Growing Green

The challenge of sustainable agricultural development in Sub-Saharan Africa

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Executive summary

Agriculture is the dominant economic sector in most Sub-Saharan nations and Africans depend almost entirely on domestic production for their food. Millions of farmers in the region face environmental challenges, such as poor soil, while simultaneously being denied access to markets as a result of a hostile policy environment. Poverty and malnutrition are widespread.

Under these circumstances, Sub-Saharan Africa (SSA) stands to benefit greatly from the development of agriculture through modern technologies and public policies which support agriculture, commerce and entrepreneurship.

No Green Revolution for Africa…Yet

The "Green Revolution" saved hundreds of millions of lives, mainly in Asia, between the middle 1960s and the 1980s. Yet SSA never benefited from Green Revolution technologies, such as fertilizers, pesticides or hybrid seeds. As a result, diets in SSA are inferior in terms of energy intake to those in every other part of the world. This contributes heavily to widespread malnutrition and poor health.

Why African agriculture is generally unproductive

The past quarter-century has been marked by severe economic under-performance in most Sub-Saharan African countries, caused by, inter alia:

- Widespread price controls, parastatal monopolies and overstaffed bureaucracies, which marginalized the private sector and created large fiscal deficits.
- A lack of political and economic freedom, similar to other parts of the world.

For decades following independence, most African governments pursued policies which decreased agricultural productivity. Political leaders viewed agriculture as a "milk cow" for non-agricultural sectors. Worse, little was done to keep the milk cow healthy and growing, namely:

- In the two decades following independence, agriculture was largely ignored by national leaders.
- With few exceptions, leaders lacked strong connections to agriculture and tended to dismiss the rural sector. Political rulers emphasized industrialization and urbanization, to the detriment of agricultural production. Donor-funded projects tended to serve the political elite rather than poor rural producers.
- Farming exports were taxed punitively, while artificially low prices were maintained for urban consumers.
- Government investment in rural transportation infrastructure – roads, bridges and other public goods – was wholly inadequate. A lack of adequate infrastructure continues to hinder the movement of inputs to farmers and outputs to market.

Meanwhile, international donor agencies did little to improve the situation. For example:

- Donors often provided technical assistance for the establishment of marketing boards and other mechanisms for the implicit taxation of agriculture.
- Donors tended to favor extension services. Local elites approved since emphasizing extension permitted the expansion of government employment at the expense of donors. Between

1959 and 1980, 36,000 extension agents were hired in the region.

- In recent decades, bilateral and multilateral donors have turned their ear to powerful NGO constituencies in their respective countries.
- Between 1986 and 2001, the total amount of aid in Africa spent on social infrastructure and projects (the pet projects of NGOs) doubled, from 23 to 56 percent. At the same time, the amount allocated to agriculture, forestry and fisheries declined from 27 to 10 percent.

For reasons such as these, African countries have experienced declining crop yields in recent decades. Crop yields in many parts of SSA declined in the last two decades of the 20th Century. Thus, most of Africa's millions of farmers continue to engage in subsistence agriculture, and produce barely enough to feed themselves – if that.

The environmental toll of subsistence agriculture

It is no coincidence that land degradation is often severe where agricultural productivity is depressed:

- Lacking widespread use of inputs such as fertilizer, subsistence agriculture has increased erosion and other forms of land degradation, in large part by depleting soil of nutrients and moisture.
- When small-scale farmers encounter these problems, they tend to relocate to areas where land degradation has not proceeded.
- This agricultural extensification is a primary cause of deforestation; the proportion of forests being converted for agricultural use is greater in Sub-Saharan Africa than any other region.

Benefits of modern agriculture

The benefits of more efficient farming, using modern technologies and methods, would be immense. Among other things, it would:

- Reduce the cost of food, and thus improve nutrition.
- Increase profitability of agricultural exports.
- Free up human resources for other jobs, leading to greater job diversity, specialization and economic stability.
- Increase government's tax revenues, which can be invested in infrastructure.
- Create environmental benefits such as reduced erosion and diminished deforestation.

Challenges for public policy

Since the 1990s, a trend towards liberalization has born fruit in some areas of SSA – notably by encouraging diversification of exports and better marketing methods. However, this has typically been in places which have good access to markets and an open approach to the adoption of technology. However, a variety of government policies continue to penalize agriculture, aggravate rural poverty and inhibit overall economic progress, including

- Government regulation and barriers to trade, including food-price controls and currency over-valuation.
- Widespread trade barriers between African countries. In many instances these exceed the barriers encountered by African exporters when trying to penetrate markets in Europe and other affluent settings.

The way forward

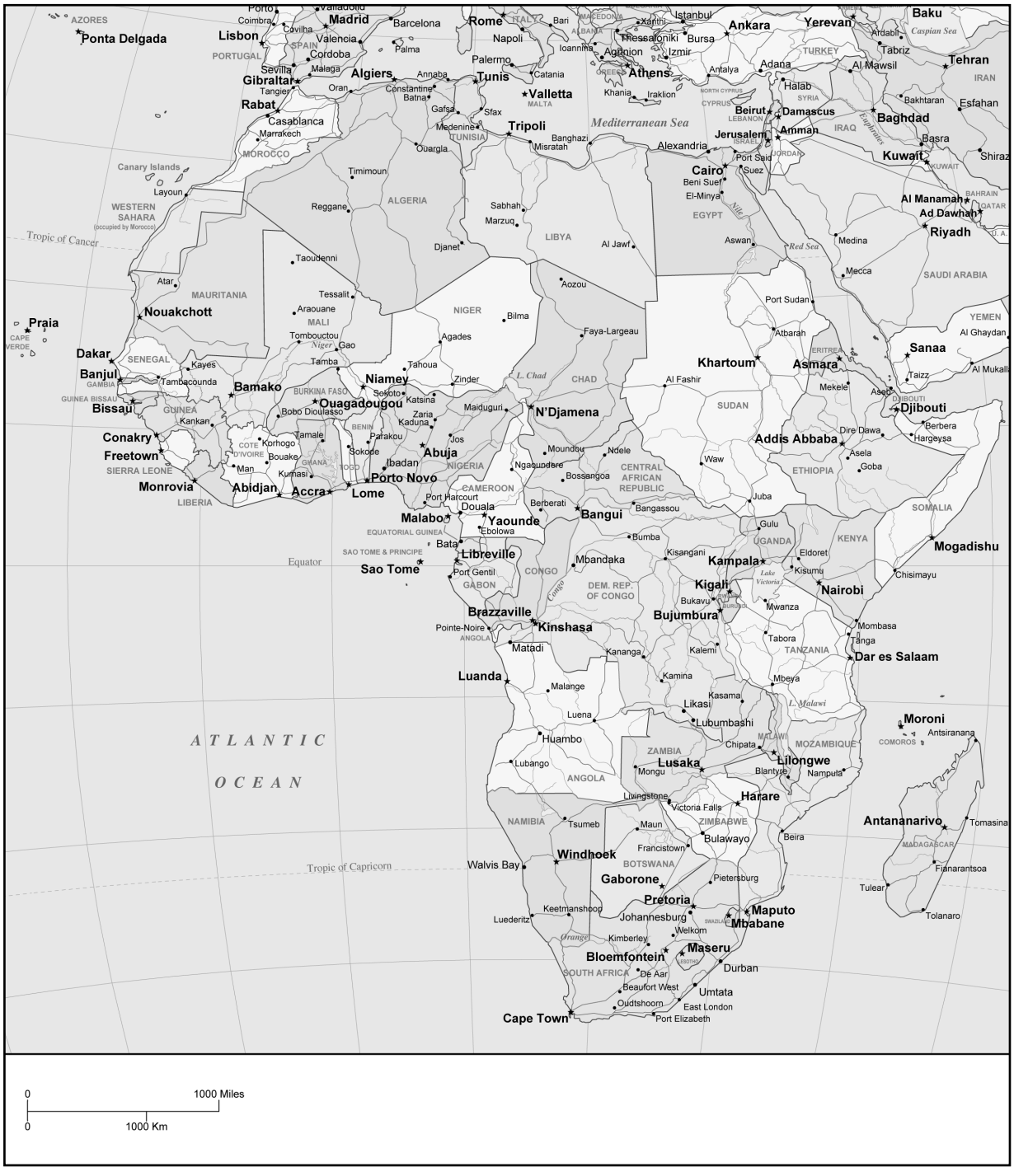
Sub-Saharan Africa is not doomed to misery. To address a series of inter-linked problems – rampant malnutrition, nutrient depletion and land degradation, and economic underperformance – the political elite must not succumb to the temptations of regulation and trade protectionism.

Instead, governments need to supply basic public goods and infrastructure, including the legal institutions required for property rights and enforcement of contracts. These provide the basic framework without which the market economy cannot truly exist.

Solving these problems will also require decentralized

research and development, and renewal of agricultural extension services, to make these client-oriented and demand-driven.

Modern technologies, including fertilizer, pesticides and water management methods (irrigation), as well as biotechnology, have a prominent role to play in the alleviation of hunger and rural poverty. Their role should not be underestimated, whether by governments, the private sector, NGOs or agricultural research agencies.



Introduction[1]

Sub-Saharan Africa is the cradle of humanity, the part of the world where every family tree is rooted. Yet by and large, the region has been an inauspicious setting for farming, which is the activity that has allowed the human population to climb from fewer than ten million at the time our Neolithic ancestors first domesticated rice, wheat and other crops to more than six billion today.

Many of the difficulties that African farmers must address are environmental. Most soils south of the Sahara are of ancient geological origin and consequently highly weathered and not very fertile. In addition, many parts of the region receive too little precipitation for non-irrigated agriculture. Droughts are a frequent occurrence in vast stretches of the continent. In other settings, such as the Congo River Basin, torrential rainfall can be disadvantageous for farmers. Furthermore, crops are under constant attack from insects and other pests.

Even the region's great geographical expanse has proved so far to be a disadvantage rather than an advantage. Where the countryside is sparsely inhabited, as it is in much of Africa, and the majority of people are impoverished, the costs of infrastructure required for trade and development are far beyond local financing capacities. Often, then, capital formation never happens. When investment does occur - usually as a result of foreign government aid - development activities can easily prove impossible to sustain, as exemplified by decaying roads, abandoned schools and clinics, and other crumbling monuments to previous donor largesse that dot the landscape.

Another consequence of Africa's huge size is that much of the population lives very far inland, and therefore away from the trading opportunities available along the coast. An indicator of geographic isolation is that one-third of the independent nations in the continent are landlocked. Just as Bolivia is poorer than the rest of South America, and Afghans and the Nepalese have lower average incomes than other Asians, GDP per capita is below regional norms in countries like Burkina Faso, Chad, Malawi, and Rwanda.[2]

While the Sub-Saharan environment is daunting, the challenges of development have been compounded by the misdeeds of rulers. Africa was carved up by European powers during the late 1800s but structures required for effective governance were not firmly established. Also, colonial boundaries, which later became national frontiers, were drawn with little or no regard for ethnic identifications and cleavages. After countries achieved independence, their leadership was generally characterized by an absence of statecraft in the face of dysfunctional ethnic and regional groupings (Bates, 2000; Herbst, 2000; Salih, 2001).

All too often, civil strife ensued. Sometimes, national populations have split violently along ethnic lines, such as Burundi and Rwanda in the 1990s. In large countries, population clusters in remote areas have rebelled against ascendant groups in capital cities from time to time (Herbst, 2000, pp. 145-152). This happened in Nigeria in the 1960s and in Angola, Ethiopia, and

1 Much of this report is extracted from Southgate, Graham, and Tweeten (2006).

2 There are exceptions to the rule that landlocked nations tend to be poor. An exception in Africa is Botswana, which has enormous mineral wealth and where a small and ethnically homogenous population has enjoyed democracy for decades. Europe has a number of prosperous countries that lack a seacoast. But it is instructive that, into the 1800s, Switzerland (mountainous and landlocked, like Bolivia and Nepal) was one of the poorest countries in the continent.

Mozambique from the 1970s through the 1980s. During the Cold War, it was common for one faction to align itself with the United States and other Western nations, and for its opponents to side with the USSR and its satellites. More recently, rival bands have squabbled over mineral wealth – diamonds, for instance, in Liberia and Sierra Leone.

Aside from taking a tragic human toll, warfare has crippled many African economies. But even where armed conflict has been avoided, countries have often followed policies that discourage trade and investment (Collier and Gunning, 1999). Sub-Saharan Africa's limited involvement in global commerce – and even regional commerce – has contributed to generally slow economic growth.

South Africa has the only national economy of appreciable size in the region. Its GDP is four times that of Nigeria, which is the region's most populous nation, and second-largest economy as well as one of its leading oil producers. A scattering of other countries export fossil fuels, copper, and other natural resources, but the proceeds generally accrue to leaders and the political elite, rather than to local populations. It is telling that GDP for the entire region is comparable to the annual economic output of Belgium and that median national GDP is approximately $2 billion, which is about the same as the yearly output of a city of 60,000 people in Western Europe or the United States (World Bank, 2000A, p. 7).

In 1958, when the Gold Coast attained independence from Great Britain and renamed itself Ghana, Ethiopia and Liberia and South Africa were the only three self-ruling states south of the Sahara. By the mid-1970s, when the Portuguese completed their withdrawal from Angola, Mozambique, and other possessions, virtually the entire continent was independent, although white minorities ruled in South Africa, Namibia, and Rhodesia (now Zimbabwe).

Broadly speaking, the three to five decades in which countries have been independent have proved to be precious little time to develop the habits of modern statecraft, such as the ability for leaders to broker compromises among groups with varied interests. This is particularly true in light of inhospitable natural conditions and bitter ethnic fragmentation. It is hardly surprising that most African governments are ineffectual, with foreign aid totaling 10 to 20 percent of GDP in many countries and reaching as much as 25 to 30 percent of GDP in others (World Bank, 2000B, Table 21).

Yet there are glimmers of hope in the region. Nelson Mandela adroitly guided the transition from apartheid to majority rule in South Africa. Uganda has made notable progress in the fight against HIV/AIDS. Long dominated by military strongmen, Nigeria now has a democratically elected government. The challenges of getting economies on track and alleviating poverty are not insurmountable.

In particular, Sub-Saharan Africa is in a position to benefit much more from the development of agriculture, which is the dominant economic sector in nearly every country in the region. A classic article by Johnston and Mellor (1961) identified the economy-wide repercussions of agricultural development, which are both positive and varied. The following are effects of more efficient farming and an increase in supplies of commodities:

- Food prices fall, which contributes to improved nutrition while simultaneously allowing people to increase spending on non-food items (thereby accelerating diversification of the economy) and to save more (thereby fomenting investment and growth);
- An increase in foreign-exchange earnings from agricultural exports;
- Labor and other resources are reallocated from agriculture to other sectors of the economy; and
- Tax revenues increase and governments may invest more in public goods such as transportation infrastructure and research and development.

In a recent assessment of Asia's economic progress, Mellor documented that these same factors explained rapid growth in GDP per capita in countries like Thailand (Mellor, 1995, pp. 10-16) – contributions, it must be said, that have been weak or lacking entirely in much of Africa since independence was achieved.

Broad Economic and Demographic Trends

Although living standards have improved in most Sub-Saharan nations since 2000 (Table 1, column 9), the past quarter-century has been marked by severe economic under-performance. During the 1980s, exports stagnated (column 2). In addition, macroeconomic instability was rife, as indicated by high inflation (column 3), which discouraged capital formation (column 4). Price controls were widespread and key sectors were dominated by parastatal monopolies, which along with overstaffed bureaucracies and insolvent government-owned banks marginalized the private sector while simultaneously creating large fiscal deficits (World Bank, 2000A, pp. 18-28; Collier and Gunning, 1999). Under these circumstances, GDP per capita (column 1) rose appreciably in just a few nations but contracted in many more.

As emphasized subsequently in this study, the burden was especially severe for rural producers, who lacked the political clout of urban elites and laborers. State-run marketing boards, which were authorized to purchase all commodity output, paid low prices to farmers. Another element of the anti-rural bias of public policy was deficient support for education and public health in the countryside as well as for agricultural research and development.

The last decade of the twentieth century brought some measure of relief. The recessionary conditions of the 1980s abated, leading to an improvement in global economic growth rates, which allowed exports to recover among Africa's commodity producers (Table 1, column 6). Also, inflation (column 7) decelerated in a number of countries, which helped to stimulate investment (column 8). In addition, the downfall of the USSR in 1991 ended the Cold War, which in turn caused proxy conflicts to wind down and obliged a number of former Soviet allies to abandon Marxist economic practices.

Market-based reforms were also pursued in other African nations, often as part of structural adjustments recommended by the IMF and the World Bank. Some state-owned enterprises were privatized and prices were deregulated, and some barriers to efficient international trade were reduced as well. For example, much-needed currency devaluation occurred in Francophone countries which formerly had maintained fixed exchange rates with the French franc.

Among nations where GDP grew appreciably faster than human numbers during and after the 1990s were Eritrea (which achieved independence from Ethiopia), Ethiopia, and Mozambique (Table 1, column 5). The greatest improvement in living standards was registered in Uganda, which along with Mozambique was an enthusiastic convert to market-friendly policies. However, per-capita GDP stagnated or shrank in most African nations during the waning years of the twentieth century. As in other parts of the world, poor economic performance in the region tends to coincide with a lack of political and economic freedom (columns 10 and 11).

Particularly instructive in this regard is Zimbabwe, where octogenarian Robert Mugabe – the only leader the country has known since 1980, when white-minority rule came to an end – is systematically dismantling speech and press freedoms and debauching electoral processes and, in so doing, is driving the national economy into the ground. One of Mugabe's special targets has been commercial farms, which formerly employed over 250,000 Zimbabweans and accounted for most of the country's agricultural exports. After violent invasions by the dictator's followers, these farms have been dismantled and subdivided (Lloyd, 2002).

Table 1: Patterns of Economic Growth in Sub-Saharan African Countries, 1980 through 2003

A. Average Annual Rate of Growth 1980-90 (%)					B. Average Annual Rate of Growth 1990-99 (%)					C. Average Annual Rate of Growth 2000-2003 (%)			
Country (ranked by *Column 1)*	GDP per *Capita* (1)	Export (2)	Inflation (3)	Gross *Investment* (4)	**Country** (ranked by *column 6)*	GDP per *Capita* (5)	Export (6)	Inflation (7)	Gross *Investment* (8)	**Country** (ranked by *column 9)*	GDP per *Capita* (9)	**Economic** Freedom *Index - 2002* (10)	**Freedom** Status *2001-02* (11)
Botswana	8.2	10.6	13.6	---	Uganda	4.2	16.3	13.7	9.9	Mozambique	5.0	3.05	PF
Mauritius	5.3	10.4	9.5	10.2	Mozambique	4.1	13.4	36.4	13.1	Botswana	4.5	2.90	F
Swaziland	3.8	14.4	13.8	---	Mauritius	3.9	---	---	---	Chad	4.5	3.60	NF
Burundi	1.6	3.4	4.4	4.5	Eritrea	2.5	0.5	9.7	---	Tanzania	4.3	3.40	PF
Lesotho	1.6	4.1	13.8	6.9	Lesotho	2.2	11.3	9.6	2.3	Sudan	4.0	---	NF
Chad	1.4	6.5	2.9	19.0	Ethiopia	2.0	9.3	7.4	13.4	Mauritius	3.8	3.00	F
Burkina Faso	1.1	-0.4	3.3	8.6	Benin	1.9	1.9	9.4	5.3	Mali	3.5	2.90	F
Angola	1.0	3.7	5.9	-6.8	Botswana	1.9	2.5	10.0	-1.3	Angola	3.3	---	NF
Kenya	0.8	4.3	9.1	0.8	Sudan	1.7	---	---	---	Rwanda	3.3	3.40	NF
Uganda	0.7	1.8	104.0	9.6	Ghana	1.6	10.8	27.2	4.2	Sierra Leone	3.3	---	PF
Cameroon	0.5	5.9	5.6	-2.7	Guinea	1.6	4.7	6.2	2.4	Uganda	2.8	3.00	PF
Congo, Rep.	0.5	5.1	0.5	11.9	Burkina Faso	1.4	0.4	6.2	4.8	Ghana	2.5	3.40	F
Mali	0.4	4.8	4.5	5.4	Malawi	1.4	4.9	33.5	-7.5	Nigeria	2.5	3.60	PF
Senegal	0.3	3.7	6.5	3.9	Mauritania	1.3	1.6	6.1	6.8	Cameroon	2.5	3.25	NF
Benin	0.1	-2.4	1.3	-6.2	Ivory Coast	1.1	4.7	8.0	17.6	Zambia	2.3	3.25	PF
Mozambique	0.1	-6.8	38.3	-2.5	Mali	0.8	9.6	8.5	-0.8	Senegal	2.3	3.20	PF
Zimbabwe	0.1	4.3	11.6	1.3	Namibia	0.8	4.3	9.8	2.5	Burkina Faso	2.0	3.20	PF
Ghana	-0.3	2.5	42.1	4.5	Senegal	0.6	2.6	5.2	3.1	Congo, Rep.	1.8	3.75	PF
Guinea	-0.5	---	---	---	Swaziland	0.2	---	---	---	Mauritania	1.8	3.30	PF
Rwanda	-0.5	3.4	4.0	3.7	Tanzania	0.2	9.5	23.2	-1.7	Lesotho	1.8	3.40	PF
Ethiopia	-0.8	2.4	4.6	3.5	Zimbabwe	0.2	11.0	23.8	-0.7	South Africa	1.3	2.90	F
Mauritania	-0.9	3.6	8.4	-4.1	Gabon	-0.1	---	---	---	Ethiopia	1.0	3.55	PF
Malawi	-1.0	2.5	14.6	-2.8	South Africa	-0.1	5.3	10.2	3.0	Guinea	0.8	3.30	NF
South Africa	-1.0	1.9	14.9	-4.8	Cent. Afr. Rep.	-0.3	6.7	4.9	-1.7	Namibia	0.5	2.90	F
Sudan	-1.2	0.9	31.3	---	Nigeria	-0.4	2.5	34.8	5.8	Swaziland	0.5	3.10	NF
Tanzania	-1.2	-1.5	25.1	---	Kenya	-0.5	0.4	14.8	4.9	Niger	0.3	3.50	PF
Namibia	-1.4	-0.1	13.9	11.9	Chad	-0.6	5.0	7.6	4.4	Gabon	-0.3	3.25	PF
Nigeria	-1.4	-0.3	16.7	-8.6	Togo	-0.8	1.5	8.3	11.6	Burundi	-0.5	---	NF
Togo	-1.4	0.1	4.8	2.9	Niger	-0.9	1.7	6.4	5.4	Madagascar	-0.8	3.10	PF
Sierra Leone	-1.5	2.1	64.0	-6.5	Madagascar	-1.2	3.6	20.6	0.9	Togo	-1.0	3.60	PF
Congo, Dem. Rep.	-1.7	9.6	62.9	---	Cameroon	-1.4	2.7	5.5	0.0	Kenya	-1.0	3.20	NF
Madagascar	-1.8	-1.7	17.1	4.9	Zambia	-1.7	1.8	56.9	11.3	Malawi	-1.5	3.50	NF
Cent. Afr. Rep.	-2.0	-1.2	7.9	1.8	Congo, Rep.	-1.9	4.3	7.1	4.7	Eritrea	-2.3	---	NF
Zambia	-2.2	-3.4	42.2	-2.7	Angola	-2.4	8.2	813.8	12.9	Cent. Afr. Rep.	-2.5	3.10	PF
Gabon	-2.7	3.0	1.9	-4.6	Rwanda	-3.5	-6.0	16.3	2.1	Dem. Rep. Congo	-2.8	---	NF
Ivory Coast	-2.9	1.9	2.8	-28.8	Burundi	-5.1	2.4	11.7	-12.4	Ivory Coast	-4.0	2.90	PF
Niger	-3.2	-2.9	1.9	-5.9	Sierra Leone	-7.2	-12.2	31.2	-10.3	*Zimbabwe	-8.0	4.30	NF
					Congo, Dem. Rep.	-8.3	-5.5	1423.0	-3.5				

Sources: World Bank (2001), pp. 278-279, pp. 294-295; World Bank (2005). The Economic Freedom Index ranges from 1.00 (completely free markets) to 5.00 (completely repressed markets); see Heritage Foundation (2002).
Political Freedom Status is F (Free), PF (Partly Free) and NF (Not Free), see Freedom House (2002).

Population Growth

Improving GDP per capita is a challenge in Sub-Saharan Africa because human numbers are increasing very rapidly. As in other parts of the world, population growth has been a consequence of the demographic transition which is set in motion as the threat of mortal disease diminishes. At least for a while, the crude death rate (CDR) – conventionally defined as the number of deaths in a year per thousand people – falls faster than the crude birth rate (CBR), which is expressed as the number of births per thousand.

One reason for this is that it takes some time for women and their partners to perceive and respond to diminished mortality by lowering human fertility – normally measured as the total fertility rate (TFR), which is the number of births per woman. Another reason for the slower decline in the CBR is that infants and young children are major beneficiaries of reductions in mortality. As a result, the number of people of child-bearing age increases after the demographic transition begins, which causes the birth rate to stay high. As long as the CBR exceeds the CDR, the rate of natural increase (the difference between the two) is positive. Eventually, however, birth and death rates converge, which reduces the rate of natural increase.

Through the 1970s and into the 1980s, Sub-Saharan Africa appeared to be in the early phases of demographic transition. CDRs had fallen dramatically, to well under 20 per thousand in most of the region. Meanwhile, CBRs had barely budged from pre-transition levels, exceeding 40 per thousand in many countries. Annual rates of natural increase of 3 percent or more were not at all unusual.

Largely because human fertility remains elevated, rapid population growth continues to this day. The reasons for high TFRs are readily discerned. Incomes are low throughout the region, which matters because poor families tend to be larger than those with more financial means. Urbanization is not very advanced, with 70 or even 80 percent of the population of several countries living in rural areas.[3] In addition, economic empowerment of women is limited, as indicated by high female illiteracy. Where women are impoverished, live in the countryside, and have few economic prospects because of a lack of education, they tend to have more children than their better educated, urban counterparts.

Human fertility has been affected by economic deprivation. People are marrying at a later age, in the hope of finding work first. Likewise, spousal separation, often resulting from employment-related migration by men, has become more common. Such behavioral changes obviously diminish reproduction. Nevertheless, the trend toward lower human fertility is weaker south of the Sahara than anywhere else on the globe. TFRs are approaching or have fallen below the replacement level – a little more than two births per woman – in Brazil, China, Iran, Thailand, and many other developing nations. However fertility rates greater than or equal to five births per woman remain the norm in Sub-Saharan Africa, including in three of the region's four most populous nations – the Democratic Republic of Congo (DRC), Ethiopia, and Nigeria.

Unique in the developing world, Sub-Saharan Africa faces the prospect of decelerating natural increase not just because of a decline in CBRs, which is happening in many countries, but because of growing CDRs as well. Mortality is elevated in the region in part because of infectious diseases that have long plagued the region. Malaria carries off up to two million Africans a year, for example. But in recent decades, a new threat has arisen in the form of HIV/AIDS.

This threat is especially severe in Southern Africa. Because of high death rates, TFRs will not have to fall to what under normal circumstances is the replacement level for natural increase to turn negative. For example, Botswana is on the brink of demographic contraction even though most families in the country have three or more children. In South Africa, which has a TFR of approximately 2.4 births per woman, natural increase might already be negative (UNPD, 2003).

HIV/AIDS is nearly as widespread in East Africa, although the incidence of the disease is lower in other parts of the continent. With TFRs remaining high, in spite of modest declines that many countries have experienced in recent years, natural increase shows no

3 However, there is now a trend towards urbanization in many African nations.

Table 2: Per-Capita Food Production as a Share of Per-Capita Production in 1961-1965, Various Years

Continent	1961-65	1971	1981	1991	2001
	(1)	(2)	(3)	(4)	(5)
Africa	100	103	94	90	90
Asia	100	104	114	134	173
South America	100	100	115	118	144
World	100	107	112	115	126

Sources: FAO (1976), p. 45; FAO (1983), p. 85; FAO (1993), p. 53; FAO (2003), pp. 50-51

signs of abating. Indeed, the annual rate of population growth is not expected to slip much below two percent for some time to come.

Changes in Per-Capita Food Availability

Needless to say, agricultural output must increase rapidly in Africa if per-capita consumption is to improve, or at least to avoid a turn for the worse, in the face of demographic expansion. During the 1960s, the region's food production outpaced human numbers (Table 2, columns 1 and 2). In fact, the African record that decade was comparable to contemporaneous trends in Asia.

By the early 1970s, however, the Green Revolution had taken hold in Asia but newly independent states south of the Sahara could no longer benefit from the legacy of investments in agriculture dating back to the colonial era. Incentives for raising productivity in Africa's rural areas were weak and per-capita food production diminished during the 1970s and 1980s (Table 2, columns 2, 3, and 4). The decline abated during the 1990s, though it was not reversed (columns 4 and 5).

Diets in Sub-Saharan Africa are now inferior, in terms of energy intake, to those in every other part of the world. As of the late 1990s, daily per-capita energy availability (from imports as well as domestic agricultural production) amounted to 3,010 calories in the Middle East and North Africa, 2,899 calories in East and Southeast Asia, and 2,830 calories in Latin America and the Caribbean. Daily food energy availability was considerably lower in South Asia at 2,400 calories. However, even this figure compared favorably with the per capita average in Sub-Saharan Africa 2190 calories per day(FAO, 2002). Significantly, this average measure of food energy availability is approximately the same as the 2,200 calories that is considered the minimum that a person must consume day in and day out to lead a healthy and productive life. However, this average figure conceals the large number of people who must live on considerably less that 2,200 Cal/day.

In addition to this lack of food energy (which is a standard indicator of malnutrition), Africans lack a range of vital vitamins and micronutrients. Iron deficiency is widespread, especially among women and children, with attendant anemia and associated ill health. In addition, diets lack iodine, vitamin A, zinc, and other micronutrients. As a result, the incidence of goiters, rickets, and other maladies is elevated. Likewise, protein deficiency is a severe problem, with average calorie intake from animal products below 200 per day in 32 African nations (World Resources Institute, 2006). Ironically, malnutrition is particularly severe in rural areas, with diets consisting almost entirely of roots, tubers, and grains which contain starchy carbohydrates and little else.

Another standard indicator of food security (or lack thereof) is the percentage of children who are underweight, stunted, or wasted (i.e., on the verge of starving to death). In 1993, the World Health Organization (WHO) estimated that 27.4 percent of all children in Sub-Saharan Africa were underweight and that the stunted and wasted shares were 38.6 and 7.2 percent, respectively (Onis *et al*., 1993). Seven years later, at the turn of the twenty-first century, the stunted share was estimated to have fallen only slightly, to 35.2 percent (Onis *et al*., 2000). Since the effects of disease are exacerbated by the toll taken by malnutrition, hunger has been identified as a contributing factor in the majority of childhood deaths in the region (Pelletier *et al*., 1994; Black *et al*. 2003), of which there are far too many.

Agricultural Development

In terms of economic output, food security, and other measures of human well-being, the general picture in Sub-Saharan Africa is not encouraging, despite a scattering of positive trends. The same pattern holds for agricultural development. Progress has occurred in a few places, but overall, the results of recent decades have been discouraging.

Positive exceptions are partly an outcome of favorable geography. However, public policies that at the very least do not discriminate against economic activity in rural areas are also a very important part of the story. This combination of circumstances has been present in South Africa, where farms employing up-to-date technology produce sugar, citrus and deciduous fruits, wine, and sunflower oil for international markets. Cut-flower enterprises and tobacco farms enjoyed similar success in Zimbabwe until the late 1990s, when commercial agriculture was largely destroyed by rural invasions instigated by the Mugabe dictatorship. Closer to the equator, cocoa producers in Ghana and the Ivory Coast are internationally competitive, as are farms yielding pineapples and other horticultural products in the same two nations and Kenya. Additional examples of commercial agriculture linked to global markets include coffee, tea, and oil palm estates in a number of countries.

Otherwise, Africa's farmers struggle. Facing difficult environmental conditions as well as neglect or worse by national governments, they generally do not avail of purchased inputs such as fertilizer, pesticides, or hybrid seeds, and thus are barely able to feed themselves and their families.

Factor Use

In a classic article, Hayami and Ruttan (1985, pp. 232-237) identify changes in the use of inputs to crop and livestock production which occur as the agricultural sector develops. According to their hypothesis of induced innovation, development is accomplished by raising the productivity of either land or labor - whichever is scarcer.

For example, land was much more plentiful than labor in the U.S. countryside as recently as the early twentieth century. Under these circumstances, mechanization of agriculture – which involved substituting machinery for labor and which raised the productivity of human inputs to crop and livestock production – was a central feature of agricultural development. Mechanization, which allowed each farmer to cultivate more land, had the additional advantage of releasing labor to other sectors of the economy in which demand for workers was growing.

By contrast, the situation in Japan during the same time period was very different. The country's rural population densities were one or two orders of magnitude greater than population densities in the rural United States. Since land was far scarcer than labor, agricultural development emphasized higher land productivity. Rates of fertilizer application rose and irrigation networks expanded. In addition, the Japanese invested in agricultural research, which created varieties of rice that yielded more grain per cultivated hectare.

In the late twentieth century, increases in agricultural output have been achieved in most countries primarily through yield-enhancing measures. During the 1970s and 1980s, at the height of the Green Revolution, greater production per hectare accounted for 82 percent of all

Table 3: Agricultural Inputs in Sub-Saharan African Countries, for Selected Periods 1979 through 2001

Country (ranked by income per capita in 2000)	Rural Density people per sq. km 1999	Fertilizer use (kg per ha)		Cereal Yield (kg per ha.)		Agricultural Machinery (Tractors per sq.km of arable land)	
		1979-1981	1999-2001	1979-1981	1998-2000	1979-1981	1997-1999
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Mauritius	691	255	332	15.0	18.2	0.3	0.4
South Africa	129	87	53	8.4	8.5	1.4	0.6
Botswana	233	3	12	0.5	0.3	0.5	1.8
Namibia	146	0	0	0.6	0.9	0.4	0.4
Gabon	73	2	1	2.4	3.0	0.4	0.5
Swaziland	448	105	33	34.0	38.3	1.7	1.7
Lesotho	450	15	17	---	---	0.5	0.6
Zimbabwe	252	61	55	3.1	3.5	0.7	0.7
Guinea	556	2	3	7.9	6.4	0.0	0.1
Ghana	325	10	5	0.2	0.2	0.2	0.1
Mauritania	230	6	1	22.8	9.8	0.1	0.1
Cameroon	127	6	7	0.2	0.5	0.0	0.0
Sudan	119	5	4	14.4	11.5	0.1	0.1
Ivory Coast	286	26	31	1.0	1.0	0.2	0.1
Senegal	222	10	12	2.6	3.1	0.0	0.0
Togo	134	1	8	0.3	0.3	0.0	0.0
Uganda	368	0	1	0.1	0.1	0.1	0.1
Angola	283	5	1	2.2	2.1	0.4	0.3
Cent. Afr. Rep.	112	1	0	---	---	0.0	0.0
Kenya	499	16	35	0.9	1.5	0.2	0.4
Benin	210	1	26	0.3	0.6	0.0	0.0
Burkina Faso	265	3	14	0.4	0.7	0.0	0.1
Eritrea	654	---	17	---	4.8	---	0.1
Rwanda	901	0	0	0.4	0.4	0.0	0.0
Chad	163	1	4	0.4	0.6	0.0	0.0
Madagascar	417	3	3	21.5	35.1	0.1	0.1
Mozambique	339	11	2	2.1	3.2	0.2	0.2
Nigeria	250	6	6	0.7	0.8	0.0	0.1
Mali	162	6	8	4.5	3.0	0.1	0.1
Zambia	105	15	9	0.4	0.9	0.1	0.1
Niger	168	1	0	0.7	1.3	0.0	0.0
Ethiopia	520	---	16	---	1.8	---	0.0
Malawi	458	20	27	1.1	1.4	0.1	0.1
Burundi	792	1	4	4.5	6.7	0.0	0.0
Congo, Rep.	642	3	27	0.6	0.5	0.5	0.4
Tanzania	640	11	8	3.1	3.3	0.4	0.2
Sierra Leone	653	6	2	4.1	5.4	0.1	0.0
Congo, Dem. Rep.	518	1	0	0.1	0.1	0.0	0.0

Sources: World Bank (2004).

the additional crops produced in India. For the entire developing world outside of China, this share was 69 percent (Alexandratos, 1995, p. 170).

Yield growth has been much more disappointing south of the Sahara. One reason is that farmers use fertilizer sparingly or not at all. When a fixed area of land is continuously farmed, the soil is depleted of nutrients and minerals, such as phosphorous, potassium and nitrogen. If these nutrients and minerals are not replaced, the soil will become barren and crop yields will decline. Nutrient depletion then contributes to topsoil erosion, and more generally, to the conversion of marginal lands for agricultural use through traditional slash-and-burn agriculture. Water management is also crucial to the utility of fertilizer; even where fertilizer is applied, lack of soil moisture can mean an inefficient uptake of nutrients by plants.

In contrast with the general upward trend in Asia and Latin America, fertilizer application rates have declined in most African nations since the 1980s (Table 3, columns 2 and 3). The current average rate is a mere 8 kilograms per hectare, which is well below the developing-world norm of 107 kilograms per hectare (Dixon and Gulliver with Gibbon, 2001, p. 44). Land degradation often results where farmers are, in effect, mining nutrients because of under-fertilization (see below).

Where declines have occurred in the use of purchased inputs such as fertilizer, the blame is often assigned to diminished input subsidies, which in turn are linked to the structural adjustment programs that insolvent governments have implemented. But this analysis ignores the impetus that structural adjustment creates for agricultural development generally, and yield growth specifically, because of the scaling back of policies that long have discouraged farm production. These policies include food-price controls, export taxes, and currency over-valuation (Collier and Gunning, 1999).

Even where governments have not expressly hindered access to fertilizer (for example through monopoly "extension" services), fertilization rates have often not increased because rural areas are impoverished and/or sparsely populated (Table 3, column 1). Such conditions make local financing of roads and bridges – which are needed to move inputs to farmers and output to market – all but impossible. Even if an outside source, such as a development agency, covers the capital expenses of public goods, operations and maintenance are often beyond the financial reach of local communities. The fact that fertilizer application rates are well below 30 to 40 kilograms per hectare in all but a handful of Sub-Saharan nations is related undoubtedly to a general lack of transportation infrastructure, which is a great barrier to specialization and trade of all sorts.

The causes of limited irrigation are similar. Financial constraints on the local financing of dams, canals, and other infrastructure are severe. Moreover, many parts of Africa lack groundwater reserves and good reservoir sites. The latter limitation is common where rainfall is sparse and the topography is generally flat, as opposed to a landscape featuring rivers and narrow gorges that can be dammed easily and filled quickly.

The problem of limited agricultural water development in Sub-Saharan Africa is indicated by the fact that just five of the countries listed in Table 3 irrigated more than 10 percent of their cropland 25 years ago (column 4) and, because of a major increase in rain-fed farmland in the Sahelian nation of Mauritania, only four did so in the late 1990s (column 5). Two of the four, Madagascar and Mauritius, are insular. Swaziland benefits from excellent conditions for the irrigated production of sugar and other crops. Irrigated farming of fertile land alongside the Nile River, which Egyptians have been doing for millennia, also takes place upstream in Sudan, with cotton and groundnuts being major crops. Outside of these four nations and a few others, at least nineteen out of every twenty cultivated hectares is rain-fed.

Finally, just as fertilizer use and irrigation are limited in Sub-Saharan Africa, few nations in the region have experienced significant mechanization. In Botswana, where GDP per capita is high by regional standards and the ratio of rural population to arable land is modest, tractor use has risen since the 1980s (Table 3, columns 6 and 7). Also, production of sugar and other commercial crops is somewhat mechanized in Swaziland. The ratio of tractors to arable land has declined in South Africa, mainly because the country has reduced subsidies for agriculture and farm inputs (captured entirely by white producers) in order to qualify for WTO membership.

Table 4: Trends in Crop Area, Yield, and Output in Sub-Saharan African Countries, 1970 to 2000

	2000 Production (million tons) (1)	Average Annual Change, 1970 to 2000 Area (2)	Yield (3)	Production (4)
A. Crops				
Roots & Tubers	154	1.7	1.0	2.8
Fruits	47	1.6	0.0	1.6
Maize	38	1.5	1.2	2.7
Vegetables	22	1.9	0.8	2.6
Sorghum	18	1.2	0.5	1.6
Millet	14	1.4	0.4	1.8
Rice	11	2.4	0.6	2.9
Pulses	7	1.6	0.2	1.9
Oil crops	6	0.9	0.7	1.6
B. Animal Products				
Total Milk	19	---	---	1.8
Total Meat	8	---	---	2.0
Total Eggs	1	---	---	3.7
Cattle Hides	0.5	---	---	1.7

Source: Dixon and Gulliver with Gibbon (2001), pp. 44-45.

Elsewhere, farm machinery - which must be imported at great cost along with the fossil fuels to run these implements - is used infrequently. Even animal traction, which has the side benefit of organic fertilization, is limited, both because many farmers are too poor to afford oxen and other draft livestock, and because of tsetse flies and other pests.

Intensification, Extensification, and Trends in Output

With commercial fertilizer used sparingly and irrigation unheard of in many places, Sub-Saharan food supplies vary primarily because of changes in land use. For each of the crops listed in Table 4, annual growth in production from the 1970s through the 1990s (column 4) has resulted much more from increases in planted area (column 2) than from improved yields (column 3). Annual yield increases have equaled or exceeded one percent for just two commodity groups: roots and tubers, and maize. In contrast, yields of millet and pulses (important sources of nutrition for the rural poor) have changed little over the years, while fruit production per hectare has not varied at all.

In line with modest trends for other crops, cereal output per hectare has grown slowly. Indeed, yields in many of the countries listed in Table 5 were lower at the end of the twentieth century than two decades earlier (columns 1 and 2). In a number of other places, grain yields stagnated. Only in West Africa – Benin, Burkina Faso, Ghana, and Mauritania – and Cameroon, the Central African Republic, Mauritius, and Mozambique did output per hectare increase by more than 50 percent.

Aside from not increasing, cereal yields have been very low. Output exceeds 1.5 tons per hectare – a level long since surpassed in other developing regions – in just seven nations: Cameroon, Gabon, Madagascar (with substantial irrigation development), Malawi, Mauritius, South Africa, and Swaziland. In many more countries,

Table 5: Agricultural and Food Output in Sub-Saharan African Countries, 1979 through 2000

Country (ranked by income in 2000)	Cereal Yield (kg per ha.)		Arable & Permanent Cropland (1,000 ha.)		Food Production Index (1989-1991=100.)		Food Production per capita (average annual % growth)			Agricultural Productivity (value added per worker-1995$)	
	1979-1981	1998-2000	1980	1999	1979-1981	1998-2000	1975-1984	1985-1989	1990-1999	1979-1981	1998-2000
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Mauritius	2,536	5,094	107	106	89.7	104.0	-1.7	1.0	-0.9	3,087	4,977
South Africa	2,105	2,332	13,572	15,712	92.6	103.4	-1.6	2.1	-1.4	2,899	3,866
Botswana	203	196	1,360	346	87.2	94.2	-2.8	-5.2	-2.7	630	688
Namibia	377	285	657	820	107.2	97.0	-5.2	2.5	-3.1	919	1,468
Gabon	1,718	1,662	452	495	79.0	114.0	-0.1	-0.1	-1.3	1,814	1,882
Swaziland	1,345	1,836	204	180	80.2	91.0	0.3	-1.8	-4.1	1,671	1,731
Lesotho	977	974	292	325	89.1	98.6	-1.5	0.7	-1.7	723	540
Zimbabwe	1,359	1,184	2,539	3,350	83.3	105.2	-4.6	0.8	-0.5	307	336
Guinea	958	1,312	1,570	1,485	96.3	143.9	-0.8	-4.3	1.3	---	292
Ghana	807	1,306	2,760	5,300	68.7	162.9	-4.0	0.9	2.9	670	558
Mauritania	384	916	195	500	86.5	105.7	0.3	0.7	-1.8	299	480
Cameroon	849	1,551	6,930	7,160	79.9	129.6	-2.1	-0.9	0.1	834	1,104
Sudan	645	514	12,417	16,900	105.1	158.4	-1.7	-1.2	3.5	---	---
Ivory Coast	865	1,136	3,880	7,350	70.8	130.5	0.2	0.3	0.8	1,074	1,136
Senegal	690	721	5,225	2,266	74.0	114.2	-6.3	5.5	-1.3	336	304
Togo	729	933	1,420	2,300	77.1	135.9	-1.5	0.6	1.4	345	538
Uganda	1,555	1,377	5,680	6,810	70.4	116.6	-4.5	1.5	-1.4	---	353
Angola	526	646	3,500	3,500	90.0	144.1	-3.3	-1.6	0.8	---	121
Cent. Afr. Rep.	529	1,084	1,945	2,020	79.7	132.3	-0.4	2.4	1.2	377	469
Kenya	1,364	1,434	2,275	4,520	67.5	105.3	-1.6	3.6	-1.9	262	225
Benin	698	1,056	1,795	1,850	63.1	151.3	0.3	0.6	2.5	311	586
Burkina Faso	575	868	2,563	3,450	62.7	135.5	-0.1	3.8	0.7	134	180
Eritrea	---	822	---	500	---	139.4	---	---	1.6	---	---
Rwanda	1,134	930	975	1,116	85.3	91.6	0.8	-3.5	-1.8	371	235
Chad	587	650	3,150	3,550	80.1	152.0	-1.3	1.6	2.1	155	227
Madagascar	1,664	1,891	3,000	3,108	83.8	109.4	-1.5	-1.7	-1.9	197	181
Mozambique	603	919	3,080	3,350	100.9	131.0	-4.1	0.3	0.8		134
Nigeria	1,265	1,206	30,385	30,738	57.2	152.3	-2.2	4.2	2.5	414	672
Mali	804	1,163	2,050	4,650	76.7	125.7	0.8	3.2	0.2	241	283
Zambia	1,676	1,391	5,108	5,279	72.9	100.8	-4.3	5.7	-2.3	196	214
Niger	440	379	3,350	5,000	97.9	141.7	-0.6	3.1	-0.2	222	214
Ethiopia	---	1,141	13,880	10,728	---	119.9	---	---	1.7	---	138
Malawi	1,161	1,514	2,320	2,000	93.2	152.7	-1.4	-4.2	3.3	109	140
Burundi	1,081	1,283	1,305	1,100	79.9	90.3	-2.1	0.5	-3.0	177	141
Congo, Rep.	838	687	669	220	82.3	117.1	-0.5	-1.1	-0.8	385	475
Tanzania	1,063	1,295	5,160	4,650	76.7	106.0	0.4	-0.9	-2.3	---	189
Sierra Leone	1,249	1,116	1,766	540	84.5	87.0	-1.2	-0.3	-2.7	367	341
Congo, Dem. Rep.	807	785	6,314	7,880	72.2	92.0	-0.8	0.1	-4.1	241	252

Sources: Southgate, Graham, and Tweeten (2006).

fewer than 1,000 kilograms of grain are harvested yearly from each cultivated hectare.

With crop yields that are minimal and/or increasing slowly, the primary response to increases in food demand (resulting entirely from accelerated demographic expansion, since living standards have stagnated for decades) has been to expand the geographic domain of farming, and rapidly so. Between 1980 and 2000, farmed area increased by one-half or more in four West African nations – Ghana, the Ivory Coast, Mali, Mauritania, and Togo – as well as Kenya (Table 5, columns 3 and 4). Of the fourteen countries listed in Table 5 where crop yields declined during this same period, agricultural land use declined only in tiny Lesotho, Sierra Leone, the Republic of Congo, and Botswana. Sudan, Rwanda (where agricultural land-clearing was already at an advanced cumulative stage many years ago), and eight other nations experienced agricultural extensification (a process by which more land is converted from non-agricultural to agricultural uses).

Between 1980 and 1999 agricultural land use declined in only about ten Sub-Saharan nations, including Mauritius and Swaziland (both of which have small national territories), Botswana and Senegal (although in the latter, agricultural land use increased again in 2000), Ethiopia (which lost arable land when Eritrea gained independence after a long and bloody civil war), and Sierra Leone (which was racked by brutal internal conflict).

The rapid expansion of farmed area in most African countries combined with modest intensification has had a positive impact on food production (Table 5, columns 5 and 6). However, the increases, which averaged a little less than 25 percent during the 1990s, were only about half the output growth that occurred in Asia during the same period. Furthermore, in the same time period human numbers grew considerably faster in Africa, so that per-capita production actually declined during the final decade of the twentieth century in more than half the countries listed in Table 5 (column 9). There were several exceptions to this trend in West Africa, such as Benin, Ghana, the Ivory Coast, and Togo. Elsewhere, weak or absent output growth has resulted from the full range of impediments to agricultural development identified in this study, ranging from inhospitable environments to policy-induced market distortions to civil conflict.

Finally, the same impediments to development have depressed the productivity of rural labor practically throughout the entire continent. Reflecting per-capita GDPs that are high by regional norms, agricultural value added (Table 5, columns 10 and 11) is above $1,000 per worker in Mauritius, South Africa, and other small Anglophone countries in Southern Africa. This threshold is also exceeded in the plantation economies of Cameroon and the Ivory Coast. Elsewhere, however, value added amounts to no more than a few hundred dollars for everyone who farms.

Environmental Consequences of Agricultural Underdevelopment

Experience in various parts of the world indicates that as agriculture intensifies, the adverse environmental impacts of crop and livestock production can multiply. However, this consequence of intensification needs to be put into perspective. Developments such as the Green Revolution have allowed humanity to respond to unprecedented growth in the demand for food without resorting to widespread agricultural extensification. As a result, many natural habitats have been left intact. Furthermore, land degradation is often severe where agricultural productivity is depressed, which is not a coincidence. Unproductive farmers tend to mine soil nutrients. This mining may yield temporary dividends if the initial nutrient content of the soil is high. But as the process continues, a point is reached at which per-hectare output trails off. Farmers who engage in this practice can be trapped in a cycle of chronic poverty and environmental deterioration. The environmental symptoms of this cycle are clearly evident in Sub-Saharan Africa.

Nutrient Mining and Land Degradation

In most of the developing world, fertilizer use has increased in recent years (Table 6). Already high 25 years ago, application rates in East Asia have risen to elevated levels (235 kilograms per hectare) not observed in any other part of the world. Although previously low, application rates have tripled in South Asia and are now approaching levels characteristic of wealthy nations. Significant increases also have occurred in Latin America and the Caribbean and in the Middle East and North Africa. Sub-Saharan Africa has been the lone exception to the upward trend. No part of the world had lower levels of fertilization a quarter century ago. Since then, per-hectare application rates have actually gone down, from 16 kilograms in 1979-1981 to a mere 13 kilograms in 1998-2000.

Henao and Baanante (1999) have assessed the extent of nutrient mining throughout Africa, excepting Egypt (where fertilizer use is substantial). Part of their study included estimation of the nutrients that are lost annually because of crop uptake, leaching, soil erosion, and other processes. Also considered was nutrient replacement, by fertilization and other means. In three places – Mauritius and Reunion in the Indian Ocean, as well as Libya – replacement was found to exceed losses. Everywhere else, the reverse was true. Annual depletion of nitrogen, phosphorus, and potassium was modest in South Africa, amounting to just 14 kilograms per hectare. Elsewhere, the study found accelerated nutrient depletion. Net per-hectare losses exceeded 60 kilograms per annum throughout the eastern part of the continent, from Ethiopia and Somalia south to Tanzania and over to Madagascar. The same was true of the DRC, as well as Ghana, the Ivory Coast, Nigeria, and other parts of West Africa.

The same researchers attempted to estimate the costs of nutrient mining. Their approach was simple, involving the multiplication of net annual losses – 385,800 metric tons in North Africa, 110,900 metric tons in South Africa, and 7,629,900 metric tons in the rest of the continent – by the market values of nitrogen, phosphorus, and potassium contained in commercial fertilizer. The estimate they arrived at was $1.5 billion per annum (Henao and Baanante, 1999). While this finding reinforced the point that nutrient mining creates sizable economic losses, Henao and Baanante conceded that their analysis is not at all definitive and that the costs are likely to be larger still. For example, it would have been useful to investigate the yield increases that are forgone because nutrient losses are not fully offset

by fertilizer applications.

As we have already mentioned, few locations in Africa are blessed with a generous endowment of fertile land. Most of the continent's soils are of ancient geological origin and thus highly weathered, which means that nutrient mining takes an immediate toll on plant growth. The finding that soil fertility is being depleted rapidly - which remains the case, according to Henao and Baanante (2006) - suggests that in the African context, we should reconsider conventional measures used to gauge economic productivity of agriculture, such as "value added" in the sector.

Value added in agriculture is found by subtracting the costs of fertilizer, capital goods, and other inputs purchased from other sectors and industries from the value of crop and livestock output. Not incorporated in this calculation are the economic losses incurred because farming and ranching damage natural resources. Obviously, this omission leads one to exaggerate agricultural value added at any particular date, not to mention growth in this indicator of productivity over time.

For example, the conventional measure of value added per agricultural worker in Rwanda, a small nation in the highlands of East Africa, went from $371 in 1979-1981 to $235 in 1998-2000 (Table 5, columns 10 and 11). Since no other country in the region has had a higher annual rate of nutrient loss - 136 kilograms per hectare - part of this decline in value added was likely the result of resource depletion. If estimates of agricultural value added were to take this depletion into account, it would reveal an even greater reduction in the productivity of Rwandan agriculture.

Mainly because of data limitations, attempts to incorporate resource values in economic assessments of African agriculture have been few and far between. Of the small number of available studies, one undertaken in Mali - where nutrient depletion is moderate by continental standards (Henao and Baanante, 1999) - has yielded solid evidence that the costs of resource depletion indeed are significant. In this study, the Universal Soil Loss Equation (USLE), which was developed originally to estimate erosion on fields in the United States (Wischmeier, 1976), was adapted to African conditions. In addition, data from the International Institute for Tropical Agriculture (IITA), located in Nigeria, were used to analyze the linkage between erosion and crop yields. It was found that losses in agricultural output resulting from erosion were equivalent to 1.5 percent of Mali's GDP and well above the cost of conserving soil (Bishop and Allen, 1989).

Such findings have given considerable impetus to initiatives to reverse land degradation in Sub-Saharan Africa and other settings. Some of the people and agencies involved in these initiatives have specific ideas about how soil nutrients should be replenished. Advocating manure use and the planting of trees and other vegetation that transfer nitrogen from the atmosphere to the soil, they have undertaken pilot projects to make the case that alternatives to commercial fertilizer are viable.

Although some of these projects yield interesting results, the general case for alternative fertilization (i.e., organic farming) is not very convincing. In many areas where nutrient mining is occurring, manure (a primary source of organic fertilizer) is in very short supply, sometimes because livestock production is impeded by tsetse flies and other pests, and sometimes because edible plants that could be fed to cattle and other domesticated animals are instead consumed directly by people. Regardless, it is difficult to envision manure being spread in sufficient quantities to arrest land degradation.

As discussed above, the effect of government policies such as currency over-valuation and food-price controls, in combination with inadequate investment in roads and other public goods, has been to diminish the incentives to spend money on fertilizer and other inputs which are required to improve output. A large segment of the rural population has few other options than to engage in subsistence farming – using no purchased inputs aside from hand-tools and producing barely enough to feed itself, if that.

Table 6: Average Fertilizer Application Rates, 1979-1981 and 1998-2000

Region	Kilograms per Hectare of Cropland in 1979-1981 (1)	Kilograms per Hectare of Cropland in 1998-2000 (2)
East Asia	112	235
Eastern Europe and Former Soviet Union	145	34
Latin America and Caribbean	59	90
Middle East and North Africa	42	79
South Asia	36	107
Sub-Saharan Africa	16	13
Western Europe, USA and Canada, Australia and New Zealand, Japan and South Korea, etc.	133	125

Source: World Bank (2003), p. 126.

Table 7: Forested Area in 2000 and Deforestation during the 1990s

Region	Forested Area in 2000, '000 Hectares (1)	Annual Change, 1990-2000, '000 Hectares (Percent) (2)
East and South Asia	507,403	-801 (-0.2)
Eastern Europe and Former Soviet Union	937,169	+814 (+0.1)
Latin America and Caribbean	964,358	-4,669 (-0.5)
Middle East and North Africa	27,748	+65 (+0.2)
Sub-Saharan Africa	643,604	-5,296 (-0.8)
Western Europe, USA and Canada, Australia and New Zealand, Japan and Korea, etc.	789,168	+496 (+0.1)

Source: FAO (2003), Data Table 2.

Expansion of Agricultural Land Use at the Expense of Tropical Forests

If a rural family can neither raise agricultural productivity nor abandon subsistence farming for other work, it may still maintain its living standards, or at least forestall a decline, by relocating to a place where land degradation has not yet happened. This latter response underlies much of the agricultural encroachment on tropical forests and other natural habitats that is happening in many parts of Africa.

Nowhere in the world are forests in greater danger than in Sub-Saharan Africa. Deforestation is accelerating in many parts of the region, as shown by the decline in forested area since 1990 (Table 7, Column 2). This phenomenon is observed in several West African countries – Benin, Cameroon, Ghana, Liberia, Sierra Leone, and Togo – and several in the eastern and southern parts of the continent, including Botswana, Kenya, Namibia, Uganda, Zambia, and Zimbabwe. Deforestation is also accelerating in Mali and Sudan in the semi-arid Sahel, just south of the Sahara, as well as in Burundi, the DRC, and Rwanda, in Central Africa.

In the DRC, which has more tropical forests than any other nation aside from Brazil, land-use change as a portion of remaining tree-covered land is only 0.4 percent per annum. In all other countries where habitat destruction has accelerated since the late twentieth century, not to mention several where the number of hectares cleared annually fell after the early 1980s, yearly deforestation rates are at or above one percent. Land-use change is especially dramatic in Burundi and Rwanda. In the latter country, annual clearing increased from 5,000 hectares in the early 1980s to 15,000 hectares in the 1990s. Even worse is the case of Burundi, where annual clearing went from 1,000 to 15,000 hectares during the same period. The more recent rate is equivalent to 9 percent of remaining forests in the country (WRI, 1992, p. 286; FAO, 2003, Data Table 2).

Far more often that not, the agents of deforestation in Africa are small farmers, many of whom are relocating from areas with advanced nutrient depletion and land degradation. It is no coincidence, in other words, that peak deforestation and peak land degradation (brought about by accelerated nutrient mining) are both happening in the same part of the world.

Agricultural Underdevelopment and Impaired Human Health

A minority of the world's nations lack comparative advantage in crop and livestock production, and therefore can and should feed themselves by producing and exporting non-agricultural goods and services and importing edible products. Singapore is obviously a case in point, as are several oil-rich countries in the Middle East. In Sub-Saharan Africa, Botswana probably should not strive for food self-sufficiency and has wisely sought instead to exploit its comparative advantage in diamonds and tourism. In most settings south of the Sahara, however, agriculture is a mainstay of the economy and development of the sector is critical for human health. In these settings, adequate diets depend almost entirely on domestic food production.

As previously indicated, average daily energy intake is less than 2,200 calories per capita in Sub-Saharan Africa, which is the minimal level required for a healthy and productive life. This means that, at any given time, a large segment of the region's population is in a weakened state due to hunger, and therefore particularly susceptible to disease. In addition, agricultural under-development results in meager incomes for rural households, thereby putting pharmaceuticals and the attention of medical professionals out of their reach. Arrested development of agriculture, poverty, hunger, and frequent illness, then, all go hand in hand.

There is a direct parallel here with the trap of chronic poverty and environmental deterioration described in the preceding section of this study. Impoverished rural households not only mine nutrients in order to produce paltry amounts of food, thereby causing farmland to degrade. They also place a severe burden on their own bodies, which have limited capacity for work due to inadequate nutrition and frequent morbidity. To put it simply, subsistence farming is characterized both by the mining of nutrients and other environmental resources and by the mining of human stamina, which is the most fundamental of human resources.

If existing and potential threats to human health are to be addressed and contained, there is little doubt of the need for agricultural development (Fritschel, 2006). Along with providing individual families with the wherewithal for medicines, visits to the doctor, and so forth, improved performance of the agricultural sector and higher living standards in the countryside allow for financing of the public goods needed to deal with epidemic disease. For example, monitoring networks for tracking and containing avian flu are very poorly developed in Africa. To a certain extent, these networks can be strengthened through projects financed by international donors. But disease-prevention and related initiatives ultimately depend on local financing, which will not be forthcoming in rural areas as long as the vast majority of the rural population remains impoverished.

The Evolution of Public Policies Influencing African Agriculture

This study suggests clearly that environmental conditions in Sub-Saharan Africa are a primary cause of agricultural difficulties. As Reardon (1998) points out, colonial-era researchers addressed these conditions by experimenting with and extending soil-conservation practices, the planting of legumes, and farming systems featuring a mix of crop production and animal husbandry. Most African nations continued to experience the benefits of this work even after they achieved independence. For example, 28 years of investigation and field trials in Southern Rhodesia (now Zimbabwe) culminated in the early 1960s in an improved maize variety, SR-52, which was adopted by large numbers of farmers.

Rather than sustaining such efforts, post-independence governments have exhibited neglect or worse for the agricultural sector. By and large, support for research has been negligible. Where extension services have been funded, usually through development agencies, national leaders have been at least as interested in finding jobs for their supporters as in transferring technology to rural producers. Furthermore, many governments have enacted public policies that actively discourage incentives for crop and livestock production.

Agriculture: The forgotten sector during the 1960s and 1970s

During the first two decades or so after independence, local political elites and international donor agencies could not have conspired more effectively to destroy incentives for production in the Sub-Saharan countryside. With few exceptions, national leaders lacked strong connections to agriculture and tended to view the sector dismissively,[4] in part perhaps in reaction to the positive attention that crop and livestock production had received during colonial times. These leaders focused instead on industrial and urban growth, which was in keeping with the biases of many international development experts of the time. To support this growth, agricultural exports were taxed punitively, while price controls and monopsonistic marketing boards were used to maintain artificially low food prices for city-dwellers (Collier and Gunning 1999). To put it simply, these leaders viewed agriculture as the "milk cow" for non-agricultural sectors. Moreover, little was done to keep the milk cow healthy and growing.

International agencies tended to accommodate this approach; quite often they provided technical assistance for the establishment of marketing boards and other mechanisms for the implicit taxation of agriculture. In addition, these agencies favored the creation of extension services rather than agricultural research centers. This emphasis met with the satisfaction of local elites because governmental employment was expanded at the expense of donors. From 1959 to 1980, 36,000 extension agents were hired in the region (Eicher and Rukuni, 2003).

The working assumption underlying the preference of extension over research was that technology was available "off the shelf" and merely had to be brought to Africa for quick adoption (Eicher and Rukuni, 2003). During the 1960s, for example, new seed varieties and extension practices from the United States and Asia were introduced – an example of similar efforts undertaken in later decades. Donors' support for research efforts only began to emerge in the 1970s through the efforts of the Consultative Group for

4 One of the exceptions was Jomo Kenyatta, whose political movement had a strong rural base. Significantly, policies detrimental to agriculture have been less extreme in Kenya than in other countries.

International Agricultural Research (CGIAR). At the beginning, these efforts focused on crops of major concern in Asia, especially rice and wheat. Traditional African crops, including maize, cassava, millet, sorghum, yams, and cowpeas, were not on the CGIAR's radar screen until the late 1980s and 1990s, and even then with modest budgets. With a few minor exceptions, such as the development in Zimbabwe of a hybrid maize variety described above, no major productivity-enhancing technologies for Africa emerged during the 1960s and 1970s.

Economic Collapse, Structural Adjustment, and Donor Fatigue in the 1980s

The effects of incentive-destroying policies at the national level and ill-conceived support from foreign sources were not apparent during the first decade or so after African countries achieved independence. As already observed, trends in per-capita food production were about the same in Africa as in Asia (Table 2). But by the early 1980s, the picture had changed dramatically. Recessionary conditions from 1981 to 1984 – the worst downturn in the global economy since the Great Depression of the 1930s – took a heavy toll on commodity prices. This was severely injurious for the many African nations that earned practically all their foreign exchange from exports of just a few unprocessed goods. Later the same decade, Ethiopia and the rest of East Africa suffered prolonged drought, as did many other parts of the continent.

Sub-Saharan governments did not respond to these setbacks by relaxing the penalization of agriculture. To the contrary, policy reform only started to occur during the late 1980s, usually as part of structural adjustment insisted upon by the IMF and the World Bank in exchange for assistance with fiscal and current-account deficits. However, once structural adjustment was undertaken, prices and exchange rates were deregulated and trade barriers were reduced. In addition, government-owned marketing boards were dismantled, as were state banks. As a result, free markets started to play a greater role in allocating goods, services, and resources.

As reform proceeded, international assistance for agriculture declined. This started after the crisis years of 1985 and 1986 and has continued until today (Eicher, 2003). One of the three factors often used to explain this decline is a lack of interest by African leaders in crop and livestock production. Insofar as foreign aid reflects demand in the recipient country and insofar as national governments in the region have been neglectful of the rural sector, it is hardly surprising that donors reduced their support for agriculture.

A second reason for the reduction in assistance for agriculture is commonly referred to as "donor fatigue", resulting from the disappointing results of multiple projects focused on crops and livestock from the 1960s through the early 1980s. Of all the approaches that received international support – including community development, simplistic copying of American-style land grant universities, promoting livestock ranches, distributing agricultural credit through state-owned banks, and emulation of the training and visit (T&V) extension models that were successful in Asia – none really succeeded in the African context.

These and other approaches rested on the simple but invalid notion that technologies and institutions could be transferred unaltered to markedly different settings in Africa (Kane and Eicher, 2004). Regardless, the donors that had provided funds and technical assistance grew disenchanted with the whole enterprise.

A third factor explaining the decline in donor support for African agriculture was that in the 1990s, new NGO lobbies emerged which argued that health services, education, the environment, and microfinance were the best vehicles to reduce poverty. Representing powerful constituencies in their respective countries, these lobbies decisively reshaped the contours of foreign aid in their favor from the early 1990s onwards, both in bilateral aid programs and multilateral programs through the World Bank.

The share of total aid in Africa directed toward social infrastructure and services championed by the NGOs doubled from 23 percent in 1986 to 56 percent in 2001. Over the same period, the share allocated to agriculture, forestry, and fisheries declined from 27 to 10 percent (Kane and Eicher, 2004). Lost in this myopic

enthusiasm for NGO initiatives was the recognition that these programs did not address the productive side of the rural economy - and it is only a transformation of the productive technologies and institutions which serve small farmers and the rural poor that will in the long run combat poverty successfully.

The Fruits of Liberalization in the 1990s

By the last decade of the twentieth century, African governments were pulling back from socialism (when the Soviet Union disappeared as a sovereign state, it left client states in the region bereft of support), undergoing structural adjustment, or both. As a result, there was an easing of the policy-bias against agriculture. The response was apparent in countries that had access to national and international markets (via improved roads, airports, etc.) and that could make use of available technology.

One example of this development has been the production of pineapples, melons, and other fruit for Western European markets in the Ivory Coast, Ghana, and Burkina Faso, each of which has undergone some policy reforms towards economic liberalization. In East Africa, Kenya has taken advantage of new opportunities, as have producers located close to transportation hubs in Tanzania and Uganda. Until the mid-1990s when Robert Mugabe launched his attack on commercial farms, Zimbabwe had increased its output and exports of cut flowers and a range of horticultural products.

A major advantage of the development that countries like Ghana and Kenya have experienced has been the diversification of exports, with the respective countries now much less dependent on a small number of traditional cash crops. By definition, foreign-exchange earnings – which formerly had fluctuated dramatically as international prices, domestic production, or both went up and down – have become more stable.

Nations which have increased their non-traditional exports have experienced a number of other positive changes. For the sake of achieving the scale economies required to be competitive, small farmers have banded together in marketing and cooperative groups. At the same time, better methods of marketing and supply-chain management have been adopted. One of the new methods is contract-farming, which features variable pricing. Under this arrangement, payments to growers are based on quality and the degree to which European Union (EU) standards on pesticide residues and other criteria are met. In addition, contracts are terminated if random monitoring reveals a serious breach of standards.

Both variable pricing and contract-termination clauses provide incentives for farmers to monitor their own activities more closely, and thereby deliver the high-quality goods that consumers demand with minimal transaction costs – an important concern in settings where legal institutions are not very effective (Okello and Swinton, forthcoming). Quality is also enhanced through technical assistance that buyers and input suppliers provide to farmers.

It must be emphasized, however, that these developments have occurred mainly in selected areas – typically, places which have good access to markets and that lend themselves well to the application of existing technology. But most of the African countryside is poorly connected to international and even domestic markets. Rural producers' use of fertilizer and other inputs is minimal (Table 3) and agricultural yields are abysmally low (Reardon, 1998), comparing unfavorably to production per hectare in Asia and Latin America.

In more than a few countries, the vital first step of market liberalization has yet to be taken. These same countries, and many more which have satisfied the necessary conditions of liberalization, must still find ways to supply the public goods on which agricultural development depends. These include legal institutions required for property rights and enforcement of contracts, research and extension networks capable of developing and disseminating technological advances, as well as transportation infrastructure.

Achieving Sustainable Agricultural Development in Sub-Saharan Africa

For many years after African nations severed their colonial ties with Europe, the norm in the region was to apply a mix of macroeconomic and sectoral policies that reduced incentives for crop and livestock production. The general effect of these policies, which included food-price controls and currency over-valuation, was not to stimulate economic growth and diversification, as many advocates of governmental meddling had expected or hoped. Instead, the penalization of agriculture aggravated poverty in the countryside and inhibited overall economic progress.

Suppression of market forces in rural areas (and elsewhere) is much less severe than before. One reason for this change is that the Soviet Union, which was the chief external sponsor of African socialism, is extinct. Another reason is that structural adjustment has been implemented, at least partially, in much of the continent. Trade barriers still exist between countries in the region, and in many instances these exceed the barriers that African exporters encounter when trying to penetrate markets in Europe and other affluent settings. Regardless, acceptance of markets, though grudging in some quarters, is nearly universal.

Free markets and other elements of economic orthodoxy stimulate efficient specialization and trade, which in turn allow maximum well-being to be derived from available resources and technology. Nevertheless, economic orthodoxy does not comprise a comprehensive strategy for development, at least as far as African agriculture is concerned. Also required is investment in public goods, so that productive capacity can be enhanced and better levels of human well-being can be attained.

Public goods of all kinds are in short supply everywhere in Africa. This is certainly true of primary-level education, especially in rural areas. Institutional public goods – to be specific, systems for the administration of justice, to enforce property rights and contracts – also require substantial improvement. It is no exaggeration to say that the market economy cannot truly exist in the absence of such an enabling institutional framework.

Moreover, evidence suggests that this framework also improves environmental conditions, for instance by facilitating soil conservation. This contribution is highlighted in a recent study carried out in Ethiopia, a country that adopted a range of institutional and market reforms in the 1990s. Gebremedhin and Swinton (2003) discovered that poor Ethiopian farmers would undertake costly investments to control erosion over the long term only if their ownership rights were secure. In contrast, farmers whose land tenure was insecure did not consider soil conservation measures which were more complicated (or costly) than the construction of soil-conserving bunds.

Aside from the challenge of financing transportation and irrigation infrastructure, we emphasize another category of public goods: the development and dissemination of better technology for crop and livestock production. Contrary to what many believe, at least implicitly, there is no objective basis for pessimism about technological improvement in Sub-Saharan agriculture. That breakthroughs are indeed possible has been proven on various occasions – for example, the development and adoption of higher-yielding maize varieties in what is now Zimbabwe (discussed above) and genetically-modified (GM) cotton with superior traits in South Africa (Grouse *et al*., 2005).

In addition, researchers from around the world are harnessing biotechnology to resolve a variety of problems. In South Africa, scientists are currently seeking ways to control the potato tuber moth as well as

Box 1: Making Use of Pesticides and Herbicides in Africa

Ever since humans began to domesticate grains in the Fertile Crescent over 10,000 years ago, farmers have had to contend with pests consuming or competing with their crops and thereby diminishing productivity. To address this threat, they have used a variety of techniques and technologies, from manual weeding and intercropping to synthetic pesticides and pest-resistant crop varieties.

Globally, pesticides, which include both natural and synthesized chemicals, have played an increasingly important role in reducing crop losses from weeds, insects, fungi, rodents and other pests. Pesticides have been employed in agriculture for thousands of years, often in the form of harsh chemicals such as mercury, copper and sulphur. In the 20th century, these earlier more basic chemicals were increasingly replaced by more sophisticated, less harmful, synthetic chemicals. Even though some synthetic pesticides potentially are highly toxic, in practice they are typically less toxic than the chemicals they replaced because they are applied in much smaller doses and with far more accuracy. As a result, these modern chemical pesticides generally have fewer negative ecological and toxicological effects.

Of all the pests with which farmers must contend, weeds are arguably the most important. Weeds compete with cultivated plants for soil nutrients, water and light. Parasitic weeds attack and eventually destroy the cultivated plants. The seeds produced by weeds are often extraordinarily robust, and can survive harsh soil conditions over years. If weeds are not removed or controlled, they prevent mechanical harvesting, suppress the growth of crops, provide habitat for other pests (such as insects) and ultimately diminish crop yields. At a global level, "weeds are the most important yield constraint, the potential losses worldwide are estimated to be 28.8% (range 22-35%)" (Oerke et al. 431). In Africa, estimates suggest that losses from weeds "range from 25% to total crop failure" (Vissoh et al. 2004).

For much of history, farmers have combated weeds mainly through manual and mechanical weeding. However, as with other pesticides, the twentieth century saw an explosion in the development of chemical herbicides, which through careful use can reduce losses substantially. Thus, in North America and Europe, farmers are able to reduce the losses caused by weeds by about half (46 per cent in North America and 51 per cent in Europe – Oerke et al., p. 431). By contrast, in large parts of Sub-Saharan Africa, farmers manage to reduce losses from weeds by barely 11 per cent (ibid.).

The reason for the poor record of weed control in Africa is the reliance by the majority of farmers in that continent on manual labor, which is time-consuming and inefficient. The consequences are dramatic. For small farms, labor generally comes from inside the family, including women and children. For families involved in rice production, for instance, one study estimates that African women spend 40-60% of their time weeding (Harsch 2004). If these families were able to use chemical herbicides to control weeds, they would likely increase yields, liberate women for more productive activities, and enable children to attend or spend more time in school.

In addition to their direct economic and social benefits, broad-spectrum herbicides have longer-term benefits for sustainable agriculture. In particular, they enable the practice of conservation tillage, which can reduce or eliminate various problems associated with conventional tillage, namely reduced soil fertility, loss of moisture, pesticide run-off and soil erosion (Fawcett et al. 1994).

The need for pesticides and fertilizer

Despite clear benefits in terms of environmental protection and by augmenting food security in recent decades (Goklany 1999), the use of pesticides and fertilizers has often been questioned by people in affluent, food secure nations. Regulatory agencies, aid agencies and non-governmental organisations often claim that "agrochemicals themselves are the actual threat to the world's food supply" (Oerke *et al*. 1994, 42) and disparage their use in developing countries.

Oerke *et al*. (1994) challenge this view, pointing out that "in the less affluent parts of the world, where the population is still increasing year by year, without the use of agrochemicals to protect the crops more catastrophic famines would be inevitable. It is unrealistic to assume that the risks for world agriculture and for the world population are the same, and that food supplies are equally secure, the world over" (42).

The opinions of farmers themselves are also surely worth consideration. An FAO opinion survey of smallholder farmers in West Africa indicated that "the current level of crop protection in their country is too low" and that they lack equipment and pesticides. The FAO report explained that:

Inconsistent pesticide availability is a major constraint to good pest control. Due to limited infrastructure and an inefficient supply chain, pesticides are not present when needed, thus defeating one of their most significant advantages, that of rapid effectiveness during sudden pest population increases. Another major problem is poor availability of application equipment and its appropriate maintenance (van der Meijden 1998).

In terms of global food supply in coming decades, "it is likely that an additional one billion metric tons of cereal grain will be needed annually by 2030, which is a 50 percent increase over world cereal production in 2000…Roughly 80 percent of the increasing food demand must be supplied through yield improvements on lands already in production. Large gaps exist between actual and potential crop yields in much of the developing world, especially in smallholder agriculture in sub-Saharan Africa, South Asia and Latin America" (Borlaug and Dowsell 2004).

Back in 1994, Oerke et al. observed that "It will not be possible to produce enough food and fibre for an additional 2,139 million people in the period from 2000 to 2025 in developing countries without a gradual shift from subsistence farming to an increasingly commercially-oriented form of agriculture. There will have to be an increase in the use of purchased farm inputs and technological improvements, and better control and management of input use" (Oerke et al. 1994, 764).

More recently, Indur Goklany suggested that over the next 50 years there will ultimately be a tradeoff between increased agricultural productivity and used in agricultural productions:

Assuming that the human population will be 8.9 billion in 2050 and that crop production per capita will grow at the same rate between 1997 and 2050 as it did between the early 1960s and late 1990s, and if conventional agricultural productivity increases 1 percent per year between 1997 and 2060, then 325 million hectares (800 million acres) of forests or other habitat will have to be converted to cropland. That's a 21.5 percent increase over the 1510 million hectares of existing cropland (Goklany 2001, 60).

While agricultural biotechnology (see Box 2) holds much promise for future developments in productivity, for the foreseeable future it will largely complement rather than replace existing agricultural technologies – especially herbicides and other pesticides. Indeed, as Nobel Prize winner Norman Borlaug has observed, yield gains and improvements in productivity are still likely to come in the main from applying conventional technologies that have not yet been fully utilized (Borlaug and Dowsell 2004). That is to say, improving the productivity and sustainability of existing farmland will generally result from an increase in the use of inputs (hybrid and modified seeds, fertilizer, pesticides) and improved methods (conservation tillage, water management).

stem borers that damage maize. In Kenya, researchers are developing a sweet potato variety that resists the feathery mottle virus, as well as maize plants that can ward off stem borers. The banana weevil is a focus of biotechnological research in Uganda. Cowpeas that can resist the pod borer are being developed for West Africa. Furthermore, scientists around the world are working on cassava, which is second only to maize as the region's most important food crop (Eicher, Maredia, and Sithole-Niang, 2005).

As emphasized in this study, Sub-Saharan Africa was largely bypassed by the Green Revolution during the 1970s and 1980s, at an inestimably high cost for the region. It would be tragic if history repeated itself in the early twenty-first century. The adoption of modern agricultural technologies, including agricultural biotechnology, will have to be expanded considerably if food supplies are to keep up with growth in human numbers and food demand. To date, for example, very little work has been done to improve various crops that tens of millions of Africans rely upon as staples, including sorghum, millet, beans, and cowpeas. These issues are considered in Boxes 1 and 2.

Inadequate support at the national level for the scientific and technological underpinnings of agriculture has much to do with government spending priorities. As Pardey and Beintema (2001) have documented, the ratio of R&D expenditures to the value of agricultural output is low in Africa, even by the modest standards of other parts of the developing world. The same two investigators also point out that scientific advances are cumulative, with any given scientific breakthrough building on a series of past research findings. Accordingly, if under-investment in R&D is chronic, then lost opportunities for the improvement of agricultural technology multiply as the years go by.

Throughout the developing world, Africa included, agricultural R&D has generally been undertaken almost entirely in public-sector research institutes and universities, with much if not most of the financing and technical assistance provided by international donors. To this day, the CGIAR still plays a major role south of the Sahara. But if the promises of modern agricultural technologies are to be realized, the private sector will have to play a more prominent role.

An appropriate model could be that of South Africa, where processes, protocols, and legislation are in place for GM products and where various companies have established partnerships with host-country institutions for work on maize, potatoes, cotton, fruit, and other crops (Kirsten and Gouse, 2002). In a typical partnership, the international company supplies scientific know-how for a fee and the local institution harnesses this know-how to produce seeds and other products for local markets.

For other Sub-Saharan nations to adopt this model, development of suitable host-country counterparts is essential – research institutes and universities capable of adapting GM varieties to local conditions, for example. National and donor investment must be channeled in this direction. In addition, agricultural extension, for which governments have been primarily responsible, requires renewal and transformation. These programs need to emphasize solid training of a limited number of technology-transfer specialists, rather than creating employment based on political patronage.

Moreover, the current trend toward extension strategies that are decentralized and pluralistic (involving competition among private, NGO, and governmental providers of technology-transfer services) is welcome. One feature of this trend that merits special encouragement is greater emphasis on extension that is client-oriented and demand-driven, which is needed for the right sort of technology for crop and livestock production to be developed and transferred to farmers (Gemo, Eicher, and Teclemariam, 2005).

By far the poorest part of the world, Sub-Saharan Africa nevertheless is not doomed to misery. For hunger and poverty to be reduced, markets must be allowed to work. Rather than succumbing to the temptations of regulation and protection, governments must focus on the sorts of investments that are not typically provided by the market economy. With improved administration of justice, infrastructure, R&D and extension, and other public goods, agriculture will provide adequate food supplies to a growing region and will become a powerful engine for economic development.

Box 2: A biotech revolution for Africa? Is anti-GM activism having an adverse effect? Are African leaders sufficiently supportive?

Agricultural biotechnology offers the potential to increase yields, enable adaptation to more extreme environments, and improve nutritional content. However, its uptake and progress has been slowed by a variety of concerns, including environmental safety issues such as gene flow/gene transfer, pest/pathogen effects, impacts on other crops, and the development of pest resistance, as well as human and animal safety issues, such as possible toxicity and altered nutritional content of edible products.

While testing for environmental and food safety is an appropriate part of approval and regulatory processes that should precede the commercialization of GM products, the concerns that have been raised by interest groups seem disproportionate to the risks posed. Of course, the precise balance to be struck between the benefits of agricultural biotechnology and its risks is bound to differ from one part of the world to another. In rich countries, virtually everyone is adequately fed and aversion to environmental and other risks is acute. Accordingly, approval and regulatory processes for GM products are costly and lengthy. However, an entirely different balance is to be expected in less affluent places, where large segments of the population are food-insecure.

Unfortunately, however, African authorities cannot base their decisions exclusively on national priorities and assessments of risk. The EU is an important market for the region's agricultural output, which implies that tastes and preferences in Europe need to be taken into account when deciding whether or not to approve GM products. One might even speculate that the high costs and long periods of time that characterize approval and regulatory processes in Europe, which has the strongest anti-GM movement in the world, are in part a signal to other regions that adopting the products of agricultural biotechnology could lead to the loss of European markets.

But if African authorities respond to this signal by rejecting GM products, they will harm large numbers of their fellow citizens and agricultural biotechnology might well bypass the region. The EU will be partly to blame but not entirely: African governments have a choice. So far, the only nation to take a firm stand against external pressure is South Africa, which has permitted commercialization of two GM crops and is continuing to investigate a number of others.

Other actors in the debate over GM products include national authorities as well as the donor community. Outside of South Africa, national leaders have not been particularly supportive of agriculture in general and agricultural biotechnology in particular. Multiple roadblocks in regulatory and approval processes for these crops have been created. Furthermore, with modest exceptions, African governments have not invested significantly in the prime movers of agricultural technology, namely universities with strong agricultural science departments and productive agricultural research centers. For the most part, African leaders have become too donor-dependent to undertake such investments entirely or mainly on their own, which as emphasized in this paper is a major impediment to agricultural development in the region.

For four decades, international donors have exhibited more interest than national authorities in the agricultural sector. Many of the projects and programs underwritten by these donors have not turned out to be durable, and more than a few have been counterproductive. In contrast, positive contributions have come out of the CGIAR. Practically all of the modest yield improvements of African crops registered from the 1980s onwards resulted from the transfer of germplasm from international centers to national agricultural research systems (NARS). The general pattern for these transfers has been for the CGIAR to undertake most of the scientific effort and for the NARS to adapt improved varieties to local conditions. The contribution of the NARS is limited, of course, by modest professional staffing and inadequate budgets.

Finally, it has to be said that the donor community has not stood up forcefully to the anti-GM lobby in Europe and other parts of the world. For example in 1993 the CGIAR decided against developing GM products. Currently, just 10 percent of the system's budget is allocated to GM research. The World Bank and most bilateral donors also have largely avoided any significant funding for this research. Although at least 45 percent of the CGIAR's annual budget is utilized for Africa-related research, donor support for the system itself has been declining substantially in recent years, which in the end curtails agricultural R&D of all kinds in Africa.

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The Sustainable Development Network is a coalition of individuals and non-governmental organizations who believe that sustainable development is about empowering people, promoting progress, eliminating poverty and achieving environmental protection through the institutions of the free society.

The SDN promotes the view that sustainable development can only be achieved with evolutionary institutions that harness human initiative, including property rights, contracts, the rule of law, open markets and open trade, and accountable, transparent government.

The SDN develops and promotes policy solutions to achieve real sustainable development, by enabling people to improve their own wellbeing (and that of others), pursue their own goals, and protect the environment, without bureaucratic intervention (whether local, national and international). Members of the SDN generate policy materials, participate in global fora and engage with the news media to encourage public discussion of this institutional approach to sustainable development.

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