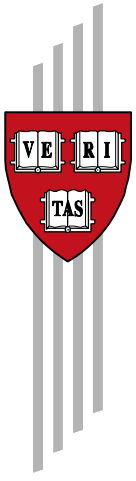
Framing the Fundamental Issues of Sustainable Development in Sub-Saharan Africa

Akin L. Mabogunje

CID Working Paper No. 104
March 2004

Sustainable Development Program, CID



Working Papers

Center for International Development
at Harvard University

Framing the Fundamental Issues of Sustainable Development in Sub-Saharan Africa

Akin L. Mabogunje

Abstract

This paper frames the fundamental issues of sustainable development in sub-Saharan Africa. The paper begins by considering the general problems of development in sub-Saharan Africa and then frames the issues as the maintenance or enhancement of the region's capital stocks. It describes the integration of the region into the global capitalist economy and considers how to integrate science and technology into the development culture of the region through greater concern with social learning. A concluding section reflects on the imperative of a new value and cultural orientation if sub-Saharan Africa is to meet the Millennium Development Goals of the United Nations and those of the New Partnership for Africa's Development articulated by African governments themselves.

Keywords: Sub-Saharan Africa, sustainable development, sustainability science, social learning, science and technology, S&T, globalization, social capital, knowledge systems

JEL Codes: F02, N57, O19, O33, Q01, Q56, Z13

Citation, Context, and Program Acknowledgements

This paper may be cited as:

> Mabogunje, Akin L. 2004. "Framing the Fundamental Issues of Sustainable Development in Sub-Saharan Africa." CID Working Paper No. 104. Cambridge, MA: Sustainable Development Program, Center for International Development, Harvard University; also published as TWAS Working Paper 1. Trieste, Italy: Third World Academy of Sciences.

It is available at http://www.cid.harvard.edu/cidwp/104.htm. However, as a work in progress, this does not constitute formal publication, and your comments are especially welcome and may be directed to Akin Mabogunje via email at mabogun@skannet.com.

This paper was presented as the opening lecture at the Ad Hoc Advisory Group meeting of the Consortium for Science and Technology for Sustainability, which was held in Paris, 24-26 January 2004. The Consortium for Science and Technology for Sustainability is co-sponsored by the Initiative for Science and Technology for Sustainability (ISTS), the Third World Academy of Sciences (TWAS), and the International Council for Science (ICSU). The underlying purpose of the Consortium will be to promote and strengthen efforts around the world to enhance the contribution of science and technology to sustainable development.

Dr. Mabogunje is Co-Convener of the Initiative on Science and Technology for Sustainability. The Initiative is an international, open-ended network with the goal of enhancing the contribution of knowledge to environmentally sustainable human development around the world. The Initiative was founded in late 2000 by an independent group of scholars and development practitioners gathered at the Friibergh Workshop on Sustainability Science. Since that time, it has worked to strengthen cooperation between two communities: practitioners involved in promoting human development and environmental conservation and researchers involved in advancing science and technology relevant to sustainability. Membership is open to all interested individuals and institutions. Information on activities and opportunities are available at http://sustainabilityscience.org/ists. Funding for the Initiative has come from the David and Lucile Packard Foundation and the U.S. National Oceanic and Atmospheric Administration's Office of Global Programs, with additional support from numerous governments and institutions around the world. The Initiative's secretariat is based at Harvard's Center for International Development.

The Sustainable Development Program at Harvard's Center for International Development is concerned with factors shaping goals, prospects, and policies for a transition toward sustainability. The Program builds bridges between the local, place-based character of many sustainability challenges and the increasingly global context within which solutions to those challenges must be shaped. It is concerned with the role of "partnerships" among governments, civil society, the private sector, and academia in shaping solutions for a sustainability transition. Finally, it seeks to foster interdisciplinary approaches to sustainability issues that would be difficult to pursue within a single department or school.

Further information on the Initiative and the Sustainable Development Program at Harvard's Center for International Development can be found at http://sustainabilityscience.org/ists and http://www.cid.harvard.edu/sd, respectively, or by contacting Nancy Dickson at nancy_dickson@harvard.edu.

Table of Contents

Introduction

A World Bank Development Report noted the progressive decline of development effort in most sub-Saharan African countries especially in the last quarter of the last century in the following terms:

> Africa's deepening crisis is characterised by weak agricultural growth, decline in industrial output, poor export performance, climbing debt, and deteriorating social indicators, institutions and environment. Agricultural output has grown annually by less than 1.5 per cent on average since 1970, with food production rising more slowly than population. Although industry grew roughly three times as fast as agriculture in the first decade of independence, the past few years have seen an alarming reversal in many African countries where de-industrialization seems to have set in. With export volumes barely growing at all since 1970, Africa's share in world markets has fallen by almost half. [Consequently], to maintain income and investment, governments borrowed heavily from abroad. Africa's long-term debt has risen 19-fold since 1970 and is now equal to its gross national product (GNP), making the region the most heavily indebted of all. (World Bank 1989, 2)

Although written in 1989, the trend in the above quotation has not been significantly reversed until now. It has led to the fact that over the period 1987 to 1999, the number of people in sub-Saharan Africa living below the poverty line of US$1.00 per day rose from 217 million to 300 million (World Bank 2002). Although relative to total population this figure represents a slight decrease from 46.6 to 46.3 per cent over the period, it still indicates the persistence of serious developmental problems in most African countries. Various reasons have been adduced for how the continent quickly slid into this parlous situation. Of special interest is the reason provided again by the World Bank. According to the Bank (1990, 3):

> The post-independence development efforts failed because the strategy was misconceived. Government made a dash for "modernization," copying but not adapting, Western models. The result was poorly designed public investments in industry; too little attention to peasant agriculture; too much intervention in areas in which the State lacked managerial, technical, and entrepreneurial skills; and too little effort to foster grassroots development. This top-down approach demotivated ordinary people, whose energies most needed to be mobilized in the development effort.

What then are the fundamental issues of sustainable development in sub-Saharan Africa? How does one frame these issues in the context of a region "copying" but not "adapting" Western models in its development effort? How could such adaptation of "Western models" have ensured that development was sustainable? How could the sustainability of such development be assured in the context of a globalizing market economy? What role could science and technology (S&T) play in ensuring that such a development was sustainable? What would have been the priorities of S&T in such a circumstance? How could it have done this without "demotivating" the ordinary people whose energies needed to be mobilised for the huge development effort required?

In this paper, I intend to provide some answers to these questions. Accordingly, the paper has been organized into five parts. The first considers the general problems of development in sub-Saharan Africa. The second part then frames issues arising from conceptualizing sustainable development as the maintenance or enhancement of the capital stocks of the region. The third part identifies issues due to the growing integration of the region into the global capitalist economy whilst the fourth examines issues or challenges that this poses for S&T. The fifth part considers issues connected with how to integrate effectively S&T into the development culture of the region through greater concern with social learning. A concluding section then reflects on the imperative of a new value and cultural orientation if sub-

Saharan Africa is to meet the millennium goals of the United Nations and those of the New Partnership for Africa's Development articulated by African governments themselves.

The Problems of Development in Sub-Saharan Africa

Discussions of development in any part of the world must begin with an appreciation of what has been happening to the human population. For the world as a whole, concern about sustainable development grew as we watched the world population grow from under 3 billion in 1960 to some 6 billion in the year 2000. Current projections envisage that this number will rise to around 9 billion in 2050 and hopefully could level off at about 10 to 11 billion by the end of present century. Meeting the basic needs of a population almost twice as much as at present, most of which will be found in developing countries, is a daunting prospect that must make any serious governments or leaders highly concerned and anxious.

For sub-Saharan Africa, we have seen the population go from just over 200 million in 1960 to some 642 million in 1999. Even allowing for estimation errors, a roughly three-fold increase of the population within a period of forty years must make even the most optimistic proponent of development ponder the implications of this trend. Certainly, it has made the region a lot more crowded, more consuming and, it would appear, much poorer than it needs be. We have seen the best projections with regard to growth in per capita gross national product far from being realized. With pervasive poverty and continued relatively high fertility rates, infant mortality rates also remain at an unacceptably high level at 90 per 1,000 live births compared to an average of 6 per 1,000 live births in OECD countries (World Bank 2001, 25). The situation has been further aggravated by the HIV/AIDS pandemic, leading to rising infant mortality in several African countries. Between 1990 and 1997, the infant mortality rate rose from 62 to 74 in Kenya and from 52 to 69 in Zimbabwe. Maternity mortality also remains exceptionally high exceeding 1,000 deaths per 100,000 mothers in a number of African countries. All of this has meant that life expectancy in sub-Saharan Africa has remained in 1997 at only 52 years—13 years less than the average for developing countries as a whole. It has also meant that the dependency ratio in the population is worsening with the increase in the proportion of the population that has to be supported for reasons of youthfulness, old age or impaired health.

Educational institutions in many African countries, whether at the primary, secondary or tertiary level, have not received the attention they deserve due to relatively low public investment in the sector. Consequently, gross primary enrolment for many countries has remained unchanged at 74 per cent between 1982 and 1996 and, in fact, actually declined in some of them. By the same token, the number of illiterate people increased by as much as 3 million in the region over the same period. Health institutions in many of the countries are no longer in a position to cope, and most of the people now resort to less effective traditional but cheaper alternatives. More recently, the scourge of HIV/AIDS sweeping the region along with the traditional diseases such as malaria and tuberculosis has raised the levels of morbidity and mortality among the population. Water supplies in most settlements in the region are remarkable more for their shortages than for their accessibility, and electricity outages have become an accepted order of the day.

One can go on listing the range of failures of developmental efforts in sub-Saharan Africa, failures that have left many of the people poorer today than they were some twenty or thirty years ago. What this will not adequately capture are the multiple pressures these failures have compelled the population to put on the environment. Although agriculture accounts for as much as 66 per cent of the region's labour force, 33 per cent of its GDP and 40 per cent of its exports, close to a quarter of the total population still faces problems of chronic food insecurity. Subsistence agricultural technology still dominates the production strategy all over the region. The failure to improve dramatically on this technology in most parts of the region has meant the shortening of the fallow period of farming and the continued "overmining" of the

fertility of the soils. Increased demand for food has thus meant increased deforestation and environmental degradation. The Food and Agriculture Organization's specific study on the process of deforestation and forest degradation on the African continent between 1980 and 1990 found that about 8.4 per cent of the closed forest cover was altered over that 10-year period. Of that amount, 34.1 per cent went into short-fallow agriculture, primarily a result of increased resource pressure from rural populations; 24.8 per cent degraded to open forest; 16.1 per cent was converted for other land uses such as permanent agriculture and urban development; and 19 per cent became fragmented forest, a result of clearing many small tracts of land dispersed in the original closed-forest area (FAO 1993, 33-36).

It is known, of course, that most of the world's biodiversity is located in the tropics with some 40 to 90 per cent of the world's species living in tropical forest (Raven 1988). The extensive deforestation on the continent has meant, among other things, widespread destruction of habitat where most species are found. Habitat loss, however, takes several forms including outright loss of areas used by wild species; degradation from vegetation removal and erosion, which deprive native species of food, shelter, and breeding areas; and fragmentation when native species are squeezed onto small patches of undisturbed land surrounded by areas cleared for agriculture and other purposes. Although habitat loss is difficult to measure, some experts agree that in calculating what habitat is left, the presence of large carnivores and grazing animals can be used as indicators. The rationale here is that, if the biggest animals (often referred to as the umbrella species) still survive within the region, there is enough wilderness left to support most of the other inhabitants within the ecosystem, as smaller species generally require less range (Reid et al. 1993, 14). The presence of elephants, for instance, is critical to maintaining African grasslands. In some areas where savannah elephants have been removed, grasslands have reverted to bush, changing the complement of native species. Various projections, based largely on current trends of habitat destruction in the tropics, suggest that between 1 and 11 per cent of the world's species per decade will go extinct between 1975 and 2015 whilst pollution will greatly threaten biodiversity, particularly in wetlands and aquatic areas.

Water, especially fresh water, has increasingly become a rather scarce commodity in most parts of sub-Saharan Africa. With a little over 4,000 cubic kilometres of annually renewable internal water resources (WRI 1994, 346), sub-Saharan Africa has less than 10 per cent of the annually renewable internal water resources of the world. This amount is also unequally distributed with a large part of the region being in deficit most of the time. Indeed, sub-Saharan African is one of the areas of highest rainfall variability in the world where rainfall varies more than 40 per cent over the long-term average. And yet, especially since the 1950s, water usage in the region has been increasing rapidly due to growing demands from households, agriculture, and industry. Population growth and increasing urbanization have particularly made the availability of drinking water supplies a matter of great concern over large parts of the region. Household uses include water for drinking, washing, and removing and treating sewage. According to the UNCHS (1999), no more than 37.6 per cent of urban households in Africa have access to potable services and only 12.7 to sewerage utility services. Agricultural irrigation has also been growing although irrigated land is no more than 4.2 per cent of total cropland of the region. Agricultural water use, nonetheless, accounts for as high as 88 per cent of the sectoral water withdrawal compared to 7 per cent for domestic use and 5 per cent for industry (WRI 1994, 346). Although industrial water use is still rather limited, its contribution to water pollution in the region, especially with heavy metal and other toxic substances, is growing rapidly.

An adequate and reliable energy supply is central to meeting the goals of sustainable development. Although with an impressive range of potential energy sources, ranging from coal, petroleum, and natural gas through hydro-electricity to wind and solar energy, sub-Saharan Africa has the lowest developed energy capacity in the world. Available data indicate that the generation mix is dominated by fossil fuel generating plants, which account for 81 per cent of total electricity generation with hydroelectricity accounting for just about 15 percent (ADB 1999, 117). Countries like Nigeria, Cameroon, Chad, and

Gabon have significant petroleum resources while most countries of southern Africa depend largely on coal. Much of the gas associated with the petroleum is presently simply flared although efforts are being made to reduce the amount involved through developing capacity for turning it into liquefied natural gas largely for export. Because of low income and the inability to purchase modern energy sources such as electricity, gas or kerosene for domestic use, many households, especially in rural areas, have turned to the use of charcoal and wood and have further heightened the rate at which the forest resources of the region are being denuded. It is estimated, for instance, that although biomass (wood, animal dung, and agricultural waste) supplies only 16 per cent of world's energy, it provides over 80 per cent of the energy needs of an African villager (Ward 2002, 6). The World Resources Institute noted that Africa accounts for as much as 20 per cent of the global loss of above-ground biomass estimated at some 2.5 gigatons per year (WRI 1994, 134).

Not unexpectedly, Africa's contribution to atmospheric pollution and climate change has on the whole been marginal. This, of course, is not to say that it makes no contribution to the increasing volume of "greenhouse gases" that are promoting significant changes in climate throughout the world. Of the increase in greenhouse gas concentration, some 60 per cent is carbon dioxide from burning fossil fuels. The other 40 per cent is caused by deforestation due to fewer trees being available to absorb the carbon dioxide in the air, by methane and nitrous oxide from agriculture, and by chlorofluorocarbons (CFCs) used in refrigerators and aerosol cans. The increasing "greenhouse effect" has meant a significant rise in the average global temperature with implications for the melting of the polar ice caps and temperate region glaciers, a general rise in sea level, excessive rainfall with increased flooding in some parts of the region and prolonged drought in others. Consequently, there is no room for complacency and sub-Saharan Africa with its rapidly increasing rate of urbanization must, like other parts of the world, embark expeditiously on a conscious programme of diversifying its sources of energy and reducing their negative impact on the environment.

Sustainable Development as the Maintenance/Enhancement of Capital Stock

In his Millennium Report to the General Assembly, the United Nations Secretary-General Kofi Annan noted that the three grand challenges facing the international community at the dawn of the 21st century are "Freedom from want, Freedom from fear and the Freedom of future generations to sustain their lives on this planet" (Annan 2001). These three grand challenges, especially the third, follow on the growing international concern about not only the poverty that pervades most developing countries, especially those in sub-Saharan Africa, but also how well humankind as a whole has been using the natural planetary resources and keeping the earth's life-support systems wholesome enough to continue to sustain human species well into the future.

Consequently, in framing the fundamental issues of sustainable development, the first question to ask is: what exactly is being sustained? According to Robert Solow (1992, 15):

> The duty imposed by sustainability is to bequeath to posterity not any particular thing—with rare exceptions such as Yosemite, for example—but rather to endow them with whatever it takes to achieve a standard of living at least as good as our own and look after their next generation similarly. We are not to consume humanity's capital, in the broadest sense.

For Solow, sustainability would appear to be an obligation to preserve or maintain society's broad "stock of capital" or present-day productive capacity for the future. This notion of sustainability as the maintenance of the capital stock was further elaborated by Serageldin (1996; 1999) who identified four types of capital: natural, human, social, and human-made. Carney (1998; 1999) and Scoones (1998) in their research on sustainable livelihoods for the British Department of International Development

separated economic capital from social capital to make a fifth type. Thus, whilst natural capital includes soil, land, water, wildlife, and biodiversity, human capital comprises skill, knowledge, ability to provide labour, and health. Economic capital, on the other hand, relates to savings, credit, remittances, and profits whilst social capital includes networks, status, membership of informal institutions, and access to more formal institutions. Human-made capital comprises basic infrastructure, machinery, equipment, and tools. Within such a framework, a sustainable society is thus one that nurtures and, if possible, enhances the value of these capital stocks for posterity.

A fundamental aspect of this "capitals school" approach to sustainable development is that the maintenance of these stocks of capital is strongly interdependent. Thus, the maintenance of natural capital, that is, the natural resources of an area, depends equally especially on the maintenance of the social systems and human skills (Reardon 1995; Pieri and Steiner 1997). To conserve natural capital is thus possible only through conserving human communities. In this way, the approach seeks to bring nature and society into one practical and, if possible, analytical framework. Applying this framework to the analysis of sustainable livelihoods in various parts of sub-Saharan Africa reveals that many rural households tend to be engaged in manipulating the different types of capital available to them not only to maintain and enhance their capabilities and assets but also to cope with and recover from stresses and shocks as well as provide opportunities for the next generation.

The "capitals school" approach has been criticized on a number of grounds. First, that as a framework for policy, it implicitly tends to promote an interventionist posture on the part of the authorities (Warren et al. 2001) in the guise of ensuring that the different types of capital are playing their presumed role in the development of particular communities. Secondly, that as an approach, it tends to underplay the conflict that arises within a particular society in the process of sustainable development, for example, conflict instigated by those who seek to appropriate scarce resources and political power (Bryceson 2000). Thirdly, it is argued that the undue focus of the approach on households and single communities draws attention away from the many constraints such as globalization, economic liberalization, and political mismanagement which rural households face and over which they have no control whatsoever (Brett 2000; Bryceson 1999). Fourthly, it is claimed that there are difficulties in measuring any of the capitals or the flows arising from or between them (Neefjes 2000).

Notwithstanding these criticisms, the "capitals school" approach enables us to distinguish between the capital assets of society and the flows of income, services, and amenities to which they give rise. Thus, according to this approach, society may enjoy the fruits of the accumulated capital available to it including environmental resources whilst ensuring that the integrity of this capital is not undermined. In the African context, therefore, sustainability represents, as it were, a modern version of a traditional concept of "usufruct" whereby every generation is seen as no more than trustee with rights of beneficial use (or usufruct) of the capital stock which it inherited from its ancestors and has responsibility to pass it to posterity as much as possible unimpaired by mismanagement. What is modern or different in this new formulation is the need to see "income flow" as representing overall living standards and the sum total of capitals as the productive capacity of a particular society. Preserving the natural capital base in such circumstance does not imply that non-renewable resources such as minerals and fossil fuels must be conserved which is likely to be unrealistic and unfeasible. Equally unfeasible is the idea that proceeds from such wasting assets should be set aside and re-invested so that the yield from these investments can compensate for the dwindling resource. Rather, if society's broad stock of capital is to be maintained, non-renewable resources that are used up would need to be replaced with something else through channelling the rents on society's use of such resources into capital formation, any form of capital formation—physical or human—which allows future generations to sustain indefinitely the income or capacity to consume which it inherited from the present generation (Anand and Sen 2000).

This new formulation arising from the "capitals school" conceptualization of sustainable development thus frees us from the trap of what has been called "strong sustainability" framework. This insists that, for sustainable development, as much natural capital as possible must be maintained and has reservations as to how far technology can substitute natural capital with other types of capital. Consequently, this framework requires that communities must live as much as possible within the constraints imposed by their environment (Eswaran et al. 1997; Wackernagel and Rees 1997). Proponents of this strong sustainability idea had dominated much of the earlier discussion of sustainability and made the conservation of the environment the major plank in sustainable development. A second tradition argues that human-made capital can be substituted for natural capital provided that the total stock of capital is maintained or even enhanced (Hartwick and Olewiler 1986). Proponents of this school of thought, characterised as the "weak sustainability" school, maintain that such substitution is possible because market-driven technological innovation will find substitutes for depleted resources and that such depletion may have been necessary and crucial for economic growth and the satisfaction of human needs. An intermediate position between the two schools was provided by Serageldin (1996) who argues that, in regions such as sub-Saharan Africa, the poor have little capacity to forgo consumption by way of conserving the environment and have to convert some natural capital into other assets, though they may not do this excessively. In consequence, sustainable development in this case requires the maintenance of what Serageldin calls "critical natural capital," which, in turn, defines his "sensible sustainability" position.

The Limits to Globalizing Market Economy

One of the most significant factors impinging on any of these conceptualizations is the impact of the global capitalist economy over which communities in sub-Saharan Africa have hardly any control. Since the closing decades of the 19th century, the thrust of development of most colonizing European powers has been to integrate the largely pre-capitalist social formations of the region into the global capitalist economy. This has meant installing some skeletal infrastructural and transportation framework, promoting the export of primary commodities and undertaking wide-ranging socio-economic reforms, especially in health and education. It has also meant that, for sustainable development, the farmers who are the most important users of the "critical natural capital" of the region have to contend with trying to satisfy not only the subsistence needs of their own expanding households but also the demands of a burgeoning domestic market and the price volatility of an international commodity market. Each of these categories of demands has been growing rapidly in recent times, often in the context of gross instability in environmental conditions, particularly in rainfall variability. Household subsistence, for instance, has been facing the effects of rising growth in population. Although fertility rates in sub-Saharan African countries would appear to have started on the transition path, this is more strongly noticeable in urban than in rural areas. For rural households particularly in eastern and southern Africa, orphaned children whose parents have fallen victim to the HIV/AIDS pandemic further compound the growing size of households. The demands of the domestic market are being increasingly fuelled by the rapid rate of urbanization and industrial development with growing sophistication for different types of crops and livestock products whilst the export market has proven very risky with its frequent price fluctuations and generally downward trend.

In the meantime, the globalization process has meant that an increasing share of world production is traded internationally, and the productive systems of different countries are becoming increasingly integrated. This process, which became more discernible soon after the end of the Second World War, has accelerated in its global impact in the 1980s as a result of the rapid progress made in information and transport technology and the effects of trade liberalization (Krugman 1995). For sub-Saharan Africa, globalization has meant the exposure of the regional economies to various external shocks, especially those emanating from falling commodity prices, deteriorating terms of trade and adverse climatic

conditions. The region's excessive reliance on the export of primary commodities has made it highly vulnerable to precisely the kind of global slow-down now underway in many of the countries. Eighty-three per cent , or 39 of 47, African countries are dependent on just two primary commodities for over 50 per cent of export earnings (ADB 1999). Furthermore, such dependence on primary products—greater than in any other developing region—has meant that with falling prices, farmers have had to expand their production into new and fragile areas rather than intensify production. Such expansion has often been the cause of much land degradation and unsustainable use of natural resources. Land degradation, of course, can take a number of different forms including encroachment into fragile areas, reduced duration of fallows, nutrient depletion, soil erosion, salinization, agrochemical pollution, vegetative degradation from over-grazing, and the cutting of forests for farmland (Scherr and Yadev 2001).

Nonetheless, it has been claimed that globalization is not necessarily the factor responsible for the negative impact of productive activities on the environment. Most African crop and animal production are practiced under low-input agricultural systems, often because of low accessibility to external inputs, low economic returns from inputs and market risks. Inadequate investments in rural infrastructure and agricultural R&D have taken a severe toll on rural development. The road system in Africa today is only a fraction of what India had decades ago (Spencer 1994) and leaves about 70 per cent of farmers poorly connected to markets. Many farmers can neither procure fertilizers and other inputs at affordable prices nor market their own products effectively. Poor telecommunications infrastructure also keeps farmers in isolation and without access to market information or relevant technological innovations. Similarly, poor access to health and education services diminishes agricultural productivity, contributes to the spread of infectious diseases, and locks rural people into a poverty trap. More importantly, the hasty retreat of many African governments from service delivery to rural communities in response to the dictates of structural adjustment and market liberalization has created a vacuum and severe shocks which have worsened the conditions of rural communities, causing backsliding from market reforms. Inadequate presence of effective producers organizations in many African countries has made it difficult for farmers to gain value from market and trade system development, investments in technology systems, improved access to micro-finance, and effective cooperation in natural resource management.

It must, however, be emphasized than none of the issues raised above can support the thrust of much of the earlier literature that tended to give the impression that African smallholders were recklessly destroying their natural resources by inappropriate land use practices in response to market demands. This viewpoint which was extended to the desertification debate in the 1970s and 1980s represents the doomsday scenario for dryland Africa which has easily obscured the evidence through self-reinforcing repetition of claims, backed by governments or international institutions such as the United Nations Environment Programme (UNEP 1993; Thomas and Middleton 1994; Stiles 1995). The growing scepticism about these claims was not reflected in the formulation of the International Convention to Combat Desertification, which became binding on its signatories on 26 December 1996. Such dire environmental scenarios rarely extend their investigations to the complex economic and social adjustments that embody the everyday decisions of ordinary people who have to manage their natural resources as responsibly as possible and prejudge the abilities of human communities to develop adaptive responses to processes in which they are already deeply immersed as participants.

Consequently, Mortimore (1998, 6-7) posits the following five questions to underscore the contradictory paradoxes inherent in the present situation concerning sustainable development in Africa's dryland:

> a) Why has the "advancing Sahara," the subject of scientific claims for nearly a century, failed to eliminate the Sahel and its peoples; and why does the concept of desertification after two decades of promotion, remain controversial?
> b) If overgrazing affects vast areas of the drylands (61 per cent, according to UNEP 1992, 5) and has done so for several decades at least, why has the livestock economy not collapsed?

> c) If cultivated land is degrading, and has been doing so for several decades, how do increasing numbers of people support themselves? If indigenous technologies are conservative, inappropriate, and destructive, why do they continue to be preferred?
> d) If overcutting is "mining" the woodlands, why has a scarcity of wood fuel not led to the collapse of rural energy systems, even in the most densely populated areas?
> e) Why do human fertility rates remain relatively high in the face of such powerful environmental constraints? If markets undermine local food sufficiency, why is increased participation in markets desired by dryland smallholders? If risk threatens the viability of primary production in the drylands, why is permanent out-migration not more extensive than it is?

Richards (1983) suggests that this controversy might be the product of an epistemological divide between "scientific" and "indigenous" knowledge systems in managing natural resources. This divide, according to Lambin (1993), could also be a function of the scale of investigation. The doomsday scenario for the African drylands is partly dependent on a global perspective, making use of monitoring and predictive techniques that depend very much on extensive data sets. Micro-scale studies of natural resource management, on the other hand, are more likely to reflect indigenous perceptions, to be holistic and to be specific to place and community. It is thus not surprising that the outcomes of such divergent systems of thought are often difficult to unify. Yet this challenge must be confronted if the end of sustainable development must be served.

The Challenge of Science and Technology

This issue of scale and of the need to bring on board both indigenous and "scientific" knowledge are some of the challenges confronting S&T in the context of sustainable development. In responding to these challenges, perhaps the first thing to do is to recognise the nuance of distinction between science and technology. Technology has been defined as the systematic study of techniques for making and doing useful things. The term itself is a combination of the Greek *technê*, "art or craft," with *logos*, "word or speech." It was used in ancient Greece to mean a discourse on the arts, both fine and applied (Encyclopaedia 1991a, 451). Technology thus embraces a growing range of means, processes, and ideas, in addition to tools and machines, by which man seeks to change or manipulate his environment and has always been an integral part of the cultural repertoire of every society in coping with its day-to-day activities.

Whilst technology is thus concerned with the fabrication and use of artefacts, science is devoted to the more conceptual enterprise of understanding the environment and depends very much on the comparatively sophisticated skills of literacy, numeracy, assiduous data collection, and analysis. Consequently, the history of technology is longer and distinct from the history of science. Indeed, the decisive contribution of science to technology or engineering was not made until the second half of the 19th century, long after the heyday of the industrial revolution was over. Or, as Polanyi (1944, 119) reminded us on this issue:

> To the practical bridge or canal builder, the designer of machines or engines, knowledge of the general law of nature was utterly useless before the new applied sciences in mechanics and chemistry were developed. Telford, founder and life-long President of the Society of Civil Engineers, refused membership in that body to applicants who had studied physics and, according to Sir David Brewster, never made himself acquainted with the elements of geometry.

Consequently, one of the priorities of science and technology in responding to the challenges of sustainable development in sub-Saharan Africa must be to recognise the existence and seek to mobilize as

much of “indigenous knowledge” and technology that would enable it to start to appreciate local societal capabilities for sustainability.

In the second half of the last century considerable advances were also made in geographic information technologies as well as in the broader spectrum of information and communication technologies that include telephones, radios, and the Internet. Geographic information technologies which include geographic information systems (GIS), global positioning systems (GPS), cartographic, surveying, and remote sensing technologies are already being applied to some of the major issues of sustainable development in sub-Saharan Africa. These include finding solutions to problems of food insecurity, combating deforestation, conserving biological diversity, managing health, and reducing vulnerability to natural disasters. The Famine Early Warning System Network (FEWS NET) initiated by the USAID in 1980 to empower countries in the region to find solutions to food insecurity problems now represents the principal food security information-based approach to preparedness and planning in the region (NRC 2002, 29). The Food and Agriculture Organization is also using these technologies in its Multipurpose Africover Database for Environmental Resources to obtain reliable, geographically referenced information on natural resources for use in forest and rangeland monitoring, catchment management, and biodiversity and climate change studies in ten countries of the East African sub-region. But none of these sophisticated techniques and technologies would have achieved their purposes unless they were part of decision-support involving participatory communities and other agencies and organizations.

One of the most important uses to which such advanced technologies still need to be put in sub-Saharan Africa is in dealing with the pervasive poverty on the continent through the expeditious and relatively cheap production of cadastres for both the urban and rural areas of individual countries. A cadastre is a map accompanied by a register showing the ownership or possession of individual units of land. Its role is thus to facilitate the process of providing individuals with economic assets which would empower and enhance their capacity to operate effectively in a free market economy. For the majority of the population of sub-Saharan Africa, access to such assets has not been possible because of the widespread communal ownership of land. Individualizing such ownership and making it secure through titling not only provides a powerful basis for tackling the problem of poverty but also promotes individual care and concern for possession which could have significant positive environmental implications. Owning land provides individuals with capital assets that can be traded in land markets, used as collateral to raise credit or as security for various forms of economic improvements out of poverty. The development and production of relatively cheap cadastres in virtually all countries of sub-Saharan Africa can thus be seen as a first and necessary priority step for science and technology in grappling with the pervasive problem of poverty of the continent.

Other priorities of science and technology must include ensuring that sustainable development entails that the human impact on the environment in the process of exploiting and transforming natural resources and disposing of the wastes there from is essentially benign and with minimal negative externalities for the global ecosystems. To this end, any technological innovations must be based on the three pillars of efficient use, renewable resources, and industrial ecology. Efficient use means radically reducing the required resource inputs for each unit of production and consumption. Renewable resources means living off nature’s flows while maintaining its capital stocks whilst industrial ecology means largely eliminating waste through recycling, reuse, remanufacturing, and product life extension.

In addition to enhancing the capabilities of information and communication technology (ICT), the recently concluded World Summit on Sustainable Development (WSSD) in Johannesburg, South Africa, indicated five major areas of priorities for science and technology in its WEHAB (water-energy-health-agriculture-biodiversity) programme. For most of sub-Saharan Africa, freshwater has to be provided in sufficient quantity for domestic needs, economic activity, and environmental stability. Such provision to both rural and urban areas is now a national problem of gigantic proportions. In areas such as the Niger

Delta of southern Nigeria, water is available in large quantities, but it is either highly mineralised or highly polluted. Over a larger area of the region, rainfall seasonality and increasing variability deepen the sense of crisis as to the growing inadequacy of freshwater supply to meet human needs on a sustainable basis. Consequently, S&T is already being challenged to develop various strategies to meet this emerging crisis. Numerous unconventional supply methods such as small-scale water harvesting schemes, rainwater capture, desalination in coastal cities, and recycling of treated wastewater are already well-known but need to be deployed in the circumstances of the region. Following on the experience of a number of developed countries, for example, water recycling is already becoming an important strategy of choice. It is claimed, for instance, that by the time the water in the River Rhine gets to the ocean in Holland, it has been recycled seven times. Applying such strategies to the rivers that flow through the region is a possibility whose realization is still much in the future. Other water conservation technologies include metering to reduce wasteful uses and the use of geographic information systems (GIS) for reducing transmission losses especially in urban areas. In respect to the rural areas, efficiency improvements are being promoted in irrigation use of water through new crop varieties and improved cropping methods.

The energy challenge for most of sub-Saharan Africa is for clean, convenient, affordable, and reliable energy services without compromising sustainability both in urban and rural areas. Reliance on traditional fuels and cooking methods results in widespread respiratory illnesses and other disabilities especially in rural areas and among the urban poor. It accentuates the related problems of deforestation and soil erosion apart from perpetuating gender inequality as the burden of fetching firewood falls mainly on women and girls. Existing technologies, if effectively and more widely introduced, could go far to solve some of the problem. For example, the improved biomass stoves—primarily for cooking but also for heating—developed and massively introduced in the last 20 years, have resulted in significant improvements in terms of reduced household and local air pollution and of convenience. Rural electrification, however, continues to be essential for modern agriculture and for rural industry as well as improvements in living standards for rural population. The existing centralized approach to electrification based on an expansible national grid is not likely to be able to take into account the more sparsely populated rural areas of the region or provide for the poorest segments of the population who cannot afford it. Efficiency of production, distribution, and end use thus becomes a very critical issue in the energy economy of the region.

The global trend towards decentralized electricity generation and distribution systems holds new and challenging possibilities for countries in sub-Saharan Africa, particularly for their rural communities. Some of these developments are new whilst others are traditional. They include photovoltaics, solar thermal techniques, small-scale wind turbines, small-scale hydropower, bio-power from producer gas, small gas turbines, geothermal, fuel cells, reciprocating engines, and hybrid combinations of all of the above. Decentralized generation systems with mini grids avoid the high costs and inevitable losses of conventional transmission and distribution networks and are better suited to serve remote and sparsely populated rural areas. They are relatively clean and avoid the heavy maintenance and fuel transport demand and pollution of diesel. But their real advantage in sub-Saharan African countries is that they provide local engineers opportunities on which to “break their teeth” in learning how to install such systems, permit local ownership and management and the deployment of private capital. Their promise for sustainable development stems not only from technical progress and institutional development that facilitate supplying locally generated electricity into national grids but also from significant cost reductions.

The implications for sustainable development of meeting the energy challenge in this manner is best appreciated when one considers how much worker productivity in many cities of sub-Saharan Africa can increase if they operate in an air-conditioned environment. At present, such facilities are available largely for the higher echelon of labour and largely for white-collar executives except where the needs of the machinery or equipment make this imperative. Given the favourable location of the region with respect to

solar energy, the cleanest of all energy sources, one can only conceptualize what would happen to the productivity of the average urban worker in the region if energy costs were such that most buildings—residential, office, industrial, and institutional—in which he has to work could all be air-conditioned? A situation in which the design of buildings can entail using materials and construction techniques that facilitate the efficient use of solar energy can only serve to promote higher human productivity and sustainable development in countries of the region. But even if the path to such a solar future is as yet not too clear, its vast possibilities can only serve to stress its priority for science and technology in the region. Such concern for extensive and efficient energy use compels paying greater attention to the planning and development of urban settlements in the region to make them a lot more compact so as to reduce travel time and costs and derive greater advantage from information and communication technology.

A major consumer of energy in most sub-Saharan countries is, of course, transportation. The gauge, speed, and technology of the railways inherited from the colonial period have not been improved significantly and are, therefore, no longer as important in the overall transportation economy of these countries. Instead, there is considerable dependence on vehicular transportation that, in recent times, has been based increasingly on second-hand vehicles imported from Europe. These are having serious environmental consequences. As substantial producers of CO_2 and NOx as well as small particulate and lead emissions, they contribute heavily to air pollution and adverse health effects, especially in cities. So also do the two-wheeled motorcycles that have become very popular for quick and relatively cheap passenger transportation in many sub-Saharan cities. Although in the last two decades much progress has been made in developed countries in producing vehicles with cleaner combustion outputs and, therefore, with lower emissions of these pollutants, one can only expect that with time such improved vehicles will become available for transportation in sub-Saharan African countries. But like Brazil and a number of other developing countries, there is much scope for developing cleaner and more efficient fuels for use by vehicles in this region of the world.

Threats to human health both directly and indirectly have increased in recent times. Direct threats include those arising from exposure to environmental factors such as air pollution, heavy metals, and synthetic chemicals, whilst indirect threats arise through loss of natural biological controls over opportunistic agents and vectors of infectious disease. For most of sub-Saharan Africa, the 1980s and 1990s have seen not only the emergence of some new diseases but also the resurgence of a number of “old” ones especially malaria and tuberculosis. Forest land conversions have been associated with higher incidences of malaria and leishmaniasis, through habitat creation conducive to tick and other insect vector breeding. The forest fringes are places where contact between disease organisms and human populations are most efficient in disease transmission. Rising surface temperatures associated with deforestation in the region are believed to be responsible for accelerating the life cycle of mosquitoes (Lindsay and Birley 1996). Similarly, tuberculosis has resurfaced in the region with increasing poverty and homelessness in urban areas and the importance of multidrug resistance (WHO 1996). But neither of these upsurges has anything of the virulence with which the HIV/AIDS has affected the region. The very rapid urban spread of HIV/AIDS, with an infection rate estimated as four times higher in urban than rural areas in some African countries, (Boerma et al. 1999), has led to some significant urban mortality increases. Indeed, the seroprevalence rates are even much higher in the capital or major cities of most countries, especially in eastern and southern Africa due largely to the fact that these are the destinations of many migration streams. Coping with these various diseases and the environment that breeds them continues to constitute a major challenge for S&T in the region.

With respect to food, the challenge is how to sustain the provision of sufficient food for all while preserving soil quality, protecting biodiversity, and preserving the ecosystems. The “green revolution” in the Asian parts of the developing world has had great success in raising crop yields but it has not been easy to replicate in sub-Saharan Africa. Its heavy dependence on the use of chemical fertilizers has polluted the soils and groundwater and does not make it too attractive an option. There is need, therefore,

to embark on promoting farming practices that are more knowledge-intensive and less chemical-demanding in sub-Saharan Africa. Indeed, a production ecological approach is being canvassed for sustainable agricultural development in the region. This approach seeks to disentangle growth-defining factors (genetic potential and solar radiation), growth-limiting factors (water and nutrients) and growth-reducing factors (weeds, pests, and diseases) in such a way that technological opportunities for improvement can be more directly recognised, developed, and applied (Ittersum and Rabbinge 1997). Such systematic analysis of underlying eco-physiological processes encourages improved understanding of the dynamics of plant and animal behaviour to the point where it is possible to identify the relative importance of growth factors and inputs to productivity. This in turn presents considerable opportunities for evaluating the effectiveness of new technologies and input measures in improving productivity. The approach thus facilitates communication among various disciplines in agricultural science and allows for comprehensive analyses of agricultural systems.

In this connection, it is worth noting that Africa has a huge reserve of biological resources that it has hardly started to exploit either for food or for pharmaceutical purposes. The rich biodiversity of the region constitutes a remarkable challenge for biotechnological innovations. Biotechnology thus holds tremendous promise of increasing yields, reducing chemical input, conserving water use, and improving the nutritional content of crops. Notwithstanding its risks, such as those of reducing crop diversity, degrading the ecosystem through accidental release of pest-resistant organisms into the wild, and increasing farmers' dependence on transnational agribusinesses, there is need to confront seriously the challenge of developing strong biotechnological capabilities in the region. Local pharmaceutical companies have started in small ways to exploit this potential. One such Nigerian firm developed a pharmaceutical remedy with the patented name of "*Jubi Formula*" which won the first prize in the year 2000 in Accra, Ghana, in a competition organised by the United States Agency for International Development for such local pharmaceutical developments in Africa. *Jubi Formula* is based on improved indigenous knowledge of the efficacy of particular herbs and is reputed to be a safe and effective herbal preparation substitute for blood transfusion and drug therapy for the management of such anaemic states as sickle-cell anaemia, breast cancer, leukaemia, multiple myeloma, skin cancer, and HIV/AIDS. It has already gone into international e-commerce from its base in Lagos. This development, among other things, emphasizes the very rich prospects for biotechnological innovations and calls for greater capacity for integrating indigenous knowledge into scientific and technological research in the process of fully exploiting the biological resources of the region.

The Importance of Social Learning

Although all of these challenges underscore the primary importance of S&T, it is noteworthy that in the first two decades after the 1980s, when the idea of sustainable development for humankind gained political impetus, it was propelled quickly forward in public discourse all over the world without much attention paid to the crucial contribution of S&T. The emphasis in the public discourse tended to give the impression that all that was needed was for policy re-orientation to reconcile society's developmental goals with the limits of the life-support system provided by the environment. This development increasingly distanced the sustainability issue from its scientific and technological base. Consequently, the knowledge and know-how needed to make significant headway in this respect have not been available even where the political will to do something about sustainable development has been evident. It was in this circumstance that, in order to re-invigorate the essential strategic connections among scientific research, technological innovations, and society's effort to achieve environmentally sustainable development, the United States National Research Council commissioned its Board on Sustainable Development to examine the role of science and technology in the transition to sustainability. That study, titled *Our Common Journey: A Transition toward Sustainability* (NRC 1999), re-opened the discourse. This time around, the deliberations were within the scientific community and they already underscored

the need for a new scientific paradigm that would in its structure, method, and content be fundamentally different from scientific and technological endeavours as they are presently conceived.

What was clear from the clarion call to the scientific community is that the knowledge and know-how involved in illuminating the critical challenges and opportunities inherent in the pursuit of the goals of sustainable development would need to be more interdisciplinary and more integrative, especially between the humanities, the natural sciences, and engineering. This is because it is becoming increasingly evident that nature-societal interactions are very complex, non-linear in their results, and usually with very long time-lags between actions and their consequences. These characteristics have been making familiar scientific approaches to developing and testing hypothesis or technological innovations involving nature-societal interactions no longer adequate. This inadequacy is fuelling the search for the new paradigm of "sustainability science" (which includes engineering sciences) to help mankind navigate the transition to a more populous, more consuming, more connected, and, in many parts, more diverse world into which mankind is moving.

As is obvious from what has been said above, no single scientific discipline can, in fact, provide answers about what to do in ensuring sustainable development. Most environmental sciences always have to conclude their studies with estimates or evaluation of the human impact on their particular problem. Social and developmental studies, on the other hand, record considerable environmental influences on the economic and social well-being of the communities they study. Clearly, to address seriously any major environmental problems requires an integrated scientific effort focused on both the social and ecological characteristics of particular places across the full range of scales from local, through regional, national to global. Consequently, sustainability science seeks to enhance scientific capacity to analyze and predict the behaviour of these complex organizing systems of nature and society. It attempts to characterize and evaluate the impact of multiple and interacting stresses on the earth system, interpret the impact at different scales of organization, and assess the roles of various social actors in promoting this impact both in terms of their divergent expectations and the conditions of uncertainty and limited information within which they have to operate.

What makes sustainability science challenging, therefore, is the urgency in its recognition of the fact that scientists, engineers, and policy makers can no longer pretend that they can stand outside the nature-society system, ordering and promoting specific technical solutions to problems as if they already know all the answers. Indeed, for most environmental problems, it is clear that the common sequential analytical phases of scientific enquiry, involving the conceptualization of the problem, the collection of data, the developing of hypothesis and theories, the designing of technical artefacts, and the application of the results to real world situations is increasingly proving inappropriate. What is emerging (and is already helping to define the nature of sustainability science) is the appreciation of the need to enhance the parallel functions of social learning through incorporating into the design process elements of action, adaptive management, and policy, all as part of an on-going and sometimes iterative experiment as to the best way to ensure sustainable development.

The implications of this new approach are very instructive. A good example is provided by the challenge to deal with the energy situation in South Africa especially in the low-income household energy sector (Ward 2002). Little information was available about energy for users or development workers. What information did exist was confined to electricity and came from the electricity suppliers. The lack of energy information became more critical when community representatives were invited to participate effectively in the making of a new energy policy in 1995. The need for such a participatory programme was motivated by the Women's Energy Group (WEG). It was carried out by WEG, the Energy & Development Group, and the Energy for Development Research Centre and funded by the Department of Minerals and Energy. At workshop after workshop, people stated as their highest priorities that they needed information and more skills to deal with energy issues in local government and with development

workers. Consequently, the Department of Minerals and Energy commissioned the Energy & Development Group to develop a low-income household energy communication and capacity building strategy. This programme was called HEAT (Household Energy Action Training) and has now become part of the Sustainable Energy for Environment and Development (SEED) Programme which places Energy and Environment Advisors with local government and housing NGO partners to promote a national information, training, and policy programme.

This type of social learning effort compels sustainability science to employ new methodologies such as those that would generate semi-quantitative models from qualitative data**,** build upon lessons from case studies, and extract inverse approaches that start from outcomes to be avoided and, through working backward, identify relatively safe pathways for circumventing many difficulties encountered in standard environmental assessment and cost-benefit accounting. Consequently, sustainability science encourages processes of co-production of knowledge. It predicates success on situations in which scientists, engineers, and stakeholders interact to define the important questions, the relevant evidence, and the convincing forms of arguments that are scientifically sound and rooted in social understanding. These participatory procedures involving scientists, stakeholders, advocates, active citizens, and other users of knowledge are needed to transform knowledge claims into trustworthy, socially-robust, and usable notions about the realities that matter in social and environmental change and in the transition to sustainability. They require factoring the linguistic factor into the co-production of scientific information. Greater effort would need to be devoted, for instance, to ensuring that communities in different parts of sub-Saharan Africa appreciate, within the context of their own vernacular languages, the basic notions and concepts of what is involved in the idea of biodiversity and the challenges of the genetic resource potentials that it represents, all in the context of sustainable development.

It is important to remind ourselves of the increasing vulnerability of the life-support systems on which mankind depends. That vulnerability is due both to the rapidly growing population in all countries of the region and the sophistication of the technological and organizational capabilities now available to promote consumption styles that are proving more and more unsustainable. Scientists must be humble enough to acknowledge the limitations in the understanding of the dynamic and complex interactions between the environment and society in many of the ecosystems found in each country of the region. Consequently, the people themselves must be empowered to become active agents of sustainable and equitable development through involving them in the co-production of the requisite knowledge. Effective systems and mechanisms must be developed which can better integrate research, assessment, decision-support activities, and development, particularly at the regional and local levels as indicated in the South African example. This is needed more than anything else in confronting the increasingly intractable problems of environmental degradation in many parts of the region due to present systems of production and consumption.

Sustainability science provides a more effective means of managing the environment by emphasizing that research and management are not ordered linearly in the familiar fashion in which management actions lie outside the research domain. Rather, it calls attention to the fact that these are combined in entangled patterns relating to the problems to be tackled and the practical constraints of inquiry, policy formulations, and programmatic activities. Its progress will require the fostering of problem-driven, interdisciplinary research; building capacity for such research in many of the countries of sub-Saharan Africa; and attempting technological solutions to sustainability problems in an iterative manner.

Conclusion: The Imperative of New Value Orientation

Clearly, then, framing the fundamental issues of sustainable development is articulating the framework of a new vision of society. This is a vision whose orientation revolves around the four pillars of equity,

caring, sharing, and security. Equity denotes a principle of fair and equitable treatment to all (including generations yet unborn) to be respected equally by individuals, institutions, and the State. Care is the opposite of power and control and is concerned with promoting and protecting the quality of life, providing a just framework for life. Sharing is about participation, of civic engagement of all citizens in all decisions that closely affect their lives, whilst security transcends the traditional concept of safety from injury, accidents, disasters, diseases, and violence to embrace equally the notion of protection from loss of livelihood or damaging environmental change.

Most advocates of sustainable development recognize that, for it to be realized, would require changes in human values, attitudes, and behaviours. Raskin et al. (2002) suggest that such critical value changes are needed to promote new quality of life, human solidarity, and ecological sensibility to counter the present value system that places much emphasis on consumerism, individualism, and the domination of nature. Minimally, such changes must ensure that human needs of the much larger global population are met, hunger and poverty substantially reduced, and the life-support systems of the planet are preserved and maintained.

Despite the importance of such value changes, however, relatively little is known about the long-term global trends in values, attitudes, and behaviours that will both help or hinder a sustainability transition. There are, of course, a number of isolated studies that attempt to show how integrated conservation and development projects have, over the medium term, assisted in changing local attitudes and behaviour. Global data on sustainability values, attitudes, and behaviour, however, do not exist, although some multinational, national, and local data sets on relevant themes are available. One such is that provided by Abbot et al. (2001) showing that, by improving incomes and livelihoods from the land in and around the Kilun-Ijim Forest in the Bamenda Highlands of the Cameroon, pressure on the forest decreased and livelihood activities had a conservation impact through explicit changes in local attitudes and behaviour over more than a decade of the project. Much more needs to be done.

Kates and others (2003) are launching a new project to study long-term trends in values, attitudes, and behaviours (VABs) related to sustainability. Their study seeks to investigate three sets of VABs that might impact on a sustainability transition. The first set relates to examining trends in contextual values, notably modernization, globalisation, and democracy. The second set relates to VABs specifically related to the environment and development and their nexus in sustainable development. This will include an examination of attitudes towards each of the so-called driving forces of environmental impacts and resource depletion (IPAT: population, affluence, and technology) as well as human development drivers, including development assistance and entitlements. The third set concerns VABs related to material and energy production, distribution, and consumption which are critical to a sustainability transition. In all three cases, the intention is to juxtapose the VABs as expressed by survey respondents to aggregate measures of behaviour such as fertility, consumer purchases, election results, market valuations, and rates of technological substitution.

Whatever the outcome of this study, for sub-Saharan Africa, there is clear need for a new orientation in the promotion of sustainable development. Such new orientation is critical for meeting the eight Millennium Goals to which African governments have committed themselves. Although only Millennium Goal 7 specifically relates to environmental sustainability, especially in terms of reducing by half the proportion of people without sustainable access to safe drinking water by 2015 and ensuring that at least 100 million slum dwellers have access to improved sanitation and secure tenure, six of the other Millennium Development Goals also do impact positively on sustainable development through insisting on improved access, particularly of the poor, to basic services. Certainly, such improved access is expected to reduce the poverty gap ratio, cut down the proportion of people suffering from hunger, increase the literacy rate and the proportion of children attending schools, promote gender equality and

women empowerment, reduce child mortality by as much as two-thirds, and combat effectively HIV/AIDS, malaria, and other environmental diseases.

The NEPAD (New Partnership for Africa's Development) Declaration (2001), agreed to by all African Governments, underscores the urgency of these efforts. It challenges African governments to "develop the capacity to sustain growth at levels required to achieve poverty reduction and sustainable development." This, in turn, it notes, "depends on other factors such as infrastructure, capital accumulation, human capital, institutions, structural diversification, competitiveness, health, and good stewardship of the environment." To this end, it sees science and technology as critical for "developing and adapting information collection and analytical capacity for supporting productive activities as well as exports." This challenge, therefore, provides a very strong leverage for mobilizing the science and technology community to confront the many fundamental issues of sustainable development presently facing many countries of sub-Saharan Africa.

References

Abbot, J. I. O., D. H. L. Thomas, A. A. Gardner, S. E. Neba, and M. W. Khen. 2001. "Understanding the Links between Conservation and Development in the Bamenda Highlands, Cameroon." *World Development* 29 (7): 1115-1136.

ADB (African Development Bank). 1999. *African Development Report 1999: Infrastructure Development in Africa*. New York: Oxford University Press.

Anand, S., and A. Sen. 2000. "Human Development and Economic Sustainability." *World Development* 28 (12): 2029-2049.

Annan, Kofi. 2000. *We, the Peoples: The Role of the United Nations in the 21st Century*. New York: United Nations.

Boerma, J. T., A. J. Nunn, and A. G. Whitworth. 1999. "Spread of HIV Infection in a Rural Area of Tanzania." *AIDS* 13:1233-1240.

Brett, E.A. 2000. *Development Theory, Universal Values and Competing Paradigms: Capitalist Trajectories and Social Conflict.* DESTIN Working Paper 00-02. London: LSE Development Studies Institute, http://www.lse.ac.uk/Depts/destin/workpapers/developmenttheory.pdf.

Bryceson, D. F. 1999. *Sub-Saharan Africa Betwixt and Between: Rural Livelihood Practices and Policies.* ASC Working Paper 43. Leiden: Afrika-Studiecentrum.

Bryceson, D. F. 2000. *Rural Africa at the Crossroads: Livelihood Practices and Policies*. Natural Resources Perspectives 52. London: ODI, http://www.odi.org.uk/nrp.

Carney, D., ed. 1998. *Sustainable Rural Livelihoods: What Contributions Can We Make?* London: Department for International Development.

Carney, D. 1999. *Approaches to Sustainable Livelihoods for the Rural Poor*. Poverty Briefing 2. London: Overseas Development Institute, http://www.odi.org.uk/publications/briefing/pov2.html.

Encyclopaedia Britannica. 1991. *The New Encyclopaedia Britannica, vol.28*. Chicago: Encyclopaedia Britannica, Inc.

Eswaran, H., R. Almaraz, P. Reich, and P. Zdruli. 1997. "Soil Quality and Soil Productivity in Africa." *Journal of Sustainable Agriculture* 10 (4): 75-94.

FAO (Food and Agriculture Organization of the United Nations). 1993. *Forest Resources Assessment, 1990; Tropical Countries*. FAO Forestry Paper 112. Rome: FAO.

Hartwick, J. M., and N. D. Olewiler. 1986. *The Economics of Natural Resource Use*. New York: Harper and Row.

Ittersum, M. K., and R. Rabbinge. 1997. "Concepts in Production Ecology for Analysis and Quantification of Agricultural Input-Output Combinations." *Field Crop Research* 52:197-208.

Krugman, P. 1995. "Growing World Trade: Causes and Consequences." *Brookings Papers on Economic Activity.* 1:327-377.

Lambin, E. F. 1993. “Spatial Scales and Desertification.” *Desertification Control Bulletin* 23:20-23.

Lindsay, S. W., and M. H. Birley. 1996. “Climate Change and Malaria Transmission.” *Annals of Tropical Medicine and Parasitology* 90 (6): 553-555, 585.

Mortimore, M. 1998. *Roots in the African Dust: Sustaining the Drylands.* Cambridge, England: Cambridge University Press.

Neefjes, K. 2000. *Environments and Livelihoods: Strategies for Sustainability*. Oxford: Oxfam.

NEPAD (The New Partnership for Africa’s Development). 2001. “The NEPAD Framework Document.” Abuja, Nigeria, http://www.nepad.org.

NRC (United States National Research Council). 1999. *Our Common Journey: A Transition toward Sustainability*. Washington, D.C.: National Academy Press, http://www.nap.edu/books/0309067839/html/.

NRC (United States National Research Council). 2002. *Down to Earth: Geographic Information for Sustainable Development in Africa.* Washington, D.C.: National Academies Press, http://www.nap.edu/books/0309084784/html/.

Pieri, C., and K. G. Steiner. 1997. “The Role of Soil Fertility in Sustainable Agriculture with Reference to Sub-Saharan Africa.” *Agriculture and Rural Development* 4 (1): 22-25.

Polanyi, Karl. 1944. *The Great Transformation: The Political and Economic Origins of our Time*. New York: Basic Books.

Raskin, P., et al. 2002. *The Great Transition: The Promise and Lure of the Times Ahead.* Boston: Stockholm Environment Institute, http://gsg.org/gsgpub.html#GT.

Raven, P. H. 1988. “Biological Resources and Global Stability.” In *Evolution and Coadaptation in Biotic Communities,* ed. S. Kawano, J. H. Connell, and T. Hidaka. Tokyo: University of Tokyo Press.

Reardon, T. 1995. “Sustainability Issues for Agricultural Research Strategies in the Semi-arid Tropics—Focus on the Sahel.” *Agricultural Systems* 48 (3): 345-359.

Reid, Walter V., J. McNeely, D. Tunstall, et al. 1993. *Biodiversity Indicators for Policy-makers.* Washington, D.C.: World Resources Institute.

Richards, P. 1983. *Indigenous Agricultural Revolution: Ecology and Food Production in West Africa.* London: Hutchinson.

Scherr, S. J., and S. Yadev. 2001. “Land Degradation in the Developing World: Issues and Policy Options for 2020.” In *The Unfinished Agenda: Perspectives on Overcoming Hunger, Poverty and Environmental Degradation,* ed. P. Pinstrup-Andersen and R. J. Lorch, 133-138.. Washington, D.C.: IFPRI.

Scoones, I. 1998. *Sustainable Rural Livelihoods: A Framework for Analysis.* IDS Working Paper 72. Brighton: Institute for Development Studies, http://www.ids.ac.uk/ids/bookshop/wp.html.

Serageldin, I. 1996. *Sustainability and the Wealth of Nations: First Steps in an Ongoing Journey.*

Environment and Sustainable Development Studies, Monograph Series, No.5. Washington, D.C.: The World Bank.

Serageldin, I. 1999. "New Partnerships and New Paradigms for the New Century." *Current Science* 75:501-506.

Solow, R. M. 1992. *An Almost Practical Step toward Sustainability.* Washington, D.C.: Invited Lecture on the Occasion of the Fortieth Anniversary of Resources for the Future.

Spencer, D. 1994. *Infrastructure and Technology Constraints to Agricultural Development in the Humid and Subhumid Tropics of Africa.* EPTD Discussion Paper No.3. Washington, D.C.: IFPRI.

Stiles, D. 1995. "Desertification Is Not a Myth." *Desertification Control Bulletin* 26:29-36.

Thomas, D., and N. Middleton. 1994. *Desertification: Exploding the Myth.* Chichester: John Wiley.

UNCHS (United Nations Commission on Human Settlements). 1999. *Global Urban Indicators Database.* UNCHS (Habitat) web site, http://www.unhabitat.org/programmes/guo/guo_indicators.asp.

UNEP (United Nations Environment Programme). 1992. *World Atlas of Desertification.* Nairobi: UNEP.

Wackernagel, M., and W. E. Rees. 1997. "Perceptual and Structural Barriers to Investing in Natural Capital: Economics from an Ecological Footprint Perspective." *Ecological Economics* 20:3-24.

Ward, Sarah. 2002. *The Energy Book for Urban Development in South Africa.* Noordhoek, South Africa: Sustainable Energy Africa.

Warren, A., S. Batterbury, and H. Osbahr. 2001. "Sustainability and Sahelian Soils: Evidence from Niger." Paper submitted to *Geographical Journal*, Special Issue on Sustainability.

World Bank. 1989. *World Development Report 1989.* New York: Oxford University Press.

World Bank. 1990. *Sub-Saharan Africa: From Crisis to Sustainable Growth—A Long-Term Perspective Study.* Washington, D.C.: The World Bank.

World Bank. 2001. *World Development Report 2000/2001: Attacking Poverty.* New York: Oxford University Press.

World Bank. 2002. *Global Economic Prospects and the Developing Countries 2002: Making Trade Work for the World's Poor.* Washington, D.C.: World Bank.

WHO (World Health Organization). 1996. *Groups at Risk: WHO Report on the Tuberculosis Epidemic 1996.* Geneva: WHO Global Tuberculosis Programme.

WRI (World Resources Institute). 1994. *World Resources 1994-95.* New York: Oxford University Press.

The Center for Global Development works to reduce global poverty and inequality through rigorous research and active engagement with the policy community to make the world a more prosperous, just, and safe place for us all.Â Set Homepage: U.S. International. Ideas to Action: Independent research for global prosperity. Connect with Us. Attend an Event. For Media. Donate. Center for Global Development. Search. Our Work. Our Work. With rigorous economic research and practical policy solutions, we focus on the issues and institutions that are critical to global development. Explore our core themes and topics to learn more about our work. Learn About Our Work. The Center for International Development (CID) at Harvard University is a university-wide center that works to advance the understanding of development challenges and offer viable solutions to problems of global poverty. The CID is Harvardâ€™s leading research hub focusing on resolving the dilemmas of public policy associated with generating stable, shared, and sustainable prosperity in developing countries. Our ongoing mission is to apply knowledge to and revolutionize the world of development practice. In order to effectively address the worldâ€™s most intractable problems, CID seeks to bridge t See more of Center for International Development at Harvard University on Facebook. Log In. Forgotten account?Â Center for International Development at Harvard University. College & University in Cambridge, Massachusetts. 4.7.