Mineral Fertilizer Quality: Implications for Markets and Small Farmers in Tanzania*

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Abstract

Small farmers in Sub-Saharan Africa exhibit low adoption rates for mineral fertilizers. A promising hypothesis explaining these puzzlingly low rates remains untested: a perception among farmers that fertilizer in the market has been compromised in ways that raise concerns about its effectiveness. Information about fertilizer quality problems is anecdotal rather than backed by reliable evidence. A challenge: little research to date has focused on understanding the relationships between input supply chains and product quality. To achieve a clearer understanding of this problem, this research links results from tests of the quality of 661 samples of fertilizers for sale in the markets of the Morogoro Region of Tanzania with data from a survey of the region's 225 input dealers. Fertilizer nutrient and moisture content tests are performed on the same samples in multiple laboratories located in East Africa and in the United States. Results from our research provide the first assessments of market-available fertilizer quality in the region, as well as the first analysis of relationships between fertilizer quality and mineral fertilizer supplier characteristics.

Introduction

Compared with regions of the world where agricultural productivity increased rapidly and significantly during the Green Revolution, crop yields in most of Sub-Saharan Africa have remained stagnant over the past 50 years. A primary explanation for this stagnation may be the widespread failure to adopt modern agricultural inputs such as mineral fertilizer (Sanchez 2002).

In Tanzania, the use of mineral fertilizer is low; on average, farmers apply less than nine kilograms of mineral fertilizer per hectare and application rates among small farmers are even lower (Tanzania Fertilizer Assessment 2012). Small farmers in Tanzania who purchase mineral fertilizer often purchase it in small quantities (as little as one kilogram at a time) from open fifty-kilogram bags in input shops. Mineral fertilizer purchased from open bags is vulnerable to two primary kinds of quality problems: product degradation due to exposure to moisture and nutrients settling in the bag and adulteration by the seller. Anecdotal evidence suggests that farmers believe that the fertilizer available in input shops has quality issues and periodic news stories chronicle adulteration. In 2014, a local newspaper in Tanzania reported that the Tanzania Fertilizer Regulatory Authority had seized and destroyed counterfeit fertilizer found in the marketplace (Lugongo 2014). However, little hard evidence exists evaluating neither the presence of substandard or compromised fertilizers in the region, nor the density and magnitude of such issues throughout the supply chain.

To achieve a clearer understanding of this problem, this paper provides evidence on the quality of fertilizers for sale in the input shops and markets of Morogoro, Tanzania. The Morogoro region is an area of high agricultural potential exhibiting exceptionally low mineral fertilizer use, with less than one percent of maize farmers in Tanzania's 2007 agricultural census reporting application of the input. Results from our research provide the first assessment of market-available fertilizer quality in Sub-Saharan Africa linked with details about the fertilizer supply chain, as well as the first analysis of relationships between measured fertilizer quality and purchase quantities. Results are fundamental to the design of effective policy to increase agricultural production and food security in the region.

Our data include both quality assessments of fertilizer samples from shops and details about the transactions and purchase locations, allowing us to examine the following critical questions:

- What agro-dealer characteristics are related to measured fertilizer quality characteristics such as moisture content and nutrient content?

- What agro-dealer characteristics are related to *observed* mineral fertilizer quality characteristics such as clumping, foreign material and discoloration?

- How is the supply chain for mineral fertilizer structured in the Morogoro region? What are the bottlenecks and challenges for input dealers and consequently for farmers?

- What is the relationship between fertilizer prices and measured and observed quality characteristics? Does price signal fertilizer quality to farmers?

A special contribution of this paper is its focus on the regional supply chain for mineral fertilizer in a developing country; the research sits at the important and sparsely occupied intersection of development economics and supply chain analysis. The survey includes 225 input dealers selling mineral fertilizer in Morogoro Region, Tanzania between November 2015 and May 2016 – a period beginning just before the primary maize growing season and continuing through planting. Our survey includes detailed information about the mineral fertilizer supply chain, agro-dealers' fertilizer sales, and agro-dealers' perceptions of the types of fertilizer quality issues in the region. We use these data to test for the presence and magnitude of mineral fertilizer quality issues and to assess how quality issues vary over the agricultural season and across input shops. Input suppliers were identified by an independent census conducted by the researchers. We provide the first comprehensive description and analysis of the fertilizer supply chain in a region of East Africa and link insights from this analysis to hypotheses related to small farmer productivity.

Contribution to the Literature

With over 75% of Tanzanians employed in the agrarian sector, mineral fertilizer could be an important tool for increasing production and increasing farmers' incomes—both approaches are critical to improving nutrition in the rural sector. However, use of mineral fertilizer remains low in the country, particularly in production of staple crops. The International Fertilizer Development Center (IFDC) estimates that in 2009-2010, Tanzanian farmers applied, on average, less than nine kilograms of fertilizer per hectare (Tanzania Fertilizer Assessment 2012).

Low fertilizer use rates are a persistent puzzle in the economic development literature. Researchers have explored the effects of credit constraints (Croppenstedt et al 2003), farmer behavioral biases (Duflo et al 2011), and input and output market uncertainty (Binswanger and Sillers 1983) on small

farmer mineral fertilizer use. One promising and complimentary hypothesis that remains underexplored is whether farmers perceive that fertilizer available for purchase in the market has been compromised in ways that raise concerns about its effectiveness.

One reason that small farmers might be suspicious of the quality of mineral fertilizer that they purchase has to do with the way that mineral fertilizer is packaged and sold in the region. Mineral fertilizer is sold in large standard quantities; 50 kg bags at a per bag price of $30-$50. Because the expense of a full 50 kg bag can exceed the limited budget of a small farmer during planting season, farmers often choose to purchase smaller quantities of fertilizer from open 50 kg bags in markets or inputs supply stores. This means that input shops measure the amount of mineral fertilizer that the farmer wants to purchase out of an open 50 kg bag or that the farmer purchases small bags of re-bagged fertilizer sold in 1 kg or 2 kg plastic bags. The quality of fertilizer sold and stored in open bags could be comprised in one of three ways: first, deterioration in fertilizer quality could result from the inputs dealer adulterating the product; second, the fertilizer, due to its sensitivity to environmental or storage conditions, may degrade naturally; or third, the granules within fertilizer blends may separate during transport or storage, meaning that farmers purchasing less than a full bag are likely to receive a product with inadequate nutrient content.

Anecdotal evidence from farmers is consistent with the hypothesis of quality issues in the fertilizer supply chain. A 2012 International Food Policy Research Institute report, "The Supply of Inorganic Fertilizers to Smallholder Farmers," presents qualitative evidence that low use of mineral fertilizer could be related to farmers' perceptions of the quality of the fertilizer. In particular, the report suggests that farmers perceive that small quantities of fertilizer purchased from input dealers' opened bags are of lesser quality than fertilizer purchased from unopened bags. In fact, a recent survey of 841 farmers in Tanzania, conducted by the Earth Institute at Columbia University and the University of Illinois at Urbana-Champaign, found that 71.6% of farmers believe that purchasing 2 kg of fertilizer from a previously opened bag would be of lesser quality than purchasing an entire 50 kg bag.

We are aware of only one working paper testing the quality of fertilizer in the marketplace in East Africa. In Uganda, Bold, Kaizzi, Svensson, and Yanagizawa-Drott (2015) investigate the measured quality of fertilizer and seed and link these results to farmers' subjective assessments of fertilizer and seed performance. They determine that farmers' expectations of poor quality fertilizer in local inputs

dealers are accurate, as their measured fertilizer nutrient content results indicate widespread quality issues in local input shops. Consequently, they find that farmers expect lower yields after applying substandard fertilizer. Based on farmers' rate of return estimates, they find positive and significant returns on purchasing authentic fertilizer, whereas they find negative return rates for fertilizer purchased at input-shop locations near the farmer. As the return rates imply, their work suggests that farmers' expectations of input quality may adversely affect farmers' decisions to purchase and to adopt the input.

Bold et al. (2015) make an important contribution to our understanding of the presence and effects of variable input quality. However, the paper has three primary limitations:

- First, in order to measure quality, Bold et al. (2015) test only fertilizer sample nutrient content. Yet, additional critical parameters beyond nutrient content determine the quality and performance of fertilizer; namely, the moisture content and for Urea fertilizer, the biuret content (FAO 2016, Mikkelsen 1990, Kilmer & Engelstad 1973). In addition, nutrient content testing in the Bold analysis appears to have been completed at a single Ugandan laboratory rather than multiple laboratories to check inter-lab reliability of the results.
- Second, although the farmers in Uganda had accurate expectations of the quality of fertilizer available in local retail markets, the authors do not investigate the signals that farmers use to infer the quality of the good. In the case of fertilizer, whether it is bought in a closed or a previously opened bag or other observed characteristics such as the presence of caked clumps, discoloration, and/or foreign materials may influence or drive farmers' inferences on the quality of the fertilizer.
- Third, while the Bold et al. paper identifies quality issues in mineral fertilizer in the market, the analysis neither investigates *why* there are quality issues nor *where* the quality issues exist and persist in the supply chain.

Our work complements the work of Bold et al. (2015), but addresses these shortcomings. In particular, we focus on the characteristics of the supply chain for fertilizer in Tanzania in order to identify limitations and choke points; we measure and analyze both observed (caking, discoloration) and measured fertilizer quality characteristics and study the relation between these; and we survey and measure agro-dealers' assessments of fertilizer quality, linking these characteristics and assessments with measured and observed mineral fertilizer quality parameters.

Data and Methods

Input dealer census and surveys

We began the agro-dealer census by verifying two different lists of agro-dealers. The first list was provided at the district level by the Ministry of Agriculture in Morogoro for the Morogoro Rural district and included 61 input shop names and locations. List verification was completed through in-person visits by members of the research team. The second list was provided by the Alliance for Green Revolution in Africa (AGRA), for all eight districts of Morogoro region. This list consisted of 173 persons who participated in agro-dealer trainings (CNFA/TAGMARK), overseen by AGRA, to participate in the National Agricultural Input Voucher Scheme. Participants in AGRA trainings included individuals with previously established agricultural inputs shops and individuals interested in accepting fertilizer vouchers as part of the program. Initial verification of this list was done via phone by members of the research team. The research team determined whether the individual was selling fertilizer and also confirmed the location of the store from which it was sold.

The lists verification determined that lists from the government and AGRA were both incomplete and inaccurate; numerous individuals contacted from the lists reported no involvement in input operations and known agro-dealers operating in the Morogoro Region were not included on the lists. We developed a route and itinerary for the agro-dealer census. Although we had some information that we verified from AGRA on agro-dealer locations, the research team used the following process to complete the list of agro-dealers operating in the Morogoro Region:

1. First, we devised a census and survey schedule based on a regional map of Morogoro following the primary and secondary road networks.

2. At each ward office, the research team visited the ward level agricultural extension officers to identify and locate agro-dealers.

3. In locations where the village level agricultural extension officer was not available, the research team conducted its own search but also interviewed two or three local informants from the village about agro-dealers in the area.

4. At every agro-dealer location surveyed, we employed a snowballing method and asked the respondent to identify additional agro-dealers in the current location or in the following village or location.

As a result of these methods, we identified and surveyed 225 agro-dealers throughout Morogoro Region. In a small number of cases, we were unable to survey an identified agro-dealer. This generally occurred because the shop was closed at the time of the interview, the shop did not actually sell fertilizer and only sold other agricultural inputs, or the agro-dealer refused to participate in our survey. It is important to note that we were mostly refused in the Morogoro Municipal district.

The agro-dealer survey collected information about the scale and history of the operation, the demographics of the owner, storage and transport facilities owned and rented, participation in government input and capacity programs, identities of the wholesalers and/or retailers where input shops source mineral fertilizer, types of fertilizer stocked and in which months, and terms of shop transactions (financing, transport) when purchasing and selling mineral fertilizer. In addition, we collected the geographic coordinates of all shops in the sample, which allows us to study spatial relationships between suppliers, retailers, quality parameters and transport distances in the supply chain. These data allow us to comprehensively map the regional fertilizer supply chain, something which has never been done before in Tanzania. Figure 1 presents the locations of 225 input dealer shops located in Morogoro Region, Tanzania. Colors indicate per kg Urea prices in November, 2015. Table 1 presents the number of agro-dealers identified and surveyed in Morogoro Region, by district.

Mineral Fertilizer Samples

Fertilizer samples were purchased in two rounds from all surveyed shops: before the start of the primary agricultural season in November and December 2015 and during planting and cultivation in March and April 2016. We used a covert shopper approach to make two types of purchases during the primary agricultural season: we purchased 1 kg samples from previously opened bags; and we randomly chose a type of a closed bag to purchase.

In the case of the 1 kg samples purchased from previously opened bags in the shops, we employed a covert approach. An enumerator different from the enumerator who conducted the agro-dealer's

interview purchased the samples. The enumerator followed a pre-defined script: he greeted the shopkeeper and asked the shopkeeper to buy 1kg of Urea, DAP, and CAN. If the shop had all three types available, the enumerator purchased all three. If the shop had only two types or one type available, the enumerator purchased the type(s) that were available. As is culturally appropriate for a Tanzanian farmer, enumerators dressed in the way that a farmer would dress if he/she were making a visit to town; namely, this meant that our male enumerators wore collared shirts, trousers, and sandals. In the case that enumerators were asked additional questions by the agro-dealer, they were prepared to respond with locally appropriate responses. For example, on occasion, our enumerators were asked by agro-dealers on which crop they intended to apply the fertilizer(s). As a result of earlier survey, our enumerators were aware of the major crops grown in the location, and, as such, were able to engage the agro-dealers in a locally appropriate way.

In the case of the samples from closed bags, we developed a randomized method for shops from which to purchase the closed bags. Closed bags of fertilizer from the manufacturer can range in amount from 5 kg to 50kg. In order to ensure that the samples of closed manufacturer bags were representative of the region, we developed a purchasing quota based on the proportion of agro-dealer shops in each district relative to the regional total. Next, we identified the semi-urban and urban locations where we expected closed bags to be available. When we arrived in these locations, the first enumerator made the covert purchase of the 1 kg sample(s). Afterward, a second enumerator visited all of the shops in the location and inquired about the availability of closed bags (ranging from 5 kg to 50 kg) and the types of fertilizer available. We randomized purchasing over two dimensions across shops within a village: the store and the type of fertilizer we purchased.

During the November 2015 round, the samples were purchased at the time of interview. The research team was instructed to purchase 1kg samples of any fertilizer available from the following types: Urea, DAP and CAN. We purchased the following number of samples: 160 Urea, 75 DAP, and 95 CAN. Of the 176 purchasing transactions our enumerators engaged in at the time of the survey, 61.9% found that the previously opened bags of fertilizer were visible within the store. Moreover, of these transactions, 90.5% occurred directly in front of the enumerator.

Purchased samples were stored in their original plastic bag packaging and labeled with the store and purchase information for the purposes of creating unique sample identifications. Samples were placed in airtight plastic bins for storage. In the first round, the samples were packed and sealed

doubled Ziploc bags and coded throughout the six weeks of the purchasing round. In the second round, the sample packing was completed after the two-week sample collection.

In total, 661 samples were purchased. Table 2 presents the number of fertilizer samples purchased by survey round. The 661 samples are currently being tested at Thornton Laboratories in Florida, ICRAF labs in Nairobi, and at Mlingano and Selian Agricultural Research Institutes in Tanzania. At ICRAF, samples are tested with MIR and pXRF spectrometry technology. This technology allows us to identify what type of substance the fertilizer has been adulterated with or to determine whether the sample has been mixed with another type of fertilizer. Preliminary evidence suggests the presence of both quality degradation due to poor storage conditions and adulteration. Table 3 summarizes the characteristics that are being tested by each laboratory.

Supply Chain Descriptive Analysis

Fifty-three percent of the input dealers surveyed are located in urban or semi-urban areas, whereas 47% are located in rural areas. We define urban locations as the areas which host district level government offices, as these areas have higher populations and higher population density. Morogoro Region is made up of eight districts: Gairo, Kilombero, Kilosa, Morogoro Rural, Morogoro Municipal, Malinyi, Mvomero, and Ulanga. We define semi-urban areas as other locations with observed population density.

In urban areas, input dealers tend to cluster along major roads or thoroughfares. In rural areas, input dealers tend to also be roadside among other shops within the village. It is uncommon for input shops to be located in isolated areas that are away from major roads or additional shops and businesses.

Of the shops surveyed, 81% sell fertilizer year-round. Of the 43 shops that do not sell fertilizer year round, 19 begin selling fertilizer in December and 12 in January, and the remaining begin selling fertilizer at different months of the year. Most shops reported that they continue to sell fertilizer until April. This period of time is considered to be the long rains season and main cultivation period for Morogoro region. The difference between rural and urban shops and whether the shops sell every month of the year or a only during a few months of the year is insignificant. Among the 43 shops that do not sell fertilizer year round, 20 are located in rural areas, 14 in urban areas, and 9 in semi-urban areas.

All of the input shops that we surveyed in the region are privately owned and operated businesses. Notably, however, our sample of input shops includes shops with official and unofficial status. In *The Fertilizers Act, 2009*, the Tanzanian national government established a regulatory body, the Tanzanian Fertilizer Regulatory Authority (TFRA), to oversee the manufacturing, importation, and inspection of fertilizers. The TFRA was also empowered to distribute licenses to register input shops, which officially permitted input dealers to sell fertilizer. According to our data, 130, or 59%, of input-shops were not licensed by TFRA to sell fertilizer. Of those that are not licensed by TFRA, 58 are located in semi-urban and urban areas and 72 are located in rural areas. Of the shops that do have a TFRA license, 32 are located in rural and the remaining 50 in semi-urban and urban areas.

Beyond the location of the input store, only 24% of the input dealers surveyed have access to a warehouse for the storage of their fertilizer stock. However, among the various types of primary storage facilities for all of the agro-dealers surveyed, all of the facilities feature metal roofing and concrete floors; however, 25% do not store their fertilizer stock on pallets, 91.1% do not have a fan, and 99.6% do not have an air conditioner to keep the temperature of the storage facility cool. These factors are generally considered important for fertilizer storage facilities in the tropics, as humidity affects the moisture tolerance of fertilizer.

Storage capacity varies greatly among input shops, as input shop owners may store with in the store, rent/own a storage location, or store within their personal home. In total, however, in the first quartile, the average kilograms of storage capacity are 500 kg. Input shops at the third quartile have a mean storage capacity of 10,000 kg. The input store with the largest capacity, however, has a storage capacity of 1,758,000 kg. Overall, the storage capacity mean is 25,541 kg, yet the median is 2500 kg. Figure 2 shows the distribution of storage capacities across the agro-dealers that we surveyed and Table 4 provides summary statistics on the total storage capacity.

At the time of the interview, agro-dealers had an average of 2,046.2 kg of fertilizer in stock; however, the average amount of fertilizer sold in 2014 by shop was 19,780.5 kg. The average amount sold includes the total amount of Urea, DAP, and CAN, sold, but also factors in other fertilizers such as Minjingu and SA. Moreover, in some cases, agro-dealers were able to report the total amount sold, but were unable to report the total amount sold per type of fertilizer. Table 4 provides an overview of the volume of sales for the agro-dealer survey, including the median and standard deviation. In 2014, the predominant fertilizer sold was Urea, with a mean of 5944.7 kg, followed by

DAP and CAN, with respective means of 1970.0 kg and 1851.0 kg. Ninety-eight percent of the input shops sell Urea, 64.4% sell DAP, and 80% sell CAN. Seventy-one percent of the inputs shop sold less than 10,000 kg (less than 200 50 kg bags) of fertilizer in 2014, whereas the remaining input shops sold a range from 10,000 to 580,985.5 kg. Furthermore, the medians for each type of fertilizer further characterize our population of agro-dealers as large small input shops with relatively small sale volumes. The median kilograms sold in 2014 was only 2000 kilograms; for Urea the median was 400 kilograms, whereas for DAP and CAN it was 0 kilograms. Within our survey, we also asked input dealers to report whether they sold NPK, Minjingu, and SA. Only 50.7% reported selling NPK, 36.1% sell Minjingu, and 30.7% sell SA.

Agro-dealers overwhelmingly reported that the bulk of their sales were to smallholder farmers. Only 4.9% reported that they sell the greatest proportion of their stock to large farmers and 2.7% to farmers' organizations. Thirty nine percent of the agro-dealers reported that they will sell fertilizer to smallholder farmers on credit and mostly expected smallholder farmers to repay in cash. Nearly 10% of the agro-dealers reported that they were willing to accept payments in-kind of harvested grains or a combination in-kind payment and cash. Only 68 agro-dealers reported that they sell fertilizer to large farmers. Eighteen percent of agro-dealers were willing to allow large farmers to purchase fertilizer on credit, but all expected their large farmers to repay for the fertilizer in cash. Forty-three agro-dealers reported that they sell fertilizer to farmers' organizations, yet only 30.2% provided the farmers' organizations with credit, with payment largely expected to be in cash. Twenty-one agro-dealers reported that they supply other agro-dealers with fertilizer, but this was largely a cash sale, with 23.8% of inputs dealers who allowed their customers to purchase fertilizer on credit.

In general, agro-dealers in our survey rely on multiple fertilizer manufacturers and fertilizer suppliers for the stock of their fertilizer. Only 19.6% of our agro-dealers had an exclusive relationship with a particular manufacturer. Of the first supplier reported, nearly half, 45.8%, of agro-dealers are being supplied fertilizer from Morogoro, 28.9% from Dar, and 16% from Ifakara. There are, however, two major chokepoints within the supply chain. There are two particular agro-dealers located in Morogoro who supply 31.1% of the agro-dealers within Morogoro region. Sixty-five percent of agro-dealers are purchasing fertilizer from their primary supplier every month of the year.

Finally, we collected data on agro-dealers opinions and perceptions of fertilizer quality at the shop and market level. We asked agro-dealers for their market-level assessments about the quality of

fertilizer across four dimensions, adulteration, caked appearance, age, and a nutrient content different than what is advertised, and also asked whether they had purchased fertilizer with the previous issues before. Thirty percent believe that adulterated fertilizer is a problem but affects less than half of the fertilizer available on the market. Yet, 21.6% of input dealers said that they had purchased adulterated fertilizer before. Next, we asked agro-dealers about their concerns of fertilizer being caked or clumpy. Forty percent thought that it was an issue with less than half of the fertilizer on the market, and 21.3% thought that it was an issue that affected half of the fertilizer on the market. However, 62.6% of our respondents indicated that they had purchased caked or clumpy fertilizer before. Finally, we asked whether agro-dealers were concerned that the nutrient content of the fertilizer was different than what was advertised. Sixteen percent of respondents indicated that they thought the nutrient content of fertilizer was an issue, but affected less than half of the fertilizer on the market. Thirteen percent reported having purchased fertilizer with such issues.

Sample Quality Results and Analysis

Forthcoming

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Appendix

Figure 1: Locations of 225 input dealer shops surveyed in November 2015. Colors indicate per kg Urea prices.

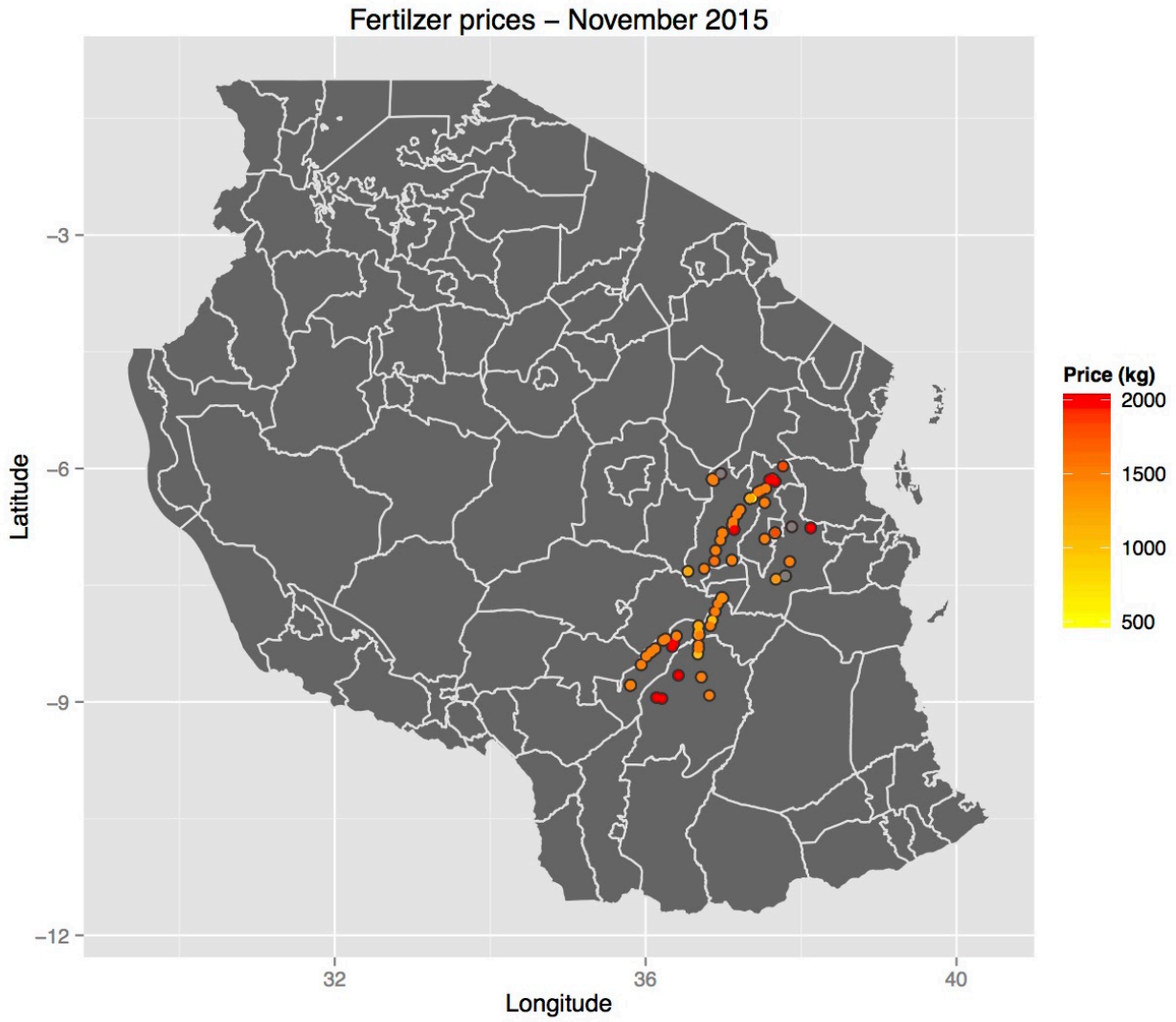

Figure 2: Histogram of Total Storage Capacity among all Agro-dealers' Storage Facilities

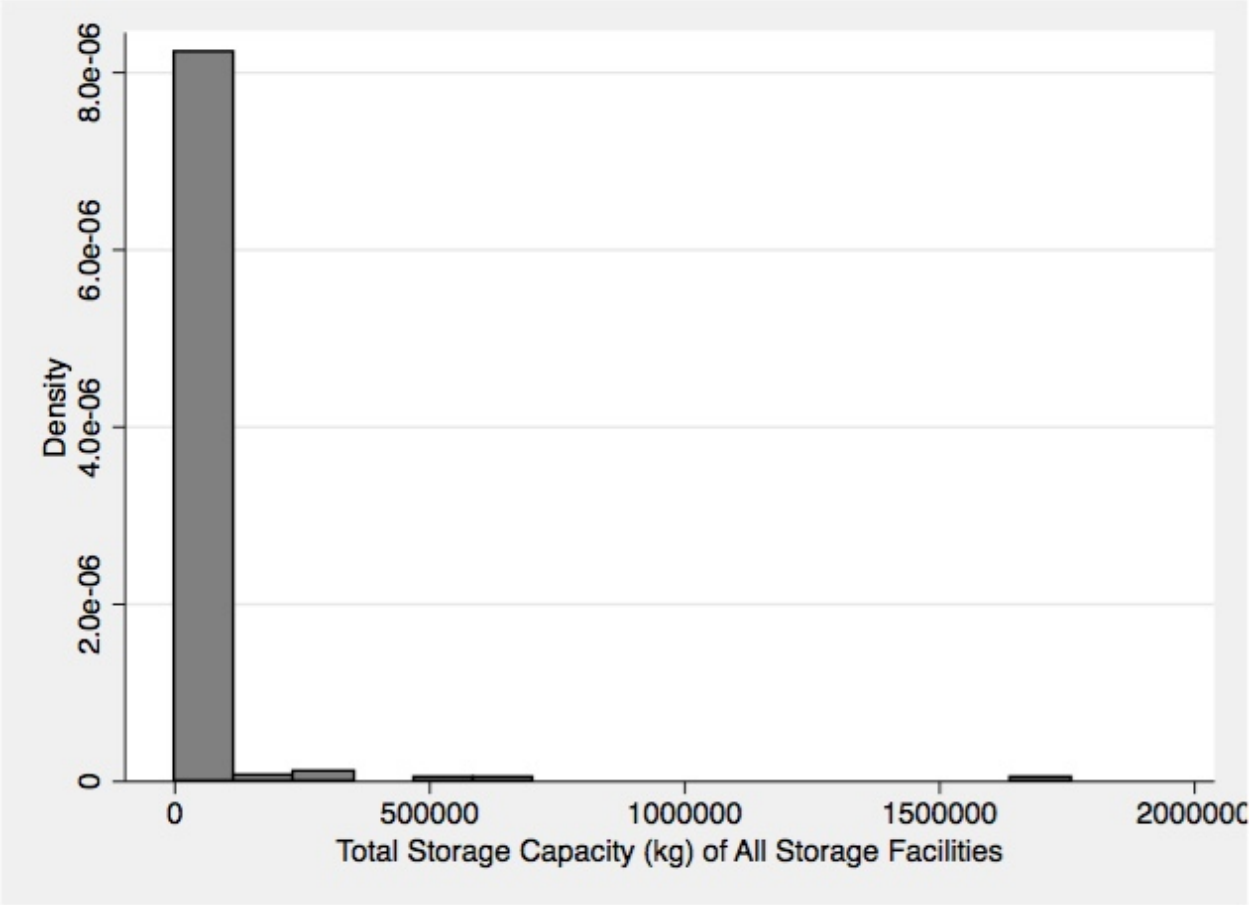

Table 1: Agro-dealers surveyed in Morogoro Region, Tanzania, by District.

District	Agro-dealers Surveyed
Gairo	9
Kilombero	80
Kilosa	44
Malinyi	8
Morogoro Municipal	20
Morogoro Rural	19
Mvomero	35
Ulanga	10
Total	225

Table 2: Fertilizer sample type purchased by survey round

Fertilizer Type	Pre-growing Season (November 2015)	Growing Season (March 2016)
Urea	160	159
DAP	75	70
CAN	95	102
TOTAL	330	331

Table 3: Lab testing of samples, properties tested and methods used

Laboratory	Testing Sub-set or All	Nutrient Content	Moisture Content	Biuret Content (Urea only)	Method
ICRAF, Nairobi	All	Yes	No	No	Spectrometry
CropNuts, Nairobi	All	No	Yes	Yes	Wet Chemistry
Mlingano ARI, Tanga	Sub-set	Yes	No	No	Wet Chemistry
Thornton Laboratory, USA	Sub-set	Yes	Yes	Yes	Wet Chemistry

Table 4: Total Fertilizer Sold & Total Storage Capacity in Kilograms, 2014

Fertilizer Type	Mean (kg)	Median (kg)	Standard Deviation (kg)	Minimum (kg)	Maximum (kg)
Urea	5944.2	400	23,415.7	0	312,000
DAP	1970.0	0	8290.0	0	89,000
CAN	1851.0	0	6894.9	0	60,000
Total Quantity Sold in 2014	19,780.5	2,000.0	58,678.7	0	580,985.5
Total Storage Capacity	17,741	2500	133,220.8	0	1,758,000