Drivers of Inorganic Fertilizer Use in Tanzania: A Comparison of the TZNPS and FF Datasets

Katie Stahley, Amy Pennington, C. Leigh Anderson and Mary Kay Gugerty

EPAR Brief No. 201

Prepared for the Agricultural Policy Team of the Bill & Melinda Gates Foundation

Professor Leigh Anderson, Principal Investigator
Associate Professor Mary Kay Gugerty, Principal Investigator

September 12, 2012

Introduction

Evidence suggests that farmers in developing countries can increase agricultural production by adopting technologies such as inorganic fertilizer and improved seed varieties, leading to positive economic and nutritional impacts (Feder, 1985; Foster, 2010). The diffusion of agricultural technologies has, therefore, been a cornerstone of many development programs. However, efforts to promote agricultural technologies have had mixed results, particularly in sub-Saharan Africa, indicating that there is still an incomplete understanding of the factors that lead to technology adoption in developing countries (Nkonya, 1997; Toenniessen, 2008).

This brief explores how two datasets – The Tanzania National Panel Survey (TZNPS) and the TNS-Research International Farmer Focus (FF) – predict the determinants of inorganic fertilizer use among smallholder farmers in Tanzania by using regression analysis. The (TZNPS) was implemented by the Tanzania National Bureau of Statistics, with support from the World Bank Living Standards Measurement Study – Integrated Surveys on Agriculture (LSMS-ISA) team and includes extensive information on crop productivity and input use. The FF survey was funded by the Bill and Melinda Gates Foundation and implemented by TNS Research International and focuses on the on the behaviors and attitudes of smallholder farmers in Tanzania. The two datasets produce relatively comparable results for the primary predictors of inorganic fertilizer use: agricultural extension and whether or not a household grows cash crops. However, other factors influencing input use produce results that vary in magnitude and direction of the effect across the two datasets. Distinct survey instrument designs make it difficult to test the robustness of the models on input use other than inorganic fertilizer. This brief uses data inorganic fertilizer use, rather than adoption per se. The TZNPS did not ask households how recently they began using a certain product and although the FF survey asked respondents how many new inputs were tried in the past four planting seasons, they did not ask specifically about inorganic fertilizer.

Literature

Feder *et al.*'s (1985) influential analytic framework for modeling agricultural technology adoption in the developing world assumes that farmers implement a technology in order to maximize expected utility, or net benefits, during a given time period (often a growing season). A farmer's expected utility is bounded by factors such as initial resource allocations, input and output prices, and informational constraints, including expectations of a technology's profitability or suitability. Over time, opportunities for individual or group learning, farmer resource accumulation, or decreases in input price might increase technology uptake; while farmer isolation, resource losses, or increases in input price may have the opposite effect.

Subsequent adoption studies used statistical modeling to demonstrate the adoption process, but generally focused on either economic, knowledge, or attitudinal constraints which led to three distinct strands in the literature (Doss 2006). While many adoption models focus on the economic, credit, and access constraints to technology uptake (Dercon, 2010; Kaliba, 1998; Shiferaw, 2008; Zeller, 1997), others center on the role of learning, either through agricultural extension or social networks and demonstration effects, on the adoption decision (Rogers, 1986; Cameron, 2007; Conley 2007). Still others focus on the farmer's perception of technology characteristics (Negatu, 1999; Adesina, 1995). More recently, a small body of work has developed around behavioral economics, focusing on the influence of attitudinal variables such as time preference and risk aversion on technology adoption (Duflo, 2009; Yesuf, 2009). All models generally control for a number of individual and household characteristics, including age, education level, farm location and gender. Still, most adoption studies assume that technology adoption results in net benefits for the farmer, which is not necessarily the case, and gathering the data necessary to accurately measure profit is difficult (Doss, 2006; Rosenzweig, 2010; Suri, 2011). Doss (2006) further suggests that many agricultural technology adoption studies are incomplete if the study design and sample do not take into account the ability to transfer study results into policy implications. A more comprehensive literature review of agricultural technology adoption will be included in the forthcoming EPAR Requests 194 and 195.

Data

This brief compares household data collected during the 2008 TZNPS and the 2009 FF surveys, both conducted in Tanzania. While both surveys include information on input use neither the TZNPS nor the FF survey was designed exclusively to explain or predict farmer input use. There are notable differences in each survey's sampling plan and survey instrument, limiting a complete comparison of inorganic fertilizer use models.[1]

Although there is substantial overlap – both surveys were conducted in Tanzania and collected farmer data -, the two datasets have different primary foci. The TZNPS asks in detail about input quantities and prices, making the data well-suited for modeling economic and access constraints. In contrast, the FF survey asks about farmer perceptions and attitudes, allowing for a model centered on behavioral determinants of use.

Sampling strategies also differed. The TZNPS data was collected from October 2008 to October 2009. The FF data was collected in 2010. The FF used a probability proportion to size sampling strategy to randomly select sampling points, while the TZNPS used a random, stratified and clustered sampling method to produce nationally representative statistics. The TZNPS set the rural stratum to comprise 65% of the mainland sample and evenly split the urban stratum between Dar es Salaam and other urban areas. The FF sample only includes rural wards and excludes large farms. It also excludes the regions of Zanzibar, Pemba and Dar es Salaam. While only one respondent from each household responded to the agricultural portion of the TZNPS, the FF includes responses from both a male and female household member for each sampled households, allowing for some intra-household analysis. However, with the exception of the attitudinal variables, all of the variables included in our models were only answered by the head of the household The TZNPS sample provides sufficient data to compare male- and female-headed households, while the FF sample, perhaps skipping households where a male and female head were not present, resulted in coding very few female-headed households (less than 2%). The resulting FF sample may therefore underrepresent female-headed households. *Appendix 1* discusses the TZNPS and FF sampling plans in more detail.

Descriptive Statistics

Table 1 gives descriptive statistics for the FF and TZNPS samples, and includes a description of the survey question, where distinct. For example, the TZNPS asks *"Did you receive advice from any type of extension worker?"* whereas the FF asks *"Are you aware of extension services in your area, regardless of whether or not you use them?"* The TZNPS crop specific data only include observations from the long rainy season, while the FF data includes observations for the entire year. Most notably, the FF sample reports much higher rates of household inorganic fertilizer use than the TZNPS sample (36% compared to 17%).[2]

---

[1] A prime example of the implications of survey design: The LSMS-ISA and FF both survey inorganic fertilizer use. The LSMS-ISA asks separately about improved variety seed use and surveyed herbicide, pesticide or fungicide use in a combined question. The FF does not survey farmers on improved variety seed use, and it asks about herbicide and pesticide use in separate questions. Thus, the only input that can be compared across datasets is inorganic fertilizer.

[2] The LSMS-ISA survey distinguishes between Tanzania's long and short rainy seasons, and this brief focuses on long rainy season inorganic fertilizer use. Short rainy season fertilizer use rates are lower. While some households that did not use fertilizer in the long rainy season did so in the short rainy season, adding in short rainy season observations increases the total number of households in the sample and the annual LSMS-ISA fertilizer use rate decreases to 13%. The FF does not distinguish between

growing seasons, so we examine fertilizer use during the past year. Excluding the regions of Zanzibar, Pemba, and Dar Es Salaam (to mirror the FF sample), LSMS-ISA annual fertilizer use remains at 13%.

Table 1: Comparative Descriptive Statistics for the TZNPS and FF Base Regression Samples

	TZNPS	FF
Number of Agricultural Households	1525	1703
Percent Households Using Inorganic Fertilizer* TZNPS: *If household used inorganic fertilizer on any plot.* RI: *If household used chemical fertilizer on your farm.*	13%	35%
Percent Females TZNPS: *Female household heads.* FF: *Female primary respondents.*	26%	2%
Median Age of Respondents TZNPS: *Household head's age (regardless of whether they are the respondent).* FF: *Primary respondent's age (regardless of whether they are the household head).*	45	45
Median Years of Education TZNPS: *Household head's education (regardless of whether they are the respondent).* FF: *Primary respondent's education (regardless of whether they are the household head).*	7	7
Median Household Members	5	5
Median Land Size (ha)* TZNPS: *Size of land owned and/or cultivated in the long rainy season* FF: *Land cultivated during the year (whether rented or owned)*	1.42	1.62
Median Distance to Market (km)* TZNPS: *The average distance from each plot to market for all household plots cultivated during the long rainy season.* FF*: Distance from household to nearest market center*	6	1
Percent Households Growing Cash Crops* TZNPS*: Yes, if household grew a crop of which, on average, more than 50% of the harvest is sold.* FF: *Yes, if household grew any crop only for the purpose of sale.*	16%	41%
Percent Households with Material Floor TZNPS: *Material = concrete, cement/tiles, or timber; Other = earth.* FF: *Material = stone, bricks, wood, cement, or tiles/linoleum; Other = earth, mud or cow dung.*	16%	35%
Percent Households with Material Roof TZNPS: *Material = concrete/cement, metal sheets, asbestos sheets, or tiles; Other = grass/leaves/bamboo or mud/grass.* FF: *Material = corrugated iron sheets or tiles; Other =grass or mud/ wood.*	48%	69%
Percent Households with Extension Access TZNPS: *If household received advice from any type of agricultural extension worker.* FF: *If government extension is regularly available in the area, regardless of whether the household used it or not.*	23%	52 %
Percent Households with Credit Access TZNPS: If a SACCO (Savings and Credit Cooperative) is available in the village. FF: If credit is available if someone wanted to borrow money.	28%	17%
Percent Households with Access to a Farmer's Coop TZNPS: *If farmer cooperatives are available in the village.* FF: *If a family member belongs to a farmer group or cooperative.*	44%	14%

**Long rainy season observations for TZNPS data*

Regression Analysis and Methodology

To analyze the factors that influence inorganic fertilizer use, we use four separate probit models, two utilizing the TZNPS dataset, and two utilizing the FF dataset. The outcome variable measures whether or not the household used inorganic fertilizer (1 if the household used fertilizer and 0 if it did not).

Models 1 and 2: These base TZNPS and FF regressions use the most comparable variables from the two surveys to highlight the similarities and differences of the use models that the two datasets produce.

Model 3: This model builds on *Model 1* by adding in variables and regions not available in the FF data. It includes the households in the regions of Zanzibar, Pemba, and Dar Es Salaam and controls for additional factors that may affect the decision to use inorganic fertilize. It includes the *Minimum* and *Maximum Distances* from the plot to market (in place of the mean distance to market in the base model), *Soil Quality* and the *Price* per kilo of fertilizer.

Model 4: This model adds simple attitudinal variables to the FF model to predict how behavioral factors contribute to the use of inorganic fertilizer. The variable *Willingness* uses approximately 40 FF survey questions about the respondent's attitudes toward farming to develop a weighted 100 point scale, indicating the farmer's willingness to adopt agricultural technologies (a higher score indicates increased willingness). The variables *Weather, Land and Labor,* and *Prices* are derived from a factor analysis on approximately 40 survey questions that ask about specific worries that the farmer might have. The higher the value for *Weather*, for example, the more the respondent worries about weather related concerns such as flooding or drought.

Figure 1: What are Marginal Effects?

Marginal effects are used to interpret the raw coefficients of a probit regression model. The marginal effect coefficient here gives the percentage point change in the outcome variable for a 1 unit change in the explanatory variable of focus, *holding all other explanatory variables at their means*. For dummy variables, the marginal effect measures the change from 0 to 1.

For example, in *Model 1*, being female increases the likelihood of inorganic fertilizer use by 1.64 percentage points, a small and insignificant effect. The same model shows that each additional year of education significantly increases the probability of use by 0.99 percentage points, holding all other variables at their means.

Because the probit model is nonlinear, it is important to specify the values at which the explanatory variables are held (often their means). For example, the effect of an additional year of education may be different if the gender variable is held at 0 (male) or 1 (female).

We chose to control for administrative zone instead of region, because not all regions in the sample had observations of households using inorganic fertilizer. *Appendix 2* shows a map of the administrative zones in Tanzania. When examining zonal effects, all zones are measured in comparison to the Central Zone, which had the lowest rates of inorganic fertilizer use in the FF survey, and one of the lower usage rates in the TZNPS. A negative coefficient on a zonal dummy, therefore, indicates that being located in that zone decreases the probability of fertilizer use, relative to the Central Zone.

Additional methodology includes techniques to remove improbable outliers from the data and fill in missing data where it was systematically absent. The standard errors were also clustered by ward (for the FF) or sample cluster (for the TZNPS) to account for the potential correlation of characteristics of respondents belonging to the same sampling point.[3] 36 households in the TZNPS dataset who reported receiving a government voucher for fertilizer were not included in the analysis. The FF instrument did not ask about government vouchers, so we could not remove this group from analysis in the FF models.

Results

A comparison of *Models 1 and 2* shows that some of the TZNPS and FF variables produce similar effects when predicting the likelihood of inorganic fertilizer use, but other variables have conflicting magnitudes and signs. Note that we report the marginal effects of the regressions, which are used to interpret the raw probit coefficients (see *Figure 1*). *Table 2* shows the marginal effects for the four regression models.

[3] In urban areas the primary sampling unit is an enumeration area from the 2002 population and housing census. In rural areas the enumeration areas constitute entire villages.

Table 2: Marginal Effects for the Predictors of Inorganic Fertilizer Use

Marginal Effects (percentage points)	***Model 1:* TZNPS**	***Model 2:* FF**	***Model 3:* TZNPS, all regions**	***Model 4:* FF, behavioral**
Base Variables				
Female^	1.64	0.84	1.97	1.86
Age	0.11**	-0.21	0.10**	-0.23
Years of Education	0.99***	1.86**	0.94***	1.56**
Household Land Size (ha)	0.03	1.42***	0.02	1.15**
Household Member ≥ Age 10	-0.53	0.43	-0.62*	0.58
Hired Labor^	2.63**	3.01	2.50**	3.92
Cash Crop^	15.5***	5.54	16.11***	8.21**
Average Distance to Market (km)	0.08	-0.30*		-0.30**
Material Floor^	5.43**	7.28*	5.09*	7.64*
Material Roof^	4.28***	-1.13	4.24***	-1.14
Extension^	9.02***	8.29*	8.77***	8.31*
Credit^	-0.16	-2.41	0.21	-1.73
Co-op^	1.07	1.95	1.18	3.92
Economic Variables				
Price (USD/kilo)			-9.42	
Maximum Distance to Market (km)			0.34***	
Minimum Distance to Market (km)			-0.32***	
Average Soil Quality^			3.04**	
Poor Soil Quality^			3.43	
Behavioral Variables				
Willingness				-0.28*
Risk-taking^				-1.91
Weather Worries				1.70**
Land and Labor Worries				-4.58***
Price Worries				-1.53
N	*1525*	*1703*	*1647*	*1703*

Marginal effects are significant at * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
^ indicates dummy variable.

Extension and Education are Strong Predictors of Inorganic Fertilizer Use in all models
In all models, Extension is a strong and significant determinant of inorganic fertilizer use. In the TZNPS *Model 1*, farmers that received advice from extension agents increased their likelihood of inorganic fertilizer use by 9.02 percentage points over those that did not receive advice.[4] In the FF Model 2, if a farmer was aware of extension services in his area, regardless of whether he used them, his likelihood of inorganic fertilizer use was 8.29 percentage points greater. *Years of Education* is consistently significant, though the magnitude is much weaker, with each additional year of education increasing the likelihood of using inorganic fertilizer by 0.94 to 1.86 percentage points.

Households Growing Cash Crops are more likely to Use Inorganic Fertilizer in all models
Whether or not a household grew cash crops also had a strong and significant effect on the likelihood of inorganic fertilizer use in each model except for *Model 2*, which still had a positive effect, although it was not significant. The level of significance and magnitude of *Cash Crop* varies across the TZNPS and RI models, possibly due to the distinct wording of the corresponding questions in the two surveys, but the variable indicates that farmers that grow crops primarily for sale are more likely to use inorganic fertilizer.[5]

[4] All marginal effects are calculated holding all other variables at their means.
[5] In the LSMS-ISA, cash crops were determined by calculating the crops for which at least 50% of yields were sold in the market, on average for all farmers. In the FF, farmers were asked if they grew specific crops for sale only, consumption only, or both; farmers that grew at least one crop only for sale were indicated as cash croppers.

Gender, Credit and Co-ops effects are largely insignificant
Female, *Credit*, and *Co-op* predict similar effects on use of inorganic fertilizer across the models, although the magnitudes vary and the coefficients are all insignificant. Surprisingly, the marginal effects of *Credit* were negative in three out of four models, although it was not significant in any of the models.

Labor and Wealth Variables Produce Insignificant or Conflicting Results
Hired Labor and the wealth proxy variables *Material Floor* and *Material Roof* were fairly strongly and significantly associated with the likelihood of inorganic fertilizer use in the TZNPS, but not so in the FF. While *Material Floor* was significantly associated with fertilizer use in the FF models, *Material Roof* was negatively associated, though not significant. Wealth and income measures suffer from potential endogenity issues, as causality could work either way: the probability of fertilizer use could either increase with greater wealth, or wealth could increase with fertilizer use. We use asset measures, rather than income or expenditure measures in an attempt to address this concern, but the magnitude of the marginal effects may still be biased. Additionally, a high correlation with other asset measures, which differed considerably across the two samples – could explain the conflicting signs.

Distance to Market, Age and Land Size also Produce Insignificant or Conflicting Results
Distance to Market (and age) also produce inconsistent findings across the models. Though these predictors vary in sign across the TZNPS and FF fertilizer use models, they have very small magnitudes and are not significant, with the exception of the negative association of distance to market with fertilizer use in the FF models. In the TZNPS, distance to market was measured by plot, rather than by the household. Since households have plots at differing distances, this measure is not comparable to that used by FF. While *Land Size* is positive and significant in the FF models, the coefficient is negligible and insignificant in the TZNPS models.

Attitudinal Variables have Unexpected Effects on Fertilizer Use
The FF *Model 4* adds behavioral variables to the socioeconomic and economic inorganic fertilizer use model. The marginal effects produced by these variables are only weak in statistical significance, and some have unexpected signs. The *Willingness* scale, measured on a 100 point scale with higher values indicating greater willingness to adopt technologies, produces a slightly negative and significant effect. For each additional point of *Willingness*, the likelihood of using fertilizer decreases by 0.3 percentage points. Similarly, more risk taking farmers are less likely to use fertilizer, though this effect is not significant. Farmers that worry about land and labor are 4.6 percentage points less likely to use fertilizer, while farmers that worry about the weather are 1.7 percentage points more likely to use fertilizer. Worrying about prices was also negatively associated with fertilizer use, although the coefficient was not significant.

Running *Model 4* separately on male respondents and female respondents from the same household produced interesting results. *Willingness* is unexpectedly negative for males, but a positive predictor of inorganic fertilizer use for females. *Risky* is a strong and marginally significant predictor only for women. While the three factors that measure the respondent's worries about specific constraints are all insignificant for women, both the *Weather Factor* and *Prices Factor* have opposite signs for males and females. Hence while the *Female* variable is insignificant in both RI models, the attitudinal results in the gender-pooled *Model 4* regression may be cancelling each other out. Attitudinal concerns may vary greatly across gender and warrant further examination.

Zonal Effects vary widely between Models
The largest difference between the TZNPS and FF models appears with the magnitude of the zonal effect on inorganic fertilizer use (not shown here). The zonal effects are generally larger in the FF model, with estimates of up to 64 percentage points, likely because inorganic fertilizer use ranges so drastically across zones in this sample (from 11% in the Central Zone to 74% in the Southern Highlands). Such strong zonal effects may be capturing different farming systems, agro-ecological zones, or even government policies, but it is unclear why the differences are so strong between the models.

TZNPS *Model 3* adds households in the Zanzibar zone and Dar es Salaam in the Eastern Zone that are excluded from base *Model 1.* Including these areas changes the TZNPS model very little.

Conclusion

The most comprehensive inorganic fertilizer use model would combine the detailed economic indicators of the TZNPS survey data (many of which are excluded here because there is no FF counterpart) with the attitudinal factors found in the FF data. With a sufficiently large sample size, attitudinal variables could be better examined for subpopulations, such as female-headed households. Additionally, large regional samples could help concentrate the model on a single region, reducing the potential over weighted effect given to the regional variables. Though these models are relatively comparable for inorganic fertilizer use, differences in survey design prevent comparison for other inputs such as improved variety seed, pesticides and herbicides.

References

Adesina, A. (1995). Farmers' perceptions and adoption of new agricultural technology: evidence from analysis in Burkina Faso and Guinea, West Africa. *Agricultural Economics*, *13*(1), 1-9. Retrieved from http://dx.doi.org/10.1016/0169-5150(95)01142-8

Cameron, L. A. (2007). "The Importance of Learning in the Adoption of High-Yielding Variety Seeds." *American Agricultural Economics Association*. Retrieved from http://www.jstor.org/pss/1244452

Conley, T., & Udry, C. (2007). "Social Learning through Networks: The Adoption of New Agricultural Technologies in Ghana." *Frontier Issues in the Microeconomics of International Development*. Retrieved from http://www.jstor.org/pss/1245097

Dercon, Stefan & Christiaensen, Luc. (2010). "Consumption risk, technology adoption, and poverty traps: Evidence from Ethiopia." *Journal of Development Economics*, 96(2), 159-173.

Doss, Cheryl R. (2006). "Analyzing technology adoption using microstudies: limitations, challenges, and opportunities for improvement." *Agricultural Economics* 34(3), 207-219.

Duflo, E., Kremer, M., & Robinson, J. (2009). "Nudging Farmers to Use Fertilizer: Evidence from Kenya." *American Economic Review,* 101, 2350-2390.

Feder, Gershon, Just, R.E. & Zilberman, D. (1985) "Adoption of Agricultural Innovations in Developing Countries: A Survey." *Economic Development and Cultural Change* 33(2), 255.

Foster, A. D., & Rosenzweig, M. R. (2010). "Microeconomics of Technology Adoption." *Annual Review of Economics*, 2(1), 395-424. *Annual Reviews*. Retrieved from http://www.annualreviews.org/doi/abs/10.1146/annurev.economics.102308.124433

Kaliba, Aloyce R.M., Hugo Verkuiji, Wilfred Mwangi, Alfred J. Moshi, Amos Chilagane, Joseph. S. Kaswande, & Ponniah Anandajayasekeram. *Adoption of maize production technologies in Eastern Tanzania*. CIMMYT (1998).

Negatu, W. & A. Parikh. (1999). "The impact of perception and other factors on the adoption of agricultural technology in the Moret and Jiru Woreda (district) of Ethiopia." *Agricultural Economics*, 21(2), 205-216.

Nkonya, Ephraim, Schroeder, Ted & Norman, David. (2008). "Factors affecting adoption of improved maize seed and fertilizer in Northern Tanzania." *Journal of Agricultural Economics*, 48(1), 1-12.

Rogers, Everett M. (1995). *Diffusion of Innovations;* the fourth edition. The Free Press, New York.

Shiferaw, B. A., Kebede, T. A., & You, L. (2008). "Technology adoption under seed access constraints and the economic impacts of improved pigeonpea varieties in Tanzania." *Agricultural Economics*. Retrieved from http://doi.wiley.com/10.1111/j.1574-0862.2008.00335.x

Sury, T. (2011)." Selection and Comparative Advantage in Technology Adoption." *Econometrica*, *79*(1), 159-209. Retrieved from http://doi.wiley.com/10.3982/ECTA7749

Toenniessen, Gary, Adesina, Akinwumi & DeVries, Joseph. (2008). "Building and alliance for a green revolution in Africa." *Annals of the New York Academy of Sciences*, 1136, 233-42.

Yesuf, M., & Kohlin, G. (2008). Environment for Development Market Imperfections and Farm Technology Adoption Decisions. *Soil Conservation*, (March).

Zeller, M., Diagne, A., & Mataya, C. (1997). "Market Acess by Smallholder Farmers in Malawi: Implication for Technology Adoption, Agricultural Productivity, and Crop Income." *Food Policy*, (35).

Appendix 1: Sampling Strategies

Tanzanian administrative units, from largest to smallest, are zones, regions, districts, wards, and villages.

Farmer Focus
The TNS-RI Farmer Focus used a probability proportion to size sampling strategy to randomly select sampling points. In this strategy, the probability of selecting a sample point is proportional to the size of its population, as determined by the most recent Tanzanian census. Sampling points were wards, Tanzania's smallest administrative unit. Because the survey focused on rural farming households, urban wards were excluded from the sample selection. Zanzibar and Pemba were also excluded.

The total number of sampling points was determined based on the desired total sample size, the sampling point size, and sampling point demographics. The total number of sampling points in Tanzania was about 300. Final sampling points were distributed across districts and wards based on population, where districts with a proportionally larger population received proportionally more sample points. Within the sampling points, households were chosen using the random walk method. For each sampling point, a defined start point was chosen. Households were sampled outward from this point using the left-hand rule, sampling households at defined intervals on the left side of the walking path.

Notably, the RI Farmer Focus survey is an intra-household survey that seeks a male and female respondent from each household. Where possible, a male was given the role of primary respondent, making it potentially difficult to accurately distinguish female-headed households.

TZNPS
The Tanzanian National Panel Survey TZNPS used a random, stratified and clustered sampling method to produce nationally representative statistics on 3,280 households. Four strata— mainland rural areas, Dar Es Salaam, other mainland urban areas, and Zanzibar—were used to produce sufficiently large estimates on subpopulations. The survey was also stratified by administrative zone. Based on the desired subpopulation sample sizes, a proportion of the sample was allotted to each rural/urban and zonal stratum. Within zones, regions were allotted a sample size proportional to their population.

In rural areas, the primary sampling units were villages. The sampling strategy included a multilevel, clustered sample, where each primary sampling unit made up a cluster of eight households. Ultimately, sampling weights were applied to account for the probability that a given cluster, household, or individual was selected.

Appendix 2: Administrative Zones of Tanzania

Appendix 3: Raw Coefficients and Standard Errors for TZNPS and FF Inorganic Fertilizer Use Models

	Model 1: TZNPS	*Model 2:* FF	*Model 3:* TZNPS, all regions	*Model 4:* FF, behavioral
Female	0.145	0.023	0.173	0.051
	(0.119)	(0.209)	(0.120)	(0.213)
Age	0.011**	-0.006	0.010**	-0.006
	(0.004)	(0.004)	(0.004)	(0.004)
Years of Education	0.092***	0.051**	0.088***	0.043**
	(0.020)	(0.021)	(0.019)	(0.022)
Household Land Size (ha)	0.003	0.039***	0.002	0.032**
	(0.020)	(0.015)	(0.020)	(0.015)
Household Member over Age 10	-0.050**	0.012	-0.059**	0.016
	(0.028)	(0.026)	(0.030)	(0.027)
Hired Labor	0.241**	0.083	0.229**	0.109
	(0.100)	(0.089)	(0.099)	(0.085)
Cash Crop	0.901***	0.153	0.925***	0.227**
	(0.192)	(0.120)	(0.191)	(0.113)
Average Distance to Market (km)	0.008	-0.008*		-0.008**
	(0.008)	(0.004)		0.004
Material Floor	0.409**	0.199*	0.389**	0.210*
	(0.164)	(0.118)	(0.171)	(0.117)
Material Roof	0.393***	-0.031	0.390***	-0.032
	(0.116)	(0.139)	(0.121)	(0.140)
Extension	0.637***	0.231*	0.621***	0.233*
	(0.112)	(0.130)	(0.113)	(0.312)
Credit	-0.016	-0.068	0.019	-0.049
	(0.200)	(0.141	(0.202)	(0.145)
Co-op	0.100	0.054	0.110	0.108
	(0.183)	(0.174)	(0.184)	(0.174)
Price (USD/kilo)			-0.089	
			(0.244)	
Maximum Distance to Market (km)			0.031***	
			(0.010)	
Minimum Distance to Market (km)			-0.030***	
			(0.011)	
Average Soil Quality			0.279***	
			(0.107)	
Poor Soil Quality			0.267	
			(0.255)	
Willingness				-0.008*
				(0.005)
Risk-taking				-0.054
				(0.166)
Weather Factor				0.047**
				(0.021)
Land and Labor Factor				-0.128***
				(0.033)
Prices Factor				-0.043
				(0.037)

Continued	*Model 1:* TZNPS	*Model 2:* FF	*Model 3:* TZNPS, all regions	*Model 4:* FF, behavioral
Eastern Zone	-0.033	0.496	0.077	0.630
	(0.410)	(0.395)	(0.418)	(0.436)
Southern Highlands	1.263***	1.759***	1.330***	1.933***
	(0.347)	(0.306)	(0.357)	(0.360)
Lake Zone	-0.995*	0.428	-0.863	0.451
	(0.529)	(0.290)	(0.564)	(0.335)
Northern Zone	0.469	0.981***	0.582	1.086***
	(0.365)	(0.308)	(0.390)	(0.346)
Southern Zone	0.919***	1.092***	0.996***	1.200***
	(0.343)	(0.377)	(0.362)	(0.412)
Western Zone	0.110	0.275	0.196	0.340
	(0.399)	(0.321)	0.404	(0.358)
Zanzibar			0.062	
			0.406	
Constant	-3.542***	-1.169***	-3.620***	-1.234***
	(0.425)	(.374)	0.489	(0.427)
N	1525	1703	1647	1703