COUNTRY WATER RESOURCES ASSISTANCE STRATEGY

Ethiopia

Managing Water Resources to Maximize Sustainable Growth

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Ethiopia: Managing Water Resources to Maximize Sustainable Growth

A World Bank Water Resources Assistance Strategy for Ethiopia

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Acronyms and Abbreviations

CAS	Country Assistance Strategy
CEM	Country Economic Memorandum
CWRAS	Country Water Resources Assistance Strategy
ERA	Ethiopian Road Authority
GDP	gross domestic product
GoE	Government of Ethiopia
ha	hectares
IDP	Irrigation Development Program
MoWR	Ministry of Water Resources
NBI	Nile Basin Initiative
SDPRP	Sustainable Development and Poverty Reduction Program
SNNP	Southern Nations, Nationalities, and Peoples' regional states

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Executive Summary

Ethiopia's primary water resource management challenges are its extreme hydrological variability and seasonality and the international nature of its most significant surface water resources. Variability is most obviously manifest in endemic, devastating droughts and floods. Less apparent is the broad range of impacts variability and seasonality have on the Ethiopian economy, even in good rainfall years.

This report looks at, and beyond, the management hydrological variability to interventions aimed at decreasing the vulnerability of the economy to these shocks. It helps clarify linkages between the country's economic performance and its water resources endowment and management. It then uses this analysis to recommend both water resource strategies and economic and sectoral policies that will enhance growth and insulate the Ethiopian people and economy from the often devastating, economy-wide effects of water shocks. The objectives of this report are to:

- Investigate and describe the role of water in the economic performance of Ethiopia from a cross-sectoral, economy-wide perspective.
- Identify broad strategies for mitigating negative and enhancing positive impacts of water on the economic performance of Ethiopia.
- Define an overarching Country Water Resources Assistance Strategy for World Bank support to water management in Ethiopia, which will provide an integrated framework for developing and harmonizing strategies in water-related sectors.

This report finds that unmitigated hydrological variability currently costs the economy more than one-third of its growth potential. The very structure of the Ethiopian economy with its heavy reliance on rainfed subsistence agriculture makes it particularly vulnerable to hydrological variability. Its current extremely low levels of hydraulic infrastructure and limited water resources management capacity undermine attempts to manage variability. These circumstances leave Ethiopia's economic performance virtually hostage to its hydrology.

To de-link economic performance from rainfall and enable sustained growth and development, three strategic shifts appear necessary. First, major investments in water resources infrastructure, institutions, and capacity to manage flows and develop storage at all scales must be seen as an economy-wide development priority. Ethiopia's growth will continue to be undermined until the country achieves water security by acquiring a minimum platform of infrastructure, institutions, and capacity to manage its water resources. Investment on this scale may initially show low returns—much like a road investment, which shows little return until it joins two cities—but growth will continue to be hindered until water security is achieved. Particularly in the Nile River Basin, international cooperation on shared waters will be crucial to achieving sustainable water security without international tensions.

Second, investments in water infrastructure should be multipurpose in nature and should be made in combination with the market infrastructure investments and related reforms needed to fully leverage their growth potential. Particularly given the vast scale of investments needed in water and transport infrastructure, it may be necessary to adopt a "growth pole" strategy (World Bank 2005a) ensuring the resilience of the primary engines of economic growth. The combination of water, irrigation, hydropower, roads and other market infrastructure investments should produce dramatic synergies, and provide the incentives and opportunity for farmers to shift out of subsistence agriculture into surplus/commercial agriculture and nonagricultural activities. While it is common practice to spread different types of investment across regions, such isolated investments will not have the same growth impact as coordinated, co-located investments.

Finally, in addition to managing the variability of water resources, the vulnerability of the Ethiopian economy to hydrology must also be managed. Economy-wide, policies and investment decisions need to shift the pattern of development and the structure of the economy away from the country's heavy reliance on rainfed agriculture to make it less vulnerable to its hydrologic legacy.

THE CHALLENGE OF ETHIOPIA'S HYDRO-ECONOMY

Ethiopia's water resources

Water has always played a central role in Ethiopian society. It is an input, to a greater or lesser extent, to almost all production. It is also a force for destruction. In Ethiopia, as in all societies, there has always been a struggle to reduce the destructive impacts of water and increase its productive impacts. This struggle has intensified over the past century or so as the population has grown dramatically. Today, Ethiopia's development is seriously constrained by a complex water resources legacy and a lack of access to, and management of, these water resources.

Water legacies: Natural and historical

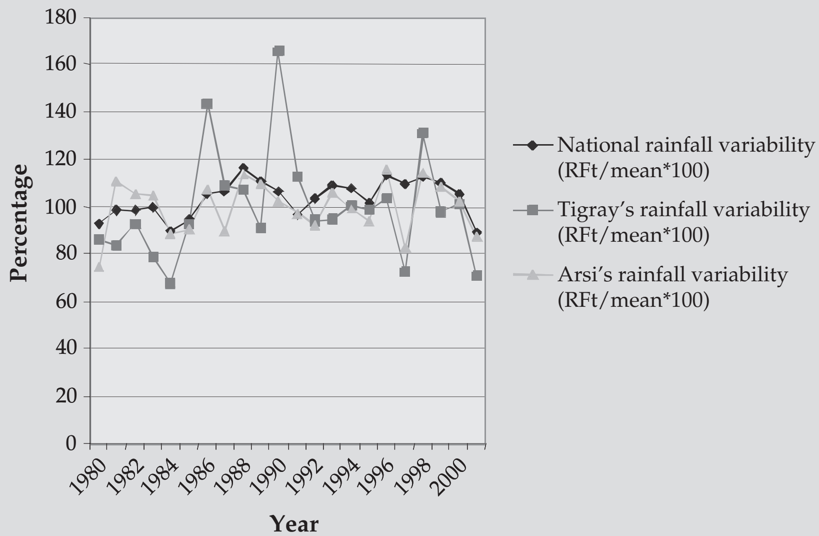
Ethiopia's water resources can be characterized by two principal features, a natural legacy and an historical legacy. The natural legacy is one of very high, and apparently intensifying, hydrological variability, coupled with marked rainfall seasonality (see Figure ES.1). At first sight, Ethiopia's water resources endowment appears generous, with a mean total surface water flow of about 122 billion cubic meters per year. The country has several major rivers and lakes, and significant groundwater resources and annual rainfall. However, rainfall across much of the country is both highly seasonal—with most of the rain falling in a single, short season—and exceptionally variable and unpredictable, both in time and space.

With poorly protected watersheds and almost no investment in water storage, a consequence of this hydrological variability is endemic and unpredictable drought and flood. The historical legacy is one of several international rivers, of which the Nile is the most important. Ethiopia provides 85 percent of the natural Nile River flow into Egypt. In the Nile River Basin, tensions have long been high, and without the bold affirmative action for cooperation that Ethiopia is currently adopting, these tensions would likely grow as demand for water grows with populations and economies in the basin.

Water resources challenges: Land degradation and sedimentation

Hydrology plays a pivotal role in erosion, land degradation, reduced soil fertility and productivity, and siltation. Ethiopia's high intensity storms cause significant erosion. The erosive effects of rainfall are significantly augmented by Ethiopia's mountainous terrain, severe deforestation, and traditional agricultural practices of cultivating steep slopes without protective measures. The loss of forest cover, in turn, is generally associated with greater hydrological variability. Associated sedi-

Figure ES.1. Rainfall Variability: National, Tigray, and Arsi



Source: Demeke (2004).

mentation compromises productivity and shortens the lifespan of water infrastructure for river regulation, municipal water supplies, agriculture, and hydropower generation. The reduced regulation capacity also increases flood risks for downstream communities, which poses a particular risk to the poor, who tend to live in the most vulnerable locations.

Water resources challenges: Droughts and floods

Droughts and floods are endemic, with significant events every 3–5 years. Droughts destroy watersheds, farmlands, and pastures, contributing to land degradation and causing crops to fail and livestock to perish. During the 1984–5 drought, for example, GDP declined by 9.7 percent, agriculture output declined 21 percent, and gross domestic savings declined 58.6 percent. Drought can also severely undermine hydropower generation, Ethiopia's main source of electricity.

If rains fail, or simply come too early or too late, the entire agricultural cycle can be disrupted, because there is inadequate water storage capacity to smooth and schedule water delivery. This sensitivity of production to seasonal timing and the spatial distribution of rainfall means that hydrology can constrain growth in years that appear "good" or "bad" according to average national data. Flooding meanwhile causes significant damage to settlements and infrastructure, and the inundation and water-logging of productive land undermines agriculture by delaying planting, reducing yields, and compromising the quality of crops, especially if the rains occur around harvest time.

Water resources, water supply, and sanitation

The Government of Ethiopia's (GoE) Comprehensive and Integrated Water Resources Management Policy (endorsed in 1999) states that the highest priority use of water is human and livestock consumption, which amounts to less than 1 percent of total water usage. Major efforts are being made to meet the Millennium Development Goals (MDGs). Nevertheless, only a minority of Ethiopians, some 25 percent, have access to potable water services and 15 percent to improved sanitation. These circumstances are particularly onerous for women and girls who must fetch water and then care for those who become ill from waterborne diseases. In addition to low coverage ratios, water supply and sanitation in both urban and rural communities is characterized by low service levels and lack of sustainability. The primary source of raw water for urban and rural water supply is groundwater. Where surface water is used, siltation in rivers and reservoirs has substantially increased treatment and maintenance costs. The extension and improvement of water supply and sanitation services is a necessary precondition for growth.

Water resources and the environment

The World Bank's Country Environmental Analysis for Ethiopia concludes that the country's principal environmental challenges involve complex cross-sectoral linkages. Two of the key environment-development linkages identified by that study relate directly to the challenges posed by Ethiopia's hydrology. They are the lack of integrated water resources management and the land degradation–food insecurity–energy access–livelihood nexus. The latter includes unsustainable agricultural land management practices and heavy reliance on biomass energy. The use of biomass spurs deforestation and erosion and contributes to a significant environmental health problem: exposure to smoke and indoor air pollution, which causes elevated under age five mortality and a high incidence of respiratory diseases, mainly in women and children. Using crop residues and dung as fuel, rather than returning this organic matter to the soil, causes a decline in soil fertility and deterioration in soil structure.

The degraded land is also more prone to erosion, leading to loss of fertility in the topsoil and to a reduction in soil depth, both of which can have an adverse effect on crop yields. The consequences of both deforestation and degraded soil structure include less infiltration of rainfall, which diminishes groundwater recharge; more runoff, which contributes to erosion and siltation; and reduced water storage capacity in the soil, which makes crops less able to withstand drought.

Water resources and agriculture

The dominant agricultural system in Ethiopia is small-holder production of cereals under rainfed conditions, leaving the population and economy extremely vulnerable to hydrology. Ethiopia has the largest livestock population in Africa. Livestock is an integral part of nearly all the mixed type highland farming systems and the principal store of farmer wealth. Agriculture employs 80 percent of the population and accounts for almost 50 percent of the gross domestic product (GDP). Small-holder farmers, generally with less than 1 hectare of land, account for about 95 percent of the agricultural output. In times of good weather, roughly 75–80 percent of the annual output is consumed at the household level.

It is striking that less than 5 percent of the estimated potential 3.7 million hectares of irrigable land in Ethiopia has been developed. Variations in rainfall and weather conditions cause considerable volatility in agriculture growth. Hydrological variability affects both high- and low-potential areas of the country, although the impact is much greater in the latter. Weather variability can both reduce yields and lead to land degradation. Yields typically fall if there is too little rain, but they can also be damaged by excessive rain and flooding. Declining agricultural productivity, in turn, inhibits investments in land management and encourages the extension of agricultural lands rather than intensification of production. This practice can lead to further land degradation, closing a vicious circle that leaves the landscape increasingly vulnerable to drought and rainfall-related erosion.

Because of agriculture's dominant share of the economy, fluctuations in agriculture are reflected in the GDP. These fluctuations undermined the country's ability to sustain per capita growth in the 1980s and 1990s.

Water resources and hydropower

Ethiopia has considerable hydropower potential, about 30,000 megawatts. Presently, 95 percent of national energy consumption is derived from fuelwood, dung, crop residues, and human and animal power. The remaining 5 percent is from electricity, 90 percent of which is generated by hydropower. The current dependable power capacity in Ethiopia is 731 megawatts. Only two percent of the country's economically feasible hydroelectric potential has been developed.

Power interruption is common in years of severe drought when water shortages disrupt hydroelectric power generation. The 2002–3 drought caused power interruptions that lasted for about four months with a one-day-per-week complete interruption throughout the country. A one-day interruption was estimated to result in a loss of 10–15 percent of the GDP for the day (EEPRI 2003).

Because only about 15 percent of the population has access to electricity, there is great reliance on biomass and fuelwood. This reliance intensifies deforestation and soil degradation, and increases the burden on women and children who traditionally gather and transport fuelwood and other organic fuels and also suffer most from indoor air pollution. While electricity will not be a feasible substitute for all biomass fuel uses in the near term, the availability of hydropower will begin to shift energy use away from biomass and strengthen environmental sustainability. The GoE's growth and poverty reduction strategy includes the aggressive expansion of access to affordable electricity, which will also reduce the demand for biomass and thereby protect watersheds.

Water resources, transportation, and market infrastructure

Current limited access to transportation and markets undermines incentives for surplus agricultural production and reinforces the highly vulnerable subsistence-oriented structure of the economy. Road transport accounts for roughly 95 percent of the country's passenger and freight traffic and provides the only form of access to most rural communities. On average, Ethiopian farmers live 10 kilometers from the nearest paved road and 17 kilometers from the nearest commercial transport (Dercon and Chistiaensen 2005).

A notable characteristic of the network is that most all-weather roads radiate from the capital, Addis Ababa, to major towns. Direct links between regions are rare, which discourages interregional trade. The cost of building and maintaining roads is high because of rugged topography and torrential tropical rains. Because of this high cost, the systems expand slowly and many new roads are left unpaved.

Today 90 percent of Ethiopia's roads are dry-weather roads that cannot be used effectively during the four-month-long wet season. The reliance of the economy on this small network of mostly dry-weather roads makes commerce highly vulnerable to floods and heavy rainfall. Over the period 2000–2 almost 60 percent of the reported defects in unpaved roads and 35 percent of defects in paved roads were directly related to water. These figures do not include rain-induced landslides or infrastructure washouts. Moreover a clear correlation is seen between hydrological variability and the percentage of maintenance costs attributable to water damage. When it rains in remote areas, farmers can produce crops but often cannot get them to markets.

Water resources and urbanization

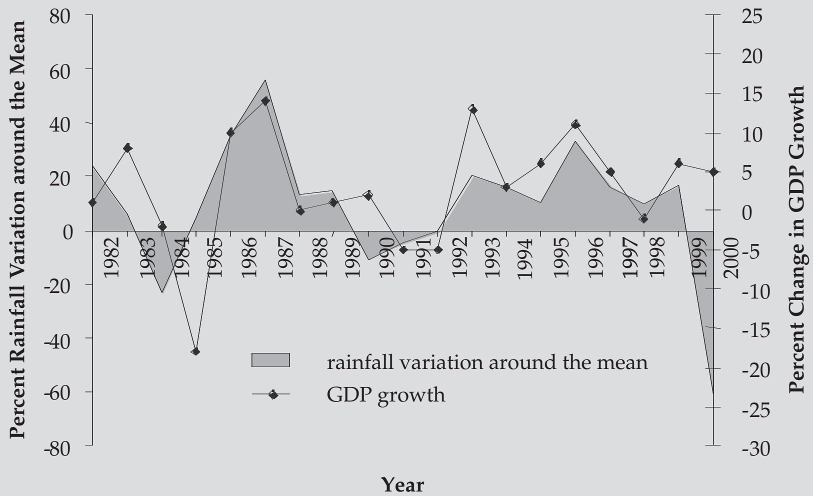
Ethiopia is less urbanized than most developing countries in Africa and the rest of the world, with a current level of urbanization at just 12 percent. The largest city, Addis Ababa, is 12 times larger than the second largest city. Addis Ababa alone provides about one-fifth of the overall GDP of the country and 52 percent of the modern sector value added. Urban productivity, or value added per urban inhabitant, is nearly four times that of rural areas, and Addis Ababa is 2.5 times more productive than the average of other cities and towns. These great disparities between urban and rural productivity were recognized explicitly in the GoE's Abbay River Basin master plan, which found that urbanization contributes to economic diversification and provides "the only" viable base for long-term growth in average incomes. By withdrawing labor from the agricultural sector, urbanization also contributes to the sustainability of agriculture and the conservation of the resource base.

As noted above, market towns are rarely interconnected laterally, and where roads exist, passability is uncertain much of the year. Thus, their growth is inhibited. The dispersed settlement pattern leaves a greater percentage of the population more directly dependent on natural resource-related livelihoods and therefore more vulnerable to hydrological variability. The rural settlement pattern also compounds the challenge of mitigating hydrological variability because dispersed populations cannot be provided drought and flood mitigation services (that is, water storage and river regulation) as cost effectively as more concentrated populations.

Hydrology and economy-wide performance

Ethiopia's extreme hydrological variability is echoed in its economic performance. The vast majority (80 percent) of Ethiopia's population subsists on rainfed agriculture, and thus their welfare and economic productivity are linked to the volatile rains. The correlation between rainfall and overall GDP is strong, as can be seen in Figure ES.2. The impact of rainfall variability, unchecked by either physical infrastructure or strong man-

Figure ES.2. Rainfall Variation Around the Mean and GDP Growth



Source: Compiled from SIMA and African Rainfall and Temperature Evaluation System data.

agement practices, can be felt not only on agricultural output but on the environment, electricity (which is 90 percent hydropower), manufactured goods, incomes and consumption, and prices. Poor market access and costly transportation services have created a highly fragmented economy in which average grain prices differ 30–70 percent across regions. This fragmentation reflects forgone opportunities to make both buyers and sellers better off. It also amplifies drought and flood shocks by hampering trade between surplus and deficit regions in the country.

Dynamic effects and incentives for growth

The fragility of the Ethiopian landscape and the dependence of the Ethiopian population and economy on rainfed agriculture create a web of effects that result—at least in part—from the country's extreme hydrological variability. This variability has economy-wide impacts in good and bad years. Rainfall variability has direct impacts on the landscape, agricultural output, transport passability, and water-intensive industry and power production. These impacts are generally unmitigated because there is little hydraulic infrastructure to regulate or store water. They are often amplified by the fragmented nature of the Ethiopian economy, which does not facilitate trade between affected and non-affected regions of the country, and transmitted through input, price, and income effects onto the broader economy.

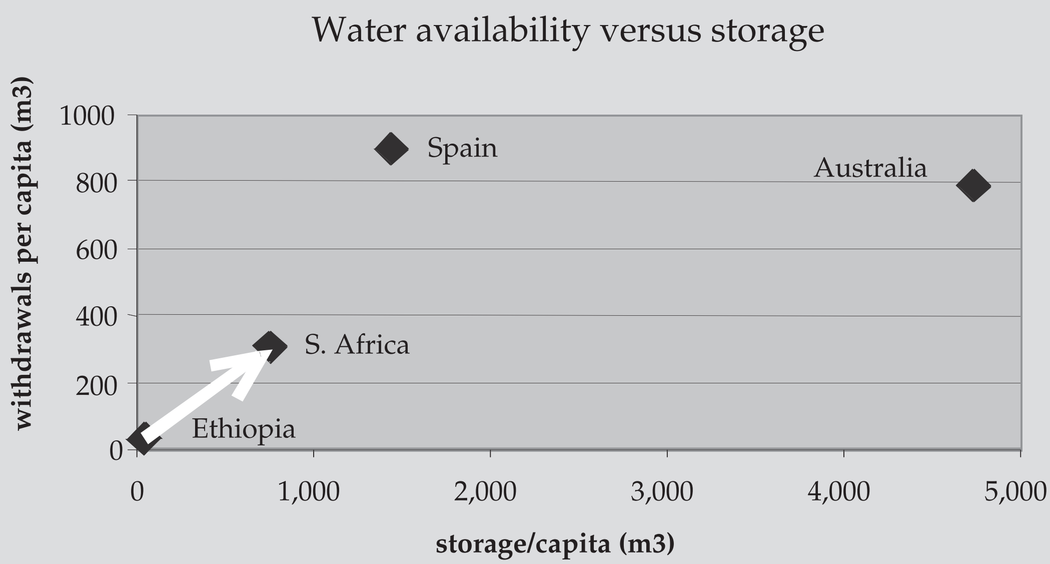
Many of these dynamics conspire against structural change in the economy. Endemic drought, fragmented and inadequate infrastructure, and expectations that food aid shipments will disrupt transportation and tamp down food price spikes during shortages, all promote a risk-averse subsistence economy and undercut incentives for farmers to produce surplus, marketable crops.

Classic water management responses

Ethiopia cannot fully mitigate the impact of hydrological variability through water infrastructure and management investments alone. It is estimated that artificial reservoir storage in Ethiopia is about 43 cubic meters per capita in contrast to 750 cubic meters per capita in South Africa (see Figure ES.3). (Note that reservoir storage in North American is 6,150 cubic meters per capita.).

If we take the storage in South Africa as a crude benchmark of water security, it can be shown using conventional coefficients that Ethiopia would need to invest five times its annual GDP (US$35 billion) just to achieve a similar infrastructure stock, with significant additional investments needed for the institutions and capacity required to complement

Figure ES.3. Water Storage Per Capital in Selected Countries



Source: Compiled from SIMA and KOID databases.

those investment. This order of magnitude calculation only serves to demonstrate that strategies focused purely on water management and infrastructure responses are not affordable.

Clearly, it will be necessary to look beyond what is traditionally considered water resources management in order to curtail the negative effects of hydrological variability on the performance of the Ethiopian economy, by identifying both interventions aimed at managing hydrological variability, and interventions aimed at decreasing the vulnerability of the economy to these shocks.

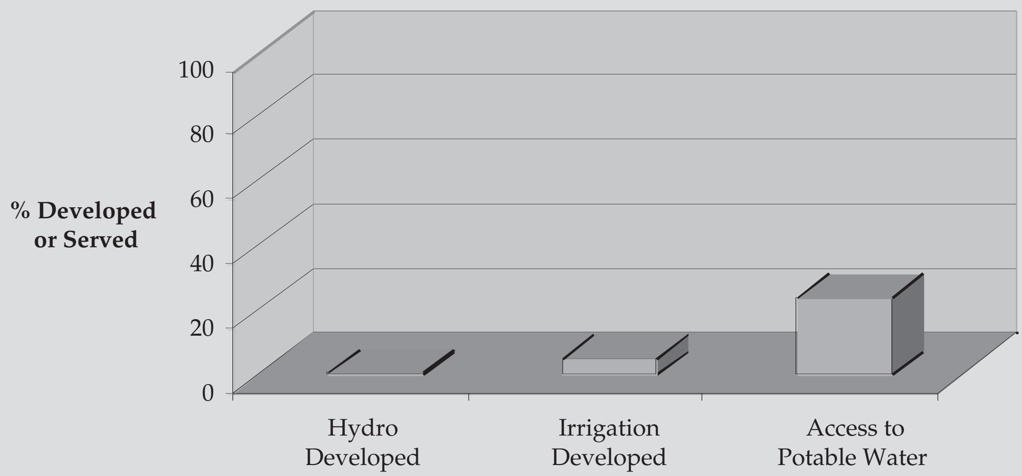
Incentives for building resilience

Efforts to address variability start with the variety of means traditionally associated with water resources management, with all interventions designed and implemented cognizant of environmental and social challenges and priorities. As described previously, these interventions include watershed management, with programs to provide sustainable livelihoods, and investments in multipurpose hydraulic infrastructure, which could potentially be designed to include hydropower production, irrigation systems, and storage adequate to mitigate both drought and floods. These investments are envisaged to provide the security and incentives necessary to prompt private sector investment in inputs that will enhance productivity. This is often described as an "input impact" on patterns of investment for surplus production. Figure ES.4 shows the current low level of Ethiopia's water infrastructure including hydro and irrigation development and access for potable water.

For longer-term growth, investments must also be considered to promote less water-dependent, more resilient, livelihoods. Current policies focus on food aid and other palliatives to ease the impact of drought on the population and the economy, but much of the problem lies in the very structure of the economy, which leaves its people vulnerable to hydrological variability. The majority of the population depends directly upon rainfall for subsistence agriculture, and the broader economy is built on domestic demand that is as unpredictable as the rains. This is compounded by inadequate infrastructure, fragmented national markets, and the current policy environment, which all prove to be disincentives for investments in more weather-resilient activities such as irrigated agriculture, manufacturing, and services.

Proactive interventions are needed outside the water sector to enhance the economy's resilience

Figure ES.4. Water Infrastructure



Source: Authors.

to the impacts of hydrological variability. The development of resilient growth poles would appear to be a promising strategy in this regard. The scale of variability is simply too great to fully mitigate by structural or management interventions. Unless the structure of the economy changes, stable economic progress will continue to be both intensely disrupted by drought and flood and quietly undermined by risk aversion.

Economywide Impacts of Ethiopia's Water Resources: A Hydro-Economic Model

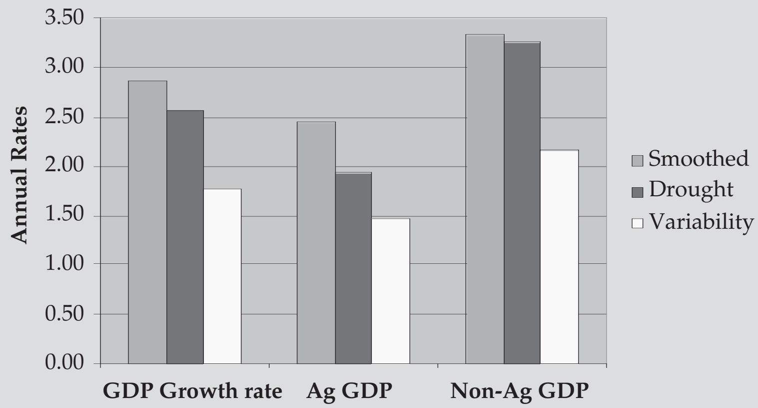
Based on these insights, a model was constructed to quantify the economy-wide impacts of Ethiopia's water resources endowment, variability, and management. An economy-wide multimarket model was modified explicitly to incorporate hydrology into growth and poverty projections.[1] The model is dynamic, running for a period long enough to explore the implications of variability over time. The following key characteristics of the Ethiopian economy and hydrology were drawn from the discussion above and incorporated into the model:

- Highly variable rainfall and endemic droughts and floods
- Fragile and degrading landscapes
- Low levels of infrastructure investment to mitigate hydrologic variability
- Fragmentation of the economy, particularly regional segmentation in agricultural markets
- High transportation and marketing costs

The model was run with three variations. All model variations are regional, multisectoral, multimarket models that incorporate hydrology within the agricultural production function. They differ only with regard to their assumptions of rainfall variability. Specifically:

- *Smoothed rainfall:* This variation assumes 1995–2002 average rainfall in all years. Smoothed rainfall is the underlying assumption in virtually all economy-wide modeling.
- *Stylized drought:* This variation assumes 1995–2002 average rainfall except for a stylized, two-year drought of average severity. It captures the isolated "shock" of a single drought.

Figure ES.5. Effects of Hydrology on GDP Growth



Source: Authors.

- *Historical variability:* This variation is a stochastic extension of the model that more fully reflects Ethiopia's historical levels of rainfall variability, and, in addition, captures the negative impacts of excessive rains on the agricultural and non-agricultural sectors.

Growth and Poverty Costs of Drought and Variability

The model shows that hydrological variability costs the Ethiopian economy 38 percent of its potential growth rate and causes a 25 percent increase in poverty rates, clearly demonstrating the extraordinary impact of drought, and particularly variability, on the Ethiopian economy.

A single drought event in a 12-year period—a very conservative estimate for Ethiopia—will decrease average GDP growth rates 7–10 percent. If historical levels of variability and the partial impacts of floods are incorporated, GDP growth rates fall 20–43 percent. Figure ES.5 shows the difference in GDP growth rate projections when rainfall is modeled as a smoothed average, when a single drought event is incorporated, and when historical levels of variability are assumed.

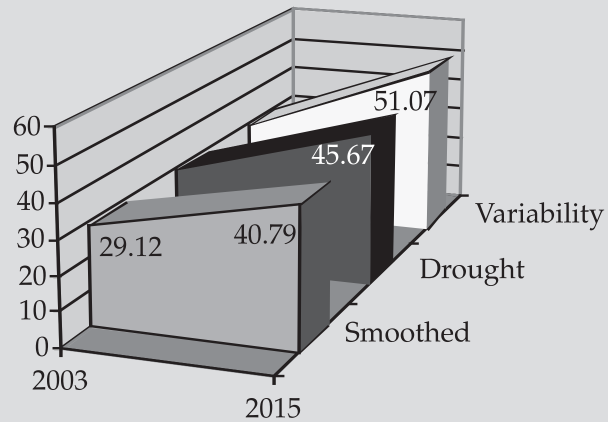
In terms of poverty, the impact of a single drought will increase poverty rates 12–14 percent, causing an additional 5 million Ethiopians to be living in poverty by the year 2015 (relative to the nondrought case), 17 million more than today. With hydrological variability, projected poverty rates rise 25–35 percent and project 51 million people living in poverty, 22 million more than today. Figure ES.6 shows the difference in the number of people projected to live in poverty when rainfall is modeled as a smoothed average, when a single drought event is incorporated, and when historical levels of variability are assumed.

It is important to note that drought shocks, which tend to be a primary focus for weather risk analysis in Ethiopia, represent just part of the story. The historical variability model, while still quite conservative, better reflects the real hydrological impacts endured in Ethiopia. It captures year-on-year stochastic variations, and some of the impacts of floods as well as droughts. These models clearly suggest that variability, rather than a narrow focus on drought, must be the central water resources challenge for development in Ethiopia.

Investment Scenarios

Figures ES.7 and ES.8 summarize the relative agricultural and nonagricultural GDP growth rates by investment scenarios, using the smoothed rainfall and the historical variability models. Overall GDP

Figure ES.6. Effects of Hydrology on Poverty Rates



Source: Authors.

growth rates are lower in the model with variability because the enormous costs of hydrology are not factored into the smoothed rainfall model.

The smoothed rainfall model shows relatively low agricultural GDP growth rates and relatively low returns to irrigation investments. This model smoothes, or averages, rainfall extremes, but it is at these extremes—during periods of drought and flood—that the returns to irrigation and drainage are greatest. Smoothed models therefore fail to capture the extent of benefits offered by irrigation in countries such as Ethiopia that are subject to great variability.

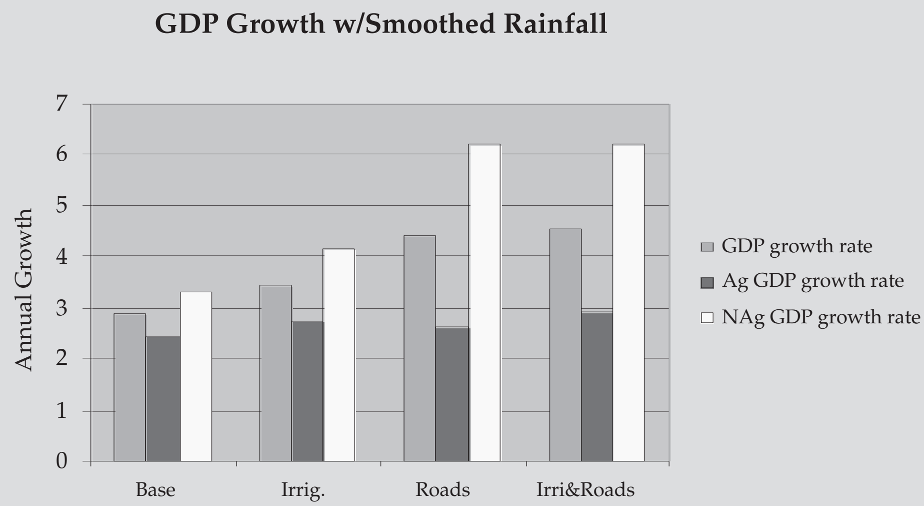
Under the model that incorporates historical levels of rainfall variability, overall growth rates are comparable for scenarios that allow either investments in irrigation or in infrastructure. But the two scenarios give rise to very different relative growth rates between agricultural and non-agricultural GDP. The infrastructure investment scenario gives rise to much greater non-agricultural benefits, which would have a markedly different impact on the structure of the economy over time, possibly reducing its vulnerability to hydrological variability and shocks.

Apparent synergies between irrigation and infrastructure investments are much more pronounced under the historical variability model. Under both the smoothed rainfall model and the stylized drought model, the lion's share of benefits appear to derive from market infrastructure investments, with irrigation investments only adding marginally to total growth and poverty gains. Under the historical variability model, however, the gains are virtually additive. This finding reflects the greater benefits of irrigation under highly variable climatic conditions, and suggests that the complementarity of combined investments is particularly pronounced under such conditions. It also suggests that investments in roads and market infrastructure are essential for leveraging returns to irrigation investments, although the reverse relationship (that investments in irrigation leverage returns on market infrastructure) may not be strong.

The model clearly calls for coordinated investment in irrigation and market infrastructure to manage the impact of hydrological variability on the Ethiopian economy. Such coordinated investment should exploit opportunities for multipurpose infrastructure. River regulation and storage infrastructure can be designed at all scales to meet several objectives: delivery of irrigation and municipal water, generation of hydropower and the public good benefits of drought and flood mitigation, and protection of roads and other infrastructure.

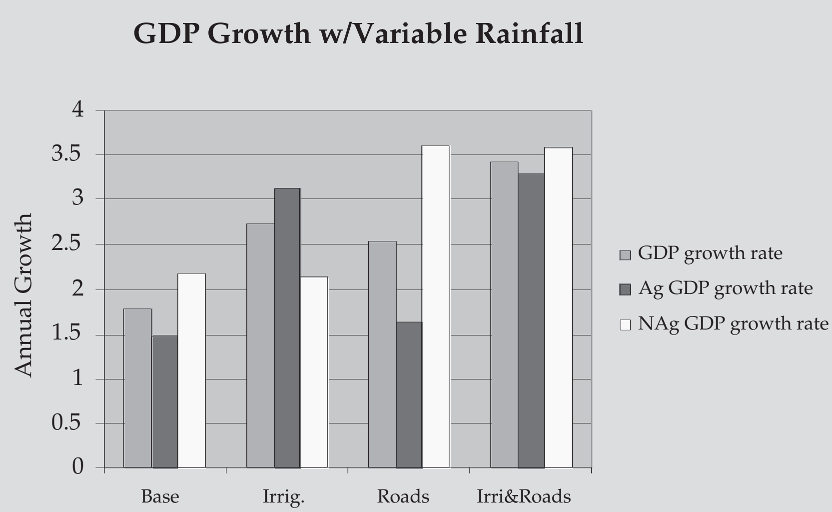
The model does not explicitly incorporate hydropower. Generally, there are tradeoffs

Figure ES.7. Growth Rates With Smoothed Rainfall and Different Investment Scenarios



Source: Authors.

Figure ES.8. GDP Growth With Variable Rainfall and Different Investment Scenarios



Source: Authors.

between the use of water for hydropower or for upland irrigation as the consumptive use of water above a hydropower plant means less power will be generated. Choices may need to be made. There appear to be opportunities in highland Ethiopia, however, for substantial irrigation development without requiring a significant tradeoff in terms of hydropower generation. For example, in large areas around Lake Tana, river regulation and drainage will provide the incremental water required for irrigation. In addition, there appear to be many cases where small to medium hydropower coupled with irrigation can be economic but where single-purpose investments might not be (for example, on the rivers that feed Lake Tana). Moreover, the larger storage capacity justified by combined investments would provide even greater public benefits. Hydropower development at all scales is potentially an integral part of both irrigation and market infrastructure development, and abundant energy is clearly needed to diversify the economy.

The GoE is currently undertaking major development programs in irrigation and market infrastructure, particularly roads and power. It is difficult to choose a national priority between the two types of investment from the results of the model. To hasten a structural shift toward nonagricultural activities, the model suggests a somewhat disproportionate investment in market infrastructure, but this will not necessarily be the priority in all locations. Specific investment decisions will need to be made cognizant of local hydrological, environmental, economic and social conditions, and the existing stock of both irrigation and market infrastructure.

Water and Growth in Ethiopia: Achieving Water Security

Water security and the minimum platform of water infrastructure and institutions

This analysis of Ethiopia's water resources legacy and challenges deepens our understanding of the concept of water security (Grey and Sadoff 2005). Investments in bulk water resources and water for food, energy, industry, and navigation and in associated institutions are initially made by all societies in search of some implicit level of water security.[2] Water security is defined here as the reliable availability of an acceptable quantity and quality of water for production, livelihoods, and health, coupled with an acceptable level of risk of high social and economic impacts of unpredictable water events, including the extremes of drought and flood. Water security is achieved when the overall impact of water enhances economic growth rather than undermines it. Water security is a dynamic state: different in different parts of the world, reflecting geographic, social, epidemiological, economic, and political factors, and changing over time as these factors shift with development.

We postulate that there is a basic level of water security that incorporates the idea of a minimum platform of water infrastructure and institutions. Below this minimum platform, society and the economy is unacceptably impacted by water (by any mix of water shocks and/or unreliable water availability for production or livelihoods). The tipping point in achieving water security is the acquisition of a minimum platform of management capacity and infrastructure investment. The minimum platform has not been achieved in Ethiopia. The scale of social and related economic impacts is such that Ethiopia's social fabric is significantly affected and economic growth cannot be reliably and predictably managed.

Implications for investment

In Ethiopia significant public investment will be needed to provide adequate security for private investment to follow and growth to ensue. This thinking follows the model of public investment in a road, which will have little return until it joins two cities, but then will attract private investment in transportation services and economic growth for both cities. If this is the case, it has important implications for how we assess the cost-effectiveness of early investments in water resources infrastructure in Ethiopia. But if the hypothesis holds true, growth in Ethiopia will be slowed until such investments are made.

Institutions/infrastructure balance

In all countries, development of water resources requires investments in both institutions and infrastructure, but when stocks of hydraulic infrastructure are low, investments in infrastructure are likely to receive priority. Investment in management capacity and institutions becomes increasingly important as larger and more sophisticated infrastructure stocks are built. Without the infrastructure to store and deliver water and manage flows, there is neither the need nor the incentive for sophisticated management structures and practices.

While developed countries are appropriately focused on the implementation of integrated water resources management, Ethiopia and other developing countries may do better to adopt a principled and pragmatic approach to management while putting greater emphasis on concurrent infrastructure investments.[3] Failure to understand the issue of balance and sequencing within the context of specific country circumstances may lead to poor investment choices.

Transboundary institutions/infrastructure case

International river management is of growing importance in a world with 260 international rivers and is a particular challenge for Ethiopia, whose most significant water resources are shared. Although a basic premise of water resources management is that river basins are best developed and managed as an integrated whole, integrated management is always legally and politically complex, due to the challenges of allocation between users and between uses.

The management and development of international rivers is particularly challenging because there is no apex authority through which differences can be resolved. Because the complexity of riparian relations is an obstacle to the development of the full potential that international rivers embody for growth and poverty alleviation, nations often develop river segments within their own territories, settling for second or third best investments. In extreme cases, tensions over international rivers can effectively halt their management and development.

On the other hand, the need for river infrastructure is often a major driver in reaching agreements where river flow—water quantity—is the issue. This is the case beginning to be demonstrated by Ethiopia and its neighboring riparian states on the Nile. The Nile Basin Initiative (NBI) offers considerable potential for major cooperative development of the Nile River, including large-scale hydropower and irrigation development located in Ethiopia. In addition, opportunities for regional cooperation and integration in a range of activities "beyond the river" have arisen as a consequence of strengthened relations built on the NBI.

Water, poverty, and wealth

In Ethiopia the centrality of water is clear. With little water resources infrastructure, relatively weak management institutions and capacity, extreme hydrological variability and seasonality, and a highly vulnerable economy, Ethiopia faces an enormous challenge in building the minimum platform of water infrastructure and management capacity needed to achieve water security. Major public investment in water resources infrastructure and institutions will be needed, but until water security is achieved, growth will continue to be severely constrained.

The GoE clearly recognizes the scale and complexity of the water challenge and is undertaking a wide range of programs in response. Many of these programs can be categorized as national water resource management programs. Others promote international cooperation (particularly on the Nile), and still others seek to mitigate the impact of hydrologic variability on the Ethiopian economy by looking beyond the traditional water sector to encourage alternative livelihoods that are more resilient to water shocks.

Lessons

- Ethiopia's growth will be undermined until it attains water security, and it will require very large investment to achieve a nationwide minimum platform of water infrastructure and management capacity. Unmitigated hydrological variability increases poverty rates by about 25 percent and costs the Ethiopian economy about 40 percent of its growth potential, leaving growth rates hostage to hydrology. Managing this variability will be a prerequisite to sustained growth and development and should be a priority for public investment.
- Economy-wide models that fail to incorporate hydrological variability will be poor predictors of growth and poverty in Ethiopia. Rainfall variability is shown to be highly relevant and negatively correlated to economic performance; that is, the greater the level of variability modeled into the system, the worse the growth and poverty outcomes.
- Returns to irrigation and drainage investments are systematically underestimated in models that fail to capture hydrology, because returns to irrigation and drainage are highest in times of drought and flood. In Ethiopia, modeling with hydrological variability doubles returns to irrigation and drainage.
- Current incentives trap farmers in highly vulnerable rainfed subsistence agriculture. Achieving hydrological resilience will require structural change in the economy. Growth cannot be managed if 80 percent of the population and 50 percent of the economy is essentially dependent upon rainfall. Bank-supported investments and interventions in Ethiopia should be analyzed to deter-

mine whether they provide opportunities and incentives for structural changes that would make the economy less vulnerable to hydrological variability.

- Multipurpose hydraulic/hydropower infrastructure can enhance resilience both by directly regulating flows and by promoting structural shifts in the economy. Investments can be designed that will directly mitigate variability by providing over-year storage for drought and flood mitigation and irrigation to address both annual variability and unpredictable seasonality. Investments in power may also help non-agricultural sectors of the economy by promoting a structural shift in the economy toward greater hydrological resilience.
- Parallel investments in irrigation and market infrastructure can generate synergies for growth and poverty reduction, because together they will provide significant incentives for increased farmer investments in agricultural inputs as well as incentives and opportunities outside of agriculture. The model suggests there are greater synergies from colocated investment as hydrological variability increases, and that synergies are particularly strong for leveraging returns to irrigation investments.
- Investment is needed in water supply and sanitation to support growth and welfare. Where appropriate, urban water supply planning should be accompanied by investments in watershed management, bulk water infrastructure, and river regulation infrastructure.
- Water resources management capacity and institutions must be strengthened. Investment in research and education in particular will be crucial in developing the capacity needed to design effective and appropriate water resource management interventions, watershed management, irrigation schemes, and water and sanitation services. An increased focus on groundwater should also be seen as a priority in this regard.
- Solutions to water resources challenges need to be sought outside the "water sector," with a greater emphasis on alternative livelihoods to decrease the share of the population most vulnerable to hydrological shocks. Investment in market infrastructure and hydropower development would both help mitigate the direct impacts of drought and at the same time coax the economy toward a more resilient structure.
- A focus on all-weather roads and regional interconnection is essential in creating incentives for the production of surplus agriculture. Road connections should emphasize links between complementary regions to enable national trade that will lessen the regional food price shocks of drought and floods, thus reducing dependency on food aid.
- Alternatives should be sought to the practice of storing wealth in livestock, which increases rural economic vulnerability to weather shocks. "Drought proof" stores of wealth and related financial tools such as credit and weather insurance should be explored to provide asset stability during drought episodes.
- Given the scale of investments needed in water and transport infrastructure, it may be necessary to adopt a "growth pole" strategy,[4] ensuring the resilience of the primary engines of economic growth as a priority. This resilience is needed to ensure the sustained growth that will allow water security to be achieved nationwide.

A Strategy for World Bank Support

The analysis in this report provides a roadmap for a more coherent approach to Bank support for Ethiopia's water resources challenges. To enhance Ethiopia's resilience to drought and hydrological variability, and to promote more dynamic and sustained growth, there are several areas that stand out as priorities and comparative advantages for Bank support. They include:

- *Multipurpose hydraulic infrastructure development:* Multipurpose dam development could provide an excellent platform for addressing many of the vulnerabilities discussed in this paper and shifting the structure of the economy toward a more water-resilient path. The far-reaching potential benefits of such development, and the unique qualifications of the Bank to support these investments, strongly recommends multipurpose hydraulic infrastructure development, with an emphasis on hydropower generation and regional interconnection, as a first priority for future Bank assistance in water resource management.

- *Water supply and sanitation:* Given the GoE's high priority for water supply and sanitation, and the Bank's ongoing successful engagement in the sector, the Bank should continue its support and increase its efforts to attract and coordinate with additional financiers to help Ethiopia meet the water supply and sanitation MDGs.
- *Watershed management:* The Bank should undertake targeted watershed management projects in conjunction with any dam development and road-building projects it supports. Most immediately, priority support should be given to the cooperative watershed management project now under consideration within the framework of the NBI. The Bank might also have a comparative advantage in supporting projects that require facilitated cooperation in other international watersheds or those that are eligible for carbon finance.[5]
- *Transport, market infrastructure, and private sector development:* Investments in fully functioning market cities (growth poles) with regional infrastructure and communications interconnections are potentially powerful investments for managing hydrological risk in Ethiopia and could be very effective in providing alternatives and incentives to shift vulnerable populations toward more resilient livelihoods. The Bank should therefore support the development of growth poles with adequate hydraulic infrastructure, all-weather roads, and market infrastructure.

1 Introduction

Water has always played a central role in Ethiopian society. It is an input, to a greater or lesser extent, to almost all production. It is also a force for destruction. In Ethiopia, as in all societies, there has always been a struggle to reduce the destructive impacts of water and increase its productive impacts. This struggle has intensified over the past century as the population has grown dramatically. Today, Ethiopia's development is seriously constrained by a complex water resources legacy and a lack of access to, and management of, these water resources.

The primary characteristics of Ethiopia's water resources are extreme interannual and intra-annual rainfall variability, and the international nature of its most significant water resources. This variability is most obviously manifest in endemic, devastating droughts and floods. Less apparent is the broad range of impacts this variability has on the Ethiopian economy, even in good rainfall years.

This report seeks to clarify the scope and scale of the impacts of hydrological variability on Ethiopia's economic performance, poverty, natural resources, and socioeconomic conditions, as well as the manner in which water shocks are transmitted through the economy. By understanding what makes the economy vulnerable to hydrological shocks, a strategy can be developed to make it more resilient.

The Bank's support to Ethiopia has always included assistance to water-related sectors. It has financed projects in land and water management, urban and rural water supply and sanitation, hydropower, irrigation, food security, and international waters. But this assistance has generally been in response to specific requests from the GoE rather than part of a comprehensive, integrated strategy.

In recognition of the complex economy-wide impacts of water resources management, and the consequent need for cross-sectoral strategies that integrates the range of Bank-financed programs that affect, or are affected by, water resources, the Bank's Water Resources Sector Strategy (2003) introduced a new vehicle, the Country Water Resources Assistance Strategy (CWRAS). The CWRAS is a Bank strategy document—agreed with the GoE—that lays out a comprehensive approach for Bank support to water-related sectors.

This CWRAS for Ethiopia will assist the Bank in defining a more strategic approach to assisting water-related sectors and supporting implementation of Ethiopia's Water Sector Strategy (2001) in its efforts to regulate rivers, better manage watersheds, improve access to basic services for households and industries, intensify agricultural production, increase power production, and more effectively de-link economic performance from rainfall and runoff.

This strategy looks beyond the management of hydrological variability to interventions aimed at decreasing the vulnerability of the economy to these shocks. The report helps clarify linkages between the country's economic performance and its water resources endowment and management. It then uses this analysis to recommend both water resource strategies and economic and sectoral policies that will enhance growth and insulate the Ethiopian people and economy from the often devastating economy-wide effects of water shocks. Specifically, the objectives of this CWRAS are to:

- Investigate and describe the role of water in the economic performance of Ethiopia from a cross-sectoral, economy-wide perspective.
- Identify broad strategies for mitigating negative and enhancing positive impacts of water on the economic performance of Ethiopia.
- Define an overarching strategy for Bank support to water management in Ethiopia, which will provide an integrated framework for developing and harmonizing strategies in water-related sectors.

The focus of our analysis is the challenge of water resources: the management, development, allocation, and impact of the country's overall hydrology and water resources. It is not intended to provide detailed investment recommendations. Nor is the report intended in anyway supercede the GoE's current, sound water, resources strategy. Rather, this report provides analysis to strengthen understanding of the dynamics of water in the Ethiopian economy and sets out a roadmap for a more coherent approach to Bank support for Ethiopia's efforts to manage its water resources challenges.

The report is structured as follows: Section 2 describes the devastating impact of hydrological variably on Ethiopia's economy and its people. Section 3 provides a cross-sectoral analysis of the impacts of water management on the Ethiopian economy, encompassing the environment, agriculture, energy, water supply and sanitation, industry, and transport sectors. Section 4 outlines some of the development strategies proposed to improve conditions. Section 5 presents a quantitative model, based on the qualitative description of Ethiopia's hydro-economic dynamics, that is used to project economy-wide growth and the effects of hydrological variability under different policy and investment scenarios. Section 6 makes a case for why developing countries with variable hydrology, such as Ethiopia, need investment in water-related infrastructure. Section 7 offers a brief summary of lessons. Section 8 outlines a strategy of Bank support for Ethiopia's efforts to manage its water resources to maximize sustainable growth.

2 Ethiopia's Water Resources

At first glance, Ethiopia's water resources endowment appears generous. The country has adequate average annual rainfall, several major rivers and lakes, and significant groundwater resources (see map 2.1). The total renewable surface water resources are estimated at 122 billion cubic meters per year from 12 major river basins (see map 2.2), as shown in figure 2.1, and 22 lakes. Renewable groundwater resources are estimated to be about 2.6 billion cubic meters (MoWR 2002a). Although less than 2 percent of these resources are diverted for use, the current estimated per capita renewable freshwater resources of 1,900 cubic meters (MoWR 2002b) indicates an abundance of water.

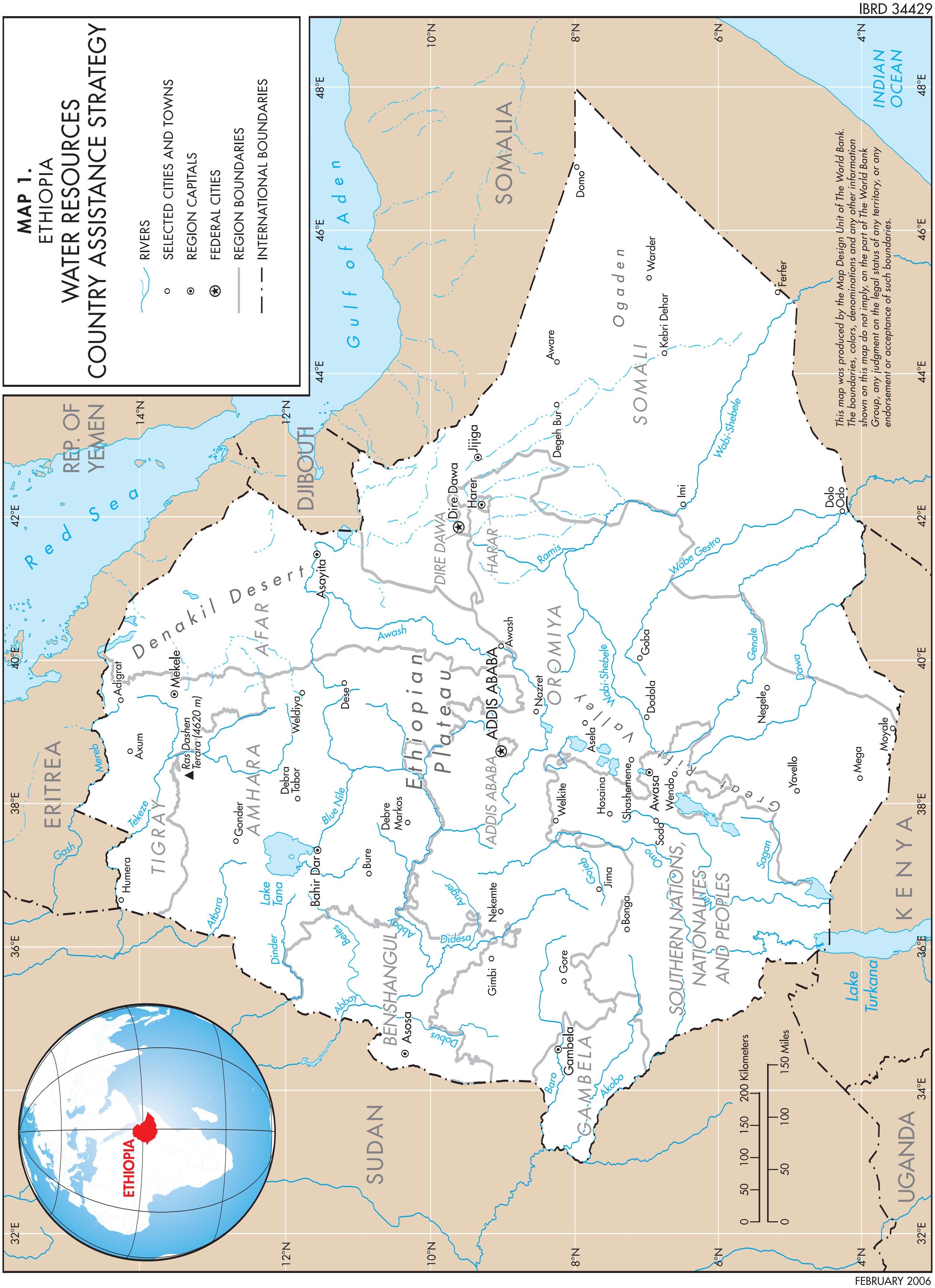
However, the development and management of Ethiopia's water resources faces two significant challenges, a natural legacy and an historical legacy. The natural legacy is one of high hydrological variability. Rainfall across much of the country is exceptionally variable and unpredictable, both in time (within and between years) and space. With highly vulnerable watersheds and almost no investment in water storage, a consequence of this hydrological variability is endemic and unpredictable drought and flood.

The historical legacy is one of several international rivers, of which the Nile is the most important. The Abbay, or Blue Nile, Basin contributes 62 percent of the annual average flow reaching Aswan. When combined with the Tekezze and the Baro-Akobo Rivers, the total contribution from Ethiopia to the flow of the Nile at Aswan is 86 percent (BCEOM 1999). In the Nile Basin, tensions have long been high. In recent years, Ethiopia has placed great emphasis on developing the Nile in cooperation with its neighbors. Without such bold, affirmative action for cooperation, tensions would grow, as demand for water grows with populations and economies in the basin

RESOURCE

Ethiopia's hydrology is greatly influenced by its highly varied topography. The heart of the country is a vast highland plateau, lying at an elevation of 1,500–3,000 meters with some peaks rising to more than 4,500 meters. This central massif is divided by the deep Rift Valley, which runs from northeast to southwest. To the west, the plateau slopes gently away to the Sudan and to the wide plains of the White Nile and Main Nile. To the east, a steep escarpment drops to the

Map 2.1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MAP 1.
ETHIOPIA
WATER RESOURCES
COUNTRY ASSISTANCE STRATEGY
RIVERS
SELECTED CITIES AND TOWNS
REGION CAPITALS
FEDERAL CITIES
REGION BOUNDARIES
INTERNATIONAL BOUNDARIES
ETHIOPIA
0 50 100 150 200 Kilometers
0 50 100 150 Miles
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FEBRUARY 2006
ERITREA
REP. OF YEMEN
DJIBOUTI
SOMALIA
SUDAN
KENYA
UGANDA
Red Sea
Gulf of Aden
INDIAN OCEAN
Denakil Desert
Ethiopian Plateau
Great Rift Valley
Ogaden
TIGRAY
AFAR
AMHARA
BENSHANGUL
ADDIS ABABA
DIRE DAWA
HARAR
OROMIYA
SOMALI
GAMBELA
SOUTHERN NATIONS, NATIONALITIES, AND PEOPLES
ADDIS ABABA
Dire Dawa
Harer
Jijiga
Asayita
Mekele
Adigrat
Axum
Ras Dashen Terara (4620 m)
Gonder
Humera
Debra Tabor
Weldiya
Dese
Bahir Dar
Bure
Debre Markos
Nekemte
Gimbi
Asosa
Gore
Gambela
Bonga
Jima
Welkite
Hosaina
Shashemene
Awasa
Wendo
Sodo
Asela
Nazret
Awash
Goba
Dodola
Negele
Yavello
Mega
Moyale
Dolo Odo
Imi
Degeh Bur
Aware
Kebri Dehar
Warder
Ferfer
Domo
Lake Tana
Lake Turkana
Mereb
Tekeze
Gash
Atbara
Dinder
Beles
Abbay
Blue Nile
Didesa
Anger
Dabus
Baro
Akobo
Gojeb
Omo
Sagan
Dawa
Genale
Wabi Shebele
Wabe Gestro
Ramis
Awash
32°E 34°E 36°E 38°E 40°E 42°E 44°E 46°E 48°E
4°N 6°N 8°N 10°N 12°N 14°N

Map 2.2

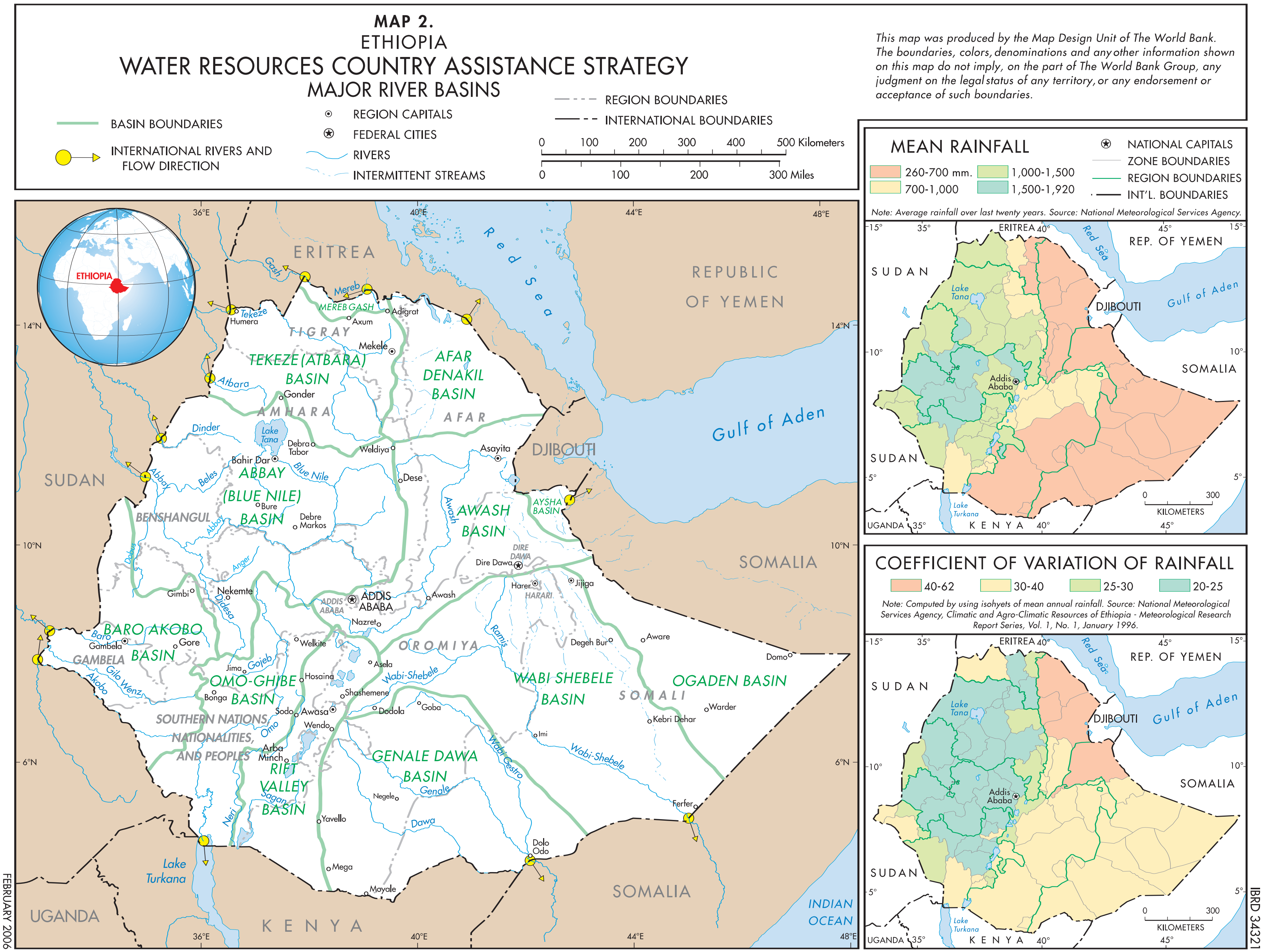
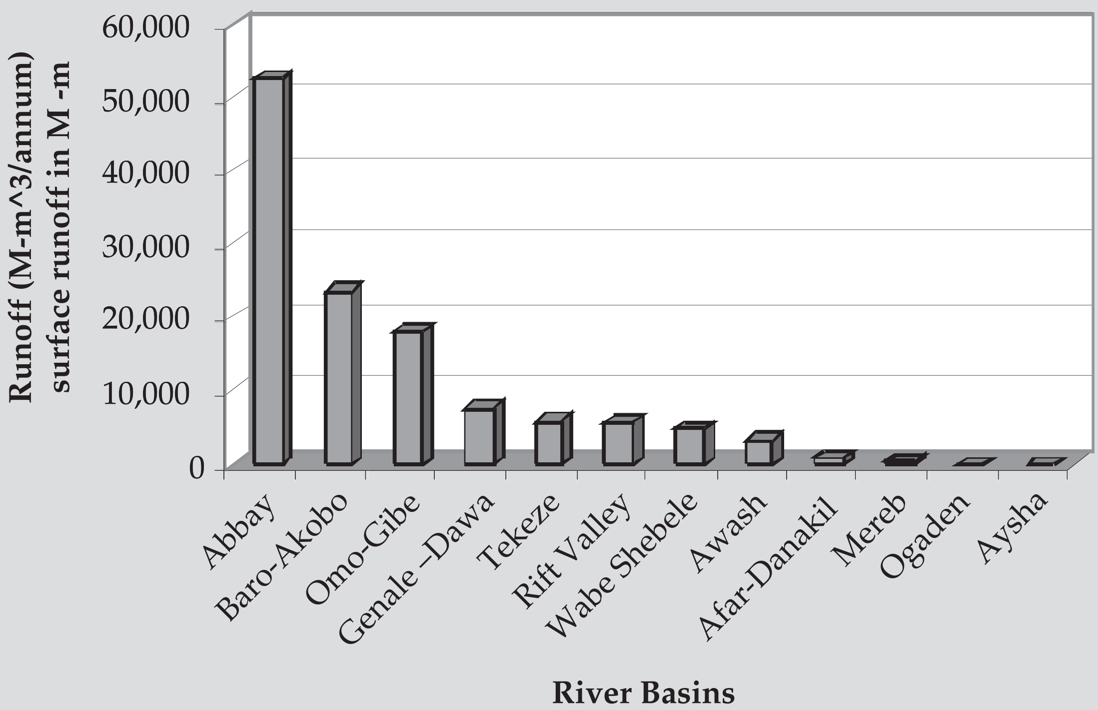

MAP 2.
ETHIOPIA
WATER RESOURCES COUNTRY ASSISTANCE STRATEGY
MAJOR RIVER BASINS
BASIN BOUNDARIES
INTERNATIONAL RIVERS AND FLOW DIRECTION
REGION CAPITALS
FEDERAL CITIES
RIVERS
INTERMITTENT STREAMS
REGION BOUNDARIES
INTERNATIONAL BOUNDARIES
0 100 200 300 400 500 Kilometers
0 100 200 300 Miles
This map was produced by the Map Design Unit of The World Bank. The boundaries, colors, denominations and any other information shown on this map do not imply, on the part of The World Bank Group, any judgment on the legal status of any territory, or any endorsement or acceptance of such boundaries.
ETHIOPIA
ERITREA
REPUBLIC OF YEMEN
Red Sea
Gulf of Aden
DJIBOUTI
SOMALIA
SUDAN
KENYA
UGANDA
INDIAN OCEAN
Lake Turkana
TEKEZE (ATBARA) BASIN
AFAR DENAKIL BASIN
ABBAY (BLUE NILE) BASIN
AWASH BASIN
AYSHA BASIN
BARO AKOBO BASIN
OMO-GHIBE BASIN
RIFT VALLEY BASIN
GENALE DAWA BASIN
WABI SHEBELE BASIN
OGADEN BASIN
TIGRAY
AMHARA
AFAR
BENSHANGUL
GAMBELA
OROMIYA
SOMALI
SOUTHERN NATIONS, NATIONALITIES, AND PEOPLES
ADDIS ABABA
DIRE DAWA
HARARI
ADDIS ABABA
Dire Dawa
Harer
Jijiga
Asayita
Mekele
Adigrat
Axum
Humera
Gonder
Debra Tabor
Bahir Dar
Bure
Debre Markos
Weldiya
Dese
Awash
Nazret
Asela
Welkite
Nekemte
Gimbi
Gore
Gambela
Jimo
Bonga
Hosaina
Shashemene
Awasa
Wendo
Sodo
Dodola
Goba
Arba Minch
Yavello
Mega
Moyale
Negele
Dolo Odo
Imi
Degeh Bur
Aware
Kebri Dehar
Warder
Domo
Ferfer
Gash
Mereb
MEREB GASH
Tekeze
Atbara
Dinder
Beles
Abbay
Blue Nile
Lake Tana
Anger
Didesa
Dabus
Baro
Akobo
Gilo Wenz
Gojeb
Omo
Neri
Sagan
Genale
Dawa
Wabi Gestro
Wabi-Shebele
Ramis
Awash
36°E
40°E
44°E
48°E
14°N
10°N
6°N
FEBRUARY 2006
MEAN RAINFALL
260-700 mm.
700-1,000
1,000-1,500
1,500-1,920
NATIONAL CAPITALS
ZONE BOUNDARIES
REGION BOUNDARIES
INT'L. BOUNDARIES
Note: Average rainfall over last twenty years. Source: National Meteorological Services Agency.
COEFFICIENT OF VARIATION OF RAINFALL
40-62
30-40
25-30
20-25
Note: Computed by using isohyets of mean annual rainfall. Source: National Meteorological Services Agency, Climatic and Agro-Climatic Resources of Ethiopia - Meteorological Research Report Series, Vol. 1, No. 1, January 1996.
REP. OF YEMEN
Addis Ababa
KILOMETERS
0 300
IBRD 34321

Figure 2.1 Surface Runoff from Ethiopia's Major River Basins



Source: MoWR

plains of the lowlands; farther south, these merge into the great stretch of the Ogaden Desert.

The Ethiopian highlands contribute to three major river systems, the Nile, Awash, and Omo. The northern and central highlands drain westward into Ethiopia's largest river system, the Abbay, or Blue Nile, into the Tekeze River, a tributary of the main Nile, and into the Baro River, a tributary of the White Nile. The eastern highlands drain into the Awash River, which never reaches the sea, but is ultimately absorbed into a succession of lakes and marshes near the Djibouti border. In the south, the Omo River drains into Lake Turkana, and a number of streams flow into the other Rift Valley lakes. In the southeast, the mountains of Arsi, Bale, and Sidamo drain toward Somalia and the Indian Ocean, but only the Genale or Juba River permanently flows into the sea. Apart from the larger rivers, there are few perennial streams below 1,000 meters (Abate 1995).

Elevations vary from the Afar Depression in the northeast, which is 110 meters below sea level, to the top of Ras Dashen Mountain in the north, which is 4,620 meters above sea level. In between there are high mountains, high plateaus, deep gorges, incised river valleys, and low-lying plains (Gebeyehu 2002). This variation in altitude produces a wide variation in climatic and microclimatic conditions, as well as in soil and vegetation conditions. Mean annual temperatures vary from 45oC in the Afar Depression to below 0oC in the highest lands. Forty-three percent of the country, where 88 percent of the population lives, is more than 1,500 meters above sea level.

Lake Tana, with an area of 3,600 square kilometers, is the largest of 15 natural lakes in Ethiopia, with a total surface area of about 6,900 square kilometers. Seven of the eight major natural lakes are found in the Rift Valley. Most Ethiopian lakes except Zeway, Tana, Langano, Abaya, and Chamo are ter-

Table 2.1. Mean Annual Rainfall and Coefficients of Variation in Selected Drought-Prone and Non-Drought-Prone Areas (1980–2001)

Regions/zones	Average annual rainfall levels (in mm)	Coefficient of variation (in percent)
Drought prone		
Tigray	710	23.2
Amhara/North Wollo	832	27.3
Amhara /South Wollo	901	21.3
Non-drought prone		
Oromiya/Arsi	878	11.2
Oromiya/Jimma	1,505	10.0
Amhara/Gojjam (east and west)	1,180	15.4

Source: Demeke (2004).

minal lakes. Lakes Shala and Abayata have concentrations of chemicals used in production of soda ash.

Ethiopian lakes and large perennial rivers are rich in fish. The sustainable yield of fish from the major lakes is estimated to be about 35,300 tons per year.

There is limited information on Ethiopia's renewable groundwater resources, which are estimated at about 2.6 billion cubic meters, although the Ethiopian Geological Survey is currently conducting groundwater investigations. Groundwater is an important source of raw water for urban and rural drinking supplies, and, although the country's complex geology does not lend itself to major groundwater developments, there does appear to be potential to develop smaller aquifers for irrigation and water supply and to explore opportunities for artificial recharge.

Ethiopia's rainfall shows high spatial and temporal variability. The highest mean annual rainfall (more than 2,700 millimeters) occurs in the southwestern highlands, and then it gradually decreases in the north (to less than 200 millimeters), northeast (to less than 100 millimeters), and southeast (to less than 200 millimeters).

Based on the annual rainfall distribution patterns, three major rainfall regimes can be identified:

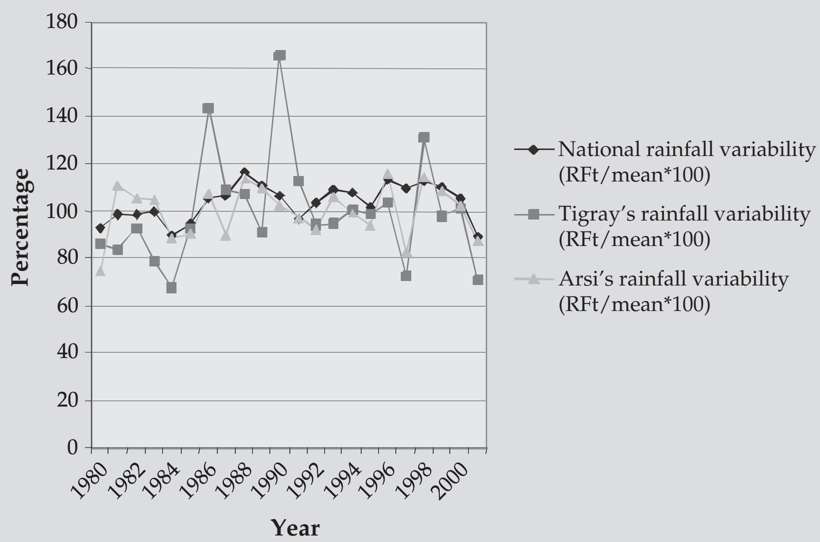
- The southwestern and western areas of the country are characterized by a mono-modal (single peak) rainfall pattern, with the length of the wet season decreasing northward.
- The central, eastern, and northeastern areas of the country experience a nearly bi-modal (two peak) rainfall distribution. The two rainy seasons are called Belg (smaller rains from February to May) and Kiremt (big rains from June to September).
- The southern and southeastern areas of the country are dominated by a distinctly bi-modal rainfall pattern. The rainy seasons are September to November and March to May, with two distinct dry periods separating them.

Ninety percent of the country's water resources occur in four river basins[6] that host only 40 percent of the population. Sixty percent of the population lives in the higher lands of the eastern and central river basins and depends on less than 20 percent of the country's water resources (MoWR 2001).

National average rainfall figures do not capture the large spatial variations in rainfall across different parts of the country. Not only do arid and semiarid or drought-prone areas have lower average annual rainfall, but they also exhibit significantly larger interannual rainfall variability. Figure 2.2 shows rainfall variability, calculated as "rainfall in year t" (RFt in the figure) as a percentage of the mean of average annual rainfall levels during 1980–2001. Variability is shown for the country as a whole, for drought-prone state of Tigray and for rainfall-adequate state of Arsi. Tigray, which has a generally lower average annual rainfall, exhibits substantially larger interannual rainfall variability.

Table 2.1 shows mean and coefficients of variation of average annual rainfall levels for 1980–2001.

Figure 2.2 Rainfall Variability: National, Tigray, and Arsi



Source: Demeke (2004).

These are extremely unfavorable in selected drought prone areas relative to non-drought-prone parts of the country.

Rainfall variability may actually be worsening in Ethiopia. Table 2.2 shows meteorological data that suggest rainfall was more variable in the 1980s and 1990s than in the 1970s, although the overall mean in the 1970s was lower.

HYDROLOGICAL VARIABILITY: EXTREMES OF DROUGHT AND FLOOD

The direct economic impact of hydrological extremes (drought and flood) everywhere in the world is well recognized. Ongoing work by the Bank in Africa is providing quantitative analyses of just how serious these hydrological shocks can be. The scale of the shock on the Kenyan economy of the 1997–8 flood and the ensuing 1999–2000 drought, for example, has been estimated at roughly 40 percent of annual gross domestic product (GDP) spread over a three-year period, with most of this impact occurring beyond the water-related sectors (that is, infrastructure damage and falling industrial production).

Many of the poorest regions of the world have the highest levels hydrological variability, and the poorest of the poor and women are often those most sharply affected. Where this is not the case, it will often be because sufficient investment was made in the hydraulic and institutional infrastructure to provide a reasonable measure of water security (such as in Australia and the southwestern United States).

The general environmental and economic impacts of too much or too little rain, as well as of extreme variability in rainfall, are described below. Section 3 discusses the impacts of this variability on each economic sector.

Too Little Rain

Drought

In drought years, providing drinking water is particularly challenging. For example, during the 2002–3 drought, some urban centers went without normal water supplies for weeks or even months. Water shortages in both rural and urban areas had serious negative health and sanitation consequences and seriously disrupted economic production. In addition, rainfall variability affects

Table 2.2. Trends in Rainfall Variability 1970–2001

	Year	Average annual rainfall	Year	Average annual rainfall	Year	Average annual rainfall
	1970	955	1981	991	1991	971
	1971	862	1982	989	1992	1040
	1972	909	1983	1000	1993	1095
	1973	912	1984	904	1994	1083
	1974	815	1985	949	1995	1017
	1975	944	1986	1059	1996	1136
	1976	943	1987	1068	1997	1100
	1977	994	1988	1166	1998	1130
	1978	1033	1989	1111	1999	1105
	1979	924	1990	1070	2000	1055
	1980	935			2001	898
Standard deviation		58.63		78.39		72.43
Coefficient of variation		6.31		7.60		6.85

Source: Ethiopian Meteorological Services Enterprise.

recharge of groundwater in some areas resulting in failure of wells. For example, in the city of Mekele, where the several-year-old water supply system includes eight deep groundwater wells, it was discovered that the wells supplied 30–40 percent less water than expected. Because the capacity of the new system did not meet the needs of the population, additional, deeper, wells will be needed.

Droughts destroy vegetation in watersheds, farmlands, and pastures. Surviving vegetation is also at risk because during droughts livestock are concentrated on overgrazed lands, compressing soils and pulling out roots, which decreases the likelihood of regeneration. Food shortages during droughts drive people to strip natural resources such as fuelwood, crafts supplies, and wild foods. Droughts create conditions conducive to wildfires and wind erosion. They compromise the ability of wetlands to absorb and slow stream flows, filter and remove sediments and pollutants, and sustain habitats for wildlife.

Drought causes crops to fail and livestock to perish. If rains fail, or simply come too early or too late, the entire agricultural cycle can be disrupted because the sector has inadequate storage capacity to smooth and time water delivery.

Drought can also severely undermine hydroelectric generation. During the 2002–3 drought the water level in Koka Reservoir was an unprecedented 3–4 meters below normal. Electric power was rationed, with a one-day interruption per week, in order to use available water economically until the next rainy season.

Famine

The history of drought and famine in Ethiopia is as old as the history of the land itself. Such crises have been traced as far back as 250 B.C. A major drought was recorded in the ninth century, and in the twelfth century another famine was chronicled that caused the death of many cattle. The 1888–92 famine was unprecedented in its scale of destruction. Drought, along with heavy infestation of pests, destroyed about 90 percent of the cattle and wiped out a third of the population. More than 19 periods of widespread and severe food shortages have been recorded in the past 100 years alone. It is clear that the problem has gradually expanded from the north to the rest of the country and its intensity has deepened (see table 2.3).

Over the past 20 years, agricultural growth has fallen far short of the rapid population growth: Production levels have fluctuated with the rainfall patterns and land degradation has intensified. About 10.3 percent of the population (more than 5 million people) has required emergency food aid each year (see table 2.4). More importantly, the number of people affected by droughts is increasing. During the broadly publicized 1984–5 drought, 8 million people required assistance. In 2002–3, more

Table 2.3. A Chronology of Ethiopian Drought and Famines Since 1895

Year	Affected area	Triggers and severity
1895–6	Ethiopia	Loss of livestock and human lives
1899–1900	Ethiopia	Drought deduced from levels of the Lake Rudolf and Low Nile floods
1913–4	Northern Ethiopia	Lowest Nile floods since 1695; grain price said to have risen thirtyfold
1920–2	Ethiopia	Moderate drought similar to 1895–96
1932–4	Ethiopia	Deduced from low level of water in Lake Rudolf in northern Kenya
1953	Tigray and Amhara (Wollo)	Severity unrecorded
1957–8	Tigray and Amhara (Wollo)	Rain failure in 1957; locust and epidemic in 1958
1962–3	Western Ethiopia	Very severe
1964–6	Tigray and Amhara (Wollo)	Undocumented; said to be severe
1969	Eritrea	Estimated 1.7 million people suffered food shortage
1971–5	Ethiopia	Sequence of rain failures, estimated 250,000 dead; 50 percent of livestock lost in Tigray and Wollo
1978–9	Southern Ethiopia	Failure of belg (small rain season) rains
1982	Northern Ethiopia	Late meher (major rain season) rains
1984–5	Ethiopia	Sequential rain failure; 8 million people affected, estimated 1 million dead, and many livestock lost
1987–8	Ethiopia	Drought of unrecorded severity in peripheral regions
1990–2	Northern, eastern, and southeastern Ethiopia	Rain failure and regional conflicts; estimated 4 million people suffered food shortage
1995–6	Southern Oromiya and Afar	Cattle death
1999–2000	Afar, Somalia, South Oromiya, Tigray, and Amhara	Cattle death and severe water shortage
2002–3	Ethiopia	11.3 million people required food assistance; additional 3 million needed close monitoring

Source: Webb et al. (1992) and Berkele (2002).

than 14 million people (22 percent of the population) required food assistance to survive. A total of 1.7 million tons of food aid was provided during that period, with the United States alone donating some US$500 million worth of food aid. Even in normal years, some 5 million people require food assistance.

Too Much Rain

Flooding

Flooding is a problem mainly along the riverine areas affecting productive agricultural land, settlements, and infrastructure. Flooding and sedimentation also cause damage by inundating and water-logging productive land, encouraging growth of undesirable species, and blocking road access and trekking routes. Flooded fields often delay planting, thus reducing yields and quality of crops.

Both floods and droughts cause severe damage to roads, making many roads impassable during the rainy season and even during the dry season, due to poor conditions and inadequate river crossings. According to a recent survey, the market roads in three of the more populous regions are impassable between three and five months of the year (IFPRI/ILRI 2002). Many of the small-scale irrigation schemes developed in recent years have been in food-insecure areas and are inaccessible by road, making it difficult for farmers to reach markets with the products of their irrigated fields.

Floods do not significantly threaten major cities or towns in Ethiopia. However, the river plains of the Abbay, Awash, Baro-Akobo, and Wabi-Shebele

Table 2.4. Drought- and Disaster-Affected Populations

Year	Drought/disaster- affected population (million)	Proportion affected (percent)
1980–1	2.82	7.7
1981–2	3.70	9.8
1982–3	3.30	8.5
1983–4	4.21	10.5
1984–5	6.99	17.0
1985–6	6.14	14.5
1986–7	2.53	5.8
1987–8	4.16	9.3
1988–9	5.35	11.6
1989–90	3.21	6.8
1990–1	7.22	14.8
1991–2	7.85	15.6
1992–3	4.97	9.6
1993–4	6.70	12.6
1994–5	3.99	7.3
1995–6	2.78	4.9
1996–7	3.36	5.8
1997–8	4.10	6.8
1998–9	7.19	11.7
1999–2000	10.56	16.6
2000–1	6.24	9.6
Average	5.37	10.3
2002–3	14.30	22.0

Source: Demeke (2004).

basins are prone to flooding. Urbanization contributes to flooding risk because large paved and impervious areas increase runoff. Furthermore, the construction of stormwater sewers and the realignment and culverting of the natural stream channels allows water to be transmitted to the drainage network more quickly. Urbanization also increases the potential costs associated with floods as investments are made in productive assets that are vulnerable to flood damage.

Massive Soil Loss and Land Degradation

Seventy-nine percent of Ethiopia's land has a slope in excess of 16 percent, and at least one-third of this area has a slope of 30 percent or more (Campbell 1991). Torrential or tropical rains, combined with the absence of adequate cover, result in a heavy flush of water that washes away the soil. Crops that have not yet adequately rooted during the early part of the rainy season may also be washed away along with the soil. Farmers cultivating the rugged terrains in the regions of Tigray and Amhara (Wollo, North Gondar, and North Shoa) frequently abandon their farmland after the topsoil is washed away.[7] The soil depth is reported to be 10 centimeters or less in many areas (Hurni 1988.).

Studies indicate that in many areas erosion exceeds soil formation. Soil formation is estimated at about 15 tons per hectare per year. In the highland regions of the Abbay Basin, soil loss in areas cultivated through traditional practices amount to 122–128 tons per hectare per year. This figure more than doubles in the absence of vegetation. In the Baro subcatchment, the upper plateau with 5–60 percent slope produced soil loss of 46–425 tons per hectare per year. In the Tekeze Basin, Quiha subcatchment soil loss amounted to 33 tons per hectare per year (NEDECO 1997).

The erosive effects of rainfall are significantly augmented by Ethiopia's severe deforestation, its mountainous terrain, and traditional agricultural practices of cultivating steep slopes without protective measures. The loss of forest cover, in turn, is generally associated with greater hydrological variability. Ethiopia's high-intensity storms cause significant erosion, especially at the beginning of the season when the soil is dry. Landslides, gully erosion, and stream bank erosion commonly result from a combination of hydrology and human disturbance.

Deforestation, watershed degradation, road building, and quarrying all contribute to the frequency of landslides that destroy farm lands and infrastructure. Gullies are created mainly as a result of concentrated runoff in natural drainage lines where there is little or no vegetation cover and along footpaths or tracks, such as those near watering points, settlement areas, and frequently used grazing fields. Stream bank erosion causes damage to grazing and croplands adjacent to rivers, destroys the approaches to bridges and culverts, and causes bridge failure by undermining footings.

Where soils fail to drain properly following heavy rains and floods, the water table rises and deposits salt on the soil surface. The salt inhibits plant growth by disturbing the osmotic relations in the root zone. Secondary salinity is also induced by inadequate drainage in irrigation schemes and frequently flooded areas.

Power Generation and Irrigation Reduced by Sedimentation

High sediment loads in rivers can reduce power generation capacity, interfere with irrigation, contribute to flood risk, and affect clean water supplies. Ethiopia's annual average sediment yield ranges between 10 tons per square kilometer (in the southwestern parts of the country) to about 1,500 tons per square kilometer (in the northern and eastern parts of the country).

When sediments settle in reservoirs, the capacity for power generation is reduced in proportion to the sediment ingress into the reservoir. In addition, concentration of sediment at the power inlets has hampered operation of dam bottom outlets as well as power intakes.

While the impact of flooding on the energy sector has been relatively limited, flooding has caused damage to generation equipment at the Melka Wakana and Tis Abbay power plants. The Koka Dam—which provides the only control on the Awash River for irrigation and hydropower generation and regulates water supplies to more than 70 percent of the nation's large-scale irrigation—has lost its flood control capacity because of siltation. Available water for downstream development has sharply declined. The reduced regulation capacity has caused flood damage on farmlands in the upper and middle valleys (MoWR 2002b).

Irrigated agriculture is also threatened by sedimentation in the storage reservoirs and conveyance structures, which adds to the overall operating and maintenance costs. Sedimentation affects water supply to towns that rely on surface water sources as well.

In the city of Gonder, for example, during construction alone, 20–30 percent of the projected volume of the new water system's capacity was lost due to siltation caused by deforestation upstream in the Angereb River. An additional five wells and a pipeline had to be constructed at a cost of approximately Br5 million to augment the town's water supply during the rainy season.

INTERRELATED EFFECTS ON NATURAL RESOURCES AND THE ENVIRONMENT

The Bank's recently completed Country Environmental Analysis for Ethiopia concludes that the country's principal environmental challenges involve complex cross-sectoral linkages. Two of the key environment-development linkages identified by that study relate directly to the challenges posed by Ethiopia's hydrology. They are the lack of integrated water resources management and the "land degradation–food insecurity–energy access–livelihood" nexus. The latter includes unsustainable agricultural land management practices and heavy reliance on biomass energy.

The use of biomass spurs deforestation and erosion and contributes to a significant environmental health problem: exposure to smoke and indoor air pollution, which causes elevated under age five mortality and a high incidence of respiratory diseases, mainly in women and children. Using crop residues and dung as fuel, rather than returning this organic matter to the soil, causes a decline in soil fertility and deterioration in soil structure. The degraded land is also more prone to erosion, leading to loss of fertility in the topsoil and to a reduction in soil depth, both of which can have an adverse effect on crop yields.

The consequences of both deforestation and degraded soil structure include less infiltration of rainfall, which diminishes groundwater recharge; more runoff, which contributes to erosion and siltation; and reduced water storage capacity in the soil, which makes crops less able to withstand drought.

HYDROLOGICAL VARIABILITY: ENDEMISM AND EXPECTATIONS

While the catastrophic effects of drought and flood extremes are apparent, it is less well recognized that even in years of average precipitation, expectations of high variability and endemic droughts and floods affect economic performance and potentially the structure of the economy. In countries where hydrological variability is high and investments to achieve water security are inadequate, variability is a constant economic risk to small investors (such as farm families) and large ones (such as industries), as well as to the nation.

The expectation of variability and the unpredictability of rainfall and runoff are likely to constrain growth and diversification by encouraging risk-averse behavior at all levels of the economy in all years, as economic actors, particularly the poor, focus on minimizing their downside risks rather than maximizing their potential gains. Because they know they could lose everything in a single flood or drought, farm families quite rationally will not invest in land improvements, advanced technologies, or agricultural inputs, and thus constraining agricultural output and productivity gains. Lack of such investments can lead to land degradation and desertification, which will result in a vicious circle of reducing production and deteriorating assets.

Controlling these real and perceived risks can produce an "input impact" whereby farmers invest in inputs that will increase yields and sustain productivity. Recent research carried out by Dercon and Christaensen (2005) suggest that when downside risks to farmers are reduced by one standard deviation, the use of fertilizer may increase by about 7 percentage points and fertilizer application rates by 43 percent.

Similarly, interruptions in water supply and transportation services caused by hydrological variability are a significant disincentive for investments in industry and services. This disincentive will slow the diversification of economic activities and maintain an economic structure that is based largely on low-input, low-technology, agricultural production.

Understanding and mitigating the full impact of hydrological variability on economic performance will require a better understanding of the role of expectations and the incentives created by entirely rational risk aversion.

INTERNATIONAL WATERS: TENSIONS AND OPPORTUNITIES

A serious challenge for Ethiopia is the fact that it shares so many international rivers. Ethiopia sits at the headwaters of three significant transboundary rivers: the Nile, the Gash, and the Juba-Shebele.[8] These waters are shared with numerous riparian states: Burundi, Democratic Republic of Congo, Egypt, Eritrea, Kenya, Rwanda, Somalia, Sudan, Tanzania, and Uganda.

There are tensions, to a greater or lesser extent, between riparian nations on all international rivers. In some cases these tensions undermine broader relations among riparian states and inhibit potential economic growth by blocking regional integration, both in river-related production and in trade and infrastructure interconnection "beyond the river" (Grey and Sadoff 2002). Tensions over shared rivers encourage the adoption of less economically efficient polices that focus on self-sufficiency (for example, in agriculture and power) rather than on trade and integration. There is a real risk that these tensions could result in the diversion of strategic human resources and policy focus from economic development to security concerns related to water and even a diversion of financial resources to military preparedness.

Recognizing this, the GoE is engaged in a serious effort to promote cooperative development and management of the largest of its shared rivers, the Nile, through the Nile Basin Initiative (NBI). Ethiopia is playing a leadership role in the NBI, which is building trust and capacity across the Nile Basin and provides the framework for preparing and implementing a major program of investment.

Within the Eastern Nile Subsidiary Action Program, Egypt, Ethiopia, and Sudan are currently preparing investments in irrigation, hydropower, watershed management, and flood mitigation and have begun to identify a longer-term program of major, cooperative, multipurpose development of the river. This riparian cooperation brings huge opportunities and even the potential for transformational change in Ethiopia.

3 Water Resources and Key Economic Sectors

This section looks at the specific impacts of Ethiopia's extreme hydrological variability on its key economic sectors and services: water and sanitation, agriculture (including livestock and fisheries), transportation and market infrastructure, energy, urban development, and industries such as manufacturing, banking, and tourism.

WATER SUPPLY AND SANITATION

The GoE's National Water Resources Policy states that the highest priority use of water is human and livestock consumption, which amounts to less than 1 percent of total water usage. Still, according to the GoE, only a minority of Ethiopians—42 percent—has access to potable water services and some 11 percent have access to improved sanitation. Coverage is highest in urban areas, where about 83 percent of the population has access to improved water supply and 55 percent to improved sanitation facilities.

In most areas, women and girls spend considerable time fetching water from wells or rivers, and then care for those who become ill from waterborne diseases, tasks which keep them from engaging in income-generating activities and attending school.

The primary source of raw water for urban and rural water supply is groundwater, though some towns rely on surface water. Groundwater contamination is not generally a problem, but in some areas there are high concentrations of substances such as iron and fluoride. However, rainfall variability can affect recharge of groundwater, resulting in failure of wells, as in Mekele.

Where surface water is the source of raw water, such as in Gonder, Ambo (80 kilometers west of Addis Ababa) and Nazret, siltation has driven up the cost of drinking water. Surveys of Legedadi Reservoir (upper Awash River basin), which provides the water supply to Addis Ababa, indicate that between 1986 and 1996 raw water turbidity increased from an average of 123 formazine turbidity units to 520 formazine turbidity units, with consequent increases in treatment costs as well as other operation and maintenance costs (Addis Ababa Water and Sewerage Authority 2000).

Competing Uses

Although the National Water Resources Policy gives highest priority to drinking water for the population and livestock, regulations regarding allocation of water resources between consumptive uses are not always enforced. In Harar, for example, a new water supply system must now be constructed at a very high cost because Lake Alemaya, the source of the city's water supply, was practically pumped dry by farmers growing chat for export (see Box 3.1).

Coverage Targets and Required Investment

Ethiopia's population is expected to grow by almost 27 million by 2015. Most of the growth will continue to be in rural areas, but 17 percent will be in medium-sized towns and 5 percent in urban areas, putting stress on already inadequate water and sanitation systems (see table 3.1).

The GoE's Sustainable Development and Poverty Reduction Program (SDPRP) identifies water and sanitation among the key issues to be addressed in order to reduce poverty by enhancing rapid economic growth and improving service delivery. The SDPRP targets for the medium and long term, consistent with the Millennium Development Goals (MDGs), are to halve by 2015 the proportion of people without sustainable access to safe drinking water and sanitation. To achieve this about 35 million more people in rural areas will need improved water and sanitation services and 8 million more people in urban areas will need sanitation facilities (see Table 3.2 and Figure 3.1). The estimated investment required to meet the MDGs is over $170 million.

The GoE, with international support, is making real progress in the sector. Between 2002 and 2005 the percentage of people with access to potable water increased from 30 to 42 percent, and the percentage of those with access to sanitation services increased from 7 to 11 percent. Current aid allocations for water and sanitation from the Bank and the African Development Bank amount to US$164 million, with another US$60–70 million per year allocated by the GoE.

Water supply and sanitation in both urban and rural communities are characterized by low levels of service and lack of sustainability. User fees are often so low that they do not even provide for adequate maintenance of existing facilities. Urban piped water supply systems often operate well below capacity due to maintenance problems. Rationing and service interruptions are frequent. Water utilities tend to be understaffed and staff are often underpaid, inadequately trained, and lacking in the resources required to do their jobs.

Although water supply systems in the larger cities have recently been improved, they need to be expanded to meet the demands of population growth and the planned industrial zones. In rural communities, water systems have too often been installed without adequately training the communities to manage and maintain them. When systems break down, communities often do not have the wherewithal to obtain spare parts and maintenance support.

Box 3.1. Weak Regulation of Competing Consumptive Uses in Harar

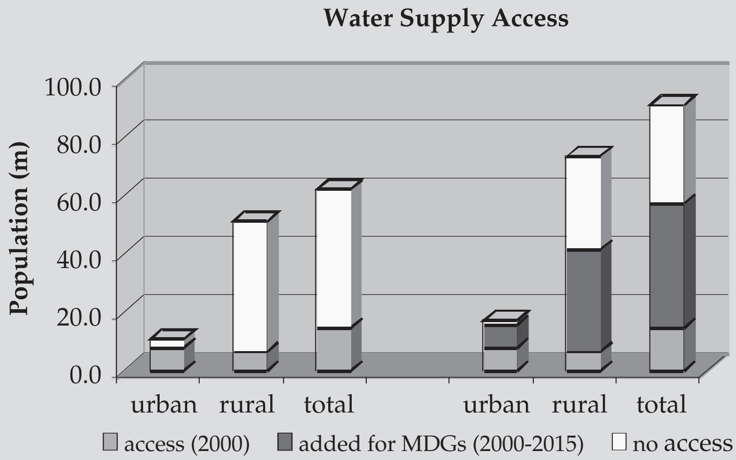
For about 50 years, the people of the city of Harar relied on Lake Alemaya for water supply. As recently 2000, the depth of the lake was approximately 8 meters. But a combination of low rainfall and increased reliance on the lake for irrigation caused the lake level to drop to 20 centimeters. The lake has virtually disappeared.

Farmers in the area had been growing chat for local consumption. Since about 2000, the demand for chat increased and is now Ethiopia's second leading export crop. To meet demand, farmers brought in high volume pumps and drew water from the lake around the clock for irrigation. Ethiopia has regulations for allocation of water resources between consumptive uses, but owing to lax enforcement, Lake Alemaya is now almost gone.

The water supply situation in the town is desperate. Families are paying a high price to have water delivered by vendors. The town has stopped giving licenses for new commercial and industrial businesses until the water supply situation is solved.

Source: Authors.

Figure 3.1 Access to Water Supply: Millennium Development Goals



Source: Adapted from World Health Organization Joint Monitoring Program.

Limited Financing

Budget resources combined with donor and bilateral assistance have been insufficient to significantly improve coverage and will be insufficient to meet Poverty Reduction Strategy Paper and MDG targets for water supply and sanitation unless funds can be channeled more efficiently and effectively. Donors and bilaterals have funded a myriad of projects with different policies and implementation arrangements, some through the federal GoE and some directly to regions, towns, or rural communities. As a result, transaction costs have been high.

For urban water supply, full cost recovery requires that user fees are set at a level sufficient to cover operating and maintenance costs as well as investment costs for systems improvements and expansion. Ethiopia has not achieved full cost recovery in the past, and as a consequence utilities have not been in a position to expand or improve their systems, nor to attract private sector financing to do so. The GoE is actively exploring ways in which to align the immediate imperatives of providing affordable services to growing populations (which may require time-bound, targeted subsidies), with the financing needs and options of utilities whose long-term goal is full cost recovery.

Decentralization and Capacity Constraints

Until recently, the federal GoE has been responsible for identifying, planning, and implementing

Table 3.1. Population Distribution by Settlement Size

	Rural	Small towns	Medium towns	Urban	Total
Settlement size (by population)	**<2,000**	**2–10,000**	**10–75,000**	**>75,000**	
Population 2000	51.5 m (82%)	1.4 m (2%)	7.0 m (11%)	2.6 m (4%)	62.5 m
Population 2015	67.8 m (76%)	1.7 m (2%)	14.8 m (17%)	4.9 m (5%)	89.2 m
Number of settlements	125,000	580	65	1	

Source: MoWR (2002).
Note: "m" = millions

Table 3.2. Access to Water Supply and Sanitation

	2000			2015 MDG			GAP (2000–15)	
	Population (million)	Access (million)	Access (percent)	Pop (million)	Access (million)	Access (percent)	Added (million)	Investment (US$/year)
Water								
Rural	51.5	6.7	13	73.8	41.7	57	35.0	97
Urban	11.0	8.0	73	17.5	15.8	90	7.8	34
Total	62.5	14.7	24	91.3	57.4	63	42.8	131
Sanitation								
Rural	51.5	3.1	6	73.8	39.1	53	36.0	12
Urban	11.0	6.1	62	17.5	14.2	81	8.1	28
Total	62.5	9.2	15	91.3	53.3	58	44.1	40

Source: Adapted from World Health Organization Joint Monitoring Program.

water supply and sanitation improvements. Many of these responsibilities are now being shifted to the regional and local governments, consistent with the GoE's policy on decentralization.

The GoE's overall policy on decentralization is reflected in the National Water Resources Policy, which states that ownership and management autonomy should be devolved to the lowest possible local level. The GoE has provided block grants to woredas (districts), which can be used to improve water supply, among other things, at the discretion of the local governments. But regional and local governments have limited capacity to carry out these new responsibilities. In the future, the Ministry of Water Resources (MoWR) will focus on facilitation and regulation of the sector rather than on implementation.

There is wide disparity in capacity between the more developed regions (Amhara, Oromiya, Tigray, Harari, and outhern Nations, Nationalities and Peoples [SNNP]) and the emerging regions (Afar, Somali, Benshangul, and Gambela). The standard approaches to improving water supply in the highlands simply do not work in the pastoralist regions. Emerging regions will likely need significant capacity building and continued support from the MoWR until they develop capacity to plan, prioritize, implement, and monitor their own investment programs.

Sanitation

With the exception of Addis Ababa, which has a sewerage system, households are expected to finance, install, and maintain their own sanitation facilities—latrines and septic tanks—though some subsidies are provided for demonstration projects. The GoE's role has typically been to promote sanitation and hygiene and to provide an enabling environment for private sector service providers. The low coverage level—15 percent of the population—is partly attributed to the fragmentation of responsibilities across different government institutions and lack of effective coordination. In addition, towns and cities have not integrated planning for sanitation and hygiene with water supply improvements, as called for in the National Water Resources Policy.

Most towns do not have adequate means of septic removal (vacuum trucks) and many do not have designated areas for waste disposal or do not adequately enforce regulations. This situation contributes to environmental degradation of the cities and, in some cases, to contamination of the water supply. The SDPRP recognizes the need for sewerage systems in a number of growing cities and for expansion of the Addis Ababa sewerage system over the coming 10 years. The investment needs for urban sanitation will be considerable.

Table 3.3. Sectoral Shares of GDP (Percentages)

Sector/year	1980–1 to 1991–2	1992–93 to 2000–1
Agriculture	52.9	48.2
Industry	11.9	10.8
Services	35.2	44.0

Source: MoFED.

Urban Wastewater

Urbanization, industry, and services all create additional water demand and generate wastewater, potentially diminishing both water quantity and quality. Abstraction for these purposes will lower flow levels and require tradeoffs among users. Flows from urban watersheds are likely to contain significant quantities of pollutants.

A reduction in the natural river flow together with a discharge of poor quality drainage water can have severe negative impacts on downstream users and the environment. The health of downstream settlements is at risk. Habitats both within and alongside rivers are particularly rich, often supporting a high diversity of species. A large reduction in riverflow combined with a heavy pollution load will alter micro-habitats, of which wetlands are a special case. It is particularly important to identify any endangered species whose survival is endangered because of their restrictive ecological requirements. In addition, fish and other animals may become contaminated by untreated wastewater, which has significant implications for product quality and public health.

AGRICULTURE, LIVESTOCK, AND FISHERIES

Agriculture accounts for the lion's share of the Ethiopian economy (almost 50 percent of GDP), followed by services (38 percent) and industry (11 percent), and employs the majority of the population (80 percent). The economy has shown little sign of transformation over the past two decades: the share of agriculture remains high, with only a slight decline, from 52.9 percent in the 1980s to 48.2 percent in the 1990s (see Table 3.3.)

Because of its dominant share in the economy, fluctuations in agriculture are reflected in the GDP, as shown in Figure 3.2. These fluctuations have undermined the country's ability to sustain per capita growth rate in the 1980s and 1990s.

Until the late 1950s, Ethiopia was not only self-sufficient in staple food but was actually a net exporter of food grain. In the 1960s the average per capita food production was about 280 kilograms per year. However, since the early 1970s, domestic food supply has often failed to meet the food requirements of the people. Even though sufficient food has been produced in most good years, average food production during the last decade remained almost stagnant. Over the past 30 years, per capita food production has declined to about 160 kilograms per year.

At present, more than half of the population is food insecure, mainly because of limitations of rural land holdings, where more than one-third of the households farm less than 0.5 hectares of land under rainfed agriculture with minimal agricultural inputs. Depending on rainfed agriculture puts Ethiopians at the mercy of the country's extreme hydrological variability. Drought is by far the most important constraint on agriculture at national level, but flooding and frost can be equally important in specific areas.

In addition to crop loss or damage in a given year, flood and drought can take a heavy toll on long-term productivity. The loss of topsoil because of heavy rains diminishes organic matter and available nutrients, compromising soil fertility. Loss of vegetation cover in the highlands and degradation of soil structure reduces water infiltration rates, which lowers base flows, and hence water availability for crops. Lower infiltration rates, in turn, can increase runoff and thus the likelihood and intensity of floods.

Declining agricultural productivity, in turn, inhibits investments in land management and encourages the extension of agricultural lands (rather than intensification of production) leading to further land degradation, closing a vicious circle that leaves the landscape increasingly fragile and increasingly vulnerable to drought and rainfall-related erosion.

Given the dominance of agriculture in the Ethiopian economy, the weak and variable performance of this sector will significantly impact the broader economy. Impacts will be transmitted through price and income effects, loss of assets, disincentives to investment, and public health.

Rainfed Agriculture

This section describes in detail the impacts of hydrological variability on the country's major rainfed crops: cereals, pulses, oilseeds, and coffee. It discusses the limited amount of irrigated agriculture. It also describes the current situation and trends regarding livestock and fisheries.

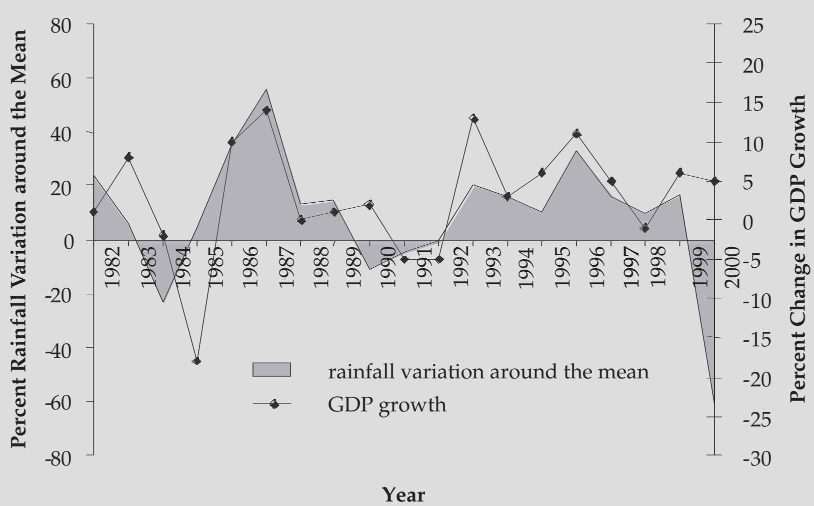
The dominant agricultural system in Ethiopia is small-holder production of cereals under rainfed conditions, with a total area of approximately 10 million hectares.

Cereals

Fluctuations in cereal yield levels are extremely high and closely follow the pattern of rains. There is a significant correlation between national cereal yield and national average rainfall.0 National yield levels declined by as much 25 percent in 1984, 17 percent in 1994, and 10 percent in 1997. Because of these fluctuations, the mean cereal yield showed little change over the years and remained at less than 12 quintals per hectare. With less than 1 percent growth rate in yield, nearly all increase in production over the years was due to expansion in the area of cropland. Expanding cropland area, rather than enriching the soil of current cropland, can contribute to deforestation and land degradation.

Farmers do not plant if there is no rain at planting time. Planting during the small rainy season (belg) is often interrupted if there is no rain early in the season (February–March). Little or no rain in June could also mean that most cereals (with the exception of teff, which can be planted in July) cannot be planted. If the rains decline or disappear after planting, near complete or complete crop failure is

Figure 3.2 Rainfall Variation Around the Mean and GDP Growth



Source: Compiled from SIMA and African Rainfall and Temperature Evaluation System data.

possible. Seriously affected areas are generally excluded from reporting, and, hence, the area under cultivation declines sharply in years of unfavorable weather.

Pulses and Oilseeds

Pulses and oilseeds yields are even more sensitive to weather and pest conditions than cereals. The annual yield of pulses declined by 37 percent in 1998, 24 percent in 1984, and more than 10 percent in 1983, 1985, 1987, and 1993. Fluctuations in the yield of oilseeds were of an even greater magnitude, declining by 10 percent or more in 8 of the 21 years. There is a similar extreme swing in the area under cultivation of pulses and oilseeds, as virtually no planting occurs under adverse weather conditions. Because the risk of crop failure is so high, farmers may be unwilling to spend money on fertilizers and other inputs. Fertilizer is applied to only 14 percent of pulses and 7 percent of oilseed crops.

Coffee

Coffee is Ethiopia's most important export earner, accounting for 40–60 percent of exports in value. Various taxes on the crop constitute an important source of government revenue. About 15 million people in Ethiopia are believed to depend on coffee for their livelihoods. However, Ethiopia's coffee production is very sensitive to rainfall conditions: Drought and untimely rains have frequently caused severe fluctuations in the level of the coffee harvest.

Total coffee output has showed no sustained increase over the last two or three decades. Coffee production has not yet rebounded to the level attained just before the 1984–5 drought. After the drought, production dropped 40 percent, much greater than the drop in food crop production. In 2002–3, the coffee harvest declined by 30 percent due to drought in coffee-producing areas of the western, southwestern, and eastern parts of the country, according to the U.S. Famine Early Warning System Network. Unlike the annual crops that may rebound the next year, coffee production takes up to four years to recover to its original level.

Because of drought and low coffee prices, farmers in many parts of the country are reportedly uprooting their coffee trees and replacing them with chat (a mild, leafy stimulant) or with maize. An estimated 75 percent of coffee farmers in the Hararghe highlands (home to the famous, highly aromatic Harar coffee beans) have uprooted their trees and planted chat, according to the Oromiya Coffee Farmers Cooperative Union. Removal of tree crops, and the forest cover often associated with coffee cultivation, contributes to deforestation and soil erosion.

Irrigated Agriculture

Less than 5 percent (about 200,000 hectares) of the estimated potential 3.7 million hectares of irrigable land in Ethiopia is under irrigation. Four types of irrigation are practiced: traditional (38 percent), modern communal (20 percent), modern private (4 percent), and public (38 percent).

- Traditional irrigation: Has been practiced in Ethiopia for centuries. The traditional schemes are generally based on community-constructed diversions, which are frequently washed away with rainy season floods, requiring significant investments in labor by the community during the growing season.
- Modern communal: Small-scale irrigation was promoted after the 1974 land reforms and actively encouraged following the 1983 drought. These schemes were developed by the GoE or nongovernmental organizations with beneficiary farmers usually operating and maintaining them through users' associations.
- Modern private: Were initially developed in the 1950s and 1960s by foreign investors for sugar and cotton farms. This category ceased to exist when these farms were nationalized in the 1970s, but they have begun to re-emerge in the past 10 years through denationalization and the development of new enterprises.
- Public systems: Replaced the private systems after nationalization and are now being abandoned or privatized.

Irrigation Development Program

The GoE's Irrigation Development Program (IDP) calls for an additional 274,000 hectares to come under irrigation within its 15-year plan period of 2002–16, an increase of 135 percent over current levels. Total investment requirements for the plan are estimated at US$1,683 million.

The IDP has set average annual growth rate targets for developing irrigated areas. These include: 4.5 percent during the short term, 5.5 percent during the medium term, and 6.5 percent during the long term. For the short term, these targets translate into irrigated area of 147,000 hectares of large- and medium-scale irrigation schemes and 127,000 hectares of small-scale irrigation schemes. According to these targets, new projects will add 274,000 hectares to the 197,000 hectares already under irrigation, resulting in a countrywide total of 471,000 hectares of irrigated farmland by 2016.

Since the IDP was launched, more recent government plans aim to develop about 750,000 hectares of irrigated land by the end of the planning period. Currently three projects (Kesem, Tendaho, and Koga) are under construction, totaling 97,000 hectares. Another 12 projects are scheduled for completion by 2010, adding about another 259,000 hectares (Tafesse 2004).

The IDP projects are expected to reduce the national cereals deficit by 11 percent and deficits in seed cotton and sugar crops by 24 percent each. These estimates are based on the assumption that 50 percent of newly irrigated areas will be devoted to cereals and 50 percent to cotton and sugar crops.

Livestock

Ethiopia has the largest livestock population in Africa, about 35 million tropical livestock units. At the national level, livestock accounts for 11 percent of export earnings, second only to coffee, and about 15 percent of GDP (30 percent of the agricultural GDP). It is estimated that 40–90 percent of the cash income of rural households is generated through the livestock sector. In addition, cattle provide draft power and rural transport. Cattle dung is a source of soil fertility and fuel for household energy (Tafesse 2004).

Livestock are an integral part of nearly all mixed-type highland farming systems. Livestock is also the major component of the livelihoods of the pastoralists in the arid and semiarid lowlands of the country. Pastoralism is practiced extensively, particularly in the Somali and Afar regions, in the Borana zone of the Oromiya region, in the South Omo zone of the SNNP region, in the Benshangul region, and in the Gambela region. Ethiopia's lowland pastoral areas encompass more than 60 percent of the country (500,000 square kilometers) and contain more than 11 million animals and 7 million people.

Increasing human and livestock population pressure has caused serious natural resource degradation, and droughts are becoming more frequent. The pastoralists' capacity to cope with drought has declined to the point where survival of viable pastoral production systems is threatened.

Drought in a pastoral system can degrade both land and water resources, making recovery more difficult with each cycle. When water is scarce, livestock populations become concentrated around the remaining water sources, removing vegetation, compacting soil, polluting water, and accelerating land degradation. The high concentration of animal waste often pollutes the water sources, which can spread parasitic infestation to both animals and humans, posing major risks for public health.

Historically, pastoralists coped with drought by migrating to greener pastures. However, migration is now constrained by the expansion of settlers due to fast population growth. Some pastoralists still try to cope with drought by moving beyond their normal range. For instance, in 1999–2000, Somali pastoralists from the zones of East Gashamo and Warder traveled hundreds of kilometers toward Gode looking for pasture and water. Such movement beyond traditional boundaries may result in conflict and loss of lives.

Drought reduces the availability of livestock fodder. In the highland areas the availability of crop residues limits the impact of drought, but in pastoral areas grazing land is the only source of feed. A rough estimate of the feed balance in good and bad rainfall years shows that feed production covers all the requirements only in exceptionally good years. There is a 35 percent deficit in normal years, and a 70 percent deficit in drought years.

As supplies of grazing and water diminish, households reduce herd size by selling first small ruminants and later cattle such as older males and young animals unlikely to survive stress. But mass sales of this nature saturate the market, leading to a decline in the value of livestock and, as happened in 2003, a reduction in the price of meat. The decline in livestock prices is in sharp contrast to the rise in cereal prices during drought. The eroded livestock-cereal terms of trade during drought often puts herders and mixed farmers in marginal areas at a considerable disadvantage (Webb et al. 1992).

Many livestock owners do not sell their animals in time, hoping that the rains will come before it is too late. But the animals lose weight and value and eventually die under prolonged drought.Losses of animals and shrinkage of grazing resources due to recurrent drought have reduced the number of animals per household in the pastoral areas.

Mesfin (2002) estimated that during the 1999–2000 drought, herd size declined by as much as 80 percent in Oromiya and Somali, and between 45 and 50 percent in Afar and the SNNP region. In Borana, South Oromiya, the number of heads of cattle per household reportedly fell 37 percent from 1980–1 to 1996. The impact of such decline in the number of animals owned is obviously devastating since the pastoralists have no other store of wealth.

Full recovery from a given drought year has become increasingly difficult (Webb et al. 1992) because of the increase in the frequency of the drought and shortage of feed even in normal years. In 1999–2000, a rural household on average owned 4.1 head of cattle (including oxen) and about 21 percent were found to have no cattle at all (MoFED 2002). This loss of assets undermines consumer expenditures and future investments in the economy.

Fisheries

Although fish consumption is not commonplace in Ethiopia, it has increased in popularity in Addis Ababa and other urban centers in and around the Rift Valley lakes area over the last 20 years. Catching fish in the Rift Valley lakes has so far kept pace with the increased demand. Elsewhere the fishing potential has hardly been touched.

About 120,000 square kilometers of Ethiopia's area is covered by water and water courses, which may be exploited for fisheries directly or through enhancement. However, knowledge of stock sizes and the means to exploit them are not yet known for each fishery waters. Empirical estimates put the country's total fishery potential at 40,000–50,000 tons per year. Currently only 20–30 percent of this amount is exploited, leaving considerable room for expansion.

TRANSPORTAION AND MARKET INFRASTRUCTURE

In many years, areas of Ethiopia with high agricultural potential can produce enough food to meet the needs of the people in the food deficit areas. However, because of poor communication and transport infrastructure and the lack of storage and marketing facilities, people living in food-deficit areas continue to face famine and food insecurity while producers in surplus regions endure unattractively low prices.

In most areas, farmers sell their surplus in small open-air local markets because high transport costs prevent them from accessing market towns and urban areas that have a wider range of participants, including wholesalers, retailers, part-time farmer-traders, brokers, agents, assemblers, processors, and consumers.

Anywhere outside the small all-weather road network, farmers and potential investors must assume there will be disruptions and unpredictable costs involved in moving their goods to market. The risk associated with these uncertain costs, and the additional uncertainties associated with inadequate market infrastructure once goods are delivered, is a strong disincentive for investment in marketable agricultural surpluses and non-agricultural production, which helps keep the economy trapped in a low-level subsistence equilibrium.

Improved market functioning would benefit both producers and consumers by reducing marketing margins, thereby raising and stabilizing farm incomes and reducing the cost of food to consumers. Well-functioning agricultural markets promote farmers' incentives to use productivity-enhancing inputs, invest in land management, and reduce dependence on food aid for survival.

Road Network

Ethiopia's rugged topography and torrential tropical rains make the cost of building and maintaining roads extremely high. Inadequate road maintenance adds so greatly to the costs of transport that many operators are reluctant to provide services during the rainy seasons. Human portages and pack animals are still the main means of transport in the country.

Only 25 percent of Ethiopia's area is served by a modern road transport system, and only a relatively small percentage of those roads are paved and generally passable year round (see Table 3.4 and Map 3.1)The road network is made up of an estimated 33,000 kilometers of roads, 3,800 kilometers (12 percent) of which are paved all-weather roads and the remaining 29,000 kilometers are gravel or earth surfaced. More than half of the road network needs to be rehabilitated or reconstructed,

Table 3.4. Road Passability

Region	Number of months the dry season road is impassible	Number of months the dry season road is impassible for four-wheel vehicles	Percent of woreda cut off during the impassable period
Tigray	5.4	6.0 (probably 4.0)	22.0
Amhara	4.6	3.3	27.9
Oromiya	3.2	2.3	28.8
Total	4.3	3.5	26.4

Source: Amha and Gabre-Madhin (2003).

and most of the remaining network is either in, or falling into, a state in which routine and periodic maintenance may be insufficient.

Road density in Ethiopia is one of the lowest in Africa: At 27 kilometers of roads per 1,000 square kilometers of land it is well below the African average of 50 kilometers per 1,000 square kilometers. Some 70 percent of farms were reported to be more than half a day's walk from an all-weather road in 2002 (FDRE 2002) and 17 kilometers to the nearest commercial transport (World Bank 2005b). Even so, road transport accounts for roughly 95 percent of the country's passenger and freight traffic and provides the only form of access to most rural communities.

Most of the all-weather roads radiate from the capital, Addis Ababa, to major towns. Direct links between regions are rare, with few roads directly linking regional towns to one another. As a consequence, the road distance between two towns is often twice the air distance.[13] This significantly diminishes the potential returns to interregional trade, and little such trade is seen. If it were profitable, interregional trade could help to integrate and strengthen the national economy by creating trade between surplus and deficit regions and regions producing complementary outputs.

Rain Damages Roads

Unpaved roads are extremely vulnerable to floods, landslides, and gully erosion. Unless rain water drains properly from unpaved roads, the road surfacing construction material is washed away, resulting in a bumpy washboard surface. Such roads require frequent expensive maintenance. In addition, they create significant inconvenience for travelers and costs for vehicle owners. According to Pavement Management Branch of the Ethiopian Road Authority (ERA), water-related damage accounted for over 35 percent of the defects in federal paved roads and 60 percent of the defects in unpaved roads reported from 2000 through 2002 (see Tables 3.5 and 3.6).

Tafesse (2004) demonstrates that water/hydrology related defects are markedly more pronounced where the mean annual water surplus (that is, runoff) is higher (see Figure 3.3). The actual costs for water-related road maintenance vary according to the annual rainfall, from a low of 4 percent in Dire Dawa, where annual rainfall is less than 100 millimeters, to 28 percent in Sodo, where the average annual rainfall is 700 millimeters.

The ERA also reports that floods following torrential rains cause frequent landslides and washouts of drainage structures. Few records exist, however, as to the extent, location, cause, duration, and cost of traffic disruptions. ERA identifies watershed degradation as the root cause of increased flood intensities.

Road Sector Development

In 1997, the GoE launched a 10-year Road Sector Development Program (RSDP) (1997–2007). Under the first five years, completed in 2002, the focus was on rehabilitation of the core road networks. Substantial progress was achieved in reopening nearly all of the classified roads,[15] and accessibility improved and the percentage of roads in good condition was increased. The total length of paved roads was increased to 1,760 kilometers from 840 kilometers in 1994, and total length of unpaved road was increased from 2,877 kilometers to 3,585

Map 3.1

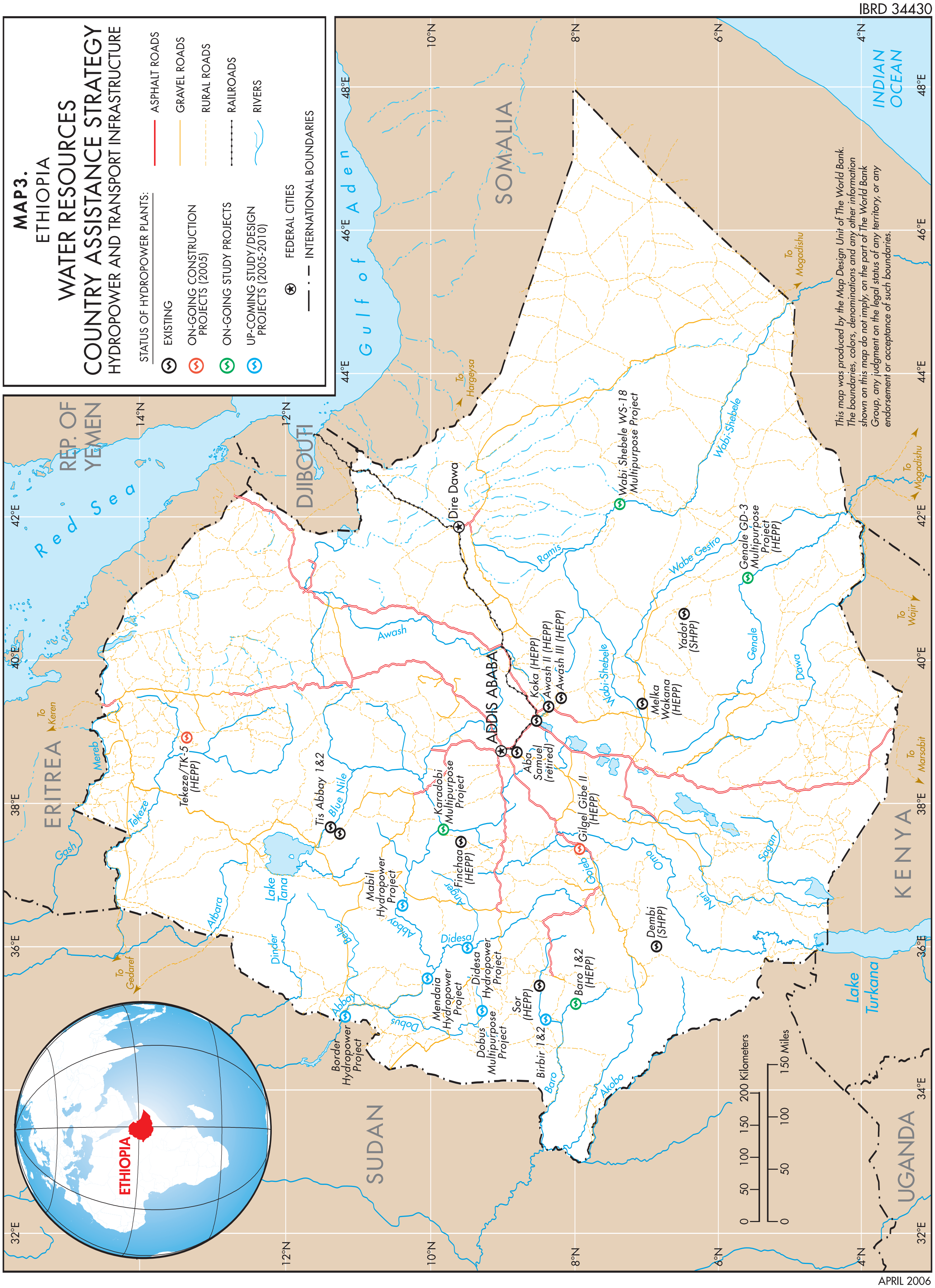

IBRD 34430
MAP 3.
ETHIOPIA
WATER RESOURCES
COUNTRY ASSISTANCE STRATEGY
HYDROPOWER AND TRANSPORT INFRASTRUCTURE
STATUS OF HYDROPOWER PLANTS:
EXISTING
ON-GOING CONSTRUCTION PROJECTS (2005)
ON-GOING STUDY PROJECTS
UP-COMING STUDY/DESIGN PROJECTS (2005-2010)
FEDERAL CITIES
INTERNATIONAL BOUNDARIES
ASPHALT ROADS
GRAVEL ROADS
RURAL ROADS
RAILROADS
RIVERS
ERITREA
REP. OF YEMEN
DJIBOUTI
SOMALIA
KENYA
UGANDA
SUDAN
ETHIOPIA
Red Sea
Gulf of Aden
INDIAN OCEAN
Lake Tana
Lake Turkana
ADDIS ABABA
Dire Dawa
To Keren
To Gedaref
To Hargeysa
To Mogadishu
To Wajir
To Marsabit
Tekeze/TK-5 (HEPP)
Tis Abbay 1&2
Karadobi Multipurpose Project
Mabil Hydropower Project
Fincha (HEPP)
Didesa Hydropower Project
Mendaia Hydropower Project
Border Hydropower Project
Dobus Multipurpose Project
Sor (HEPP)
Birbir 1&2
Baro 1&2 (HEPP)
Dembi (SHPP)
Gilgel Gibe II (HEPP)
Aba Samuel (retired)
Koka (HEPP)
Awash II (HEPP)
Awash III (HEPP)
Melka Wakana (HEPP)
Yadot (SHPP)
Genale GD-3 Multipurpose Project (HEPP)
Wabi Shebele WS-18 Multipurpose Project
Gash
Tekeze
Mereb
Atbara
Blue Nile
Abbay
Dinder
Beles
Angar
Didesa
Dobus
Baro
Akobo
Gojeb
Omo
Awash
Wabi Shebele
Ramis
Wabe Gestro
Genale
Dawa
Sagan
Neri
0 50 100 150 200 Kilometers
0 50 100 150 Miles
32°E 34°E 36°E 38°E 40°E 42°E 44°E 46°E 48°E
4°N 6°N 8°N 10°N 12°N 14°N
This map was produced by the Map Design Unit of The World Bank. The boundaries, colors, denominations and any other information shown on this map do not imply, on the part of The World Bank Group, any judgment on the legal status of any territory, or any endorsement or acceptance of such boundaries.
APRIL 2006

Table 3.5. Percentage of Reported Defects in Paved Roads

Year	Water related	Deformation related	Other
2000–1	56.45	11.40	8.1
2001–2	21.74	17.84	4.5

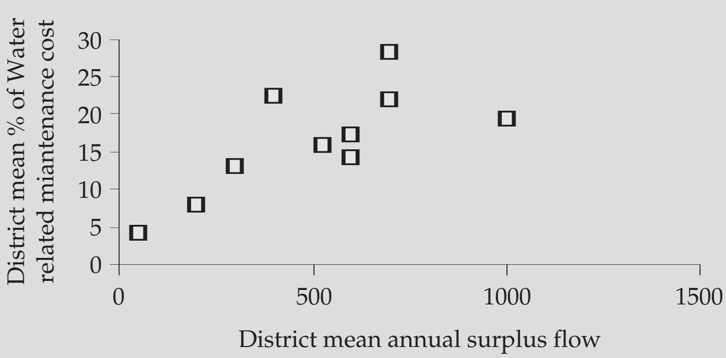
Notes: Water-related defects include ditch clearing, gully formation, and culvert/bridge maintenance; deformation-related defects include rutting, potholes, high traffic, and heavy axle load; other defects include pavement cracking and so on.

Table 3.6. Percentage of Reported Defects in Unpaved Roads

Year	Water related	Deformation related
2000–1	67.76	26.17
2001–2	51.60	29.54

Source: Tafesse (2004).

Figure 3.3 District Mean Annual Surplus Flow Versus District Mean Percent of Water-Related Maintenance Cost



Source: Tafesse (2004).

kilometers. At the same time, substantial progress was made in institutional capacity building and in securing the required levels of funding for maintenance and capital works. Road condition surveys indicate significant improvement in the performance of both paved and unpaved roads.

Based on the lessons learned from the first phase of program, the second phase has been planned through 2015 under low- and high-cost scenarios. The low-cost scenario envisions the rehabilitation of 1,014 kilometers, the upgrading of 1,864 kilometers, the construction of 5,693 kilometers including low-class roads, and the implementation of comprehensive policy and institutional reforms that commenced during RSDP I. In addition it includes heavy and routine maintenance in several types of roads, bridge works, and studies for follow-on operation. The estimated cost is Br19.5 billion (US$2.2

Table 3.7. High-Cost Scenario Road Investment Targets to 2015

Indicators	2003–4	2014–5
Proportion of asphalt roads in good condition	49%	86%
Proportion of gravel roads in good condition	34%	88%
Proportion of rural roads in good condition	36%	52%
Road density/1,000 km2	33 km	91 km
Road density/1,000 population	0.51 km	1.07 km
Proportion of area more than 5 km from a road	63%	28%
Average distance to a road	11 km	4 km

Source: Government of Ethiopia (1996a).

billion). The high-cost scenario involves the rehabilitation of 1,168 kilometers, the upgrading of 2,045 kilometers, and the construction of 8,383 kilometers of roads at an estimated cost of Br62.7 billion (US$7.2billion) (see Table 3.7).

ENERGY AND HYDROPOWER

Ethiopia has an immense renewable energy potential in the forms of hydropower, solar, and wind, as well as significant untapped geothermal resources. However, the per capita electricity consumption is among the lowest in the world. According to the GoE, only 15 percent of the population has access to electricity, and the bulk of consumption (82 percent) is in the household sector.

Presently, 95 percent of national energy consumption is in the form of fuelwood, dung, crop residues, and human and animal power. The remaining 5 percent is electricity, 90 percent of which is generated by hydropower.

This dependence on biomass energy causes increased deforestation, shortages of fuelwood, and degradation of rural ecosystems. The country's forests have diminished to less than 7 percent of their estimated natural extent. The demand for wood products, especially fuelwood, is expected to increase at around 3 million tons annually.

Deforestation in watersheds has contributed to high rates of siltation in the country's reservoirs, which limits the useful life of hydropower structures (and those used for municipal water supplies and irrigation as well), which further increases the cost of modern energy. For example, the Bati and Kombolcha reservoirs in Wello, Amhara,have completely silted up, night storage reservoirs in the sugar estates of Wonji and Metahara near Addis Ababa suffer from sedimentation, and the storage capacity of the Koka Dam in the Awash Valley was reduced by 21 percent between 1959 and 1981 (HALCROW 1997). This loss of reservoir capacity has caused reduced hydropower generation, reduced water availability for irrigation, and reduced capacity to regulate the river, thereby exposing the river basin to general water shortages and to flooding.

Ethiopia currently has 731 megawatts of dependable power, most of it hydropower. The Ethiopian interconnected system provides electricity primarily to the cities of Addis Ababa, Nazret, Dire Dawa, and Harar, and their immediate surroundings and presently has 600,000 customers. The self-contained system provides electricity to the remaining load centers in Ethiopia from isolated mini-hydro and diesel installations.

The present network is severely overloaded and subject to low and fluctuating voltages, which limits its ability to provide connections for large-scale commercial and industrial users. The main issues facing the power sector are the low level of access to electricity provided, the inability to connect large new commercial and industrial customers, and the high cost of future generation investments.

Hydropower electrical systems are especially prone to disruption by drought. During the 2003 drought, for example, power disruptions (caused by load shedding)[16] were common. Each one-day interruption in power during this period was estimated to result in a loss of 10–15 percent of that day's GDP (EEPRI 2003.) Energy-intensive and water-intensive farms were among the hardest hit. This vulnerability can be mitigated by developing alternative sources, such as geothermal, or by expanding generation and the grid so that temporal and spatial variations in hydrology can be balanced.

Inexpensive, reliable electricity could promote significant investment in the more power-intensive industry and service sectors. In agriculture, it could increase the profitability of fertilizer production and pumping for irrigation, both of which would help improve crop reliability and yield.

The GoE's strategy is to aggressively improve the supply of affordable electricity in hopes of reducing the demand for biomass and, thereby, protecting the watersheds. Other key facets of the strategy include development of the country's substantial hydropower resources by both the private and public sector; liberalization of generation transmission, distribution, and supply in isolated areas; commercialization and decentralization of operations; and strengthening the regulatory environment.

Ethiopia's economically feasible hydroelectric potential is estimated to be 100 times more than current production.[17] Recognizing the potential of this resource and the country's need for reliable energy, MoWR has designed an ambitious five-year development program to meet the country's projected demand. MoWR has two projects currently under construction (Tekeze and Gilgel Gibe II), five more in development, and an additional seven under study. While these developments will further increase the dependency of the system on hydropower, future energy developments are anticipated to be an alternating mix of thermal and hydropower (EEPCO 2003). See Table 3.8.

URBAN, MANUFACTURING, AND SERVICES

Urban Centers

Ethiopia is less urbanized than most developing countries in Africa and the rest of the world. Only 12 percent of the population lives in cities. In 2003 there were roughly 300 urban centers with populations of more than 5,000. Only 23 of these had a population of more than 50,000, and only one had more than 250,000 inhabitants. The largest city, Addis Ababa, is 12 times larger than the second city, Dire Dawa. Addis Ababa is growing at a rate of 3.3 percent, quite low by world standards and only slightly above the natural growth rate. The average growth rate of Ethiopia's urban centers has declined from 5.5 percent in 1960–75 to 4.5 percent in 1975–89 and to only 3.8 percent in 1989–99, while the growth of the population as a whole has remained almost constant.

Urban areas contributed 34 percent of Ethiopia's GDP in 1997, compared with 30 percent in 1987. Addis Ababa alone provides about one-fifth of the overall GDP and 52 percent of the modern sector value added. Urban productivity, or value added per urban inhabitant, is nearly four times that of rural areas, and Addis Ababa is 2.5 times more productive than the average of other cities and towns. The GoE's Abbay River Basin master plan states that urbanization contributes to economic diversification and provides "the only" viable base for long-term growth in average incomes.

Ethiopia suffers from the relative weakness of its network of second rank cities, or regional capitals. These market towns are rarely interconnected laterally, or at all, to major road arteries. In many parts of the country the topography and frequent dissection by rivers make both road construction and maintenance extremely expensive. High and intense rainfall and uncontrolled runoff from degraded lands cause floods and road washouts. The dispersed population pattern leaves most of the population more directly dependent on natural resource–related livelihoods and therefore more vulnerable to hydrological variability. The rural settlement pattern also compounds the challenge of mitigating hydrological variability because a dispersed population cannot be provided drought and flood mitigation services (that is, water storage and river regulation) as cost effectively as more concentrated populations.

With 80 percent of the population in agriculture, weak performance in that sector slows demand throughout the economy by diminishing and destabilizing incomes and thus demand for non-agricultural production. Much of Ethiopia's non-agricultural production relies on raw materials from the agricultural sector, which can be in short supply during droughts. The unreliability of raw materials, particularly in combination with unreliable water supplies, discourages prospective investors.

Weak and unpredictable growth in non-agricultural opportunities keeps labor in subsistence agriculture on fragile lands. This contributes to land degradation as poor farmers extend cultivated

Table 3.8. Ongoing and Planned Hydropower Projects

List of projects	Status as of 2005	Installed capacity (megawatts)
Ongoing construction projects (2005)	**Year of completion**	
Tekeze/TK_5	2008	300
Gilgel Gibe-II	2008	420
Ongoing study projects	**Level of of study**	
Baro Hydropower Project	Feasibility study	800
Karadobi Multipurpose Project	Prefeasibility study	1,700
Genale GD-3 Multipurpose Project	Feasibility study	245
Genale GD-6 Hydropower Project	Prefeasibility study	244
Wabe Shebele WS-18 Multipurpose Project	Feasibility study	87
Upcoming study/design projects (2005–10)	**Level of study/design**	
Baro Hydropower Project	Design	800
Genale GD-3 Multipurpose Project	Design	245
Wabe Shebele WS-18 Multipurpose Project	Design	87
Karadobi Multipurpose Project	Feasibility/Design	1700
Genale GD-6 Hydropower Project	Feasibility/Design	244
Mendaia Hydropower Project	Prefeasibility/ Feasibility	1,700
Border Hydropower Project	Prefeasibility/ Feasibility	1,780
Tams Multipurpose Project	Prefeasibility/ Feasibility	1,020
Mabil Hydropower Project	Prefeasibility/ Feasibility	1,440
Birbir Hydropower Project	Prefeasibility/ Feasibility	467
Dobus Multipurpose Project	Prefeasibility/ Feasibility	741
Didesa Hydropower Project	Prefeasibility/ Feasibility	308

Source: MoWR.

areas without the means and incentives to invest in land stewardship and modern inputs, further lowering agricultural productivity.

Manufacturing

Manufacturing is at a very early stage in Ethiopia, with less than a 7 percent share of the GDP. Processing of agricultural raw materials is the dominant manufacturing activity, with food and beverages, tobacco, textiles, clothing, leather, and wood accounting for 65 percent of the manufacturing output in the 1990s. The share of food and beverage production in the manufacturing value added increased from 31 percent during the prereform period of 1983–4 to 1991–2 to 39 percent in the reform period of 1992–3 to 1999–2000.

The manufacturing and services sector is characterized by a weak enabling environment, low levels of domestic and foreign investment, and low growth and productivity. Operations generally run well below capacity due to the high cost and difficulties associated with transportation and marketing, and the unreliable supply of raw materials and power. This uncertainty regarding supply and marketing, plus an inconsistent local demand for non-agricultural products, undermines investments.

A survey of public and private industries conducted by the Central Statistical Authority estimated that capacity utilization averaged 60 percent in public and 39 percent in private manufacturing enterprises in 1998–9. About 40 percent of the manufacturing enterprises claimed market-related problems as the most serious constraint and 29 percent reported that a shortage of raw materials was the most serious constraint (CSA 2000). Shortages of raw materials derive directly from the weakness and unreliability of production in the agricultural sector, which in turn is driven in large part by the variability of hydrology.

Every major drought leaves hundreds of thousands of livestock dead and many more weak and prone to disease. As a result, the cycle of drought continuously diminishes potential growth in the livestock population and compromises the quality of the national herd. Poor quality of hides and skins has contributed to low capacity utilization in the leather sector, which in turn has affected labor productivity. Labor productivity in the leather sector is very low and declining (Ministry of Trade and Industry 2003).

Large- and medium-scale edible oil enterprises were reported to exploit only about 20 percent of their production potential, mainly because edible oil is imported through food aid. One nongovernmental organization was reported to be selling edible oil, which it received as development assistance from U.S. Agency for International Development, at 21 percent below the market price (Befekadu et al. 2000/1).

The performance of the non-agricultural sector is also affected by power interruption in years of severe drought when water shortages cause interruptions in hydroelectric power generation. For instance, during the drought of 2002–3 power was unavailable throughout the country on one day a week for about four months. Each interruption was estimated to result in a loss of 10–15 percent of the GDP for that day (EEPRI 2003). According to the Ethiopian Economic Policy Research Institute, the country appeared to be moving from rainfed agriculture to "rainfed industry."

Banking

Since the early 1990s, the banking sector has been restructured and liberalized to lay the groundwork for private entry into the financial sector and to provide for licensing and supervision of banks and insurance banks. The number of banks increased to nine (six of which are private) and the number of branches expanded rapidly. Total deposits held by the banks increased by 130 percent (from Br10.1 billion in 1994–5 to Br21.1 billion in 2000–1). Loans disbursed to the nongovernment sector increased from Br5.4 billion in 1992–3 to Br17.4 billion in 2000–1 (FDRE 2002).

However, a high rate of default has severely constrained the activities of the banking sector. The ratio of nonperforming to total loans was estimated at around 36 percent in September 2002 (World Bank 2003). Poor lending practices, the war with Eritrea, and fluctuations in agricultural prices (due to variations in weather, leading to changes in supply) have contributed to the deterioration of the banks' portfolios. Default rates on fertilizer loans are also high in rural areas, but the Commercial Bank of Ethiopia (the only supplier of loans in recent years) is protected against such bad loans by the regional governments.[18]

The banking system in Ethiopia is characterized by excess liquidity, reflecting low return to capital, high risk, and inadequate lending practices. Loans to the agricultural sector account for less than 15 percent of total lending and are largely composed of short-term fertilizer loans. The high risk of crop failure and fluctuations of agricultural prices, together with a land policy that disallows the use of land as collateral, have made agriculture unattractive for the financial sector. The industrial sector is also too weak (partly to the weakness in agriculture) to attract loans. Agricultural and industrial sector loans together account for less than 30 percent of the total lending, while the service sector accounts for over 60 percent (World Bank 2003).

Drought-induced default has affected the performance of microfinance institutions and other credit programs in the rural areas.[19] Agricultural loans tend to default all at once during drought, making them unattractive (undiversified) portfolios for banks as well as for microfinance institutions. Borrowers have also been affected by the risk of low prices and depressed economic activities even in normal years.

The challenge is to lay an institutional and infrastructural foundation to protect agriculture and industry from weather risks and thereby attract investment loans. Foreign investors cannot be attracted when the domestic banking sector is sick or weak and foreign banks are absent.

Tourism

Ethiopia has enormous potential as a tourism destination. Apart from the African game and cultural experiences available to visitors, it has a rich array of historic and natural sites that are truly world class. A number of problems, including the high cost and poor quality of tourism services, have constrained the development of the tourism industry. Ethiopian tourism promotion also needs to overcome the images of drought, famine, and war that many foreigners associate with the country.

FOOD AID

Food aid has saved many lives in Ethiopia over the years, and it cuts across other sectors, including agriculture, transport, and manufacturing. However, food aid may actually be creating disincentives for the types of agricultural investments that could result in long-term food security and more sustainable livelihoods. Until Ethiopia develops the infrastructure and market incentives to grow and market its own agricultural produce, it will remain highly vulnerable to the vagaries of the weather.

Safeguarding the lives and health of vulnerable groups is the rational, overriding concern of national drought relief programs. From a political perspective, it is often more palatable for donor countries to provide food aid than financial aid, because the donated crops are produced and purchased in their own economies. However, a system of donated food aid that is relatively easily accessible and not fungible creates incentives to rely on food aid as a rational response to drought rather than investing fungible development funds in proactive drought risk management.

In practice, emergency aid or relief assistance usually supplies specified goods, such as seeds, medicines, and trucks or specific emergency measures such as repair of the water supply and sinking bore holes. Food aid, while greatly valued, is inflexible and usually cannot be redirected to reconstruction or more general development support at the end of the drought if a more rapid than anticipated agricultural recovery is achieved.

Food aid can also create perverse incentives. The expectation of food aid can discourage domestic private sector investment in marketable agricultural production. In years of shortage, when prices are potentially highest, it is reasonable to assume that food aid will arrive and both lower prices (by supplying deficit regions and often leaking into the broader economy) and drive up costs (by competing for transport and distribution services). Continuous food aid also enables people to maintain subsistence agriculture on marginal lands, thereby sustaining settlements and livelihoods that are extremely vulnerable to water shocks and advanced environmental degradation.

Food aid has a significant influence on the transport sector and on incentives for surplus agricultural production. When food aid arrives at the port, transport prices soar and trucks become unavailable to national farmers marketing their product. During the 1984–5 drought, while overall GDP fell 9.7 percent, transport and communication distributive services rose by 8.7 percent, probably to an increase in the long-haul transport of food aid.

Since there is no coordination in the arrival of ships and domestic transport, and to the emergency nature of the food import, all available trucks are diverted to the Port of Djibouti to meet the ships, leaving few to transport food from any remaining productive agricultural areas to the food deficit areas.

A recurring problem has been the stop-go attitude toward drought planning: efforts to mitigate the effects of drought often fall by the wayside once the rains return. National policies favor food aid over proactive contingency planning, ignoring the need to build effective mitigation and response strategies at subnational levels.

Without the active involvement of affected local populations in planning responses, strategies to mitigate the effects of drought often ignore what local people do to help themselves in times of drought, with the unintended effect of undermining local coping strategies and weakening local social capacity. As a consequence, planning for drought is frequently centralized at the national level, and early warning systems are largely designed to serve as tools for food aid planning as opposed to active contingency planning.

4 Water Resources Challenges: Some Priority Responses

The previous two sections have detailed how Ethiopia's dependence on rainfed agriculture creates a web of effects on agricultural output, industry, and power production, which are exacerbated by a lack of both hydraulic and market infrastructure. These impacts are transmitted through input, price, and income effects onto the broader economy. By creating continual uncertainty, the impacts of hydrology can be seen in investments and patterns of growth. Many of these dynamics conspire against structural change in the economy. Endemic drought, fragmented and inadequate and infrastructure, and expectations that food aid shipments will disrupt transportation and tamp down food price spikes during shortages all promote a risk-averse subsistence economy and undercut incentives for farmers to produce surplus, marketable crops.

This section looks at management options to address the complex situation described above. Obviously, it is crucial to develop water storage infrastructure at all scales. But Ethiopia cannot fully mitigate against the impact of hydrological variability through water infrastructure investments alone. Clearly, it will be necessary to look beyond traditional water resources management in order to curtail the negative effects of hydrological variability on the Ethiopian economy by also identifying interventions aimed at decreasing the vulnerability of the economy to these shocks. Unless the structure of the economy changes, stable economic progress will continue to be both intensely disrupted by drought and flood and quietly undermined by risk aversion.

STRENGTHENING WATER RESOURCES DEVELOPMENT AND MANAGEMENT

Opportunities exist to significantly strengthen water resources development and management practices. Attention must be given to interventions that moderate hydrological variability, mitigate the physical impacts of hydrologic shocks on the environment and watersheds, and arrest land degradation. Such interventions will include infrastructure investments to provide storage and regulate river flows and runoff and land and soil management practices to enhance the natural capacity of watersheds to moderate hydrology.

Strengthening Institutions and Capacity

Water resources management is a core issue for development in Ethiopia. In all countries, information and human and institutional capacity are essential for effective water resources management. Given Ethiopia's challenging hydrology, the need for such capacity is great, but capacity in the country is low. Efforts to strengthen capacity are ongoing in Ethiopia and should be seen as a continued priority.

Investment in research and education in particular will be crucial to develop the capacity needed to design effective and appropriate water resource management interventions, watershed management, irrigation schemes, and water and sanitation services. An increased focus on groundwater should also be seen as a priority in this regard.

Increased Water Storage

To mitigate against the economic impacts of water shocks in Ethiopia, greater water storage capacity, both natural and manmade, large scale and small scale, will be needed. Given both seasonal and interannual variability, significant over-year storage will be particularly important. Storage design must take explicit account of the country's extreme hydrologic variability and high sedimentation rates. A wide range of infrastructure investments is needed.

Public investments are needed to provide the water security and incentives necessary to promote private sector investment in inputs that will enhance productivity. This is often described as an "input impact" on patterns of investment for surplus production.

Large-Scale Water Storage

Artificial reservoir storage in Ethiopia is currently estimated to be about 43 cubic meters per capita in contrast to 750 cubic meters per capita in South Africa and 6,150 cubic meters per capita in North America (with most developed countries having figures in the thousands) (see Figure 4.1). Ethiopia would need to invest five times its annual GDP (US$35 billion) to achieve the water storage capacity of South Africa, taking such capacity as an arbitrary benchmark of water security. This order-of-magnitude calculation demonstrates that strategies focused purely on water infrastructure responses are not affordable, so a number of other approaches are also outlined in this section.

Any hydrologic infrastructure developed for Ethiopia must be designed to meet multiple needs. Reservoirs can regulate the variability of surface water in streams or rivers. They can retain excess water from periods of high flows for use during periods of drought and store floodwaters to reduce flood damages downstream. Reservoirs can deliver irrigation water; generate hydropower; slow sedimentation downstream; create fisheries; provide tourism opportunities; help manage watersheds; control flooding; mitigate drought; and provide drinking water, local transport, and recreation.

In Ethiopia, many natural sites are well suited to create storage reservoirs at relatively low costs and with relatively little environmental and social disruption. In the design and economic analysis of potential hydropower development, the benefits associated with drought and flood protection, with sedimentation control, and even with navigation should be—but rarely are—explicitly considered in figuring the economic rates of return.

The Koka reservoir is an good example of a multipurpose reservoir whose construction made it possible to develop about 50 medium- and large-scale irrigated farms totaling 65,000 hectares distributed along the valley from Wonji (80 kilometers southeast of Addis Ababa) to Asayita, and to generate 110 megawatts of hydropower at three run-of-the-river power stations. However, severe soil erosion is leading to rapid loss of Koka's storage capacity.

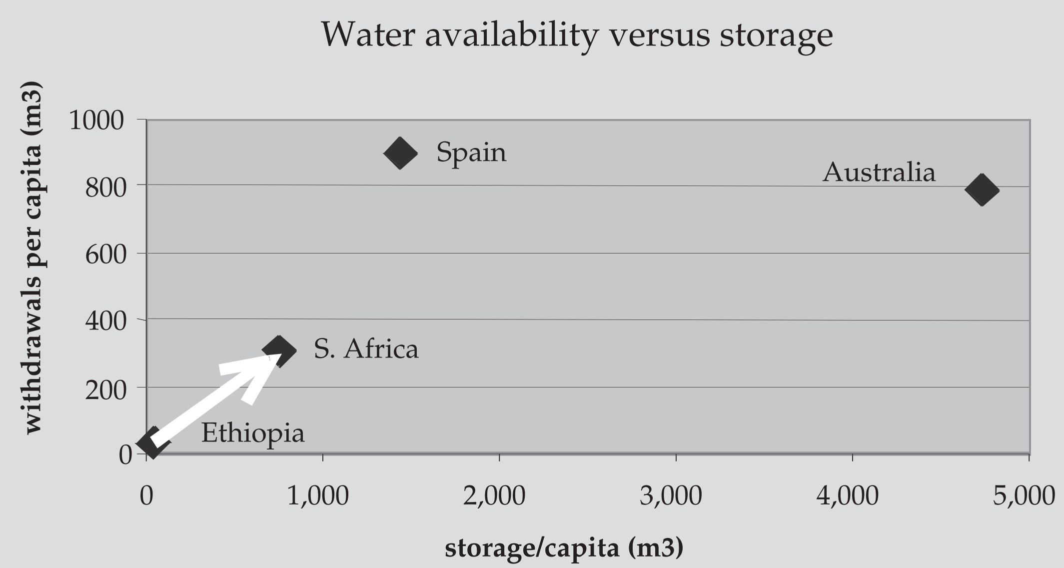
When reservoirs serve multipurpose uses, complex operational tradeoffs arise and are most acute where hydrology is variable and droughts and floods endemic. For example, reservoir levels must be kept low enough to provide flood retention capacity while at the same time full enough to conserve water in the event of a drought. Similarly, water releases for power generation must be weighed against requirements for irrigation, all in line with system requirements such as environmental flows. Issues such as these are commonly resolved through the adoption of reservoir operating rules agreed upon by the various stakeholders.

Given the shared nature of most of Ethiopia's rivers, this broad range of potential benefits and potential positive and negative externalities need to be explored in a transboundary context.

Small-Scale Water Storage

Water harvesting at the household level is an important strategy to bridge water deficits and assist in addressing food insecurity. However, harvest-

Figure 4.1 Water Storage Per Capital in Selected Countries



Source: Compiled from SIMA and KOID databases.

ing structures must be designed in accordance with intended usage and local circumstances, if rainwater harvesting is to be cost effective. The amount of water needed to sustain household agriculture in drought years is substantial.

There is an ongoing debate about the current water harvesting program, which involves construction of a household water storage structure (commonly a concrete-lined pit with a capacity of 40 cubic meters of water, which will irrigate about 100 square meters of land) intended for life-saving irrigation for field crops as well as for vegetable gardening. One writer has claimed (Bezabih 2003) that the structures cost an individual farmer a minimum of Br1,500 (a little less than US$200). However, the return is only Br40–50 per annum. Nevertheless, farmers have reported using the small amount of water in their structures to grow vegetables for home consumption and in some cases for market sales. The amount of water collected can also be increased in some cases.

Water harvesting in the form of runoff management for supplemental irrigation may have significant potential to enable double cropping. For example, Vertisol[20] areas near major cities (for example, Ada and Becho areas around Addis Ababa), which currently grow mainly teff,[21] could use water harvesting to add a crop of vegetables during the long dry season. Water harvesting could be particularly successful in these areas since the temperature is cooler and seepage is lower.

Water Supply and Sanitation Services

The first priority for water is for human and livestock consumption. The benefits of improving clean water supply and sanitation services are well known. The potential economic impacts include decreased incidence of waterborne diseases, which promotes better health and greater productivity and incomes; savings on medication; and time savings, particularly for women and girls, which could allow for more study or opportunities for income generating activities.

Since the setting of wastewater goals and standards is the responsibility of river basin authorities and other public water resources management agencies, planning will require close collaboration between utilities and these bodies. The clear need for investments in infrastructure will require accompanying reform, much of which is underway, to focus on the financial sustainability of utilities, to make them more accountable for their performance, and to integrate sanitation planning and hygiene promotion with improvement of water supply.

In some cases, effective urban water supply planning may require concomitant investments in watershed management, bulk water infrastructure, or river regulation infrastructure. In these cases, sequencing onsite and offsite investments will be important. These decisions should be made in tandem with local demand and the capacity of local institutions. Benefits of water and sanitation services, such as cleaner downstream water, should be considered explicitly in planning.

Irrigation and Drainage

Appropriately designed irrigation investments can provide a secure supply of agricultural water to buffer production during all but the most extreme climatic events and protect the subsector from the greater part of hydrological variability. It can enhance food security and the reliable delivery of marketable and exportable agricultural products, helping to stabilize prices and encourage investment in both the agricultural and non-agricultural sectors.

Ethiopia has significant potential for irrigated agriculture. Critical to its development is the active participation of the private sector in small-, medium- and large-scale enterprises. Attracting private investment requires, in addition to access to relatively reliable water resources at reasonable costs, the appropriate policy environment for investors, security of land tenure, and the necessary access to financial resources.

Investment in irrigation should also be accompanied by attention to water conservation, soil conservation, soil conditioning, and soil productivity. Crops to be grown under irrigation should be carefully selected to maximize the return from investment. Most cereals are not as profitable as cash crops (cotton, sugarcane, and so on), horticulture products (fruits and vegetables) and floriculture products. Developing fisheries in lakes and reservoirs could provide additional income and food for the population.

Potential for Irrigation From Groundwater

Ethiopia's groundwater resource potential is estimated at 2.6 billion cubic meters. One distinct advantage of groundwater is its relative reliability because it is buffered from rainfall variability. The Ethiopian Geological Survey plans to conduct an assessment of groundwater for sustainable exploitation and determine its location and extent.

Groundwater availability estimations indicate that a significant proportion of this resource could be economically used for irrigation and that tubewell irrigation is likely to be a cost-effective option. These wells, ranging from small diameter on-farm single farmer–managed to large community-owned wells, may also be used for domestic water by rural households. Tubewell irrigation can supplement canal irrigation as well as irrigate areas that do not have canal irrigation facilities.

Affordable water-lifting devices, such as small diesel or electric pumps or muscle-powered treadle pumps, have dramatically improved poor people's access to groundwater in Bangladesh, eastern India, and Nepal. For smallholders, the capital requirements to develop groundwater irrigation are generally low and its productivity is higher compared to surface irrigation (Sally 2002).

Drainage Improvement to Protect Soil Productivity

Where drainage is inadequate, the surface runoff from irrigation may accumulate in vertisol fields and cause waterlogging, which can lead to soil degradation. Management practices should be developed to minimize water accumulation on the soil surface in vertisol areas. Subsurface drainage techniques could be costly but effective and long lasting. Other options such as camber beds, broadbed, and furrows and open ditches may be less costly but are only short-term solutions.

Watershed Management

Improvements in watershed management will be a crucial element in managing water resources and, more broadly, riverine ecosystems. Improved watershed management can slow watershed erosion, moderate the hydrological cycle, regulate runoff and groundwater, improve infiltration (hence water retention and base flows), and reduce potential flood damage. Good watershed management will help minimize the impacts of drought and flood on agriculture and sustain agricultural productivity. It can also reduce soil erosion and sedimentation rates, thereby extending the live-storage (useable) capacity of reservoirs, reduce water treatment plant costs, and diminish the costs and increase the life of irrigation infrastructure.

Increasingly, reservoir operators recognize that substantial amounts of storage are lost each year due to sedimentation, and that sediment management in both watersheds and dams is vital for maintaining asset value. Programs for integrated watershed management will improve the sustainability of hydropower production, particularly in watersheds upstream of the existing and planned reservoirs. Hydropower providers are fully aware of the impact of sedimentation on reducing the effectiveness of the assets and are increasingly advocating sound watershed management practices to reduce sedimentation.

An important lesson from experience in Ethiopia is the need to include stakeholders effectively in the planning, design, and management of watershed interventions. This includes extensive consultation with stakeholders, ensuring that resettlement is done well, investing in community management of watersheds, and ensuring that local people become beneficiaries. A strong positive feedback loop in this arrangement is that the development of hydropower to provide electricity will meet the energy needs of more of the population, thereby reducing the demand for biomass and reducing the pressures on the watersheds.

Drought Preparedness

Adjustments to minimize agricultural losses during a drought include the development of local warning systems, grain storage arrangements, selection of climate-appropriate crops, development of a flexible mixed crop and livestock economy, and a system for supplementing income through secondary occupations and seasonal migration for employment. The importance of each of these responses and their degree of success will depend on the present system of land use in any area, the type of soil, the local level of technology, the economic linkages, and the social milieu. However, the response must also depend upon what communities and individuals perceive as the options open to them (Sally 2002).

Early Warning Systems

Effective early warning systems are a critical component of any drought preparedness program, with major benefits for agricultural and hydropower production. However, there is currently a deficiency of reliable meteorological data and observation networks, as well as an inadequate information delivery system. The country must further develop a number of drought preparedness tools by strengthening early warning systems, market information systems, and permanent diagnosis and research centers (agriculture, hydrology, meteorology). These tools can be used to collect and analyze agricultural production data in order to identify and target potential risk areas, thus allowing agencies to initiate appropriate urgent operations.

Livestock Survival

To improve drought preparedness in the livestock sector, investments are needed in small feeder roads, improved water management, fodder banks, and range improvement. Funds should also be set aside to provide rapid responses such as destocking, water tankering, and the control of human and animal disease outbreaks.

ENHANCING ECONOMIC RESILIENCE

The following sections offer options for proactive interventions outside the water sector to enhance the economy's resilience to the impacts of hydrological variability.

Encourage Alternative Livelihoods

Most Ethiopians depend directly on rainfall for subsistence agriculture. Thus, Ethiopia's broader economy is built on domestic demand that is as unpredictable as the rains. Investments and policies must be considered to create opportunities for less water-dependent, more resilient livelihoods.

In a large part of the highlands, the rapidly growing population is outstripping the carrying capacity. As more and more people collect fuelwood and expand their agricultural holdings, the critical upland areas of watersheds are becoming deforested and prone to erosion. Ultimately, population planning, community action, and alternative livelihoods will become the keys to the restoration of highland watersheds. Interventions to provide alternative energy sources, sustainable fuelwood production, and alternative livelihoods (either outside of traditional extensive agriculture or outside of sensitive watersheds) would not only improve livelihoods but would also help to preserve forest cover and soils and moderate the hydrological cycle.

The most vulnerable livelihoods are those reliant on rainfed agriculture in fragile and degrading watersheds. It is always the poorest farmers who expand production on the most vulnerable land—with the steepest slopes and thinnest soils—and who have the least capacity to invest in land management and soil conservation. Investments in irrigated agriculture, resettlement outside degrading watersheds, and off-farm employment would both protect vulnerable populations and slow land degradation, which in turn could moderate the impacts of hydrological shocks.

Seek Price and Income Stabilization

With 85 percent of Ethiopia's population dependent on agricultural incomes, shocks to farm productivity must be reduced. Better road and market infrastructure for agricultural production could deepen the domestic market and help to smooth food supplies and prices. Expanded opportunities for off-farm employment would also help lessen the economic shocks arising from fluctuations in the agriculture sector by providing supplemental income to a greater share of the population.

Furthermore, the prevalent assumption that emergency aid should be food for work or food-based income-supplementing programs should be challenged. In increasingly better integrated and more complex systems, cash for work, food coupons, and other cash transfer mechanisms may be more efficient than food-based interventions, and help to smooth incomes in rural drought-prone areas.

Enable Private Investment in Irrigation and in Non-Agricultural Activities

The historical development focus on rural rainfed agriculture has served to sustain a highly vulnerable agrarian economy. Investment policy in irrigated agriculture and energy sectors need to be further liberalized to attract both domestic and foreign private investors. The investment climate and property rights regimes should ensure long-term security and adequate return on investments. Investors must be assured that land tenure and water use rights are flexible enough to promote comparative advantage in food staples and cash crops. Ownership and transfer rights in land should guarantee sufficient incentives to induce long-term investment in Ethiopia.

These rights must be matched by access to rural credit and finance and dissemination of technology and good practices in water use. Strategies are needed that combine formal irrigation systems with informal pro-poor systems and affordable technologies, such as small-scale irrigation, water harvesting, and tubewell irrigation. Agricultural extension and credit policies need to be geared toward creating easy access to small-scale, affordable technologies. In addition, policies need to promote access to affordable power (likely hydropower) once the necessary infrastructure is put in place.

Invest in All-Weather Roads and Market Infrastructure to Shift Expectations and Incentives

To mitigate against the economic impact of Ethiopia's endemic flooding and high erosion rates, all-weather roads should be a priority intervention in affected areas. Improving the coverage and quality of Ethiopia's road network will make the economy less vulnerable to disruptions caused by water shocks, ensuring that producers can move their product to market. This would diminish current disincentives to investment in all sectors that arise from the high costs and uncertainty of transport services.

It is particularly important for the agriculture sector that roads are dependably passable and adequate storage and marketing facilities are available in order to limit the fluctuations in marketed outputs, reducing risks, and enhancing expectations. Better functioning markets will provide incentives for investment both within and beyond the agriculture sector.

Invest Strategically in Interregional Roads

Interregional roads could promote interregional trade, and offer marketing and transport alternatives that would mitigate the economic impacts of water-related transport disruptions. The existing pattern of roads radiates from the capital, Addis Ababa, to major towns, while adjacent regions often lack links between them. Such interregional roads, if they existed, would facilitate the growth of trade between regions, bring surplus production to deficit areas, help smooth weather related price shocks, and promote a more integrated national economy and greater national unity.

Ensure That Other Infrastructure Investments are Designed to Withstand Erosion and Flooding

Where high rates of sedimentation are seen or predicted, hydraulic infrastructure such as reservoirs and canal systems should be designed with adequate sediment capture capacity. Treatment systems should be budgeted adequate funding for operation and maintenance.

Expand Hydropower Generation Capacity

Ethiopia has enormous potential for hydropower development; that is, national water resources are estimated to have the potential to generate as much as 30,000 megawatts of power. Hydropower production, and hence the economy, can be better insulated from the effects of water shocks by increasing installed generation capacity, which is a medium-term goal of the energy strategy and of the Water Sector Development Plan (MoWR 2002b).

The hydropower development plan aims to promote the achievement of national socioeconomic goals through efficient and sustainable development of water resources to produce hydro-electricity. Reliable and sufficient supplies of electricity will spur investment. A grid of spatially disbursed generation facilities would improve the reliability of power supplies for the economy.

Access to electricity as an alternative to the use of biomass fuels will have a significant impact on the land and forest resources of the country, boosting environmental sustainability and agricultural productivity. To the extent that hydropower can be substituted for biomass fuels, women in particular with benefit from such a shift. In addition, hydropower infrastructure can be designed and operated to mitigate against flood, drought, and sediment transport, all of which have major economic impacts in Ethiopia.

Promote Regional Power Trade

Ethiopia's vast hydropower potential offers opportunities for mutually beneficial power trade in the region. While current national demand may be inadequate to justify rapid expansion of hydropower capacity, regional power trade offers a significant opportunity to make large-scale projects economic. The availability of cheap power would help make the Ethiopian economy more competitive. In addition, the revenues earned from regional power trade could help the economy develop.

By developing a network of linked energy producing facilities, Ethiopia can increase economic resilience to water shocks. For example, two or more interconnected hydropower-based systems may prove complementary in reducing the effects of seasonal river flows, interannual flows (including droughts and floods), and differences in reservoir capacity. Whereas thermal generation has high variable operating costs relative to hydropower, savings can be achieved by using hydropower when it is available.

Likewise, hydropower can generate power during excess flows for thermal plants and receive power from thermal plants when reservoirs are depleted. Power plants can benefit from mutual assistance during maintenance or forced outages. Reservoirs on an interconnected system could be operated in such a way that each power plant (or country) might not need large reserve capacity. Economies of scale might be attained in new generating capacity as markets improve.

Regional cooperation in power production could strengthen regional relations and promote increased economic cooperation and integration. Ethiopia is currently exploring opportunities for regional power trade with Sudan and Egypt through the NBI and with Djibouti. In particular, cooperative power investments with Egypt and Sudan, producing sufficient energy to meet Ethiopia's domestic demand and to justify transmission to Sudan and Egypt, could potentially ease long-standing historical concerns arising from the three countries' dependence on the Nile. The economic rate of return of supplying power to Sudan and Egypt has been estimated to be 32 percent (MoWR 2002a). The EIRR for providing power to Djibouti is lower at around 20 percent (Demeke 2004), but still financially very attractive.

Ethiopia could potentially transmit power through Egypt's grid to the Middle East and even to Europe. As a clean, renewable source of power, hydroelectricity may be a very attractive alternative to diesel- or coal-fired and nuclear-powered sources of energy for Europe. In addition, developing this renewable energy might make Ethiopia eligible for carbon credits.

In addition to hydropower, cooperatively constructed dams could have other downstream benefits. They would regulate sediment transport that is washed from Ethiopia's denuded hillsides through irrigation infrastructure in Sudan to Lake Nasser in Egypt. Unless the runoff is controlled, silting will severely damage downstream reservoirs (Thurow 2003). In addition, should the countries work cooperatively on operating rules, it may be possible to store Nile waters in the cool climate of the Ethiopian highlands and provide evaporative savings in the river system, thereby increasing the total volume of water available to the riparians.

Diversify and Export Manufactured Goods

Expansion of reliable electricity coverage will broaden opportunities for other economic investments and likely promote non-agricultural activities such as industry and services that are less vulnerable to water shocks. Similarly, improving the cost and reliability of transport will enable the success and expansion of manufacturing and services. Increased exports of manufactured goods could help insulate urban manufacturing from the negative effects of diminished local demand during times of drought. Increasing the resilience of the agriculture, energy, and transport sectors will therefore also improve the resilience of urban production.

Promote Financial Risk Mitigation and Credit

Current credit and banking systems do not provide robust risk mitigation products. Whatever the extent of investment made in hydrologic infrastructure and water resources management, Ethiopia's hydrologic variability is so extreme that it will likely always pose significant risks for agricultural and non-agricultural investors. Japan, for example, suffers flood damage each year despite multibillion dollar expenditures on structural flood protection. It is therefore important to explore opportunities to provide insurance, credit, or banking vehicles to help producers manage this risk. Ethiopia has just launched a highly innovative pilot program in weather risk insurance.

Shift Assets From Livestock to Rural Banks

Storing wealth in livestock increases rural economic vulnerability to weather shocks. During droughts, when incomes collapse, livestock asset values also decline. The correlation of these incidents increases the vulnerability of the population, and it is clear that in a drought cycle the loss of assets marks a turning point toward poverty. "Drought proof" stores of wealth and related tools such as credit and weather insurance should be explored to provide asset stability during drought episodes. Furthermore, smaller livestock herds would require less drinking water, diminish the potential for animal waste-related waterborne diseases, and slow degradation of the landscape.

5 A Hydro-Economic Model of Ethiopia: A Summary of Findings

To help clarify and quantify the impacts of Ethiopia's current water resources variability, and to explore potential impacts of mitigating interventions including investments in irrigation and market infrastructure described in the previous section, we developed a computer model that examines three proposed interventions under three rainfall patterns.

The results of the model should provide a better understanding of these dynamics and inform efforts to formulate and develop interventions that will enhance growth and insulate the Ethiopian people and economy from the often-devastating economy-wide effects of water shocks.

A complex series of model runs provides the following insights for policymakers:

- Standard economic models, which assume average rainfalls over a long period, are inappropriate for Ethiopia because they fail to capture the significant economic impact of the country's hydrological variability. A model that accounts for this variability projects a much bleaker—but more realistic—picture of the country's economic future.
- Investments in irrigation appear much more profitable when hydrological variability is taken into consideration.
- Investments in irrigation and market infrastructure (roads, storage facilities, and so on) appear to spur similar growth impacts, and there appear to be synergies between these types of investments, particularly under conditions of hydrological variability.
- Investments in market infrastructure will also help non-agricultural sectors of the economy, thus promoting a structural shift in the economy toward greater diversification and hydrological resilience.

VARIATIONS OF THE MODEL

The first task in developing an effective quantitative economic model for Ethiopia was to find a way to incorporate the country's extremely variable hydrology, which has such a great influence on its economy. Most economic models project average growth rates in agriculture, which implicitly assumes average, steady, and constant rainfall over time. This type of model misses the hydrological shocks and uncertainties that plague Ethiopian farmers. We tested three variations of our model as described below. All variations are regional, multisectoral, multimarket models that incorporate hydrology within the agricultural production function. They differ only with regard to their assumptions of rainfall variability.

The model does not incorporate groundwater, hydropower or the dynamics of food aid, and that data are always imperfect. For the assumptions used in the model, as well as more detail on the variations, see appendix 1.

- *Variation 1: Smoothed rainfall.*[22] This variation assumes 1995–2002 average rainfall in all years. This type of model is used in virtually all economic modeling. Rainfall is implicitly incorporated into models through the assumption of average agricultural growth trends, because the assumption of average production implies average annual rains (or irrigated agriculture.) However, this assumption is unrealistic virtually everywhere. In the case of Ethiopia it proves to be drastically misleading.
- *Variation 2: Stylized drought.* This deterministic variation of the model seeks to capture the implications of drought by incorporating a stylized, two-year drought (Diao et al. 2004).
- *Variation 3: Historical variability.* The final variation is a stochastic extension of the base model that attempts to more fully reflect Ethiopia's historical levels of rainfall variability. Rather than using a smoothed hydrology with a single shock event, this model captures annual fluctuations whose associated cumulative losses affect growth performance and potential over time. Where the smoothed rainfall and the stylized drought models assume that the yield function plateaus at a certain level of rainfall, this model shows declining yields when rainfall is greater than a 50-year flood level, so that the negative impact of excessive rains (waterlogging and floods) is also captured, both for agricultural and nonagricultural sectors. This variation provides a finer, less stylized—and truer—picture built on Ethiopia's hydrological record, yet is still quite conservative (Strzepek et al. 2004).

IMPACTS ON GROWTH AND POVERTY

In the absence of increased investment, the model indicates that the national economy and the agricultural sector will grow at a lower rate than projected population growth through the year 2015. Assuming historically average trends in agricultural production and without incorporating any hydrological variability, per capita incomes will fall and 11 million more Ethiopians will be living in poverty by the year 2015.

However, the situation is probably much worse. The two models that incorporate the country's variable hydrology show a bleaker—and probably more realistic—future. The impact of a single, two-year drought within the model's 12-year time horizon will lower the projected average rate of GDP growth by 10 percent and will mean another 5 million Ethiopians will live in poverty, 16 million more than today.

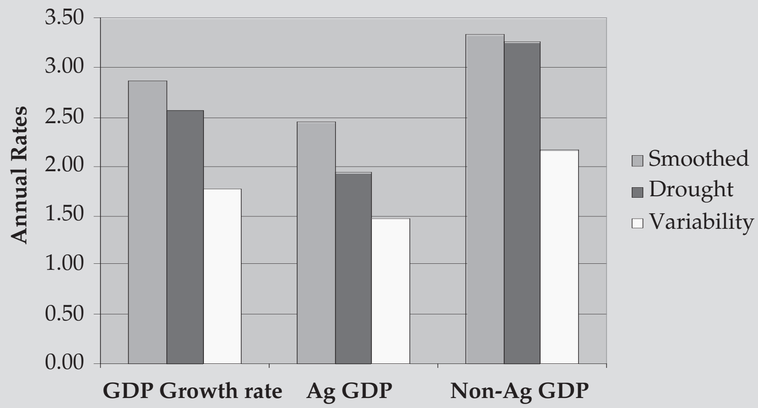
When historical levels of rainfall variability, and the impacts of both drought and flood are conservatively captured in the model, projected GDP growth rates decline by 38 percent and the number of people living in poverty to increase by 25 percent, for a total of over 51 million.

Figure 5.1 clearly demonstrates the extraordinary impact of drought and, particularly, hydrological variability, on the Ethiopian economy. A single drought in a 12-year period will decrease average GDP growth rates 7–10 percent. If historical levels of variability and the partial impacts of floods are incorporated, GDP growth rates fall 20–43 percent. Figure 5.2 shows that the impact of a single drought will increase poverty rates 12–14 percent, and that hydrological variability of the magnitude Ethiopia has historically experienced, raises poverty rates 25–35 percent.

The historical variability variant of the model best reflects the real hydrological impacts endured in Ethiopia. It captures year-on-year stochastic variations, and impacts of floods as well as droughts.

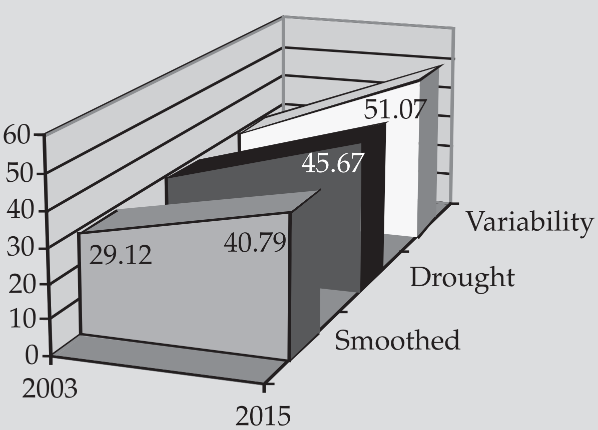
The historical variability model provides a range of results rather than a single result for each simulation. Figure 5.3 shows this range, or ensemble, of results in green. While this ensemble does not encompass all possibilities, the wide range of annual results for the 12-year series suggests potential catastrophic scenarios. Figure 5.3 compares GDP growth

Figure 5.1 Effects of Hydrology on GDP Growth



Source: Authors.

Figure 5.2 Effects of Hydrology on Poverty Rates



Source: Authors.

rate projections using the smoothed rainfall model (the red line), and the mean of the historical variability model ensemble (blue). From this graph it is clear that as greater hydrological variability is captured significantly lower growth rates are projected.

When poverty rates are compared (figure 5.4), the results are even more dramatic. The historical variability model (mean in blue) shows significantly higher levels of poverty. Again, the wide range of green line scenarios suggests potentially devastating poverty rates.

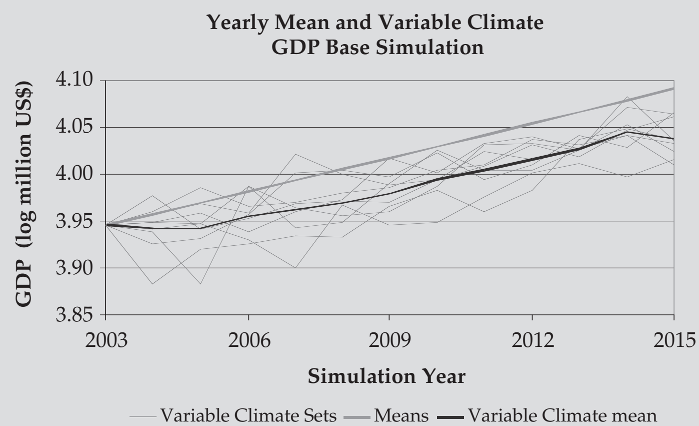
These models clearly demonstrate the critical importance of explicitly incorporating hydrological variability in modeling the Ethiopian economy.

Assumptions regarding hydrological variability have a considerable impact on growth and poverty projections, and the level of variability is negatively correlated to economic performance; that is, the greater the level of variability modeled into the system, the worse the growth and poverty outcomes. Simply put, models of the Ethiopian economy that fail to incorporate hydrological variability will be poor predictors of growth and poverty.

INVESTMENT SCENARIOS

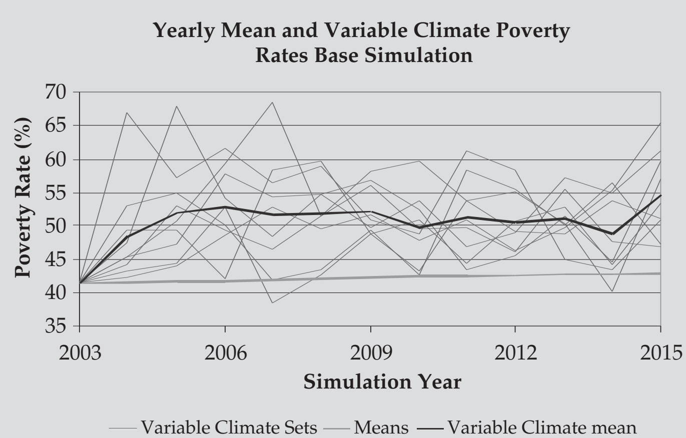
Next we modeled three investment options: investment in irrigation, in market infrastructure, and in both irrigation and market infrastructure. We investigated each investment scenario under each of the three hydrological variations described above, producing nine scenarios. This section compares the results of the three investment

Figure 5.3 Projected Log GDP Using Smoothed Rainfall and Variable Rainfall Means and Variable Rainfall Ensemble



Source: Authors.

Figure 5.4 Projected Poverty Rates Using Smoothed Rainfall and Variable Rainfall Means



Source: Authors.

scenarios to the baseline scenario described earlier, and describes their differing results under each of the three hydrological variations, all in terms of their impacts on GDP growth and poverty rate reduction. Tables 5.1 and 5.2 give a comparison of the overall results. The following section examines the results of each investment scenario using only the historical variably rainfall model, deemed the most realistic in making planning projections for Ethiopia. Additional technical details regarding the investment scenarios can be found in Appendix 1.

IRRIGATION INVESTMENT SCENARIO

The effect of irrigation is modeled as the yield differential between irrigated and rainfed crop production. The irrigation investment scenario uses the GoE's irrigation plan, which calls for moderate irrigation expansion. According to the 2002 Irrigation Development Program of the Water Sector Development Plan, the GoE plans to double the current irrigated area of grain from the current 137,000 hectares to 274,000 hectares and triple the irrigated area of cash crops from the current 63,000

Table 5.1. GDP Growth Rates Under Differing Investment Scenarios

GDP Growth rates (2003–2015)

Model assumptions	Smoothed rainfall	Percent change from baseline with smoothed rainfall	Stylized single drought	Percent change from baseline with drought	Historical variability (stochastic)	Percent change from baseline with variability
Scenarios						
Baseline	2.87		2.57		1.78	
Irrigation Investment	3.43	19.51	3.09	20.23	2.73	53.37
Infrastructure Investment	4.42	54.01			2.53	42.13
Irrigation and Infrastructure Invesment	4.56	58.89	4.25	65.37	3.43	92.70

Source: Authors.

Table 5.2. Poverty Rates Under Differing Investment Scenarios

Poverty (percent of population living in poverty 2015)

Model assumptions	Smoothed rainfall	Percent change from baseline with smoothed rainfall	Stylized single drought	Percent change from baseline with drought	Historical variability	Percent change from baseline with variability
Scenarios						
Baseline	45.89		51.38		57.45	
Irrigation Investment	42.52	-7.34	47.9	-6.77	53.18	-7.43
Infrastructure Investment	39.39	-14.16			54.39	-5.33
Irrigation and Infrastructure Invesment	37.92	-17.37	43.43	-15.47	50.42	-12.24

Source: Authors.

hectares to 200,000 hectares by the end of the 15-year planning period. This would increase the total irrigated area to approximately 470,000 hectares. Of the increased irrigated area, half (about 130,000 hectares) are to be small-scale projects, equally divided into short-term (2002–6), medium-term (2007–11), and long-term (2012–6) projects. The other half (about 147,000 hectares) are large- and medium-scale projects, most of which will be completed by 2015–7. Note that more recent government targets are more ambitious, aiming to complete 100,000 hectares by 2006 and develop 750,000 hectares by the end of the planning period.

The program estimates the average cost of large- and medium-scale irrigation development at about US$7,000 per hectare. It assumes that small-scale irrigation development costs are approximately US$4,800 per hectare. The costs of other inputs, such as the fertilizers and improved seeds that are often needed to increase yields on the irrigated land, were not included in the model estimates owing to a lack of available information. Thus, the returns to irrigation investments are potentially overstated. On the other hand, the 12-year time horizon does not capture the full benefits of later-year investments. All irrigation assets can be assumed to have a functional life considerably longer than 12 years.

Under the smoothed rainfall model, significant increases in both GDP (6.7 percent) and agricultural GDP (3.5 percent) are projected. The total population living in poverty is projected to be about 37.8 million by 2015, 3 million less than the baseline scenario projections, but still 9 million more than the current level (see Tables 5.1 and 5.2).

In the stylized drought scenario, the benefits of irrigation investments increase. Investment in irrigation saves 3 million people from falling into poverty. Although projected returns on irrigation investments in cash crops do not change significantly, returns to irrigation investments in cereal production more than double so that investments in small-scale irrigation could be recovered over the 12-year period.

Under conditions of historical variability, the projected benefits of irrigation are even greater. A 53 percent increase in the GDP growth rate is predicted under this model, compared with a roughly 20 percent increase under both the smoothed rainfall and stylized drought models. This result is fairly intuitive because it is at the greatest extremes of drought and flood that the returns to irrigation investment are greatest. Not only does the exclusion of rainfall variability bias all growth projections, but it especially underestimates returns to investments in irrigation. Poverty results under the three variants of the model were similar.

Market Infrastructure Investment Scenario

This scenario evaluates the potential gains from public investment in market infrastructure, including transportation and storage facilities, to reduce the farmer's marketing costs. Transportation investments can enable interregional trade, which could strengthen food security during droughts and floods, lessen price shocks, sustain services year round, and promote structural changes in the economy toward less water-vulnerable activities.

We assumed that investments in roads and other market infrastructure could improve the service sector's productivity and reduce marketing margins between producers and consumers. We estimated this as a 1.7 percent annual increase in the service sector's productivity, which lowers the marketing margins steadily over time. In total, productivity in the service sector is projected to rise by 20 percent in 12 years, with marketing margins falling about 1 percent per year.

Under the smoothed rainfall model, total GDP increases 19.6 percent above the no-investment scenario. The total poverty ratio falls to 39.4 percent, compared with 46 percent in the baseline scenario (5.8 million fewer people) and 42.5 percent (2.8 million fewer people) in the irrigation investment scenario (see Table 5.2).

Under the smoothed rainfall model, improvements in transport and market infrastructure delivered more than twice the growth rate of investments in irrigation. But under the historical variability model, the impacts of the two investment scenarios were similar.[23] This is explained by the fact that the historical variability model on one hand captures far greater returns to investments in irrigation but, on the other hand, captures diminished returns to roads and non-agricultural activities because it takes into account the damage done by flooding. Under the variability model, investments in market infrastructure will increase the rate of GDP growth by 42 percent and lower the poverty rate by 5 percent (see Tables 5.1 and 5.2).

Combined Infrastructure and Irrigation Investment Scenario

Parallel investments in irrigation and market infrastructure produce the greatest GDP growth and poverty reduction and, of course, require the greatest investment. When the model with smoothed rainfall is run with combined investments in agriculture and infrastructure, the overall GDP growth rate increases 58.9 percent over the no-investment baseline scenario (rising from 2.9 to 4.6 percent). This is the highest increase in overall GDP growth rates in any scenario. The irrigation-alone scenario gives a growth rate of 19.5 percent and the infrastructure-alone scenario give a growth rate of 54 percent (see Table 5.1).

Strong synergies can be seen in the impact of this combined investment on the cumulative returns to irrigation investment. The per hectare return to irrigation under this scenario increases to US$10,350 (from US$4,400), raising both returns to grain production (up to US$9,600 from US$2,800) and non-grain production (up to US$11,100 from US$6,100) (see table 5.3).

Combined investment also produced significant gains in the other rainfall models. The stylized drought model projects a 65 percent increase in GDP growth rates, and the historical variability model shows a 93 percent increase, the largest increase of all.

Poverty rates also decline significantly with combined investments, 15 percent under a stylized drought assumption and 12 percent assuming historical variability (see Table 5.2). Each rainfall variation model achieves its greatest reduction in poverty under the combined investment strategy.

Under both the smoothed rainfall model and the stylized drought model, the lion's share of benefits appear to derive from market infrastructure investments, with the irrigation investments only adding marginally to total growth and poverty gains. Under the historical variability model, however, the gains are virtually additive.

These findings suggest three conclusions. First, irrigation has greater returns under highly variable climatic conditions. Second, the complementarity of combined investments will be particularly pronounced in Ethiopia. Third, investments in roads and market infrastructure are essential for leveraging returns to irrigation investments, although the reverse relationship (that investments in irrigation leverage returns on market infrastructure) may not be strong.

Agricultural and Non-Agricultural GDP Growth: Changing the Structure of the Economy

Figures 5.5 and 5.6 show the results of the different investment scenarios according to the smoothed rainfall model and the rainfall variability model. These figures separate the GDP growth into Agricultural GDP and non-agricultural GDP growth. Agricultural GDP growth is essential in the short run, but growth in non-agricultural GDP—manufacturing and services—should be encouraged because, over time, it will shift the structure of the

Table 5.3. Agricultural Production and Irrigation Returns Under the Combined Investment Scenario, Smoothed Rainfall Variant

	Grain production by 2015 (million tons)	Value of grain production by 2015 (million $US)	Value of other crops (million $US)	Returns to irrigation (2003–15)
Baseline	11.0	3,236	1,335	—
Irrigation	11.3	3,259	1,451	US$4,400/hectare US$2,800 (grains) US$6,100 (other crops)
Combined irrigation and infrastructure	11.5	3,398	1,552	US$10,350/hectare US$9,600 (grains) US$11,100 (other crops)

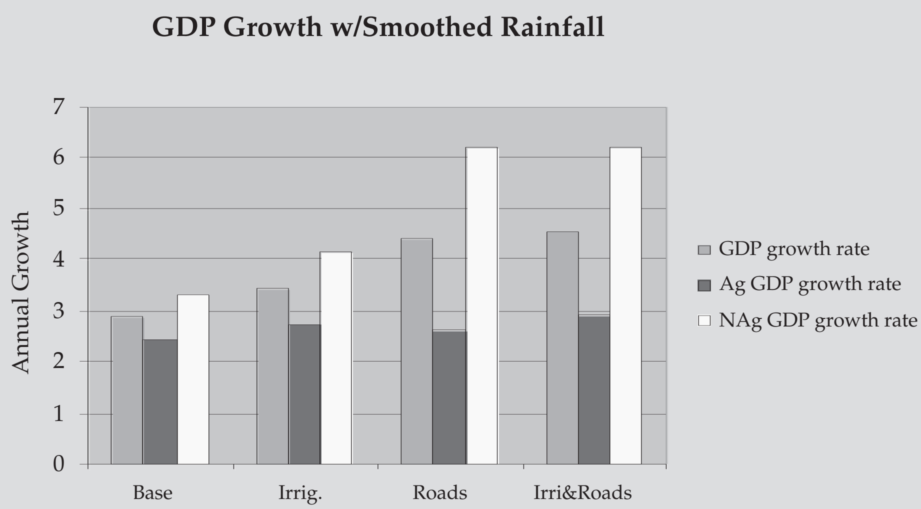
Source: Authors.

economy away from agriculture and toward more drought-resilient activities.

The smoothed rainfall model (Figure 5.5) shows relatively low agricultural GDP growth rates and relatively low returns to irrigation investments. Since returns to irrigation are highest when climates are variable, smoothed models fail to capture the extent of benefits offered by irrigation in countries such as Ethiopia.

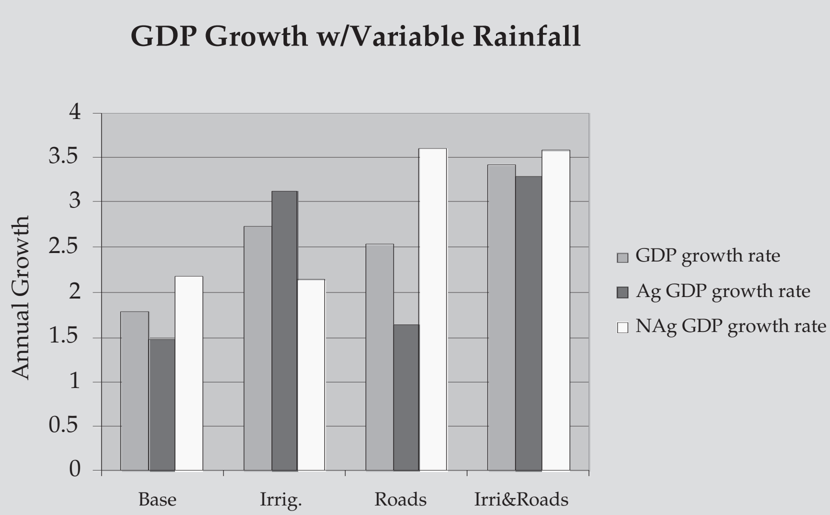
The historical variability model (Figure 5.6) shows that investments in irrigation have a much greater impact when swings between drought and flood are assumed to be the norm. Overall GDP growth rates are still lower in the historical vari-

Figure 5.5 Growth Rates With Smoothed Rainfall and Different Investment Scenarios



Source: Authors.

Figure 5.6 GDP Growth With Variable Rainfall and Different Investment Scenarios



Source: Authors.

Table 5.4. Baseline Scenario (No Investments) With Historical Variability

2003–15	Baseline
GDP growth rate	1.78
Agriculture GDP growth rate	1.47
Nonagriculture GDP growth rate	2.17
Poverty rate 2003	44.23%
Poverty rate 2015	57.45%

Source:Authors.

ability model because the enormous costs of hydrology are not factored into the smoothed rainfall model. Combined investment in both irrigation and market infrastructure provides real gains in the agriculture GDP growth rate over the single-sector investment scenarios.

For investments in irrigation or infrastructure singly, overall growth rates (blue) are comparable but the two scenarios give rise to very different relative rates of growth between agricultural (red) and non-agricultural GDP (white). This, in turn, will have markedly different impacts on the structure of the economy over time and its likely vulnerability to future hydrological variability and shocks. To hasten a structural shift toward non-agricultural activities, the model suggests a disproportionate investment in market infrastructure. This type of investment will help shift the structure of the economy toward a more water-resilient growth path that will also have a lesser impact on Ethiopia's vulnerable and highly degraded landscape.

COMPARISON OF INVESTMENT SCENARIOS USING THE HISTORICAL VARIABILITY MODEL

Since the historical variability rainfall model is the most accurate for Ethiopia, this section explores in detail the three investment scenarios under this model.

BASELINE SCENARIO

The model that most fully captures Ethiopia's annual rainfall variability projects a striking 38 percent decline in the GDP growth rate and a 25 percent increase in the number of people living in poverty (11 million people) by 2015. Table 5.4 shows the no-investment baseline for the GDP growth rate, the agricultural GDP growth rate, the non-agricultural growth rate, and the poverty rates in 2003 with projections for 2015 under the historical variability model.

IRRIGATION INVESTMENT SCENARIO

Increasing irrigation has long been seen as the most direct strategy to alleviate the impact of drought and ensure food security. It is generally assumed that increased irrigation will reduce the risk farmers face from climate variability, giving them the incentive to purchase fertilizers, improved seeds, and other inputs that can increase agricultural productivity. Without increased irrigation, the great unpredictability of rains in Ethiopia is an overwhelming disincentive to investments in agricultural improvements.

Currently only 2 percent (200,000 hectares) of Ethiopian cropland is irrigated; that is, 60 percent is used for cereal production and the other 40 percent for other crops. Cereal production occupies about 70 percent of all cultivated land. Irrigation accounts for just 1.5 percent of total cereal production compared with more than 2 percent of other crop production.

The effect of irrigation is modeled as the yield differential between irrigated and rainfed crop production. According to the Agricultural Sample Survey data of 1997 and 2000, this differential for grain is 40 percent (that is, on average, irrigation can increase grain yield up to 40 percent). A simple back-of-the-envelope calculation shows that if increased irrigation areas can help close this yield gap in the next 12 years, it would increase annual growth in grain production 3 percent. The model projects that if all of Ethiopian grain production could achieve this growth rate, the national poverty rate would fall to 33 percent by 2015 and the absolute number of people living in extreme poverty would fall by 1 million.

However, given that irrigation currently accounts for only 1.5 percent of total cereal production, it is unrealistic to expect that investments in irrigation alone can significantly reduce the yield gap nationwide. Many researchers have shown strong diminishing returns to the large-scale irrigation investment, and there is increasing concern that irrigation cannot be the primary focus for addressing food security. Caution is therefore needed in promoting large irrigation investment projects as panaceas for food security.

Returns from irrigation investments are extremely sensitive to price changes, which derive from many sources. For example, prices may be affected by food aid. In drought years when demand exceeds supply, grain prices rise. If food aid grains fill this gap, or are sold in domestic markets at controlled prices, price spikes will be tamped. The flow of cheap grain will undercut the profitability of investments in grain irrigation and serve as a broader disincentive for surplus production by farmers who could otherwise reap a profit through interregional trade in drought years.

For exportable crops, such as coffee, returns to investment will largely be driven by world market prices. External price shocks can significantly alter the calculation of potential returns from irrigation investments. When irrigation is used to increase the production of nonexport cash crops, the increased supply could drive down prices and reduce net returns from the investment.

The irrigation investment scenario with historical variability shows a 53 percent increase in the projected GDP growth rate, far greater returns than either the smoothed rainfall or stylized drought model, because when variability is modeled in all years, irrigation becomes much more profitable (see Table 5.5).

Market Infrastructure Investment Scenario

An important contrast between the scenarios is their potential equity implications. Irrigation benefits can easily be captured by a small set of farmers, while improved roads and lower marketing costs in general benefit the majority of farmers. The benefits derived from improved transport and market infrastructure[24] are nonexcludable public goods that can be shared by all agricultural and non-agricultural traders, generating social welfare benefits by reducing marketing margins and enabling less water-vulnerable activities.

A final, important point is that this scenario, which raises incomes without significant increases in production, would have a lesser impact on Ethiopia's vulnerable and highly degraded landscape. Because soil degradation is an extremely serious issue in Ethiopia, this difference is not trivial.

Investments in market infrastructure will increase the rate of GDP growth by 42 percent and lower the poverty rate by 5 percent under the historical rainfall variability model (see Table 5.6). Irrigation and market infrastructure investments would have roughly equal impacts.

Table 5.7 shows that the historical variability model suggests both types of investments would reduce poverty by a similar amount. The model points to a relatively high rate of growth in nonagricultural (less water vulnerable) production in response to investments in market infrastructure, suggesting this type of investment will help shift the structure of the economy toward a more water-resilient growth path (see Table 5.8).

Table 5.5. Irrigation Investment Scenario, Historical Variability Model

	Baseline	Irrigation investment	Percent change
GDP growth rate	1.78	2.73	53
Agriculture GDP growth rate	1.47	3.13	113
Nonagriculture GDP growth rate	2.17	2.14	-1
Poverty rate 2003	44.23	44.23	0
Poverty rate 2015	57.45	53.18	-7

Table 5.6. GDP Growth Rates, Market Infrastructure Investment Scenario, Historical Variability Model

2003–15	Historical variability	Percent change over baseline
No investment (baseline)	1.78	
Irrigation investment	2.73	53
Infrastructure investment	2.53	42

Source: Authors.

Table 5.7. Poverty Rates Under the Market Infrastructure Investment Scenario

2003–15	Percent of population living in poverty in 2015	Percent change from baseline
No investment (baseline)	57.45	
Irrigation investment	53.18	-7
Infrastructure investment	54.39	-5

Source: Authors.

Table 5.8. Impacts of the Market Infrastructure Investment Scenario, Historical Variability Model

2003–15	Baseline: No investment	Market infrastructure investment	Percent change
GDP growth rate	1.78	2.53	42
Agriculture GDP growth rate	1.47	1.64	12
Nonagriculture GDP growth rate	2.17	3.61	66
Poverty rate 2003	44.23%	44.23%	0%
Poverty rate 2015	57.45%	54.39%	-5%

Source: Authors.

Combined Market Infrastructure and Irrigation Investment Scenario

This scenario examines the potential synergy of combining investments[25] in irrigation and market infrastructure. It finds that parallel investments in both would significantly increase growth, reduce poverty, and double returns to irrigation both for grain and nongrain crops regardless of hydrological assumptions.

This model captures only the synergies generated through price and income effects of these combined investments. The qualitative analysis provided in this report, however, strongly suggests that significant additional synergies will derive from colocating investments in irrigation and in roads and market infrastructure because together they will provide strong incentives for increased farmer investments in agricultural inputs, and incentives and opportunities outside of agriculture. It is interesting to note that apparent synergies between irrigation and infrastructure investments are much more pronounced under the historical variability model. Under both the smoothed rainfall model and the stylized drought model, the lion's share of benefits appear to derive from market infrastructure investments, with irrigation investments only adding marginally to total growth and poverty gains. Under the historical variability model, however, the gains are virtually additive.

Table 5.9. Impacts of the Combined Market Infrastructure and Irrigation Investment Scenario, Historical Variability Model

2003–15	Baseline	Combined investments	Percent change
GDP growth rate	1.78	3.43	93
Agriculture GDP growth rate	1.47	3.29	124
Nonagriculture GDP growth rate	2.17	3.59	65
Poverty rate 2003	44.23%	44.23%	0%
Poverty rate 2015	57.45%	50.42%	-12%

Source: Authors.

This reflects the greater benefits of irrigation under highly variable climatic conditions, and suggests that the complementarity of combined investments is particularly pronounced under such conditions. It also suggests that investments in roads and market infrastructure are essential for leveraging returns to irrigation investments, although the reverse relationship (that investments in irrigation leverage returns on market infrastructure) may not be strong.

The combined investment scenario generates more growth in the economy overall and, like the infrastructure investment scenario, gives rise to differing agricultural and non-agricultural rates of growth that will shift the structure of the economy away from agriculture and toward more water-resilient non-agricultural activities, though at a more measured pace than the infrastructure-alone scenario (see Table 5.9).

MULTIPURPOSE DEVELOPMENT

Although the model described above does not explicitly incorporate hydropower, a coordinated investment strategy should clearly exploit opportunities for multipurpose infrastructure to manage the impact of hydrological variability on the Ethiopian economy. River regulation and storage infrastructure can be designed at all scales to meet several objectives: delivery of irrigation and municipal water, generation of hydropower, the public benefits of drought and flood mitigation, and protection of roads and other infrastructure. Hydropower development at all scales is potentially an integral part of both irrigation and market infrastructure development, and abundant energy is clearly needed to diversify the economy.

Generally, there are tradeoffs between the use of water for hydropower or for upland irrigation; that is, the consumptive use of water above a hydropower plant means less power will be generated. Choices may need to be made, but in highland Ethiopia—for example, the large areas around Lake Tana—there appear to be opportunities for substantial irrigation development without diminishing the potential for hydropower generation. In addition, there appears to be many cases where small to medium hydropower developments coupled with irrigation can be economic, but where single-purpose investments might not be (for example, on the rivers that feed Lake Tana). Moreover, the larger storage capacity justified by combined investments would provide even greater public benefits. Hydropower development at all scales is potentially an integral part of both irrigation and market infrastructure development, and abundant energy is clearly needed to diversify the economy.

The GoE is currently undertaking major development programs in irrigation and market infrastructure, particularly roads and power. It is difficult to generalize a priority between the two types of investment from the results of the model. To hasten a structural shift toward non-agricultural activities, the model suggests a somewhat disproportionate investment in market infrastructure, but this will not necessarily be the priority in all locations. Specific investment decisions will need to be made cognizant of local hydrological, environmental, economic, and social conditions, and the existing stock of both irrigation and market infrastructure.

6 Water Resources and Growth

Since the origins of human society, there has been a constant struggle to reduce the destructive impacts of water and increase its productive impacts.[26] Many of the earliest civilizations, and particularly those on the floodplains of the world's great rivers, succeeded by harnessing and managing water, thereby increasing production and reducing the risk of destruction.

Today, water resources development and management remain at the heart of the struggle for sustainable development, growth, and poverty reduction. This has been the case in all industrial countries, most of which invested early and heavily in both water infrastructure and institutions,[27] and it is the case in all developing countries, most of which have not invested sufficiently in water infrastructure and institutions. In some developing countries, such as Ethiopia, the unmet challenge of managing their water legacy is almost without precedent. Unless they are able to do so, sustainable growth and poverty eradication cannot be achieved.

WATER SECURITY AND THE MINIMUM PLATFORM OF WATER INFRASTRUCTURE AND INSTITUTIONS

Water Security

Investments in water for food, energy, industry, and navigation, and in associated institutions, are initially made by the state, the city, the firm, the farm, or the family. Their goal is to achieve some implicit level of water security. We can define water security as the reliable availability of an acceptable quantity and quality of water for production, livelihoods, and health, coupled with an acceptable level of risk of unpredictable water events (including the extremes of drought and flood) that have high social and economic impacts.

Water security is achieved when water underpins economic growth rather than undermining it, or, in other words, when the net impact of water on growth is positive. Water security is demonstrated when investments in water focus on enhancing growth rather than meeting basic needs and mitigating risk. It is the point at which vulnerability to drought, flood, and disease, or a lack of access to water-related services, no longer creates an overwhelming obstacle to growth. Water security is a dynamic state: different in different parts of the world reflecting geographic, social, epidemiological, economic, and political factors and changing over time as these factors shift with development.

The Minimum Platform of Water Infrastructure and Institutions

We can postulate that there is a basic level of water security, which incorporates the idea of a minimum platform of water infrastructure and institutions. Below this minimum platform, society and the economy are unacceptably impacted by water shocks and/or unreliable water for production or livelihoods. The tipping point in achieving water security will be the acquisition of a minimum platform of management capacity and infrastructure investment. Below the minimum platform, water obstructs growth; above the minimum platform water enhances growth. Until the minimum platform is achieved, the scale of social impacts (for example, morbidity, mortality, and resource conflict) and related economic impacts (for example, from institutional failure, production inefficiencies, and disaster shocks) can be such that social fabric is significantly affected and economic growth cannot be reliably and predictably managed.

THE CHALLENGE OF ACHIEVING WATER SECURITY

The level of institutions and investment required for water security will differ across countries and across economic actors as a consequence of the natural hydrology, the structure of the economy, its resilience to water shocks, and risk aversion. A nation's hydrology—the absolute levels of water resource availability, its variability, and its spatial distribution—will largely determine the institutions and the types and scale of infrastructure needed to manage, store, and deliver the resource.

An Easy Hydrologic Legacy

Relatively low rainfall variability, with rain distributed through the year resulting perennial river flows sustained by baseflows, results in hydrology that is "easy" to manage. In temperate parts of the world, much of which are now industrialized, achieving the minimum platform for water security was straightforward and required comparatively low levels of skill and investment, primarily because water was sufficient, widespread, and relatively reliable.

Once the minimum platform was achieved, growth was able to proceed without water as a significant constraint. Growth allowed further water-related investments, which increased water security beyond the minimum platform. As returns from new water investments gradually diminished, the infrastructure and institutional platform became mature, with water a reliable input to production and risks (that is, insurance costs) that were fully acceptable. At maturity, the need and incentive for *developing* new investments are low, while the returns from, and the incentives for, *managing* existing assets are high.

A Difficult Hydrologic Legacy

"Difficult" hydrology, on the other hand, includes areas of absolute water scarcity and, at the other extreme, low-lying land where there is severe flood risk. Even more difficult hydrology is where rainfall is markedly seasonal as in the tropics where one or two rainy seasons per year is typical, because a short season of torrential rain followed by a long dry season requires the storage of water. More difficult still is high interannual climate variability, where extremes of flood and drought create unpredictable risks to individuals, nations, and regions. Perhaps most difficult of all is a combination of extreme seasonality (intra-annual) and variability (interannual), which is characteristic of many of the world's poorest countries. Ethiopia clearly is a country with extremely difficult hydrology.

With increasingly difficult hydrology, the level of institutional refinement and infrastructure investment needed to achieve water security becomes significantly greater. Thus in these countries water is a much higher constraint to growth than in the temperate nations with their easy hydrology. In addition, achieving the minimum platform is also much higher, a quantum leap in some cases. This leap has not been achieved in many poor countries, so basic water security is lacking and water remains a key constraint on growth, an unreliable input to production and the cause of major economic shocks. In countries with difficult hydrology, there are few incentives to manage what little infrastructure there is. While the returns to society from investing in water security could be very high, there may simply be insufficient wealth to invest.

Taking this argument further, we postulate that societies in areas of water scarcity and/or high climate variability have remained poor and in a low-level equilibrium trap at least in part because it has been impossible for them to make the comparatively large investments needed to reach the minimum water infrastructure platform.

A Transboundary Hydrologic Legacy

The management and development of rivers whose basins fall within the borders of more than one state is exceptionally complex owing to the anarchy of international relations. The UN Convention on the Non-Navigational Use of International Watercourses, which seeks to address many of these difficult issues, was under preparation for some 20 years and adopted by the UN General Assembly in 1997 (Salman and Boisson de Chazournes 1998). Even after such prolonged negotiations, however, the convention has not yet entered into force because an insufficient number of states have ratified it.

Over generations, the border between France and Spain evolved so that today it mostly follows the watershed, a line of least dispute. In developing countries, colonial rule resulted in geographic divisions that usually have no geographic logic and seriously compound the challenge of achieving water security. Britain, France, Portugal, Italy, and Germany carved up Africa in a way that has led to a complex legacy of international river basins. Guinea has 14 international river basins, Mozambique has eight. Similarly, river basins are shared by a large number of countries: the Nile Basin has 10 countries, the Niger Basin has nine. Similar types of colonial boundaries challenge other areas, such as South Asia.

Cooperating with one state on one river is a challenge for poor nations. With more than one state on a river, or if on more than one river, or both, the challenge can be extremely high. Planning for optimal development is also complicated by the fact that relevant historical and current data—where it exists at all—is likely to be fragmented, nonuniform, and owned by different riparian states. In fact, there may be few if any studies of the river system as a whole.

Poor river basin management can result in many lost opportunities and increased costs: environmental costs to the river, economic costs in suboptimal development of the river, costs from political tensions over the river, and costs of all the other opportunities foregone through non-cooperation (Grey and Sadoff 2002). The legacy of international rivers can significantly affect the potential for managing and developing water for growth and poverty alleviation.

ECONOMIC STRUCTURE AND RESILIENCE

The structure of the economy will affect the minimum level of institutions and infrastructure necessary for water security. How much does the economy rely on water resources for income generation and employment? How vulnerable is it to water shocks? For example, a country like Ethiopia, whose rainfall is highly seasonal and/or variable and relies heavily on rainfed agriculture, is highly vulnerable. A country whose most productive assets or areas lie in flood plains is vulnerable. Vulnerable countries may require more extensive investments to achieve water security.

Water vulnerability will affect geographic regions and sectors differently, creating incentives and disincentives for specific economic activities. These activities will influence both the structure of the economy and spatial patterns of growth, thus affecting overall growth and equity outcomes. Not only will vulnerable economies regularly suffer greater setbacks from water shocks, but their vulnerability will likely prove a strong disincentive for domestic or foreign entrepreneurial investments that could shift the economy toward a more diversified, water-resilient structure. More diversified economies that are less water dependent or wealthier economies that can more easily compensate those harmed by drought or flood, might accept higher levels of hydrological uncertainty without slowing growth-focused investment.

This analysis suggests that efforts to guide structural change in the economy toward achieving greater economic resilience to water shocks can help a country attain and improve water security.

Risk Aversion

In the poorest countries, where survival is a real concern for much of the population and there are few functional social safety nets, economic actors tend to be extremely risk averse, investing only after there is significant demonstration of returns. Levels of risk aversion will influence the threshold at which water security can be achieved.

While the catastrophic effects of drought and flood extremes are apparent, it is less well recognized that even in years of average precipitation, expectations of high variability and endemic droughts and floods will affect economic performance and, potentially, the structure of the economy.

The expectation of variability constrains growth and diversification by encouraging risk-averse behavior at all levels of the economy in all years, as economic actors, particularly the poor, focus on minimizing their downside risks rather than maximizing their potential gains. Farm families will quite rationally not invest in land improvements, advanced technologies, or agricultural inputs, thus constraining agricultural output and productivity gains. Insecure land tenure arrangements compound these disincentives to invest in land management.

Lack of such investments can lead to land degradation and desertification, which will result in a vicious circle of reducing production and deteriorating assets. Similar disincentives for investments in industry and services will slow the diversification of economic activities and maintain an economic structure that is based largely on low-input, low-technology agricultural production.

The poorest countries may well face the highest risks, yet have the most risk-averse populations, the lowest infrastructure investment, and the weakest institutions. This could well be a very serious low-level equilibrium trap: These countries begin at a very low level, but must ascend to quite a high level of institutions and investment to achieve water security.

Financing Water Security

Generally, early investments in water security were made by governments. In Wealth of Nations, Adam Smith wrote that government should construct public works when these works are "of such a nature, that the profit could never repay the expense of any individual or small number of individuals, and which it therefore cannot be expected that any individual or small number of individuals should erect or maintain." When basic water security is achieved and additional investments in water (for example, in irrigation or power generation) can be highly profitable. At that point private investors will respond. All rich countries have achieved water security with a publicly funded minimum platform in place. Most poor countries not have achieved this level.

THE DYNAMICS OF INSTITUTIONS AND INFRASTRUCTURE

The Institutions/Infrastructure Interrelationship

All countries require investments in both water institutions and infrastructure. But what is the balance and sequencing between the two types of investments?

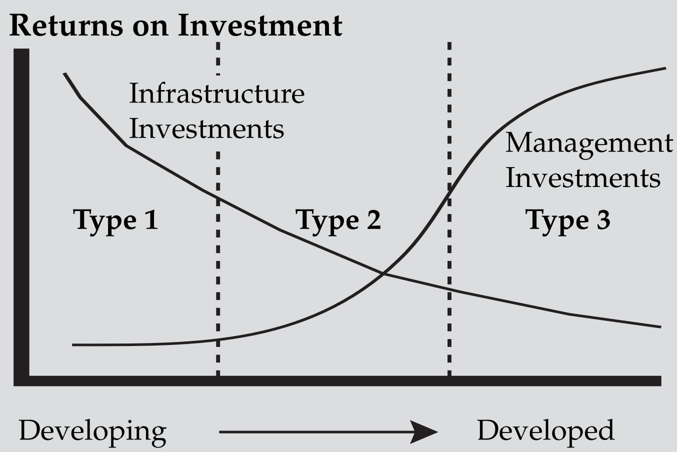
Human society has always managed water. Village wells and ponds, canal systems, and earthen embankments in the flood plains of great rivers have all been developed for millennia and each has been accompanied by institutional systems to plan, develop, manage, and maintain it. In some cases, such institutions were an early form of government, an emerging public sector to manage public goods. A private sector emerged to provide services to meet public demand. Water institutions reflect the culture and political economy within which they fit: public to private, centralized and hierarchical to decentralized and participatory, and rules-based to market-based.

When we look across the world at the development of water resources, particularly during the period of industrialization, we see a pattern (see Figure 6.1). At all times, concomitant investments must be made in infrastructure and institutions, but when stocks of hydraulic infrastructure are low, investment in them will be a priority. Investment in management capacity and institutions becomes increasingly important as larger and more sophisticated infrastructure stocks are built.

Most developed countries fall into the Type 3 category, where significant infrastructure investments have been made (in some cases arguably excessive investments) and where efforts are best directed toward strengthening water resources management. In Type 1 countries, most of the world's poorest countries, infrastructure stocks are so low that investments in management do not have the same high returns. Middle-income economies are often in the Type 2 category.

Without the infrastructure to store and deliver water and manage flows, there is neither the need nor the incentive for sophisticated management practices. While developed countries are appropri-

Figure 6.1 Balancing and Sequencing Investments in Water Infrastructure and Management



Source: World Bank (2002).

ately focused on implementing integrated water resources management, developing countries may do better to adopt a principled and pragmatic approach to management while putting greater emphasis on concurrent infrastructure investments.[28]

The Institutions/Infrastructure Balance

Failure to understand the issue of balance and sequencing within the context of specific country circumstances may lead to poor investment choices. One potential danger is that most donor nations are Type 3 countries strongly focused on water resources management, but the priority of Type 1 client countries may be investment in water resources infrastructure. Type 3 donors must not let their perspectives misinform the development priorities of Type 1 countries. Of course, there must be management and capacity investments at all stages, but the emphasis in investment may vary according to the "type" of the country.

The Transboundary Institutions/ Infrastructure Case

Shared management of international rivers is of growing importance in a world of 260 international rivers, shared by about 90 percent of the world's population. A basic premise of water resources management is that river basins are best managed and developed as an integrated whole. In practice, however, management is always legally and politically complex, due to the challenges of allocation between users and uses. There is no final authority through which differences can be resolved.

Although criteria for allocating water and its benefits can be drawn from a growing body of customary international water law, there is no consensus on the criteria for equitable allocation (Sadoff et al. 2003). Developed (Type 3) economies have usually achieved a relative equilibrium in establishing fit-for-purpose institutional arrangements, including treaty regimes, dealing with issues of river infrastructure, and the quantity and quality of water flows. In many cases, the need for river infrastructure, such as navigation locks, weirs and dykes for flood management (for example, the Rhine), or hydropower facilities (for example, the Columbia River), drove the neighboring countries to adopt institutional solutions. Recently there has been a growing emphasis on improving water quality through joint institutional solutions to restore riverine and lacustrine ecosystems (for example, the Danube). The success of such arrangements is enabled by broader international relations and agreements.

Both middle-income (Type 2) and developing (Type 1) economies continue to face great challenges. Because the complexity of riparian relations is such an obstacle, some nations seek to develop river segments within their own territories independently, often settling for the second or third best option from a basinwide perspective. In extreme cases, tensions over international rivers can effectively halt their management and development.

The need for river infrastructure often drives countries to reach agreements about river management. For example, the 1960 Indus Basin Treaty between India and Pakistan was a prerequisite for the Indus Basin development program that divided the rivers. The 1959 Nile Agreement between Egypt and Sudan was for the Aswan High Dam that stores water for Egypt. A focus on the benefits of cooperative management—say, for water quality—and of agreed (even cooperative) development—say, for irrigation and power—can lead to viable transboundary institutions.

Ethiopia and Water Security

Ethiopia is an economy with little water resources infrastructure and relatively weak management institutions and capacity. It also suffers from extreme variability and seasonality. It is a highly vulnerable economy dependent on rainfed subsistence agriculture and pervasive risk-averse behavior, all of which put it into a particularly "deep hole" in terms of achieving a minimum infrastructure platform and water security. Major public investment in water resources infrastructure and institutions will be needed to enable Ethiopia to achieve its growth potential.

7 Insights for Interventions

This section briefly summarizes the lessons of the past several sections and examines their implications for interventions. In the next two sections we examine what the GoE and the Bank have done and are planning to do to deal with Ethiopia's water resources problems. Finally, we make specific recommendations for Bank investments. Although the Bank can address many issues, there are some recommended interventions that it will probably not address. Thus, this section serves as a short summary of findings and recommendations.

We have documented Ethiopia's extreme hydrological variability and shown how it has kept the country in a poverty trap. The risk caused by hydrological variability discourages individual investment in irrigation, market infrastructure, and agricultural inputs.

The appearance of food aid during times of famine saves lives, but can also undermine the development of a national market economy in agriculture. An economy based on rainfed agriculture cannot prosper in the face of such extremes of drought and flood, but the GoE, even with the help of donors, has not been able to invest in sufficient water infrastructure projects to provide a base of water security. Meanwhile, the country's environmental resource base suffers continuing degradation as the poor strip watersheds for fuelwood, siltation plugs up hydropower and irrigation reservoirs, and erosion and poor drainage destroy cropland.

The way out of the trap seems to be through combined investments in water infrastructure projects and management, irrigation, and market infrastructure. Investments in water infrastructure and irrigation will help smooth out the spikes of variability that plague the country and help it achieve a base level of water security. Investment in market infrastructure will help it move away from an overdependence on agriculture and toward development of its manufacturing and service sectors. As these investments help stabilize the economy, changes need to be made in banking and credit management so that funds are available for individual investment and healthy market processes can develop.

LESSONS

- *Water resources development and management is a core issue for development in Ethiopia.* Ethiopia, which experiences extreme hydrological variability and is highly dependent on rainfed agriculture, lacks the minimum infrastructure, institutions, and capacity to achieve water security. Without serious investment in water security, Ethiopia will be held hostage by its hydrology and be unable to break out of its cycles of famine and food aid.
- *Droughts are only part of the story, which includes variability, seasonality, and floods.* The models demonstrate that while measurable droughts significantly shock the economy, "normal" year-on-year variability, unpredictable seasonality, and the impacts of waterlogging and flood (which did not even capture the full range of infrastructure damage) consistently undermine growth and poverty gains.
- *Failure to incorporate hydrological variability into economywide modeling will result in significant and systematic overestimations of growth and underestimations of poverty.* Most models make projections based on average rainfall and agricultural production. Because such models smooth over the production and price spikes caused by significant hydrological variations, they mask the extreme incidents that thrust vulnerable poor farmers into poverty. This is particularly significant in Ethiopia, where rainfall is highly variable, droughts and floods are endemic, and a significant portion of the population subsists on rainfed agriculture.
- *Failure to incorporate hydrology into economywide modeling will disproportionately undervalue returns to irrigation and drainage investments.* Our suite of models clearly demonstrated that as variability increases, returns to irrigation and drainage increase. This is fairly intuitive because it is at the extremes—during periods of drought and flood—that the returns to irrigation and drainage are greatest. Economywide models without explicit hydrology will systematically undervalue the contribution of irrigation and drainage, in particular, in the Ethiopian economy.
- *Increased multipurpose water infrastructure is a powerful investment.* To mitigate the economic impacts of variability, greater water storage capacity, both natural and manmade, small scale and large scale will be needed. Future schemes, wherever possible, should be designed as multipurpose projects, potentially providing benefits such as watershed management, flood control, drought mitigation, drinking water, irrigation, fisheries, local transport, sediment management, and systemwide reduction of evaporation losses and recreation. Providing hydropower as an alternative to biomass fuel and integrating targeted watershed management protection can also help slow deforestation and soil degradation, which will mitigate some hydrological impacts.
- *Investments in irrigation and drainage can help ensure agricultural production and incomes.* Appropriately designed irrigation and drainage investments can provide a secure supply of agricultural water to buffer production during all but the most extreme climatic events and protect the subsector from the greater part of hydrological variability. It can enhance food security and the reliable delivery of marketable and exportable agricultural products, helping to stabilize prices and encourage investment in both the agricultural and nonagricultural sectors.
- *Water resources management capacity and institutions must be strengthened.* Given Ethiopia's challenging hydrology, the need for such capacity is great—but capacity in the country is low. Efforts to strengthen capacity are ongoing and should be seen as a continued priority. Investment in research and education in particular will be crucial to develop the capacity needed to design effective and appropriate water resource management interventions, watershed management, irrigation schemes, and water and sanitation services.
- *Groundwater resources should be more fully explored.* Ethiopia's groundwater resources are estimated to amount to 2.6 billion cubic meters, but significant work remains to be done in determining how to develop these resources sustainably. One distinct advantage of groundwater is its relative reliability, due to buffering from rainfall variability.
- *Dependable clean water supplies are needed for human health and productivity and as an incentive for investing in manufacturing and services.* The clear need for investments in infrastructure will require accompanying reform, much of which is underway. In some cases, effective

urban water supply planning may require concomitant investments in watershed management, bulk water infrastructure, or river regulation infrastructure.

- *Watershed management is crucial for water resources, livelihoods, and the environment.* Improvements in watershed management, land use planning, and forest management will be crucial in managing water resources and riverine ecosystems more broadly. Improved watershed management can slow watershed erosion; moderate the hydrological cycle; regulate runoff and groundwater; improve infiltration, water retention, and base flows; and reduce potential flood damage. An important lesson from experience in Ethiopia is the need to effectively include stakeholders in the planning, design, and management of watershed interventions.
- *Limited and costly power supplies force reliance on biomass, the collection of which is women's burden and degrades watersheds.* Ethiopia's current energy balance relies heavily on the use of fuelwood, crop residues, and dung. In rural Ethiopia women traditionally gather and transport fuelwood and other organic fuels, and women suffer from indoor air pollution from the smoke of cooking with biomass fuels. At the same time, removing these organic materials from the soil contributes significantly to land degradation.
- *Parallel investments in irrigation and market infrastructure generate synergies for growth and poverty reduction.* Synergies can be expected to derive from co-locating investments in irrigation with investments in roads and market infrastructure, because together they will provide significant incentives for increased farmer investments in agricultural inputs and incentives and opportunities outside of agriculture. The model suggests there are greater synergies from co-located investment as hydrological variability increases and that synergies are particularly strong for leveraging returns to irrigation investments.
- *Proactive interventions are needed outside of the water sector to enhance the economy's resilience to the impacts of hydrological variability.* They might include policies that promote alternative livelihoods to decrease the share of the population most vulnerable to hydrological shocks, protection of agricultural incomes, and infrastructure investments explicitly designed to withstand hydrological shocks to diminish costly infrastructure damage and associated cost increases in other infrastructure using sectors.
- *Market infrastructure investments promote nonagricultural growth and provide immediate growth and poverty gains. In the medium term, they shift the structure of the economy away from agriculture, making it less vulnerable to hydrology.* In the infrastructure investment scenario, GDP growth comes primarily from nonagricultural sources. Immediately, and more markedly over time, the structure of the economy will shift away from agriculture and toward more drought-resilient, nonagricultural activities.
- *Investments in market infrastructure have less impact on the landscape.* The infrastructure investment scenario raises incomes without significantly increasing agricultural production by lowering transactions and marketing costs and encouraging nonagricultural activities. This suggests that welfare gains could be captured under this scenario without the use of additional land and water resources for agriculture and might therefore have a lesser impact on Ethiopia's vulnerable and highly degraded landscape.
- *Infrastructure investments are public goods at less risk of capture than irrigation investments.* Irrigation benefits can easily be captured by a small set of farmers, while improved roads and lower marketing costs benefit the majority of farmers. The benefits derived from improved transport and market infrastructure are nonexcludable public goods that can be shared by all agricultural and nonagricultural traders, generating social welfare benefits by reducing marketing margins and enabling a range of less water-vulnerable activities. Road investments are arguably more socially productive because their gains are derived from a decrease in transactions costs to both producers and consumers (a real public-good effect) rather than a transfer from consumers to irrigated farmers.
- *Drought preparedness and agricultural resilience needs further strengthening.* Greater emphasis could be placed on the development of local warning systems, selection of climate-appropriate crops, and a range of cultivation practices and animal-rearing systems and technologies.

Alternatives should be sought to the practice of storing wealth in livestock, which increases rural economic vulnerability to weather shocks. Drought-proof stores of wealth and related tools such as credit and weather insurance should be explored to provide asset stability during drought episodes.

IMPLICATIONS FOR INTERVENTIONS

- Bank-supported investments and interventions in Ethiopia should be analyzed to determine whether they provide opportunities and incentives that will make the economy less vulnerable to hydrological variability.
- Any economic modeling done for Ethiopia should incorporate the country's hydrological variability. Returns to irrigation and drainage investments are systematically underestimated in models that fail to capture hydrology because these returns are highest in times of drought and flood. In Ethiopia, modeling with hydrological variability doubles returns to irrigation and drainage.
- Water infrastructure and management capacity should be priorities for public investment. Ethiopia's growth will be undermined until it attains water security, and it will require significant investment to achieve a minimum platform of water infrastructure and management capacity.
- Road development should focus on quality and regional interconnection. Investments in high-quality all-weather roads leading to regional centers will create incentives for the production and marketing of surplus agriculture. Roads should also be built between complementary regions to enable national trade during droughts and floods.
- Interventions should be analyzed to determine whether their spatial location leverages the potential for synergies across investments in hydraulic infrastructure, irrigation, and roads and market infrastructure.
- Infrastructure and road building projects, wherever appropriate, should include a watershed management component to ensure that projects are environmentally and economically sustainable and not undermined by siltation, inundation, or erosion.
- Infrastructure investments require complementary institutional strengthening and capacity building, and potentially reforms to enhance effectiveness, efficiency, sustainability, and accountability.
- Opportunities should also be explored to complement water investments with insurance, credit, or "drought proof" stores of wealth to help producers manage weather risk. Ethiopia has just launched a highly innovative pilot program in weather risk insurance.
- Solutions to water resources challenges should be sought outside the water sector. Investment in market infrastructure and hydropower development would both help to mitigate the direct impacts of drought and at the same time coax the economy to a more resilient structure. Investments in market infrastructure will promote a structural shift toward growth in services and manufacturing, which are less vulnerable to rainfall variations.
- Regional cooperation in power production could strengthen regional relations and promote increased economic cooperation and integration.
- Food aid programs should be designed mindful of their impacts on longer term development. Development projects should be designed keeping in mind the complexities introduced by emergency food aid programs.

8 A Water Resources Assistance Strategy for the World Bank

The previous sections lay out the real challenges faced by Ethiopia in developing and managing its water resources. This section examines ongoing government and donor initiatives and seeks to define a strategy for Bank assistance that focuses on high impact interventions for which the Bank has some comparative advantage.

ETHIOPIA'S WATER SECTOR STRATEGY (2001)

The GoE has recently developed a Comprehensive and Integrated Water Resources Management Policy (endorsed in 1999), followed by a Strategy and a Sector Development Program, aimed at taking an integrated approach to water resources development. The policy establishes the overall goal of promoting efforts to utilize available water resources efficiently and equitably, thereby contributing to the country's socioeconomic development on a sustainable basis.

The GoE clearly recognizes the scale and complexity of the water challenge and is undertaking a wide range of programs to meet this challenge. Many of these programs can be categorized as national water resource management programs. Others promote international cooperation (particularly on the Nile), or seek to mitigate the impact of hydrologic variability on the Ethiopian economy by looking beyond what is traditionally considered the water sector to encourage alternative livelihoods that are more resilient to water shocks. The objectives of some of the programs are described below.

National water management programs include activities that:

- Seek to better secure the timely availability and effective use of water, such as investments in watershed restoration and conservation, water storage (including ponds, surface and subsurface dams, and rainwater harvesting at household, community, local, and regional levels), irrigation infrastructure, and urban and rural water supply (and sanitation).
- Reduce water-related risks faced by the farmers and families most vulnerable to water shocks through agricultural cooperatives, rural credit programs, expansion of agricultural extension programs, incentives for crop diversification, and community-driven development assistance targeted to food-insecure and pastoralist areas.

- Incorporate multipurpose investments (for example, addressing power, irrigation, flood control, and watershed protection in an integrated way).

Programs that address international watershed cooperation include fostering cooperative development of transboundary waters (particularly on the Nile River, where major progress is being achieved) to increase the benefits that can be derived from Ethiopia's water resources and to stabilize regional relations.

Programs to encourage changes in the structure of the Ethiopian economy to make it less vulnerable to hydrological variability include:

- Voluntary resettlement schemes designed to move populations into lower-risk and higher-productivity areas
- Private sector reform and investment incentives to encourage more diversified investment and the adoption of more advanced and less vulnerable production methods and technologies
- Transport infrastructure investments that will improve market access and the function of markets within the country that will allow inter alia the transfer of food from surplus to deficit areas
- Investments in hydropower production, transmission and rural electrification, reducing dependence on fuelwood, creating new productive opportunities, and potentially earning foreign exchange

Most of Ethiopia's international assistance for water-related projects currently goes to irrigation and water supply and sanitation efforts. (See table 8.1 and appendix 2.)

WORLD BANK ASSISTANCE IN ETHIOPIA

The Bank's broad engagement in Ethiopia is guided by a set of strategic documents including the Poverty Reduction Strategy Paper, the recent Country Economic Memorandum (CEM), and the forthcoming Country Assistance Strategy (CAS). The recommendations arising from this Country Water Resources Assistance Strategy are consistent with, and reinforce, those of CEM and will help to inform the forthcoming CAS.

More specifically, the Bank's recent CEM highlights Ethiopia's extreme vulnerability to drought that is sustained by a heavy reliance on rainfed traditional agriculture. It recommends that the GoE adopt a more balanced growth strategy that will foster deeper inter-sectoral linkages. Key recommendations includes:

- Rehabilitate and/or complete existing dams and related irrigation schemes in order to attract private investment.
- Speed up privatization of state farms and provide the appropriate complementary public goods to attract private investors.
- Develop multipurpose dams in strategic locations for irrigation and hydropower, with physical linkages—such as roads and telecom—to urban areas.
- Develop complimentary economic infrastructure to reap the potential for large-scale mechanized rainfed agriculture.
- Support livestock production in particular areas.

The Bank currently supports a portfolio of ongoing projects that deal directly or indirectly with water resources. They include the Water Supply and Sanitation Project, the Ethiopian Social Rehabilitation Development Fund, the Food Security Project, the Energy II Project, the Energy Access Project, the Agricultural Research and Training Project, and the Pastoralist Community Development Project. Ongoing research in small-scale irrigation and rainwater harvesting is also being supported. In addition, the Bank is providing substantive support to the NBI, in which Ethiopia is the leading donor and facilitator. Appendix 3 details existing projects.

However, to date, there has been no attempt to look across these projects, rationalizing and/or leveraging activities to support the country's new integrated water resources management policy and strategy and to specifically address the need to maximize resilience to hydrological variability and associated economic shock. The current Bank-supported portfolio breaks down as follows:

Alignment of the Portfolio

The sectoral balance of the portfolio aligns reasonably well with the insights provided in this study. The bulk of resources are committed for transport

Table 8.1. Ongoing International Assistance to the Water Sector in Ethiopia

			Amount	
Project/program type	**Project/program name**	**Financier**	**US$ (thousands)**	**In thousands, other currency**
Capacity building	Water Resources Development and Utilization Program	UNDP	5,000	
	Institutional Setup Studies of the Abbay Basin	France		1,540 Euro
	Ground Water Development and Water Supply Training Center	Japan	4,453	
	Wide area and local area networking	World Bank	300	
Hydropower	Baro and Karadobi Hydropower Feasibility Study	Norway		NKr40,000
Irrigation	Small-Scale Irrigation Project			
	5,300 ha	IFAD	22,600	
	2,400 ha	France	10,050	
	600 ha	Ireland	1,340	
	Agricultural Support Program 7,500 ha	AfDB	33,992	
	Koga Irrigation and Watershed 6,000 ha	AfDB	42,460	
Water resources	Genale Dawa Master Plan	AfDB	4,950	
	Awash Flood Mitigation	AfDB	2,488	
Water Supply and Sanitation	Rural Water Supply	UNICEF	12,120	
	Water Supply and Sanitation	World Bank	100,000	
	Kibremengist Town	BADEA	6,000	
	Debrebirhan Town Water Supply and Sanitation	AFD/France	6,399	
	Three Towns Water Supply and Sanitation Study	Germany (KfW)		€553
	Harar Water Supply	ADB	28,263	

Notes: ha, hectares; UNDP, United Nations Development Programme; IFAD, International Fund for Agricultural Development; AfDB, African Development Bank; UNICEF, United Nations Children Fund; BADEA, Arab Bank for Economic Development in Africa; AFD, Agence Française de Devéloppement.
Source: MoWR Policy and External Relations Department.

and roads investments, with similarly large investments designated for agriculture and energy. It is notable, and consistent with this analysis, that a large proportion of resources are committed to emergency activities. A clear goal over time will be to diminish emergency needs and focus more resources on transforming the Ethiopian economy.

While watershed management is addressed through components in several Bank projects,[29] it is striking that there is no dedicated watershed support in the Bank portfolio. There are, however, some activities under preparation. Other donors are active in these areas. Private sector development is yet another important area where activities are under preparation.

This analysis found that the current weak incentives for commercial agricultural production and non-agricultural activities contribute to the continuation of an extremely vulnerable, subsistence-based agrarian economy. To better align its portfolio with opportunities for increasing the resilience of the Ethiopian economy to drought, the Bank should make priority investments in multipurpose water infrastructure, water supply and sanitation, irrigation and drainage, market infrastructure and private sector development, and targeted watershed management.

Proposed Modifications to the Current World Bank Portfolio

Several relevant infrastructure projects that are in the planning stage should be reviewed with the recommendations of this report in mind.

Table 8.2. World Bank Portfolio Distribution by Major Sectors, FY2005

Sector	US$ (million)	Percent
Agriculture/rural development	309.5	13.05
Capacity building	151.2	6.38
Energy	332.7	14.03
Education	40.0	1.69
ESRDF	136.8	5.77
Health	100.0	4.22
HIV-AIDS	59.7	2.52
Transport/road	596.9	25.17
PRSC	130.0	5.48
Water supply and sanitation	100.0	4.22
Others (emergency, cultural)	414.4	17.48
Total	2371.2	100

Notes: ESRDF, Ethiopian Social Rehabilitation and Development Fund; PRSC, Poverty Reduction Strategy Credit.
Source: Government of Ethiopia (1996b).

For example the successors to the Energy II Project are under preparation, and planning is underway on projects addressing roads and irrigation and drainage. In particular, the Bank should examine the spatial distribution of these projects to see whether synergies might be captured by adopting a growth pole approach.

Planned roads projects should give special consideration the balance to between all-weather versus dry weather roads and to strategic interconnections between regions with potential trade opportunities.

Targeted watershed management projects should also be considered to complement ongoing or planned investments (by the Bank or others) in roads or dams.

Food-based emergency aid, while a traditional and politically expedient response, undermines incentives for surplus production and domestic trade. All emergency aid should be designed with impacts on longer-term national development kept in mind.

Support for ongoing weather insurance pilot programs should be continued, and rural banking and credit schemes should be explored. From the perspective of water vulnerability, farmers and pastoralists should increasingly be encouraged to use banks for their savings. In direct contrast to livestock, the traditional store of wealth, savings accounts can sustain asset values during droughts. Furthermore, managing herd sizes will diminish demands on water during droughts and help control pollution loads where drinking water sources and livestock are in close proximity.

The Bank is in discussions with the GoE regarding potential support for ongoing resettlement programs. Before lending support, the Bank should analyze these programs to determine whether the proposed settlement patterns and livelihoods will be adequately resilient to hydrological variability. Since the objective is to move farmers away from vulnerable food-insecure areas, adequate incentives and investments should be put in place to ensure that their livelihoods are more diversified and less dependent on rainfall.

A STRATEGY FOR WORLD BANK SUPPORT IN WATER RESOURCES

The needs in Ethiopia are great, and it is difficult to draw comparisons regarding the urgency of needs across different sectors. From the perspective of enhancing Ethiopia's resilience to drought and hydrological variability, however, there are several areas that stand out as priority investments:

- Multipurpose hydraulic infrastructure development, including both hydropower and irrigation
- Water supply and sanitation
- Watershed management
- Transport, market infrastructure, and private sector development

Multipurpose Storage Development

Multipurpose storage development addresses many of the vulnerabilities discussed in this report and would help shift the structure of the economy toward a more resilient path. Multipurpose dams can be large or small. They can be designed to create storage capacity, regulate flows during droughts and floods, generate hydropower, provide irrigation water, and develop fisheries opportunities. In light of our finding that returns to irrigation should be greater than expected in Ethiopia, irrigation should be given particular consideration.

Any project of this nature includes both investment in the infrastructure itself and in the institutions and capacity required to operate it appropriately and sustainably. Properly designed multipurpose dams necessarily include concomitant investments in watershed management. Investments should be targeted and co-located to capture synergies. Because Ethiopia's most promising development sites are on transboundary rivers, continued international cooperation will be essential. This cooperation could strengthen regional relations and economic integration, bringing additional benefits.

The potential costs and complications that may arise as a consequence of safeguard requirements and potential opposition to dam development must be accepted by both parties before major efforts begin. If and when the parties are satisfied that the development benefits outweigh the costs of engagement, the partnership will hold great promise.

Drought and Flood Control

Water storage capacity will immediately provide the country's water resources managers with a powerful and direct means to mitigate the devastating impacts of drought and floods. To fully utilize this capacity, concomitant investments in early warning systems and capacity building are needed. In addition, the river regulation provided by this infrastructure could be used to develop productive uses such as hydropower, irrigation, and fisheries and to safeguard ecosystem needs by ensuring adequate environmental flows.

Hydropower Development

Ethiopia's untapped hydropower potential is enormous, and many of the potential development sites pose moderate environmental and social impacts. The development of hydropower is a nonconsumptive use of water that would provide a clean, renewable source of energy to help fuel the Ethiopian economy. The availability of electricity could reduce fuelwood reliance, with all of the associated benefits to the environment, women, and children previously discussed. Reliable energy is an essential factor in providing the means and incentives to transform the economy.

While the current expressed demand for energy is small, historically most countries have successfully developed energy infrastructure ahead of demand. In a country where less than 15 percent of the population has access to modern energy, it is appropriate to assume that demand will grow. Given this extraordinarily low level of energy access, it might be appropriate to consider the provision of energy as a basic need analogous to roads and water supply, a crucial component of the minimum infrastructure platform needed to transform the country's subsistence economy into a more vibrant and diversified one.

There also appears to be real potential for energy export to Djibouti, Sudan, and Egypt, which could help justify significant investments in hydropower development beyond Ethiopia's immediately projected needs. Having trade relations could also help stabilize regional relationships and integrate regional economies. Under the NBI, Ethiopia is exploring opportunities to develop its hydropower potential cooperatively with its downstream neighbors, Sudan and Egypt. Downstream neighbors could also benefit from Ethiopian hydropower developments because hydropower is a nonconsumptive use of water and operation of the plant could regulate downstream flows and diminish sediment loads.

Irrigation and Drainage Development

The model developed in this study suggests that returns to irrigation and drainage are routinely underestimated when hydrological variability is not explicitly incorporated into economic modeling. Irrigation opportunities exist in many parts of the country. Some indications suggest that the potential for cost-effective irrigated cereals is limited, and that irrigation investments will be most attractive for the production of higher value cash crops. However, the potential for irrigation and drainage investments is clear, and these benefits will grow dramatically when concurrent investments are made in market infrastructure and private sector–friendly policies are strengthened. If power becomes available locally and domestic fertilizer production grows, agriculture may become increasingly profitable. Similarly, if agri-processing industries expand in response to both energy and infrastructure availability, demand for raw materials should grow.

Synergies: Greater Than the Sum of the Parts

The development of multipurpose dams, by definition, will capture many of the synergies discussed here. Co-located investments in market infrastructure and targeted watershed activities, discussed below, will also greatly strengthen the impact of multipurpose investments. Such development can put in place the opportunities and the incentives needed to provide more resilient and more diversified economic growth.

Caveats

The Bank's rigorous safeguard policies are an important assurance of the quality of its work. At the same time these requirements are sometimes viewed as onerous by our clients and may be perceived to slow project preparation and add costs to the bottom line. It must also be anticipated that development of dams in Ethiopia will meet with significant scrutiny and potential opposition locally and internationally, particularly if it is found that large dams are the best option for certain sites. These risks must be clear before the Bank engages, and both parties must be willing to accept them before major efforts begin.

World Bank's Comparative Advantage

The Bank has a strong comparative advantage in supporting Ethiopian development of multipurpose dams, demonstrated most recently by the success of Gilgel Gibe. Multipurpose dams, whether large or small, can be complex and costly, requiring considerable financing and expertise. Many of the most promising development sites are in the Nile River Basin, which, historically, made them difficult to develop. Even now with the impressive successes of the NBI, development of the sites will require significant diplomacy, particularly if regional partners are to be deeply involved. The Bank, as the lead donor and facilitator of the NBI, is uniquely well placed to help Ethiopia develop these sites within the framework of the NBI.

The far-reaching potential benefits of multipurpose dam development, and the unique qualifications of the Bank to support these investments, strongly recommends support of multipurpose dam development with an emphasis on hydropower generation and regional interconnection as a first priority for future Bank assistance in water resource management.

Water Supply and Sanitation

Investments in water supply and sanitation should aim to help Ethiopia achieve the MDG of reducing its unserved population by half by 2015. This will require more financing as well as a concerted effort to strengthen institutions and national capacity for implementation by public and private sector actors.

To ensure that funds can be channeled more efficiently and effectively, the GoE has developed a strong policy and strategy for reform. Its investment program now has "rules of engagement," streamlined implementation arrangements, and principles of monitoring and evaluation to improve transparency and accountability. In addition, it is essential that water resource concerns, such as groundwater management, siltation, and watershed management, be integrated into water supply and sanitation projects.

Caveats

Past interventions by the GoE and various donors have not always been well coordinated, resulting in inefficiency and low sustainability. The Bank recently approved the $100 million Water Supply and Sanitation Project to help finance implementation of the GoE's water supply and sanitation investment program. This project represents only one-fifth of the level of investment needed over the coming five years for Ethiopia to be on target for achieving the MDGs for water supply and sanitation. It primarily supports capacity building in the public and private sector through training and on-the-job support.

World Bank's Comparative Advantage

The Bank's ongoing involvement in the Water Supply and Sanitation Project points to the need to continue its support to the sector as well as increase efforts to attract additional financiers and help coordinate support to Ethiopia in meeting the water supply and sanitation MDGs.

Watershed Management

Good watershed management can slow soil erosion in the watersheds, moderate runoff and potential flood damage, and improve infiltration of water into soils and groundwater acquifers. These changes help moderate the hydrological cycle and sustain agricultural productivity. In addition they could reduce sedimentation rates, thus extending the useable capacity of reservoirs and reducing water treatment plant costs.

Moderate Hydrology

Effective watershed management can help regulate runoff and augment groundwater recharge, limiting the impacts of drought and flood on agriculture and reducing costly flood damage to roads and other transport infrastructure.

Mitigate Land Degradation and Slow Sedimentation in Rivers and Reservoirs

Appropriate watershed management can also reduce soil erosion, help to sustain agricultural livelihoods, and diminish the costs and increase the life of downstream reservoirs and irrigation infrastructure.

Caveats

There have been many efforts to strengthen watershed management in Ethiopia, undertaken by a wide range of actors. These experiences have highlighted the need to effectively include stakeholders in the planning, design, and management of watershed interventions. An important lesson from the analysis in this study is that watershed management may significantly promote economic growth if the current pattern of settlement and economic activities is maintained. Watershed management efforts should be designed to address the core issues—sustainable livelihoods and ecosystems—and may require real innovations in methodology, financing, alternative livelihoods, or migration.

World Bank's Comparative Advantage

Many groups support the GoE in watershed management. For some projects, however, the Bank has a comparative advantage. First, in any watershed where the Bank is supporting a multipurpose dam project, it should implement a watershed management plan. The Bank would have a clear advantage in designing and implementing the two, either as two components of a single project or two standalone projects if, for example, the watershed management project began implementation prior to the finalization of the dam project. Analogously, Bank-supported road investments might also benefit from associated watershed management investments.

The Bank might also have a comparative advantage in projects that confer significant benefits to downstream countries. Given the Bank's involvement in the NBI, this advantage could be particularly pronounced with regard to sedimentation benefits on the Nile. Finally, the Bank may have a comparative advantage in watershed management investments that are eligible for carbon offsets, a new and promising area of potential finance.

Most immediately, a cooperative watershed management project is under consideration within the framework of the NBI. This should be given priority support in the Bank's portfolio.

Transport, Market Infrastructure, and Private Sector Development: Growth Poles

Although investments in transport, market infrastructure, and private sector development are generally considered to fall outside the realm of water resources management, they are powerful hydrological risk-management investments. Investment in these areas will help diminish the internal fragmentation of the Ethiopian economy, which compounds the impacts of regional water shocks and helps shift the economy toward a more water-resilient structure. Their scale, scope, and priority should therefore be enhanced.

Transport disruptions and interregional trade

Improving the coverage and quality of Ethiopia's road network will make the economy less vulnerable to transportation disruptions caused by floods, ensuring that producers can move their product to market. Interregional roads would facilitate the growth of trade between regions, bringing surplus production to deficit areas, helping to smooth weather-related price shocks, and promoting a more integrated national economy.

Economic diversification

In the medium term, this study suggests that investments in fully functioning market cities with regional infrastructure and communications interconnections could be particularly effective in providing alternatives and incentives to shift vulnerable populations toward more resilient livelihoods. It also suggests that the quality of roads is essential, and thus investments in all-weather roads should take increasing priority.

Investments in fully functioning market cities (growth poles) with regional infrastructure and communications interconnections are potentially powerful investments for managing hydrological risk in Ethiopia. The Bank should therefore support the development of growth poles with adequate hydraulic infrastructure, all-weather roads, and market infrastructure.

Appendix 1. Technical Notes on the Model

The model is explicitly dynamic, running for a period long enough to explore the implications of hydrological variability and drought or flood events over time. In constructing the model consideration was given to the fact that Ethiopia's economy and hydrology are characterized by:

- Highly variable rainfall and endemic droughts and floods
- Fragile and degrading landscapes
- Low levels of infrastructure investment to mitigate against hydrologic variability
- Fragmentation of the economy, particularly regional segmentation in agricultural markets
- High transportation and marketing costs

A national multisectoral and multiregional model was modified to capture these characteristics. It builds on a spatial multimarket model that is enhanced to capture cross-sectoral linkages, particularly between agricultural and non-agricultural sectors. It also captures the important links between water demand and supply and economic activity, focusing largely on agriculture. The model disaggregates agricultural commodities by region of origin, where regions are defined to correspond as closely as possible to watersheds.

The model captures key features of the Ethiopian context, such as weak or nonexistent linkages between prices on world markets and prices in Ethiopian regions that are geographically and economically "distant" from access points to world markets. In such an environment, regional hydrological variability will have potentially more serious impacts, since the local impact cannot be buffered or ameliorated through market links to other regions. There also may be significant threshold effects whereby prices must rise above critical values before inducing trade with other regions or fall below a certain level to gain access to world markets.

Regional differentiation was modeled by classifying nine development domains; that is, spatial representations of three factors considered important for rural development: agricultural potential, market access, and land altitude.

The structure of the economy is modeled as including 34 disaggregated agricultural commodities and two aggregate non-agricultural commodities. Production of all the 36 commodities is further disaggregated into 56 zones. The supply function for the 28 crop products at the zonal level is a combination of a yield function (a function of own price and productivity parameters) and an area function (a function of the prices for all the 36 commodities, including the prices for the two aggregated non-agricultural commodities and a shift parameter). The supply functions for the livestock and non-agricultural sectors depend on the prices for all the commodities and productivity parameters. While constraints on total agricultural land or other resource factors are not modeled explicitly, the model does impose constraints on the elasticities employed in the supply functions in order to avoid a simultaneous increase in the output of all products in a given year.

At this stage of the model's development it cannot explicitly address:

- The dynamics of food aid
- The direct impact of hydrology on power
- The tradeoff between hydropower and agriculture

Hydrology is incorporated into the model primarily as an input in agricultural production through the agricultural yield function. Multimarket models typically specify only commodity supply functions (that is, output as a function of prices rather than inputs) and, hence, do not explicitly specify production technology. In this model, technology differences are captured by incorporating two types of supply (or yield) functions for the same crop: one production function for irrigated and a second for rainfed yields. The difference in technologies is reflected by the yield gap between the two supply functions for the same crop.

DATA FOR HYDROLOGICAL VARIATIONS

The smoothed rainfall variation assumes 1995–2002 average rainfall in all years. The stylized drought variation models the variability of rainfall and its effect on the economy as exogenous shocks to the yield and area only for rainfed crops.

Rainfall shortages are modeled as deviations from a 100-year mean rainfall level calculated for each of the 56 zones. We assume that the drought affects both the yield and area cultivated, and the negative effect at the zonal level is assumed to be proportional to the value of the rainfall deviation in each zone during the benchmark drought of 1997–8. The difference between the results derived from the smoothed rainfall scenario and the stylized drought scenario were interpreted to reflect the impact of the drought on economic performance and poverty projections and, also importantly, the significant impact of explicit hydrological modeling on the predictive power of the model itself.

The historical variability variation captures annual rainfall fluctuations whose associated cumulative losses affect growth performance and potential over time. An ensemble of historical hydrographs was used to derive yield functions reflecting the impact both of drought and of flood in a given year. Nine 12-year combinations were taken from the 100 years of recorded data available: 1900–12, 1913–24, 1925–36, 1937–48, 1949–60, 1961–72, 1973–84, 1985–96, and 1989–2000. All of the combinations were modeled to start from the same base year, 2003, for ease of comparison. This stochastic model provides a range of results rather than a single result for each simulation.

DATA FOR POVERTY RATES AND GDP

For all scenarios:

- To model rural incomes and poverty, per capita demand for rural and urban areas was specified for each commodity at the zonal level as functions of all commodity prices and zonal-level rural and urban per capita incomes. It was constrained by zonal-level rural and urban budget constraints such that average rural and urban per capita expenditures on all commodities were equal to the average rural and urban per capita income.
- Zonal level rural and urban total incomes are endogenously determined in the model and equal to the sum of production revenues from zonal level agricultural and nonagricultural activities. The average rural and urban per capita income at the zonal level is obtained by dividing the zonal level total income by its rural and urban population. The population growth rate is assumed the same across zones. Since the model does not take into account of intermediate input costs, prices for the agricultural goods are adjusted such that total agricultural revenue is close to the value of agricultural GDP. Together with the two nonagricultural sectors, which represent industrial and service GDP, total income equals the country's total GDP.
- The poverty rate in the initial year (2003) is taken from the GoE's official poverty rate based on 1999/2000 Household Income, Consumption, and Expenditure Survey. According to the survey, the national absolute poverty rate is 44.2 percent, with a rate of 45.5 percent in rural and 36.9 percent in urban areas.

DATA FOR AGRICULTURE AND TRADE

We assume an integrated national market with different marketing margins across zones. Thus for each individual commodity, total supply at the national level, net trade, equals total demand at the national level. Marketing margins reflect both the distance from Addis Ababa, a proxy for market access, and food deficit or surplus situations for each region. For a commodity produced in a region with a food surplus, producer prices will be lower than that in the Addis Ababa market, and the farther from the capital city, the lower the price. For the same commodity produced in a food deficit region, consumer prices will be higher than that in the capital city, and the farther from the city, the higher the price.

The model also considers the price gap between domestic and international markets. The import parity prices are defined as border prices (CIF prices) plus transportation and other marketing costs from the port to Addis Ababa. Export parity prices are FOB prices minus transportation and marketing cost. For a specific commodity, if trade data show the commodity is imported, we assume that the domestic price faced by consumers is higher or equal to the import parity price. Similarly, if trade data show the commodity is exported, domestic producer prices are assumed to be lower or equal to the export parity price. For these traded commodities, domestic prices are linked to world prices, and hence are exogenously determined in the model.

For most agricultural products, such as pulses, roots, oil crops, and livestock products, the trade data show no significant imports or exports. We therefore assume that they are not initially traded, and domestic prices are modeled as endogenously determined in the domestic markets at a level below the import parity price but above the export parity price. If growth in domestic supply cannot match growth in domestic demand, which is mainly driven by population growth, prices for some of these products will rise in the domestic market and imports may occur over time.

Productivity increases over the period are based on 1995–2002 average growth rates in individual crop yields, area expansion, livestock production, and the industrial and service sector GDP. During this period, about 80 percent of the increase in total crop production was due to area expansion, which occurred at an annual growth rate of about 1.5 percent. Growth in crop productivity (yield) has been extremely slow, reaching only about 0.5 percent per year.

Appendix 2. Water-Related Programs in Ethiopia

Ongoing and Upcoming Irrigation Projects

Ongoing study/design projects	Status (2005)	Hectares
Kesem	Design	30,000
Tendaho	Design	60,000
Gumera	Feas/Design	13,976
Arjo Dedessa	Feas/Design	14,280
Upcoming study/design projects (2005–10)	**Level of study/design**	**Hectares**
Megech	Feasibility/Design	31,821
Ribb	Feasibility /Design	19,925
Anger	Feasibility /Design	14,450
Negesso	Feasibility /Design	22,815
Humera	Feasibility /Design	42,965
Errer and Gololch	Feasibility /Design	14,000
Angereb	Feasibility/Design	16,535
Upper Beles irrigation project	Feasibility/Design	53,700
Bilate (Rift Valley) irrigation project	Feasibility/Design	7,800
Gilgel Abbay irrigation project	Feasibility/Design	23,577
Ongoing construction projects	**Status (2005)**	**Hectares**
Kesem	Construction	30,000
Tendaho	Construction	60,000
Koga	Construction	7,000
Upcoming construction projects (2005-10)	**Status (2005)**	**Hectares**
Part of Gode West	Construction	6,600
Gumera	Construction	13,976
Arjo Dedessa	Construction	14,280
Megech	Construction	31,821
Ribb	Construction	19,925
Anger	Construction	14,450
Negesso	Construction	22,815
Humera	Construction	42,965
Errer and Gololch	Construction	14,000
Angereb	Construction	16,535
Upper Beles	Construction	53,700
Bilate (Rift Valley)	Construction	7,800

Source: MoWR.

Ongoing and Upcoming Hydropower Projects

Ongoing study projects	Level of of study	Installed capacity (megawatts)
1 Baro Hydropower Project	Feasibility study	800
2 Karadobi Multipurpose Project	Prefeasibility study	1,700
3 Genale GD-3 Multipurpose Project	Feasibility study	245
4 Genale GD-6 Hydropower project	Prefeasibility study	244
5 Wabe Shebele WS-18 Multipurpose Project	Feasibility study	87
Upcoming study/design projects (2005–10)	**Level of study/design**	
1 Baro Hydropower Project	Design	800
2 Genale GD-3 Multipurpose Project	Design	245
3 Wabe Shebele WS-18 Multipurpose Project	Design	87
4 Karadobi Multipurpose Project	Feasibility/design	1700
5 Genale GD-6 Hydropower Project	Feasibility/design	244
6 Mendaia Hydropower Project	Prefeasibility/ feasibility	1,700
7 Border Hydropower Project	Prefeasibility/ feasibility	1,780
8 Tams Multipurpose Project	Prefeasibility/ feasibility	1,020
9 Mabil Hydropower Project	Prefeasibility/ feasibility	1,440
10 Birbir-R Hydropower Project	Prefeasibility/ feasibility	467
11 Dobus Multipurpose project	Prefeasibility/ feasibility	741
12 Didesa Hydropower project	Prefeasibility/ feasibility	308
Ongoing construction projects (2005)	**Year of completion**	
1 Tekeze/TK_5	2008	300
2 Gilgel Gibe-II	2008	420

Source: MoWR.

Donor-Supported Watershed-Related Projects in Ethiopia

Project	Budget in US$ (million)		Donor	Project starting date	Project ending date	Project location	Collaborators	Remarks
	Donation	Loan						
Aquifer studies for potable water supply	4.45	-	JICA	1998	2005	To train regional staff	MoWR	A number of staff in the regions trained
Awash River Flood Control studies		-	AfDB	2002	2005	On the Awash River	MoWR	
Biodiversity strategy action plan	5.00	-	UNDP/GEF	1999	2005	At federal level	IBCR	Conservation and use of biodiversity resources for sustainable agriculture
Dynamic farmers	2.50	-	UNDP/GEF	1995	2004	ORS, SNNP region, TRS, AfRS	IBCR with the regional offices	Conservation of land races in drought prone areas and use of the materials
Emergency drought recovery project	15.00	-	World Bank	2003	2006	35 drought affected woredas in AfRS, TRS, SNNP regional state, ORS, AfRS, and SRS	MoARD, Woreda Bureau of Agriculture and Communities	Community-driven development
Ethiopia Nile Basin Conservation Study Project	3.00	-	AfDB and CIDA	2003	-	AfRS, ORS, TRS, SNNP regional states, BRS, GRS	MoWR, EMA	
Ethiopian Nile Basin Development Authority Project	1.56	-	French government	2002	2005	Nile Basin	MoWR, CSA, EGS, and MoARD	Based on the results, holistic developmental approach to be followed
Food security capacity building	2.18	-	BMZ	2002	2005	AfRS,ORS, TRS, and SNNP regional states	MoFED	Giving support to food security coordination offices
Food security project	-	85.0	WB	2002	2009	AfRS, ORS, TRS, and SNNP regional states	MoARD with the four regional agricultural offices	Community-driven development
Forest management in Adaba-Dodola	7.50	-	BMZ	1995	2004	ORS	GTZ and ORS Bureau of Agriculture	Develop feasible approach for conservation of forests
Genalle-Dawa Basin master plan studies	0.52	-	AfDB	2001	2005	Southern east of Ethiopia (ORS, SNNP regional states, and SRS)	MoWR, EMA, EGS, and NSL	

Donor-Supported Watershed-Related Projects in Ethiopia (continued)

Project	Budget in US$ (million)		Donor	Project starting date	Project ending date	Project location	Collaborators	Remarks
	Donation	Loan						
Household energy and protection of natural resource	3.30	-	BMZ	1998	2005	AfRS, ORS, TRS, and SNNP regional states	GTZ , MoARD	GTZ assists MoARD research and development and implementing agencies in four regions to increase biomass energy efficiency
Hydropower site studies	1.44	-	Norwegian government	1995		AfRS and ORS	MoWR, regions	
Koga Irrigation Development Project	1.35	39.69	AfDB	2002	2007	Wechecha Woreda, Wastern Gojam	MoWR, EMA, and AfRS	Good progress has been achieved
Land use planning and resource management in ORS	8.23	-	BMZ	1997	2006	ORS	GTZ, ORS land and natural resource office	Support and disseminate integrated watershed manage ment
Microenterprise development and agricultural extension	17.00	-	USAID	2002	2007	AfRS	Virginia Technical University and AfRS offices	Integrated food security and environmental protection in the Amhara region
Pastoral Community Development Project	60.00	-	World Bank	2003	2008	AfRS, SRS, ORS, and SNNP regional states	MoFA and the four regional agricultural offices	Community-driven development
Promotion social forestry in Tigray	10.50	-	BMZ	1997	2005	TRS	Bureau of Agriculture and Natural Resources of Tigray	Extend services with agro-forestry actions to farmers
Small irrigation projects	15.61	31.53	Irish and French governments	1999	2005	AfRS, ORS, TRS, and SNNP regional states	MoWR, regions	Small-scale irrigation projects started in four regions
Small-scale irrigation projects	-	23.5	World Bank	1996	2004	In all the regions except SRS	ESRDF with communities	Demand-driven community investment; communities have to be prepared to cover 10% cost
Support to the Biodiversity Institute	1.70	-	BMZ	1998	2004	At federal level	IBCR	Preserve forest genetic resources as a requirement for sustainable utilization

Donor-Supported Watershed-Related Projects in Ethiopia (continued)

Project	Budget in US$ (million)		Donor	Project starting date	Project ending date	Project location	Collaborators	Remarks
	Donation	Loan						
Sustainable environmental management	4.50	-	UNDP	2003	2006	Regional and federal EAP offices	EAP	Policy formulation and implementation of the policies
Technology transfer and market accessibility	15.00	-	CIDA	2004	2008	All regional states	MoARD, ILRI, and regions	Launched in July 2004
The rehabilitation of dryland agri-culture and forests in Ethiopia: ecology and management	11.00	-	Belgian government	2004	2009	TRS	Katholieke Unviersity, Leuven; Mekele University; RES	Improved agricultural management and environmental pro-tection
Water resources development and utilization	5.00	-	UNDP	2002	2007	In 10 regions	MoWR with the regional offices	Rehabilitation of irrigation schemes, water supply, and sanitation

Notes: JICA, Japan International Cooperation Agency; AfDP, African Development Bank; UNDP/GEF, United Nations Development Programme/Global Environment Facility; CIDA, Canadian International Development Agency; BMZ, German Federal Ministry for Economic Cooperation and Development; USAID, U.S. Agency for International Development. ORS, Oromia national regional state; TRS, Tigray Regional State; AfRS, Afar Regional State; SRS, Somali Regional State; BRS, Benishangual Gamuz National Regional State; GRS, Gambella National Regional State; EAP, East Asia and the Pacific.
IBCR, Institute of Biodiversity Conservation and Research; MoARD, Ministry of Agriculture and Rural Development; EMA, Ethiopian Mapping Authority; CSA, Central Statistical Authority; EGS, Ethiopian Geological Survey; MoFED, Ministry of Finance and Economic Development; GTZ, German Technical Cooperation; NSL, National Soils Laboratory; ESRDF, Ethiopian Social Rehabilitation and Development Fund; ILRI, International Livestock Research Institute; REST, Relief Society of Tigray.
Source: A desk study by Abiy Astatke for the ENSAP watershed management project background paper.

Appendix 3. World Bank Projects in Ethiopia

World Bank–Supported Projects in Ethiopia

Current portfolio				
Lending:				
P050383	Food Security Project The development objectives are to build the resource base of poorer rural households, increase their employment and incomes, lower the real costs of food, and improve nutrition levels especially for children under five years of age and pregnaant and lactating mothers (by e.g., better management of rainfed agriculture; investment in small-scale irrigation; better natural resource management through "zero tillage" techniques on farms; and watershed-level activities to conserve soil, reverse soil degradation, improve water harvesting, and so on)	Total costs: US$110.16 million; IDA US$85.0 million	Other agriculture	2002
P081773	Emergency Drought Recovery Project The objective is to enable the GoE to help affected families survive the crisis, retain productive assets, and develop sustainable livelihoods, as well as contribute to stabilizing the macroeconomy. The main outcomes of the project will be to contribute to: (1) defend critical human development expenditure by the GoE during the next year from the pressures caused by the current crisis; (2) maintain the availability of critical economic inputs (particularly those needed in rural areas) and support the economic recovery process; (3) rehabilitate and/or create communal assets using community labor of the affected population; and (4) provide income supplements and protect private assets of the affected population. The project uses a community-driven development approach, and, based on community priority investment needs, small-scale water development operations could be financed. The Food Security Office under the newly restructured Ministry of Agriculture and Rural Development is managing the project.	Total costs: US$61.7 million; IDA US$60.0 million	Food Security, Natural Resource Management	2003
P000736	Energy II The objectives are to increase the efficiency and sustainability of Ethiopia's power sector and to increase electricity use for economic growth and improved quality of life and to improve utilization efficiency of rural renewable energy. The project comprises the following components: (1) decentralization of	Total costs: US$295.0 million IDA US$200.0 million	Power and Energy	1998

continued

World Bank–Supported Projects in Ethiopia (continued)

P000736 (continued)	the Ethiopian Electric Power Corporation's (EEPCO) accounting system; (2) decentralize part of EEPCO's billing system as a pilot, which requires branch office renovation, computer, software, and accessory installation, as well as other training and consulting services; (3) manpower development to support EEPCO's restructuring to give more control to regional management; (4) construction of the Gilgel Gibe hydroelectric plant to increase generation capacity; (5) establishment of a dam safety, maintenance management system, and optimization of water use; (6) strengthen rural energy capability by adapting technology and training research personnel overseas in various energy fields; (7) complete the Woody Biomass inventory data collection and remote sensing survey indicating the extent and productivity of grazing lands and undertaking a livestock carrying capacity analysis; (8) studies including sector restructuring study, a generation expansion study, a tariff study, and a valuation of fixed assets; and (9) assistance converting the state-owned utility (EEPCO) into a commercial operation, as well as other restructuring measures.			
P049395	Energy Access Project — PE The objectives are to: (1) establish a sustainable program for expanding the population's access to electricity and improving the quality and adequacy of electricity supply, thus supporting broad-based economic development and helping to alleviate poverty; (2) reduce environmental degradation and improve energy end-use efficiency; (3) reduce the barriers to the widespread adoption of renewable energy technologies, in particular solar photovoltaic and micro hydropower generation in rural areas, thereby contributing to the reduction in greenhouse gas emissions via displacement of kerosene and diesel that would otherwise be used for lighting and electricity generation; and (4) provide technical for institutional and capacity building of key sector agencies, including for regulatory, fiscal, and institutional reforms in the mining sector.	Total costs: US$199.12 million; IDA US$132.7 million	Power and Energy	2003
P000733	Agricultural Research and Training Project The project will make the Ethiopian agricultural research system more efficient and sustainable by: (1) building institutional capacity to manage the entire agricultural research system; (2) rationalizing the way the programs are identified, designed, and prioritized according to an acceptable economic criteria; (3) improving their relevance through decentralization; (4) drawing on the relevant pool of knowledge available internationally; (5) consolidating and strengthening the existing research centers; (6) expanding research facilities into less favorable agro-ecological settings; and (7) building human resource capacity in collaboration with the Alemaya University of Agriculture. There are three components in this project. First, agricultural research management will assist in operationalizing the Ethiopian Agricultural Research Organization, designing and implementing a decentralized research system, implementing new systems and procedures for efficient agricultural research management, and developing a strong program of research-extension-farmer linkages.			

continued

World Bank–Supported Projects in Ethiopia (continued)

P000733 (continued)	Second, strengthening of the agricultural research system will rehabilitate and expand the existing research system to make its operation more efficient and its work environment more conducive to research work. Third, human resource development will provide technical assistance and training for the researchers in the research system and those at the university.	Total costs: US$60.0 million; IDA US$60.0 million	Research	1998
P000764	Water Supply Development and Rehabilitation Project The main objectives are to ensure the long-term viability of water supply and sanitation operations in line with the GoE's regionalization policies and, in the long run, improve the health and productivity of the population. The objectives will be met by providing assistance for: (1) capacity building of the regional governments and water supply and agencies for management of urban water supply and sanitation schemes and rural water supply operations; (2) formulation of policies to ensure long-term financial and managerial viability of water supply operations, establishment of regulatory arrangements, and sound investment planning by the regional governments and water supply agencies; and (3) short- and medium-term physical rehabilitation, augmentation, and establishment of urban water supply and sanitation schemes in war-affected and the most deficient regions. The project will consist of the following components: (1) institutional capacity building, which includes water supply sector capacity building and rural water supply pilot scheme (this component will provide studies, technical assistance, training, equipment, service rigs, mobile workshops, vehicles, and the construction of pilot schemes); (2) feasibility and engineering, which will consist of water and sanitation scheme feasibility, engineering designs, and building works designs; and (3) physical works comprising water and sanitation scheme rehabilitation as well as building works.	Total costs: US$65.5 million; IDA US$35.7 million	Urban water supply	1996
P000771	Social Rehabilitation Project The project will provide to poor, mainly rural communities the assets and services needed to improve their economic and social standards and will provide financial and technical support to communities and community groups to construct or rehabilitate and maintain basic economic and social infrastructure and services that they have prioritized and in which they are willing to invest. In addition, it will support community actions aimed at environmental conservation and rehabilitation. Efforts will be focused on poor communities and, especially, poor women. To achieve these goals, the project will strengthen community capacity in project identification, implementation, and maintenance. The project will also support the establishment of a Welfare Monitoring System to strengthen capacity to collect and analyze information related to causes, patterns, and incidence of poverty and to improve the basis for developing poverty reduction strategies, assessing the impact on the poor of economic policy reform, and evaluating the benefits of other poverty reductions interventions. The components of this project will be as follows: (1) construction and rehabilitation of social and economic infrastructure	IDA US$120.0 million	Social protection	1996

continued

World Bank–Supported Projects in Ethiopia (continued)

P000771 (continued)	and improvement of related services, including basic health and education, small-scale irrigation, urban sanitation, and rural water supply; (2) welfare monitoring system; and (3) capacity building, training, and research.			
P075915	Pastoral Community Development Project The proposed project would consist of (1) the development of an institutional framework that would empower pastoral communities and facilitate demand-driven investments at community and zonal levels, (2) a social and economic investment fund with components for demand-driven micro-investments and for larger zonal infrastructure investments, and (3) a component for research and extension on a variety of social and economic issues	Total costs: US$60.0 million; IDA US$30.0 million	Community action program	2003
P073925	Capacity Building for Decentralized Service Delivery Program The proposed project aims to enhance decentralized service delivery performance by initiating long-term public sector capacity building at the federal, regional, and local levels. Building public sector capacity through institutional reforms, systems development, and training would promote effective policy formulation and implementation, particularly in key sectors such as infrastructure, health, and education. The proposed project, envisaged as a first phase of long-term Bank lending and nonlending support, seeks to enhance service delivery performance through a coordinated program of: (1) federal civil service reforms, (2) regional capacity building, and (3) local government restructuring and empowerment. Over the life of the proposed project, key reform and capacity building activities will be piloted in selected federal, regional and local government entities.	Economic and Sector Work	Decentralization	2003
AAA:				
Standard:				
P059215	Small-Scale Irrigation and Conservation Project The project, supported by Credit l765-ET for US$7.0 million equivalent, was approved in FY87. The project was cofinanced by the International Fund for Agricultural Development (US$11.0 million equivalent), and the Organization of Petroleum Exporting Countries Fund (US$4.0 million equivalent). The credit was closed in FY97. The project's principal objectives were to increase food production in drought prone areas through the development of small-scale irrigation for 25,000 farm families and control land degradation in the highlands to benefit 300,000 families. There were five components: (1) institutional capacity building through technical assistance, staff training, and provision of equipment; (2) construction of small-scale irrigation infrastructure; (3) provision of agricultural support services; (4) soil conservation through biological bund stabilization; and (5) support for women's activities. The project was implemented during a period of intense political, administrative, and social turmoil that dramatically slowed	Total costs: US$22.0 million; IDA US$7.0 million	Irrigation and drainage	1999

continued

World Bank–Supported Projects in Ethiopia (continued)

	implementation. The project, the institutional capacity-building components, were very successful in training a cadre of competent irrigation, agricultural extension, and soil conservation professionals in the line agencies. Farmers have formed themselves into water users' associations that have taken responsibility for scheme operation and maintenance and achieved a substantial level of cost recovery.			
Future portfolio				
Lending:				
P076735	Water Supply and Sanitation Project By shifting from the centralized approach to identifying, financing, and implementing water supply and sanitation projects to a demand-driven approach, whereby local governments and communities would identify projects and appraisal and fund management would be carried out at the regional and/or woreda level, the project would support the GoE's policies of decentralization of resources management to the lowest possible local level and promote the involvement of all stakeholders so as to improve efficiency in service delivery. By requiring demonstration of financial and economic feasibility of proposed investment and financing, operations and maintenance plans and tariffs phasing in full-cost recovery for urban water supply and sanitation project proposals, the project would support the GoE's policy of recognizing water as an economic good and improve the level of cost recovery in both urban and rural water supply to ensure sustainability.	Total costs: US$120.00 million; IDA US$100.00 million	Water and sanitation	2004
P074020	Public Sector Capacity Building Project			
	The objective is to improve the scale, efficiency, and responsiveness of public service delivery at the federal, regional, and local level; to empower citizens to participate more effectively in shaping their own development; and to promote good governance and accountability. This objective will be achieved by scaling up Ethiopia's ongoing capacity building and institutional transformation efforts in six priority areas: civil service reform, district-level decentralization, urban management capacity building, tax systems reform, justice system reform, and information and communications technology.	Total costs: US$397.80 million; IDA US$100.00 million	Civil service reform, decentralization, public financial management, institutional development, judicial reform	2004
AAA:				
P076064	Irrigation note	Economic and sector work	Irrigation and drainage	2002
Standard:				
P049250	SPEC.CTRY PROG. II	Unidentified (standard International Fund for Agricultural Development project)	Irrigation and drainage	2004

continued

World Bank–Supported Projects in Ethiopia (continued)

P075405	Ethiopia: Poverty Reduction Strategy Paper For 2002–5; finished and circulated in August 2002. Prepared by the Ethiopian authorities and contains a declaration of the GoE's commitment to poverty reduction, a description of the existing extent and patterns of poverty, the main elements of its existing poverty-reduction strategy, and a three-year macroeconomic framework as well as a three-year policy matrix. It presents a broad outline for reducing poverty that is grounded in the development strategy laid out in the National Development Program. The poverty reduction strategy is centered around promoting economic growth and increasing the income-earning capacity of the poor. It comprises four elements: (1) an agriculture development-led-industrialization strategy, and food security; (2) civil service and judicial reforms; (3) governance, decentralization, and empowerment; and (4) capacity building. It identifies preliminary quantitative targets for various dimensions of poverty, as well as targets for increases in average income.	Poverty Reduction	Unidentified	2003

Notes: IDA, International Development Association (of the World Bank Group).
Source: Authors.

Endnotes

1. The model includes 56 climatic zones, 34 agricultural commodities, two nonagricultural commodities, and distinguishes between irrigated and nonirrigated areas.
2. Here the term "institutions" incorporates capacity, organizations, policies, rules, and agreements, and integrated water resources management includes investment in water institutions and infrastructure.
3. This is the message of the World Bank's 2003 Water Resources Sector Strategy.
4. See the World Bank's recent (2005) Country Economic Memorandum, "Ethiopia: A Strategy to Balance and Stimulate Growth.".
5. Carbon finance provide resources for projects that reduce greenhouse gas or carbon emissions (for example, through clean energy or reafforestation).
6. These include the Abay (Blue Nile), Tekeze, Baro Akobo, and Omo Gibe basins, largely occupying the western and southwestern parts of the country.
7. For instance, a farmer cultivating steep slope in Delanta Dawunt reported to have lost 1 hectare of his 3 hectare land over a period of 10 years. The bedrock is all that remains once the top soil is washed away (Demeke et al. 2003).
8. There is debate whether the Awash River should be considered a transboundary river shared with Djibouti.
9. Bojo and Cassells (1995) estimated a gross annual financial loss of US$117 million due to nutrient losses and a further US$6 million due to soil erosion.
10. The correlation coefficient between national cereal yield and national average rainfall is 0.338 (significant at slightly less than 10 percent level of significance).
11. Chat has been banned in the United States, Canada, and the United Kingdom.
12. Tropical livestock units = 250 kilograms live weight.
13. For instance, the existing road distance between Bure (a town in west Gojam, close to Wollega) and Dese (Wollo) is 618 kilometers. The air distance between the two is only 298 kilometers and the proposed direct road link (between Gojam and Wollo) is estimated at 381 kilometers.
14. This calculation might well underestimate costs. The actual financial expenditures for the two consecutive years were analyzed to determine what percentage of the total maintenance cost went to water- related defects. Only those activities that are purely related to water-related measures such as ditch clearing, culvert maintenance, and so on are considered, while on the other hand activities such as regraveling and resurfacing activities that may have been caused by washing away of surface material or weakening of the subgrade by capillary action and a combination of other factors were not considered due to difficulties of refining the data.
15. Those designed and maintained for long-term vehicular use.
16. When the power supply is too low to meet the demand of all customers, utilities are forced to temporarily cut off power to some of their consumers—or shed customer loads—in order to protect and stabilize the power system. This is termed "load shedding."
17. To establish the economic potential of energy in Ethiopia, water regulation options were considered that require dam/diversion weir lengths below 750 meters and dams heights below 120 meters. Installed capacity corresponding to output of 145,000 gigawatts per hour per year, at an average plant utilization factor of 0.6, would be about 87,000.
18. Under the new arrangement (introduced in 2000) regional governments pay from their budget for defaulting farmers.
19. More than 80 percent of the fertilizer sales are financed through government credit in Ethiopia. See, for instance, Demeke (2004).
20. Vertisols are dark black soils rich in expandable clay minerals which swell and shrink substantially with moisture.
21. Teff is a staple crop used to produce traditional injera bread.
22. Results for this model are taken from Diao et al. (2004).
23. A stylized drought model was not run for this scenario because that variant of the model would show no impact.
24. Market infrastructure includes roads, transport and storage facilities, communications, and other infrastructure investments that will decrease the costs of transporting and marketing goods.
25. One must be cautious in comparing the results of these scenarios. It must be recognized that the impacts of these two investment tracks are somewhat interdependent. The two scenarios are also drawing on different types of data and making different, heroic, assumptions. While information about approximate costs of irrigation investment per hectare is available, there is no similar information currently available for the costs of investment in roads or other market infrastructure. Direct comparisons cannot be drawn between similar investments targeting irrigation versus road networks. Moreover, it may be unrealistic to believe that roads and market infrastructure can be improved simultaneously nationwide over the next 12 years. Some regions and farmers will neither be able to access improved roads and markets or capture their benefits. However in the road scenario there is less concern about potential negative price effects from increased supplies of grain and other crop products, because improving roads and market conditions can make prices more favorable to both consumers and farmers without affecting those farmers who cannot access markets through price effects.

26. This section is drawn from Grey and Sadoff (2006).
27. Here the term "institutions" incorporates capacity, organizations, policies, rules, and agreements; integrated water resources management includes investment in water institutions and infrastructure.
28. This is the message of the World Bank's 2003 Water Resources Sector Strategy.
29. Watershed interventions are potentially supported through community driven development components under the Small-Scale Irrigation Project, the Pastoral Community Development Project, the Food Security Project, and the Emergency Drought Recovery Project.

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