CHAPTER 7

Challenges of Sustainable Agriculture and Food Security in the Sub-Sahara.

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Abstract

This paper examines the challenges of Sustainable Agriculture in Nigeria in respect of possibilities of achieving food security in sub-Saharan countries in Africa. It establishes the concept of sustainability as being achievable and provides evidence of food insecurity in Nigeria. The paper identifies the Sub-Sahara region as a mega-diverse one where rainfall and temperature regimes vary greatly. Low agricultural productivity in the Northern sub-sahara is attributed more to nutrient deficiency than shortage of water. Factors responsible for loss of Nitrogen and Phosphorous were highlighted and remedies were suggested. Nitrogen loss could be abated by planting tree species that are endemic to the savanna region as well as legumes that are involved in biological nitrogen fixation. Aerial application of phosphorous, in addition to nutrients from animal droppings are confirmed to be capable of stimulating the growth of naturally occurring leguminous plants which will in turn provide food for livestock. Pastoralist grazing was identified as a good option for restoration of productivity in the Sahel and Savanna regions. The high potential of ecological agriculture in improving soil biotic conditions by restoring soil microarthropod populations, thereby enhancing decomposition and nutrient release were stressed. Food insecurity in Nigeria in particular is attributed to the failure of successive agricultural programmes and policies since independence. Biotechnological techniques that are reliable in increasing agricultural productivity in the sub-sahara in respect of crop and livestock production as well as food processing are highlighted. Those that are not feasible due to technical problems and huge costs are also identified. Microbial inoculant technology was recommended as the most promising biotechnical technique that is highly desirable in many Sub-Saharan countries. Attention was drawn to the fact that food insecurity in Sub-Saharan countries is due to poverty, inequality and lack of access to food and not overpopulation, because there are sparsely populated countries where the citizens are hungry. In order to ensure food security in the Sub-Sahara, it is recommended that application of appropriate agricultural technologies based on environmentally friendly agroecological principles is intensified.

Key words: Sub-Sahara, sustainable agriculture, food security, agricultural productivity, nutrient deficiency, microarthropods, ecological agriculture, biotechnological techniques, agroecology.

Introduction

In the first half of the 20th Century, Agriculture was simply Agriculture. The adjective ‘Sustainable’ crept in, in the second half of the century when it became glaring that reforms and innovations in Agriculture had followed a trajectory towards hunger and destruction.

When the population of the world was less than 3 billion, the fallow system in Sub-Saharan countries was sustainable. In one of my latest works, Badejo and Badejo (2019), I expressed the opinion that "The latest United Nations estimates on global human population indicate that the world population rose from 3billion in 1960 to 7.5billion in the year 2017." This is a 150% increase in human population in 57 years which implies a 2.6% increase per annum within this period. Table 1 below indicates that the world population will reach 9.3 billion in the year 2050 which implies a 18.3% increase in the next 31 years. There is no doubt that rate of increase in the world's global population is terrific and frightening. The implication of this is that food consumption must also increase in line with the rate of population increase.

Table 1. Total Population of the World by Decade, 1950–2050 Source: https://www.infoplease.com/world/population-statistics/total-population-world-decade-1950-2050

Year	Total world population (mid-year figures)
1950	2,5b
1960	3,0b
1970	3,7b
1980	4,5b
1990	5,3b
2000	6,1b
2010[1]	6,8b
2020[1]	7,6b
2030[1]	8,2b
2040[1]	8,9b
2050[1]	9,3b

To achieve food security which is in the context of the UN Sustainable Goal 2 (Zero Hunger), agricultural production or productivity must pace up rapidly and kept at a sustainable level.

Is Agricultural Sustainability Achievable?

In December 2011, I delivered a Lecture in this university (FUTA) on Biotechnology Transfer and Agricultural Production. In that lecture, I explained how I took a trip into the realm of Philosophy to be able to answer questions on how feasible or achievable sustainability is. According to Oke (1998), *"if a given human population, say* ***x****, requires* ***y – 1*** *quantity of a certain crop at a given time and* ***z*** *production technology is used in meeting* ***y*** *quantity in such a way that this* ***y*** *quantity is within the carrying capacity of the production base that can potentially accommodate a steady growth in* ***x*** *in perpetuity, then* ***z*** *technology could be said to be sustainable. The central idea in the foregoing context can be read mutatis mutandis into other contexts such that we can take as the essence of the term 'sustain' the idea of 'keeping going', the idea of continuation."* The philosopher gave convincing evidences that the concept of sustainability in agricultural lands is realistic. *"The concept is neither logically invalidated nor empirically empty. As a concept, sustainability in agroecosystems is both rationally intelligible and empirically investigatable. It will therefore, not be an exercise in futility or absurdity to want to embark on a study of how agricultural lands could be sustained."*

Agricultural lands, as modifications of natural systems, are viable not only in thought but also in reality. The idea is concretely rooted in physical experiences and observable data. The first challenge therefore for researchers is to provide the means or methods for sustaining any given agricultural land. Experience has shown that if they are not continually maintained, things and systems in nature could deteriorate. This must have been observed about the agricultural lands to have given rise to the question of whether and how such systems could be made to continue to function indefinitely without regression in either quality or quantity. A primary and ultimate challenge of man is therefore how to break nature's tendency to self-destruction so that the continued existence of the human race could be guaranteed with an ever-improving quality of life (Oke, 1998).

Food Security

In a paper I presented at the Fifth University of Ibadan Conference on Biomedical on July 14, 2016. I explained what Food Security means by first defining Food Insecurity as: *"lack of access to enough food … which can be either chronic or temporary"* (see Badejo, 2016). In chronic food insecurity, which arises from a lack of resources to produce or acquire food, the diet is persistently inadequate (Adeoti, 1989).

According to Reutlinger (1983) and Idachaba (2004), a country is food-secure when majority of its population have access to food of adequate quantity and quality consistent with decent existence at all times. What this implies is that food security can be taken to mean access by all people at all times to sufficient food for an active and healthy life (Reutlinger, 1985).

Sub-Saharan Countries

Sub-Saharan countries include all countries south of the Sahara. There are however varying delineations of the upper boundary of the Sub-Sahara. A map that appears to have been endorsed by the United Nations is reproduced below (see Fig. 1). The country indicated in light green is Sudan which, as an integral part of the Arab League is sometimes not listed as Sub-Saharan.

If the Sahara desert is the demarcating line, Sudan, being geographically located below this line should be a sub-saharan country. Arab states of north Africa that are clearly above this line include Morocco, Algeria, Tunisia, Libya and Egypt but for political reasons Sudan is included in spite of its predominantly non-Arab populations. South Africa was also not considered a Sub-Saharan country until 1994 when they achieved black majority rule. The geographical expression called Sub-Sahara, has therefore been influenced by political leanings so much that many global ecologists avoid using the expression.

Fig. 1. Map of Africa indicating the Sub-Saharan zone.
Source: https://en.wikipedia.org/wiki/Sub-Saharan_Africa

Fig. 2 Map of Africa, showing the ecological break that defines the Saharan area. Source: https://en.wikipedia.org/wiki/Sahara

Those familiar with the geographic name debates all over the world know that the concept of Sub-Sahara Africa has been extensively criticized. While some believe that it is a racist term borne from an imaginary divide between northern Arabic countries and the rest of Africa, many others believe that it is not a euphemism because of their conviction that it is a genuine geographic term to delineate a very real physical separation between North Africa and the rest of Africa. Some geographers have argued that the Sub-Sahara cannot be found in any continent other than Africa, and as such, they do not see any reason why Africa should be included in describing the Sub-Sahara.

The difference between countries north or south of the Sahara must have been determined by climate which in turn defines the vegetation zones and biomes (see Fig 2.) The vegetation map of Africa (Fig. 3) reveals that the Sahel (semi-desert + steppe) is the transitional zone in-between the Sahara and the tropical savanna below which is the forest-savanna mosaic of East, West and upper Southern Africa which overlays the semi-tropical or temperate lower south Africa where a dry winter alternates with a wet summer season amidst the more desert or semi-arid regions in Namibia and Botswana.

It is a herculean task therefore to address the issue of challenges facing the achievement of sustainability in the mega-diverse regions of the sub-sahara and at the same time link them with food security in each of the regions. In Nigeria alone, there are as many sustainable agricultural strategies as there are agro-ecozones.

As biological scientists, we should regard the Sub-Sahara as regions where precipitation is usually more than 250mm per year. This confirms that in addition to the five aforementioned countries that are clearly within the Sahara desert, the northern parts of countries such as Chad, Mali, Mauritania, Niger and Western Sahara are within the Sahara region (Figs. 3 and 4). The rest of the countries in Africa down to South-Africa belong to the Sub-saharan region. Badejo *et al.* (1998) have already discussed the inextricable link between temperature, precipitation and biomes in the world (see Fig. 5)

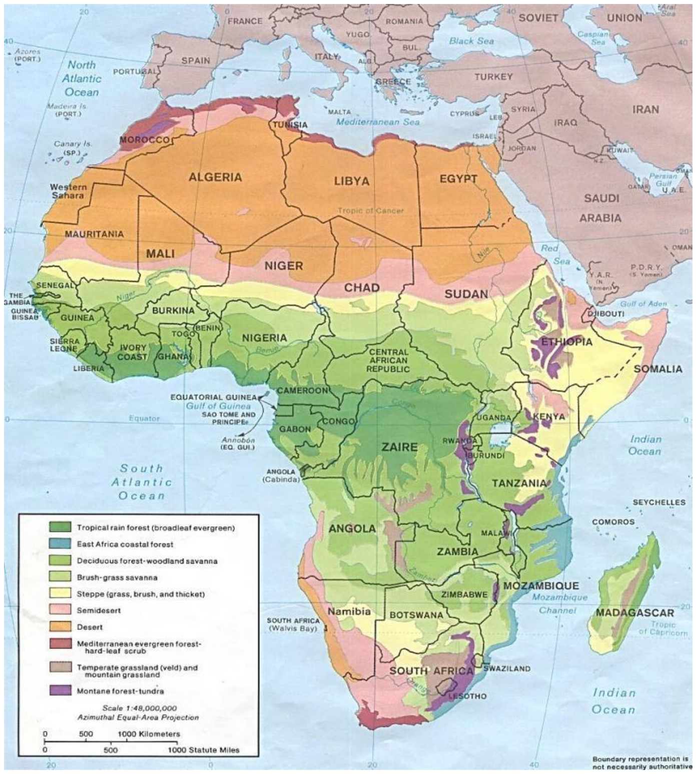

Fig 3. The vegetation map of Africa. *(The Sahel is divided here into Semi-Desert and steppe.)*
Source: https://www.ncpedia.org/media/map/map-africa

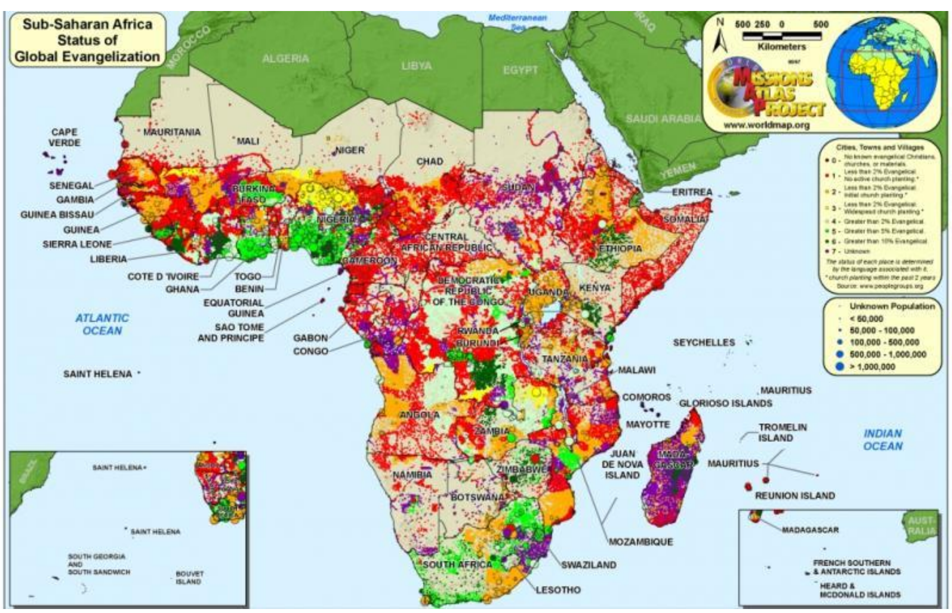

Fig. 4. Map of Africa showing the eco-geographical zones.
Source: https://www.nationalgeographic.org/encyclopedia/africa-physical-geography/

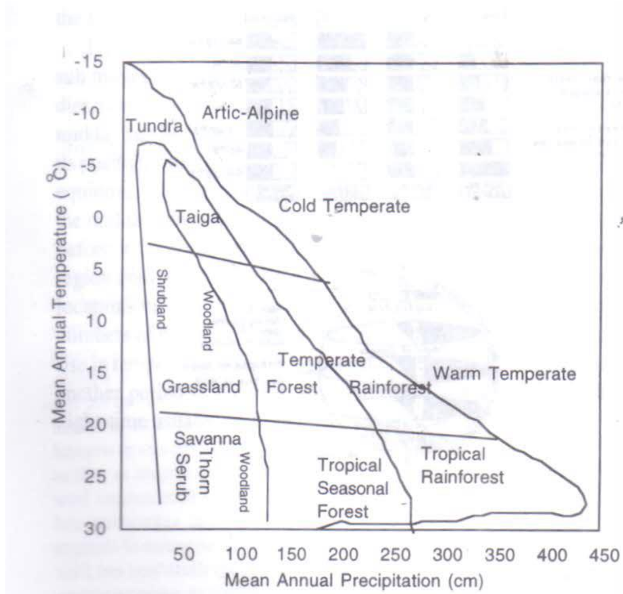

Fig. 5. A simplified representation of the relationship of biomes to precipitation and temperature (after Whittaker, 1975).

Nutrient problems in the Northern Sub-Sahara

Badejo (1998) delved into the concept of Agroecological Restoration of Sahelian and Savanna agroecosystems which incidentally dominate the upper and lower regions of the Sub-Sahara by focusing on nutrient problems in the savanna. In sharp contrast to forest agroecosystems, trees are very scanty in Sahel and Savanna agroecosystems. Trees not only serve as nutrient pumps in the forests, they also provide shade and preserve the little amount of water available due to low rainfall. This natural role of trees is jeopardized when their densities are reduced tremendously as a result of agricultural activities.

In the Sahel, nutrient deficiency due to the absence of trees poses a more serious threat to productivity than lack of water. An experiment carried out in the Southern Sahel in Mali by Breman and de Wit (1983) revealed that although water and nutrient should be in optimum supply, productivity can be increased five times under natural rainfall conditions when nutrients are in optimum supply. Data presented in this study is illustrated in Fig. 5. This result suggests that lack of nutrients is a more serious problem in the Sahel than low rainfall. While reviewing research findings on productivity problems in the semi-arid regions of Africa, Hekstra (1985) explained that plants only make limited use of rainfall because at the end of the growing season, about 10 to 20% of soil water is still available in the soil within the reach of roots. In other words, the growth of grasses and herbs in the Sahel stops before the soil water content is depleted. In the fertilized plots of Breman and de Wit (1983), water was used more efficiently and the run-off was decreased by more rapid growth of vegetation, which allowed a longer growing period, the consequence of which was an increase in biomass production.

The broad objective of the research project of Breman and De Wit was to investigate the impacts of exploitation of the Sahel on rangeland productivity. Another finding of this project is that the transition from growth determined mainly by nutrients to that determined by water occurs at a mean annual rainfall of about 300 mm. This implies that water is the limiting factor in the desert and the grasslands (steppes) of the northern Sahel but not in the bush grasslands and the Sahel and Sudan Savanna. This indicates that solutions to the environmental problems in the Sahara may not be applicable in the southern Sahel.

Comparison of the fodder in the Sahara and Sudan Savanna by Hekstra (1985) revealed that the quality of fodder in terms of protein content was highest in the Sahara (15%) and lowest in the Sudan Savanna (4%) where biomass production was highest (3 t/ha). A decrease in the protein content of fodder was also found to occur with increase in rainfall. In August 1983 for example, the protein content of fodder in the Sahara was about 20%. In the Sahel, the protein content of fodder was about 15% in places where rainfall was about 200 mm/year and 10% in more humid areas where rainfall was almost 600mm/year. In the Sudan Savanna where rainfall was 800mm/year, the protein content of fodder was 7%. All these suggest further that increasing the level of water in the Sahel would increase biomass but decrease the protein content of fodder. The implication of this is that irrigation in the absence of nutrients may not solve the problem of low food quality for livestock in the southern Sahel and Sudan Savanna. The Sahel (marginal savanna) extends to the extremely northern part in North-East Nigeria while the Sudan Savanna occupies a very large part of Northern Nigeria (see Figs 6 and 7).

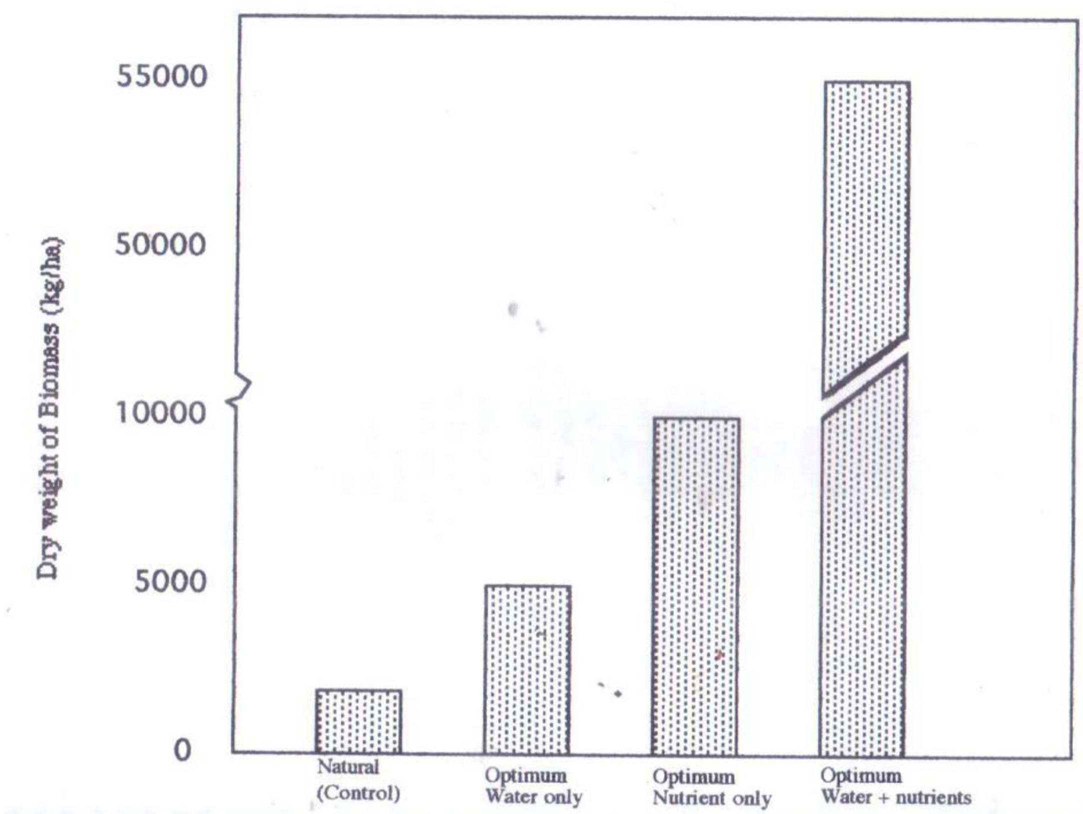

Fig. 6. Illustration of the relative and combined effects of water and nutrients (N and P) in Mali (after Breman and de Wit, 1983a).

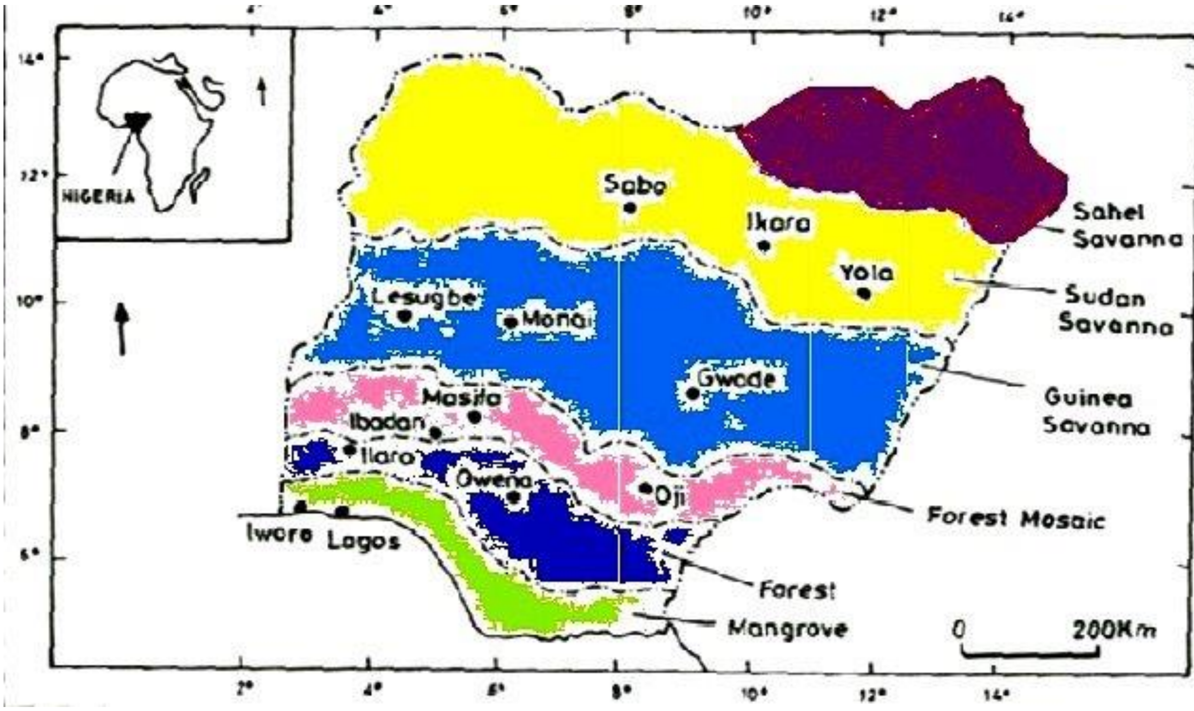

Fig 7. A map of Nigeria showing the six broad ecological zones. Source: https://www.researchgate.net/figure/A-map-of-Nigeria-showing-the-six-ecological-Zones

The Sahel was formerly home to large populations of grazing mammals, including the oryx, the gazelles, buffalos, wild dogs, cheetah, and the lion. The Scimitar-horned oryx and the Bubal hartebeest are now extinct.

Nutrient Loss in the Sahel and Sudan Savanna.

According to Hekstra (1985), the optimum protein content fodder that can keep livestock in good condition throughout the year is about 7%. When Nitrogen is limiting, the protein content in plants that supply fodder for livestock decreases rapidly from 12-18% to about 3-6%. In the case of phosphorous, fodder becomes difficult to digest when its concentration is very low. It is in the light of these that a discussion on nutrient loss in the Sahel and Sudan Savanna when restricted to phosphorous and nitrogen levels only, would be very adequate (Badejo, 1998).

Phosphorous loss

Phosphorous availability varies from 0.5 - 10 kg/ha in the Sahel (Hekstra, 1985). Loses as a result of volatilization from vegetation and soil are practically nil. The loses that reduce soil phosphorous significantly include:

i) Loses due to soil and wind erosion (dust storms) which can be up to 10 kg/ha in unprotected cultivated soils under high rainfall.
ii) Nomadic grazing account for loses of about 0.20 - 0.23 kg/ha per year in urine, faeces and animal bodies.
iii) Burning of vegetation displaces in form of dust over long distances. It has often been said that Saharan and Sahelian dust contributes to the mineral balance of the rainforests.

Nitrogen loss

Unlike phosphorous which has to be added to the soil, Nitrogen loss can be compensated for by rain and dust from the Northern Sahel and also by nitrogen-fixing legumes that grow naturally in the Sahel and Sudan savanna. Sources of Nitrogen loss include the following:

i) Loss from vegetation by volatilization in the Sahel and Sudan savanna – between 1 - 10 kgN/ha
ii) Loss during burning of vegetation – all nitrogen is lost
iii) Loss through erosion – about 2.5 kgN/ha
iv) Loss through evaporation from urine and faeces – about 5 kgN/ha
v) Loss through crop removal – up to 59 kgN/ha.

According to Hekstra (1985), about 0.65 – 7.5 kgN/ha is blown through the dust from northern Sahel to the southern Sudan savanna while about 0.4 - 3.0 kgN/ha is fixed by pasture legumes whose growth can only be hampered by loss of phosphorous. The amount of nitrogen fixed by these legumes is extremely low when compared with the amounts fixed by some cultivated grain legumes such as cowpea (*Vigna unguiculata*), and soybean (*Glycine max*) which fix 60kgN/ha and 100kgN/ha respectively (Danso, 1992). If planting of legumes is intensified in the savanna, biological nitrogen fixation will be harnessed to its fullest extent.

The tree species that are endemic to the savanna region are listed in Table 2. Many of these trees are generalists which have broad niches and are therefore able to survive the wide range of environmental conditions provided in the savanna at different times of the year. These trees are highly compatible with crops, fix atmospheric nitrogen and provide fodder and fruits for games and livestock (Igboanugo, 1989). Unfortunately, they remain scattered all over the savanna in spite of the call by Igboanugo and Badejo (1998) that their plantations should be established as part of a viable agroecological process to ensure sustainability of agriculture in the savanna. This suggests clearly that the iterative process between policy and science is completely missing in this country.

Solving productivity problems in the savanna.

The change over from traditional to high-input mechanized agriculture has not been successful in West Africa (Van der Werf, 1983a). Heavy dependence on imported fertilizers and construction of grandiose irrigation schemes have failed (Igboanugo and Badejo, 1998). Strategies for the future development and exploitation of the Sahel Savanna should include the possibilities of introducing nutrient from animal sources (e.g. urea and animal droppings) to rangelands. Emphasis should be placed on development of rangelands in the Sahel because it is more suitable for production of livestock than crops. Phosphorous is the only nutrient that has to be imported into the Sahel. According to Hekstra (1985), phosphorous can be applied from airplanes so as to get to where it is needed. In the past, inadequate means of transportation, defective logistics and poor management have made it difficult for phosphorous fertilizers to get to the rural farmers. If after aerial application of phosphorous, the farmers use the land for sedentary farming indiscriminately, the purpose will be defeated. **Pastoralist grazing** is the only good option after aerial application of phosphorous which in addition to nutrients from animal sources is capable of stimulating the growth of naturally occurring leguminous plants which will provide food for livestock. Cowpea (*Vigna unguiculata*) and groundnut (*Arachis hypogaea*) could be planted by the farmers because they can fix nitrogen, their seeds are consumed by people and their shoot can be used as protein-rich forage for fattening cattle.

Table 2. The various roles played by some trees in the savanna. Source: Badejo (1998).

Tree Species	Leaves edible to livestock	Fruits edible to livestock	Coppices well	Living fence
Nitrogen-fixers Acacia ataxachanta	+	+		+
Acacia auriculiformis	+			
Acacia cyanophlla	+	+	+	
Acacia nilotica	+			
Acacia tortilis	+			
Albizia amara	+			
Albizia ebbeck	+			
Callioandra collothyrsus	+		+	
Cassia fistula	+		+	
Dalbergia sissoo	+			+
Gliricida sepium	+		+	
Leucaenea leucocephala	+	+		
Prosopis Africana	+		+	+
Prosopis cineraria	+		+	+
Prosopis juliflora	+		+	+
Samaea saman	+		+	
Sesbania grandifoliola			+	
Zizipus mauririana	+		+	+
Non-nitrogen fixers *Adansonia digitata*	+			
Anogeisus letocarpus	+			
Balanites aegyptiaca	+		+	+
Dichrostachis cineria	+	+		+
Faidherbia albida	+	+		
Mangifera indica			+	
Moringa oliferia	+	+	+	+
New boldia laevis			+	+
Psidium guajava	+			
Tamarindus indica	+	+		
Vitellaria paradoxa	+		+	
Vitex doniana				+

For the small scale farmer in all savanna ecosystems, **ecological agriculture** offers the necessary sustainability for their long-term social and economic well-being. Van der Werf (1983a) has explained that ecological agriculture is focused on the establishment of high and lasting soil productivity which permits the conservation and re-establishment of a well-balanced environment that ensures the future existence of humanity within sound ecological systems. This method of agricultural production which is based on low external input and self reliance has been successfully practiced in Agomeda in South-east Ghana by the Agomeda Agricultural Project (A.A.P.) (Van der Werf, 1983b). Agomeda which was formerly located in the moist semi-deciduous forest zone in Ghana was clearly in the derived savanna zone when this project was carried out. The main aim of the A.A.P. was to restore the ecological balance of the derived savanna in Agomeda by using **eco-farming** and **reforestation** in order to achieve ecologically sustainable agricultural production.

The history of A.A.P. dates back to 1973 when Shai Chief Nene Nagai Kassa VII invited a Dutch family to Agomeda to start a small scale agricultural project. The Dutch family established an extension farm in Agomeda where cultivation methods were based on maintenance and improvement of soil fertility. Instead of the traditional slash and burn method used in clearing land for shifting cultivation, all organic materials (weeds, shrubs and small trees) on the extension farm were gathered for compost. Tree stumps were dug out to make uniform line cultivation possible. As much as possible, organic matter produced on the farm, such as weeds, cover crops, green manures, cuttings, etc. was returned to the soil. Crop residues, kitchen waste and night soil were composted and used as fertilizer. Towards the end of the first cropping season of a newly cleared plot in October, a local leguminous plant (*Crotalaria* spp.) is sown as green manure. In subsequent years, the *Crotalaria* self seeds and establishes as a cover crop again when weeding is stopped in the second half of the raining season. From time to time, extra seeding is necessary to keep a complete soil cover during the dry season to get a complete soil cover during the dry season and to get a sufficient fertilizing effect from this combined nitrogen-fixing green manure/cover crop. The *Crotalaria* variety suitable for this purpose grows 0.50 m to 0.60 m high as a bushy plant and is relatively deep rooting. It may be cut once at a height of 0.20 m to establish a more dense soil cover. At the beginning of the new planting season, the *Crotalaria* is cut off just below the surface or pulled out to be used as mulch enriching the soil with organic matter relatively high in Nitrogen content and improving soil structure. During the dry season, the *Crotalaria* limits the increase of soil temperature and prevents wind erosion. Fire is prevented from entering the extension farm by establishing fire breaks which consist of a local *Cassia* variety, sisal (*Agave sisalama*) and young and fresh grass. After two years, the crown of the edge formed by the cassia and sisal plants act as a break for high flames while the grass below is inflammable. The overall effects of all these practices in the extension farm is improvement of soil fertility and various soil characteristics such as water holding capacity, nutrient holding capacity, soil structure, soil life, soil enrichment and nutrient release. Together, these effects simulate the growth and productivity of the crop that is planted after. Similar results have been reported by Lal (1978) in Nigeria.

This way, agriculture is done permanently in the derived savanna zone of Ghana without recording lower yields. Land is cleared and taken into production in stages. The result is that a visitor, at any moment, can distinguish by mere visual observation from soils of the original annually burnt bush land (just outside the farm), taken into cultivation just recently and land under eco-farming for six years. Local farmers, who hitherto had been acquainted with land decreasing in fertility when under cultivation, were able to see for the first time soil improving under cultivation. Chemical fertilizers were not used and soil fertility which was the main focus of the A.A.P. did not decline. This is exactly what sustainable agriculture implies.

Results of esearch conducted on organic agriculture in the International Livestock Research Institute (ILRI) in Fashola village, a suburb of Ibadan and Oyo as well as in Rio de Janerio where organic residues and cover crops (live mulches) were used to improve soil fertility and increase crop yield in the derived savanna zones of Nigeria and Brazil respectively, were similar to those of the A.A.P. in Ghana. Badejo *et al.* (2004b) monitored the population dynamics of soil detritivorous mites under different legume mixtures and natural pasture in maize plots established after grazing and reported that the legume mixture of *Centrosema pascuorum*, *Aeschynomene histrix*, *Centrosema pubescens* and *Arachis pintoi* supported more detritivorous mites than other legume mixtures and natural pasture. The palatability of *Aeschynomene histrix* and *Centrosema pubescens* were identified as being responsible for this potential effect of the mixture in improving soil fertility in the maize plots, since their combination was unique when compared with other legume mixtures.

In a more extensive study, Tian *et al.* (2007) studied the effects of residue quality and climate along a transect from humid forest to Sahel in the West African belt. Locations where samples were collected during the dry and rainy seasons include Ijebu-Ode, Minna and Kano in Nigeria and Zinder in Niger Republic. Plant residues used in this study were leaves collected from the following woody species: *Alchornea cordifolia*, *Dactyladenia barteri*, *Gliricidia sepium, Senna siamea,* and *Pterocarpus santalenoides*. Based on the abundant evidence from literature that decomposition of plant residues is related to their C/N ratio and their lignin and polyphenol contents (Frankenberger and Abdelmagid, 1985; Berendse *et al*., 1987; Tian *et al*. 1992), a plant reside index (PRQI) which was developed by Tian (1995) was revised to integrate properly the effect of the residue C/N ratio and polyphenol concentration (%) and lignin concentration (%) on the decomposability of the residues. This revised decomposition equation which was defined as.
PRQI = [1/(0.423*CX/N + 0.439*lignin + 0.138 *polyphenol)]*100 was applied to each of the agroecozones investigated and three hypotheses were confirmed the following:

i) the increase in rate of decomposition and nutrient release of plant residues with the increase in residue quality can be observed only in wet regions
ii) the decrease in the rate of decomposition and nutrient release of plant residue from humid to arid regions of West Africa can be observed only for higher quality residues
iii) the low quality plant residue could decompose and release N and P faster in the dry than wet zones and in the dry regions it could decompose and release N and P faster than the high quality plant residue.

Prior to this investigation, Tian *et al*. (1995) had calculated the PRQI of 18 plants species used in agroforestry whose values ranged from 3.0 in the prunings of *Dactyladenia barteri* (previously known as *Acioa barteri*) to 14.1 in the leaves of *Leucaena leucocephala.* This formula has been a useful tool for projecting rates of plant residue decomposition and effects of plant residues on soil microclimate, soil faunal density, and in assessing their effects on crop performance.

In Brazil, Badejo *et al*. (2003) compared the densities and dynamics of soil oribatid mite communities under three species of perennial cover crops namely *Arachis pintoi, Macroptilium atropupureum* and *Peuraria phaseoloides* with *Panicum maximum* (grass) and bare plots in the derived savanna zone and reported that legume cover crops, especially *Arachis pintoi*, and their residues have potential in restoring oribatid mite populations to pre-cultivation levels. The selective influence of the cover crops on different species of soil-dwelling oribatid mites was also reported. As illustrated in Figs. 8 and 9, the densities of species such as *Nothrus seropedicalensis, Archegozetes magna* and *Scheloribates* spp improved tremendously under the cover crops while *Galuma* spp though higher in densities under the cover crops than in the pasture, were still less than their densities in plots where there was no vegetation cover.

Similarly, investigations of the oribatid mite fauna of organically maintained plots in the same zone revealed that there was always an initial reduction in the populations of soil mites and the activity of epigeic forms whenever a plot was opened up and disturbed mechanically in preparation for cultivation (Badejo *et al.* 2004a). Moreover, this investigation revealed that oribatid mite diversity was higher in the organic plots than in the pasture but lower than in the forest, where relatively large species of mites such as *Belba* sp. and many Eremobelboid bracyphiline genera were present, but absent in the organic plots and pasture. It has been widely reported in literature that oribatid mites being the most abundant microarthropod group in forest and arable soils, as well as earthworms, play a major role in the early stages of decomposition and as a result are indicators of soil health and fertility (Tian and Badejo, 2001; Badejo 2004).

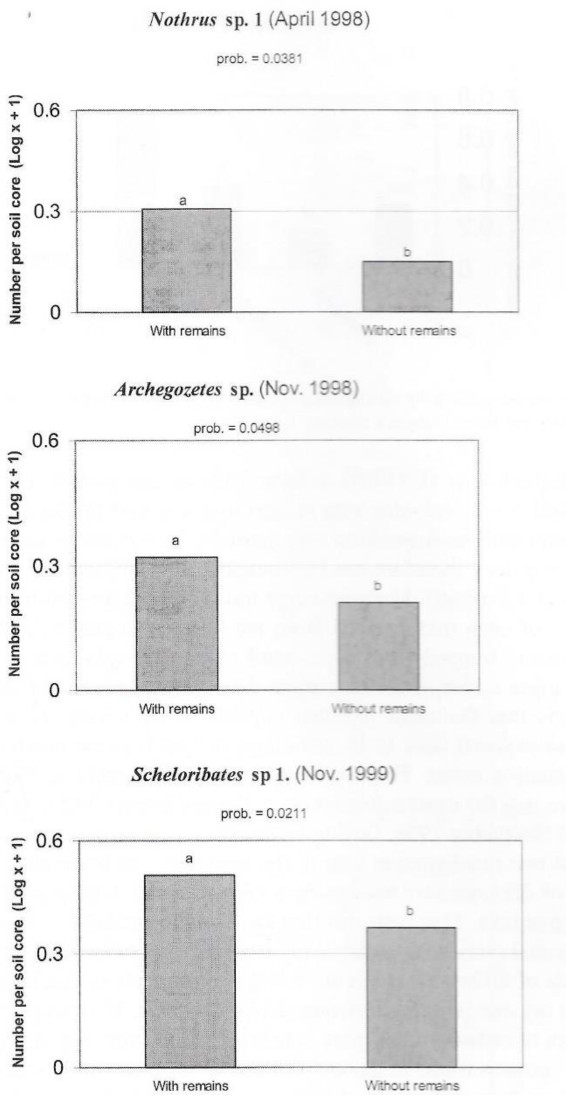

Fig 8. Semi-Logarithm plot of the numbers of oribatid mites trapped from the soil surface in the experimental plots. Values on each bar are x + 1 to eliminate zero vales. Source: Badejo et al. 2002.

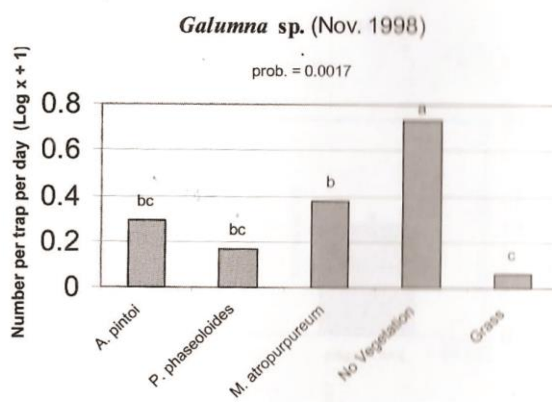

Fig. 9. Comparison of activity of *Galumna* sp. among treatments. Bars with same letters are not significantly different using Duncan's Multiple Range Test. Source: Badejo et al. 2002.

From the foregoing, it is clearly evident that organic agriculture can raise the fertility status of degraded soils in the Sub-Sahara where there is abundant evidence that intensive mechanisation, exposure of soil to the sun and indiscriminate application of pesticides decrease the fertility of soils over time (Badejo, 2004).

The most topical issue in Nigeria today is the decision of the Federal Government, in June 2019, to establish Rural Grazing Areas (RUGA) in states that are interested. A few weeks after this decision was taken, the Federal Government suspended RUGA on the excuse that it was inconsistent with the National Livestock Transformation Plan (NLTP) from 2019 to 2028 which was published in May 2019. This clearly demonstrates that there is lack of coordination among government agencies working on related issues. Policy somersaults such as this had been a frequent recurrent phenomenon is Nigeria since independence.

Food Insecurity

In the latter part of the 20th Century, food insecurity was seen as a failure of agriculture to produce sufficient food at the national level. The 21st Century notion of food insecurity has advanced beyond this. Food insecurity is now seen as a failure of livelihoods to guarantee access to sufficient food at the household level. (Clover, 2003).

It is quite disheartening to note that in the pre-colonial era, Nigeria did not have to contend with the problem of food insecurity. Peasant farmers were able to feed their households and the system was able to feed her citizens and at the same time export to neighbouring communities the surplus food items. Every region of the country specialized in the production of specific food or cash crops, The North produced groundnut in excess of local demands, the West produced cocoa, the east produced oil palm and kernel heaps while the Midwest was known for the rubber plantations that yielded foreign exchange. Crude oil discovery in Nigeria in 1956 and exportation of it in 1958 changed the whole situation. Hoes and machetes went on holiday and the door was locked to sustainable mechanized farming.

Omonona and Agoi (2007) investigated the incidence of food security in urban households in Nigeria and reported that food insecurity in Nigeria is influenced by factors such as the age, gender, profession and level of education as well as income of household heads. They concluded that Nigeria was yet to attain food security as defined by the World Bank. The main goal of food security is for individuals to be able to obtain adequate food needed at all times, and to be able to utilize the food to meet the body‘s needs thereby ensuring an active and healthy life.” (World Bank, 1986). Food security obtains when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO, 1996).

Akinyele (2010) took a glimpse at rural food and nutrition security in Nigeria and declared that malnutrition is widespread in Nigeria especially in rural areas. He reported further that Nigerians are vulnerable to chronic food shortages, erratic supply, poor quality food, and fluctuating food prices and concluded that the huge investment in ensuring food and nutrition security for Nigerians has recorded limited success.

In order to guarantee food security in Nigeria, Attah (2012) suggested the following strategies: Rural development; easy access to basic farm inputs; adequate budgetary allocations; appropriate policies for food sub-sector; political stability; reduction in poverty at the rural level; peasant farmers' education. None of these measures can be faulted when considered individually. However, when viewed as a whole, Agricultural Biotechnology is conspicuously missing. This is not surprising because this concept had never featured in successive agricultural policies of the country since independence in 1960. It was only recently that there was a spirited effort by the Federal Government of Nigeria to regulate and control biotechnological research in the country. The National Biotechnological Development Agency (NABDA) was established through Federal Executive Council approval on the 23rd of April, 2001 with a mandate to coordinate, promote and regulate the development of biotechnology in the country (see Badejo, 2011).

A review of Nigeria's agricultural policies since 1960

The first republic witnessed uncoordinated efforts between the regions in respect of agricultural policies. The gains of cocoa production in the Western region, the groundnut pyramids in the North and palm oil in the east have all vanished. When the military truncated democracy in 1966, there was a civil war and food insecurity became aggravated. The military embarked on a massive importation of rice in the early 1970s to ensure food security but this could not tackle the problem of food security. There were suggestions that the over-bloated army which became redundant after the civil war should be drafted to the farm to boost agricultural production. This policy option was discarded for security reason. In 1976, the military government under a different leadership embarked on Operation Feed the Nation, (OFN). Government advised the citizenry to plant anything, plant something, anywhere. This policy somersaulted because it lacked adequate planning and intellectual input. Unfortunately, the successive civilian government that took over in 1979 embarked on a mere change of name from OFN to Green Revolution without any significant change in conception, content or context of the policy. When this civilian government was truncated by the military in 1983, the country witnessed 14 more years of policy somersaults under the military. There was the Directorate of Food, Roads and Rural Infrastructure, DFRRI in 1985 which was supposed to be a comprehensive, integrated programme for massive food production and rural transformation. It was a colossal failure.

When democracy was restored in 1999 greater attention was given to food production. A number of food security initiatives were launched. As listed by Bello, (2004) and Ojo and Adebayo (2012), they include:

1. Special Programme for Food Security (SPFS)
2. Root and Tuber Expansion Programme
3. Fadama Development Project
4. Community-based agricultural and rural development schemes
5. Provision of infrastructures
6. Collaboration with the United States - The government commissioned the American-based International Centre for Soil Fertility and Agricultural Development (ICSFAD), to study the problems militating against increased agricultural production in the country.
7. Banning of importation of some agricultural products.
8. Selling of fertilizers to farmers at subsidized rate

9. Facilitating increased investment in agriculture by strengthening the financial capacity of state-owned agricultural banks to grant soft-loans, and pleading with the private commercial banks to extend low-interest loan facilities to large-scale and small scale farmers.

In spite of all these policies, food insecurity still stares us in the face in Nigeria.

An overview of Biotechnological techniques

Badejo (2011) has thrown an extremely illuminating light on the history of biotechnological techniques in the world. Right from 6,000 BC when the Sumerians and Babylonians in the Near East started beer and wine production to the 19th century when Louis Pasteur [1857-1976] demonstrated the fermentative ability of microorganisms. The 21st Century situation is that biotechnology has expanded tremendously beyond fermentation processes. Advances in molecular biology, genetic engineering and waste treatment technology have widened the scope of biotechnology. In the agricultural sector, application of biotechnology can be divided into three fields: crop production, livestock production and food processing. Emphasis will be on crop production in this presentation.

Crop production

Various biotechnological techniques by which increased crop productions have been enhanced include tissue culture, microbial inoculation of plants, diagnostic tests, protoplast fusion and plant genetic engineering.

Tissue culture technique is very recent being less than 70 years old. The aim is to regenerate whole plants from single cells in the laboratory and later transfer the plant to the soil. Unless there is a major breakthrough in tissue culture research that reduces the cost of production tremendously, application of tissue culture in Nigeria will bring about an increase in the cost of food.

Microbial inoculation of plants is particularly useful in the areas of improved plant nutrition and pest control. Because soils are often low in nitrogen content, good plant growth often means supplementing soil nitrogen with NPK fertilizers which are expensive to produce and therefore too costly for many small scale farmers to buy. Fortunately, some plants can form mutually beneficial relationship [symbiosis] with microorganisms which convert atmosphere nitrogen to ammonia, which is then used by the plants to make protein (Roskoski, 1992). Nitrogen fixing bacteria, mycorrhiza fungi and plant growth-promoting rhizobacteria are various biological agents whose artificial inoculation into the soil can increase the nutrient status of soils. Artificial inoculation of *Rhizobium* into the soil ensures the synthesis of proteins from atmospheric nitrogen by crops. A study carried out in the University of Ife (now Obafemi Awolowo University) has revealed that some *Rhizobium* strains increased the yield of some legumes to between 64 and 251% (Odeyemi *et al*, 1982).

A more recent finding Okafor (1994) is that if nitrogen fixing bacteria could be engineered into tropical cereals and other crops, their yields would increase without the need for the current heavy expenditure on fertilizer importation. The immense fraud and racketeering involved in fertilizer importation in some African countries is probably an important factor affecting the exploitation of the *Rhizobium* inoculants alternative.

In Nigeria and many Sub-Saharan countries, nitrogen fixation occurs naturally on a large scale in groundnut, which was an important export crop in Nigeria in the 1960s. Cowpea was also widely grown during this period when the Sub-Sahara contributed as high as 90% of the world's cowpea production (Dobereiner and Campello, 1977). The decline in the production of these leguminous foods in Nigeria has reduced the protein intake of Nigerians where many people have been predisposed to fatal diseases as a result of malnutrition and unbalanced diets (Odeyemi and Okoronkwo, 1985).

Some microorganisms are natural pesticides. The use of microbial inoculants in pest control is being encouraged worldwide because of its advantages over the use of chemicals. Some of these advantages include low cost of production low operator risk and less negative impact on the environment. One disadvantage of microbial inoculants is their sensitivity to environmental changes in the field (Broerse, 1990). As a result, special protectants and adjuvants have been formulated to prolong the residual activity of various microbial inoculants in the field (Matanmi, 1995). In order to increase the effectiveness of biocontrol agents in the field, research and development on them is top on the priority list of international agricultural institutions. It is pertinent to stress here that research and development on microbial inoculants do not cost up to one tenth of the amount spent on chemical pesticides (Broerse, 1990).

Generally, the advantages of microbial inoculant technology, which has not been well developed in many Sub-Saharan countries, are better yields, lower costs and reduced dependence on agrochemicals. Most of them are not difficult to produce. According to Davison, [1988], unsophisticated fermentors of modest volume can be used to produce significant quantities of inoculants whose prospects for sustainable agriculture in less intensive, low-input agricultural systems are very good.

Other techniques

Other Biotechnological techniques that are not so desirable in the Sub-Sahara include Genetic Engineering, Livestock Production, Embryo Transfer Technology (ET) and Fermentation Technology. All these techniques have enormous attendant application problems in Sub-Saharan counties. The reagents and enzymes needed are very costly and because of their unstable nature, they cannot be stored for a long time. There must be uninterrupted power supply and the laboratory must be well staffed and fully equipped (UNDP, 1989). The huge costs involved make them a non-profitable means of boosting food production in a country like Nigeria (Igboanugo and Badejo, 1998). It is unlikely that application of these techniques is feasible for large-scale application in Sub-Saharan countries not only now but also in the future. In the case of fermentation technology, the situation in industrialized countries is that microorganisms are used in bioreactors and large factories to produce traditional fermented foods (e.g. yoghurt, cheese) and alcoholic beverages (e.g. ale, beer, wine, etc). I do not know of any Sub-Saharan country where traditional fermented dairy and other food products (*waara, fura, kunnun, ogi*, "*Iru*" (*Dawadawa*), *ogiri*, etc) and alcoholic beverages (*pinto, burukutu*, etc.) have been as refined as to withstand competition with factories in industrialized nations. A list of the different sources of fermented foods in different parts of the world as well as the microorganisms responsible for the fermentation processes has already been presented by Badejo and Okoh (2001).

Biotechnology, hunger and the environmental question

The notion that biotechnology is the magic bullet solution to all of agriculture's ills is not true. The claim by biotechnology companies that genetically altered seeds are essential scientific breakthroughs needed to feed the world, protect the environment and reduce poverty in developing countries has been challenged (Altieri and Rosset, 1999). Although the more the human populations in a country, the more their food demand, the prevalence of hunger in a country has nothing to do with the size of the human population. For every densely populated and hungry nation like Bangladesh or Haiti, there is a sparsely populated and hungry nation like Brazil and Indonesia (Table 3). The reality is that the world today produces more food per inhabitant than ever before. Enough food is therefore available for the world's teeming population. The real causes of food insecurity are poverty, inequality and lack of access to food. Too many people are too poor to buy the food that is available that is not evenly distributed globally. Very many people lack the land and resources to grow food themselves (Lappe, *et al;* 1998).

Table 3. Comparison of the populations and Gross Domestic Products (GDP) of Selected Hungry Nations. Source: Badejo (2016)

Country	Area	Population	Density	GDP (PPP)
		Densely Populated		
Bangladesh	147,570km^2 92nd	171.7m (2016) 8th	1,319/km^2 10th	USD 572,440bn
Haiti	27,750 km^2 140th	10.6m (2015) 85th	382/km^2 22nd	USD 19.8bn
		Sparsely Populated		
Brazil	8.5mkm^2 5th	205.3m (2015) 5th	23.8/ km^2 190th	USD 3.2 trillion
Indonesia	1.9m km^2 15th	225.4m (2015)	124.66/km^2 84th	USD 2.84 trillion

Moreover, genetically engineered plants have been planted on many millions of hectares globally without proper biosafety standards [Altieri and Rosset, 1999]. Ecological theory predicts that the larger scale landscape homogenization with transgenic crops will exacerbate the ecological problems already associated with monoculture agriculture. Unquestioned expansion of this technology into developing countries may not be wise or desirable. There is strength in the agricultural diversity of many of these countries, and it should not be inhibited or reduced by extensive monoculture, especially when consequences of doing so results in serious social and environmental problems (Altieri *et al*: 1998).

The ecological risk posed by products of biotechnology has not been receiving adequate attention globally. Funds for research on environmental risk assessment are very limited. For example, the USDA spends only 1% of the funds allocated to biotechnology research on risk assessment, about $1-2 million per year. Given the current level of deployment of genetically engineered plants, such resources are not enough to even achieve adequate results. If more funds are made available for agroecologically based agricultural research, such funds would be directed towards finding lasting solutions to all the biological problems that biotechnology is trying hard to solve. More importantly, publicly controlled regulatory regimes for assessing and monitoring the environmental and social risks of biotechnology industry should be put in place so as to ensure public interest and safety, as against profit.

More food can be produced by small-scale farmers located throughout the world using agroecological technologies (Uphoff and Altieri, 1999). In fact, new rural development approaches and low-input technologies spearheaded by farmers and NGOs around the world are already making a significant contribution to food security at the household, national and regional levels in a few countries in Africa, Asia and Latin America. Yield increases are being achieved by using technology approaches that are based on agroecological principles (Van der Werf, 1998a & b), that emphasize diversity, synergy, recycling and integration as well as social processes that emphasize community participation and empowerment (Rosset, 1999). When such features are optimized, yield enhancement and stability of production are achieved, as well as a series of ecological services such conservation of biodiversity, soil and water restoration and conservation, improved natural pest regulation mechanisms as highlighted by (Altieri *et al*., 1998).

Conclusion

The nutrient problems of biomes in the Sub-Sahara have been elucidated in this presentation. It has been established that loss of nutrients is a more serious problem in the Southern Sahel and all the relatively more humid savanna ecosystems than shortage of water. The process of agroecological restoration of these nutrients has also been explained and proposed as a process that is second to none not only in restoring degraded soils in the Sub-Sahara but also in ensuring sustainability in agriculture. While many countries in the temperate region are having problems with nitrogen pollution because human activities are speeding up the release of nitrogen from long-term storage in soils and organic matter, tropical soils are highly deficient in this element (Badejo, 2000). This inherent difference between temperate and tropical agroecosystems suggests that solutions to problems in temperate agroecosystems may not be applicable to tropical problems. The advantages of cover crops, plant residues as mulch and organic farming in general in increasing the fertility of arable soils in the Sub-Sahara have been elucidated with empirical data. Application of biotechnological techniques and their limitations in ensuring sustainability and improvement of plant nutrition in the Sub-Sahara were highlighted as **microbial inoculation** was identified as the most promising biotechnological technique that should be encouraged due to their high prospects in increasing crop yield.

It is recommended that countries in the Sub-Sahara in the tropical belt should as a matter of priority and expediency identify areas of agriculture that could be improved upon using acceptable biotechnology, such that the gains of the exercise will be affordable to the citizenry. It is the responsibility of governments of developing counties to ensure improving the quality of existing biotechnological products based on environmentally friendly agroecological principles. This of course implies that 'round pegs must be put in round holes'. A situation in which people who know nothing about biotechnology are appointed to run biotechnology agencies will certainly be counter-productive and should be avoided. Government should also ensure that appropriate legislations are put in place to compel the industrial sectors to utilize the products of sustainable biotechnology research in the Sub-Sahara and de-emphasize the continuous importation of materials for which there are alternatives at home.

In respect of sustainability in Livestock production, setting up of ranches is not the issue. The issue is management of the ranches. Nigeria is in the current mess because the elements of sustainability have been missing in our livestock production. The semi arid regions in Nigeria can produce enough livestock for local consumption as well as export if we practice Pastoralist grazing within the ranches. Cows and herdsmen trecking from the North to the south in search of fodder is worthless. Every State in Nigeria has enough landmass to establish ranches that can supply adequate beef for their indigenes. They can even earn foreign exchange from the ranches. It is doubtful if there are Fulanis in Botswana where there are more cows than human beings. If the north cannot find market for their cows in the south, they will be forced to export and earn foreign exchange from them. Nigeria has no excuse for not being one of the largest leather producers and exporters in the world.

One country that Nigeria should understudy in respect of productivity in the dry regions is Israel where the Negev Desert which covers over 60% of the country has shrunk in size over the past century as agricultural activity has turned sand into green fields, the opposite to the desertification trend which much of the rest of the world is battling to prevent. It is on record that Israel manages to produce 95% of its own food requirements in spite of the large desert area. So also, the Netherlands where there are no Fulanis and their cows are thrice as big as our cows in Nigeria, should be understudied in respect of livestock production.

According to Ojo and Adebayo (2012), "…Food is an essential component of welfarism. In order to avoid recapitulation, public policy makers must as a matter of urgency should see food as a component of welfarism and as such develop sufficient political will to achieve increased food production, evolve sustainable food policy and eventually attain food security for all. …Any government that makes her citizens go hungry will definitely run into trouble."

Finally, Sub-Saharan countries should as a matter of priority and expediency identify other areas of appropriate biotechnology that could be improved upon to be synergistic with sustainable biotechnology so that the gains of the exercise will be affordable to the present citizenry as well as future generations. A sustainable agricultural system must be **ecologically sound, economically viable, and socially responsible**. These three dimensions of sustainability are inseparable, and thus, are equally critical to food security on the long run.

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