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# Quantifying Spillover Effects from Large Farm Establishments

## The Case of Mozambique

*Klaus Deininger*
*Fang Xia*
*Aurelio Mate*
*Ellen Payongayong*

## Abstract

Almost a decade after large land-based investment for agriculture increased sharply, opinions on its impact continue to diverge, partly because (positive or negative) spillovers on neighboring smallholders have never been rigorously assessed. Applying methods from the urban literature on Mozambican data suggests that changes in the number and area of large farms within 25 or 50 kilometers of these investments raised use of improved practices, animal traction, and inputs by small farmers without increasing cultivated area or participation in output, credit, and non-farm labor markets; or, once these factors are controlled for, yields. The limited scope and modest size of the estimated benefits point toward considerable unrealized potential. The paper discusses ways to systematically explore the size of such potential and the extent to which it is realized.

# Quantifying Spillover Effects from Large Farm Establishments:
# The Case of Mozambique[1]

Klaus Deininger[†], Fang Xia [‡], Aurelio Mate[♯], Ellen Payongayong[♦]

[†]World Bank, Washington DC
[‡] Central University of Finance and Economics, Beijing
[♯]Ministry of Agriculture, Government of Mozambique
[♦]Michigan State University, East Lansing MI

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**Quantifying Spillover Effects from Large Land-Based Investment: The Case of Mozambique**

## 1. Introduction

The 2007/08 food price spike, together with the recognition that a number of countries had large amounts of seemingly unoccupied or unclaimed land resources, triggered an enormous increase in private sector demand for agricultural land (Deininger and Byerlee 2011) and, implicitly, water (Rulli *et al.* 2013) to satisfy new demand for food, fuel, and fiber. Though often denounced as a 'land grab' (Hall 2011; Pearce 2012), this phenomenon, which was most acutely felt in Africa (Anseeuw *et al.* 2012), also gave rise to hopes for private capital to complement public investment to help make up for decades of underinvestment in agriculture. This, it was often hoped, could then provide a steppingstone towards more rapid rural development and poverty reduction for countries with ample land resources that had remained heavily dependent on agriculture for growth and poverty reduction (Collier and Dercon 2014).

A key argument in this debate relates to spillover effects associated with such investment. Supporters note that, via discovery of agro-ecological suitability and provision of demonstration effects to provide local people with new technology and access to credit, input, and labor markets, 'pioneer investors' can generate positive spillovers. In fact, the argument that public subsides, up to the net present value of the stream of spillover benefits generated, may be justified (Collier and Venables 2012) underpins activity by agricultural investment promotion agencies. Critics retort that, especially if subsidies are in the form of cheap land, they may be regressive or attract speculators rather than pioneers who may monopolize factor markets or encroach on land or water resources to which they have no right and which provided a source of livelihood for local populations,[2] causing negative spillovers. Empirical evidence to direct the debate on this issue is thus very desirable.

While some studies document spillovers from specific investments, most of them in agro-processing rather than agricultural production, we know of no effort to quantify land-based agricultural them more generally. Yet, a large volume of case studies suggests that expected positive spillovers rarely materialized as expected. Governments were often unable to spot pioneers and institutional fragmentation and weak governance (Arezki *et al.* 2015) and high levels of corruption (Bujko *et al.* 2015) in many target countries attracted

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[2] Many cases have been documented where the main strategy to attract investors was to transfer 'state land' to which local people had use rights without them having been informed or consented to such development. Such distributionally regressive strategies rarely worked and often led to conflict instead of promoting development and enhance welfare.

speculators (Sitko and Jayne 2014). Similar to earlier periods with high failure rates (Tyler and Dixie 2013), investors may have lacked the technical qualification, financial staying power, and ingenuity to deal with the complexity of agricultural production and associated, narrow margins, variable returns, and susceptibility to exogenous shocks.

This paper aims to show that obtaining quantitative evidence on nature, time profile, crop specificity, and magnitude of spillovers from large farm establishment is possible, illustrate how this can be done with (arguably less than ideal) data from Mozambique, and use the results to draw conclusions for policy, data collection, and future research. Our data are from the 2012 and 2014 rounds of Mozambique's *Trabalho do Inquérito Agrícola* (TIA), a survey that includes data from all of the country's large farms plus a sample of small & medium producers.[3] We assume spatial proximity to be the main channel for spillover transmission, e.g. via learning about new technology or better functioning of local factor markets,[4] and use GPS coordinates for 419 large farms established after 2012 to construct, for every small farm in the sample, a measure of whether at least one new large farm was established and total large farm area cultivated (with specific crops) in concentric circles with 0-25 km, 25-50 km, and 50-100 km around it.

Results point towards external benefits from large farm establishment in terms of small farmers' adoption of agricultural practices and input access for small farms less than 50 km from newly established large ones. Yet, large farm establishment decreased perceived well-being within a 25 km band and did not facilitate better access to jobs or output markets, cultivation of larger areas or, once other factors are controlled for, increased yields. While this allows us to reject the notion of generalized negative spillover effects from large farm establishment, it does not justify large unconditional subsidies to attract investors.

In interpreting these results, one has to bear in mind that data limitations allow us to only estimate average effects accruing in the relatively short-term. Longer-term effects and the way they vary with modalities of land acquisition, the nature of the investment, investor attributes, and other conditions are likely of high policy interest. We discuss low-cost ways to generate such estimates through additions to already planned surveys and links to readily available administrative data and lay out how this could feed into an evidence-driven analytical agenda that would, by increasing transparency and the scope for accountability and proper management, benefit investors, local communities, and public institutions.

The paper is structured as follows: Section two describes Mozambique's agricultural sector, the challenge of supporting smallholder productivity growth for broad-based poverty reduction, and the potential role of spillovers from large land-based investment. Section three presents data to describe performance of small

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[3] Throughout this paper, we use 'small' to refer to small and medium scale producers.
[4] We assume external effects regarding adoption of cultural practices and use of fertilizer, pesticides, or seeds, will emanate from any large farm while only large farms growing the crop in question will help increase yields.

farms over time, compare large and small farms' performance, assess and proximity of the latter' to newly established large farms. Section four provides results for short-term general or crop-specific spillovers from large farm establishment. Section five concludes with implications for policy and future research.

## 2. Motivation and methodology

To highlight the potential relevance of spillovers emanating from large land-based investment, we provide a sketch of Mozambique's agricultural endowments, the importance of its agricultural economy for poverty reduction, the potential for increasing productivity, the associated challenges, and the role investors could possibly play. If, as sometimes claimed, subsidies to attract investors may be socially desirable if their value is less than the net present value of the (positive) spillovers from such investments, it will be important to quantify the size of such effects and we outline a methodology for doing so.

### 2.1 Mozambique's place in the global 'land rush' debate

Mozambique is endowed with some 35 million ha of land suitable for agriculture that has fertile soils, ample rainfall and enormous potential for irrigation. Domestic and neighboring countries' markets offer scope for import substitution and the country's long coastline along the Indian Ocean with major ports also provides international market access. But these favorable endowments notwithstanding, low agricultural productivity is one of the key reasons for why rural poverty remains pervasive (Arndt *et al.* 2012). Although 80% of Mozambique's population is in agriculture, the sector contributes only 20% of GDP and poverty may actually be worsening (Cunguara and Hanlon 2012). The impact of low agricultural productivity is compounded by the fact that, with some 6 million ha actually cultivated, the country uses only a fraction of its large land endowment (Arndt *et al.* 2010; Deininger and Byerlee 2011). A need to increase smallholder productivity, together with the availability of large amounts of seemingly uncultivated land, would seem to provide a favorable framework to benefit from increased land demand by investors.

To allow effective ways of developing the country's land resources, a comprehensive land law was passed in 1997, following a long consultative process. The law declares that all land belongs to the state and prohibits sales but recognizes existing use rights. As community-investor partnerships that might internalize some of the spillover effects associated with land-based investment will be possible only if land rights are well defined, the law establishes a participatory process of 'community land delimitation' to formalize rights to community land, agree on its boundaries, and decision-making structures are clear (Norfolk and Tanner 2007). Yet, while there have been some successful delimitation cases, implementation remained slow, partly due to a fear that, once local rights have been recognized, the government may no longer be able to transfer 'unused' land to investors. This limited the scope for such partnerships (deWit and Norfolk 2015). A second way for investors to access land is through a lease (DUAT) awarded by the government

based on submission of an investment plan.[5] A key policy issue related to this is that, as sales are not allowed, land acquired by failed investments cannot just be transferred to others but requires elaborate state intervention to cancel and reassign the lease. Together with weak and incomplete land records, this makes it difficult to unambiguously ascertain or extinguish pre-existing claims, an issue that has consistently been raised as a challenge for investors (OECD 2013; UNCTAD 2012). It implies that, despite the country's land abundance, the amount of land for which ownership or absence of competing claims can be easily established may be quite limited.

One reason for the relative neglect of agriculture is the country's rich mineral resource endowment that led the government to pursue a development strategy focused on 'mega-projects'.[6] Yet, hopes that these projects, with strong government support, would generate jobs and local linkages were often disappointed. Large investments to rehabilitate the sugar industry (Buur *et al.* 2012) and establish irrigation for rice (Kajisa and Payongayong 2011) notwithstanding, Mozambique's level of agricultural public investment is low even by African standards.[7] Moreover, it has been argued that the impact of such spending may have been compromised by a preference for high-visibility projects with short gestation periods compared to alternatives with higher payoff (Mogues and Do Rosario 2015).

To more effectively reduce rural poverty and promote a more inclusive pattern of development, the government's latest strategic plan for agricultural development (PEDSA) puts priority on smallholder-driven agricultural growth. It includes efforts to improve technology, reduce small farmers' capital constraints, and increase the extremely low levels of modern input use some of which show potentially interesting results (Carter *et al.* 2014). Support to smallholders at a micro-level is to be complemented by development of 6 growth corridors to provide infrastructure and public services.[8] Ideally these corridors would provide a springboard for 'pioneer' investors to create market links, fine-tune technology packages, and develop local infrastructure in ways that help increase small farmers' productivity and the area cultivated by them along the lines of Collier and Venables (2012). To provide incentives, the country offers attractive conditions for agricultural investment including low corporate income taxes (with effective rates as low as 2% to increase to 5% over the next decade) and cheap land (with 50-year leases at USD 1/ha and year). A center for promotion of agriculture (CEPAGRI) complements the national (CPI) and several regional investment promotion agencies to attract, nurture, and coordinate investment.

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[5] In theory, submission of an investment plan will trigger receipt of a provisional DUAT that will, after a period of two years, either be converted into a definitive one or cancelled. In practice, it appears that most of the documents held by investors are still provisional.

[6] Mega-projects include the Mozal aluminium smelter in Maputo province, the Inhambane Sasol/Temane gas extraction and pipeline projects, the Moma titanium ore (heavy sands) project in Nampula, the Moatize coalmine in Tete, and Corridor Sands in Gaza (Cunguara 2012).

[7] Mozambique's spending on R&D in agriculture is less than 0.25% of agricultural GDP, about one third of the 0.69% achieved in Africa overall and one sixth of the l.5% target agreed upon by African countries (World_Bank 2011).

[8] These are Maputo and Limpopo (with focus on rice, horticulture, cattle and poultry), Pemba-Lichinga (focus on wheat, beans, maize, soja, cotton, potato, tobacco, and poultry), Nacala (cassava, maize, cotton, fruit, poultry, and groundnut), Zambezia (rice, maize, potato, cattle, goats, cotton, and poultry), and Beira (maize, wheat, horticulture, poultry, soja, rice and cattle).

While large land allocations are not a new phenomenon in Mozambique, given the country's violent history that often included repeated and multiple displacements (Myers 1994), the size and long-term impact of the challenges are illustrated by the fact that, following the 2007/08 food price spike, the investment agency received expressions of interest for some 12 million ha., mostly for bio-fuels (Arndt *et al.* 2010). Evidence of capacity constraints in specific cases (Borras *et al.* 2011) and a desire to avoid serious mistakes led to the imposition of a moratorium and an effort to better map available resources in 2009 (Hanlon 2011). Beyond concerns regarding the environmental benefits from such ventures,[9] socio-economic impacts will depend on whether labor-intensive outgrower or capital-intensive plantation models are adopted; if food crops will be displaced; and the extent to which technology spillovers to other crops materialize (Arndt *et al.* 2011).

## 2.2 Rationale for and approaches to estimating spillovers

Large farms may benefit neighboring smallholders via access to improved techniques, factor and output markets, and technology. If transport or other transaction costs are high, smallholders may be rationed out of input and output markets (Key *et al.* 2000) as quantities involved may be too small to defray these costs even without credit constraints. To the extent that they use these inputs, large farms can provide them to neighboring smallholders, potentially on implicit credit. Large farms tend to employ casual workers on an irregular basis, allowing them to pick up simple techniques such as crop rotation to reduce pesticide pressure and manage nutrients, intercropping to enhance soil nutrient and moisture content, and line sowing to make weed control easier are also easily transmitted from large to small farms. Some case studies point to positive impacts of agro-processing on labor demand (Maertens *et al.* 2011; Minten *et al.* 2007) or of outgrower schemes for smallholder food production (Negash and Swinnen 2013).

Impacts from mechanized production of bulk commodities differs from these cases in two ways. First, if land to labor ratios are much higher, positive labor market effects will be less and negative land-related impacts, in particular displacement, more likely. Second, without perishability, aggregation of smallholder output has to confront with side-selling and quality of its own (Hueth *et al.* 2007; Saenger *et al.* 2013). As all of these factors tend to lower benefits and increase risks, it is not surprising to find that in cases involving direct agricultural production of bulk commodities, studies often find ambiguous or negative effects (German *et al.* 2013; Schoneveld 2014). Reasons may include failure to adhere to legally required processes of local consultation (Nolte and Voget-Kleschin 2014) and possibly displacement (Hall 2011) and lack of transparency due to limited disclosure or failure to monitor implementation of contracts (Cotula 2014).

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[9] Expansion of Jatropha production will most likely lead to the conversion of miombo forest areas to Jatropha, which implies a reduction in above and below-ground carbon stocks. The carbon debts created by the land use change can be repaid by replacing fossil fuels with Jatropha-based biodiesel. A repayment time of almost two centuries is found with optimistic estimates of the carbon debt, while the use of pessimistic values results in a repayment time that approaches the millennium (Vang Rasmussen *et al.* 2012).

Adewumi *et al.* (2013) is the only study describing impacts of large farm establishment on neighboring smallholder producers in a case study setting we are aware of. To assess direction and size of impacts from large agricultural investments in a more systematic way, complementing case studies with survey-based evidence seems to be very desirable.

Although we know of no studies that have done so for agricultural production, a number of studies have done so in an industrial context. Henderson (2003) uses panel data for machinery and high-tech industries to estimate firm-level production functions that allow for scale externalities from other local plants in the same industry and from the diversity of local economic activity, finding strong evidence of information spillovers for high tech industries only and little evidence of benefits from diversity beyond the own industry. Moretti (2004) looks at human capital externalities finding that within a city spillovers will be larger between industries that are economically closer. Currie *et al.* (2015) link firm-level with other data to assess the impact of opening or closing of 1,600 US industrial plants in the 1990-2002 period, finding significant impacts on toxic air emissions, housing values, and the incidence of low birthweight in the vicinity of these plants. Applying this to gold mines suggests that openings and closings have different effects (Chuhan-Pole *et al.* 2015) and that mining can empower women (Kotsadam and Tolonen 2015).

We build on Ali *et al.* (2015) who use a similar methodology to estimate impacts of large farm establishment on smallholders in Ethiopia over the 2004-14 period. Although the time period covered by our data is much shorter, the TIA includes GPS coordinates for 419 large farms that were either newly established or changed owner after 2012 as well as all smallholders in the 2012 and 2014 rounds. The location of large and small farms is illustrated in figure 1. We use this to create a measure for the distance between any small and the next large farm newly established that was newly established during this period as well as the number of newly established large farms in a concentric circle with inner and outer radius of 0-25, 25-50, and 50-100 km from any small and medium scale farm. Combining this with information on smallholders' performance in each year (i.e. before and after large farms were established), we run a linear probability model of the form

$$Y_{ijt} = \alpha + \beta L_{ijtd} + \gamma X_{ijt} + \delta_t + \delta_j + \epsilon_{ijt} \ (1)$$

where $Y_{ijt}$ is the outcome variable of interest for small farm $i$ in enumeration area (EA) $j$ in year $t$; $L_{ijtd}$ is a vector of indicator variables that equal 1 if at least one large farm was established after 2012 in a concentric ring of radius $d$ around small farm $i$; $X_{ijt}$ is a vector of control variables;[10] $\delta_t$ is a time trend; $\delta_j$ an EA fixed effect, and $\beta$ as well as $\gamma$ are parameter vectors to be estimated. In practice, we limit the distance to be

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[10] Control variables include farm size, household composition (no. of children, adults and old people), head's gender and age, and highest education. For regressions on crop yields, control variables also include indicator variables for crop-specific use of fertilizer, pesticide and irrigation, hiring of temporary or permanent workers, use of animal traction, crop rotation, inter-cropping, and line sowing at household level, and a rainfall shock.

considered to a maximum of 250 km and compute values of $L_{ijtd}$ for the cases with inner and outer radius $d$ of 0 to 25, 25 to 50 and 50 to 100 km. The parameter of main interest, $\beta$, is the estimated effect of a new farm having been established within a concentric circle (or ring) with inner and outer radius $d$ from small farm $i$ on the given outcome variable (i.e. adoption of practices, input use, output and labor market participation).

To complement the zero-one indicator of large farm establishment at the extensive margin with a measure the intensity of treatment, we also run regressions where $L_{ijtd}$ is replaced by $A_{ijtd}$, a vector containing the log of total area cultivated by newly established large farms in the concentric ring of radius $d$ around the small farm of interest (e.g. $A_{ijt(25-50)}$ would denote the area cultivated by new large farms in the 25-50 km range from small farm $i$). Use of logs implies that relevant elements of the coefficient vector $\beta$ can be interpreted as elasticity.

## 3. Data and descriptive statistics

Data from both large and small farms provide evidence on (i) the smallholder sector's stagnation in terms of access to extension, use of modern practices and purchased inputs as well as yields; (ii) vast differences in yield and intensity of input use between large and small farms and by region that could create potential for spillovers; and (iii) different levels of spatial proximity between small and newly established large farms that can serve as a basis for econometric identification of such effects.

### 3.1 Data and basic characteristics of the smallholder sector

To explore the interaction between large farm establishment and smallholder productivity, we use various years of the *Trabalho do Inquérito Agrícola* (TIA), a nation-wide survey of all of the country's large farms together with a rather large sample of small and medium ones that is regularly carried out by the Ministry of Agriculture (Megill 2011).[11] The sample for each survey is drawn from a master list that uses information from population and agricultural census (Keita and Gennari 2014). While this design limits the scope of using panel estimation techniques, the 2012 and 2014 small and medium scale survey was carried out in the same enumeration areas (EA) allowing us to use at least EA fixed effects. Also, while earlier attempts to use GPS to record interviewed farms' location were unsuccessful, we have coordinates for large farms that entered the sample in 2014 as well as smallholders in the 2012 and 2014 rounds.

Use of survey weights allows us to compute the number of farms and distribution of cultivated area as well as crops planted across farm size classes. Table 1 suggests that less than 6 million of the country's estimated

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[11] Small holdings are defined as cultivating less than 25 ha overall, with less than 10 ha of annual crops and less than 5 ha irrigated land as well as less than 10 cattle, 50 small ruminants or pigs, and less than 200 poultry. Large holdings are defined as cultivating a total of more than 100 ha or more than 50 ha of annual and permanent crops or having at least 100 cattle, 500 small ruminants and pigs or 2000 poultry. Any farm that is neither large nor small will be categorized as medium.

35 million ha of agriculturally suitable land is cropped. Of these, 5.5 million ha or some 90.7% of total area is in the smallholder sector which comprises 3.9 million or 99.8% of all farms.[12] By comparison, 8,123 farms (with 2.4% of cropped area) are in the 10-50 ha group and less than 400 above 50 ha. Smallholders cultivate 92% of total cropped area with annual and 1.1% with perennial crops, leaving 5.8% partially fallow. With about 10%, the share of perennials is highest in the 200-1,000 ha size group, declining to 5.4% for the largest size farms. Crop patterns differ markedly by farm size: Smallholders cultivate mainly maize (32%), cassava and pulses (16% each), rice and peanuts (8% each), sorghum (6%) and by vegetables and cotton (4% each). Medium scale farms in the 50-200 group focus on rice, vegetables, and cotton. Large farms focus almost exclusively on sugarcane which makes up 84% of their cropped area.

Descriptive data for the 2002 to 2014 period suggest Mozambique's small scale sector was rather stagnant (table 2). Mean area cultivated per farm decreased markedly, from 2.4 to 1.7 ha. The share of perennials dropped from 8% to 1%. The share of farmers receiving extension advice decreased from 15% to 10% although extension increased income (Cunguara and Moder 2011). Use of (animal/mechanical) traction, improved seed, and fertilizer remained stable while that of pesticide and manure decreased. There is also a decline in the share of farmers practicing crop rotation (from 35% in 2005 when the question was introduced to 24% in 2014), inter-cropping (88% to 81%), and market integration with the share of farmers selling crops decreasing from 59% in 2002 to 49% in 2014. Modest declines in the share of those with off-farm jobs (17%) or practicing line sowing (45%) also reveal a lack of dynamism in rural areas.

Average national yields fluctuated considerably over time with few clear trends.[13] To assess the extent to which such short-term variation can be attributed to climatic conditions, we use publicly available NOAA data to generate mean precipitation during the growing season for the 146 districts in the sample. Average daily (annual) rainfall in the 1990 to 2001 period is 1.82 (664.3) mm with a standard deviation of 0.57 mm. Compared to this long-term average, smallholders in our sample experienced normal conditions in 2008 and 2012, suffering drought in 2002 and 2005 and flooding in 2014.[14]

Table 3 provides descriptive statistics on distances between small and newly established large farms. We note that 41% of small farmers had at least one new large farm (with total cultivated areas of 258 ha) crop up in a 25 km radius, a figure that was, with 82%, 50%, and 11%, respectively, highest in the South, followed by the Center and the North. Nationally, 55% and 74% of small farmers had at least one new large farm (with areas of 467 ha and 966 ha) emerge within a 25-50 or 50-100 km range, respectively. Spillovers that result in yield changes after controlling for practices and purchased input use are likely driven by crop-

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[12] As virtually all of this area is cropped rather than being under pasture, the smallholder sector accounts for 95.6% of cropped area.
[13] The increase of sugarcane yields, partly due to rehabilitation programs after the war, highlights the potential for catch-up productivity growth.
[14] For 2012 and 2014 we have precise GPS coordinates of farms' location, allowing us to compute rainfall deviations at farm level. Including these instead of the district-level estimates reported above reduces the no. of observations but does not result in any significant change of regression results which are available upon request.

specific technology, i.e. require not just establishment of any large farm in the vicinity but one that actually grows the same crop. Table A1 in the appendix reports relevant descriptive statistics. The share of small farms who had a large farms growing the same crop newly established within a distance of 25 (50-100) km is 33% (64%) in maize, 13% (34%) for cassava, 3% (8%) in sorghum, 15% (30%) for peanuts, 5% (23%) for rice, and 7% (24%) for sugarcane with regional variations in line with what was discussed earlier.

**3.2 Comparing productivity and modern input use between large and small farms**

Beyond spatial proximity, a high potential for catch-up as evidenced by large gaps between large and small farms will be conducive to spillovers. Based on 2014 data, table 4 shows clear differences between large and small farms in terms of cultivation practices, access to water and improved inputs, and adoption of measures to conserve soil fertility such as use of organic manure, fertilizer, and yields.[15] These, together with evidence on the spatial distribution of production in figures 2 and 3, are discussed below.

Maize, the main staple, is grown by 55% of large (with mean areas of 18, 14, and 7 ha in the North, Center, and South, respectively) and 83% of small and medium producers (76%, 92%, and 86% in Center, South, and North, respectively). Average yields are among the lowest in Africa without significant difference between large and small producers, despite vast differences between them in the share of area irrigated (19% for large vs. 1% for small and medium farmers), improved seed use (40% vs. 9%), and application of fertilizer (29% vs. 2%), pesticide (21% vs. 1%), and manure (17% vs. 1%).

Cassava is grown by 53% of small & medium producers on an average area of 0.4 ha per farm, compared to 12% of large ones with an average of 1.9 ha. In line with the crop's limited input requirements, smallholders obtain much higher yields than large farms (2.9 vs. 0.8 t/ha with yields above 3 t/ha in the South and Center). Neither large nor small farms use significant levels of modern inputs. The same is true for sorghum, a crop that is grown by 24% of smallholders (about one-third each in the North and the Center) but only 7% of large farms, about 16% of which use improved seeds.

Although domestic rice consumption is growing rapidly,[16] the crop is grown by few (5% of large and 13% of small) farmers. Average large farm yields are, with 0.8 vs. 0.5 t/ha, about 60% above those for small farms, partly due to higher use of irrigation (86% vs. 3%), improved seed (73% vs. 5%), fertilizer (73% vs. 3%) and pesticides (68% vs. 1%),. Sugarcane is the main large farm crop with (monetary) yields about double those by smallholders but large differences among large farms (19.3 vs. 22.0 MT/ha in Center vs. South) mirrored by those of smallholders (15.1 vs. 14.2 and 6.7 MT/ha in North, South, and Center).

**3.3 Estimating yield regressions**

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[15] Unfortunately, a failure to record quantities of purchased inputs applied by large farms makes it impossible to compute profits.
[16] Rice consumption more than doubled from 2000 to 2010 to 550,000t of which 63% is imported and demand is expected to increase at 7% per year over the next decade or so.

Although lack of input prices and labor input in our data makes it difficult to compute profits or estimate a production function, low incidence of purchased input use by small farmers suggests that indicator variables for whether or not certain inputs or practices were applied may be a reasonable approximation. To assess the impact of purchased input use and improved cultivation practices on output for specific crops and at the same time provide a simple test of the farm size-productivity relationship, we use data for 2008, 2012 and 2014 to run simple yield regressions.[17] Our estimating equation takes the form

$$Y_{kijt} = \alpha + \beta_1 A_{kijt} + \beta_2 A_{kijt}^2 + \gamma_1 Z_{kijt} + \gamma_2 X_{ijt} + \gamma_3 R_{jt} + \delta_t + \delta_j + \epsilon_{ijt} \ (2)$$

where $Y_{kijt}$ is the natural log of yield from a main crop $k$ (maize, cassava, sorghum, peanut, rice or sugarcane)[18] for small farm $i$ in district $j$ in year $t$; $A_{kijt}$ is the natural log of farm size; $Z_{kijt}$ is a vector of indicator variables for crop-specific input use including improved seed, fertilizer, pesticide and irrigation; $X_{ijt}$ is a vector of basic household characteristics and indicator variables for hiring workers, animal traction, and agronomic practices; $R_{jt}$ is a vector including the absolute value of the $z$ score of the rainfall deviation from the long-term trend and an indicator variable indicating whether this deviation is positive or negative shock; $\delta_t$ is a time trend; and $\delta_j$ is a district fixed effect.[19]

Results, in table 5, point to three conclusions. First, improved cultivation practices seem associated with higher yields although the relationship, which is strongest for maize where use of intercropping, line sowing, animal traction, and crop rotation -estimated to be associated with yield increases by 15.5, 12.1, 11.1 and 8.3 points, respectively- is not always significant. Animal traction, line sowing and irrigation (15.1%, 13.7% and 56.2%) are significant for cassava, while intercropping, line sowing, and crop rotation are so for peanuts (11.6%, 9.1% & 8.8%). Intercropping and line sowing are weakly significant for sorghum, but none seem to affect yields for rice or sugarcane. Second, once other factors are controlled for, 2012 and 2014 yields are indeed significant above 2008 ones for all crops. Third, with the exception of peanuts and sugarcane, the relationship between farm size and yield is U-shaped with the minimum attained for maize, cassava, sorghum, and rice estimated at 184, 2930, 593, and 15 ha, respectively, well beyond the range for which we have data, implying a negative relationship over the entire support.

Lack information on household characteristics and agronomic practices for large farms makes even simple yield regressions difficult to interpret. Figure 4 thus plots the kernel-weighted local polynomial relationship between farm size and yields for different crops. While there is a strong negative relationship between farm size and productivity for farms below 1 ha in all commodities except rice, yields tend to increase with farm

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[17] We do not include earlier years because we do not have crop-specific use of inputs.

[18] Yield is value (MT) per hectare for sugarcane and kilogram per hectare for other crops.

[19] We include a EA fixed effect in equation (1) but a district fixed effect in equation (2), because the 2008 data set is not a panel with 2012 and 2014 data sets at EA level.

size thereafter for rice and sugarcane (though confidence bands are very wide) decrease for cassava, follow a U-shaped pattern for Sorghum and peanuts, and virtually flat for maize.

## 4. Testing for spillovers between large and small farms

Our data provide evidence of positive spillover effects from large farm establishment within a 0-50 km radius on smallholders' adoption of cultural practices (including animal traction) and input use but not on area cultivated, off-farm employment, output market participation, access to credit or, for farms growing the same crop, on yields, possibly due to the short time elapsed since large farm establishment. In addition, the fact that establishment of large farms within a 25 km radius also triggered an increase in the share of smallholders who perceive their situation now to be worse than 3 years warrants exploration.

### 4.1 Estimating spillovers on technology and market participation

Estimated impacts of new farm establishment/expansion on adoption of cultural practices and modern input use as displayed in table 6, where the top panel reports results for large farm establishment and the bottom panel those for increases in large farm area, point towards significant limited effects on adoption of agronomic practices and input use in relatively close proximity to new large farms. Large farm establishment within 25 km is estimated to have led to an increase in the incidence of crop rotation, intercropping, and animal traction by 6.9, 6.5, and 2.9 percentage points respectively compared to the base category of a large farm having opened within a 100-250 km radius. For animal traction, the estimated effect is (with 4.7 points) slightly larger, similar to what is observed for intercropping (5.9 points) compared to only insignificant effects for use of crop rotation at a distance of 25-50 km.

With the exception of a weak and imprecisely estimated effect for intercropping, we do not find evidence of an impact of new large farms established at a distance of 50-100 km compared to 100-250 km. Opening of large farms within 25 km is also estimated to have led to a 2 or 2.8 point increase in the incidence of fertilizer and pesticide use, an effect that carries over to the 25-50 km radius for fertilizer (which is the only input for which area of new large farms is also significant with elasticities of 0.005 and 0.004 for 0-25 and 25-50 km. By comparison, opening of farms beyond 50 km is not found to have any effect. For animal traction, intercropping and crop rotation, estimated coefficients on the net increase in new farm area are also significant, estimated magnitudes are much smaller, with a doubling of large farm area estimated to lead to a 1.3 point increase in the incidence of intercropping.

Table 7 suggests that, over the time horizon considered here, large farm establishment not improve small farmers' access to off-farm jobs or other factor or output markets, consistent with findings elsewhere,. Although establishment of large farms has a significant positive impact on use of animal traction, we find no significant effect on total area cultivated, possibly because we are looking at short-term effects only.

The relevance of factors that are unrelated to productivity is reinforced by the fact that having seen a new large farm established in the immediate vicinity (< 25 km) is estimated to have resulted in a significant increase by 4.4 points in the likelihood of small farmers' feeling to be worse off than 3 years ago, consistent with highly significant positive point estimates on the likelihood to perceive the current situation worse than 3 years ago in the equation with area of new large farm establishment as the relevant independent variable. Exploring potential reasons for this result in more detail would be of interest.

## 4.2 Evidence of spillover effects on yields

Assuming that transfers of technology that result in increased yields large farms are more likely to have spillover effects on smallholders growing the same crops, we replace the relevant indicators ($L_{ijtd}$ and $A_{ijtd}$) in equation (1) with equivalent measures for new large farms growing at least 1 ha of the same crop as the small farm in question. Results, in panel A and B of table 8, suggest that, once other inputs are controlled for, with the exception of the weakly positive effect (25-50 km) on rice yield, there is no significant effect of large farm establishment on smallholder yields. While this is contrary to what was found in Ethiopia (Ali *et al.* 2015), it seems plausible in light of the limited overlap in main crops between large and small farms, the fact that in all crops except rice and sugarcane, mean differences in yield between large and small farms are either negligible or negative thus limiting the scope for technology spillovers, and -in the case of rice-relatively short time elapsed since large farm formation.

## 5. Conclusion and policy implications

Our contribution is both methodological and substantive. Methodologically, we show that it is possible to assess spillover effects from large land-based investment by combining locational information from household and large farm survey data that are, in many countries where such investment is relevant, routinely available. Although existing data may not be ideal, protocols to ensure that future surveys readily provide such information can be implemented at low marginal cost, implying that it should be possible to have a ready stream of relevant data for future research and analysis.

From a substantive point of view, we indeed find evidence of positive spillovers from large farm establishment on neighboring small and medium farmers in terms of adopting some practices and accessing fertilizer and pesticides. At the same time we fail to find positive spillover effects on markets for other factors, in particular labor, output market participation, and–if other inputs are controlled for– yields. Most spillover effects are quite localized, i.e. there is no support for the hypothesis of establishment of large farms beyond a 25 or at most 50 km radius to have any impact on smallholders. Also, a significant negative impact of large farm establishment on neighboring smallholders' subjective well-being implies that, the positive learning effects notwithstanding, those in close proximity (within 25 km) perceive unobserved

negative external effects. Further research to explore whether this perception can be attributed to specific events, such as loss or degradation of resources smallholders have traditionally relied upon, or the general uncertainty and disruption of traditional patterns of life due to sudden appearance of an unfamiliar farming operation next door will be important to help shape a proper response (i.e. either regulation and enforcement of existing rules or communication).

To properly interpret our results and to identify ways in which their robustness and relevance may be improved two caveats need to be borne in mind. First, our results hinge on the data including all new large farms formed and, as data pertain to changes in large farms in 2012-14, can only identify short term spillover effects. There are many reasons why these may be different from what would be expected in the long term. Having a question regarding large farms' year of establishment included in the TIA survey would allow to address this.[20] In addition, the importance of having a complete list of large farms, other countries' experience, and the potential relevance of such data to guide administrative action (e.g. on failed ventures) imply that extra effort may be warranted in three respects, namely (i) cross-checking of the sample frame with other administrative data (investment licenses, tax office) to ensure completeness, in particular inclusion of farms that had been established after the sample frame for the agricultural census had been completed; (ii) verification with local authorities to ensure 'informal' ventures that were either missed in the census or established after its conduct are included; and (iii) clear procedures on how non-responses are dealt with and farms that ceased operations are identified. In the medium term, this could be complemented with use of remotely sensed imagery to ascertain accuracy of information on key variables, in particular the size and boundaries of area actually used for crop cultivation.

Second, while we can estimate mean spillover effects from recent large farm establishment, policy makers may be interested in how such impacts differ between different types of investments (or investors) and the modality of land acquisition. One can think of several interesting aspects in these dimensions, namely (i) access to infrastructure; quality, transparency, and outreach in conducting legally prescribed community consultation during land acquisition; (ii) contractual obligations and profit sharing arrangements and production practices (pure crop or livestock production vs. integration with processing with capacity to add value to neighboring smallholders' produce) regarding the nature of investments; (iii) corporate structure; (iv) country of origin; (v) clarity of business plans, initial availability of resources for implementation, and CSR activities envisaged in them; (vi) technical efficiency; and (vii) participation in certification schemes or commodity roundtables as relevant investor attributes. Information on each of these dimensions is available either in administrative records (e.g. project files maintained by investment authorities) or can be obtained by including relevant questions in future survey rounds. Efforts to do so would be a high priority

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[20] In fact, a question to this effect had been included in earlier years of the TIA but was then dropped.

to provide feedback on policies and test the efficacy of specific regulations.[21] They would also allow us to assess if the lack of significance of our coefficients is due to aggregation bias.

Subject to the caveats posed by the data, the evidence of positive indirect effects and the fact that, with the exception of subjective well-being, we fail to find negative ones suggests that in Mozambique large land-based investment can provide local benefits. The fact that estimated spillovers are limited to a subset of the indicators used, modest in size, and counterbalanced by a decrease in perceived welfare, suggests that private large farm investment cannot overcome long-standing under-investment in Mozambique's agricultural sector. It will thus need to be complemented by public investment to have maximum effect. Exploring longer-term effects and heterogeneity in various relevant dimensions is likely to provide useful insights for the policy debate. If complemented by an assessment of the impacts of investments higher up in the value chain and evidence on the magnitude and channels for such effects elsewhere, this could open up a relevant and fruitful line of investigation that will be of relevance well beyond Mozambique.

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[21] Examples could include qualification criteria (e.g. in terms of documented assets) for investors, minimum standards for business plans or documentation of local consultations to be accepted, and the time profile, level, and destination of lease payments.

**Table 1: Basic characteristics by farm size group**

| | Farm size group | | | | | |
|---|---|---|---|---|---|---|
| | **0.1-10** | **10.1-50** | **50.1-200** | **200.1-1000** | **1000.1-5000** | **above 5000** |
| **Distribution of farms & area** | | | | | | |
| No. of farms | 3,893,083 | 8,123 | 176 | 91 | 66 | 19 |
| Share of farms (%) | 99.7828 | 0.2082 | 0.0045 | 0.0023 | 0.0017 | 0.0005 |
| Total area in farms | 5,543,515 | 137,680 | 16,976 | 48,291 | 134,661 | 231,255 |
| Share of farm area | 90.6932 | 2.2525 | 0.2777 | 0.7901 | 2.2031 | 3.7834 |
| Total area cultivated | 5,543,450 | 136,816 | 13,105 | 15,363 | 37,279 | 53,800 |
| Share of cultivated area | 95.5798 | 2.3590 | 0.2260 | 0.2649 | 0.6428 | 0.9276 |
| **Distribution of cultivated area** | | | | | | |
| Partial fallow | 0.058 | 0.134 | 0.613 | 0.474 | 0.665 | 0.399 |
| Perennials | 0.011 | 0.027 | 0.071 | 0.099 | 0.049 | 0.054 |
| Annuals | 0.920 | 0.785 | 0.316 | 0.427 | 0.286 | 0.547 |
| Maize | 0.317 | 0.324 | 0.257 | 0.091 | 0.062 | 0.001 |
| Cassava | 0.158 | 0.079 | 0.014 | 0.003 | 0.001 | 0.000 |
| Sorghum | 0.061 | 0.058 | 0.020 | 0.000 | 0.000 | 0.000 |
| Peanuts | 0.076 | 0.093 | 0.014 | 0.002 | 0.001 | 0.000 |
| Rice | 0.075 | 0.004 | 0.140 | 0.109 | 0.002 | 0.018 |
| Sugarcane | 0.006 | 0.001 | 0.088 | 0.152 | 0.401 | 0.838 |
| Millet | 0.011 | 0.010 | 0.006 | 0.000 | 0.000 | 0.000 |
| Pulse | 0.163 | 0.184 | 0.045 | 0.040 | 0.020 | 0.001 |
| Sweet potato | 0.017 | 0.059 | 0.037 | 0.032 | 0.020 | 0.002 |
| Cotton | 0.039 | 0.072 | 0.117 | 0.085 | 0.000 | 0.000 |
| Tobacco | 0.007 | 0.001 | 0.025 | 0.011 | 0.000 | 0.000 |
| Other cash crops | 0.022 | 0.021 | 0.084 | 0.243 | 0.486 | 0.137 |
| Vegetables | 0.041 | 0.096 | 0.152 | 0.221 | 0.008 | 0.004 |

*Source:* Own computation from 2014 large, medium, and small TIA survey.

**Table 2: Evolution of the small and medium farm sector**

| | Small and Medium Farms | | | | |
|---|---|---|---|---|---|
| | **2002** | **2005** | **2008** | **2012** | **2014** |
| Total area cultivated | 2.40 | 2.49 | 2.23 | 1.77 | 1.71 |
| … of which with annuals | 0.88 | 0.91 | 0.92 | 0.92 | 0.92 |
| … of which with perennials | 0.08 | 0.03 | 0.02 | 0.01 | 0.01 |
| … of which in partial fallow | 0.04 | 0.06 | 0.05 | 0.05 | 0.06 |
| Received extension advice | 0.15 | 0.18 | 0.09 | 0.07 | 0.11 |
| Used tractor | 0.04 | 0.04 | 0.03 | | 0.04 |
| Used animal traction | 0.20 | 0.21 | 0.20 | 0.18 | 0.21 |
| Used improved seed | | 0.09 | 0.12 | 0.10 | 0.11 |
| Used fertilizer | 0.05 | 0.05 | 0.04 | 0.03 | 0.05 |
| Used pesticide | 0.07 | 0.07 | 0.03 | 0.04 | 0.04 |
| Used manure | 0.09 | 0.05 | 0.03 | 0.03 | 0.03 |
| Practiced crop rotation | | 0.35 | 0.26 | 0.28 | 0.24 |
| Practiced inter-cropping | | 0.88 | 0.83 | 0.79 | 0.81 |
| Practiced line sowing | | 0.49 | 0.45 | 0.45 | 0.45 |
| Sold crops | 0.59 | 0.53 | 0.53 | 0.50 | 0.49 |
| Any off-farm employment | | 0.19 | 0.17 | 0.12 | 0.17 |
| Received credit | | 0.04 | 0.03 | 0.02 | 0.02 |
| Better off than 3 years ago | | 0.20 | 0.29 | 0.34 | 0.45 |
| Worse off than 3 years ago | | 0.49 | 0.35 | 0.31 | 0.21 |
| **Yields** | | | | | |
| Maize (kg/ha) | 973 | 781 | 717 | 949 | 1,024 |
| Cassava (kg/ha) | 2,961 | 4,098 | 2,554 | 3,566 | 2,921 |
| Sorghum (kg/ha) | 725 | 511 | 473 | 720 | 714 |
| Peanuts (kg/ha) | 414 | 324 | 287 | 422 | 470 |
| Rice (kg/ha) | 558 | 463 | 382 | 492 | 494 |
| Sugarcane (MT/ha) | NA | 8,638 | 9,549 | 13,783 | 13,379 |
| **Rainfall** | | | | | |
| Daily rainfall (mm) | 1.58 | 1.42 | 1.77 | 1.89 | 2.23 |
| \|Z\| of daily rainfall compared to 1990-2001 | 0.87 | 0.68 | 0.56 | 0.84 | 0.84 |
| Share of negative z score | 0.70 | 0.91 | 0.58 | 0.51 | 0.11 |
| Share of z-score < -1 | 0.23 | 0.19 | 0.05 | 0.05 | 0.00 |
| No. of observations | 4,840 | 6,000 | 5,783 | 6,430 | 5,772 |

*Source:* Small and medium farmer data from various TIA survey rounds

*Note:* Output of sugarcane is in 2014 MT using the World Bank's consumer price index as a deflator (http://data.worldbank.org/indicator/FP.CPI.TOTL.ZG/countries/MZ?display=default).

**Table 3: Smallholders' distance to large farms established between 2012 and 14, overall and by region**

| | Total | By region | | |
| --- | --- | --- | --- | --- |
| | | North | Center | South |
| Had new large farm <=25 km | 0.41 | 0.11 | 0.50 | 0.82 |
| … if yes, number of large farms | 6.31 | 1.44 | 4.03 | 8.62 |
| … if yes, cultivated area of large farms | 258.20 | 283.37 | 364.67 | 192.27 |
| Had new large farm 25-50 km | 0.55 | 0.23 | 0.69 | 0.93 |
| … if yes, number of large farms | 11.06 | 1.65 | 5.13 | 18.89 |
| … if yes, cultivated area of large farms | 466.51 | 585.75 | 377.97 | 480.13 |
| Had new large farm 50-100 km | 0.74 | 0.51 | 0.89 | 0.98 |
| … if yes, number of large farms | 22.99 | 2.23 | 9.67 | 51.44 |
| … if yes, cultivated area of large farms | 965.66 | 581.48 | 1136.53 | 1137.14 |
| No. of obs. | 5,772 | 2,602 | 1,530 | 1,640 |

*Note:* North includes Cabo Delgado, Nampula, Niassa, and Zambezia; Center includes Manica, Sofala, and Tete; South includes Gaza, Inhambane, and Maputo.

**Table 4: Inputs and outputs for main crops in 2014**

| | Total | | North | | Center | | South | |
|---|---|---|---|---|---|---|---|---|
| | Large | S.& M. | Large | S.& M. | Large | S.& M. | Large | S.& M. |
| **Maize** | | | | | | | | |
| Crop cultivated (yes/no) | 0.55 | 0.83 | 0.65 | 0.76 | 0.64 | 0.92 | 0.51 | 0.86 |
| Area (ha) | 9.57 | 0.65 | 18.00 | 0.47 | 13.72 | 0.87 | 7.42 | 0.68 |
| Yield (kg/ha) | 1,034 | 1,025 | 970 | 981 | 1,387 | 1,095 | 902 | 1,015 |
| Share of area irrigated (%) | 0.19 | 0.01 | 0.09 | 0.00 | 0.06 | 0.01 | 0.25 | 0.01 |
| Used improved seed | 0.40 | 0.09 | 0.36 | 0.04 | 0.65 | 0.14 | 0.30 | 0.09 |
| Used fertilizer | 0.29 | 0.02 | 0.36 | 0.00 | 0.43 | 0.06 | 0.23 | 0.01 |
| Used pesticide | 0.21 | 0.01 | 0.27 | 0.00 | 0.27 | 0.01 | 0.18 | 0.02 |
| Used manure | 0.17 | 0.01 | 0.00 | 0.00 | 0.30 | 0.02 | 0.13 | 0.02 |
| **Cassava** | | | | | | | | |
| Crop cultivated (yes/no) | 0.12 | 0.53 | 0.29 | 0.66 | 0.02 | 0.21 | 0.14 | 0.63 |
| Area (ha) | 1.90 | 0.37 | 3.40 | 0.43 | 1.63 | 0.22 | 1.73 | 0.34 |
| Yield (kg/ha) | 821 | 2,922 | 651 | 2,742 | 671 | 3,539 | 852 | 3,040 |
| Share of area irrigated (%) | 0.07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.09 | 0.00 |
| Used improved seed | 0.08 | | 0.00 | | 0.00 | | 0.10 | |
| Used fertilizer | 0.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.07 | 0.00 |
| Used pesticide | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.01 |
| Used manure | 0.10 | 0.01 | 0.00 | 0.00 | 0.50 | 0.02 | 0.10 | 0.02 |
| **Sorghum** | | | | | | | | |
| Crop cultivated (yes/no) | 0.07 | 0.24 | 0.00 | 0.32 | 0.22 | 0.34 | 0.03 | 0.02 |
| Area (ha) | 3.20 | 0.30 | | 0.24 | 3.79 | 0.39 | 2.03 | 0.26 |
| Yield (kg/ha) | 434 | 714 | | 643 | 512 | 841 | 262 | 476 |
| Share of area irrigated (%) | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Used improved seed | 0.16 | 0.02 | | 0.01 | 0.24 | 0.02 | 0.00 | 0.00 |
| Used fertilizer | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Used pesticide | 0.00 | 0.00 | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Used manure | 0.03 | 0.00 | | 0.00 | 0.05 | 0.01 | 0.00 | 0.03 |
| **Peanuts** | | | | | | | | |
| Crop cultivated (yes/no) | 0.20 | 0.44 | 0.18 | 0.44 | 0.12 | 0.30 | 0.22 | 0.56 |
| Area (ha) | 1.78 | 0.28 | 0.67 | 0.25 | 2.16 | 0.24 | 1.77 | 0.34 |
| Yield (kg/ha) | 381 | 467 | 690 | 532 | 171 | 420 | 404 | 402 |
| Share of area irrigated (%) | 0.02 | 0.00 | 0.33 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 |
| Used improved seed | 0.10 | 0.05 | 0.00 | 0.02 | 0.27 | 0.08 | 0.07 | 0.08 |
| Used fertilizer | 0.02 | 0.01 | 0.33 | 0.00 | 0.00 | 0.03 | 0.01 | 0.00 |
| Used pesticide | 0.01 | 0.01 | 0.33 | 0.00 | 0.00 | 0.01 | 0.00 | 0.01 |
| Used manure | 0.02 | 0.01 | 0.00 | 0.00 | 0.00 | 0.02 | 0.03 | 0.01 |
| **Rice** | | | | | | | | |
| Crop cultivated (yes/no) | 0.05 | 0.13 | 0.18 | 0.21 | 0.00 | 0.11 | 0.06 | 0.03 |
| Area (ha) | 31.30 | 0.54 | 134.00 | 0.49 | | 0.65 | 15.08 | 0.61 |
| Yield (kg/ha) | 789 | 494 | 622 | 423 | | 588 | 819 | 983 |
| Share of area irrigated (%) | 0.86 | 0.03 | 0.00 | 0.00 | | 0.00 | 1.00 | 0.49 |
| Used improved seed | 0.73 | 0.05 | 0.67 | 0.03 | | 0.05 | 0.74 | 0.33 |
| Used fertilizer | 0.73 | 0.03 | 0.33 | 0.00 | | 0.01 | 0.79 | 0.33 |
| Used pesticide | 0.68 | 0.01 | 0.33 | 0.00 | | 0.01 | 0.74 | 0.18 |
| Used manure | 0.00 | 0.01 | 0.00 | 0.00 | | 0.01 | 0.00 | 0.06 |
| **Sugarcane** | | | | | | | | |
| Crop cultivated (yes/no) | 0.05 | 0.03 | 0.00 | 0.03 | 0.04 | 0.03 | 0.05 | 0.02 |
| Area (ha) | 260.06 | 0.24 | | 0.26 | 1079.17 | 0.21 | 71.04 | 0.22 |
| Yield (MT/ha) | 21,569 | 13,379 | | 15,115 | 19,260 | 6,716 | 21,954 | 14,150 |
| Share of area irrigated (%) | 0.75 | 0.01 | | 0.00 | 0.67 | 0.00 | 0.77 | 0.03 |
| Used improved seed | 0.63 | | | | 0.25 | | 0.73 | |
| Used fertilizer | 0.79 | 0.02 | | 0.01 | 0.50 | 0.00 | 0.87 | 0.06 |
| Used pesticide | 0.68 | 0.01 | | 0.00 | 0.50 | 0.00 | 0.73 | 0.06 |
| Used manure | 0.21 | 0.01 | | 0.00 | 0.00 | 0.00 | 0.27 | 0.06 |
| No. of obs. | 419 | 5,772 | 17 | 2,602 | 94 | 1,530 | 308 | 1,640 |

Note: The North comprises Cabo Delgado, Nampula, Niassa, and Zambezia; the Center Manica, Sofala, and Tete; and the South Gaza, Inhambane and Maputo.

**Table 5: Yield functions for small farms**

| | Maize | Cassava | Sorghum | Peanuts | Rice | Sugarcane |
|---|---|---|---|---|---|---|
| Farm size (ln) | -0.386*** | -0.463*** | -0.498*** | -0.453*** | -0.482*** | -0.839*** |
| | (0.016) | (0.024) | (0.032) | (0.024) | (0.034) | (0.258) |
| Farm size (quadratic ln) | 0.037*** | 0.029** | 0.039* | 0.020 | 0.088*** | 0.173 |
| | (0.011) | (0.011) | (0.020) | (0.017) | (0.015) | (0.142) |
| Hired workers permanent | 0.129*** | 0.251** | 0.223* | 0.115 | 0.163 | 0.070 |
| | (0.049) | (0.097) | (0.128) | (0.071) | (0.131) | (0.549) |
| Hired workers seasonal | 0.345*** | 0.138*** | 0.297*** | 0.285*** | 0.336*** | 0.093 |
| | (0.024) | (0.047) | (0.042) | (0.036) | (0.056) | (0.315) |
| Used animal traction | 0.111** | 0.151*** | 0.079 | 0.042 | -0.081 | 0.215 |
| | (0.045) | (0.052) | (0.107) | (0.049) | (0.170) | (0.699) |
| Used improved seed | -0.019 | | 0.007 | -0.004 | -0.140 | |
| | (0.042) | | (0.118) | (0.058) | (0.159) | |
| Used fertilizer | 0.108 | | | -0.037 | 0.283 | 1.747 |
| | (0.096) | | | (0.222) | (0.204) | (1.178) |
| Used pesticide | -0.128 | | | 0.286 | 0.803*** | |
| | (0.264) | | | (0.287) | (0.209) | |
| Did crop rotation | 0.083*** | 0.055 | 0.059 | 0.088** | 0.067 | 0.075 |
| | (0.022) | (0.039) | (0.045) | (0.035) | (0.054) | (0.308) |
| Did inter-cropping | 0.155*** | 0.010 | 0.096* | 0.116*** | 0.085 | 0.319 |
| | (0.031) | (0.054) | (0.055) | (0.042) | (0.060) | (0.359) |
| Used irrigation | 0.060 | 0.562*** | | | 0.162 | 0.518 |
| | (0.108) | (0.205) | | | (0.203) | (0.451) |
| Did line sowing | 0.121*** | 0.137*** | 0.104** | 0.091*** | 0.086 | 0.409 |
| | (0.023) | (0.037) | (0.047) | (0.033) | (0.058) | (0.302) |
| Number of children | 0.017*** | 0.022** | 0.012 | 0.010 | 0.001 | -0.025 |
| | (0.005) | (0.009) | (0.012) | (0.009) | (0.014) | (0.062) |
| Number of adults | 0.032*** | 0.055*** | 0.031 | 0.016 | 0.037** | 0.111 |
| | (0.007) | (0.012) | (0.019) | (0.011) | (0.014) | (0.087) |
| Number of old people | 0.016 | 0.015 | 0.018 | -0.070** | 0.032 | 0.508 |
| | (0.024) | (0.042) | (0.048) | (0.031) | (0.053) | (0.388) |
| Highest education | 0.011*** | 0.012* | 0.016** | 0.016*** | 0.035*** | -0.017 |
| | (0.003) | (0.006) | (0.006) | (0.005) | (0.007) | (0.052) |
| Female head | -0.159*** | -0.075** | -0.185*** | -0.180*** | -0.186*** | -0.189 |
| | (0.026) | (0.037) | (0.051) | (0.034) | (0.058) | (0.246) |
| Head's age | 0.001* | 0.003* | 0.001 | 0.004*** | -0.001 | 0.005 |
| | (0.001) | (0.001) | (0.002) | (0.001) | (0.002) | (0.012) |
| \|Z\| of rainfall | -0.012 | -0.091 | -0.019 | -0.076* | 0.108* | 0.364 |
| | (0.038) | (0.056) | (0.041) | (0.044) | (0.061) | (0.400) |
| Negative z of rainfall | 0.033 | 0.267*** | -0.066 | -0.014 | -0.008 | 1.336*** |
| | (0.044) | (0.098) | (0.077) | (0.059) | (0.085) | (0.466) |
| Year 2012 | 0.183*** | 0.211*** | 0.270*** | 0.285*** | -0.053 | 0.652** |
| | (0.042) | (0.080) | (0.059) | (0.058) | (0.062) | (0.292) |
| Year 2014 | 0.324*** | 0.176** | 0.353*** | 0.374*** | 0.178** | 1.167** |
| | (0.033) | (0.078) | (0.068) | (0.051) | (0.076) | (0.525) |
| Observations | 14,128 | 9,289 | 4,275 | 7,086 | 2,338 | 260 |
| R-squared | 0.189 | 0.124 | 0.179 | 0.208 | 0.271 | 0.589 |

*Note:* Data from 2008, 2012, and 2014 are used. Dependent variable is ln output quantity in kg/ha for maize, cassava, sorghum, peanut and rice and ln output value in MT/ha for sugarcane. Control variables include household composition (no. of children, adults and old people), headship, head's age, and highest education in the household. District fixed effects are included but not reported throughout. Standard errors are clustered by district. Estimates for 2012 and 2014 with EA fixed effects are qualitatively similar and available upon request. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

**Table 6: Impact of proximity to large farms on modern input use**

| | Agronomic practices | | | Modern input use | | | | Access to |
|---|---|---|---|---|---|---|---|---|
| | **Rotation** | **Intercrop** | **Line sow** | **Traction** | **Imp. seed** | **Fertilizer** | **Pesticide** | **Extension** |
| | | | | **Panel A** | | | | |
| Any new large farm <= 25 km | 0.069** | 0.065*** | -0.002 | 0.029* | 0.033* | 0.020** | 0.028** | 0.013 |
| | (0.027) | (0.024) | (0.028) | (0.017) | (0.018) | (0.009) | (0.011) | (0.016) |
| Any new large farm 25-50 km | 0.009 | 0.059** | 0.053* | 0.047*** | 0.019 | 0.022*** | 0.012 | 0.005 |
| | (0.030) | (0.026) | (0.029) | (0.015) | (0.016) | (0.008) | (0.014) | (0.016) |
| Any new large farm 50-100 km | 0.046 | 0.048* | -0.014 | -0.001 | -0.017 | -0.009 | 0.001 | 0.004 |
| | (0.031) | (0.025) | (0.030) | (0.012) | (0.014) | (0.009) | (0.014) | (0.018) |
| Observations | 12,202 | 12,202 | 12,202 | 12,202 | 12,202 | 12,202 | 12,202 | 12,202 |
| R-squared | 0.166 | 0.190 | 0.295 | 0.574 | 0.166 | 0.305 | 0.250 | 0.128 |
| | | | | **Panel B** | | | | |
| Any new large farm <= 25 km | 0.011** | 0.013*** | -0.002 | 0.006* | 0.003 | 0.005** | 0.004** | 0.000 |
| | (0.005) | (0.004) | (0.005) | (0.003) | (0.003) | (0.002) | (0.002) | (0.003) |
| Any new large farm 25-50 km | 0.005 | 0.011*** | 0.007 | 0.007*** | 0.006** | 0.003** | 0.003* | 0.002 |
| | (0.005) | (0.004) | (0.005) | (0.002) | (0.003) | (0.001) | (0.002) | (0.003) |
| Any new large farm 50-100 km | 0.006 | 0.005 | 0.002 | 0.003* | 0.000 | -0.000 | 0.002 | 0.003 |
| | (0.004) | (0.004) | (0.004) | (0.002) | (0.002) | (0.001) | (0.002) | (0.002) |
| Observations | 12,202 | 12,202 | 12,202 | 12,202 | 12,202 | 12,202 | 12,202 | 12,202 |
| R-squared | 0.166 | 0.189 | 0.295 | 0.574 | 0.166 | 0.305 | 0.250 | 0.128 |

*Note:* Other control variables that are included throughout but not reported are farm size, household composition (no. of children, adults and old people), headship, head's age, and highest education in the household and a time dummy. EA fixed effects are included throughout and standard errors are clustered by EA. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

**Table 7: Impact of proximity to large farms on practices market integration, and subjective welfare**

| | Area cult. | Sold crops | Rec. credit | Employ't | Sit. now vs 3a ago | |
| --- | --- | --- | --- | --- | --- | --- |
| | | | | | better | worse |
| **Panel A** | | | | | | |
| Any new lg. farm <= 25 km | 0.009 | 0.005 | -0.002 | 0.018 | -0.025 | 0.044** |
| | (0.107) | (0.025) | (0.008) | (0.019) | (0.026) | (0.021) |
| Any new large farm 25-50 km | 0.077 | 0.033 | 0.004 | 0.027 | 0.021 | -0.010 |
| | (0.095) | (0.027) | (0.008) | (0.019) | (0.027) | (0.022) |
| Any new lg. farm 50-100 km | -0.056 | -0.033 | -0.007 | -0.046** | -0.014 | 0.017 |
| | (0.089) | (0.027) | (0.010) | (0.020) | (0.027) | (0.022) |
| Observations | 12,202 | 12,202 | 12,202 | 12,202 | 12,202 | 12,202 |
| R-squared | 0.215 | 0.274 | 0.126 | 0.144 | 0.172 | 0.152 |
| **Panel B** | | | | | | |
| New lg. farm area <= 25 km | 0.008 | 0.003 | 0.000 | 0.002 | -0.007 | 0.008** |
| | (0.021) | (0.005) | (0.001) | (0.004) | (0.005) | (0.004) |
| New lg. farm area 25-50 km | 0.021 | 0.002 | 0.001 | 0.005 | 0.001 | 0.004 |
| | (0.017) | (0.004) | (0.002) | (0.003) | (0.004) | (0.004) |
| New lg. farm area 50-100 km | -0.004 | -0.004 | -0.001 | -0.001 | 0.004 | -0.001 |
| | (0.016) | (0.004) | (0.001) | (0.003) | (0.004) | (0.003) |
| Observations | 12,202 | 12,202 | 12,202 | 12,202 | 12,202 | 12,202 |
| R-squared | 0.216 | 0.274 | 0.127 | 0.143 | 0.172 | 0.153 |

*Note:* Other control variables that are included throughout but not reported are farm size, household composition (no. of children, adults and old people), headship, head's age, and highest education in the household and a time dummy. EA fixed effects are included throughout and standard errors are clustered by EA. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

**Table 8: Impact of proximity to large farms on yields of main crops**

| | Maize | Cassava | Sorghum | Peanuts | Rice | Sugarcane |
|---|---|---|---|---|---|---|
| **Panel A** | | | | | | |
| Any new same-crop large farm <= 25 km | 0.034 | 0.082 | 0.306 | -0.050 | 0.197 | -4.083 |
| | (0.072) | (0.150) | (0.445) | (0.126) | (0.402) | (4.791) |
| Any new same-crop large farm 25-50 km | 0.023 | -0.029 | -0.192 | -0.142 | 0.532* | |
| | (0.068) | (0.135) | (0.510) | (0.110) | (0.297) | |
| Any new same-crop large farm 50-100 km | 0.056 | 0.165 | 0.167 | -0.161 | -0.046 | 2.715 |
| | (0.065) | (0.131) | (0.354) | (0.111) | (0.210) | (2.469) |
| Observations | 9,483 | 6,479 | 2,767 | 4,879 | 1,573 | 169 |
| R-squared | 0.276 | 0.262 | 0.280 | 0.345 | 0.473 | 0.934 |
| **Panel B** | | | | | | |
| New same crop large farm area <= 25 km | -0.002 | 0.084 | -0.000 | -0.030 | -0.081 | -0.583 |
| | (0.026) | (0.084) | (0.082) | (0.093) | (0.122) | (0.771) |
| New same crop large farm area 25-50 km | 0.007 | 0.068 | 0.002 | -0.069 | 0.142 | |
| | (0.023) | (0.067) | (0.123) | (0.074) | (0.091) | |
| New same crop large farm area 50-100 km | 0.021 | 0.007 | 0.092 | -0.050 | 0.024 | 0.336 |
| | (0.016) | (0.052) | (0.096) | (0.049) | (0.041) | (0.306) |
| Observations | 9,483 | 6,479 | 2,767 | 4,879 | 1,573 | 169 |
| R-squared | 0.276 | 0.262 | 0.280 | 0.344 | 0.473 | 0.934 |

Note: Dependent variable is ln of output (kg/ha) for maize, cassava, sorghum, peanut and rice and ln of output value (MT/ha) for sugarcane. New large farms growing the same crop are included if they cultivate more than 1 ha of the crop in question. Control variables include ln farm size, quadratic ln farm size, indicator variables for crop-specific use of fertilizer, pesticide and irrigation, hiring of temporary or permanent workers, use of animal traction, crop rotation, inter-cropping, and line sowing at household level, a rainfall shock, household composition (no. of children, adults and old people), headship, head's age, and highest education in the household and a time dummy. EA fixed effects are included throughout and standard errors are clustered by EA. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.
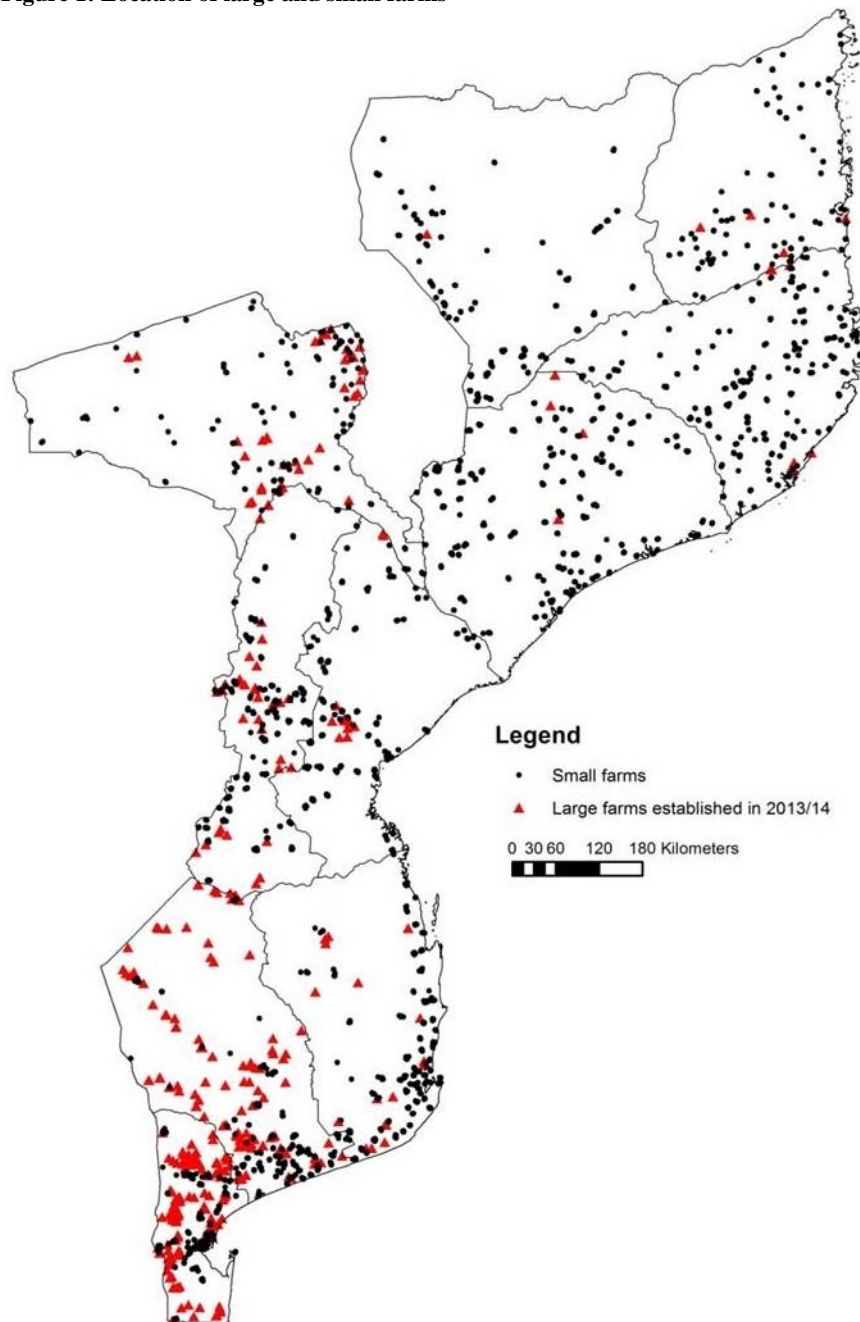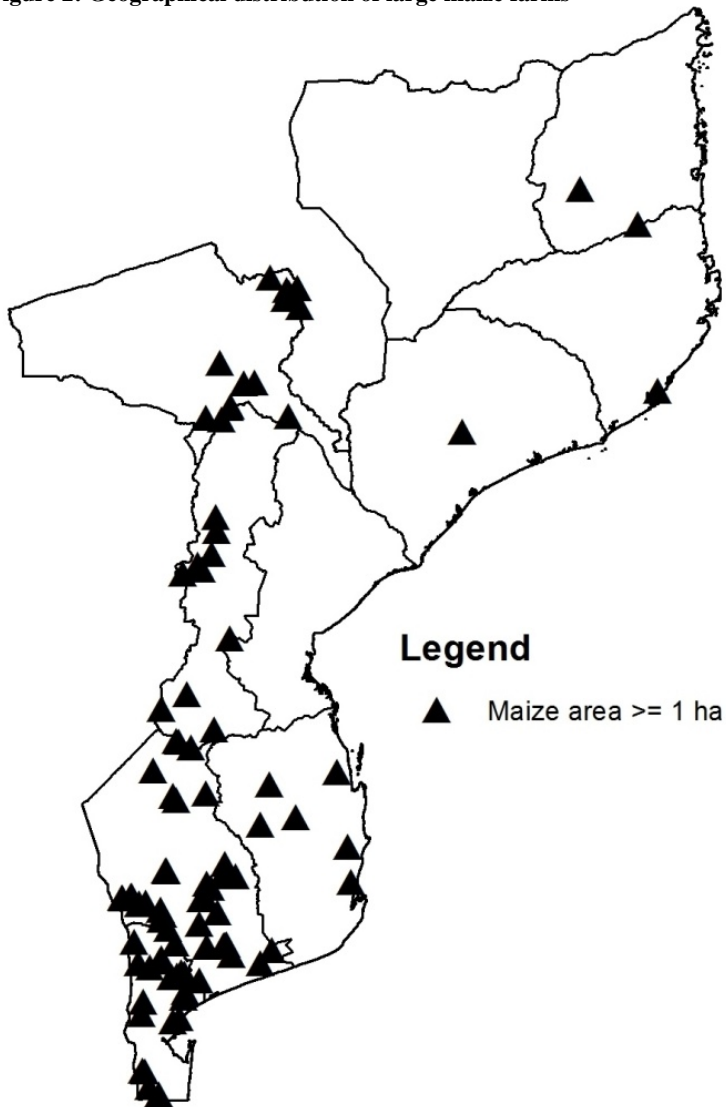
**Figure 1: Location of large and small farms**



Legend

- Small farms
- ▲ Large farms established in 2013/14

0  30 60    120    180 Kilometers

**Figure 2: Geographical distribution of large maize farms**[22]



Legend

▲  Maize area >= 1 ha

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[22] While data to draw similar maps for other commodities are available and have been used in the analysis, they cannot be displayed for reasons of confidentiality.

**Figure 3: Location of smallholders by main crop produced**

**Figure 4: Graphical illustration of the farm size-productivity relationship for all farms in 2014**
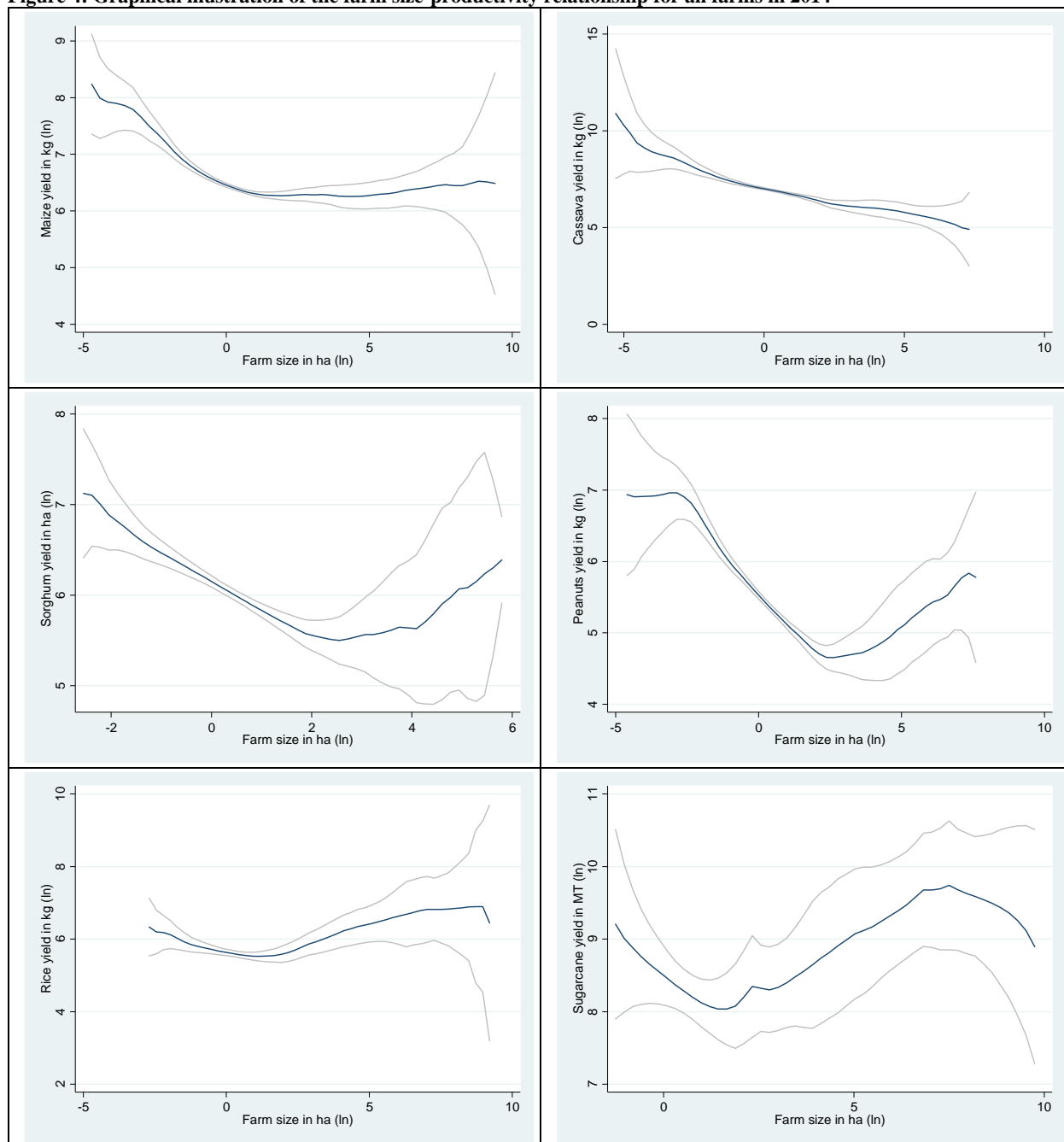
**Table A1: Distance matrix to newly established large farms by smallholders in main crops 2014**

| | Total | North | Center | South |
|---|---|---|---|---|
| **Maize** | | | | |
| Had large farms <=25 km & >=1 ha | 0.33 | 0.09 | 0.32 | 0.72 |
| … if yes, number of large farms | 3.55 | 1.38 | 3.56 | 3.95 |
| … if yes, maize area | 37.48 | 25.18 | 70.09 | 26.27 |
| Had large farms 25-50 km & >=1 ha | 0.47 | 0.18 | 0.50 | 0.89 |
| … if yes, number of large farms | 5.92 | 1.33 | 4.17 | 8.28 |
| … if yes, maize area | 51.91 | 10.98 | 78.32 | 50.81 |
| Had large farms 50-100 km & >=1 ha | 0.64 | 0.40 | 0.72 | 0.95 |
| … if yes, number of large farms | 11.27 | 1.82 | 5.77 | 21.51 |
| … if yes, maize area | 104.32 | 42.33 | 92.36 | 154.48 |
| **Cassava** | | | | |
| Had large farms <=25 km & >=1 ha | 0.13 | 0.04 | 0.04 | 0.37 |
| … if yes, number of large farms | 1.38 | 1.27 | 1.00 | 1.44 |
| … if yes, cassava area | 4.24 | 6.85 | 3.00 | 3.95 |
| Had large farms 25-50 km & >=1 ha | 0.26 | 0.09 | 0.03 | 0.75 |
| … if yes, number of large farms | 1.91 | 1.52 | 1.00 | 2.01 |
| … if yes, cassava area | 5.15 | 5.58 | 3.02 | 5.14 |
| Had large farms 50-100 km & >=1 ha | 0.34 | 0.15 | 0.06 | 0.91 |
| … if yes, number of large farms | 3.51 | 1.78 | 1.01 | 4.11 |
| … if yes, cassava area | 9.31 | 6.77 | 2.99 | 10.35 |
| **Sorghum** | | | | |
| Had large farms <=25km & >=1 ha | 0.03 | 0.00 | 0.09 | 0.03 |
| … if yes, number of large farms | 3.10 | | 3.88 | 1.00 |
| … if yes, sorghum area | 14.63 | | 19.18 | 2.29 |
| Had large farms 25-50 km & >=1 ha | 0.03 | 0.00 | 0.12 | 0.01 |
| … if yes, number of large farms | 4.06 | | 4.15 | 3.00 |
| … if yes, sorghum area | 17.97 | | 18.45 | 12.00 |
| Had large farms 50-100 km & >=1 ha | 0.08 | 0.00 | 0.25 | 0.05 |
| … if yes, number of large farms | 3.58 | | 3.90 | 2.26 |
| … if yes, sorghum area | 14.02 | | 16.03 | 5.46 |
| **Peanuts** | | | | |
| Had large farms <=25 km & >=1 ha | 0.15 | 0.00 | 0.07 | 0.46 |
| … if yes, number of large farms | 1.75 | 1.00 | 1.01 | 1.87 |
| … if yes, peanuts area | 4.33 | 1.00 | 5.62 | 4.20 |
| Had large farms 25-50 km & >=1 ha | 0.25 | 0.03 | 0.10 | 0.74 |
| … if yes, number of large farms | 2.31 | 1.00 | 1.46 | 2.48 |
| … if yes, peanuts area | 4.71 | 1.00 | 6.53 | 4.69 |
| Had large farms 50-100 km & >=1 ha | 0.30 | 0.06 | 0.14 | 0.84 |
| … if yes, number of large farms | 5.08 | 1.01 | 1.57 | 6.07 |
| … if yes, peanuts area | 10.84 | 1.04 | 5.87 | 12.68 |
| **Rice** | | | | |
| Had large farms <=25 km & >=1 ha | 0.05 | 0.01 | 0.00 | 0.15 |
| … if yes, number of large farms | 3.94 | 1.68 | | 4.11 |
| … if yes, rice area | 46.01 | 1.68 | | 49.37 |
| Had large farms 25-50 km & >=1 ha | 0.12 | 0.06 | 0.00 | 0.33 |
| … if yes, number of large farms | 5.05 | 1.42 | | 6.03 |
| … if yes, rice area | 117.31 | 196.79 | | 95.72 |
| Had large farms 50-100 km & >=1 ha | 0.23 | 0.13 | 0.00 | 0.59 |
| … if yes, number of large farms | 7.45 | 1.41 | | 9.49 |
| … if yes, rice area | 160.33 | 206.36 | | 144.80 |
| **Sugarcane** | | | | |
| Had large farms <=25 km & >=1 ha | 0.07 | 0.00 | 0.08 | 0.17 |
| … if yes, number of large farms | 2.54 | | 1.62 | 2.92 |
| … if yes, sugarcane area | 527.66 | | 1360.96 | 174.76 |
| Had large farms 25-50 km & >=1 ha | 0.11 | 0.00 | 0.10 | 0.28 |
| … if yes, number of large farms | 3.50 | | 1.54 | 4.18 |
| … if yes, sugarcane area | 477.49 | | 1087.10 | 267.19 |
| Had large farms 50-100 km & >=1 ha | 0.24 | 0.00 | 0.26 | 0.59 |
| … if yes, number of large farms | 4.79 | | 1.89 | 5.99 |
| … if yes, sugarcane area | 974.03 | | 2353.49 | 400.32 |

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