Woreda-Level Crop Production Rankings in Ethiopia: A Pooled Data Approach

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Abstract

A detailed understanding of farm production at the *woreda*-level is essential to plan and evaluate interventions because many agricultural policy decisions are implemented at this level. Unfortunately, there are no nationally representative *woreda*-level agricultural production statistics in Ethiopia. Even though the largest Ethiopian agricultural data survey, the Agricultural Sample Survey (AgSS), interviews approximately 40,000 agricultural households annually, the sampling frame is designed for zonal level, not *woreda*-level production estimates. We re-weight four years of the AgSS data (2010-2013) to provide *woreda* production rankings in the four main agricultural regions of Ethiopia (Amhara, Tigray, Oromia and the SNNP) for eight staple crops (wheat, maize, barley, sorghum, teff, chickpea, sesame, and coffee).

The research is unique because it disaggregates zonal production data (approximately 51 zones) into the smaller *woreda* administrative units (approximately 550 rural *woredas*) and uses a pooled, multi-year data approach to check for both consistency and stability of the production ranking estimates. The results for each *woreda* were statistically stable over each of the four years and suggests that *woreda*-level estimates are robust. Further, the rankings were crosschecked with other, smaller, agricultural data sources, and the results were consistent with AgSS estimations. The purpose of the rankings is to identify, at a more localized level, the high-production areas. This information has a variety of potential uses, which include identifying geographic *woreda*-level clustering for targeted policy interventions.

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1. Introduction

Ethiopia has significant agro-ecological variability that shapes crop production areas across the country. The purpose of this research is to produce localized production estimates from the zonal to the *woreda* level. This research will provide a more nuanced, finer view of where production is taking place given the relative diversity of production within the zones. This information can also provide policymakers with abetter understanding of high-production *woreda* clusters that can cross zonal boundaries.

In Ethiopia, the *woreda* is the administrative unit where major agricultural development decisions take place. As a result, *woreda*-level agricultural production data is essential to help plan, implement, monitor, and evaluate agricultural interventions at that level. Unfortunately, *woreda*-level data, which is generated through a standard data collection methodology and can allow national level comparisons, do not exist. Each year, Ethiopia's Central Statistics Agency (CSA) issues the Agricultural Sample Survey (AgSS), a detailed, nationally representative agricultural production survey. While this survey is by far the largest agricultural survey in the country (with approximately 40,000 households surveyed annually) and widely recognized as the authoritative source of agricultural production data in Ethiopia, these production estimates are presented at the zonal level. There is a growing need, however, for agricultural production data, disaggregated by *woreda*, to support evidence-based decision-making at the local level. The Ethiopian Agricultural Transformation Agency (ATA) asked the Research for Ethiopia's Agriculture Policy (REAP) project led by the International Food Policy Research Institute (IFPRI) to generate *woreda*-level crop production estimates from the available data sets in the country. The purpose of this short-term research is to provide production-based rankings at the *woreda* level and to identify potential areas for interventions.

This report includes *woreda-level* production rankings for eight major crops (wheat, maize, barley, sorghum, teff, chickpea, sesame, and coffee) that are grown in the four major agricultural states (Amhara, Oromia, SNNP, and Tigray). Given the large scale of the survey and its use of a consistent methodology, we used the CSA's AgSS data collected in 2009/10, 2010/11, 2011/12, and 2012/13 for our weighted downscale *woreda* production rankings. In addition, we used IFPRI's 2012 ATA Baseline Survey and Ethiopia's Agricultural Growth Program (AGP) survey data to verify these rankings. These additional estimates further confirmed our results.

This paper is divided into five sections. Section 2 provides a detailed description of the data used for the analysis and the methods used for the estimations. Section 3 presents the estimated results by crop through tables and maps. Section 4 proposes areas for further research, and the final section concludes.

2. Methodology

2.1 Data Sources

The analysis included estimating production rankings at the *woreda* level over four *Meher* crop seasons and then verifying the estimated results and rankings. Multiple data sets were used, though the primary data used for production estimates were the CSA's AgSS data collected in 2009/10, 2010/11, 2011/12, and 2012/13. The AgSS is an extensive survey that covers the country. However, the focus of this research is on the four principal crop-producing areas (Tigray, Amhara, Oromia, and SNNP) that reflect about 90% of the AgSS survey. More specifically, the AgSS evaluates over 500,000 agricultural plots, 38,000 households in 1,850 Enumeration Areas (EAs) that reside in approximately 540 agricultural *woredas* in these four regions. The actual number of surveyed *woredas* varies from 527 in 2009/10 to 541 in 2012/13.

To estimate *woreda*-level production, a *woreda* population sampling weight was derived using the 2007 Ethiopian population census data (Population Census Commission 2008) and theWorld Bank's annual population growth rates for Ethiopia to measure *woreda*-level counts inflated over time (World Bank 2013). One assumption was that family size remained constant over all of the years estimated and that all *woreda* populations and number of households grew according to the average growth rates for the country. In other words, we did not account for net migration since the 2007 census.

For reliability, the *woreda* estimates were aggregated to the zonal level and then contrasted with the CSA's figures, which was accomplished by using the 2009/10, 2010/11, 2011/12 and 2012/13 CSA's AgSS production reports (CSA, multiple years).

The estimates produced with AgSS data were then compared with estimates produced by using additional agricultural data sets. More specifically, IFPRI's 2012 ATA Baseline Survey and Ethiopia's Agricultural Growth Program (AGP) survey data were used. The 2012 ATA Baseline sample included 3,000 households in 100 *woredas* covering the four regions (IFPRI 2012). A subset of the AGP's 2011 crop season was provided by IFRPI-ESSP and covers approximately 7,700 households in 95 *woredas* in the four regions (IFPRI-ESSP 2014).

For clear data visualization and presentation, production data were mapped by *woreda*. Publicly available geographic shapefiles from the United Nations' Office for the Coordination of Human Affairs (UN-OCHA) were used for mapping. In addition, the ATA provided a master list of *woredas* and identified 625 *woredas* for the four regions (ATA 2014).

The rankings were also compared against two measures of food insecurity: The UN-OCHA publishes a list of food-insecure *woredas* (UN-OCHA 2012), and theWorld Food Program (WFP) produces a list because*woredas* are included in it's Productive Safety Net Program (PSNP) (World Food Program 2006). These lists are not perfectly correlated, so they need to be addressed independently. While only a small number of woredas, which we identify as high producers, were also included in these lists, we have confidence in our estimates (see Appendix G for further details).

2.2 CSA Sampling Methodology

Regarding the four main production regions, the CSA's AgSS data set is an extensive agricultural survey that typically evaluates over 500,000 agricultural plots, 38,000 households in 1,850 Enumeration Areas (EAs) that reside in approximately 540 agricultural woredas.[1] Given its overall size, the survey inadvertently covers a majority of woredas but, as previously mentioned, the sampling procedure is not designed for this purpose. For this reason, ten rural woredas in the four regions are typically not sampled in any given year. However, because the sampling methodology is population-based, those woredas that are not included have less than 40% of the average population of the sampled.[2] Since the non-sampled woredas have small populations, they are also more likely to have smaller production estimates and, therefore, are less likely to be top producing woredas in any particular crop. Overall, the CSA determines particular EA's as individual groups of approximately 150-200 households based on geographical considerations that, importantly for our purposes, do not cross kebele borders.

Next, the CSA amalgamates EAs according to a methodology that reflects broader zonal, administrative areas. Production estimates are determined at the agricultural household level by projecting the sampled household production onto the overall projected agricultural population of the area. The CSA employs a

[1] Enumeration areas are smaller than *kebeles* but are fully contained within a *kebele* boundary.
[2] For example, in the 2012/13 AgSS the typical sampled *woreda* had a population that was approximately 270% larger than the non-sampled *woredas*. This is important for ranking production purposes as projections are based on number of households. These lesser-populated *woredas* therefore will have smaller projected productions because there are fewer growers. None of the non-sampled *woredas* projected to be in the top 50 2012/13 *woreda* production rankings of any of the eight crops estimated. Of course, this does not take into consideration the potential of large, non-sampled AgSS farms in these relatively small-populated *woredas*.

stratified sampling technique that selects EAs according to a CSA algorithm that chooses a random sample of twenty households within each of their identified EAs. In addition, EAs are chosen for a three-year period of estimation for the AgSS survey. The EAs sampled are almost identical over the 2010/11-2012/13 AgSS sampling frame. This three-year EA sampling frame is confirmed when the EAs chosen from 2010/11-2012/13 are compared to the 2009/10 survey (which has a much different EA sampling frame).[3] Given this information, we see that the projected three years of analysis (2010/11-2012/13) measures production of similar EAs and the rankings are, therefore, expected to be fairly stable over these years. However, we use the fact that productivity rankings remained relatively stable when 2010/11, 2011/12, and 2012/13 data are compared to 2009/10 (a different EA sampling frame) as a positive indicator of statistical robustness, because even when different areas within each woreda are sampled, the rankings remain relatively stable.

The CSA samples both area and production for the AgSS. When sampling at the EA level, the CSA takes a sample crop cut from a maximum of five farmers, averages the yields across the number of crop cuts,and then projects this average for all of the farmer's area plots at the EA level. In other words, while the CSA takes area measurements for all sampled agricultural plots, they do not measure yield estimates from each plot. This means that for a sampled minimum of twenty households within a *woreda*, five crop cuts at most ultimately determine the productivity for an entire *woreda* for any given year. Since every plot is assumed to have the same yield in a given EA, there are very few yield samples per *woreda*.[4]

2.3 Reconfiguring Production Estimates to the *Woreda* Level

As indicated in section 2.2, there are several important statistical estimation methodology issues to consider before these *woreda*-based estimates can be used for planning purposes. The following methodology reconfigures the 51 zonal CSA production estimates into 552 *woreda*-level estimates. We reconfigured the EA samples, located within their given kebeles, to be included in their *woredas* and then computed *woreda*-level estimates.

[3] Between 2010/11-2012/13 the typical number of similar EAs sampled was approximately 97%, which can be contrasted with the 20% similarity between 2012/13 and 2009/10.

[4] This is less problematic at the zonal level for which the sample is designed to produce agricultural estimates. The zone is much larger than a *woreda* and therefore will have many more observed values of yield for every crop.

The following maps present the sampling issue.[5] Figure 2.1 identifies samples taken of North Gondar, a typical zone in Amhara. The distribution appears random and to be representative at the zonal level. However, when projecting *woreda* boundaries on this zonal map as in Figure 2.2, the difficulties of calculating agriculture production at the *woreda* level are apparent in the areas sampled.

Figure 2.1

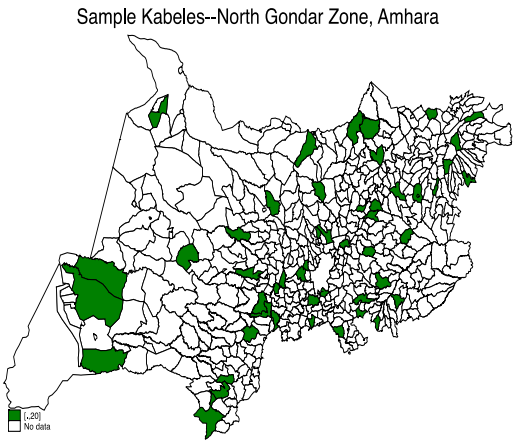
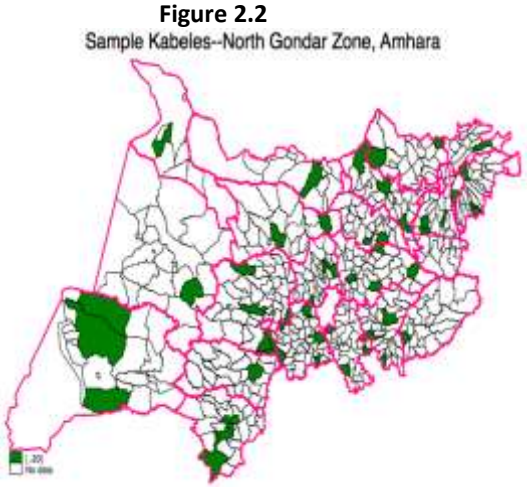


Figure 2.2



As seen in Figure 2.2, where *woreda* boundaries are outlined in pink, several *woredas* have only one sample. However, by using multiple EAs over several years, we augment one year of data with additional years to improve our estimates. That is while one year may not be fully representative of any particular *woreda*, using multiple years of data builds sampling confidence by increasing the number of observations.

The *woreda* estimates cover 552 *woredas* within the four principal regions (Amhara, Tigray, SNNP, and Oromia). While a master list of *woredas* for the four regions included 625 total *woredas*, only 541 *woredas* were sampled by the AgSS in 2012/13.[6] Of the remaining 84, 63 were deemed as urban *woredas* with low agricultural potential, small size, and relatively high population density. Ten additional *woredas* were removed becasue they were either national parks or towns. The remaining 11 were projected with averages of agricultural production. In the 2012/13 AgSS, six were projected using

[5] The map is somewhat misleading as it depicts samples as taken at the kebele level. In fact, EAs are really areas located at the sub-*kebele* level. However, since EAs do not cross kebele boundaries and we do not have mapping abilities at the EA level, the maps provide a rough approximation of the issue.

[6] A master list of *woredas* was obtained from the Agricultural Transformation Agency (ATA).

zonal averages of the *woreda's* respective zone and the remaining five were given 50% of the estimated production output from the *woreda* that were recently split.[7] Because the 2009/10 AgSS used a different EA sampling frame (estimating a total of 527 *woredas)*, different *woredas* from those in 2012/13 were not sampled in 2009/10 and zonal averages were used in these cases.

Since this analysis changed the sampling frame from the zonal to the *woreda* level, new sampling weights were the estimated number of households in a *woreda* divided by the number of sampled households. This number then served as the initial sample weight for the *woreda*.[8] It should be noted that the sample weights were roughly similar to CSA's because the total number of households estimated are the same and only differ by geographic estimating areas (weights here ranged from 22 to 1650 while the CSA's weights ranged from 14 to 1848). As would be expected with the weighting reconfiguration, when *woreda* production projections were summed to the zonal level for direct comparison, they were somewhat different than CSA's estimates. To better conform to the CSA estimates, the sample weights were adjusted so that the estimates roughly approximated the CSA's zonal estimates. Our original estimates varied by an absolute average of approximately 15%, which was reduced to about 3% after the adjustments were made (see Appendix A).

2.4 Determining the Production Rankings

After the sampled data had been weighted, and *woreda*-level production estimates were normalized to the CSA zonal data, *woreda* production rankings were produced. Rankings were produced as weighted averages of multiple years of rankings in the normalized descending weight scheme as follows: $\text{Finalcroprank}=.4*\text{croprank}_{2012/13} + =.3*\text{croprank}_{2011/12} + =.2*\text{croprank}_{2010/11} + .1*\text{croprank}_{2009/10}$.[9] This gives the most weight to the most recent year while still taking prior years into consideration. The final weighted rank was itself ranked to provide final ordered rankings. If data were not available in any particular year, the final crop rank average was computed with that year omitted, and the new rankings were normalized to be comparable to other final rankings.

[7] The six *woredas* for which zonal averages were used include Berehet, Legehida, Menz Lalo Meder, Halu, Basona Worena, and Guba Lafto. The *woredas* which had split include Zigem, Haro Limu, Dega, N/Benja and I/Gelan.
[8] For example, assume a *woreda* had 20,000 households and a sample of 40 households. The sampling weight would then be 20,000/40 or 500. This would mean that each of the sampled households represents an estimated 500 households.
[9] In the event that a one-year ranking was dropped (27 cases) the remaining weight values were kept and where then used to normalize the overall ranking (i.e. if 2012/13 was dropped the remaining weights would be used and then the value would be divided by .6 to normalize the ranking).

The rankings were created for each of the eight crops by *woreda* (552) for each of the four years. This created a total of 17,664 rankings. Of particular interest was whether the individual *woreda* rankings for each of the eight crops were stable over all the years. If the rankings remain relatively similar, then this would give better statistical credence to the panel data aggregation method. In other words, if Kewet *woreda* was ranked 54th in sorghum production in 2012/13, how close was the predicted ranking for the other years? Absolute value differences of ranking between years were taken of each crop by each *woreda* to determine the amount of ranking change between years[10]. For example, if Kewet was ranked 54th in Sorghum production in 2012/13 and then 83rd in 2011/12 the difference would be negative (-29). The absolute value of this would be added to all the differences between 2012/13 and 2011/12. In order to put the rankings into proper statistical context, a statistical simulation was run to see what the values would be if the rankings were randomly generated. The difference between the simulation and our rankings turned out to be highly significant and suggested relatively low variation in rankings (see Appendix D). More specifically, in absolute value terms, the total difference between rankings in 2012/13 and 2011/12 for wheat (38), maize (47), barley (45), sorghum (52), teff (45), chickpea (93), sesame (118), and coffee (96) was well below the 183 average value generated by the statistical simulation. Even more encouraging is that the measure of dispersion was reduced if only the top producers were included. This suggests that there is greater stability and less variation in the rankings of the higher producers. Additionally, correlations between the rankings by crop by year were also found to be significant (see Appendix E).[11]

2.5 Adjustments to the *woreda* data

Two principal adjustments were made for perceived outliers or anomalies in the data. Firstly, estimates of yield (quintals per hectare) and normalized area estimates (hectares per farmer) were adjusted so that they were within three standard deviations of the sample mean (see Appendix B).[12]

After the three standard deviation outlier analysis was performed, a coefficient of variation was applied to the production rankings to check for internal ranking consistency. If a coefficient of variation value of the four years of rankings for each crop by each *woreda* had a coefficient greater than one (the standard

[10] If the results were merely summed the results would approximate zero as relatively equal number of *woreda* rankings would be above and below the initial ranking.

[11] All the rankings were cross correlated between years and crops. The only correlation above .5 was the rankings between wheat and barley (Appendix E). Additional correlations of top producers could be performed.

[12] Assuming that the data is normally distributed, only 0.135% of data should be three standard deviations above the mean. Therefore these adjustments are designed to reduce the influence of large extreme values which are statistically improbable on production rankings.

value for "high variation") the *woreda* was singled out as a potential problem *woreda* and additional analysis was performed.[13] A total of 78 rankings were found to have a coefficient of greater than one. Of these, 45 had plausible explanations and were either kept as they were, or the one-year outlier observation was dropped. If a one-year ranking was dropped, the remaining three years served as data for ranking the *woreda*. Thirty-three or about 0.7% of our total rankings (33 out of 4,416 rankings) have a higher variation in rankings and no immediately plausible explanation for the variation (see Appendix C for additional details).

3. Results

3.1 Introduction

One result of disaggregating into *woredas* is depicted in Figures 3.1 and 3.2 using SNNP coffee production as an example. The 2012/13 AgSS zonal estimates of coffee production are mapped in Figure 3.1. The map depicts Bench Maji as one of the most productive zones. However, Figure 3.2 shows new estimates indicating *woredas* that are farther north in the zone are the most productive *woredas* while the southern *woredas* do not produce much coffee. This could be significant for policymakers in terms of identifying more specific coffee priority areas within the zone or at the *woreda* level. In addition, clustering of priority *woreda* interventions could now be configured across zones and regions using more specific technical indicators.

[13] The coefficient of variation is a normalized statistical measure of variance determined by taking the standard deviation of a set of observations and dividing by its mean. In this way, variations can be directly compared across different variables with much different values. Typically, a coefficient of variation less than one is considered low variance and greater than one high variance.

Figure 3.1 SNNP Coffee by Zone

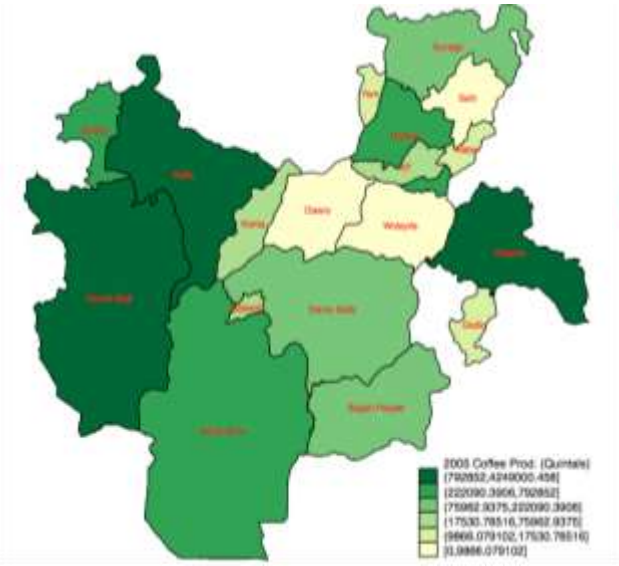
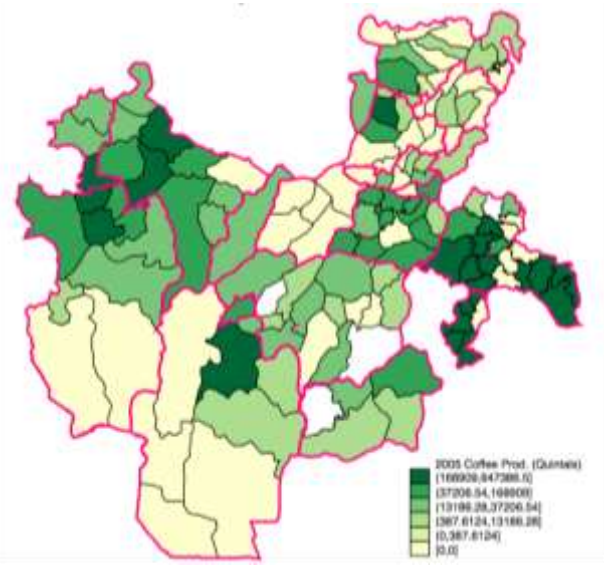


Figure 3.2 SNNP Coffee by *Woreda* Estimates



The following section presents the results of the cross-sectional production rankings of each of the eight crops in the four regions. The tables highlight the top-ranked *woredas* and their annual relative rankings across the four years. The maps provide a spatial relationship of the higher producing *woredas*[14].

3.2 Production-Based Rankings for Major Crops by *Woreda*

In this sub-section, the top twenty-five *woredas* by crop, ranked according to the four-year weighted average are presented in tables. In addition, a map highlighting the top 100 *woredas* is provided for spatial depiction. A brief discussion follows each of the crops.

Wheat

Figure 3.3 shows the top 100 wheat producing *woredas*. They are primarily located in Oromia, Amhara, and Tigray. As the map indicates, the higher producing *woredas* are clustered in four main locations. While these groups vary in size, the largest is located in the Arsi-Bale area of Oromia. Of the top 25

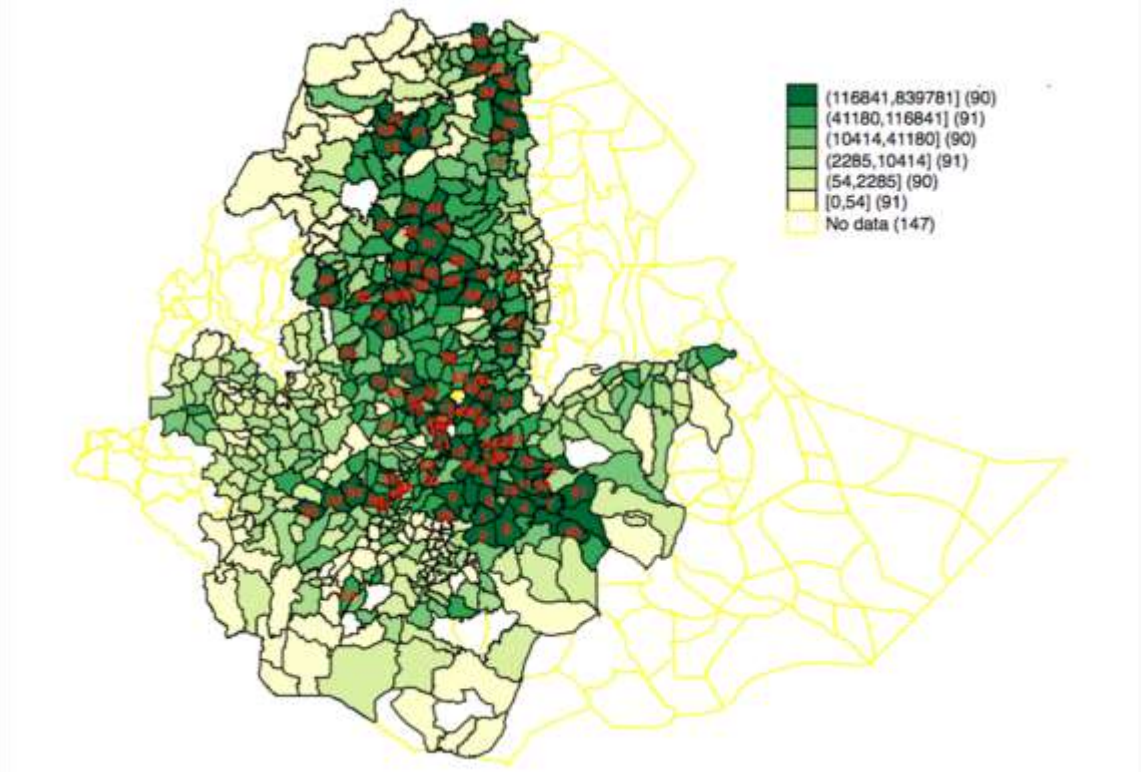
[14] A supplemental spreadsheet is available from the authors. The spreadsheet includes individual *woreda* rankings by crop by year as well as the weighted average ranking for each *woreda* of all four production years. Finally, data availability for each *woreda* (whether zonal average predicted or AgSS samples were used) is provided.

woredas, 19 were in Oromia, five in Amhara and one in Tigray. Overall, the highest producing wheat production *woredas* are principally located in three Oromia zones (West Arsi, Arsi, and Bale). This area, the "wheat belt" of Arsi-Bale zones, has nine of the top ten producing *woredas* as well as 16 of the top 25.

Table 3.1: Top 25 Wheat Producing *Woredas* 2009/10 – 2012/13

Region	Zone	*Woreda*	2009/10	2010/11	2011/12	2012/13	Avg	Final
Oromia	West Arsi	Gedeb Asasa	2	4	2	1	2	1
Oromia	Bale	Ginir	0	1	4	4	3.33	2
Oromia	West Arsi	Dodola	3	5	3	3	3.4	3
Oromia	West Arsi	Arsi Negele	7	11	1	2	4	4
Oromia	Bale	Agarfa	31	9	8	7	10.1	5
Oromia	Arsi	Digeluna Tijo	54	2	5	8	10.5	6
Amhara	East Gojjam	Baso Liben	10	3	11	16	11.3	7
Oromia	Bale	Gasera	13	8	15	10	11.4	8
Oromia	Arsi	Limuna Bilbilo	16	30	7	5	11.7	9
Oromia	Arsi	Munesa	0	14	10	12	11.78	10
Oromia	West Arsi	Adaba	24	17	12	6	11.8	11
Oromia	Bale	Sinana	0	12	16	9	12	12
Amhara	North Shewa	Minjar Shenkora	19	6	22	11	14.1	13
Oromia	Arsi	Robe	4	32	9	21	17.9	14
Oromia	East Shewa	Dugda	8	34	17	14	18.3	15
Oromia	Arsi	Hitosa	1	10	29	22	19.6	16
Tigray	South Tigray	Enderta	40	23	13	19	20.1	17
Oromia	South West Shewa	Sebeta Hawas	34	7	18	25	20.2	18
Amhara	North Gonder	Wegera	122	19	6	13	23	19
Oromia	East Shewa	Gimbichu	28	29	24	20	23.8	20
Oromia	Arsi	Tiyo	65	31	21	15	25	21
Oromia	Arsi	Shirka	128	13	19	18	28.3	22
Oromia	Arsi	Sire	108	18	20	28	31.6	23
Amhara	North Gonder	Jan Amora	205	15	14	17	34.5	24
Amhara	South Gonder	Misrak Este	14	16	38	47	34.8	25

Figure 3.3 *Woreda*-Level Wheat Producers 2009/10 – 2012/13



Maize

Higher maize producing *woredas* are primarily located in both the western parts of Oromia and Amhara as well as the northern area of Oromia. Roughly speaking, there are two main clusters with the largest existing along the western border of Amhara and Oromia. The other cluster falls to the northern portion of Oromia and groups eastward. Of the top 25 *woredas*, 15 are located in Oromia, nine in Amhara, and one in SNNP.

Figure 3.4 *Woreda*-Level Maize Producers 2009/10 – 2012/13

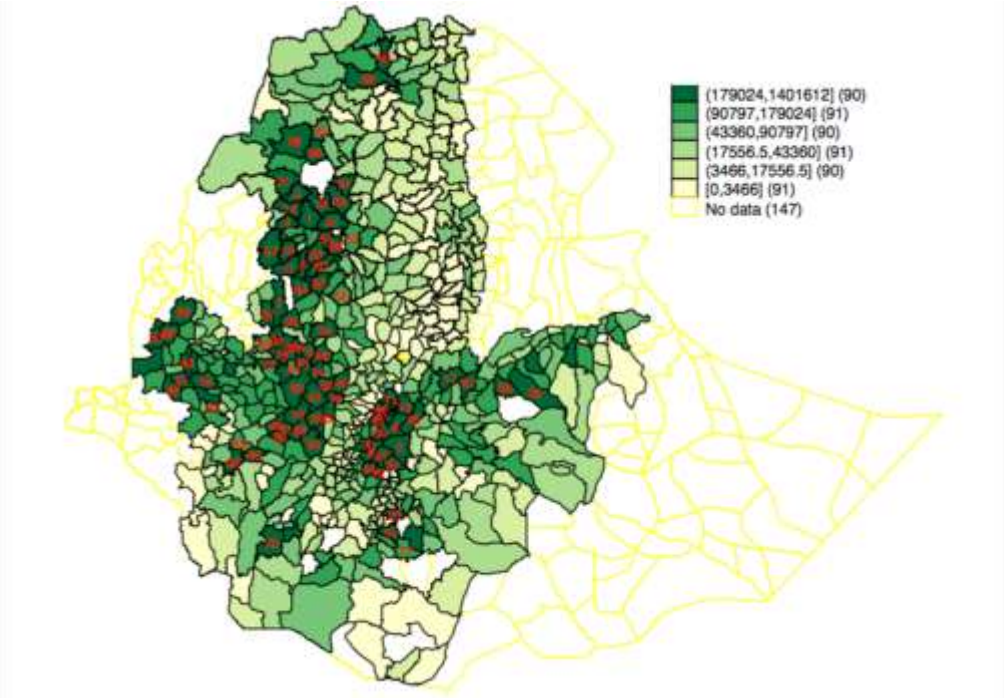


Table 3.2: Top 25 Maize Producing *Woredas* 2009/10 – 2012/13

Region	Zone	*Woreda*	2009/10	2010/11	2011/12	2012/13	Avg	Final
Amhara	West Gojjam	Mecha	2	1	3	1	1.7	1
Oromia	West Arsi	Arsi Negele	8	2	6	3	4.2	2
Oromia	West Shewa	Bako Tibe	5	3	5	5	4.6	3
Amhara	Awi	Dengila	6	12	15	7	10.3	4
Amhara	West Gojjam	North Achefer	36	7	17	4	11.7	5
Amhara	West Gojjam	Bure	7	16	11	16	13.6	6
Oromia	East Wellega	Gida Keremu	4	21	19	9	13.9	7
SNNP	Alaba	Alaba	27	14	12	14	14.7	8
Oromia	East Shewa	Adami Tulu Jido	15	10	8	28	17.1	9
Oromia	Jimma	Limu Kosa	38	26	25	2	17.3	10
Amhara	West Gojjam	Wenberma	22	8	4	33	18.2	11
Amhara	West Gojjam	South Achefer	3	13	29	17	18.4	12
Oromia	East Shewa	Dugda	147	11	1	6	19.6	13
Oromia	West Shewa	Dano	59	23	16	12	20.1	14
Amhara	Awi	Ankasha Guagusa	81	18	13	15	21.6	15
Oromia	Ilu Aba Bora	Darimu	11	38	26	19	24.1	16
Oromia	East Shewa	Boset	34	45	34	8	25.8	17
Amhara	West Gojjam	Bahir dar zuriya	23	20	23	34	26.8	18
Oromia	East Wellega	Sibu Sire	32	32	24	27	27.6	19
Amhara	West Gojjam	Dembecha	75	22	20	26	28.3	20
Oromia	East Wellega	Limu	166	24	10	10	28.4	21
Oromia	Qeleme Wellega	Hawa Gelan	13	40	33	23	28.4	22
Oromia	Guji	Bore	9	100	14	11	29.5	23
Oromia	Horo Gudru Wellega	Gudru	17	28	47	21	29.8	24
Oromia	Horo Gudru Wellega	Abe Dengoro	31	34	35	24	30	25

Barley

Wheat and barley are often thought to be the most substitutable crops in Ethiopia's agriculture sector, and while there are important similarities between wheat and barley production, there are also important differences. As the map indicates, there is significant overlap with high-producing wheat *woredas* with Arsi-Bale being the highest producing area. The clustering can be placed into two groupings including the Arsi-Bale area and a "long thin" cluster that is located along the eastern edge of Oromia-Amhara-Tigray. In the top 25, 18 are located in Oromia, five in Amhara and two in Tigray. Similar to wheat, none of the top 25 *woredas* are located in the SNNP. The Arsi-Bale area represents a significant Barley producing area with ten of the top 25, although this is fewer than the wheat concentration. Structurally for malt barley, the country's two malt factories are located in the two identified clusters including North Gondar zone in Amhara and Arsi zone in Oromia.

Figure 3.5 *Woreda* Barley Producers 2009/10 – 2012/13

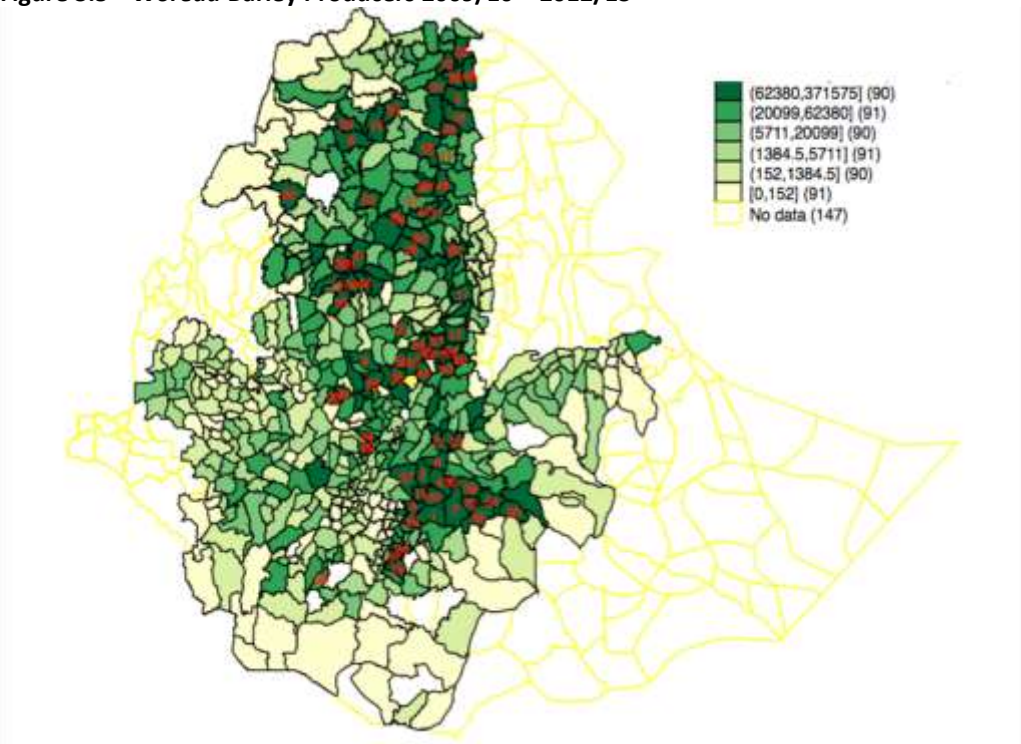


Table 3.3: Top 25 Barley Producing *Woredas* 2009/10 – 2012/13

Region	Zone	*Woreda*	2002	2003	2004	2005	Avg.	Final
Oromia	West Arsi	Dodola	1	5	1	1	1.8	1
Oromia	Arsi	Munesa	8	1	11	2	5.1	2
Oromia	West Arsi	Kofele	5	3	10	3	5.3	3
Oromia	Arsi	Limuna Bilbilo	12	7	6	4	6	4
Tigray	South Tigray	Enderta	32	9	3	5	7.9	5
Amhara	North Gonder	Wegera	13	11	5	9	8.6	6
Oromia	West Arsi	Adaba	7	2	18	7	9.3	7
Oromia	Arsi	Digeluna Tijo	4	6	26	8	12.6	8
Oromia	West Shewa	Jeldu	36	18	7	10	13.3	9
Oromia	West Arsi	Gedeb Asasa	10	16	4	21	13.8	10
Oromia	North Shewa	Sululta	3	14	12	19	14.3	11
Amhara	North Shewa	Menz Gera Meder	40	32	9	6	15.5	12
Amhara	North Shewa	Basona werana	51	10	21	12	18.2	13
Oromia	West Arsi	Kore	2	4	17	33	19.3	14
Oromia	Bale	Ginir	0	35	25	11	21	15
Tigray	South Tigray	Hintalo Wajirat	33	12	16	27	21.3	16
Amhara	North Gonder	Jan Amora	47	38	15	13	22	17
Oromia	North Shewa	Kimbibit	28	24	14	26	22.2	18
Amhara	East Gojjam	Gozamin	27	39	23	17	24.2	19
Oromia	Guji	Uraga	67	21	22	22	26.3	20
Oromia	West Shewa	Jibat	185	8	2	16	27.1	21
Oromia	Arsi	Hitosa	64	13	35	20	27.5	22
Oromia	Guji	Bore	9	27	13	47	29	23
Oromia	Arsi	Deksis	103	20	19	25	30	24
Oromia	North Shewa	Degem	37	30	50	14	30.3	25

Sorghum

High-producing sorghum *woredas* tend to be located in the northern and northeastern parts of Tigray, Amhara, and Oromia. The two primary clusters are in the northern parts of Amhara and Tigray and the northeastern parts of Amhara and Oromia. Several top 100 producing *woredas* are located westward in Oromia. Of the top 25, 13 are located in Amhara, seven are in Tigray and five in Oromia.

Figure 3.6 *Woreda*-Level Sorghum Producers 2009/10 – 2012/13

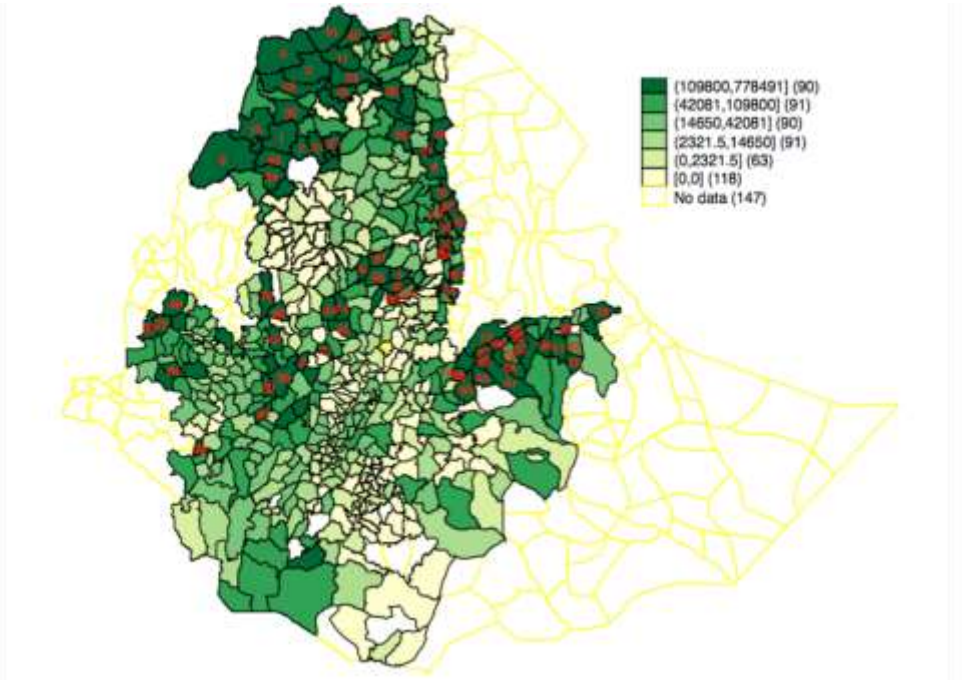


Table 3.4: Top 25 Sorghum Producing *Woredas* 2009/10 – 2012/13

Region	Zone	*Woreda*	2009/10	2010/11	2011/12	2012/13	Avg.	Final
Amhara	North Gonder	Chilga	2	10	2	4	4.4	1
Tigray	Western Tigray	Welqayet	8	20	5	2	7.1	2
Tigray	Western Tigray	Qafta Humera	17	9	10	3	7.7	3
Oromia	West Shewa	Dano	57	7	1	1	7.8	4
Amhara	North Gonder	Dembia	1	15	3	17	10.8	5
Amhara	North Shewa	Mida Oromo	21	1	22	5	10.9	6
Amhara	North Wollo	Kobo	41	3	4	13	11.1	7
Amhara	North Shewa	Merhabete	14	5	19	10	12.1	8
Amhara	North Gonder	Quara	12	4	6	24	13.4	9
Amhara	North Wollo	Habru	28	17	11	14	15.1	10
Tigray	North Western	Asegede Tsimbila	64	2	8	15	15.2	11
Oromia	West Hararge	Meiso	72	8	15	12	18.1	12
Amhara	North Gonder	Debark	0	24	25	11	18.56	13
Amhara	North Gonder	Metema	22	18	14	26	20.4	14
Tigray	North Western	Tahitay Adiyabo	6	41	31	6	20.5	15
Oromia	West Shewa	Abuna Gindeberet	83	35	9	8	21.2	16
Oromia	East Hararge	Girawa	10	26	20	30	24.2	17
Tigray	South Tigray	Rya Azebo	52	42	7	22	24.5	18
Amhara	South Wollo	Kalu	65	19	12	37	28.7	19
Amhara	Oromia	Bati	45	30	28	25	28.9	20
Amhara	North Gonder	Adiarikay	73	25	47	9	30	21
Amhara	North Gonder	Gondar Zuriya	58	22	29	33	32.1	22
Oromia	West Hararge	Mesela	163	32	16	16	33.9	23
Tigray	Western Tigray	Tsegede	33	55	61	7	35.4	24
Tigray	North Western	Tselemt	37	50	21	41	36.4	25

Teff

Teff is centrally located in the country, with many *woredas* in Amhara around Lake Tana and between Bahir Dar and Addis Ababa. High-producing *woredas* are grouped in a single cluster. Of the top 25 producing *woredas*, 15 are located in Amhara and the remaining ten are in Oromia.

Figure 3.7 *Woreda*-Level Teff Producers 2009/10 – 2012/13

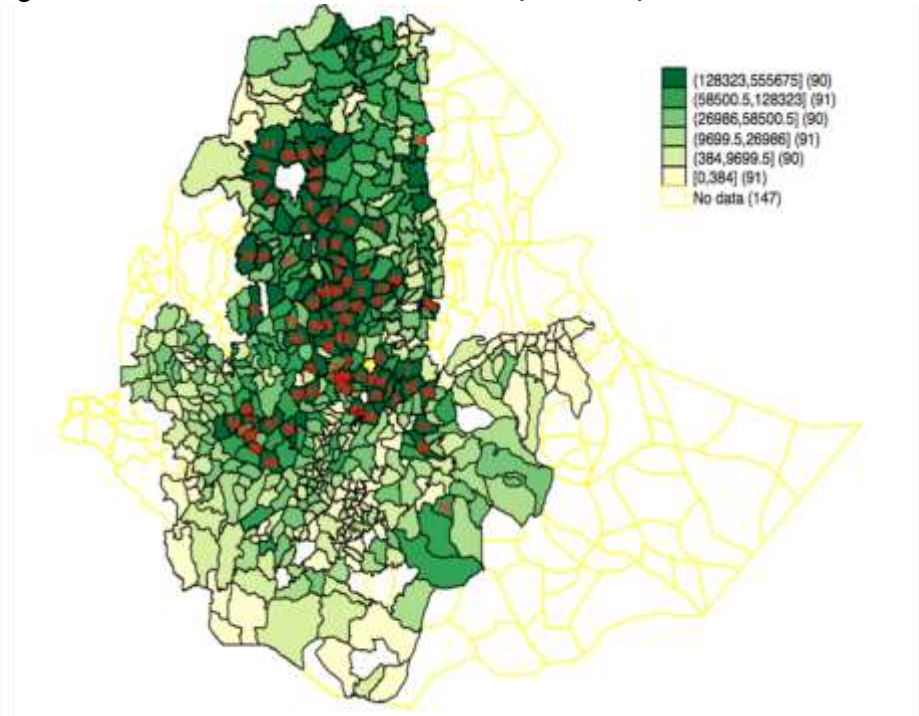


Table 3.5: Top 25 Teff Producing *Woredas* 2009/10 – 2012/13

Region	Zone	*Woreda*	2009/10	2010/11	2011/12	2012/13	Avg.	Final
Oromia	East Shewa	Lomme	3	1	1	1	1.2	1
Amhara	East Gojjam	Enemay	2	3	7	2	3.7	2
Amhara	East Gojjam	Huletej Enese	4	2	2	10	5.4	3
Oromia	East Shewa	Adea	1	9	5	13	8.6	4
Amhara	West Gojjam	Yilmana Densa	5	10	21	12	13.6	5
Oromia	North Shewa	Dera	49	4	24	3	14.1	6
Amhara	North Shewa	Minjar Shenkora	36	8	28	4	15.2	7
Oromia	East Shewa	Adama	7	5	23	18	15.8	8
Amhara	South Gonder	Dera	34	30	12	8	16.2	9
Oromia	South West Shewa	Sebeta Hawas	71	14	13	11	18.2	10
Oromia	South West Shewa	Becho	32	12	35	6	18.5	11
Amhara	Awi	Ankasha Guagusa	92	7	3	19	19.1	12
Amhara	East Gojjam	Awabel	12	35	30	7	20	13
Amhara	South Wollo	Wogidi	27	52	31	5	24.4	14
Amhara	East Gojjam	Enarj Enawuga	104	42	14	9	26.6	15
Amhara	South Gonder	Simada	24	49	19	22	26.7	16
Amhara	South Gonder	Misrak Este	38	11	42	21	27	17
Oromia	West Shewa	Abuna Gindeberet	9	63	26	16	27.7	18
Oromia	North Shewa	Were Jarso	10	25	33	30	27.9	19
Oromia	South West Shewa	Ameya	40	13	27	34	28.3	20
Amhara	East Gojjam	Aneded	8	33	48	17	28.6	21
Amhara	East Gojjam	Dejen	22	20	9	51	29.3	22
Oromia	West Shewa	Adea Berga	174	27	4	14	29.6	23
Amhara	East Gojjam	Shebel Berenta	23	48	40	15	29.9	24
Amhara	North Gonder	Alefa	57	21	49	20	32.6	25

Chickpea

Although there is slightly more dispersion than teff, chickpea is also located in the central parts of Ethiopia. Chickpea has a single cluster that primarily exists in the Amhara-Oromia area. Again like teff, 15 of the top 25 producing chickpea *woredas* are located in Amhara and the remaining ten are in Oromia.

Figure 3.8 *Woreda*-Level Chickpea Producers 2009/10 – 2012/13

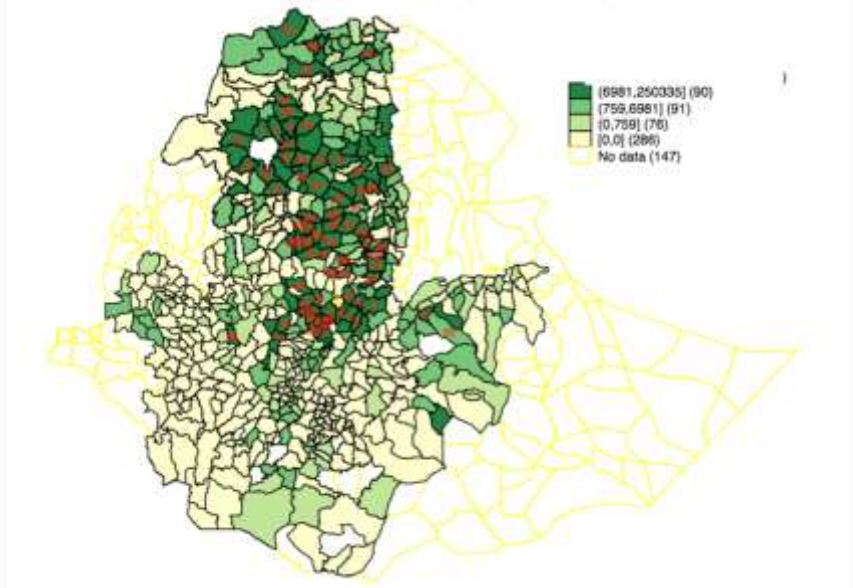


Table 3.6: Top 25 Chickpea Producing *Woredas* 2009/10 – 2012/13

Region	Zone	Woreda	2009/10	2010/11	2011/12	2012/13	Avg	Final
Amhara	North Gonder	Dembia	2	2	1	3	2.1	1
Amhara	North Shewa	Minjar Shenkora	3	25	3	1	6.6	2
Oromia	South West Shewa	Sebeta Hawas	42	5	2	2	6.6	3
Amhara	North Gonder	Merab Belesa	27	1	6	5	6.7	4
Oromia	East Shewa	Adea	7	8	4	10	7.5	5
Oromia	East Shewa	Lomme	1	7	9	9	7.8	6
Oromia	South West Shewa	Tole	11	10	13	4	8.6	7
Oromia	East Shewa	Akaki	25	9	7	6	8.8	8
Amhara	North Gonder	Gondar Zuriya	50	3	5	8	10.3	9
Oromia	South West Shewa	Becho	6	4	8	20	11.8	10
Oromia	South West Shewa	Ilu	8	31	10	11	14.4	11
Amhara	North Gonder	Chilga	0	20	17	12	15.4	12
Oromia	South West Shewa	Ameya	26	6	20	17	16.6	13
Amhara	East Gojjam	Enemay	5	12	12	28	17.7	14
Amhara	North Gonder	Takusa	73	15	16	7	17.9	15
Oromia	East Shewa	Gimbichu	4	17	22	19	18	16
Amhara	North Shewa	Basona werana	38	14	21	13	18.1	17
Oromia	West Shewa	Ejerie	30	13	18	18	18.2	18
Amhara	South Wollo	Wogidi	21	32	15	16	19.4	19
Amhara	South Gonder	Simada	60	29	11	23	24.3	20
Amhara	West Gojjam	North Achefer	14	21	46	14	25	21
Amhara	South Gonder	Ebinat	0	42	26	21	27.3	22
Amhara	South Gonder	Fogera	12	27	52	15	28.2	23
Amhara	South Gonder	Misrak Este	70	30	19	25	28.7	24
Amhara	East Gojjam	Enarj Enawuga	84	37	14	26	30.4	25

Sesame

While there is some dispersion around the country, most sesame production is located in the northernmost parts of the country. Two basic clusters exist, with the primary cluster in the northern parts of Tigray and Amhara regions. A second, smaller, cluster exists in western Amhara and Oromia. Tigray dominates the highest producing sesame *woredas* with five of the top ten producers being located in this region. In terms of the top 25 *woredas*, Amhara has 12 of the top 25. Oromia has eight in the top 25 and SNNP has none.

Figure 3.9 *Woreda*-Level Sesame Producers 2009/10 – 2012/13

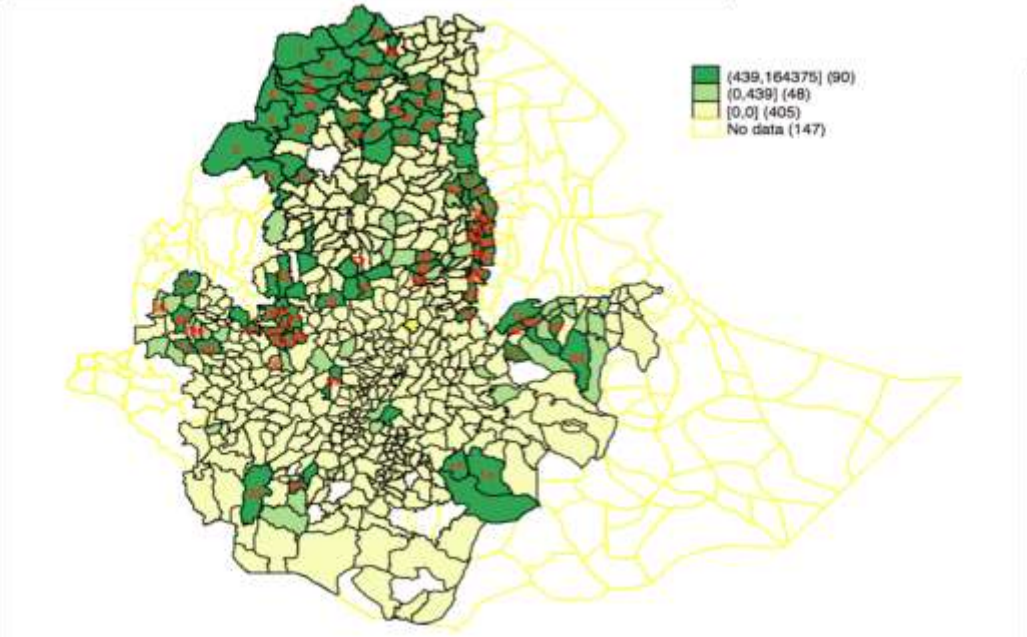


Table 3.7: Top 25 Sesame Producing *Woredas* 2009/10 – 2012/13

Region	Zone	*Woreda*	2009/10	2010/11	2011/12	2012/13	Avg	Final
Tigray	Western Tigray	Qafta Humera	4	2	2	1	1.8	1
Amhara	North Gonder	Quara	1	1	1	4	2.2	2
Tigray	Western Tigray	Welqayet	3	3	3	2	2.6	3
Amhara	North Gonder	Metema	6	4	5	5	4.9	4
Tigray	Western Tigray	Tsegede	5	6	4	6	5.3	5
Amhara	North Gonder	Mirab Armacho	7	15	6	3	6.7	6
Tigray	North Western	Tahitay Adiyabo	2	11	9	10	9.1	7
Amhara	West Gojjam	Bure	0	7	7	14	10.1	8
Oromia	West Wellega	Gimbi Asegede	0	20	11	8	11.7	9
Tigray	North Western	Tsimbila	18	5	17	15	13.9	10
Amhara	Wag Himra	Abergele	28	12	19	9	14.5	11
Amhara	North Gonder	Tach Armacho	9	18	20	12	15.3	12
Oromia	East Wellega	Limu	0	25	13	13	15.6	13
Amhara	North Gonder	Debark	0	17	28	7	16.2	14
Oromia	Horo Gudru Wellega	Abe Dengoro	0	21	16	16	17.1	15
Amhara	Awi	Jawi	10	8	21	23	18.1	16
Oromia	Horo Gudru Wellega	Amuru	0	16	30	11	18.4	17
Oromia	Bale	Meda Welabu	0	10	8	31	18.7	18
Amhara	East Gojjam	Baso Liben	0	13	18	25	20	19
Oromia	West Hararge	Meiso DeloMena	52	23	12	17	20.2	20
Oromia	Bale	Angetu	37	14	15	29	22.6	21
Amhara	Oromia	Bati	15	33	24	20	23.3	22
Amhara	North Gonder	Alefa	17	0	40	19	26.6	23
Oromia	East Wellega	Sibu Sire	22	29	32	28	28.8	24
Amhara	West Gojjam	North Achefer	46	19	41	21	29.1	25

Coffee

Coffee production is primarily located in southern parts of the country, including the SNNP and Oromia regions. Production is grouped in three main clusters, including two in southern Oromia and SNNP and one cluster in northwestern Oromia. In terms of the top 25, Oromia dominates with 18 of the top 25. More specifically, Jimma zone in Oromia has five of the top 25 producing *woredas*. The remaining top coffee producing *woredas* are located in SNNP.

Figure 3.10 *Woreda*-Level Coffee Producers 2009/10 – 2012/13

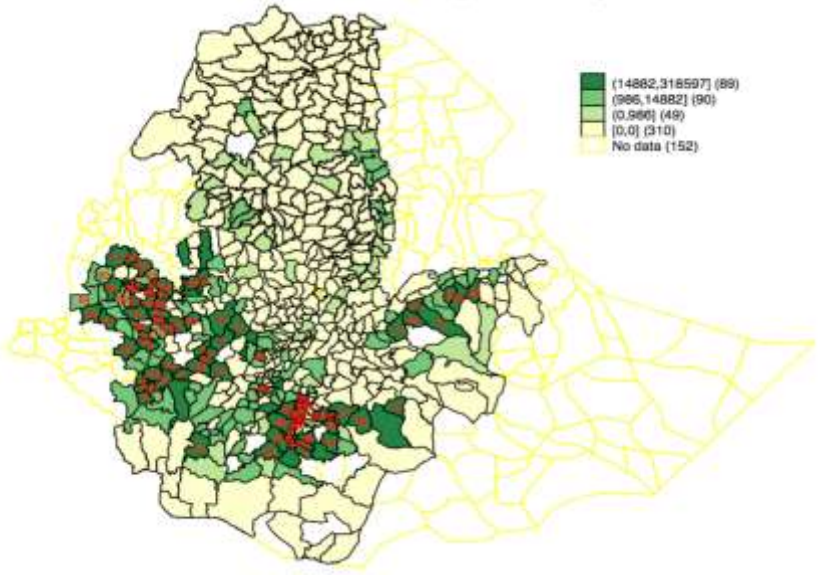


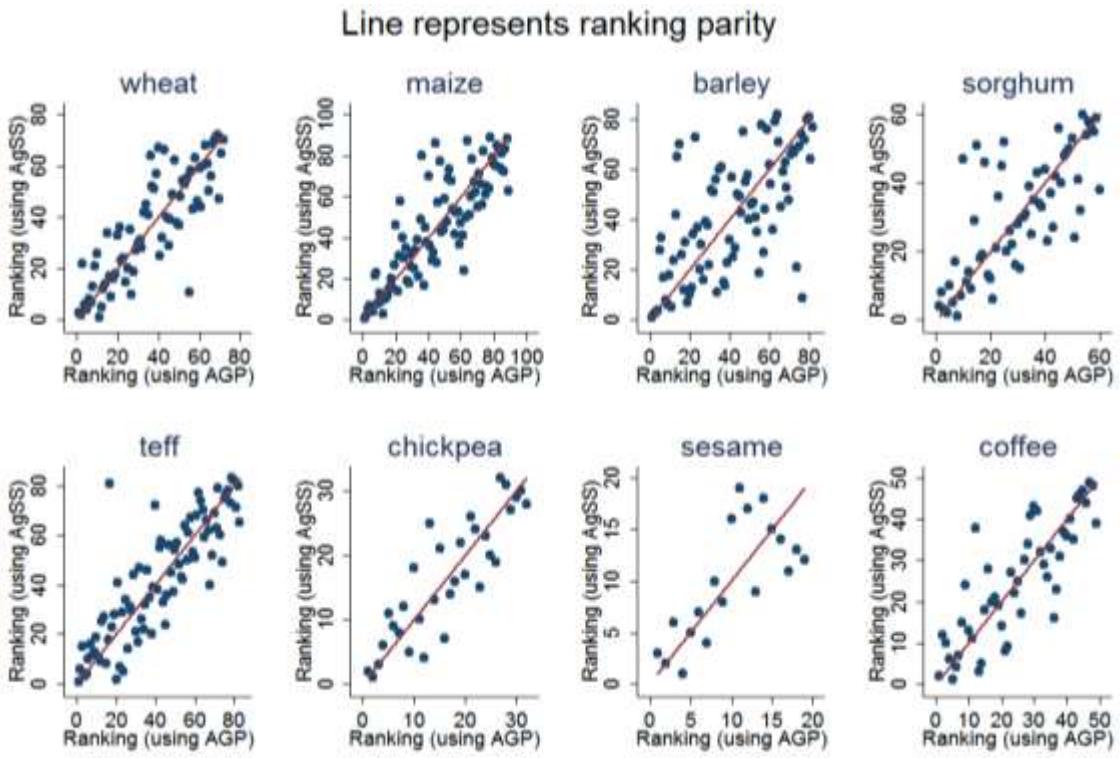
Table 3.8: Top 25 Coffee Producing *Woredas* 2009/10 – 2012/13

Region	Zone	*Woreda*	2009/10	2010/11	2011/12	2012/13	Avg	Final
Oromia	Guji	Qercha	2	1	3	1	1.7	1
Oromia	Jimma	Limu Kosa	3	2	1	8	4.2	2
Oromia	Borena	Bule hora	0	10	5	2	4.8	3
SNNP	Sheka	Yeki	16	4	4	5	5.6	4
Oromia	Jimma	Gomma	1	3	2	11	5.7	5
Oromia	Jimma	Mana	4	12	6	6	7	6
SNNP	Sidama	Dale	14	8	12	16	13	7
SNNP	Gedeo	Yirgachefe	13	16	17	13	14.8	8
SNNP	Bench Maji	Sheko	65	15	13	4	15	9
SNNP	Gedeo	Kochore	12	37	16	7	16.2	10
SNNP	Bench Maji	Southern Bench	21	14	33	9	18.4	11
Oromia	Jimma	Chora Boter	134	11	7	3	18.9	12
SNNP	Sidama	Aleta Wondo	64	7	14	18	19.2	13
Oromia	Arsi	Gololcha	15	22	34	12	20.9	14
Oromia	Bale	Delo Mena Angetu	0	31	36	10	23.3	15
Oromia	West Wellega	Haru	11	18	18	36	24.5	16
Oromia	Guji	Hambela Wamena	36	20	39	15	25.3	17
Oromia	Ilu Aba Bora	Yayu	18	26	27	26	25.5	18
Oromia	West Arsi	Nensebo	37	39	28	14	25.5	19
Oromia	West Wellega	Lalo Asabi	27	23	15	35	25.8	20
Oromia	Jimma	Gera	28	28	25	0	26.5	21
Oromia	Qeleme Wellega	Anfilo	5	6	10	56	27.1	22
Oromia	West Hararge	Boke	23	41	37	21	30	23
Oromia	West Wellega	Mene Sibu	81	50	31	17	34.2	24
Oromia	Guji	Odo Shakiso	0	74	29	20	35	25

3.3 Cross-Checking the Estimates with Other Sources

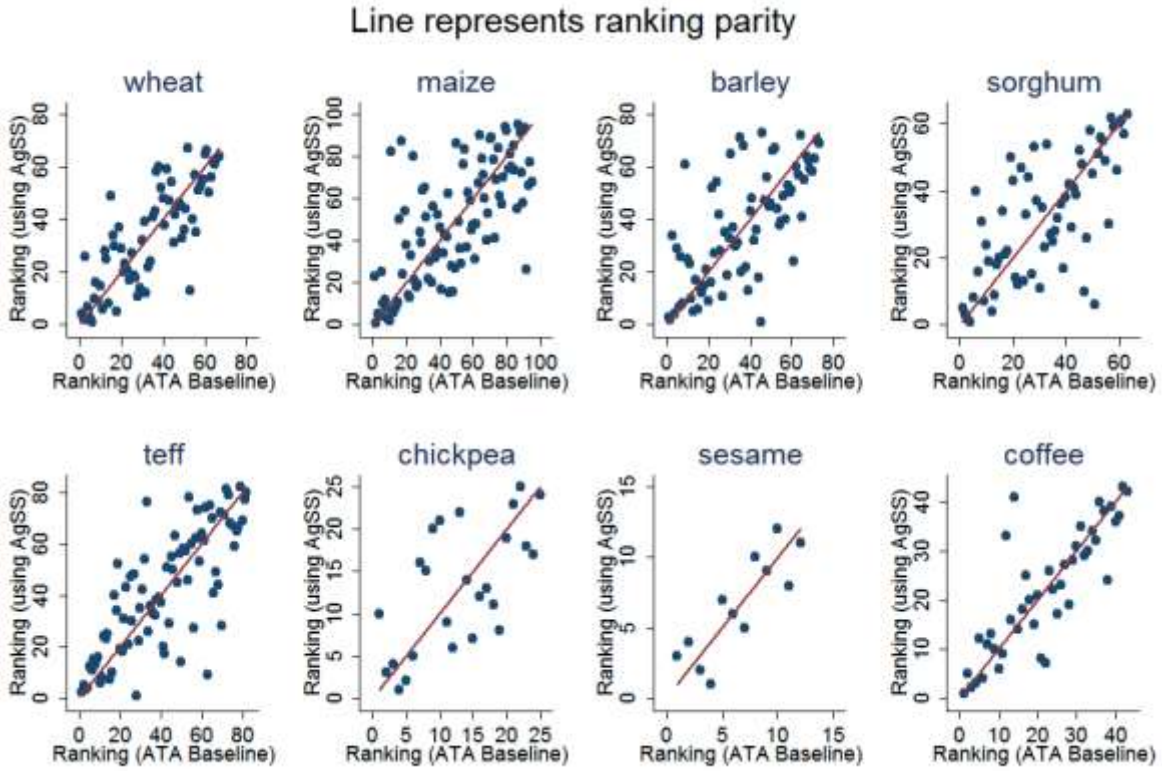
The CSA AgSS data source is the most comprehensive data source available for Ethiopian agricultural production data. However, two smaller recent agricultural surveys also exist, and these data sets were contrasted with identical *woredas* in the AgSS to serve as a robustness check of the *woreda* rankings produced with AgSS data. We obtained the ATA Baseline survey data (2011/12) and the AGP Baseline survey data (2010/11) and replicated the *woreda*-level production and ranking estimation process with these data sets. The rankings produced using the AgSS data were compared with rankings generated from both the ATA baseline and AGP baseline data in the respective sampled years and only among sampled *woredas* common to both surveys. Agricultural plots were sampled in only approximately 100 *woredas* in both the ATA and AGP baseline data. Comparisons vary from a low 12 *woredas* for sesame to approximately 100 for wheat. The results are very robust, and correlations between our AgSS sub-samples and the two other data sets range from a low of .64 to a high of .86 (see Appendix F). Given the entirely different sample design and framework for collection, the results show remarkably strong corroboration for our pooled data methodology.

Figure 3.11: Crop rankings comparing AGP baseline and AgSS data in 2010/11



Figures 3.11 and 3.12 directly compare the rankings produced using the ranking in the year of the corroborating data source. The individual rankings are highly correlated with the final rankings produced using the AgSS data in all crops and for both data sources. This confirms e that the AgSS data is reliable for ranking production of the eight crops. Specific Pearson correlation coefficients are available for the rankings in Appendix F.

Figure 3.12: Crop rankings comparing ATA baseline and AgSS data in 2011/12



4. Future Research Areas

There are many potential extensions that could be undertaken with this research. Several are discussed below.

1. Supplementing the current rankings with data to come from the 2013/14 AgSS. Rankings from 2009/10-2012/13 were expected to be highly correlated because essentially the same areas were sampled, but 2013/14 is anticipated to have a significantly different set of EAs in the sample. The additional data will add robustness to our current rankings.

2. Placing in value terms (price*crop) allows for value aggregation of crops and value rankings. Values could also be used for specific crops or specific groups of crops (e.g. cereals).
3. There are a variety of additional data sources that could be used in conjunction with AgSS production data. This data could be merged with other *woreda*-based attribute data. For example, the CSA uses agro-ecological depictions to help shape their sampling techniques. Data exists at the *woreda* level that depicts land type and quality. In addition, the Water & Land Resource Centre (WLRC) collects detailed agro-ecological data at a sub-*kebele* level. This information could be used for either evaluating production estimates or determining specific production and agro-ecological characteristics at the *woreda*, *kebele* or even a smaller level of analysis.
4. Combining political boundaries with other geographic information (roads, water bodies, major population centers, etc.) could lend sophistication to determining production amounts or geographic clustering. To give a sense of productivity within area, density maps could also be presented. Density maps provide a strong indication of *woreda* production clustering; however, like the current maps, these do not have a strong empirical focus. With household GIS coordinates, production concentrations could be determined at the inter-*woreda* level.
5. Beyond the visual inspection of *woreda* "clustering" (groups of *woredas* with similar production or rankings) in the above maps, additional spatial analysis could be researched. Empirical estimates could be used to quantify the degree of clustering. Quantifying the clustering could provide more explicit rankings of the extent of *woreda* groupings beyond just a visual approach.
6. While potentially creating some statistical sampling issues, some trends might be determined to show the changing nature of crop production at the *woreda* level. As the data collected is panel data, production changes could be evaluated over time.
7. A great deal of ancillary data was created by this analysis that could be used for more detailed analysis. Estimated production area, number of farmers growing individual crops, and other aspects of the AgSS estimates could be projected at the *woreda* level. Finally, additional data from the AgSS could be included for *woreda*-level estimation. We did consider food security data sources, thinking that food insecure *woredas* should not generally be high producers of crops. This assessment generally held up; however the data is inconsistent with sources, and further discussion can be found in Appendix G.

5. Conclusion

This paper reweighted the data, using multiple years of the largest existing agricultural data set, to produce 51 CSA zonal agricultural estimates to obtain 552 *woreda*-level estimates. To accomplish this, we used a variety of sampling methodologies. Most notably, we expanded our data set to include four years of agricultural production estimates, corrected for perceived outliers and reconfigured sampling weights to reflect *woreda*, not zonal, projections. As is the case with panel data analysis, we felt the expanded data provides a more robust estimate of major crop production at the *woreda* level. Studying both the extreme values (limiting observations to three standard deviations from the mean) and the volatility of rankings (coefficient of variation analysis) indicated some anomalies in the data and estimates. Nonetheless, these issues are minor compared to the overall data set, and less than 1% of all projections were not reconciled. The results provide a basic overview of *woreda*-level production in the four main producing areas of Ethiopia. While these rankings could be refined with future research and additional data, overall, we believe these rankings are relatively accurate and potentially very useful for policy interventions at the *woreda* level.

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Appendix A – CSA Zonal Estimate Comparison

In order to better align the new production estimates with the estimates produced by the CSA, the results were compared at the zonal level by summing the new production figures by crop to the zonal level. The two zonal production estimates were compared using the mean absolute value of percentage error. The original estimates missed CSA estimates by absolute percentages ranging from 8.5 to 22.8. Since the errors at the zonal level were high, the percentage error was computed, and all the *woreda* production estimates in each zone were adjusted by the percentage difference across the zone. This was accomplished by changing the weighting scheme for each *woreda* to incorporate the zonal percentage error. A second set of production estimates were then produced, and these adjusted production estimates had mean absolute errors that ranged between 1.1 – 7.2 percentage points. The adjusted *woreda* estimates better reflect the CSA estimates at the zonal level with lower errors; however, there are still differences between the adjusted estimates and the CSA estimates because each set of estimates is produced using different weighting schemes and each has a different geographic unit of analysis. A fourth year of errors was not determined due to data inconsistencies in estimates produced for Oromia in 2009/10.

Table A.1: Comparison of Errors Before and After Zonal Adjustment for CSA Figures 2012/13

	Mean Absolute % Error	Std. Dev.	Min	Max
Original Wheat Error	15.2	14.7	0.1	80.8
Adjusted Wheat Error	4.4	10.1	0.0	65.2
Original Maize Error	11.8	11.7	0.1	61.9
Adjusted Maize Error	2.7	5.9	0.0	38.4
Original Barley Error	16.3	15.2	0.1	69.8
Adjusted Barley Error	4.9	9.7	0.0	48.8
Original Sorghum Error	12.4	12.5	0.1	71.0
Adjusted Sorghum Error	3.1	7.5	0.0	50.4
Original Teff Error	11.6	11.3	0.6	46.0
Adjusted Teff Error	2.6	4.6	0.0	21.2
Original Chickpea Error	14.7	10.4	0.4	40.7
Adjusted Chickpea Error	3.2	4.0	0.0	16.6
Original Sesame Error	22.8	14.2	4.2	75.7
Adjusted Sesame Error	7.2	10.4	0.2	57.2
Original Coffee Error	14.7	11.0	0.2	50.9
Adjusted Coffee Error	3.3	4.7	0.0	25.9

Table A.2: Comparison of Errors Before and After Zonal Adjustment for CSA Figures 2011/12

	Mean Absolute % Error	Std. Dev.	Min	Max
Original Wheat Error	17.7	15.9	0.3	83.4
Adjusted Wheat Error	5.5	10.8	0.0	69.5
Original Maize Error	12.9	12.1	0.1	72.3
Adjusted Maize Error	3.0	7.1	0.0	49.1
Original Barley Error	15.6	13.9	0.5	62.6
Adjusted Barley Error	4.3	7.6	0.0	39.2
Original Sorghum Error	15.7	19.1	0.2	121.4
Adjusted Sorghum Error	3.1	4.5	0.0	19.2
Original Teff Error	13.1	11.7	0.1	51.0
Adjusted Teff Error	2.9	4.6	0.0	24.1
Original Chickpea Error	16.1	18.4	0.1	99.5
Adjusted Chickpea Error	5.9	15.7	0.0	96.5
Original Sesame Error	19.9	15.6	0.3	76.6
Adjusted Sesame Error	6.3	10.7	0.0	56.8
Original Coffee Error	15.6	12.1	0.1	51.3
Adjusted Coffee Error	3.6	4.5	0.0	18.0

Table A.3: Comparison of Errors Before and After Zonal Adjustment for CSA Figures 2010/11

	Mean Absolute % Error	Std. Dev.	Min	Max
Original Wheat Error	14.8	11.8	0.3	72.8
Adjusted Wheat Error	3.5	7.7	0.0	53.0
Original Maize Error	10.5	7.8	0.5	37.2
Adjusted Maize Error	1.7	2.5	0.0	13.8
Original Barley Error	13.0	10.4	0.6	56.3
Adjusted Barley Error	2.7	5.1	0.0	31.7
Original Sorghum Error	8.5	6.4	0.8	32.2
Adjusted Sorghum Error	1.1	1.7	0.0	10.3
Original Teff Error	11.6	9.6	0.1	41.9
Adjusted Teff Error	2.3	3.5	0.0	17.6
Original Chickpea Error	11.8	7.7	0.1	24.5
Adjusted Chickpea Error	2.0	1.9	0.0	5.6
Original Sesame Error	13.7	8.4	0.4	28.5
Adjusted Sesame Error	2.6	2.7	0.0	8.2
Original Coffee Error	13.6	8.7	1.0	31.6
Adjusted Coffee Error	2.5	2.6	0.0	10.0

Appendix B — Data Adjustments

Data were adjusted downward if they were above the values presented in the tables below. These values represent the mean value added to three times the standard deviation. In parenthesis is the number of adjustments that were made in each year by crop. *Woredas* with high values of quintals per hectare showed almost no correlation between years, implying that there was an unusually high average crop cut in the *woreda*. *Woredas* with high values of hectares per farmer were sometimes correlated among years; however, this may be because the same EAs were sampled in the years 2010/11-2012/13. An example of the methodology is provided following the tables.

Table B.1: Hectares per Farmer Maximum Values by Crop

Crop	2009/10	2010/11	2011/12	2012/13
Wheat	0.984 (8)	0.926 (9)	0.873 (11)	0.923 (13)
Maize	0.809 (7)	0.773 (10)	0.715 (7)	0.693 (6)
Barley	0.721 (12)	0.700 (8)	0.631 (10)	0.608 (8)
Sorghum	1.049 (4)	0.935 (5)	0.946 (6)	0.861 (5)
Teff	1.254 (7)	1.167 (5)	1.156 (5)	1.120 (5)
Chickpea	0.572 (4)	0.594 (3)	0.557 (4)	0.570 (4)
Sesame	1.067 (2)	1.083 (4)	0.857 (3)	0.872 (3)
Coffee	0.492 (9)	0.521 (9)	0.499 (7)	0.507 (8)

Table B.2: Quintals per Hectare Maximum Values by Crop

Crop	2009/10	2010/11	2011/12	2012/13
Wheat	34.58 (0)	35.83 (4)	38.39 (3)	40.64 (3)
Maize	45.64 (1)	44.52 (4)	55.98 (4)	57.98 (6)
Barley	31.15 (4)	32.56 (6)	32.71 (3)	33.74 (4)
Sorghum	38.78 (0)	41.25 (0)	41.30 (2)	44.85 (2)
Teff	28.16 (0)	28.60 (8)	27.53 (5)	29.50 (6)
Chickpea	28.45 (0)	32.52 (0)	34.61 (4)	36.03 (4)
Sesame	24.81 (0)	25.82 (1)	20.40 (4)	22.86 (3)
Coffee	12.06 (0)	13.24 (0)	13.35 (0)	16.04 (5)

When the hectares per farmer data were above the threshold value, they were adjusted downward. After *hectares per farmer* had been adjusted, if there were extreme values of quintals per hectare, these were adjusted by the same type of rule. After both adjustments had been completed, then area and production were estimated. The following examples demonstrate this procedure.

Suppose a *woreda* had a value of hectares per farmer of 1.52 for wheat in 2012/13. This value is greater than the threshold value of 0.923 in Table B.1, the sum of the mean and three times the standard deviation. That data point of *hectares per farmer* would be reduced from the 1.52 to 0.923.

The area would be recalculated by multiplying 0.923 and the number of farmers growing wheat in the *woreda.* If it is assumed that there are 10,000 farmers in the *woreda*, then the area value would be 10,000 farmers * 0.923 Ha / farmer = 9230 hectares. Finally, production is recalculated by multiplying the adjusted area value with the yield estimate. If the yield is assumed to be 25 quintals per hectare, then the production value would be 9230 Ha * 25 Q / Ha = 230,750 quintals.

Once *hectares per farmer* is adjusted, extreme values of quintals per hectare can be adjusted. Fewer quintals per hectare adjustments were made than hectares per farmer adjustments and extreme area measurements tended not to be correlated with extreme yield measurements, so few, if any *woredas* had both adjustments made at the same time. Suppose a different *woreda* had an average wheat yield of 80 quintals per hectare in 2012/13. This is beyond the 40.64 threshold value indicated in Table B.2, which again was the sum of the mean and three times the standard deviation. The quintals per hectare figure would be adjusted downward from 80 to 40.64, and this value would be used to calculate a new output figure. Output is recalculated by multiplying the adjusted yield figure with the total area estimate. If the area in this *woreda* was 4500 hectares, then the production amount of wheat in the *woreda* is estimated to be 4500 Ha * 40.64 Q / Ha = 182,880 quintals.

Appendix C – Coefficient of Variation Analysis

This list identifies 78 entries in 69 *woredas* (nine *woredas* had two crop ranking issues) where the coefficient of variation among all four years of rankings is greater than one. It should be emphasized that there was a total of 4,416 rankings (552 *woredas** eight crops) and only 33 or 0.7% (33/4,416) had no immediate cause for the variation. The table also identifies the year of the unusual outlier and the potential cause. Of the 78 identified, 45 were given one of the following four solutions: A—zonal average used (1 case) and that one year was dropped, B—small or unusual sample (26 cases) and the year was dropped, C—authors did not percieve the actual variation to be that significant (17 cases) and D—small sample size in all samples, so the sample was retained (1 case). A total of 33 *woreda* production rankings were deemed to be the result of different enumeration areas, and no plausible explanation of the significant variation could be offered.

Table C.1: *Woredas* with High Coefficient of Variation

Region	Zone	*Woreda*	Crop	Year	Code	Avg	2005	2004	2003	2002
Tigray	North Western	Asegede Tsimbila	Sorghum	2009/10	C	11	15	8	2	64
Tigray	South Tigray	Enderta	Barley	2009/10	C	5	5	3	9	32
Amhara	North Gonder	Jan Amora	Wheat	2009/10	E	24	17	14	15	206
Amhara	North Gonder	Debark	Sorghum	2009/10	B	42	11	25	24	409
Amhara	North Gonder	Debark	Sesame	2009/10	B	19	7	28	17	112
Amhara	North Gonder	Dabat	Wheat	2009/10	E	32	26	26	26	182
Amhara	North Gonder	Wegera	Wheat	2009/10	E	18	13	6	19	121
Amhara	North Gonder	Gondar Zuriya	Chickpea	2009/10	C	9	8	5	3	50
Amhara	North Gonder	Chilga	Teff	2009/10	E	43	33	6	56	255
Amhara	North Gonder	Chilga	Chickpea	2009/10	B	30	12	17	20	262
Amhara	North Gonder	Alefa	Sesame	2009/10	B	38	19	40	124	17
Amhara	North Gonder	Merab Belesa	Chickpea	2009/10	C	4	5	6	1	27
Amhara	North Gonder	Misrak Belesa	Chickpea	2009/10	E	26	22	33	11	158
Amhara	North Gonder	Takusa	Chickpea	2009/10	C	14	7	16	15	73
Amhara	South Gonder	Ebinat	Chickpea	2009/10	B	44	21	26	42	262
Amhara	North Wollo	Kobo	Sorghum	2009/10	C	6	13	4	3	41
Amhara	South Wollo	Mekdela	Chickpea	2009/10	B	35	32	40	18	157
Amhara	South Wollo	Kutaber	Sorghum	2009/10	B	107	136	71	13	409
Amhara	North Shewa	Minjar Shenkora	Chickpea	2010/11	C	3	1	3	25	3
Amhara	East Gojjam	Huletej Enese	Maize	2012/13	E	52	126	9	19	20
Amhara	East Gojjam	Enarj Enawuga	Teff	2009/10	C	15	9	14	42	104
Amhara	East Gojjam	Baso Liben	Sesame	2009/10	B	24	25	18	13	112
Amhara	West Gojjam	Bure	Sesame	2009/10	B	13	14	7	7	112
Amhara	West Gojjam	Wenberma	Wheat	2009/10	E	55	41	28	25	305
Amhara	Awi	Ankasha Guagusa	Maize	2009/10	E	15	15	13	18	80
Amhara	Awi	Ankasha Guagusa	Teff	2009/10	E	12	19	3	7	92
Oromia	West Wellega	Gimbi	Sesame	2009/10	B	14	8	11	20	112
Oromia	East Wellega	Limu	Maize	2009/10	E	22	10	10	24	168
Oromia	East Wellega	Limu	Sesame	2009/10	B	18	13	13	25	112
Oromia	East Wellega	Gida Keremu	Sesame	2009/10	C	30	53	14	9	112

Region	Zone	*Woreda*	Crop	Year	Code	Avg	2005	2004	2003	2002
Oromia	Jimma	Gomma	Coffee	2012/13	C	4	11	2	3	1
Oromia	Jimma	Gera	Coffee	2012/13	E	104	234	25	28	28
Oromia	Jimma	Chora Boter	Coffee	2009/10	E	11	3	7	11	134
Oromia	Jimma	Guma	Teff	2009/10	E	78	100	15	17	426
Oromia	West Shewa	Ambo	Barley	2011/12	B	208	72	493	160	50
Oromia	West Shewa	Ambo	Teff	2009/10	B	60	56	18	19	362
Oromia	West Shewa	Dano	Sorghum	2009/10	E	7	1	1	7	96
Oromia	West Shewa	Nono	Chickpea	2011/12	E	82	57	232	19	40
Oromia	West Shewa	Adea Berga	Teff	2009/10	E	24	14	4	27	181
Oromia	West Shewa	Metarobi	Teff	2009/10	E	39	46	8	37	208
Oromia	West Shewa	Abuna Gindeberet	Sorghum	2009/10	C	15	8	9	35	82
Oromia	West Shewa	Toko Kutaye	Sorghum	2009/10	E	72	63	37	66	342
Oromia	West Shewa	Toko Kutaye	Teff	2009/10	E	48	31	39	39	259
Oromia	West Shewa	Jibat	Barley	2009/10	E	20	16	2	8	185
Oromia	North Shewa	Dera	Sorghum	2009/10	E	26	32	17	11	173
Oromia	North Shewa	Dera	Teff	2009/10	C	6	3	24	4	48
Oromia	North Shewa	Degem	Sorghum	2009/10	B	87	52	75	68	409
Oromia	North Shewa	Aleiltu	Wheat	2009/10	E	73	70	43	37	278
Oromia	East Shewa	Dugda	Maize	2009/10	E	13	6	1	11	151
Oromia	Arsi	Dodota	Wheat	2009/10	E	59	39	53	39	279
Oromia	Arsi	Zeway Dugda	Maize	2009/10	E	48	53	40	17	192
Oromia	Arsi	Chole	Barley	2009/10	B	124	124	57	37	486
Oromia	Arsi	Shirka	Wheat	2009/10	E	21	18	19	13	128
Oromia	Arsi	Digeluna Tijo	Wheat	2009/10	E	5	8	5	2	54
Oromia	Arsi	Munesa	Wheat	2009/10	B	11	12	10	14	63
Oromia	Arsi	Ludehetosa	Barley	2009/10	B	56	84	20	19	208
Oromia	West Hararge	Meiso	Sorghum	2009/10	C	12	12	15	8	63
Oromia	West Hararge	Mesela	Sorghum	2009/10	E	22	16	16	32	166
Oromia	East Hararge	Midega Tole	Sorghum	2010/11	E	80	51	27	310	23
Oromia	Bale	Ginir	Barley	2009/10	B	58	11	25	35	486
Oromia	Bale	Ginir	Wheat	2009/10	B	22	4	4	1	284
Oromia	Bale	Sinana	Wheat	2009/10	A	12	9	16	12	72
Oromia	Bale	Delo Mena Angetu	Coffee	2009/10	B	50	10	36	31	355
Oromia	Bale	Meda Welabu	Sesame	2009/10	B	21	31	8	10	112
Oromia	Borena	Bule hora	Coffee	2009/10	B	31	2	5	10	355
Oromia	South West Shewa	Ameya	Maize	2009/10	E	40	25	28	36	213
Oromia	South West Shewa	Sebeta Hawas	Chickpea	2009/10	D	2	2	2	5	41
Oromia	South West Shewa	Sebeta Hawas	Teff	2009/10	C	10	11	13	14	71
Oromia	Guji	Bore	Maize	2010/11	E	23	11	14	100	9
Oromia	Guji	Odo Shakiso	Coffee	2009/10	B	54	20	29	74	263
Oromia	West Arsi	Shala	Maize	2009/10	C	27	55	2	9	82
Oromia	West Arsi	Dodola	Barley	2010/11	C	1	1	1	5	1
Oromia	Qeleme Wellega	Anfilo	Coffee	2012/13	E	19	56	10	6	5
Oromia	Horo Gudru Wellega	Amuru	Sesame	2009/10	B	20	11	30	16	112
Oromia	Horo Gudru Wellega	Abe Dengoro	Sesame	2009/10	B	17	16	16	21	96
SNNP	Gurage	Sodo Woreda	Teff	2009/10	E	62	70	16	61	240
SNNP	Sidama	Aleta Wondo	Coffee	2009/10	C	12	18	14	7	64
SNNP	Bench Maji	Sheko	Coffee	2009/10	E	8	4	13	15	65

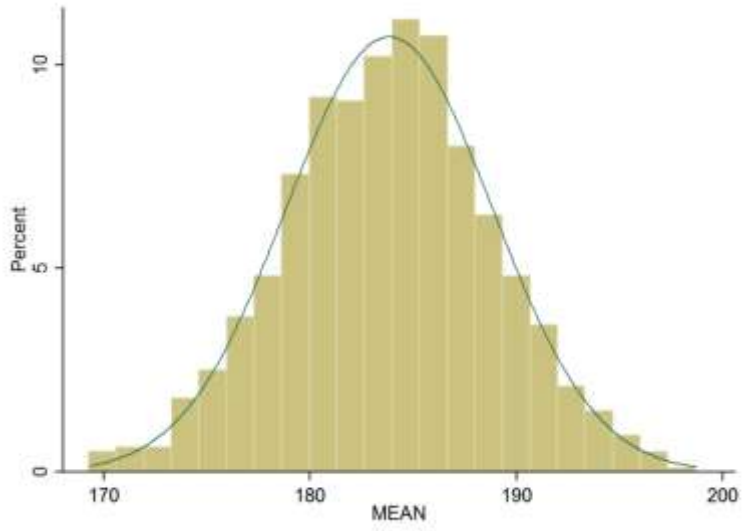
A--Used zonal average, no data
B--Small sample relative to other years (drop small sample year)
C--Coef. of variation not significant (authors' determination)
D--Small numbers of actual farmers in sample (Chickpea/Sesame)
E--No explanation, different EAs sampled

Appendix D – Projected Simulation of Random *Woreda* Rankings

There is variation in the *woreda* production rankings by year. In other words, a typical *woreda* will have a different ranking in all three years of the evaluation. This is cause for concern if the production rankings vary excessively across years. In order to study this observation further, a simulation was conducted in which one set of integers from 1 to 552 was ranked in ascending order and another set of integers from 1 to 552 was ordered randomly. The two sets were compared by their absolute difference, and the simulation was conducted 1000 times independently. This random ranking experiment can be compared to the actual ranking to see if the rankings are grouped better together than a randomly assorted ranking.

The mean average difference between any one ranking and another random ranking was approximately 183 rankings. Given the observed rankings of *woreda* production, the rankings are well outside the Figure D.1 distribution that suggests a mean difference of between 170 and 200.

Figure D.1: Means for 1000 simulations



Appendix E — Correlations between Rankings

High correlations between rankings suggest that rankings are stable over time. The only cross crop correlation above .5 was between wheat and barley. This is presented in Table E.1. Other correlations between rankings are presented by crop in Tables E.2 through E.9.

Table E.1: Wheat and Barley Ranking Correlation

	Rank for wheat 2012/13	Rank for wheat 2011/12	Rank for wheat 2010/11	Rank for wheat 2009/10	Rank for barley 2012/13	Rank for barley 2011/12	Rank for barley 2010/11	Rank for barley 2009/10
Rank for wheat 2012/13	1							
Rank for wheat 2011/12	0.952***	1						
Rank for wheat 2010/11	0.941***	0.947***	1					
Rank for wheat 2009/10	0.808***	0.804***	0.795***	1				
Rank for barley 2012/13	0.695***	0.673***	0.691***	0.633***	1			
Rank for barley 2011/12	0.699***	0.710***	0.714***	0.631***	0.927***	1		
Rank for barley 2010/11	0.655***	0.643***	0.687***	0.590***	0.919***	0.916***	1	
Rank for barley 2009/10	0.595***	0.576***	0.588***	0.684***	0.761***	0.747***	0.749***	1

Table E.2: Wheat Ranking Correlation

	Rank for wheat 2012/13	Rank for wheat 2011/12	Rank for wheat 2010/11	Rank for wheat 2009/10
Rank for wheat 2012/13	1			
Rank for wheat 2011/12	0.952***	1		
Rank for wheat 2010/11	0.941***	0.947***	1	
Rank for wheat 2009/10	0.808***	0.804***	0.795***	1

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table E.3: Maize Ranking Correlation

	Rank for maize 2012/13	Rank for maize 2011/12	Rank for maize 2010/11	Rank for maize 2009/10
Rank for maize 2012/13	1			
Rank for maize 2011/12	0.909***	1		
Rank for maize 2010/11	0.872***	0.872***	1	
Rank for maize 2009/10	0.798***	0.790***	0.774***	1

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table E.4: Barley Ranking Correlation

	Rank for barley 2012/13	Rank for barley 2011/12	Rank for barley 2010/11	Rank for barley 2009/10
Rank for barley 2012/13	1			
Rank for barley 2011/12	0.927***	1		
Rank for barley 2010/11	0.919***	0.916***	1	
Rank for barley 2009/10	0.761***	0.747***	0.749***	1

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table E.5: Sorghum Ranking Correlation

	Rank for sorghum 2012/13	Rank for sorghum 2011/12	Rank for sorghum 2010/11	Rank for sorghum 2009/10
Rank for sorghum 2012/13	1			
Rank for sorghum 2011/12	0.909***	1		
Rank for sorghum 2010/11	0.858***	0.903***	1	
Rank for sorghum 2009/10	0.777***	0.743***	0.682***	1

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table E.6: Teff Ranking Correlation

	Rank for teff 2012/13	Rank for teff 2011/12	Rank for teff 2010/11	Rank for teff 2009/10
Rank for teff 2012/13	1			
Rank for teff 2011/12	0.926***	1		
Rank for teff 2010/11	0.916***	0.919***	1	
Rank for teff 2009/10	0.805***	0.802***	0.793***	1

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table E.7: Chickpea Ranking Correlation

	Rank for chickpea 2012/13	Rank for chickpea 2011/12	Rank for chickpea 2010/11	Rank for chickpea 2009/10
Rank for chickpea 2012/13	1			
Rank for chickpea 2011/12	0.847***	1		
Rank for chickpea 2010/11	0.847***	0.854***	1	
Rank for chickpea 2009/10	0.679***	0.662***	0.685***	1

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table E.8: Sesame Ranking Correlation

	Rank for sesame 2012/13	Rank for sesame 2011/12	Rank for sesame 2010/11	Rank for sesame 2009/10
Rank for seasame 2012/13	1			
Rank for seasame 2011/12	0.862***	1		
Rank for seasame 2010/11	0.834***	0.851***	1	
Rank for seasame 2009/10	0.656***	0.644***	0.670***	1

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table E.9: Coffee Ranking Correlation

	Rank for coffee 2012/13	Rank for coffee 2011/12	Rank for coffee 2010/11	Rank for coffee 2009/10
Rank for coffee 2012/13	1			
Rank for coffee 2011/12	0.865***	1		
Rank for coffee 2010/11	0.871***	0.967***	1	
Rank for coffee 2009/10	0.804***	0.878***	0.866***	1

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Appendix F – Rankings Based on Additional Surveys

Table F.1 shows the correlation coefficients between the rankings produced using the AgSS data and the rankings produced using either AGP or ATA baseline data.

Table F.1: Correlation Coefficients

Crops	AGP – AgSS Data (2010/11)	ATA– AgSS Data (2011/12)
Wheat	0.8375 (72 obs)	0.8014 (67 obs)
Maize	0.8511 (89 obs)	0.6922 (95 obs)
Barley	0.6467 (82 obs)	0.6877 (73 obs)
Sorghum	0.7517 (60 obs)	0.6902 (63 obs)
Teff	0.8551 (83 obs)	0.7847 (82 obs)
Chickpea	0.8662 (32 obs)	0.6346 (25 obs)
Sesame	0.7298 (49 obs)	0.8462 (12 obs)
Coffee	0.8287 (49 obs)	0.8301 (43 obs)

Appendix G – Food Insecurity Data

While data on food security was considered in the analysis, few clear patterns emerge to adjust the rankings systematically. Table G.1 includes *woredas* that were listed as high priority food insecure *woredas* for UN-OCHA. Table G.2 includes *woredas* in which one-third of the population were participating in the PSNP. It should be noted that eight *woredas* are on both the UN-OCHA and PSNP lists.

Table G.1: UN-OCHA High Priority in Top 50 Production Ranking

Woreda	Maize	Wheat	Barley	Sorghum	Teff	Chickpea	Sesame	Coffee
Tselemt	79	461	508	**37**	173	88	**47**	454
Degua Temben	347	**47**	**44**	236	288	108	343	427
Tanqua Abergele	195	526	295	53	175	340	**46**	410
Enderta	383	**21**	**8**	277	172	286	387	443
Rya Azebo	426	261	153	**27**	72	147	152	405
Jan Amora	502	**36**	**23**	416	399	356	461	380
Merab Belesa	365	475	309	153	102	**37**	**49**	442
Kobo	361	278	180	**12**	98	125	154	266
Delanta Wereda	467	159	90	161	180	**44**	217	389
Abergele	448	363	377	105	297	362	**15**	416
Bati	427	459	434	**29**	442	195	**23**	323
Metarobi	462	118	185	207	**50**	364	325	305
Dera	304	144	297	**38**	**14**	56	266	309
Adami Tulu Jido Kombolcha	**5**	213	244	331	331	408	257	471
Doba	271	276	344	**42**	535	357	128	174
Mesela	227	260	324	**34**	427	232	117	91
Habro	112	434	267	**39**	307	77	357	87
Boke	**34**	342	254	**41**	445	78	134	**35**
Haromaya	164	405	487	**38**	521	363	195	199
Girawa	163	352	378	**24**	416	417	130	259
Gololcha	267	**40**	125	403	382	257	317	92
Shala	**34**	223	333	302	183	402	167	367
Shashemene	**44**	**42**	196	294	414	363	377	253
Dara	373	390	233	368	484	399	346	**49**
Lanifaro	**40**	**44**	136	217	470	142	340	350

Table G.2: Outliers with Greater Than 30% PSNP and Top 50 Ranking

Woreda	Maize	Wheat	Barley	Sorghum	Teff	Chickpea	Sesame	Coffee
Tselemt	79	461	508	**37**	173	88	**47**	454
Degua Temben	347	**47**	**44**	236	288	108	343	427
Tanqua Abergele	195	526	295	53	175	340	**46**	410
Saesi Tsadamba	408	138	**38**	378	354	226	455	453
Klite Awlalo	334	72	**49**	288	192	118	235	399
Enderta	383	**21**	**8**	277	172	286	387	443
Hintalo Wajirat	428	**50**	**22**	156	141	336	437	437
Rya Azebo	426	261	153	**27**	72	147	152	405
Adiarikay	349	508	515	**30**	258	458	89	404
Jan Amora	502	**36**	**23**	416	399	356	461	380
Merab Belesa	293	326	154	**41**	55	**7**	55	381
Merab Belesa	365	475	309	153	102	**37**	**49**	442
Tach Gayint	508	**38**	86	214	204	112	358	434
Simada	207	96	123	228	**27**	**24**	279	456
Mekdela	446	157	80	138	90	**44**	495	250
Kalu	302	311	309	**29**	172	205	119	316
Sayinit	416	74	**34**	229	193	**50**	385	371
Kelala	423	75	229	182	103	**39**	459	481
Bati	427	459	434	**29**	442	195	**23**	323
Meiso	188	491	466	**15**	467	309	**20**	491

(Maize and Coffee have no top 50 rankings)