

MARKET ACCESS, TEFF PRODUCTION, AND FERTILIZER USE OVER TIME

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This chapter aims to provide a spatial interpretation of teff production while exploring changes in infrastructure and agricultural inputs over time. Geographic overlap between transportation investments, fertilizer application, and increases in teff production provide a qualitative assessment of how road expansion, agricultural production, and agricultural inputs have changed over time in more remote areas of Ethiopia. The study covered in this chapter uses a rich set of data on agricultural indicators collected by Ethiopia's Central Statistical Agency (CSA) as well as Geographic Information Systems (GIS) data on roads, agroecologies, and other biophysical information to analyze the transformation of teff production patterns in Ethiopia since 1997.

The remainder of the chapter is as follows. The first section provides an overview of teff production in Ethiopia as well as a brief literature review of previous studies that examined the overlap of agricultural potential with regards to infrastructure development. The next section describes the data and methodology used to explore teff production, fertilizer application, and infrastructure development over time. The chapter then discusses the spatial heterogeneity of teff production patterns over time taking into account agroecological conditions, transportation infrastructure, and market access. Fertilizer application trends on teff production over time and links to major markets within the country are explored before the chapter ends with a conclusion.

Teff Production in Ethiopia

Cereals dominate crop production in Ethiopia, and teff (*Eragrostis tef*) is one of the most important crops in the country. In the meher season of 2012/2013, cereals were grown on 71 percent of the total area cultivated and made up approximately 61 percent of total agricultural production (Ethiopia, CSA 2013). Teff accounted for the largest share of cereal area and second largest share of cereal production after maize. Teff and maize comprise

roughly 49 percent of area planted and half of total cereal production. Almost 28 percent of total cereal area and 19 percent of total cereal production was dedicated to teff in 2012/2013 (Ethiopia, CSA 2013).

Teff production area continues to expand, and a greater number of farmers are producing teff. Approximately 6.3 million farmers were growing teff in 2013, compared with 4.4 million farmers in 2001/2002. Similarly, teff area planted increased from 1.8 million hectares in 1997 to 2.7 million hectares in 2013 (Table 6.1). Although teff area continues to increase, the growth in production has been driven more by yield increases (that doubled) over time than area increases. This increase is due to a number of factors including relatively high market prices of teff grain and straw. In addition, teff is versatile, as it grows in a wide variety of agroclimatic conditions, including elevations from sea level to 2,800 meters above sea level (masl), under a similarly wide variety of moisture, temperature, and soil conditions. Although teff area has expanded over time, other cereal area has increased as well, and the overall area share of teff remains relatively unchanged from previous years.

Earlier studies have looked at effects of transportation infrastructure on agricultural production and input choices in Africa south of the Sahara and Ethiopia. Dorosh and Schmidt (2010) underlined the risk of constrained production due to demand constraints in terms of low population densities and large travel times to urban centers. Reducing travel time from remote rural areas expands the feasible market size. Dorosh et al. (2009) found that agricultural production is highly correlated with the amount of time it takes to reach an urban market. Research, specifically analyzing teff production in Ethiopia, reported an increasing intensification of teff production in rural areas that are well connected to cities (Minten et al. 2013a). Minten et al. (2013b) reported that teff producer prices decreased (particularly of white teff) as farmers became farther from Addis Ababa. They note that increasing investments in road infrastructure to decrease transportation costs increases the prices that farmers receive on teff.

Previous research also suggests that distance to a market affects fertilizer application choices. An earlier study by Demeke et al. (1998) underlined the need for efficient access to markets to ensure profitability of fertilizer. For example, the Value to Cost Ratio (VCR) for teff declined by 55 percent between 1992 and 1997 due to rising fertilizer prices relative to output prices. Similarly, analysis by Dorosh et al. (2010) report that adoption of high-productive and high-input technology was negatively correlated with travel time to urban centers. Yu et al. (2011) found that households in Ethiopia that adopted fertilizer tended to have better market access and improved

TABLE 6.1 Teff production characteristics

| Season | Number of holders (millions) | Area (millions of hectares) | Production (millions of metric tons) | Yield (metric tons per hectare) | Total cereal area (millions of hectares) | Teff area share (%) |
|-----------|------------------------------|-----------------------------|--------------------------------------|---------------------------------|--|---------------------|
| 1997/1998 | — | 1.75 | 1.31 | 0.7 | 5.6 | 31.2 |
| 1998/1999 | — | 2.09 | 1.64 | 0.8 | 6.7 | 31.0 |
| 1999/2000 | — | 2.12 | 1.72 | 0.8 | 6.7 | 31.5 |
| 2000/2001 | — | 2.18 | 1.74 | 0.8 | 7.6 | 28.6 |
| 2001/2002 | 4.4 | 1.82 | 1.63 | 0.9 | 6.4 | 28.5 |
| 2002/2003 | — | — | — | — | — | — |
| 2003/2004 | 4.6 | 1.99 | 1.68 | 0.8 | 7.0 | 28.4 |
| 2004/2005 | 4.9 | 2.14 | 2.03 | 0.9 | 7.6 | 28.0 |
| 2005/2006 | 5.2 | 2.25 | 2.18 | 1.0 | 8.1 | 27.8 |
| 2006/2007 | 5.4 | 2.40 | 2.44 | 1.0 | 8.5 | 28.4 |
| 2007/2008 | 5.9 | 2.57 | 2.99 | 1.2 | 8.7 | 29.4 |
| 2008/2009 | 5.8 | 2.48 | 3.03 | 1.2 | 8.8 | 28.3 |
| 2009/2010 | 5.6 | 2.59 | 3.18 | 1.2 | 9.2 | 28.0 |
| 2010/2011 | 6.2 | 2.76 | 3.48 | 1.3 | 9.7 | 28.5 |
| 2011/2012 | 6.3 | 2.73 | 3.50 | 1.3 | 9.6 | 28.5 |
| 2012/2013 | 6.3 | 2.73 | 3.77 | 1.4 | 9.6 | 28.4 |

Source: Ethiopia, CSA (various years).

Note: — = data not available.

infrastructure (measured in terms of road density). This chapter compares teff production, area, and fertilizer application with a set of travel time models that span from 1997 to 2010 at woreda level. Using geographic information systems to explore production patterns and trends of teff, we find greater teff yields and fertilizer applications tend to be associated with better access to major roads and cities. Although improved varieties of teff seed exist within Ethiopia, under 2 percent of farmers on only 1.3 percent of teff production area are using this technology.¹ Thus the primary focus of this chapter is to

1 It is important to note, however, that low adoption of improved seed may be driven by inconsistency in the definition of improved seed application during data collection. Spielman, Kelemwork, and Alemu (2012) underline the challenge of analyzing data on improved seed given differences in application of open pollinated cereals (such as teff), which do not require purchase/application of improved seed every year.

understand the geographic patterns of teff production, fertilizer application, and transportation infrastructure over time.

Data and Methodology

A variety of spatial and tabular datasets were used to analyze teff production patterns and market access over time. Teff production, area, and fertilizer application data for the years 1997/1998, 2006/2007, and 2010/2011 were obtained from Ethiopia's Central Statistical Agency (Ethiopia, CSA 1998, 2007, 2011), published data of the Annual Agricultural Sample Survey (AgSS), as well as the Ethiopian Agricultural Sample Enumeration (EASE) (2001/2002) report. It is important to note that the AgSS is representative at the zone level, but for purposes of this study, woreda-level figures were estimated by calculating the woreda share of teff production, area, and fertilizer use for each zone recorded in the 2001/2002 census. We decided to use these AgSS data as no other datasets in Ethiopia have continuous data over time at this level of disaggregation. Woreda shares are estimated and updated for each of the analysis periods (1997/1998, 2006/2007, and 2010/2011) using AgSS data. Given that the woreda boundaries, names, and codes vary over time, a spatial database was constructed that allows for spatial consistency and comparable woreda boundaries with a unique spatial identifier following the AgSS codebook. While this method is simplistic in nature and will not capture intra-annual and interannual dynamics and determinants of production, it does provide insight into the importance of transportation infrastructure and market links on teff production patterns in the country.

In order to pair agricultural statistics with transportation infrastructure improvements, a set of travel time models were built for three study years: 1997/1998, 2006/2007, and 2010/2011.² The travel time models calculate time required to access the (1) nearest market and (2) paved or gravel road from any point within the country.³ For each year considered in the analysis, a travel time grid was built by considering the transportation network (road network condition and speed limits), off-road travel time across various land cover and land use types, water bodies (rivers and lakes), and slope considered as an

2 In order to create the travel time model for 2010/2011, a variety of roads data sources were used to update the 2006 roads database, including Open Street Map (<http://download.geofabrik.de/africa/ethiopia.html>), Google Earth, and groundtruthing.

3 Following Schmidt and Kedir Jemal's (2009) methodology, a travel time model is constructed that calculates time required to access the nearest market (city of at least 50,000 people) from any point within the country.

impedance factor for uphill movement and an accelerator factor for downhill movement. Using GIS, the overlap between the average travel time from a woreda to the nearest city (and nearest paved and gravel road) is compared with a variety of agricultural statistics. Production patterns emerge suggesting that transportation infrastructure is vital to enhancing agricultural productivity as well as increasing agricultural input use.

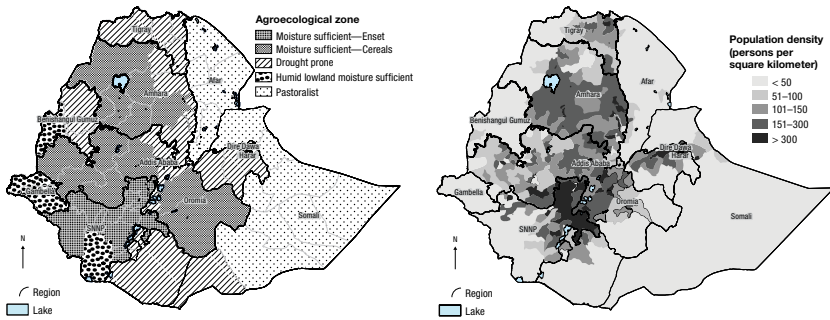
Spatial Heterogeneity of Teff Production Pattern

In Ethiopia most agricultural production takes place in the Weyna Dega and Dega (highland areas between 1,500 to 2,300 and 2,300 to 3,200 meters above sea level) agroecological zones, where land productivity has traditionally coincided with the densest rural populations (Figure 6.1). The optimal growing conditions for teff corresponds to its traditional production areas: 1,800–2,100 meters above sea level, average annual rainfall of 750 to 1,000 millimeters, and an average annual temperature of 10°C to 27°C (Chamberlin and Schmidt 2012; Seyfu 1997). However, there is great variation in production and yield within this growing area.

Oromia and Amhara represent the largest teff-producing regions given that a majority of the land area in these regions are in the rainfall-sufficient highlands agroecological zone. In addition to proper growing conditions, these regions also have the most connected transportation network, linking some of the largest cities in the country (Figure 6.2). In 2010/2011, Oromia and Amhara regions comprised approximately 85 percent of the national teff production volume and 84 percent of area cultivated (Figure 6.3). The Southern Nations, Nationalities, and Peoples' (SNNP) region was the third largest teff-producing region; however, its contribution to national teff production and area coverage was considerably lower, comprising 8.5 percent and 9.6 percent in 2010/2011, respectively.

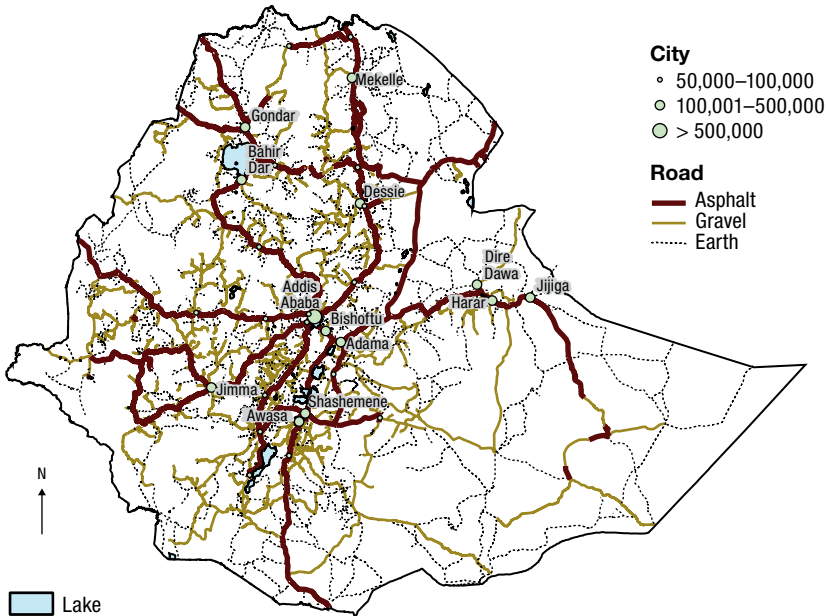
Woreda-level teff production estimates suggest that selected woredas in Amhara and Oromia account for the high production in their respective regions. A total of 23 woredas make up 25 percent of national teff production in Ethiopia (10 and 13 woredas comprise approximately 10 percent and 15 percent of national production in Amhara and Oromia, respectively). Ada'a Chukala woreda in East Shewa zone was the highest teff-producing woreda, contributing almost 3 percent to national production. The remaining top teff-producing woredas are distributed among East Gojjam, West Gojjam, North Shewa, West Shewa, North Gonder, and South Gonder zones.

FIGURE 6.1 Agroecological zones and population density

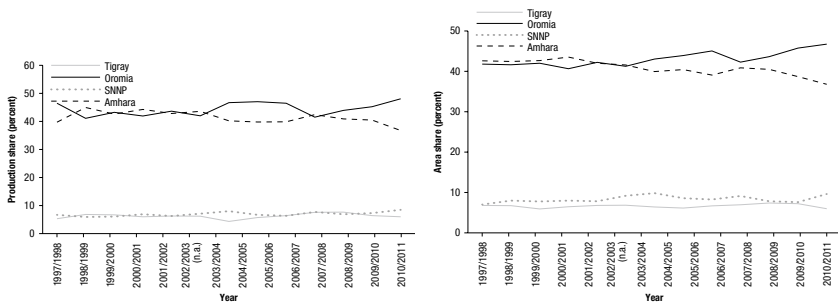


Source: Authors' calculations.

FIGURE 6.2 Roads in Ethiopia, 2010–2011



Source: Ethiopian Roads Authority, with road information updated using Open Street Map, Google Earth, and groundtrutting.

FIGURE 6.3 Production and area share of teff by region, 1997/1998–2010/2011


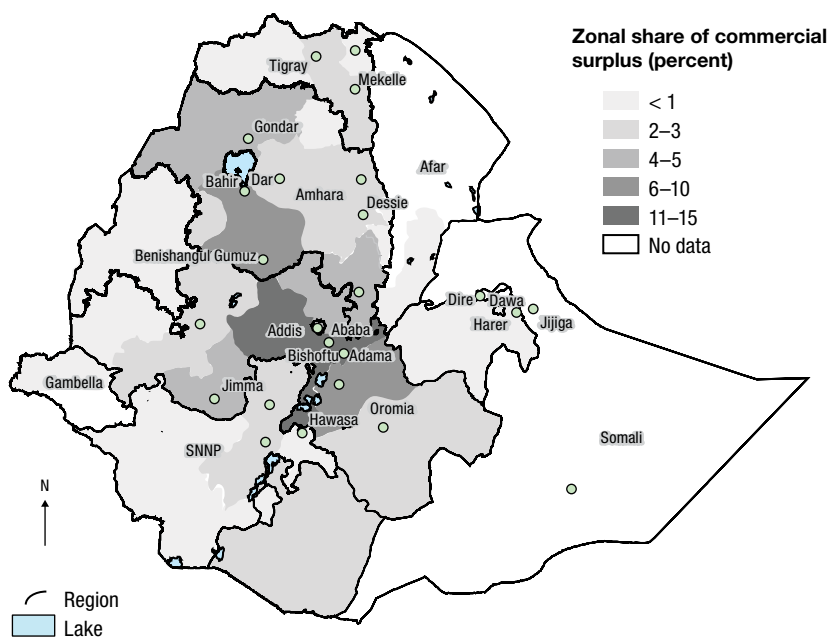
Source: Ethiopia, CSA (2015).

Note: SNNP = Southern Nations, Nationalities, and Peoples' region. n.a. = not applicable.

These high-producing areas also comprise a majority of the commercial teff surplus in the country (Figure 6.4). In total, approximately 31 percent of teff production is sold as commercial surplus (AgSS, 2010/2011). Oromia region supplies 42 percent of marketed teff, while Amhara region contributes 33 percent to overall commercial surplus. Six zones (West Shewa, East Shewa, and Arsi from Oromia region, and East Gojjam, West Gojjam, and North Shewa from Amhara region) make up more than 50 percent of commercial surplus in Ethiopia. Given the increase in urbanization (Ethiopia has grown by 3.7 percent per year on average), there is greater demand for food from urban populations (Schmidt and Kedir Jemal 2009). Mapping teff surplus by zone suggests that areas closer to urban centers with facilitated access to markets are providing the bulk share of surplus teff production.

Exploring Teff Production over Time

Between 1997/1998 and 2010/2011 the total amount of teff produced in Ethiopia almost tripled from 1.3 million metric tons to approximately 3.5 million metric tons, while total teff cultivated area grew by 58 percent. The increase in teff production and cultivated area is reflected in all major teff-producing regions (Table 6.2). The greatest change in teff production and area occurred in the SNNP region, where teff production increased from about 90,000 metric tons in 1997/1998 to approximately 300,000 metric tons in 2010/2011. Over this period, area cultivated by teff in this region grew from 123,000 hectares to 265,000 hectares. Although less teff is grown in Tigray, production increased from nearly 70,000 metric tons in 1997/1998 to over 210,000 metric tons by 2010/2011, while teff cultivated area grew by almost 39 percent.

FIGURE 6.4 Share of national teff commercial surplus by zone

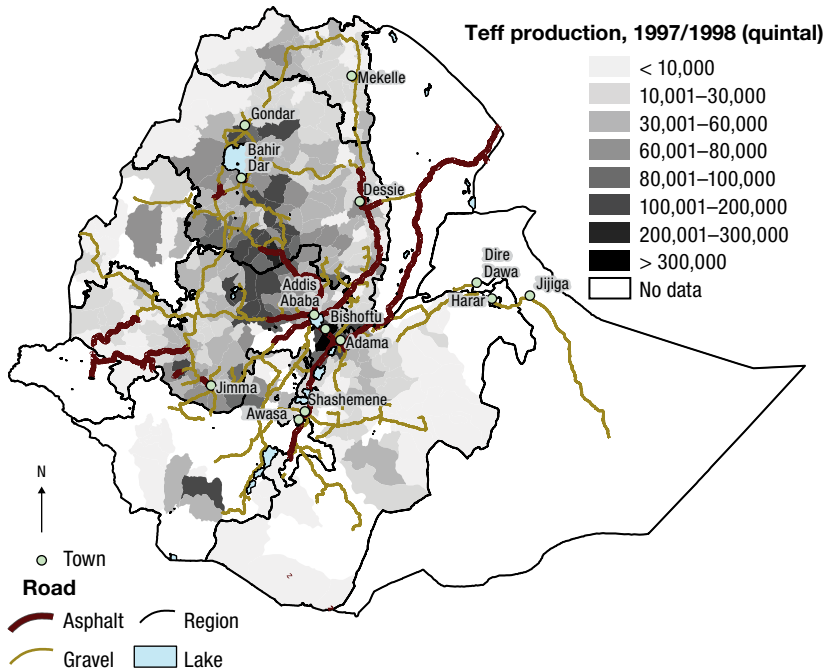
Source: Ethiopia, CSA 2011.

TABLE 6.2 Teff cultivated area and production, 1997/1998, 2006/2007, and 2010/2011

| Region | 1997/1998 | | 2006/2007 | | 2010/2011 | |
|-------------------|-------------------------|----------------------------------|-------------------------|----------------------------------|-------------------------|----------------------------------|
| | Area (million hectares) | Production (million metric tons) | Area (million hectares) | Production (million metric tons) | Area (million hectares) | Production (million metric tons) |
| Tigray | 0.12 | 0.07 | 0.16 | 0.16 | 0.17 | 0.21 |
| Amhara | 0.74 | 0.52 | 0.94 | 0.97 | 1.01 | 1.28 |
| Oromia | 0.73 | 0.61 | 1.08 | 1.13 | 1.29 | 1.67 |
| Benishangul-Gumuz | 0.02 | 0.02 | 0.02 | 0.01 | 0.02 | 0.02 |
| SNNP | 0.12 | 0.09 | 0.20 | 0.16 | 0.27 | 0.30 |
| Ethiopia | 1.75 | 1.31 | 2.40 | 2.44 | 2.76 | 3.48 |

Source: Ethiopia, CSA, various years.

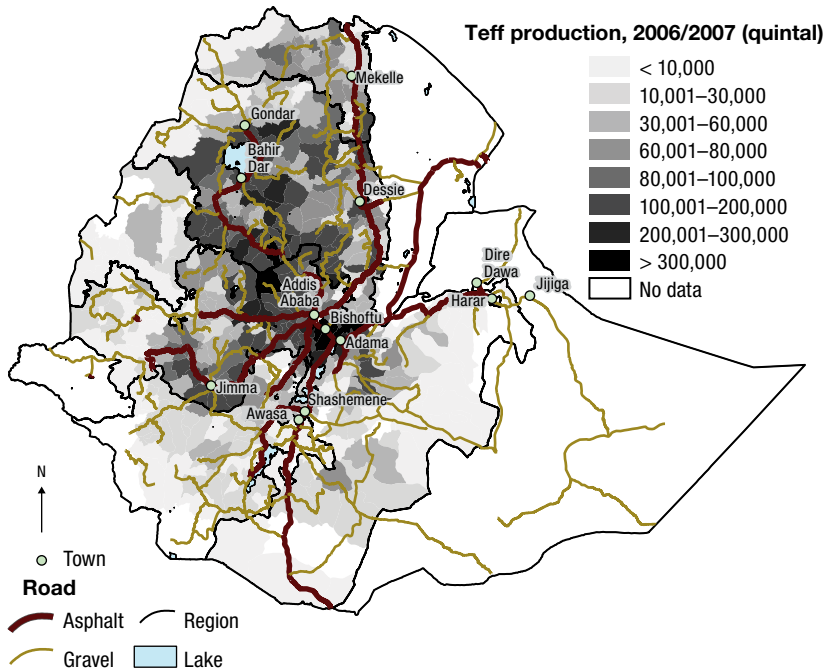
Note: SNNP = Southern Nations, Nationalities, and Peoples' region. Area planted and production of teff were not reported or insubstantial in Addis Ababa, Somali, Afar, Gambella, Harar, and Dire Dawa.

FIGURE 6.5 Woreda-level teff production estimates, 1997/1998

Source: Authors' calculations.

Comparing teff production in 1997/1998 with available road infrastructure at the time suggests that higher-producing areas were not only in optimal agroecological zones but were also associated along major transportation corridors (Figure 6.5). High-producing woredas in Oromia region included areas adjacent to the Addis Ababa–Adama corridor as well as the road network stretching from the capital west to Nekempte. Similarly, high-producing regions in Amhara were found along the major road stretching from Addis Ababa to Bahir Dar and Gondar.

As road infrastructure continued to expand throughout the rainfall-sufficient highland regions, teff production also expanded. Geographic comparisons of the road network and teff production suggest that greater production was reported in areas that were closer to a road. Compared to 1997/1998, in 2006/2007 there were three times more gravel roads that linked rural woredas to larger paved corridors. In addition, production increased along the major corridor that runs from Addis Ababa to Mekelle, whereby 230 more kilometers of paved roads were present in 2006/2007 compared to 1997/1998 (Figure 6.6).

FIGURE 6.6 Woreda-level teff production estimates, 2006/2007

Source: Authors' calculations.

By 2010/2011 travel time to a major city decreased dramatically in the four major agricultural regions of Ethiopia (Table 6.3).⁴ Whereas in 1997/1998, only 7 percent and 12 percent of teff area in Amhara and Oromia was within three hours of a major city, 37 percent and 48 percent of teff area was within three hours of a major city in Amhara and Oromia in 2010/2011, respectively. Similarly, rural populations continue to gain better access to roads (Figure 6.7). In 1997/1998, 19 percent of teff area in Amhara was within two hours of a gravel or paved road, whereas in 2010/2011, 52 percent was within two hours of a gravel or paved road. In Oromia region, 42 percent more area was within two hours of a gravel or paved road in 2010/2011 compared to 1997/1998. This expansion and improvement in road infrastructure has not only facilitated market access but has also impacted the transportation of goods and access to such services as fertilizer and agricultural extension services as well as enhanced communication and knowledge transfer.

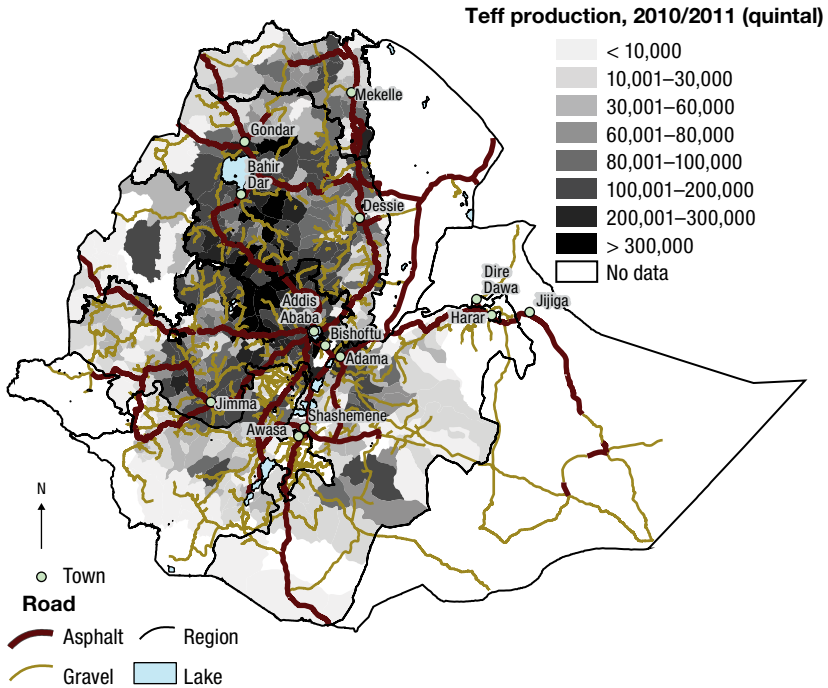
4 A major city is defined as having at least 50,000 people.

TABLE 6.3 Travel time to a major market (% area)

| Region | 1997/1998 | | 2010/2011 | |
|-------------------|-------------------------------------|------------------------------------|-------------------------------------|------------------------------------|
| | Teff area (share) under three hours | Teff area (share) over three hours | Teff area (share) under three hours | Teff area (share) over three hours |
| Tigray | 3.3 | 96.7 | 28.9 | 71.1 |
| Afar | 0.0 | 100.0 | n.a. | n.a. |
| Amhara | 6.7 | 93.3 | 37.4 | 62.6 |
| Oromia | 11.7 | 88.3 | 47.9 | 52.1 |
| Benishangul-Gumuz | 0.0 | 100.0 | 0.0 | 100.0 |
| SNNP | 5.2 | 94.8 | 56.6 | 43.4 |
| Ethiopia | 8.5 | 91.5 | 43.3 | 56.7 |

Source: Authors' calculations; AgSS 1997/1998 and 2010/2011.

Note: n.a. = not applicable; SNNP = Southern Nations, Nationalities, and Peoples' region. Area planted of teff were not reported or insubstantial in Addis Ababa, Somali, Gambella, Harar, and Dire Dawa.

FIGURE 6.7 Woreda-level teff production estimates, 2010/2011


Source: Authors' calculations.

Market Access and Fertilizer Application

Although urban growth remains relatively slow in Ethiopia, investment in connective infrastructure has dramatically reduced transportation costs to market centers.⁵ Given the limited infrastructure during the 1980s and early 1990s, the Ethiopian government prioritized road construction and rehabilitation investments to enhance links between markets. Beginning in 1997, a 10-year Road Sector Development Program was formulated to improve the quality and size of road infrastructure. In 1996/1997 transportation infrastructure connected Addis Ababa to a limited number of urban markets such as Bahr Dar, Dire Dawa, Jimma, and Mekelle (Figure 6.8). By 2010/2011 secondary cities linked to each other, and major corridors linking key market centers were fully constructed. Whereas in 1997/1998, only 15 percent of the population was within three hours of a market, 47 percent was within three hours of a market in 2010/2011 (Figures 6.8 and 6.9).

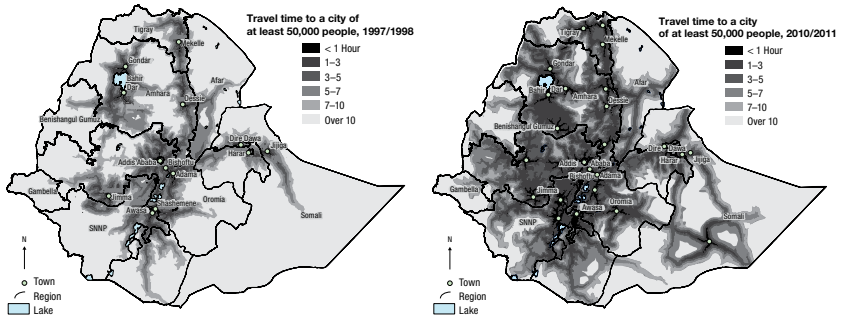
Fertilizer application on teff fields across the four main grain-producing regions shows a notable difference over time (Figure 6.10 and Figure 6.11). In 1997/1998 fertilizer application was concentrated in woredas near Addis Ababa and Adama as well as northern Oromia and southern Amhara near Bahir Dar. According to Minten et al. (2013a), the intensity (kilograms per hectare) of chemical fertilizer application on teff fields has increased by nearly 77 percent within the past decade. Nationally, of the total fertilizer used on teff and areas that were under fertilizer in 2010/2011, more than 85 percent was located in areas less than three hours to a road.

Taking into account only production and input use in the highland rainfall-sufficient agroecological zone where the majority of teff is grown, fertilizer application was greater in areas closer to a major city. Comparing teff production and area over time between high access areas and low access areas, it is important to note the dynamic processes occurring. Not only are road networks expanding, but more households are growing teff throughout the country. In 1997–1998 total teff production and area was greater in low-access areas accounting for 730 million kilograms and 981,000 hectares, respectively, compared to 120 million kilograms and 128,000 hectares in high-access areas.

Similarly, total quantity of fertilizer used was higher in low-access areas in 1997/1998. However, when assessing the annual growth rate of production and fertilizer use between 1997/1998 and 2010/2011, areas within three hours

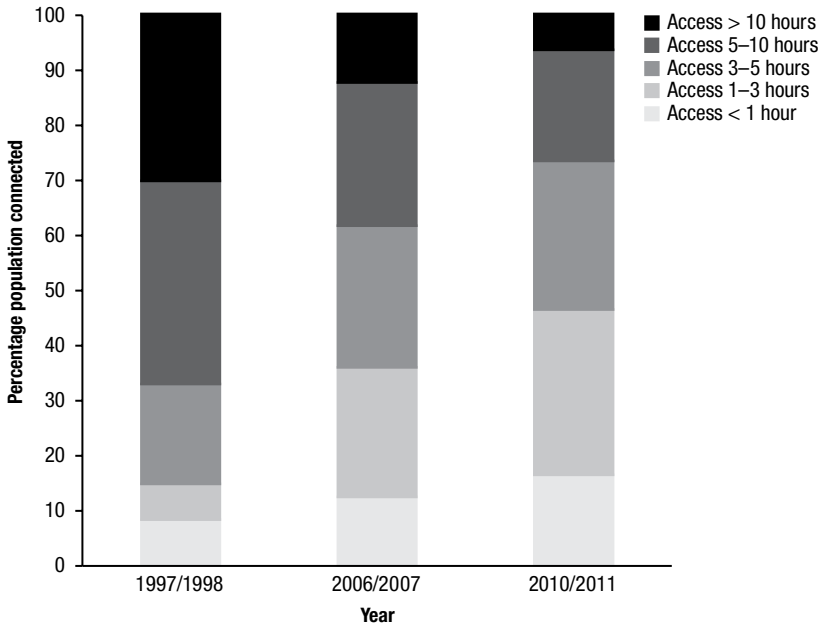
5 The total share of urban residents was approximately 14.2 percent in 2007 according to the agglomeration index (Schmidt and Kedir Jemal 2009), compared with an average 30 percent urbanization rate for all of Africa south of the Sahara.

FIGURE 6.8 Travel time to a city of at least 50,000 people, 1996/1997 and 2010/2011



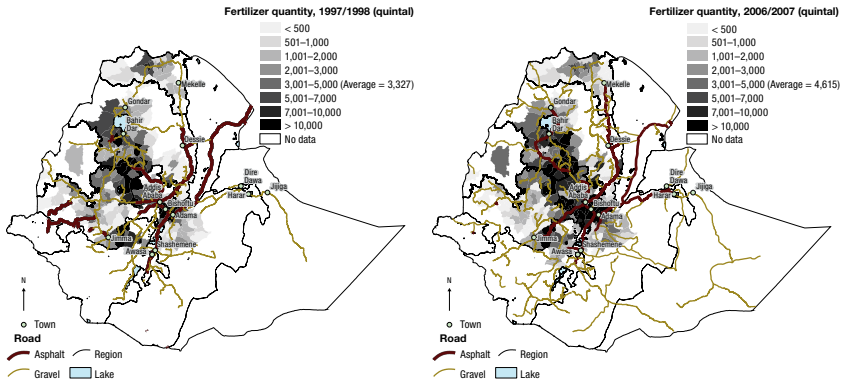
Source: Authors' calculations.

FIGURE 6.9 Percentage of population connected to a city of at least 50,000 people



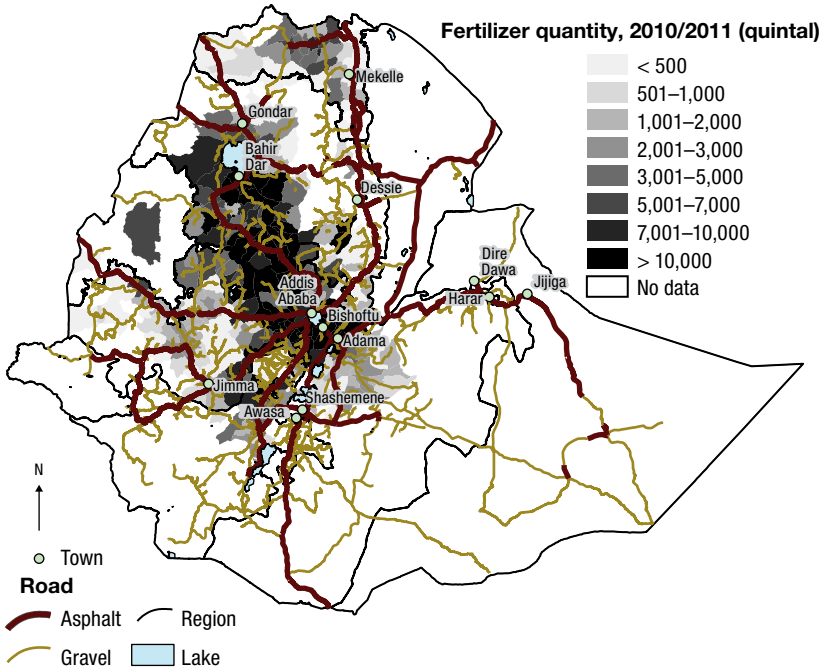
Source: Authors' calculations.

FIGURE 6.10 Average fertilizer applied on teff fields, 1997/1998 and 2006/2007



Source: Authors' calculations.

FIGURE 6.11 Fertilizer quantity applied on teff fields, 2010/2011



Source: Authors' calculations.

of a major city experienced large rates of growth in teff production and in fertilized area at 20 percent, respectively, per year. In low-access areas, annual growth of teff production increased by only 4 percent, and the area planted with teff decreased between 1997/1998 and 2010/2011. Although these numbers suggest a trend of greater teff production and input use along main corridors and major cities, it is important to note that these figures represent a snapshot of agricultural processes and do not take into account the portfolio of other possible agricultural enhancing investments that occurred in these areas.

Finally, focusing on intensity of fertilizer use and agricultural yields, households within three hours of a city have consistently applied more fertilizer per hectare, however not at substantially larger volume than areas that lie more than three hours from a city. This is due to several factors: first, this analysis looks at overall total values of production and input levels. In high-access areas the area dedicated to teff increased by 17 percent per year, while low-access areas did not experience considerable growth in teff area nor in fertilizer use on teff (Table 6.4). Although fertilizer use per hectare was lower in areas greater than three hours from a city, overall teff yields in low- and high-access areas were similar in 2010/2011. This suggests that other conditioning factors may have an influence on teff yields, including favorable weather patterns, political processes, and knowledge and agricultural extension campaigns to bolster teff yields (row planting, weeding, and improved seed development). Further research is needed to identify the specific determinants of yield increases in teff. It is clear that not only total production and fertilizer use is increasing throughout the primary teff-growing regions (rainfall-sufficient highlands), but yields are also increasing in both the high- and low-access areas.

Conclusion

Teff production area continues to expand and a greater number of farmers are producing teff. Oromia and Amhara represent the largest teff-producing regions given that a majority of the land area in these regions are in the rainfall-sufficient highlands agroecological zone. In addition to proper growing conditions, these regions also have the most connected transportation network, linking some of the largest cities in the country. In 2010/2011, Oromia and Amhara regions comprised approximately 85 percent of the national teff production volume and 84 percent of teff area cultivated. Access to markets has improved dramatically over time in Amhara and Oromia regions, whereby approximately 37 percent and 43 percent of the population respectively were

TABLE 6.4 Production and input use in the highland rainfall-sufficient agroecological zone, 1997/1998, 2006/2007, and 2010/2011

| | | 1997/ 1998 | 2006/ 2007 | 2010/ 2011 | Annual % change (1997/1998– 2010/2011) | |
|--|-------------------------------|--------------------------|---------------|---------------|---|------|
| | Units | | | | | |
| High access (less than three hours from a city) | Number of woredas | 19 | 86 | 119 | | |
| | Total teff production | kilograms (thousands) | 120,103 | 661,175 | 1,270,754 | 19.9 |
| | Total teff area | hectares (thousands) | 128.4 | 609.8 | 982.1 | 16.9 |
| | Area under fertilizer | hectares (thousands) | 70.4 | 479.6 | 725.9 | 19.7 |
| | Share fertilized teff area | % | 54.8 | 78.6 | 73.9 | 2.3 |
| | Total fertilizer on teff | kilograms (thousands) | 7,940 | 45,008 | 70,181 | 18.2 |
| | Fertilizer per hectare | kilograms per hectare | 112.8 | 93.8 | 96.7 | –1.2 |
| | Teff yield | kilograms per hectare | 935.3 | 1,084.20 | 1,293.90 | 2.5 |
| Low access (more than three hours from a city) | Number of woredas | 189 | 171 | 132 | | |
| | Total teff production | kilograms (thousands) | 730,123 | 998,993 | 1,186,518 | 3.8 |
| | Total teff area | hectares (thousands) | 981 | 1,069 | 951 | –0.2 |
| | Area under fertilizer | hectares (thousands) | 427 | 504 | 464 | 0.6 |
| | Share fertilized teff area | % | 43.5 | 47.2 | 48.8 | 0.9 |
| | Total fertilizer on teff | kilograms (thousands) | 40,755 | 39,234 | 39,590 | –0.2 |
| | Fertilizer per hectare | kilograms per hectare | 95.4 | 77.8 | 85.4 | –0.9 |
| | Teff yield | kilograms per hectare | 744.2 | 934.8 | 1,247.50 | 4.1 |

Source: Authors' calculations and Ethiopia, CSA, various years.

connected to a major city within three hours in 2010/2011 (compared to 11 percent and 13 percent in 1997/1998, respectively).

Ongoing investments in road infrastructure in the highlands have decreased transportation costs for rural farmers. Previous research suggests that improvements in market access increases the adoption of fertilizer and

enhances communication and knowledge transfer, which in turn leads to improvements in agricultural production (Demeke et al. 1998; Dorosh et al. 2010; Minten et al. 2013b). GIS analysis of market access and agricultural production suggests that areas of greater teff production, teff area, and fertilizer application are closer to major roads and cities. Whereas in 1997/1998, teff was primarily grown along the transportation corridor between Addis Ababa and Bahir Dar, and Addis Ababa and Adama, teff production in 2010/2011 increased along the Mekelle, Nekempte, and Jimma corridors as well. A similar trend is observed for fertilizer use along these major roads.

Ethiopia continues to invest in road infrastructure to expand links to rural areas. Although the country has invested significantly in roads over the past several decades, it remains a country with one of the lowest road densities in the world (von Braun and Olofinbiyi 2007; Gwilliam et al. 2008), and transport costs are still relatively high compared with international standards (Minten, Stifel, and Tamru 2012). Improvements in market access will likely continue to have an effect on production patterns and input use within the country. More efficient transportation of goods, as well as enhanced communication, improved mobility of rural farmers, and facilitated access to extension agents are important elements to agricultural innovation and technical adoption. Paired with increasing demand for teff in urban areas as well as a growing urban population and relatively high market prices for teff grain suggests strong potential for further growth and geographic expansion of teff production in Ethiopia.

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