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Crop Planting at the Extensive and Intensive Margins: Evidence from Tanzania's National Panel Survey

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KEY FINDINGS

- Aggregate, national-level changes in proportion of area planted by crop conceal farm-level changes: Average farm size increased by 0.17 hectares from 2008-2010. However, the net change at the household level was an increase or decrease of nearly 1 hectare.
- A similar pattern was detected for area planted of annual crops: On aggregate across households, maize area planted increased by 2 percentage points from 2008-2010. At the household level, the average farmer changed the proportion of maize planted by 28 percentage points.
- Smallholder households plant a significantly greater proportion (59%) of their agricultural land than non-smallholders (52%).
- Over 80% of households changed proportions of crop area planted from 2008-2010. Seventy three percent of households also had a change in farm size.
- At the national level, only two crops showed a significant change in proportion of total area planted from 2008 to 2010: rice (increase) and groundnuts (decrease).

Introduction and Research Questions

A farmer's decision of how much land to dedicate to each crop reflects their farming options at the *extensive* and *intensive* margins. The *extensive* margin represents the total amount of agricultural land area that a farmer has available in a given year (referred to interchangeably as 'farm size' or 'agricultural land'). A farmer increases land use on the extensive margin by planting on new agricultural land. The *intensive* margin represents area planted of crops as a proportion of total farm size. A farmer increases the intensive margin by increasing output within a fixed area. This analysis examines cropping patterns of households in Tanzania between 2008 and 2010 using data from the Tanzania National Panel Survey (TZNPS). [1,2]

[1] Considering that there were global crop price increases in 2008, examining substitution choices between these two years of available may not be representative of substitution behavior during times when the economy is more stable.

[2] Priority crops in this analysis include maize, rice, sorghum, millet, beans, groundnuts, sweet potatoes, and cowpeas. We do not include cassava and mango since they are categorized a fruit and permanent crops, and we only analyze annual crops here. Wheat and yams are excluded due to low and missing observations.

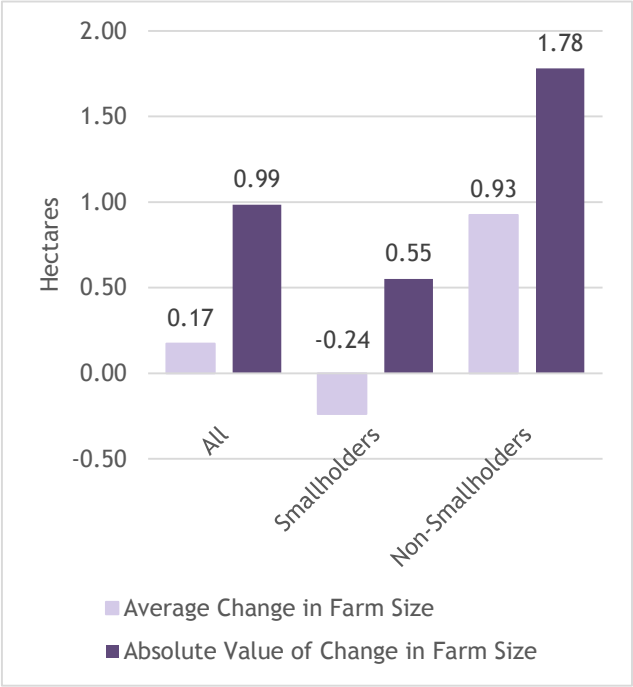
This brief describes changes in farm size, total area planted, and area planted of select annual crops to highlight the dynamic nature of farmer's cropping choices. [3] The sample population includes 2,246 agricultural households that reported having any agricultural land in 2008 or 2010.[4] In 2008, there were 1,554 smallholders and 692 non-smallholders. In 2010, there were 1,491 smallholders and 755 non-smallholders. In total, 56% of households were smallholders both years, 24% were non-smallholders and 21% switched categories between 2008 and 2010. Throughout the brief, we present summary statistics at the national level and compare them with household-level data to show how results vary depending on how the sub-population is defined and how average measures can mask household level changes. We analyze these questions in the context of smallholders (defined as households with total agricultural land area as less than two hectares) and farming systems.[5]

For the 2008-2010 data, the descriptive analysis in this brief will answer the following research questions:

1. Changes on the extensive margin: How much does farm size change?
2. Changes on the intensive margin: How much do farmers change the proportion of land dedicated to growing annual crops?
3. The relationship between the intensive and extensive margins: How do changes in area planted vary with changes in farm size, between smallholder and non-smallholder farmers, and between various farming systems?

Farm size is defined as the sum of plot sizes that a household *owned* or *cultivated* during the year, which reflects various ownership, rental, or use agreements.[6] A detailed description of our household identification strategy and FAO farming systems is provided in **Appendices A** and **B.**

Figure 1: Change in Farm Size (ha) from 2008 to 2010



Section 1. Changes on the Extensive Margin: Farm Size

Nearly half of all households increased or decreased farm size by half a hectare or more between 2008-2010

Household farm size is a parameter that frames household crop planting decisions. One way to expand production is to increase planting on the extensive margin, either by acquiring more land or converting existing land for agricultural use.

Our analysis revealed that households significantly changed farm size, with average farm size for all households increasing from 1.88 ha in 2008 to 2.05 ha in 2010. [7]

As shown in *Figure 1*, the average change in farm size was 0.17 ha, including all households in the sample that gained or lost land, or had no change in agricultural land area. For an average magnitude of farm size change, we controlled for negative and positive change by taking the absolute value of the integers at the household level. After taking the absolute value, the average change in farm size was nearly 1 hectare (0.99). This implies that the average household shifted farm size by 1

[3] Area planted is the total number of hectares planted with any crop across all household plots. It represents responses for survey questions s4aq3 "Was [crop] planted in entire area of plot?" (yes/no) and s4aq4 "Approximately how much of the plot was planted with [crop]?" (¼, ½, or ¾). See Methodology in Appendix C for details of how it was calculated.
[4] We excluded below households three standard deviations above the mean for farm size which corresponded to the top 1% of households reporting plots. Farm size variable was created from survey questions S2aq1 "Did you or anyone in this household own or cultivate any plots in the long rainy season?" (yes/no) and s2aq4 "Area (acres) farmers estimate." See Appendix C.
[5] Smallholder and farming systems categories defined according to 2010 survey unless otherwise noted.
[6] In the TZNPS survey, a household reports agricultural plots available in that year, provides an estimate of area, and indicates the proportion planted with each crop. A household may not plant all agricultural land in a given year for a variety of reasons, including fallow periods, livestock use, rental agreements or other obligations.
[7] $p<.001$

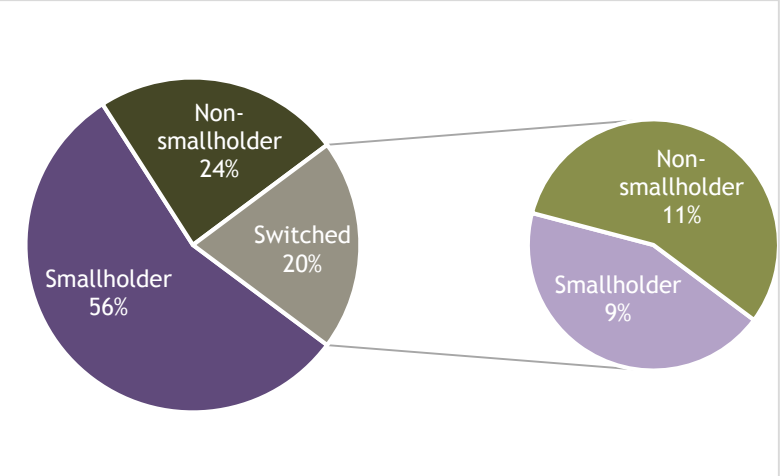
hectare from 2008 to 2010, either by gaining or losing agricultural land. In total, 49% of all households increased or decreased farm size by 0.5 ha or greater. A detailed summary of changes in farm size is in **Appendix E**.

Smallholder and Non-Smallholder Farm Size

Fifty six percent of households were smallholders both years, 24% were non-smallholders and 21% switched categories between 2008 and 2010.

Between 2008 and 2010, the average smallholder's farm size decreased by 0.24 ha, while the average non-smallholder's farm size increased by 0.93 ha, both of which are statistically significant (see F*igure 1*).[8] Within these subgroups, farm size decreased for 47% of smallholders and 27% of non-smallholders from 2008-2010.

Figure 2: Household Categories in 2010



In 2010, 66% of households had less than 2 hectares of agricultural land and are considered smallholders, and 34% are considered non-smallholders. However, some households switched categories from 2008 to 2010. *Figure 2* charts this movement. Across both years, 56% of households were smallholders, 24% were non-smallholders, 9% switched from non-smallholders to smallholder, and 11% switched from smallholder to non-smallholder.

Figure 3a shows a distribution of the change in farm size disaggregated by smallholders and non-smallholders in 2010. It plots change in hectares on the horizontal axis and percent of corresponding farmers on the vertical axis. Dark purple markers represent smallholder farmers' change in farm size and light purple represents non-smallholders. Smallholders are defined according to their 2010 farm size and therefore categorically cannot exceed a two hectare increase, otherwise they would be defined as non-smallholders. As a consequence, non-smallholders have more representation on the positive axis. Much of the distribution is concentrated between a loss and gain of one hectare for both smallholders and non-smallholders.

A 0.5-ha change in farm size is a proportionally greater change for a smallholder than a non-smallholder since they start from a smaller base. To control for variation in the starting point in 2008, we calculated the percent change in farm size for both groups.[9] *Figure 3b* shows the percent change in agricultural land area allowing comparison of the relative gains and losses regardless of initial farm size in 2008. It shows a relatively even distribution of gains and losses for both categories, though a greater percentage of non-smallholders (light purple) are represented on the positive side of the horizontal axis.

[8] $p<0.001$. In absolute value, smallholder households changed by an average of 0.55 hectares and non-smallholders changed by 1.78 hectares.
[9] Percent change calculated with the midpoint formula to bound results by ±200%.

Figure 3a: Distribution of Change in Farm Size for Smallholders and Non-Smallholders from 2008 to 2010

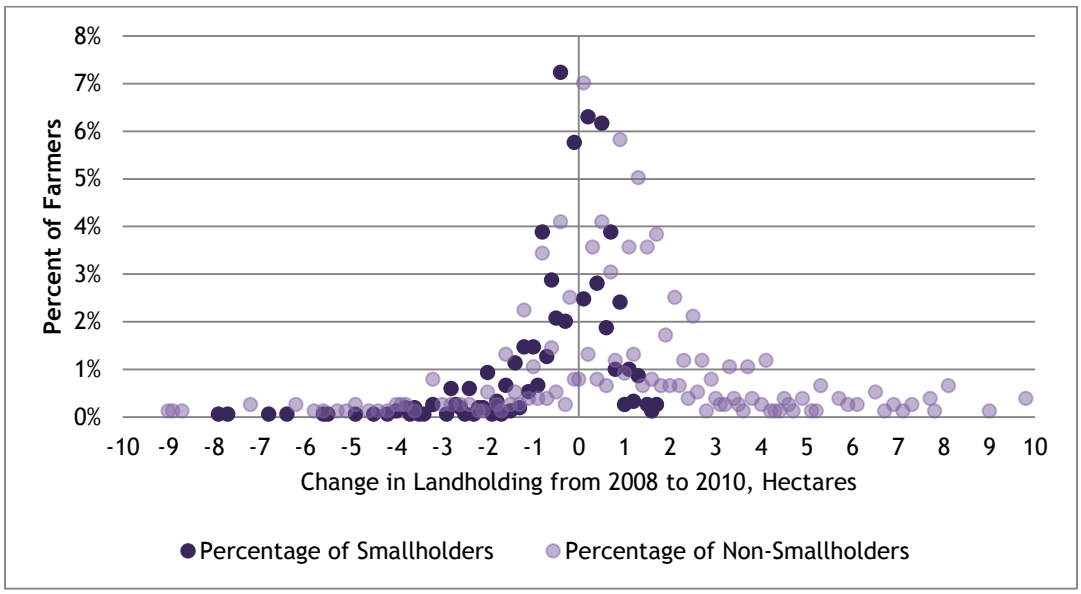
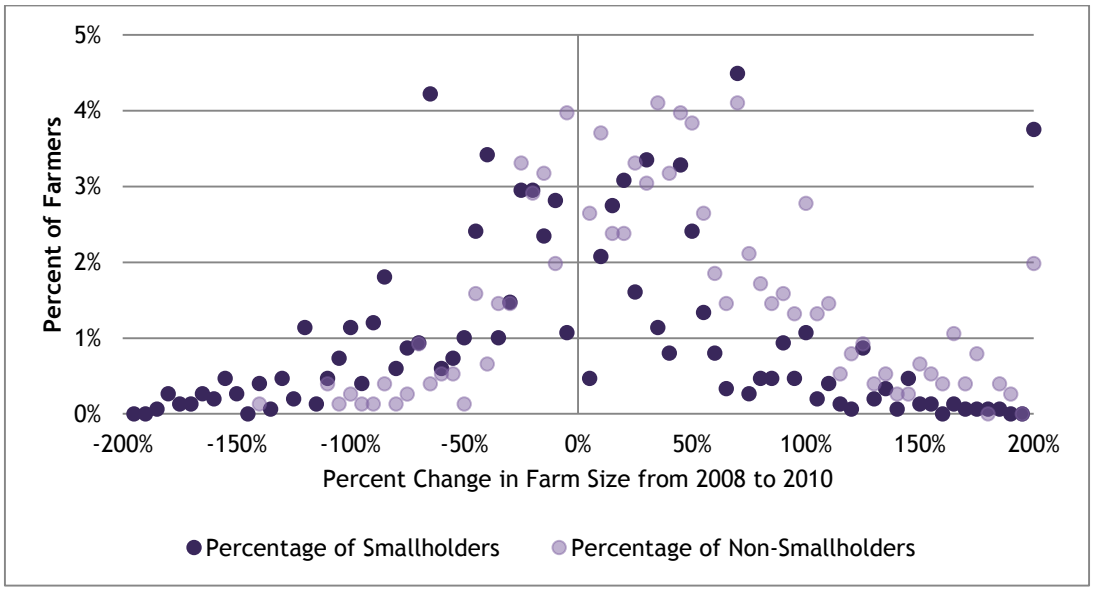


Figure 4b: Distribution of Percentage Change in Farm Size for Smallholders and Non-Smallholders from 2008 to 2010



Section 2. Changes on the Intensive Margin: Crop Area Planted

In the following section, we describe the proportions of area planted for each crop out of the total area planted, representing household crop portfolios. This provides a picture of area planted among crops by smallholder and non-smallholder groupings and the two dominant farming systems based on changes at the intensive margin. To examine variation in area planted, we use household crop-level data and 1) examine the average crop portfolio as a baseline in 2008; 2) discuss how crop area changed from 2008 to 2010 and 3) correlate changes between pairs of crops.

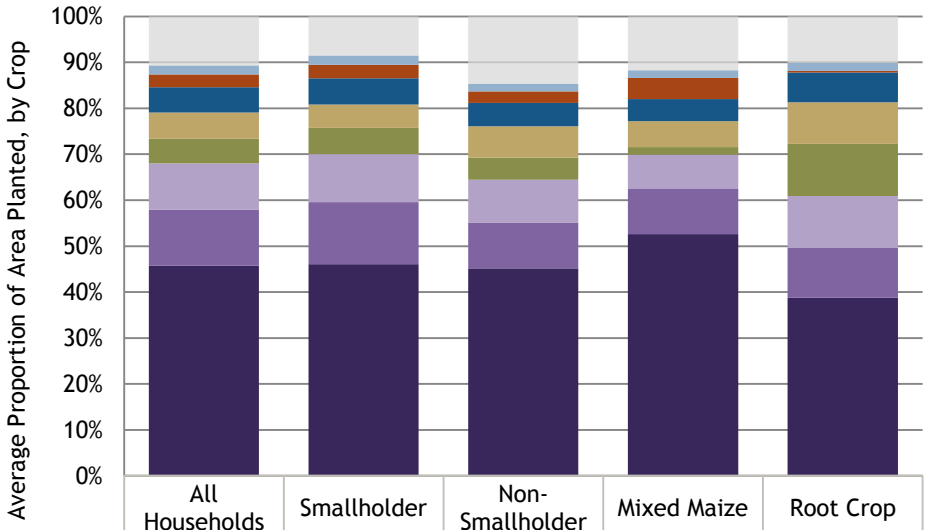
We define total area planted as the total number of hectares planted with any annual crop across all household plots (see **Appendix C** for more detail on our methodology). It represents the amount of land that a household dedicates to all annual crops in a given season and is a reflection of farmers' crop planting choices. A household may choose to increase agricultural production on the intensive margin by increasing the proportion of farm land area dedicated to a particular crop. A household may not plant a part of their agricultural land due to crop rotation, fallow periods, soil quality, labor shortages, rental arrangements or other reasons. We use the percent of total area planted in order to compare across households with different farm sizes and exclude agricultural land not in use.

Average Crop Portfolio in 2008

On average, households planted 45% of total crop area with maize, followed by 12% with beans, and 10% with rice.

Figure 4 below presents the average proportions of agricultural land planted with priority crops. There are seven FAO farming systems represented in Tanzania; "Mixed Maize" and "Root Crop" are highlighted here as the two most common systems. See **Appendix B** for more details on FAO farming systems in Tanzania. Disaggregating by farming system revealed statistically significant differences in crop selection patterns. In 2008, households in the Mixed Maize farming system planted an average of 52% of their total area planted with maize compared to 38% of households in the Root Crop systems.[10] Root Crop system households planted 11% of total area planted with sweet potatoes compared to 2% of land for Maize Mixed households.[11] A comparison of smallholder to non-smallholder farmers showed that most differences in crop proportions of area planted were not significant.

Figure 5: 2008 Average Household Crop Portfolio by Subgroup



	All Households	Smallholder	Non-Smallholder	Mixed Maize	Root Crop
Other non-priority crops	10.49%	8.28%	14.44%	11.54%	9.95%
Cowpeas	1.85%	1.96%	1.66%	1.69%	1.70%
Millet	2.77%	2.90%	2.51%	4.48%	0.33%
Sorghum	5.34%	5.53%	5.00%	4.73%	6.38%
Groundnuts	5.59%	4.97%	6.71%	5.56%	8.87%
Sweet Potatoes	5.26%	5.57%	4.72%	1.68%	11.16%
Rice	9.89%	10.19%	9.34%	7.31%	11.00%
Beans	11.91%	13.13%	9.73%	9.72%	10.75%
Maize	44.78%	44.90%	44.55%	51.79%	38.09%

[10] p<0.01 for Maize
[11] p<0.01 for Sweet Potatoes

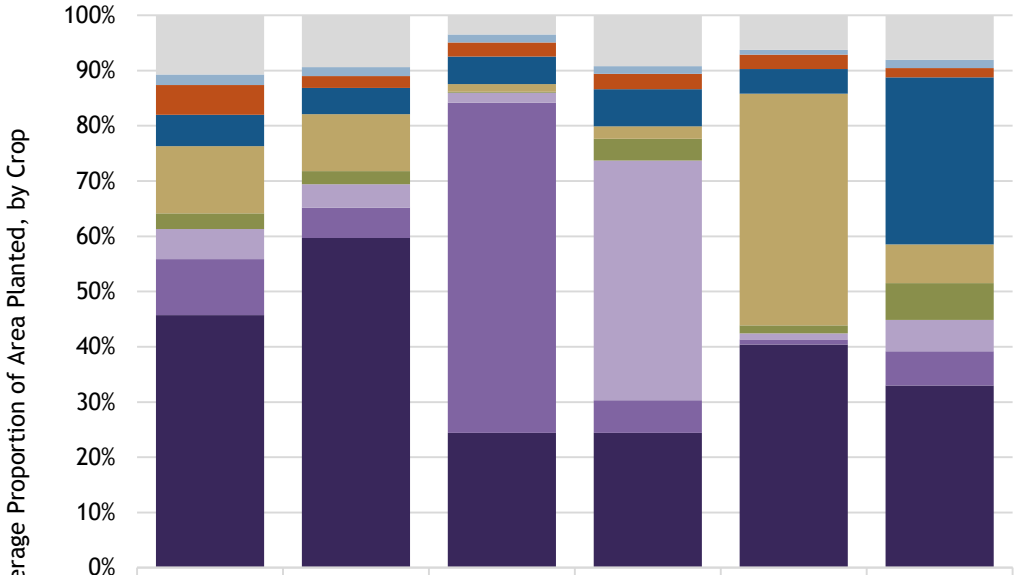
Average Portfolio for Crop-Growing Households

Sorghum represented 5% of total area planted across all households but 43% of area planted among sorghum-growers

Figure 5 shows the proportion of area planted per annual crop among households that reported planting the crop. Thus, the "maize" column includes average area planted of farmers that reported planting maize (1,234 households), while the "groundnuts" column includes only farmers that reported planting groundnuts in 2008 (289 households). A household can be counted in more than one sub-category if they grew multiple crops during the reporting period. Separating out area planted by crop is valuable to identify the average proportion of area planted devoted to crops *among households that plant such crops*. For example, across all households in the sample, sorghum is a relatively small proportion of total area planted (5%). However, examining only farmers that reported planting sorghum, the proportion of total area planted increases to 43%.

Figure 5 includes the average area planted of other crops that households plant. On average, sorghum farmers plant 24% of their plots with maize and 6% with rice. Bean farmers plant 41% of their plots with beans and 40% with maize, and maize farmers dedicate 59% of their plots to maize and 10% to beans. The average across all households is relatively similar to the average for maize growers due to the large number of maize households (1,234) compared to the total number of households in the sample (1,334). For example, there are 390 rice-growing households and only 228 sorghum growers. The comparatively small sample of rice and sorghum-growing households results in larger differences between the national average and the average among rice and sorghum-growing households. See **Appendix D** for total number of observations each year by crop grown.

Figure 6: 2008 Average Crop Portfolio, Disaggregated by Crop-Growing Households



	All Households n=1334	Maize Households n=1234	Rice Households n=390	Sorghum Households n=228	Bean Households n=426	Groundnut Households n=289
Other Non-priority	10.49%	9.25%	3.45%	9.10%	6.15%	7.87%
Cowpeas	1.85%	1.61%	1.45%	1.35%	0.87%	1.46%
Sweet Potatoes	5.26%	2.07%	2.53%	2.78%	2.58%	1.66%
Ground-nuts	5.59%	4.71%	4.92%	6.62%	4.44%	29.51%
Beans	11.91%	10.14%	1.41%	2.21%	41.44%	6.84%
Millet	2.77%	2.34%	0.15%	3.93%	1.38%	6.53%
Sorghum	5.34%	4.21%	1.80%	42.89%	1.10%	5.57%
Rice	9.89%	5.42%	59.35%	5.80%	0.93%	6.02%
Maize	44.78%	58.84%	24.28%	24.14%	39.92%	32.25%

Changes in Crop Portfolio from 2008-2010

The average household decreased maize area planted by 28 percentage points from their 2008 baseline.

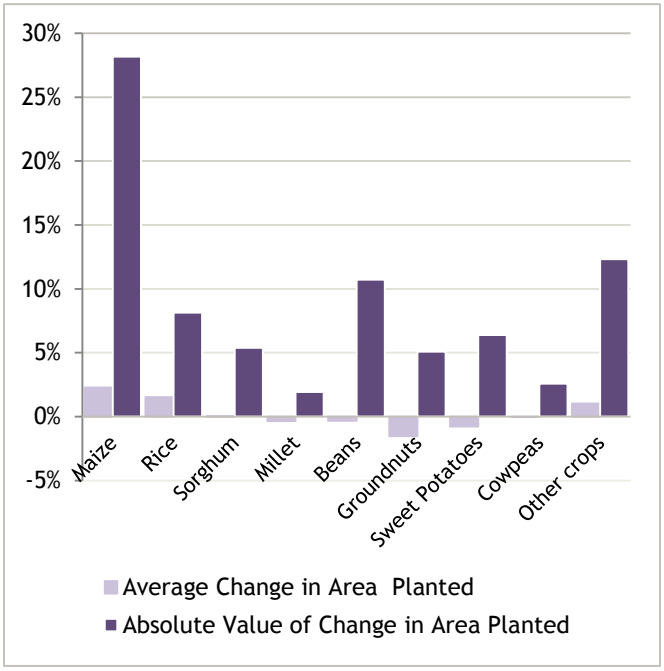
As shown in *Table 1*, maize occupied the highest proportion of average area planted in both years at 45% in 2008 and 46% in 2010. Secondarily, beans accounted for 12% of area planted in 2008 and 11% in 2010. The only crops with significant differences in the proportion of total area planted between 2008 and 2010 were rice (increased by 1.5 percentage points) and groundnuts (decreased by 1.5 percentage points). [12,13] *Table 1* displays the average change in area planted and the average net change, calculated by taking the absolute value of the change at the household level and then averaging across observations.[14] See **Appendix G** for tables of area planted by subgroups: smallholder, non-smallholder, Root Crop farming system, and Mixed Maize farming system.

Table 1: Changes in Proportion of Total Crop Area Planted between 2008 and 2010 at the Household Level[15]

	Maize	Rice	Sorghum	Millet	Beans	Ground-nuts	Sweet Potatoes	Cowpeas	Other crops[16]
2008 Average Area Planted‡	44.78%	9.89%	5.34%	2.77%	11.91%	5.59%	5.26%	1.85%	10.49%
2010 Average Area Planted	46.31%	11.38%	5.30%	2.30%	11.27%	3.73%	4.25%	1.78%	11.42%
Average Change in Area Planted 2010-2008 (percentage points)	2.28%	1.52%**	0.00%	-0.35%*	-0.32%	-1.53%***	-0.78%	0.00%	1.03%
Absolute Value of Change 2010-2008 (percentage points)	28.18%	8.14%	5.38%	1.93%	10.71%	5.09%	6.38%	2.57%	12.31%

*p<0.10, **p<0.05, ***p<0.01 for differences between 2008 and 2010

Figure 7: Household Level Changes in Crop Area Planted: Absolute Value Compared to Average Change



Average changes in area planted from 2008-2010 for each crop appear small because positive and negative changes tend to cancel each other out when aggregated across households. *Figure 6* displays the average change in area planted from 2008-2010 (light-purple bars) alongside the absolute value of that change (dark purple bars). This graph reveals that individual farmers changed crop proportions, but when the direction of the change in crop area is averaged across all households, the aggregate change in crop area planted remains relatively constant.

For example, the average change in maize proportion planted was an increase of 2% from the baseline. However, the absolute value of the change at the household level shows that the average household increased or decreased maize area planted by 28 percentage points from their 2008 baseline. The

[12] p-value<0.05
[13] p-value<0.001
[14] Average area planted calculated as a percent of total farm size; Households that reported growing a crop in one or both years.
[15] These household averages of proportions of area planted with each crop and remaining other long-rainy season crops sum to 98.1% in 2008 and 97.7% in 2010.
[16] Excludes fruit and permanent crops, yams, and wheat due to fewer than 30 observations in each year. See Appendix D for a complete list of these crops.

absolute value of change reveals that individual households substantially changed maize area planted year to year.

Distribution of Change in Maize Area Planted

As noted in *Figure 6*, maize area planted had the greatest change in total proportion planted relative to other priority crops. *Figure 7* graphs the distribution of change in maize by smallholder and non-smallholder households in hectares.[17] The smallholder farmer distribution is clustered around a positive or negative change of 0.4 hectares and the non-smallholder distribution is clustered around negative one hectares and positive two hectares.

Figure 7: Distribution of Change in Maize Area Planted, Smallholders and Non-Smallholders

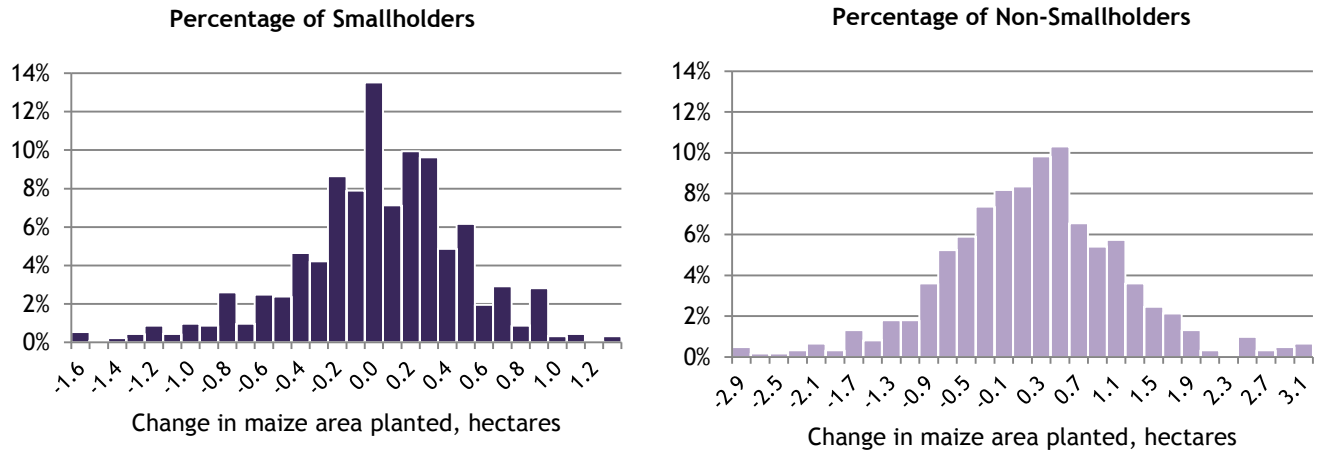
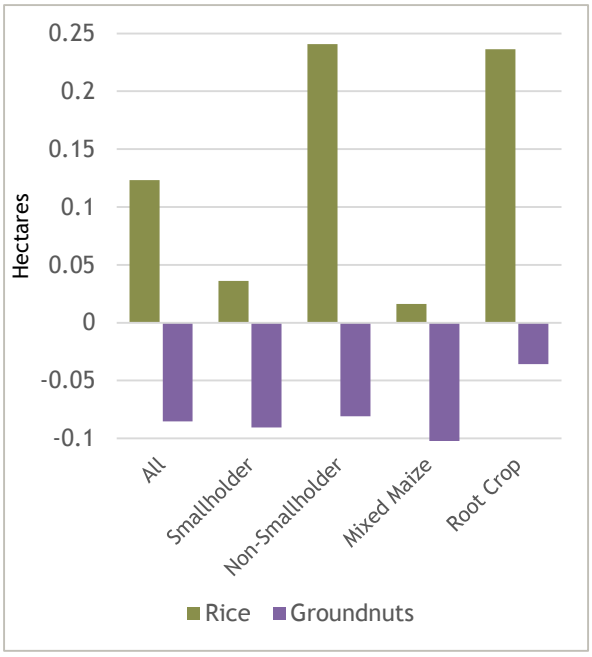


Figure 8: Change in Area Planted by Subgroup: Rice and Groundnuts



Crop-Specific Changes in Area Planted

On aggregate, rice area planted significantly increased and groundnut area planted significantly decreased.

Two priority crops had significant differences between 2008 and 2010 in average proportion of area planted: rice and groundnuts. *Figure 8* shows that, across all subgroups, groundnut area planted decreased and rice area planted increased. Proportions of rice area planted increased to a greater degree among non-smallholders and Root Crop farmers than for smallholders and Mixed Maize farmers.

[17] Figures represent results without survey weights.

Tradeoffs among Crop Pairs

To examine changes in crop combinations, we calculated correlations of crop pairs to evaluate if the change in area planted of one crop was associated with a change in area planted of other crops. See **Appendix H** for a complete table of pairwise correlations and their sample sizes. Not surprisingly, the majority of pairwise correlations were negative, indicating substitution on the intensive margin: across all households, increasing the proportion of area dedicated to one crop implied decreasing the area dedicated to another crop.

Table 2: Change in Maize Area Planted Correlated with Changes in other Crops

Crop	Correlation	Number of Households
Sorghum	-0.4424	265
Millet	-0.4144	102
Rice	-0.4111	321
Sweet Potatoes	-0.3839	197
Other non-priority	-0.3739	567
Groundnuts	-0.2514	336
Beans	-0.2083	560
Cowpeas	-0.1921	185

As shown in *Table 2,* maize is negatively correlated with every crop. An increase in the maize area planted is associated with a decrease in the area planted of the other crops in the table for households growing both crops (household numbers are listed in the third column). Maize and sorghum have the greatest negative correlation (-0.4424). *Figure 9* is a scatter plot that represents the relationship between the change in area planted of maize and sorghum for those households (each marker represents a household). Maize and cowpeas have the lowest correlation (-0.1921), implying a weaker negative association between the two crops. Beans also have a weak negative relationship with maize and the highest number of farms that grow both (560). Beans and cowpeas are commonly reported to be intercropped with maize (see EPAR brief #216 on intercropping); that is, more complementary than substitute crops.

Section 3. Describing Interactions between the Intensive and Extensive Margins

Smallholder households planted a greater portion of their agricultural land than non-smallholders.

To examine the relationship between relative crop area planted (the intensive margin) and farm size (the extensive margin), this section focuses on crop-level data as it relates to changes in farm size among different smallholders, non-smallholders and farming systems.

Figure 10 illustrates the distinction between the extensive and intensive margin. It shows the average farm size overlaid with the average area planted by farming system and smallholder and non-smallholder households in 2008 and 2010. Households are categorized as smallholder or non-smallholder *and* as pertaining to a farming system, so these categories are not mutually exclusive.

Figure 8: Scatter Plot of Change in Maize and Sorghum Area Planted

Smallholders' farm size decreased on the extensive margin and area planted increased on the intensive margin

Across all households, farm size increased by 0.17 hectares but area planted remained statistically the same (it increased by 0.04 hectares but the difference was not significant). Therefore, on average, households had more agricultural land in 2010 but did not plant significantly more area. Disaggregating the data shows that smallholders decreased area planted by 0.09 ha, while non-smallholders increased by 0.29 ha; and the difference was statistically significant.[18] On average,

[18] $p<0.001$

smallholders *decreased* farm size *and* area planted from 2008 to 2010, but increased the *proportion* of agricultural area planted from 57% to 59%. This signals that a drop in farm size corresponded to a drop in area planted, but that area planted decreased by a lesser degree than farm size. This is also evidenced in percentage terms. From 2008-2010, the average smallholder decreased farm size by 13% and increased area planted by 2%.

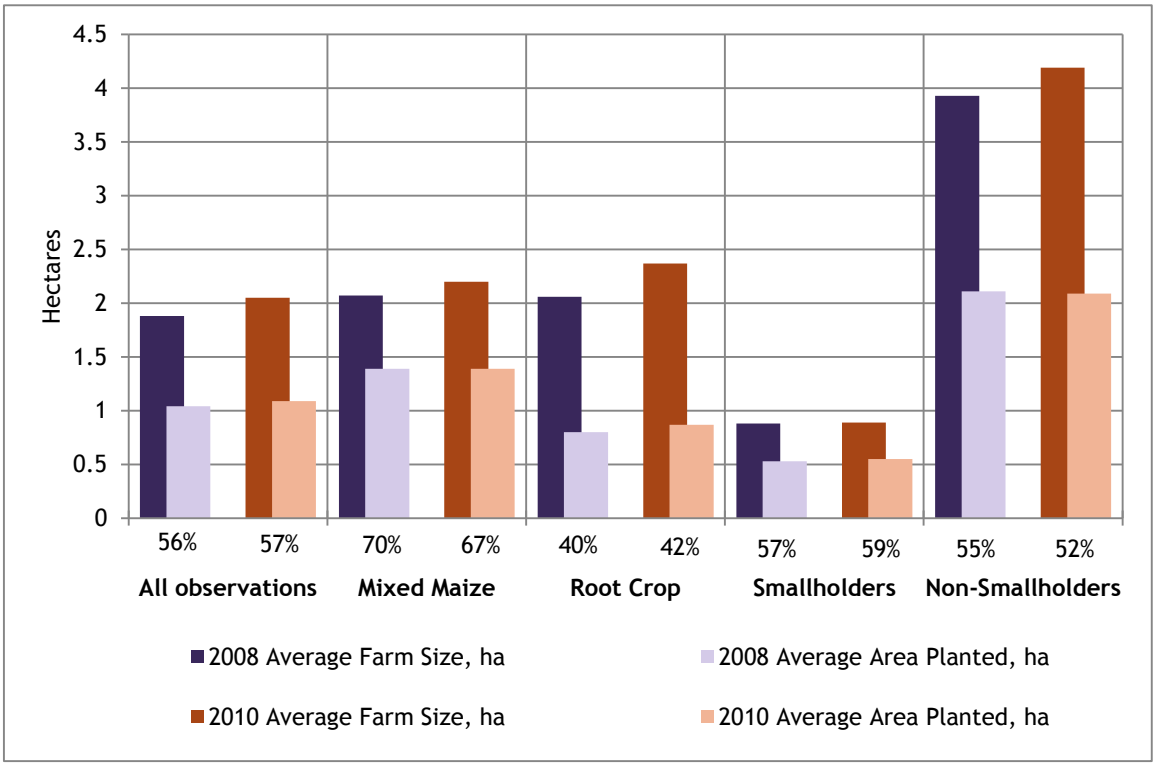
For non-smallholders, farm size and area planted *increased*, but area planted *decreased*. Non-smallholders, on average, increased farm size by 32% and increased area planted by 14%, corresponding to a lower overall proportion for 2010 compared to 2008. **Appendix F** summarizes changes in area planted among smallholder and non-smallholder famers in greater detail.

Figure 10 highlights the proportion of area planted to total farm size for smallholders and non-smallholders described above. The average proportion of land planted with crops among smallholders increased slightly from 57% in 2008 to 59% in 2010 and decreased slightly for non-smallholders from 55% to 52%. The difference in the proportion of land planted between smallholders and non-smallholders was significant in 2010.[19] Thus, smallholders decreased on the extensive margin while increasing on the intensive margin, but the opposite was true for non-smallholders.

Mixed Maize farmers plant a significantly higher proportion of land than Root Crop farmers

Farmers categorized in the Mixed Maize farming system planted a greater proportion of their total agricultural land compared to farmers in the Root Crop system. In 2010, Mixed Maize farmers planted an average of 67% of their total agricultural land, which is significantly greater than the 42% planted by Root Crop farmers.[20]

Figure 9: Average Area Planted and Average Farm Size by Subgroup in 2008 and 2010



[19] p<0.01
[20] p<0.001

Changes in farm size provide context to see how changes on the intensive margin in proportions of area planted for priority crops differs with changes at the extensive margin. *Figure 11* shows average change in proportion of crop area planted for each crop, disaggregated by changes in farm size (increasing or decreasing). Some crops increased in area planted, despite a decrease in farm size, as shown for maize, rice, and sorghum on the graph. Conversely, average area planted decreased for millet, beans, groundnuts, and sweet potatoes, even for households that increased farm size.

For households that had no change in farm size, area planted with maize, rice, sorghum, and sweet potatoes increased slightly on average, while area planted with millet, beans, groundnuts, and cowpeas decreased slightly on average.

Table 3 summarizes the percentage of households that changed area planted and farm size. Eighty one percent of households changed area planted from 2008 to 2010, defined by changes in any of the proportions of crop areas planted (changes at the intensive margin). Most households (73%) also changed at the extensive margin (increasing or decreasing farm size). **Appendix I** provides the proportions of households substituting or not substituting by smallholder designation and farming system.

Figure 10: Average Difference in Area Planted 2008-2010, by Change in Farm Size

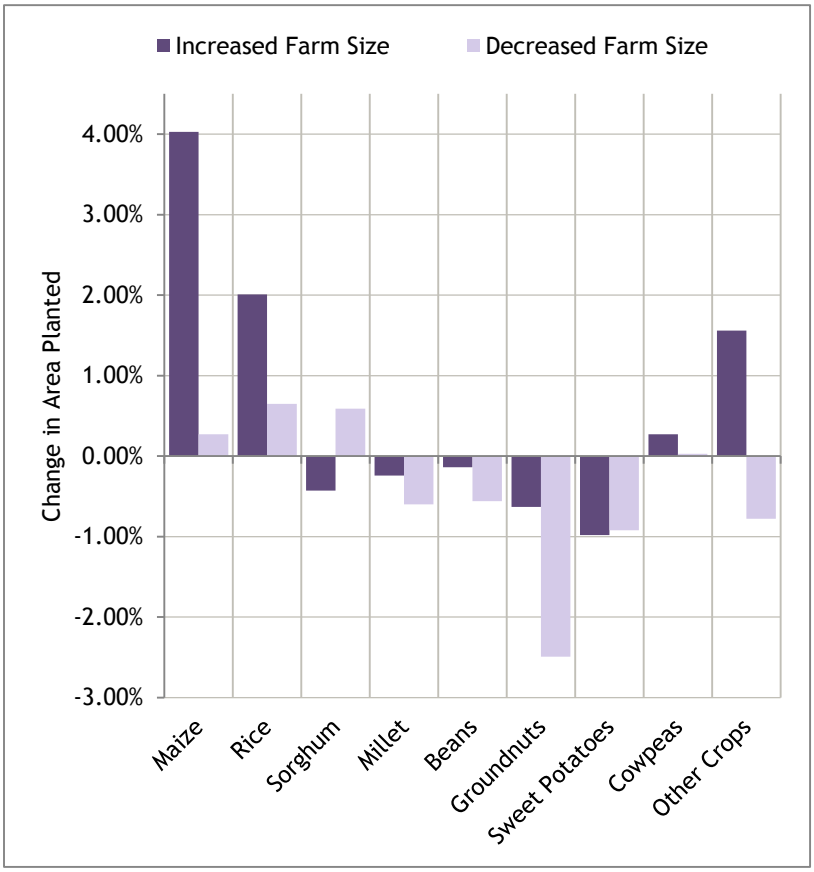


Table 3: Summary of Households' Area Planted and Farm Size

	Change in Area Planted	No Change in Area Planted
Change in Farm Size	73%	16%
No Change in Farm Size	8.1%	3.3%
Total	**81%**	**19%**

Strategic Implications and Outstanding Questions

The area planted of annual crops varies from year to year and is reflected in changes at the extensive margin (changes in farm size) and changes at the intensive margin (changes in the proportion of crop area planted over a fixed area of land). Over 80% of households between 2008 and 2010 changed the proportions of crops they grew, and most of these households also experienced a change in farm size (73% of the sample). Smallholder farmers, by definition, have less agricultural land available and, on average, decreased agricultural land between 2008 and 2010. These farmers may be more limited in their planting decisions at the extensive margin.

Crop substitution patterns vary between smallholders and non-smallholders and between households in different farming systems. When averaged across all households, relative proportions of area planted of priority crops appear to remain relatively constant, even though individual farmers changed area planted substantially. Disaggregated crop and plot-level data show the nuances of substitution patterns within subgroups. National averages of aggregate data are not able to detect this household-level variation.

Negative pairwise correlations between crops reveal that increasing the area of any crop will, on average, decrease the area dedicated to other crops. Though these interactions vary year to year, long-term net changes in crop area proportions could impact other crops in the farming system, as in the example of maize and sorghum. If planning crop-specific interventions in Tanzania, policymakers should be aware of the potential to pick "winners" and "losers" for certain crops. These interventions may influence farmer decision-making mechanisms based on intervention-induced incentives for farmers rather than calculations about climate, price, risk, or other traditional considerations that have developed over time.

Please direct comments or questions about this research to Leigh Anderson and Mary Kay Gugerty, at eparx@u.washington.edu

Appendix A: Characteristics of Smallholder Households

Throughout the analysis we examine how crop planting patterns differ between "smallholder" farmers (defined as households with total agricultural land area of less than two hectares) and non-smallholder farmers.

Sixty-five percent of households in this sample were smallholders in 2010. The table below summarizes household characteristics for smallholder and non-smallholder farmers included in this sample by gender, age, and education level of the household head, family size, and whether the household received agriculture advice. Key differences include:

- Smallholder households had significantly more female-headed households than non-smallholders. Thirty percent of smallholder household-heads are women, compared to only 12% for non-smallholders.
- Smallholders also had younger household heads and fewer household members. Smallholder household heads' average age was 48 years compared to 51 years for non-smallholders, and average household size was 5.10 and 6.67, respectively.
- Smallholders were significantly less likely to receive agricultural advice[21] across both years of the survey. Eleven percent of smallholders received advice in 2010 compared to 20% of non-smallholders in 2008.
- A significantly greater proportion of non-smallholders (32%) lived in the Root Crop farming system than smallholders (24%). Forty-nine percent of smallholders and 54% of non-smallholders were in the Mixed Maize farming system, though the difference was not significant.

Household Characteristics

	Smallholders	Non-Smallholders
Female Head of Household	30.09%	12.37%***
Education (years)	4.49	4.65
Age of Head of Household	48.35	50.9***
Family Size	5.10	6.67***
Extension Services	11.19%	20.11%***
Mixed Maize	49.49%	54.07%
Root Crop	23.74%	31.91%***
*p<0.10, **p<0.05, ***p<0.01		

Appendix B: FAO Farming Systems

Our analysis traces cropping patterns according to farming systems as defined by the Food and Agriculture Organization of the United Nations (FAO). FAO defines a farming system as "*a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate.*"[22] We focused on the two dominant cropping systems in Tanzania: Mixed Maize and Root Crop.[23]

Maize is the most common crop in the **Maize Mixed**[24] farming system though it also includes cassava, millets, sorghum and sweet potato. This system is usually found at elevations between 800-1600 meters above sea level and the climate varies from dry sub-humid to moist sub-humid. The **Root Crop**[25] farming system encompasses moist sub-humid and humid agro-ecological zones. The main crops include yams, cassava, sweet potato, and, in some areas, sorghum, maize and rice.

[21] Advice could come from government extension workers, NGOs, cooperatives or farmer's associations, large scale farmers, or other sources (survey question s13q1).
[22] http://www.fao.org/farmingsystems/description_en.htm
[23] The FAO identifies eight main farming systems in Tanzania 1) maize mixed, 2) root crop, 3) coastal artisanal fishing, 4) highland perennial, 5) agro-pastoral millet/sorghum, 6) tree crop, 7) highland temperate mixed, and 8) pastoral.
[24] Waddington (2014) "Farming Systems for Environment Interaction Overview EPAR Brief"
[25] Ibid.

Since farmers that share a farming system use similar farming techniques and plant similar crop groupings, analyzing crop allocation by farming system puts crop-specific planting decisions in the context of systems that rely on agro-ecological zones.

Farming Systems in Tanzania

Farming System	Proportion of Households
Maize Mixed	**51.1%**
Root Crop	**26.5%**
Coastal Artisanal Fishing	9.2%
Highland Perennial	6.5%
Tree Crop	4.0%
Highland Temperate Mixed	2.0%
Agro-pastoral Millet/Sorghum	0.1%

Appendix C: Methodology

Defining the sample

We started with household level data for agricultural households, n= 3077 households. Households that did not report having agricultural land for both 2008 and 2010 are excluded from analysis and households that had zero agricultural land for both 2008 and 2010 are excluded from analysis. These exclusions resulted in an initial sample size of 2304 households. Some households had agricultural land observations one year but not the other. To determine whether these households owned agricultural land, we used three survey filter questions: 1.) ST2Q2. Does anyone in the HH own a farm plot that they do not cultivate? 2.) ST2Q3. Did anyone in the HH own or cultivate a plot during LRS [long rainy season]? 3.) ST2Q4. Did anyone in the HH own or cultivate any plot during SRS [short rainy season]? If a household consistently recorded "No" for all three answers, we determined that they did not own any agricultural land for that survey year. Thirty six households had inconsistent responses to the filter questions and we thus could not determine whether or not they owned land and subsequently dropped those households from the analysis. The resulting sample size was 2268 households.

All averages and medians use survey weights unless noted otherwise.

Removing outliers

We removed outliers that were more than three standard deviations above the mean for agricultural land in 2010 (18.16 ha), across both years. We then dropped the corresponding household pair in case the observation for the other year was below the cutoff. This resulted in excluding 22 households. It corresponded to dropping the top 1% of households. After removing outliers, the sample we used for analysis included **2246** households.

Analysis definitions

Agricultural land, or Farm Size is the sum of all plot areas, based on farmer estimates. Farm size variable was created from survey questions S2aq1 "Did you or anyone in this household own or cultivate any plots in the long rainy season?" (yes/no) and s2aq4 "Area (acres) farmers estimate."

Smallholder is defined as a household that has less than or equal to two hectares of total agricultural land, calculated by the sum of all farmer-reported plot sizes.

Area planted is the total number of hectares planted with any crop across all household plots. It is calculated as the sum of crop proportions by plots planted with each crop, in 0.25 increments of plot size for each household, or $\sum_{i=1}^{n}[\sum_{j=1}^{m}(\%\, plot_i\, planted\ with\ crop_j * size\ of\ plot_i)]$. All values were farmer-reported. The area planted variable was calculated using survey questions s4aq3 "Was [crop] planted in entire area of plot" (yes/no) and s4aq4 "Approximately how

much of the plot was planted with [crop]?" (¼, ½, or ¾). Changes from 2008 to 2010 in crop area planted proportions in this analysis reflect farmer-reported changes based on incremental estimations rather than precise measurements. Area planted only accounts for land that was used for annual crops. Fruit and or/permanent crops may also be present but they are not included in this analysis. We used area planted rather than area harvested to show the intent of the farmer with his or her planting decisions.

All of the analysis is for long rainy season only [26] and all reports of statistical significance are at the 95% level of confidence or higher.

Appendix D: Lists of Crop Classifications and Number of Household Observations for Priority Crops, of 2246 Households in Each Year

List of annual priority crops grown in the long rainy season with number of observations for households growing these crops in 2008 and 2010:

Annual Priority Crops*	Observations in 2008	Observations in 2010
Maize	1234	1284
Rice	390	447
Sorghum	228	218
Bulrush and Finger Millets	88	68
Sweet potatoes	193	145
Cowpeas	111	129
Groundnuts	289	231
Beans	426	445

*Excluding yams and wheat due to fewer than 30 observations in each year

List of annual cash crops grown in the long rainy season. This includes a total of 126 households in 2008 and 118 households in 2010:

Annual Cash Crops
Cotton
Tobacco
Pyrethrum
Seaweed

List of annual non-priority crops grown in the long rainy season. This includes a total of 605 households in 2008 and 550 households in 2010:

Other Annual Crops	
Cocoyams	**Chillies**
Onions	**Amaranths**
Ginger	**Pumpkins**

[26] The majority of Tanzania has one long rainy season that typically lasts from December through April. The North and Northeastern parts of the country have a long rainy season lasting from March through May and a short rainy season with lighter rainfall from October to December [Minot, N. (2010). *Staple food prices in Tanzania*. Washington, D.C. International Food Policy Research Institute].

Green gram	**Cucumber**
Chick peas	**Eggplant**
Field peas	**Watermelon**
Sunflower	**Cauliflower**
Simsim	**Okra**
Soyabeans	**Fiwi**
Ccabbage	**Tungamaa**
Tomatoes	**Wheat***
Spinach	**Yams***
Carrot	

*Fewer than 30 observations per year in this sample and excluded from analysis; added 'other' category to account for these crops

Appendix E: Summary Statistics of Changes in Farm Size

	All Observations	Mixed Maize	Root Crop	Smallholder	Non-Smallholders
Number of Households 2008	2246	963	549	1554	692
Number of Households 2010	2246	963	549	1491	755
2008 Average Farm Size, ha	1.88 (2.00)	2.07 (1.97)	2.06 (1.99)	0.88 (0.52)	3.93 (2.28)
2010 Average Farm Size, ha	2.05*** (2.30)	2.20* (2.32)	2.37*** (2.21)	0.89 (0.54)	4.19** (2.66)
Average Change in Farm Size, ha	0.17 (1.82)	0.12 (1.82)	0.31 (1.82)	-0.24*** † (0.99)	0.93*** † (2.54)
Absolute Value Change in Farm Size, ha	0.99 (1.54)	1.03 (1.56)	1.12 (1.50)	0.55 (0.85)	1.78 (2.06)
Average Percent Change in Farm Size	0.0281	-3.94%	0.1385	-13.30%	32.38%
2008, Median Farm Size, ha	1.21	1.42	1.42	0.81	3.24
2010, Median Farm Size, ha	1.42	1.42	1.62	0.81	3.24
Median Change in Farm Size, ha	0.00	0.00	0.10	0.00	0.81

*p<0.10, **p<0.05, ***p<0.01
† Difference between Smallholders and Non-Smallholders / p<0.01

Appendix F: Summary Statistics of Changes in Area Planted

	All Observations	Mixed Maize	Root Crop	Smallholders	Non-Smallholders
Number of Households, 2008	2246	963	549	1554	692
Number of Households, 2010	2246	963	549	1491	755
2008 Average Area Planted, ha	1.04 (1.39)	1.39 (1.44)	0.80 (1.18)	0.53 (0.51)	2.11 (1.87)
2010 Average Area Planted, ha	1.09 (1.52)	1.39 (1.66)	0.87 (1.10)	0.55 (0.51)	2.09 (2.08)
Average Change in Area Planted, ha	0.04 (1.42)	0.00 (1.44)	0.07 (1.37)	-0.09***† (0.77)	0.29***† (2.09)
Absolute Value of Change in Area Planted	0.75 (1.21)	0.81 (1.24)	0.82 (1.12)	0.45 (0.62)	1.31 (1.68)
Average Percent Change in Area Planted	6.36%	-4.86%	16.24%	2.05%	13.86%
2008, Median Area Planted	0.61	1.01	0.40	0.40	1.82
2010, Median Area Planted	0.63	0.91	0.51	0.40	1.82
Median Change in Area Planted, ha	0.00	0.00	0.00	0.00	0.15
Average Proportion Planted (Area planted/farm size), 2008	56%	70%	40%	57%	55%
Average Proportion Planted, 2010	57%	66%	42%	59%	52%
Change in Proportion Planted	0.4%	-3.4%	2.4%	3.8%	-5.6%

*p<0.10, **p<0.05, ***p<0.01

† Difference between Smallholders and Non-Smallholders / p<0.01

Appendix G: Descriptive Statistics for Crop Area Planted by Percent of Total Farm Size

	Category	Maize	Rice	Sorghum	Millet	Beans	Ground-nuts	Sweet Potatoes	Cowpeas	All Other Annual crops[†]
All Observations	2008	44.78%	9.89%	5.34%	2.77%	11.91%	5.59%	5.26%	1.85%	10.49%
	2010	46.31%	11.38%**	5.30%	2.30%*	11.27%	3.73%***	4.25%	1.78%	11.42%
	Average Change in Area Planted	2.28%	1.52%	0.00%	-0.35%	-0.32%	-1.53%	-0.78%	0.00%	1.03%
	Absolute Value of Change in Area Planted	28.18%	8.14%	5.38%	1.93%	10.71%	5.09%	6.38%	2.57%	12.31%
Smallholders	2008	44.90%	10.19%	5.53%	2.90%	13.13%	4.97%	5.57%	1.96%	8.28%
	2010	46.15%	11.93%*	5.30%	2.20%	12.06%	2.90%***	4.34%*	1.71%	10.77%**
	Average Change in Area Planted	3.09%	1.71%	0.12%	-0.42%	-0.02%	-1.36%	-1.30%	-0.25%	2.14%
	Absolute Value of Change in Area Planted	28.61%	8.04%	5.56%	1.75%	11.61%	3.83%	6.52%	2.71%	11.39%
Non-Smallholders	2008	44.55%	9.34%	5.00%	2.51%	9.73%	6.71%	4.72%	1.66%	14.44%
	2010	46.59%	10.45%	5.33%	2.49%	9.94%	5.12%**	4.12%	1.89%	12.50%
	Average Change in Area Planted	0.86%	1.19%	0.42%	-0.23%	-0.84%	-1.81%	0.12%	0.35%	-0.91%
	Absolute Value of Change in Area Planted	27.44%	8.33%	5.06%	2.24%	9.14%	7.29%	6.14%	2.31%	13.89%
Mixed Maize	2008	51.79%	7.31%	4.73%	4.48%	9.72%	5.56%	1.68%	1.69%	11.54%
	2010	55.67%***	7.22%	5.26%	3.89%	9.82%	3.89%***	1.18%	1.56%	9.80%**
	Average Change in Area Planted	2.60%	-0.22%	0.40%	-0.62%	-0.09%	-1.63%	-0.49%	-0.14%	-1.82%
	Absolute Value of Change in Area Planted	28.52%	4.76%	4.79%	329.00%	9.64%	538.00%	2.34%	2.37%	10.76%
Root Crop	2008	38.09%	11.00%	6.38%	0.33%	10.75%	8.87%	11.16%	1.70%	9.95%
	2010	38.67%	17.17%***	5.71%	0.48%	9.01%	5.32%**	11.68%	1.79%	8.47%
	Average Change in Area Planted	2.35%	5.56%	-0.23%	0.14%	-0.89%	-2.45%	0.97%	0.16%	-0.72%
	Absolute Value of Change in Area Planted	31.68%	14.20%	7.11%	0.41%	10.40%	7.19%	13.75%	2.58%	10.83%

*p<0.10, **p<0.05, ***p<0.01

Appendix H: Pairwise Correlations Results

Note: The top right side of the table shows the sample size and the bottom left shows the correlation result. Correlations with less than 30 observations are shaded in grey. The dark purple cross sectional line is the total number of observations for each crop.

	Maize	Rice	Sorghum	Millet	Sweet Potatoes	Cowpeas	Ground-nuts	Beans	Other Non-priority
Maize	1536	321	265	102	197	185	336	560	567
Rice	-0.4111	548	66	11	80	50	102	48	114
Sorghum	-0.4424	-0.2094	327	33	43	55	93	29	113
Millet	-0.4144	0.0331	-0.5227	112	8	16	46	37	50
Sweet Potatoes	-0.3839	-0.2893	-0.1163	-0.1879	288	33	68	86	110
Cowpeas	-0.1921	-0.4970	-0.2702	-0.3697	-0.0705	213	58	41	85
Groundnuts	-0.2514	-0.3384	-0.2737	-0.3024	-0.3553	0.1806	387	123	147
Beans	-0.2083	-0.3523	-0.6022	-0.3925	-0.2962	0.1902	-0.3207	620	244
Other Non-priority	-0.3739	-0.3506	-0.4279	-0.1599	-0.5595	0.027	-0.1314	-0.4419	685

Appendix I: Crop Substitution Categories for Smallholder and Non-Smallholder Farmers

	Substitution		No Substitution		
Category of Household	**Change** in Farm Size & **Change** in Crop Proportions	**No change** in Farm Size & **Change** in Crop Proportions	**No Change** in Farm Size & **No Change** in Crop Proportions	**Change** in Farm Size & **No Change** in Crop Proportions	**Observations**
All Households	73%	8.1%	3.3%	16%	2246
Non-smallholder	82%	4.4%	1.3%	12%	755
Smallholder	68%	10%	4.4%	18%	1491
Maize Mixed	76%	8.2%	2.5%	13%	963
Root Crop	75%	5.8%	4.3%	15%	549