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Prepared by SDR

I. INTRODUCTION

Africa, whose most people are farmers, is unable to feed itself, and has been in this situation for decades now. Persistent low agricultural production, coupled with increased population growth, has meant that imports of agricultural products have been rising faster than exports since the 1960s. If current trends persist, the numbers of undernourished will increase by 2015, in contrast to the other developing regions. In the coming decades Africa will have to feed a population that is expected to increase from 832 million people in 2002 to over 1.8 billion in 2050. Therefore, there is urgent need to generate a uniquely African green revolution that is long overdue.

In many regions of the world, namely Asia and Latin America, the yield of the major cereals (rice, wheat and maize) more than doubled during the period 1960-1990. This was due to the introduction of improved varieties with technological packages that allowed the yield potential of the crops to be realized more fully and under conditions experienced by medium to large scale farmers of developing countries. These increases and the conditions that made them possible have been called the “Green Revolution”.

The analysis of the impact of the Green Revolution in different regions, over a 40 year period, indicates that the gains obtained were larger in the late period (1980s and 1990s) than in the early period (1961 to 1980), contrary to widely accepted perceptions that the Green Revolution was already over by 1980. The early period had limited effect in Africa , in part due to the food crops grown in the region (root crops and tropical maize as dominant food crops) and to the agroecological complexities but also due to the institutional and political failures. The yield growth realized in Africa was almost entirely contributed by the improved varieties with little contribution from fertilizer and other inputs. However, the evidence from the late period is more promising. Research efforts targeted specifically to African conditions have been producing improved varieties of cassava, maize, rice and other crops since the 1980s and 1990s.

This paper analyses the main trends foreseen for developments in African agriculture, food and nutrition, inputs and natural resource use, and also the challenges emanating from the trends. It discusses the role of research and technology dissemination and adoption as key elements that need to be incorporated into a long-term, sustainable, strategy for the agricultural development of Africa. Finally, the last section highlights the main components that require more short-term, immediate actions and investments to avert food insecurity in Africa.

II. TRENDS OF AGRICULTURAL DEVELOPMENT IN AFRICA

2.1 Agricultural Production, Food Security, Nutrition and Poverty

In Africa, the agricultural sector accounts for 57 percent of total employment, 17 percent of Gross Domestic Product (GDP) and 11 percent of export earnings. In Africa the number of undernourished people stands at 204 millions. Africa is the only region in the world where the regional average of food production has declined over the last 40 years. African countries share the characteristics of variability of output, relatively low yields and dependency on

primary exports with low income elasticity of demand and high price volatility. Africa's agriculture is undercapitalized, uncompetitive and underperforming.

The food insecurity and malnutrition trends closely follow the poverty trend. While the number of poor (subsisting on less than US$1 a day) in the developing world is expected to decline considerably and this trend is maintained in North Africa, in Sub-Saharan Africa (SSA) the number of absolute poor is expected to rise (Table 1).

Table 1: Food and Hunger Indicators by Region

Year	Sub-Saharan Africa	Near East and North Africa	South Asia	East Asia	Latin America and Caribbean	Developing Countries
Millions of persons undernourished						
1997-99	194	32	303	193	54	776
2015	205	37	195	135	40	610
Millions of Persons in Poverty (US$1/day)						
1999	300	7	490	260	77	1134
2015	345	6	279	59	60	749

2.2 Major Agricultural Sub-Sectors

A range of agricultural indicators for Africa are presented in Table 2. These show that the region falls below other developing regions in the proportion of area irrigated, value added per worker, fertilizer levels, and productivity growth in crops and livestock activities.Only 7 percent of Africa's arable land is irrigated compared to 37 percent in Asia; value added per worker in agriculture has to double to equal Latin America, and cereal yields would have to more than double to match South Asia. For the region as a whole, only 22 kg of fertilizer is applied per hectare of arable land and this level decreases even further in SSA which uses only 9 kg per hectare.

If the hunger, poverty and environmental degradation trends are to be reversed, African agriculture has to be transformed through an enabling environment of policy, institutions, infrastructure and investment in scientific research, technology development and dissemination. The longer these basic enabling mechanisms are delayed the less competitive agriculture becomes as the costs to produce, process and market agricultural products increase.

Table 2: Agricultural Indicators by Region

	Africa	Sub-Saharan Africa	Near East and North Africa	South Asia	East Asia and Pacific	Latin America and Caribbean	Middle income countries	High income countries	World
Proportion of arable land irrigated	7.0	3.8	28.7	39.3	31.9	11.6	19.9	11.9	20.0
Per capita cereal production 1997/99 (kg/year)	147	128	128	224	336	259	339	746	349
Cereal yield 1997/99 (kg/ha)	1 225	986	1 963	2 308	4 278	2 795	2 390	4 002	2 067
Livestock productivity 1997/99(kg/ha)	164	128	147	121	150	198	191	248	193
Fertilizer use 1997/99 (kg/ha)	22	9	69	109	241	85	111	125	100

The livestock sub-sector is estimated to contribute about 30 percent to agricultural GDP. It contributes significantly to food supply and nutrition, is a source of livelihoods to million of Africans and enhances productivity of crop agriculture through manure and draught power. Africa's livestock resource is estimated at 231 million cattle, 244 million sheep, 22 million pigs and 1,398 million poultry producing a total of 30, 12 and 2 million tonnes of meat, milk and eggs respectively.

Overall, livestock production and productivity growth has not been sufficient to keep up with the demands of expanding populations, and has led to increasing levels of imports of livestock products into Africa, currently valued at close to US$700 million per year and projected to further increase. In order to keep pace with the human population growth, and so avoid declining self-sufficiency ratios and rising import bills, the output of livestock products in Africa would have to increase by at least 2.7 percent annually. Based on FAO projections available for sub-Saharan Africa, total livestock production would have to grow at an average rate of 4.2 percent per annum by the horizon 2015 to meet the needs of the growing population, improve nutrition and progressively eliminate food imports, while required growth rates for the individual components would be 2.5, 4.9 and 4.4 percent per annum for meat, milk and eggs respectively.

The fishery sector makes important contributions to African economies. FAO projections suggest that per capita fish consumption levels will not grow from their relatively low 1999 levels (6.8 kg) during the next 15 years. Local wild stocks are close to being fully exploited so imports would have to expand by 46 percent by 2015 to maintain 1999 consumption levels. Led by Egypt, aquaculture has expanded rapidly in Africa during the past decade. In 1999, Egypt accounted for 80 percent of total African production. Aquaculture contributes less than one percent of total fish supplies.

Fishery production (including capture production from inland and marine waters plus aquaculture production) in African countries ranged from 4.9 million to 5.9 million metric tonnes in the 1990-98 period. Since 1994, fishery production has been increasing at an average rate of 3.5 percent per year. Among the five African geographical groupings, West Africa and Southern Africa are the two major contributors to the total fishery production of the continent.

Forestry continues to play a significant role in the formal economy of many countries of the region. The Congo Basin is home to the second largest continuous tropical forest block in the world. In Africa wood is the most important source of household energy, used mainly for cooking, but also for food drying and brick-making. Fuel wood consumption in the region is projected to increase. However, the forest cover is being depleted and between 1990 and 2000 the highest average annual loss of forest cover was recorded in Africa, with 0.78 percent, compared to 0.41 percent in South America and 0.2 percent at world level.

2.3 Natural Resources

O Africa's share of global freshwater resources of about 9 percent nearly matches its share of the world population at 12 percent. However, the average water availability per person in Africa is about 70 percent of the global average. The Intergovernmental Panel on Climate Change (IPCC) predicts that the average runoff and water availability will decline, especially in the countries of northern and southern Africa, impacting on freshwater ecosystems and advancing desertification in the Sahelian zone and in Northern Africa.

Pastures comprise 38.4 percent of the land area in Africa and are a source livelihood in a number of farming systems. But due to increased population density and overgrazing the productivity and sustainability of pastures is threatened. This is affecting livestock and crop production and causing environmental degradation.

Most African countries have substantial underutilized potential for irrigation expansion. Two thirds of African countries have developed less than 20 percent of their potential. The scope for expanding irrigation is therefore considerable. However, many economic studies on large-scale irrigation projects indicate a higher level of efficiency for small-scale irrigation schemes, including rain water harvesting techniques, shallow lift from rivers, lakes and streams and well exploitation of shallow underground aquifers that have natural recharge.

Depletion of nutrients from soils has caused crop production and yields to stagnate or decline in many African countries, with concurrent economic losses. Africa is required to quadruple its fertilizer consumption to 11.7 million tonnes of NPK to maintain its current levels of crop production. Currently the continent's average NPK use is 22 kg/ha, and there is wide gap in the fertilizer use, as reflected in yield levels, from subregion to subregion, with SSA using 9 kg/ha. Against this, East Asian farmers use some 241 kg of fertilizer per hectare to produce some 4300 kg of cereal; farmers in high-income countries use 125 kg to produce 4000 kg of cereals.

III. MAJOR CHALLENGES

Despite possessing abundant natural resources base of land, soils, water, forests and wildlife, Africa continues to be in an impoverished state, unable to attain its development potential. If anything it is falling further behind with each passing decade. The reasons advanced for Africa's little or lack of development are many and varied. These include, among others, the following: proliferation of wars and conflicts; weak governments, poor development policies; unsustainable use of natural resources; droughts; geographic position (lacking access to sea); diseases and pestilences; lack of rural infrastructure and services.

Achieving and maintaining economic development has been the main challenge facing Africa during the last forty years. This has been exacerbated by the inability of African nations to harness and utilize their natural resources in a sustainable manner, inability to promote and apply science and technology to generate agricultural production technologies that can circumvent unpredictable rainfall, drought, as well as reduce the impact of natural disasters. However science and technology are not a panacea for economic development. By themselves they will not solve Africa's stubborn legacies of underdevelopment, but they can contribute positively and decisively to improving current conditions. African countries must follow a multifaceted approach of strengthening their national agricultural research systems and their networks at the intraregional as well as at the global level. They need to develop a systematic sustainable drive to generate, import, adapt, and disseminate scientific knowledge and technologies.

The weak aggregated growth performance of the agricultural sub sectors, crops, livestock, forestry, fisheries, is due to their low rate of growth. This has led not only to loss of market share in world export but is also responsible for the persistent food insecurity, malnutrition and poverty in Africa. The challenge for Africa is to provide an enabling environment for sustainably increasing the output of the smallholder farmer's major agricultural subsectors. These will include better policies to promote production, productivity and diversification within the subsectors and better integrate the heterogeneous and diverse farming systems that dominate African agriculture.

It is recognized that women play an important role in African agriculture. Therefore African governments need to respond to the challenge of empowering women so that they can have access to the production resources of land, credit, inputs and technologies in all the subsectors.

In order to meet the United Nations Millennium Development Goals (MDG) of reducing hunger and poverty Africa must ensure that food and agricultural production are not only coupled with poverty reduction and environmental conservation but also occur in complex smallholder farming systems. The natural resource base is key to sustainable food and agricultural production. This entails the need to put in place policies and regulations that will promote the sustainable and efficient use of the natural resources.

The challenge for Africa is the attainment of sustainable development goals of the New Partnership for Africa's Development (NEPAD), the MDGs and the Plan of Implementation of the World Summit on Sustainable Development (WSSD). This requires renewed political and financial commitment to the development and application of research and technology at national, regional and continental levels. Research and technology will play an important role in Africa's efforts to eradicate poverty, achieve food security, fight the diseases of malaria,

tuberculosis and HIV/AIDS, reverse environmental degradation and increase the pace of industrialization and trade.

The challenges that Africa faces in the development and application of science and technology include:

- Weak links between science institutions and private sector;
- Low and limited public and private sector expenditures on research and development;
- Inappropriate science and technology policies;
- Limited public understanding of science and technology;
- Brain drain of African scientists, and
- Weak and thinly spread research and technology development institutions.

IV. AGRICULTURAL RESEARCH: NEED TO PROMOTE KNOWLEDGE ASSIMILATION FOR FOOD SECURITY

In 2003 the Comprehensive Africa Agriculture Development Programme (CAADP) identified agricultural research, technology dissemination and adoption as the fourth long-term pillar for African's development. It aims at achieving accelerated gains in productivity and it will require the following: a) an enhanced rate of adoption for the most promising technologies to support the immediate expansion of African agricultural production through the more efficient linkage of research and extension systems to producers; b) technology delivery systems that rapidly bring innovations to farmers and agribusiness through the appropriate use of new information and communication technologies; c) renewed ability of agricultural research systems to efficiently and effectively generate and adapt new knowledge and technologies to increase productivity, and d) mechanisms that reduce the costs and risks of adopting new technologies.

Its implementation will require increased and sustained investments but also profound changes in current institutional arrangements, provision of new mechanisms and tools to make the institutions more relevant and efficient, and a revision of the current agricultural research agendas.

4.1 Paradigm Shift in Research and Technology Development Institutions

The environment under which agricultural and extension systems are operating is affecting their organizational structure, management style, and field operations. Basic trends of these environmental changes are based on multiple partnerships, multilevel participation and the enlargement of the scene from national to supra-national levels. Both agricultural research and agricultural extension policies are going obsolete with regard to the new options. Agricultural research and extension policies should be re-examined, re-formulated and updated to help improve their effectiveness and efficiency.

A shift is needed from a single commodity and monodisciplinary base to a farming system and a multidisciplinary based approach together with a change from a top-down extension model to a participatory approach to technology assessment and adoption. Linkages between research, extension and farmers need to be strengthened and mechanisms applied to promote

interaction for the adoption of field proven technologies. Public-private partnerships need to be promoted to improve access to inputs and service supply to farmers for reduced production cost and improved quality.

It is urgent to bridge the striking development divide between Africa and the rest of the world by taking advantage of existing advances to provide Africans with access to simple new technologies from other developing countries. African scientists are challenged to meet high levels of social responsibility and to focus on creating technologies that are specifically suited to the poor and on solving problems that can make a difference to African countries and its poor population.

Africa has a higher proportion of economically active women involved in agricultural activities relative to men, yet they have limited access to agricultural production resources, including technical information and services. Agricultural technologies specifically designed to improve the efficiency and productivity of the female labour force will thus greatly improve overall agricultural productivity.

There is lack of analytical understanding of the gender inequality. This gap contributes to the continuing inability to influence those agricultural policies, programmes, and policy makers that affect rural women. Science, especially social scientists, must help gender main streaming to fully realize this huge human capital wherewith to combat hunger and poverty.

These paradigm shifts should be comprehensively internalized in national policies on agriculture and agricultural research and technology development. It has been noted by the Economic and Social Council of the United Nations (ECOSOC) in 2004, that most developing countries are unlikely to meet the MDGs without a clear political commitment to making science and technology top priorities in their development agenda; increasing research and technology expenditures to at least 1 per cent of the GDP; strengthening universities, research institutions and developing centres of excellence and incorporating the research and technology development institutions in the various branches of government responsible for coordinating and implementing development strategies. The Council further noted that emphasis ought to be placed in the assimilation of existing knowledge in those areas that address the needs of national development.

4.2 Information and communication technologies

Recent growth in information and communication technologies (ICT) throughout Africa has greatly enhanced the potential to ensure that knowledge and information on relevant technologies and practices are accessible to farmers. The combination of increased production efficiency and new markets made possible by information technology means higher net earnings in the African agricultural sector.

Efforts must be made to strengthen informatics in agriculture by developing new databases, linking national and international databases and adding value to information to facilitate decision-making at various levels. The use of remote-sensing and geographic information systems (GIS) can be expanded to map at micro and macro levels natural and other agricultural resources and increasingly used by components of the agriculture sector. The youth with skills in computer use and information handling, should be attracted to run

technology transfer and advisory services and e-business in agriculture. Rural women should particularly be empowered by their enhanced access to information.

The ECOSOC as well as the inter-agency Commission on Science and Technology for Development (CSTD) both emphasize the need for countries to embrace information and communication technology in support of their development initiatives. This is to ensure smooth flow of information among all stakeholders and enable strong and dynamic links to international science bodies and private sector clientele. FAO has contributed to the application of ICTs to improve linkages between and within agricultural research and extension institutions by the development of the Virtual Extension and Research Communication Network (VERCON) which links institutions with the end users of the information and allows to develop, share, store and retrieve relevant information for improving agricultural productivity and food security.

4.3 Reform of the Research Agendas

The analysis done in the development of the CAADP identifies the need to build, and maintain, scientific capacity building as a long–term initiative. It further identifies four main inter-related research themes for priority action:

1. Integrated Natural Resource Management (INRM);
2. Adaptive management of appropriate germplasm;
3. Development of sustainable market chains;
4. Policies for sustainable agriculture.

Land and water are intimately interrelated and interdependent resources. Research is needed to arrest and even reverse, the degradation and erosion of land, water and biodiversity resources in Africa. Sustained soil fertility and overall soil health are prerequisites to a sustained agricultural production. Soil management technologies in the areas of soil conservation, soil tillage, including zero tillage or conservation tillage, soil-water-nutrient management in an integrated approach need to be refined appropriate to the soil types and the type of farming systems that are practiced. These practices must in the long run ensure restoration of soil quality.

The research on the adaptive management of germplasm aims at developing plant varieties and animal breeds well adapted to the conditions of Africa The research approach will need to be integrated with INRM and incorporate traditional as well as innovative approaches to develop integrated agricultural systems that will be sustainable. Biotechnology can also provide a range of important tools for adaptive management of germplam in African Agriculture. Overall capabilities in plant and animal breeding and biotechnology research need to be strengthened in order to realize the potential of biotechnology.

Most African primary products are traded raw, thus sacrificing income and employment. Greater emphasis will be needed for agro-processing and post-harvest technologies that convert primary products into quality products and add value. It will be necessary to create marketing infrastructures that pay increased attention to food safety and to minimize post-harvest losses.

African countries need to adopt a market-led productivity improvement strategy to strengthen the competitive ability of smallholder farmers. Priority areas include the intensification of

efforts to harness their rich biodiversity to identify specialty commodities, such as off-season varieties and production systems, new crops, and novel varieties and breeds to capture new opportunities. Countries have developed or are developing policies, strategies and programmes on such diversifications.

The research on policies for sustainable agriculture aims at developing policy options and implementation mechanisms to address food security, fair trade, increased incomes, and sustainable practices.

4.4 Investment in Agricultural Research and Technology Development

The efficacy and effectiveness of investment in agricultural sciences, research and technology development is closely linked with the overall investment in agriculture and rural development. Any imbalance between the two will depress the overall performance of the sector as a whole. Investments in agricultural research and technology development had very high rates of return, generally exceeding 30 percent per year and its impact on poverty reduction has been impressive. However, public spending on agricultural research in Africa has fallen from 0.8 percent of agricultural GDP in 1980s to 0.3 percent in 1990s. African governments can demonstrate their political commitment by increasing the expenditures in research and technology to at least 1 percent of GDP, particularly in areas involving the assimilation of existing knowledge that addresses the needs of national development.

Not every country can afford to develop cutting-edge technologies but every country needs a minimum of national capacity to procure, assess, and use the scientific knowledge and technology that address the needs of national development. National as well as international policies on science and technology need to address this critical issue of declining investment in agricultural research and technology development.

The national agricultural research systems (NARS) which include public research institutions, universities, non-governmental organizations, farmers' organizations and private sector together are essential elements of the regional research system. Their subregional organizations and their apex body, the Forum for Agricultural Research in Africa (FARA), are in the process of improving the articulation of all the components needed to foster African's agricultural research and technology dissemination systems as well as to provide a continental perspective.

The Consultative Group for International Agricultural Research (CGIAR), a key contributor to the Green Revolution, in cooperation with NARS, can continue to play a major role. However continued green revolutions will depend on strong programs of national and international public sector research which require sustained, long-term funding.

V. AFRICAN AGRICULTURAL DEVELOPMENT: THE WAY FORWARD

Some of the reasons for Africa's development failures have been mentioned in the preceding sections. There is overall inadequate attention to agriculture, the main engine for Africa's development and avenue for food security and poverty alleviation. If adopted and effectively implemented, the NEPAD CAADP could relatively quickly reverse the problems facing Africa. In endorsing the CAADP at the Maputo Summit of July 2003, the African Union

Heads of State and Governments also committed themselves to allocating 10 percent of their budgets to agriculture. Thus, implementing the CAADP would reflect a renewed central role for agriculture in the development of Africa.

Research and technology is an essential part of the package of measures in the CAADP for revitalizing African agriculture under the following pillars:

- Extending the area under sustainable land use management and reliable water control;
- Improving rural infrastructure and trade-related capacities for market access;
- Increasing food supply and reduce hunger;
- Agriculture research, technology dissemination and adoption.

It is important to stress that although essential for success, agricultural research and technology adoption will become most effective in causing improvement if accompanied by action under the three other pillars. It will be essential to build the capacity for accessing, adapting and disseminating existing practices and technologies for the improvement of soil fertility, small scale irrigation, water harvesting, reduction of post-harvest losses, processing of produce and many other simple technologies which are relevant to achieving food security. The Special Programme of Food Security (SPFS) supports three of the four pillars mentioned above. However, agricultural research, technology dissemination and adoption are to be considered in future expansion plans.

A draft 'Companion Document' has been prepared to integrate livestock, forestry and fisheries to the CAADP. In the livestock subsectors attention would be given to the three major production systems: a) mixed crop livestock; b) pastoral systems; and c) intensive commercial systems. Special attention would also be devoted to strengthening research and extension, specifically for addressing issues related to feed supply, animal health and genetic improvement.

The forestry component focuses on four critical areas: a) improving the policy, legislative and planning frameworks; b) strengthening the institutional structures to better implement policies and legislation; c) increased investment in sustainable forest management and enhancing the availability of goods and services; and d) complementary investment for the development of industries and infrastructures.

The fisheries component focuses priority investments in the following areas: a) fisheries policy and institutional frameworks; b) fishery equipment and infrastructure improvements; and c) development of a vibrant commercial aquaculture.

Africa needs a continued green revolution encompassing all the agricultural subsectors with a long-term horizon and sustained support, mobilization of the regional and international scientific community and an extensive platform of partners to address successfully the enormous challenges ahead.