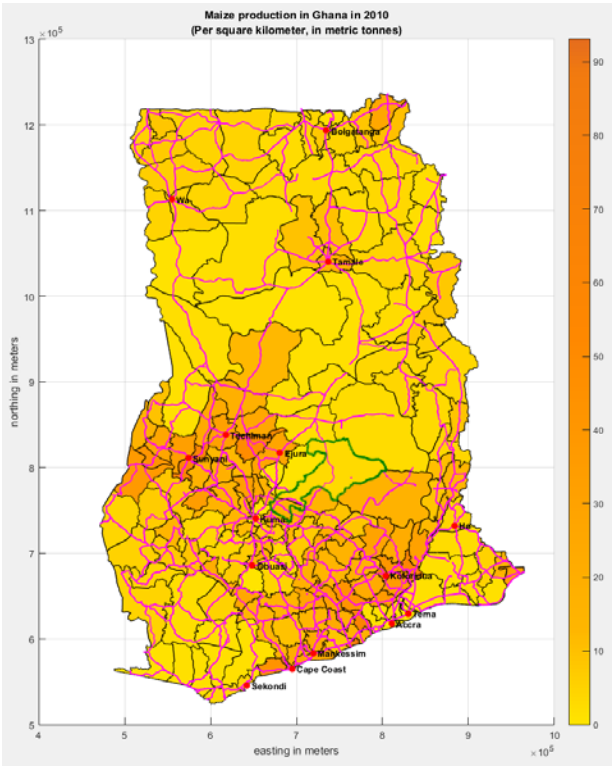
Below are "heat maps" that show which areas are leading areas in production of maize, rice and yam. This was obtained from the Ministry of Agriculture data sets (from their SRID office). Our study area is indicated in green.

Figure 8: Production per square kilometer (production density)

Rice



Maize



Yam

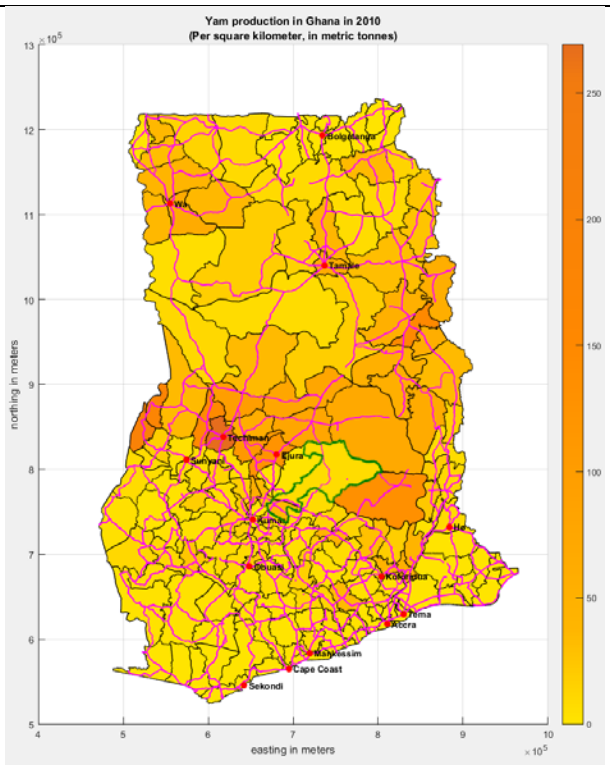
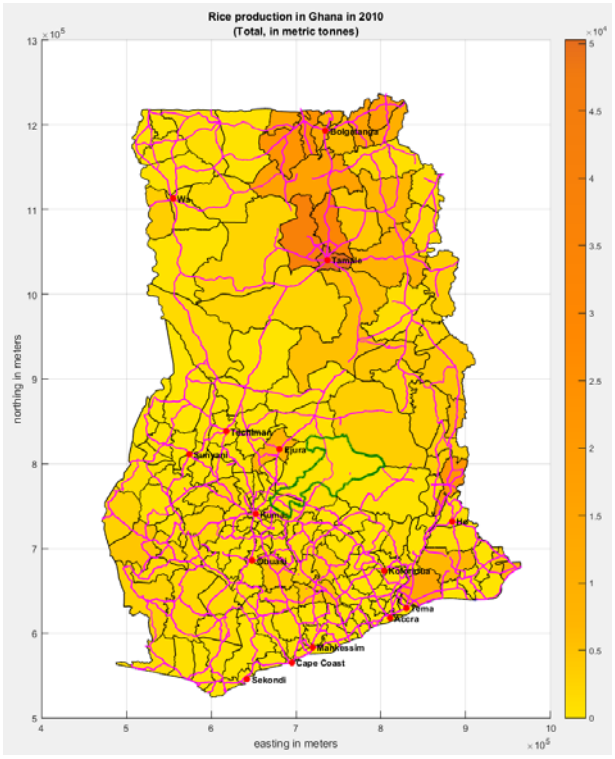
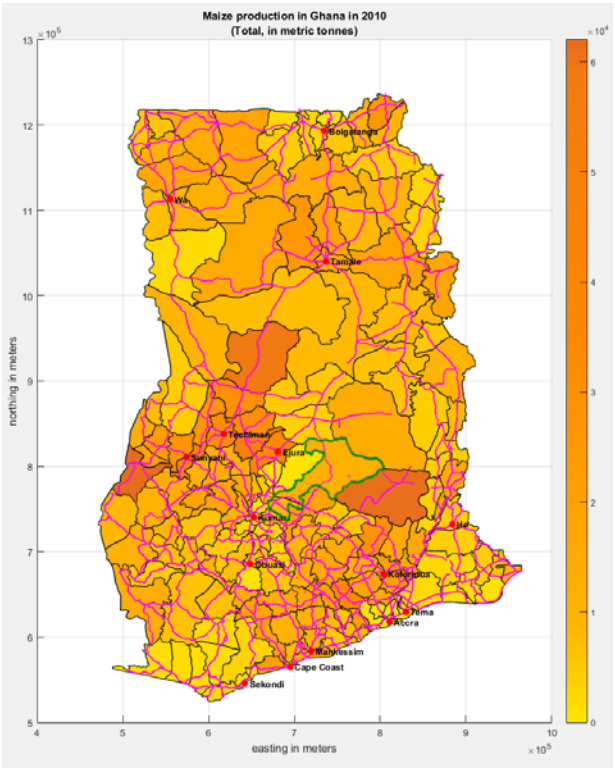
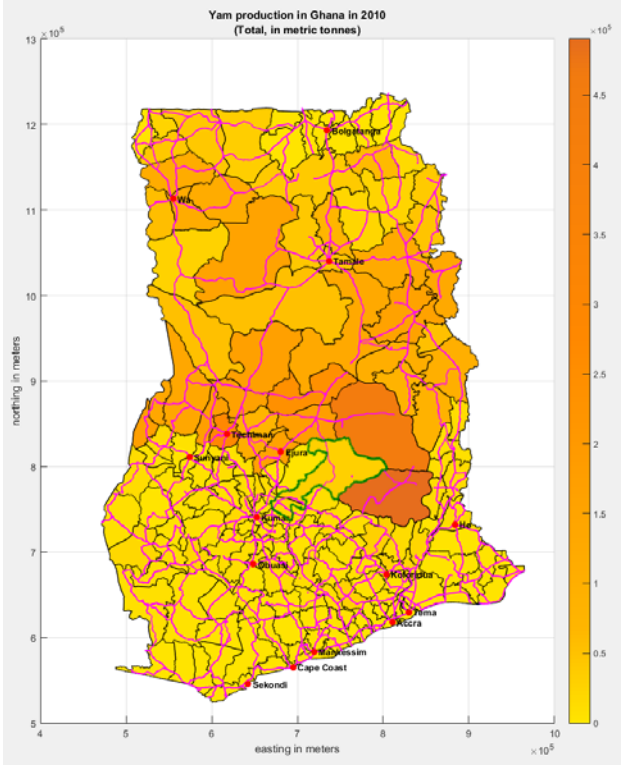

Yam production in Ghana in 2010
(Per square kilometer, in metric tonnes)
northing in meters
easting in meters
Bolgatanga
Wa
Tamale
Techiman
Sunyani
Kumasi
Koforidua
Ho
Tema
Accra
Mankessim
Cape Coast
Sekondi

Figure 9: Total production per district.

Rice	Maize
	

Yam


Yam production in Ghana in 2010
(Total, in metric tonnes)
northing in meters
easting in meters
Bolgatanga
Wa
Tamale
Techiman
Sunyani
Ejura
Kumasi
Dunkwa
Koforidua
Tema
Accra
Takoradi
Cape Coast
Sekondi

Quality Data

Next we study quality data – that is, information not on the quantity of the output produced, but instead on the quality of the output. This is a very important question with the introduction of a commodities exchange because there is the need for consistent levels of quality of the output in any given contract being traded at the exchange.

There is relatively little data on the quality of crops grown in Ghana. The Ministry of Food and Agriculture does not keep consistent records of the quality of crops. Therefore, there is very little data available on quality.

The Ghana Standards Authority (GSA) is the regulatory body that will set different standards for grading the two initial commodities to be traded on the Ghana Commodities Exchange – paddy rice and maize. In the note below we discuss some of the methods they are currently using in collecting data on the quality or grades of the food crops.

The GSA produces formal quality standards in Ghana. The GSA has very formal criteria used to classify different crops as being of different numerical quality levels. For example, the table below is from the GSA and defines criteria they use in grading maize. The grade levels used by the GSA are not used in any of the markets we studied. Instead, buyers and sellers negotiated the price of the maize based on very casual inspection of the goods.

Table 2: Maize grades

Characteristic (%)	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5
Disease	0.5	0.5	0.5	0.5	0.5
Discolored	2.0	3.0	3.0	4.0	4.0
Broken / Chipped	5.0	6.0	10.0	14.0	20.0
Insect damaged	2.0	4.0	5.0	5.0	5.0
Stained	0.0	0.5	0.5	1.0	1.0
Germinated	0.0	0.5	0.5	0.5	0.5
Shriveled	1.0	2.0	3.0	4.0	5.0
Other grains	0.5	0.5	1.0	1.0	2.0
Total defective	**11.0**	**17.0**	**24.0**	**30.0**	**38.0**
Inorganic	0.0	1.0	2.0	2.0	2.0
Organic	1.0	2.0	5.0	5.0	5.0

It is unclear how these grading levels will be implemented in practice once the GCX is started. It is challenging to grade according to the criteria outlined above as the criteria are extremely difficult to decipher in practice by the farmers and traders currently in markets for the GCX commodities.

Further, the Ministry of Food and Agriculture does not, as far as we can tell, collect data on the quality of food crops. In particular, we were unable to find production data of maize broken down into different grades of maize.

The markets in our broader study area did have some local notions of grades of maize. We heard about local versus improved varieties. There were differences in the moisture content (dryness) of the maize, whether the maize was moldy, was infested with insects or the size of the grain itself. Bigger grains typically garnered a higher price and were considered higher quality. We did observe price variation in the market according to quality as just defined. At the bottom of the quality ladder were some (but not all) of the poultry farmers who bought the lowest quality maize to feed to their chickens primarily.

Price Data

There is a good amount of data on prices, unlike that of quantities and quality. We collect data from two main sources. The first is the Ministry of Food and Agriculture (MOFA). The second is an African technology and agricultural information company, ESOKO.

While MOFA collects data regularly for statistical services, ESOKO is a demand-driven private company that collects data to send price alerts to farmers. Comparing to the MOFA dataset, ESOKO has much a more detailed classification of commodities. For example, while MOFA has only one commodity called "maize," the ESOKO dataset classifies 12 different variations of maize. However, since ESOKO is a demand driven firm that provides services at a cost, it does not always collect price data for all markets regularly. This leads to the data being incomplete with missed observations. In particular, the MOFA datasets contain information on a large number of markets that are missing from the Esoko datasets.

The MOFA data is in turn fed into international datasets like the Food and Agriculture Organization (FAO). There are also household survey datasets, which obtain food prices from

surveys of farmers and consumers – in particular the GLSS (Ghana Living Standards Survey) produced by the Ghana National Statistical Service.

Below we list some of the academic papers using price data, particularly that from MOFA for an analysis of food markets in Ghana. To our knowledge, there is no research that uses ESOKO price datasets in analyses of the food markets in Ghana.

Table 3: Academic Papers Using Ghana Price Data

Paper Title	Source	Data
ABDULAI A., 2000. Spatial price transmission and asymmetry in the Ghanaian maize market	MOFA	MAIZE Markets: Bolgatanga, Accra and Techiman - Monthly data from May 1980 to October 1997
AIDOO R. (2009) An analysis of yam consumption patterns in Ghanaian urban communities PhD dissertation	Self-collected	YAM (mostly) Household expenditure surveys August 2006 through July 2007
AIDOO R., NIMOH F., BAKANG J., OHENE-YANKYERA K.,	Self-collected	YAM Districts: Techiman, Atebubu

FIALOR S., Mensah J., ABAIDOO R. (2012) Estimation of margins and efficiency in the Ghanaian yam marketing chain	(surveys, 320 responders from 4 districts)	(Brong/Ahafo), Ejura-Sekuedumasi and Nkwanta - One-time collection of all prices for value chain: farm-gate, wholesale, retail.
ALDERMAN, H., SHIVELY, G., 1991. Prices and markets in Ghana. Working paper No. 10. Cornell Food and Nutrition Policy Program, Ithaca, NY.	MOFA	RICE, CASSAVA, MILLET, GARI, SORGHUM, MAIZE, YAMS Markets: Bolgatanga, Techiman, Cape-Coast - Monthly data from 1970 to 1990
ALDERMAN, H., SHIVELY, G., 1996. Economic reform and food prices: evidence from markets in Ghana. World Development 24 3. 521–534.	MOFA	MAIZE Markets: Bolgatanga, Techiman, Cape-Coast - Monthly data from 1970 to 1993
AMIKUZUNO J. 2011. Spatial price transmission analysis in Ghanaian agricultural markets: does the data frequency improve our estimation?	MOFA and self-collected	TOMATO Markets: Navrongo, Techiman, Tamale, Kumasi, Accra - Monthly data from January 1998 to April 2008 (excluding Accra) - Semi-weekly data from March

		2007 to May 2009
AMIKUZUNO, J., and von CRAMON-TAUBADEL, S. (2012). Seasonal Variation in Price Transmission between Tomato Markets in Ghana. Journal of African Economies	MOFA	TOMATO Markets: Navrongo, Techiman, Tamale, Kumasi, Accra - Monthly data from January 1992 to February 2011 (exceptions: Accra from March 2004, Navrongo until November 2009)
ANKAMAH-YEBOAH(2012). Spatial Price Transmission in the Regional Maize Markets in Ghana, *MPRA*	MOFA	MAIZE 5 regions: Northern, Brong-Ahafo, Ashanti, Greater Accra region and Central region - Monthly (averaged) data from January 2002 to December 2010 Missing observations were filled with average of previous 4 months
BADIANE, G. SHIVELY (1998). Spatial integration, transport costs, and the response of local prices to policy changes in Ghana	MOFA	MAIZE Markets: Bolgatanga, Makola (Accra) and Techiman - Monthly data from May 1980 to July 1993 They claim, "These prices are part of a regularly reported MOFA series

		of wholesale and retail prices for major food items in 35 markets
BADIANE, G. SHIVELY (1997). The response of local maize prices to the 1983 currency devaluation in Ghana	Previous paper, older version	
CUDJOE, C.BREISINGER, and X. DIAO, (2008). Local Impacts of a Global Crisis: Food Price Transmission and Poverty Impacts in Ghana, International Food Policy Research Institute.	GSS[9] GLSS V (05/06)	RICE, MAIZE, CASSAVA, YAM Markets: Accra, Sunyani, Tamale, Kumasi, Mankessim - Monthly market data for January 2000 to September 2008 Other data on consumption and expenditures (GLSSV)
MENSAH - BONSU, A. AGYEIWAA-AFRANE and J. K. M. KUWORNU (2011) Efficiency of the plantain marketing system in Ghana: A co-integration analysis, *Journal of*	MOFA	PLANTAIN (wholesale, 10 kg) Markets: Agboglobshie, Kumasi, Koforidua, Sunyani, Obogu, Begoro, Goaso - Monthly data from January 2004 to December 2009 (weekly data was

[9] Ghana Statistical Service.

Development and Agricultural Economics		averaged into monthly because weekly price data has several long periods for which prices are constants for almost any market)

Transport Sector

One area we expect to see change upon the introduction of the commodities exchange is in the transport sector. The number and types of cars, trucks and transportation vehicles will change. There should be more vehicles and bigger varieties plying the trade routes more often.

There have been national surveys of the transportation system. For example, there is the Ghana National Transport Household of 2007[10]. However, these surveys are done intermittently. They lack the frequency and quality to make a comprehensive evaluation of the impact of the commodities exchange over time.

In principle, there are waybills collected on the main roads as food trucks pass by with their loads. However, we have inspected many of these and realize they do not always contain the desired information from which to infer the volumes of goods traveling. However, we do have some rough information on the type of vehicles.

[10] See the Ghana National Transport Household Survey data and questionnaire web site http://www.statsghana.gov.gh/nada/index.php/catalog/28/related_materials

4. Mobile Phone Apps for Measurement and Evaluation

From the above sections, we see that there is data on official food production statistics in Ghana. However, most researchers and ministry officials would admit that this is an area which could be greatly improved. If we are to measure the continuous changes and improvements in the agricultural sector resulting from policy changes, we will have to collect much better data than what is currently available.

This improved data collection could be of interest to policy makers across sectors, not only those interested in the impact of policy innovations in agriculture, commodities exchanges, etc. Better collection of data is of importance in determining inflation rates, growth rates and in monitoring nutrition and food consumption in poorer communities.

With the widespread availability and penetration of mobile phones, the hope is that there could be alternative methods of collecting data. Indeed, the collection of information for agricultural markets may be the area by which the mobile phone achieves its much-heralded potential. In this section, we describe some of the innovations in the use of the mobile phone and other new technologies for data collection in the agricultural sector of poor developing regions. In particular, we will describe some mobile phone based apps created by the Center for Technology and Economic Development (CTED) team of New York University.

Data Sources for Agricultural Production or Output

As we discussed earlier, it is important to have accurate information on levels of food production. In the past this has been achieved through agricultural surveys of farms and, in particular, by measuring the output on randomly selected lots on farm samples and extrapolating

these figures nationally. We have developed a number of mobile phone-based interventions that allow us to collect information on a variety of agricultural outputs. We have been told by some MoFA officials piloting our intervention, and are close to confirm, that some of our innovations make this data gathering much more efficient and reduce production measurement time by more than 50%.

Mapping Farms

The first tool that we have created is a simple Android application that enables farmers to map out their farms and, for each plot, tell us the crop or crops that are grown on the field.

The app is designed to be simple enough for almost anyone with access to a basic smartphone to use. It works by using the phone's internal GPS sensor to track a user's movements as they walk around the boundaries of their farms. This results in geo-referenced data that can be combined with photos and voice notes to create spatial datasets of farming production in the region.

Figure 10: The CTED Data Collector farm mapping app.

We trained a diverse set of people, ranging from illiterate farmers to technical researchers, and asked them to map farms in their communities. The resulting map, shown below, is color-coded and shows where each crop is grown.

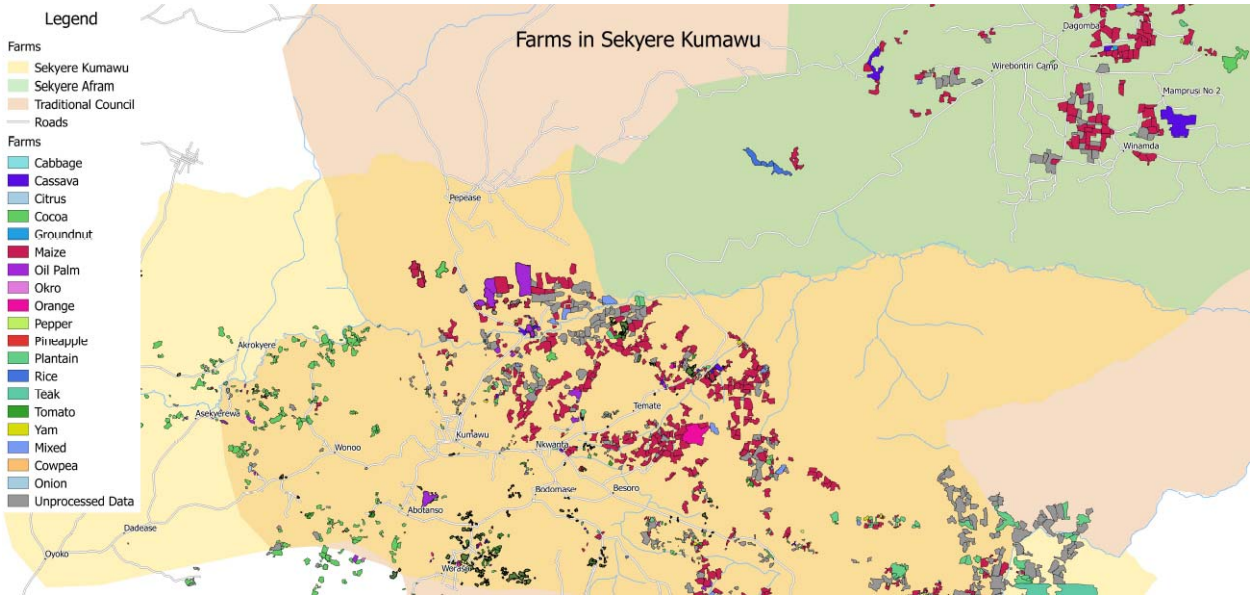


Figure 11: Farms mapped using our app throughout the Kumawu Traditional Authority.

Quantity Data and Our FarmData App

For more sophisticated crop production measurements, we have created a second app, which we call FarmData, that allows users to sample yield measurements and generate large-scale estimates of agricultural production based on standard statistical models and "crop cut" sampling methods.

FarmData builds on the mapping capabilities of the previous app by randomly generating crop sampling points throughout the farm. Users are then given specific instructions on how to sample yield measurements at these points based on conventional enumeration methods. Once

the measurements are completed and entered into the app, a quick estimate of the farmer's potential yield on the entire farm is calculated. This data can also be uploaded to a central server for storage and aggregated analysis.

This app therefore allows communities to crowdsource their own data accurately and efficiently. Measurements and statistics that previously took days could be theoretically calculated within hours, with significantly less human intervention needed.

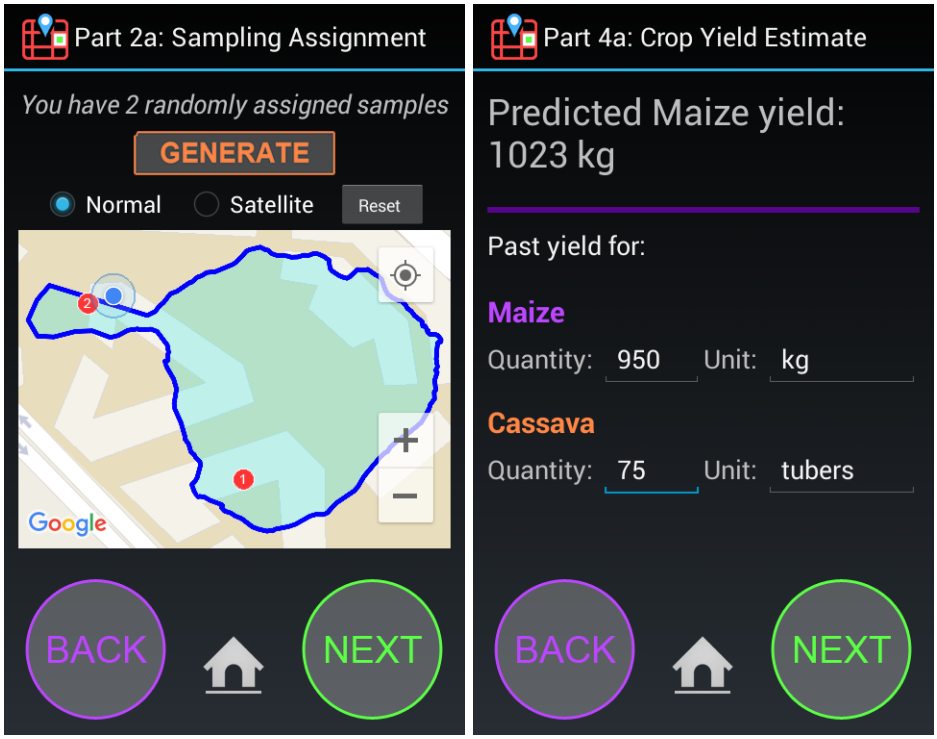


Figure 12: Sample screen shots of the FarmData app showing crop sample point assignments and yield estimates.

Data on Crop Quality

Our apps also include modules for farmers to record observations and take pictures of the crops. From this, it is easy to see how our apps could be used to obtain information on the quality of the crops both by self-assessments, as well as by showing the pictures to trained experts.

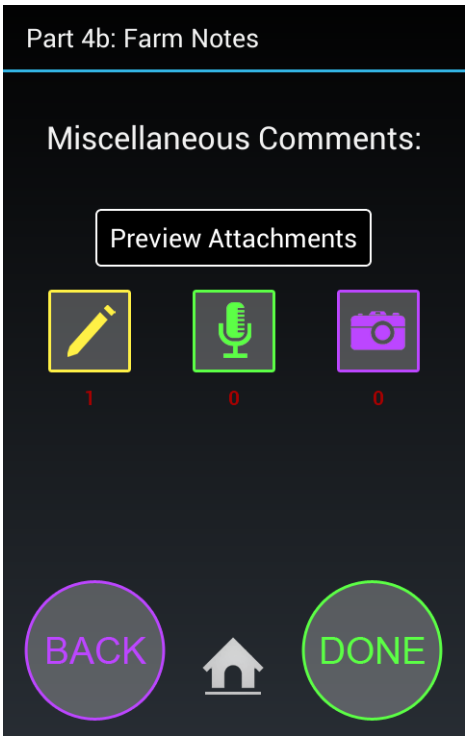


Figure 13: Multimedia, voice notes, and text can be recorded to provide additional information about each farm.

This information will be required for the baseline survey to enable information on quality upgrading upon the establishment of the commodities exchange.

Price Data

As we mentioned earlier, ESOKO, a technology firm that we have been working with, collects valuable price data in the markets from their market enumerators. We will continue to work with them to provide a source of real time market price data.

Data on the Transport Sector

We have also used various mobile apps to take a closer look at food transportation networks and costs across Ghana. For example, we worked with ESOKO to develop a mobile surveying app for their enumerators to collect weekly data on transportation prices of traded commodities between 40 key markets in the country. Surveyed entities included traders, drivers and GPRTU quoted prices. We combined these results with data that we collected using a more thorough survey on transportation costs and practices. We trained enumerators in two market areas to use this mobile app to survey both traders and drivers and send their responses back to a centralized server. These questionnaires captured more detailed practices from networks that included wholesale traders passing through the Volta region and minor trading networks between smaller towns and villages in the Ashanti region. These surveys also collected multimedia and added provisions for questions such as transportation volumes, driving times, road quality, weather conditions and loading fees.

Market Structure and Market Participants

As we have described above, there is a fairly informal system of market trading in the traditional markets. A lot of this will change once the commodities exchange is implemented. This would involve measurements of the number of market participants in the marketplaces. We are certain that, given the experience of our research teams in Ethiopia, there will be drastic changes in the microstructure of these markets.

Conclusion

Subject to funding, we seek to expand our baseline studies nationally to enable a national evaluation of the impact of commodities exchanges. Subsequent papers will provide data on our current study area – it will form the basis of a baseline study to evaluate the impact of the GCX. As our concluding remarks we will speculate what we expect to find upon the implementation of the commodities exchange, GCX.

We expect to see major changes in the market structure and market participants. Many of the middlemen and traders may be wiped out as the commodity exchange is formed, unless some of those middlemen, and particularly traders, can be trained to become members of the GCX and intermediate trade between the buyers and sellers (farmers) can occur on the trading floor of the GCX.

We expect to see increases in the quantity and quality of output of the main traded commodities caused by the introduction of the GCX. The mechanisms of the GCX will enable much better data gathering, from the GCX itself, in comparison to what is in existence now. This is for both quantity and price data.

We expect the transport system to be enhanced by the regular and organized movement of the GCX commodities from the farm to the warehouses and from the warehouses to the final buyers of the commodities. Finally, we expect new industries to flourish and benefit from the order created by the commodities exchange. Potentially, companies will be formed to aid final buyers of the produce, bagging the produce, other activities which help with clearing from the warehouse, and finally a slew of logistics and financial management companies, and many more.

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