



**Economic Commission for Africa  
Commission économique pour l'Afrique**

***Towards a Green Revolution in Africa: Harnessing  
Science and Technology for Sustainable Modernisation  
of Agriculture and Rural Transformation  
(SMART/AGRI)***

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## **EXECUTIVE SUMMARY**

### **The African Green Revolution Initiative**

This report provides a review of the history of modernisation of agriculture in Africa. It highlights the shortcomings and the significant perspectives of five major agricultural development approaches that were used in different African countries. It also highlights the economics of the available land, vegetation and water resources.

In spite of 50 years of agricultural research and development in Africa, unlike in Asia and South America, the Green Revolution in Africa has either been missed or delayed. It is argued that the delays of Green Revolution in Africa were partly caused by the subsistence, complex farming systems, inadequate land reforms, climatic changes and frequent droughts, political elite paying little attention to the promotion of science and technology and ill-conceived public agricultural development projects. On the other hand, there have been some initiatives that suggest a possibility of Green Revolution happening in some parts of Africa. There was successful diffusion of improved crop technologies of Corn, Cotton, Rice, Sorghum and Groundnuts between 1969 and 1991 in a few countries of Africa.

This paper proposes a strategy of an African Green Revolution Initiative (AGRI), defined as a system for sustainable modernisation of agriculture and rural transformation (SMART). The African Green Revolution Initiative is designed to have technological and socio-political (as its two major) perspectives.

The technological perspective has four components: 1) The biological technologies, which range from the conventional elite single selections from local germplasm to more advanced applications of biotechnology and gene technology to produce improved varieties. 2) The improved crop management technologies, including a combination of organic and inorganic soil fertility amendments plus management practices. 3) The bio-physical technologies varying from tools to simple irrigation, 4) The post-harvest handling processes and marketing technologies. Each component of the technologies has three phases. These are the technology generation and development phase that is done at basic research on station; the on-farm adaptive research for evaluation / testing phase and the dissemination phase.

The socio-political perspective of the African Green Revolution Initiative includes the community part and the government part. The community part involves the participatory planning, technology development and technical assessments used to redesign the farming systems and prime the communities for a Green Revolution. The government part mobilises governments and donors commitment and support in terms of providing human, material and financial resources. There is also logistical support needed in terms of infrastructure (roads), institutional capacities and favourable political environment. It also develops the required conditions for partnerships and networking between departments, organisations, districts, between countries among donors, among development organisations, and international agencies.

Finally, this paper suggests a strategic implementation plan, which can cause African Green Revolution Initiative to show significant result at pilot sites in three selected countries in three years and further results at promotion sites in six selected countries in five years.

## **1. BACKGROUND**

### **1.1. An African Green Revolution: Missed or Delayed?**

There has been accelerated development through the application of science and technology in the world since the second half of the 20<sup>th</sup> century. For example advanced technologies in telecommunication and transport have created a global village which includes the African continent. It is also true that the advances in science and technology had significant impacts on agriculture, first in Europe and North America, later in Asia and South America, where it was known as “Green Revolution”. Then, one wonders why the impact of simple and advanced technologies on agriculture in Africa, in spite of an era of globalisation, is not yet seen. Thus why is it that the application of modern science and technology or the Africa Green Revolution has been delayed?

The purpose of this report is to propose a strategy for sustainable modernization of agriculture/African green revolution initiative (SMART/AGRI) through the promotion of science and technology. It is hypothesised that the delayed Africa Green revolution can be triggered by concerted and synchronised efforts on two fronts:

- (a) Working with the African farmer to redesign and modernise the complex African subsistence farming systems and
- (b) Application of modern science and technology to produce robust technologies tested at farm level and adapted to the respective agro-ecological zones in Africa

### **1.2 Review of the History and Development of Modern Agriculture in Africa**

#### **1.21 Agricultural development in the last years of the colonial rule 1945+**

The African continent is the second largest after Asia with a surface area of 30.3 millions Km<sup>2</sup> and a population of about 860 million people. Most of the 53 African states gained their independence between 1957 and 1965. During the last years of colonial rule after 1945, the colonial masters had recognised their colonies’ potential economic contributions as sources of primary raw materials. Consequently, the colonial administrations made substantial investments in the agricultural production and veterinary service sectors and provided social services especially health, education and roads.

For agricultural development four implementation approaches were used, namely:

- (a) Use of development planning, where short-term 3 to 5 years and long-term 5 to 10 years agricultural development plans were incorporated in the national development plan.
- (b) Establishment of agricultural commodity-based (cotton, coffee and food crops) research systems whereby breeders, agronomists and pathologists were posted as a team to research stations.
- (c) Establishment of agricultural extension and training. Extension officers were posted to districts to train farmers and promote the use of improved agricultural

methods such as crop rotation, use of improved seeds, use of inputs like fertilisers. But a more significant perspective was the fact that in many of the colonies, their scope was widened to include expansion and diversification of agricultural production to covering both cash (cotton, coffee, tea, cocoa) and food crops (maize, beans)..

- (d) High investments in multipurpose hydroelectric dams. Examples are Owen Falls dam at the source of Nile, Jinja, Uganda; and Akosombo dam in Ghana. Although the main purpose of constructing dams was to generate and supply cheap power for initiating and supporting small-scale and medium scale industries, those dams would also have provided water for irrigation thus significantly improving agricultural production.

## **1.22 Agricultural Development Approaches of Independent African Countries**

First, under colonial rule, development planning was commonly used as a strategy of modernising agriculture in particular and the economy at large. When national governments took charge of their affairs at independence, almost every country faced a host of agricultural challenges. In countries like Kenya, Malawi, Nigeria and Senegal, high population growth rates ranging between 2.7 to 3.8 % per annum, made the population double itself in every 20 years (see table 1.1). This put a rapidly increasing population pressure on the land, threatening to cause food insecurity and widespread poverty. By 1985, the arable land available, hectares per person of the total population reduced from 0.86 to 0.73 ha/person in Malawi, 1.22 to 0.71 ha/person in Nigeria. By 2000 the per capita arable land for Malawi and Nigeria were 0.45 ha/person and 0.48 ha/person, respectively (see table 1.2).

The second challenge was weak agricultural research and extension systems. Apart from Nigeria and Kenya who had 136 and 121 full-time equivalent researchers respectively, most African countries lacked trained/skilled agriculturists (see table 1.3).

The first significant approach was development planning. By this approach, every country planned to put a lot of effort in education, health and research. Fortunately, between 1960 and 1970, world market prices of cash crops (cocoa, coffee, tea and cotton) were favourable. The agricultural sector increased at about 2.7 % p.a.. Some of the proceeds from the agricultural sector were ploughed back into education and small-scale agricultural improvements. Development planning had a significant perspective of increasing trained manpower including researchers. Thus by 1991, each of the African countries had increased its scientific research by a factor of 4 up to 7 times. For example Nigeria had achieved 1013 full-time equivalent agricultural researchers, Kenya 819, Ivory Coast 267 and Tanzania 546 (see table 1.3).

However the developments in agriculture were being overtaken by over-dependence of the national economies on agriculture for generation of both GDP and for earnings of foreign exchange from exports.

**Table 1.1: Socio-economic development indicators of selected African countries**

Indicator	Year	Country					
		Kenya	Malawi	Tanzania	Cameroon	Nigeria	Senegal
Population (million)	1965	9.5	3.9	11.9	6.1	48.7	3.4
Population (million)	2000	37.6	12	34	17	150	9.7
Population growth rate %	1965-86	3.8	3.0	3.4	2.95	3.4	2.7
Growth rate of Urbanisation %	1965-80	9.0	7.8	8.7	8.1	4.8	4.1

Source: Uma Lele, World Bank 1992, Aid to African Agriculture.  
 Technical center for agriculture and rural co-operation, ACP/EEC 1988

**Table 1.2: Agricultural Development Indicators**

Indicator	Year	Country					
		Kenya	Malawi	Tanzania	Cameroon	Nigeria	Senegal
Per capita arable land ha/person- Total population	1965	1.34	.86	3.99	5.99	1.22	2.67
Arable land ha/person	2000	.42	.45	1.44	2.09	0.48	1.04
Agricultural growth rate %	1960-87	4.0	1.4	2.8	4.4	0.6	1.2
Share of agriculture in exports %	1985	57	94	79	65	4	46
Share of agriculture GDP %	1960-87	34.9	42.6	47.3	29.2	41.5	23.6

Source: Uma lele, World Bank 1992- Aid to African Agriculture.

**Table 1.3: Agricultural research resources used by selected African countries (FTE= Full time equivalent researchers) and fertilizer use**

Resource	Year	Kenya	Malawi	Tanzania	Ivory coast	Nigeria	Senegal
Scientists FTE	1961	121	30	NA	67	136	60
Scientists FTE	1991	819	185	546	267	1013	175
Fertilizer use Kg/ha	1995	39.1	44.7	15.3	10.4	13.3	NA

Source: Johannes Roseboon and Philip Pardey 2000 - Survey of agricultural research investments in sub Saharan Africa and Sasakawa-Global 2000 Africa country reports



The share of agriculture in GDP ranged between 23.6% in Senegal to 47.3 % in Tanzania in 1987. As for exports, apart from Nigeria where the share of agriculture was only 4%, most of the other countries entirely depended on agriculture by 46% to 99 % (see table 1.2).

The second significant development approach used was that of food self-sufficiency backed by national food policies. Tanzania launched food self-sufficiency policy, which was implemented through Ujamaa or communal agricultural production in villages. Nigeria, Senegal and Kenya adopted a national plan for food self-sufficiency. Nigeria in particular started operation “Feed the Nation” at pilot sites in 1976. Then in 1978 “Accelerated Food Production Programme” was adopted nation-wide.

During 1960s and early 1970s, Nigeria was a net importer of rice, maize, and wheat, adding up to 60% of the national imports. After seeing the positive impacts of her food self sufficiency programs and policies, Nigeria put a total ban on importation of Rice, and Maize in 1985 and a ban on wheat in 1987. There are figures showing that in 1989, about 30% were a surplus, out of 5628 million tons of domestic production of maize. The production of rice and wheat were still to catch up with domestic demand in 1989 (Lawani and Babaleye, 1992).

In 1990, the African governments, seeing the urgency of food security and the limited success from their various national strategies, opted for the adoption of the Lagos Plan of Action. That was a right step in the right direction to formulate objectives and strategies that respond to Africa’s food needs. But the Lagos Plan of Action was not implemented by any of the African countries partly due to lack of socio-economic and technological capacities necessary to carry out a policy/program of food self-sufficiency as inspired by the Asian Green Revolution. But, all in all, the food self-sufficiency approach created awareness, urgency and aspirations for the possibility of an African Green Revolution.

The development approach used was the construction of multipurpose dams to provide cheap power for industrial and domestic use. Then the man made lake was to provide fishing (boosting sources of protein) and irrigation to promote intensive agricultural production. After the earlier dams, additional examples are Aswan dam 1956, Egypt, Lokoja dam, Nigeria, Kariba and Cabora Bassa hydroelectric projects on river Zambezi. However, apart from the Aswan dam, the fishing and irrigation of most of large hydroelectric dams were disappointing. Moreover their construction costs went beyond their estimates, becoming very expensive and creating debt burdens to the young countries. This approach instilled among the African countries a desire to re-organize the potentials of irrigation in modernizing agriculture ( see Table 2.3 below).

The fourth approach used by African countries was that of Integrated Rural Agricultural Development Projects (IRDP/ADP). Let us examine how the IRDP/ADP community-based projects were formulated and implemented, and assess their significant contributions to modernizing agriculture in Africa. We shall focus our analysis in six countries namely Kenya, Malawi, Tanzania, Cameroon, Nigeria and Senegal.

The aims of the IRDP or ADP approach across Africa, included part or some of the following:

- (a) to develop the agricultural sector for production of cash and food crops (cotton, tobacco, maize, rice, groundnuts, beans and potatoes and livestock).
- (b) to provide infrastructure (roads) and social services (water, education and health)
- (c) to focus on improving the welfare of the small holder/grassroots in the target project areas.

The style of the projects designs was usually based on capital-intensive equipment and activities to provide mainly infrastructure. The designs and implementation heavily depended on external funding (such as World Bank loans and donor community grants) and a large number of foreign staff.

The first ADP in Africa was in 1968 when the World Bank approved Lilongwe I ADP in Malawi. The Lilongwe I design / implementation neglected to study subsistence complex local farming systems and forgot to select the available improved technologies for the crops. Then between 1968 and 1983, 12 ADP were approved and implemented in Malawi. They included Lilongwe II, III, and National Rural Development Programme (NRDP I-IV). In 1989, when the Malawi ADPs were evaluated, they all had a positive economic rate of return (see table 1.4). In this ADP strategy, Malawi projects had some significant perspective because they were all focusing on the small-holder agriculture.

The ADP strategy with significant perspective for modernizing agriculture in Tanzania started with Kigoma ADP-1974, then Tabora ADP, and Mwanza-Shinyanga ADP. Their focus was food crops and providing social services such as water, schools and health to small-holder's grassroots in project areas using World Bank loans. Consequently, there followed many other integrated rural development projects for almost every province/region in Tanzania, which were being sponsored by various donors. The significant ones among the subsequent projects were Tanga (by Germany), Arusha (USAID), Lindi/Mtwani (UK) and Kilimanjaro (Japan). Then Iringa I, 1977-81 (by Lome I) and Iringa II 1982-86 (by Lome II). The projects design included cash and food crops, inputs (seeds, fertilisers and insecticides) and in some cases dairy cattle. The aspects of promoting improved seed and/or improved breed plus improved inputs are significant for modernization of agriculture.

In Kenya the ADP strategy started with Nyanza I ADP in 1976 and Nyanza II ADP, in 1979, both covering Nyanza and Western Province, then Bura irrigation scheme project in the coast province in 1977 and the group farm rehabilitation project. The idea of Bura irrigation was a right step on the road to modernization of agriculture.

The ADP strategy in Nigeria started with Funta, Gusau and Gombe in 1976 in Northern Nigeria. The design of the three Funta ADP components, included provision of improved seeds and improved inputs, improved production methods, agro-service centers and a network of feeder roads. Certainly the ingredients of this ADP could have made a significant move towards modernization. In close relation to this was the irrigation technology that was being promoted for cowpeas and rice in the Middle Belt of Nigeria. Convinced by the significant impacts of the ADPs in Northern Nigeria, the ADP strategy was adopted to be extended to the whole country. Other

significant ADPs started in 1987 were Ayangba, Lafia, Bida, Iloin, oyo North, Ekiti-Akoko, Bauchi, Kano and Sokoto. But the design of the later ADPs was less resource-intensive and they were not as successful as their forerunners. About nine other ADPs, which followed, tended not to have any input on modernization of agriculture.

The designs of ADP strategies in Cameroon and Senegal tended to be complex and their implementation to by-pass the line of technical ministries such as agriculture, and that of higher education and scientific research. So they had less impact on modernization of agriculture in those countries (see table 1.4).

Commodity-based projects were also designed and implemented parallel to the IRDP or ADP in the African countries. Some of the key projects were sugar in Kenya and Tanzania, maize, cotton, tobacco and tea in Tanzania, rice in Nigeria, Cameroon and Senegal, and cocoa in Nigeria and Cameroon.

The commodity based projects in Africa tended to have better designs and implementation process than the IRDP/ADPs. They promoted technologies of improved seeds and use of improved inputs. There was a higher rate of adoption by farmers thus contributing to modernization of agriculture. Generally, the commodity-based projects gave higher economic rates of return than the integrated Rural Development Projects (see table1.4).

*Our analysis therefore is that the integrated rural development project approach could almost have triggered the beginnings of an African Green Revolution, if only their designs had included transformation of the farming systems and on-farm research to select adaptable technologies.*

**Table 1. 4: Performance of some selected integrated rural agricultural development projects (IRDP) or (ADP) and commodity based development projects**

Economic Rates of Return for completed World Bank Projects (ERR)

Country	0 percent	0-10 percent >	0-20 percent	> 20 percent
Kenya	IADP Group Farms South Nyanza	Livestock Development I Livestock II Sugar Rehabilitation	Smallholder Credit I Forestry II	Tea Development I Tea development II Smallholder Credit II Tea Factory
Malawi		Lilongwe II Karonga I Shire III NRDP I	Shire II Karonga II	Shire I Lilongwe III

Country	0 percent	0-10 percent >	0-20 percent	> 20 percent
Tanzania	Kigoma ADP National Maize Tabora ADP Geita Cotton Cashewnut Development Tobacco Processing Tobacco Handling Mwanza-Shinyanga ADP Pyrethrum Fisheries Livestock	Kilombero Sugar	Flue-cured Tobacco Smallholder Tea	Sao Hill Forestry
Nigeria	Ondo Oil Palm Bandel Oil Palm Rice Livestock	Lafia ADP Ayangba ADP Bida ADP	Gusau ADP Gombe ADP Funtua ADP Cocoa II	Western cocoa
Senegal	Sine Saloum Debi-Lampsar Irrigation Eastern Senegal Livestock Development	River Polders Sedhiou II	Agriculture Credit II Terres Neuves II	Terres Neuves I Casamance Rice
Cameroon	Cocoa Plaine des M'bo ADP Development Zapi IRDP Livestock	CAMDEV II	CAMDEV I SOCAPALM I Niete Rubber Estate SOCAPALM II HIEVECAM II Rural Development Fund Western Highlands IRDP	

Source Uma lele, World Bank Aid to African Agriculture.

## 2. African Agro-Ecological Zones, Farming Systems and Natural Resources

### 2.1. Agro-Ecological Zones of Africa

Agro-ecological zones are characterised by climate (temperature, rainfall and prevailing wind), vegetation, farming systems and population density/settlement pattern. Since within each of the above factors there are many variations and a combination of those factors at any one level of variation constitutes an agro-ecological zone, then there are many agro-ecological zones in Africa. In turn climate types can be influenced by latitude, altitude, water bodies and vegetation. At the global and continental level, agro-ecological zones can be defined according to their major determining factors, namely rainfall, vegetation and farming systems.

According to these criteria, Africa can be divided into seven major agro-ecological zones. (see table 2.1 and map 2.1)

### **2.11. Tropical Rain forest and Rain forest with Grassland zones**

The tropical rainforest zones are located in central Africa (DRC, Congo, South Cameroon, Central African Republic and Gabon), and the Coastal South of Western Africa (from Port Harcourt in Nigeria to Freetown in Sierra Leone). The annual rainfall is 1500 to 2000 mm, bimodal and distributed all over the year. The vegetation is mainly tropical rain forest with a large number of species of trees and other plants. The forest forms a canopy of foliage, which provides shade and keeps ground temperatures low. The dominant farming systems are tree based (Palm oil, Cocoa and Cassava). The farming systems are characterized by Shifting Cultivation, with traditional farming practices, inter-planting many crops on the same pieces of land. The population density is low, about 20 persons / km<sup>2</sup>, but high in coastal West Africa to about 100 persons / km<sup>2</sup>.

### **2.12. The Tropical Grassland Savannah Zone**

The grassland rain forest zone is located in North and South of Congo basin, the East African Plateau and Western Africa. (see region 3, map 2.1). The annual rainfall is between 1500 – 2000 mm and is bimodal. The tropical Savannah grassland zone has vegetation with many spaced trees, which permit dense low layers of grasses or shrubs. In wetter areas, the vegetation is more woodland. In drier areas, the Vegetation has few trees that have deep roots and thick bark, which help to reduce transpiration.

The farming system in the grassland Savannah zone in West Africa is characterized by Cassava, Yams, Sweet Potatoes, Maize and Beans. In East Africa, the farming system is Banana, Coffee, Cassava, Sweet Potatoes, Beans and Maize. But the part of grassland Savannah in Southern Africa has a farming system of Cassava / Maize / Beans and Sweet Potatoes. The land management is Shifting Cultivation, except in high population density areas like Western Kenya and Western Africa where intensive farming is used.

### **2.13 The Sudan Savannah Zone**

The Sudan Savannah Zone occupies a large proportion (about 30%) of Africa. It runs across Southern Africa, parts of East Africa, and runs across Eastern – Central – West Africa from Eritrea to Conakry. (see zone 4). The annual rainfall is between 500 to 1000 mm and it has only one rainy season. In the Northern Hemisphere, the Sudan Savannah gets rains from June to September with a peak in July / August. In the Southern Hemisphere, the Sudan Savannah has rains from November to March with a peak in February. The duration of the rainy season in the Northern Hemisphere tends to be shorter than 120 days, probably due to desertification effects of the Sahara Desert. The vegetation in the Sudan Savannah zone has scanty trees and grasses. In places where the grasses are frequently burnt, the vegetation is very scanty.

The farming system is Sorghum, Millet, Cowpea based in the North and Sorghum, Millet, Beans in the South. Both have significant Pastoralism. The East African Grassland and Sudan Savannah are a home for a rich wildlife - Antelopes, Elephants, Buffalos, Lions etc.

Table: 2.1 Africa's Agro ecological Zones.

Zone	Rainfall Mm / yr.	Vegetation
1.	200+	Tropical rain forest
2.	1500 – 2000	Rain forest with grassland
3.	1000 – 1500	Tropical Grassland Savannah
4.	500 - 1000	Sudan Savannah
5.	250 - 500	Sahelian Grassland
6.	500 - 1000	Temperate / Mediterranean ever green.
7.	Less than 850	Desert

In the long dry season, grazing in the Sudan Savannah tends to be hindered by shortage of pastures and low nutritional value due to coarse dry grasses. So pastoralists tend to drive their herds Southwards from the North into Sudan Savannah in search of greener pastures, thus creating a conflict with crop farmers in the grassland Savannah. Crops grown in the Sudan Savannah have very low yields, partly due to poor soils and partly due to insufficient rains. The Mediterranean and Sahelian zones are not significant for this report.

Generally, all agro-ecological zones have had an adverse impact on agricultural modernisation in Africa. Over the years, there have been dramatic changes in rainfall patterns, unpredictability, duration and amount of annual rainfall. Farmers are not sure of the zone planting dates any more. The vegetation in some of the zones has also greatly changed. In other words, rainfed agriculture in Africa is now an extremely risky venture. However in each zone, the abundant sunshine throughout the year (that is absence of cold weather / winter) is a resource for plant photosynthetic energy.

## **2.2 Farming Systems in Africa**

Factors determining a farming system are largely similar to those determining agro-ecological zones. However additional factors differentiating between farming systems are methods of farming, topography, soil fertility levels, crops grown, cropping systems, cropping calendar and crop/ livestock interaction.

When we consider methods of farming, all types of farming systems in Africa can be divided into two major groups. Namely a) Traditional Subsistence and b) Improved Farming Systems.

In the traditional Subsistence farming, the farmer's objective is to grow enough food for on-farm consumption only. In Africa, there are still two types of subsistence farming. There is Subsistence Farming, characterized by Shifting Cultivation and Bush-Fallowing, and there is Intensive Subsistence Farming. In a Shifting Cultivation System, a farmer clears, using traditional methods of slash and burn, a piece of land from bush fallow, then cultivates it. When its soils are exhausted after 3 to 5 years he/she abandons that one and moves to another piece of land. The abandoned plot is left to bush fallow for two to three years.

However, when there is high population (pressure) density on the land, the individual farmer has no alternative land to move to. The available land has been fragmented. All there is, is one plot of land for the farm family to grow all their food crop needs. The fast growing population has necessitated intensive land use irrespective of topography (bottom valley, slope, hilltop or wetland). The farmer is forced to cultivate permanently in one location (Intensive Subsistence farming) and using traditional methods. Both the shifting subsistence and intensive subsistence farming systems can apply to crop and livestock and both have no significant perspective for modernizing agriculture.

Some types of improved farming systems also exist in Africa. Examples are a) improved farming systems under irrigation (like Gezira Irrigation scheme in Sudan) and b) improved intensive farming systems by small holders like Uboma district in Imo State, East Nigeria and c) improved (Commercial) farming on large estates like the settlers in Zimbabwe. In all these aspects of improved farming systems, there are some improved methods especially for maintaining soil fertility and land productivity. Under improved commercial farming, the objective is to specialise in producing food, non-food crops and animal products for sale while maximising profits.

The three types of improved farming systems have significant potential for modernising agriculture in Africa.

## **2.3 Improved Farming Systems: A Case of Gezira Irrigation Scheme**

Along the Blue Nile there is an improved farming system with high course crop rotation of fallow - cotton – fallow – fallow – cotton –fallow- sorghum or wheat-lubia. Farmers recognise four seasons in a year. July- October, November- December, January – April , May – June . In July – October they plant sorghum (July) followed by groundnuts, Cotton (August) and then Lubia (a leguminous fodder fallow crop) (September). At weeding, cotton is thinned to three plants per hole, two weeks after

planting. Then soil is ridged around the plants. Sorghum is irrigated three times. But Cotton is irrigated at intervals of 10 – 12 days after weeding in cooler periods at 12 – 15 days interval. Lobia, which is grown from September, takes 4 ½ months to mature and is irrigated in 15 -20 days interval.

In November, when all crops are established, the main activity is watering. December is for harvesting sorghum, then digging up irrigation channels in fallow fields in readiness for planting cotton, which must be planted after fallow. January to April is cotton picking season and is the labour peak / busiest period of the year.

In May – June all the cotton stalks are pulled out and burnt to keep the land free of pests and diseases. Grazing animals are brought in from outside into the scheme to make use of the Lobia. Fertilizers are applied to cotton fields in anticipation of the coming rains. The area has one rainy season with a peak in July / August and cut off at mid-October.

In Gezira Scheme, all farmers are tenants renting the two ha. of land from the Sudan Gezira Board for one year for specified crop rotations which must change every year. Farmers live in near by villages or towns. The scheme and all decisions are under the control of the board with aim of making profits.

## **2.4 The Impact of Natural Resources on Agriculture in Africa.**

The major natural resources for agricultural development in Africa are land, vegetation, water and sunshine.

### **2.4.1 Land Resource**

Land is the most important factor for agricultural development. With rapid population growth, land availability becomes more and more scarce. Movement towards modernisation of agriculture in Africa and strict maintenance of land productivity (as indicated by soil fertility level) become very critical.

Soil fertility may be defined as the ability of the soil to provide physical conditions favourable to root growth and to supply enough water and nutrients to enable a crop to make the most of other environmental features of the site. The major components of soil fertility are organic content, availability of NPK, and micro-nutrients. Other soil factors are physical characteristics of texture, structure, depth and nature of the profile.

Most parts of Africa have very shallow topsoils. These are usually unproductive since they provide little root room for crop anchorage and extraction of nutrients and water. They are either water logged or contain too little moisture. Unfortunately the traditional farming methods, non-use of fertilizers and irrigation have very quickly degraded most of the soils on the continent.



## 2.4.2 Vegetation

Vegetation coverage and the importance of vegetation have already been discussed in section 2.1

## 2.4.3 The water resources

Africa has enormous water resources for providing irrigation. Table 2.2 shows the water resources for potential irrigation in Africa. Data shown that water from eight major basins could irrigate 891 thousand km<sup>2</sup>.

Table 2.2 Africa's water resources for potential irrigatable areas.

River Basin	a) Surface Drainage km <sup>2</sup>	b) Surface Water Resources MM <sup>3</sup>	b) Best soil irrigable Areas Km <sup>2</sup>
1. Senegal	486,438	19599	9,489
2. Niger	2,228,110	166,327	96,622
3. Lake Chad	2,370,307	82,091	101,922
4. Congo	3,774,278	820,779	302,952
5. Orange	637,839	5,688	11,009
6. Limpopo	404,567	3541	12,645
7. Zambezi	1,354,966	120,927	120,408
8. Nile	3, 106,130	166,327	234,653
<b>Total</b>	<b>14,362,608</b>	<b>1,415,884</b>	<b>890,700</b>

Source The times world Atlas. Times books1990

FAO, irrigation and water resource potential for Africa 1987.

## 2.5 The impact of agro-ecological zones, farming systems and natural resources economics on Agriculture.

From the special analysis of the issues in this section, it is clear that all agro-ecological zones, farming systems and natural resources cuts across many countries in Africa. This feature has two significant implications for agriculture in Africa. First it implies that when a given technology is tested and proven successful in one country, the same technology can be extended to other countries having similar conditions. Secondly, it suggests that a number of African countries that have similar conditions can contribute resources to form a critical mass and team up together in order to conduct research to achieve a common goal.

## 2.6. Irrigation Schemes in Africa

Irrigation and drainage are both very important technical inputs that could constitute an ingredient for green revolution in Africa. Africa has large water resources with irrigation potential of 90 million hectares. But the irrigated land on the African continent is less than 10 % of its potential irrigatable land as compared to 26% in India, 40% in Philippines and 44% in China. Most of the irrigation schemes are located within the major drainage basins of Africa.

**Table 2.3 Irrigation Schemes in Africa**

<b>Name:</b>	<b>Size / Crop</b>
1. Sengal River Basin Senagal Delta	Paddy Rice
2. Niger River Basin Mali Delta Sokoto – Rima Rivers Nigeria Bacita Scheme Morphi	25000 ha Wheat, Vegetables 29500 ha, Paddy Rice
3. Lake Chad Basin Chad – North Nigeria	25,000 ha.
4. Congo River Basin Razizi River – Congo Lake Kivu	Sugar Cane
5. Orange River Basin Orange River S.A Great Fish + Sundays river S.A	220,000 ha. Rice , Wheat 74,000 ha Vegetable
6. Limpopo River Basin Limpopo river Kyle dam S.Africa	Sugar Cane 44,000 ha. Cotton , Maize
7. Zambezi River Basin Kafu Lali Flat , Zambia Shine River, Malawi	Sugar Cane , Wheat Cotton, Sugar Cane
8. Nile Basin Kakira / Lugazi L. Victoria Gezira Irrigation Sudan Gash + Baraka Sudan Aswan dam Nile delta Egypt	Sugar Cane 800,000 ha Cotton, Sorghum, Rice, Wheat  Cotton, Sugar Cane, Wheat

## 3. REVIEW OF CONCEPT OF GREEN REVOLUTION

### 3.1 The Concept of Green Revolution

Green Revolution refers to a historic period 1966 to 1976 in the development of modern agriculture of developing countries in Asia and South America, characterized by massive adoptions of improved cereals, mainly wheat and rice. That decade saw very dramatic adoptions of improved high yielding crop varieties of rice, wheat and

maize in many countries in Asia and South America, accompanied by the adoption of improved crop technologies including use of fertilizers, irrigation and improved management practices. Asian countries doubled their rice production per capita per year from 0.5 to 1 tons/ capita / year.

Before the Green Revolution in Asia (1956-1965), the average rice yield was 1.9 tones/ha. That could only be obtained during the wet season. But there was no production in the dry season. The Green Revolution increased the yield to 5 tones/ha. Beside the improved varieties, there was a well-developed irrigation infrastructure in many of the Asian countries like the Philippines. The irrigation system enabled farmers to have adequate control of water and grow double crops per year, thus doubling their annual output per capita.

Table 3.1 shows the trend in the average rice yield per hectare and per capita rice production per year for Lagun province, which was the heart of the Green Revolution in the Philippines. Output of rice per capita in Lagun province increased from 0.5 tones to 1.28 tones and started to decline probably due to increasing population growth rate. Between 1966–1986 the growth rate in rice yields (per country per hectare per year) across the Asian countries ranged from 1.86% in India to 3.95% in Indonesia.

Before the Green Revolution in South America the traditional rice yields were between 1.4 t/ha in Brazil and 1.8 t/h in Bolivia (see table 3.3). But by 1981 high yielding improved rice varieties were widely adopted in south American countries. (Ecuevas–Perez ,*et al* 1992). In the case of the wheat component, the Green Revolution started with the work of plant breeder Norman Borlaug, who is known as “the father of Green Revolution.” Norman Borlaug was awarded a Nobel peace prize of 1970 as one of the key plant breeders of the Green revolution in South America.

The spread and adoption of improved, high yielding rice varieties have been most pronounced in Asia, followed by South America and a few isolated cases of high yielding varieties in Africa (e.g. Zimbabwe and Kenya). The proportion of total rice area planted to improved varieties in 1983 ranged from 13% in Thailand to 85% in Philippines.

By 1981 the global impact of the Green Revolution in rice, wheat and maize across the world was very great. The same piece of land could now produce two to three times the traditional yields. For example, impact of biotechnology on the crop yields of 1981 in Europe gave average yield 5.007t/ha of rice, 3.607t/ha wheat and 4.655t/ha maize. The average yields in Asia were 2.913 t/ha rice 1.708t/ha wheat and 2.305t/ha maize. (see table 3.4).

### **3.2 Scientific and Technological Ingredients of the Green Revolution**

The fundamental scientific and technological ingredients of the Green Revolution are illustrated by the case of rice. The rice component of the Green Revolution originated from the innovative rice technologies developed by International Rice Research Institute (IRRI), which was established in 1960 in Los Banos, Philippines. The first significant accomplishment of the green revolution was the development of semi-dwarf high yielding photoperiodic insensitive varieties of rice by IRRI scientists. The

first release (IR8) by IRRI in 1966 caused a green revolution in rice production in Asia and South America.

At the same time, two other International Agricultural Research Centers had been established namely,

- (a) The International Maize and Wheat Improvement Center (CMMYT) in 1966 in Mexico, focusing on maize and wheat
- (b) Centro Internacional por Agricultura Tropical (CIAT) in 1967 in Colombia for rice, beans, cassava and pastures.

The Green Revolution comprised of biological, chemical, mechanical and hydrological science and technology.

In the case of rice, the biological component was the creation of IR8, the miracle rice variety released by IRRI in 1966 and subsequent releases of IR9 to IR34. The attributes of improved rice varieties, were short and sturdy stems, erect and pointed leaves, non-photo period sensitivity, highly responsive to inorganic fertilizers, efficient water use and early maturing with high – yields of 3t/ha / season, which was double the traditional yields of 1965. But IR8 – IR34 rice varieties were still susceptible to pests and diseases. For example pathologists and entomologists screened and characterised new genes from field grasses for resistance against major insects and diseases. These helped breeders to incorporate them into high yielding modern rice varieties. The pest resistance in rice varieties of IR36, IR64 and IR72 led to their wide adoption by 96% (1979) and 80% (1987) of the farmers in Philippines (Bingali et al., 1998, Hamayi et al., 2000).

The chemical component comprised of the use of compound inorganic fertilizers.

The mechanical engineering component comprised the use of improved farm tools (hoes, rotary weeders, hand tractors ) to ease the field labour demands for farm operations like weeding , threshing, and transportation.

The hydrological component - irrigation -, which gave farmers a complete water control, was also a very important technological component of the Green Revolution. Farmers were able to grow crops in the wet and dry seasons. Besides it is estimated that the irrigated crops produced three times more than the rain fed ones.

The advanced fundamental scientific basis for the Green Revolution was a combination of principles of biological sciences, genetic engineering, molecular biology and the applications of biotechnology with a broad genetic resource base of germplasm resources. Plant breeders used new tools of biotechnology such as *in vitro* production of haploids and somaclonal variation for plant breeding then used direct gene transfer technology to introduce in the rice plant the right attributes, e.g. producing a rice plant that is more resistant to diseases, insects, or more tolerant to salinity and drought. The semi drought genes were introduced in the high yielding rice variety to prevent lodging .The scientists also produced a hybrid plant which has apomixes, i.e the ability to reproduce asexually off-springs that are identical to their parents.

The application of biotechnology has other advantages in addition to using of gene technology to breed a plant that has many attributes. The breeders can combine genetic materials / germ-plasm from different environments. Biotechnology applications (such somatic embryogenesis) enable scientists to use plant tissue to produce new seeds. In this way they made use of rare genetic materials from South America, Africa's wetlands and Indonesia's rain forest and combined those genes to create the miracle rice variety. The tissue culture method is an application of biotechnology for rapid multiplication of plantlets. Biotechnology applications were used with selection techniques and regeneration systems making crops amenable to genetic engineering.

### **3.3 The Socio-economic Ingredients of the Green Revolution.**

The socio-economic factors that contributed to the Green Revolution in Asia are discussed below.

First, the traditional land tenure system was that of share tenants who had no legal claim on the land they cultivated. Through the share cropping arrangements, the tenure of the tenancy on that land was relatively secure and stable. The landlords helped the tenants by advancing credit and giving gifts, and tenants reciprocated by providing labour for farm work, rent and other social services plus part of the crops being produced.

Then land reform programs introduced a reduced fixed land rent at 25% of the output. This was operation leasehold, which transferred income from landlords to tenants. Operation leasehold gave tenants a right to reduce part of the income from landlords. The land reforms encouraged tenants to invest more in the land and use better technologies and increase yield even more.

Second, was the change in the farming system from extensive or expansion of land under cultivation to intensive cultivation. This created an improved and more disciplined farming system, which increased land productivity. The intensive land cultivation was triggered off partly by high population pressure on the land, which had created land scarcity, and partly due to adoption of improved farming practices.

Third, the increased public investments in irrigation systems enabled farmers to get a double crop that's planted in the wet and dry seasons. The irrigation made agricultural production activities economically viable. Assured water supply reduced risks of crop failure. It made it profitable to invest in purchased inputs like fertilizers, encouraged use of improved methods like planting younger seedlings, and improved weeding using weeders.

Fourth, availability of credit facility for purchased inputs like fertilizers and seeds enabled small scale farmers to afford a high level of improved technologies, which caused a wide adoption of both improved crop varieties and the accompanying management packages.

Finally, the farming communities had already been well sensitized and ready to embrace new technologies.

### **3.4 The Objectives of the Green Revolution were:**

- (a) to enhance the genetic potential of the rice varieties to make the plant high yielding, resistant to diseases, early maturing, efficient in the use of the water and fertilisers, tolerant to low temperatures and soil alkalinity and salinity.
- (b) to disseminate widely rice related technologies information, knowledge and skills
- (c) to maintain sustainable development of the production systems for more efficient use of inputs, the protection of water and biotic resources.

### **3.5 Methods of Implementation of the Green Revolution**

The first strategy that led to the Green Revolution in Asia and South America was the creation of the network of International Research Centers (IARCs) by the world community. In 1960, IRRI was established in the Philippines to focus on rice in Asia; CIMMYT, in 1966 in Mexico, to focus on wheat and maize globally; IITA, in 1969 in Nigeria, to focus on maize, rice, cassava, plantain, yams, sweet potatoes and sustainable production systems for Africa; and CIAT, in 1967 in Colombia, focusing on sustainable production systems plus rice, beans, cassava and pastures for South America and Caribbean. (see Table 3.5).

The primary aim/goal of the first IARC was “food first”, then technological innovations for agricultural development and environmental conservation. At each International Agricultural Research Center, a group of multi-disciplinary scientists was established, thus creating a critical mass of research efforts to concentrate on developing crop varieties. This brought together breeders, entomologists, agronomists and agricultural economists working together, and each group contributing to the common goal.

Then IRRI and CIAT maintained a programme of germplasm exchange through the International Network for Genetic Evaluation of rice for South America. This facilitated exchange of materials between IRRI, CIAT and some National programmes.

The second implementation method was to identify breeding and research testing sites, so as to maintain the diversity existing in all the agro-ecological zones and farming systems within Asia and/or South America.

Thirdly, the International Centers identified collaborating local research institutions, then strengthened the capacity of those National institutions through training and financial resources to conduct both basic and on-farm research and stabilize production in their respective areas.

Fourthly the International Centers formed networking programmes with National Research Programmes. The regional networks aimed at making effective use of the human resources in the National Research Programmes. For example, IRRI networked with the University of Philippines at Los Banos. Then the International

Centers themselves, IRRI and CIAT, each served as a resource of advanced technology in the network.

The IARC major role was therefore to provide services in the conventional and emerging technologies at the stages beyond the scope of the National Programmes. Examples of some of the services of advanced technologies provided by IARCs were:

- i. Genomic mapping of economically important traits made possible by restriction pigment length polymorphisms. Then the genomic map would be used to enhance the genetic diversity of the cultivars in each region.
- ii. The incorporation of genes for resistance to important pest and diseases.

The fifth implementation method of the Green Revolution was conducting of the on-farm research to test the adaptability and performance of the improved varieties of both rice and wheat. For example IRRI and the University of Philippines conducted on-farm research in Laguna province. About 2400 farmers participated in the trials. (Hayami et al, 2000). The on-farm trials served as training and demonstration plots for other farmers. Those trials also helped in the initial dissemination of improved planting seeds to neighbouring farmers. In the process of the trials, researchers interacted with farmers, thus making the farmers more and more sensitized. Then there was promotion of the improved rice varieties through the national extension service officers who were posted to every administrative unit of the local governments in the countries.

### **3.6 The Green Revolution Success and Failures**

The Green Revolution success include, the first successful mass adoption of improved rice technologies by the majority of the farmers, up to 80% in Philippines. Farmers adopted the high yielding rice varieties along with improved management skills. Most of the farmers in Asia and South America learnt successfully the development of a good seed bed both for nurseries that produced the seedlings, and the paddy fields with properly constructed canals for controlled irrigation. Farmers also learnt the application of improved inputs on rice, in order to realize their economic potentials. As a whole, productivity was greatly increased.

Another success of the Green Revolution was the social transformation of the farming communities. The Green Revolution activities necessarily demanded a lot of labour. They had now changed the traditional methods of work and traditional farming systems to modern production systems. The Green Revolution also in a way caused the land reforms, thus transforming completely the lives of the poor landless tenants who now could claim economic returns on operational (fixed land) leaseholds. Above all the Green Revolution guaranteed land and cash income to grassroots farmers, considerably reducing poverty.

However the green revolution had some failures.

It should be noted that the designers of the Green Revolution did not address the issue of malnutrition. They concentrated on one or two crops - either rice, wheat or maize. They overlooked the need for a complimentary crop for a balanced diet.

The second short coming of the Green Revolution was that the designers overlooked the impact of high levels of fertilizer inputs for rice on the soil structure, and eventually on the ecosystem. In this regard, they focused on irrigated rice, thus encouraging extensive use of the wetlands, which could create long term environmental adverse effects. However the CIMMYT group that bred the improved wheat and maize bred for the uplands which can use rainfed agriculture..

The most significant socio-economic constraint that remained unchanged by the Green Revolution forces was the rapid population growth. If the rate of population pressure on the land remains unchecked, experience has shown that the impact of the Green Revolution can easily be eroded away by high populations. It is also argued that the possibility of rice technologies caused rich farmers to buy off poor ones and put them out of land, because poor farmers could not sustainably afford high inputs.

**Table 3.1. Average rice yield per hectare by season and total per capita rice production Laguna province of Philippines**

Year	variety	yield (/t/ha) wet season	yield (/t/ha) dry season	Production) (t/ha/yr)	output (t/capita/yr)
1956		1.9	0	1.9	0.53
1966	IR8	1.9	2.0	3.9	1.0
1974		3.0	3.7	6.7	1.28
1975		3.2	3.2	6.4	1.14
1978		3.2	3.9	7.1	0.9
1982		3.9	3.7	7.5	0.8
1987		4.1	4.4	8.5	
1995	RC64	3.5	5.3	8.8	
1996	RC14	4.0	5.0	9	

Source: Hayami Yugiro and Masao Kikuchi

**Table 3.2. Growth in rice yields (% /ha/year) in the first two decades of green revolution, 1966-1986 in Asia.**

Country	Indonesia	Phillipines	Vietnam	India	China
Growth in rice yield %/ha/year	3.95	3.59	1.85	1.86	2.97

Source: P Bingali and M Hussein IRR1998, Impact of rice research; FAO (1996)

**Table 3.3. The traditional upland rice production in South America**

Variable	country			
	Bolivia	Brazil	Colombia	Guatemala
Yield (t/ha)	1.8	1.4	1.6	1.7
Farm size (ha)	0.5-2	1.8	1.5	>7

Source: F. Cnevas-Be'rez. CIAT/IRR 1991



**Table 3.4. Yields of crops in regions or countries in 1981 (t/ha)**

Region /country	Rice	Wheat	Maize
Europe	5.007	3.607	4.655
Asia	2.913	1.708	2.308
South America	1.782	1.337	2.212
Africa	1.752	1.160	1.455
Argentina	3.496	1.407	3.857

Source: FAO production yearbook

**Table 3.5.: The Network of IARCs Coordinated by the CGIAR**

Centre	Date of Foundation (and joining)	Headquarters location	Main commodity, disciplinary and geographical areas of focus
<b>Original members founded before the CGIAR</b>			
<b>IRRI</b> (International Rice Research institute)	1960(1971)	Los Banos, Philippines	Rice, Asia
<b>CIMMYT</b> (Centro Internacional De Mejoramiento De Maiz y Trigo)	1966(1971)	Mexico city, Mexico	Wheat, Maize, global
<b>IITA</b> (international institute of Tropical Agriculture)	1967 (1971)	Ibandan, Nigeria	Sustainable production systems for the humid lowland tropics; rice, maize, cassava, cowpea, plantain, yams, sweat potato; sub-Saharan Africa
<b>CIAT</b> (Centro Internacional de Agricultural Tropical)	1967 (1971)	Cali, Colombia	Hyderabad, India lowland tropics, rice, beans, cassava, tropical pastures; Latin America and the Caribbean
<b>Funded by the CGIAR, or co-opted into the system, in the first wave of expansion, after 1971</b>			
<b>ICRISAT</b> (international Crops Research Institute for the Semi-Arid Tropics)	1972 (1972)	Hyderabad, India	Sustainable production systems for semi-arid tropics; sorghum, pearl millet, finger millet, chickpea, pigeon pea, groundnut; Asia, sub-Saharan Africa
<b>CIP</b> (Centro Internacional de la Papa)	1970 (1973)	Lima, Peru	Potato, sweat potato; Latin America, Asia
<b>ILRAD</b> = (international Laboratory for Research on Animal Diseases)	1973 (1973)	Nairobi, Kenya	Animal disease; theileriosis, trypanosomiasis; sub-Saharan Africa
<b>ILCA</b> = (International Livestock centre for Africa)	1974 (1974)	Addis Ababa Ethiopia	Animal feed and production systems; cattle sheep, goats; sub-Saharan Africa

Table.... (continued)

Centre	Date of Foundation (and joining)	Headquarters location	Main commodity, disciplinary and geographical areas of focus
<b>IPGRI</b> *** (international Plant Genetic Resources Association)	1974 (1974)	Rome, Italy	Plant genetic resources (collection and resources conservation); global Rice; West Africa
<b>WARDA</b> * (West Africa Rice Development Association)	1970 (1970)	Bouake, cote D' Ivoire	Wheat, barley, chickpea, lentil, faba beans, pasture and forage legumes; west Asia-north west Asia-North Africa Research organisation and management; global
<b>ICARDA</b> (International Center for Agricultural Research in the Dry Areas)	1975 (1975)	Aleppo, Syria	
<b>ISNAR</b> (International Service for National Agricultural Research)	1980 (1980)	The Hague, The Netherlands	Research organisation and management; global
<b>IFPRI</b> * (International Food Policy Research Institute)	1975 (1980)	Washington, DC, USA	
<b>Joined the system in the second wave of extension, after 1990</b>			
<b>ICRAF</b> * (international centre for Research in Agro forestry)	1977 (1991)	Nairobi, Kenya	Agro forestry; multipurpose trees; global
<b>IIMI</b> * (International Irrigation Management Institute)	1984 (1984)	Colombo Sirilanka	Irrigation management; global
<b>ICLARM</b> * (International Center for Living Aquatic Research Management)	1977 (1992)	Manila, Philippines	Sustainable fisheries management; Asia
<b>INIBAP</b> ** (International Network for the Improvement of Banana and Plantain)	1984 (1992)	Montpellier, France	Plantain and Banana; global
<b>CIFOR</b> (Center for International Forestry Research)	1993 (1993)	Bogor, Indonesia	Sustainable forestry management; global

\* Co-opted into the group (i.e. not founded by the CGIAR)

= To be combined to form the International Livestock Research Institute in 1995.

\*\* Co-opted into the group in 1992 and management with IPGRI in 1994.

\*\*\* Before 1994 known as the International Board for Plant Genetic Resources (IBPGR).

#### 4. WHY THE GREEN REVOLUTION WAS MISSED OR DELAYED IN AFRICA

##### 4.1 Contextual Issues in Africa That Delayed African Green Revolution

The most significant of contextual factor that constrained and thus delayed the Green Revolution in Africa is the complex traditional farming systems and particularly the traditional shifting cultivation and range grazing pastoral livestock systems. In these systems, a farmer clears a piece of land by slash and burn from fallow and cultivates it for two to four years. When the soils are exhausted, the farmer moves to another land. This system is adapted for low population density and not compatible with the application of the Green Revolution technologies. The traditional African farming systems also consists of intercropping (mixed cropping) two or multi-cropping of three to ten crops. The traditional methods of producing a variety of food or cash

crops to satisfy their needs requires the farmers to interplant in the same field due to land scarcity, especially in highly densely populated areas which have inadequate land to grow mono-crops. The consequences of a complex shifting cultivation farming systems are rapid soil degradation causing perpetual subsistence farming. Such farming systems discouraged the demand for improved technologies, that required intensive methods.

Most African countries have failed to redesign the traditional African farming systems. In Asia, the Green Revolution took advantage of a simple rice based farming system. But in Africa the farming systems are more diverse, complex and incompatible with modern farming technologies.

In many African countries, there were large estates of government parastatals foreign settlers or experimental sites where improved high yielding crops were being grown. There, the intensive monoculture farming systems existed side by side with the traditional shifting cultivation and subsistence farming system. Even where some of the farmers were trained and/or came into contact with the improved system, the two distinctive systems still existed side by side. In some countries, when farmers tried to plant improved seeds and applied fertilizers, they did so in insufficient/low quantities, so that they did not reach the critical levels of the Green Revolution and the urgency to cause land reforms.

Closely related to complex farming systems is the problem of high population pressure on the land. In some communities, the traditional rule for inheritance of land is that the present family land is subdivided among either the wives or the surviving sons. The sharing of such land follows a topographic location. That's one piece located in the bottom valley, on the hillside and hilltop. After two successive generations, the sharing of land results into serious land fragmentation, which is uneconomical to operate and incompatible with the improved technologies of the Green Revolution.

Moreover the land tenure systems in Africa are either communal or under tenancy arrangements. Countries like Kenya and Zimbabwe who have attempted land reform programmes still left a large number of poor landless farmers uncatered for. In this respect there are very few African countries that have succeeded in making meaningful land reforms.

The third major contextual constraint of the Green Revolution in Africa is the dramatic changes in the weather / rainfall patterns. In the last twenty-five years, the rainfall pattern in Africa has greatly changed. The absolute amount of rainfall has declined and the timing of the rains has become very unpredictable in all the agro-ecological zones of Africa. This makes rainfed agriculture extensively risky. The rainfall duration has shortened, making many of the crop cultivars grown by the farmers subject to post-flowering drought and giving very low yields or even crop failure. This makes it uneconomic to grow improved crop varieties, since they cannot produce at their full potentials under such risky rainfed agriculture. The rainy seasons are characterized by intermittent rains, which are punctuated by prolonged dry spells. Under these uncertain circumstances farmers are hesitant to grow new crop varieties which require use of purchased inputs like inorganic fertilizers and seeds.

The fourth contextual constraint of the African Green Revolution is the poor state of the infrastructural network. The poor state of roads and inaccessibility to certain rural areas due to inadequate or lack of feeder roads make transportation costs in Africa very high. Most farmers are unable to market their farm produce, and whatever they can sell is bought at prices close to or below the production cost. Such people could not adopt new crop varieties.

#### **4.2 The Design and Implementation Issues that Delayed the African Green Revolution**

First, the African political elite have not fully recognised the fundamental importance of science and technology in modernisation of agriculture. This shortcoming is evident in the whole history of agricultural development approaches in almost all the African countries. The government development expenditures allocate insufficient funds to agricultural research for technology development to further the goal of food security and export.

The number of agricultural researchers in the African countries is still insufficient to make the critical mass that could make an impact. Countries lack long term commitment in establishing human and institutional research capacities. In cases like Kenya, Malawi, Uganda and Senegal the existing agricultural research resources are fragmented into many stations and programs, where the research capacity of each program is too low to make any significant impact on their respective research areas.

As some of the key informants and some authors have pointed out, African research system cannot make a breakthrough if they do not prioritize and focus on a few crops. Even within one small research program, there is discontinuity of the research focus. The discontinuities are sometimes caused by frequent transfers of staff from one program to another or shifting the research priorities every year. The national research policies are vague, unfocused or shifting from time to time or just rhetoric and not reflecting the facts on the ground.

The second cause of the delay is weakness or absence of on-farm adaptive research in National Research programs. For example, most of the Integrated Rural Agricultural Development Projects in Africa grossly left out the on-farm research. So the projects had no tested crop or animal technologies to promote to farmers. After twenty years of research and twenty years of IRDP, say in Malawi, there is still low adoption rate (less than 20% farmers) of improved maize varieties. As Uma Lele (1992) put it, most of the IRDP or ADP in African countries failed because of lack of farm level adaptive research that could have helped to accelerate the rate of technological adoption.

Donors have also paid little attention to the development of human and institutional research capacities in Africa. Donors neglect or give insufficient support to the on-farm adaptive research. Considering all the Donors' huge investments in agricultural development in Africa between 1967 and 1989, the magnitude of such huge investments could have caused a heavy Green Revolution if the efforts had included a significant proportion spent on promotion of science and technology.

Both scientists and critics have pointed out that ill-conceived public agricultural projects contributed to the stagnation. Most of the project and program designers ignored the facts on the ground. The designers and implementers did not try to understand the existing farming systems and the available technologies, nor did they bother to compare the potentials and the available opportunities. For example a project in Iringa, Tanzania, a drought prone area, had no irrigation component. Yet the project spent a lot of funds on uncomplimentary items.

African's policies, strategies and designs are not market-oriented even if they say so. Some of designers left out important cash crops; others concentrated on crops like Millet, Sorghum and Cassava, which were being produced for no-farm consumption. In such cases the farmers had no incentives to grow surpluses of Millet, Sorghum and Cassava since those crops have limited domestic and external market outlets.

### **4.3 Initiatives that Suggest Possibilities of Green Revolution Happening in Africa.**

There has been as many as five types of initiatives that suggest the possibility of a Green Revolution happening in Africa.

The first type of initiative is the successful diffusion of improved crop technologies through on-farm trials. Table 4.1 to 4.4 present some results of cotton, rice, sorghum, maize and groundnuts from on-farm research programs in different countries of Africa between 1969 and 1991. Table 4.1 shows yields of cotton from on-farm trials carried out in 1991 in Francophone countries and others carried out in 1985 in some selected counties. According to Table 4.1, the average yields of improved cotton in 1991 had increased by 55% over the traditional cotton yields obtained in 1969 from 11 African countries. Similarly according to Tables 4.2 and 4.3, the average yields of improved Sorghum in East Africa had increased by 5% and West Africa the improved sorghum yields had increased by 67% over the traditional varieties. According to Table 4.4 from the on-farm trials in North Cameroon in 1988, crop yields with improved technologies increased by 100% for Sorghum, by 130% for maize and by 54% for groundnuts.

The second type of significant initiatives is the successful irrigation projects in some African countries. There have been a few successful large irrigation schemes. The Aswan dam on the River Nile and provides irrigation for millions of farmers in Egypt.

**Table 4.1. Successful diffusion of improved crop technologies, 1991**

Country	Cotton a		Rice b	
	Yield (kg/ha) 1969-1971	1991	yield (kg/ha) 1971	1985
Benin	844	1,168		
Burkinafaso	368	894		
Cote d'voire	908	1083		
Mali	753	1279		
Senegal	1064	1118	1081	1617
Togo	730	1157		
Cameroon	552	1249	886	3699
Centra African Rep	404	500		
Chad	358	651		
Ghana	540	1103		
Nigeria	458	624	1679	2033
Average:		634	984	1215
				2449

Source: a)

Ministère de la coopération, 1991, cited in Bosc and Freud 1994.  
Bosc, Pierre-Marie and Ellen H. Freud 1994.

b) Uma lele 1992

#### 4.2 East Africa. On-farm research results, Sorghum yield (kg / ha), 1986

Country	Local	Improved
Kenya	-	1560
Uganda	1840	2860
Tanzania	3833	3889
Zimbabwe	3500	4100
Rwanda	3317	3980
Average	3278	3122

Source: Brhane Gebrekidan, 1986,

#### 4.3 West African Sorghum, On-farm yield kg/ha

Country	Local	Improved
Benin 1987	331	1210
Burkinafaso 1987	1604	2031
Average:	967	1620

Source: STRC/SAFGRAD/FSR 1985-89 technical report

#### 4.4 Cameroon, SAFGRAD/FSR on-farm trial results, kg/ha, 1988

Crop	local	improved seed +Fertilizers
Sorghum	1719	3688
Maize	1852	4351
Ground nuts	1660	2558
Average :	1744	3532

Source: Ngambeki D. et al 1989, SAFGRAD/FSR, Cameroon country report.

The Gezira irrigation scheme along the Blue Nile provides irrigation for 750,000 farmers in southern Sudan. Among other examples of successful irrigation schemes are those along the Tana River in Kenya, Mwea-Tebere irrigation scheme in Kirinyaga district Kenya, Kilombero valley in Tanzania and two dams in Sokoto – Rima village along the Niger River. Farmers in the irrigation schemes are able to grow two crops (in the wet and dry season) a year plus their yields are three to four times higher than the yields of the rainfed agriculture.

The third significant initiative that could contribute to African Green Revolution is the existence of advanced crop technologies at International Agricultural Research Centres and some of the National Research Programmes. At IITA, Nigeria, there exist some advanced technologies of maize, cowpeas and cassava, which could be tested and adapted to certain agro-ecological zones of Africa. At ICRISAT, there are some promising technologies of sorghum and ground nuts. Recently it has been reported that at WARDA, Ivory Coast, there are some improved rice varieties, with very high yields that if tested and adapted to the African farm conditions could cause a Green Revolution. In addition there are some advanced crop technologies at some National Research Programmes. NARO in Uganda has promising technologies for cassava and bananas. KARI in Kenya has technologies for composite and hybrid maize plus horticultural crops. Zimbabwe has promising hybrid maize technologies.

There also exist some International and National Agricultural Research Centres with significant capacities to use, and train others on the applications of biotechnology. IITA, Nigeria can handle tissue culture and genetic breeding of cassava, WARDA handles rice and NARO, Uganda, can handle tissue culture applications for bananas.

The fourth initiative is the instance of redesign of traditional farming system to become more productive and sustainable. See the field case study of Northern Cameroon in Appendix 2 (Ngambeki field case study 2).

## **5. PROPOSED STRATEGY, METHODOLOGY AND PLAN FOR CAUSING A GREEN REVOLUTION IN AFRICA**

### **5.11 The African Green Revolution Initiative**

The proposed strategy, “African Green Revolution Initiative”[AGRI] is a system for sustainable modernization of agriculture and rural transformation [SMART]. The proposed African Green Revolution Initiative has been inspired by the events of the Asia Green Revolution and some of the successful agricultural research and development efforts in Africa. At the field design and implementation level, the African Green Revolution Initiative, hence forth referred to as SMART/AGRI, is to have four major components namely biological, improved crop management, organic plus ½ chemical, biophysical, on-farm adaptive research activities and farming systems design.

The biological crop technologies are to include improved varieties of selected crops from among rice, maize, sorghum, beans, Irish potatoes, cassava, cotton, coffee, cocoa and bananas/plantains. The right traits in improved crop variety should be

robust plant stem, high yielding, responsive to enhanced plant nutrition, resistant to specific pests and diseases, adaptable to two or more agro-ecological zones and tolerant to salinity, alkalinity and low soil moisture but with ability to make efficient water use. A breeder may use elite crop varieties or genetically improved varieties. These are to be promoted with improved crop husbandry.

Livestock has been neglected by most agricultural designers for Africa. Yet our modeling indicates a strong correlation between crop-livestock integration (CLI) and productivity/sustainability of several African farming systems (Ngambeki et al, 1991). Therefore an African Green Revolution must take a harder look at animals in the African farming system. Our approach will involve selection of strong, healthy animals from the indigenous/local stock breeds which are adaptable to tropical conditions and tolerant to pests and diseases, to be accompanied by improved animal husbandry.

Second is organic materials plus half the rate of inorganic chemical fertilizers. Many experiments conducted in Nigeria, Kenya, Uganda, Zimbabwe, Ghana and Malawi showed that a combination of organic materials (like compost, farm yard, kraal and green manure) with half the dose of inorganic fertilizers produces high yields while maintaining the soil fertility of the land (Webster and Wilson 1991).

The biophysical technologies form the third component of SMART/AGRI, and consist of soil and water management, small-scale irrigation systems and improved hand tools/techniques. Among the soil and water technologies which have been proven successfully in Africa are tied ridges, mulches for perennial crops, nitrogen fixing and improved fallow legumes (like *mucuna*, *cajanus cajan*). Small-scale irrigation schemes to supplement low rainfall, besides being cheaper, have been more successful in Africa than the costly large-scale irrigation schemes. This has worked very well with rivers in bottom valleys, tube wells and construction of valley dams in Northern Nigeria for water harvesting. Among the biophysical technologies will be the proven improved prototype hand tools such as rolling injection planter and walking tractor developed by IITA and IRRI, herbicides for zero tillage and weed control, hoes and cutlasses.

On-farm adoptive research, as the fourth component, has three perspectives i) testing the characterized and redesigned modified farming systems, ii) farm level testing in the respective agro-ecological zones, of all the technologies being proposed for the African Green Revolution Initiative and iii) integration of livestock into the modeled farming systems. Other important perspectives are post-harvest technologies and marketing outlets.

## **5.12 State Governments' Commitment and Support**

One of the major conditions required for the African Green Revolution Initiative to happen in the field is state government commitment and support. Thus the strategy requires each participating African country to create a critical mass and invest sizable resources so as to mobilize for the promotion of science and technology, backed by long-term policy/priority commitment to sustainable modernization of agriculture and rural transformation (SMART).



As part of the African Green Revolution Initiative, a participating African country should commit material and financial aid resources to develop her institutional and human capacities to harness science and technology for modernization of agriculture. Such a country needs sufficient number of scientists and institutions for teaching, research and extension. The investments in science and technology are needed to generate new knowledge and skills, thus bringing about human capital, which is one of the critical sources of development. When many countries achieve optimum levels of investments in science and technology, high yielding technologies that are widely adopted by small-scale farmers who can at least double their production, then the African Green Revolution will have been achieved.

Under the African Green Revolution Initiative, countries that share the same agro-ecological zones will be advised and encouraged to formulate and coordinate their science and technology policies and/or programs. Besides, some countries may not have sufficient resources to invest in science and technology at optimal levels. In such cases, a group of neighbouring countries could form partnerships to share the use of germplasm and/or science and technology facilities for creation of improved varieties through cross-breeding and biotechnology (including gene technology).

The concept of partnerships and networking will be applied to stakeholders internally (say between public sector including investors) and stakeholders externally (say neighbouring countries, International Research Centers and International Donor Agencies).

## **5.2 Methodology of African Green Revolution Initiative**

### **5.21 Preparatory Activities**

- (a) Review of relevant literature-National and International research reports
  - National development project reports
  - Review national policies/strategies and trade reports,
  - Climatic and geographic information (GIS)
- (b) Reconnaissance visits to selected strategic countries
- (c) In-country participatory meetings/consultations
- (d) Division of the African continent into regions according to similarities and differences in agro-ecological zones, farming systems, natural resources and agricultural production potentials/ opportunities.

### **5.22 Methodology of Farming Systems Design**

The farming systems are to be studied using farmer participatory development and communication to generate deep understanding and basic data needed for subsequent analyses and designs. Analyses of factors of farming systems can cover agro-ecological zones, namely; climatic (temperature, rainfall and prevailing winds), location (topography, altitude, vegetation, water bodies). Other farming systems elements are biological factors - covering crops grown, cash/food crops, crop sequence, crop pests and diseases, livestock and crop-livestock interactions, cropping calendar. Physical factors – covering soils (soil types, fertility), land status, land use, methods of production. Socio-economic factors-covering people, customs, traditions, gender roles, age groups, education and employment/labour utilization. The on-farm

adaptive trials from the perspective of technologies will be at level of testing, adaptation, evaluation, validation or at the level of scientific investigation for further technology development. The on-farm trials will provide opportunities for interactions between researchers and farmers. It is also a logical step for setting off massive promotion of improved varieties. Crop-livestock integration provides crop and livestock activities, constraints of crop livestock and crop-livestock linkages.

### **5.23 Formulation and Launching of Strategic Plan**

(A) Organize and facilitate Stakeholders Strategic Planning meetings by region to discuss partnerships and priorities of science and technology policies/programs (national government, political and technocrat representatives, private sector, research and extension, international research centers, international donor agencies, NGOs).

(a) Set partnership modalities.

(b) Set priorities for science and technology policies/programs.

(c) Identify/agree on germplasm, biotechnology exchanges.

(d) Identify strategic research and testing centers.

(e) Divide/agree on roles and reciprocity of product and services.

(f) Develop a plan of action for networking.

(g) Lobby for national governments and donor communities for human, material and financial support.

(B) Appoint technical coordination teams. The team size should consist of three to seven people per team per region including the major professional disciplines according to priorities/constraints and potential of the respective regions. The team's duties will include:

- Facilitating in participatory manner the selection of promising available technologies and designing of the on-farm research programs
- Coordinating the networking of the basic and on-farm research activities

### **5.3 Implementation Plan for African Green Revolution Initiative**

The purpose of this plan is to use a practical design and management approach that can produce visible results at pilot sites in three years, and show similar results at replicated sites at two years and in addition to having had impact at the pilot sites after five years

#### **5.31 Preparatory Activities 1<sup>st</sup> year**

#### **5.32 Implementation of on-farm research at pilot sites, 1<sup>st</sup> to 3<sup>rd</sup> year.**

- a) Characterize the existing farming systems and identify the major constraints, potentials and opportunities
- b) Identify the capacities of existing international and national research centers that can serve as sources of advanced technology
- c) Identify commodities (crops, activities and livestock) for which the region or zone has comparative advantage (NB: When a measure of resource cost coefficient is used to measure the real domestic resource cost (DRC) required to earn (export) unit of foreign exchange from a commodity. When the DRC is less than 1.0, it indicates comparative advantage. A commodity whose DRC is lowest, when exported it

would maximize the returns to fixed resources (land and labour) and generate full impact on the very poor farmers.

### **5.33 Implementation of the farming systems re-design, 1<sup>st</sup> year**

Redesigning of the farming systems using stakeholders participatory and communication methods (GRASP: communities involved in reflections and their situation analysis by animation and participatory development communication process) (see 5.22).

### **5.34 Implementation of biological component at pilot sites, 1<sup>st</sup> to 3<sup>rd</sup> year**

- Establishing germplasm banks that are characterized for their usefulness by national research programs
- Select key sites for evaluating /testing and selecting elite improved lines. Sites with disease and pest evaluation methodologies, the selection process of materials with greater genetic diversity potential/ stability.
- Conduct studies on genes that can give source to incorporate resistant genes into modern improved varieties
- Make use of applications of biotechnology existing at any of the centers, to realize the production of improved crop varieties within a short time, while providing greater stability, broaden genetic base by induced genetic variability
- Establish networks for exchange of information, germplasm and making efficient use of resources available in the region

## **6. RECOMMENDATIONS**

### **6.1 The way forward**

The way forward is to develop and implement immediately a strategic plan that can cause a Green Revolution to happen in Africa. The new plan needs all the technical and social / political ingredients well synchronized.

The essential ingredients of the African Green Revolution initiative are the biological component starting from the simple selection of elite improved crop varieties, diversity of local germplasm to the more advanced applications of biotechnology and gene technology.

The second essential technological ingredient is that the biological technologies need to be accompanied by their complimentary technologies such as improved farming methods (good seed bed, planting in lines, optimal mixed cropping or monoculture, timely weeding ...) and improved inputs ( organic and / or inorganic fertilizers , tools and so on ). Crop/livestock interactions are a highly desirable integral part of the biological technologies as well as the improved farming systems.

Thirdly the biological technologies can even be more efficient when complemented by an irrigation system. Simple, small-scale irrigation systems (like sprinkle,

tubewell and river irrigation canals similar to horticulture irrigation system in Kenya) can still cause and sustain a Green Revolution in Africa.

The fourth essential ingredient is the selection of key on-farm testing sites within target agro-ecological zones. The technologies must be tested and adapted to the practical factors on the ground. Adaptation to the local conditions can be done by selection, crosses and / or genetic engineering technologies.

In addition to the on-farm testing, there is the essential basic element of characterization and redesigning of the existing farming systems. Smallholder farming systems in Africa are too complex to be dragged along the road to agricultural modernization without their modification. In the past, many researchers and development workers in Africa have tended to oversimplify, changing the local subsistence farming systems to planting of monocrops, or else overlooked the question of an improved / designed farming system.

*The political ingredients of the African Green Revolution Initiative are: a) Mobilization of state governments for long-term commitment and support. This means putting the right policies in place, then making sizable investments (in terms of human, material and financial resources) into the cause of agricultural modernization through the promotion of science and technology; b) Creation of partnerships (between state and state, state and donors) and c) Networking to share both responsibilities and benefits of a Green Revolution.*

## **6.2 Recommendations to African Agrarian Communities and Regions**

In order for an African Green Revolution to happen, it is recommended that the agrarian communities and regions reform their land ownership and land tenure from traditional and/or customary laws, in order to enable the ordinary or poor farmers to access and use the land with ease. The farmers need secure and stable tenancy on the land for them to make the necessary investments in modernization of agriculture. Where there are farmers who are tenants on the land, then there should be reform to make the tenancy long term, so that the farmers have operational legitimacy such as land lease or operational leasehold.

## **6.3 Recommendations for Agricultural and Rural Development and Other Science and Technology Experts in the Field.**

It is recommended that all agricultural and rural development personnel plus S&T experts who are working in the same sub-county, community, district or even country should get SMART – i.e. coordinated and focused to the common goal (promotion of science and technology for modernization of agriculture and rural transformation). It is further recommended that all development workers in the same district should have their objectives, priorities and work plans incorporated into one umbrella or master plan document. That way, their efforts can easily be complementary to each other and produce visible results in 3 to 5 years. When the plans of different teams are in one document and their implementations are being coordinated, they are automatically sharing responsibilities and networking. These are already two practical pre-conditions for causing the African Green Revolution Initiative to happen.

#### **6.4 Recommendations for African Governments (Local/ National)**

It is recommended that the African Governments go beyond political and enter into development partnerships. They should divide roles, exchange information about their priorities and policies for promotion of science and technologies, thus promoting joint strategic plans or policies. African Governments under similar agro-ecological conditions should harmonize their research, testing centers, germplasm collections and bio technologies applications so as to get the most efficient use of their available resources / or capacities.

The African Union and NEPAD need to mobilize and provide political support to African Governments to identify and initiate the necessary measures / policies contributing to the African Green Revolution Initiative, embracing the concept of partnership and networking.

#### **6.5 ECA and other UN Agencies**

*It is recommended that ECA start to promote to African Governments and to donors the concept of African Green Revolution Initiative. It should sell the idea, and help to launch its pilot phase in the next two years. The other UN Agencies should also promote and support the African Green Revolution Initiative in particular and promotion of science and technology in Africa in general.*

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## Key informants

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## APPENDIX

### DESIGNING THE AFRICAN GREEN REVOLUTION: CASE STUDIES AND FIELD EXPERIENCES OF DEZI NGAMBEKI, 1977-2003

The following case studies each had an instance of redesigning a farming system for modernization, productivity and sustainability, as well as, for some, introduction of Green Revolution technologies.

#### **Case Study 1: Upland Rice Farming Systems Research -Nigeria 1976-77**

Project Name: On-farm trials of upland rice

Location – Oyo and Ogun states (western Nigeria) 1976-1977

Sponsor – Nigeria Federal government – Oyo and Ogun state governments – extension staff logistics

Implementers – Ngambeki in collaboration with Oyo and Ogun state Governments and farmers

#### Problems

a) By 1976, Nigeria was a net importer of food – importation of food into the country amounted to 60% of total costs of all national imports. Both federal and state governments had formulated a policy on food self-sufficiency and were concerned to have the policy implemented

Invitation/local design

Ngambeki arrived in Nigeria October 1975 on invitation through the inter government exchange programme.

Discussions of Ngambeki's research programme were held from Ibadan University, Oyo and Ogun states, Federal Government and Agriculture researchers, farmers. The priority of alleviating food shortage emerged. Ngambeki was requested to design an intervention to address the problem of food shortage.

Ngambeki situation analysis indicated that root causes of food shortages; Oyo and Ogun states had high population and a deficit in food production. The climate and vegetation represent a typical tropical humid forest. Two rainy seasons, farming systems consisted of cassava, yams, maize, cowpeas, beans, soyabeans and okra, a few goats and hardly any cows. The varieties of cassava and yams were late maturing cassava (3years) and yams (1year). Acreage under crop was very low with poor yields. People eating habits- rice preferred dish mostly for high income group who could afford the imported rice. Gari (Cassava roasted flour) was staple food for the low class, yams and plantain (eba and dodo) for middle class. But scarce for being produced mainly in mid-belt and eastern Nigeria

b) Ngambeki proposed solution:

To introduce a new crop in the farming systems, which is early maturing and the improved technologies and a modification of the farming system to accompany the new crop. Upland rice was picked up because of the suitable climate and land resources plus its favourite place in people's diet.

C Ngambeki edited the implementation

Ngambeki designed the on-farm trials, Moor Plantation Research Station and IITA provided three promising upland rice varieties, Oyo and Ogun state governments provided vehicles and their extension staff. Two hundred farmers volunteered to participate in the trials.

In the first round of trial, most of the farmers planted the trials according to their traditional farming systems. The yields were not high. Besides poor soils, there was the problem of poor land clearing methods (left with high stumps) and birds damage.

Ngambeki designed the cropping sequence, planting dates, cropping calendar, how farmers could plant in clusters, thus modifying their farming systems. The three subsequent plantings were all of cereal/legumes/cereal/fallow and destumping their newly cleared land and applying half-rate of fertilizers enabled the farmers to use their land sustainably. For many farmers, cluster planting of upland rice on same dates in adjacent fields dramatically reduced birds damage.

Ngambeki organised two farmers' field days to lobby support from policy makers. By September 1977 both the state and Federal government officials were positively convinced. The lower levels of government adopted the upland rice trial design and extended it to whole of western and mid western Nigeria. By 1978, the same design was adopted by the Federal Government to promote, improve technologies of maize and cassava trials under the National Accelerated Food Production Programme (NAFPP)

## **Case Study 2 – Farming Systems Design, North Benin 1985, Burkina Faso 1985**

Project Name. OAU / STRC / SARGRAD / Farming System Research

Countries a) Republic of Cameroon 1985 – 1988

b) Republic of Benin 1985

c) Burkina Faso 1985 – 1986

Sponsor IFAD - International Fund for Agricultural Development

Ngambeki recruited by SAFGRAD / IFA D from IITA in Jan 1985

Common Problems - The prolonged drought of 1980 / 82 in Africa caused

- i) desertification threat from the Sahara desert across north west, central and eastern African Countries.
- ii) Depletion and further threat against livestock by the drought

Republic of Cameroon; Ngambeki made situation / problem analysis which revealed that

- iii) Forage shortage forced pastoralists to drive their herds southwards into Sudan Savannah zone in search of pasture and water. That created fierce social conflict between crop-farmers and livestock keepers.



- iv) Farmers poor response to cotton promotion project. The province of North Cameroon had been the major producers of cotton and a earner of foreign exchange. The French company SODECOTON had made a lot of investments in the Cotton project, providing extension services and input credit in form of Ox-plough, fertilizers, pumps, herbicides, insecticides, cotton seeds, tractor hire services for ploughing to farmers. Each farmer was encouraged to plant at least one acre of cotton. But farmer's response was very insignificant.
- v) Wide spread problem of food shortage. Why farmers gave luke-warm response to cotton project because the French extension staff did not pay attention to the biting problem of food shortage.
- vi) The shortened duration of the rainy season from 180 days to 90 days could no longer sustain the late maturing traditional varieties of white and red sorghum and millet that required 150 to 170 days.

Ngambeki's analysis of the existing farming systems: Traditional, Subsistence shifting cultivation.

Crops - Traditional varieties of white and red Sorghum, Groundnuts, Millet, Cotton and Mus Kwari.

Average Farm Size 2.07 ha.

Soils, Sandy soils with low moisture retention Capacity.

Rainfall season - May to November with a peak in July. But soil moisture surplus only from Mid – June to Mid September.

Labour peak periods – July / August

The cropping sequence - Cotton / Sorghum / Sorghum / Groundnuts or Sorghum / Sorghum / Sorghum / Sorghum / Groundnuts

Crop – farmers who own one or two cows keep their cows with herdsmen further North, away from the farm.

Ngambeki's design solution

- i) Redesign the farming systems i) introduced new crops which can be squeezed / fitted into the 85 days of soil moisture surplus period (early maize 75 days, early cowpeas 60 days) + cotton and Sorghum 90 days.
  - ii) Redesign cropping calendar in a participatory manner
  - iii) Promote technologies that accompany new improved crop varieties
    - a) improved management practices b) soil fertility, Kraal manure + ½ fertilizers c) Ox-plough d) Soil moisture conservation tiered ridges
- 2) Interacted with breeders and other researchers of IRA, IITA and ICRISAT to produce the required improved crop varieties and other technological components that fit into short rainy season.
  - 3) Design and Implement farmer participatory On-farm trials to test the redesigned farming systems and the technological components. Started with 300 farmers participating in 1986. By 1987 participating farmers increased to 500

N.B: Implementation of the trials utilized the opportunity of having SODECOTON selection staff.

N.B: IFAD Support ended May 1988. A French team took over the process in June 1988.

### **Case Study 3: Farming Systems Design, North Cameroon 1986-88**

Project Name. OAU / STRC / SAFGRAD Farming system research

Country, Benin

Sponsor: OAU / STRC / SAFGRAD

Location Borgou and Atacora provinces in northern Benin

Regional Common Problems: the drought of 1980 – 82 in Africa

Causes i) Desertification threat from the Sudan desert across North West, Central and Eastern African countries .

ii) Depletion and further threat against livestock by the drought.

Northern Benin

Ngambeki made situation / problem analysis revealed specific constraints:

iii) Late rains and shortened rainy seasons; annual rainfall declined by 40% -there were only 100 days of moisture surplus available per year.

iv) Frequent dry spells of more than 14 days in May/July causing severe moisture stress to the crops at their critical period of growth, Plus water logging .

v) Shortage of pasture in the dry season

vi) poor soils

vii) Frequent crop failure and food shortage.

viii) Tight schedule of farming activities – shortage of labour for soil preparation (ridging + mulching), planting, weeding.

ix) Some farmers were only crop farmers and others only livestock keepers.

Ngambeki's analysis of the existing farming systems

- traditional subsistence, shifting cultivations

Crops: Sahelian Savannah: Sorghum / Millet / Beans; Sorghum / Millet, Cotton , Groundnuts ,

Sudan Savannah : Maize / Sorghum, Cassava, Groundnuts.

Guinea Savannah: Maize / Sorghum, Millet / Yams / Beans intercrop Cassava, Yams, Groundnuts, Cotton.

Livestock: IN Sahalian, Sudan and Guinea Savannah zones 60, 54 and 50 per cent of farmers keep livestock cattle, goats and sheep

Use of animal traditional Sahalian zones over 80%, Sudan zones 78% and Guinean zones 12% of farmers with animal tradition.

Rainfall: May/ June to mid – October . 400 – 800mm

Soils: Sandy soils with low moisture retention capacity.

Ngambeki's design solutions

a. redesign an integrated improved farming system consisting of

i) Improved varieties of Cassava, Sorghum and Millet.

ii) Crop-trees and livestock interactions (trees – leguminous shrubs – Sun hemp ( *Crotalaria* sp.) + other

- trees as source of green manure for crop and foliage for animals.
  - iii) Soil – water conservation technologies: Tied – ridges, trenches and bund terraces.
  - iv) Labour – Saving technologies : Ox – plough , Ox – cart and roulette – a grain seeder
- b. Interacted with other Researchers, Agronomists, Breeders and Engineers for the appropriate technological components.
- c. July 1985 – 6 (Implementation of the trials testing the components and the Design of the improved farming systems. The integrated farming systems showed economic viability.

#### **Case Study 4: Farming Systems Design, Mityana District, Uganda 1991-95**

- a) Project Name: On-farm research with farming systems perspective under Manpower for Agriculture Development (MFAD)  
Country : Uganda  
Sponsors : USAID and Uganda government  
Implementers: National Agriculture Research Institute and Faculty of Agriculture and Forestry, Makerere University – Ngambeki led the implementation of on-farm research.  
Ngambeki arrived in Uganda August 1990 , having been recruited from Purdue University by Ohio and Makerere universities and USAID to lead the on-farm research work and to teach post graduate courses at Makerere University
- b) Basic problems during the political turmoil in Uganda of 1975 – 1985, the country’s research system was hit by brain drain, looting of research facilities including all documentation and the collapse of the entire agriculture research system. There was no improved seed nor planting material of any crop in NAS (National Agriculture System) .Agricultural production was at its worst MFAD / USAID had been working 8 years on rehabilitation program of the whole infrastructure of agricultural research including – training and re-training, rehabilitating buildings, reviving germplasm collection and breeding work. But for those 8 years no research results had been adopted by farmers
- c) Ngambeki’s situation analysis:-

Analysis indicated that the research teams had assembled size amounts of germplasm for annual crops like maize and cassava. The breeders were using conventional breeding methods of cross pollination of fertile parents. Then evaluating the f1 and f2 materials on station and at multi locations researcher managed trials at sub stations .

Researchers and extension officers were using top down approaches, unable to link up the research to the problems at grassroots. Further analysis ( by participatory focus group discussion and baseline survey of 720 farmers) showed that the exiting farming systems was subsistence, shifting cultivation with poor soils, mono culture and multiple intercropping maize/beans/cassava or maize/beans/groundnuts. The farm yields were very poor at 0-600kg per hectare. Traditional crop varieties had low genetic potential.

- d) Ngambeki's proposed solution
  - i) Incorporate bottom-up participatory approaches in the NAS; starting from and ends up with grassroots.
  - ii) Introduce relatively new crop varieties, namely soyabeans, sunflower and cassava then use improved crop varieties along with improved crop production technologies evaluated in on-farm farmer participatory trials
  - iii) Redesign the farming systems incorporating
    - crop rotation: maize – beans or soyabeans – maize
    - improved fallow plus incorporation of livestock (goats, sheep or cattle)
  - iv) perennial crops – coffee based farming systems in the Victoria lake crescent zone
- e) Ngambeki led the implementation of on-farm research
 

The country Uganda, was divided into 8 agro ecological zones, namely Victoria lake crescent, central wood land savanna, south western highlands, south grassland savanna, etc. Over 1000 farmers participated in on-farm trials of annual crops namely cassava, maize, soya beans, sun flower for two years and 500 farmers participated in coffee trials.

After 3 years improved varieties of each crop were released and widely adopted by farmers .The occurrence of the food shortage problem was significantly reduced .The communities in Mityana transformed themselves from subsistence to market oriented production.

**Case Study 5: Integrated Farming Systems with Development Planning Approach, Mbozi district, Tanzania, 1999-2000**

- a) Integrated participatory planning for sustainable development – Tanzakesho (Tanzania of Tomorrow)  
Country: Tanzania 1999 – 2000  
Location: Mbozi district  
sponsors UNDP and Tanzania government  
Implementers : Mbozi district local government  
Ngambeki recruited by UNDP and posted to Mbozi to start pilot project in Tanzania
- b) General problem : After 30 years of research and development no significant impact on the ground .Chronic food shortage, very low production% low income and widespread poverty.
- c) To pilot integrated participatory planning for the sustainable development – linking up village, division, district, province and national development plans incorporating sustainable management of natural resources
- d) Ngambeki's situation analysis revealed the following gaps / constraints
  - no linkages between village and district development plans
  - no linkages between district and national development plans
  - all plans lacked participatory planning input and poorly coordinated
  - weak, unmotivated team work of technical staff at all levels
  - expected output not sufficiently operationalised into tangible benefits
  - low levels of revenue collection

Ngambeki's proposed solution

  - conducted 4 training workshops in participatory planning at division , district and central government development planning levels, to create the missing development planning linkages .

- conducted 2 participatory situations and/or SWOT analyses of the existing development planning systems at district and division levels
- introduced new development activities in the integrated development planning model /modified farming systems, and the introduction of upland rice and rehabilitation and liberalization of coffee marketing.
- \_Recommended increases of local government investments in infrastructure (rural feeder roads, health centers, education and rural markets)
- \_Recommended broadening tax base at the level.

#### Outcomes after 2 years

- 1000 farmers enrolled for rice production
- 500 farmers licensed to carry out marketing activities and/or getting petty trade in farm produce marketing.
- Mbozi district revenue collection increased by 30 percent from the second year of implementing the recommendations.
- sales of seeds and fertilizers increased

### **Case Study 6: Redesigning a Fragile Farming System in Uganda: Improvement of Kigezi Farming Systems with Environmental Considerations 1997, 2000-2002**

Project Name: Sustainable farming in a fragile mountain ecosystem: The case of central Kigezi, Uganda, 1997

Location: Nyakishenyi, South Western Uganda

Sponsors: University of Guelph, Environmental capacity enhancement project (ECEP), Canadian International Development Agency (CIDA). Implementers:

Team led by Ngambeki:

Project Name: How to improve household income and eradicate poverty through modernization of Agriculture in the Kigezi region, 2000.

Location: Kigezi, south western Uganda

Sponsor: Ministry of Finance, Uganda government

Implementers: Consultants team led by Ngambeki - continuation of work started in 1997.

Ngambeki analysis of root causes and the existing farming systems indicated

#### Problems

- a) Poor crop yields and frequent crop failures
- b) Severe food insecurity
- c) Rampant poverty

1. Severe land degradation caused by
  - i) destruction of terraces on cultivated land along the hill slopes
  - ii) abandonment of alternate fallow strips and plots when cultivating on mountain ranges due to the relaxation of soil conservation by laws
  - iii) continuous cultivation and mono cropping on the same piece of land without use of fertilizer nor fallowing

2. Population pressure on the land with a high population density of 260 per km<sup>2</sup> coupled with inheritance cultural practice of sub dividing land to the surviving sons led to multiple land fragmentation
3. Exhausted soils with very poor pH, little organic matter, inadequate nitrogen and phosphorus
4. Farming systems intensive substance farming and multiple intercropping of sweet potatoes / sorghum / maize / beans of bananas / sorghum / maize / beans
5. Lack of cash crop fallowing. A history of unsuccessful searches ( by colonial and national governments ) for a suitable crops ranging from black wattle trees, tobacco, castor plant to pyrethrum .Some farmers have 8 to 18 small and uneconomical sources of income

Poor farm income

- i) 25% of farmers earn less than \$20 per year
- ii) 49% of the farmers earn between \$21 and \$200 per year
- iii) lack of knowledge of improved farming methods

Ngambeki's proposed solution

- i) mobilize and sensitize farming communities through community participatory problem analyses and individual farmers or local community's development strategies
- ii) redesigning of the existing farming systems where improved system to include major food crops sweet potatoes, peas, beans, millet, sorghum, dual purpose cash/ food crops: bananas, passion fruits
  - ++ cash crops – arabica coffee, tobacco
  - ++ animal component – chicken with improved cockerels, goats, sheep and cows
- iii) community mobilization for the restoration of soil fertility
  - + promoting resumption of the use of terraces
  - + use of improved farming methods and farmer investments in land improvement
  - + use if improved crop seeds

NB: Currently in Nyakishenyi :

About 300 farmers have improved chicken stock. These are 8 farmer groups, one village bank, and farmers can now produce 10 tones of clean available arabica coffee worth about \$20,000 and are connected to market outlets

### **Case Study 7: Redesigning Banana based Farming Systems in Central Uganda, 1991-1994, 1998, 2000-2003**

Diagnostic survey

Sponsors-Rockefeller Foundation

Banana based Farming systems Research Phase II 1998-, 2000-03

Sponsors- Rockefeller Foundation, DFID, Canadian International Agency, Gatsby Foundation.

Location—Luwero Benchmark site, Bamunanika Sub-county

Implementers-Uganda National Banana Research Programme Kawanda, Ngambeki is one of the key researchers in the team and he also leads the activities of on- farm research.

Basic problems: --Severe decline of banana production

--frequent annual crop failure and food insecurity

--Low farm income

Community Participatory situation analysis by research team  
On-farm research team led by Ngambeki.

- Shrinkage in banana acreage from 2 ha to 1.7 ha. per household.
- Decline in banana yield from 60 t /ha to 6 t /ha?
- Build up of banana pests and diseases; susceptible low genetic potentials of traditional banana varieties
- Exhausted soil fertility
- Existing farming systems consist of: crop shifting from banana cultivation to annual crop cultivation, i.e maize, millet, cassava, sweet potatoes, beans, ground nuts and kayinja (beer banana)
- Bamunanika sand soils which were prone to drought
- A bimodal rain season punctuated by prolonged dry spells.
- Women provided 60% of farm labour yet women's contributions to rural development including food security is not properly recognized.
- Also women not actively participating in decision making for farming activities.

#### Proposed Solutions by Research Team

1. Redesigning the existing farming systems to include:
  - a) Reviving banana production in the region to address food security and sources of income issues.
    - i) Introduce 4 elite / improved East African Highland banana cultivars and 4 exotic / introduced bananas cultivars which are tolerant / resistant to drought, pests and diseases.
    - ii) Mobilize, sensitize and train farmers including 6 farmer trainers about improved banana management practices.
    - iii) Promote soil and water improved management practices
    - iv) Empower women, through community participatory training to participate in farm decision making and rural development as a whole.
2. Design and conduct 200 community participatory on-farm banana trails to test and promote the proposed technologies in Bamunanika Sub County.
3. Outcomes
  - a) Over 20% of farm households in Bamunanika Sub County have adopted improved banana technologies. Over 16 hectares, 18,000 improved banana suckers have been disseminated to new farmers.
  - b) About 15% of the women population are actively participating in the cultivation of bananas for food and to earn their income as activity or banana plot leaders and participating in farming decision making as household partners.
  - c) Women involvement in the management of the trails has promoted early farmer acceptability of exotic banana cultivars (Which are slowly capturing its share of the local banana market) and rapid adoption of banana improved technologies.
  - d) Food security in Bamunanika is now assured and the average farm income has improved to 240,000 shillings/= per house hold per annum.

- e) Many communities in neighboring subcounties are seeking improved banana planting materials and training to adopt banana improved technologies.
4. NGOs have now joined the promotion of banana technologies in Luwero and neighbouring districts.