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THE SCIENTIFIC AND TECHNOLOGICAL PERSPECTIVE FOR THE RECOVERY AND SUSTAINABLE DEVELOPMENT OF AFRICA, WITH PARTICULAR EMPHASIS ON ENVIRONMENTAL ASPECTS

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I. INTRODUCTION

By taking the initiative to call this multi-faceted Conference, marking the United Nations special session on Africa, the Economic Commission for Africa (ECA), the Organization for African Unity (OAU), and the African Development Bank (ADB) are demonstrating not only their awareness of the interrelated character of the development process, but also a genuine desire to link causes with effects in order to identify changes that are necessary to bring about both African recovery and development.

This is reflected in the objectives of the Conference which include:

(a) The critical assessment of the real chances for economic recovery and medium-term development;

(b) The analysis of the required changes in the political, social, institutional, and scientific environment;

(c) The review and assessment of the implementation of the United Nations Programme of Action for African Economic Recovery and Development (UN-PAARED) based on Africa's own Priority Programme for Economic Recovery, 1986-1990 (APPER); and

(d) The re-evaluation of the overall prospects for long-term development in Africa as reflected in the Lagos Plan of Action (LPA).

Those objectives go well beyond the diagnosis of the African situation. In the past, lack of imaginative insights into the complexities of development as an interrelationship between people, resources, and environment, coupled with undeterred rummaging around discredited economic models, brought the continent to the verge of disaster. Even failure did not instil in some of our policy makers and economists an element of humility, and the dismal results are glaringly before us. Those economic policies that did not take account of Africa's social biochemistry, the needs of its most marginalized people, and the characteristics and limitations of its ecosystem were not only limited in their vision, they were also wrong-headed in their approach.

From among those interrelated issues, this paper is to deal with the scientific and technological perspectives emphasizing, in particular, the environmental aspects. This is treated as a sub-theme within the broader theme of the historical, social, political, and scientific environment of economic recovery and development.

Awareness among African policy makers of the importance to development of science and technology application and environmental protection has increasingly sharpened since the 1970s. The place reserved by the Lagos Plan of Action to the application of science and technology to development is unparalleled in any other regional development plan. Not only is the chapter on science and technology application the largest and most elaborate chapter of that plan, references to science and technology application abound in all the sectoral chapters.

On the other hand, consciousness of environmental degradation, particularly following the shuddering agonies caused by the drought of the 1970s, made environment a recurring theme in nearly all African development plans. It took us such agonies to realize, at least intellectually, the fallacy of the stultifying misconception about the marginality of environment in the development process.

But while there was a professed realization of the importance to development of both science and technology and environmental protection that realization was seldom translated into action. Both issues were abundantly intellectualized but scarcely, if ever, internalized. Chapters on science and technology continue to appear in the preambular parts and normative sections of development plans, only to disappear in the operative sections of those plans. Programmes rarely provide for tools of implementation or elaborate policies for the choice, management, and control of scientific and technological application to development.

A similar situation obtains with regard to the environment. Environmental protection agencies were created in many countries, but rarely armed with the tools of action or empowered to influence decisions on fundamental issues pertaining to the environment. They were, in effect, fashionable adjuncts, out of touch with the institutions that really run the economy and often are also the ones responsible for environmental damage.

Economic policy makers failed to appreciate fully the interlocking nature of science and technology, environment and development in their wider social, cultural, and human dimensions. To traditional economists these links were marginal because they failed the cost and benefit test, in the limited pecuniary sense. Thus science and technology application to development was only seen as one of several alternatives, weighed in terms of labour and capital intensity, available to produce a given product in a more efficient and 'economic' way. It was never recognized as an all-embracing process that affects people's cultural traits and attitudes as well as public instiutions and the natural environment.

Equally, environmental issues were viewed as 'externalities', since they have no monetary expression and were not subject to market transactions. This assumption is half-fraudulent if not outright false: economists never account for environmental degradation in figuring the costs of production, nor do they account for the way in which this degradation imperils the potential for future development.

It was precisely because of this gnawing gap in perception (not only in Africa) that the United Nations General Assembly sought to create in the fall of 1983 a Special Commission (later known as the World Commission on Environment and Development) to recommend long-term environmental strategies that would take into account the interrelationship between people, resources, environment and development. This long-term strategy, focused on the year 2000, was to be translated into greater co-operation among developing countries and between countries at different stages of economic and social development leading to the achievement of mutually supportive objectives.

The Commission, in its wisdom, adopted a wider and more liberal interpretation of this mandate for, according to the Commission's report, "the environment does not exist as a sphere separate from human action, ambitions, and needs, and attempts to define it in isolation from human concerns have given the very word 'environmental' a connotation of naivity in some political circles".

This is the context within which this paper aims at approaching the subject of science and technology in Africa. Unescapably, references are made, here and there, to external and internal economic factors that have a direct or indirect impact on the environment. Those factors shall certainly be dealt with more elaborately in other papers presented to the Conference. However, reference to them, far from being meant to pad the report with irrelevances, are necessary if the issue is to be seen within its wider perspective.

SCIENCE AND TECHNOLOGY INTERRELATIONSHIP WITH SUSTAINABLE DEVELOPMENT

1. Sustainable development: the environmental perspectives

Environmental protection is a function of sustainable development. Sustainability means the capacity to continuously grow, and there are no limits to growth except those imposed by the dialectic laws of nature. Such growth cannot be achieved, therefore, without first identifying the conditions required by the ecosystem to endure without giving way. The idea of sustainability was for some time associated with the growth paradigm, and therefore with a purely economic idea of a continuous investment process that permits the economy to permanently expand. But such a mode of growth loses sight of the supply of global resources compared to the growing demand on them by population pressures, higher living standards and the unmet aspirations of newcomers. Emphasis on the acceleration and diversification of material consumption has inevitably put nature under stress; in Africa, the tolerance of the natural system has reached a critical threshold. Sustainable development is only possible if ecological boundaries are not transgressed.

The World Commission on Environment and Development has defined sustainable development as a development that meets the needs of the present without compromising the ability of future generations to meet their own needs. This verdict contains within it two key concepts:

(a) The concept of "needs", in particular the essential needs of the poor, to which overriding priority should be given; and

(b) The concept of limitations to be imposed on patterns of growth, lifestyles, and social organization that curtail the environment's ability to meet present and future needs.

The report of the World Commission on Environment and Development noted that the satisfaction of human needs and aspirations is the major objective of development. "The essential needs of vast numbers of people in developing countries - for food, clothing, shelter, jobs - are not being met, and beyond their basic needs these people have legitimate aspirations for an improved quality of life. A world in which poverty and inequity are endemic will always be prone to ecological disasters."

"Growth by itself is not enough. High levels of productive activity and widespread poverty can coexist, and can endanger the environment. Hence sustainable development requires that societies meet human needs both by increasing productive potential and by ensuring equitable opportunities for all."

When the World Conference on the Human Environment met in Stockholm in 1972, it largely reflected the environmental concerns of the industrialized countries. Greater emphasis was then placed on the need to promulgate laws and to design instruments to deal with environmental problems peculiar to countries that are at a particular stage of development. The real environmental problems of developing countries were only considered to the extent that they were also having an impact on developed countries or because their magnitude was such that concern about them was worldwide in character.

For example, the developed countries were focusing mostly on interdependent environmental phenomena, like air and water pollution, and the movement of hazardous wastes. Though such issues impact on developing countries too, the most urgent environmental problems preoccupying them were rapid deforestation, soil erosion, desertification and the destruction of biological diversity.

The most critical African problems were hardly discussed at Stockholm. The most serious and daunting of those problems is desertification. Albeit a global phenomenon, it was most destructive to Africa, with the Sudano-Sahelian zone suffering the most. Countries in this zone are entirely located in arid and semi-arid regions and shall continue to suffer; indeed they are threatened with extinction, following the pattern of ancient civilizations whose economic base was destroyed if action is not taken. Within the last 50 years, 65 million hectares of once productive lands became desert, and the process is continuing.

Solutions to this problem were not wanting. As early as 1977, the United Nations Environment Programme's Plan of Action to combat desertification provided both the description and the prescription for both the global problem and the African one. The plan is based on a set of 28 interrelated recommendations, including (as far as Africa is concerned) the creation of a green belt both north of the Sahara and south of it, from the Atlantic to the Red Sea, and the exploitation of major aquifers in north-east Africa. The implementation of that Plan is yet to materialize. For lack of the needed funds, the plan stands as testimony to the cynical neglect of the international community in the face of a crisis of such mighty dimensions, a crisis of survival.

The African famine was, in large part, due to this environmental degradation. Famine is not just an African phenomenon nor should it be an inevitability. Great famines of the past occurred in Asia and many African countries were then cited as examples of countries that were able to feed themselves. Today, the situation has changed dramatically. China, India, and Thailand, which once suffered from famine, have become cereal exporters. The experience of these countries, where population was also growing at impressive rates, explodes the stubborn myth that famines are the inevitable result of a crude relationship between rapid population growth and a limited 'natural' carrying capacity of the land.

Survival issues of this magnitude cannot be faced by one country alone, or even by a group of countries, they require an international solution. The inadequancies of present responses convinced the World Commission on Environment and Development that a return to multilateralism is now urgent. "The challenge of reconstruction after the Second World War was the real motivating power behind the establishment of our post-war economic system. The challenge of finding sustainable development patterns ought to provide the impetus - indeed the imperative - for a renewed search for multilateral solutions and a restructured economic system of co-operation."

The African famine is a result of an interplay of internal and external factors. The external factors, for which Africa is blameless, are rooted in past colonial legacies, current patterns of international trade and the way African economies are inverted in the international market. More than 60 per cent of African countries' export earnings comes from cash crops and minerals whose prices have been progressively declining while those of manufactured goods soared. Failure to reach international commodity agreements, indeed to negotiate them, has left the African countries in the cruel grip of the international commodity market. And whatever some ideologues may say about the magic of the market-place and the virtues of free trade, global commerce in those commodities is virtually monopolized by three to six corporations, according to United Nations Conference on Trade and Development. 85-90 per cent in coffee, 85 per cent in cocoa, 90 per cent in forest products, 85-90 per cent in cotton, 60 per cent in sugar, 80 per cent in tea, 70 per cent in bananas, 90 per cent in pineapples, 80-85 per cent in copper, 50-60 per cent in phosphate, and 80-85 per cent in bauxite. This is hardly free trade.

As a result of internationally-imposed unfavourable economic terms, Africa lost more than 20 per cent of the purchasing power of its exports between 1973 and 1983. The ensuing decline in the GNP forced African countries to turn to the international money market, only to be saddled with heavy debt burdens. Debts grew at an annual rate of 22 per cent during the 1970s reaching by the middle of 1986 about $US70 billion - and this only in sub-Saharan Africa. Though the African debt is dwarfed beside the Latin American one, its impact is more ruinous in terms of human suffering and economic pressure. Annual debt repayments represent between 40 to 100 per cent of foreign exchange earnings in the 1980s. The Sudan, for example, would have had to pay 100 per cent of its export earnings in 1985 were it not for debt rescheduling.

Paradoxically, while the impact of the African debt on people and the economy is so devastating, more considerate attention is being paid by the international money market to the Latin American countries, not out of kindness, but because the impact of their debts on the Western banking system is greater. This lack of concern is reflected in the progressive decrease of private capital flow to Africa from the international money market. So while there was a net inflow of about $2 billion in 1980 from private creditors; by 1985, Africa became a net loser of $700 million because of debt repayments, dwindling capital investments and decline in export earnings.

However, there is a mounting awareness of the plight of Africa. For example, the Organization for Economic Co-operation and Development's Ministerial Conference meeting in Paris last May considered ways and means of alleviating the debt burden, 80 per cent of which originates in western countries. According to a plan emerging from that conference, government loans are to be converted into grants and repayment of officially guaranteed export credits are to be rescheduled for repayment within 20 years with an 11-year period of grace. But on the thorny issue of accumulating interests on these debts the Organization for Economic Co-operation and Development countries were divided, with the United Kingdom, Italy, France, and Canada pleading for excusing Africa from paying these accumulated interests, while the United States and Germany disagreed to avoid setting a precedent for other regions.

But while one appreciates all those efforts, Africa's economic crisis remains a deep one. The Programme of Action for African Economic Recovery and Development and the Declaration of African Ministers Responsible for Trade and Development Preparatory to UNCTAD VII have all the ingredients of the action needed by the international community to help Africa overcome its pressing economic problems. To these the World Commission on Environment and Development has added its voice: "The vast misery brought on by the drought in Africa is now generally acknowledged, and the world community has responded with substantial emergency programmes. But emergency food aid is only a short-term reaction and, at best, a partial answer. The roots of the problem lie in national and international policies that have so far prevented African economies from realizing their full potential for economic expansion and thus for erasing poverty and the environmental pressures that it generates."

The internal problems, on the other hand, are no less important, if only because Africans have themselves to blame for them. And if some of us feel that Africa has weathered the worst because of emergency aid or debt rescheduling, they may be grossly mistaken. We still need to gaze inwards into regional disparities and distribution of power and influence within the society. Those regional and class disparities increase social tension which is the antithesis of sustainability. There is an inverse relationship between what African plans say about equity and social justice, and what policy makers do to achieve them. Those plans will count for nothing if they are not coupled with the political will to change course.

2. Science and technology response to and role in sustainable development

Socio-economic development depends on the transformation and exploitation of the natural system by society. One of the most powerful social instruments for the utilization of nature and the fostering development is science and technology. Nowadays, the major global issues are at the interface of social and natural systems and are characterized by a strong scientific and technological dimension.

But science and technology cannot be developed in a vacuum, they are not a realm of their own. They are the link between humans and nature. And to make them more responsive to sustainable development, they have to have a new orientation, particularly in the developing world. For our capacity for technological innovation should be greatly enhanced so that it can respond more effectively to the challenge of sustainable development. Also, the orientation of technology development must be changed to pay greater attention to environmental factors.

In this perspective, one of the most striking features of underdevelopment is technological backwardness. A large population in the developing countries still depends on technologies that are incapable of generating levels of income to meet even the most elemental basic needs. These technologies often are also inadequate to transform, without destroying, the natural environment. Moreover, their productive capacity is so low that significant steps cannot be made towards increasing output and improving utilization of the natural environment until they are replaced.

Scientific and technological knowledge and application are necessary if we are to avoid the continuous disruption of the natural system. Although even resource-rich and lightly populated countries may suffer serious environmental disturbance, a shortage of natural resources need not in itself lead to environmental pressure. This can be avoided if technological capabilities appropriate to the environmental conditions of the particular region are introduced.

Science and technology are global phenomena, but their integration in the production process differs between developed and developing world. In the former, such an integration takes place through close linkages with the productive sector, which orient and provide resources for research and development and, finally 'consume' the resulting innovation. The research and development integration with the productive activity frequently reduces the time lag between the research phase and the commercial production of innovations, hence accelerating the diffusion phase.

Technology became a commercial good in itself, and as a result, an object of specialization, used by developed countries to retain their influence over raw material sources of production and, in general, over the economic activities of the developing world. This influence has been strengthened by the concentration and monopolization of applied research and technological development, leading to the perpetuation of the dependency of the developing world.

In developing countries, on the contrary, the links between the scientific and technological sectors are very weak, while those between research and development activities and the productive system are almost non-existent. Developing countries imitate, if anything, the organization, structure, purposes and methods of the research and development activities of the developed world, while their scientists and technicians consider themselves as members of the world community of scientists, with loyalties and responsibilities to that community rather than to the home base. Inevitably the developing countries are precluded from establishing a scientific and technological base linked to their productive activity and conscious of the constraints and potentialities of its natural environment. Scientific institutions consequently become isolated from their socio-economic, cultural, and natural environment and unresponsive to the urgent needs and problems of the population. In the process of penetration by 'modern' technology, the indigenous technological structure is typically abandoned, if not threatened with outright extinction.

Developing countries have thus become consumers of an imported technology which they have done nothing to generate. The assumption is that the absorption of foreign technology can raise the socio-economic system towards higher levels of development. This indiscriminate and uncritical acquisition of alien technology has led to increasing dependency, for the mere assimilation of technology implies the acceptance of a linear concept of development and suggests that the stages that have characterized the development of industrialized countries would have to be replicated in developing countries.

From the environmental perspective, there are additional implications. Modern industrialized societies have developed technologies in accordance with their own peculiar characteristics, their natural and human resources endowment, their historical development, and the interrelationships between their resources, capital and environment. Critical economic analysis informs that these technologies are not well adapted to the circumstances of developing countries, but rather to conditions of labour scarcities, capital abundance, and large markets which permit the exploitation of scale economies leading to a reduction of cost per unit of production.

3. Problems of uncritical transfer of technology: examples from agriculture

With particular reference to Africa, one may single out one specific activity in this field, namely agriculture. Northern agricultural technologies are developed for temperate regions, while Africa is mainly tropical.

This aspect deserves a more detailed examination, if only because the Lagos Plan of Action has underlined the importance of agriculture to African development and the need to increase productivity in food through the application of science and technology. The Plan called on member States to "direct their efforts for spelling out a strategy for development, which should guide their thinking, planning, and action on bringing about socio-economic changes necessary for improving the quality of life of the majority of the people. This objective requires them to invest in science and technology resources for raising African standard of living and for relieving misery in the rural areas..." The Plan goes on to say that more attention should "...be paid to the role of science and technology in integrated rural development". This would require, among other things, "the generation of financial resources and political will and courage on the part of the policy and decision makers of the continent to induce profound change with far-reaching effects on the use of science and technology as the basis of socio-economic development as a matter of the utmost importance and urgency at this fateful juncture in history". No plan could be more explicit on this issue.

Tropical climates affects over 75 per cent of the African continent, the only regions beyond the tropics are the mediterranean countries in the North and South Africa, Lesotho, and Swaziland in the extreme south. The basic difference between temperate and the tropical regions is that in the former temperature mainly determines the potential and constraints of the natural system, while in the tropics the fundamental factor is rainfall variations. Thus in temperate areas temperature determines the emergence of four well-defined seasons, while in the tropical regions, the frequently erratic rainfall determines two types of seasons: the wet and the dry. However, it would be a gross over-simplification to think that all tropical areas have the same features, since one encounters different types of tropical climate, depending on rainfall patterns and their interrelationship with the ecological conditions of each area, for example soil, altitude, etc.

Roughly one may identify several climatic zones in tropical Africa: the wet equatorial zone distinguished by constant heat, rainfall, and humidity; the dry tropical zone close to the tropics of Cancer and Capricorn, with a hot arid climate and scarce and erratic rainfall affecting rainfed agriculture. A third zone occupies a middle ground between these two, characterized by an alternating climate, the wet season when the sun is overhead and the dry season when the sun is lower. The Congo basin, the north coast of the Gulf of Guinea in West Africa, and the coastal areas of East Africa (Kenya and Tanzania) are examples of the first zone, Mauritania, Mali, Niger, Chad, and northern Sudan of the second, while inland Kenya and Tanzania, and southern Sudan are examples of the third.

Within this rough picture there are other variations, for example, the subtropical highlands (over 5,000 feet) that exist in Ethiopia and Central and Western Kenya. In these areas, the altitude introduces changes in the climate with temperatures generally dropping at higher levels, resulting in a reduction of evaporation and humidity. All these climatic aspects interrelate with ecological characteristics, in particular soils that provide specific environmental potentialities and impose certain constraints.

The characteristics of soils in African tropical areas also are different from those in temperate regions, not only because the nutrients in the latter are accumulated in a thick layer of humus, while in the tropical areas there is a rapid circulation of nutrients through vegetation, also their physical, chemical, and structural characteristics are different. Tropical soils frequently have high content of alumina. The rapid circulation of nutrients and the rapid decomposition of organic matter due to an all-year high temperature results in poor nutrient content and little organic material. Besides, the leaching of nutrients leaves in many places a reddish clay rich in oxides of iron and hydroxide of aluminium which makes the soil unsuitable for agriculture.

Soils in the tropics also need to be protected from both extreme heat and torrential rain that falls after the dry season. Extreme heat increases soil temperature and accelerates oxidation, while torrential rain washes away the thin humus layer, leaches out nutrients, and seals off the underlying soil from the air.

On the other hand, the structural characteristics of temperate soils permit them to accumulate water and since the temperature is moderate, there is little evaporation; the soil continues to have a reserve of moisture for the growing season. In the tropical areas not only does rain fall during short periods, also high temperatures also produce elevated rates of evaporation. So torrential rains, reduced soil capacity for water retention and high temperatures directly result in considerable water waste.

A large part of the African tropical lands are unreclaimed acid soils or are only used for extensive traditional agriculture and animal grazing with minimum inputs and thus low fertility. Traditionally, those areas are used for cultivation of crops that are soil acidity-tolerant and can adapt to low phosphorous content, like cassava which constitutes one of the most important African food crops.

Another important difference is solar radiation which has an important role in photosynthesis. In the temperate regions of the north, solar radiation is less in winter and more in summer when days are longer. In tropical areas, and particularly near the equator, the day length is more or less the same all the year round. So solar radiation in temperate regions is higher in summer when it is most needed for the ripening season thus having an important effect on productivity. Yields per crop for this reason, tend to be higher in temperate areas, albeit the yield per day is frequently higher in the tropics than in temperate regions.

Differences between tropical and temperate regions are not only limited to climatology and soil structures, they also extend to biological diversity. Biological diversity is significantly greater in tropical areas. A recent estimation of the United States National Research Council (NRC) indicates that the number of species of organisms in the tropics is twice the number of those existing in temperate areas. However, only 17 per cent of tropical organisms have been studied or identified for taxonomic purposes: this diversity offers, from the point of view of development, great potential, but it also poses some problems.

The problems arise from the fact that this enormous diversity is rampant with noxious species like weeds and pathogenes. Dr. Swaminathan reported that rice in tropical areas is facing between 500 and 600 diseases while in temperate areas it encounters not more than 54; in the case of corn the relation is 125 to only 85; in beans between 250 and 280 to only 52 in temperate areas; and for 278 diseases that tomatoes face in tropical areas they face only 32 in temperate climates. This factor alone represents a limitation on agricultural expansion and poses a challenge to our scientists.

All those reflections have implications for science and technology policies in Africa. One important implication is that the natural systems of the Continent, particularly in the tropics, are yet to be discovered, a large part of the available knowledge about these systems has been developed in order to satisfy the demands of the world market rather than local needs. The potential for research in this area is enormous and untapped. A second implication is that agricultural technologies and practices developed in temperate areas cannot be directly duplicated or indiscriminately copied. In other words, uncritical transfer of technology in agriculture is likely to fail or, at least, not reproduce the same good results in productivity.

This is probably why indiscriminate technology transfers have failed to make substantial impact in the developing countries' agricultural systems. The catalogue of such failures in African agriculture is appalling. As early as the 1940s, the British peanut scheme in Tanganyika was one of the most spectacular failures: 1.2 million hectares of land were allocated to a giant peanut scheme. The area did not get the needed amount of water. After 10 years, the area was eroded, turning, in the dry season, into a cement-hard desert. The cost of that project was £35 million. In this case, planners never considered the recurrent low rainfall and the low water-holding capacity of the soil.

A more recent example from Tanzania is the Hanang wheat project, which cost the Canadian and Tanzanian governments more than $US 80 million but provided jobs for only 250 Tanzanians and resulted in accelerated erosion because of heavy mechanization. And it displaced Barbaig pastoralists to poor areas that became rapidly overgrazed, thus deepening the environmental degradation.

An example from West Africa is the Sefo scheme in southern Senegal, which ignored the environmental impact of large-scale mechanical clearing which resulted in high rates of soil erosion, crop loss, and the eventual failure of the project.

Another scheme that failed is the Mopti rice project developed in the delta of the Niger in the Mopti region of Mali during the 1970s. The great variations of rainfall were not considered, so by October 1984 rice was only harvested in 10 per cent of the area because of the strong unimpeded flow of the river.

Also in the Ejura farms maize project in Ghana, the best northern technology was applied: improved varieties, mechanization, fertilizers, pest control, post harvest storage, etc. Yet the yields remained well below those expected while costs were higher than planned. An interrelated web of neglected environmental factors explained the failure: heavy mechanized clearing left large areas of soil too much exposed, leading to accelerated erosion. Faced by all these difficulties from the start the project was condemned to failure.

The Gezira scheme in my own country, the Sudan, is yet another example of a development that went awry because it ignored environmental considerations. The Gezira is an intensive agricultural scheme which started with good results, creating high hopes only to be dashed afterwards. The scheme heavily depended, for long, on chemical fertilizers and pesticides which resulted in increasing soil debility, chemical contamination and hazards to humans and animals. The government of Sudan, like any other government, was faced with the paradox of choosing between short-term gain, i.e. increasing production, and the long-term loss reflected in environmental collapse. But not only is that collapse no longer an eventuality, even the short-term gain has become a fallacy. With all those inputs tied to international market trends and foreign currency availability, cultivation schedules were seldom met and the project suffered accordingly.

Serious attempts are being made, with the help of World Bank financing to rehabilitate the Gezira scheme from scratch but sadly the same over-dependence on imported inputs persists, the only saving grace in this rehabilitation effort is the limited action initiated by FAO to introduce into the scheme elements of biological control and organic fertilization.

III. SCIENCE AND TECHNOLOGY AND SUSTAINABLE DEVELOPMENT: THE LONG-TERM PERSPECTIVE

Sustainable development, science and technology, and the environment have an important element in common: the long-term perspective. Sustainability cannot be achieved by short-term policies oblivious to the future. It requires an analysis that will anticipate the immediate impact of present policies as well as their long-term implications. Environmental phenomena often mature slowly. The effects of today's actions over the natural environment may only surface in the medium or the long term. This poses a challenge to economists who think in terms of short-term gains. Similarly, the recovery of deteriorated ecological systems is a task that requires long periods of time, constant monitoring and permanent and flexible planning and management.

Science and technology is also an activity in which the long-term horizon predominates. The large time-frame is needed for an invention to become accepted and for technological innovation to be diffused. It is also required for technological systems to go through their life cycles; significant effects on nature and society may result from technologically-induced modifications requiring long-term maturation.

The implications of all those considerations are manifold; they derive not only from the inherent nature of the questions at issue but also from the objectives of this conference: recovery and sustainable development. Recovery implies actions to solve immediate and urgent needs of Africa, particularly halting the deterioration of the natural environment. This requires short-term actions that would generate immediate positive results. Development, per contra, implies a look over a larger horizon and requires different policies. But in both cases scientific and technological policies must be adopted.

The task is complex and the Catch-22 of this situation is how to solve today's urgent problems without jeopardizing long-term development. But neither should the solution of today's urgent needs of the large part of African people be jeopardized by favouring long-term development. Need they be in conflict?

From a scientific and technological perspective, Africa must rely for solving its present problems on the available array of technologies and existing institutions and mechanisms. There is no time for the development of innovations, nor for instant modifications of the present institutional setting. Innovations in, and diffusion of, new technologies is costly and time consuming, and with uncertain results. Institutional changes also take time to materialize, especially when change is hindered by those who are concerned more with turf than with societal progress.

The question, therefore, is how to choose from the available set of technologies, the ones that can contribute most to the solution of today's problems without creating rigidities that would impede the adoption of emerging new technologies. This applies particularly to the use of emerging technologies.

In this connection African scientists are faced with the responsibility of assessing the potentialities of those emerging technologies not only to ascertain their applicability to the African condition but also to ensure participation in the process of their development. Scientists must find answers to questions such as what institutional arrangements are necessary for handling those emerging technologies? What type of human resources are required? And what are the economic implications of their incorporation in the development process?

In recent years the idea that mankind is at the turning point of a new technological revolution similar to the industrial revolution has gained more and more adepts. The basic characteristic of this revolution is that it is information and scientific intensive. This characteristic implies a drastic modification in the present prevalent technological pattern.

The informatics revolution is no longer science fiction, it is a present day reality with a direct impact on the lives of our citizens in its two forms: computer and telecommunication technologies. However, its development and application is largely concentrated in the industrialized world and grows at the rate of 20 per cent annually.

In a recent seminar organized by the North-South Roundtable of the Society for International Development (SID) at Scheveningen in the Netherlands (September 1985) attended by the best available talents in the trade both from the North and the South, the seminarists concluded that the primary and urgent need is 'to ensure that developing countries have full access to knowledge of the rapid changes taking place in the information technologies and their applications so that they may develop the capacity to evaluate the implications of these changes'. One area where action is immediately needed and where the impact will be greatest is the development of human resources. The informatics revolution requires a quantum change in each country's education and training systems; and paradoxically, it also helps to facilitate those changes.'

Emerging technologies, it is assumed, will have great impact on the development of the Third World, in particular those related with informatics, microelectronics, and biotechnologies. It is often contended, in support of this assumption, that many of the newly emerging technologies are "natural-resource-augmenting", meaning that they help expand supply of natural resources that can be exploited for economic purposes, particularly those needed for the satisfaction of urgent basic needs. It is also contended that many of the new technologies do not require huge capital investment, and in fact that they can develop in decentralized systems, thus facilitating the process of rural development.

One additional advantage of the new technologies is that they are not necessarily energy-intensive, and in particular not oil-intensive. They are material-saving and because their reduced wastes permit a more integral use of raw materials, they have their positive environmental impact.

Equally, emerging technologies, it is maintained, can be applied for the revitalization and upgrading of vernacular or traditional technology and therefore can be assimilated by the population without major cultural conflicts. This suggests that a policy oriented to the merging of new and traditional technology would help avoid the negative aspects of the technological dualism that has so far characterized transfer of technology from the industrialized to developing countries.

The idea of technological blending, or merging of new and traditional technologies, implies a completely different approach to technology policy and planning. The objective should no longer be "bridging the gap" between technological advanced areas and those presumed to be backward. It also would not require a long process of socio-economic adjustment and change.

In effect, the concept of merging implies the possibility of a technological "jump" in which it would be possible to benefit from the advantages of new technologies without having first to undergo fundamental investment in technological infrastructure, as it was necessary with the exclusively imported technologies.

The revailing concept of importation condemns the developing countries to perpetual backwardness. If we persist in that classical approach "...Our future shall always be the past of others" according to a renowned African historian.

Africa, and the developing world in general, are indeed in the horns of a dilemma. For, to quote another distinguished African scientist (Edward Ayensu), "the economics of the 20th century industrial development have placed the Third World in a double bind. It is suggested that a double bind is always such that it cannot be resolved on its own terms. The way out is to escape from its terms. For the Third World information technology provides that escape."

IV. THE INSTITUTIONAL FRAMEWORK FOR SCIENTIFIC AND TECHNOLOGICAL POLICY IN AFRICA

To master the application of technology to the identified priority areas for recovery and sustainable development, African countries will have to reorganize their human and material resources, reorient their policies and modify their institutions. The ingredients of this reorganization and reorientation are to be found in the African economic development master plan, the Lagos Plan of Action.

More specifically, scientific development and technological application depend upon a functional interrelationship among three social sub-systems. The first is the government which synthesizes the goals of society and has the responsibility to establish priorities and to allocate resources to achieve those goals. The second is the scientific and technological infrastructure made up of research institutions, the scientific community, the educational system and institutions created for extension purposes and for the diffusion of science and technology among the populace. Financial mechanisms and allocation of resources for research and development and the diffusion of science and technology are part of this process. The third is the productive sector which is in fact the most important user of the products of science and technology.

While the government has the responsibility to catalyse the development of science and technology and promote and facilitate their application in accordance with the objectives of development, the scientific and technological infrastructure should provide society with the capacity to create, adopt, adapt and transmit knowledge. The productive sector, both public and private, has also an important role to play in the scientific and technological development directly through their participation in, or support of, research and development activities undertaken by governmental institutions, universities and research centres. Interaction among those three sub-systems is a pre-requisite if science and technology is to become a dynamic factor in development.

Several elements can be identified in this science and technology infrastructure:

(a) The educational system responsible for the production of the human resources needed in terms of quantity and quality;

(b) The quality of research and researchers, and the adequacy of research centres located in the universities, government departments and the productive sector;

(c) The co-ordination and planning of science and technology and the administrative and financial tools needed for the implementation and management of science and technology activities;

(d) The extension system that would carry the results of science and technology to those who need it most, the rural people and the marginalized sectors of society like women.

The situation in Africa in relation to all these elements gives something to ponder. To begin with, the educational system is hardly oriented to the production of a science and technology linked to the environment or developmental purposes. One important task, therefore, is to integrate education into the overall planning of science and technology.

However, this task should be balanced with the most urgent one of reducing illiteracy and educational marginality. And in promoting literacy, particularly in the rural areas, efforts should be focused on issues like efficient land use, water management, and protection of forests. Special attention in this regard should be given to women whose access to education is still woefully inadequate.

Also education barely takes stock of environmental considerations. Basic scientific knowledge is often non-existent in the lower grades of education. At higher levels, education is class-room bound with very little exposure to the field.

To this end the educational system must be restructured, diversified and decentralized. Basic sciences, particularly biology, should be extended to even primary levels. The young should know their environment and its fauna and flora. They should know, from young age, how to husband and protect it. In higher institutions, students must have the right orientation towards community needs and local people, particularly in rural areas. Both students and scientists can learn from traditional farmers who are more conversant with the local environment. Curricular also should be indigenized for, despite all our claims of cultural authenticity, they are, in the large part, still modelled on western systems and fail to reflect local realities.

The most important weakness, however, appears to be in the planning, administration and financial mechanisms entrusted with the design and management of science and technology. The adoption of a national policy for science and technology requires an awareness of the pervasive nature of science, which includes non-economic variables like education. The interrelationship between education and science and technology development is not recognizable in economic plans, education always falls by the wayside when it comes to the allocation of resources. It also requires the creation of organs specifically empowered to carry out and control such policy. The work of those organs must be co-ordinated with other institutions responsible for development policy. It must be permanently able and ready to advise policy makers and planners on matters relating to science and technology. Many African countries have national bodies responsible for research in science and technology, but many of them are not integrated in the overall planning process.

The scientific community itself, largely a product of the type of education just outlined, falls victim to the inherent limitations of that system. It is a sad commentary on our system of education that, in a continent suffering from famine, graduates of agricultural colleges remain unemployed and governments and private institutions feel that they can do without them. Because of their often irrelevant training and lack of exposure to the traditional community there is no common language between those graduates and the traditional communities nor are they able to develop in situ technologies appropriate to those communities.

But let us not blame the victims, this situation is a reflection of the obtuseness of the policies of those same governments. It is no wonder, therefore, that many of Africa's scientists feel more comfortable in foreign institutes, on whose models of education they were trained, than they do in their own homeland.

But the lack of dialogue is not only between the scientific community and the local population; there is also an absence of dialogue between the scientific community and policy-makers scientists trained in the western liberal tradition are generally reluctant to be involved in the political process. There is also a widespread opinion among them that science and technology should be free from any intervention and not be subordinated to any political or economic priorities. Scientists, particularly some of the ivory-tower-dwellers of academia, often seek to assume a dominant role, not only in the management and quality control of science and technology application (which is fair), but also in the planning and setting of priorities for such application, which is the domain reserved for policy makers, who are, supposedly, mandated by, and accountable to, the general public.

In the productive sector, one of the most striking characteristics has been the emphasis on the process of linear transfer of technology, and we have alluded to examples of this in agriculture. The industrialization process based on import substitution is no better. In a great measure it is associated with strong economic protectionism from foreign competition which contributes to the creation of a local entrepreneurship that is not concerned with improving productive capacity and efficiency through local research and development. The situation is aggravated where governmental policies grant almost unconditional terms for importing technology in the form of patents, equipment, semi-finished products, technical personnel and consultants.

All these factors undermine confidence in the internal capacity to supply technology, hence weakening even more the already extremely fragile links between the science and technology system and the productive system. This process is not helped by the attitude of foreign industries, particularly transnational corporations, who have their own sources of know-how and technology to draw upon. Developing indigenous capacities is simply not one of their priorities.

However, one of the greatest inadequacies in our science and technology infrastructure is the shortage in intermediate skills, the indispensable link between the scientists and the end-user in the field. Not only is Africa's grand design for a science and technology revolution threatened, even our modest goals for self-sufficiency in food production cannot be achieved without paying attention to this miserably neglected field. No agricultural development can be achieved without those who maintain pumps and agricultural machinery, guide farmers in the use of agricultural inputs and diffuse knowledge to the local community on the use of seeds, animal breeding, cropping, etc. Here again, heed should be given to women whose contribution to food production reaches up to 73 per cent in some African countries, they should have access to training in intermediate skills be trained and be more involved in extension work.

V. SCIENCE, TECHNOLOGY AND ENVIRONMENTAL ELEMENTS IN THE LAGOS PLAN OF ACTION AND THE UNITED NATIONS PROGRAMME OF ACTION FOR AFRICAN ECONOMIC RECOVERY AND DEVELOPMENT, 1986-1990

Having sketched all those stark realities, what are the perspectives of African recovery and long-term sustainable development, particularly within the framework of the Lagos Plan of Action and the United Nations Programme of Action for African Economic Recovery and Development?

The Lagos Plan of Action, based on the Monrovia Declaration, is a long-term plan for all Africa up to the year 2000, which is already staring us in the face. Its fundamental objective is to establish self-sustained development based on collective self-reliance. The United Nations Programme of Action for African Economic Recovery and Development is a short-term programme to overcome the most serious effects of the economic crisis in Africa aggravated by environmental deterioration, inadaptable structures and negative international economic trends reflected in deteriorating terms of trade and increasing external debt.

So, while the Monrovia strategy and the Lagos Plan of Action are based on Africa's own effort, without neglecting the extremely important influence of interdependence with the world economy, the United Nations Programme of Action for African Economic Recovery and Development is basically an international effort calling for immediate action by all member States of the United Nations and full participation of all the organizations within its system.

The different purposes of both programmes call for different policy instruments. The United Nations Programme of Action for African Economic Recovery and Development should only be considered as a complementary effort to the implementation of the Lagos Plan of Action which, alone, defines the basic strategy for the long-term sustainable development of Africa. The economic, social, and environmental crisis Africa is experiencing in fact jeopardizes the possibilities to implement the Lagos Plan of Action.

Cognizant of those fundamental differences, it is also important to keep in mind that the promotion of science and technology is <u>explicit</u> and represents an essential ingredient of the Lagos Plan of Action. While references to science and technology are rather marginal in the United Nations Programme of Action for African Economic Recovery and Development. They are <u>implicit</u> in the recommended actions (e.g. development of capacity for the utilization of resources of energy and the like) or very specific in character (creation of a network of agronomical research stations).

So whereas the Lagos Plan of Action sets about to revolutionize traditional concepts of science and technology policy application to Africa, the United Nations Programme of Action for African Economic Recovery and Development remains bound to the traditional approach, both in terms of <u>implicit</u> science and technology policy as well as the relevance it attributes to the transfer of technology, and the role it assigns to international assistance. The Lagos Plan of Action also proposes a strategy to produce structural and drastic modifications of scientific and technological patterns in Africa oriented to the reduction of technological dependency (for this is what self-reliance is all about), but these aspects are, understandably, missing in the United Nations Programme of Action for African Economic Recovery and Development, given its limited horizon.

In the long term, science and technology development is not only a necessary condition for raising productivity, creating new employment opportunities and increasing incomes, it is an invevitable process. But what is yet to be adequately recognized is that technological change should be guided by well formulated and consistent policies closely linked with development policy, and be well adapted to environmental conditions. The latter aspect is of paramount importance for several reasons: Africa will remain a predominantly rural region for at least the next 20 years, and its most critical problems today are associated with food production and the rational use of the natural system.

The Lagos Plan of Action amply recognizes this. It emphasizes agricultural priorities and the need for integrated rural development in order to achieve food security, increase agricultural productivity, arrest rural to urban drift and improve living conditions, particularly in the rural areas. Agricultural sustainable development and consequently rural development, is only possible to the extent that the natural base is preserved and enhanced. The United Nations Programme of Action for African Economic Recovery and Development also states this view.

However, while both plans are conscious of the environmental aspects of development, the United Nations Programme of Action for African Economic Recovery and Development, due to its specific short-term and emergency character only focuses on those environmental issues that are at the basis of the immediate African crisis. Some of those issues, such as desertification, deforestation, restoring arable land and developing a capacity for the utilization of renewable sources of energy, especially biomass, require a long-term approach. At the same time, they need immediate action to stop the serious process of environmental deterioration that is undermining the natural base of development.

The fundamental difference between the Lagos Plan of Action and United Nations Programme of Action for African Economic Recovery and Development, therefore, derives from their objectives and characteristics. The Lagos Plan of Action is based on an integrated approach covering different economic, social and environmental dimensions, and takes into account their mutual interdependence. By its very nature such a process can only be envisaged over a wide time span. The United Nations Programme of Action for African Economic Recovery and Development, on the other hand, is short-term oriented and basically a problem-solving programme.

Also the Lagos Plan of Action is structured round the internal effort of African countries and is, therefore, coherent with the principle of self-reliance and oriented to the reinforcement of this aspect of the African development process. Conversely, United Nations Programme of Action for African Economic Recovery and Development is basically an international effort to permit Africa to overcome the critical situation of the 1980s. This is mostly reflected in the approaches of both plans to science and technology application.

Whereas the Lagos Plan of Action pleads in favour of an explicit indigenous scientific and technological policy adequately integrated in national economic development plans, the United Nations Programme of Action for African Economic Recovery and Development is rooted in the traditional approach based on the implicit scientific and technological policy. In this approach science and technology elements are not spelled out and they are dependent on indirect economic policies. And for this reason, there is an imminent risk that the United Nations Programme of Action for African Economic Recovery and Development may reinforce traditional and technological patterns, thus conflicting with the purposes of the Lagos Plan of Action. This risk is to be avoided, and it is in this context that the scientific and technological aspect of African recovery and development plans should be examined.

For a long time, traditional agricultural policies have been largely based on the idea that increasing agricultural productivity is possible by accelerating diffusion of "modern" technologies developed in the North. With this understanding, a top-down approach was adopted based on the unrealized expectations of the trickle down effect theory. Technologies, originating in the temperate regions of the North, were oriented to the obtention of economies of scale. But when transferred to African rural areas they tended to by-pass the main producers: the small scale farmer. Given the importance of small-scale producers in African agriculture and the fact that the vast majority of African population is rural, while most cultivation is done by women, policies should be geared to stimulating those technologies that can best be used by small producers in order to increase productivity in small agricultural units.

Furthermore, adopted northern technologies have ignored the characteristics of local climate, ecology and resource endowments, an aspect largely commented on in section 3 of this paper. The main instruments of those technological policies have been orthodox short-term economic measures invoking price-fixing, subsidies, tax concessions, overvalued exchange rates, etc. In effect, those policies encouraged the transfer of inappropriate technologies and favoured large producers against small ones, high technology over appropriate intermediate-stage technology, and urban consumers over rural producers.

The shortcomings of those policies were accentuated by the absence of complementary policies to maximize the effect of technology development and application, such as physical infrastructure, research institutes, and appropriate diffusion and extension programmes. It is no surprise, therefore, that the impact of those policies in the agricultural sector have been very meagre, sometimes negative. Productivity remained in general very low, and where it increased it was not matched by increases in employment and income. Moreover, the indiscriminate use of poorly assessed technologies has damaged the environment, in some cases irreversibly, hence increasing insecurity and deterioration of the natural base for development.

Despite these experiences, the same policies are recommended in the United Nations Programme of Action for African Economic Recovery and Development. This includes measures like: intensive mechanization and increased use of chemical inputs, without guarding against the ill-effects of those measures. The programme emphasized the need to establish assistance programmes to small farmers "especially women", placing at their disposal necessary input for increased yields, without indication as to how this should be done, particularly in light of the inadequacies of the educational and extension systems. Consequently, the risk exists that the same inappropriate technological measures will be used. In short, there is a gap between some of the policy statements and the existing mechanisms for their implementation, while there are contradictions between the long-term goals and the short-term policies.

There is, therefore, an urgent need for action in two directions. Firstly, efforts should be made to co-ordinate the short-term with the long-term policies. Secondly, available technologies offered by the world market should be evaluated to identify the ones that are best suited to the solution of Africa's immediate problems without hampering the long-term goal of sustainable development.

VI. SCIENCE AND TECHNOLOGY AND AFRICAN DEVELOPMENT

Both the Lagos Plan of Action as well as the United Nations Programme of Action for African Economic Recovery and Development recognize that the priority area for technology development in Africa is agriculture, for that is where developmental and environmental pressures are most obvious. Earlier we questioned whether agricultural technologies developed in the industrialized countries of the North were invariably applicable in Africa. Two important implications ensue: first, the need for development of an indigenous agricultural technology, and second, the realization of the potential of South-South co-operation in this regard. Historically, agricultural productivity has only advanced when there was substantial indigenous agricultural research and extension.

Developing indigenous technology cannot be done in isolation from technological development elsewhere. The problem here is not catching up with the advanced countries; rather it is managing ethno-science with modern science. Science and technology policies in Africa should strive to strike a balance between indigenous technological development and imported technnology. Our aim should be the achievement of a technological pluralism in which foreign technology (including frontier technologies) can be utilized side by side with traditional technologies.

African scientists and policy makers should get over the myth of catching up with the advanced countries in science and technology. As Amiya Bagchi notes, countries which respond with a fixed lag to changes taking place abroad can never really "catch up" with new frontier technologies. With the exception of Japan, most countries, including Western Europe, have often fallen further behind, at some state, because they failed to preceive correctly the direction of technical change.

Africa should also strive to take part in the development and application of new frontier technologies. Increasing efforts in those technologies are now undertaken by some developed countries in order to redefine international competition and achieve comparative advantages. But these efforts are no longer limited to developed countries; several Third World countries have undertaken aggressive policies to participate in the development of those technologies, e.g. Brazil, particularly with a view to increasing productivity and reducing costs in export-oriented activites in order to retain old, or capture new, markets. This is true even in traditional sectors like textiles and leather which are, of late, reactivated in industrialized countries.

African countries cannot remain indifferent to all this revolution and remain passive importers of technologies. They have to be active participants in its development in order to benefit from 'learning by doing' and reducing, in the process, their technological dependency. The merging of new technology with conventional and traditional technologies is an approach that could permit both a quantitative and qualitative jump by-passing, in some cases, intermediate steps.

This approach is also necessary for integrating Africa's immediate problems: "urgent recovery", and long-term goal: self-reliant sustainable development. The short-term goal shall thus be combined with the long-term strategy. Merging of frontier technologies with traditional ones is not only desirable, it is also possible, particularly in the fields of agriculture and food production.

This can be illustrated with few examples. The United Nations Programme of Action for African Economic Recovery and Development recommends increasing use of fertilizers and chemical pesticides to improve productivity and raise production in agriculture. Obviously there are immediate results that would be achieved by these methods. However, those methods are energy intensive and additional reliance on imported energy sources would create a new dependency.

Intensification of agriculture and maximization of crop yields cannot be overemphasized in the light of the increasing demand for food, animal fodder, and edible oils. Modern farming in Western affluent economies achieves high crop yields by sound agronomical practices, including the judicious use of fertilizers, herbicides, insecticides, fungicides, and plant growth factors. So the enhancement of crop productivity, evidently, requires the increasing use of those inputs. During 1974-1976, Africa received 948,000 tonnes of fertilizer (NPK) and according to FAO scenarios for the year 2000, the requirement will be of the order of 4,083,000 to 5,611,100 tonnes. This increasing use, in the light of the current African condition, imposes a heavy burden on the scarce foreign currencies available to African countries.

One of the frontier technologies that recommends itself in this regard is biotechnology. The impressively rapid development in biotechnology over the past few years has made available a whole battery of totally new techniques for the plant breeder and agronomist to manipulate. The application of those innovative techniques, given their rapid results as compared to conventional farming methods, holds particular promise for the food starved population of Africa. Biotechnology would immensely contribute to the improvement of soil productivity through genetic engineering either by incorporating nitrogen fixing genes, or by the innoculation of nitrogen fixing agents. In many crops, yield is largely governed by the availability of nitrogen. Conventional farming resorts to supplementing the soil with vast amounts of nitrogen, phosphate, and potassium fertilizers. But the drawbacks of those practices are by now common, e.g. pollution and biologically disruptive effects on the environment, not to mention prohibitive costs.

Not all plants, however, require extraneous macro-minerals to satisfy their metabolic needs, some having naturally evolved the capacity of symbiotic association with specific micro-organisms, highly efficient in their capacity for fixing atmospheric nitrogen. The most biologically significant of these mutually beneficial symbiotic associations is that between legumes and the nitrogen fixing bacterium, rhizobium, which inhabits nodules along their root system. It has been calculated that less than a kilogramme of high-quality innoculant, when properly applied, can replace more than 100 kg of fertilizer nitrogen per hectare and therefore can save large amounts of foreign currency.

Besides rhizobium, the most important nitrogen fixing agents are the free-living blue algae; the blue-green algae (BGA) anabaena, and the symbiosis of BGA with the water fern azolla. Blue-green algae can contribute up to 77 kg/n/ha per cropping season when it is fixing nitrogen under non-symbiotic conditions; in symboisis with azolla, the biological nitrogen fixation can be up to 425 kg/n/ha/100 days.

In addition, BGAs can operate in a wide variety of conditions with temperatures ranging from $0^{o}C$ to $60^{o}C$, including desert regions where they use early mornings and nocturnal moisture. And not only does the BGA use in rice fields contribute to reduce dependency on chemical fertilizers, increase paddy yields, and improve soil conditions by gradually increasing its organic matter content, it also reduces environmental contamination that usually results from the leaching of nitrogen into ground water.

Micro-organisms, like BGAs, yeasts, and fungi equally constitute a hitherto hardly tapped source of protein that has an enormous potential role in satisfying the long-term needs for food and animal feed. The BGA spirulina was considered a nuisance to the salt extracting industry from the alkaline waters of Lake Texcoco in Mexico until research elsewhere demonstrated its potential value as a source of protein. Interestingly, this discovery came from Africa, from the alkaline ponds of Kanem near Lake Chad. For generations this organism has been harvested as seaweed, sun-dried, and eaten as green biscuit called 'dihe' by the Chadians. Consequently, a large plant, producing over 400 tonnes per year was set up in Mexico to commercially exploit the organism. The absence of cellulosic outer cell walls, which in spirulina is composed of easily digestible micoproteins, the exceptionally high content of proteins, vitamins, and minerals, and its non-toxicity make this algae an ideal food supplement to be mixed with cassava, maize, rice or sorghum.

So what Africans have traditionally known for generations can be improved upon by our scientists using the manipulation techniques of biogenetics. For example, identifying and suppressing the expression of the genes coding for the blue pigment and producing a white protein which has a composition similar to milk. Spirulina can thus be used as a milk substitute.

There is no revelation in all those practices to African scientists. For example, the innoculations of BGA in rice fields in Egypt has increased biological fixation by 24-48 kg/no/ha and increased yields by 14 to 30 per cent. In other words, consumption of nitrogen fertilizer is reduced by about 30 per cent with the added advantage of increasing crop yields.

Another innovation in Africa agriculture is the use of tissue-culture technologies. Tubers constitute an important food crop in many African countries and they are propagate vegetatively or asexually. Frequently, parts of the plant used for propagation are disease-ridden, leading to the contamination of other plants. Tissue culture allows the production of whole plants from single cells. The technique is used to facilitate the propagation of plant cells and plants and permit the production of uniform disease-free plant material.

Until recently, improvement in plant stock was achieved by the well-established, but slow, techniques of conventional selection and classical genetic breeding of varieties for high yield and maximum natural resistance to pests and diseases. The drawbacks inherent in these old methods of selective breeding, namely the large dependence on cross fertilization and the restriction of the available pool of sexually compatible and hence closely related plant systems, have been largely circumvented by several ingenious modern techniques. It is thus now possible to bring about the fusion of two naked somatic cells (protoplasms) of different varieties of crops and to produce, without the intervention of any sex factor whatsoever, viable intact, sexually fertile whole hybrid plants. The stable propagation of such desirable newly produced hybrids is facilitated by the modern technique of micro-propagation and in vitro culture of plants, whereby tiny fragments of surface sterilized plant leaf or stem are induced, by the provision of optimal nutrients and growth factors in suitable media, to produce numerous, identical intact whole plants. Such cloning techniques, now being honed to a fine art, not only accelerated and facilitate plant propagation, but also maintain and safeguard the genetic stability of the desirable traits in such new hybrids. Micro-propagation is already being successfully applied to many plants including potatoes, tomatoes, forage lugumes.

Tissue culture techniques have already been applied to two important tropical products: cassava and oil palm tree. Cassava root is a basic food for more than 500 million people around the world and is cultivated mainly in small holdings throughout the tropics. In Africa, cassava is cultivated almost everywhere and it is part of a process of rotation of cultures, in particular with maize and peanuts. It is grown in subsistence agriculture by small farmers and is harvested when other products are out of season or when, due to climatic conditions, their production is insufficient. Africa ranks as the second world producer with 56.6 million tonnes in 1985, used mainly for human consumption in the domestic market.

Equally, in-vitro propagation has obtained disease-free planting material of cassava at the International Institute of Tropical Agriculture (IITA) in Ibadan (Nigeria) and healthy clones of cassava were deposited by IITA at the Kenya Agricultural Research Institute and distributed to other African countries. This is a living example of the application of frontier technologies to African agriculture by African scientists.

Another major African indigenous food crop where research can be developed using modern techniques is sorghum. Sorghum is grown mostly in the semi-arid tropics in the belt stretching from Senegal to Chad in the West, to the Sudan and Ethiopia in the North East, and down to South Africa. Sorghum is the major cereal crop in Burkina Faso, Nigeria and the Sudan and second to millet and maize in Cameroon, Ghana, Mali, Senegal, Chad, Tanzania, Mozambique, and Zambia. According to FAO data, 32 per cent of the world area under sorghum is in Africa, yet Africa produces only 14 per cent of the total world sorghum production. Bad as this is, still worse is that while productivity in sorghum is growing at a high level in the rest of the world, productivity in Africa is not keeping up with the population growth and thus is directly contributing to the critical shortage of food. Between 1971 and 1981 world sorghum yield per hectare increased by 22.7 per cent, while in Africa it only increased by 4.7 per cent.

ICRISAT has obtained important results in new varieties of high-yield sorghum but so far, the diffusion process of those new varieties has failed to make impact on Africa agriculture. The problem with sorghum is its great diversity associated with different environmental conditions. No single variety is suitable for all Africa regions and conditions such as resistance to disease, soil quality, and drought stress.

Despite these constraints, important results were achieved by ICRISAT with new varieties adapted to specific conditions as can be illustrated in the following examples:

In Burkina Faso, where the average national yield for sorghum is 600 kg p/ha ICRISAT released in 1983 a new variety called Framida which has an average yield of 1811 kg/ha;

In Ethiopia, ICRISAT released a variety called ESIP 11 with an average yield of 6307 kg/ha, while the national average is of 1498 kg/ha;

In Sudan, the national average is 520 kg/ha but the new varieties released in 1983 known as Hageen Durra has a productivity of 5190 kg/ha;

In Zambia, the national average is about 630 kg/ha, ICRISAT released in 1980 the variety ISCV 111 with a productivity of 7753 kg/ha.

Other examples for Kenya, Senegal, and Tanzania can be found in the ICRISAT reports. They demonstrate that there is a great potential to increase agricultural production in Africa. But this is not achievable without decentralization making research more sensitive to local farming conditions.

But such steps will not convince farmers to use new varieties if they are not assured of good prices. Regretably, in many African countries farmers abandon agriculture because it simply does not pay; the existing price support system for food mainly favours town dwellers, the vociferous minority which makes and breaks governments. They demand cheap food as if it were their birth-right. Governments will have to turn the terms of trade in favour of farmers. And in this respect, one cannot help recalling the relief worker in the Sahel who asked: "Starve the city dwellers and they riot; strave the peasants and they die. If you were a politician, which would you chose?" But are we as callous as all that?

Be that as it may, indigenous research is vital for African agriculture not only because of its economic returns, also because of the nefarious effects on the environment that may result from the indiscriminate use of imported varieties. The switch to foreign-bred productive strains is often suggested as one alternative for increasing agricultural productivity in Africa. Those suggestions often emanate from seed companies who promote the products of their private gene banks or from economic planners who are more concerned with the international market than with the requriements of the local population or the characteristics of the local ecosystems.

Apart form the need for an increasing amount of costly chemical fertilizers for new varieties, the most serious danger is the neglect and the extinction of traditional crop varieties well adapted to the local ecosystem and highly resistant to local pests. New varieties may have no such resistance, and the more genetically homogenous the crop fields are, the higher is their vulnerability to pests, diseases, or weather changes. The rice homogenization in South East Asia was recurrently subject to devastations because of these causes.

Indiscriminate biological diversification may introduce a new and extremely serious uncertainty into African agriculture. Such uncertainty does not exist in the developed countries that have the technological and economic capacity that permits them to establish warning systems and an adequate mechanism to anticipate and respond to situations announced by that system. And in the eventuality of a crisis, they have the capacity to cope, either because of the availability of strategic food stocks and commodities, or because their economic capacity allows them to resort to the international market.

Africa's situation is dramatically different. Even where a warning system exists and works, it is rarely complemented with adequate institutional mechanisms and does not have the technical and economic capacity to cope with the emergency when it arises. The 1984 famine is a case in point. The famine was not a secret; FAO had been warning about it long before the October 1984 BBC television broadcast which is popularly credited for starting international relief mobilization.

Early warning systems alone are never enough. They should be adequately complemented by technical and economic mechanisms to deal with emergencies. And, in the absence of buffer stocks, there should be an economic capacity to buy on international markets, which tend to react with increasing prices in the case of increased demand. In view of the lack of all that, African countries had no recourse but to appeal to international solidarity. Alas, food aid perpetuates the cycle of misery by eventually flooding the market and reducing the incentive to improve domestic food production. All this goes to prove the wisdom of the call for self-reliance reflected in the Lagos Plan of Action

Throughout this paper references were made to new technologies directly applicable to agriculture. Still, we cannot neglect the importance of new technologies that go beyond agricultural development. For example, remote sensing can be used for weather forecasting, evaluation of natural resources and pest control. Equally, the application of informatics and microelectronics, as alluded to earlier, would enhance the efficient use of other technologies, as well as serving agriculture and livestock monitoring. WHO has done some pioneering work in the use of informatics and telematics in health, particularly in the developing countries, and there is something to be learned from their experience by other institutions.

Science and technology is one field where integration is not only desirable, it is an imperative. The majority of African countries are either too small or too poor to afford the full range of scientific research facilities. This problem can only be solved through the establishment of a cluster of regional institutes dealing with the global scientific and technological needs of the continent and made up of national institutes on the basis of their depth and expertise. Only in this way can we bridge gaps in national capabilities and provide a back-up in basic research.

It is worth mentioning here a new initiative which is of particular relevance for science and technology development, the initiative for the OAU, ECA, and the United Nations University (UNU) to creat an Institute for Natural Resources for Africa. Among the basic functions of the Institute is research in agriculture and mining with three sub areas in the former and one in the latter. Subjects related to water resources, animal resources and energy are considered for a later action.

The Institute will be financed through an endowment fund which is expected to reach the amount of $US 50 million. So far, Cote d'Ivoire and Zambia have already pledged $US 5 and 2 million, respectively and offered physical facilities. France and Italy 2 million francs and $US 15 million respectively, while the African Development Bank is considering a $US 5 million interest-free loan for four years and UNDP has informally expressed its willingness to provide $US 5.6 million to support the programme during the first three years.

However, for the Institute to succeed it will have to be complemented with national institutions dealing with those areas of activity that are vital for African development. Relevant departments of the OUA and ECA should take the lead in launching policies aimed at coordinating the efforts of such institutions.

One hopes that in addition to the co-ordination of research in Africa, the Institute will also lead the way for a meaningful South-South co-operation in fields where the technology of the North is irrelevant to Africa's needs. South-South co-operation is another theme to which we often pay lip service, the vertical penetration (North-South dialogue) cannot be achieved without horizontal integration (South-South co-operation). In the specific field of science and technology, several countries of the South have made strides in research, including those in biotechnology and informatics, either independently or jointly with other countries of the region. Examples of such endeavours are the co-operation between India and China in areas related to energy generation from biomass and natural nitrogen fixation, between Cuba and Mexico for the production of single-cell protein (SCP) from sugar cane molasses and bagasse, and between Brazil and Argentina on biotechnology application to pharmaceuticals. Earlier, we referred to the co-operation between (IITA) in Ibadan and the Kenya Agriculture Research Institute (KARI).

In the end, if there is one event that should have made us all - policy makers, development planners, and scientists - ransack our conscience it should have been African famine. What do we need more than this to be morally embarrassed? The issue is not famine, but the way business as usual prevails in some parts of the continent. The causes for the crises in Africa that brought us perilously close to Apocalypse cannot be all placed on our door, but there are also those causes that are home-grown. If only for the sake of credibility, we have to apply all our energies to solve them. If we are to be taken seriously, we have to take ourselves seriously.

The Lagos Plan of Action has defined the goals and set the tone, and there are leaders who are ready to live up to its goals. In many parts of the continent, however, the Plan still lies gathering dust in foreign offices. How many African countries have aligned their national plans with the Lagos Plan of Action? How many African development institutes have initiated studies on African economic integration in order to repare future planners of Africa? How many of the public opinion moulders in the media are aware of the existence of the Plan, not to mention their potential role in imparting its message to their audience? How many African research institutes are engaged in a sustained and co-ordinated effort to find indigenous solutions to problems that are peculiarly African? Those are pertinent questions we need to ask ourselves with transparent frankness. Paying lip service to lofty causes would not carry us far. Africa's situation is woesome but woe, in part, is us.

In the end, if Africa's present agonies are not to turn into future dreads, we will have to live up to our commitments. And for that we need this political will and the enlargement of imagination; there is no witch doctor cure for our ailment. As an inspired son of Africa has recently said: "The drought has dried up our lands, let it not dry up our dreams."

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