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ESSP 2 Discussion Paper 003

Urbanization and Spatial Connectivity in Ethiopia: Urban Growth Analysis Using GIS

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THE ETHIOPIA STRATEGY SUPPORT PROGRAM 2 (ESSP2)
DISCUSSION PAPERS

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ABSTRACT

In comparison to other African countries, Ethiopia has a low urbanization rate. According to the World Bank World Development Report (WDR) 2009, Sub-Sahara Africa is 30% urbanized, whereas Ethiopia is only 10.9% urbanized. Urbanization rates differ according to methodologies and data base utilized: the United Nations classifies Ethiopia as 14.9% urban, while the Central Statistical Agency of Ethiopia reports a 16% urbanization rate. In an effort to standardize and measure Ethiopian urbanization over time, we use the WDR agglomeration index methodology which incorporates a series of GIS data and analyses including: travel time rasters, population density (namely GRUMP and LandScan gridded population), and other nationally collected biophysical and infrastructure variables.

We spatially allocate urban versus non-urban areas by creating specific thresholds following two criteria whereby locations are categorized as urban if populations have: a population density greater than 150 people per km2; and are located within 1 hour travel time from a city of at least 50,000 people. Utilizing road and population data from different years between 1984 and 2006, we are able to model growth in urbanization and reductions in remoteness over time. Using the agglomeration index methodology, we find that the overall share of urban population increased from 3.7 percent in 1984 to 14.2 percent in 2007. The results indicate substantial improvements in travel time between urban centers over the past two decades, though a large share of the population still resides more than 10 hours travel time from an urban center.

Keywords: Ethiopia, urbanization, remoteness, agglomeration index, poverty reduction, GIS

INTRODUCTION

In comparison to other Sub-Saharan African (SSA) countries, Ethiopia's urbanization rate is low -- only 16% of the population is urbanized according to data published by the country's Central Statistical Agency. This is far less than the average for all SSA, at approximately 30 percent (World Bank World Development Report, WDR, 2009).

Urbanization rates differ according to methodologies and the database utilized, for example the United Nations classifies Ethiopia as 14.9% urban, while the World Bank reports a 10.9% urbanization rate. In an effort to provide standardized measures of Ethiopian urbanization over time, we use the WDR agglomeration index methodology which incorporates a series of GIS data and analyses including: travel time rasters, population density rasters (namely GRUMP and LandScan gridded population), and other nationally collected biophysical and infrastructure variables.

We spatially allocate urban versus non-urban areas by creating specific thresholds following a set of criteria whereby locations are categorized as urban if populations have: a population density greater than 150 people per km2; and are located within 1 hour travel time from a city of at least 50,000 people. Utilizing road and population data from corresponding census years, we are able to model growth in urbanization and reductions in remoteness over time. The results indicate substantial improvements in travel time between urban centers over the past two decades, though a large share of the population remains more than 10 hours travel time from an urban center.

This paper seeks to provide a more dynamic assessment of Ethiopia's urban growth during the last 25 years, but also places this transformation within the context of ongoing debate of economic development and poverty reduction strategies. First, we briefly review some of the recent theoretical and empirical work concerning rural – urban linkages, agglomeration economies, and the forces that drive urbanization. We then assess the evolution of urbanization in Ethiopia from 1984 to 2007. In doing so, we describe the data and methodology applied to calculate a time series agglomeration index for Ethiopia, as well as the transformation of underlying components that make up the index calculation. Finally, we assess our results within the current urbanization strategy and policy outlined by the Ministry of Works and Urban Development.

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GEOGRAPHY AND GROWTH

Urban development and rural growth strategies are frequently discussed as separate issues with competing objectives and contradictory policy implications. Recent studies on urbanization and agglomeration economies, however, avoid using a rigid boundary between "the rural" and "the urban" in order to provide a more realistic approach to fostering an economically productive landscape. In this new approach, economic development strategy addresses a spectrum of settlements ranging from rural villages and towns, to small urban hubs and secondary cities.

Some economic activities require spatially dispersed production such as agriculture, mining, lumbering, and tourism services. Others benefit from spatial concentration. When labor mobility is not hindered, the manufacturing sector may seek benefits derived from firm level economies of scale and concentrate production in specific urban locations, offering greater access to consumers and input suppliers (Renkow, 2007). Thus, factories cluster while farmers, miners and lumberjacks disperse. Since urban workers require food and raw materials from rural areas and since rural workers require machinery, fuel and clothing from urban factories, rural and urban economies must interact. A continuum of population density creates a portfolio of interrelated places, and these places, when functioning properly, will bring about greater economic interaction and ultimately spur development within all spatial spheres.

From a policy perspective, facilitating these interactions is essential for economic growth. Industrial growth depends on scale economies. But industrialization is unachievable without sufficient increases in agricultural productivity, enabling farmers to release family labor to staff growing factories in the cities, while also maintaining food production at home (Rondinelli, 1988). For agriculture to grow rapidly, farmers must have access to inputs, repair services, competitive output markets and processing industries. These emerge most economically in small cities and rural towns.

Small cities and rural towns not only provide important inputs to agricultural processes, but also provide local markets for agricultural produce: essential for small-scale farmers. Unless farmers are able to respond to demand from urban consumers, through access to natural resources, credit, labor and inputs, local markets are limited to very low-level transactions (Tacoli and Satterthwaite, 2003). Thus, more productive agricultural regions will often spur greater rural - urban interaction, facilitating opportunities for non-farm income generating opportunities as well.

Globally, non-farm income, whether earned in rural areas or in neighboring small towns and secondary cities, comprises 35 – 42 percent of household income among farmers. In many cases, this non-farm income eases seasonal food insecurity pressures experienced in rain-fed agricultural production (Feder and Lanjouw 2001). Although non-farm income (i.e. from the construction or service sectors) may not be directly related to local agricultural production activities, it continues to stimulate growth in agriculture as profits from nonfarm

activities are reinvested in more high-yielding agriculture inputs and improved farming methods. Small towns and secondary cities provide larger demand for agricultural goods and labor. Networked access to these cities among small towns and rural villages stimulates agricultural productivity and rural income in less urbanized areas, which as a result generates increased demand and labor supply for more rural/agricultural goods and services (Ellis and Harris, 2004; Hardoy and Satterthwaite, 1986; and Karaska and Belsky, 1987).

Not only are there positive geographic spillovers (rural – urban virtuous circles) with appropriate regional development planning, but urban linkages and growth itself are major aspects of short and long term development. Urban areas facilitate social and economic interactions. These exchanges lead to increased efficiency in flows of goods and services, more efficient matching of workers to jobs, and enhanced information and knowledge spillovers. According to the 2009 WDR on Reshaping Economic Geography, no country has developed without city growth. “As countries become richer, economic activity becomes more densely packed into towns, cities, and metropolises” (World Bank 2009). This growth requires policy decisions which shape the rate of growth and integration between rural and urban areas, as well as a framework for how a city addresses the needs of a rapidly expanding urban population.

Countries urbanize at different rates for various reasons, however. Examining the specific market forces of agglomeration (including incentives for migration), as well as national and regional government policies that help or hinder these transformations may give insight to future policy challenges and opportunities. Given the observed positive agglomeration effects in many urbanized countries, Ethiopia (with the majority of the population living in rural areas) may need to facilitate increases in economic density and aim to create networks of small towns and urban centers that will increase demand for rural goods and labor.

In particular, concerns have been raised that Ethiopia lacks a sufficiently large urban (non-farm) population to generate enough demand for its own agricultural products. Much of the urban economic theory contends that urbanization emerges from the transformation of agriculture. A region where agricultural productivity is quickly increasing is often where urban centers are growing the most rapidly as well (Montgomery et al. 2003). But agricultural growth could ultimately be constrained by inadequate demand. Hine argues that much of Ethiopia’s development problems are due to the low percentage of urban population: “58 million rural dwellers will not get rich trying to compete to sell food to 11 million urban dwellers” (World Bank 2005). The issues for Ethiopia may be much more complex than suggested by these basic calculations, but nonetheless, there appears to be ample room for expanded urbanization to accelerate economic growth.

In addition, urbanization in Ethiopia may be constrained by lack of labor mobility. Institutions that secure land rights lay the foundation for incentivizing rural populations to seek non-farm opportunities in order to supplement agricultural incomes. In Ethiopia, there are only limited

opportunities for transfer of land rights in rural areas. But if migration or labor mobility is restricted, population settlement is not responsive to economic forces. The WDR 2009 argues that well functioning institutions responsible for governing land tenure and policy are critical to increasing rural-urban interactions. In the rural context, secure property rights provide incentives for greater investment in rural / agricultural lands, as well as provide a contingency plan for individuals interested in pursuing more urban-focused activities (secure land tenure pushes individuals to seek higher profit opportunities in small towns or urban centers without the overwhelming risk of losing prior income-earning assets – in this case agricultural land). In the urban context, secure tenure pushes individuals to invest in more formal housing materials and infrastructure.

Although urban growth has remained relatively slow in Ethiopia,, investment in connective infrastructure has reduced distance to economic density (i.e. urban centers). Improving and restoring primary road infrastructure reinforces secondary and primary market interactions. Maintaining and constructing rural roads that connect agricultural surplus areas with small towns and urban centers also bolster inclusive geographic supply and demand networks. The objective of these investments and interventions is to facilitate the movement of goods and people to areas that demand specific products and labor. Increasing opportunities through greater access to markets, thus spreading risk by encouraging a portfolio of income generating activities will not only strengthen urban areas, but contribute to rural growth as well. Ultimately a balance is required between promoting productivity gains in agriculture and facilitating labor mobility, urban zoning and urban growth necessary to support commercial agriculture as well as economic transformation.

THE RURAL – URBAN LANDSCAPE IN ETHIOPIA

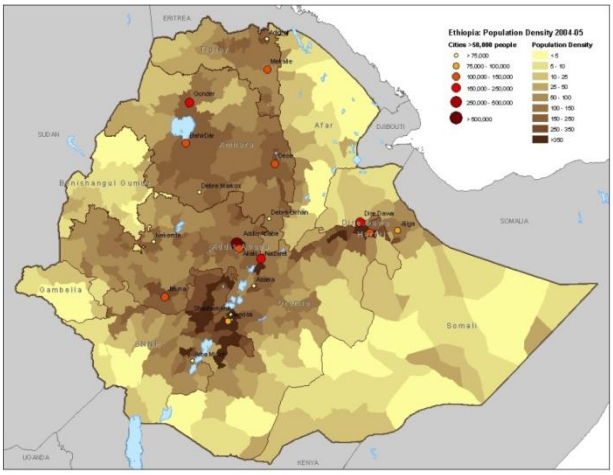
After Nigeria, Ethiopia is the second most populated country in SSA. Of the estimated 73 million people living in Ethiopia in 2007, roughly 84 percent live in rural areas and derive their income primarily from agriculture based activities. The remaining 16 percent of the population live in the urban, highland areas which comprise 35 percent of Ethiopia's territory (Figure 1). Most urban inhabitants live in small cities[1,] and in comparison to other Sub-Saharan African countries, Ethiopia's urbanization rate is low. Due in part to this low urbanization rate, the economic weight of cities in Ethiopia remains low in comparison to other countries. In 2006/07, output of non-agricultural sectors (much of which is concentrated in Ethiopia's urban areas) contributed 54 percent to GDP whereas non-agricultural sectors contributed 85 percent in SSA as a whole, and 75 percent of GDP in low income countries in 2005 (Arndt et al. 2009, MoFED 2005).

Given the overwhelming revenue generated from agricultural activities in Ethiopia, policymakers have focused primarily on Agricultural Development Led Industrialization

[1] Out of 924 cities and towns identified by the Central Statistical Agency, only 10 cities have more than 100,000 people (CSA, 2007)

(ADLI), but continuous growth of urban centers (up to 6 percent per year), requires a better understanding of the dynamic geographic and economic transformations occurring throughout the country. The recent publication of Ethiopia's 2007 census, reports urban population figures at the city level and allows for greater insight of how Ethiopia's demographic landscape has evolved. In order to analyze urban growth and transformation in Ethiopia, we seek to provide a standardized comparison of urban growth over the last 3 census periods (1984, 1994, 2007).

Figure 1: Large Cities and Population Density in Ethiopia



Source: EASE, 2004

Since the first Ethiopian census was implemented in 1984, the Central Statistical Authority (CSA) has defined urban areas as localities with 2000 or more inhabitants. Urban areas also include all administrative capitals of regions, zones, and woredas, as well as localities with at least 1000 people who are primarily engaged in non-agricultural activities, and / or areas where the administrative official declares the locality to be urban. Thus, urban areas do not remain constant between census years. A locality that was declared urban in 1984 may be defined as rural in 1994 (and visa versa) even though population growth and movement in these areas may have been minimal between census years. Given the flexible classification of urban areas defined by CSA, we use a standardized methodology developed by Uchida and Nelson (2009) in order to provide a consistent definition of urban areas which can be compared over time, across countries and within national boundaries. It lends itself to the study of market "thickness", rural – urban linkages and networks, and the costs (defined in travel time) associated with engaging in a specific market or city center.

DATA AND METHODOLOGY USED FOR THE ETHIOPIAN AGGLOMERATION INDICES

The agglomeration index provides a measure of the economic significance of urban areas rather than a definition of urban based on political status and the presence of particular urban services or activities. People and firms tend to concentrate in urban areas because

the economic benefits of agglomeration outweigh the costs of remaining in dispersed settlements. Uchida and Nelson argue that the key sources of these agglomeration economies can be summarized into three indicators: population size of a major city, population density within and around the major city, and travel time to a major city. For Ethiopia, we assume that a city of 50,000 people or more and a population density of at least 150 people per square kilometer can be regarded as a key market area that would spur agglomeration economies. In order to benefit from backward and forward linkages related to the market center, an individual or firm must be reasonably near, in terms of travel time, to an urban center (city of 50,000). Thus, we define a maximum travel time of 1 hour from a city (while also meeting the 150 people per square kilometer density criterion) for areas that are not within the city center but still benefit from economic density, and can thus be classified as urban. (These parameters are the same as those used in WDR, 2009.)

Cities do not expand evenly and at the same pace in all directions. Aerial photography of large urban areas displays irregular polygons that follow key infrastructure and geophysical attributes. Understanding population density in relation to these factors is key to understanding why and how a city (and a country) develops over time. For example, urbanization in an area with limited infrastructure and large biophysical constraints would likely result in a highly concentrated urban area near the center of the city. Conversely, a region with well-networked infrastructure that offers facilitated commuting possibilities as well as linkages to other market centers will tend to have a more expansive distribution of population density, and ultimately a larger urban area.

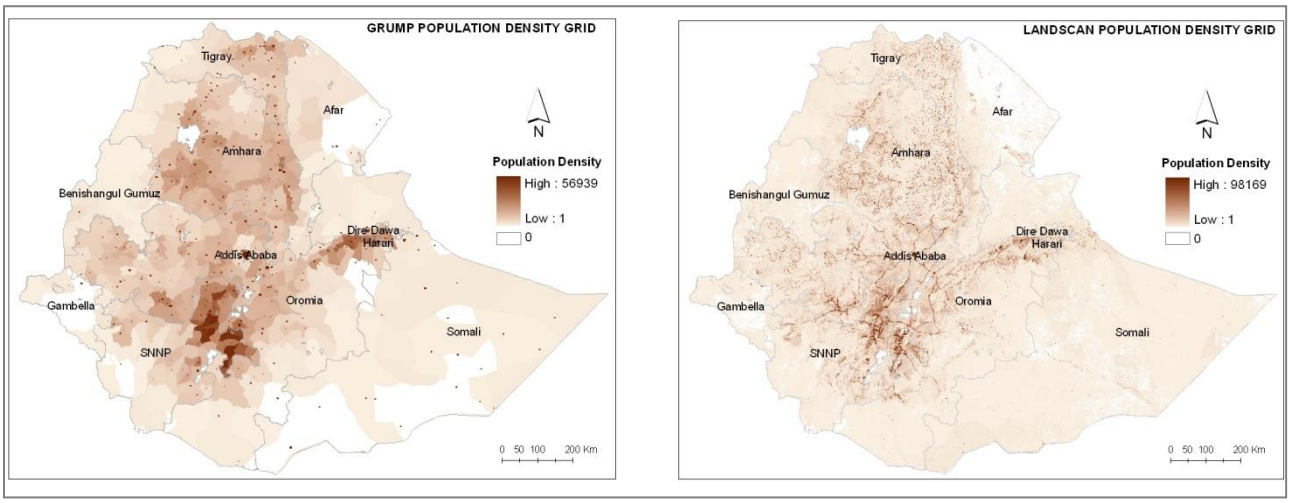
This study uses road networks in order to measure accessibility by assigning a specific travel speed to each road type (asphalt concrete, gravel, earth, etc.). We also assign walking speeds, assuming that the primary mode of transportation for villages that are not connected by road infrastructure is on foot and/or by animal. A travel time model is then generated that calculates the travel time from any point within Ethiopia to cities of at least 50,000 people, taking into account land cover and walking speed over specific terrain (grassland versus water bodies), slope (if one is walking or driving uphill, travel speed will be less), and transportation infrastructure defined by road maintenance and surface type.[2]

Given the rich panel data on road infrastructure in Ethiopia, as well as three census rounds that report population data at the city level, we are able to build an agglomeration index for three consecutive census years (1984, 1994, 2007) using nationally collected data.[3] As in the index built by Uchida and Nelson, we are constrained by the spatially disaggregated population density data which was only published for one year (2000)[4]. In order to analyze

[2] See travel time methodology in Annex 1
[3] See agglomeration index detailed methodology in Annex 2
[4] LandScan and GRUMP population density data were both published for the year 2000. Landscan uses high resolution satellite imagery (1 meter resolution) to detect variations in land cover and calculates a spatial allocation algorithm that estimates population per 1 square kilometer grid cell by allocating sub-national census data based on the relative likelihood of population occurring at different proximities to a road, along terrains of differing slope, and under different categories of land cover, including constructed buildings. GRUMP (Global Rural-Urban Mapping Project) human settlement data is developed by Center for International Earth Science Information Network (CIESIN) at Columbia University and based on the data available and applying UN growth rates, population was estimated for 2000 (http://sedac.ciesin.columbia.edu/gpw/index.jsp) for the lowest level administrative unit available.

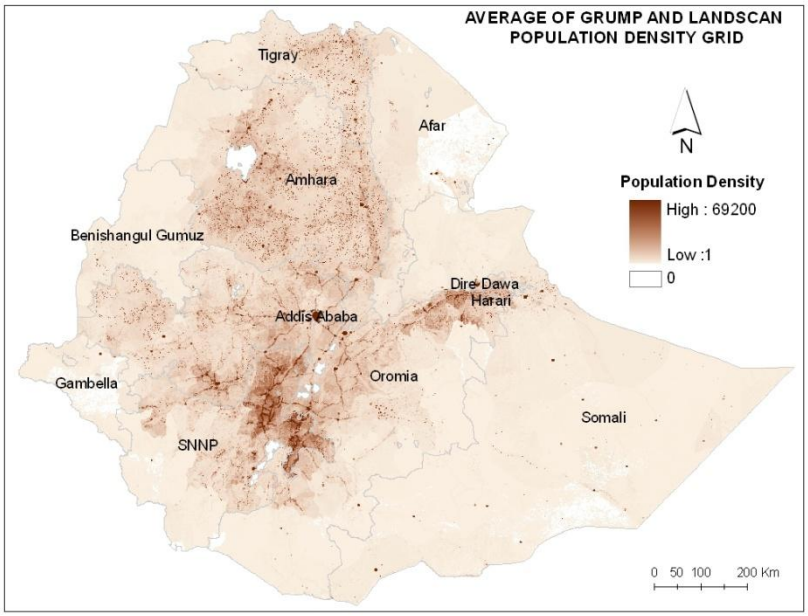
population data at a more disaggregated scale (1 kilometer resolution), we average the Global Rural and Urban Mapping Project (GRUMP) population data with the LandScan 1 kilometer resolution data in order to attain a more precise picture of the demographic layout of the country. Each dataset (GRUMP and LandScan) has advantages and weaknesses. The GRUMP dataset is based on the 1994 Ethiopian census, and uses the lowest available administrative unit (woreda level – 523 units[5]) in order to allocate urban population within woreda boundaries, whereas LandScan calculates a spatial allocation algorithm that estimates population based on the relative likelihood of population occurring at different proximities to a road, along terrains of differing slope, and under different categories of land cover (Figure 2 and Figure 3). By averaging both datasets, we are able to take into account actual urban figures from the 1994 census, adjusted for 2000 (GRUMP), as well as recognize the impact of demographic clustering due to key infrastructures (LandScan spatial allocation algorithm). In order to build the index for three years, we assume a 3 percent growth rate and adjust the population density grid accordingly in order to account for changes in population density. We realize that by calculating density based on growth rates, we are unable to take into account changes in micro settlement patterns and behavior (i.e. possibly more people are moving into the southwest area of Addis Ababa and less are moving to the eastern area of the city), but we believe that this analysis still brings interesting insights to the transformation of city growth and transportation networks over the last 25 years.

Figure 2: GRUMP and LandScan Population Density Grids



[5] Ethiopia input data from GRUMP is quite disaggregated in comparison to other countries which have a total of 15-25 administrative units as input data.

Figure 3: Average of GRUMP and LandScan Population Density Grid



RESULTS

Ethiopia remains one of the least urbanized countries in the world with the total share of urban residents at 14.2 percent[6] according to the agglomeration index (Table 1).[7] Currently, all of the cities with at least 50,000 people are geographically located in the four major regions (Amhara, Tigray, Oromia, and SNNPR), with the exception of Jijiga city in Somali region, which is in the northern area of Somali, bordering Oromia (Table 2). Since the previous census in 1994, new cities have been created, and economically viable cities have experienced large growth in population count and density (Annex 5). Given that growth in the number of cities with at least 50,000 people mainly occurred in the four major regions, we find that increased urbanization rates are primarily confined to these regions. The city administrative areas, of Addis Ababa and Dire Dawa, as well as Harari, a small urban region in the east, experienced the greatest urbanization from 1984 to 1994, with a difference in urbanization rates of 24, 38, and 21 percent respectively, whereas from 1994 to 2007 the change in urban share was less than the previous decade at 14, 8 and 10 percent respectively. All other regions, with the exception of Afar, Benishangul-Gumuz, and Gambella, experienced greater growth over the 1994 to 2007 census period.

[6] This figure differs slightly from the WDR figure, of 10.9 percent, using the same methodology because we use national roads datasets, as well as national city population datasets. We were able to replicate the WDR figure following the methodology by Uchida and Nelson for 2000, but found that national datasets gave us more accurate results in terms of travel time and population count during the census years.

[7] The percentage share of the urban population derived, using the parameters outlined by the Ethiopian government, from the latest population census is 16.2 percent according to the Central Statistical Authority.

Table 1: Agglomeration Index* – Percent of people considered urban by region

Regions	*Total Population (thousands)*	*Percentage Urban*	*Total Population (thousands)*	*Percentage Urban*	*Total Population (thousands)*	*Percentage Urban*
	1984**		1994		2007	
Addis Ababa	1,423	61.2	2,113	85.5	2,738	99.3
Afar	780	-	1,061	-	1,411	-
Amhara	10,686	2.0	13,834	3.7	17,214	7.5
Benishangul – Gumuz	351	-	460	-	671	-
Dire Dawa	158	20.3	252	58.2	343	66.3
Gambella	172	-	182	-	307	-
Harari	82	55.2	131	76.2	183	86.0
Oromia	14,016	1.7	18,733	4.6	27,158	9.2
SNNPR	7,501	-	10,377	2.2	15,043	21.1
Somali	2,006	0.2	3,199	1.6	4,439	1.9
Tigray	2,692	2.0	3,136	3.8	4,314	8.0
Ethiopia	**39,869**	**3.7**	**53,477**	**7.1**	**73,919**	**14.2**

* Population density per square kilometer (derived by GRUMP and LandScan for the year 2000), a major component in the agglomeration index, was projected using a growth rate of 3% per annum to adjust for different census years .
**Population figures for 1984 were approximated due to changes in administrative boundaries after 1984. In order to maintain consistency across all years, we geographically allocated population to the current regional boundaries. For the figures reported by province in 1984, see Annex 4

Table 2: Number of cities over 20 and 50 thousand people during the census years

	*Cities in 1984**		*Cities in 1994*		*Cities in 2007*	
Region	Over 20,000	Over 50,000	Over 20,000	Over 50,000	Over 20,000	Over 50,000
Tigray	1	1	5	1	10	3
Oromia	7	3	17	4	32	8
Amhara	5	3	7	3	18	7
SNNPR	4	0	7	1	18	5
Gambella	0	0	0	0	1	0
Benishangul - Gumuz	0	0	0	0	1	0
Harari	1	1	1	1	1	1
Dire Dawa	1	1	1	1	1	1
Addis Ababa	1	1	1	1	1	1
Somali	1	0	4	1	5	1
Afar	0	0	0	0	0	0
Total	**21**	**10**	**43**	**13**	**88**	**27**

* In 1984, Ethiopia considered Eritrea as a region of Ethiopia and reported Asmara (total population 281,110), Keren (26,339) and Assab (32,457) as Ethiopian cities over 20,000 population. We do not include those cities in this table.

Although urbanization rates fluctuated between census years, it is important to note that this fluctuation is due to city networking and improved infrastructure between cities and across regions. For example, Addis Ababa didn't show as large of an increase in urbanization between 1994 and 2007 in comparison to the previous decade, but its urbanized area expanded significantly into other regions. Given improved travel time between major cities, as well as increased population density on these corridors, urban areas in Ethiopia look more like networks in 2007 than the isolated communities typical of the 1984 urban landscape (Figure 4 and Figure 5). In 1984, Addis Ababa was primarily confined to its city administrative boundaries. By 1994, its urban network expanded, creating an urban corridor between Sebeta in the southwest and Bishoftu in the southeast, linking to Adama (previously Nazreth) - another city of 50,000 people in Oromia region. Population growth and improved transportation infrastructure in Shashamene and Awasa also facilitated linkages to form an urban network between Oromia and SNNP regions.

By 2007, urban linkages are clearly visible throughout Oromia, SNNPR, and Amhara regions. Addis Ababa expanded to connect not only Sebeta and Bishoftu, but also Asela in the South. Ambo in the west, and Debre Berhan in the east connected with Addis Ababa. Further south, Shashamene and Awasa connected to Dila. Hosaena grew considerably during the last 10 years and linked to Sodo and Shashamene to form a triangle of agglomeration economies. Linkages between Arba Minch and Sodo also seem to be forming, and Jimma has grown into an impressive southwestern hub with opportunities to link with Nekemte to the north. Underlying this growth is the improvement of transportation to market centers. The upgrading of major roads not only facilitates access to urban areas for populations living on these corridors, but also continues to draw people to these networks in search of greater mobility and increased economic benefits.

Figure 4: Agglomeration Index 1984 and 1994

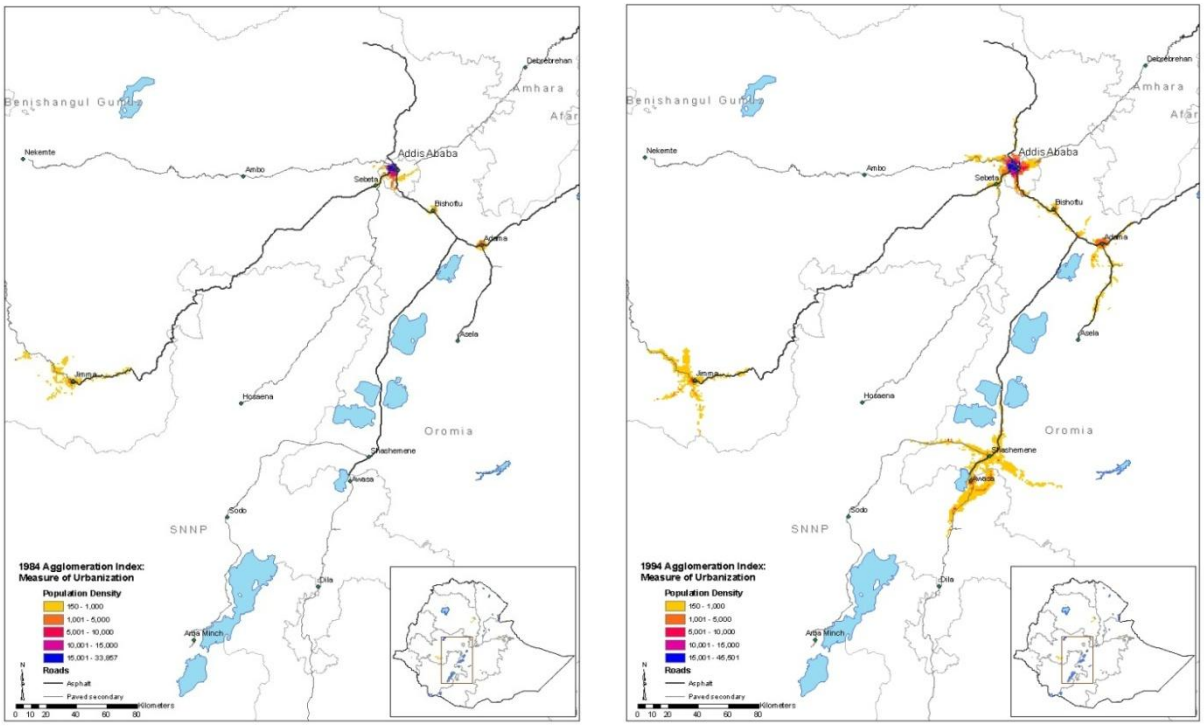
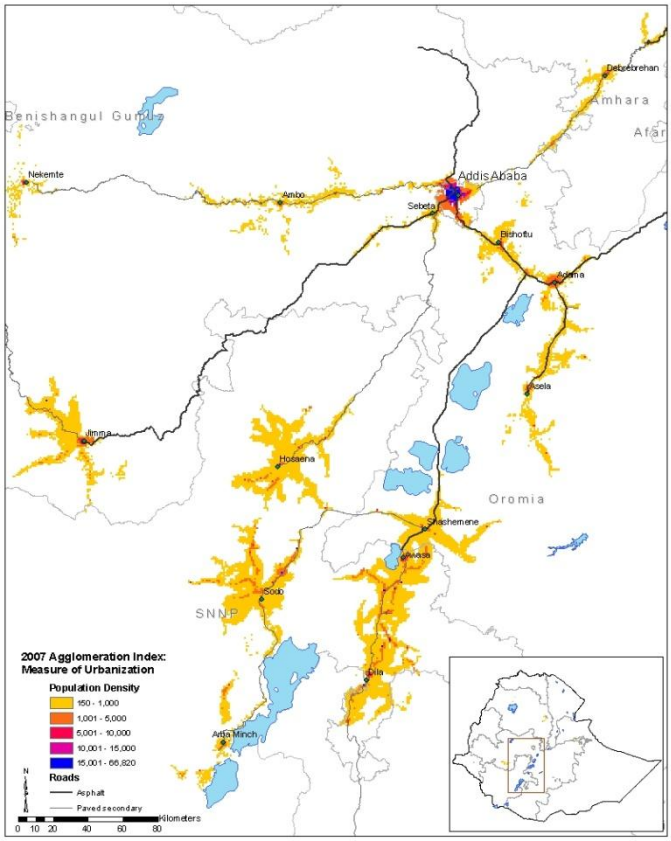


Figure 5: Agglomeration Index 2007



It is important to note, however, that population densities and quality/density of transportation infrastructure affect diverse regions in different manners. In Ethiopia, the central and peripheral regions represent two very different economic, geographic and demographic landscapes. While in the main central regions (Amhara, Oromia, SNNPR, and Tigray), higher population densities and a more integrated road network is characteristic of the economic landscape, in the peripheral regions, limited road access and dispersed settlements creates larger challenges for linking remote populations to the benefits of agglomeration economies. Improving transportation infrastructure along main access roads will benefit those already in densely populated areas, but maintaining and building select rural road infrastructure in areas with economic (agricultural) potential will be critical for poverty reduction and economic growth strategies in the more rural remote areas.

IMPROVEMENTS IN TRANSPORTATION INFRASTRUCTURE

Given the limited infrastructure during the eighties and early nineties, the Ethiopian government prioritized transportation infrastructure investment in order to enhance linkages between major cities. A 10-year Road Sector Development Program was formulated to improve the quality and size of road infrastructure beginning in 1997. The construction and

rehabilitation of roads outlined in the RSDP improved travel time within the country considerably. In 1984, 40 percent of the population was over 10 hours from a city of at least 50,000 and 42 percent were over 5 hours away from a large city (Table 3 and Figure 6). Only three regions in 1984 (as well as the urban administration areas) had populations that were within 1 hour of a large city, but only 2.5 to 4 percent of the population in these regions fell into this category. By 1994, 31 percent of total population was greater than 10 hours travel time from a major city and five of the nine administrative units had populations that could reach a city within an hour (Table 4 and Figure 6).

Given limited city and infrastructure development in the peripheral regions, the only improvements in travel time between 3 and 5 hours were experienced in the 4 major regions. In SNNPR, 7 percent more of the population was within 3 hours of a major city, and 25 percent more people were within 5 hours of a city in 1994 compared to 1984. Although larger cities in the 4 main regions were better linked in 1994, at least a quarter of the population in all regions was over 10 hours travel time from a city of at least 50,000 people.

Since 1994, the Ethiopian government and international donors have continued to invest in key road infrastructure. Currently, only 3.2 percent of the population in Amhara, and 4.5 percent in SNNPR are more than 10 hours from a major city (Table 5 and Figure 7). SNNPR showed the most improvement in travel time, by connecting 45 percent more people to a city within 3 hours travel time. In Tigray and Oromia, 21 percent of the population improved market access from over 10 hours to between 3 and 10 hours travel time to a major city. At present, every region except Gambella has a city of at least 50,000 people, and many of these cities have built networking transportation infrastructure in order to harness the potential of economic corridors between cities. Although urban centers are linking to other large cities through improved infrastructure, only 5 to13 percent of the population in any region, including the major 4 regions where primary roads stretch between urban centers, are within one hour travel time to a city of at least 50,000.

Table 3: Percent population connected to a city of at least 50,000 people in 1984

Region	*Access < 1 hour*	*Access 1 - 3 hours*	*Access 3 - 5 hours*	*Access 5 - 10 hours*	*Access > 10 hours*
Tigray	3.76	-	6.13	52.82	37.28
Afar	-	-	-	5.62	94.38
Amhara	2.49	3.93	16.63	38.21	38.74
Oromia	4.04	2.62	11.82	47.05	34.46
Somali	-	-	-	12.72	87.28
Benishangul-Gumuz	-	-	-	-	100
SNNPR	-	-	1.58	57.59	40.83
Gambella	-	-	-	16.55	83.45
Harari	100	-	-	-	-
Addis Ababa	100	-	-	-	-
Dire Dawa	100	-	-	-	-
Ethiopia	6.74	1.96	9.22	41.77	40.31

Table 4: Percent population connected in 1994

Region	*Access < 1 hour*	*Access 1 - 3 hours*	*Access 3 - 5 hours*	*Access 5 - 10 hours*	*Access > 10 hours*
Tigray	3.76	3.35	16.20	47.73	28.96
Afar	-	-	-	5.62	94.38
Amhara	2.82	8.04	18.12	44.47	26.55
Oromia	5.29	7.66	20.55	36.72	29.78
Somali	7.99	-	-	10.95	81.05
Benishangul-Gumuz	-	-	-	11.24	88.76
SNNPR	3.38	7.28	26.87	39.61	22.86
Gambella	-	-	-	-	100
Harari	100	-	-	-	-
Addis Ababa	100	-	-	-	-
Dire Dawa	100	-	-	-	-
Ethiopia	8.38	6.44	18.19	35.96	31.03

Table 5: Percent population connected in 2007

Region	*Access < 1 hour*	*Access 1 - 3 hours*	*Access 3 - 5 hours*	*Access 5 - 10 hours*	*Access > 10 hours*
Tigray	10.89	15.36	12.48	53.71	7.57
Afar	-	-	1.77	9.73	88.49
Amhara	5.05	22.72	37.06	31.98	3.20
Oromia	9.03	18.06	36.39	27.84	8.68
Somali	7.99	-	-	13.57	78.44
Benishangul-Gumuz	-	-	-	29.15	70.85
SNNPR	12.55	52.65	12.28	18.05	4.47
Gambella	-	-	-	-	100
Harar	100	-	-	-	-
Addis Ababa	100	-	-	-	-
Dire Dawa	100	-	-	-	-
Ethiopia	12.48	23.56	25.73	26.03	12.20

Figure 6: Travel time 1984 and 1994

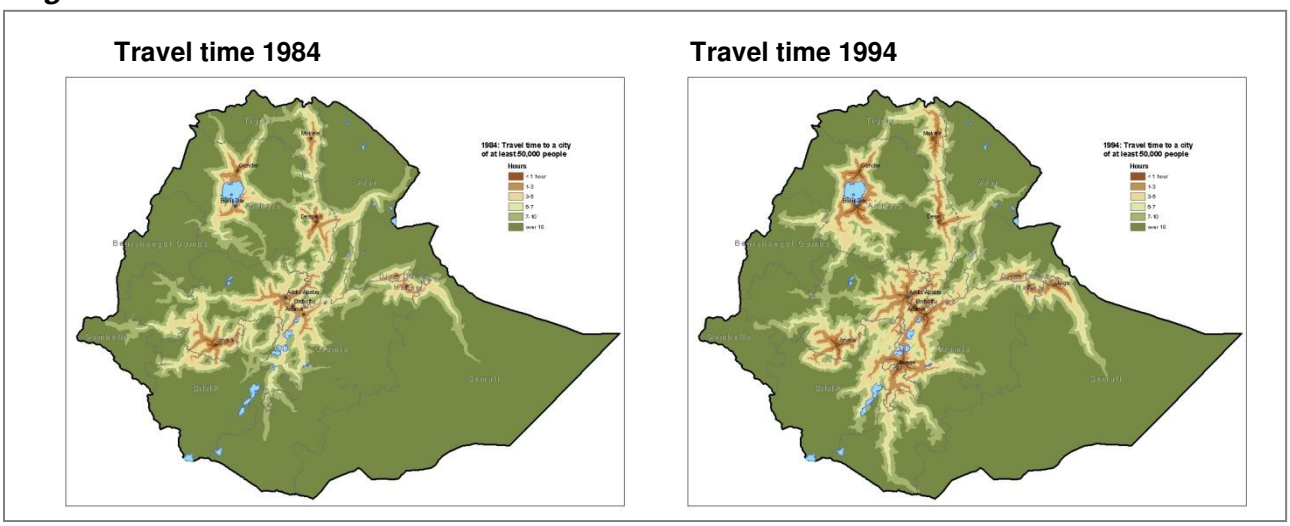
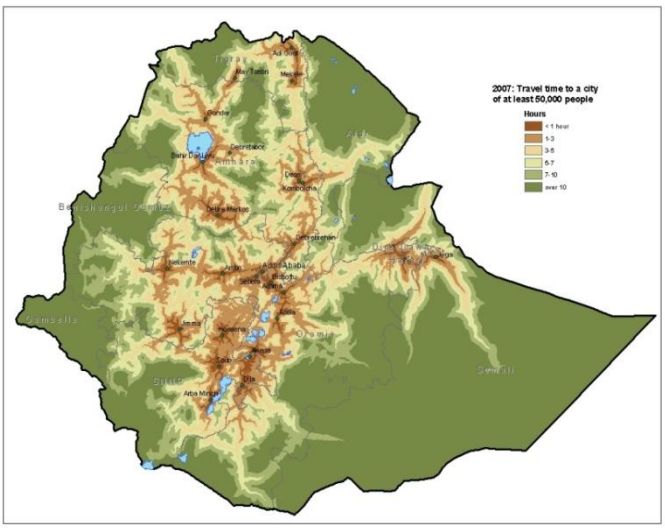


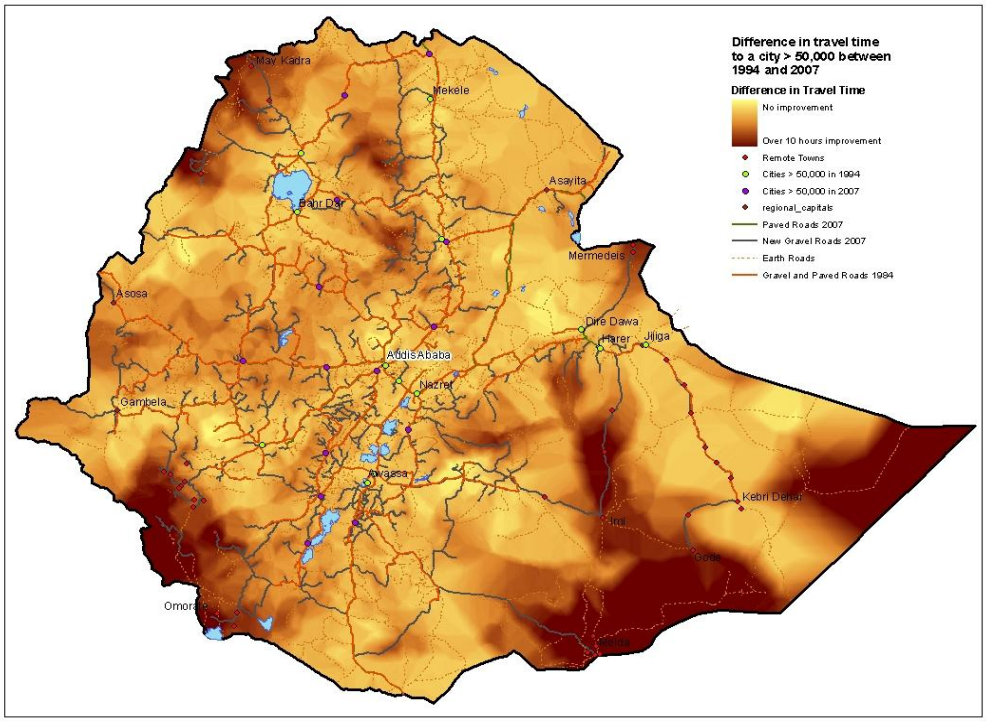
Figure 7: Travel time for 2007



It is clear that the investments laid out in the 10-year Road Sector Development Program improved access to major cities and enhanced links between cities. Although investments in key transportation corridors are important for urban growth, the main beneficiaries of these investments tend to be people already living in more densely populated, connected regions. Peripheral areas with limited market access and population density will remain left out of the urban economic linkages developing in the central areas of the country.

Low density of all-weather road systems and low population density (urbanization) in the peripheral regions are major factors influencing market access in Ethiopia. In 2007, between 23 and 98 percent of the population in every region was further than 5 hours travel time from a major city. Between the years of 1994 and 2007, the government invested in several key gravel roads that improved access for rural populations on the periphery (Figure 8). The new gravel roads that were built between Kebri Dehar and Gode, and between Harar and Imi eased access constraints in Somali region considerably. Earth roads that were rehabilitated also increased access in the far reaches of Somali region. Although access was improved in these regions by over 10 hours, populations remain very remote (78 percent of the population in Somali region is still further than 10 hours from a major city). Extended evaluation of the economic benefits of nurturing the nascent corridors between Jijiga and Kebri Dehar, and between Harar – Imi – Gode, could be undertaken to understand the tradeoffs of investing in these areas.

Figure 8: Difference in travel time to a city of at least 50,000 people between 1994 and 2007



URBAN GROWTH AND RURAL POVERTY REDUCTION IN ETHIOPIA

Poverty reduction strategies in Ethiopia have relied primarily on agricultural and rural development investments. This is due to the overwhelming numbers of inhabitants that derive their livelihoods from rural activities.[8] Although the majority of the population lives in rural areas, the government of Ethiopia has identified the need to not only enhance rural – urban linkages, but also address the overwhelming need for urban planning and infrastructure improvement. The Ministry of Planning and Economic Development of Ethiopia contends that "while the focus of much pro-poor development must inevitably remain rural-based, urban development will play a more central role in the next phase of Ethiopia's development…"(2006).

The Ministry of Finance and Economic Development (MoFED) outlined the challenges facing Ethiopia's urban centers. According to MoFED, 70% of the urban population is considered slum dwellers on the basis of quality of housing, overcrowded living spaces, access to and quality of infrastructure, and security of tenure. Poverty levels in large cities are especially acute. Sixty percent of residents in Addis Ababa are estimated to be living below the poverty line (Meheret 2001). Overall, while rural poverty rates have dropped from 48 to 39 percent from 1995 to 2005, urban poverty rates have increased from 33 to 35 percent over the same period (Table 6). These figures suggest that although investment in agriculture remains a priority, investments in urban areas may need to be re-evaluated to address underperformance in poverty indicators in the cities. The 2004/05 Ethiopian Household Survey shows that urban and rural poverty rates are similar in regards to depth, severity and poverty rate. It is against this setting that the Government of Ethiopia drafted the National Urban Development Policy which became operational in 2005. Two principal packages make up this policy; the Urban Development Package and the Urban Good Governance Package. These packages consist of a set of initiatives and targeted programs which include: a rural – urban linkages program, a housing development program, land and infrastructure development, construction industry capacity building, Justice reform, and Ministry of Water and Urban Development capacity building.

Table 6: Ethiopia Poverty Rates by Rural and Urban

	1995/96			*1999/2000*			*2004/05*		
	P0	P1	P2	P0	P1	P2	P0	P1	P2
Rural	47.5	13.4	5.3	45.4	12.2	4.6	39.3	8.5	2.7
Urban	33.2	9.9	4.1	36.9	10.1	3.9	35.1	7.7	2.6
National	45.5	12.9	5.1	44.2	11.9	4.5	38.7	8.3	2.7

Note: P0 denotes % of population below the poverty line; P1 measures the average depth of poverty; P2 is a measure of the severity of poverty.

Source: Ethiopia Central Statistics Agency, Household Income, Consumption and Expenditure Survey (HICES) data.

[8] In 1984, the population and housing census revealed that of 42 million inhabitants in Ethiopia, 88.6 percent of the population lived in rural areas. According to CSA, while the population grew to near 53 million in 1994, the structure and distribution of rural versus urban inhabitants remained nearly the same at 86.3 percent rural. The recently released data from the 2007 census show that approximately 84 percent of inhabitants live in rural areas.

In addition to the National Urban Development Policy, the second Plan for Accelerated and Sustained Development to End Poverty (PASDEP) document[9], which extends to 2009/10, attempts to redress strategies and support programs to enhance urban development as well. Several of the underlying components of this strategy include investments in urban areas to improve roads, markets, power, water supply and housing. Job creation schemes for micro and small enterprises within the urban areas have also been identified as a key component to promoting urban livelihood strategies.

As well as urban infrastructure improvement, the Ethiopian government prioritized transportation infrastructure investment in order to enhance linkages between major cities. A 10-year Road Sector Development Program was formulated to improve the quality and size of road infrastructure beginning in 1997. During the first phase of the road sector development program, the Government of Ethiopia and various donors financed a total of US$ 1.78 billion to upgrade 6,848 km of federal trunk roads and construct 7,687 km of regional roads (RSDP, 2002-2007). This program was recently extended (through 2010) to include a third stage of the project which aims to construct / rehabilitate 509 km of trunk and link roads, as well as upgrade 70 km of main access, regional roads.

Although these strategies are crucial for urban poverty reduction, a more holistic approach is needed in order to address critical rural – urban linkages and gain the most benefit from properly functioning agglomeration economies. An important policy reform needed in order to assure greater labor mobility and enhanced rural-urban linkages is the land tenure and certification program. Landholders in Ethiopia are not allowed to sell, exchange, or mortgage land, and failure to meet any of the obligations[10] set forth by Article 40 of the constitution would result in forfeiture of one's land rights. Given restrictions on land ownership, and unclear regulations on land tenureship, rural farmers are reluctant to invest in high potential agricultural technologies and are fearful of moving towards economic opportunity (rural towns and urban centers) in the event that they fail to secure work in the city. In order to address these uncertainties of land tenure, the government set forth a land registration and certification program in 2004/05. Even with this new system, a work commissioned by USAID in 2004 found that rural landholders do not perceive a strong system for tenure rights and contend that although they have land certification papers, they are not protected from government expropriation and periodic land redistribution. Given continued uncertainty, the land certification program has shown little effect at incentivizing investment and migration thus far. Urbanization requires labor mobility. If farmers perceive disincentives to migration, they will not respond to economic forces, and efficient gains from greater economic and geographic interaction are lost.

[9] The first Plan for Accelerated and Sustained Development to End Poverty (PASDEP) program document was drafted in 2001 and focused on smallholder agricultural strategies including access to improved technologies and farming practices, with a large emphasis on agricultural extension.

[10] Obligations include: 1)landholder in engaged in farming for his/her livelihood; 2)the landholder is resident of the given rural kebele; 3) the land is farmed on a regular bases and not left unused; and 4) the holder takes "proper care" of holdings – "proper care" is not defined in the documents.

CONCLUSIONS

Although Ethiopia has placed a primary emphasis on rural and agricultural led development, the country continues to urbanize and agglomeration economies are beginning to link and form corridors of economic growth. The transformation of these patterns and organization of production and consumption systems (in this case, increasing urbanization) has significant spatial effects, both in an urban and rural geographic context. By calculating an agglomeration index for Ethiopia over the 3 census years from 1984 to 2007, we are able to assess how urbanization and city linkages have expanded, as well as identify potential areas for further growth. Improved transport within Ethiopia has facilitated greater mobility of capital, goods, and people.

Individuals tend to seek economic opportunities, and a main driving force behind city growth is greater mobility of labor, capital and production. Improvements in road infrastructure between large cities, as well as increases in population density along these corridors, have increased urbanization rates from 3.7 to 14 percent over the last 2 decades, almost quadrupling the national urban share. Although this represents quite a dramatic transformation in the economic landscape, Ethiopia remains one of the least urbanized countries in Sub Saharan Africa.

Looking forward, it is important that Ethiopia set in place the policies needed to incentivize city growth while also supporting the agricultural backbone of the Ethiopian economy. If designed and managed properly, Ethiopia has the opportunity to further develop market centers and cities that provide effective linkages to rural areas and vice versa. Within large cities, demands of good urban governance and accountability, as well as efficient and effective mechanisms for providing key services and infrastructure will be necessary in order to reduce urban poverty. Rural areas will need consistent basic service provision, as well as secure land rights in order to incentivize more efficient and effective linkages to markets. By developing a more holistic strategy that takes into account both the need for rural capacity building and income portfolio diversification, as well as urban development and demand-supply linkages, it is expected that many of the demands echoing from Ethiopia's cities and hinterlands could be recognized.

REFERENCES

Arndt, C.; Hashim Ahmed; Sherman Robinson; and Derk Willenbockel (2009) Climate Change and Ethiopia. *Climate Change: Global Risks, Challenges and Decisions IOP Conference Series: Earth and Environmental Science*.

Baker, J., ed. (1990) *Small Town Africa: Studies in Rural Urban Interaction*. Scandinavian Institute of African Studies, Uppsala.

Brown, Molly E. (2008) *The Famine Early Warning Systems and Remote Sensing Data*. New York: Springer.

Bloom, David E.; David Canning and Günther Fink (2008) *Urbanization and the Wealth of Nations* Vol. 319. no. 5864, pp. 772 – 775; DOI: 10.1126/science.1153057

CI Rakodi (2005) The urban challenge in Africa, in Keiner, M., Koll-Schretzenmayr, M. and Schmid, W.A. (eds) *Managing Urban Futures: Sustainability and Urban Growth in Developing Countries*, Aldershot: Ashgate ISBN 0-7546-4417-0

Ellis, F. and Nigel Harris. (2004) New Thinking about Urban and Rural Development. *Keynote paper for DFID Sustainable Development Retreat*, University of Survey.

Fay, M. and C. Opal (2000) Urbanization Without Growth: A Not-so Uncommon Phenomenon. *Policy Research Working Paper #2412*. Washington, DC: World Bank.

The Federal Democratic Republic of Ethiopia Ministry of Works and Urban Development: Ethiopian Roads Authority (2008) *RSDP Performance: Eleven Years Later*.

FDRE Population Census Commission (December 2008) *Summary and Statistical Report of the 2007 - Population Size by Age and Sex*. Federal Democratic Republic of Ethiopia (FDRE).

Hardoy, Jorge E. and David Satterthwaite (1986) Small and Intermediate Urban Centres: Their Role in National and Regional Development in the Third World. Boulder, Colorado: Westview Press.

Hine, John. L. (2005) *Unpublished note.* World Bank, Washington, DC.

Hugo, G. (2006) *Africa on the Move: African Migration and Urbanization in Comparative Perspective* M. Tienda, S. Findley, S. Tollman, E. P. Whyte, Eds. Wits University Press, Johannesburg.

Karaska, Gerald J. and Belsky, Eric S. (1987) Rural/Urban Dynamics in Regional Planning: Examples from Underdeveloped Regions. in Bar-el et.al. eds. *Patterns of Change in Developing Regions*. Boulder, Colorado: Westview Press.

Kassahun, S. (2004) *Locality Development, Social Capital, and Synergic Partnership: Development of Poor Localities in Urban Ethiopia*. Cuvilier Verlag Gottingen.

Lanjouw P. and Feder G. (2001) Rural Non-farm Activities and Rural Development: From Experience towards Strategy. World Bank, Washington, DC.

Meheret Ayenew (2001) Decentralized municipal management in Ethiopia: a rapid appraisal of five municipalities. Addis Ababa, World Bank.

Ministry of Economic Development and Planning MoFED (December 2005) *The Millennium Development Goals needs assessment: synthesis report.* Development Planning and Research Department, Addis Ababa, Ethiopia.

Montgomery, Mark, Richard Stren, Barney Cohen, and Holly E. Reed, eds. (2003) *Cities Transformed: Demographic Change and its Implications in the Developing World*.Washington, D.C.: National Research Council of the National Academies, National Academies Press.

Nelson, Andrew and Uchida, Hirotsugu. (2008) Agglomeration Index: Towards A New Measure of Urban Concentration. *Background Paper for the WDR 2009.* World Bank, Washington, DC.

Renkow, Mitch (2007) “Cities, Towns and the Rural Nonfarm Economy.” In Haggblade, Hazell and Reardon, editors *Transforming the Rural Nonfarm Economy*. Johns Hopkins University Press.

Rondinelli, Dennis A. (1988) “Market Towns and Agriculture in Africa: The Role of Small Urban Centres in Economic Development.” African Urban Quarterly 3(1): 3-12.

Stephanie Hanson (2007) Urbanization in Sub-Saharan Africa, Council on Foreign Relations (Associate Director and Coordinating Editor).

Tacoli, C. and D. Satterthwaite (2003) “The urban part of rural development: the role of small and intermediate urban centres in rural and regional development and poverty reduction.” Rural-Urban Interactions and Livelihood Strategies Working Paper 9. London: International Institute for Environment and Development.

United Nations, Office for the Coordination of Humanitarian Affairs, *Reliefweb* (2007) www.reliefweb.int.

The World Bank (2009) *The World Development Report: Reshaping Economic Geography.* World Bank, Washington, DC.

ANNEX I: METHODOLOGY FOR ESTIMATION OF TRAVEL TIMES

Our definition of market accessibility is defined as the time required to travel from any point in Ethiopia to the nearest city of 50,000 people or more within the respective country. In order to evaluate travel time, a 1km resolution raster was built using geographic and demographic characteristics of the country. Each pixel in the raster records the time in minutes to travel from a specific pixel to a defined target (in this case, the closest city of at least 50,000 people).

Travel time is estimated based on a series of GIS layers that are merged into a 'friction layer' which represents the time required to cross each pixel. As a pixel value increases, the time required to cross that pixel increases accordingly. We built our friction layer based on A. Nelson's methodology for the global 1 km accessibility model (2007), but adapted his model in order to capture greater detail and variations in travel time. We used country-level datasets which contain detailed attributes on road quality and surface, as well as collected travel time data in country which were used to calibrate the model in order to reflect actual travel times between places.

The friction layer is composed of a series of GIS data layers and reclassed to reflect the assigned friction value. For example, assuming an average speed of 60km per hour on a good gravel road we assign each pixel that contains a good gravel road a value of 1 because at 60km per hour, it takes 1 minute to cross a 1km pixel (See Table 7 for assigned model speeds). Slope values, derived from a digital elevation model, is reclassed differently. Given that slope is a continuous surface that affect a majority of the other infrastructure layers (steeper slope typically causes slower travel times), and is used as a multiplying factor over the entire friction surface rather than reflecting specific friction values[11].

The effect of slope on travel speeds is computed as follows, and is based on Van Wagtendonk and Benedict (1980)

$$v = v_0 e^{-ks}$$

where:
v = off road foot based velocity over the sloping terrain
v0 = the base speed of travel over flat terrain, 5km/hr in this case
s = slope in gradient (meters per meter)
k = a factor which defines the effect of slope on travel speed

For this case we assume a base speed of 4km/hr and k is 3.0 and constant for uphill and downhill travel. The velocities over the slope grid were computed and then converted into a friction factor by dividing the base speed by the slope speed. This was then used as a multiplier against the other friction components. We applied this slope factor to both road and off road travel speeds.

[11] Slope friction multipliers are used as designated in the Global 1km. Accessibility Model by A. Nelson (2007)

After each of the layers has been reclassed to reflect their friction values, they are combined into a single friction layer in ArcGIS 9.2 as follows:

$$\text{Friction} = \text{MERGE}((\text{Rivers}, \text{waterbodies}, (\text{roads} * \text{slope}), (\text{background} * \text{slope}))$$

The MERGE function combines the layers with rivers and water bodies, having priority over roads, and roads having priority over walking speed or background values) Thus, by using the MERGE function, priorities in speed are taken into consideration. For example, in Ethiopia, rivers and water bodies are not a mode of transportation, but rather an obstacle to accessibility, thus waterbodies are allocated a speed of 1 km per hour and take precedence over a gravel road (which would normally allow for a 60km per hour speed). If there is no bridge that crosses the river, the cost distance immediately increases in order to reflect the alternative path needed in order to cross the river. These delays take precedence in the model over normal infrastructure that would normally reflect a faster speed.

This friction layer is then used as an input into the COSTDISTANCE function in ArcGIS 9.2 in order to compute the travel time in minutes from each pixel to the nearest designated populated place. In our study we analyzed travel time to cities of 50,000 people or more.

We calibrated the travel time model for specific segments within Ethiopia using actual travel times, supplemented with data from key informant interviews. Nonetheless, the estimates obtained from the travel time model remain only approximate indicators of travel time and the degree of accessibility from a given area to a city of at least 50,000 people. Further improvements in the model would require additional data on road congestion, road maintenance, road outages and differences in road conditions by season, as well as additional data on actual travel time for specific roads and road classes in a variety of regions.

ANNEX 2: METHODOLOGY FOR CALCULATING THE ETHIOPIAN AGGLOMERATION INDEX

In order to calculate the agglomeration index the following data are used:

- Population density (a threshold of 150 person per km^2) using GRUMP and LandScan population density grids and adjusting for population growth
- Cities with at least 50,000 people using the 1984, 1994, and 2007 Ethiopian Population and Housing Census Reports
- Travel time to cities of at least 50,000 people using roads datasets from 1984 (csource), 1994 (csource), and 2007 (Ethiopian Roads Authority)

Data preparation

For this particular analysis both globally available and local data are used.

- For the population density there are two globally available grid data

    1. GRUMP (Global Rural-Urban Mapping Project) population density grid
    2. Land Scan population density grid

Despite the fact that both data are depicting population density for the same year they are however derived through different methods and scales. The GRUMP dataset estimates population density based on population data derived at the lowest available administration unit and human settlement point data. In contrast, the LandScan (developed by Oak Ridge National Laboratory; http://www.ornl.gov/sci/landscan/) density grid estimates the distribution of population at large units and then further refines population density across the unit's grid cells based on likelihood coefficients, which are derived from other spatial data such as distance to roads, slope, and land cover. Both GRUMP and LandScan offer interesting but varying interpretations of population density, thus, as Uchida and Nelson, we use both datasets by averaging both density grids.

- Cities with a population size of 50,000

    For the year 2000 the GRUMP human settlement data were used in order to replicate the analysis by Uchida and Nelson. For the census years (1984, 1994, and 2007), we use the nationally reported urban city population data reported by the Central Statistical Agency of Ethiopia)

- Travel time to a city of at least 50,000 people

Accessibility is computed using a cost-distance algorithm which computes the "cost" of traveling between two locations on a 1 km resolution raster dataset. Generally this cost is measured in units of time. The cells in this raster contain values which represent the cost

required to travel across a defined area. This friction-surface contains information on the transportation network and environmental factors that affect travel times between locations.[12]

Data Analysis

In calculating the agglomeration index, we used the WDR (2009) thresholds of:

- minimum population density of 150
- maximum travel time of 60 minutes
- minimum city population size of at least 50,000 people

In order for an area to be considered urban, or within the agglomeration index, a 1 km^2 grid is created whereby each grid cell must satisfy the above three criteria. In order to create a raster dataset that classifies each grid cell as either urban or not urban, the following techniques were applied in the ArcGIS Environment using Map Algebra functions:

CON ((avGRUMP_LS >= 150 & traveltime <=60), avGRUMP_LS)

This function outputs and defines grid cells that have a population density of at least 150 people per square kilometer, and cells are within 60 minutes travel time from the center of large cities. Since the output grid contains urban population density per kilometer square the total urban population can be found by multiplying the value grid which is population density by the grid count for each row and then summing the total record.

The agglomeration index is therefore calculated as the ratio of the urban population calculated above and the total Ethiopian population for a specific year.

[12] See Annex 1 for further information on calculating travel time

ANNEX 3: YEAR 2000 CALCULATIONS USING GLOBAL DATA

Table A: Percent population connected in 2000 using global

VMAP0* and GRUMP databases

Region	*Access < 1 hour*	*Access < 3 hour*	*Access < 5 hour*	*Access < 10 hour*	*Access > 10 hours*
Tigray	7.85	41.97	34.73	11.98	3.47
Afar	-	-	1.77	97.02	1.21
Amhara	4.28	15.56	45.44	28.33	6.39
Oromia	5.53	18.80	30.82	38.59	6.25
Somali	7.99	-	13.57	64.68	13.75
Benishangul-Gumuz	-	-	-	57.76	42.24
SNNPR	4.91	13.28	41.45	35.25	5.12
Gambella	-	-	-	26.77	73.23
Harari	100	-	-	-	-
Addis Ababa	100	-	-	-	-
Dire Dawa	100	-	-	-	-
Ethiopia	9.38	15.69	33.77	34.65	6.51

Figure A: Agglomeration Index*: *2000

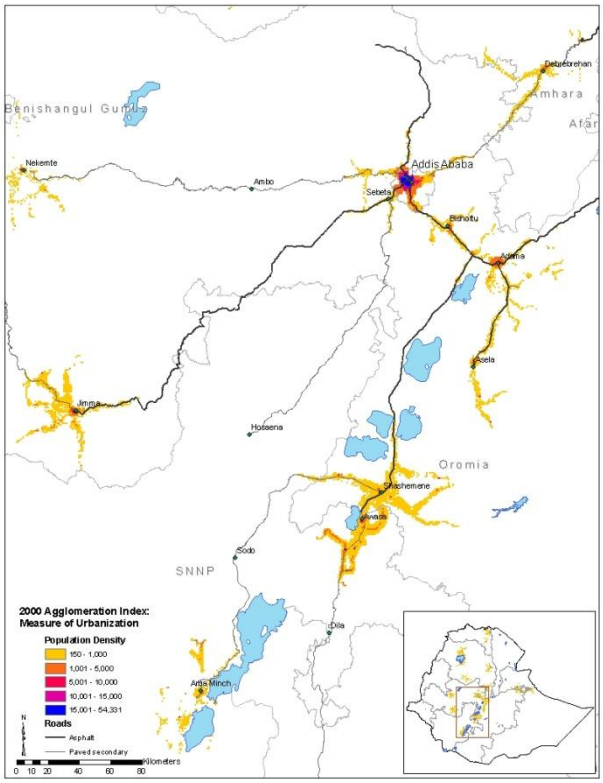
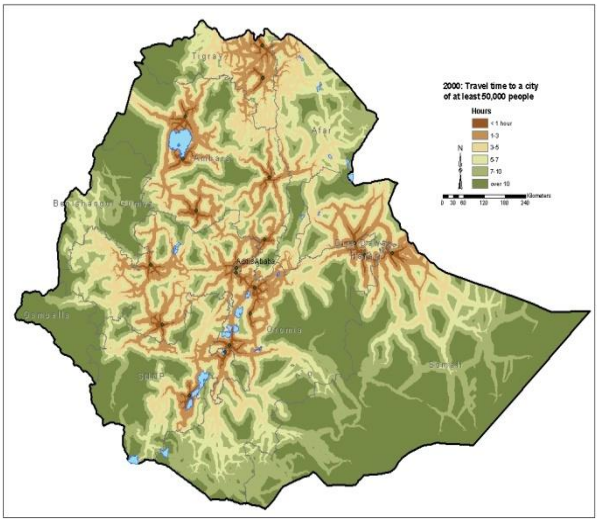


Figure B: Travel Time using VMAP0* data: 2000



*The VMAP0 global roads dataset is a fantastic effort at creating a standardized GIS roads database, although it lacks details common in national roads datasets such as road surface type and condition. For Ethiopia, the VMAP0 dataset classifies all roads as primary roads, and thus does not provide the necessary information to understand connectivity and market access

ANNEX 4: POPULATION FIGURES BY PROVINCE IN 1984

Table B: Population figures for 1984 using 1984 provinces (currently denominated as Regions)

Provinces	*Total*	*Urban*	*Rural*
Arsi	1,662,790	129,591	1,533,199
Bale	1,017,336	79,316	938,020
Gamo Gofa	1,269,477	70,266	1,199,211
Gondar	3,018,909	232,460	2,786,449
Gojjam	3,273,524	258,556	3,014,968
Hararge	4,192,898	345,610	3,847,288
Illubabor	975,658	68,283	907,375
Keffa	2,478,957	152,867	2,326,090
Sidamo	3,813,075	250,189	3,562,886
Shewa	8,102,326	774,847	7,327,479
Tigray	2,415,871	240,977	2,174,894
Wellega	2,478,425	158,407	2,320,018
Wello	3,746,144	268,966	3,477,178
Addis Ababa	1,423,182	1,423,182	0
Asab	126,738	32,457	94,281
Eritrea	2,621,566	383,315	2,238,251
Total	42,616,876	4,869,289	37,747,587
Total less (Eritrea + Assab)	39,868,572	4,453,517	35,415,055

ANNEX 5: CITIES OF OVER 20,000 POPULATION DURING THE LAST 3 CENSUS PERIODS

Table C: Population of Cities over 20,000

City Name	*1984*	*1994*	*2007*
Addis Ababa	1,423,182	2,084,588	2,738,248
Dire Dawa	99,980	173,188	232,854
Adama Special Zone	77,256	127,842	222,035
Gondar Town	80,675	112,249	206,987
Awasa Town	36,367	69,169	158,273
Bahir Dar	54,773	96,140	155,355
Jijiga	24,716	58,360	125,584
Mekele Town	62,668	96,398	122,850
Jimma Spe Town	60,218	88,867	120,600
Dese Town	71,565	97,314	120,029
Shashemene Town	31,884	52,080	102,062
Bishoftu Town	55,657	73,372	100,114
Harer Ketema	63,070	76,378	99,321
May Tsebri Town	-	-	92,696
Dila Town	22,864	33,734	81,644
Nekemte Town	28,703	47,258	76,817
Sodo Town	24,278	36,287	76,780
Arba Minch Town	20,280	40,020	74,843
Hosaena Town	-	31,701	69,957
Asela Town	32,954	47,391	67,250
Debrebrehan Town	25,637	38,717	65,214
Debere Markos Town	41,138	49,297	62,469
Kombolcha Town	-	39,466	58,642
Adi Girat Town	-	37,417	57,572
Sebeta Town	-	-	56,131
Debretabor Town	-	-	55,157
Ambo Town	-	27,636	50,267
Burayu Town	-	-	48,864
Arsi Negele Town	-	23,512	48,092
Robe Town	-	21,516	47,296
Shire Enida Silase Town	-	-	46,382
Woldiya Town	-	-	46,126
Akisum Town	-	27,148	44,629
Zeway Town	-	20,056	43,610
Gode	-	40,585	43,134
Adwa Town	-	24,519	40,502
Gambela Town	-	-	38,994

Weliso Town	-	25,491	37,867
Negele Town	-	23,997	36,699
Meki Town	-	20,460	36,214
Chiro Town	-	-	33,643
Butajira Town	-	20,509	33,393
Alamata Town	-	26,179	33,198
Goba Town	23,052	28,358	32,916
Haromaya Town	-	-	31,686
Yirgalem Town	-	24,183	31,468
Gimbi Town	-	20,462	31,311
Wekero Town	-	-	30,208
Degehabur	-	25,464	29,956
Metu Town	-	-	29,627
Mojo Town	-	21,997	29,540
Dembi Dolo Town	-	-	29,249
Welikite	-	-	28,856
Areka Town	-	-	28,293
Boditi Town	-	-	27,684
FicheTown	-	21,187	27,487
Kulito Town	-	-	26,850
Hagere Mariyam Town	-	-	26,600
Kebridehar	-	21,521	26,479
Dolo Odo	-	-	26,296
Mota Town	-	-	26,173
Agaro Town	-	-	25,719
Finote Selam Town	-	-	25,388
Kobo Town	-	20,788	24,861
Dangila Town	-	-	24,564
Tepi Town	-	-	24,489
Durame Town	-	-	24,454
Holeta Town	-	-	24,030
Shakiso Town	-	-	23,924
Mizan Aman Kifele Ketema	-	-	23,562
Maychew Town	-	-	23,484
Gerbe Guracha Town	-	-	23,481
Sawula Town	-	-	23,370
Chagini Town	-	-	23,225
AdolaTown	-	-	22,937
Assosa	-	-	22,725
Sekota Town Administration	-	-	22,342
Aleta wendo	-	-	22,090
Dodola Town	-	-	21,504

Genet Hara	-	-	21,504
Humera Town	-	-	21,387
Wereta Town	-	-	21,217
Injebara Town	-	-	21,058
Bonga Town	-	-	20,855
Debarq Town	-	-	20,830
Asassa Town	-	-	20,647
Jinka Town	-	-	20,522
Bure Town	-	-	20,406