Infrastructure and Agricultural Development in AGRA Countries

A Report Prepared for the Bill & Melinda Gates Foundation

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Table of Contents

i. Executive summary 4
i.1 Main findings 4
i.2 Missing pieces 5
1. Introduction 7
2. Previous literature 9
Section summary 9
2.1 Introduction 11
2.2 Transportation infrastructure and agriculture 12
2.2.1 Effect of transport infrastructure on agricultural productivity 14
2.2.2 Effect of transportation infrastructure on adoption of agricultural technologies 19
2.2.3 Effect of transportation infrastructure on market participation 20
2.3 Electricity 23
2.4 Storage 24
2.5 Communications 25
3. Infrastructure in Gates' target countries 28
Section summary 28
3.1 Introduction 30
3.2 Transportation infrastructure 30
3.2.1 Across-country comparisons 30
3.2.2 Within-country comparisons 35
3.3 Communications infrastructure 42
3.3.1 Across-country comparisons 42
3.3.2 Within-country comparisons 44
3.4 Electricity access and infrastructure 49
3.4.1 Across-country comparisons 49
3.4.2 Within-country comparisons and trends across time 54
3.5 Storage infrastructure 59
4. Current efforts to improve infrastructure 62
Section summary 62
4.1 Overall lending by source and sector 64
4.2 Lending by country 66
4.3 A note on small infrastructure projects 83
4.3.1 CLUSA in Mozambique 83
4.3.2 Inventory credit in Ghana 83
4.3.3 Disseminating price information in West Africa 84
5. Next steps 85
5.1 Baseline data 85
5.2 Compilation and interpretation of existing data 85
5.3 Research projects 86
5.4 Convening 86

References 88
Appendix 1: Main data sources 94
Appendix 2: Examples of DHS regional maps 98
Appendix 3: Examples of transportation maps using data from the Digital Chart of the World 99
Appendix 4: Examples of infrastructure maps using data from the Digital Chart of the World 107
Appendix 5: Infrastructure investment by project and country for 2006 110
Appendix 6: Development Domain Mapping 126
Appendix 8: Description of main investors in infrastructure 127

i. Executive summary

i.1 Main findings

This report first examines the existing literature to shed light on the links between transportation, communications, electricity, and storage infrastructure and agricultural development, including productivity, technology adoption, and the functioning of rural markets. With this review as a framework it then presents basic statistics on the availability of these types of infrastructure in the A Green Revolution for Africa (AGRA) countries. Section 4 details, to the extent possible, current efforts to address infrastructural deficiencies by both public and private agents.

As one might expect, all of these types of infrastructure are very important for agricultural development. The evidence that roads are an essential force in rural development is incontrovertible, though detailed analysis of the channels through which it does so are not always available. Roads increase the flow of information and the ability of farmers to receive inputs, get goods to market, and access information. There is a strong documented relationship between participation of farmers and traders in markets (either buying or selling) and road quantity and quality. The literature also suggests a relationship between transport infrastructure and technology adoption, though this has not been well-studied.

Analyses of the effect of electricity by itself on agricultural productivity are difficult to find, perhaps because of difficulties in disentangling causality. However, electricity is a driving force behind large-scale irrigation, and common sense dictates that it must be present before the development of value-added agricultural industries.

In terms of the availability of these services in AGRA countries, several patterns emerge. All AGRA countries, with perhaps the exception of Zambia, fall far short of any reasonable benchmark for transport infrastructure. Ethiopia finds itself rated very poorly on all transport infrastructure measures, along with Mali, Uganda, and Nigeria, while Senegal, Cameroon, and Ghana are the best off. In terms of communications infrastructure, Senegal, Ghana, Nigeria, and Kenya find themselves relatively well-off, while the countries with the least telephone and internet access are Ethiopia, Rwanda, Mali, and Malawi. Electricity access shows a similar distribution. Urban-rural statistics show large disparities in access,

with Senegal having one of the highest rural-urban disparities in electricity access, along with Ethiopia and Cameroon.

Current efforts to alleviate infrastructure weaknesses in Africa are growing, though it is difficult to tell how much fruit they will bear. In terms of total public aid to AGRA countries, Ethiopia receives the most aid and Burkina Faso the least. When measured by per capita spending, Senegal receives the most and Nigeria the least. Public aid in particular sectors follows country needs relatively well, with more transport aid going to countries in greater need of roads and more energy aid going to countries with less electricity access. The opposite trends occur in private investment in infrastructure. Private investment is dominated by capital flows to the telecommunications sector, which increases with the number of residents with telephone access in a country – just the opposite of the World Bank funding trend. Nigeria receives by far the most private investment, followed distantly by Mozambique, and Malawi and Rwanda the least.

i.2 Missing pieces

It may be the case that this report is more effective at revealing a lack of information than conveying the relevant research and statistics regarding infrastructure in AGRA countries. While the literature relating infrastructure to agricultural development is vast, there are some glaring holes. In the area of transport infrastructure, the dominant focus has been on roads, with little attention given to railroad, river, port, and air networks. In addition, in many cases researchers have studied the effects of infrastructure on agricultural productivity without necessarily shedding light on the mechanisms through which this productivity might be affected. Storage infrastructure is another research orphan. Though its importance in reducing price variability has long been established in the theoretical and case study literature of agricultural economics, empirical studies are sorely lacking. Finally, very little research has been undertaken looking at the role of communications infrastructure – telephone, cellular phone, and internet – on agricultural development.

In terms of the data available to assess the quality and quantity of infrastructure in Africa, there is a wealth of information that allows comparisons to be made across countries. However, much of the readily available data which would allow for disaggregation of indicators within countries is either out of date or not yet in a useable format. For example,

the digital road maps displayed in this report are from 1993. Fortunately, current efforts being undertaken by the Center for International Earth Science Information Network (CIESIN) and the International Food Policy Research Institute (IFPRI) promise to make considerable headway in this area. In terms of communications and electrical infrastructure, there is a myriad of random household and census data sets available which contain variables that could be used to assess regional access to these services. At the moment, however, the data has not been made available in an easily usable geographic format. CIESIN is leading the effort to push this area of research forward – they are in possession of a large collection of censuses from various countries, and have used some of them already to generate poverty maps. In terms of information regarding storage infrastructure, there is not even data available that would allow for the assessment of quantity or quality between countries, let alone within them.

The last section of this report was able to provide considerable detail regarding the distribution of transportation, energy, and communications infrastructure aid from both public and private sources. Storage infrastructure remains a black hole in terms of determining the allocation of funding to it, although it is likely to have been subsumed in other financing categories.

1. Introduction

In all of the currently wealthy countries, all of the middle income countries, and almost all of the countries climbing from the low to middle income range, agriculture has been an essential part of the engine of growth. The linkages between the agricultural sector and other sectors have long been recognized as having important multiplier effects (Johnston and Mellor, 1961). More importantly, one of these effects is to reduce poverty. Gallup, Radelet, and Warner (1997) showed that a 1% increase in per capita agricultural output led to a 1.6% increase in the incomes of the poorest quintile, while Thirtle, Irz, Lin, McKenzie-Hill, and Wiggins (2001), using cross-country data, have shown that the same increase is associated with a .83% decrease in extreme poverty.[1]

Recognizing the role of the Green Revolution in lifting millions out of poverty in Latin America and Asia, and acknowledging that this same revolution left Africa's agricultural productivity unchanged, the Bill and Melinda Gates Foundation, together with the Rockefeller Foundation, are making substantial investments in a new Green Revolution for Africa. This commitment includes funding research in crop varieties appropriate for the challenges of the African climate and soils, training African scientists to continue this process, and supporting local networks to distribute improved seeds to farmers.

As this effort begins to gain momentum, there are various impending questions: what will happen once these improved seeds start bearing fruit? How will the crops get to market? Will farmers have access to the price information necessary to make the most of higher productivity? If everyone's yields increase and they all bring their crops to market at the same time, will the downward pressure on prices outweigh the benefits of having produced more? All of these questions fall under the umbrella of infrastructure, which leads to the question that inspires this report: To what extent will the lack of infrastructure in the AGRA countries limit the ability of a new Green Revolution to occur?

This report represents a first step towards answering this question. The next section of this document provides a literature review of infrastructure and agricultural development, with a focus on empirical works. The third details existing data to assess the state of roads,

[1] The last two citations come from DFID (2005)'s wonderfully thorough report on agriculture, growth, and poverty reduction.

railways, ports, storage facilities, electrification, and communications infrastructure in those same countries. To the extent that it is possible, Section 3 also compares the current state of infrastructure in the countries of interest to that of India on the eve of its Green Revolution. Section 4 summarizes existing and proposed infrastructure projects in AGRA countries and Section 5 concludes by highlighting open research questions in this area.

2. Previous literature

Section summary

This section of the report presents a review of the existing literature regarding the effects of transportation, electricity, storage, and communications infrastructure on agricultural productivity, adoption, and the functioning of rural markets. It does not touch upon irrigation infrastructure or upon education, which is likely to be quite important for agricultural productivity, given that irrigation reduces variation in water available for crops as well as extending the productive capacity of land, and education increases the ability of farmers to adopt new technologies. This report also does not touch on legal infrastructure – i.e., laws and institutions giving buyers and sellers the capacity to enforce contracts should disagreements occur – though this is clearly a necessary foundation for market development and is mentioned in several works reviewed in this section.

As one might expect, all of these types of infrastructure are very important for agricultural development. There is considerable evidence that good roads are an essential force behind increases in productivity of the agricultural sector, though the mechanisms for this effect are not always well-described. Roads increase the flow of information and the ability of farmers to receive inputs, get goods to market, and access information. This suggests that they may affect both the shape of the demand curve and movements of the supply curve in response to technological change. There is a strong documented relationship between participation of farmers in markets (either buying or selling) and road quantity and quality. Studies in Benin, Malawi, and Ethiopia show a large effect of transportation costs on the transactions costs of grain traders.

The literature also suggests a relationship between transport infrastructure and technology adoption, though this has not been well-studied. A clear missing piece in this area of research is the effect of other sorts of transportation infrastructure – railways, waterways, and airports – on agricultural development. It seems likely that these will be more important for regional and international trade than for local exchanges. The general consensus is that transport infrastructure is essential for rural development. However, it is important to keep in mind that the development of such infrastructure is not without its

risks – there is a substantial branch of literature, not reviewed here, discussing environmental degradation and accelerated transmission of diseases along major transport routes.

Electricity is a driving force behind large-scale irrigation, and common sense dictates that it must be present before the development of value-added agricultural industries. It is difficult to disentangle the causality between electricity access/consumption and development in general or agricultural development in particular. A couple of studies have detailed electricity's effects on agricultural productivity, but the estimates of these effects are not very large. This is likely because electrification is highly correlated with the development of other types of infrastructure that are important for rural development, like roads and education.

The importance of storage infrastructure in reducing price variability has long been established in the theoretical and case study literature of agricultural economics. Empirical studies of its role are sorely missing, although there has been some interesting recent work on the effect of price variation on technology adoption, showing that new technologies are less likely to be adopted when price variation is high. There is also some suggestion in the literature that a lack of storage has severely impeded efforts at market liberalization in developing countries, as without adequate storage it is impossible for producers and traders to take advantage of seasonal price changes.

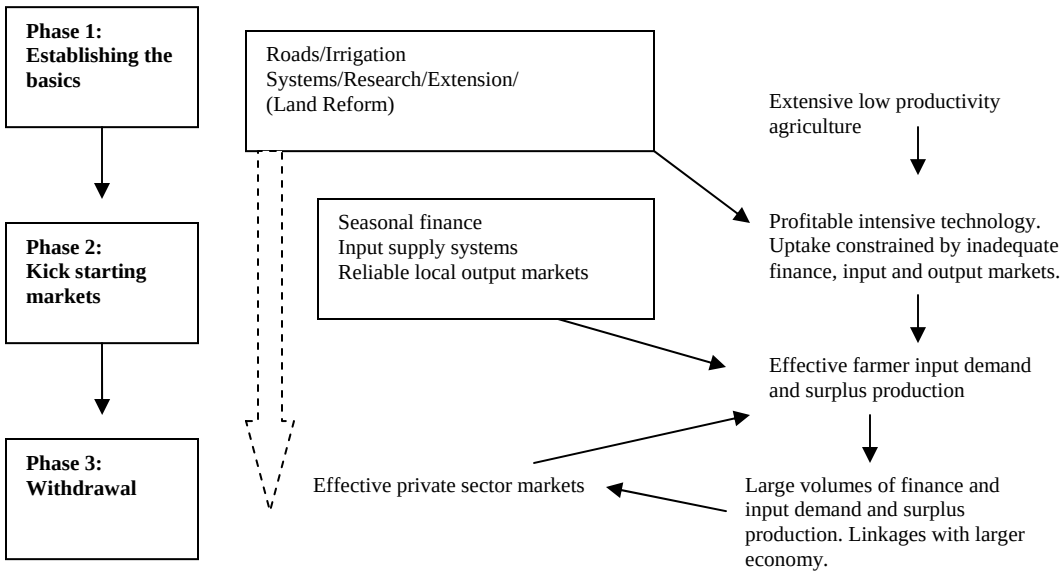
Finally, very little research has been undertaken looking at the role of communications infrastructure, meaning telephone, cellular phone, and internet, in agricultural development. Some studies have suggested its importance in lowering trade costs, and promising new experiments in India have shown great success in using the internet to both connect farmers to traders as well as to disseminate information regarding pest infestations.

2.1 Introduction

Taking the relationship between agricultural development and poverty reduction as given, this section of the report takes on a more subtle task – establishing the relationship between various types of infrastructure and agricultural development. In order to provide a context for the contents of sections 3 and 4, the following pages review the available literature linking transportation, electrification, storage facilities, and communications infrastructure to agricultural development.

Before beginning the literature review, it is instructive to consider the following diagram detailing the different phases of agricultural development provided by Kydd and Dorward (2004) and referred to by Pinstrup-Andersen and Shimokawa (2006):

Figure 2.1: Phases of agricultural development



According to these authors, government intervention is crucial during phases 1 and 2, when large public investments are necessary to supply basic infrastructure and subsidies required to cover transactions costs. Once output and input markets are functioning well, there is little reason to continue this sort of intervention. This literature review concentrates on the first box in the middle – the necessary infrastructure needed to make the initial transformation from extensive low productivity agriculture to more productive systems. It

intends to provide considerable detail regarding the relationships between infrastructure and overall agricultural development, and will begin with the transportation sector.

2.2 Transportation infrastructure and agriculture

The notion that location is important for economic prosperity has experienced something of a rebirth in the economic literature (see Krugman, 1992). The idea, however, is hardly a new one. Johann Heinrich von Thünen (1783-1850) declared quite some time ago that producers who are isolated and cannot move their sources of production (like farmers) can only be successful if they can afford to bear the costs of transporting their goods to market (von Thünen 1966). Clearly, one of the main contributors to the cost of transport is the quality of the infrastructure upon which vehicles travel.

The effects of transportation infrastructure on agricultural productivity have been well-studied by academics and policymakers alike. Logic dictates that these effects must be large and important, and indeed, empirical studies have shown that this is the case. Without well-functioning roads, railways, ports, and air transport, essential inputs cannot arrive at a producer's field, and goods cannot leave that field to get to market, be it local or international. In fact, improving agricultural yields in *inaccessible* areas may theoretically have a perverse effect; increasing supply in a market where demand and outside trade are limited could lower prices. If the goods being produced are necessities – i.e., the amount purchased doesn't increase very rapidly with decreases in price – such falls in price could hurt the very producers the yield-improving technology was intended to help by lowering their revenues. A useful review of the theory behind this conclusion is given in Jayne and Myers (2006), who point to transport costs as the biggest barrier to efficient food market function in Africa.

To summarize their arguments requires two graphs depicting supply and demand in the food market. On the vertical access is the price of food, and on the horizontal, the quantity. Figure 2.2 shows the situation where demand for food (the downward sloping line labeled D) is very insensitive to changes in price. This is the case where markets are quite isolated. Here, when yields are increased, more production occurs for any given price level, and the supply curve shifts from S to S'. This results in an increase in quantity produced from Q to Q', and a decrease in price from P to P'. Because the price decrease is larger than the quantity increase, as a result of the insensitivity of consumer demand, revenues with the

new supply curve, which are given by the rectangle whose diagonal corners are P' and Q', are less than those with the original supply curve, with diagonal corners at P and Q.

Figure 2.2: Isolated markets and technical change

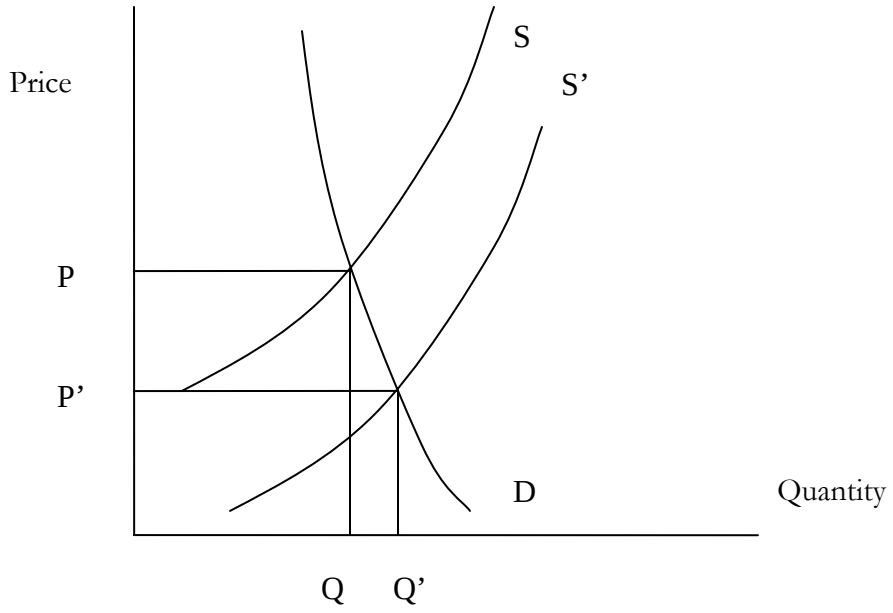
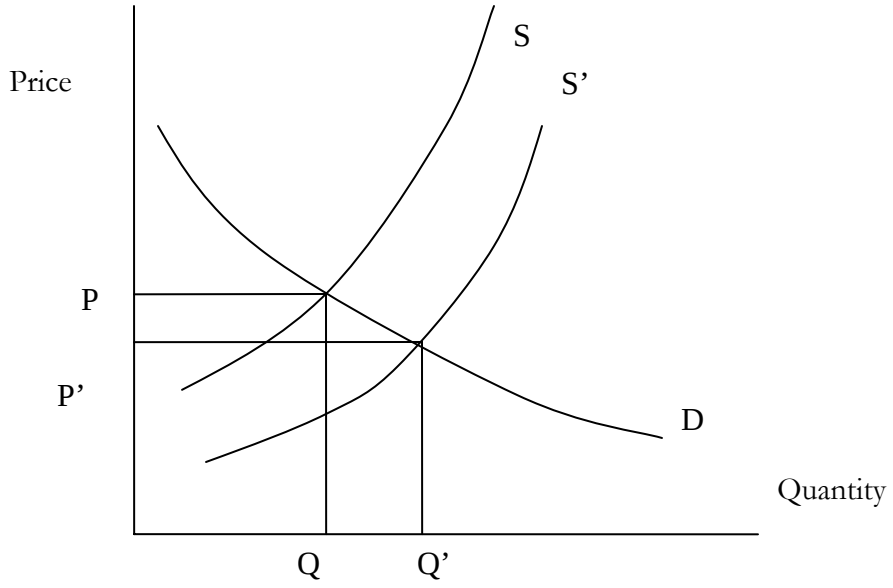


Figure 2.3 shows the situation where demand is much more sensitive to price changes. One reason that the demand curve might change in this particular way is if the market facing farmers is now larger because they can sell their goods in markets that are outside of their immediate area or even their country. This could occur were transport costs to be lowered, among other reasons. In this case, an increase in supply associated with technical change results in an increase in quantity sold that is greater than the decrease in price, and revenues increase – the rectangle outline by PQ is smaller than that with diagonal corners at P'Q'.

Figure 2.3: Connected markets and technical change



This framework can be used to think about many of the effects of infrastructure on agricultural development that will be discussed below, and will be referred to later in the report as well.

2.2.1 Effect of transport infrastructure on agricultural productivity

Raising agricultural productivity is the goal of AGRA, and it is therefore instructive to understand how infrastructure alone contributes to this goal, which is analogous to trying to understand how infrastructure affects the distance that the supply curve will shift in the figures above. It is even more useful to understand how this contribution compares to the contribution of investment in agricultural research and development, and to the extent that it is possible, this comparison will be included in this section.

The correlation between agricultural output and investment in infrastructure is strong and positive. Pinstrup-Andersen and Shimokawa (2006) usefully summarize the results of recent empirical studies on this topic. Table 2.1 is based upon their work, but contains only the results which refer to the relationship between transportation

infrastructure and agricultural productivity. One of the main challenges in this area of research is controlling for what is known as a "reverse causality" or endogeneity problem – in this case, that improvements in agricultural productivity might themselves lead to greater investment in infrastructure. Ignoring this issue may result in biased estimations of the effect of infrastructure on agriculture. Studies which do address endogeneity are noted in the table below, where "year" refers to the years of data used in the study. The last column gives an interpretation of the effects described in the column labeled "effects." Studies where the impacts were found to be statistically significant are marked with asterisks.

Table 2.1: Summary of studies relating transportation infrastructure to agricultural productivity

Country	Year	Source	Endogeneity controlled?	Agricultural productivity indicator	Infrastructure indicator	Effect	Interpretation
China	1997	Fan, Zhang, and Zhang (2002)	Yes	Ag GDP	Inv in Road	2.12	+ 1 yuan in roads ⇒ 2.12 yuan + in ag GDP
	1982-1999	Fan and Chan-Kang (2005)	Yes	Ag GDP	+ 1 km low quality road	1.16 mil	+ 1 km ⇒ 1.16 mil yuan + in ag GDP
					Inv in low quality road	1.57	+ 1 yuan road ⇒ 1.57 yuan + in ag GDP
India	1970-1994	Fan, Hazell, and Thorat (1999)	Yes	Ln(TFP)	Ln(Road density)	0.23**	+ 10% road density ⇒ + 2.3% TFP
	1971-1994	Zhang and Fan (2001)	Yes	Ln(TFP)	Road density	0.043**	+ 1 road density ⇒ 4.3% + TFP
Indonesia	1971-1998	Mundlak, Larson, and Butzer (2002)	No	Ag GDP	Road	0.084**	+10% road length ⇒ +.8% ag GDP
Thailand	1971-1995	Mundlak, Larson, and Butzer (2002)	No	Ag GDP	Road	0.081**	+ 10% total road length ⇒ .8% + ag GDP
	1977-2000	Fan, Jitsuchon, and Methakunnavut (2004)	Yes	Ag output (baht) per worker	Length of roads per worker	0.14	+ 1km road per worker ⇒ + .14 output per worker
Vietnam	1993-2003	Fan, Huong, and Long (2004)	Yes	Ag total product value	Inv. in roads	3.01	+ 1 $ road inv ⇒ + 3.0 value ag
67 LDCs	1961-1990	Craig, Pardey, and Roseboom (1997)	No	Output per worker	Road density	0.012	
43 LDCs	1980-1998	Fan and Rao (2003)	No	FAO ag output index	Road density	0.177**	+ 1 road density ⇒ + .17 output index

Note: Ag. = Agriculture; Inv. = Investment; TFP = total factor productivity; ln = natural log function.
Source: Pinstrup-Andersen and Shimokawa (2006) and author.

In all cases, the effect of increases in infrastructure on agricultural productivity was found to be positive. The magnitude of these effects varies according to the regions studied and the years of data examined. In Fan, Zhang, and Zhang (2002) a 1 yuan investment in roads is correlated with a 2.12 yuan increase in agricultural productivity – a sizable return. In this particular study, 2.12 is the average return to road investment in China, with returns in the 3 regions varying from 1.67 to 3.84. The average returns to investment in agricultural research and development (R & D) were considerably higher at 9.59, with a range from 8.60 to 12.69.

Most of the studies which control for endogeneity use what is known as a simultaneous equation approach, meaning that they estimate a system of equations which depend upon each other in order to assess the feedback effects of different parts of the economy. For example, in Fan, Hazell, and Thorat's (2000) study of India, the effect of spending on roads on total factor productivity in agriculture (aggregate output minus aggregated inputs) works through the number of kilometers of roads that that spending creates. In this case, increasing spending by 10% results in a 3% increase in road density. This 3% increase in road density is then associated with a .69% increase in agricultural total factor productivity (TFP). An interesting comparison can be made in this case between the effect of increasing road density and the effect of increasing spending on agricultural R&D; a 10% increase in the former results in a 2.3% increase in agricultural TFP, while a 10% increase in the latter a 3.0% increase.

Of particular interest for this report are the last two studies listed in Table 2.1, as they include at least some African countries. Fan and Rao (2003) measure the impact of government expenditures on agricultural productivity as measured by an FAO index. The impact of increasing road density by 1 km per 1000 kilometers squared increases the output index by .17. This is compared to a coefficient of .04 for spending on agricultural research – implying a one unit increase in research spending results in a .04 unit increase in the index. As the authors do not define the units of their variables, it is difficult to actually compare these two impacts.

In Craig, Pardey, and Rosenboom (1997), a one unit increase in road density is associated with a .02 unit increase in agricultural output per worker while the effect of increasing research spending by one dollar per agricultural worker increased productivity by

.09. Neither of these studies controls for how regional productivity may affect investment in roads.

Fan, Thorat, and Rao (2004) analyze the returns to various government investments in India over the period from 1960-2000. It is instructive to see how the returns to spending on roads versus agricultural technologies change over the period. In the period immediately following the Green Revolution, returns to road spending were more than twice that of returns to research and spending on HYV (high yield variety) agriculture (8.79 and 3.12, respectively). By the 1990s, the positions of these two were reversed, with returns to HYV spending considerably higher than road investment (6.93 and 3.17). Also interesting is the comparison between the cost-effectiveness of poverty reduction through spending in these two areas. Initially, the cost of per poor person lifted above the poverty line was 10 rupees for roads and 64 for HYV spending; by 1990 those numbers had nearly equalized, at 40 and 41 rupees. One conclusion that one might draw from this analysis is that investment on roads increases the returns to investment in agricultural research and development, or that infrastructure is a necessary condition for the success of agricultural technology adoption programs. The quantitative results are reproduced in abbreviated form in Table 2.2 below. Included in the same table are some additional results from the study. In the 1960s, education and fertilizer subsidies also yielded high returns to government spending, though not as high as spending on roads. By the 1990s, however, spending on HYV research and development far exceeded returns to any other form of investment tracked by the authors.

Table 2.2: Agricultural growth and poverty reduction of Indian government spending by year

	Returns to Agricultural GDP (Rps per Rps spending)				Cost per poor person lifted above the poverty line			
	1960s	1970s	1980s	1990s	1960s	1970s	1980s	1990s
Roads	8.79	3.80	3.03	3.17	10	10	45	40
HYV agriculture R& D	3.12	5.90	6.95	6.93	64	41	39	41
Education	5.97	7.88	3.88	1.53	32	28	30	123
Irrigation investment	2.65	2.10	3.61	1.41	73	106	68	199
Irrigation subsidies	2.24	1.22	2.28	n.s.	89	198	117	n.s.
Fertilizer subsidies	5.27	4.06	0.52	0.74	55	55	468	398

Source: Kydd and Dorward (2004) from Fan, Thorat, and Rao (2004)

Finally, using household level data, Stifel, Minten, and Dorosh (2003) focus on separating the factors determining the amount of rice produced by a particular household in Madagascar, and find that, holding the actual distance to the nearest market constant, increases in travel time (a proxy for road quality) have negative and significant effects on the amount of rice produced. The authors break down the effect of increased travel time into direct and indirect – with indirect effects reflecting changes in the use of inputs and direct effects changes in production other than inputs. The total effect of a one minute increase in travel time (holding distance constant) is a 27 kilogram average decrease in rice production (where median kilograms of rice produced per hectare is 22.7). The indirect effect of road quality (travel time) through input use is a decrease of 17 kilograms of output per one minute increase.

All of the research in this area focuses on roads as the measure of hard infrastructure, though clearly rail and waterways could serve similar purposes. Common sense suggests that airports and waterways must be integral for international trade, though I have not been able to find previous work on this topic. An important caveat to this section is that it has considered neither the environmental effects of roads nor their potential for allowing diseases to spread more rapidly to remote areas. There is a large body of literature on both of these topics that should not be ignored, but must be left out due to the space constraints of this report.

To summarize the results contained here, most studies agree that infrastructure, as measured by roads, has a large and important effect on productivity in the agricultural sector. These effects vary over space (as shown in the studies on China) and time (see table 2.2). The magnitude of their effects relative to the effects of increased spending on agricultural research have also been shown to vary over time in India, with larger returns on roads being found in the earlier stages of the Green Revolution.

2.2.2 Effect of transportation infrastructure on adoption of agricultural technologies

An even more pertinent relationship for the AGRA project is the direct effect of infrastructure on the adoption of agricultural technologies, which is one mechanism through which agricultural productivity can increase. Referring to the supply and demand framework presented above, the rate of technology adoption plays a role in how *far* the supply curve might shift in Figures 2.2 and 2.3. There has been much research on technology adoption in agriculture, with seminal work being done by Griliches (1957) in whose footsteps followed many researchers (see Feder, Just, Zilberman 1985). The most recent focus of this literature has been on the dynamics of learning, be it learning by doing or learning from others (Besley and Case 1997, Foster and Rosenzweig 1995, Conley and Udry 2003, Munshi 2004).

The statistical techniques used in the cited studies of technology adoption do not allow for the measurement of the impact of regional or village-level characteristics on the household level choice to adopt, which means that none have been able to examine the relationship between road access and quality and adoption. However, a related strand of work on market size/access and adoption has shown a positive correlation between better market access and technology adoption. Desmet and Parente (2006) develop a theory to show how access to large markets leads to a greater propensity to adopt new technologies. They demonstrate rigorously that adopting new technology can only be profitable when the decrease in price associated with the introduction of the technology results in a proportionately largely increase in the amount purchased by consumers. This is the case when producers are operating in larger markets, either because the immediately accessible population is larger or as a result of trade. This is analogous to a change in the demand curve from the one in Figure 2.2 to the one in Figure 2.3.

While they do not offer concrete empirical evidence, one of the situations inspiring their research is the lack of economic growth in sub-Saharan Africa. The logic of their model suggests that if market size is too small as a result of "low population, isolation, and inadequate infrastructure," new technologies are unlikely to be adopted. Empirical work by Alesina, Spaloare, and Wacziarg (2000) show that countries with small populations have lower economic growth *only* if they do not trade extensively with other countries. If adoption of new technologies drives economic growth, and there are good reasons to think that it does, then this suggests that the lack of adoption associated with low populations can be compensated for by trade with other countries. This trade, however, is certainly likely to depend upon adequate infrastructure to transport goods (see below).

2.2.3 Effect of transportation infrastructure on market participation

Transportation costs, associated with road quality, place a wedge between the price at which it is profitable for a seller to enter the market and the price at which a buyer can afford to enter the market. This means that in regions and countries with high transportation costs, there can be a significant number of households which produce goods for their own consumption – i.e., they are "autarkic". Were transport costs to be lowered, markets would become more integrated, meaning there would be more trade over greater distances. This corresponds to rightward shifts (and changes in the slope) of both the supply and the demand curves. An important benefit of this spatial integration of trade is the reduction of price volatility – local weather and economic shocks can be buffered by the movement of goods. In addition, as the difference between buying and selling prices disappears, overall production becomes more efficient since households are able to purchase goods (which they previously produced at home) at a lower cost and devote the energies that they previously spent producing these goods on other productive activities.

In an early study on the relationship between transportation infrastructure and the market, Chibber (1988) estimated the supply response of small farmers. He found that a one percent increase in output prices would result in a supply response of 0.3-0.5 percent in areas with poor infrastructure and 0.7-0.9 in areas with good infrastructure. This suggests that producers in areas with good infrastructure respond more easily to changes in price, which means that if prices fall for these particular goods, those farmers in areas with better infrastructure will lose less revenue than those in areas with poor infrastructure.

An interesting paper by Key, de Janvry, and Sadoulet (2000) estimated the effect of distance to market and transport costs on the price at which households choose to switch from being buyers to neither buying nor selling, and then to selling maize in Mexico. They found that an increase in crop transport costs of one hundred pesos per metric ton (about ten dollars) increases the price at which a household is willing to sell maize by four pesos. This confirms that households are less likely to bring goods to market over bad roads.

Renkow, Hallstrom, and Karanja (2004) corroborate that such a differential between buying and selling prices for households in Kenya also exists, and that this differential is at least partially explained by distance to the nearest market. Kelley and Byerlee (2003) estimate that 60% of Africa's population lives in areas with good agricultural potential but poor access to markets.

In a fascinating analysis of traders, rather than producers, in Malawi and Benin, Fafchamps and Gabre-Madhin (2006) find that transportation costs represent the highest part of traders' variable costs – i.e., those costs which depend upon the amount of commodity transacted. The share of transport in variable costs – including loading costs, payment at road blocks, and commission paid to brokers, as well as the standard cost per unit distance – amounts for 60% of variable costs in Benin and 49% in Malawi. The implication is that lowering these costs would lower prices and therefore increase the quantity of goods transacted in these markets.

In Ethiopia, only 26 percent of grains produced are actually marketed, the remaining being retained for household consumption. An analysis of the costs incurred by traders is somewhat different from those of Malawi and Benin. Transport costs make up, on average, 31% of total cost. However, handling, sacking, and road stop fees, which might reasonably be included in transport, compose another 31% of costs (Gabre-Madhin 2001).

On a national level, a study of Uganda's international trade flows from 1987 to 1997 shows that, while barriers to trade in the form of tariffs have largely disappeared, the implicit taxation resulting from transportation costs due to poor infrastructure range from a low of 20% for fish to up to 100% for manufactured items, with the implicit tax on food items as a result of poor roads at 40% (Milner, Morrissey, and Rudaheranwa 2000). A separate study on Uganda found that transport costs exceeded 70% of the total value of exports, and that in a third of African countries they account for 25% of this value (von Braun, Wobst, and Grote 2002).

This description of studies relating transport infrastructure to agricultural productivity concludes with a study by Spencer (1994) to which we will return in Section 3 of this report. This paper does not analyze the mechanisms through which infrastructure might affect agricultural development, rather, it estimates the "necessary" transport and irrigation infrastructure for the humid and subhumid tropics of Africa (including much of sub-Saharan Africa) to be equal to that of India in 1950. In 1994, the average road density for this region was 63 km/1000 km squared, where to be equal to India they would need to be 388 km/1000 km squared – ranging from 47 in Congo to 718 in Nigeria (adjusted for population density). The relevant table from Spencer's calculations is reproduced below in Table 2.3.

Table 2.3: Rural road network in humid and sub-humid African countries

Country	Total (km)	Density (km/1000 km^2)	
		Existing	Required[2]
Benin	4,066	36	291
Cameroon	18,000	38	168
CAR	14,400	23	33
Congo	200	1	47
Cote d'Ivoire	30,224	94	258
Ecuatorial Guinea	450	16	103
Gabon	2,400	9	30
Ghana	4,000	17	429
Guinea	11,500	47	161
Guinea-Bissau	1,404	39	186
Liberia	3,615	33	159
Madagascar (1/2)	19,750	67	137
Mozambique (1/2)	6,725	17	135
Nigeria (3/4)	67,425	97	718
Sierra Leone	5,767	80	391
Tanzania (1/3)	20,760	66	181
Togo	4,181	73	447
Zaire	84,100	36	110
HST[3]	298,967	63	388

Source: Spencer (1994)

[2] To achieve a coverage equivalent to that of India in 1950. Where population densities are less than that of India in 1950, required road densities are adjusted downwards in proportion to the present population density of the country.

[3] HST refers to humid and sub-humid tropics of Africa. The fractions associated with Madagascar, Mozambique, Nigeria, and Tanzania refer to the fraction of the country found in these ecosystems.

2.3 Electricity

Although the relationship between irrigation and agriculture is outside of the mandate of this report, electricity (which is clearly linked with irrigation) is one of the important infrastructure components to be discussed here. There is very little work directly analyzing the effect of electricity upon agricultural development, however, its indirect effects work through the availability of irrigation and industries which add additional value to agriculture. In addition, electricity expands the number of hours during the day which can be used for productive activities. In this sense, it affects the responsiveness of farmers to the introduction of new technologies, and hence changes the distance which the supply curve moves in Figures 2.2 and 2.3. It also increases the probability of access to radios and television, which, in addition to providing entertainment, are also a source of information which can help markets function more effectively.

Some of the articles discussed above in the section on the effect of transport on agricultural productivity also include in their analysis electricity consumption and the effect of this consumption on productivity (as well as the potential to increase non-agricultural employment). Fan, Zhang, and Zhang (2002) calculate the returns to agricultural productivity of electricity in China at .54 (recalling from above that the returns to agricultural R& D were 9.59 and to roads 2.12). Mundlak, Larson, and Butzer (2002) found that roads and electricity were so highly correlated that they could not include both variables in their statistical analysis. Their solution was to include only roads, which means that any effects of electricity on agricultural productivity generated by their study are implicitly included in the measured effect of roads (see Table 2.2 above). Finally, Fan, Jitsuchon and Methakunnavut (2004) find that rural electricity consumption in Thailand increases labor productivity in agriculture – a 1 kilowatt increase in electricity consumption per capita increases output per worker by .175 Baht.

A final article on agricultural productivity growth that includes electricity (but not roads or agricultural research and development) is Bravo-Ortega and Lederman (2004). Using data from 86 countries between 1961 and 2000, the authors find that a 10% increase in electricity generating capacity results in an increase in agricultural productivity growth of .004 percent. The absence of these other variables means that, to the extent that they are correlated with electricity, their effects will be reflected in the estimate of its effect.

2.4 Storage

Timmer (1974) is one of the earliest economists to have noticed the flow of grains from rural to urban zones immediately after harvest, as well as their return from urban to rural zones just prior to the following year's harvest. Various other economists have studied this phenomenon (Ellsworth and Shapiro 1989, Barrett 1996), with a main conclusion being that this movement of goods results from the lack of storage in rural areas.

The importance of storage to agricultural development, and technology adoption in particular, is multifold. The main economic role of storage is to reduce price variability. In markets with surplus supply, where prices may be quite low, producers or intermediaries can store stocks to await markets where supply is limited. This redistribution of stocks plays the role of equalizing prices across time, therefore reducing variability. This role of storage has been well documented both theoretically and empirically (see Williams and Wright 1991, Shiveley 1996, Karugia, Wambagu, and Oluoch-Kosura 2007, Gabre-Madhin 2001, Deaton 1999, Deaton and Laroque 1996).

Price volatility, the result of a lack of storage, can affect the adoption of agricultural technologies. Although this has not been shown empirically for agriculture, there are strong theoretical reasons to believe that this is true (Kim, Hayes, and Hallam 1992). Empirical evidence for the negative effect of price variability on technology adoption in Chilean manufacturing firms has been shown (Kasahara 2003), and the topic has been extensively investigated in the context of option values. In particular, when investment is "irreversible" (such as a change in the manufacturing mode, construction of a dam, etc.), such investments are less desirable in the face of greater price uncertainty (Dixit and Pindyck 1994).

On a larger scale, many authors believe that lack of storage (among other infrastructure) lies behind the failure of many of the attempts of developing countries to liberalize markets (Bivings 1997, Poulton, Kydd, and Dorward 2006). This is because such liberalization attempts assume well-functioning markets, and a country without the ability to smooth prices over time through storage of surpluses suffers from a failed inter-temporal market.

Storage also has important effects on household level well-being. Although some authors argue that households store grain as a source of insurance, Park (2006) posits that grain storage, where it is possible, is simply a price hedge. If it is the case that grain storage acts as an emergency fund, then this capability may prevent the household from doing

something more productive with the proceeds from the sale of the grain (Fafchamps and Pender, 1997). In the latter case, such storage is a boon, allowing the household to take advantage of seasonal price fluctuations. A recent paper by Kazianga and Udry (2004) shows that, at least in Burkina Faso, household storage of food stocks serves as the main source of households' ability to smooth consumption over time, but with minimal effectiveness.

A fascinating paper on storage in medieval Europe holds some lessons for developing countries today (McKloskey and Nash 1984). In particular, the authors show how it is possible that increasing the availability of storage actually decreased the commodity rate of interest facing farmers, therefore increasing their ability to access credit and to insure themselves against shocks.

2.5 Communications

Communications, via either telephone, cellular phone, or internet, are a key part of a well-functioning market. Informational asymmetries have long been known to result in market failures (Akerlof 1970), and agricultural market failures, as discussed above, discourage investment in agricultural technologies and the choice of households to take goods to market.

In an early effort to look at the role of information in market participation, Goetz (1992) considers the choice of whether to buy, sell, or remain autarkic in grains by sub-Saharan African households. He finds that one of the most important reasons for lack of participation is high fixed transactions costs in the form of a lack of information. In particular, households that do not have access to information (where the proxy for information is living in a region with better communications and transportation infrastructure) are considerably less likely to take their goods to market, though lack of information does not appear to affect their propensity to purchase market goods.

In the same study of African traders discussed above, Fafchamps and Gabre-Madhin (2006) find that the main source of information on prices for traders in other markets is other traders (64% of Benin traders and 84% of Malawians cited this as their main source of information). This means that the vast majority of traders are making decisions not based upon public sources of information. The vast majority of transactions also take place in person: on average, traders make 4 to 8 business related phone calls *per year*. This means an

enormous amount of time is spent by traders traveling from one market to the next. On average, Benin traders travel 250 times per year to purchase and sales markets and Malawian traders 92 times. In the authors' words: "The need for thousands of traders to travel to the sale market in person-instead of placing an order over the phone -- undoubtedly contributes to higher trading costs." (p 53) Similar results were found by Gabre-Madhin (2001) in her study of Ethiopian traders – they were almost always physically present at exchanges in order to inspect the quality of grains. In addition, in Ethiopia traders have no resource which allows them to access information on markets outside of those that they can physically visit. In contrast to Benin and Malawi, however, Ethiopian traders make extensive use of brokers ("middlemen of the middlemen") to conduct their longer-distance transactions.

Osbourne (2004), using Ethiopia as a case study, illustrates how "news," where news is defined as information about future prices, can help reduce price variability, the role of which has been discussed above. If this is truly the case, then increasing access to market information, either through television, radio, telephones, or the internet, can help improve livelihoods both by making markets more efficient and by increasing the probability of technology adoption by decreasing uncertainty regarding the level of future prices.

Access to communications technology, either phones or the internet, could be an enormous benefit to agricultural extensionists, who often spend inordinate amounts of time traveling from one village to another simply trying to find times to meet with farmers in order to demonstrate new technologies. Although the relationship between communications infrastructure and extension effectiveness has not been formally analyzed, it is worthwhile noting that in a review of studies measuring the impact of extension in various countries, 6 out of 8 of the studies found a positive and significant impact of extension on agricultural productivity measures.

Feder, Willett, and Zijp (1999) give a broad overview of agricultural extension systems worldwide, identifying both challenges and potential solutions. One of the key barriers to effective extension identified by the authors is the scale and scope of coverage required of extension agents – one agent is often responsible for serving thousands of farmers making decisions about hundreds of different crops. Although they propose various solutions to the problem, including privatization of extension and single-crop extension specialists, an important suggestion that they give includes effective use of communications, including both traditional sources, such as television and radio, as well as the internet.

Banerjee (2005) details the successful use of the internet in serving Indian farmers by a private firm – ITC, which developed what are now popularly known as e-chaupals (internet kiosks). These kiosks are installed in farmers' homes for use by the larger community as sources of information on market prices, stocks, the weather, farmer practices, and other relevant topics. The portal viewed by farmers is translated into the local language. They are reported to be wildly popular, and have played diverse roles, ranging from providing warnings of pest infestation to reducing the distance across which farmers ship their goods. Other sources note that farmers selling their crops through an e-chaupal receive a price that is 2.5% higher than the average price of the same crop at a wholesale market (about $6 per ton), and it eliminates middlemen and their fees, which lower transactions costs by an estimated 2.5%. ITC, the firm which installed many of the e-chaupals, claims that in 2003 these services reached more than 1 million farmers in 11,000 villages (DESI, 2007).

3. Infrastructure in Gates' target countries

Section summary

This section provides an overview of transport, communications, electricity, and storage infrastructure in AGRA countries. In terms of road infrastructure, all of the countries with the exception of Zambia fall far short of the relatively low benchmark of road density in India in 1950. Those countries with the most work to do in terms of road building are Ethiopia, Nigeria, and Mali, while the best-off countries are Zambia, Cameroon, and Ghana. Malawi, with quite a low road density, has a substantial percentage of paved roads and a relatively high rail density, as does Senegal. Mali again finds itself on the very low end of rail density, along with Uganda and Zambia. Publicly available information on transport networks is scarce and what is available is out of date. However, current efforts being undertaken by CIESIN and IFPRI promise to make considerable headway in this area. The available information, however, suggests large regional variation in transport network quality and density.

In terms of communications infrastructure, Senegal, Ghana, and Kenya find themselves relatively well-off in terms of phone access, while the countries with the least access are Ethiopia, Rwanda, and Malawi. Kenya, Ghana, Senegal, and Nigeria have the highest number of internet users, while Ethiopia and Malawi again find themselves at the bottom of the pack, along with Burkina Faso and Mali. This distribution, perhaps unsurprisingly, is similar to that of electricity access, where Senegal, Ghana, and Nigeria have the greatest access, and Ethiopia, Uganda, and Malawi the least. Senegal, however, wins the dubious honor of having one of the highest rural-urban disparities in electricity access, along with Ethiopia and Cameroon. An interesting study regarding small African business owners' perception of the importance of particular infrastructure for business suggests that electricity presents a greater barrier than telecommunications to small business growth.

While there is plenty of household level data available that would allow for more detailed estimates of regional access to electricity and telecommunications, the transposition of this data into geographically useful formats has not yet occurred. There are various open questions regarding the appropriate methodological tools to ensure that this mapping occurs

in such a way as to represent the true underlying distribution of the services. CIESIN is leading the effort to push this area of research forward.

Finally, this report has done relatively little to elucidate the variation in agricultural storage facilities across countries. While there is a clear consensus in the literature that storage plays an important role in market functioning, there is simply very little information available that would allow even simple comparisons across countries.

3.1 Introduction

This section of the report details the state of infrastructure in AGRA target countries. Most comparisons can only be made across countries. To the extent that it is possible, variation within countries' infrastructure will be included.

3.2 Transportation infrastructure

3.2.1 Across-country comparisons

Inspired by the methodology of Spencer (1994), Table 3.1 lists the existing kilometers of road in each country. It then estimates the kilometers of road that would be necessary to make the road density equal to that of India in 1950 (on the eve of its Green Revolution), weighted for differences in population density. Clearly, the required road density for production and markets to function well would vary significantly by country, however, the table provides an interesting comparison nonetheless. With the exception of Zambia, every single AGRA country falls far short of India's 1950 road density. In fact, in almost all cases, these countries need to more than double their existing road networks in order to meet this threshold. The greatest number of additional kilometers required is in Nigeria, whereas the largest factor increase is in Ethiopia, which would have to increase its existing road network by a factor of more than 14 in order to give it the same road density as India in 1950.

Table 3.1: Kilometers of road required to give countries the same road density as India in 1950

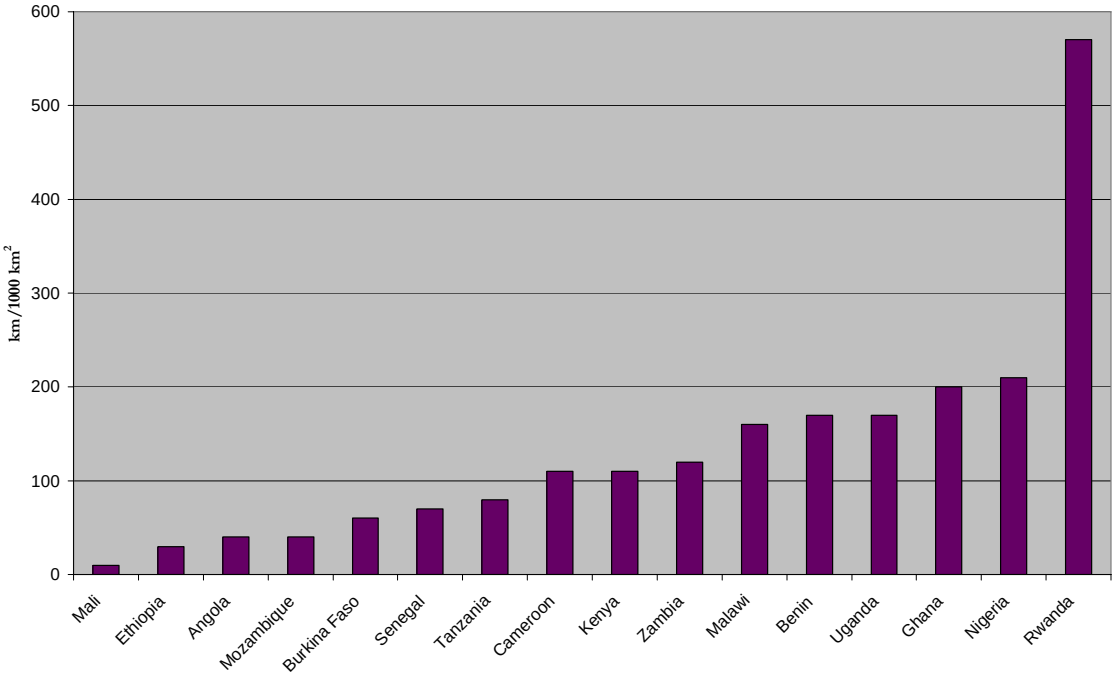
Country	2004 Km of road	2004 Road density (km/km²)	2004 Population density (people/km²)	"Required" kilometers of road[4]	Difference between required and actual
Angola	49868	0.04	12.4	103737	53869
Benin	18805	0.17	73.9	54763	35957
Burkina Faso	16416	0.06	46.9	85867	69451
Cameroon	51194	0.11	34.5	107405	56211
Ethiopia	30000	0.03	70.0	468528	438528
Ghana	45508	0.20	95.2	145087	99579
Kenya	62605	0.11	58.8	224131	161525
Malawi	15053	0.16	134.0	84438	69385
Mali	12202	0.01	10.8	87892	75690
Mozambique	31364	0.04	24.8	130082	98718
Nigeria	191262	0.21	141.3	861964	670702
Rwanda	14062	0.57	360.0	59485	45423
Senegal	13477	0.07	59.1	76251	62774
Tanzania	70687	0.08	42.6	251987	181300
Uganda	33507	0.17	141.1	186314	152807
Zambia	89207	0.12	15.4	76874	-12333

Source: International Road Federation (2006)

Figure 3.1 below ranks the countries in Table 3.1 from lowest to highest road density, where the road density is *not* weighted by population. Rwanda is a clear outlier, with a density which is more than double that of the country with the next most dense road network – Nigeria. Mali has by far the sparsest road network, with Ethiopia, Angola, and Mozambique following close behind.

[4] Required is defined as the kilometers of road needed to make the kilometers of road per kilometer squared equal to that of India in 1950, weighted for population.

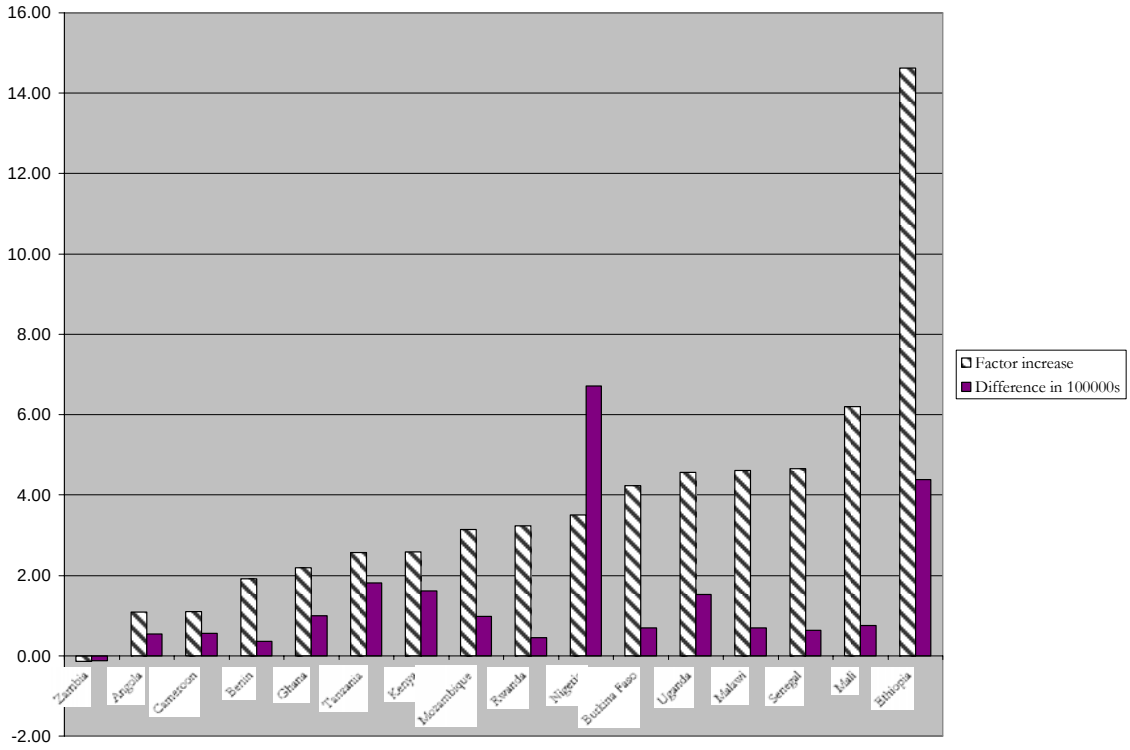
Figure 3.1: AGRA countries ranked according to road density



Source: Author's calculations from IRF (2006)

The ranking according to absolute road density does not paint the most accurate picture of which countries are closest to the "required" density as benchmarked by India in 1950. Figure 3.2 shows the countries ranked according to the factor by which they would need to increase their current road network in order to achieve the benchmark population-weighted density. For each country the increase in kilometers needed to reach the benchmark is also included. Note that Rwanda, which has the densest road network of all the countries, falls in the middle in terms of "required" increases due to its high population density. The greatest factor increase is in Ethiopia, with Mali in a distant second. Zambia appears with negative numbers, as its current road density already exceeds that of India in 1950. Angola and Cameroon also have relatively little new construction to do in order to reach the benchmark.

Figure 3.2: Ranking according to distance from India's 1950 road density



Source: Author's calculations from IRF (2006)

Although size of a road network is a strong indicator of the strength of transport infrastructure, there are other useful metrics that are readily available. Table 3.2 lists these – passenger cars per 1000 people, percent of paved roads, kilometers of rail lines, rail density, goods hauled by rail, and air freight container traffic. Note that some of these indicators are quite imperfect – for example, a paved road is not necessarily a higher quality road than an unpaved one – a well-maintained dirt road can be much faster than a poorly maintained paved one. In addition, "goods hauled by rail" is likely to be not so much a function of rail density but rather of economic development. The data is for all of the AGRA countries but the discussion here focuses on the four countries with MCC commitments. The rank of these countries according to these indicators differs by metric. While Burkina Faso has the highest percentage of paved roads, it ships no freight by air and has relatively low density of railways. By most measures, Mali has the weakest transport infrastructure in this group – a low density of railways and very few goods shipped by rail and air, though the latter necessarily results from a combination of railway quantity/quality and a lack of goods to

transport. However, cars appear to be more accessible in Mali than in Mozambique, and its percentage of paved roads is not the lowest of the group. With the exception of Mozambique, all of these countries have more passenger cars on their roadways than India in the late 1970s. On the other hand, none of them even come close to the extent of India's railway, the density of which far exceeded that of any of these countries currently, even in the early 1950s.

Table 3.2: Other transport indicators

Country	Passenger cars per 1000 people	Paved roads (%)	Rail lines (km)	Rail density (km/1000 km²)	Goods hauled by rail (mill tons/km)	Air freight (mill tons/km)
Angola	17.7	10.4	3572	2.9	1945	64
Benin	6.7	9.5	438	4.0	86	7
Burkina Faso	3.7	31.2	622	2.3	nd	0
Cameroon	7.2	10	974	2.1	1115	23
Ethiopia	1	19.1	nd	nd	nd	117
Ghana	5.1	17.9	997	4.4	242	7
Kenya	8.1	14.1	1917	3.3	1399	193
Malawi	2.9	45.2	710	7.5	88	1
Mali	2.7	18	733	0.6	189	7
Mozambique	0.3	18.7	2072	2.6	808	5
Nigeria	7.7	15	3505	3.8	39	10
Rwanda	2.3	19	nd	nd	nd	nd
Senegal	10.6	29.3	906	4.7	371	0
Tanzania	0.8	8.6	2600	2.9	1351	2
Uganda	2.1	23	259	1.3	218	27
Zambia	17	22	1273	1.7	554	0
India (1979)	1.5	47.3	53597[5]	16.3	16.3	nd
India (2004)	5.9	47.4	63221	19.2	381241	689

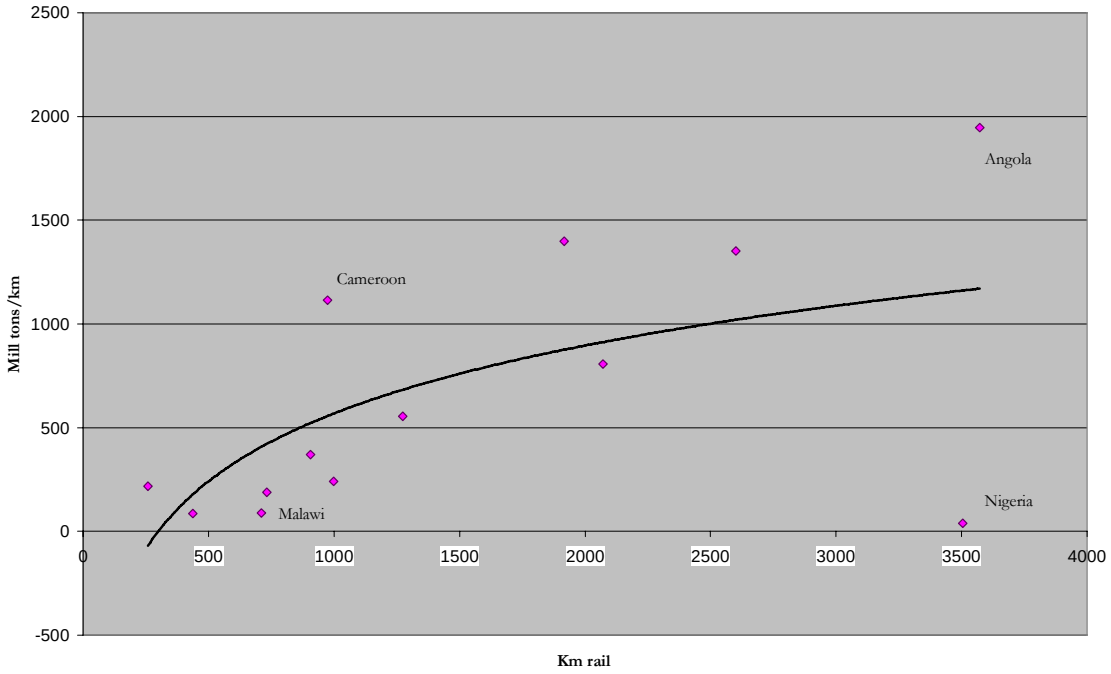
Source: World Development Indicators (2006) and International Road Federation. Where 2005 statistics were not available, the most recent available year was used instead.

Figure 3.3 tracks the relationship between the kilometers of rail lines available in a country and the amount of goods hauled by rail. Despite clear outliers, the relationship is positive on

[5] This figure is from 1953 and comes from the Transport Corporation of India, LTD, **http://www.tcil.com/rail.asp**.

average, though the increase with each additional kilometer of rail lines occurs at a decreasing rate.

Figure 3.3: Railways versus goods hauled by rail



Source: Author's calculations from WDI (2006)

3.2.2 Within-country comparisons

Angola is the only country for which there was complete and easily accessible geographic data. This allows us to look at road availability by province. Total road length, length of paved roads, and density are detailed by province in Table 3.3. The numbers were calculated using a digital road map provided by the UNDP for 2005. It is not possible to tell much about road quality, aside from differentiating between dirt, paved, and roads under construction. The country's drawn-out war is likely to have made these numbers overstate the accessibility of Angola's rural areas.

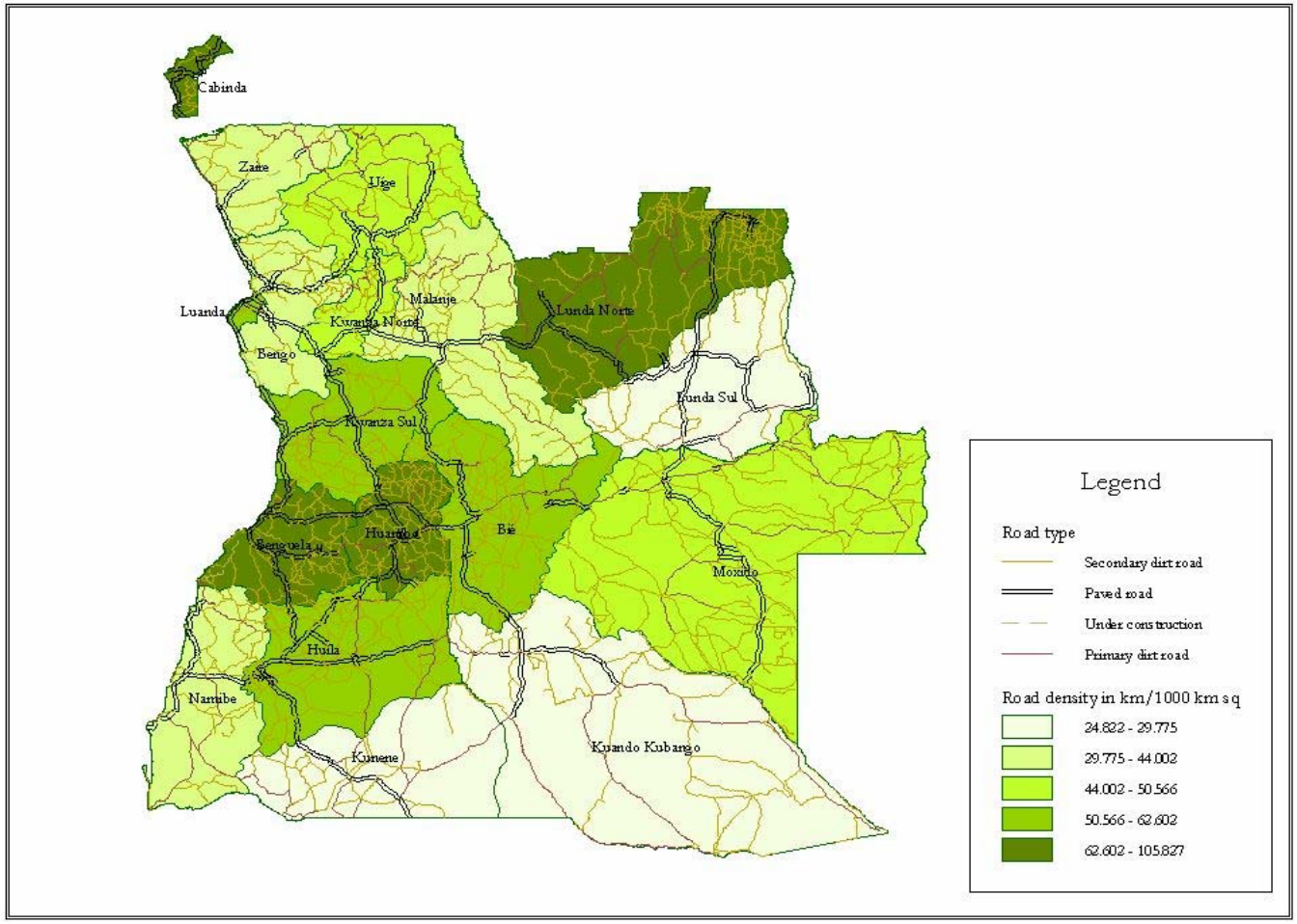
Table 3.3: Road densities by province in Angola, 2005

Province Name	Area (km²)	Total roads (km)	Paved roads (km)	% paved	Density (km/1000 km²)
Bengo	39203	1725	431	25	44.00
Benguela	39694	3019	606	20	76.06
Bie	72413	4322	648	15	59.69
Cabinda	7006	559	225	40	79.79
Kuando Kubango	200328	5122	421	8	25.57
Kwanza Norte	19321	977	266	27	50.57
Kwanza Sul	55609	3263	618	19	58.68
Kunene	77582	2310	227	10	29.77
Huambo	33309	3525	438	12	105.83
Huφla	79008	4946	984	20	62.60
Luanda	2445	149	63	42	60.94
Lunda Norte	108477	9071	790	9	83.62
Lunda Sul	78277	1943	731	38	24.82
Malanje	82607	3608	317	9	43.68
Moxico	200657	9460	664	7	47.15
Namibe	58308	2464	336	14	42.26
Uige	62392	2980	438	15	47.76
Zaire	36621	1334	103	8	36.43

Source: Author's calculations from UNDP (2005)

The corresponding map of this information is shown in Figure 3.4 below, where the color gradations indicate increasing road density as they progress from light to dark.

Figure 3.4: Road densities in Angola



Source: Author's calculations from UNDP (2005)

Pennsylvania State University hosts a site containing the Digital Chart of the World (DCW) Database. This site contains a variety of geographic information for every country in the world, and has been created from data originally provided by the US Defense Mapping Agency. However, the source is from 1993, so it is unclear how accurate a reflection it might be of the current state of infrastructure. In addition, it does not contain level 1 administrative boundaries, which means that it is not possible to calculate the provincial road densities as for Angola above. Finally, the data is very coarse – the estimates are from a 5 by 5 degree grid. Appendix 3 contains examples of maps made with the transportation data from the DCW.

Current efforts are underway to remedy this lack of current and accessible information. CIESIN and IFPRI, together with other contributors, are in the process of improving the quality and quantity of information available. Their efforts can be followed at:

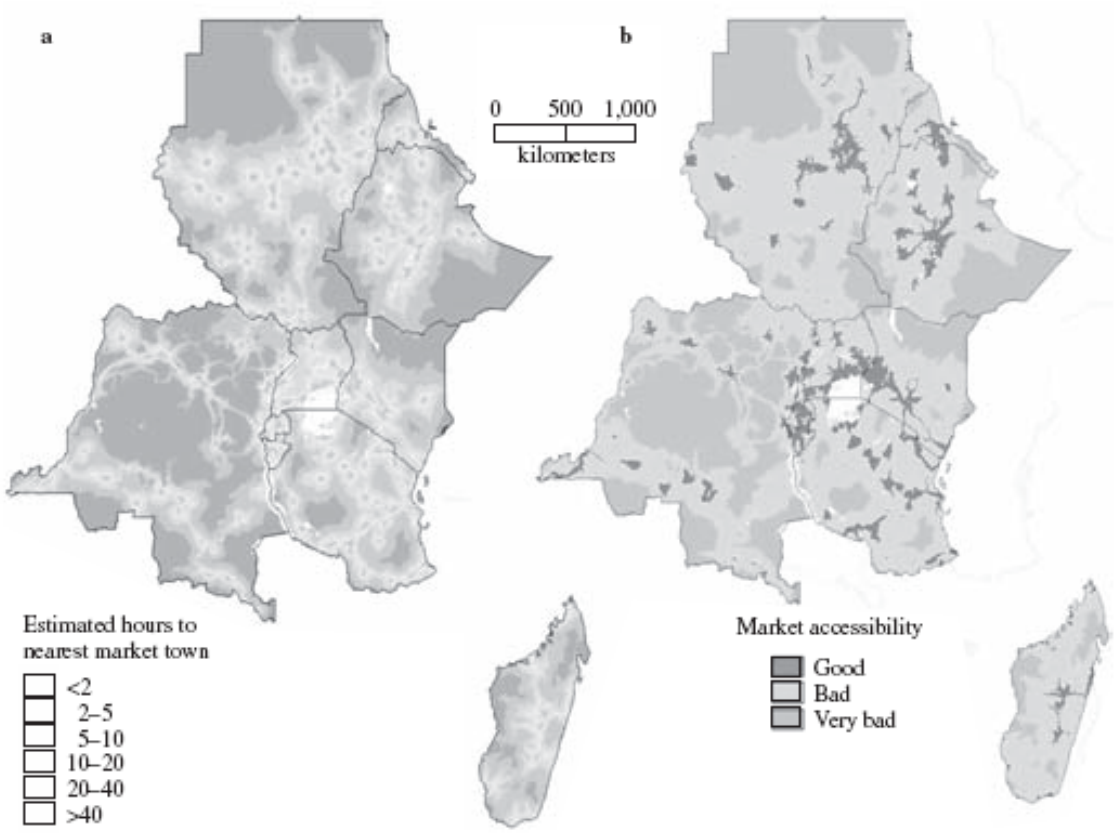
http://www.ciesin.columbia.edu/confluence/display/roads/Global+Roads+Workshop+-+Home+Page, where they are currently organizing their first conference on the topic. IFPRI has also done considerable work on the concept of "development domains", which combine information on population density, road networks, and agricultural productivity to determine which areas of a country have high and low potential for economic development. One example of this can be found at **http://www.ifpri.org/divs/eptd/dp/eptdp159.asp**. A simplified picture of the layers used to create a development domain is shown in Appendix 6. As a part of the development of this methodology, IFPRI has done a sample study in Central and Eastern Africa (Figure 3.5), which includes various AGRA target countries. Figure 3.6 shows the maps of market accessibility, which includes transport infrastructure. It is hard to extract very much from the pictures in terms of exact statistics for each region within the countries, however, the existence of such maps indicates the availability of data which will make it possible to undertake such an analysis.

Figure 3.5: IFPRI study region – Central and Eastern Africa



Source: Omamo et al. (2006)

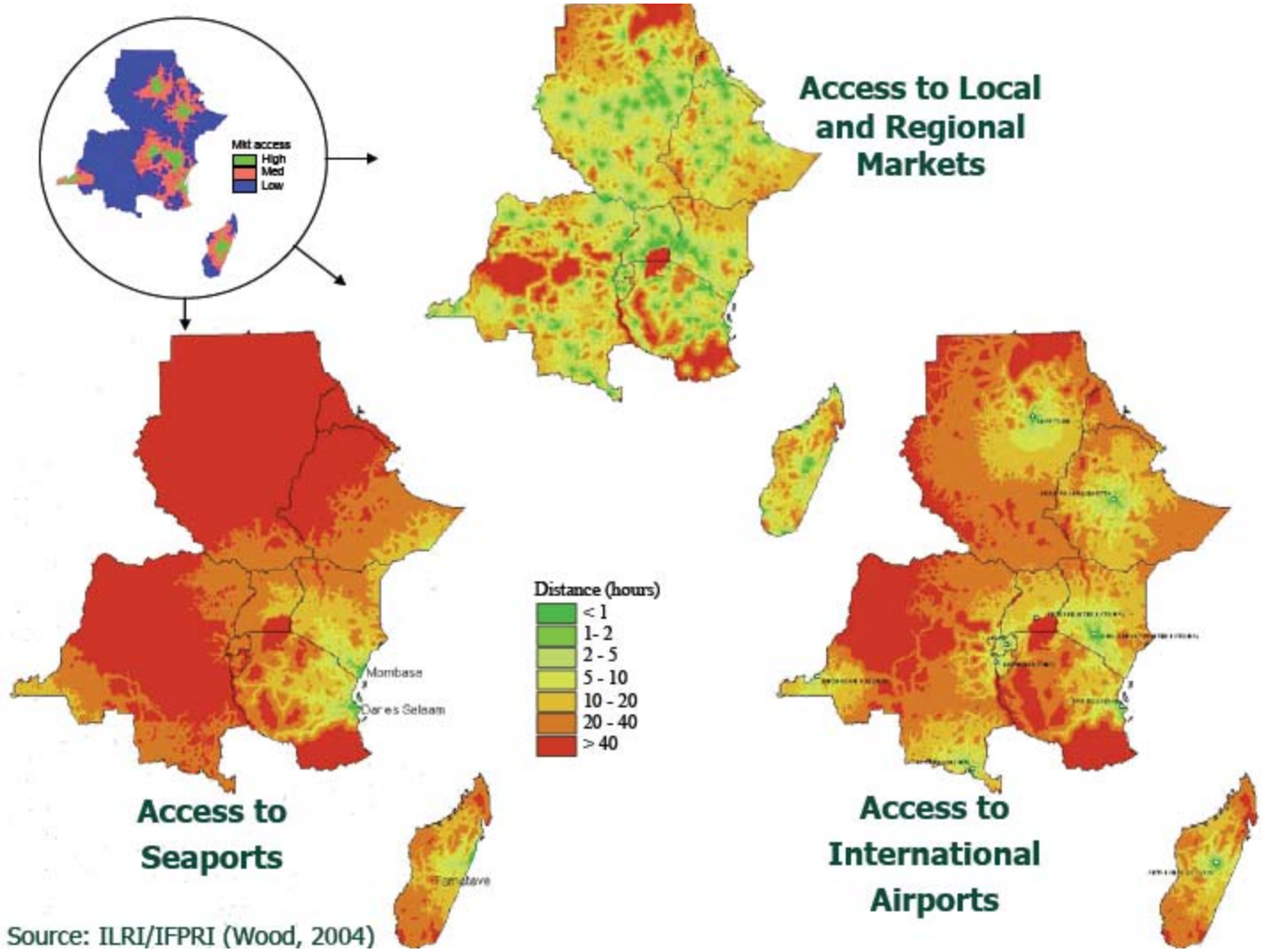
Figure 3.6: Market accessibility in Central and Eastern Africa



Source: Omamo et al (2006)

The same study also considered access to ports and airports, the final maps for which are pictured in Figure 3.7, along with color maps of the left panel of Figure 3.6.

Figure 3.7: Transport accessibility in Central and Eastern Africa



3.3 Communications infrastructure

3.3.1 Across-country comparisons

Table 3.4 contains indicators of communications infrastructure, including main telephone lines, fixed and mobile phone subscribers, internet users, and, as an indicator of the potential for making use of more complex technologies, the adult literacy rate. It is heartening to note how much greater telephone access is in all of the AGRA countries listed today than it was in India in 1960, especially if one includes mobile phones as well as fixed line subscribers. In addition, Ghana's literacy rate is quite close to India's today, as is the number of internet users in many of the AGRA countries.

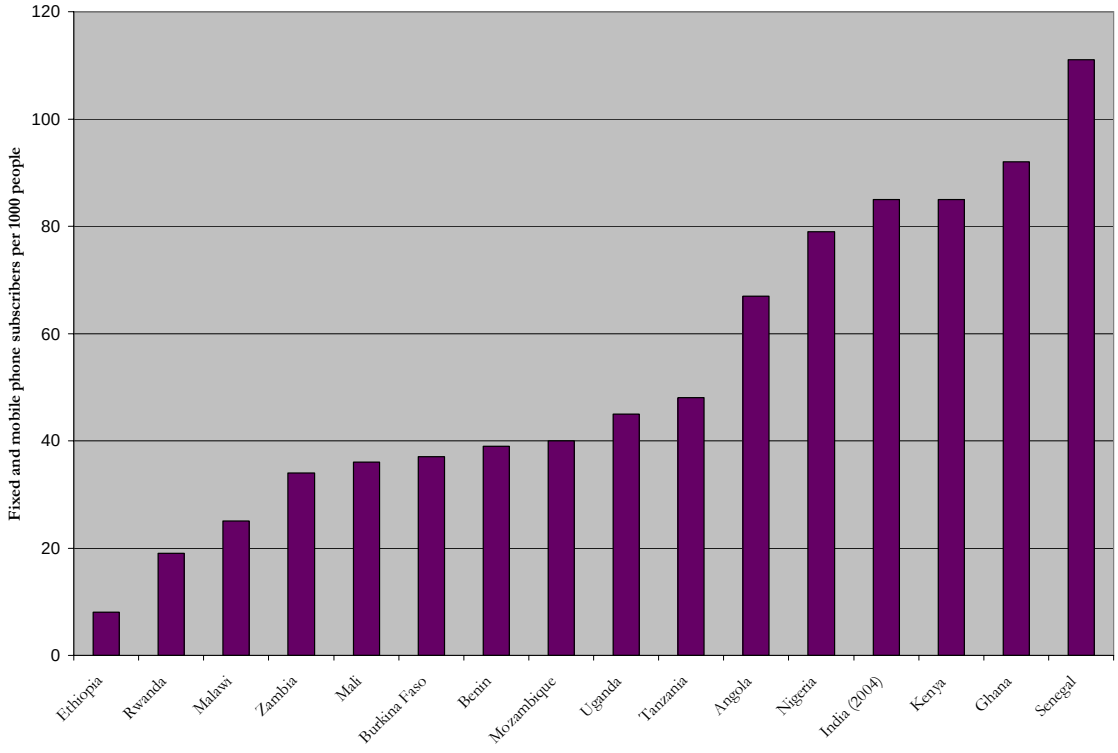
Table 3.4: Communications indicators

Country	Fixed line phone subscribers per 1000 people	Mobile phone subscribers per 1000 people	Internet users per 1000 people	Adult literacy rate
Angola	6	61	11	67.4
Benin	9	30	12	34.7
Burkina Faso	6	31	4	21.8
Cameroon	6	96	10	67.9
Ethiopia	6	2	2	nd
Ghana	14	78	17	57.9
Kenya	9	76	45	73.6
Malawi	7	18	4	64.1
Mali	6	30	4	19
Mozambique	4	36	7	nd
Nigeria	8	71	14	nd
Rwanda	3	16	4	64.9
Senegal	21	90	42	39.3
Tanzania	4	44	9	69.4
Uganda	3	42	7	66.8
Zambia	8	26	20	68
India (1960)	1	nd	nd	nd
India (2004)	41	44	15.9	61

Source: World Development Indicators (2006)

Figure 3.5 ranks the countries from least to most "connected" in terms of telephone users. As with roads, Ethiopia finds itself near the bottom of this ranking, along with Rwanda. Interestingly, several countries – Kenya, Ghana, Senegal, and Nigeria – find themselves with phone subscribers near or exceeding that of contemporary India.

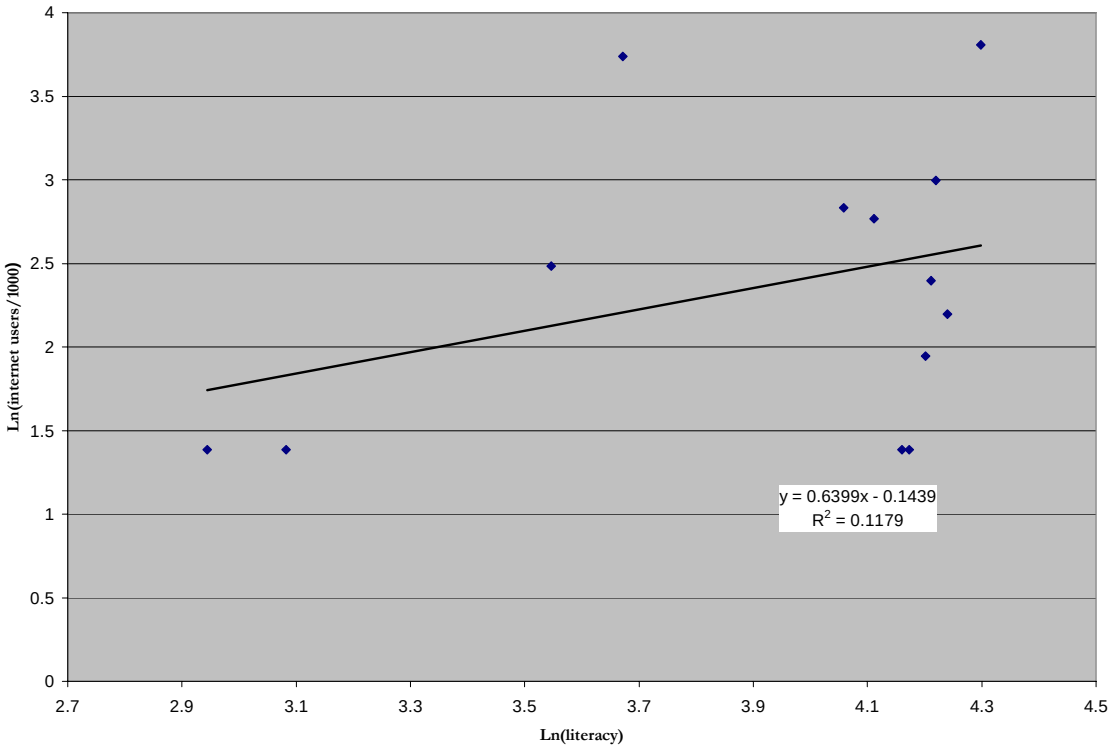
Figure 3.5: Countries ranked according to phone subscribers



Source: Author's calculations from WDI (2006)

A final relationship of interest is shown in Figure 3.6, which shows a simple regression line relating the natural log of literacy to natural log of the number of internet users. This transformation allows us to interpret the regression coefficient as an elasticity – the percentage change in the number of internet users with a percent change in the literacy rate. Here, a ten percent increase in the literacy rate is associated with a 6.3% increase in the number of internet users per 1000 people. The variation in the literacy rate explains 11% of the variation in number of internet users, which is a strong correlation for data of this nature.

Figure 3.6: Relationship between literacy and internet use



Source: Author's calculations from WDI (2006)

3.3.2 Within-country comparisons

For some countries, it is possible to find data disaggregated by region. This requires either finding census or household survey data. This section will include within-country descriptions of electricity access according to surveys from the Demographic and Health Surveys (DHS) conducted by Macro International. Appendix 1 contains a table detailing the availability of these surveys by country. The descriptive statistics detailed here are to be taken with caution, as the sampling strategy of the DHS surveys is not intended to create within-country comparability beyond broad DHS-defined regions, which usually include at least two "state-level" administrative regions. DHS data has been used to map out poverty indice (CIESIN 2007), but the other data contained in the surveys, such as access to telephones and electricity, has not yet been analyzed spatially. It would be a relatively simple task to map out other DHS data, but only at the DHS regional level, examples of which are shown in Appendix 2. The further disaggregation of this information is an open topic of research among GIS experts, and there is considerable interest in going beyond the standard

"poverty-mapping" – using a combination of LSMS and national census data – to the mapping of other types of household data.

Table 3.5 shows DHS data on telephone access divided into rural and urban categories. Unsurprisingly, phone access is considerably greater in urban than in rural areas. Where the information is available, it shows that access to phones in capital cities dominates that of other urban areas within the same country.

Table 3.5: Percent households with telephones/mobile phones

Country	Service	Capital city	Other urban	Urban	Rural	Total
Benin 2001						
	Telephone	8.7	0.7	0.6	8.2	3.7
Burkina Faso 2003						
	Telephone	25.1	9.6	17.6	0.3	3.8
Cameroon 2004						
	Telephone	5.6	2.3	3.5	0.1	1.8
	Mobile phone	62	29.7	41.6	4.9	23.8
Ethiopia 2005						
	Telephone			28.2	0.1	4.2
	Mobile phone			11.4	0	1.7
Ghana 2003						
	Telephone			14.3	0.7	6.9
Kenya 2003						
	Telephone			32.7	6.2	12.8
Malawi 2004						
	Telephone			8.3	0.5	1.8
	Mobile phone			20.8	1.5	4.7
Mali 2001						
	Telephone	15.7	3.9	9.3	0.1	2.4
Mozambique 2003						
	Telephone			5.5	0.1	1.6
Rwanda 2005						
	Telephone			4.8	0.1	0.8
	Mobile phone			24.1	1.3	4.6
Senegal 2005						
	Telephone			27.7	5.4	16.2
Tanzania 2005 (mainland)						
	Telephone			27.5	2.3	8.9
Uganda 2004						
	Telephone			3.2	0.1	0.5
	Mobile phone			45.1	4.6	10.1
Zambia 2001						
	Telephone/mobile			10.2	0.4	3.8

Source: DHS final survey reports from each country.

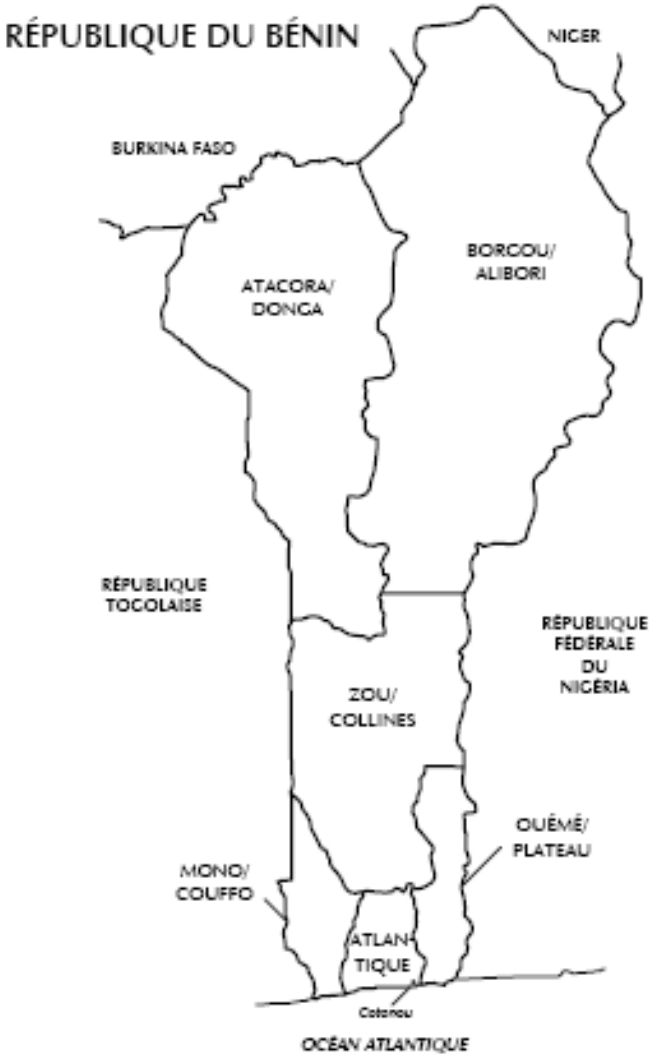
It is difficult to compare access to communications across countries, as the question regarding phones appears to have been posed differently depending upon the country and year. The data was further disaggregated for Benin and Mozambique, though there was not a clear explanation for this exercise. The numbers are listed in Table 3.6, with corresponding maps following in Figures 3.7.1 and 3.7.2.

Table 3.6: Households with telephone

Country	Region	% households with telephone
Benin 2001		
	Atacora	2.9
	Atlantique	12.7
	Borgou	1.6
	Mono	1.6
	Oueme	5.8
	Zou	1.1
	Total	3.7
Mozambique 2003		
	Niassa	0.3
	Cabo Delgado	0.1
	Nampula	0.6
	Zambezia	0.3
	Tete	0.9
	Manica	1.1
	Sofala	1.7
	Inhambane	1.3
	Gaza	0.7
	Maputo	3.7
	Maputo Cidade	15.5
	Total	1.6

Source: DHS final reports from Benin 2001 and Mozambique 2003 surveys.

Figure 3.7.1 Map of Benin



Source: DHS (2001)

Figure 3.7.2 Map of Mozambique



Source: DHS (2003)

3.4 Electricity access and infrastructure

3.4.1 Across-country comparisons

Table 3.7 shows two metrics of access to electricity in AGRA countries – percent of the population with access to electricity and kilowatt hours of consumption per capita. It also includes the poverty rate in order to show the correlation between poverty and electricity access – the correlation coefficient is -.49. Interestingly, electricity access and power consumption in Ghana today are very close to that of India today. Electricity consumption, where the data is available, is considerably higher in all of the African countries than it was in India in the early 1970s. The comparison between percentage of the population with access and consumption of electricity per capita suggests that there are a very few people consuming an extraordinary amount of electricity in the majority of these countries.

Table 3.7: Electricity access and other indicators

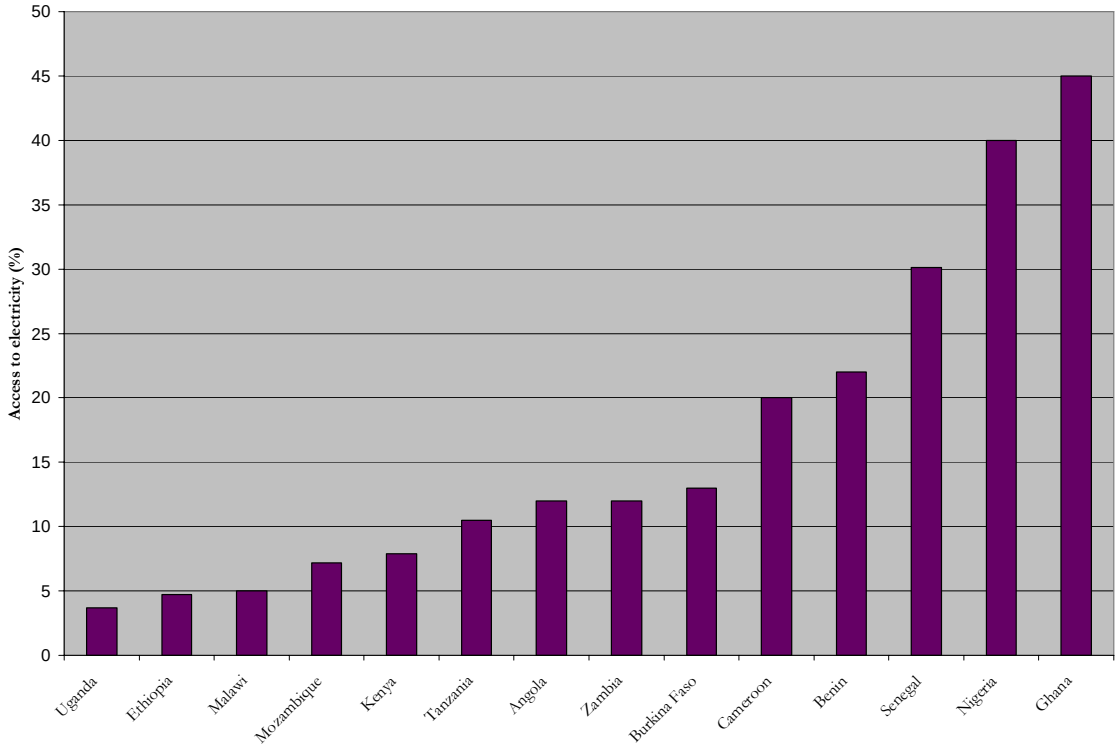
Country	Access to electricity (%)	Electric power consumption (kwh/capita)	Poverty rate
Angola	12	100.2	nd
Benin	22	65.6	29
Burkina Faso	13	nd	46.4
Cameroon	20	170.33	40.2
Ethiopia	4.7	21.8	44.2
Ghana	45	340.9	39.5
Kenya	7.9	134.8	52.0
Malawi	5	nd	65.3
Mali	nd	nd	63.8
Mozambique	7.2	266.1	69.4
Nigeria	40	82.2	34.1
Rwanda	nd	nd	60.3
Senegal	30.1	129.7	33.4
Tanzania	10.5	58.5	35.7
Uganda	3.7	nd	37.7
Zambia	12	584.6	72.9
India (2000)	43	364.7	28.6
India (1971)	nd	92.3	57[6]

Source: World Development Indicators (2006) and World Resources Institute (2007)

[6] This number reflects only rural poverty in India in 1971.

Figure 3.8 ranks the AGRA countries according to their aggregate electricity access. Uganda, Ethiopia, and Malawi are at the bottom, with less than 5% of the population having electricity in their homes, while Ghana, Nigeria, and Senegal are at the top, with Ghana's electricity access exceeding even that of India today.

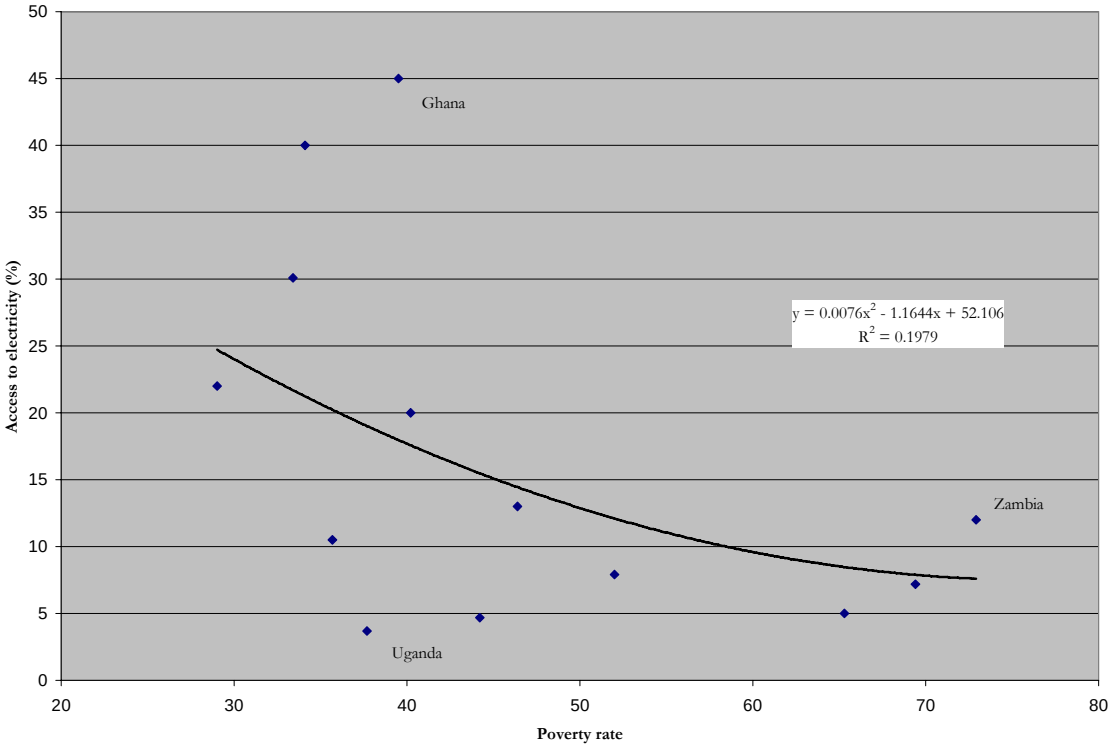
Figure 3.8: Countries ranked according to electricity access



Source: Author's calculations from WRI (2007) and WDI (2006)

Clearly, electricity access is strongly related to the wealth of a country, and vice versa. Figure 3.9 details the relationship between the two. The variation in poverty explains nearly 20% of the variation in electricity access. The relationship is negative and decreases at a decreasing rate, with poorer countries having significantly lower access to electrical power.

Figure 3.9: Relationship between poverty and electricity access



Source: Author's calculations from WRI (2007) and WDI (2006)

From a sustainability and environmental perspective, it is interesting to know the main sources of energy in particular countries. Table 3.8 gives the main sources of electricity for each of the AGRA countries. In contrast with India, the main source of electricity for the African countries is hydropower, with oil serving as a secondary source for many of them.

Table 3.8: Main sources of electricity

Country	Hydro	Coal	Oil	Gas
Angola	62.2	0	37.8	0
Benin	2.6	0	97.4	0
Burkina Faso	nd	nd	nd	nd
Cameroon	95.8	0	4.2	0
Ethiopia	99.3	0	0.7	0
Ghana	65.5	0	34.2	0
Kenya	67	0	16.8	0
Malawi	nd	nd	nd	nd
Mali	nd	nd	nd	nd
Mozambique	99.7	0	0.3	0.1
Nigeria	38.8	0	22.7	28.5
Rwanda	nd			
Senegal	15.7	0	74.6	1.6
Tanzania	93	2.7	0	0
Uganda	nd	nd	nd	nd
Zambia	99.5	0.2	0.4	0
India (1990)	24.8	65.3	4.3	3.4

Source: IEA (2002)

In order to highlight what a small role electricity demands play in overall energy demands in these countries, Table 3.9 shows the main sources of energy as a percentage of total consumption. In all cases, solid biomass dominates as the main energy source, though its main use is likely for cooking and heating houses. Hydropower plays a minimal role in all countries as a source of energy.

Table 3.9: Energy consumption and sources, 2003

Country	Total consumption (1000s tons of oil equivalent)	Coal (%)	Geothermal (%)	Hydro (%)	Natural gas (%)	Oil (%)	Solid biomass (%)
Angola	9,120.00	0.0	0.0	1.2	5.8	27.7	65.4
Benin	2,387.00	0.0	0.0	0.0	0.0	32.1	66.0
Burkina Faso	nd						
Cameroon	6,837.00	0.0	0.0	4.4	0.0	17.9	77.6
Ethiopia	20,509.00	0.0	0.0	1.0	0.0	7.8	91.2
Ghana	8,489.00	0.0	0.0	3.9	0.0	29.4	66.6
Kenya	15,753.00	0.4	4.3	1.8	0.0	15.9	77.6
Malawi	nd						
Mali	nd						
Mozambique	8,303.00	0.2	0.0	10.7	0.0	7.1	85.1
Nigeria	97,825.00	0.0	0.0	0.7	7.4	12.6	79.4
Rwanda	nd						
Senegal	2,593.00	0.0	0.0	1.1	0.3	57.8	40.7
Tanzania	17,162.00	0.2	0.0	1.3	0.0	6.6	91.9
Uganda	nd						
Zambia	6,781.00	1.3	0.0	10.5	0.0	9.2	79.7
India 2003	548,661.00	32.6	0.0	1.2	4.2	22.6	38.5
India 1990	361,598	29.2	0.0	1.7	2.7	17.3	48.6

Source: World Resources Institute Earthtrends Database (2007)

It is also useful to understand how the population perceives the existing infrastructure of their country. Table 3.10 shows results from a survey of small businesses in various African countries. The businesses were asked a variety of questions regarding obstacles to business development and availability of infrastructure. For all of them, electricity represented a more important barrier than telecommunications. This fact is reflected in the large number of days of power outages per year – in all cases more than a month, and in most more than two.

Table 3.10: Infrastructure and small businesses

	Services as an obstacle to business (0 to 4)		# days of power outages per year
Country	Telecommunications	Electricity	
Ethiopia	1.5	2.1	Nd
Kenya	2.1	2.3	84
Tanzania	1	2.6	67
Uganda	0.7	2.1	71
Zambia	1.6	2	38

Source: Arnold, Mattoo, and Narcisol (2006)

3.4.2 Within-country comparisons and trends across time

As is true with all the infrastructure that we have considered up to this point, figures aggregated at the national level obscure regional differences within a country. This is clearly the case with electricity – regional level estimates are presented in Table 3.11. In Sub-Saharan Africa, urban dwellers are over 7 times more likely to have access to electricity – in India, they are just over twice as likely.

Table 3.11: Rural versus urban electricity access in Sub-Saharan Africa and India

	Rural	Urban	Total
Sub-Saharan Africa (2005)	8	58.3	25.9
India (2000)	29	69	43

Source: IEA (2002)

Table 3.12 shows the trend in electrification across South Asia (which includes India) and Sub-Saharan Africa. Although electrification in Africa is fairly dismal and still lags far behind that of Asia, it is heartening to see the steady increase. In particular, the increase in electrification in Sub-Saharan African from the 1970s to the 1990s was 77% (88% for South Asia), and from 30% 1990 to 2000 (compared to 28% for South Asia).

Table 3.12: Trends in electricity access in Sub-Saharan Africa and South Asia

Region	1970	1990	2000
Sub-Saharan Africa	9	16	23
South Asia	17	32	41

Source: IEA (2002)

Table 3.13 shows electricity data contained in final DHS reports on AGRA countries disaggregated by rural and urban regions. Unsurprisingly, urban areas always have greater access to electricity than rural ones.

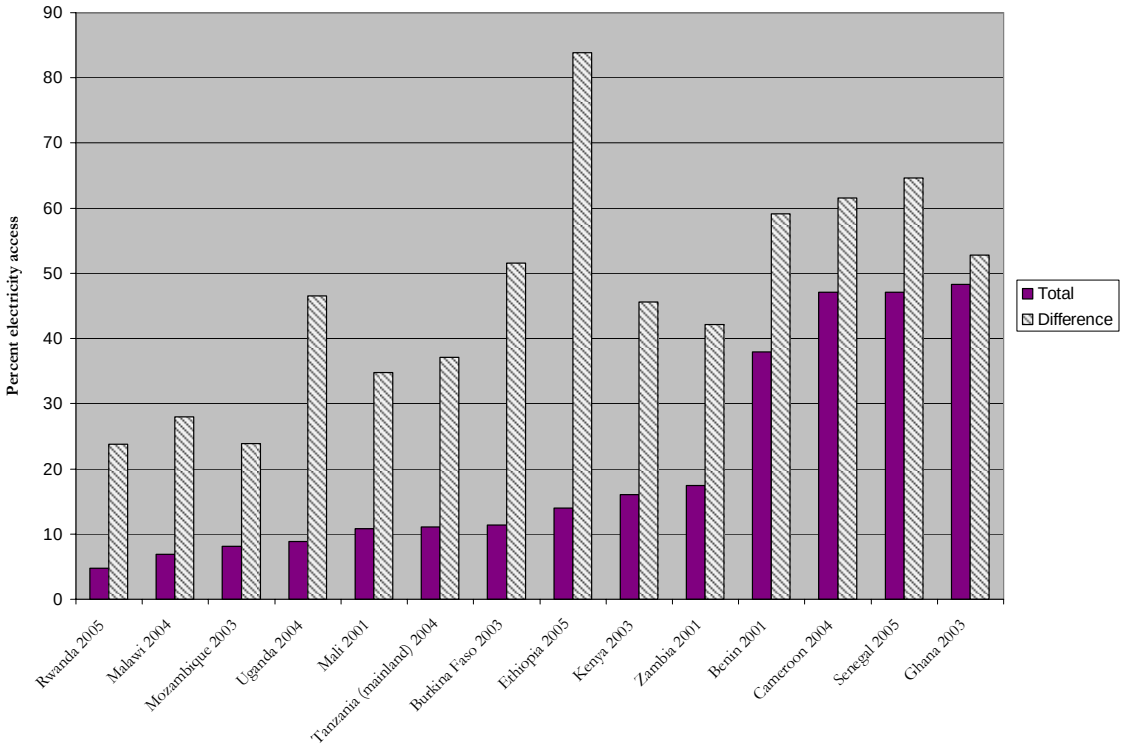
Table 3.13: Percent household access to electricity

Country and survey year	Capital city	Other urban	Urban	Rural	Total
Benin 2001	85.3	66.2	73.1	14	38
Burkina Faso 2003	56.7	47.8	52.4	0.8	11.4
Cameroon 2004	96	66.1	77.1	15.5	47.1
Ethiopia 2005			85.7	1.9	14
Ghana 2003			76.9	24.1	48.3
Kenya 2003			50.2	4.6	16
Malawi 2004			30.2	2.2	6.9
Mali 2001	55.8	21	37	2.2	10.8
Mozambique 2003			25	1.1	8.1
Rwanda 2005			25.1	1.3	4.8
Senegal 2005			80.4	15.8	47.1
Tanzania (mainland) 2004			38.4	1.3	11.1
Uganda 2004			49	2.5	8.9
Zambia 2001			45.1	2.9	17.4

Source: DHS final survey reports for each country

Figure 3.10 shows the countries ranked according to overall electricity access with an additional bar (in pink) showing the difference between urban electricity access and rural. The ranking varies slightly from that of the aggregate WRI statistics, though the general location of the countries in the ranking is quite similar. All of the countries show substantial rural-urban differentials in electricity access, with Ethiopia having the largest, followed by several countries with considerably greater overall electricity access – Senegal, Cameroon, and Benin.

Figure 3.10: Rural urban electricity disparities



Source: Author's calculations from DHS survey reports

As mentioned in the previous section on communications, in a few of the DHS reports, data was further disaggregated by region. This disaggregation for electricity is shown in Table 3.14. The corresponding maps are the same as in the previous section, with the additional map for Kenya included in Figure 3.11.

Table 3.14: Regional electricity access

Country	Region	% access
Benin 2001		
	Atacora	16.7
	Atlantique	65.5
	Borgou	23.6
	Mono	24.2
	Oueme	48.7
	Zou	26.3
	Total	38
Kenya 2003		
	Nairobi	71.4
	Central	19.2
	Coast	19.3
	Eastern	6.9
	Nyanza	5.1
	Rift Valley	10.5
	Western	1.6
	North Eastern	3.2
	Total	16
Mozambique 2003		
	Niassa	3
	Cabo Delgado	1.5
	Nampula	5.1
	Zambezia	2.9
	Tete	4.9
	Manica	5.1
	Sofala	6.8
	Inhambane	6.2
	Gaza	8.2
	Maputo	21.4
	Maputo Cidade	52.1
	Total	8.1

Source: DHS final survey reports

Figure 3.11: Map of Kenya



Source: DHS (2003)

For Ghana, Malawi, and Tanzania, World Bank Living Standards Measurement Surveys (LSMS) are available. The years and coverage are indicated in Appendix 1. Only Ghana had a final report including summary statistics available. The results for electrical lighting by region are included in Table 3.15. Unfortunately, there was no map available detailing the location of the various regions. Comparing Table 3.15 with Table 3.12 suggests

that Ghana as a whole has increased its electrification substantially between 1998 and 2003, and that the majority of their efforts have been in rural areas.

Table 3.15: Electricity access by region in Ghana, 1998

	Urban			Rural				
	Accra	**Other**	**All urban**	**Coastal**	**Forest**	**Savannah**	**All rural**	**Ghana**
Percent	90.6	72.2	77.4	26.7	19	4.3	17.1	39.2

Source: LSMS (1998)

The Digital Map of the World data can also be used to chart out utilities infrastructure (though again, the estimated network is from 1993). Maps of this data for selected AGRA countries are shown in appendix 4. This data is quite sparse, though it is not clear if this is the case because infrastructure is so weak or information regarding it is lacking. Obviously, there is no way to make province-level estimates of electricity access.

3.5 Storage infrastructure

It is extremely difficult to find statistics reflecting the agricultural commodity storage capacity of African countries. This may be due to the large percentage of storage that occurs on a very small scale (at the household level). FAO estimates suggest that "between 60 and 70% of grain production in Africa is stored at farm level, generally for family consumption but also for sale and seed." (FAO 1994)

One source of information on storage is given by studies of grain traders in Benin, Malawi, and Ethiopia (Fafchamps and Gabre-Madhin 2006, Gabre-Madhin 2001). In their analysis of traders in Benin and Malawi, Fafchamps and Gabre-Madhin find that half of all traders store grains at their residence. 24 and 39% of traders in Benin and Malawi, respectively, store at facilities outside of their home that they either rent or own. The median combined storage capacity of these two types of facilities is 1.4 tons (about 15 bags of grain). About one third of traders have access to a collective storage facility located near the market at a cost of $3 per ton per day in Malawi, and around half of the surveyed Beninese traders have such access, at a cost of 25 cents per ton per day. Ninety percent of traders surveyed keep goods for less than a month. The average stock held is 1% of annual sales. This suggests that, contrary to popular belief, "middlemen" do not play a significant role in arbitrage over time in Malawi.

In Ethiopia, Gabre-Madhin observes an average household grain storage capacity of 100 tons, and two thirds of traders complain of the inadequacy of storage availability, capacity, and location. 2,200 modern storage warehouses with a capacity of 1 million tons are available throughout the country, though in 1992 they were only half filled. About 40 percent of Ethiopian traders own their own storage and 69 percent rent. The average days of storage is 46 – considerably higher than in Malawi – but ranges from a low of 16 to a high of 92 days depending upon the region. Even the maximum number of storage days, however, suggests that traders are not necessarily buying at the harvest and selling in the "lean" season, when prices are likely to be highest.

As the authors note, grain traders do not collaborate to take advantage of returns to scale for transport and storage, and markets are organized much as they were in Europe and the Mediterranean hundreds of years ago. Researchers studying the history of this type of market have noted that the small scale of these traders' interactions was the result of the lack of formal mechanisms for contract dispute resolution (Greif 1993).

The scant evidence on storage just presented implies a vast majority of grains are stored on a very small scale using traditional methods. Table 3.16 shows losses from household storage of grains, excerpted from FAO (1994). The low rates of loss found in this study imply that storage at the household level is of fairly high quality.

Table 3.16: Rate of loss through storage of millet and sorghum in traditional granaries in Africa

Country	Product	Loss (%)
Senegal	Millet in ear	2.2
	Sorghum in ear	5.3
	Sorghum as grain	9.5
Northern Nigeria	Sorghum in ear	4.0
	Sorghum as grain	4.0
	Mali in ear	2 to 4
Niger	Millet in ear	10.1
	Millet as grain	3.4
Burkina Faso	Millet in ear	6.9
	Millet as grain	8 months storage

Source: Proctor (1994)

It is important to note that these findings are far from the consensus in the field. In fact, FAO studies in Tanzania report losses as high as 30 percent and averaging 8.7 percent during a 3 to 6 month storage period (Golop and Hodges, 1982 in R.L. Semple, P.A. Hicks,

J.V. Lozare, and A. Castermans, 1992). Group for Assistance on Systems Relating to Grain after Harvest state that grain storage losses in rural areas rarely fall below 15% per year, and are sometimes as high as 50% (GASCA n.d.). According to Proctor (1994), however,

> There has been a tendency to overestimate storage losses, and to base estimates on extreme cases or guess-work rather than on sound empirical testing. Figures of 30 per cent or more are not uncommon (Greeley, 1987, p. 13ff). By contrast, the results of detailed field studies suggest that under traditional storage systems in tropical countries losses are typically around 5 per cent over a storage season (Tyler and Boxall, 1984), depending upon the crop, the ambient conditions, the period of storage and other factors. Somewhat higher levels have been encountered in the wetter parts of West Africa and Central America.

Clearly, however, storage plays some role in the enormous price volatility seen in African countries (Proctor (1994) shows up to 260% fluctuation in prices in Mali from 1986 to 1991). It could also be the case that these estimates are quite low as a result of the short period of time that most households actually store their grain.

Though strategic grain reserves are operated by various governments, they do not in fact reflect farmer access to storage facilities. They are government-owned food stocks intended to deal with regional food emergencies. In some places, such as Zambia, they also serve as a buyer of last resort for small farmers. Though in theory these reserves can be used for price stabilization policies, in practice this has proven to be quite costly. All of the countries of interest for this note have strategic grain reserves. Mozambique's reserves fluctuates around 60,000 metric tons (IMF 2007, FAO 1997). Information was not available regarding capacities in the other countries.

4. Current efforts to improve infrastructure

Section summary

This section presents the most current information possible regarding efforts to help improve infrastructure in the AGRA countries. The available statistics show considerable promise – commitments to infrastructure improvement have grown considerably over the past few years and are substantial. There is substantial investment by both private and public entities, with private investors more likely to put their money into communications infrastructure and public entities more likely to invest in the energy and transport sectors. Again, the information on agriculture storage is extremely limited.

In terms of public aid by Infrastructure Consortium for Africa (ICA) participants (who comprise the vast majority of public monies committed to infrastructure), Ethiopia receives the most aid and Burkina Faso the least. When measured by per capita spending, Senegal receives the most and Nigeria the least. The relationship between this aid and poverty is weak – at very low levels of income per capita, overall aid decreases slightly with increases in income. However, at high levels of income, total public aid increases. The relationship between infrastructure aid per capita is the opposite – over most of the range, aid per capita increases with income per capita.

The pictures differs somewhat using more refined measures of infrastructure need. Here one observes that World Bank investment in the transportation and energy sectors reflect needs fairly well, with spending increasing as the quantity of needed roads increases and as the percentage of population with access to electricity decreases. The relationship between World Bank spending on communications projects and phone access in AGRA countries is non-linear and appears not to reflect need as much as spending in other sectors.

Private investment in infrastructure, a category of increasing importance in AGRA countries, generally moves in the opposite way of public investment. Specifically, it is larger in the telecommunications sector, where it tends to increase with access to telephones. This suggests that private investment does not follow needs as closely as public investment. The much smaller private investment in energy and transport also moves in the opposite direction of the World Bank funding – it flows to countries with greater electricity access and better road infrastructure. Nigeria receives a much larger amount of private investment

than any of the other AGRA countries, while Malawi and Rwanda receive the least. There is very little information available on investment in agricultural storage infrastructure, however, it is not safe to assume that there is no investment in this area. It is quite likely that any projects focusing on storage are included in other lending categories, such as rural or agricultural development.

Finally, this section ends with a few words on "alternative" efforts to relieve infrastructure constraints. There are an untold number of smaller NGOs, universities, and even private companies working on agricultural marketing and development, and many of them have come up with innovative solutions, including the efforts of TechnoServe, Michigan State University, and the Cooperative League of the USA (CLUSA).

4.1 Overall lending by source and sector

The purpose of this section is to give an overview of present efforts to improve infrastructure in AGRA countries. The Infrastructure Consortium for Africa (ICA) in its 2006 annual report has put together an impressive array of statistics describing infrastructure investment in Africa as a whole. The ICA formed in 2005, and serves as an organizing force for various institutions which invest in African infrastructure and focus on four basic sectors: water sanitation and resource management, energy, transport, and ICT (internet and communications technology). In its own words it

> "is intended to make its members more effective at supporting infrastructure in Africa by pooling efforts in selected areas (such as information sharing, project development, and good practice) without necessarily pooling financing decisions. Although the Consortium is not a financing agency, the Consortium would act as a platform to broker more donor financing of infrastructure projects and programs in Africa (AfDB)." (ICA 2006)

Members include African institutions, G8 bilateral agencies, and multilateral agencies. Among the African members are the African Development Bank (ADB), the AU Commission, the New Partnership for African Development (NEPAD), and the Regional Economic Communities (RECs). Multilateral members are the World Bank, the European Commission, and the European Investment Bank. Although some supplemental sources are used, the ICA has generated the majority of the information described in this section of the report.

Table 4.1 lists infrastructure development commitments in Sub-Saharan Africa (minus South Africa) for 2005 and 2006. These figures include all investment for the four main infrastructure areas for ICA. They are the results of the survey conducted by the ICA.

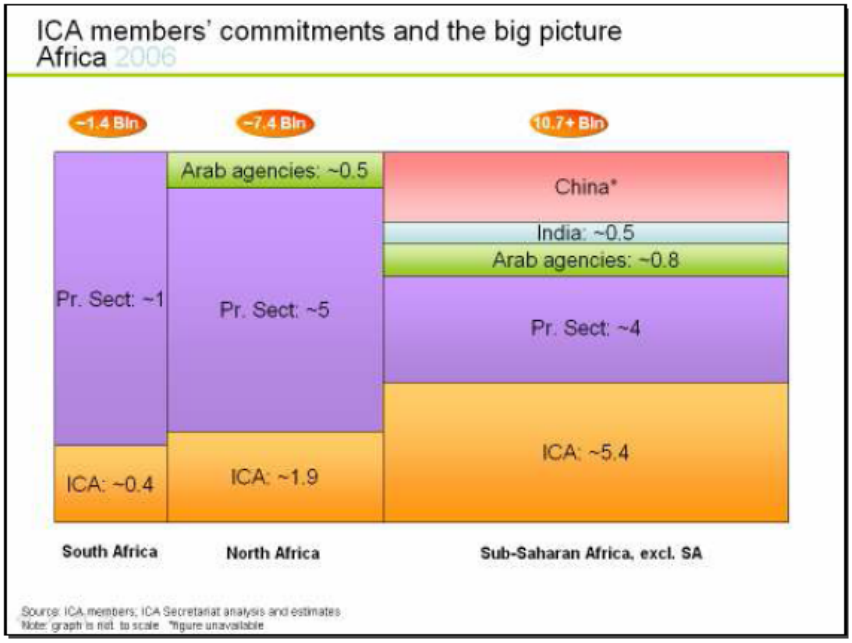
Table 4.1: Commitments to infrastructure in Sub-Saharan Africa for 2005/2006 (US $m)

Source		Official development assistance	Non-Concessional capital flows
2005			
	Multilateral agencies	2,850	410
	Bilateral agencies	1,500	7
2006			
	Multilateral agencies	3,800	255
	Bilateral agencies	1,325	35

Source: ICA (2006)

Figure 4.1 gives a sense of the importance of ICA member investments in Africa. Note that the private sector is playing an increasingly large role in all regions of Africa, even Sub-Saharan Africa, a region which has not traditionally been very attractive to private investors.

Figure 4.1: ICA member commitments in Africa relative to total



Source: ICA (2006)

Table 4.2 shows the flow of private investments over the period 2000-2005. The increase has been somewhat volatile, though positive overall, as is shown by the percent changes in investment from year to year.

Table 4.2: Private investment in infrastructure in sub-Saharan Africa, 2000-2005, $US m

Sector	2000	2001	2002	2003	2004	2005
Energy	447	626	484	397	240	782
WSS	--	3	--	9	--	--
Transport	180	--	101	318	187	504
ICT	927	2,187	1,697	2,825	2,634	3,382
Total	1,553	2,817	2,263	3,549	3,061	4,668
% change on previous year		81.39	-19.67	56.83	-13.75	52.50

Source: ICA (2006) calculated from PPI (Private Participation in Infrastructure) project database of the World Bank and PPIAF. www.ppi.worldbank.org.

Investment in infrastructure by ICA members was quite steady in the decade prior to 2004, a year which showed considerable growth in commitments (ICA, 2006). Commitments by ICA donors for the year 2006 are shown in Table 4.3. In transportation, the World Bank and EU are the largest donors on the multilateral side, while US investments in this sector are by far the largest amongst the bilateral agencies surveyed. According to the ICA, other bilateral agencies not surveyed, including Belgium, Denmark, Ireland, Netherlands, Spain and Switzerland, generally account for around 5% of total infrastructure investment in Africa. Private investment flows clearly dominate in the communications sector. The ICA provides extensive statistics on investment by sector and country. The complete tables are shown in Appendix 5.

Table 4.3: Commitments by source and sector in $US m for 2006

Sector	ADB	EU	WB	Japan	France	Germany	USA	Italy	ICA total	Private	Arab funds & India
Energy	239.7	48.3	479.6	16.4	10.0	8.8	6.8	--	809.6	--	702.9
Transport	513.4	897.8	610.2	162.3	44.0	63.0	498.9	26.3	2,815.9	27.0	326.3
ICT	--	--	80.0	--	--	--	7.6	23.7	111.3	3,381.9	--

Source: ICA (2006)

4.2 Lending by country

Table 4.4 breaks down ICA commitments by country for all of the AGRA countries. The table also includes per capita income for each country, total population in 2003, and ICA aid per capita.

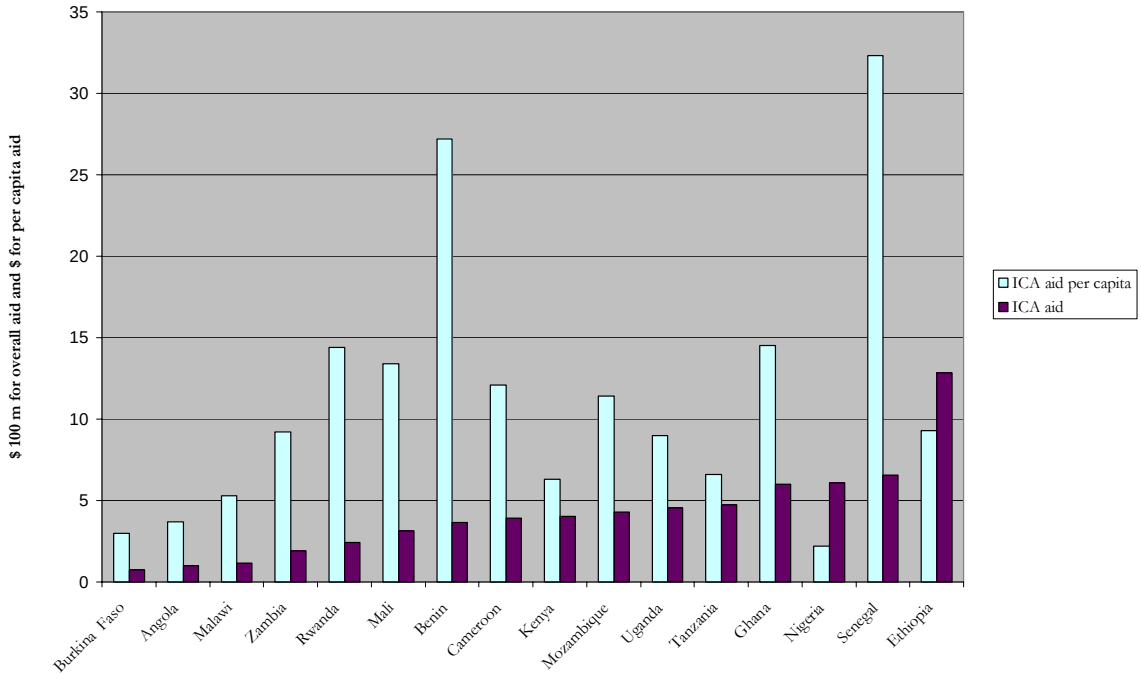
Table 4.4: ICA member commitments in AGRA countries

Country	2003 per capita income ($)	2003 population (millions)	ICA aid ($m)	ICA aid per capita (4)
Angola	1,910	13.5	99.7	3.7
Benin	1,110	6.7	364.3	27.2
Burkina Faso	1,170	12.1	72.9	3
Cameroon	1,990	16.1	391.2	12.1
Ethiopia	710	68.6	1,283.30	9.3
Ghana	2,190	20.7	600	14.5
Kenya	1,030	31.9	403.2	6.3
Malawi	590	11	116.1	5.3
Mali	960	11.7	314.4	13.4
Mozambique	1,060	18.8	430.5	11.4
Nigeria	900	136.5	607.1	2.2
Rwanda	1,290	8.4	241.2	14.4
Senegal	1,620	10.2	658.3	32.3
Tanzania	620	35.9	474.4	6.6
Uganda	1,430	25.3	454.7	9
Zambia	850	10.4	192.1	9.2

Source: ICA (2006)

Figure 4.2 shows the AGRA countries ranked according to total ICA infrastructure aid. This ranking is juxtaposed with the infrastructure aid received per capita. While Burkina Faso receives the least overall aid and Ethiopia the most, the ranking according to $ per capita is quite different, with Nigeria receiving the least and Senegal the most.

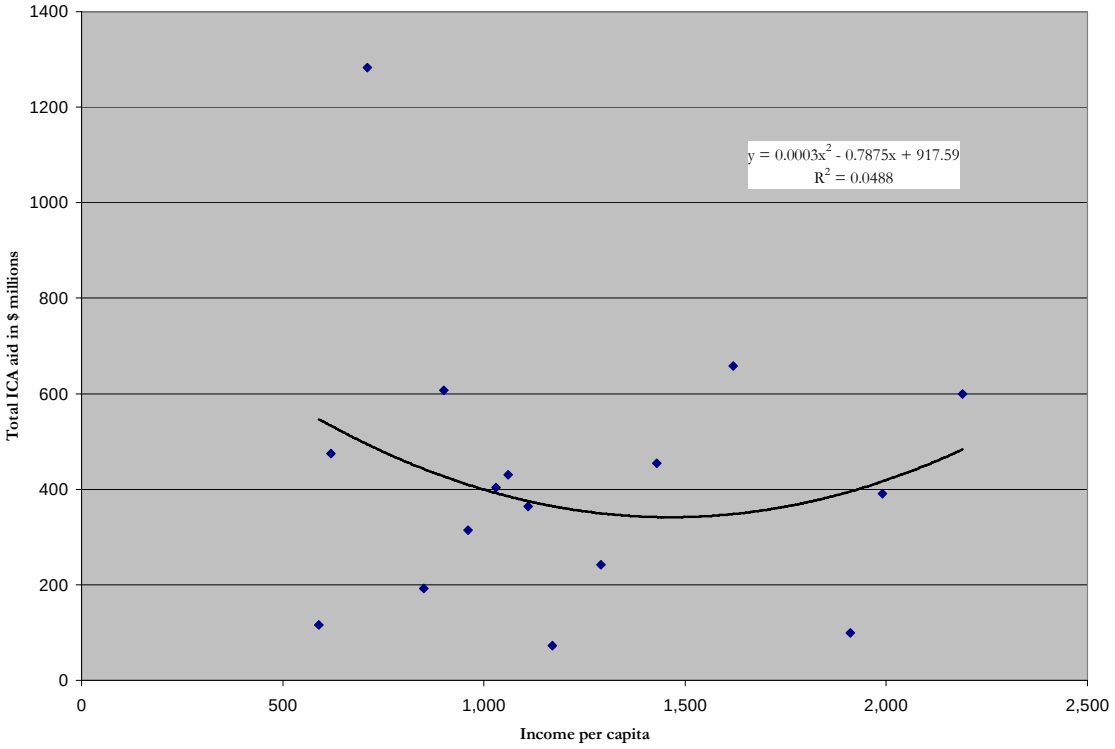
Figure 4.2: AGRA countries ranked by infrastructure aid in $ 100 m



Source: Author's calculations from ICA (2006)

Figure 4.3 shows the relationship between total aid committed by ICA members and income per capita in AGRA countries. One would hope to observe increasing commitments for lower income countries, which on this graph would be shown by a line with a negative slope. This appears to be the case for the lower end of the income scale, though the relationship is quite weak. For higher level income countries, higher incomes per capita are associated with greater ICA aid.

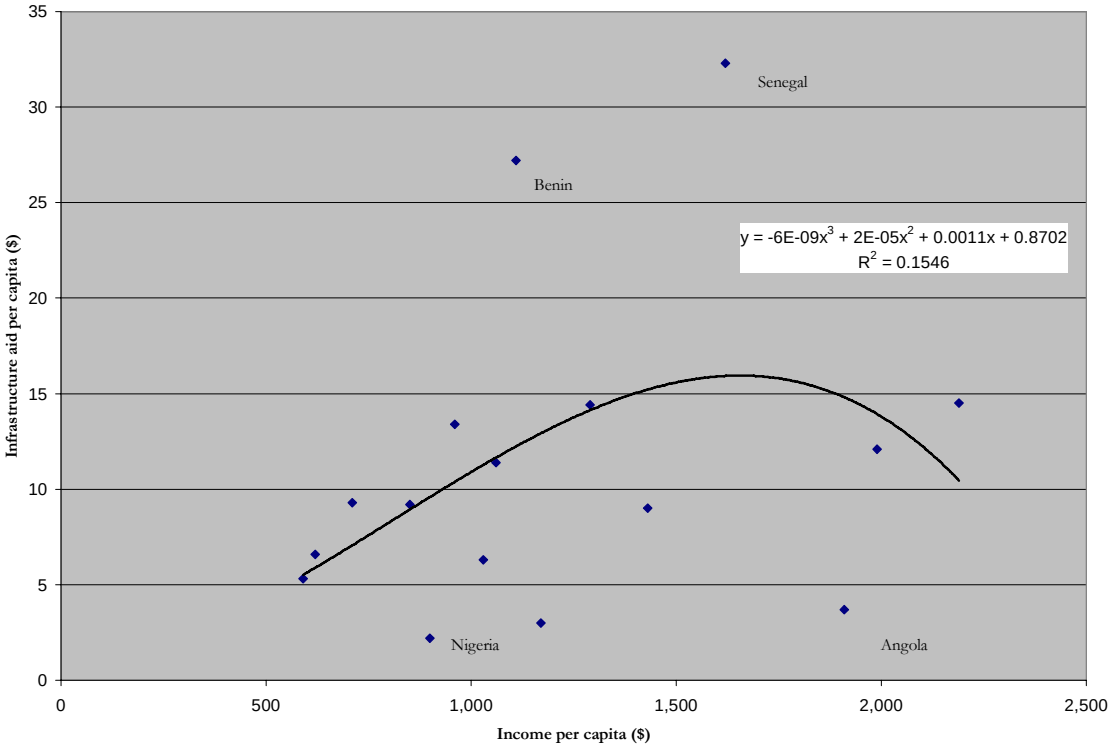
Figure 4.3 Total ICA aid versus income per capita



Source: Author's calculations from ICA (2006)

Figure 4.4 plots out the relationship between ICA aid *per capita* and income per capita, which is first increasing and then decreasing, suggesting that for lower levels of income per capita, increases in income are associated with increases in investment, while for higher levels, increases in income are associated with decreases in investment. In both cases, the observed relationship is not exactly what one would hope for, however, the amount of aid received by various countries clearly depends on more than just income per capita. One possible explanation for the divergence between need and receipt is that more aid goes to countries that are able to distribute it more effectively, a capacity which would be positively correlated with income per capita. In addition, it is possible that income per capita is not necessarily the best measure of need for infrastructure aid.

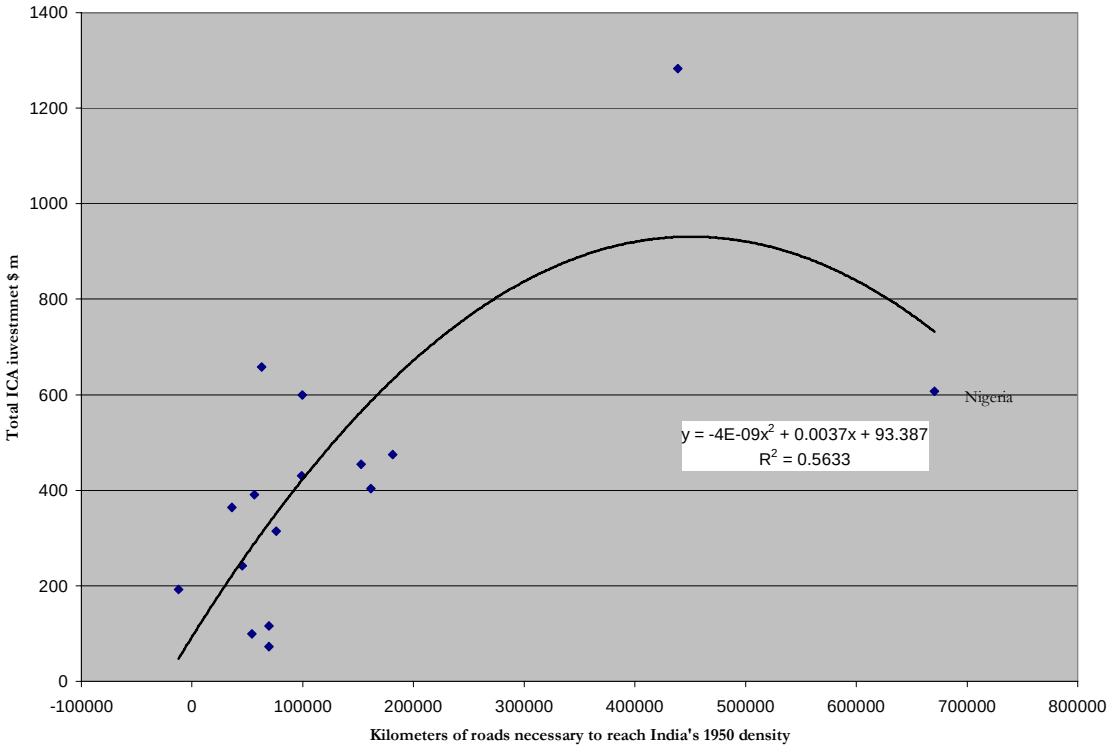
Figure 4.4 Infrastructure aid as a function of income per capita



Source: Author's calculations from ICA (2006)

Therefore, a relationship of even greater interest is that between the amount of required roads as determined in section 3 with total ICA investment, which is shown in figure 4.5. Here one observes nearly the hoped-for relationship – countries with a greater number of kilometers required in order to reach India's 1950 road density are receiving greater infrastructure investment. Nigeria, a large outlier, is the point which pulls down the relationship at the high end of the necessity scale.

Figure 4.5: Total ICA infrastructure investment versus kilometers required roads



Source: Author's calculations from ICA (2006)

Given that the World Bank is one of the largest players in this field, it is worthwhile to look at their involvement by sector and country. Table 4.5 breaks down World Bank lending between 2003 and 2007 by country.

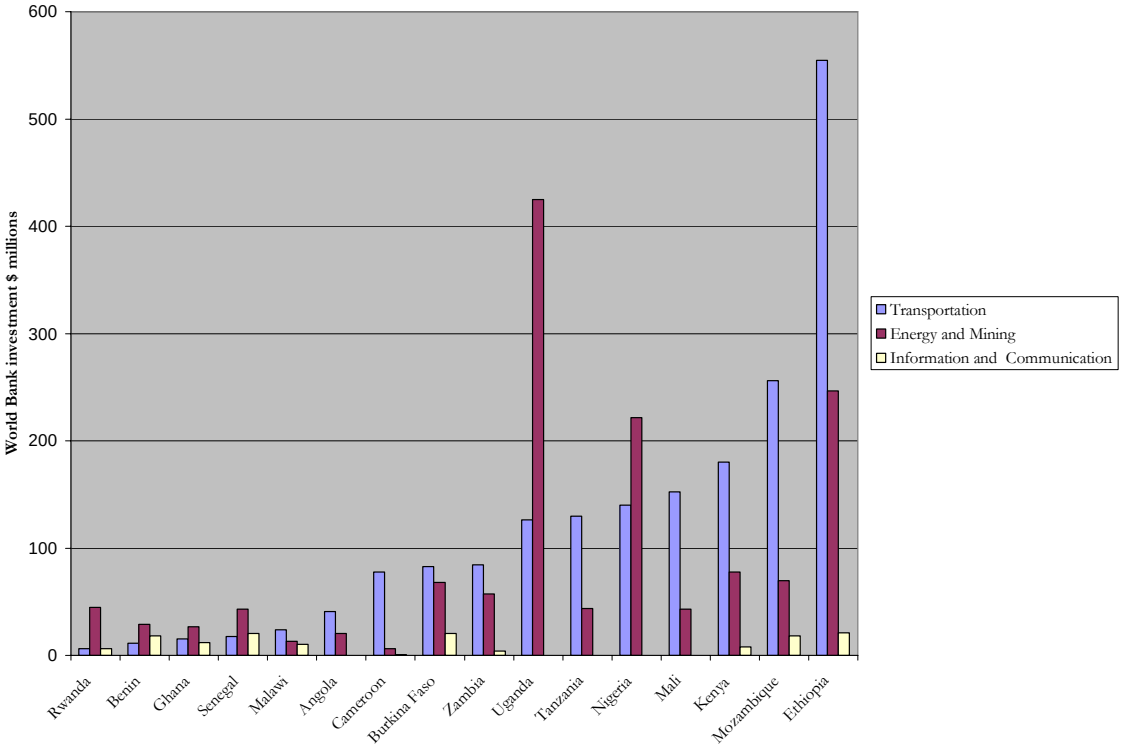
Table 4.5: World Bank lending for infrastructure 2003-2007 ($ mil)

Country	Transportation	Energy and Mining	Information and Communication
Angola	40.8	20.4	0
Benin	11.35	28.8	18
Burkina Faso	82.89	68.13	20.63
Cameroon	77.62	6.3	0.331
Ethiopia	554.83	246.73	21
Ghana	15.1	26.5	12
Kenya	180.09	77.6	8.2
Malawi	24	13.2	10
Mali	152.51	43	0
Mozambique	255.9	69.41	18
Nigeria	140	221.68	0
Rwanda	6	44.5	6
Senegal	17.5	42.99	20.5
Tanzania	129.86	43.8	0
Uganda	126.35	425	0
Zambia	84.64	57.22	4

Source: World Bank Website, 2007

Figure 4.6 ranks AGRA countries according to World Bank infrastructure lending in transportation. The magnitude of lending in other sectors generally mirrors this ranking, with the exception of a few countries. Here we see that in general, Rwanda receives the least lending and Ethiopia the most, although lending to Uganda and Nigeria for energy and mining is considerable.

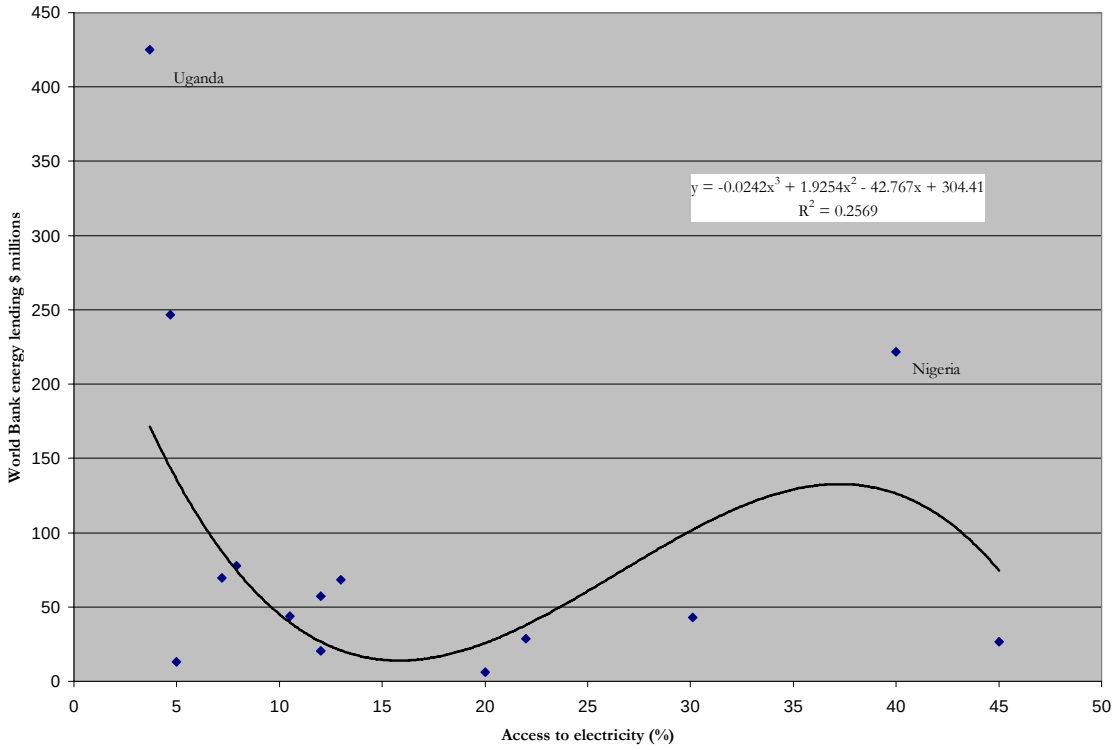
Figure 4.6: World Bank lending in AGRA countries



Source: Author's calculations from World Bank (2007)

As above, one would hope to observe patterns of lending that reflect greater outlays to countries with higher needs. Figure 4.7 plots out World Bank lending to the energy and mining sector against electricity access. Clearly, both measures are imperfect, as the lending measure includes lending for non-electrical projects and electricity access across a country is only the crudest measure of the energy infrastructure needs of its residents. Nonetheless, for lower levels of access we observe higher levels of Bank funding – just as we would hope. The relationship breaks down at higher levels of access, though this upward slope is clearly the result of the outlier Nigeria.

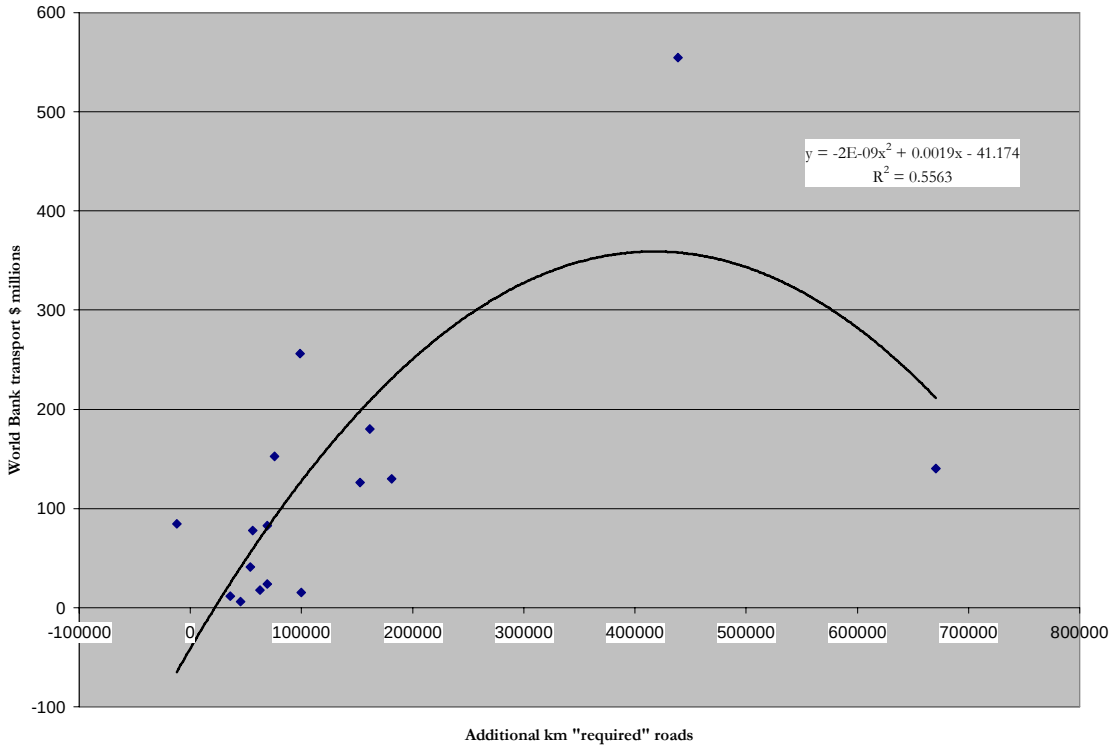
Figure 4.7: World Bank lending against electricity access



Source: Author's calculations from World Bank (2007)

Figure 4.8 depicts the relationship between World Bank lending for transportation and "required" kilometers of roads as defined above. Here again we see the hoped-for relationship where lending increases with the needs of a country.

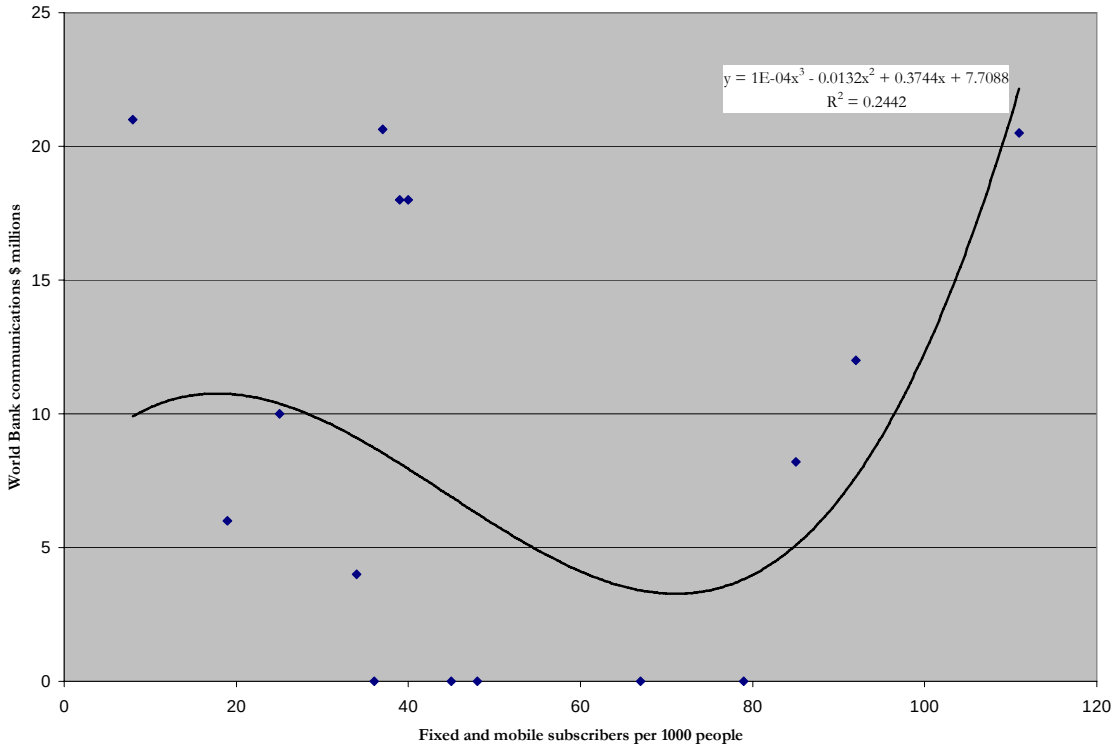
Figure 4.8: World Bank lending for transportation versus "required" roads



Source: Author's calculations from World Bank (2007)

Finally, Figure 4.9 graphs out the correlation between lending for communications infrastructure and the number of fixed and mobile phone subscribers per 1000 people. Were it the case that lending followed need, and were the measures of both to be accurate, one would expect a downward slope line on this graph. The data pattern shows this to be true for very low levels of access, although countries with total subscribers in the middle of the range receive very little communications lending, and those at the high end receive very high levels.

Figure 4.9: Bank communications lending versus phone subscribers



Source: Author's calculations from World Bank (2007)

Given that private investment is becoming increasingly important, it is useful to observe the patterns in its distribution across AGRA countries. Table 4.6 shows the distribution of private investment across country and sector for all of the AGRA countries. Although the totals run from 1990 to 2005, the vast majority of this investment occurred after 2000. These totals include investment both by private entities alone as well as private-public partnerships.

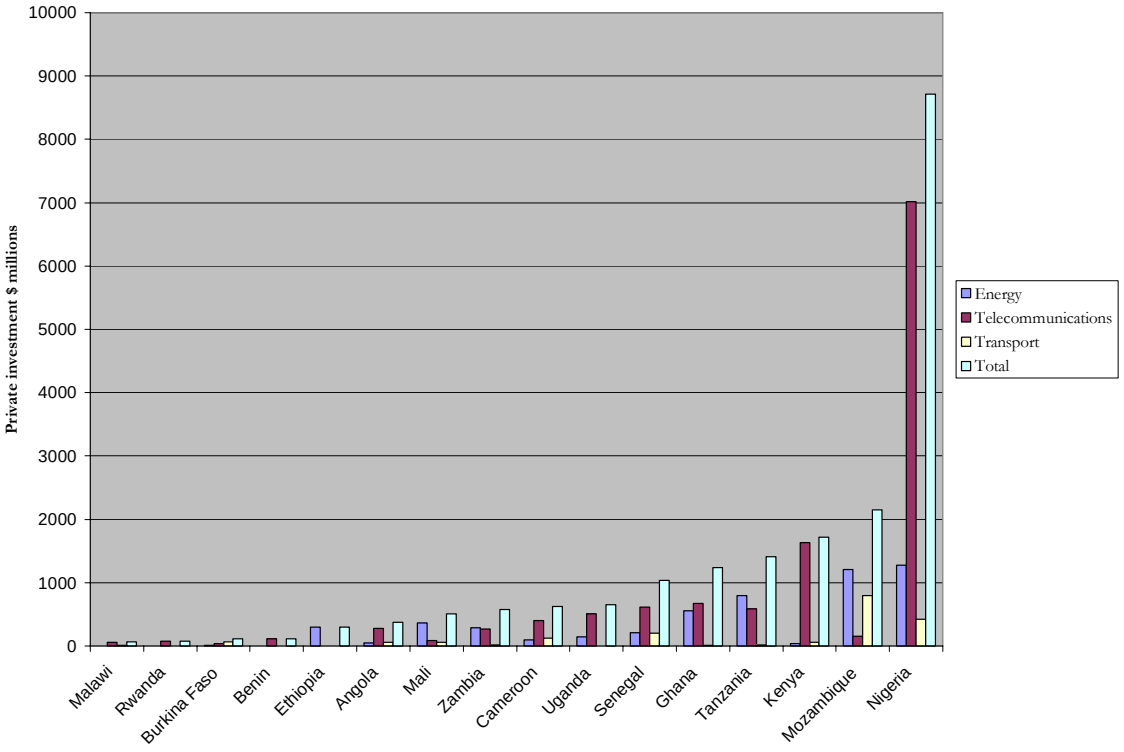
Table 4.6: Private investment in AGRA countries, 1990-2005

Country	Energy	Telecommunications	Transport	Total
Angola	45	279	55	379
Benin	0	117	0	117
Burkina Faso	6	42	63	111
Cameroon	92	407	121	620
Ethiopia	300	0	0	300
Ghana	560	668	10	1238
Kenya	38	1627	53	1718
Malawi	13.2	59	6	65
Mali	366	83	55	504
Mozambique	1,206	152	793	2151
Nigeria	1275	7020	423	8718
Rwanda	0	80	0	80
Senegal	211	619	205	1035
Tanzania	797	589	23	1409
Uganda	142	511	0	653
Zambia	289	273	16	578

Source: World Bank PPI database www.ppi.worldbank.org.

Figure 4.10 ranks the AGRA countries according to total private investment. The largest investment by far has occurred in Nigeria, with the majority in the telecommunications sector, while the lowest levels of investment ocurred in Malawi, Rwanda, and Burkina Faso.

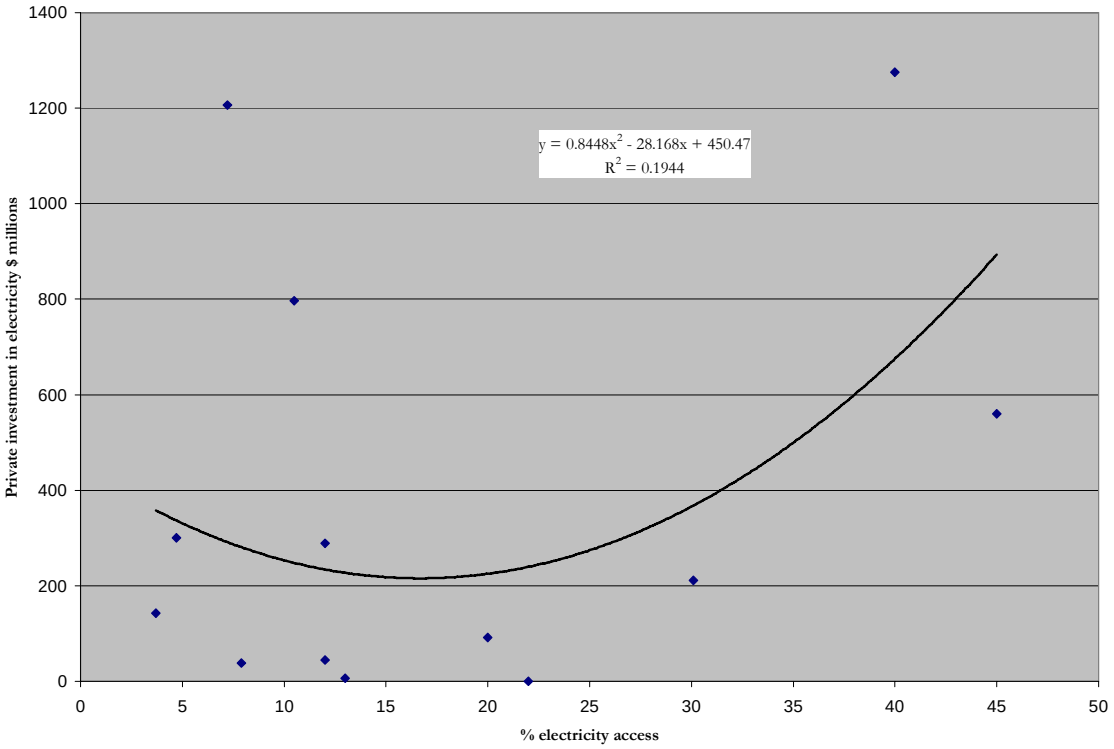
Figure 4.10: Private investment in AGRA countries by sector



Source: Author's calculations from World Bank (2007)

Paralleling the analysis above, Figure 4.11 shows private investment in energy versus electricity access. The trend line in the figure shows that, on average, higher investment goes to countries with greater access to electricity, although this relationship is not very robust, and at very low levels of access there is some evidence of higher investment for countries with higher needs (i.e., lower access).

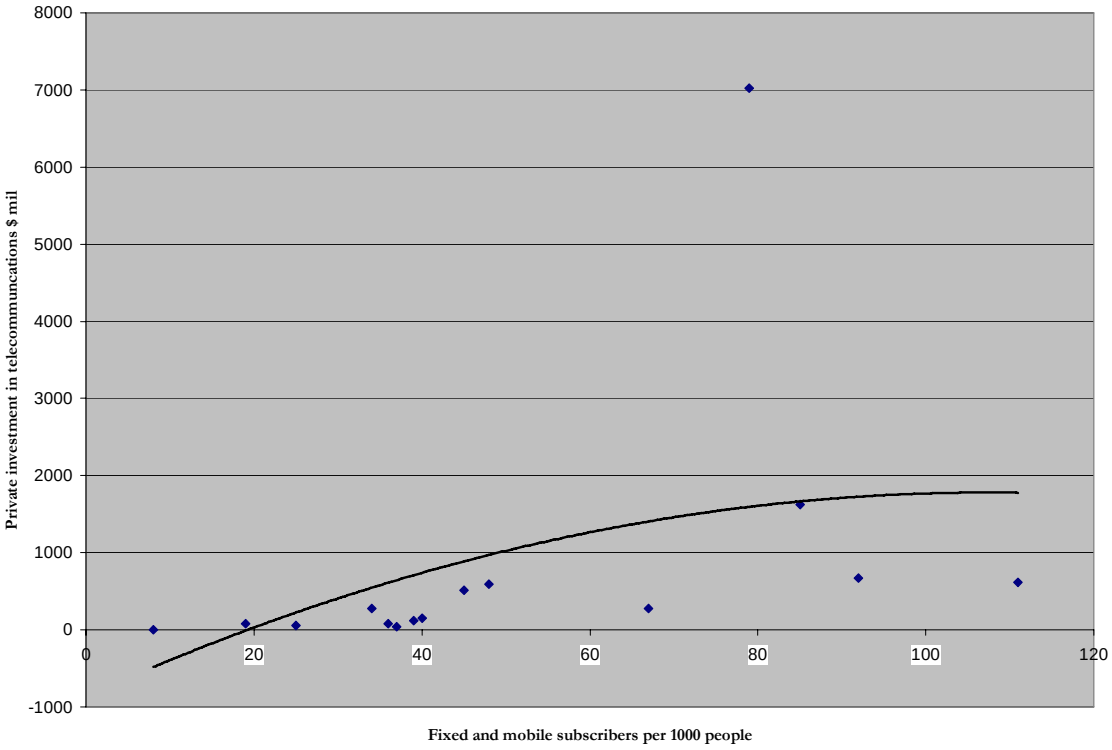
Figure 4.11: Private investment in energy versus electricity access



Source: Author's calculations from World Bank (2007)

Figure 4.12 shows the relationship between investment in telecommunications and total fixed and mobile phone subscribers. Here again we observe that investment does not necessarily follow needs – countries with more phone subscribers receive greater investment in telecommunications.

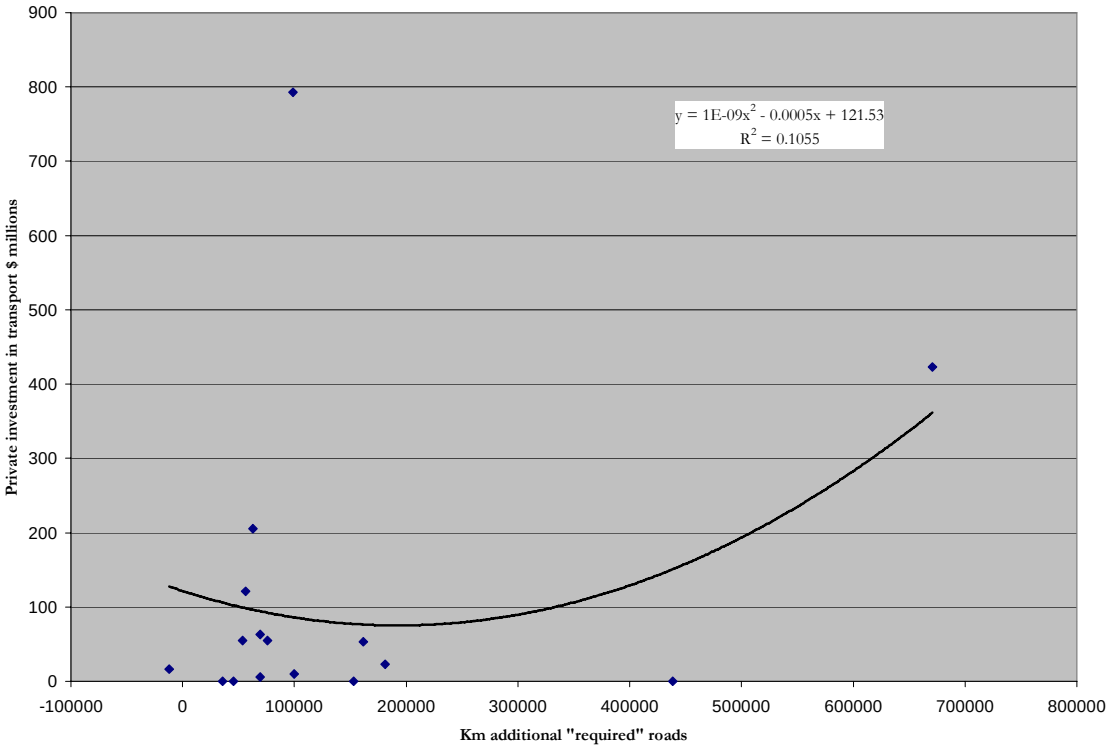
Figure 4.12: Private telecommunications investment versus phone subscribers



Source: Author's calculations from World Bank (2007)

Finally, Figure 4.13 shows the relationship between additional "required" kilometers of road and investment in transportation infrastructure. Here the trendline shows the relationship that one would hope for – higher investment in countries with greater need, although the upward part of the slope seems solely driven by one outlier.

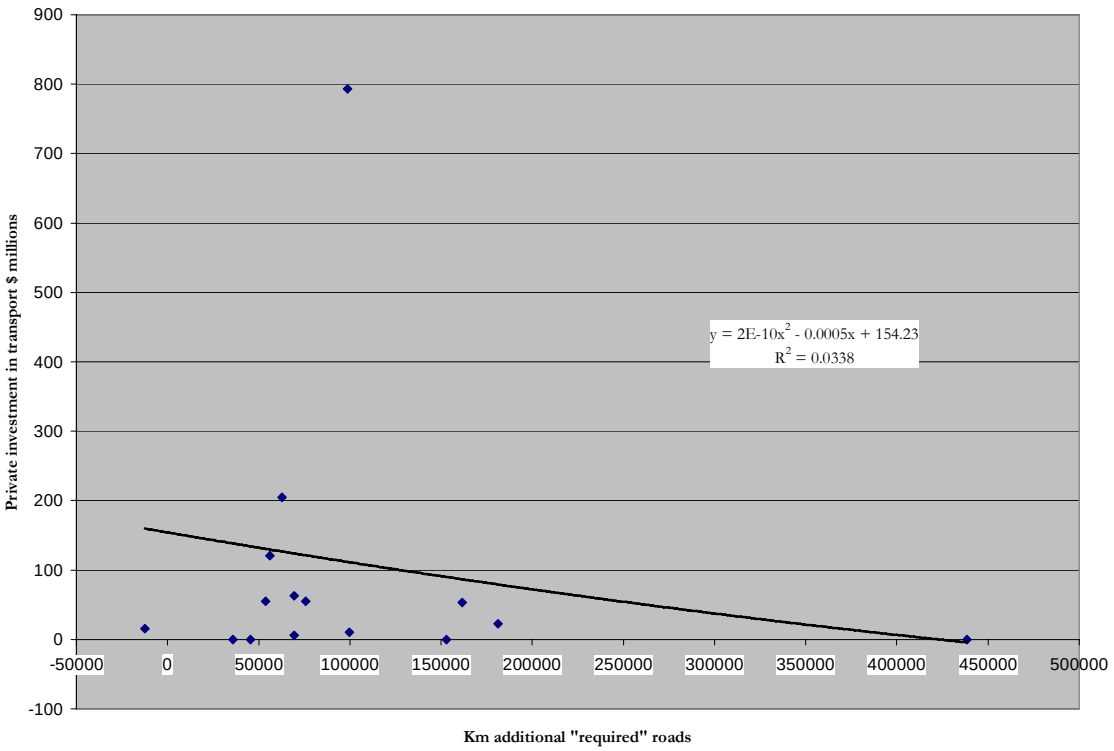
Figure 4.13: Private investment in transportation versus "required" roads



Source: Author's calculations from World Bank (2007)

Figure 4.14 shows the same data as in 4.13 with the far right outlier removed. Here we observe, as before, that private investment does not necessarily follow the needs of the countries – a greater number of additional "required" roads is associated with lower private investment in transportation.

Figure 4.14 Private transport investment versus needs – minus outlier



Source: Author's calculations from World Bank (2007)

It is worth noting there are clear causality problems with these sorts of graphs, since the outcomes are often measured after the investments have been made. Despite these issues, this analysis gives suggestive evidence that public lending, such as that given by the World Bank, is somewhat more likely to follow the needs of the receiving countries than is private lending. That said, these relationships are far from perfect, and the countries in most need are not necessarily receiving the most support.

In a final comment, it is important to note that there has been no information in this section regarding investments in storage infrastructure. This is because, as was true in the previous section, organizations do not separate out agricultural storage investments in a separate category. It may well be the case that substantial investments are being made in this area in projects which fall under the heading of "agricultural and rural development," a category which receives large amounts of funding by various organizations.

4.3 A note on small infrastructure projects

Before closing this section, I would like to note that there are an uncountable number of small scale efforts to help alleviate the infrastructure constraints faced by rural Africans. The e-chaupal example from section 2 of the report is the first of this. In this case, the interests of a private organization aligned perfectly with those of small farmers, the result of which provided internet access to more than 100,000 farmers. This section provides a few further examples of such targeted efforts in AGRA countries.

4.3.1 CLUSA in Mozambique

In 1995, the Cooperative League of the USA (CLUSA) launched a program to help overcome the barriers to marketing (including poor transportation and communications infrastructure) encountered by poor farmers in Mozambique. CLUSA began its efforts by bringing together existing farmer associations to create a network of more than 800 associations in 3 provinces, each association consisting of about 30 smallholders. They provided training to farmers to conduct quality control, collect and weigh harvest, organize temporary storage, coordinate transportation of products, as well as negotiate new contracts. At the same time, CLUSA began to increase access to market price information via newsletters and radio broadcasts. According to CLUSA reports, "After six years of CLUSA support, the associations' cumulative sales exceeded US $3.6 million; more than 21,000 metric tons of agricultural products had been successfully marketed; and average annual sales by farm households participating in an association grew from $40 in 1996 to $70 in 2001 (adjusted for inflation). Farm revenues continued to grow in subsequent years, reaching an average of $74 in 2003." (CGAP 2005)

4.3.2 Inventory credit in Ghana

In 1989 TechnoServe introduced a program of inventory credit in Ghana. Inventory credit allows farmers to use stored grains as collateral for loans, in addition to giving them a place to keep their grains until the "lean season" when prices are at their peak – often from 75 to 250 percent above harvest time prices. Since starting the program, the model has been modified and expanded to other areas of Ghana. In 1997/98, 133 farmers' groups assisted by TechnoServe were extended loans amounting to approximately $170,000 and participating farmers have maintained a 100% on-time loan repayment record, increased

incomes and production, and reduced post-harvest losses. Farmers using this model in Ghana earn profits ranging from 40 to 100 percent higher (Hicks, nd).

4.3.3 Disseminating price information in West Africa

Michigan State University is currently piloting an effort to decrease informational constraints for producers in Mali, Niger, and Guinea. The West Africa Market Information and Agricultural Trade Promotion project, operating out of Mali, is the brainchild of two professors from Michigan State University, John Staatz and Nango Dembele, who have helped set up the system with support from the Hewlett Foundation. The project will coordinate the national Market Information Systems of the three countries, gather information from agricultural markets, analyze the data and diffuse the information through radio broadcasts. The project builds upon the MIS system that already exists in Mali, where around 70 percent of its population of 11 million routinely listen to the market reports (Iyioke, 2007).

5. Next steps

This report has presented an overview of the available information on infrastructure and agricultural development in Sub-Saharan Africa. It has also highlighted deficits in data and research. This section serves to specify more carefully some of those deficits, and to propose potential pieces of information which may help the Foundation more effectively carry out the furthering of this research. These next steps can be classified into three general groups: collection of baseline data, compilation and interpretation of existing data, and more detailed research projects.

5.1 Baseline data

In the area of baseline data, it is clear that information on storage capacity and use, both within and between countries, is entirely absent. Detailed statistics on transportation costs within countries is also missing, including not only payments to drivers, but also loading/unloading costs, bribes, and other contributors to the costs of getting production from farmer to market. There is room for a number of studies to be undertaken in these areas, which will be discussed in section 5.3. More detailed baseline data on private investment in infrastructure is also required. This report has presented information on the magnitude of private investment, but the full identity of these investors remains unexplained, as do the main country and sector beneficiaries of private investment.

5.2 Compilation and interpretation of existing data

There is considerable work to be done in the compilation and interpretation of existing data. Most countries have conducted censuses, and all of the AGRA countries have had nationwide household surveys within the past 10 years. This information needs to be translated into a geographically useful format and inserted into an augmented "Development Domain" analysis. Access to electricity and communications are particularly important for the Foundation's efforts to add value to basic food crops and extend the marketability of dairy and other perishable items. Overlaying new infrastructure projects onto this picture will help give a sense of which regions will be ripe for adoption of new technologies and processes, and understanding how market access, agricultural productivity, and infrastructure mesh together will be integral to assessing the effectiveness of proposed regional

development schemes including those housed under NEPAD. Such a combination of information will be helpful for both planning and advocacy.

Existing data can also be used to calculate rough estimates for the investment required to bring AGRA countries up to some benchmark level of infrastructure development. This report has used a benchmark of pre-Green Revolution India, although one might consider South Africa as a possible comparison country as well, especially for the development and use of cold storage infrastructure.

5.3 Research projects

There are also a variety of important questions whose answers could inform the development of the AGRA program as well as any advocacy that the Foundation might wish to do in the area of infrastructure. Beginning with transportation, there is room for studies which link railway, port, and water transport infrastructure to agricultural productivity, as well of as the contribution of these particular types of transportation to marketing costs. While the rapid spread of communications technology, including cellular phones and the internet, to Sub-Saharan Africa is widely known, there is very little understanding its relationship to agricultural technology adoption, marketing, market participation, and productivity, especially for smallholder farmers. It is also unclear whether such technology exacerbates rural-urban disparities or is serving as an equalizing force. Finally, in the area of storage there are various questions above and beyond the baseline data needs described above. Storage capacity does exist in various countries due to price stabilization boards (many of which no longer operate), and it is an open question how this capacity is being used. Anecdotal reports suggest that much of it lies empty, which begs the question of why. There is room in this literature for a detailed description of a storage system which does work well – such as cold storage for dairy in South Africa. In addition, the basic empirical measurements of the effect of storage on prices, marketing, and market participation, needs to be considered.

5.4 Convening

It is possible that a convening of experts in the field could serve well to shed light on some of the open questions mentioned here and help the Foundation with future planning. In particular, bringing together various individuals working in the area of infrastructure

development could help the Foundation develop a more accurate estimate of the required financing to bring the AGRA countries up to a particular benchmark position. In order to help guide such a meeting towards concrete results, it would be important to invite people who work in the financing of different types infrastructure projects in Sub-Saharan Africa, rather than those who study the impacts of such endeavors. These individuals could be asked to bring to the table costs of recent projects in various countries in order to establish average, minimum, and maximum values for the prices of developing electrical, transport, communications, and storage infrastructure. In addition, their expertise would inform the methodology with which an estimate of the infrastructure financing gap would be constructed.

A second possibility is to hold a convening focused upon regional infrastructure development. A meeting of businesspeople, academics, and individuals with field experience in agricultural development in various regions of Sub-Saharan Africa could be used to create an outline of what types of infrastructure development corridors might be most effective in making markets work to support agricultural development. A convening of this nature will need to be targeted on a regional basis (e.g. limited in scope to regional trade blocks where there is high probability for promotion and advancement of intra-regional trade) and will also need to include planning and strategy input from key stakeholders such as the Infrastructure Consortium for Africa and its funding partners.

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Appendix 1: Main data sources

This appendix contains more detail regarding the data sets mentioned in this report.

1. International Road Federation World Road Statistics (www.irfnet.org)

Included data: road networks (km), production & export of motor vehicles, first registration & import of motor vehicles, vehicles in use, road traffic, multimodal traffic comparisons, motor fuels, road accidents, rates & basis of assessment of road user taxes, examples of taxation for five common categories of motor vehicles, annual receipts from road user taxation, road expenditure. 1999-2004 are available for free, but contain only road density statistics. Other years are available for purchase.

2. World Development Indicators

World Development Indicators are available online through the World Bank website. The print edition allows the consultation of over 900 indicators from 150 economies. The CD-ROM contains time series data from more than 200 countries from 1960-2005. A web subscription can also be purchased. The indicators contain no information disaggregated within-countries.

3. World Resources Institute Earthtrends

Earthtrends is a free online database that compiles information from various sources. Its focus is environmental, but it also contains a substantial amount of economic information.

4. International Energy Agency

As the name would suggest, the IEA houses statistics related to energy. Most of their data is available only for purchase, but they do release aggregated statistics on energy consumption by country for free. Much of the information that they have is usefully summarized within the Earthtrends database.

5. DHS surveys

Demographic and Health Surveys (DHS) are conducted by Macro International and funded by USAID and other donors. The surveys are conducted at the household level and focus on health outcomes and behaviors. They do not contain any income information but do have variables related to assets that they use to construct wealth indicators. For the purposes of this report, the two most useful variables they collect are electricity access and the presence of a telephone/mobile in the house. They interview men and women in the same household separately. Some surveys are conducted at health facilities instead of households. The data is available for free but requires obtaining permission. DHS surveys come in a variety of types, which are described by the following acronyms:

a. AIS – AIDS Indicator Survey (household)
b. SPA – Service Provision Assessments (conducted in health facilities)
c. HIV/AIDS SPA – SPA with more AIDs questions
d. KAP – Knowledge, Attitude and Practices survey
e. MIS – Malaria Indicator Survey

6. LSMS Surveys

The Living Standards Measurement Study, which generates the Living Standards measurement surveys was established by the World Bank in 1980 to explore ways of improving the type and quality of household data collected by government statistical offices in developing countries. LSMS are extensive household level surveys that usually contain very detailed information on household income and expenditures, as well as a variety of other topics. They can always be useful for generating poverty maps, and often contain information related to transportation (distance to towns, road quality), communications (telephone/mobile), and electrical infrastructure (household access). They are available for free, though they have been conducted in relatively few AGRA countries. The DHS and LSMS coverage is listed in Table A1.1.

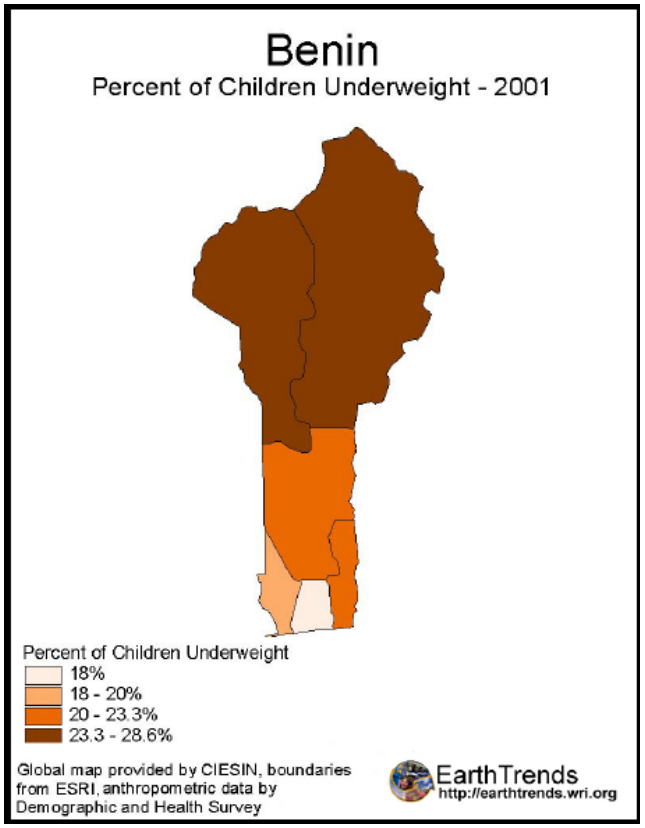
Table A1.1 LSMS and DHS Survey Availability

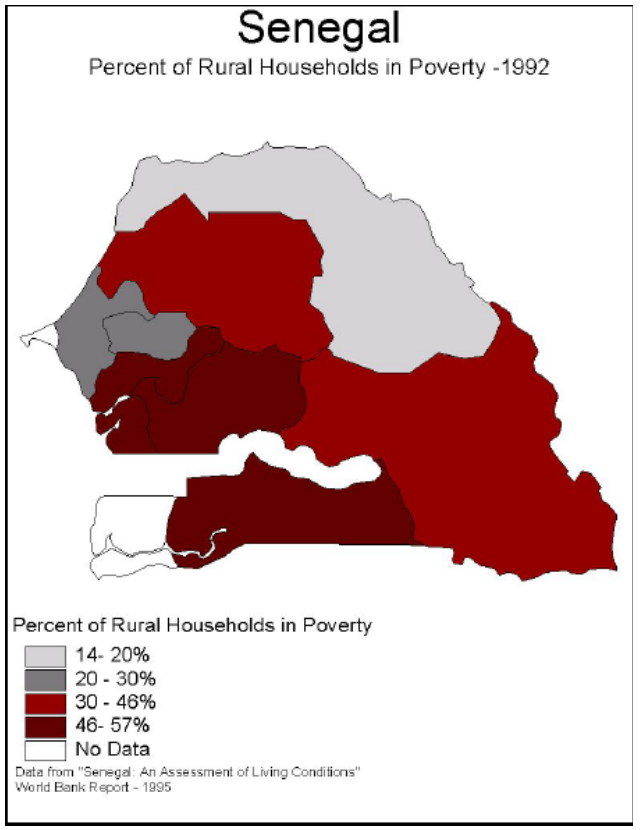
AGRA countries:	LSMS years	DHS type	DHS years
Angola		MIS	2006/2007
Benin		standard	1996, 2001, 2006
Burkina Faso		standard	1992/1993, 1998/1999, 2003
Cameroon		standard	1991, 1998, 2004
Ethiopia		standard	2000, 2005
Ghana	1987/88, 1988/89, 1991/92, 1998/99	standard (SPA 2002)	1988, 1993, 1998, 2002, 2003
Kenya		standard (SPA 1999, HIV SPA 2004)	1989, 1993, 1998, 1999, 2003, 2004
Malawi	2004/2005	standard (KAP 1996)	1992, 1996, 2000, 2004
Mali		standard	1987, 1995, 2001, 2006
Mozambique		standard	1997, 2003
Nigeria		standard	1990, 1999, 2003
Rwanda		standard (SPA 2001)	1992, 2000, 2001, 2005
Senegal		standard (MIS 2006)	1986, 1992, 1997, 1999, 2005, 2006
Tanzania	Kagera 1991/1994, 2004 national 1993	standard (KAP 1994, in depth 1995, interim 1999, AIS 2003, HIV SPA 2006, AIS 2007)	1994, 1995, 1999, 2003, 2006, 2007
Uganda		standard (in depth 1995, AIS 2004, HIV SPA 2006)	1988,1995, 2000, 2004, 2006
Zambia		standard (HIV SPA 2005)	1992, 1996, 2001, 2005, 2006

7. There are also a variety of household surveys, some of which are publicly available, described on the World Bank's website: http://www4.worldbank.org/afr/poverty/databank/survnav/default.cfm. Many of the datasets listed here require contacting the relevant countries' statistical agencies.

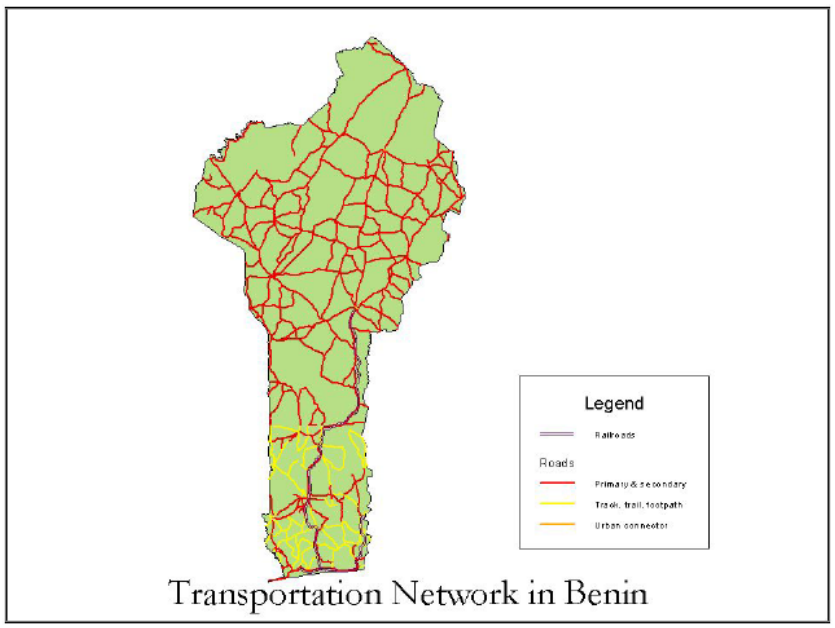
8. Michigan State University also has a variety of data collection efforts underway in Africa: http://africa.msu.edu/projects/directory.php?category=1

Appendix 2: Examples of DHS regional maps

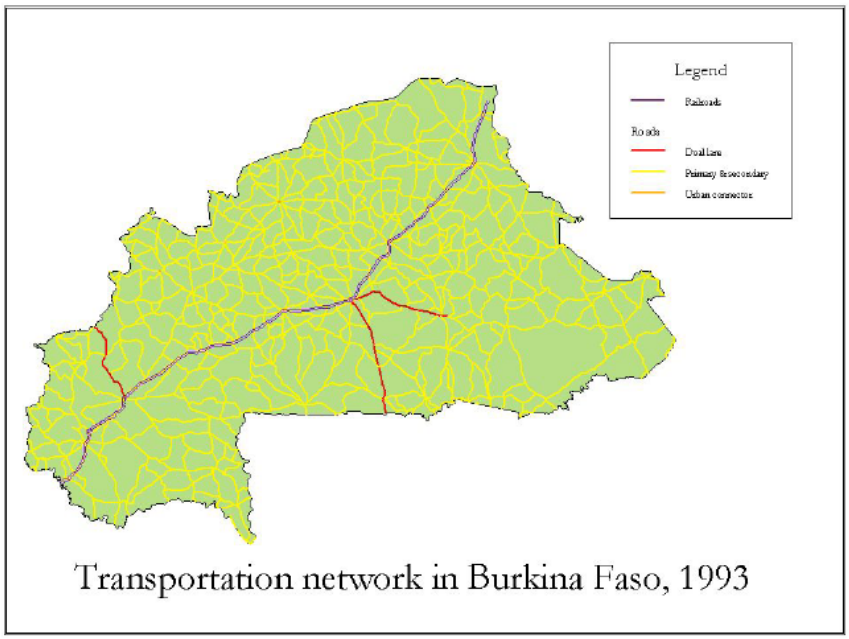




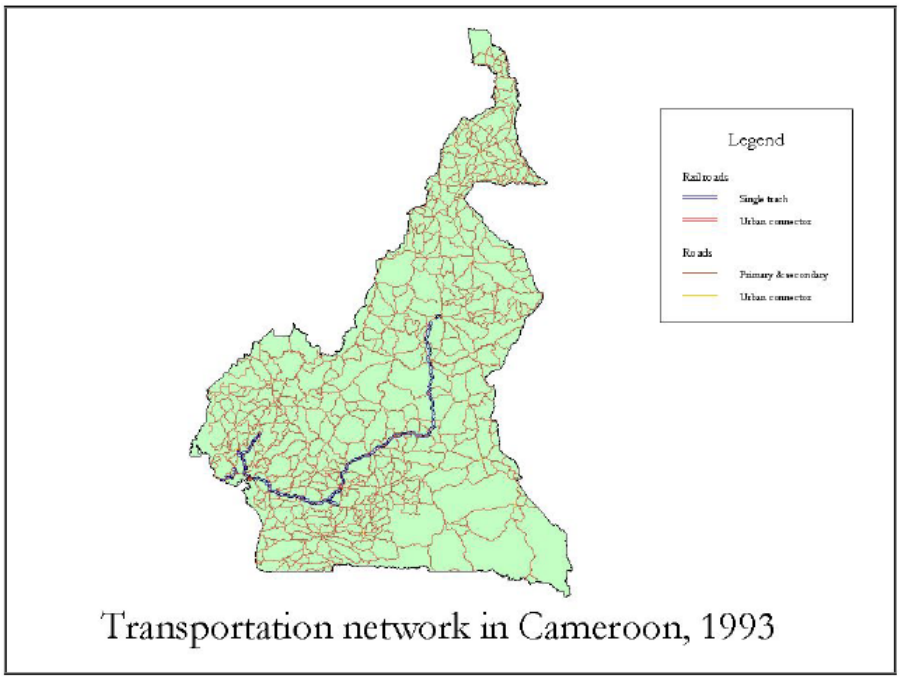
Appendix 3: Examples of transportation maps using data from the Digital Chart of the World



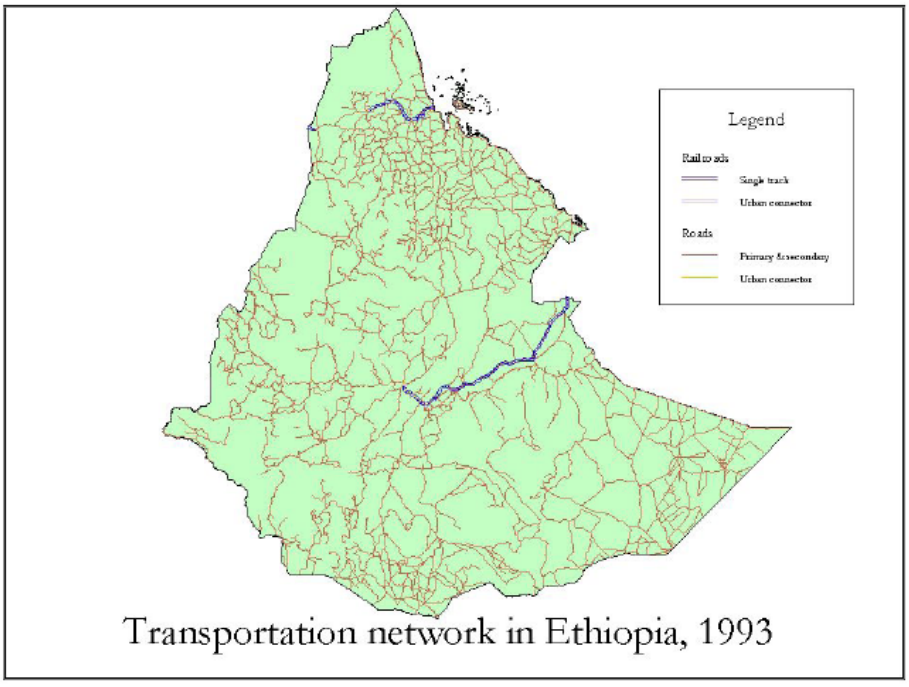
Transportation Network in Benin



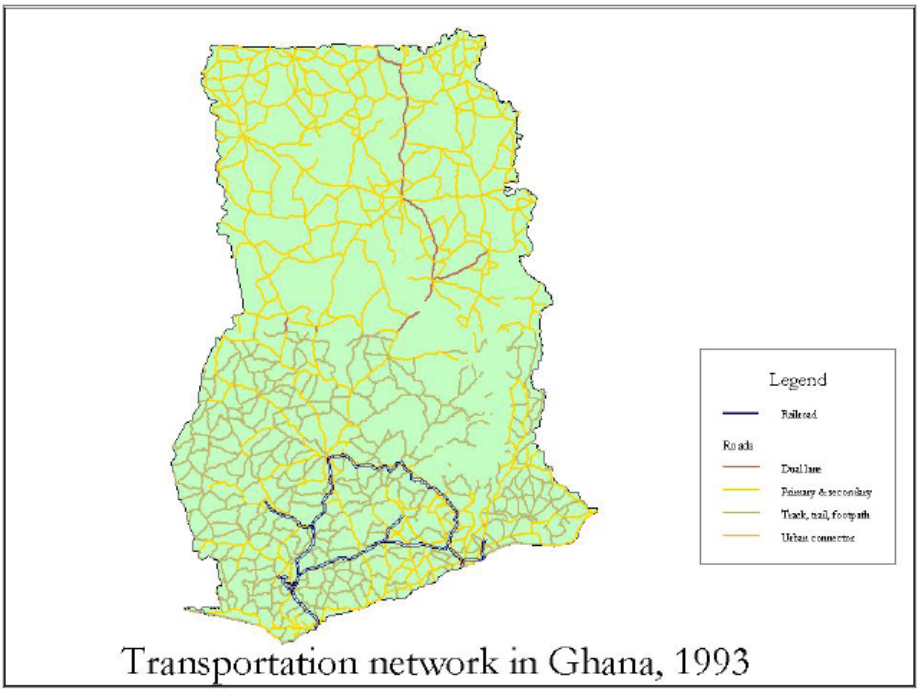
Transportation network in Burkina Faso, 1993



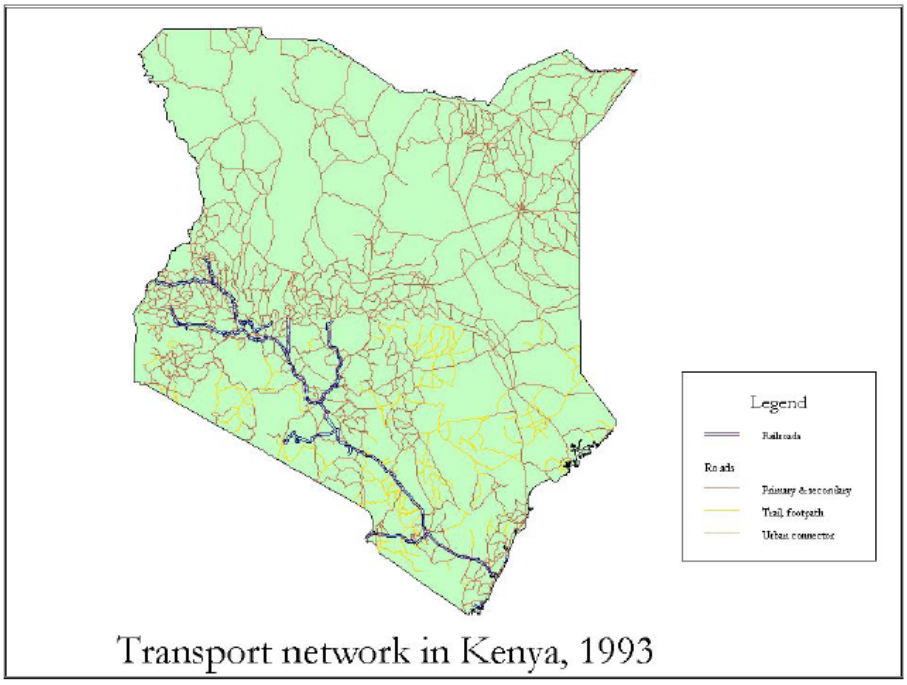
Transportation network in Cameroon, 1993



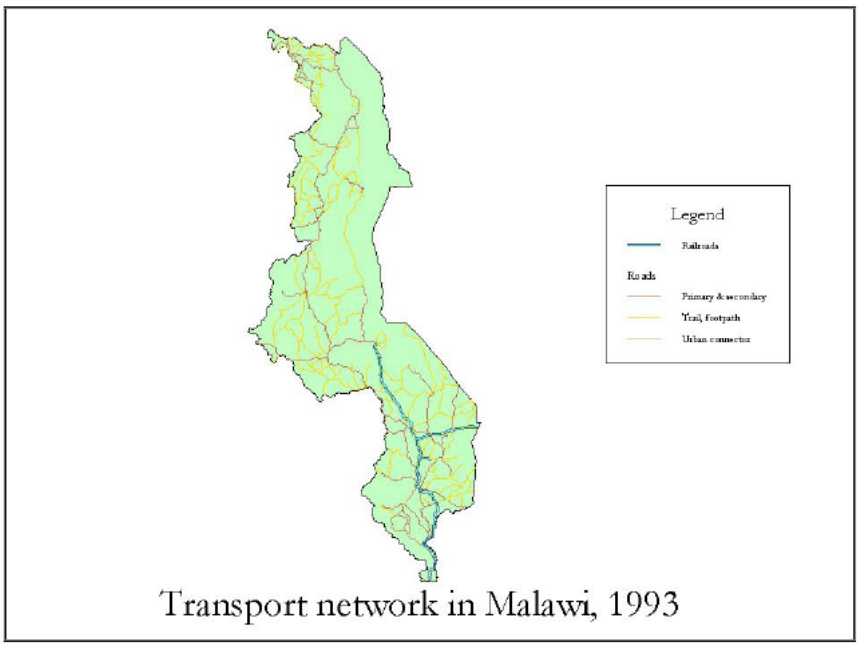
Transportation network in Ethiopia, 1993



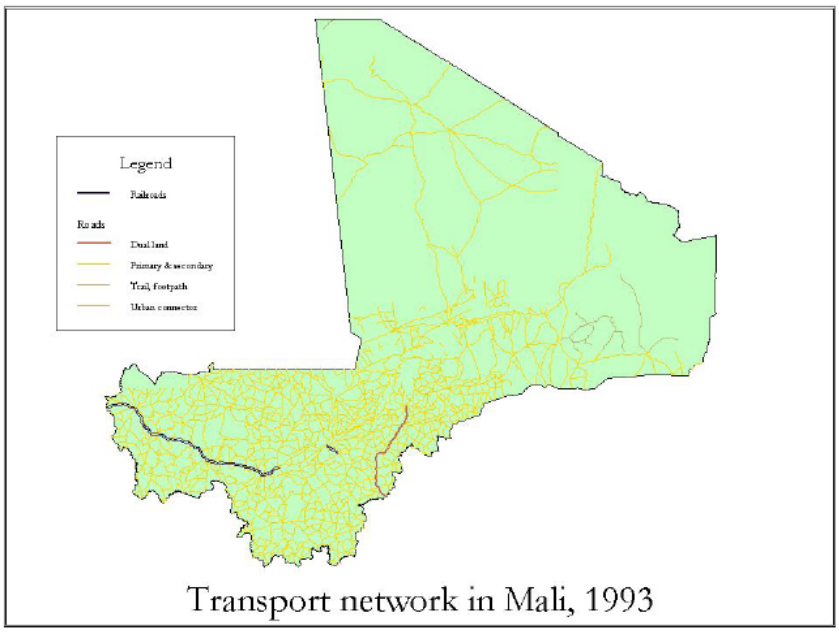
Transportation network in Ghana, 1993



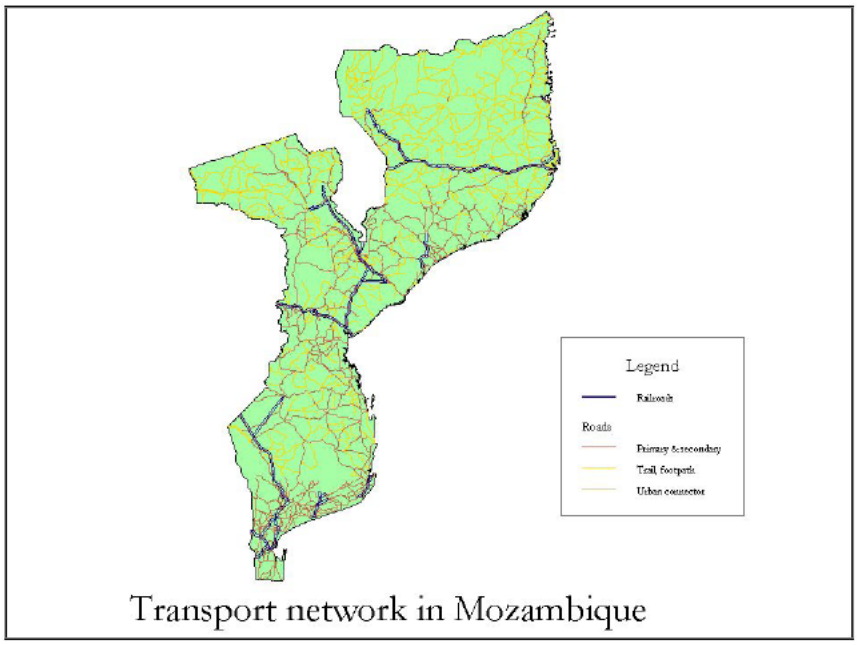
Transport network in Kenya, 1993



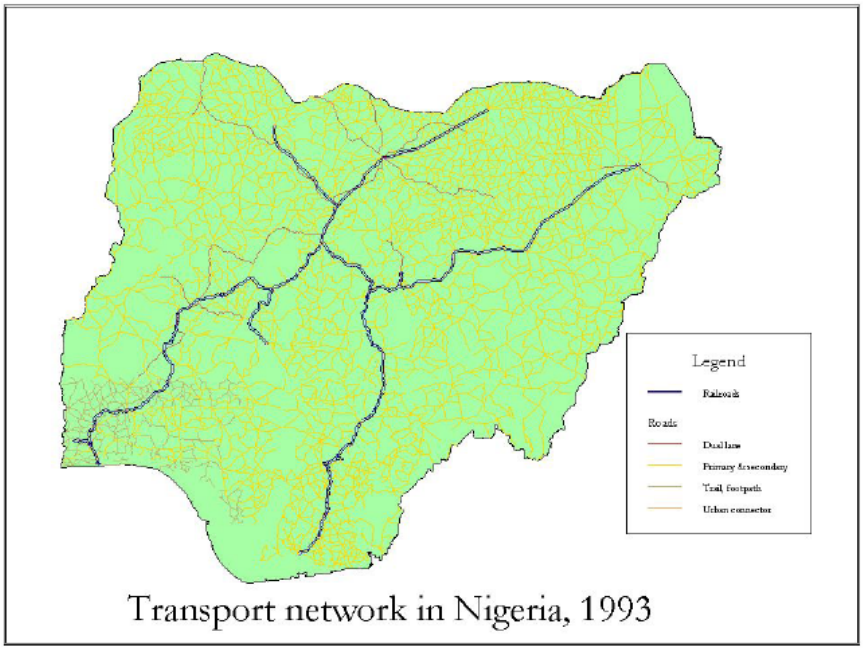
Transport network in Malawi, 1993



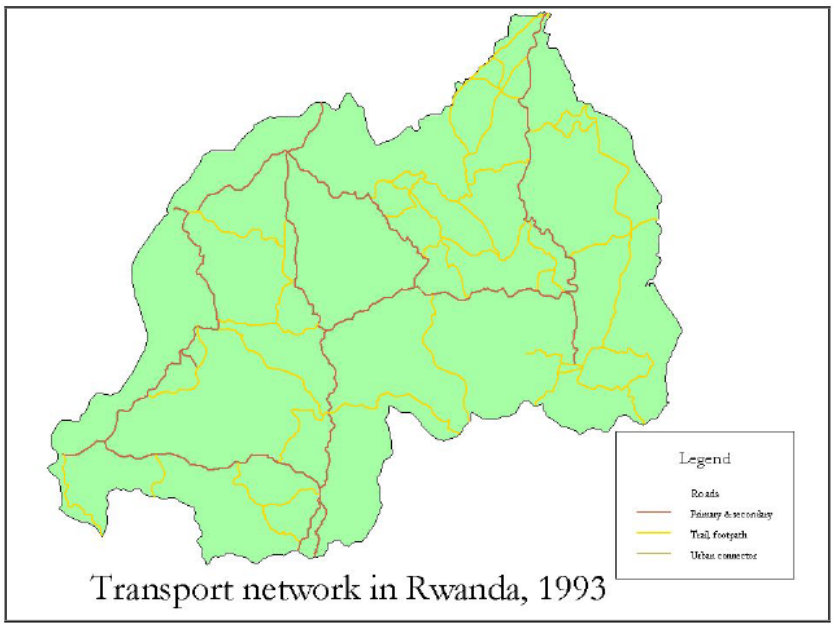
Transport network in Mali, 1993



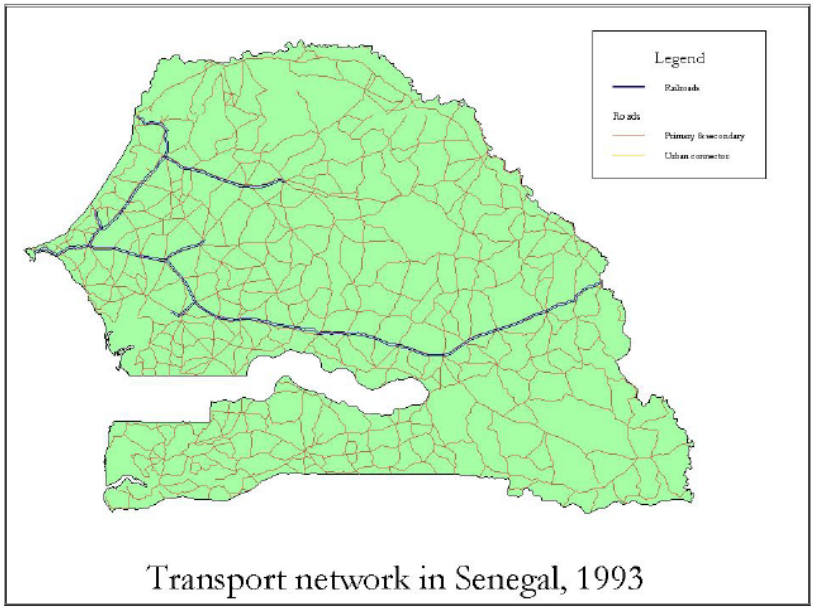
Transport network in Mozambique



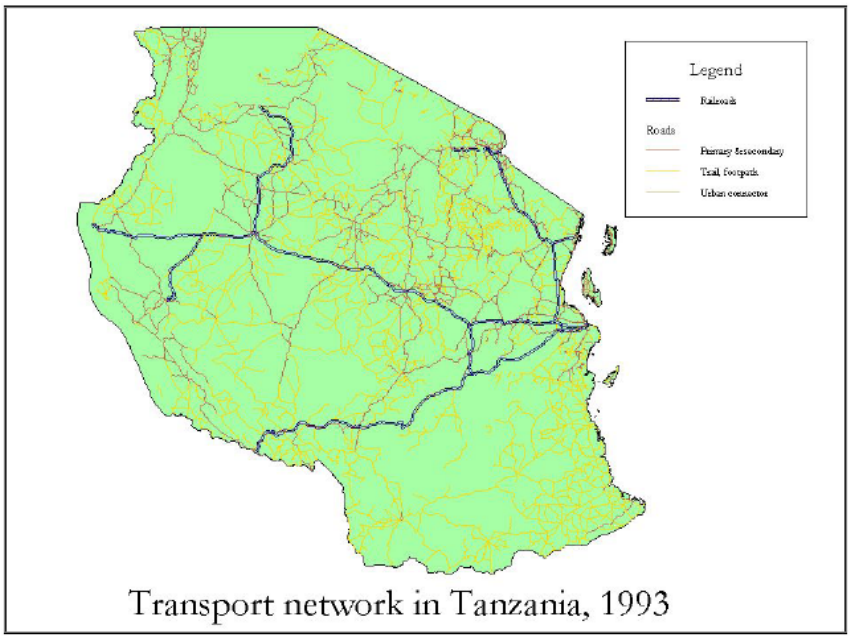
Transport network in Nigeria, 1993



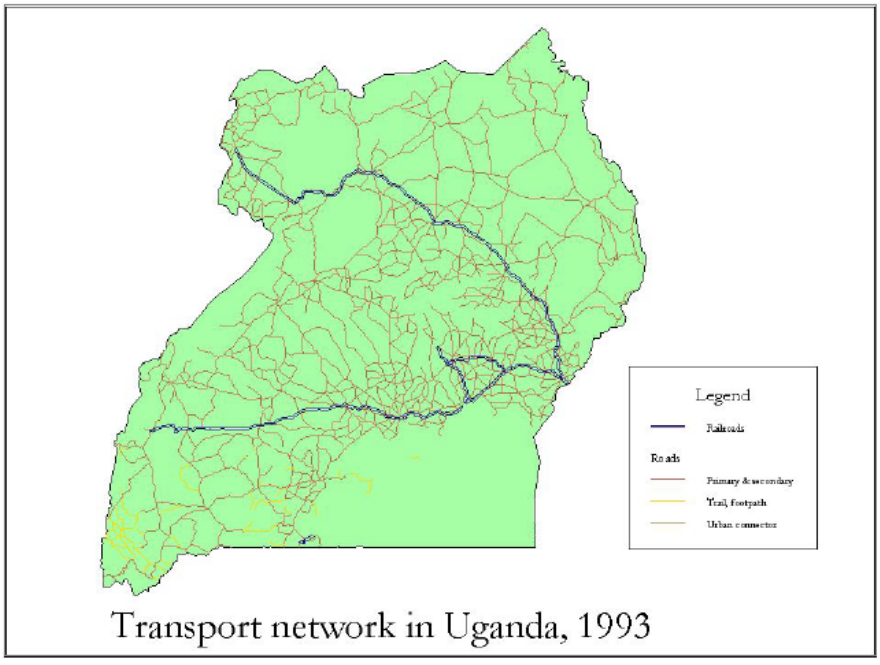
Transport network in Rwanda, 1993



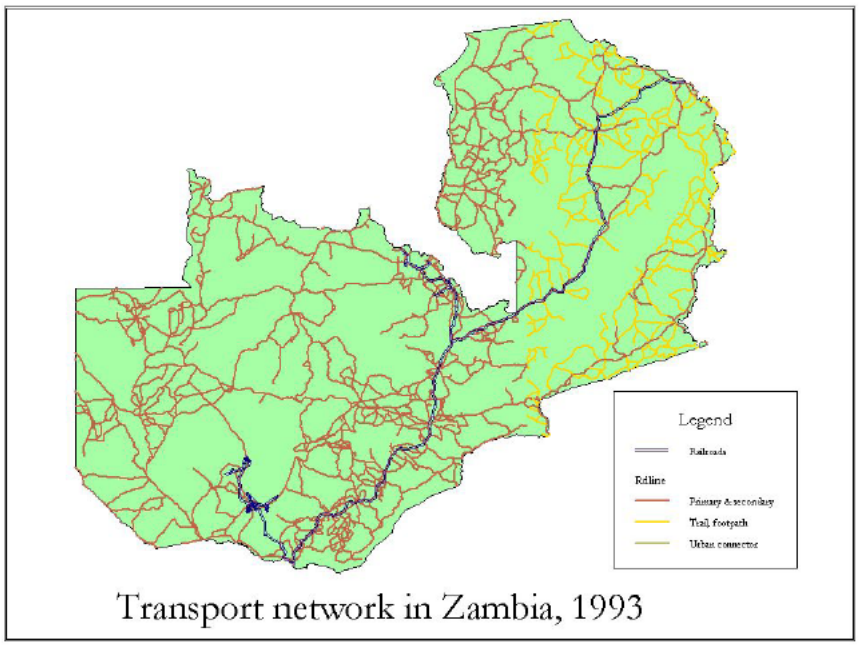
Transport network in Senegal, 1993



Transport network in Tanzania, 1993

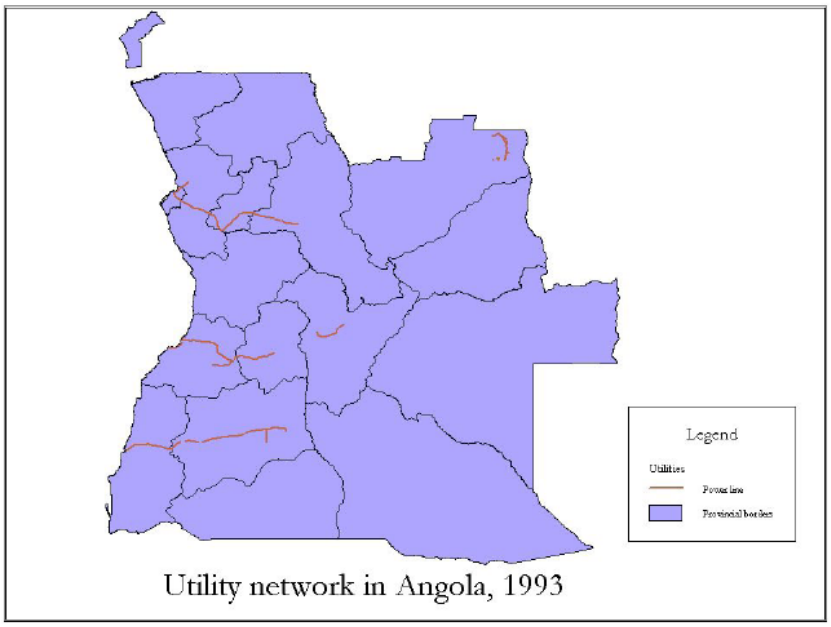


Transport network in Uganda, 1993

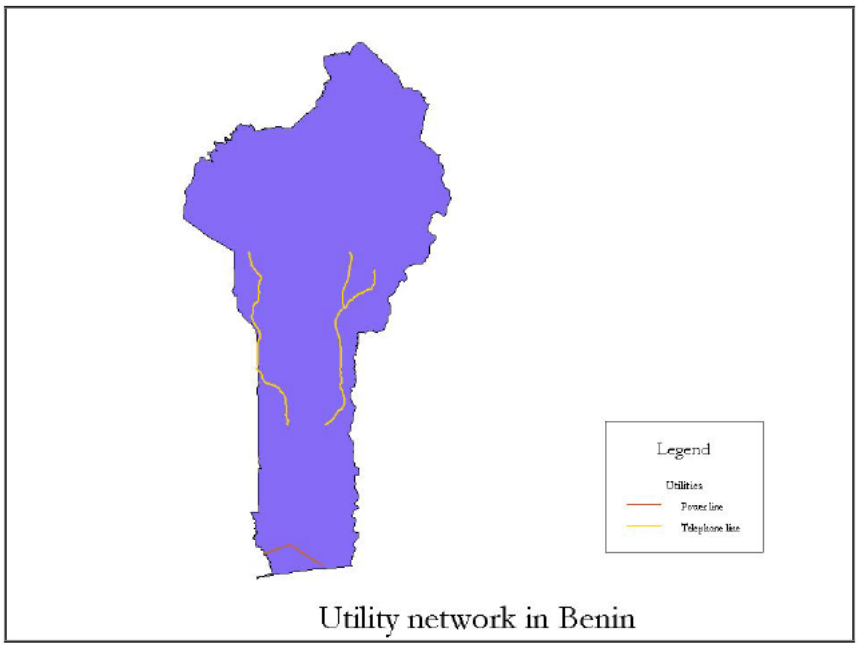


Transport network in Zambia, 1993

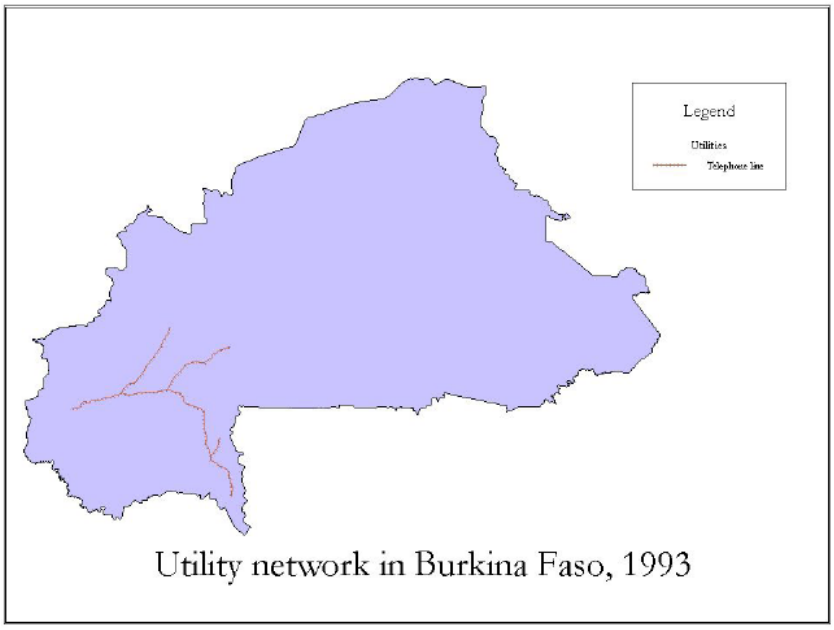
Appendix 4: Examples of infrastructure maps using data from the Digital Chart of the World



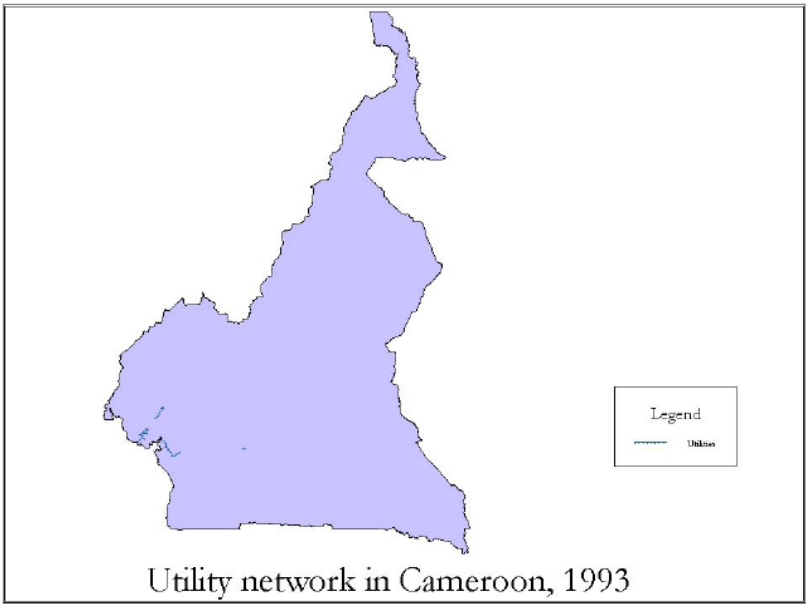
Utility network in Angola, 1993



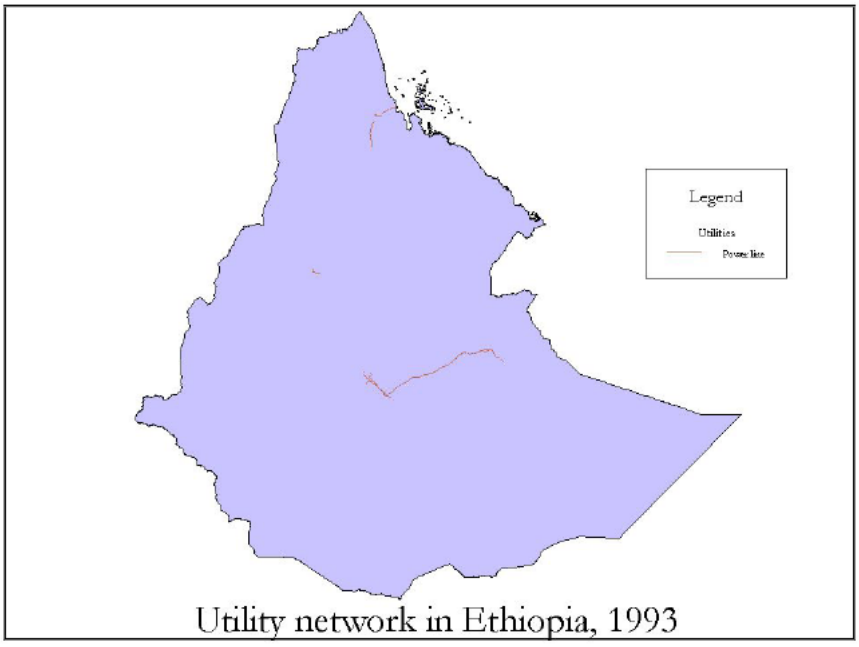
Utility network in Benin



Utility network in Burkina Faso, 1993



Utility network in Cameroon, 1993



Utility network in Ethiopia, 1993

Appendix 5: Infrastructure investment by project and country for 2006

Table A.5.1: ICA member investments in transportation infrastructure, 2006

Country	Project	Total cost	Gov't	Beneficiaries	ADB	EC	EIB	WB	Japan	France	Germany	UK	USA	Italy	Canada
Angola															
	Study Urgent Port Rehab	0.4							0.4						
Benin															
	AkproMisserete-Kpedekpo	31.2													
	Port of Cotonou Upgrade												169.5		
	Bridge Lac Nokoué										8				
Burkina															
Cameroon															
	Batibo-Bachoua-Akagbe Rd	76.5	12.8	0.2	63.5										
	Road programme					105									
	Rehabilitation of Bridges										5				
Ethiopia															
	Road Sector Development	132.3	45					87.3							
	Jimma-Mizan Road	144	52		92										
	Support Road Sector Prog.					198									
	Trunk road improvement	14.1							14.1						

Country	Project	Total cost	Gov't	Beneficiaries	ADB	EC	EIB	WB	Japan	France	Germany	UK	USA	Italy	Canada
	Rehab Addis-Jimma road					77									
Ghana															
	Trunk road improvement	12.7							12.7						
	Transport Infra. Programme					13									
	Transport Infra. Programme					6.5									
	TA Rural br. & rd. network	0.5							0.5						
	Hwy. upgrades & road rehab												195		
	Volta Lake Ferry improve't												5		
Kenya															
	Dundori – Njabini Road	37.8	7.8												
	Rural roads	28	3							25					
	Rural roads, Mt. Kenya area										5				
	TA Road Mtce. Mgt. Unit	0.4							0.4						
Malawi															
	Inst'l support trpt. Bodies	9.4				9.4									
	TA Br. Mtce. Mgt. system	0.4							0.4						

Country	Project	Total cost	Gov't	Beneficiaries	ADB	EC	EIB	WB	Japan	France	Germany	UK	USA	Italy	Canada
Mali															
	Upgrade Kayes Airport	15	2												
	Urban access roads	12.9	2.4												
	Bamako Airport Upgrade												89.6		
	Pave Niono-Goma Coura rd.												35.2		
Mozambique															
	MontePuez-Lichinga Road	102.5	7.5		43				28						
	Gurua – Magige Road	11.8	1.8												
	Study Milange-Mocuba rd.					1.9									
	Beira port dredging capacity	9.2							9.2						
	Caia Br. on R. Zambesi													26.3	
	Improve roads,Inhambane Pr.										13				
	Study Nampula-Cuamba Rd.	3							3						
	TA Capacity-bldg. Dredging	0.1							0.1						
Nigeria															
	TA Port Computerization	0.4											0.4		

Country	Project	Total cost	Gov't	Beneficiaries	ADB	EC	EIB	WB	Japan	France	Germany	UK	USA	Italy	Canada
Rwanda															
	Road infra. support program					45									
	Public transport restoration	2.8						2.8							
	TA Public Trpt. Mgt. System	0.3						0.3							
Senegal															
	Upgrade dual expwy. VDN	37													
	Participatory Local Dev.	159	60					80		19					
	Port for Matam Phosphate	0.3											0.3		
	Study multi-commodity Port	0.3											0.3		
Tanzania															
	Road widening Kiruwa	10						10							
	Rehab Mwanza Border-					38									
	Tinde & Nzega-Isaka roads														
	Capacity-bldg. Rd. proj. mgt.	0.4							0.4						

Country	Project	Total cost	Gov't	Beneficiaries	ADB	EC	EIB	WB	Japan	France	Germany	UK	USA	Italy	Canada
Uganda															
	Kabale-Kisoro-Bunagan Rd				47										
	Kampala traffic improv't	2.7							2.7						
	Upgrade North Corridor rd.					24									
	Study Kampala Rd. Network	0.5							0.5						
	Backlog Road Mtce Prog.					19									
Zambia															
	Periodic Mtce. of roads					26									
	Agric. Dev. Support Prog.							37.2							
	Study Urban Dev. Lusaka	0.3							0.3						
	Rehab Zimba-Livingstone					19									
Regional projects															
Senegal/Mali															
	Road improvement and transport facilitation								8.4						
Burkina Faso and Niger															
	Tera - Dori Road	44	4.5					39.5							
Guinea and Senegal															
	Labe-Seriba-Medina Gounass-Tambacounda Road	210	21.2					80							

Country	Project	Total cost	Gov't	Beneficiaries	ADB	EC	EIB	WB	Japan	France	Germany	UK	USA	Italy	Canada
Burkina Faso, Cameroon, Guinea, Mali															
	W. & Cent. Africa Air Transport Safety & Security Project	33.6						33.6							
Rwanda and Burundi															
	Kikukiro Nemba - Gasenyi Kirundu Road	76	6		43										
Kenya, Tanzania, Uganda, Rwanda															
	E. Africa Trade and Transport Facilitation	280	63.8		13.2			199							
Kenya, Uganda															
	5-yr. Investment Program Joint Rlwy Concessions	111						32			32				
Kenya, Tanzania															
	Arusha – Namanga – Athi River Road	140	8		76				56						
Ethiopia, Djibouti															
	Rehab Djibouti-Ethiopia Railway line					13									
Botswana, Zambia															
	Study of N-S Trpt. Corridor (SADC),incl. Kazungula Br.	4.1	0.2		3.4										

Country	Project	Total cost	Gov't	Beneficiaries	ADB	EC	EIB	WB	Japan	France	Germany	UK	USA	Italy
Lesotho, Mozambique, S. Afr, Swaziland														
	Southern Africa Trade Hub											1.6		
	Project and Customs Reform													

Acronyms: ADB: African Development Bank, EC: European Community, EIB: European Investment Bank, WB: World Bank

Table A.5.2 Private and non-ICA investment in transportation infrastructure, 2006

Country	Project	Private dom	Private for	China	India	Nordics	Islamic db	Kuwait	Saudi Arabia	BA-DEA	AF-ESD	Opec	Reg banks	For'n other
Angola														
Benin														
	AkproMisserete-Kpedekpord						5							
Burkina														
	Study Koungousi-Mali Road									0.3				
Cameroon														
	Batibo-Bachoua-Akagbe Rd.													60
Ethiopia														
Ghana														
	Seven Bridges project									8				

Country	Project	Private dom	Private for	China	India	Nordics	Islamic db	Kuwait	Saudi Arabia	BA-DEA	AF-ESD	Opec	Reg banks	For'n other
Kenya														
	Dundori – Njabini Road								10	10		10		
Malawi														
	Thyolo-Bangula Road											10		
Mali														
	Upgrade Kayes Airport									13				
	Urban access roads						10.5							
Mozambique														
	MontePuez-Lichinga Road													52
	Gurua – Magige Road						10							
Nigeria														
Rwanda														
Senegal														
	Upgrade dual expwy. VDN						32.7							
	Supply of trpt. equip't (India)				17.9									
	Dakar road rehab.							34						
Tanzania														
	Mwanza airport											6		
	Study airportin Msalato proj.									0.4				
Uganda														
Zambia														

Country	Project	Private dom	Private for	China	India	Nordics	Islamic db	Kuwait	Saudi Arabia	BA-DEA	AF-ESD	Opec	Reg banks	For'n other
Regional projects														
Rwanda and Burundi														
	Kikukiro Nemba – Gasenyi – Kirundu Road								-13	-8		-7		81
Kenya, Uganda														
	5-yr. Investment Program		27											
	Joint Railway Concessions													
Botswana, Zambia														
	Study of N-S Trpt. Corridor (SADC),incl. Kazungula Br.												0.5	

Acronyms: Islamic DB: Islamic Development Bank, BA-DEA: , AF-ESD

Table A.5.3 ICA member investments in energy infrastructure, 2006

Country	Project	Total cost	Gov't	Beneficiaries	ADB	EC	EIB	WB	Japan	France	Germany	UK	USA	Italy	Canada
Angola															
Benin															
Burkina Faso															
	Samendeni Dam & powerplant	130													
Cameroon															
	AES Sonel 5-yr. Programme	438			75			89							
Ethiopia															
	Accelerated Electricity Access	184.2	50.8					133.4							
	Universal Electricity Access	162	38		124										
	Afar region transm'n, distrib'n.	57.4													
	Study Tendaho geothermal	0.3											0.3		
Ghana															
	Rural electrification project	5.9							5.9						
	TA: RE by use of solar power	0.1							0.1						
Kenya															
Malawi															
	Infrastructure Services	41.3	1.3					40							
	TA RE Promotion Project	0.5							0.5						
Mali															
	Rural electrification	6.2	0.5												
	Rural electrification										0.3				

Country	Project	Total cost	Gov't	Beneficiaries	ADB	EC	EIB	WB	Japan	France	Germany	UK	USA	Italy	Canada
Mozambique															
	Electricity IV	55	8		37										
	N. Cabo Delgado rural electr'n.	26.2	2.7												
Nigeria															
	RE Cross River & Akwa Ibom	8.1							8.1						
	TA Shiroro, Egbin powerplants	0.5											0.5		
	Health/Safety Regulatory Stds	0.5											0.5		
Rwanda															
	Transaction Adv'r Hydro proj.	0.4											0.4		
	Poverty Redn. Support III							50							
Senegal															
	Rural electrification										8.5				
Tanzania															
Uganda															
Zambia															
	Study RE Development Prog.	1.8							1.8						

Country	Project	Total cost	Gov't	Beneficiaries	ADB	EC	EIB	WB	Japan	France	Germany	UK	USA	Italy	Canada
Regional projects															
SSA															
	Dev. of African Securities Markets for Financing of Infra.	7													
Benin, Ghana															
	Strengthen WAPP's Coastal Transm'n Backbone (APL 1)	75	15					60							
Mali, Mauritania, Senegal															
	OMVS Felou Hydro Project (WAPP APL 2)	125	10				40	75							
Rwanda, Burundi, Tanzania															
	Studies Rusumo Falls Hydroelectric potential		0.4		3.7										

Table A.5.4 Private and non-ICA public investment in energy infrastructure, 2006

Country	Project	Pri dom	Pri for	China	India	Nordics	Islamic db	Kuwait	Saudi Arabia	BA-DEA	AF-ESD	Opec	Reg banks	For'n other
Angola														
	Ministry of Energy, ph. 2					1.7								
Benin														
Burkina Faso														
	Samendeni Dam, powerplant						13.8		12					
Cameroon														
	AES Sonel 5-yr Programme		60											
Ethiopia														
	Afar region transm'n, dist'n.							37.6						
	Transmission/distrib'n. proj.				65									
Ghana														
	Rural electrification project				60									
Kenya														
Malawi														
Mali														
	Rural electrification						5.7							
Mozambique														
	Electricity IV											10		
	N. Cabo Delgado rur. electr'n						9.7							
	Gaza electrification project				20									
	Research, U. of E. Mondlane					2.2								

Country	Project	Pri dom	Pri for	China	India	Nordics	Islamic db	Kuwait	Saudi Arabia	BA-DEA	AF-ESD	Opec	Reg banks	For'n other
Nigeria														
Rwanda														
Senegal														
	Bel Air power plant							8.7						
Tanzania														
	Simanjiro Rural Electrific'n.					3.9								
Uganda														
	Power crisis support					6.4								
Zambia														
Regional projects														
	Dev. of Afr. Securities Markets for Financing of Infra.					5.5								
SSA	Support for BioEARN & Glob. Vill. Egy.Partnership					11.2								
Rwanda, Burundi, Tanzania														
	Studies Rusumo Falls Hydroelectric potential					2.5								

Table A.5.5 ICA member investments in ICT infrastructure, 2006

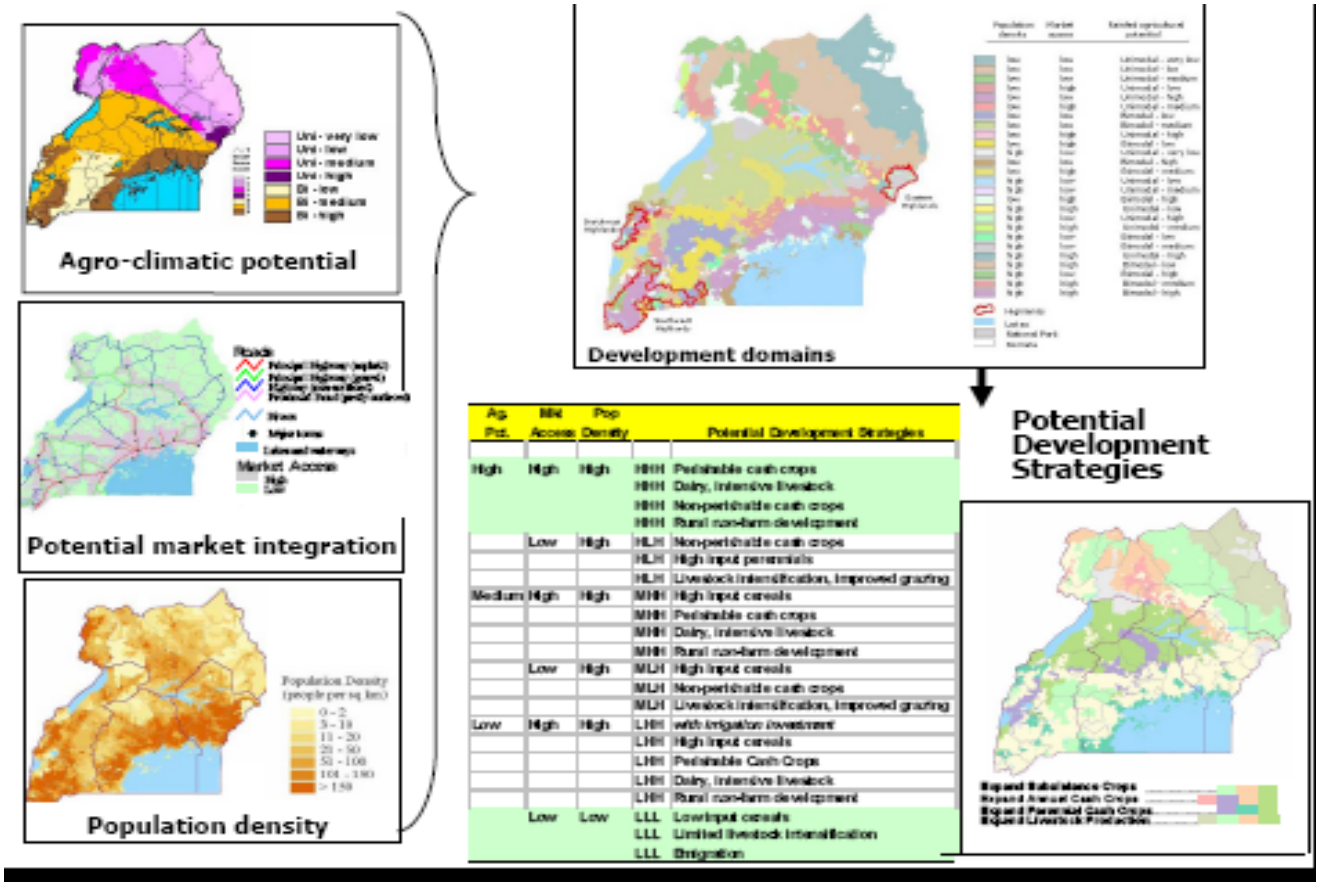
Country	Project	Total cost	Gov't	Beneficiaries	ADB	EC	EIB	WB	Japan	France	Germany	UK	USA	Italy	Canada
Angola															
Benin															
	Poverty Reduction Support							30							
Burkina															
Cameroon															
Ethiopia															
	TA Trg of ETA&ETC staff	0.2											0.2		
Ghana															
	Eghana	42	2					40							
Kenya															
	TA KBC's ITC business plg	0.2											0.2		
	TA Wananchi business eng'g	0.2											0.2		
Malawi															
Mali															
Mozambique															
Nigeria															
	Support local supplier IC Internet Protocol Backbone	0.2						2.5					0.2		

Country	Project	Total cost	Gov't	Beneficiaries	ADB	EC	EIB	WB	Japan	France	Germany	UK	USA	Italy	Canada
Rwanda															
	Erwanda							10							
Senegal															
Tanzania															
Uganda															
Zambia															

Table A.5.6: Private and non-ICA public investment in ICT infrastructure, 2006

Country	Project	Pri dom	Pri for	China	India	Nordics	Islamic db	Kuwait	Saudi Arabia	BA-DEA	AF-ESD	Opec	Reg banks	For'n other
Angola														
	Ang. Telecommunications					1.4								
Mozambique														
	Media support 2006-08					2.1								
Tanzania														
	ICT in rural dev, ph. 2					0.9								
Regional projects East Africa														
	NetTel@Africa 2006-07					0.4								

Appendix 6: Development Domain Mapping



Source: Wood, Chamberlain, and Pender (2005)

Appendix 8: Description of main investors in infrastructure

The Infrastructure Consortium for Africa (ICA) is an umbrella organization to help organize investments in infrastructure by a variety of public institutions. The member organizations represent about half the infrastructure funding in Sub-Saharan Africa and are as follows:

1. African:
    a. African Development Bank Group (Also the ICA Secretariat)
    b. Development Bank of Southern Africa
2. G8 bilateral agencies:
    a. Canada
    b. France
    c. Germany
    d. Italy
    e. Japan
    f. Russia
    g. US (Most notably the Millennium Challenge Corporation)
    h. UK
3. Multilateral agencies
    a. World Bank Group
        i. International Finance Corporation
        ii. Multilateral Investment Guarantee Agency
        iii. Public-Private Infrastructure Advisory Facility (PPAIF)
    b. European Commission
    c. European Investment Bank
    d. Private Infrastructure Development Group

The other large public investors in infrastructure are:

1. China (Primarily driven by China ExIm Bank)
2. India
3. Arab Funds: It is not clear which groups ICA refers to with this statistic. The aid organizations listed under "Arab Aid" are:
    a. Islamic Development Bank Group
    b. Abu Dhabi Fund
    c. OPEC Fund for International Development
    d. Saudi Fund for Development
    e. Arab Fund for Economic and Social Development
    f. Kuwait Fund for Arab Economic Development
    g. Arab Fund for Economic Development in Africa
    h. Arab Gulf Program for United Nations Development Organizations

In addition, private financing is extremely high in the area of communications. It is difficult to figure out who the players are in each sub-sector of the field, however, one report shows the top six investors in cellular technology are:

1. Vodacom: Based in South Africa, provides service for South Africa, Lesotho, Tanzania, Mozambique, and the Democratic Republic of Congo
2. MTN: Telecommunications company based in Africa, with different groups servicing Nigeria, Rwanda, Uganda, Swaziland, and Cameroon
3. Orange: European telecommunications company (started in UK) operating in Botswana, Cameroon, Ivory Coast, Madagascar, and Mali
4. Orascom: Started in Egypt, now serving Zimbabwe, as well as other non-SSA countries
5. Celtel: Founder from Sudan, company serves Burkina Faso, Chad, Republic of Congo, DRC Gabon, Kenya, Madagascar, Malawi, Niger, Nigeria, Sierra Leone, Tanzania, Uganda, Zambia
6. Millicom: Originally from Sweden, serves Chad, DRC, Ghana, Mauritius, Senegal, Sierra Leone, Tanzania
7. Alcatel Lucent: An emerging player, who was recently awarded the contract to develop the base infrastructure for the East Africa Submarine Cable System (EASSY), which is a NEPAD-driven project to bring broadband connectivity to East Africa

A number of private equity funds, engaged in infrastructure development in Africa are also growing in influence. These include:

1. Emerging Markets Partnership, AIG Infrastructure Funds (United States)
2. Pan African Infrastructure Development Fund (South Africa)

One also cannot overlook emerging private bank actors who are increasing risk exposure and investment in large-scale infrastructure development. These actors are emerging as co-financiers of Public-Private Partnership infrastructure projects. They are also key agents in providing private lines of credit for infrastructure development to African multinational companies. The more prominent actors include:

1. ABSA Barclays (South Africa, #1 bank in Africa)
2. Standard Bank (South Africa, #2 bank in Africa)
3. Standard Charted Bank (United Kingdom)
4. Rand Merchant Bank (South Africa)
5. INVESTEC (South Africa)