Water for Food: Everyone's Challenge

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In the United States we have tremendous potential as a result of high yields and large-scale producers. There are 47,400 farms and ranches, and 18.4 million hectares of farmland. The western part of the US corn belt produces more than 40% of the world's corn and soybean, which, sometimes, we take for granted

Despite problems and concerns, including increasing demands for food globally, we assume that what we are doing will be sustainable. There's a sense of stewardship among farmers in Nebraska, and, I suspect, elsewhere in United States, and we expect that high yields will be maintained—even in the face of major shocks—and that our agricultural practices will have acceptable environmental effects. We know that climate change will have an impact, but, because we are resilient, there is the expectation that we will keep producing and feed ourselves.

Population and Productivity

Figure 1 shows expected population increases globally until 2050; 49% of the increase will occur in Africa and 41% in Asia. Numerically, there will be a lot more people in Asia than in Africa, but given relatively poor access to resources, it is important to remember that both of these regions will experience stress.

Figure 2 shows anticipated annual productivity increases that will be needed to double output. Why will output need to be doubled when the population increase will be approximately 50% (Figure 1)? The main reason is that, as people become more affluent, their food expectations change. Particularly in India and China, people will expect to eat more expensive diets, including more meat. Also, we have to worry about land resources.

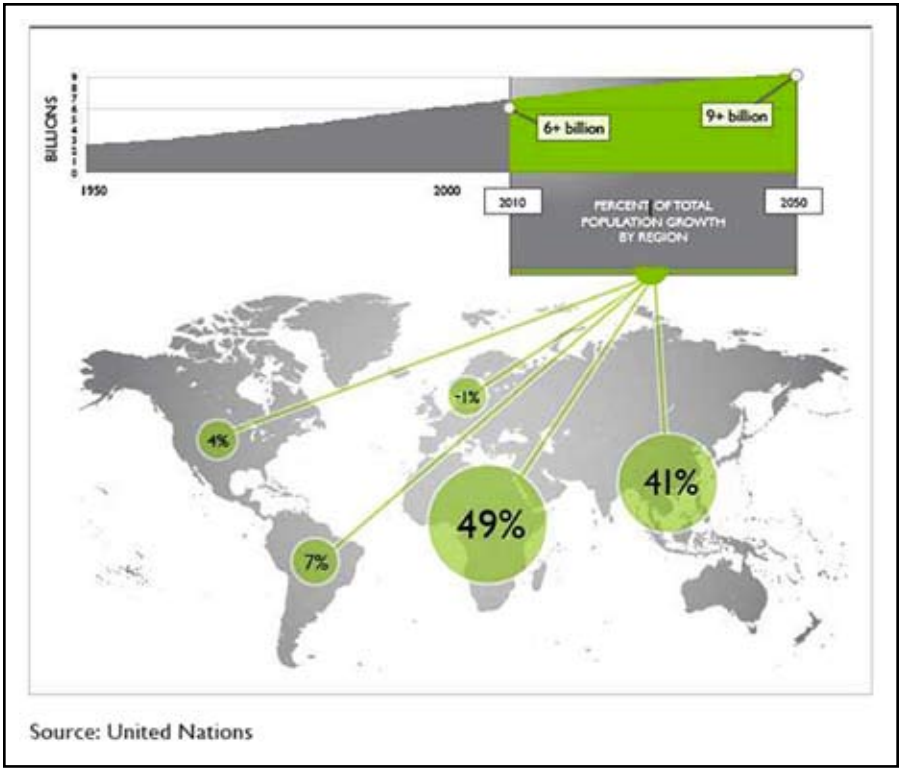

Figure 1. Population growth by region (2010–2050).

Figure 3 shows that the fraction of land area devoted globally to agriculture started leveling off in the 1990s. Africa is the main spot where arable land remains uncultivated. On the other hand, there is concern over loss of biodiversity that may result from uncontrolled expansion of agriculture. Figure 3 also shows cultivated hectares per capita; currently there are only 0.7 hectares per capita, 50% of what was available 50 years ago, as the population continues to grow.

FAO data for 2009 indicate that, in Asia, only 0.13 hectares of arable land are available per capita, whereas Oceania (which includes Australia, much of which is too dry for farming) has 32 hectares of arable land per capita. Africa has 0.31 hectare per capita, and so is in better shape in terms of land resources than is Asia.

Unsustainable Water Usage

Global crop-water demand has grown linearly since the 1960s, and doubled between 1960 and 2000 (Figure 4). One area of concern is increased use of non-renewable groundwater, *e.g.* groundwater mining in the southwest of the United States. However, there is a larger issue in India, particularly in the Indus River plain where groundwater is being mined. Half a billion people depend on food from that area and the groundwater is a finite resource

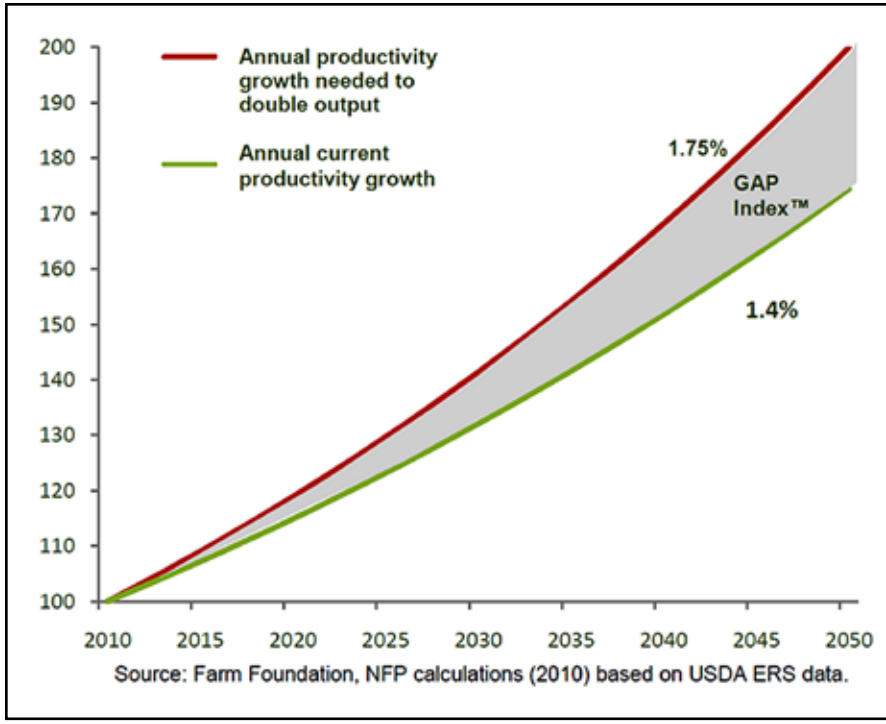

Figure 2. Productivity gap.

that is disappearing. Similar unsustainable withdrawals of groundwater are occurring in China. Therefore, not only do we have to improve water productivity, but we have to achieve it with diminished resources.

FAO data for water usage show that huge amounts are used for agriculture in Asia, and relatively little in sub-Saharan Africa. In Asia, many of the basins are closed and extensive infrastructure has been in place for thousands of years, mainly for cultivation of rice, a water-intensive crop. Africa has significant water resources. There are several major rivers but little withdrawal from them.

Figure 5 provides a water-scarcity map produced by the International Water Management Institute, showing two different types of scarcity:

- absolute physical water scarcity, and
- economic water scarcity

Physical water scarcity is a ratio of how many cubic meters fall on a country or area compared to the number of people inhabiting that country or area. Across North Africa and through the Middle East there is absolute physical scarcity. Economic water scarcity affects more of the globe; it is a measure of the ability of people to withdraw water from the system. It doesn't have a direct bearing on what is available, but indicates lack of infrastructure necessary to use water. And in some areas like the Sahel—the zone below

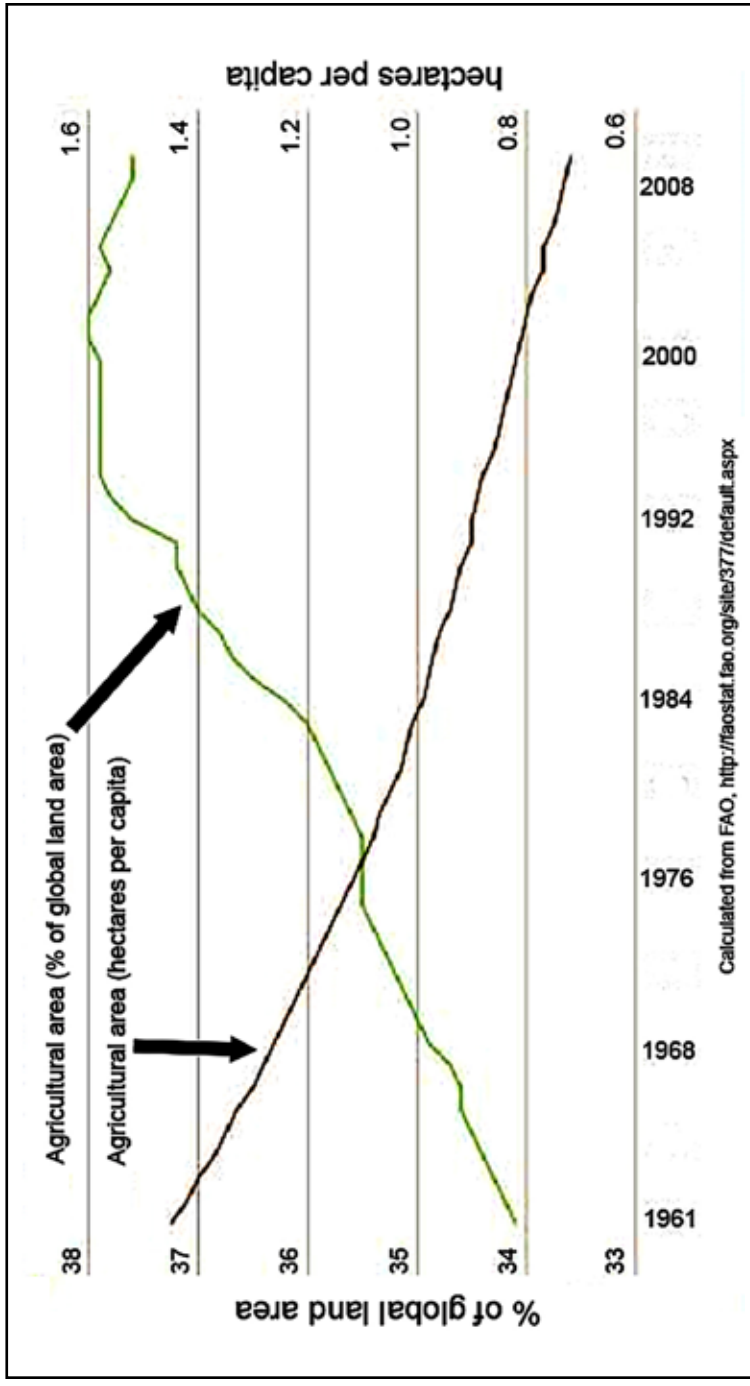

Figure 3. Land used for agriculture

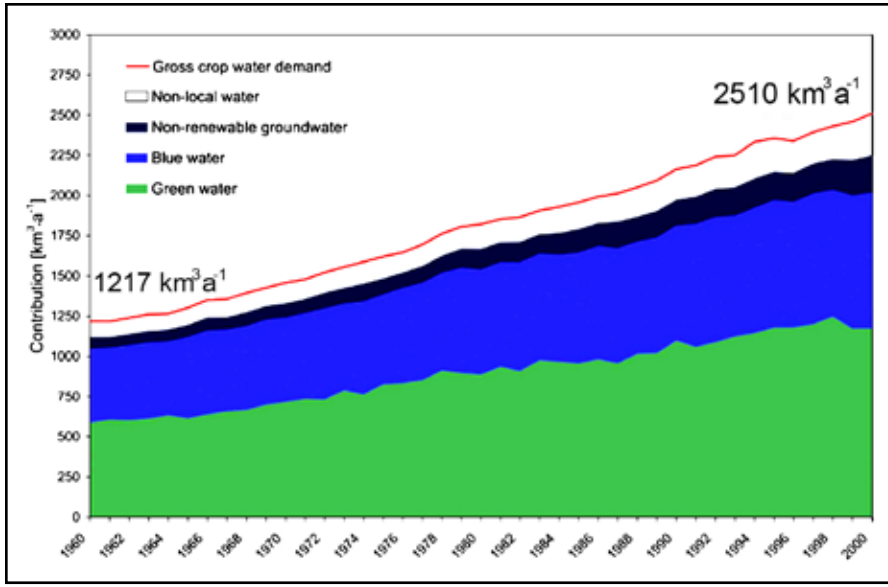

Figure 4. Global gross crop-water demand

North Africa—there is physical as well as economic water scarcity. Figure 5 reveals how dire the situation is in many parts of the world.

Second Green Revolution

The Green Revolution occurred in the late 1960s and early 1970s. Although controversial, there is no doubt that millions of people were fed. Jacques Diouf, director general of FAO has stated:

> *Science and technology must spearhead agricultural production in the next 40 years at a pace faster than the Green Revolution did during the past three decades.*

In Asia in particular, people talk about a second Green Revolution. The first Green Revolution was built on a hydraulic base; irrigation systems were already in place. Yield improvements had a lot to do with the development of input packages for rice. Africa was and remains a different situation in that the infrastructural "backbone" is still not in place. Addressing food-scarcity will be more of a challenge in Africa. Its heterogeneity will require a greater diversity of inputs.

There follow unrelated issues to provide background for discussing Africa:

- Stationarity is dead.
- Africa is a heterogeneous environment.
- National food security and agriculture are drivers of economic growth.
- Policy and practice.

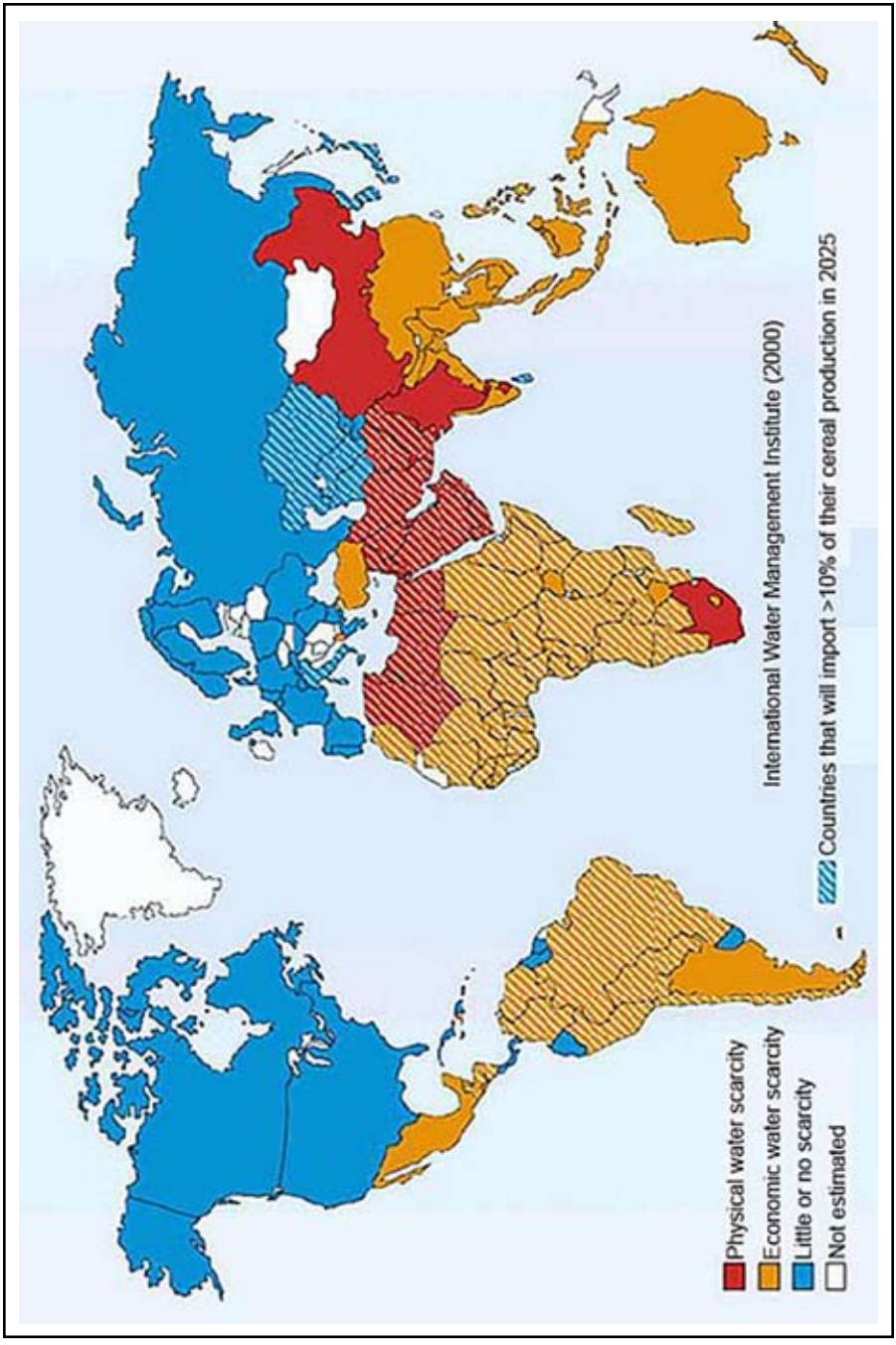

Figure 5. Physical and economic scarcity of water.

First of all, there is every expectation that stationarity is dead. In other words, what happened with rainfall last year, or even over the last 40 years, is not necessarily what we can look forward to. We are pretty sure that the planet is warming, but the implications in terms of water resources or river flows, even in the most basic sense, are poorly understood. We know that there will be more evaporation from the ocean, but it is uncertain whether that will result in more rainfall or drought.

Secondly, and extremely important, Africa is a very heterogeneous environment. I mention this because when we study something, we tend to become an advocate for it. When I studied small reservoirs I began to see utility everywhere in small reservoirs. As an engineer, I am interested in irrigation-water management, but part of me knows that rain-fed production is extremely important. In fact, it's a case of "horses for courses." In one country or region, emphasis should be placed on rain-fed production, whereas in another country or region increasing rain-fed production may mean chopping down forest and destroying biodiversity. All possible options should be carefully considered when we address problems.

In Africa and globally, there is a lot of discussion of virtual water. In other words, if we are in Nebraska and can produce corn inexpensively, by selling that corn to other countries we are exporting water. That radical policy construct is a valid consideration, but it's also important to remember that each country wants food security in and of itself. Also, if you are a farmer in Burkina Faso—where it is difficult to grow corn or anything else because of rainfall uncertainty and frequent lack of rain—that doesn't mean that there are options, such as moving to the capital city to work on computers. In other words, farming is often the only option and we should be giving our attention to farming under stressed conditions and thinking less about virtual water other than as a policy construct. The other thing is that agriculture has been and will continue to be the economic driver of growth in Africa.

Finally there's a great deal of emphasis on policy and, as far as Africa is concerned, I have a jaundiced view of policy because many African countries already have well written, enlightened policies in place. However, they don't extend too far past the agriculture ministry's front door. In other words, marrying policy with practice is a far more difficult task than just writing new policy.

Africa experiences extreme spatial and temporal variability in rainfall even without the weather extremes that are likely to occur as a result of climate change. Figure 6 shows women collecting water in head pans and carboys from a hand-pump. Most of the vessels remain empty because pumping is slow; it's the dry season and the water table is low. A sudden, heavy downpour causes the women to employ empty head pans as umbrellas.

Given this variability in rainfall, the need for storage and infrastructure is clear. Figure 7 emphasizes that although Africa has much arable land, very little is irrigated and very little of it is accessible to transport. A great deal of attention is being given to value chains and market access, so roads and water-related infrastructure are of primary importance, and, accordingly, investment is needed.

Data from the World Bank reveal that North America has more than 6,000 cubic meters of water-storage capacity per capita (Figure 8), whereas South Africa, which has

Figure 6. Dry season in Africa: an illustration of rainfall variability.

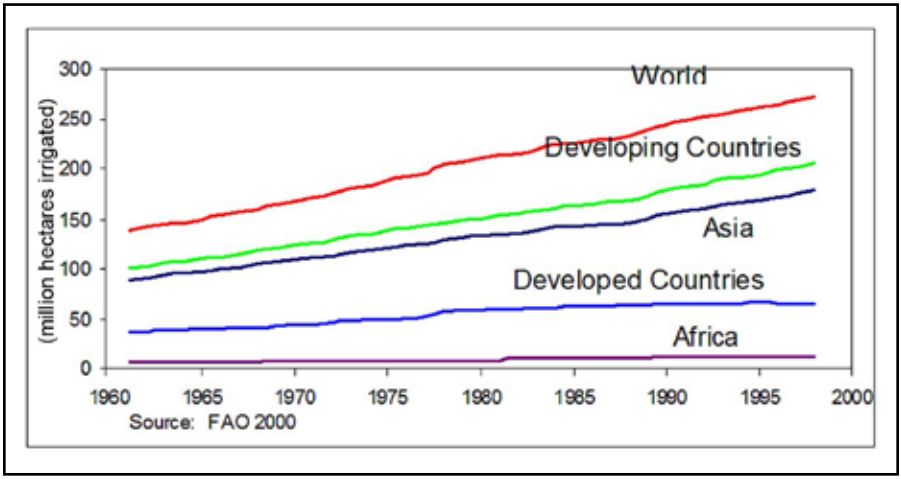

Figure 7. Africa lags in irrigation infrastructure.

the most infrastructure in the continent of Africa, has just 750 cubic meters per capita. Ethiopia and Kenya are next with 43 and 4 cubic meters per capita, In short, there is very little by way of large or medium infrastructure in Africa.

What does this mean? You have variable rainfall. You have a largely agrarian society with a limited industrial sector and you have very little water-related infrastructure to buffer rainfall variability. Figure 9 shows how closely agricultural GDP growth tracks with

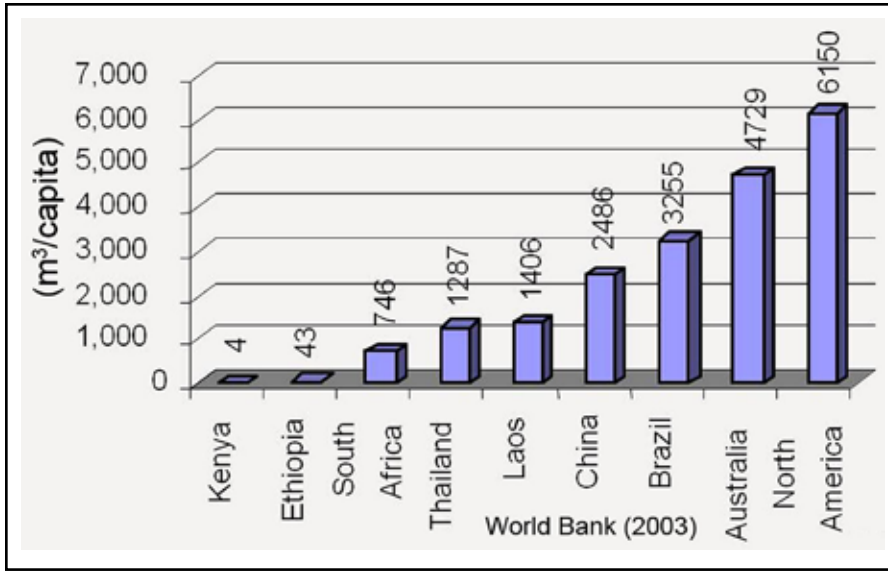

Figure 8. Water-storage capacity.

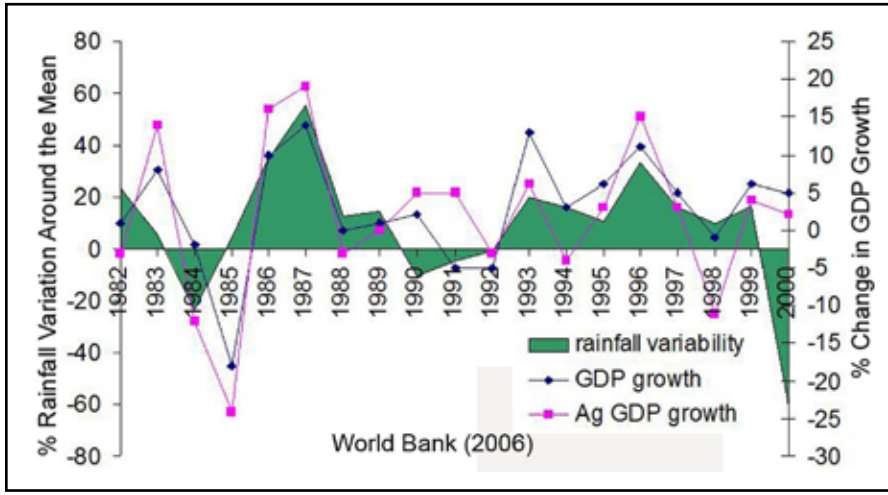

Figure 9. Impact of rainfall variability on GDP
and agricultural GDP growth in Ethiopia.

rainfall for Ethiopia. When precipitation is above the norm, growth goes up, and when it is below the norm, growth goes down. This is not a surprising outcome. To reinforce this point, Figure 10 shows similar data for Kenya. (The correlation is not as strong as for Ethiopia, in part because Kenya's economy is more diversified and the populace slightly more affluent.)

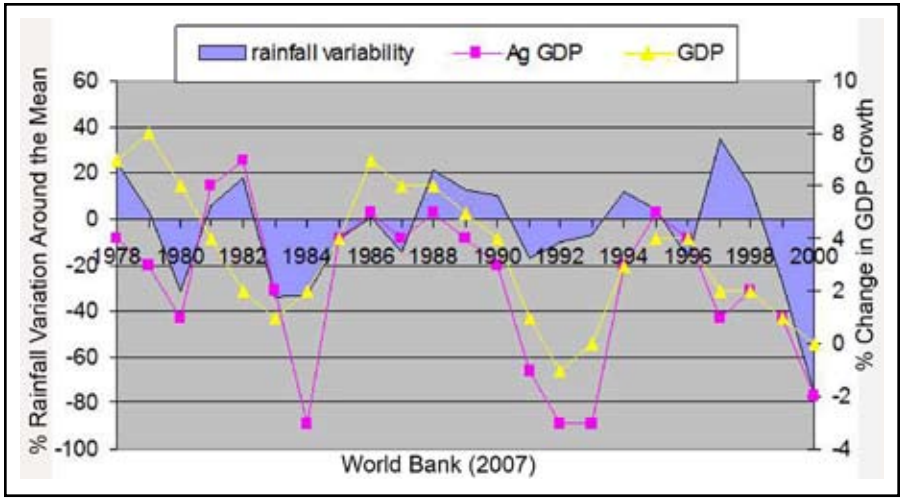

Figure 10. Impact of rainfall variability on GDP and agricultural GDP growth in Kenya.

What needs to be done to increase food production? This gets back to my point that we need to consider all options and not become fixed in our way of thinking. We can bring more dry land into production. Areas of Angola, for example, have perfect weather and fertile soils, with the potential to feed the whole of southern Africa. Yields of rain-fed crops can be improved by manipulation of drought tolerance through plant genetics. Irrigation infrastructure needs to be improved. There are major rivers in Africa—the Niger, the Congo, the Volta, the Zambezi—yet there are only three or four large dams on the whole continent. The Akosombo dam (in Ghana) is on the Volta and two are on the Zambezi, the Kariba (between Zimbabwe and Zambia) and the Cahora Bassa (Mozambique). Some construction is in progress in Zimbabwe and South Africa, but, in general, there is plenty of opportunity.

In the 1980s there was backlash against building infrastructure for a couple of reasons. Costs became enormous, some of which was real and some occurred due to lack of transparency. And pressure from environmentalists on the World Bank, and other factors, resulted in withdrawal of investments in those areas. We have learned lessons and we need intelligently designed infrastructure. We need to look at environmental studies and the active issues and to provide appropriate compensation for people who are disadvantaged. In other words, do it right and not leap forward blindly, and thus improve yields through irrigation.

Water for Africa

I'm making the argument that, for Africa, we need more instruction. How is a reliable supply of water to be achieved? First of all, storage and delivery infrastructure has to be built. Secondly—and this is extremely important—secure water rights are needed. Thirdly, farmers everywhere are risk-averse but, with a reliable water supply, they may invest in

more equipment, in more inputs and in improved seeds. Much of the behavior of small-scale farmers in the Sahel and southern Africa is rational in terms of the conditions they face. If they make a crucial mistake it may be literally fatal. I posit that they are smart and manage as best they can, but with better water supply they could make more investments and perhaps significantly increase productivity.

What are the options? As said, large dams are expensive, they take a long time to put in place, and they come with a lot of institutional overhead—medium-sized dams likewise. Small reservoirs are a good option. In many places, no groundwater is available. Where I was working in northern Ghana and southern Burkina Faso, there are thousands of small community-managed reservoirs. On the other hand, the institutions required for efficient running of these reservoirs are often poorly developed. One reservoir may be efficiently utilized for irrigation whereas another similar reservoir, just 5 kilometers distant, might be unused and baking in the sun. The reason is that this is an extremely heterogeneous environment. One may have been built by a program under which time was invested in teaching people how to farm in the irrigated perimeter, and the other may have been a product of the early "glory days" when people thought that everything was simple. There may be a million reasons why they don't work, requiring a lot of study to gain full understanding, but I am a firm believer that small reservoirs have a useful role. Boreholes are another option, but groundwater resources are poorly understood. We don't know with any certainty where they are or how reliable and sustainable their water yields will be.

Also an option, of course, is to build nothing and work with rain-fed production.

Achieving infrastructure requires responsible institutions to achieve financing, even for relatively humble projects. Tendering awards is a process rife with corruption and inefficiency. I worked on a large project in Botswana and well meaning local contractors would subcontract some of the smaller jobs for roads, housing and ancillary parts of the project, and I learned that some of these individuals were crooks, but a lot of them didn't know how to function as contractors. Some project leaders were skilled at working with them and teaching them; so instruction is a big issue and where the capabilities of subcontractors are limited, it's an area where there is enormous opportunity to improve.

When I was working in northern Ghana on a formal contract with the World Bank, building small dams, all of the specifications seemed in order. I asked, "Are any of these completed?" And the reply would often be "no," perhaps because a key worker had died in a motorcycle accident. It wasn't their fault, but there didn't seem to be any supervisory follow-up. Some of the dams were poorly constructed and collapsed after heavy rains in February of 2007. The thing I found most irritating was that maintenance responsibilities, and blame for failures, fell to the villagers, the clients, when the dams weren't well built in the first place.

Another thing to remember is that almost all water resources are multi-purpose. People swim in reservoirs, fish in them, and water their stock there. Even with a humble hand-pump water is used for ducks, small gardens, and other domestic activities; that's important. The agricultural intensification that comes with increased water availability has ecological consequences with negative implication for human health and downstream scarcity (Figure 11).

Figure 11. Agricultural intensification has ecological consequences.

Nebraska has a system of natural-resource districts (NRDs) based on watershed boundaries, which cut across political boundaries and have the power to levy taxation. However, it's a far cry from integrated water-resource management. One thing people forget is it's mostly about allocation. The British cleverly made a treaty among their former colonies, the Egyptians and, upstream, Kenya and Uganda, and allocated most of the water in the Nile basin to the Egyptians. This wasn't a fair way to do business and the countries involved are trying to renegotiate and manage the Nile better. Of course the important thing to remember is that populations in these and other countries fed by the Nile are now much higher, causing greater demands for water. They have managed to negotiate every single aspect of the treaty except allocation of the water, which has emerged as an extremely contentious issue.

In Africa there is usually no control over rivers because there are no dams and there is little removal. It is rarely a national priority. African leadership, which has been less than stellar, but is getting better, has things to worry about other than integrated water-resource management. A particular concern is insufficient data. A few weather stations, set up in the colonial era, are still operational, but, in large part, Africa is resource poor when it comes to precise weather information. There is increasing dependence on remote sensing of weather parameters, but, at some point, ground data are needed to calibrate the models. Also often ignored is the fact that stakeholders are illegitimate and/or poorly organized or not organized at all. Here in the United States, farmers are affluent and relatively well organized, as are water-utility workers and industrial users—not that they necessarily agree, but they are legitimate and relatively well organized. That's not true in African countries particularly regarding farmers. With maybe 4 or 5 acres apiece, they don't have the time or the inclination to be organized; they just don't have the resources.

In Summary

There are formidable challenges and together we can overcome them.

This isn't a well worded or profound quote, but, although the challenges *are* formidable—as I have stated here—I do believe that if we work together, with collaborative research, then they can be overcome.

MARK ANDREINI has broad international experience, having been a water adviser for the US Agency for International Development in the Bureau for Economic Growth and Trade. His recent work has focused on small reservoirs—how they are used—and areas of research to improve the livelihoods of small farmers. Before joining USAID, Andreini was a senior researcher with the International Water Management Institute, where he was the Ghana coordinator of the GLOWA Volta Project and the leader of the Small Reservoirs Project. He has contributed to projects to strengthen basin-level integrated water management and address issues of water productivity. He has worked in California and several African countries and has been involved in a variety of water-management and supply projects. A professional engineer, Andreini has studied solute movement under conventional and conservation tillage, and shallow groundwater irrigation in Zimbabwe. He built village water-supply systems in Morocco, was a physical planner for the United Nations High Commissioner of Refugees in Tanzania, and was a member of the project-coordinating unit supervising the construction of Botswana's North-South Carrier.

Q&A

Rick Bennett (University of Arkansas, Fayetteville): A slide, with water-scarcity data, had all of the United States colored in blue. It probably represented the US in general. On the other hand, regional water issues exist in various parts of the country. You talked about the situation in Africa, and we have a similar situation here. Can we deal with this in the United States the way it's being dealt with in Africa?

Andreini: National statistics are always misleading. That's my first comment. Second of all, we have states and it's good that we have those smaller political units. Arkansas can deal with Arkansas' problems, because they know them and understand them. The Land-Grant system was one of the most far-sighted pieces of legislation ever and, as a result, we are much better situated to deal with a country as large as the United States than almost anywhere else.

Ken Korth (University of Arkansas, Fayetteville): Regarding GMOs and transgenic crops, when Africa is brought up in terms of helping growers and so on, people often object and say there's a conspiracy in agrochemical industry to suppress conventional agriculture. Do you run into that? When you make recommendations regarding infrastructure for pumping water, do you get that negative?

Andreini: Of course. For example, in the 1950s they built the Kariba Dam. At that time it was Northern and Southern Rhodesia, before the unilateral declaration of independence by Ian Smith. They saved the Tonga people who lived along the river with a resettlement scheme, with mixed results. Ghana did better with the Akosombo Dam, which produced Lake Volta, the largest surface area of any reservoir in the world and which displaced many, many people. Kwame Nkrumah made a real attempt to successfully resettle the native people and tried to do it right. The small holders who operated efficiently were bought tractors, *etc.*, and encouraged to farm collectively. It was a resounding failure. The good news was they were at least making an attempt and understood issues of equity and so on, but didn't do a good job. Particularly with water dams, you find these issues. A lot of the exported agriculture goes to Europe, and there is a great deal of fear, particularly in southern Africa that, if they grow GMOs at all, any contamination could cause the loss of their European market. The other thing is that the Africans often say that they've been hard done to. Colonialism is not ancient history and so, rightly or wrongly, they are suspicious of any sort of invasion from us. Although GMOs have positive contributions to make to Africa, it will take a while.

Graham Scoles (University of Saskatchewan, Saskatoon): Can you point to any success stories regarding irrigation?

Andreini: Burkina Faso, in particular, has a program building small reservoirs which seems to be well managed. In Zimbabwe in the early 1990s, they had something called Agricultural and Technical Extension Services and I did research on gardening there on small plots. At that time, AGRITECH had an extension worker for every several hundred households, and some of the supervisors were extremely patriotic, knowledgeable and highly motivated. That system actually worked pretty well. Things have changed under Robert Mugabe. Extension knowledge is extremely important. You see this in reservoirs in northern Ghana—where people have bothered to spend the time to get things going right—things are going much better than where a reservoir was built and then left. There is reason for optimism, that's for sure.