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Large Farm Establishment, Smallholder Productivity, Labor Market Participation, and Resilience

Evidence from Ethiopia

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Abstract

Although the nature and magnitude of (positive or negative) spillovers from large farm establishment are hotly debated, most evidence relies on case studies. Ethiopia's large farms census together with 11 years of nation-wide smallholder surveys allows examination and quantification of spillovers using intertemporal changes in smallholders' proximity and exposure to large farms, generally or growing the same crop, for identification. The results suggest positive spillovers on fertilizer and improved seed use, yields, and risk coping, but not local job creation, for some crops, most notably maize. Most spillovers are crop-specific and limited to large farms' immediate vicinity. The implications for policy and research are drawn out.

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Large Farm Establishment, Smallholder Productivity, Labor Market Participation, and Resilience: Evidence from Ethiopia[¶]

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1. Introduction

The 2007/08 food price spike, together with the recognition that a number of countries are endowed with large amounts of seemingly unoccupied or unclaimed land triggered an enormous increase in private sector demand for agricultural land (Deininger and Byerlee 2011) and, implicitly, water (Rulli *et al.* 2013) to satisfy seemingly inexhaustible demands for food, fuel, and fiber. Although often described 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 expectations of private capital to complement public investment and help make up for decades of underinvestment in agriculture. This, it was hoped, could provide a stepping stone 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).

Beyond any direct increments in productivity and value added by large farms compared to earlier land uses, a key argument in this debate revolves around local spillover effects. Critics maintain that, especially if land is made available below its true value, investment promotion policies may attract speculators who fail to benefit locals and generate negative spillovers, e.g. by monopolizing factor markets or encroaching on land or water resources to which they have no right. Supporters believe that, through discovery of agro-ecological suitability and demonstration effects, newly established large farms can provide locals with access to new technology, credit, input, or labor markets and thus generate positive spillovers, similar to other forms of foreign direct investment (FDI). 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) provides the *raison d'etre* for agricultural investment promotion agencies all over the globe.

In light of the policy relevance of this issue, the marked differences between general FDI and large-scale agricultural investment (Arezki *et al.* 2015), and the fact that in many African countries the large majority of land-related investment originates with domestic rather than foreign investors, empirical evidence to explore the presence and magnitude of such effects would be highly desirable. Yet, partly due to limited data availability, often justified by the sensitive and potentially controversial nature of such investment, such evidence is currently not available. This limits not only governments' and investors' ability to make rational decisions and acquire experience, but may also constrain the availability of resources to the sector, as financial intermediaries have no basis to assess and try to insure the risk associated with such ventures.

To show how often widely available survey data can help assess the presence and magnitude of spillovers, we combine data from the smallholder agricultural production survey annually conducted by Ethiopia's Central Statistical Agency (CSA) in 2003/4-2013/14 with evidence on the evolution of the universe of currently operational large farms over this period from CSA's large farm survey. GPS coordinates for large farms and smallholder villages allow us to construct, for every village and year, the distance to the next large farm (growing the same crop) or the total or same crop large farm area in concentric circles of 0-25, 25-50, and 50-100 km radius around it. Enormous differences in yield and intensity of input use between smallholders and commercial farms make spillovers plausible while a rapid pace of large farm expansion that resulted in greater proximity between large and small producers provides a source of identification. We focus on maize, wheat, sorghum, and teff, four cereals that are widely grown by large and small farms. Spatial proximity is assumed to be the main channel through which spillovers are transmitted, with plausible mechanisms being learning about new technology, better access to input markets, or increased local labor demand.

We find that increased proximity to commercial farms had positive spillovers on input use and yield though the nature and magnitude of spillovers are highly crop-specific. There is strong evidence of significant increases in fertilizer use, yields, and to a lesser extent also use of improved seed in closer proximity to large (maize) farms, closing large pre-existing gaps for maize. The opposite is true for teff where smallholder yields already surpassed large farmers'. For wheat and maize, we find significant increases in yields as a result of establishment of large farms growing the same crop nearby, presumably due to transfer of crop-specific technology. This is consistent with evidence that, for all cereals except sorghum, larger commercial farm areas with the same crop in the proximity increases smallholders' resilience to drought. Yet, we find no impact of large farms on local labor demand, except possibly on imports of casual labor.

To the extent that they do not suffer from omitted variable bias, these results support the notion that large agricultural investment can benefit local farmers. But the properties of such investment, in terms of location, crop choice, etc. matter. Also, with the exception of market access for fertilizer, the magnitude of estimated effects is modest, implying that large farm establishment substitutes neither for provision of public goods and extension to smallholders nor for efforts to make infrastructure available to help integrate them into value chains. Thinking and experimentation on how to forge partnerships and structure contracts so as to fully harness spillovers and create synergies between public efforts to promote rural and agricultural development and responsible private investment in agricultural value chains and land development is likely to have a high payoff.

While our methodology can, with adaptations as needed, be applied in other countries where large farm establishment is a policy issue, the results have relevance for policy and research in Ethiopia. From a policy perspective, there appears scope for improved inter-institutional coordination to monitor performance of large farms and their compliance with contracts, together with a review of criteria for land transfers that can harness positive effects and be complementary to public sector efforts. Promising avenues for follow up from a research perspective include (i) exploring how spillover effects vary with commercial farms characteristics such as size, productivity, and operational status; (ii) comparing the size and nature of spillovers from the commercial farms included here to those in flowers or high value vegetables and to those from investments higher up in the agro-processing value chain; and (iii) analyzing effects of large farm establishment on input and output prices as an alternative indicator that could also clarify channels through which some of these effects are transmitted.

The paper is structured as follows: Section two motivates by discussing large agricultural investment in Ethiopia and presenting our methodology. Section three introduces the data and provides evidence on differences in performance between large and small farms, changes in smallholder productivity over time, and changes in spatial proximity between small and large farms over time due to new farm establishment. Section four presents results with respect to input use and yields, labor market participation, and resilience to climatic shocks. Section five concludes by summarizing implications for policy and future research.

2. Motivation and methodological considerations

There is little doubt that growth of smallholder agriculture is critical for poverty reduction in Ethiopia. Yet, to fully exploit its land endowments and generate spillovers for smallholders, the country also aimed to attract agricultural investors, based on the premise that doing so could help local smallholders. To test for spillovers from such investment, we argue that physical proximity, measured by either the distance between smallholders and the next large farm or total large farm area cultivated in smallholders' vicinity, can be used as a proxy. Data from 11 years of a national smallholder survey as well as the universe of large farms and their evolution over time can provide a basis for doing so in Ethiopia.

2.1 Large-scale land investment in Ethiopia

Ethiopia is one of the poorest countries in Africa and the country's highlands are among the most densely populated regions in Africa. Land constraints are a key determinant of poverty (Jayne *et al.* 2014). After 1990, a strategy of market liberalization and agriculture-led industrialization focusing on small-scale producers was adopted. In the past, the country regularly relied on food aid to meet food needs in the face of droughts (Dercon 2004). Yet, investment on land not fully utilized is identified as a strategic priority in the government's Growth and Transformation Plan. This decision to actively seek out large land-based agricultural investment implied that Ethiopia attracted interest by the global 'land rush' debate. Historically experience with large farms in Ethiopia has not been positive: Before 1974, subsidies were used to attract commercial investment for cash crops production in so-called 'model farms'. But this was often associated with tenant evictions and little employment generation with at best mediocre productive performance.[1]

[1] Although yields were above those by peasants, these farms' efficiency and contribution to national agricultural output (2%) remained low (Abebe 1990). After the 1974 revolution, most of these were converted into state farms for food production.

Supporters of large investment argue that, as most of the land in question is located in the lowlands, capital intensive investment is the only way to bring it to productive use and generate spillovers for smallholders. Critics point to cases of land transfers without proper verification of current occupancy or utilization (Rahmato 2011) and argue that such transfers failed to improve local livelihoods (Rahmato 2014). Yet, with quantitative estimates diverging widely,[2] a proper assessment is difficult.

In fact, three studies aim to use quantitative evidence for a more representative and rigorous analysis of this issue in the Ethiopian context. A review of a sample of more than 10,600 investment licenses issued by the Agricultural Investment Agency finds that less than 20% of license holders established a farm (UNDP 2013). Moreover, most lack farming experience, a business plan, or regular record maintenance, pointing towards ample scope for improvement. Based on an effort to establish an inventory of and conduct field visits to a sample of farms with more than 1,000 ha established after 2005, Keeley *et al.* (2014) draw four main conclusions, namely (i) leases cover very large areas of which only parts have been developed; (ii) there are incidences of conflict with existing occupants; (iii) the potential for job generation has not been realized; and (iv) to be effective, government efforts to make lease agreements public, while commendable as a first step, need to be followed by further efforts to improve transparency.

Ali *et al.* (2015) use the census of large farms that is annually conducted by the central statistical agency (CSA) to quantify what had been described qualitatively earlier. Doing so suggests that since the 1990s, about 1.3 mn. ha had been transferred to a total of 6,612 commercial farms,[3] most of which cultivated more than 50 ha. The annual rate of new farm establishment dropped from a peak of close to 800 in 2007/08 to some 250 in 2011/13. Also, 95% of land is transferred to Ethiopians or joint ventures rather than foreigners. With an average area of 200 ha (172 ha for Ethiopians and 840 ha for foreigners), this implies that the extent of land transferred to operational farms is well below media reports (Rahmato 2011; Rulli *et al.* 2013). By respondents' own estimates, 55% of land transferred remains unutilized, largely due to labor and technology constraints. Less than 20% of farms accessed credit, investments focused on land clearing and machinery, and only 36% made any lease payments. Below we will use these data to explore whether local people were affected by –positive or negative– spillovers from this phenomenon.

2.2 Methodological considerations

A presumption of positive economy-wide spillovers from FDI prompted creation of investment promotion agencies worldwide. But the nature of spillovers and the channels through which they materialize will be

[2] A report by the Oakland Institute (2011) suggest that "our research shows that approximately 3,619,509 ha of land have been awarded, as of January 2011" (p.18). This is in line with the land matrix (Anseeuw *et al.* 2012) which reports demand for 3.14 million ha in Ethiopia, second in the world after Mozambique. Yet the most recent revision of this database (as per Aug. 8, 2015) reports that only 1.42 mn. ha had been contracted and production started only on 39,528 ha (see http://www.landmatrix.org/en/get-involved/).
[3] Small producers are defined as those with a size below 10 hectares and all farms above this size fall into the 'commercial' category.

affected by the characteristics of agricultural production (Allen and Lueck 1998) with implications for policies aiming to attract or regulate such investment.[4] While employment-intensive agro-processing of high value crops has been shown to improve welfare (Maertens *et al.* 2011; Minten *et al.* 2007), impacts of mechanized production of bulk agricultural commodities differ from it in two respects. First, land to labor ratios are higher, making positive labor market effects less and negative land-related impacts, e.g. via displacement, more likely. Second, output is not perishable, reducing the advantage of processing facilities and leading to well-known issues of side-selling (Hueth *et al.* 2007; Saenger *et al.* 2013). As both aspects lower the benefits and increase the risks of large production-related investment, studies often find it to lead to ambiguous or even negative effects (German *et al.* 2013; Schoneveld 2014). Reasons include competition for productive land (Hall 2011), a failure to adhere to required consultation processes (Nolte and Voget-Kleschin 2014), and lack of contract disclosure or independent compliance monitoring (Cotula 2014). We know of only one case study suggesting that large farm establishment benefited neighboring smallholders through positive effects on technology transfer and factor market effects (Adewumi *et al.* 2013).

Given the topic's importance, more systematic survey-based efforts to assess the direction and size of associated impacts will be desirable. As a first step in this direction, we explore if and to what extent large farm formation in Ethiopia benefited (or harmed) neighboring smallholders by affecting (i) their use of inputs, in particular fertilizer and seed; (ii) temporary or permanent jobs; (iii) crop yields; and (iv) resilience to climatic shocks.[5] We assume the main transmission channels to be knowledge transfer or market access. Both rely on physical proximity, so we can use temporal variation in smallholders' proximity to large farms for identification. If transaction costs are high or knowledge on the potential benefits from use of certain inputs or technologies lacking, smallholders may not use them even if the benefits of doing so would exceed the cost (Key *et al.* 2000). In this case, large farms who use them may create demonstration effects, act as point of access, and potentially provide links to labor, output, or credit markets, potentially affecting the mean and variance of income. The latter is important, as with climate change the frequency and severity of extreme weather events and associated shocks impairing smallholders' ability to accumulate assets and escape poverty (Dercon and Christiaensen 2011) is expected to rise. We distinguish 'generic' effects (e.g. access to fertilizer or risk coping) from more crop specific ones (e.g. use of improved seeds) that are likely to materialize only if small and large farmers grow the same crop. Spillovers are expected to increase with similarity of technologies used, the size of gaps in yields or input use between large and small producers, and the susceptibility of crops to shocks, in particular moisture stress.

[4] One lesson from the literature on extractives is that the regulatory framework is essential to benefits materialize and are equitably shared among stakeholders (Söderholm and Svahn 2015).

[5] As will be explained below, most large farmers claim to provide benefits to surrounding smallholders, further justifying this conjecture.

While we know of no studies that systematically explore firm-level externalities in 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 in 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 U.S. industrial plants in the 1990-2002 period, finding impacts on toxic air emissions, housing values, and the incidence of low birthweight in the vicinity of these plants. Applying this to mines suggests that openings and closings have different effects (Chuhan-Pole *et al.* 2015) and that mining can empower women (Kotsadam and Tolonen 2015).

2.3 Data sources and definitions

Before developing the econometric approach, we discuss data. For large farms, we use the commercial farm survey regularly conducted by Ethiopia's Central Statistical Agency (CSA). This survey covers a sample of 10-50 ha farms and the universe of operational farms cultivating 50 ha or more. Farm level information is provided on input use, output, and year of establishment. GPS coordinates taken for every field allow us to map all farms above 50 ha that were operational in 2014.[6] For any small farm and year, this allows us to compute distance to the nearest large farm or the nearest large farm growing the same crop and the total area cultivated by large farms or devoted to large farm cultivation of a specific crop within a certain radius.

Information on smallholders comes from 11 years (2004-14) from CSA's smallholder survey which had been conducted annually since 1980 by resident enumerators on a sample of some 1,400 kebeles nation-wide. Figure 1 illustrates the location of the kebeles included in the 2013/14 round as well as that of large farms above 50 ha. As sample kebeles were changed only in 2007/8, this provides us with a panel of kebeles in the 2003/4-2006/7 and the 2007/8-20013/14 period. Recovery of kebele codes, properly adjusting for splits, mergers, etc. was, however, possible only for about half the kebeles included in the earlier period, providing us with data from about 500 and 2,000 kebeles before and after 2006/7, respectively. Information on inputs is based on a random sample of 20-40 farmers per kebele, resulting in a coverage of 28,000 to 56,000 farmers per year. Data on yield is based on crop cuts of randomly selected fields in each EA, i.e. not those of the farmers interviewed, limiting the ability to for example estimate production functions.

We complement these surveys with two data sources. First, as the smallholder production survey lacks data on labor use, we use data on labor supply at individual level from the 2011/12 and 2013/14 rounds of the

[6] Information on the year of establishment is used to reconstruct the inter-temporal evolution of large farms, following Ali *et al.* (2015). As non-operational farms are not included in CSA's sample, this implies that our results are valid for operational farms.

LSMS-ISA panel to explore labor market effects from large farm establishment.[7] Second, to account for inter-temporal variability in climatic conditions, we rely on gridded 0.1' rainfall data publicly available from NOAA since 1980 to compute long-term mean and standard deviation of precipitation for each pixel. Calculating z-scores and matching them to kebeles then allows us to determine for each year if a kebele experienced drought ($z<-1$), a flood ($1<z$), or 'normal' conditions ($-1\leq z\leq 1$).

2.4 Analytical approach and estimating equations

As we have a census of the country's large farms in 2014, we use time variation in smallholder kebeles' proximity to large farms (generally or growing specific crops) in 2003/4-13/4 period to test if smallholders' improved seed/fertilizer use, yields, employment, or resilience are affected by large farm presence. To do so, we construct, for every year, either the distance from every smallholder kebele to the next large farm of any kind (growing the same crop) or, as a measure of exposure, total large farm area (with the same crop) in a concentric circle with inner and outer radius of 0 to 25, 25 to 50 and 50 to 100 km from the kebele.

Formally, denote kebeles by i, distance bands by d, crops by k and time by t. The simplest specification then uses d_{it} or d_{ikt} the distance between the centroid of kebele i and the next commercial farm (or the next farm growing crop k) with squared distance to allow non-linear effects to estimate a regression of the form:

$$Y_{ikt} = \alpha + \beta_1 d_{ikt} + \beta_2 d_{ikt}^2 + \beta_3{}' \boldsymbol{x_{ikt}} + \gamma_t + \gamma_w + \epsilon_{ikt} \quad (1)$$

where Y_{ikt} is the outcome of interest, i.e. either an indicator variable for whether a household uses improved seeds or fertilizer on crop k or kebele-level yields for k, γ_t and γ_w are a time trend and woreda fixed effect, $\mathbf{x_{ikt}}$ is a vector of control variables and the βs are parameters to be estimated with main interest in β_1 and β_2.

Alternatively, replace d_{it} or d_{ikt} by $\boldsymbol{A}_{idt}$ or $\boldsymbol{A}_{idkt}$, a vector with the total commercial farm area cultivated (with crop k) in a concentric circle around smallholder kebele i with inner and outer radius d as above (0 to 25, 25 to 50, and 50 to 100 km)[8] to obtain an estimating equation of the form

$$Y_{ikt} = \alpha + \beta' \boldsymbol{A_{iktd}} + \beta' \boldsymbol{x_{ikt}} + \gamma_t + \gamma_w + \epsilon_{ikt} \quad (2)$$

We extend this framework in two ways. To assess labor market effects, we use the LSMS-ISA survey to compute an indicator variable of whether household i engaged in full-time agricultural or non-agricultural employment or temporary work by estimating versions of regressions (1) and (2) where Y_{ikt} denotes the employment indicator. As a counterfactual we include in d_{it} the distance between the household and the centroid of the nearest town with population greater than 2,000. To explore if large farms establishment can

[7] See the LSMS-ISA Ethiopia website for more information on sample design and data.
[8] To illustrate, $A_{ikt(25\text{-}50)}$ is the area under commercial farms growing crop k within a 25-50km range of the household living in kebele i. In all cases, yield (obtained through crop-cuts of randomly selected fields in the kebele) is measured at kebele level and input use at household level.

help improve smallholders' resilience to climate shocks, either via learning about (crop-specific) moisture saving technology or via support (e.g. with tractors) to create moisture conservation structures, we estimate

$$Y_{ikt} = \alpha + \beta' \mathbf{R}_{it} A_{itd} + \beta' \boldsymbol{x}_{ikt} + \gamma_t + \gamma_w + \epsilon_{idt} \quad (3)$$

where Y_{ikt} is the log of the yield of crop k and $\boldsymbol{R}_{it}$ is a vector of indicator variables specifying, for each pair kebele i and year t, whether rainfall was above or below the long-term mean by less or more than one standard deviation using the pixel-level data on precipitation discussed above,. The elements of $\boldsymbol{\beta}_1$ will then indicate if small farms closer to large ones be more able to maintain yields in the presence of rainfall shocks.

3. Descriptive evidence on large and small farm performance

Data on the country's main cereals highlight striking, though commodity-specific, differences in yields and input use between large and small farms. Limited presence of non-farm employment and rainfall variability. Maps illustrate the expansion of large farm presence over time. As this provides options for interaction and exchange of technology, it makes positive technology spillovers via informal interaction plausible and justifies efforts to try and identify other types of externalities from large farm formation in our data.

3.1 Comparing large and small farmers' productivity and input use

Table 1 provides data on large farms overall and for our four crops. Mean commercial farm area is 266 ha, with wheat farms largest (552) and sorghum and teff (235 and 238 ha) ones smallest. About 25% were established during the 2007/08 peak, some 22% each in 2002-2006 and 1992-2002, and some 15% and 8%, respectively in 2009/10 and 2011-13. Compared to 47% of farms overall, 68% and 61% of large teff and maize farms were established after 2007 with a corresponding shift in the level at which negotiations were held. With 55 ha per permanent employee, the average farms employs has less than 5 permanent workers; wheat being the least and teff the most employment intensive crop in our sample.[9] With 37% on average, the share of those reporting payment of lease fees ranges from 73% for wheat to 30% for sorghum. While only 6% overall, the share of farms who access credit is 15% for teff but only 5.6% for sorghum. The fact that some two-thirds of large farms (59% for sorghum, 73% for wheat, 80% for maize, and 88% for teff) claim to provide benefits to surrounding small farmers further justifies exploration of spillover effects.

Table 2 provides information on area cultivated, yield, fertilizer and seed use, for the four cereal crops of interest (maize, sorghum, teff, and wheat) based on 2013/14 data for smallholders as well as commercial farms of different sizes. Lack of data on input quantities and prices makes productivity comparison difficult but in all crops except teff, smallholders' yields (27.1, 21.3 and 21.9 Q/ha for maize, sorghum, and wheat, respectively) are 75% of or less of those by commercial farms. While part of this difference may be due to

[9] As flower farms are not included in our sample, coffee is the most employment intensive crop among large farms.

large farms' better endowments in terms of soil quality or infrastructure access, it also points towards *prima facie* potential for spillovers, either through adoption of technology or input use.[10] This is reinforced by the fact that the relationship between yields and farm size is not linear; yields are highest (42, 31, and 42 Q/ha for maize, sorghum, and wheat) for farms in the 10-20 ha range whereas those larger than 20 ha often obtain some 20% less than the top performing group in each crop.

Improved seed and fertilizer have long been identified as key to smallholder productivity in Ethiopia (Krishnan and Patnam 2014). Our data suggest significant variation in their use with differences being most pronounced for improved seed which, for maize, sorghum, wheat and teff, is used by 80%, 42%, 74% and 41% of the largest farms, 52%, 18%, 66% and 85% of those in the 10-20 ha range, but only 25%, 0.4% 7% and 4.9% of smallholders, respectively. Although, with 83%, 45%, and 74% of farms in the largest group who use fertilizer on maize, sorghum, and wheat, compared to 53%, 19%, and 66% in the 10-20 ha category and 39%, 15%, and 73% for smallholders, respectively, the incidence of fertilizer use is higher on larger commercial farms, variation is much less than for improved seed which may be a more binding constraint.

Annual data on small farms for 2004-2014 allow us to describe changes in smallholders' area, yields, input use, distance to large farms, and exposure to climatic shocks (table 3 panel A). Cultivated area per farmer increased, from 0.89 ha in 2004 to 0.96 ha in 2014 and the fact that more farmers grew maize (46% to 59%), teff (33% to 41%), and wheat (22% to 29%) points towards diversification.[11] The share of those applying chemical fertilizer and improved seed overall rose from 20% to 54% and from 8% to 20%, respectively. There was a clear decrease in the distance to the next commercial farm, from 78 km to 41 km in 2004 and 2014 and an increase of the number of large farms within a 0-25, 25-50, and 50-100 km radius from 0.37 to 2.24, 0.97 to 6.79, and 3.13 to 29.64, respectively as well as their area (from 1.3 to 8.0; 3.6 to 25.6; and 18.4 to 110.0 km^2). This is graphically illustrated in figure 2 which shows that, with commercial farm expansion, smallholders' distance to the next commercial farm decreased. Finally, using the incidence of positive or negative rainfall shocks (i.e. deviations of more than one standard deviation from the long-term average in either direction) as an indicator of climatic variability suggests that many kebeles were affected by droughts in 2004-2005 and 2011and by flooding in 2006, 2010, and 2013.

In our commodities of interest, increases in yield and input used allowed smallholders to close the gap to commercial farms but the rate of catch-up varies by crop. In maize, area per farm increased from 0.16 to 0.19 ha, yield doubled from 13 to 27 Q/ha and the share of farmers who used fertilizer or improved seeds doubled from 28% to 53% and tripled from 7% to 20%, though both remain well below the almost 70% of commercial farms using both. Smallholders' wheat area increased from 0.13 ha to 0.21 ha and yields from

[10] To translate this into information on productivity, adjustment for inputs as well as access to infrastructure etc. will need to be made.
[11] As we have information on type of output only at kebele level, a crop is said to be grown if at least 20% of kebele area is devoted to it.

12 to 21 Q/ha but the incidence of improved seed use stagnated at 3% -compared to 58% commercial farms- while that of fertilizer increased from 29% to 43% using fertilizer in this crop. Sorghum area shrunk from 0.3 ha to 0.2 ha, yields increased from 11 to 21 Q/ha, and an increase of fertilizer use -from 15% to 22%- narrowed the gap to commercial farms (23%). Yet, with 0.2% of smallholders vs. 15% of commercial farms using improved seeds, enormous differences remain. Smallholder area and yield of teff, the country's most important crop,[12] rose from 0.14 to 0.31 ha and from 6 to 13 Q/ha, respectively. Yet, compared to 73% and 69% of commercial farmers who use fertilizer and improved seed, smallholders' use of fertilizer increased (20% to 45%) to almost reach parity with large farms while seed use remains at 4%.

3.2 Changes in proximity to and area cultivated by large farms

To justify our identification strategy that relies on intertemporal changes in distance between smallholders and all or a specific type of large farms, we show that there is considerable variation in distance to the next large farm or total large farm area within a certain interval also at the crop level. Figure 3 displays the cumulative distribution of the distance from the kebele centroid to the nearest commercial farm growing the specified crop for the four crops in our regression sample. It illustrates that for all crops, the largest shift, corresponding to territorial expansion of large farms, is observed in the 2004-08 period and that post-2008 large farm expansion is most pronounced for sorghum, followed by wheat and teff with very little further in the distance from the average kebele centroid to the next farm.

Mapping large farms with certain crop and sample kebeles in 2004 and 2014 with buffers around the former in figures 4-11 highlights the dynamics and geography of large farm expansion. Commercial maize farms spread from the center leaving only kebeles in Gambella and Tigray at a distance of more than 150 km from the next large farm. In 2004, large sorghum farms were clustered in Oromia, eastern Afar, and the northwest of Amhara spilling into Tigray. Although fewer than maize, their number had expanded greatly by 2014. Teff is a smallholder crop which, in 2004, had been grown only in the central highlands and a large farm in Afar. Large wheat farms expanded from Southern Amhara and Oromia (as well as northern SNNPR) in 2004 to cover virtually the entire Oromia and considerable parts of SNNPR and southern Amhara.

To assess whether, beyond simple presence, large farm area in smallholders' vicinity increased, providing a potential source for crop-specific spillovers, table 4 presents the share of kebeles with at least one large farm cultivating the same crop within 0-25, 25-50, and 50-100 km together with large farm area devoted to this crop in any of our distance bands. For maize, sorghum, teff, and wheat, 63%, 41%, 57%, and 50% of the kebeles producing the relevant crop had at least one large farm within 50 km. In 2003/4 to 2013/4, the share of kebeles within 0-25, 25-50, or 50-100 km from a maize growing commercial farm increased from

[12] It is grown on 2.7 mn. ha by 6.3 mn. farmers and a total value of production of 1.6 bn US$ and a commercial surplus of close to 500 mn. USD, as important as sorghum, maize, and wheat together and only slightly less than coffee.

0.10 to 0.36, 0.18 to 0.63, and 0.56 to 0.89 and total commercial maize area in these bands from 50 to 417, 145 to 1,176, and 850 to 4,709 hectares, respectively implying that in 2014, about 2.123‰, 1.996‰ and 1.995‰ of the area in 0-25, 25-50, and 50-100 km from smallholder producers was occupied by large maize farms.[13] Corresponding figures for wheat (1.83‰, 1.56‰ and 1.19‰), sorghum (1.47‰, 1.37‰ and 1.45‰), and teff (0.39‰, 0.58‰ and 0.49‰) point towards lower coverage and thus scope for large farm-smallholder linkages in these crops while also suggesting close spatial association between large and small farms in wheat but much less so for teff which is a typical smallholder crop.

4. Econometric evidence on spillovers from large farm establishment

Consistent evidence of positive spillovers from large farm establishment on smallholders' yields and input use emerges in maize, though mostly in a distance of less than 25 km. Although we find negative impacts of large farm establishment on fertilizer use and no significant yield effects for teff and sorghum, this may be consistent with higher levels of efficiency, especially considering that smallholders' teff yields already exceed those by commercial farms by some 50%. We fail to ascertain any impact of changes in large farm presence on the take up of permanent or temporary work, supporting the notion that large mechanized farms can help to increase intensity of land use but not generate employment. For all crops except sorghum, the presence of large farms growing the same crop significantly enhanced small farmers' yields in drought periods, possibly by facilitating learning about ways to conserve soil moisture.

4.1 Input use and productivity

Estimated impacts of large farm expansion on the incidence of smallholders' use of fertilizer and improved seed, yield, and labor market participation are in tables 5-8. Throughout, panels A and B present regressions with the distance measure (eq. 1) and commercial farms' crop area (eq. 2) as independent variables. The sample is limited to kebeles within 150 km to the next commercial farm in 2014 and all regressions include woreda fixed effects and year trends with standard errors clustered at the woreda level.[14]

For fertilizer use, table 5 points towards significant positive effects of large farm establishment for maize but not for other crops. For maize, a reduction in mean distance to the next commercial farm in line with what was experienced during the period covered by our data (i.e. from 80 to 40 km), would be predicted to increase the share of producers applying fertilizer by 2.5 points with a further decrease from 40 km to 2 km predicted to increase fertilizer use by an additional 6.1 points. Effects are more pronounced for distance to the next maize farm where equivalent shifts would be predicted to be associated with increases of 6 and 7.2

[13] The total area in the (concentric) circles with inner and outer radius of 0-25, 25-50 and 50-100 km, is 1,963, 5,890, and 23,562 respectively.
[14] The excluded category in panel B is commercial farm area in the 100-150 km range. As for two thirds of our kebeles we have observations only only after the sample change in 2007/8, we estimate using woreda fixed effects.

points, respectively, in the propensity to use fertilizer. The magnitudes involved are not inconsequential.[15] Results in panel B for (maize) area cultivated by commercial farms suggest that spillover effects are limited to farms in very close proximity; estimated coefficients on area beyond 25 km are not significantly different from zero while those on both total and maize area in the 0-25 km range are highly significant. Rather small magnitudes,[16] though, suggest that area cultivated by commercial farms is less relevant than distance.

Results for other crops are less suggestive of spillovers-induced increases in incidence of fertilizer use; coefficients for wheat are insignificant throughout while for teff and a lesser degree sorghum, predicted intensity of fertilizer use decreases with proximity to commercial farms (or larger areas under commercial cultivation close by). This may be due to the fact that incidence of fertilizer use among small teff producers is only a little below that by commercial farms and that they obtain yields some 50% above the latter. With the incidence of improved seed use less than 1/8 of that on commercial farms for sorghum, wheat, and teff, improved seed rather than fertilizer use seems to be the main bottleneck throughout (see table 2).

Estimated impacts of proximity to commercial farms on incidence of improved seed use in table 6 suggest significant impacts of distance to any commercial farm for sorghum, from near-zero levels. For maize and teff, we find evidence of significant positive effects from larger same-crop areas by commercial farms in a 25 km radius and, for maize, also the 50-100 km range. While estimated impacts are larger for maize where area increases observed in the data would be predicted to have led to a rise of seed use by some 2.5 points, they are not large enough to suggest that commercial farm establishment could substitute for other efforts, in particular extension and farmer training, to promote adoption of improved seed.

While the above effects of commercial farm establishment on incidence of input use seem predominantly to be driven by their improving market access, impacts on surrounding smallholders' yields would reflect knowledge transfer or technology more directly.[17] Results point towards a linear and significant decrease in yields with the distance to the next commercial farm growing the same crop (table 7), partly reflecting that technology applied for this crop by large and small producers is similar and the yield gap large. The estimated magnitude is quite large: having a commercial farm growing maize closer by 10 km would be predicted to increase maize yields by 3.4 points.[18] For maize and wheat, they support the notion of large farm area with the same crop close to smallholders having significant yield-enhancing impact: for maize the coefficient on area in the 0-25 and for wheat at all three distance ranges is significant, though magnitude and significance of coefficients decrease at larger distances. For teff and sorghum coefficients are

[15] A shift in distance to the next commercial farm from 80 km to 2 km (i.e. next door) would be predicted to increase the 2004 level of fertilizer application (13.2%) by more than 50% and to double it if the reduction in distance were to the next farm growing maize.
[16] To bring about a 10-point increase in fertilizer use incidence, everything else constant, maize area would have to increase by 84 or 136 km^2.
[17] While ideally yield regression should control for conventional inputs, lack of correspondence between the (randomly chosen) plots for which yields were measured via crop cutting and input which is collected for randomly selected farmers in the kebele prevents us from doing so.
[18] For teff, proximity to any large farm is estimated to have a marginally significant yield-enhancing effect.

insignificant throughout. This failure to find impacts of large farms is not surprising for teff where small farmers' yields already higher commercial ones'. In the case of sorghum, it suggests that, beyond adoption of improved seed, there is little transfer of technology between large and small farms.

4.2 Rural labor market participation

With growing population and limited absorptive capacity in the non-agricultural sector, the ability to create gainful employment is a key concern for policy makers and considerable hopes are being pinned on large farms being integrated into agro-processing value chains. Unfortunately, CSA's smallholder survey lacks information on households' off-farm labor supply. To fill this gap, we use individual level data on off-farm labor supply from the 2011/12 and 2013/14 rounds of nationally representative LSMS-ISA surveys. Our two measures are if, over the last 12 months, individuals age 15 and above engaged in paid work or casual (non)-agricultural labor. The bottom panel of table 8 highlights that in both rounds 4% or 5% of sampled individuals engaged in paid work, the share of casual agricultural workers increased from 8% to 16% between the two rounds and only about 1% engaged in casual labor outside agriculture.

To explore if rural dwellers' proximity to commercial farms affects their labor market participation in ways comparable to those emanating from other employment centers, we compare the impact of individuals' distance to the next small town, defined as an urban center with at least 2,000 inhabitants, to that of their proximity to commercial farms or total large farm are cultivated in different distance bands. Regressions show that incidence of paid work decreases significantly with distance to towns but not distance to large farms (table 8, col. 1), in line with the notion that large farms fail to significantly contribute to generation of paid jobs.[19] The point estimate suggests that being located 10 km closer to the next town increases the propensity to engage in paid work by some 0.9 percentage points, of almost 20% of the baseline level of 4.8%. We find that, as expected distance to towns does not affect the propensity to take up (agricultural) casual work but neither does distance to large farms (table 8, col. 2 and 3), implying that, even in their immediate vicinity, such farms have no perceptible effect on casual labor demand. Using large farm area cultivated within different distance bands as an independent variable supports the notion of large farms having no impact on local labor markets but, at the same time suggests that large farm area 50-100 km away is associated with higher demand for casual agricultural labor, possibly because temporary or permanent labor is imported. More detailed labor data from large farms that are currently being collected are likely to provide the detail needed for a more definitive answer to this issue.

4.3 Resilience to climatic shocks

[19] The short time period covered by our panel implies that there is little intertemporal variation in distance to towns. We thus report regressions that include zonal fixed effects in table 8, noting that coefficients on the variables related to distance to farms are virtually unchanged if woreda- or household-level fixed effects are included.

As earlier results suggest that spillover effects are almost exclusively limited to the 0-25 km range, table 9 reports results from estimating equation (3) at the kebele level for this range with total or crop-specific area as an independent variable in the top and bottom panel, respectively. Coefficients on rainfall deviations imply that having rainfall that is up to or more than one standard deviation below the long-run mean would be predicted to reduce yields for maize and teff by 4% and 11% and 4% and 10%, respectively, compared to the base category of the z-score between 0 and 1 but not significantly different from 0 for sorghum or wheat. Maize is the only crop that benefits from higher than normal levels of rainfall over the growing season.

Coefficients on interactions between rainfall deviations and commercial farm presence suggest that having more area cultivated with the same crop by large farms in the vicinity helps to reduce, though not fully offset, negative effects of drought on yields.[20] While technologies for moisture conservation in general might play a role for teff, the fact that estimated effects are most pronounced for same crop area rather than area by commercial farms in general points towards a more technology-driven mechanism such as learning from commercial farmers' crop-specific practices rather than construction of moisture conserving structures.

5. Conclusion and policy implications

Exploring the magnitude of spillovers from large farm establishment allows us to contribute to the debate from a methodological and substantive perspective. Methodologically, we show that it is possible to assess spillover effects from large land-based investment by using data on location to link information on inter-temporal changes in large farm presence over time to household or farm survey data. As the latter are routinely available in many countries where large farms are a policy issue –and modest investments to adjust data collection instruments and sample frames can further enhance their relevance– this provides an opportunity to regularly monitor and assess the impacts of large land-based investment in a way that can complement and go beyond potentially non-representative case study evidence.

Substantively, a number of findings stand out. First, we show that, despite a secular increase of Ethiopia's smallholder yields over the last decade, gaps in productivity or input use between small and large producers persist for most crops, creating potential for spillovers. Second, although evidence of positive spillovers emerges in several instances, consistent effects on yields and input use are evident only for maize, a crop where small and large producers use similar technology and where large farm density is sufficiently high to facilitate interaction with small farmers. Most of these effects are confined to a distance of less than 25 km and contingent on large and small producers growing the same crop. Third, though rural households'

[20] As can be verified from the relevant coefficients, fully offsetting estimated drought-induced yield reductions would require a 10-15 fold increase in the area cultivated with maize or teff from the level attained in 2014.

distance to the next settlement of more than 2,000 inhabitants is positively associated with job creation, changes in their proximity to large farms have no significant impact on their propensity to take up permanent or temporary work. This supports the notion that large mechanized farms may be good at increasing the intensity of land use but not at generating local employment. Fourth, for all crops except sorghum, which is often grown because of drought resistance, large farm presence significantly enhanced small farmers' resilience and ability to withstand climatic shocks. As they were almost exclusively confined to large farms growing the same crop, learning about specific measures to conserve moisture seems a plausible channel underpinning such effects.

Lack of information on non-operational farms implies that our results are valid only for farms operational in 2014. To the extent that this or our inability to check for outmigration does not bias results, this implies that, in Ethiopia, large farm establishment generated modest but positive spillovers. It also suggests that policies affecting investors' location and crop choices, in addition to those governing levels, use, and destination of lease fees, will affect social and economic impacts from the establishment of large farms. Our finding evidence of positive spillovers even in a setting where neither responses to investor demand nor links to technology transfer or integration with value chains had been well coordinated, suggests that a more integrated approach may well result in higher spillover effects. Experimentation and rigorous monitoring, relying on a wider range of data sources that would include administrative records and remotely sensed imagery, could help to identify ways of enhancing spillovers and making some of the associated data public to facilitate third-party monitoring. Such monitoring could increase investment flows by a growing set of financial players who want to demonstrate compliance with environmental, governance, and social standards.

While we obtain interesting insights, this is only a first step with ample scope for expansion in a number of possible directions. First, it would be worthwhile to explore alternative outcome variables, especially prices. Second, there seems ample potential to deepen understanding of the channels through which spillover effects may materialize. Ways to do so would be to link survey to administrative data, or to exploit impacts of exogenous variation in large farms' contractual terms or their interaction with local communities. Third, to interpret and contextualize the magnitudes of effects found here, it will be useful to compare their size to those from other types of public goods such as irrigation or technology transfer as well as private investment, including establishment of up-stream agro-processing facilities to integrate small producers into value chains. This is a challenging agenda of great importance for rural development and poverty reduction. The fact that, after the 2008 boom, many countries are left with a large number of non-viable large farms could provide a unique opportunity in this respect.

Table 1: Descriptive statistics for large farms above 50 ha

	Total	Maize	Sorghum	Wheat	Teff
Size & utilization					
Size cultivated (ha)	266.66	377.90	234.56	551.74	237.60
.. of which maize (%)	10.34	43.82	5.27	9.07	36.47
.. of which sorghum (%)	14.34	6.30	30.12	3.80	4.50
.. of which wheat (%)	3.34	1.43	0.29	60.08	2.32
.. of which teff (%)	0.71	2.77	0.31	1.19	7.65
.. of which other (%)	71.27	45.68	64.01	25.87	49.06
Year of establishment					
Before 91 (%)	4.68	5.73	2.60	9.53	6.69
1991-92 (%)	3.49	0.82	6.75	0.00	2.08
1992-2002 (%)	21.50	11.85	22.91	37.34	4.33
2002-2006 (%)	22.61	19.70	27.26	8.52	18.70
07-2008 (%)	24.98	33.16	18.90	22.67	41.29
09-2010 (%)	14.54	21.15	15.45	17.11	16.63
11-2013 (%)	8.20	7.59	6.15	4.83	10.28
Ownership type (%)					
Government	2.74	3.02	0.93	3.87	5.67
Private	92.39	86.26	94.74	93.90	82.92
Cooperative	4.61	10.08	4.24	2.15	10.17
Ethiopian	96.62	95.87	98.30	92.49	96.91
Foreign	2.67	2.39	1.24	6.94	1.50
Joint	0.71	1.74	0.47	0.57	1.59
Type of acquisition (%)					
Direct negotiation	6.83	5.02	1.31	1.40	7.24
Woreda	51.32	30.81	66.43	47.95	31.31
Region	37.17	55.42	30.24	42.26	53.45
Fed'l Gov't	4.68	8.77	2.02	8.39	8.00
Input use					
Used fertilizer (%)	54.77	81.70	63.77	82.74	91.23
.. if yes, kg/ha	71.86	112.77	38.89	85.96	99.60
Used chemicals	68.49	64.11	85.31	82.41	64.08
Used improved seed	25.98	84.39	19.86	64.02	89.47
.. if yes kg/ha	32.86	29.96	11.51	69.99	25.73
Hectares per perm. worker	56	55	83	254	32
Temp. workers/ha	3.56	2.82	3.70	1.32	1.70
Fees, investment, credit					
Lease fee reported (%)	36.74	58.54	29.96	73.31	37.24
.. if yes Birr/ha	530	327	274	1518	203
Other payments. (%)	11.37	24.09	9.11	19.01	12.53
.. if yes Birr/ha	376	464	218	180	170
Any investment (%)	93.11	90.18	98.71	80.45	89.43
.. if yes Birr/ha	11,952	13,276	10,217	15,549	15,449
… share on roads (%)	6.86	8.95	3.31	7.91	8.29
… share on land clearing	32.61	23.61	33.83	22.40	21.14
… share on buildings	18.05	23.03	13.48	18.28	25.23
… share on machines	42.48	44.40	49.39	51.42	45.35
Any loan last 5 years (%)	20.68	17.10	24.62	14.92	16.98
.. if yes Birr/ha	18,195	16,548	17,039	39,997	12,099
Has loans (%)	5.74	11.30	5.60	9.34	15.20
.. if yes Birr/ha	9,394	10,790	7,961	9,654	10,376
Provides local benefits	67.18	79.50	59.45	73.76	88.25
Number of obs.	3484	822	1659	194	323

Source: Own computation from 2013/4 CSA large farm and smallholder farm surveys.
Note: Although data are from a census of all farms > 50 ha, weights are applied to adjust for non-response.

Table 2: Productive performance of smallholders vs. commercial farms in different farm size classes

	Maize	Sorghum	Teff	Wheat
Yield (Q/ha)				
Smallholder	27.07	21.29	13.62	21.85
Commercial farmers	37.691	27.005	8.294	25.578
< 20 ha	42.04	30.88	9.18	41.69
20-50	37.42	24.52	8.79	33.68
50-100	36.89	25.64	8.61	26.11
100-500	39.30	28.21	7.75	24.64
> 500 ha	33.81	29.51	9.90	28.32
Use fertilizer (%)				
Smallholder farmers	38.76	15.40	65.24	73.18
Commercial farmers	67.73	23.48	73.52	65.25
< 20 ha	52.85	19.48	85.44	65.79
20-50	58.39	20.18	77.00	59.62
50-100	73.79	18.28	61.34	74.22
100-500	84.31	33.18	62.44	64.74
> 500 ha	82.70	44.79	48.01	74.45
Use seed (%)				
Smallholder farmers	24.92	0.40	4.29	7.17
Commercial farmers	66.81	15.19	69.32	58.19
< 20 ha	51.99	17.58	85.44	65.79
20-50	57.87	18.66	76.23	58.25
50-100	69.57	15.88	58.66	74.22
100-500	86.21	4.21	45.86	40.32
> 500 ha	80.30	42.08	40.93	74.45
Observations				
Smallholder kebeles	1,368	910	955	634
Commercial farmers	1,659	3,077	826	464
< 20 ha	358	295	291	162
20-50	479	1122	212	109
50-100	351	833	124	28
100-500	382	724	165	128
> 500 ha	89	103	34	37

Source: Own computation from 2013/4 CSA large farm and smallholder farm surveys

Table 3: Changes in farm characteristics, input use, and rainfall over time

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Panel A: Overall information											
Share of households cultivating											
Maize	0.456	0.564	0.532	0.557	0.575	0.633	0.580	0.573	0.639	0.629	0.594
Teff	0.334	0.378	0.377	0.376	0.423	0.424	0.419	0.424	0.417	0.399	0.414
Sorghum	0.364	0.382	0.401	0.401	0.345	0.378	0.360	0.384	0.380	0.360	0.344
Wheat	0.215	0.252	0.245	0.260	0.277	0.283	0.323	0.296	0.274	0.298	0.290
Input use											
Area cult. (ha)	0.893	1.004	0.831	0.871	0.955	0.977	1.026	0.958	0.966	0.957	0.959
Use fertilizer	0.200	0.222	0.285	0.267	0.365	0.352	0.405	0.442	0.491	0.532	0.544
Use impr. seed	0.082	0.100	0.117	0.079	0.093	0.108	0.109	0.137	0.174	0.181	0.200
Distance to & area of large farms > 50 ha											
Dist. to lg. farm	77.7	71.2	59.3	56.2	51.9	46.0	48.6	46.2	42.4	40.9	40.9
# within 25 km	0.37	0.41	0.47	0.60	1.32	1.71	1.81	1.89	2.01	2.20	2.24
# in 25-50 km	0.97	1.17	1.28	1.69	4.06	5.24	5.88	5.79	6.15	6.63	6.79
# in 50-100 km	3.13	4.00	4.73	5.85	17.28	22.41	25.07	25.54	26.84	28.90	29.64
area < 25 km	1.30	1.38	1.93	2.26	4.54	6.15	6.67	6.85	7.00	7.40	7.96
area 25-50 km	3.60	4.20	6.50	7.40	15.40	19.60	22.60	22.90	24.00	24.60	25.60
area 50 - 100 km	18.40	20.60	27.40	31.70	70.00	88.50	98.20	96.80	100.30	104.70	110.00
Rainfall deviation (z-score)											
$1 < z$	0.049	0.000	0.000	0.228	0.174	0.080	0.009	0.388	0.026	0.179	0.400
$0 < z \leq 1$	0.154	0.034	0.000	0.521	0.502	0.499	0.314	0.434	0.174	0.532	0.545
$-1 \leq z < 0$	0.655	0.344	0.557	0.241	0.312	0.405	0.548	0.174	0.461	0.284	0.055
$z < -1$	0.142	0.622	0.443	0.010	0.013	0.016	0.128	0.004	0.339	0.005	0.000
No. of kebeles	487	497	493	513	1930	2041	1489	2002	2044	1968	1982
Panel B: Crop-specific information											
Maize											
Area (ha)	0.16	0.15	0.16	0.17	0.19	0.18	0.09	0.20	0.19	0.19	0.19
Yield (Q/ha)	12.65	13.12	14.97	16.30	18.27	19.24	17.99	22.44	25.23	26.33	27.14
Use fertilizer	0.28	0.36	0.36	0.35	0.41	0.45	0.44	0.46	0.51	0.52	0.53
Use impr. seed	0.07	0.06	0.10	0.06	0.09	0.09	0.10	0.13	0.16	0.18	0.20
Sorghum											
Area (ha)	0.33	0.35	0.35	0.34	0.23	0.25	0.18	0.24	0.24	0.22	0.22
Yield (Q/ha)	10.76	12.32	12.89	13.99	15.94	16.63	18.46	19.31	18.84	19.36	21.37
Use fertilizer	0.15	0.18	0.20	0.24	0.16	0.18	0.17	0.21	0.22	0.23	0.22
Use impr. seed	0.004	0.009	0.009	0.002	0.001	0.001	0.001	0.001	0.002	0.001	0.002
Teff											
Area (ha)	0.14	0.22	0.23	0.25	0.30	0.29	0.17	0.31	0.30	0.29	0.31
Yield (Q/ha)	5.62	9.31	8.55	8.77	11.78	11.70	11.89	11.66	12.00	12.82	13.39
Use fertilizer	0.19	0.24	0.27	0.29	0.34	0.34	0.37	0.41	0.42	0.41	0.45
Use impr. seed	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.02	0.01	0.02
Wheat											
Area (ha)	0.13	0.15	0.13	0.24	0.21	0.21	0.09	0.21	0.19	0.21	0.20
Yield (Q/ha)	12.61	14.61	12.89	15.39	15.33	15.92	16.87	16.04	17.40	19.07	20.92
Use fertilizer	0.29	0.33	0.35	0.38	0.39	0.37	0.43	0.41	0.40	0.43	0.43
Use impr. seed	0.03	0.02	0.03	0.03	0.02	0.03	0.01	0.04	0.06	0.03	0.03

Source: Own computation from 2003/4-2013/14 CSA smallholder farm surveys.

Note: Sample size is in terms of kebeles and, as explained in the text, a kebele is said to be growing a crop if at least 10% of the households in the kebele are growing the crop. Information on area and application of fertilizer and improved seed are collected at the farm level, but averages are calculated first within kebeles and then over all kebeles. Large farm area is in km^2.

Table 4: Descriptive statistics for smallholders at different distances to large farms

		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Maize												
< 25	%>0	0.100	0.114	0.138	0.167	0.259	0.325	0.329	0.341	0.363	0.366	0.363
	Area	0.495	0.482	0.599	0.666	2.195	2.374	2.545	3.353	3.298	3.546	4.169
25 50	%>0	0.184	0.303	0.328	0.354	0.500	0.582	0.599	0.605	0.634	0.632	0.629
	Area	1.451	1.811	1.961	2.109	6.729	8.282	9.296	10.012	10.369	10.753	11.736
50-100	%>0	0.559	0.757	0.772	0.774	0.819	0.879	0.882	0.875	0.886	0.886	0.885
	Area	8.501	9.597	10.124	10.161	24.612	31.889	37.662	38.779	39.865	42.391	47.091
km to lg, farm		89	77	77	73	60	52	51	54	51	51	52
Kebeles (%)		0.536	0.670	0.649	0.655	0.709	0.772	0.720	0.705	0.771	0.760	0.714
Sorghum												
< 25	%>0	0.075	0.067	0.072	0.158	0.264	0.319	0.328	0.330	0.341	0.359	0.366
	Area	2.322	2.065	1.895	1.665	1.204	1.591	2.388	1.981	2.008	2.176	2.936
25 50	%>0	0.162	0.178	0.196	0.258	0.294	0.322	0.355	0.369	0.403	0.424	0.413
	Area	2.795	2.741	1.716	1.718	5.132	6.384	9.807	6.175	6.326	6.681	8.117
50-100	%>0	0.412	0.444	0.454	0.525	0.572	0.627	0.703	0.697	0.772	0.775	0.769
	Area	7.644	8.197	8.141	7.022	25.550	28.348	39.008	26.066	26.804	28.612	34.261
km to lg, farm		107	105	107	104	101	97	92	89	71	70	70
Kebeles (%)		0.164	0.181	0.197	0.234	0.486	0.509	0.498	0.520	0.516	0.518	0.513
Teff												
< 25	%>0	0.078	0.099	0.128	0.160	0.276	0.337	0.328	0.394	0.408	0.412	0.405
	Area	0.507	0.395	0.263	0.283	0.416	0.589	0.566	0.702	0.746	0.786	0.768
25 50	%>0	0.234	0.317	0.297	0.340	0.398	0.458	0.481	0.524	0.547	0.565	0.568
	Area	1.092	0.958	0.963	0.995	2.193	2.478	2.826	3.214	3.336	3.431	3.391
50-100	%>0	0.390	0.475	0.547	0.612	0.739	0.794	0.816	0.809	0.845	0.857	0.861
	Area	9.019	6.307	5.046	4.602	5.265	7.761	10.274	10.165	10.521	11.319	11.634
km to lg, farm		112	113	107	98	96	78	75	76	75	68	68
Kebeles (%)		0.158	0.203	0.349	0.366	0.563	0.566	0.545	0.562	0.561	0.546	0.555
Wheat												
< 25	%>0	0.020	0.017	0.017	0.108	0.242	0.315	0.320	0.364	0.392	0.380	0.365
	Area	0.585	0.757	0.512	1.298	2.693	2.890	2.864	3.380	3.607	3.665	3.678
25 50	%>0	0.176	0.237	0.267	0.351	0.379	0.448	0.448	0.474	0.505	0.509	0.504
	Area	4.577	5.375	4.051	6.728	6.229	7.670	7.696	8.247	8.989	9.167	9.229
50-100	%>0	0.706	0.678	0.733	0.757	0.757	0.841	0.829	0.853	0.859	0.881	0.876
	Area	20.897	23.383	23.138	26.074	24.414	26.736	27.708	26.391	27.940	27.170	28.078
km to lg, farm		80	83	82	75	88	79	80	79	76	64	65
Kebeles (%)		0.105	0.119	0.122	0.144	0.373	0.390	0.405	0.408	0.389	0.409	0.399

Source: Own computation from 2003/4-2013/14 CSA smallholder farm surveys.
Note: Area is in 100 ha. Statistics are calculated using the sub-sample of kebeles that are included in the analysis for each of the crops. The criteria for inclusion in the sub-sample are that the kebele is within 150 km of a commercial farm growing the specified crop in 2014 and that more than 10% of households in the kebele grow the crop.

Table 5: Estimated impacts of changes in neighboring large farm area/distance on smallholders' fertilizer use

	Maize	**Wheat**	**Sorghum**	**Teff**
		Panel A: Distance measures		
Distance any farm				
Distance	-0.00165*	-8.75e-06	0.00111	0.00222*
	(0.000854)	(0.00206)	(0.000677)	(0.00118)
Distance^2	1.24e-05**	5.05e-06	-7.95e-06**	-1.66e-05**
	(5.52e-06)	(1.53e-05)	(3.36e-06)	(7.65e-06)
R^2	0.375	0.407	0.266	0.494
Dist. same crop				
Distance	-0.00123*	-0.000877	0.000460	0.00212**
	(0.000655)	(0.00148)	(0.000541)	(0.000805)
Distance^2	5.18e-06*	-1.29e-06	-1.50e-06	-8.26e-06***
	(2.67e-06)	(5.70e-06)	(2.40e-06)	(2.85e-06)
R^2	0.375	0.410	0.265	0.494
		Panel B: Area measures		
Area, all farms				
0 - 25 km	0.000733***	0.000424	-0.000189	-0.00105***
	(0.000215)	(0.000367)	(0.000294)	(0.000278)
25 - 50 km	-0.000432	8.96e-05	-1.59e-05	-0.000518*
	(0.000339)	(0.000234)	(8.33e-05)	(0.000270)
50 - 100 km	0.000129	0.000182	1.09e-06	-0.000212
	(0.000131)	(0.000159)	(3.24e-05)	(0.000147)
R^2	0.376	0.408	0.265	0.494
Area, same crop				
0 - 25 km	0.00119***	0.000701	-0.000775***	-0.00408**
	(0.000429)	(0.000855)	(0.000203)	(0.00189)
25 - 50 km	-0.000386	0.000221	0.000116*	-0.00284**
	(0.000665)	(0.000669)	(5.96e-05)	(0.00140)
50 - 100 km	0.000165	0.000581	-1.17e-05	-0.000993
	(0.000259)	(0.000477)	(1.86e-05)	(0.000988)
R^2	0.375	0.408	0.265	0.494
No. of obs. (hhs)	170,519	52,885	89,557	92,435

Note: Woreda fixed effects and year trends included throughout. Standard errors clustered at woreda level.

Table 6: Estimated impacts of changes in neighboring large farm area/distance on smallholders' improved seed use

	Maize	Wheat	Sorghum	Teff
		Panel A: Distance measures		
Distance any farm				
Distance	2.55e-05	0.000176	-0.000125**	0.000159
	(0.000656)	(0.000445)	(4.67e-05)	(0.000136)
Distance^2	2.64e-06	-6.63e-07	6.72e-07***	-3.28e-07
	(4.12e-06)	(2.69e-06)	(1.71e-07)	(9.07e-07)
R^2	0.323	0.071	0.013	0.050
Dist. same crop				
Distance	-7.69e-05	-0.000166	-4.71e-05	-8.92e-05
	(0.000544)	(0.000318)	(3.83e-05)	(0.000146)
Distance^2	2.09e-06	6.22e-08	1.22e-07	1.38e-07
	(1.85e-06)	(1.28e-06)	(1.35e-07)	(6.10e-07)
R^2	0.323	0.071	0.013	0.050
		Panel B: Area measures		
Area, all farms				
0 - 25 km	0.000284	-0.000202**	2.20e-05	-2.12e-05
	(0.000181)	(9.18e-05)	(1.56e-05)	(5.14e-05)
25 - 50 km	-0.000424	-3.70e-06	-1.24e-05	3.40e-05
	(0.000292)	(9.67e-05)	(7.48e-06)	(4.42e-05)
50 - 100 km	9.90e-05	-2.83e-05	-3.71e-06	1.15e-05
	(0.000116)	(4.13e-05)	(2.24e-06)	(2.63e-05)
R^2	0.324	0.071	0.013	0.050
Area, same crop				
0 - 25 km	0.000926***	-0.000166	2.38e-05	0.000861**
	(0.000334)	(0.000161)	(2.63e-05)	(0.000342)
25 - 50 km	-0.000181	-4.64e-05	-1.48e-05	0.000120
	(0.000655)	(0.000152)	(1.08e-05)	(0.000227)
50 - 100 km	0.000567**	5.75e-05	-3.79e-06	-0.000167
	(0.000277)	(8.11e-05)	(2.92e-06)	(0.000116)
R^2	0.324	0.071	0.013	0.050
No. of obs. (hhs)	170,519	52,885	89,557	92,435

Note: Woreda fixed effects and year trends included throughout. Standard errors clustered at woreda level.

Table 7: Estimated impacts of changes in neighboring large farm area/distance on smallholders' yields

	Maize	Wheat	Sorghum	Teff
		Panel A: Distance measures		
Distance any farm				
Distance	-0.00219	0.000202	0.000824	0.00100
	(0.00169)	(0.00218)	(0.00132)	(0.00160)
Distance^2	-1.34e-06	-9.84e-06	-8.64e-06	-3.14e-05*
	(1.41e-05)	(1.88e-05)	(9.23e-06)	(1.76e-05)
R^2	0.424	0.363	0.287	0.258
Dist. same crop				
Distance	-0.00339*	0.00144	-0.000178	-0.00142
	(0.00178)	(0.00181)	(0.000857)	(0.00121)
Distance^2	9.81e-06	-1.67e-06	2.54e-06	5.49e-06
	(9.19e-06)	(5.77e-06)	(3.25e-06)	(5.36e-06)
R^2	0.424	0.365	0.287	0.255
		Panel B: Area measures		
Area, all farms				
0 - 25 km	0.00110***	0.00101	0.000119	0.000856
	(0.000388)	(0.000615)	(0.000645)	(0.000725)
25 - 50 km	-0.000232	-0.000128	0.000103	7.74e-05
	(0.000201)	(0.000516)	(0.000128)	(0.000324)
50 - 100 km	3.64e-05	-0.000327	3.29e-05	-9.32e-05
	(0.000105)	(0.000231)	(4.95e-05)	(0.000246)
R^2	0.423	0.365	0.287	0.256
Area, same crop				
0 - 25 km	0.00250***	0.00393***	-0.000447	0.000575
	(0.000445)	(0.00106)	(0.000976)	(0.00327)
25 - 50 km	0.000277	0.00205**	0.000125	0.000738
	(0.000594)	(0.000841)	(0.000223)	(0.00298)
50 - 100 km	-0.000493	0.000574*	7.15e-06	-0.00230**
	(0.000320)	(0.000299)	(4.60e-05)	(0.00106)
R^2	0.423	0.367	0.287	0.256
No. obs. (kebeles)	10,768	5,295	6,973	7,767

Note: Woreda fixed effects and year trends included throughout. Standard errors clustered at woreda level.

Table 8: Impact of changes in distance to large farms or neighboring large farm area on smallholders' labor supply

	Paid work	Temp. work	
		General	**Agric.**
		Panel A: Distance measures	
Dist. to town	-0.000990***	-0.000101	0.000481
	(0.000211)	(0.000107)	(0.000324)
Distance	-0.000144	-0.000162	-0.000130
	(0.000205)	(0.000103)	(0.000314)
Distance^2	9.74e-08	6.91e-07	-1.54e-06
	(1.46e-06)	(7.38e-07)	(2.25e-06)
No. of obs.	15,738	15,738	15,701
R^2	0.110	0.043	0.156
		Panel B: Area measures	
Dist. to town	-0.00101***	-0.000120	0.000414
	(0.000209)	(0.000106)	(0.000321)
0 - 25 km	3.34e-05	-3.07e-05	4.84e-05
	(7.51e-05)	(3.79e-05)	(0.000115)
25 - 50 km	-5.19e-05	8.32e-06	5.59e-06
	(3.95e-05)	(1.99e-05)	(6.06e-05)
50 - 100 km	6.70e-05***	1.38e-05	8.64e-05***
	(1.93e-05)	(9.76e-06)	(2.96e-05)
No. of obs. (hhs)	15,738	15,738	15,701
R^2	0.111	0.043	0.157
Mean of dep. var.			
Round 1	0.048	0.012	0.081
Round 2	0.041	0.008	0.162

Note: Zone fixed effects and year trends included throughout. Standard errors clustered at zone level.

Table 9: Impact of changes in distance to large farms or neighboring large farm area on resilience of smallholders' yields

	Maize	Wheat	Sorghum	Teff
Any farm				
Area within 25 km	0.000867	0.000988	-8.46e-05	0.000826
	(0.000580)	(0.000640)	(0.000563)	(0.000762)
Negative rain shock	-0.112***	-0.0308	-0.00978	-0.100***
(z < -1)	(0.0417)	(0.0317)	(0.0382)	(0.0338)
Rain below normal	-0.0337*	0.00737	-0.0196	-0.0354*
(0 < z ≤ 1)	(0.0188)	(0.0211)	(0.0223)	(0.0190)
Positive rain shock	0.0355**	-0.0331	0.0378	-0.00894
(1 < z)	(0.0153)	(0.0330)	(0.0255)	(0.0169)
Area * (z < -1)	0.000377	0.00109	0.00113	0.00124**
	(0.000607)	(0.000818)	(0.000834)	(0.000607)
Area * (0 < z ≤ 1)	0.000681*	2.32e-05	0.000481	-0.000265
	(0.000382)	(0.000454)	(0.000310)	(0.000516)
Area * (1 < z)	-0.000481	0.000391	0.000153	0.000329
	(0.000394)	(0.000503)	(0.000466)	(0.000538)
R^2	0.423	0.364	0.287	0.256
Same crop				
Area within 25 km	0.00226***	0.00209**	-0.000522	-5.65e-05
	(0.000408)	(0.000874)	(0.000665)	(0.00286)
Negative rain shock	-0.117***	-0.0281	-0.00343	-0.0984***
(z < -1)	(0.0414)	(0.0301)	(0.0366)	(0.0331)
Rain below normal	-0.0347*	0.00911	-0.0181	-0.0350*
(0 < z ≤ 1)	(0.0196)	(0.0206)	(0.0220)	(0.0188)
Positive rain shock	0.0374**	-0.0337	0.0363	-0.00759
(1 < z)	(0.0157)	(0.0319)	(0.0247)	(0.0158)
Area * (z < -1)	0.00284**	0.00136**	0.000353	0.00668*
	(0.00118)	(0.000640)	(0.000418)	(0.00364)
Area * (0 < z ≤ 1)	0.00227***	-0.000606	0.000558	-0.00450
	(0.000617)	(0.000536)	(0.000351)	(0.00491)
Area * (1 < z)	-0.00139**	0.00115***	0.00177	0.00122
	(0.000660)	(0.000373)	(0.00114)	(0.00309)
R^2	0.424	0.366	0.287	0.255
No. of obs. (kebeles)	10,768	5,295	6,973	7,767

Note: Woreda fixed effects and year trends included throughout. Standard errors clustered at woreda level.

Figure 1: Location of large farms and sample kebeles for the smallholder survey

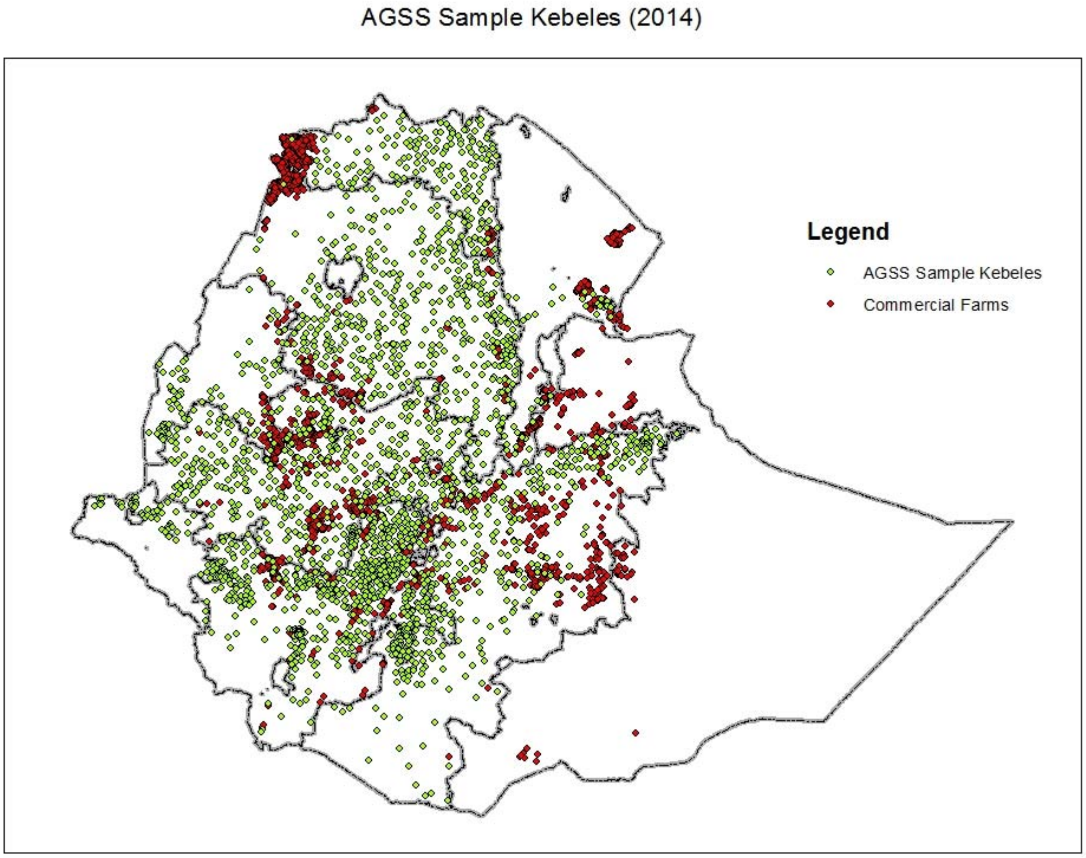


Figure 2: Inter-temporal changes in proximity between large and small farm, 2004-2014

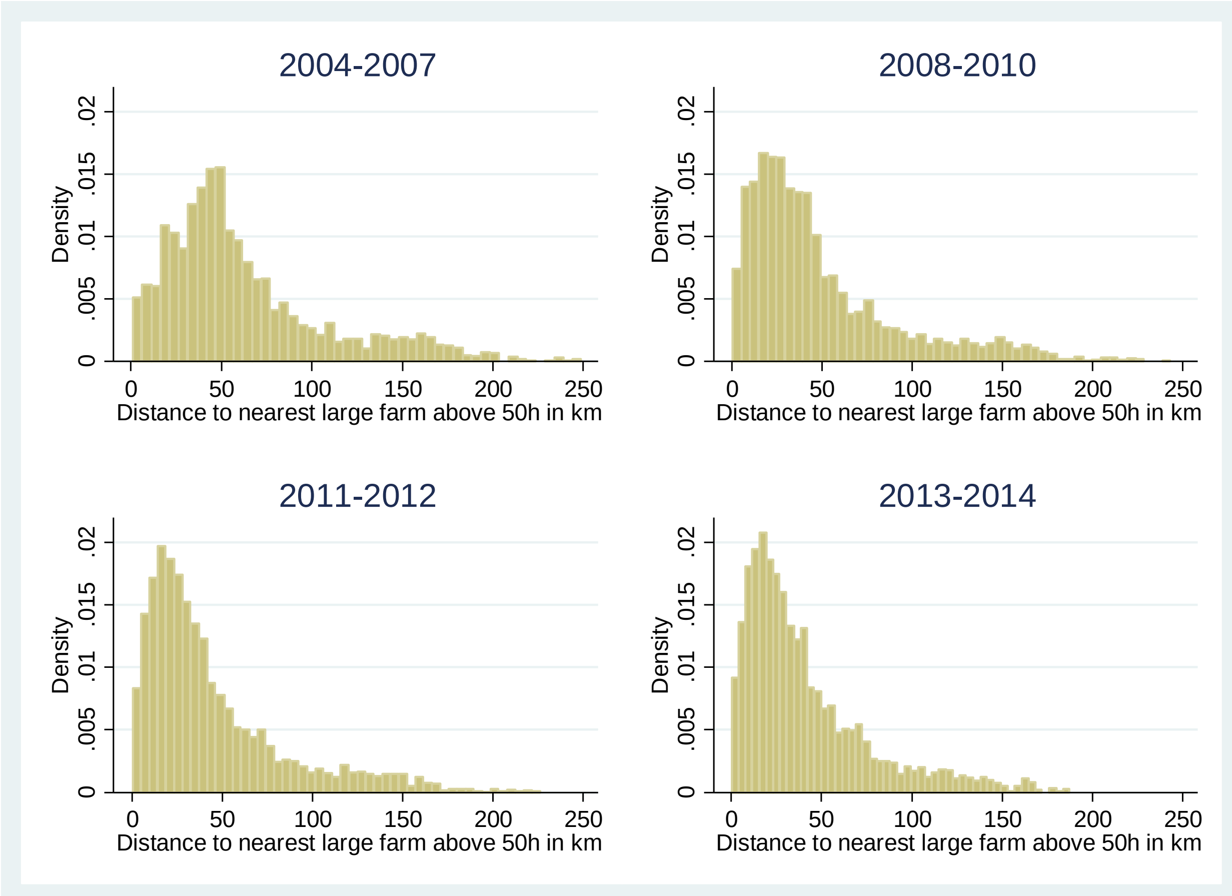


Figure 3: Distance from Kebele centroid to nearest commercial farm, by crop

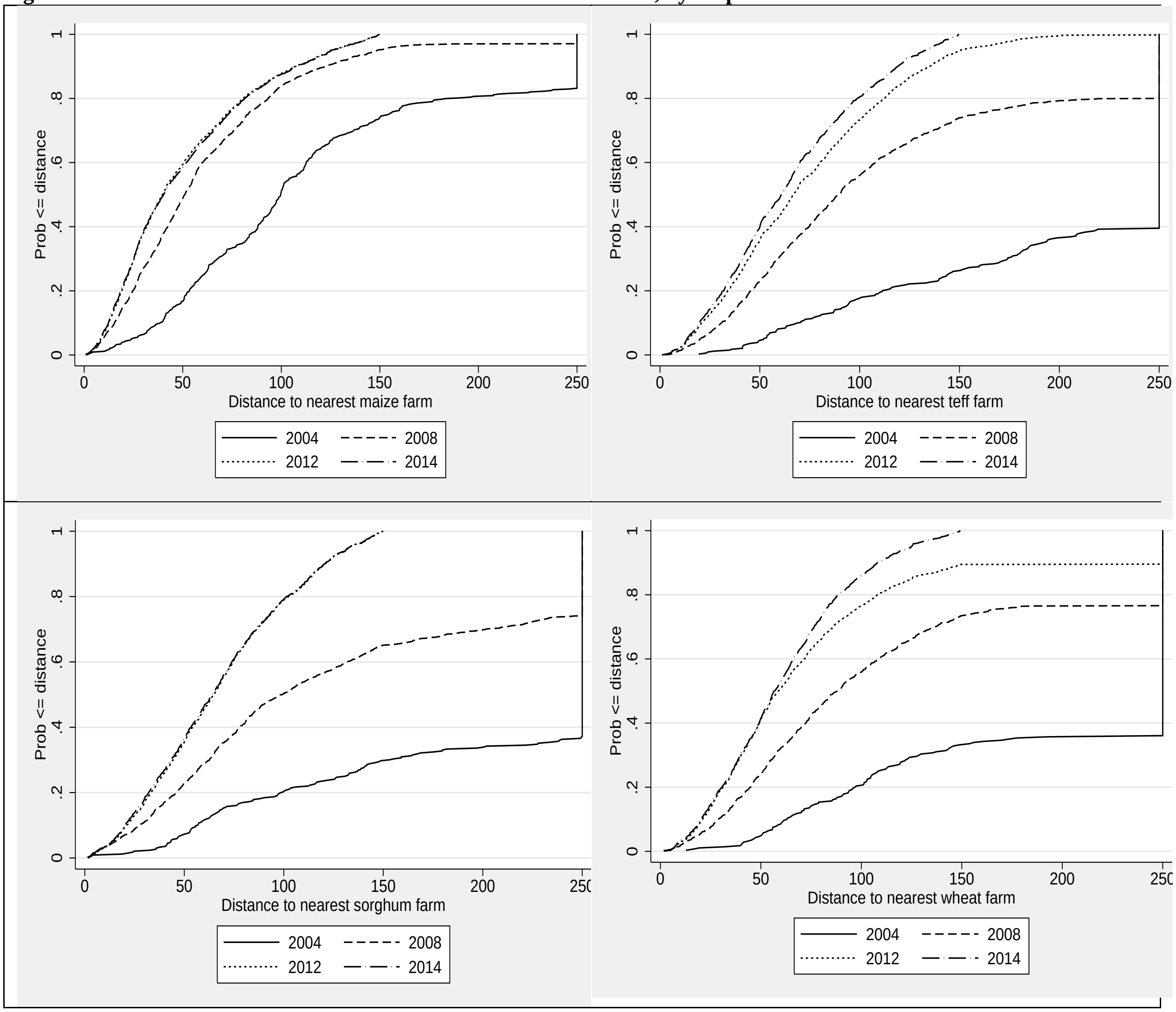


Figure 4: Location of commercial maize farms in 2003/4 with smallholder kebeles and their yields in 0-25, 25-50, 50-100, and 100-150 km distance bands

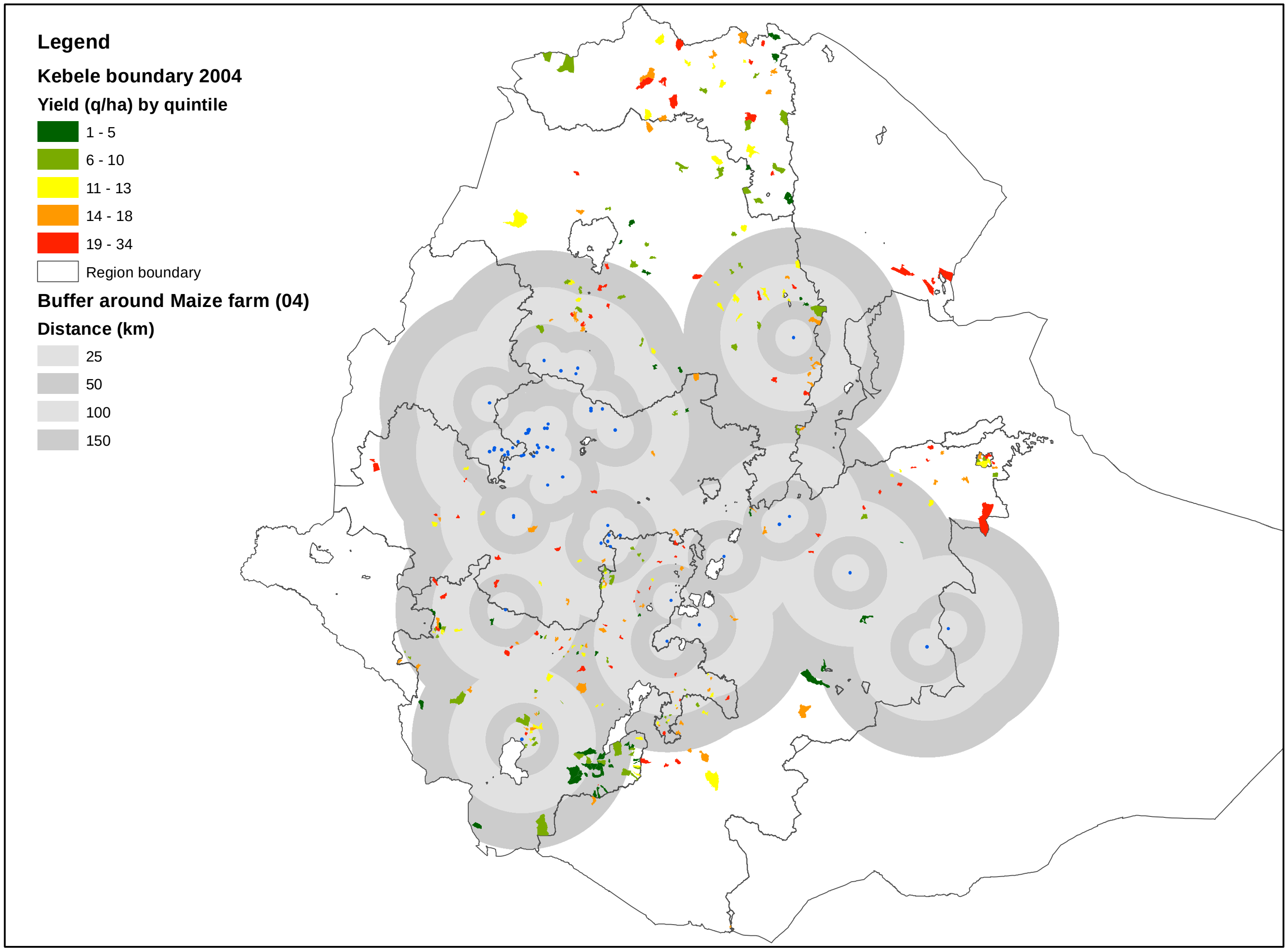


Figure 5: Location of commercial maize farms in 2001/4 with smallholder kebeles and their yields in 0-25, 25-50, 50-100, and 100-150 km distance bands

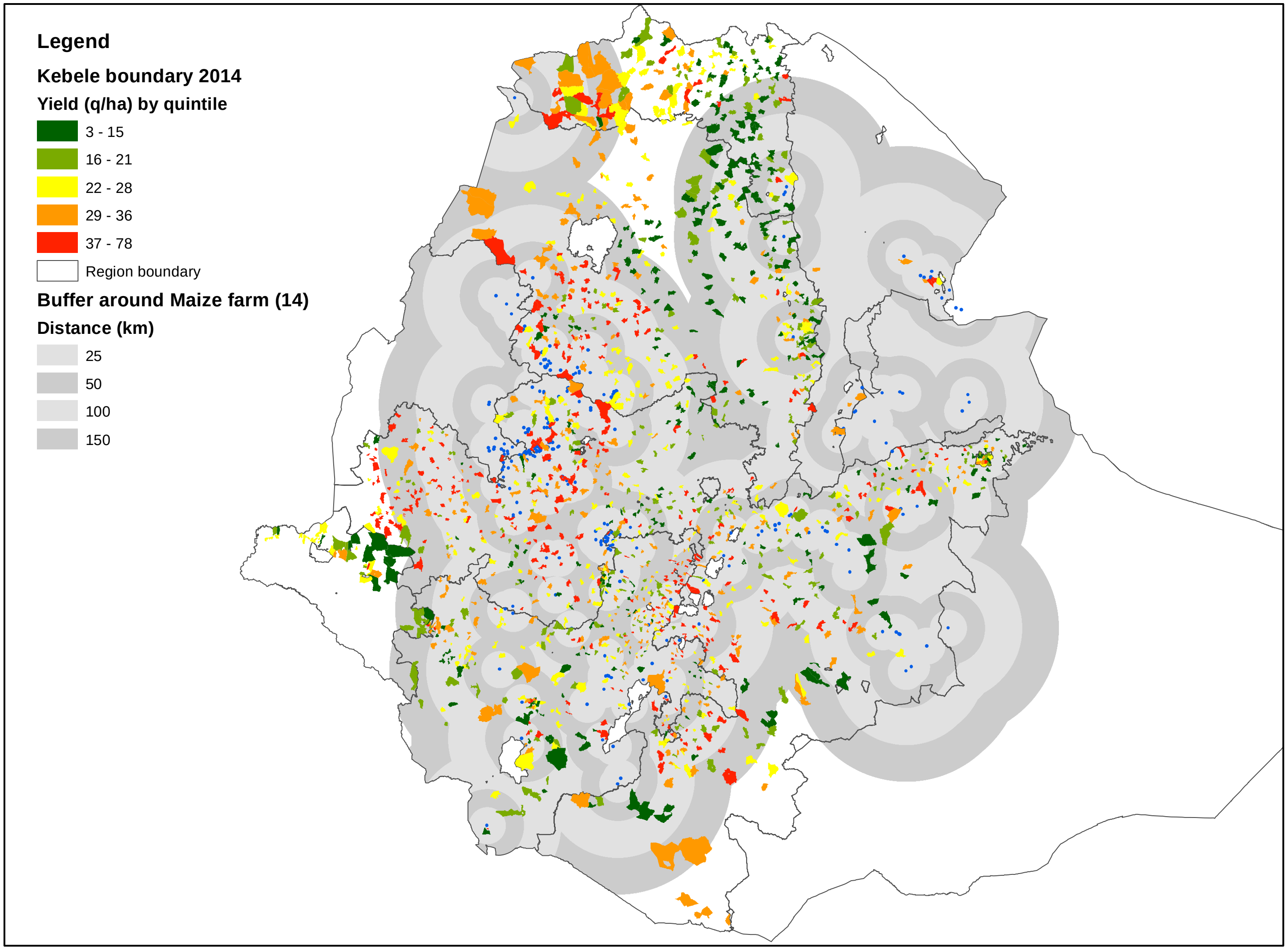


Figure 6: Location of commercial sorghum farms in 2003/4 with smallholder kebeles and their yields in 0-25, 25-50, 50-100, and 100-150 km distance bands

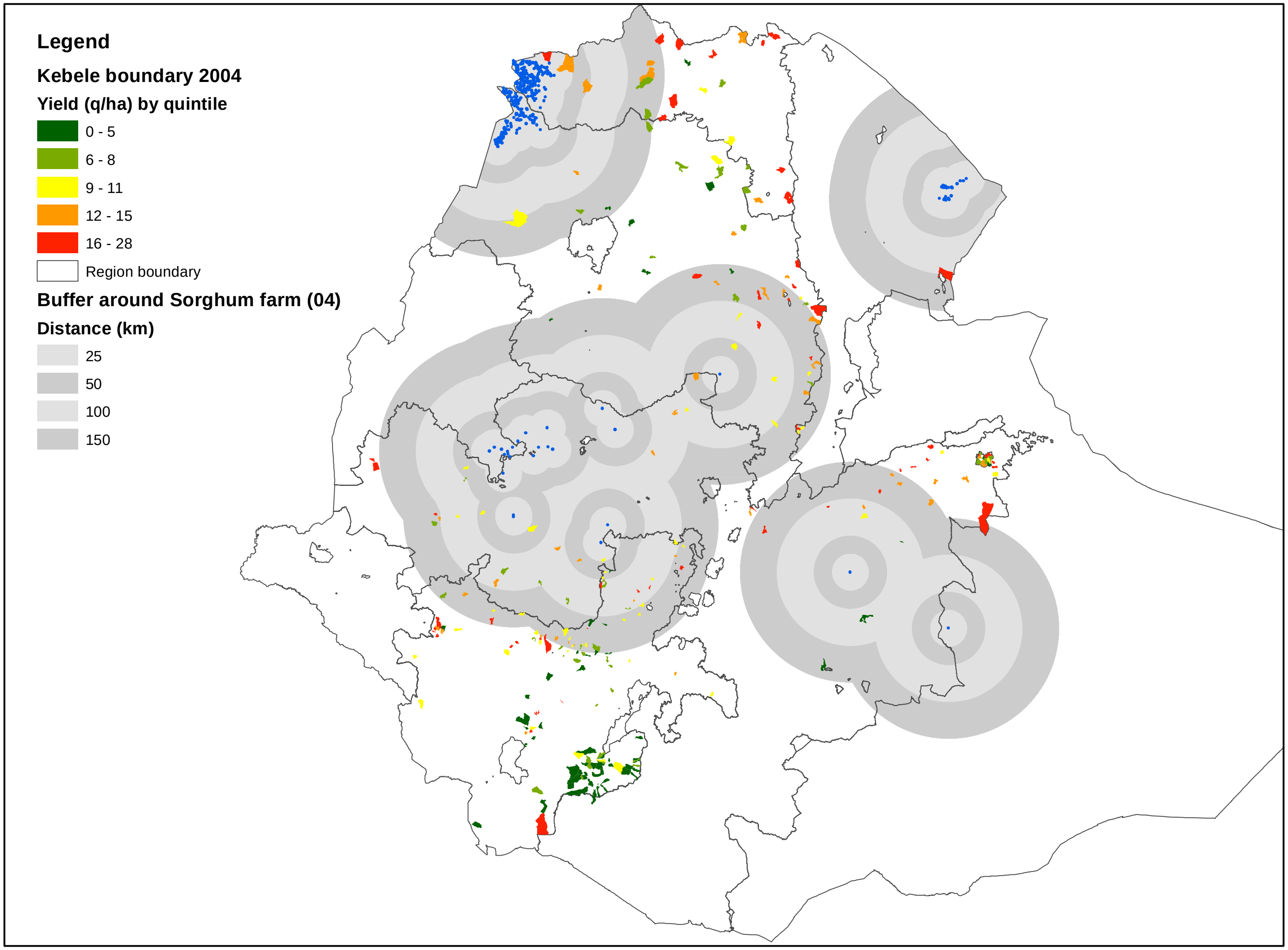


Figure 7: Location of commercial sorghum farms in 2003/4 with smallholder kebeles and their yields in 0-25, 25-50, 50-100, and 100-150 km distance bands

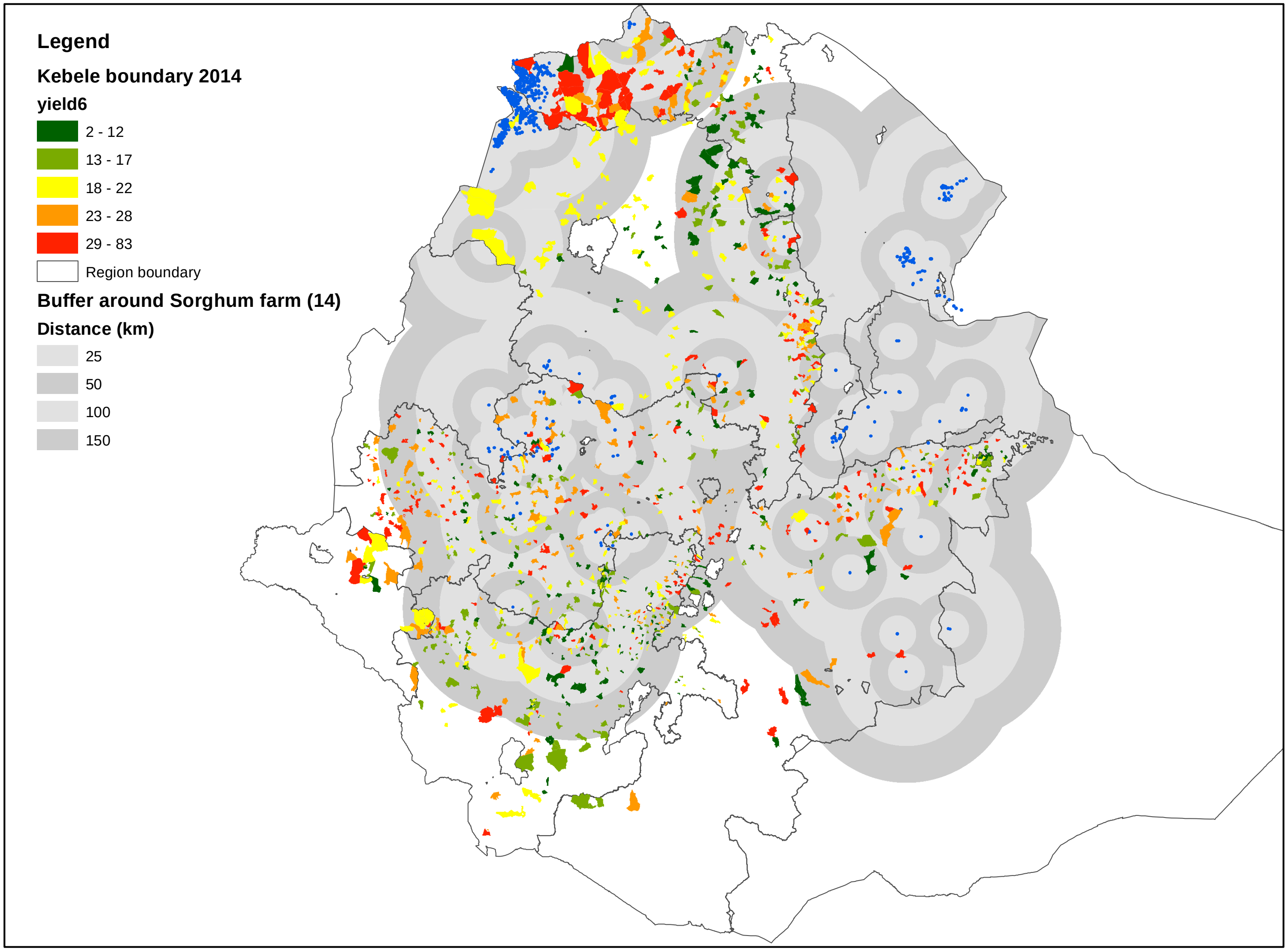


Figure 8: Location of commercial teff farms in 2003/4 with smallholder kebeles and their yields in 0-25, 25-50, 50-100, and 100-150 km distance bands

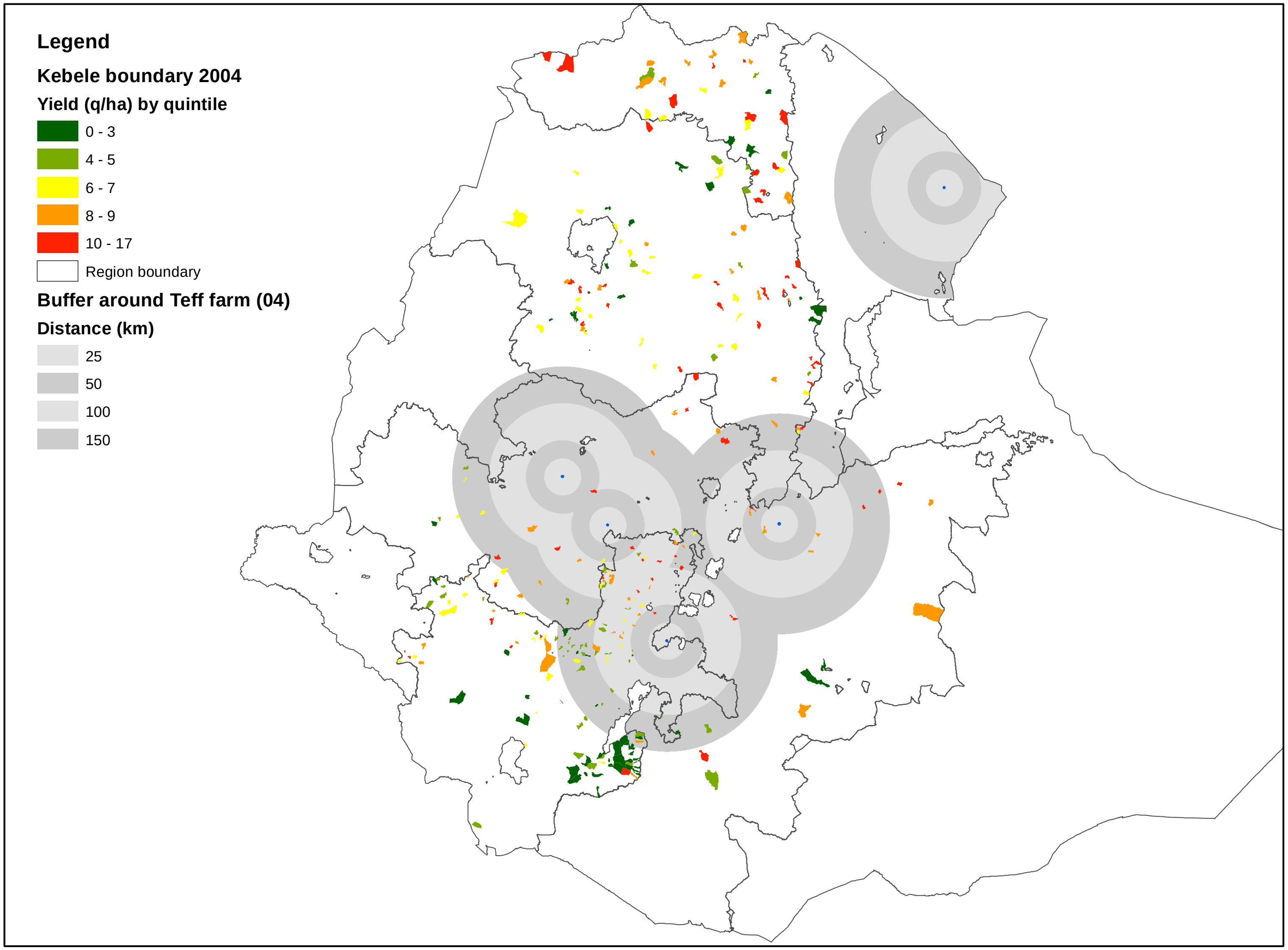


Figure 9: Location of commercial teff farms in 2013/4 with smallholder kebeles and their yields in 0-25, 25-50, 50-100, and 100-150 km distance bands

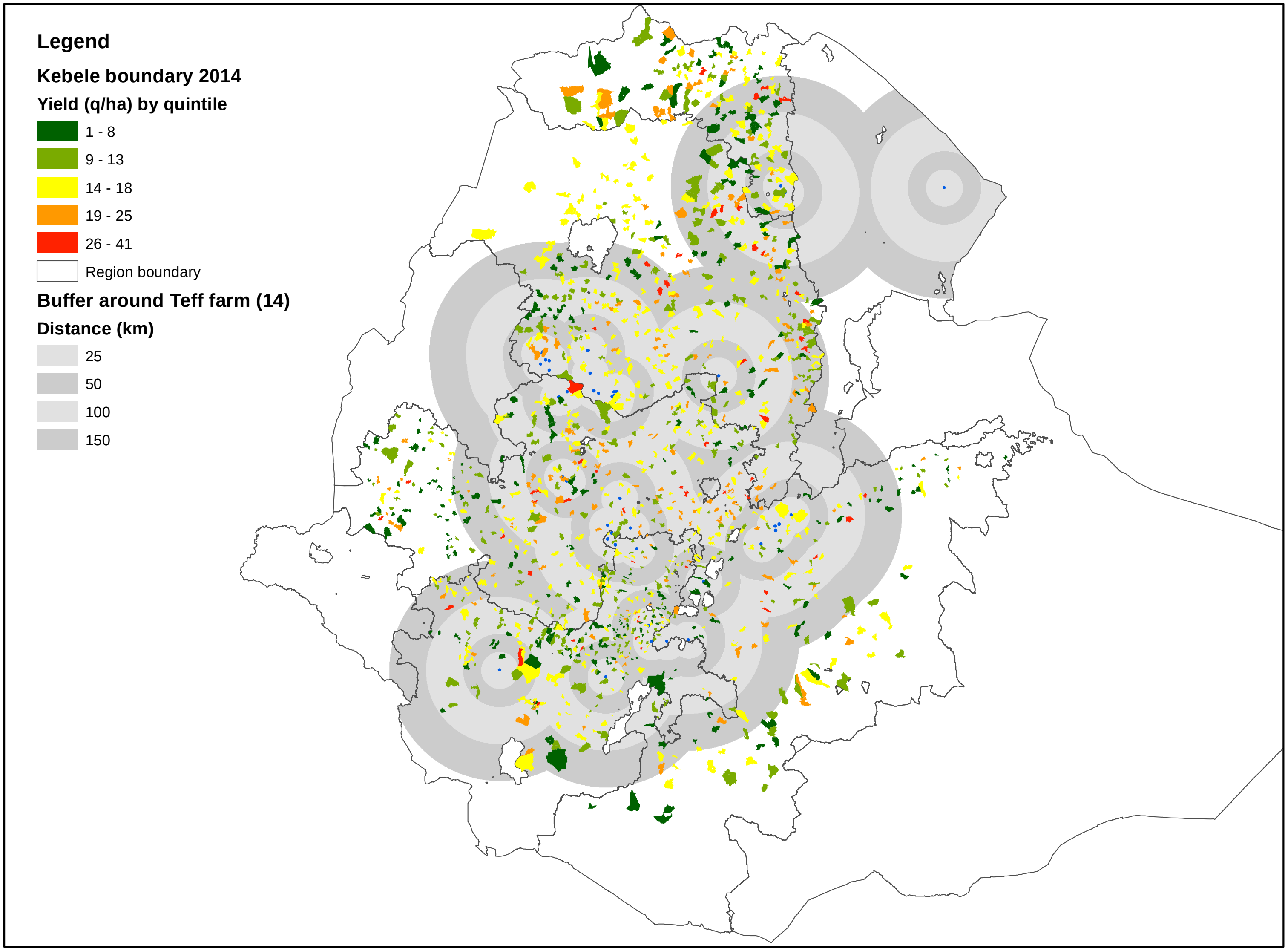


Figure 10: Location of commercial wheat farms in 2003/4 with smallholder kebeles and their yields in 0-25, 25-50, 50-100, and 100-150 km distance bands

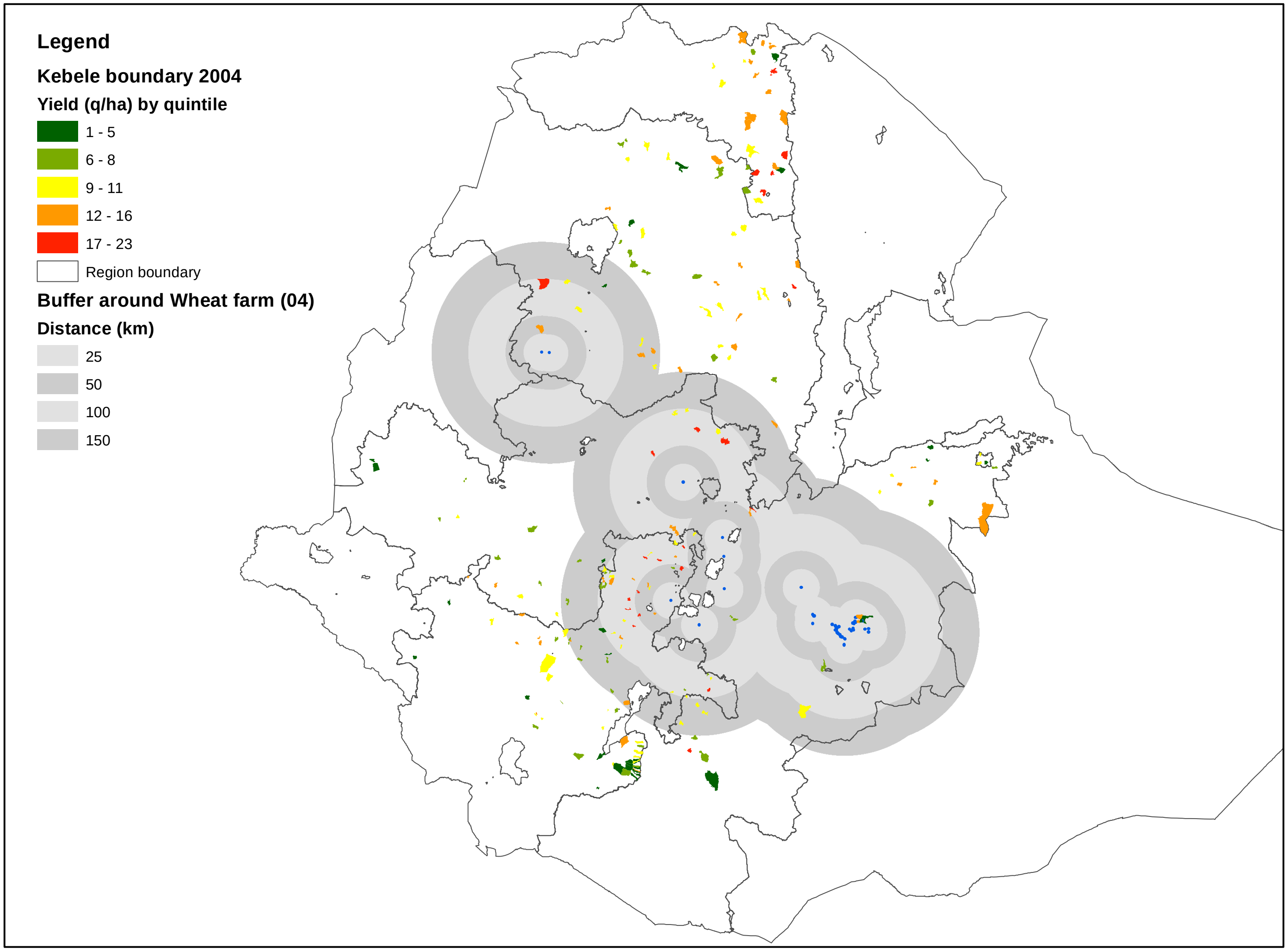
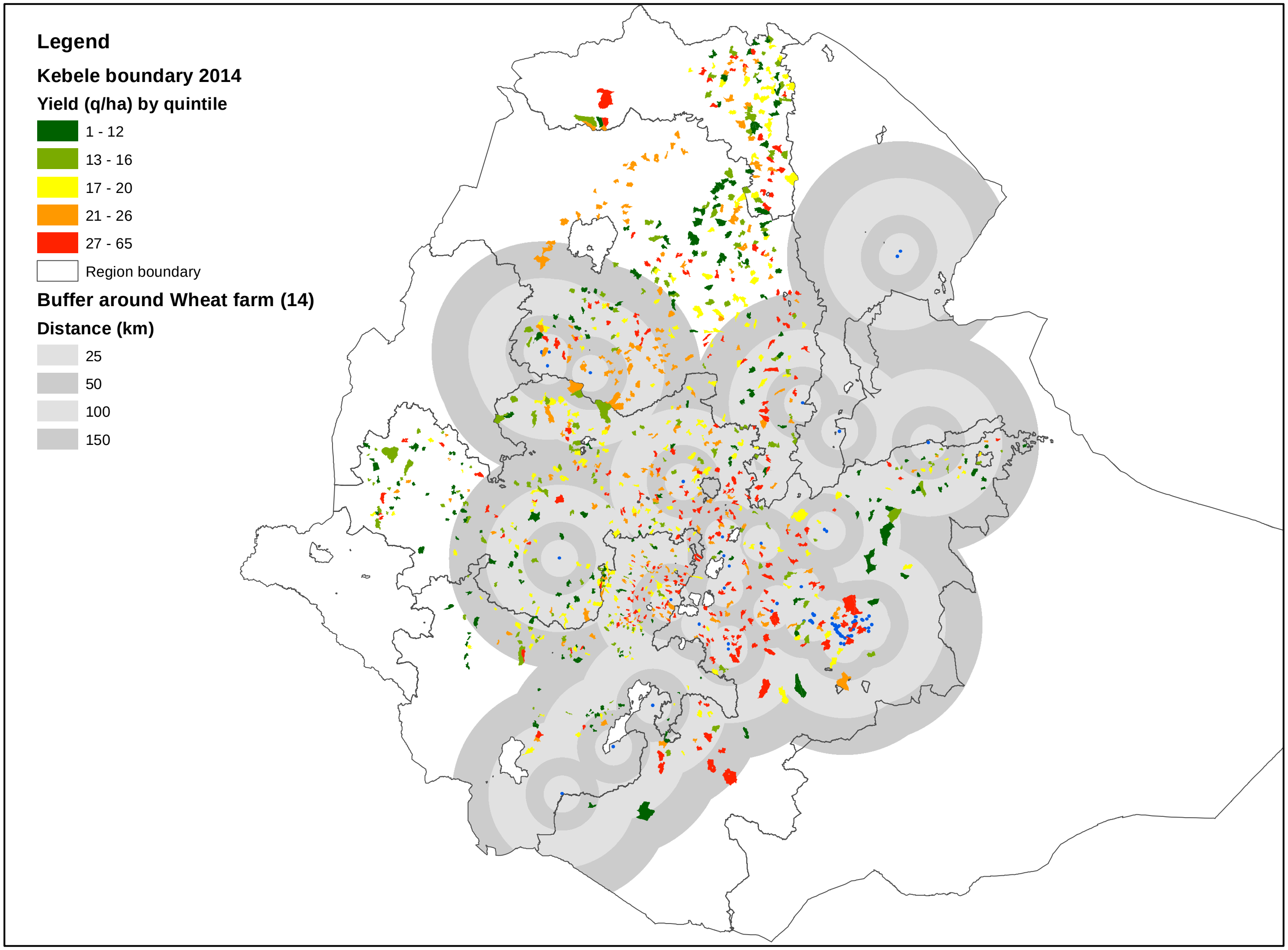


Figure 11: Location of commercial wheat farms in 2003/4 with smallholder kebeles and their yields in 0-25, 25-50, 50-100, and 100-150 km distance bands



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