



UNITED NATIONS
UNIVERSITY

UNU-IAS

Institute of Advanced Studies

UNU-IAS Report

Environment for African Development:

**A Sustainable Future through Science
and Technology**



This report was written by

Christian Webersik
Clarice Wilson

The authors wish to express their appreciation for the support of Claudia ten Have who was instrumental in developing this report. We also would like to thank the African Diplomatic Corps for their invaluable comments. The authors wish to acknowledge UNU-IAS and the Japan Society for the Promotion of Science without which this report could not have been prepared.

The authors would like to thank the following people for their contributions:

Bradnee Chambers
Alex de Sherbinin
Sam Johnston
Catherine Monagle
Rachel Schutte
Utiang P. Ugbe

Cover photo "Beaker of BioFuel made from corn on white ground, with display of corn kernels close-up"
Jonathan Vasata / Shutterstock

Design and Layout: Jose Badelles

For further information, contact:

United Nations University Institute of Advanced Studies (UNU-IAS)
6F, International Organizations Center
Pacifico-Yokohama 1-1-1 Minato Mirai
Nishi-ku, Yokohama, 220-8502 Japan
Tel: +81-45-221-2300, Fax: +81-45-221-2302
Email: unuias@ias.unu.edu
URL <http://www.ias.unu.edu>

Copyright © 2008 UNU-IAS All Rights Reserved

UNU-IAS Report

Environment for African Development: A Sustainable Future through Science and Technology

Christian Webersik

Clarice Wilson

Contents

Foreword	5
Executive Summary	7
1. Introduction	9
2. Key environmental challenges for Africa: vulnerabilities, performance and opportunities	10
2.1 Climate variability, drought and social vulnerability	11
2.2 Agriculture and sustainable development	11
2.3 Climate change and food security	13
2.4 The role of infrastructure	15
3. Identifying environmental best practice and the need for action	16
3.1 Measuring Africa's environmental performance	16
3.2 Harnessing science and technology for sustainable development	17
4. Application of science and technology to sustainable development in Africa	18
4.1 The role of international partners: Japan and Africa	19
4.2 Examples of making science and technology work in Africa	19
5. The Way Forward	21
Annex 1: 2006 and 2008 EPI objectives and design	22
Endnotes	23
References	26
List of Figures, Boxes and Tables	
Figure 1: Human well-being and the Earth: an integrated system	10
Figure 2: Distribution of economic loss risk as proportion of GDP	11
Figure 3: Shares of wealth by income group, 2000	12
Figure 4: Breakdown of different types of natural capital	13
Figure 5: Food and cereals price index (2000 – March 2008)	14
Figure 6: Comparison of 2006 EPI for sub-Saharan Africa and South East Asia	16
Figure 7: Comparison of 2008 EPI for sub-Saharan Africa and South East Asia	17
Figure 8: Linking science, technology and policy systems with sustainability	18
Box 1: Predicted impacts of climate change in Africa	10
Box 2: Selected African institutions integrating science and technology and environmental sustainability	18
Table 1: Expected number of undernourished in millions, incorporating the effects of climate change	14

List of Abbreviations

AATF	African Agricultural Technology Foundation
AMCEN	African Ministerial Conference on the Environment
AMCOST	African Ministerial Council on Science and Technology
APB	African Panel on Biotechnology
CDM	Clean Development Mechanism
CGIAR	Consultative Group on International Agricultural Research
DEFRA	Department for Environment, Food and Rural Affairs
EPI	Environmental Performance Index
G8	Group of Eight
GDP	Gross Domestic Product
IAASTD	International Assessment of Agricultural Science and Technology for Development
ICT	Information and Communication Technology
IPCC	Intergovernmental Panel on Climate Change
JICA	Japan International Cooperation Agency
KEMRI	Kenya Medical Research Institute
NEPAD	New Partnership for Africa's Development
NERICA	New Rice for Africa
ODA	Official Development Assistance
QPM	Quality Protein Maize
R&D	Research and Development
TICAD	Tokyo International Conference on African Development
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNFPA	United Nations Population Fund
UNU-IAS	United Nations University Institute of Advanced Studies
WHO	World Health Organisation

Foreword

As one of the fourteen research and training centers of the UNU system, the United Nations University Institute of Advanced Studies (UNU-IAS) undertakes research and advanced capacity development on emerging issues of importance to the United Nations and its Member States, with a special focus on the challenges facing developing countries. UNU-IAS is mandated to find workable solutions to the challenges of sustainable development and to promote interaction within the United Nations system, with other bodies, and among its Member States in this regard. As such the Fourth Tokyo International Conference on African Development (TICAD IV) and the Hokkaido Toyako G8 Summit meetings in May and July 2008 respectively, both with climate change as central agenda items, present important occasions for UNU-IAS to focus policy maker and public attention not only on the close interconnection between environment and development in Africa, but also the possibilities and pathways for global partnerships to utilise science and innovation for sustainability.

This report is part of a series of activities undertaken by UNU-IAS in the run-up to TICAD IV on the theme of Africa's sustainable development. The paper outlines key environmental challenges facing Africa and their impact in areas such as biodiversity, soil and water quality, as well as disease control. It further identifies best practices for sustainability, and addresses the question of how Africa and its international partners, including Japan, can go about harnessing science and technology interventions to attain Africa's development targets. With Africa posting impressive economic growth rates – the projected growth rate for 2008 is 6 percent – the findings of this report are as important to the new opportunities emerging for entrepreneurs, research and development communities and the public sector, as they are to ongoing efforts to reduce poverty and respond to the challenges of climate change. As the poorest continent, Africa is doubly vulnerable to the challenges of climate variability. Poor people, as the Millennium Ecosystem Assessment found, are made not just worse off, but disproportionately worse off when ecosystems are degraded. With IPCC projections indicating that Africa will experience significant water stress by 2020, with immediate knock-on effects for agriculture production and human security, the possibilities offered by various technologies – in the fields of biotechnology, clean renewable energy, information and communication technology for health monitoring, and water and sanitation – need to be carefully examined in an independent, neutral and objective manner. The task before us is to seek ways to clarify practical development interventions, at both the high and lower ends of the technology scale, and to establish operational partnerships within Africa, and with Africa, to turn these into reality. We hope this UNU-IAS report contributes to progress on this important topic at the highest level.



A.H. Zakri
Director, UNU-IAS
May 2008

Executive Summary

Global warming is considered one of the major challenges of the 21st century. It is predicted that Africa will be particularly vulnerable to climate change and associated biodiversity loss, food insecurity, water scarcity, and an increase in drought frequency. African economies are closely linked to natural resources and rely heavily on agriculture. Most of Africa's agriculture is rain-fed, thus farmers are susceptible to environmental shocks. Though agricultural development is central to African economies, it has a long history of being considered of secondary importance in economic development. As the current food crisis shows, it is important to rethink not only agricultural policies, but also agricultural practices and particularly the role science and innovation can play to address development and sustainability challenges. While is this particularly true for agriculture, this in fact also applies to other sectors of African economies. With imperatives like climate change and ecosystem services declines higher than ever on the public agenda, the possibilities offered by linking appropriate science and technology innovations to development and particularly sustainable development are timely and critical to focus on.

In recent years, African governments have begun to prioritise science and technology in efforts to attain development targets. A good example of this political energy is the establishment of the High-Level African Panel on Biotechnology by the African Union. For new technologies to have positive and sustainable impact on Africa, they must be directly linked to improving livelihoods and helping the continent to overcome the fundamental problems of poverty, hunger and marginalisation. Key is also to recognise that concern for Africa's environment goes far beyond conservation issues, to also include the threats posed by climate variability and ecosystem degradation. Each of these is intricately linked to African livelihoods.

There have been significant advances in science and technology. Major areas of development include more effective monitoring and assessment techniques, such as remote sensing, the transformation of information and communication technology (ICT), rapid advances in biotechnology and genetic modification, and more efficient and faster transportation. The developmental implications of these new technologies are already apparent. Knowledge provides tools for planning and risk management. However, investing in new technologies will require specific investments in public and private scientific and technological knowledge and research infrastructures. This implies that important policy choices and trade-offs need to be made.

Decision makers are confronted with choices concerning the use of natural resources and the environmental impacts of development policies. Indicators, such as the Environmental Performance Index, provide countries with a way of understanding national sustainability trajectories and evaluating them for appropriate action. The aggregate analysis reveals that African countries show medium scores in maintaining biodiversity and air quality while they perform poorly in the area of environmental health and water quality.

For Africa to address pressing environmental problems such as climate change vulnerability, disease, and unsustainable resource use, while improving the wellbeing of its citizens, priority has to be given to scientific research and the development of environmentally sound technologies. While advancements in science and technology have created new opportunities for innovative development solutions, the benefits from these technologies have so far been limited.

Looking forward, it is apparent that African countries cannot afford to focus on upgrading their industrial capabilities along traditional lines of economy first, environment later. Incorporating advanced technologies (e.g. ICT, biotechnology, and Geographic Information Systems) now provides Africa a range of new applications and possibilities in agriculture, health, and environmental management. Many of these technologies can assist in providing solutions to basic needs, such as cheaper diagnostic kits and high-yield seeds, and to improve productivity both in agriculture and in industry.

1. Introduction

African economies are highly dependent on natural resources and poverty and environment are complexly linked—with about two thirds of the population depending on agriculture for their livelihoods. Degradation of natural resources reduces the productivity of the poor who most rely on them, and makes them even more susceptible to extreme events (e.g. climate variability, economic decline, and civil unrest). Understanding the link between livelihoods and managing essential services provided by natural ecosystems is critical for achieving sustainable economic growth and poverty reduction. There is now a new development context in which unique and unprecedented environmental change and environmental threats—such as climate change, land and water degradation, desertification, and biodiversity loss—undermine the sustainable development processes in Africa.¹

Currently, one of the most critical issues for the continent is food security. Africa is facing diminishing agricultural stocks, high food prices, and decreasing productivity. At the same time, environmental sustainability is being lost. Soil quality and fertility, water, and biodiversity are being adversely affected as farmers are poorly rewarded for acting as stewards of almost a third of the Africa's land. In addition, human-induced climate change threatens agricultural productivity. One of the critical messages of the recently concluded Agriculture Assessment is that the course of agricultural development must be altered now and the world must cooperate in solving food insecurity and environmental degradation. Moreover, the way the world grows its food must radically change to better serve the poor and hungry if Africa is to cope with a growing population and climate change. Paradoxically, investment directed toward securing the public interest in agricultural science, education and training and extension to farmers has decreased at a time when it is most needed.²

Scientific and technological developments in the field of environment present new opportunities for solving or alleviating problems in areas such as climate change, food security, health, etc. However, a narrow understanding of the function of technology in development, particularly in terms of environmental management, has produced scepticism over the roles of new technologies in development. This scepticism has compromised efforts in developing countries to seriously examine the opportunities and risks associated with emerging technologies.³

An important aspect in the diffusion of technology is international cooperation. At the World Economic Forum this year, the Japanese government announced its intention to make its environmental technology available to Africa. This year Japan takes over the presidency of the G8 and environment and Africa are high on the agenda. The G8 Summit will be preceded by the Fourth Tokyo International Conference on African Development (TICAD IV). This presents African countries with an opportunity to develop targeted proposals for science and technology cooperation that address the most pressing economic and environmental needs of the continent.

This report provides an overview of some of the environmental issues facing Africa and examines the role of science and technology cooperation in meeting these challenges. An environmental performance country analysis is used to identify areas of best practice, as well as areas of action.

2. Key environmental challenges for Africa: vulnerabilities, performance and opportunities

Though human vulnerability to environmental change is a global phenomenon, the biggest polluters are typically not the most affected by the impacts of human activities. Africa in particular is widely accepted to be the most vulnerable to global environmental change and the least able to adapt.⁴

The key problems threatening Africa's environment are land and water degradation, biodiversity loss, and climate change. These issues are manifested as deforestation, desertification, declining soil productivity, pollution, and depletion of freshwater.⁵ Africa's economies and its peoples are particularly prone to the effects of drought and floods—the frequency and intensity of which are likely to increase with climate change (Box 1⁶). In addition, a high disease burden, including HIV/AIDS, malaria, tuberculosis and water-borne diseases contributes to extreme poverty, limiting the continent's capacity to adapt to environmental stresses.

While environmental problems are often seen as primarily conservation issues, or peripheral to

development, decline in ecosystem function usually has significant impacts on African livelihoods. Deforestation, for example, is typically regarded as reducing biodiversity. However, more than 70 percent of sub-Saharan Africa's people depend in large measure on forests for their living, and 60 percent of Africa's energy needs are met by wood. Thus, particularly for Africa's rural communities, deforestation removes key sources of food and fuel. It also adversely affects tourism and reduces the availability of medicinal plants, potentially affecting the development of new pharmaceuticals.⁷

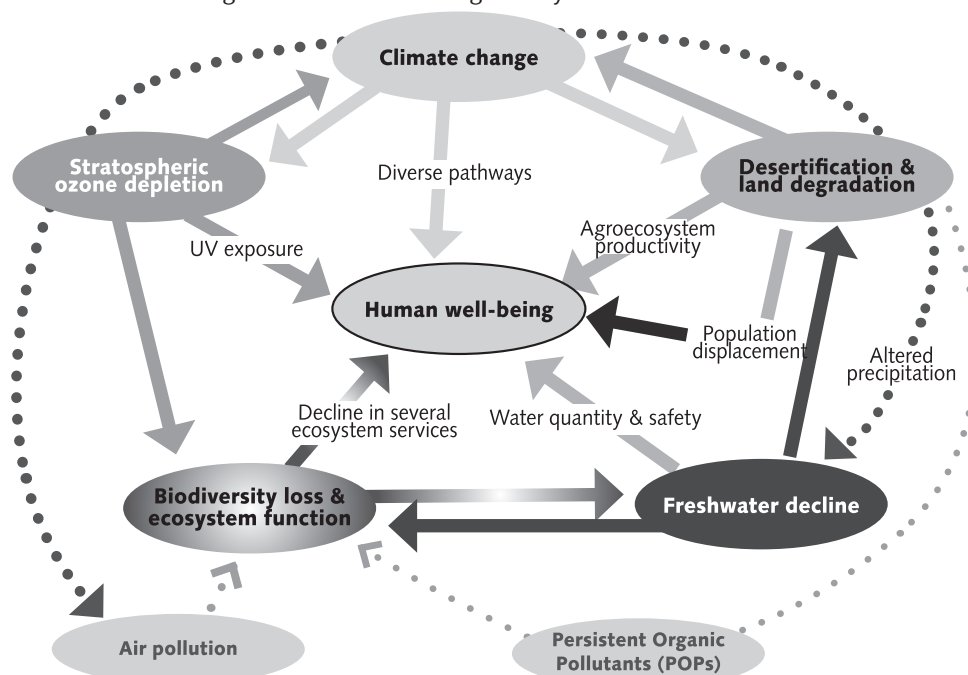
While the impact of global environmental change is not always life-threatening, it bears serious economic consequences—leaving marginalised people even more vulnerable. As shown in Figure 1, many of these issues are interrelated and interdependent and require: 1) an integrated, synergistic mix of policy processes and instruments that promote sustainable environmental management and 2) the bringing together of science and technology (innovation) with environmental policies.

Box 1: Predicted impacts of climate change in Africa

The precise impacts of climate change are not yet known, however, there is consensus on the general trends. For example, climate change scenarios for Africa forecast warming across the continent ranging from 0.2°C per decade (low scenario) to more than 0.5°C per decade (high scenario). This warming will be greatest over the interior of semi-arid margins of the Sahara and central southern Africa. Sea levels are projected to rise by 15 to 95 centimeters (6 to 37 inches) by 2100. According to a report produced by the Secretariat of the UN Framework Convention on Climate Change (UNFCCC), rising sea levels could destroy an estimated 30 percent of Africa's coastal infrastructure. Coastal settlements in the Gulf of Guinea, Senegal, Gambia, and Egypt could be flooded. Climate change will have also significant impacts on biodiversity, food security, and health in Africa.

Source: Hulme et al., 2001.

Figure 1: Human well-being and the Earth: an integrated system



Source: Adapted from WHO

2.1 Climate variability, drought and social vulnerability

Research demonstrates that high climate variability (as evidenced in increased frequency and intensity of droughts and floods) correlates with lower economic performance.⁸ Countries with high climate variability, typically located in Sub-Saharan Africa, tend to have lower GDPs per capita. The Fourth Assessment Report published by the Intergovernmental Panel on Climate Change (IPCC) shows that global climate change will lead to an increase in climate variability, reducing the resilience of African farmers to cope with environmental stress.⁹ Droughts are the single most important natural hazard in Africa and are associated, on average, with the highest loss risk measured as a proportion of GDP per unit area (Figure 2¹⁰). If global temperatures rise by 2-3°C within the next 50 years as projected, crop yields are predicted to decline; malnutrition and heat stress will increase; and around 15-40 percent of species will be driven to extinction.¹¹ Low-income countries in Africa will be least likely to be able to cope with change, as they cannot afford adaptation costs given their low GDP. In addition, population growth will increase environmental stress and increase social vulnerability.

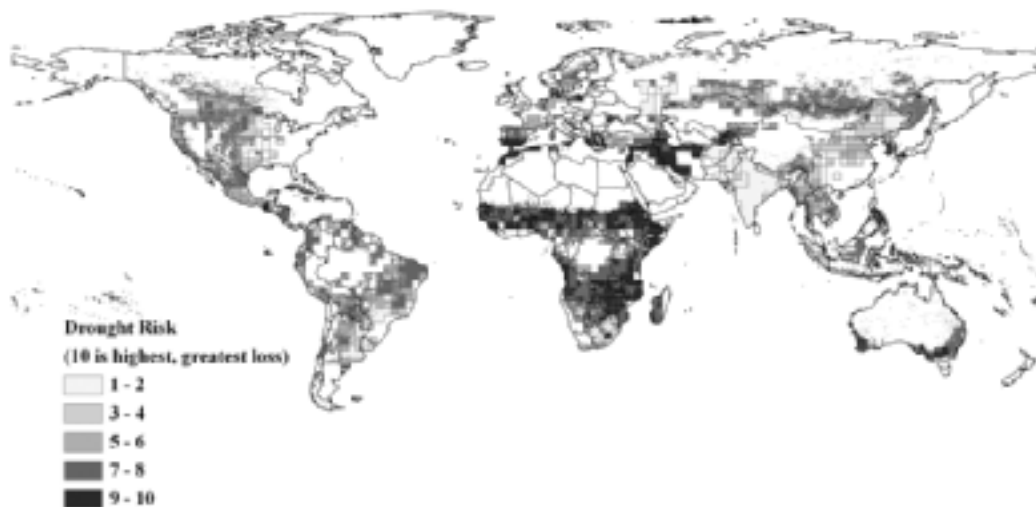
One potential outcome of increased environmental stress is higher propensity for civil unrest. In an environment with reduced economic returns caused by drought, the incentives to engage in a war economy increase. Poverty adds to political instability by widening inequalities between groups and increases a society's predisposition to violent conflict.¹² For example, in times of sharp economic decline, chronic poverty and poor economic conditions reduces the costs of recruiting rebel soldiers.¹³

2.2 Agriculture and sustainable development

Agriculture constitutes a large percentage of overall GDP, generating approximately one third of the income in Africa. In some countries, such as the Central African Republic, Ethiopia and the Democratic Republic of Congo, the share of agriculture in the gross domestic product in 2005 was as high as 54 percent, 48 percent and 46 percent respectively.¹⁴ Ninety-five percent of Africa's agriculture is rain-fed making African farmers susceptible to climate variability and change.¹⁵ Though agriculture is central to African economies, it is often regarded as separate from other sectors. Traditional attitudes view economic development as a series of stages that involve the transfer of capital from the agricultural to the industrial sector. This approach overlooks vital linkages between agriculture and other sectors of the economy.¹⁶ As stated by Professor Robert Watson, Director of the Agriculture Assessment:

"Agriculture has a footprint on all of the big environmental issues, so as the world considers climate change, biodiversity, land degradation, water quality, etc. they must also consider agriculture which lies at the centre of these issues and poses some uncomfortable challenges that need to be faced. We've got to make sure the footprint of agriculture on climate change is lessened, we have to make sure that we don't degrade our soil, we don't degrade the water, we don't have adverse effects on biodiversity. There are some major challenges, but we believe that by combining local and traditional knowledge with formal knowledge these challenges can be met."¹⁷

Figure 2: Distribution of economic loss risk as proportion of GDP



Source: Center for Hazards and Risk Research (CHRR), International Bank for Reconstruction and Development/ The World Bank, and the Columbia University Center for International Earth Science Information Network (CIESIN).

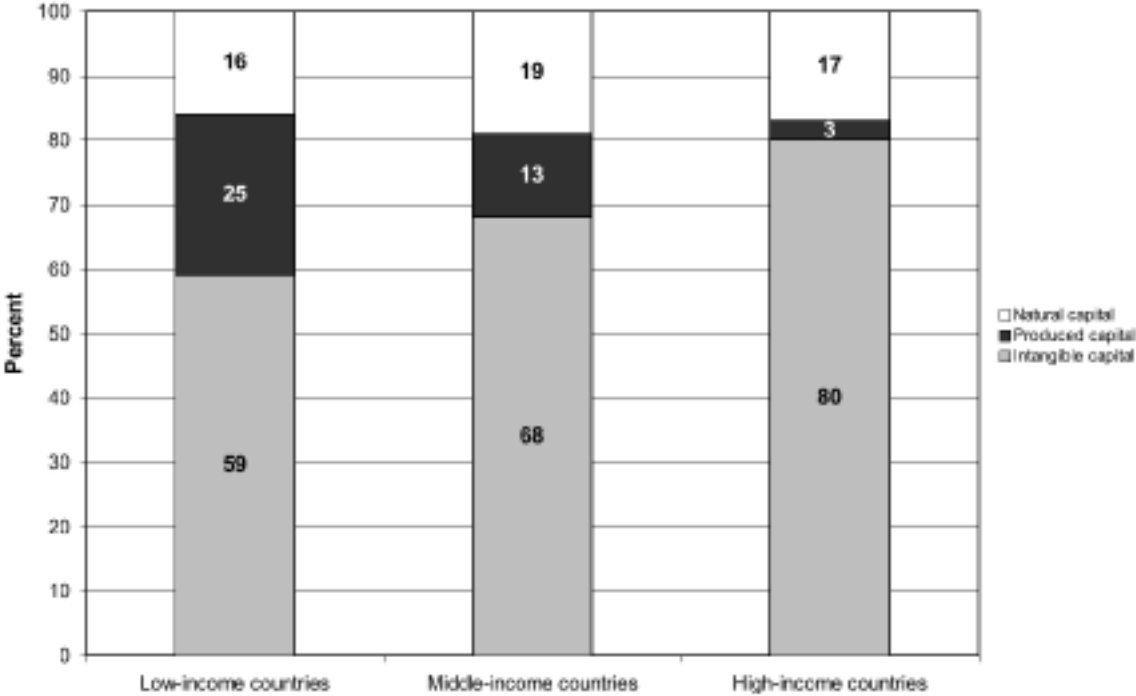
Natural capital constitutes a much larger share of total wealth in poor countries and they are therefore much more susceptible to external shocks and in particular to commodity price cycles (Figure 3). Analysis of the different types of natural capital (including cropland and pastureland, timber resources, and protected areas) shows the importance of soil for low-income countries (Figure 4). Cropland and pastureland make up almost 70 percent of natural wealth in these countries, therefore, maintaining soil quality is fundamental to achieving sustainable growth.¹⁸ It is estimated that nutrient depletion accounts for about 7 percent of the agricultural share in the average GDP of Africa with national values ranging up to 25 percent, demonstrating soil nutrient mining as a significant basis of current economic performance.¹⁹

Soil nutrient depletion is also affected by external factors. The price of nitrogen fertiliser has been increasing over the years such that it has become unaffordable to most small-scale farmers. Due to a variety of factors (e.g. high transport costs, poor dealer network, etc.), African farmers pay two to four times the average world market price for fertilisers.²⁰

Another major cause of environmental degradation is deforestation. Between 1990 and 2000, Africa lost 52 million hectares of forests, equivalent to a decrease of 0.8 percent per year and 56 percent of the global total. Approximately 60 percent of the areas of tropical forest cleared during this period were converted to permanent agricultural smallholdings.²¹ Under low-input systems and prevailing degradation processes, the potential productivity of the soils cannot be realised. If current trends of soil degradation and population growth continue, the continent might only be able to feed 25 percent of its population by 2025, according to United Nations University's Ghana-based Institute for Natural Resources in Africa.²²

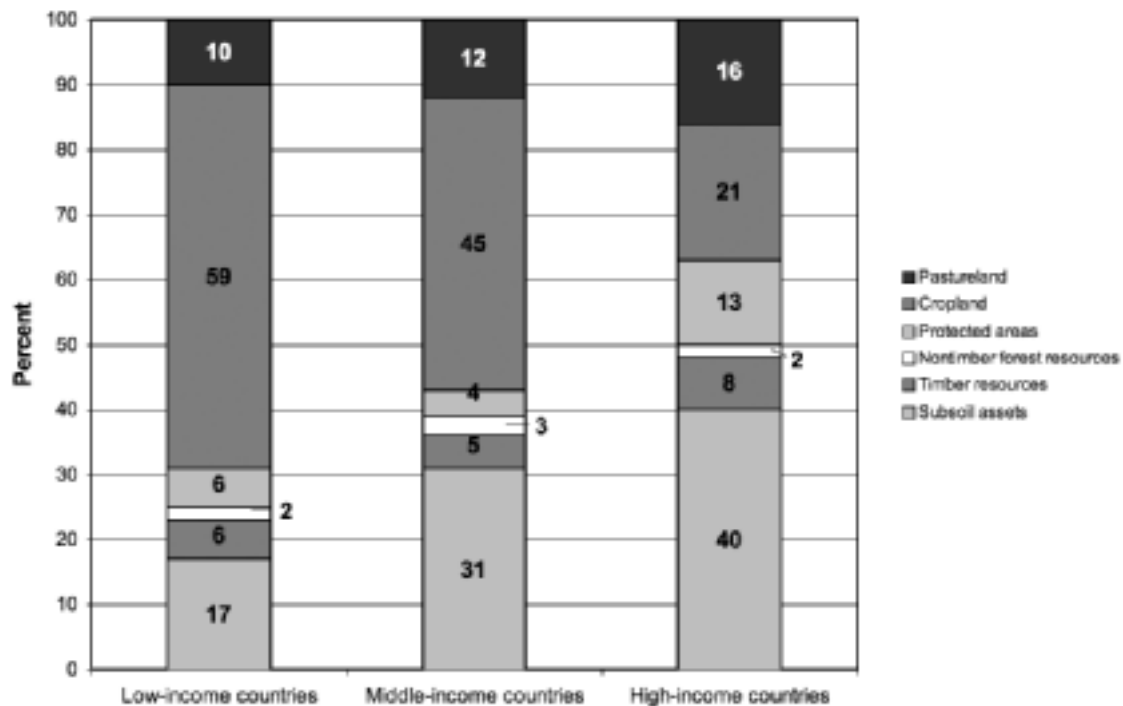
Given these constraints, the challenge to African agriculture is not only to enhance production to meet the increased food demands of the expanding population, but to finding innovative ways to overcome the fertiliser challenge and develop well thought-out use of soils so that their future productivity is sustained, especially given the projected population growth of 2.4 percent per annum.²³

Figure 3: Shares of wealth by income group, 2000



Source: Adapted from World Bank 2005

Figure 4: Breakdown of different types of natural capital



Source: Adapted from World Bank 2005

As many smallholder farmers have neither the purchasing power nor market access to capitalise on the benefits of new technologies, and incentive structures often limit the uptake of benefits from new technologies—the public sector takes on much of the responsibility for agricultural Research and Development (R&D), accounting for about 94 percent of the US\$12.1 billion spent annually on agricultural R&D in developing countries.²⁴ However, the expenditure growth rate has declined in Sub-Saharan Africa. At the same time, there has been an increase in private investment in agricultural R&D worldwide. Most private investments are not targeted at poor farmers and are rather directed at technologies that benefit farming in industrialised countries.²⁵

Given these trends, more and more emphasis is being placed on partnership approaches. Though joint investments between the public and private sectors in agriculture have been limited in most African countries, the potential exists for public-private partnerships in innovations for agricultural transformation. The motivations and incentives for public and private actors differ, but common spaces and overlapping interests can be identified.²⁶ Partnerships are particularly valuable in agricultural biotechnology R&D, where private sector resources and expertise can be applied to public research priorities in developing countries. The Consultative Group on International Agricultural Research (CGIAR) and its national, public-sector partners have recognised this potential and are undertaking several collaborative R&D programmes with the private sector to enhance yields or the nutritional content of crops such as cassava, millet, maize, rice, and wheat.²⁷ In addition, new organisations like the African Agricultural Technology Foundation (AATF) are promoting partnerships between the public

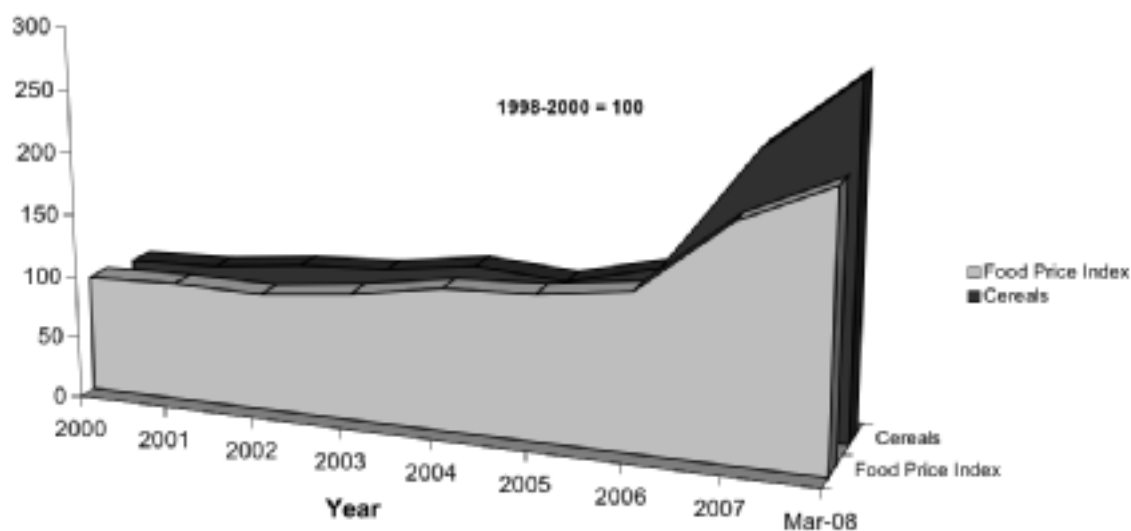
and private sectors that are designed to remove some of the barriers that have prevented smallholder farmers in Sub-Saharan Africa from accessing existing agricultural technologies that could help improve food security and reduce poverty in the continent.²⁸ The area of post-harvest operations (i.e. storage, transport and processing) could also offer good economic opportunities for public-private sector research partnerships.

Success in innovations to transform agriculture for improved livelihoods and development in Africa hinges on obtaining the right technologies, infrastructure, institutions and policies. In terms of policy, agricultural development should feature high on the agenda of the Poverty Reduction Strategies of African countries. The focus should be on the promotion of community-based and private-sector-led development.²⁹ There is still, however, a need for more critical analysis of why sustained and successful partnerships are limited, and why, as a result, opportunities for pro-poor research have been overlooked.

2.3 Climate change and food security

Increased demand for feed, food, and fuel, low agricultural stocks and slow-growing supplies of agricultural outputs, has resulted in steady increases in food prices—jumping more than 20 percent in 2007 alone. Since 2000, the price of wheat has tripled, while the prices of corn and rice have almost doubled (Figure 5)³⁰. The impact of cereal price increases on food-insecure and poor households is already considerable. For every one percent increase in the food prices, food consumption expenditure in developing countries decreases by 0.75 percent.³¹ While household spending on

Figure 5: Food and Cereals Price Index (2000 - March 2008)



Source: FAO Corporate Document Repository, 2008

food in a developed country like the US accounts for just 10 percent of income, it constitutes more than 60 percent of income in Sub-Saharan Africa.³² As mentioned above, climate change risks will have adverse impacts on food production. For example, access to food will be negatively affected by increasing aridity and lands suffering moisture stress, thereby increasing food insecurity and malnutrition. One report estimates that when taking into account the effects of climate change, the number of undernourished people in Sub-Saharan Africa may triple between 1990 and 2080 (Table 1).³³

Given these projections, countries with limited adaptive capacities to climate change are faced with significant threats to food security and social stability. The current riots protesting rising food prices among the hardest hit people in Somalia and in parts of Central and West Africa are an indication of the potential for social unrest and civil violence.³⁴ As climate change is a gradual process, there is space for creating innovative adaptation measures as an extension of good development policy.

For example, some policy suggestions that merit further investigation include: creating markets in water and environmental services, investing in research and development for enhancing soil fertility and agricultural productivity, enhancing resilience to disasters and improving disaster management, and promoting social safety nets (for example, drought insurance).

Rising food prices can also open a window of opportunity for African governments to make the agricultural sector profitable. With policies to improve access to inputs and the support of governments, Africa can move from subsistence agriculture to commercial farming. As one expert explains, "When the prices are high, African governments should do all they can to increase the food production. By supporting agricultural inputs, as the Government of Malawi has done with subsidy programs for seeds and fertilisers, the much needed African Green Revolution can be made operational."³⁵

Table 1: Expected number of undernourished in millions, incorporating the effects of climate change

Region	1990	2020	2050	2080	2080/1990 ratio
Developing countries	885	772	579	554	0.6
Sub-Saharan Africa	138	273	359	410	3
Middle East & North Africa	33	55	56	48	1.5

Source: Adapted from von Braun 2007

2.4 The role of infrastructure

Another challenge for Africa that is peripheral to the issue of environment, but crucial for economic development is high transport costs. Infrastructural development is of particular importance to Africa as many of its countries are landlocked thereby increasing the costs for trade. This is attributable to lack of access to good roads or navigable rivers driving up transport costs. A study by the United Nations Conference on Trade and Development (UNCTAD) found that international transport costs African countries almost twice the world average.³⁶ The railway system is small and inefficient, transport costs are on average about 200 percent higher than in Southeast Asia. It is estimated that Africa has fewer roads than a country like Poland.³⁷ Compared to other regions, such as Asia, where most of the population is concentrated in the coastal areas with easy access to domestic and international markets, Africa's population is more evenly distributed across the continent, with only 19 percent of the population living in coastal areas.³⁸

3. Identifying environmental best practice and the need for action

To mitigate some of the environmental problems described above, African countries need to understand national sustainability trajectories and evaluate them for appropriate action. Decision makers at all levels are confronted with choices concerning the use of natural resources and the environmental impacts of development policies. Without reliable indicators to guide these choices, it is difficult for countries to determine if they are in fact on a sustainable path.³⁹

One method of monitoring the environmental sustainability paths of individual countries is the Environmental Performance Index (EPI) developed by researchers at Yale and Columbia University.⁴⁰ The EPI provides a way of quantifying and numerically benchmarking a country's environmental performance across a suite of different issue areas such as air and water quality, biodiversity conservation, and natural resource management. The performance metrics are carefully chosen to be ones that are policy mutable (meaning government policies can actually change a country's performance on that metric) (See Annex 1). Performance targets are mostly drawn from international agreements or set by international organisations and national authorities; in several cases expert opinion is used to set the targets. The targets do not vary by country (for example, to achieve 100 percent coverage for water and sanitation provision).⁴¹ This performance analysis helps to identify those countries within a specific peer group, e.g. Sub-Saharan Africa, that may have good performance that is worthy of emulation. The EPI is in the same vein as the target setting under the United Nations' Millennium Development Goals (MDGs) and the 2010 Biodiversity targets, and indeed, it borrows a number of indicators and targets from these efforts. Ultimately,

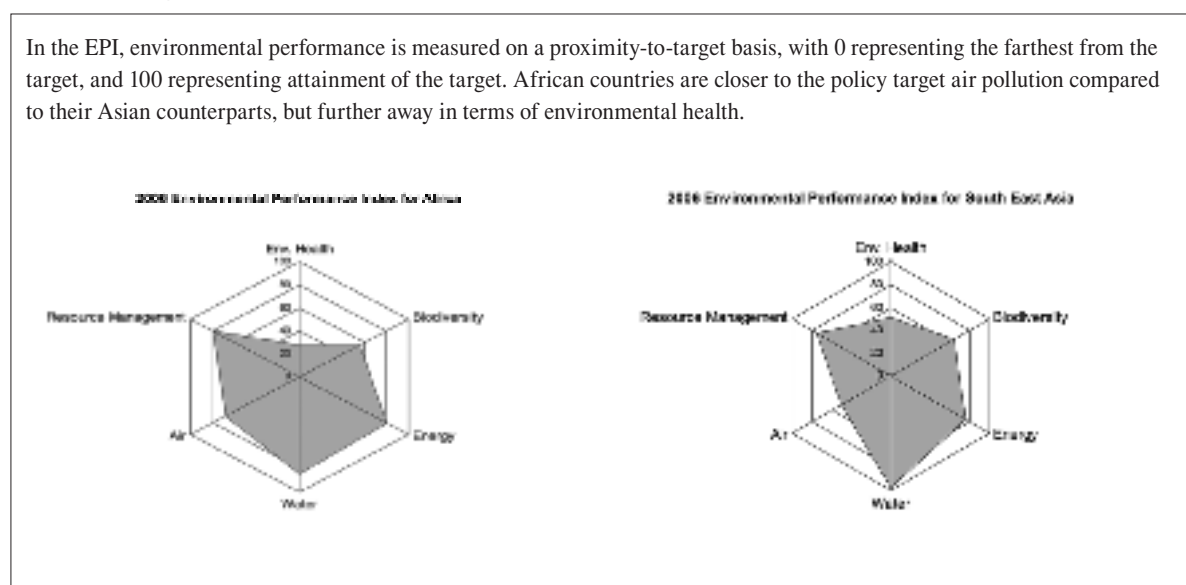
the EPI measures a country's ability to protect its citizens from environmental pollution as well as its capacity to actively manage and protect the environment.⁴²

3.1 Measuring Africa's environmental performance

The 2006 and 2008 EPI shows good to median aggregate scores for Africa on biodiversity, access to water, air quality, and ecosystem degradation, though this is largely due to low levels of industrialisation. Conversely, African countries perform very poorly on environmental health indicators (Figure 6 and 7). Indoor air pollution (largely caused by cooking and heating with solid fuels on open fires or stoves without chimneys) and poor sanitation are major health risks. It is worth noting that due to low levels of industrialisation; Africa's environmental indicators are similar compared to their Asian counterparts.

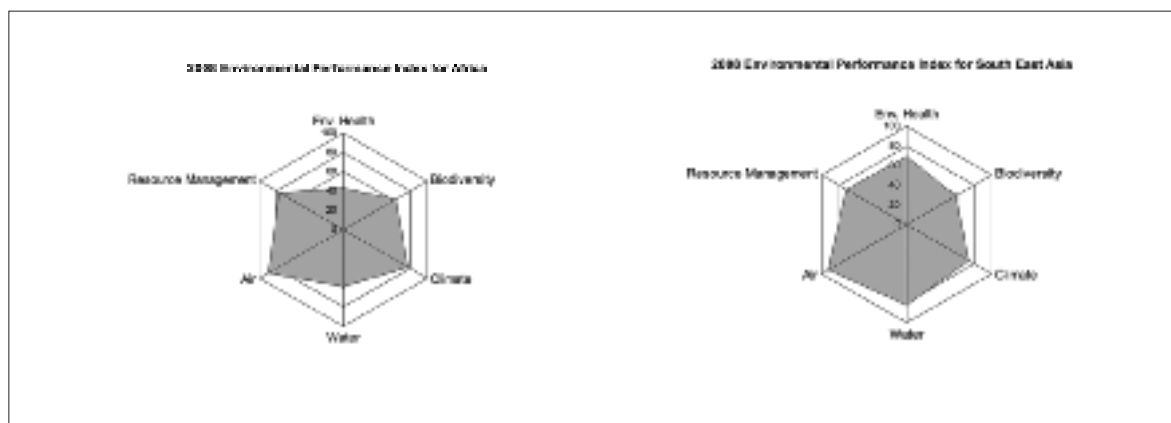
Though it represents a generalisation over the whole continent, this type of performance analysis is a powerful tool for assessing environmental investments and improving policy results and the same analysis can be performed for individual countries. Given the low levels of industrialisation, African countries perform well in comparison to some of the world's largest industrialising countries, such as China and India, who face serious challenges in establishing systems to control air and water pollution and to prevent biodiversity loss. The natural resource base, e.g. biodiversity, good water and air quality are assets that can be harnessed for development. The challenge for Africa is to avoid the pitfalls of unsustainable natural resource management while boosting economic growth.

Figure 6: Comparison of 2006 EPI for sub-Saharan Africa and South East Asia



Source: Daniel C. Esty et al., "Pilot 2006 Environmental Performance Index. New Haven: Yale Center for Environmental Law & Policy," (New Haven: Yale, 2006).

Figure 7: Comparison of 2008 EPI for sub-Saharan Africa and South East Asia



Source: Daniel C. Esty et al., "2008 Environmental Performance Index," (New Haven: Yale Center for Environmental Law and Policy, 2008)

In periods of rapid industrialisation, most indicators show environmental degradation first increasing with income growth, and only starting to decline after achieving a certain level of wealth. This suggests that without intervention, environmental degradation will get much worse before it gets any better—a time lag that African countries cannot afford. If Africa is to achieve the growth rates like those demanded by the MDGs, policy interventions are needed to address the problems of environmental degradation associated with increases in industrial activity. The implication is that policy interventions have a role in the earlier stages of development and ways must be found to achieve the kind of industrial development that will allow African countries to prevent the harmful linkage between industry and pollution. To undertake an environmentally sound industrial development strategy, countries need better integration and cohesion between industrial and environmental policies and the dissemination of environmentally sound technologies.⁴³

3.2 Harnessing science and technology for sustainable development

In the last 20 years, there have been significant advances in technology. Major areas of development include more effective monitoring and assessment techniques, such as remote sensing, the transformation of information and communication technology (ICT), rapid advances in biotechnology and genetic modification, and more efficient and faster transportation. The developmental implications of these new technologies are already apparent. For example, the rapid growth in mobile telephones has empowered rural farmers by improving access to market information. Technological innovation can offer important opportunities for responding more effectively to challenges in areas such as natural resource management, agriculture, health, water, sanitation, and energy.

A number of factors (e.g. market failure, inappropriate pricing, risks, lack of knowledge, etc.) affect the adoption

of environmentally friendly technologies. African governments, often preoccupied with other pressing needs, assign less priority to issues of environmental technology. Africa, therefore, needs science and technology policies that are rooted in African values, but informed by environmental perspectives that are directed towards sustainable growth and development.

To address these environmental concerns, particularly in areas that are far from set targets, such as environmental health, the application of appropriate science and technology is key. By investing in human resources and providing an environment for innovation, Africa can solve its own problems and improve human well-being. To be successful, however these technologies must dovetail with the broader effort of enhancing the capabilities of firms to compete in domestic and international markets.⁴⁴

Juma argues that "development cooperation has often been driven by diplomatic considerations that are devoid of serious operational content [and] much of what passes for development cooperation is focused on "discourses" about a variety of possible options for development, rather than development action."⁴⁵ To turn this situation around and overcome these obstacles, experts call for the application of a combination of high-end and low-tech science and technology. The emphasis should be on technologies that have been proven successful and can be replicated with local capacity and resources.

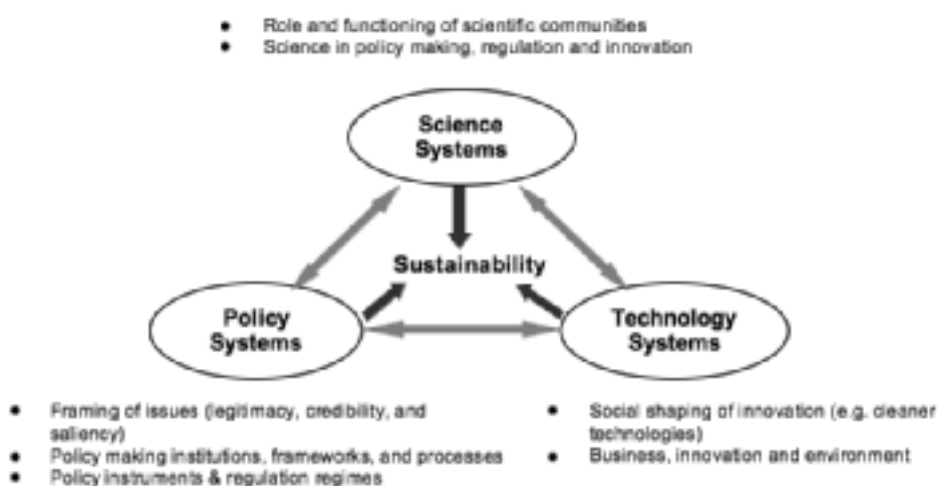
4. Application of science and technology to sustainable development in Africa

In recent years, African countries and their leaders have begun to prioritise science and technology as important factors in efforts to attain development targets. As noted by Kwansah-Aidoo and Obijiofor (2006), “various African governments have recognised the strong link between new technologies and socioeconomic development and are proceeding to put in place measures aimed at harnessing and maximising their perceived benefits.”⁴⁶ Innovation can take the form of technological innovation, or innovation in organisation, processes, and management (See Figure 8).⁴⁷ A key aspect of this is establishing sustainable management of environmental services as a central part of economic development. As outlined in the previous sections, there is a strong awareness that development and environment are inextricably linked and for the vast majority of

Africans, particularly for the poorest, environment is a development tool. As shown in Box 2, this recognition is recognised in the new kinds of institutional arrangements and programmes that are being established in African countries.

Emphasis is now being placed on identifying activities and processes that will add new and significant value to existing programmes. While there are many unmet challenges in Africa, there are also exciting opportunities for innovations in technology development that could carry global implications. Currently, Africa is commanding more attention among technologists leaving the field open to those who might wish to take a commanding leadership role quickly.

Figure 8: Linking science, technology and policy systems with sustainability



Source: Adapted from <http://www.sussex.ac.uk/spru/1-2-2-1-5.html>

Box 2: Selected African institutions integrating science and technology and environmental sustainability

Central to the new generation of institutions, the African Ministerial Conference on the Environment (AMCEN), established in Cairo in 1985 under the auspices of the AU, has taken up the mandate to provide advocacy for environmental protection in Africa while ensuring that social and economic development is realised at all levels. AMCEN led the process for the development of the action plan for the Environment Initiative for the New Partnership for Africa’s Development (NEPAD) and it has repeatedly argued that technology support and capacity building issues are key priorities in addressing the sustainable management of Africa’s environmental resources. NEPAD and the AU Commission have also established a high-level African Panel on Biotechnology (APB) to facilitate open and informed regional multi-stakeholder dialogue on, scientific, technical, economic, health, social, ethical, environmental, trade and intellectual property protection issues associated with or raised by rapid developments in modern biotechnology.

Common objectives of environmentally sustainable, socio-economic transformation of the continent are also articulated in the African Ministerial Council on Science and Technology’s (AMCOST) ‘Consolidated Science and Technology Plan’ (November 2003).

At the international level, further strengthening this position, in February 2006, the Heads of State and governments of six African countries (Burkina Faso, Kenya, Lesotho, The Gambia, Tunisia, and Rwanda) adopted the United Nations Environment Programme-led Bali Strategic Plan for Technology Support and Capacity Building in the field of environment, as an expression of their high-level political commitment to promoting technology support and sustainability measures in their countries and in Africa. The Plan complements and supplements initiatives instituted under NEPAD and AMCEN and serves as a pilot study for further initiatives.

4.1 The role of international partners: Japan and Africa

For new technologies to have a positive impact on Africa, they must be directly linked to improving livelihoods and helping the continent to overcome the basic problems of poverty, hunger and alienation. Although scepticism remains about the relationship between new technologies and economic growth in Africa, greater evidence tends towards the positive side of the new technologies. Efforts to mobilise science and technology for sustainability are more likely to be effective when they are perceived by the public to be credible, but also relevant, and legitimate.

The framing of the issues is important in garnering support for adopting or developing new technologies or investing in research. Often, the false assertion that society must choose between the economy and the environment is made. In reality, the “jobs versus the environment” choice is a misleading dichotomy—it is really a choice between short-term gain and long-term, sustained prosperity.

The relationship between developed and developing countries is generally one of providing aid, giving technical assistance, and importing raw material and natural resources. This is equally applicable to scientific research. Typically the higher value processes of commercialising innovations that take place in Africa occur in developed countries. Perhaps signifying a promising shift in this pattern, Japan’s Council for Science and Technology Policy recently argued “Japan should change its traditional mindset, and place a new emphasis on making use of the country’s superior strengths in science and technology... [through] projects to address environmental, water, and infectious disease problems that are closely related to the maintenance of human life and health, economic development and the preservation of ecosystems, particularly in Africa.”⁴⁸

In his address at the World Economic Forum in Davos, Yasuo Fukuda, the Prime Minister of Japan, announced that the world economy, climate change, and development and Africa would be key issues addressed at the upcoming G8 summit in July.⁴⁹ As Japan assumes the chairmanship of the G8 this year, the environment and Africa will be prominent on the agenda.⁵⁰ This includes a five-year, US\$10 billion fund to support efforts in developing countries to address global warming. In addition, Japan has indicated that it will share its expertise and technology to help improve access to safe drinking water and sanitation facilities in African and other developing countries. Japan is pushing for such measures as host of both the Fourth meeting of the Tokyo International Conference on African Development (TICAD IV) and the G8 summit this summer.⁵¹

In May, Japan intends to release a mid- to long-term support framework for Africa. The Government has stressed that if Africa starts to thrive and the world as a whole becomes prosperous, it will have a positive

impact on the Japanese economy as well. As the Japanese government has stated its intention to make its environmental technology available to developing countries with the participation of industry, opportunities exist for strengthening the ties between the Japanese and African research and technology communities.

The question of sustainable development creates perhaps the most exciting opportunities in Africa for scientific and technological innovations. For example, handheld computers, smartphones, the Internet, and Global Positioning Systems, can now be used to create sustainable data flow in developing countries. In Kenya and Zambia, provincial officers used EpiSurveyor, a free digital data collection system to monitor health. This method of surveying and emergency reporting could also be extended monitor environmental, energy, disaster management, or global warming-related issues.

The path to achieving sustainable development will be characterised by trade-offs. Development in Africa must occur and will occur, therefore, the current thinking shifts away from traditional environmental views of preserving or conserving, and rather focuses economic development done smartly. This means that sustainable development can offer economic opportunities, including new industries and technology approaches, to unmet problems. This is enhanced by donor funding mechanisms such as the idea is to commercialise projects that sustain the environment yet enable economic development.⁵²

4.2 Examples of making science and technology work in Africa

As indicated in the previous section, opportunities exist for cooperation and collaboration in science and technology propagation and exchange through linkages with local and regional innovations. The Japanese government has been a major aid provider to African nations, but the private sector, including scientists and nongovernmental organisations, is also increasingly involved in assistance for international development. There are several examples of successful collaborations between Japan and Africa.

In the health sector, the Japanese government and private sector worked with the UN Millennium Villages Programme in Africa to provide funding and malaria prevention. The Japanese government contributed initial funds for eight villages in 2005, while Sumitomo Chemical, Japan’s leading chemical maker, provided tens of thousands of mosquito-preventive bed nets that it had developed. The bed net, reputed to be the world’s most effective anti-malaria tool now available, is an innovative product that has a guaranteed life of five year. Production of the anti-malaria net in Africa is located in Tanzania.⁵³

With support from the Japan International Cooperation Agency (JICA), the Kenya Medical Research Institute (KEMRI) has developed an inexpensive but effective diagnostic testing kit for Hepatitis B (Hepcell). The kit is now in use in all district and provincial hospitals.

According to the World Bank, “of the 35 countries in the world with the most solar energy potential 17 are in Sub-Saharan Africa. Central African Republic, Chad, Mali, Mauritania, Namibia and Niger top the list of countries in the region with renewable energy potential.”⁵⁴ Biomass, thermal, solar, and wind generation and new energy storage technology solutions are being applied to energy in lieu of expensive and politically entangled hydroelectric and nuclear power systems. Housing and industrial developments are being designed that have self-sufficient sources of energy to avoid the expense of expanding the electrical grid. For example, in 2006, a team of South African scientists unveiled new solar technology constructed of a thin layer of a unique metal alloy. New energy storage devices and converters have been created alongside the cells making it possible for houses to be completely energy self-sufficient.⁵⁵

Some countries and communities have already embarked on projects to put development into action at the low-end scale of science and technology development. One such example is in Rwanda, where the introduction of energy efficient clay stoves helped to reduce energy needs of rural households as well as the levels of indoor pollution.

The Kyoto Protocol’s Clean Development Mechanism (CDM) enables developing countries to generate revenue by selling Certified Emission Reductions (carbon credits) from projects that reduce greenhouse gas emissions. The CDM concept was designed so that projects would contribute to poverty reduction and sustainable development. Companies, such as the insurance firm Fortis are committed to buy emissions reduction credits from developing countries. Proceeds from emissions reduction credits purchases can finance much needed investments in Africa. In this way new funds are created to invest in environmental sound projects in agriculture, industry, power, mining, and waste treatment are being prioritised. For example, in February 2005 a South African waste management company entered into an Emission Reductions Purchase Agreement with the Japanese Carbon Fund. The transaction is the largest South African CDM project to date and the first contract of the Japanese Carbon Fund.⁵⁶ So far, Africa has only registered 46 CDM projects, while Asia and Latin America the Americas have registered 2377 and 673 respectively. Given the low levels of greenhouse gas emissions in Africa, it is clear that huge opportunities for growth in the carbon sector exist.⁵⁷ Under its proposed financial mechanism on the adaptation to climate change for developing countries, Japan has selected eleven Africa countries for priority official development assistance (ODA) projects.

Perhaps the most widespread innovations are taking place in the area of biotechnology. Though there is scepticism about whether higher level biotechnology can meet the growing demand for food⁵⁸, considerable biotech discoveries have been made in the agricultural food production sector with the potential for commercial production. Improvements have been made in biofeeding, diagnostic kits, seed and crop quality innovations, and

trials of several transgenic plants. These advances are expected to permit African countries to generate more agricultural products to the point where surpluses are possible. Africa has made significant advances, especially with regard to micropropagation of banana, yams, cassava, soybeans, maize and rice. A good example of biotech collaboration and partnership to mention is the consortium of institutions from Africa, Japan and the US that cooperate to improve the nutritional content of sorghum. In addition, the Sasakawa Africa Association is leading the efforts accelerating the adoption of Quality Protein Maize (QPM) in Africa in partnership with the CGIAR.⁵⁹ In addition, maintaining and improving Africa’s biodiversity is an economic investment with the potential for tourism, biotechnology and new pharmaceutical applications.

There have also been successful efforts to develop drought-tolerant grain using conventional breeding methods in combination with genetic engineering. With the support of the United Nations Development Programme and the Japanese government, the African Rice Centre in Benin discovered a way to cross African rice with Asian rice in order to increase yields without losing important characteristics, such as drought and insect resistance. The Centre developed the New Rice for Africa (NERICA) technology adapted to thrive in harsh growing and low-input conditions.⁶⁰ This initiative has been successful in several African countries and will be expanded to Ghana, Rwanda, Tanzania and Uganda.

Furthermore, Japan supports the Millennium Villages Project. By combining rural development and infrastructure development this initiative is aimed at lifting people out of a ‘poverty trap’ to a level where they can engage in productive economic activities. The ultimate objective of the project is to make the Millennium Development Goals operational and to monitor progress. Each of the villages is located in a specific agro-ecological zone with high concentration of extreme poverty. This strategy allows for replication of the model in other regions that have similar agro-ecological conditions. Results demonstrate that science has helped to increase yields in rural farming communities by applying a combination of natural and commercial fertiliser.

The above examples provide a snapshot of some of the international collaborations that are taking place and offer insights into what is possible to achieve the long-term goal of environmental sustainability.

5. The Way Forward

For Africa to address pressing environmental problems such as climate change vulnerability, disease, and unsustainable resource use, while improving the well-being of its citizens, higher priority has to be given to scientific research and the development of environmentally sound technologies. While advancements in science and technology have brought about new opportunities for wealth creation and for innovative development solutions, the benefits from these technologies have so far been limited. Looking forward, it is clear that African countries cannot afford to focus on upgrading their industrial capabilities along traditional lines of economy first, environment later. African countries also need to make use of advanced technologies (e.g. ICT, biotechnology, and Geographic Information Systems) to provide a range of new applications in agriculture, health, and environmental management. Many of these technologies can assist in providing solutions to basic needs, such as cheaper diagnostic kits and high-yield seeds, and to improve productivity both in agriculture and in industry.

Investing in new technologies will require specific investments in public and private scientific and technological research infrastructures. This implies that important policy choices and trade-offs—from the infrastructure requirements for supporting new technologies to the ethical considerations relating to biotechnology—need to be made. As illustrated by the rapid uptake of mobile phone technology, it is possible to profitably transfer advanced technologies to poor regions using the right combination of services and a basic level of infrastructure. However, in order to scale up such initiatives to make sure there are pronounced social and economic benefits, the structural impediments such as human capital much be overcome through investments in higher technical education and a supportive institutional framework must be put in place.⁶¹

This year the G8 summit, to be held in Hokkaido, will focus on environment and African development. Japan has pledged to provide technological support for developing countries in Africa and Asia to help them fight against climate change and infectious diseases. Under the plan, to be unveiled in Hokkaido, Japan will help countries in Africa “cultivate environmental leaders” in charge of taking measures to protect the environment from water pollution and global warming.⁶² As there now is a better understanding of the importance of environmental services for economic development, African countries should seize the opportunity to move Japanese technologies to applications in Africa.

Annex 1: 2006 and 2008 EPI objectives and design

Category	2006 EPI	2008 EPI
Objective	Assesses current environmental conditions	Assesses current environmental conditions
Design	Provides an absolute measure of performance by assessing countries on a proximity-to-target basis	Provides an absolute measure of performance by assessing countries on a proximity-to-target basis
Environmental Health	Estimates environmentally-related impacts on health through child mortality, indoor air pollution, urban particulates concentration, access to drinking water, and adequate sanitation	Estimates environmental burden of disease directly using WHO developed disability adjusted life year (DALYs), local groundlevel ozone and urban particulate concentrations, indoor air pollution, access to drinking water, adequate sanitation
Air pollution	Measures air quality: Percent of households using solid fuels, urban particulates and regional ground-level ozone concentration	Measures atmospheric conditions pertaining to both human and ecological health: Health — Indoor air pollution, urban particulates, local ozone Ecosystems — Regional ozone, sulfur dioxide emissions (as proxy for its ecosystem impacts when deposited)
Water resources, water stress and water quality	Measures both water Resources, stress and quality: water consumption and nitrogen loading	Measures water stress through water stress index; assesses water quality through composite; Water Quality Index, which incorporates dissolved oxygen, pH, electrical conductivity, total nitrogen and total phosphorous concentrations
Energy / Climate Change	Links energy to climate change via CO ₂ emissions per GDP, percent of renewable energy and energy efficiency	Explicitly assesses contributions to climate change through Emissions per capita, emissions per electricity generated, and industrial carbon intensity
Biodiversity & Habitat	Focuses on biome and resource protection: Wilderness protection, ecoregion protection, timber harvest rate, and water consumption	Focuses on biome protection, including marine areas, and species conservation through Effective conservation, Conservation Risk Index, and critical habitat protection, indicators
Resource Management: Forests, Agriculture, Fisheries	Proxy for sustainable forest management: Timber harvest rate; Proxy for sustainable agriculture: Agricultural subsidies; Proxy for sustainable fisheries management: Overfishing	Proxy for sustainable forest management: Change in growing stock; Proxies for sustainable agriculture: Agricultural subsidies, Intensive cropland usage, Pesticide regulations, and Burned land area; Proxy for sustainable fisheries management: Trawling intensity, Marine Trophic Index

Endnotes

¹Africa in the text refers to sub-Saharan Africa.

²International Assessment of Agricultural Science and Technology for Development (IAASTD), "Agriculture and Development a Summary of the International Assessment on Agricultural Science and Technology for Development," (2007). Available at: http://www.panna.org/files/IAASTD_leaflet_final.pdf. Last accessed on 8 May 2008.

³Juma Calestous, "Reinventing African Economies: Technological Innovation and the Sustainability Transition. 6th John Pesek Colloquium on Sustainable Agriculture," (Iowa State University, 2006).

⁴IPCC, "Climate Change 2007 – Impacts, Adaptation and Vulnerability. Working Group II, Fourth Assessment Report," in *Report of the Intergovernmental Panel on Climate Change (IPCC) Working Group II* (IPCC, 2007), 48.

⁵For a comprehensive look at these issues, see UNEP's Global Environment Outlook 4 (<http://www.unep.org/geo/geo4/media/>) and Africa Environment Outlook 2 (<http://www.unep.org/Dewa/Africa/publications/AEO-2/aeo-2report.asp>).

⁶M. Hulme et al., "African Climate Change: 1900-2100," *Climate Research* 17 (2001).

Balgis Osman-Elasha, "Climate Change Impacts, Vulnerability and Adaptation in Africa," in *Background Paper* (Accra: UNFCCC Workshop on Adaptation, 21-24 September 2006, 2006).

⁷Calestous Juma and Ismail Serageldin, "Freedom to Innovate: Biotechnology in Africa's Development: Report of the High-Level African Panel on Modern Biotechnology," (African Union and New Partnership for Africa's Development, 2007). Available at: nepadst.org. Last accessed 26 March 2008.

⁸C. Brown and U. Lall, "Water and Economic Development: The Role of Variability and a Framework for Resilience," *Natural Resources Forum* 30, no. 4 (2006).

⁹IPCC, "Climate Change 2007 – Impacts, Adaptation and Vulnerability. Working Group II, Fourth Assessment Report," 48.

¹⁰Drought measure: 1980-2000, 3-month average precipitation, drought event was identified when the magnitude of a monthly precipitation deficit was less than or equal to 50 percent of its long-term median value for three or more consecutive months. No data results from a mask that excluded low population density and without significant agriculture. All grid cells are divided into 10 groups, so called deciles. The data is better suited for relative comparisons than for absolute figures. Reporting actual GDP figures would portray an unrealistic impression of precision. The more modest objective here is to provide a relative representation of disaster risk. For cartographic output and interpretation, therefore the authors convert the resulting numbers into index values from one to ten that correspond to deciles of the distribution of place-specific aggregate GDP figure.

¹¹Nicholas Stern, "Stern Review on the Economics of Climate Change," (London: HM Treasury, 2006), 65.

¹²J. Auvinen and E. W. Nafziger, "The Sources of Humanitarian Emergencies," *Journal of Conflict Resolution* 43, no. 3 (1999).

¹³Paul Collier and Anke Hoefler, "On the Incidence of Civil War in Africa," *Journal of Conflict Resolution* 46, no. 1 (2002), Ibrahim Elbadawi and Nicholas Sambanis, "How Much War Will We See? Explaining the Prevalence of Civil War," *Journal of Conflict Resolution* 46, no. 3 (2002), J. D. Fearon and D. D. Laitin, "Ethnicity, Insurgency and Civil War," *American Political Science Review* 97, no. 1 (2003), W. E. Nafziger and J. Auvinen, "The Economic Causes of Humanitarian Emergencies," in *War, Hunger and Displacement: The Origins of Humanitarian Emergencies*, ed. W. E.

Nafziger, F. Stewart, and R. Väyrynen (Oxford: Oxford University Press, 2000).

¹⁴World Bank, "World Development Indicators," (Washington, D.C.: 2008).

¹⁵Africa Partnership Forum Support Unit, "Climate Change and Africa," in *Briefing Paper* (Paris: Africa Partnership Forum, 2007). Available at: www.africapartnershipforum.org. Last accessed 2 May 2008.

¹⁶Calestous, "Reinventing African Economies: Technological Innovation and the Sustainability Transition. 6th John Pesek Colloquium on Sustainable Agriculture."

¹⁷International Assessment of Agricultural Science & Technology (IAASTD), "Inter-Governmental Report Aims to Set New Agenda for Global Food Production," in *Press release* (London: IAASTD, 2008), 2.

¹⁸World Bank, "Poverty and the Environment: Understanding Linkages at the Household Level," (Washington, D.C.: World Bank Environment Department, 2008).

¹⁹Pay Drechsel et al., "Population Density, Soil Nutrient Depletion, and Economic Growth in Sub-Saharan Africa," *Ecological Economics* 38, no. 2 (2001).

²⁰World Bank, "Fertiliser Toolkit: Promoting Efficient and Sustainable Fertilizer Use in Africa," (Washington, D.C.: The World Bank, 2006).

²¹United Nations Environment Programme, "Environmental Change and Socioeconomic Factors in Africa," in *Encyclopedia of Earth*, ed. Cutler J. Cleveland (Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment, 2007). Available at: http://www.eoearth.org/article/Environmental_change_and_socioeconomic_factors_in_Africa. Last accessed on 26 March 2008.

²²United Nations University, "Experts Advise World Policies to Cope with Causes, Rising Consequences of Creeping Desertification," in *Science Daily* (Tokyo: 2006). Available at: <http://www.sciencedaily.com/releases/2006/12/061214142740.htm>. Last accessed on 15 February 2008.

²³UNFPA, "Population Issues" (1999). Available at: <http://www.unfpa.org/6billion>. Last accessed on 15 February 2008.

²⁴D. J. Spielman, "Evaluating the Changing Role of Agricultural R&D, Partnerships, and Networks in Enhancing Technological Opportunities for Sub-Saharan Africa. A Position Paper Submitted for a Conference "A Roadmap Towards Making the Benefits of Gm Crops Available to Resource-Poor Farmers in Africa", September 13-17," (Bellagio, Italy: 2005). Available at: http://www.cipotato.org/research/bellagio/bellagio_agri_rd_innovation_dspielman.doc. Last Accessed on 8 May 2008.

²⁵Ibid.

²⁶D.J. Spielman and K. von Grebmer, "Public-Private Partnerships in Agricultural Research: An Analysis of Challenges Facing Industry and the Consultative Group on International Agricultural Research," (Washington D.C.: International Food Policy Research Institute, 2004).

²⁷Spielman, "Evaluating the Changing Role of Agricultural R&D, Partnerships, and Networks in Enhancing Technological Opportunities for Sub-Saharan Africa. A Position Paper Submitted for a Conference "A Roadmap Towards Making the Benefits of Gm Crops Available to Resource-Poor Farmers in Africa", September 13-17." Available at: http://www.cipotato.org/research/bellagio/bellagio_agri_rd_innovation_dspielman.doc. Last Accessed on 8 May 2008.

²⁸The African Agricultural Technology Foundation (AATF) is a public-private partnership based in Kenya, with the purpose of

developing agricultural biotechnology, including GM technology, in Africa. AATF received start-up funds from USAID, the Rockefeller Foundation and the United Kingdom's Department for International Development (DFID), as well as Monsanto, Dupont, Dow and Syngenta.

²⁹J. Dione, "Innovations to Transform Agriculture for Improved Livelihoods and Development in Africa. Keynote Address to the 3rd Fara General Assembly" (Entebe: 2005).

³⁰FAO Corporate Document Repository, "Crop Prospects and Food Situation," (2008). Available at: <http://www.fao.org/docrep/010/a1465e/a1465e06.htm>. Last accessed on 8 May 2008

³¹Joachim von Braun, "The World Food Situation New Driving Forces and Required Actions," in *Food Policy Report No. 18* (Washington, D.C.: 2007).

³²Mark Thirlwell, "Food and the Spectre of Malthus," *The Financial Times*, Tuesday Feb 26 2008. Available at: http://us.ft.com/ftgateway/superpage.ft?news_id=ft0022620081315470144. Last accessed on 6 May 2008.

³³von Braun, "The World Food Situation New Driving Forces and Required Actions."

³⁴Bank Information Centre, "Food Riots Hit West and Central Africa," 13 March 2008. Available at: <http://www.bicusa.org/en/Article.3702.aspx>. Last accessed on 8 May 2008.

³⁵The Earth Institute, "Global Food Crisis Golden Opportunity for African Farmers" *Press Room* (2008). Available at <http://www.earth.columbia.edu/articles/view/2158>. Last accessed on 2 May 2008.

³⁶UNCTAD, "Efficient Transport and Trade Facilitation to Improve Participation by Developing Countries in International Trade," (2003). Available at: http://www.unctad.org/en/docs/c3d53_en.pdf. Last accessed on 26 March 2008.

³⁷Ngila Mwase, "The Liberalization, De-Regulation and Privatization of the Transport Sector in Sub-Saharan Africa: Experiences, Challenges and Opportunities," *Journal of African Economies* 12, no. Suppl. 2 (2003). Cited in: Wim Naude and Marianne Matthee, "The Significance of Transport Costs in Africa," in *Policy Brief* (Tokyo: United Nations University - World Institute for Development Economics Research, 2007), 2.

³⁸Jeffrey Sachs, *The End of Poverty: Economic Possibilities for Our Time* (London: Allen Lane, 2005).

³⁹World Bank, "Ensuring Environmental Sustainability: Measuring Progress toward the 7th Millennium Development Goal: The International Bank for Reconstruction and Development," (Washington, D.C.: The World Bank, 2005). Available at: <http://siteresources.worldbank.org/ESSDNETWORK/1105722-1115888526384/20645232/ensuring.pdf>. Last accessed 6 May 2008.

⁴⁰Daniel C. Esty et al., "Pilot 2006 Environmental Performance Index. New Haven: Yale Center for Environmental Law & Policy," (New Haven: Yale, 2006).

⁴¹Ibid., 9.

⁴²Daniel C. Esty et al., "2008 Environmental Performance Index," (New Haven: Yale Center for Environmental Law and Policy, 2008), 32.

⁴³UNIDO Industrial Development Report (2004). Industrialisation, Environment and the Millennium Development Goals: The new frontier in the fight against poverty in Sub-Saharan Africa. Available at [http://www.un.org/special-rep/ohrls/ldc/Global-Reports/2004%20UNIDO%20Report_summary%20\(E\).pdf](http://www.un.org/special-rep/ohrls/ldc/Global-Reports/2004%20UNIDO%20Report_summary%20(E).pdf). Last accessed on 8 May 2008

⁴⁴Ibid.

⁴⁵Calestous Juma, "The 2006 Hinton Lecture: Redesigning

African Economies – the Role of Engineering in International Development," (The Royal Academy of Engineering, 2006), 4.

⁴⁶A. Kwansah-Aidoo and Levi Obijiofor, "Patterns of Internet Use among University Students in Ghana," in *African Development: What Role for Business: Proceedings of the International Academy of African Business and Development Conference, 23–27 May 2006*, ed. K. O. Ayadi (Accra, Ghana: Ghana Institute of Management and Public Administration, 2006).

⁴⁷Juma and Serageldin, "Freedom to Innovate: Biotechnology in Africa's Development: Report of the High-Level African Panel on Modern Biotechnology." Available at: nepadst.org. Last accessed on 26 March 2008.

⁴⁸M. Aizawa, "Toward the Reinforcement of Science and Technology Diplomacy," (2007). Available at: <http://www8.cao.go.jp/cstp/english/policy/stdiplomacy.pdf>. Last accessed on 26 March 2008.

⁴⁹The Ministry of Foreign Affairs of Japan, (January 26, 2008), "Special Address by H.E. Mr. Yasuo Fukuda, Prime Minister of Japan On the Occasion of the Annual Meeting of the World Economic Forum-Congress Center, Davos Switzerland." Available at: www.mofa.go.jp/policy/economy/wef/2008/address-s.html.

⁵⁰Forbes.com (2008). Dispatches from Davos: What Did Davos Achieve? by Paul Maidment. Available at <http://blogs.forbes.com/davosblog/> <http://blogs.forbes.com/davosblog/>. Last accessed on 8 May 2008.

⁵¹Kyodo News (February 22, 2008), "Japan vows to share know-how to improve safe water access, sanitation."

⁵²Edward S. Marek, "Technology for Africa," (USA in Chimera Africa Institute, 2003).

⁵³K. Kurokawa, "Challenges for Japan's Scientific Community in the 2008 G8 Summit," (2007). Available at: http://www.jiia.or.jp/en_commentary/200706/19-1.html. Last Accessed on 26 March 2008.

⁵⁴World Bank, Global Monitoring Report (2008). Spotlight on the Environment: Sub-Saharan Africa: MDGs and the Environment - Agenda for Inclusive and Sustainable Development. Available at <http://web.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTGLOBALMONITOR/EXTGLOMONREP2008/0,,contentMDK:21709133~menuPK:4843730~pagePK:64168445~piPK:64168309~theSitePK:4738057,00.html>. Last accessed on 8 May 2008.

⁵⁵Willem Steenkamp, "Sa Solar Research Eclipses Rest of the World," (2006). This article was originally published in Saturday Argus available at: <http://www.int.iol.co.za/index.php>. Last accessed on 15 February 2008.

⁵⁶<http://www.climatefocus.com/content/news/archive/Chloorkop.htm>. Last accessed on 10 May 2008.

⁵⁷United Nations Development Programme, "Fast Facts," (UNDP, 2006).

⁵⁸See International Assessment of Agricultural Science and Technology for Development (IAASTD). International Assessment of Agricultural Science and Technology for Development (IAASTD), "Agriculture and Development a Summary of the International Assessment on Agricultural Science and Technology for Development," (2007).

⁵⁹CGIAR, "A Partnership for Research and Development: Japan and the Ccgiar," (2004). Available at: http://www.cgiar.org/pdf/cg_partnership_english_final_feb2004.pdf. Last accessed on 26 March 2008.

⁶⁰See <http://www.warda.org>. Last accessed on 15 February 2008.

⁶¹UNIDO Industrial Development Report (2004). Industrialisation, Environment and the Millennium Development Goals: The new frontier in the fight against poverty in Sub-

Saharan Africa. Available at [http://www.un.org/special-rep/ohrrls/ldc/Global-Reports/2004%20UNIDO%20Report_summary%20\(E\).pdf](http://www.un.org/special-rep/ohrrls/ldc/Global-Reports/2004%20UNIDO%20Report_summary%20(E).pdf). Last accessed on 8 May 2008.

⁶²Tokyo AFP, "Japan to Offer Environmental Technology to Africa, Asia Report," (2008). Available at: http://www.energy-daily.com/reports/Japan_to_offer_environmental_technology_to_Africa_Asia_report_999.html. Last accessed on 15 February 2008.

References

- Africa Partnership Forum Support Unit. "Climate Change and Africa." In *Briefing Paper*. Paris: Africa Partnership Forum, 2007.
- Aizawa, M. "Toward the Reinforcement of Science and Technology Diplomacy." 2007.
- Auvinen, J., and E. W. Nafziger. "The Sources of Humanitarian Emergencies." *Journal of Conflict Resolution* 43, no. 3 (1999): 267-90.
- Bank Information Centre. "Food Riots Hit West and Central Africa." 13 March 2008.
- Brown, C., and U. Lall. "Water and Economic Development: The Role of Variability and a Framework for Resilience." *Natural Resources Forum* 30, no. 4 (2006): 306 – 17.
- Calestous, Juma. "Reinventing African Economies: Technological Innovation and the Sustainability Transition. 6th John Pesek Colloquium on Sustainable Agriculture." Iowa State University, 2006.
- CGIAR. "A Partnership for Research and Development: Japan and the Ccgjar." 2004.
- Collier, Paul, and Anke Hoeffler. "On the Incidence of Civil War in Africa." *Journal of Conflict Resolution* 46, no. 1 (2002): 13-28.
- Dione, J. "Innovations to Transform Agriculture for Improved Livelihoods and Development in Africa. Keynote Address to the 3rd Fara General Assembly." Entebe, 2005.
- Drechsel, Pay, Lucy Gyiele, Dagmar Kunze, and Olufunke Cofie. "Population Density, Soil Nutrient Depletion, and Economic Growth in Sub-Saharan Africa." *Ecological Economics* 38, no. 2 (2001): 251-58.
- Elbadawi, Ibrahim, and Nicholas Sambanis. "How Much War Will We See? Explaining the Prevalence of Civil War." *Journal of Conflict Resolution* 46, no. 3 (2002): 307-34.
- Esty, Daniel C., Marc A. Levy, Christine H. Kim, Alexander de Sherbinin, Tanja Srebotnjak, and V. Mara. "2008 Environmental Performance Index." New Haven: Yale Center for Environmental Law and Policy, 2008.
- Esty, Daniel C., Marc A. Levy, Tanja Srebotnjak, Alexander de Sherbinin, Christine H. Kim, and Bridget Anderson. "Pilot 2006 Environmental Performance Index. New Haven: Yale Center for Environmental Law & Policy." New Haven: Yale, 2006.
- FAO Corporate Document Repository. "Crop Prospects and Food Situation." 2008.
- Fearon, J. D., and D. D. Laitin. "Ethnicity, Insurgency and Civil War." *American Political Science Review* 97, no. 1 (2003): 75-90.
- Hulme, M., R. M. Doherty, T. Ngara, M. G. New, and D. Lister. "African Climate Change: 1900-2100." *Climate Research* 17 (2001): 145-68.
- International Assessment of Agricultural Science and Technology for Development (IAASTD). "Synthesis Report: Agriculture and Development a Summary of the International Assessment on Agricultural Science and Technology for Development." 2007.
- International Assessment of Agricultural Science & Technology (IAASTD). "Inter-Governmental Report Aims to Set New Agenda for Global Food Production." In *Press release*. London: IAASTD, 2008.
- IPCC. "Climate Change 2007 – Impacts, Adaptation and Vulnerability. Working Group II, Fourth Assessment Report." In *Report of the Intergovernmental Panel on Climate Change (IPCC) Working Group II: IPCC, 2007*.
- Juma, Calestous. "The 2006 Hinton Lecture: Redesigning African Economies – the Role of Engineering in International Development." The Royal Academy of Engineering, 2006.
- Juma, Calestous, and Ismail Serageldin. "Freedom to Innovate: Biotechnology in Africa's Development: Report of the High-Level African Panel on Modern Biotechnology." African Union and New Partnership for Africa's Development, 2007.
- Kurokawa, K. "Challenges for Japan's Scientific Community in the 2008 G8 Summit." 2007.
- Kwansah-Aidoo, A., and Levi Obijiofor. "Patterns of Internet Use among University Students in Ghana." In *African Development: What Role for Business: Proceedings of the International Academy of African Business and Development Conference, 23-27 May 2006*, edited by K. O. Ayadi, 359-65. Accra, Ghana: Ghana Institute of Management and Public Administration, 2006.
- Marek, Edward S. "Technology for Africa." USA in Chimera Africa Institute, 2003.
- Mwase, Ngila. "The Liberalization, De-Regulation and Privatization of the Transport Sector in Sub-Saharan Africa: Experiences, Challenges and Opportunities." *Journal of African Economies* 12, no. Suppl. 2 (2003): ii153-ii92.
- Nafziger, W. E., and J. Auvinen. "The Economic Causes of Humanitarian Emergencies." In *War, Hunger and Displacement: The Origins of Humanitarian Emergencies*, edited by W. E. Nafziger, F. Stewart and R. Väyrynen. Oxford: Oxford University Press, 2000.
- Naude, Wim, and Marianne Matthee. "The Significance of Transport Costs in Africa." In *Policy Brief*. Tokyo: United Nations University - World Institute for Development Economics Research, 2007.
- Osman-Elasha, Balgis. "Climate Change Impacts, Vulnerability and Adaptation in Africa." In *Background Paper*. Accra: UNFCCC Workshop on Adaptation, 21-24 September 2006, 2006.
- Sachs, Jeffrey. *The End of Poverty: Economic Possibilities for Our Time*. London: Allen Lane, 2005.

- Spielman, D. J. "Evaluating the Changing Role of Agricultural R&D, Partnerships, and Networks in Enhancing Technological Opportunities for Sub-Saharan Africa. A Position Paper Submitted for a Conference "A Roadmap Towards Making the Benefits of Gm Crops Available to Resource-Poor Farmers in Africa", September 13-17." Bellagio, Italy, 2005.
- Spielman, D.J., and K. von Grebmer. "Public-Private Partnerships in Agricultural Research: An Analysis of Challenges Facing Industry and the Consultative Group on International Agricultural Research." Washington D.C.: International Food Policy Research Institute, 2004.
- Steenkamp, Willem. "Sa Solar Research Eclipses Rest of the World." (2006).
- Stern, Nicholas. "Stern Review on the Economics of Climate Change." London: HM Treasury, 2006.
- The Earth Institute. "Global Food Crisis Golden Opportunity for African Farmers " *Press Room* (2008).
- Thirlwell, Mark. "Food and the Spectre of Malthus." *The Financial Times*, Tuesday Feb 26 2008.
- Tokyo AFP. "Japan to Offer Environmental Technology to Africa, Asia Report." 2008.
- UNCTAD. "Efficient Transport and Trade Facilitation to Improve Participation by Developing Countries in International Trade." 2003.
- UNFPA. "Population Issues ", 1999.
- United Nations Development Programme. "Fast Facts." UNDP, 2006.
- United Nations Environment Programme. "Environmental Change and Socioeconomic Factors in Africa." In *Encyclopedia of Earth*, edited by Cutler J. Cleveland. Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment, 2007.
- United Nations University. "Experts Advise World Policies to Cope with Causes, Rising Consequences of Creeping Desertification." In *Science Daily*. Tokyo, 2006.
- von Braun, Joachim. "The World Food Situation New Driving Forces and Required Actions." In *Food Policy Report No. 18*. Washington, D.C., 2007.
- World Bank. "Ensuring Environmental Sustainability: Measuring Progress toward the 7th Millennium Development Goal: The International Bank for Reconstruction and Development." Washington, D.C.: The World Bank, 2005.
- World Bank. "Fertiliser Toolkit: Promoting Efficient and Sustainable Fertilizer Use in Africa." Washington, D.C.: The World Bank, 2006.
- World Bank. "Poverty and the Environment: Understanding Linkages at the Household Level." Washington, D.C.: World Bank Environment Department, 2008.
- World Bank. "World Development Indicators." Washington, D.C., 2008.

United Nations University Global Reach

Programmes at UNU Centre, Tokyo, Japan

Peace and Governance Programme
Environment and Sustainable Development Programme
Capacity Development and Fellowships
Online Learning
Email: mbox@hq.unu.edu, URL <http://www.unu.edu>

UNU Research and Training Centres or Programmes (RTC/Ps)

UNU Institute of Advanced Studies (UNU-IAS), Yokohama, Japan

Focus: strategic approaches to sustainable development
Email: unuias@ias.unu.edu, URL <http://www.ias.unu.edu>

UNU World Institute for Development Economics Research (UNU-WIDER), Helsinki, Finland

Focus: development economics
Email: wider@wider.unu.edu, URL <http://www.wider.unu.edu/>

Maastricht Economic and Social Research and Training Centre on Innovation and Technology (UNU-MERIT), Maastricht, The Netherlands

Focus: socio-economic impacts of new technologies
Email: postmaster@merit.unu.edu, URL <http://www.merit.unu.edu/>

UNU Institute for Natural Resources in Africa (UNU-INRA), Accra, Ghana

Focus: natural resources management
Email: unuinra@inra.unu.edu.gh, URL <http://www.inra.unu.edu/>

UNU International Institute for Software Technology (UNU-IIST), Macau, China

Focus: software technologies for development
Email: iist@iist.unu.edu, URL <http://www.iist.unu.edu/>

UNU Programme for Biotechnology in Latin America and the Caribbean (UNU-BIOLAC), Caracas, Venezuela

Focus: biotechnology and society
Email: unu@reacciun.ve, URL <http://www.biolac.unu.edu/>

UNU International Leadership Institute (UNU-ILI), Amman, Jordan

Focus: leadership development
Email: mbox@la.unu.edu, URL <http://www.la.unu.edu/>

UNU International Network on Water, Environment and Health (UNU-INWEH), Hamilton, Canada

Focus: water, environment and human health
Email: contact@inweh.unu.edu, URL <http://www.inweh.unu.edu/>

UNU Research and Training Programme on Comparative Regional Integration Studies (UNU-CRIS), Bruges, Belgium

Focus: local/global governance and regional integration
Email: info@cris.unu.edu, URL <http://www.cris.unu.edu/>

UNU Food and Nutrition Programme for Human and Social Development (UNU-FNP), Cornell University, USA

Focus: food and nutrition capacity building
Email: cg3o@cornell.edu, URL <http://www.unu.edu/capacitybuilding/foodnutrition/cornell.html>

UNU Iceland-based Training Programmes, Reykjavik, Iceland:

UNU Geothermal Training Programme (UNU-GTP)

Focus: geothermal research, exploration and development
Email: unugtp@os.is, URL <http://www.os.is/id/472>
and

UNU Fisheries Training Programme (UNU-FTP)

Focus: postgraduate fisheries research and development
Email: unu@hafro.is, URL <http://www.unuftp.is/>

UNU Institute for Environment and Human Security (UNU-EHS), Bonn, Germany

Focus: environment and human security
Email: info@ehs.unu.edu, URL <http://www.ehs.unu.edu/>

UNU International Institute for Global Health (UNU-IIGH), Kuala Lumpur, Malaysia

Focus: research and capacity building in global health
E-mail: mohamed.salleh@iigh.unu.edu, URL <http://www.unu.edu/system/centres.html#iigh>

The United Nations University Institute of Advanced Studies (UNU-IAS) is a global think tank whose mission is "to advance knowledge and promote learning for policy-making to meet the challenges of sustainable development." UNU-IAS undertakes research and postgraduate education to identify and address strategic issues of concern for all humankind, for governments, decision makers and, particularly, for developing countries.

The Institute convenes expertise from disciplines such as economics, law, social and natural sciences to better understand and contribute creative solutions to pressing global concerns, with research focused on the following areas:

- Biodiplomacy
- Sustainable Development Governance
- Science Policy for Sustainable Development
- Education for Sustainable Development
- Ecosystems and People
- Urban Futures
- Global Marine Governance
- Traditional Knowledge



**UNITED NATIONS
UNIVERSITY**

UNU-IAS

Institute of Advanced Studies

United Nations University
Institute of Advanced Studies
6F, International Organizations Center
Pacifico-Yokohama, 1-1-1 Minato Mirai
Nishi-ku, Yokohama 220-8502
Japan

Tel: +81 45 221 2300
Fax: +81 45 221 2302
Email: unuias@ias.unu.edu
URL <http://www.ias.unu.edu>



printed on recycled paper using soy-based ink