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Inaugural Lecture Series 78

MAKING THE SOIL NUTRITIOUS TO PLANTS

By E. A. Adua i

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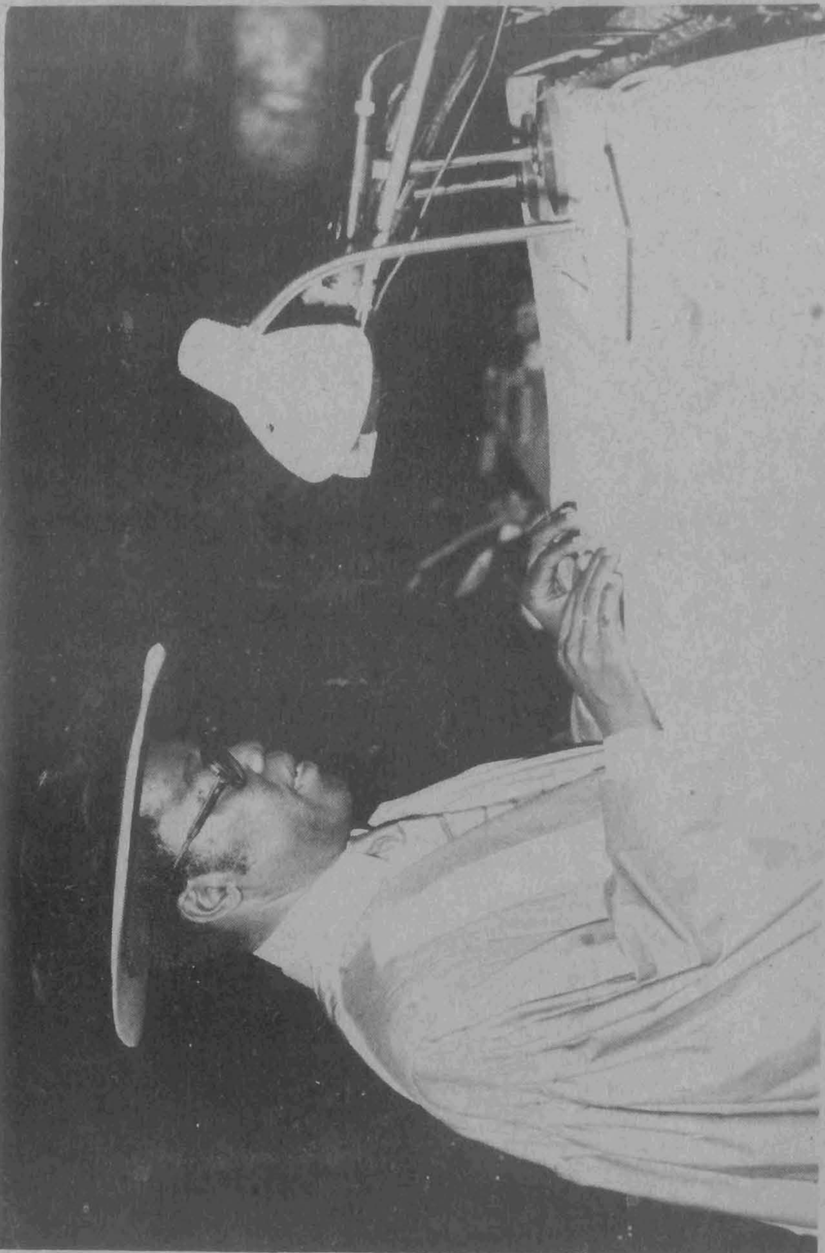

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Professor of Soil Science

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Inaugural Lecture delivered at the University of Ife
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MAKING THE SOIL NUTRITIOUS TO PLANTS

Plants are able to live without MAN, but MAN cannot live without plants. If, therefore, MAN has to survive on earth, he has to ensure that the medium in which plants grow, namely the soil, is kept nutritionally balanced. It is on this premise that my lecture will be based. And taking cognisance of the expected heterogeneity of my audience, I will try not to be too technical. With this in view, I shall attempt to develop the topic by posing the questions: *What is a soil? And how does the soil acquire its fertility status for the nourishment of plants ?*

The Soil

The soil is simply a medium for plant growth. Technically, the soil scientist defines it as the unconsolidated mineral matter on the surface of the earth that has been subjected to, and influenced by genetic and environmental factors such as rocks, climate, vegetation and topography, all acting over a period of time and producing a product (soil) that differs from the material from which it is derived. Fig. 1 gives a diagramatic sketch of the process of soil formation. Once formed, the soil is further subdivided into fine particle sizes which are classified as clay, silt and sand and on the basis of the mixtures of these classes may be described as loamy, sandy loam, sandy clay loam *et cetera* as shown in the soil textural triangle in Fig. 2.

For example, when you take up a shovel and make a vertical cut down a typical farmland, a profile of succession of layers, known as *horizons* is observed. The *horizons* differ in colour, texture, structure, consistency and porosity. The most easily recognisable feature of the profile is the distinctive colour of the layers. Consequently, it is not uncommon to come across a *"dark soil", "red soil", "gray soil", "brown soil", et cetera.* These colour variations are often directly related to the physical and chemical reactions in the soil.

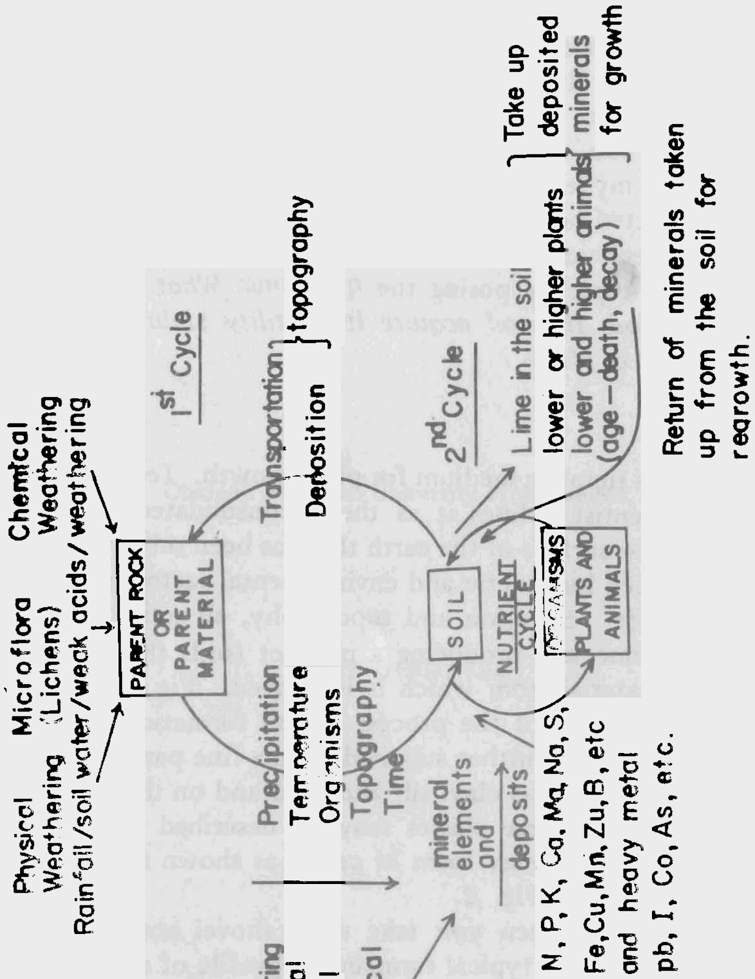

Figure 1: Diagramatic Sketch of The Process of Soil Formation.

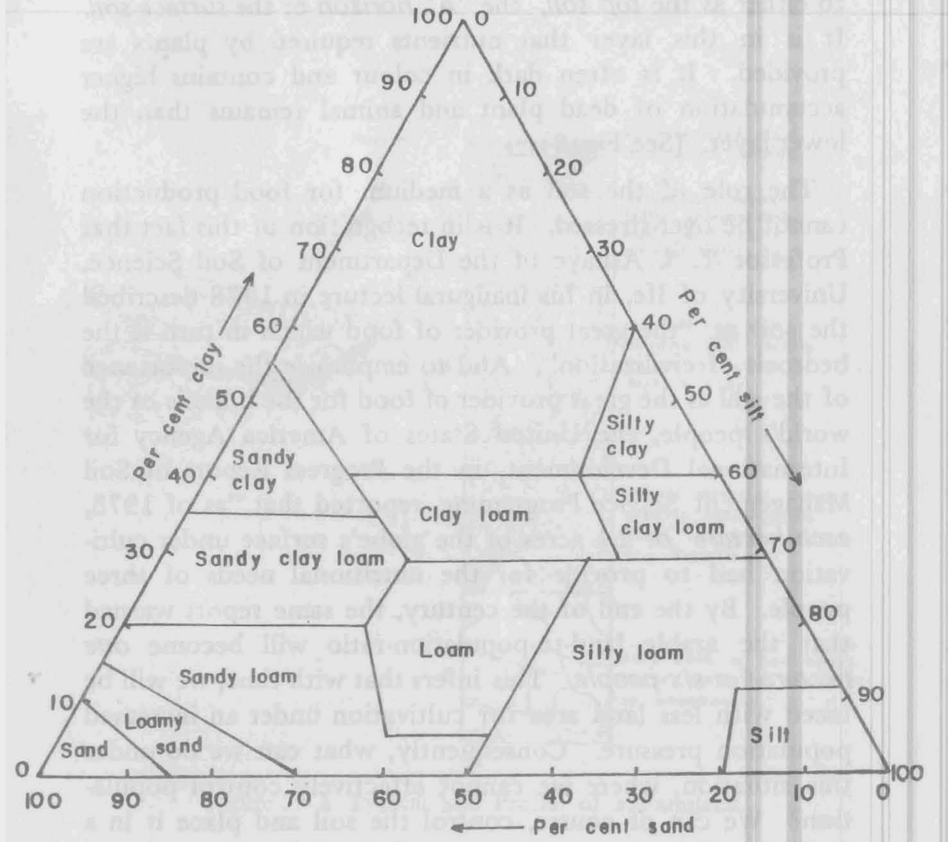

Figure 2: Soil Textural Triangle.

For the production of arable crops, the soil scientist concentrates on the first 20cm or 12 inches layer usually referred to either as the *top soil*, the *"A" horizon* or the *surface soil*. It is in this layer that nutrients required by plants are provided. It is often dark in colour and contains higher accumulation of dead plant and animal remains than the lower layer. (See Fig. 3).

The role of the soil as a medium for food production cannot be over-stressed. It is in recognition of this fact that Professor T. I. Ashaye of the Department of Soil Science, University of Ife, in his inaugural lecture in 1978 described the soil as "the great provider of food which in turn is the bedrock of civilization". And to emphasise the importance of the soil as the great provider of food for the billions of the world's people, the United States of America Agency for International Development, in the Progress Report of Soil Management Service Programme, reported that "as of 1975, *each hectare* or 2.4 acres of the globe's surface under cultivation had to provide for the nutritional needs of three people. By the end of the century, the same report warned that the arable land-to-population-ratio will become *one hectare* for *six people*. This infers that with time, we will be faced with less land area for cultivation under an increased population pressure. Consequently, what can we do under this situation, where we cannot effectively control population? We can of course, control the soil and place it in a fertile condition to produce enough food for the expected increase in population.

The Concept of Soil Fertility

A soil is regarded *fertile* if it contains all essential factors such as light, temperature, air and mineral nutrient elements in adequate and balanced proportions to support the growth of plants.

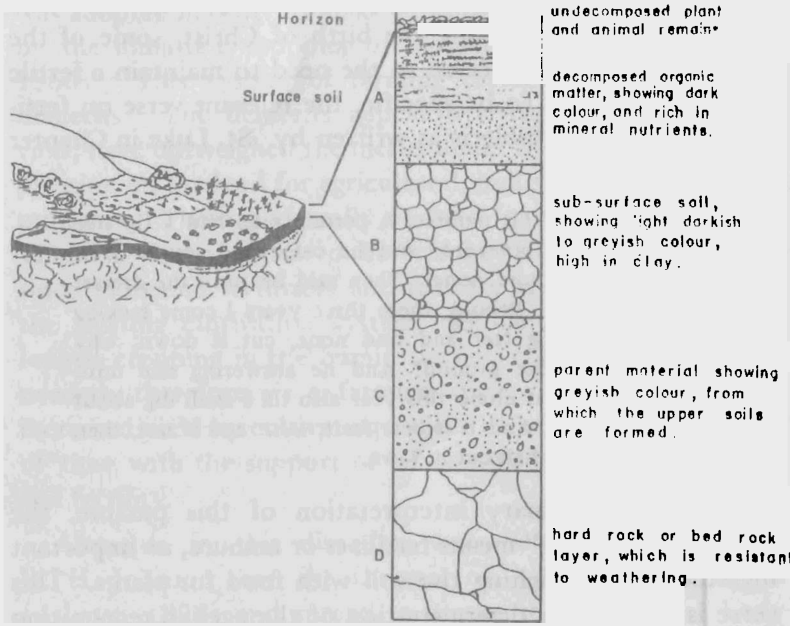

Figure 3: A Typical Soil Profile of a Farmland.

Our fore-fathers for long recognised the need to keep the soil fertile. They cultivated the soil and added manure to regenerate its "strength". As we are told by historians, before the birth of Christ, great Greek and Roman philosophers such as Aristotle, Plato, Carto, Pliny and Virgil advanced various theories on natural science some of which were practicalised into successful farming ventures. And after the period following the birth of Christ, some of the followers of Christ referred to the need to maintain a fertile agricultural land. To be specific, the relevant verse on fertility of soil in the Bible is as written by St. Luke in Chapter 13, 6–9. It reads:

> He spake also this parable; A certain man had a fig tree planted in his vineyard; and he came and sought fruit thereon, and found none. Then said he unto the dresser of his vineyard, Behold, these three years I come seeking fruit on this fig tree and find none, cut it down; why cumbereth it the ground? And he answering said unto him, Lord, let it alone this year also till I shall dig about it and dung it: And if it bear fruit, *well:* and if not, then after that thou shalt cut it down.

From my ordinary interpretation of this parable, the reference to "dung" means fertilizer or manure, an important ingredient for enriching the soil with food for plants. This verse is therefore a demonstration of the age-old recognition of the importance of the contribution of soil management to agricultural production.

Following this biblical period, a crop of dedicated agricultural chemists sprang up. And in the 19th century, German scientists such as Justus Liebig (1803-1973) and Mitscherlich (1874–1956) advanced theories on the mineral nutrition of plants, and propounded the "Law of the minimum" which states that the soil may contain almost all elements but the deficiency of one element may render it unproductive and that for a nutrient element not present in adequate amounts, a certain maximum yield was obtainable by the addition of that nutrient element. This means that all nutrients should

be available in the soil in an appropriate and balanced amount in order to promote plant growth.

From the works of Liebig and Mitscherlich, we in Africa and indeed Nigeria derived the inspiration to sustain the productive capability of our farm land.

The practice of shifting cultivation by our rural farmers was adopted in order to make good the damage or loss caused by the unnatural cropping of the land (Nye and Greenland, 1960). This system of farming certainly has merits and demerits. The demerits appear overwhelming and, in my view, have outweighed the merits under the present economic pressure on the land for agricultural, industrial and residential purposes. There is virtually no land for farmers to shift to. There is just no land to be left in fallow. Furthermore, since inorganic fertilizers and manure are rarely used under the shifting cultivation system, decline in yield after prolonged cropping in the humid tropics, could occur. What is needed, therefore, is a farming system that can result in increased yield by cultivating a piece of land for a long period of time with the support of adequate manuring to maintain soil fertility.

Attempts in this direction were initiated in 1910 by [illegible] Johnson then the Director of Agriculture in Nigeria (Ashaye, 1978) and spread to recent soil scientists. Early Nigerian farmers were taught to plant legumes in their field to produce natural forms of nitrogen. They were also taught to practice rotation farming. They alternated between leguminous (groundnut and mucuna) and non-leguminous (cotton, maize, yams) crops.

The rotation farming system gradually gave way to the mixed farming system particularly in the savanna ecological zone where farmers were induced to farm after paying a small deposit for ploughs, pair of trained draft cattle, a cultivator, a yoke, and were given credits by the Native Administration (N.A.).

As a result of the inducement provided to mixed farmers, their population increased from 1,959 in 1939 to 15,000 in 1959 and to 36,000 in 1964. It is quite likely that current figures must be approaching a hundred times the 1964 figures. Arising from this development, rural farmers began to, appreciate the need to stay much longer on a piece of farmland, and maintain its fertility by replènishing the soil with elements that have been removed from the soil through crop uptake and metabolism. The need to add nutrient elements to depleted soils heralded the birth of series of fertilizer experiments on the response of crops to nitrogen, phosphorus and potassium otherwise known as N.P.K. by indigenous soil scientists pioneered in the 50s and 60s by soil fertility experts such as Mr. B. O. E. Amon, Mr. S. A. Adetunji, Professor A. A. Fayemi, Professor W. O. Ewenzor, Professor D. M. Ekpete, Professor A. A. Agboola, and Dr. O. E. Jaiyebo, to mention a few.

Determinants of Soil Fertility

When a prospective farmer decides to acquire a new parcel of land, his initial worry is whether the farmland is "good" or "bad". That is, whether the land is *fertile* or not. He then makes an on-the-spot assessment of the land. He looks at the topography to determine the slope of the field. He looks at the general vegetation to observe the state of growth of the original vegetation. He then goes further to seek for sources of water.

The farmer then turns to us, the soil scientists. He wants a critical evaluation on the physical and chemical properties of the field. The soil expert checks amongst other things, whether the soil is loamy, sandy or clayey. A loamy soil is generally regarded good since the sand and clay contents may be in the range of 60 to 80%, and 11 to 22% respectively. However, in extreme conditions where the soil may contain about 90% sand, or above 80% clay, then agricultural activity will become difficult. The highly sandy soil will not

retain water, whereas the highly clayey soil will retain excessive amount of water and will not allow plant roots to penetrate the soil. Ploughing is usually very difficult. And in any case, a farmer who may like to cultivate such a parcel of land will have to work extremely hard to render it productive!

Chemical Properties

Whereas the parameters of soil quality based on physical assessment may be regarded as stable, the same cannot be said of the chemical factors. It is, indeed, the chemical changes that control the release and availability of nutrients for plants.

Some of the released elements have been proved to be highly *essential* to plants. This means that the absence of any of the elements can render the plant incapable of attaining a complete vegetative and productive cycle of growth; and that its deficient level in the soil cannot be replaced by substituting another element, and that the essential element must be required by a wide range of plants.

There are about 16 such essential elements. These are carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), boron (B), molybdenum (Mo), and chlorine (Cl). This list of elements is not static. Infact, the plant contains much more than the 16 elements listed when analysed, but not all of the additional elements have been proved to be physiologically and metabolically essential to plants.

However, with improvement in diagnostic procedures, many of the unidentified essential elements are now being identified. For exámple, sodium (Na), cobalt (Co), silicon (Si) and titanium (Ti) are on the verge of being proved as essential to plants. We in Ife are carrying out studies aimed at proving the essentiality of sodium (Na) to the okro plant (Hibiscus spp.) and other arable crops grown in this vicinity.

As long as the listed 16 essential elements are available in the soil in appropriate concentrations, farmers should have no problems. But this is a hypothetical wish. It is never the case in a biologically heterogenous environment such as the soil. There are complex factors in the soil that influence the composition of the released elements. Some of these factors are *soil pH, organic matter (OM) and cation exchange capacity (CEC)*

Soil pH: The soil pH may either be acidic or alkaline. There are two ions that are responsible for the state of pH of the soil. They are *hydrogen ions* (H+) and the *hydroxyl ions* (OH–). When the concentration of hydrogen ions is greater than the *hydroxyl ions,* such a soil is referred to as being *acidic,* and when the reverse occurs, the soil is referred to as *alkaline.* On the other hand, when the level of *hydrogen ions* is equal to that of hydroxyl ions, the soil is referred to as being neutral. It is necessary to mention that the heavy rainfall that usually occurs in the tropics induces acid condition in the soil. This is possible through the washing away of some dissolved elements such as potassium (K+), calcium (Ca^{2+}), and magnesium (Mg^{2+}) through the process of leaching to depths lower than those in which plant roots thrive (See Fig. 4). The vacant places left over by the leaching of these elements are then replaced by H+ ions. The hydrolysis of aluminium ions is also hastened in the presence of excessive water, thus adding more H+ ions to the soil. The situation is slightly different in the savanna region where the rainfall is relatively less than that of the humid tropics.

To the soil scientist, the role of the soil pH is similar to that of the body temperature to the medical doctor. Just as the body temperature measurement is the first critical preoccupation of the doctor, so also is the soil pH to the soil scientist for monitoring the type and form of fertilizer to be applied to the soil. For example, acid soils are known to accumulate toxic levels of highly soluble aluminium (Al^{3+}),

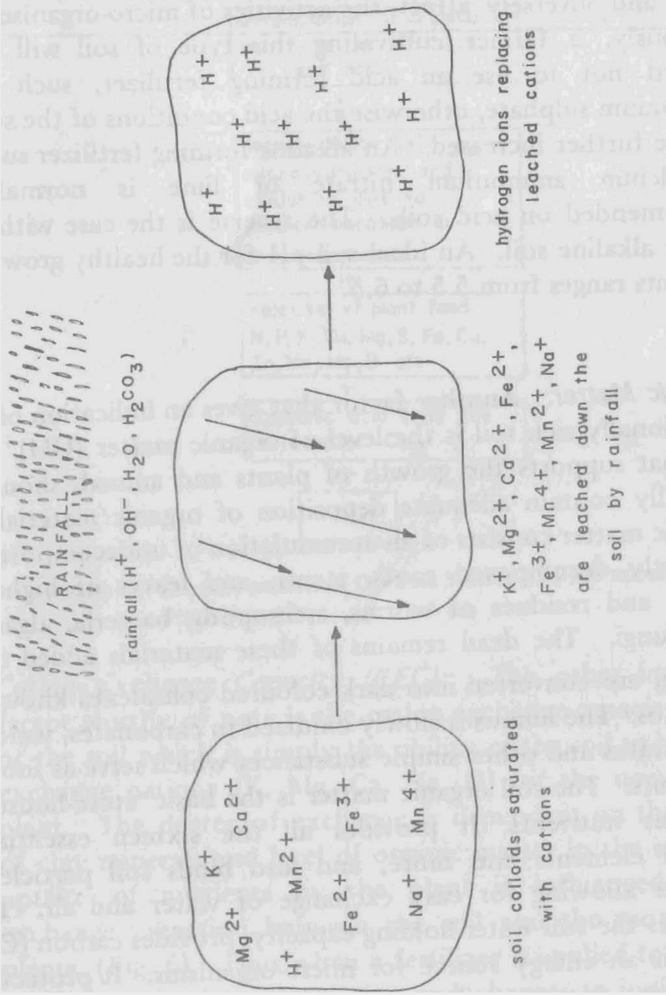

Figure 4: The Causes of soil acidity in Tropical Soils (Source, Aduayi and Ekong, 1981)

hydrogen (H^+), iron (Fe^{2+}), copper (Cu^{2+}), manganese (Mn^{2+}), and low levels of phosphorus (P), and molybdenum (Mo), and adversely affect the activities of micro-organisms. Obviously, a farmer cultivating this type of soil will be advised not to use an acid forming fertilizer, such as ammonium sulphate, otherwise the acid conditions of the soil will be further increased. An alkaline forming fertilizer such as calcium ammonium nitrate or lime is normally recommended on acid soils. The reverse is the case with a highly alkaline soil. An ideal soil pH for the healthy growth of plants ranges from 5.5 to 6.5.

Organic Matter: Another factor that gives an indication of a nutritionally rich soil is the level of organic matter (OM). A soil that supports the growth of plants and animals should normally contain adequate deposition of organic materials. Organic matter consists of an accumulation of undecomposed or partly decomposed roots, stems, and leaves of higher plants, and residues of worms, arthropods, bacteria, algae, and fungi. The dead remains of these materials added to the soil are converted into dark coloured complexes known as humus. The humus is slowly oxidized to carbonates, water and nitrates and other simple substances which serve as food for plants. The soil organic matter is the basic 'store-house' of plant nutrients. It provides all the sixteen essential mineral elements and more, and also binds soil particles together allowing for easy exchange of water and air. It increases the soil water holding capacity, provides carbon (C) which is an energy source for micro-organisms. It protects vital plant nutrients, (by acting as a chelating agent) from loss through leaching. Organic matter accumulates more in the first 20 cm of the surface soil (Fig. 5). It is conventional to aim at soil organic matter of between 1.5 to 5% to maintain soil fertility.

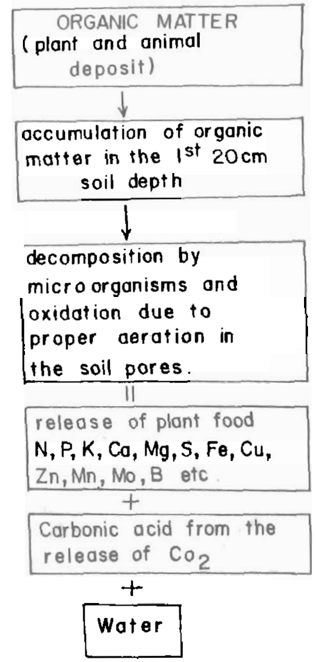

Figure 5: Decomposition of Organic Matter and the release of Plant Food.

Cation Exchange Capacity (CEC): The other important factor worthy of note is the cation exchange capacity (CEC) of the soil which is simply the ability of the soil to hold and exchange cations (K, Mg, Ca, Na, H) for the need of the plant. The degree of exchange is dependent on the nature of clay minerals and level of organic matter in the soil. The uptake of nutrients by the plant is influenced by the exchange reaction between the soil and the root hair of plants. (Fig. 6). Thus when a fertilizer is applied to the soil, it dissolves in the soil solution and changes to ionic forms. The ionic forms enter into a complex process of exchanges in the soil and around the roots and finally enter into the plant.

We have assessed in the soils of South Western Nigeria that a CEC value of less than 12 me/100g of soil is low; while values ranging from 12 to 25 me/100g of soil indicate adequacy, and above 25 me/100g of soil excesses.

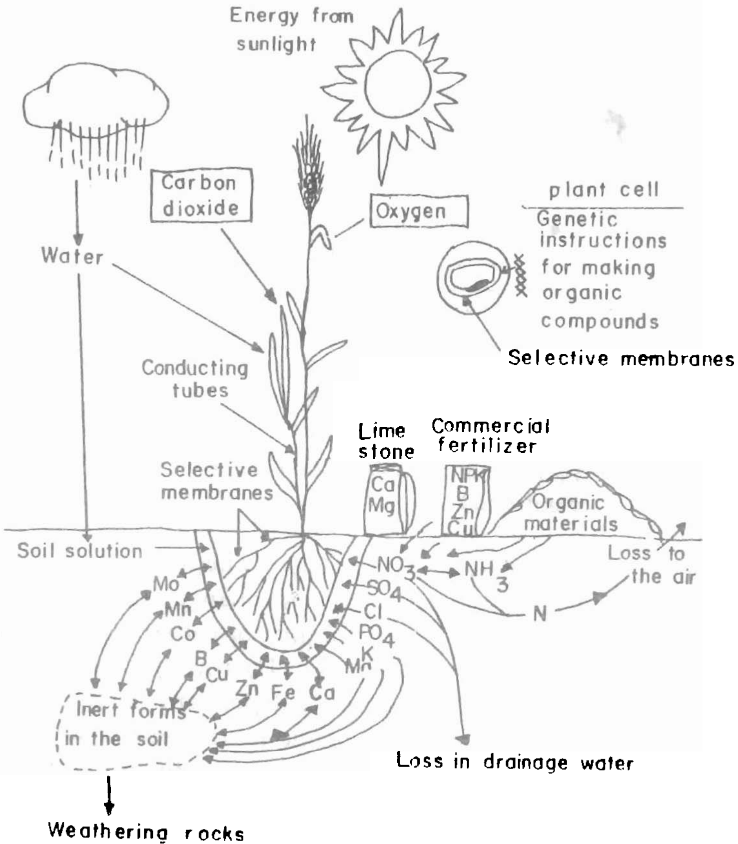

Figure 6: Nutrient uptake, absorption and utilization by Plants.

Determining the Type and Rate of Fertilizer to Apply to the Soil

The basic information I have provided on the physical and chemical properties of the soil coupled with the fact that plants consume nutrient elements in varying concentrations, has emphasised the need to evaluate the exact quantity of elements in the soil that will produce optimal plant growth. It is known that the demand for nitrogen by maize is greater than that by cowpea, whereas a tuber crop such as yam or cassava will require more potassium than the tomato or the okro plant. Consequently, a fertilizer feeding programme that does not take care of the differences in the feeding habit of plants will not only be ineffective and uneconomical but will be disastrous to crops.

On the basis of the above, my first approach to fertilizer studies was to standardize soil and plant tissue sampling techniques, the result of which showed that soil samples for fertility evaluation could be stored for up to 3 months and at temperatures between 15 to 18°C if the interpretation of the results were to reflect as close as possible, the chemical nature of the soil in the field (Aduayi, 1981). A similar study on plant tissue sampling showed that for assessing the nitrogen, phosphorus and potassium requirement of the yam plant, leaves should be obtained from the middle to the lower canopy on the stake during the period of maximum tuber development.

I also applied greenhouse nutrient solution, soil and sand culture techniques and field experiments to further amplify the roles of various rates of nutrient elements on plant growth. With the application of these techniques, it was found in Ife that whereas the yam plant *(Dioscorea rotundata)* required about 200 kg of elemental nitrogen per hectare for optimum growth and yield, the okro plant *(Hibiscus esculentus* L) required about 50 to 100 kg of nitrogen per hectare, with the yellow maize *(Zea mays* L) requiring between 150 to 200 kg nitrogen per hectare. The nitrogen source was ammonium sulphate and was applied in two splits, the first at the vegetative stage, and the second at the flowering stage of growth of the plant. It was also observed that not only did nitrogen improve yield of crops but it also enhanced the levels of nitrogen, magnesium, crude protein content of grains, and fruits and the total chlorophyll and carotene contents of the leaves, (Aduayi, 1979, 1980 a, b,). Furthermore, our nitrogen fertilizer work on yam has shown that while ammonium sulphate fertilizer increased soil acidity, it, at the same time, produced the highest fresh tuber yield, percent crude protein, starch and glucose, while calcium ammonium nitrate recorded the lowest yield but had the best storage quality of white yam.

Although fertilizers are useful in farming, they could produce some adverse side effects on our soils, if not properly used and applied. This is particularly true of the excessive use of ammonium sulphate fertilizer which can exacerbate soil acidity and also ruin the pounding and storage quality of the yam. In this regard, the claim by lovers of pounded yam, "iyan" that the elastic quality of fertilized yam is often lost, could be partly justified. Our study showed further that the yam tuber was more susceptible to rot and disease infestation when fertilized with high doses of nitrogen, and at the same time failed to store long enough to produce setts for the following planting season. Although this study has more or less confirmed some of the fears of farmers, one obvious advantage is that fertilized yams produced increased yield and contained a good amount of crude protein approaching that of cereal grains. We have, therefore, to choose between the taste of "iyan" or pounded yam prepared through pounding with the mortar and pestle, and the taste of "iyan" prepared through yam flour. As it is now obvious that nitrogen fertilized yam produced more yield and has higher crude protein content, the observed loss in storage can, however, be controlled through biochemical studies involving the control of enzymes that may be responsible for the blackening (or oxidation) and rottening of the

ruber. Still on the need for caution in applying overdose of nitrogen, Aduayi (1980) concluded that although NO_3-N in itself may not be readily toxic to animals and man, it is certain that its excessive levels in food and feeds may not be desirable under an unguided fertilizer programme. This is as a result of the possibility of NO_3-N conversion in the digestive tract of mammals to nitrite. Allaway (1975) reported that nitrates often become toxic to animals because once absorbed into the blood system, they react with haemoglobin and interfere with the transport of oxygen in the blood stream.

Micronutrient Studies

As the supply of nitrogen, phosphorus and potassium (N,P,K) to plants is intensified, little was it realized that the plant was being subjected to acute shortages of the microelements. Rather than obtain the expected high yield of crops after prolonged fertilization with N,P,K macroelements, the plant leaves exhibited diverse colours and in most cases, stunted growth. This situation called for a study on the interaction between the essential macro- and micronutrient elements while at the same time, estimating the single roles of the micro-nutrients in plants.

As I embarked on micro-nutrient studies, I soon found that the experimental methods are cumbersome and problematic. Some of the problems include the lack of intensive research on the micro-nutrients as well as instrumental facilities for the accurate detection of the elements; erratic and inconsistent results; elemental contamination; and the low requirements for these elements by plants. Furthermore, chemical reagents required for the determination of the levels of the trace elements are often under economic conditions prevailing in Nigeria, expensive and difficult to obtain and store (Aduayi, 1979).

Results of the studies carried out in South-Western Nigeria revealed that boron, zinc and molybdenum are essential to the growth of the 'Ife plum' tomato and okro plant. Specifically, the results showed that normal and healthy growth of the 'Ife plum' tomato could be attained at the application of 2 ppm B (4.5 kg B/ha) while higher B concentrations resulted in severe leaf necrosis and numerous necrotic patches at the nodes, internodes and the peduncles. Whereas the growth of tomato was enhanced at 2 ppm B, (4.5 kg B/ha), okro plants grown in nutrient solution reacted negatively. In fact, 2 ppm B (4.5 kg B/ha) when applied through the root of the okro plant resulted in severe root burn. However, when the method of application was changed to feeding the plant through the leaves, with 4 ppm B (9.0 kg B/ha) the okro plant grew normally. This indicates that plant organs behave differently when brought in contact with nutrient elements and that the roots of the okro plant are sensitive to high boron treatment. Hence foliar application of B could be regarded superior to root-application for the okro plant.

In another study, Aduayi and Idowu (1981), Aduayi (1982), observed that the okro fruit has special preference for copper and zinc than Fe and Mn. In fact the fruits accumulated as much of Mo, Cu and Zn as the leaves. The varying levels of nutrient accumulation in plant fruits and grains, should be of special interest to dieticians, who may regard edible fruits and grains as alternative sources of highly needed mineral elements, for human and animal consumption.

Aware of the fact that applying the macro- and micro-nutrients to crops singly could affect nutrient balance, I then interacted their levels and observed the effects on plant growth. Agbede and Aduayi (1978) again found that tomato plants ('Ife plum') performed best at phosphorus and magnesium fertilizer ratio of 1:2 (40 ppm P or 88.6 kg/ha and 30 ppm Mg, or 179 kg/ha) or 1:1 (80 ppm P or 179 kg/ha and 80 ppm Mg or 179 kg/ha). Still more, Aduayi and Onesirosan, (1979) working on potassium and boron relationships in the greenhouse, observed that potassium fertilization of up to 200 ppm (448 kg/ha), producing leaf –K value of

1.37% resulted in high fruit yield and growth of tomato plants grown in the greenhouse. However, treatment combinations of 100 ppm K, (224 kg K/ha) and 2 ppm B(4.5 kg B/ha corresponding to K:B fertilization ratio of 50:1 improved plant growth and effectively suppressed the adverse effects of boron toxicity in the plant.

It was also observed in nutrient solution culture that zinc deficiency in okro interfered with phosphorus metabolism subsequently enhancing the amounts of P absorbed by roots and transported to the foliage. Under conditions of high P fertilization, therefore, phosphorus accumulated to toxic levels in leaves, accentuating yellow symptoms resembling zinc deficiency or phosphorus toxicity. This effect of zinc on phosphorus metabolism in roots aided in explaining previously puzzling observations in which P fertilization induced zinc deficiency symptoms without any appreciable reduction in zinc contents of plant leaves. However, the symptoms of zinc deficiency disappeared when zinc level in the solution was increased (Loneragan, *et al,* 1982).

Multidisciplinary Approach to Soil Fertility Studies

While projecting the importance of soil fertility on food crop production, it soon became clear that the inputs of other agricultural scientists were equally essential. We have to accept the fact that optimal agricultural productivity cannot be achieved if other factors limiting the growth of plants are not effectively controlled. Hence the need for collaborative efforts of the plant pathologist, entomologist, virologist, physiologist, geneticist, and agronomist, with the soil fertility expert, in order to increase food production. It is only when the insects, fungi, bacteria, virus, weeds and crop varieties are effectively "checked" that the soil can be expected to achieve full production capacity (Fig. 7).

Based on this view, I adopted a multidisciplinary approach to problems of soil fertility management. Subsequently, I observed the agronomy of Arabica coffee production in

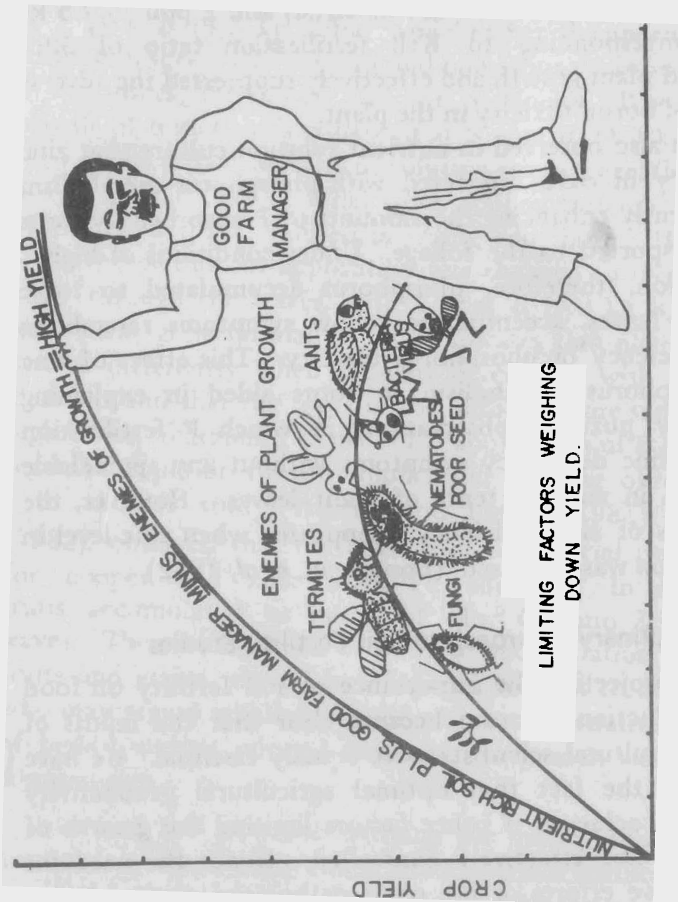

Figure 7: A good Farm Manager wages war against enemies limiting growth and manages the soil well to achieve high plant yield.

Kenya, and having been attracted by the frequency of spraying copper fungicides on the plants, by pathologists, I became curious and decided to experiment on the possible effect of elemental copper in the soil on coffee growth. I then proceeded to initiate some studies in collaboration with a plant pathologist to evaluate the implication of frequent copper fungicide application on coffee plants as a fungicide on soil fertility and incidence of copper toxicity in plants in Kenya.

Historically, the use of copper in coffee cultivation in Kenya was promoted around 1920 for its 'tonic' effects. It enhanced increased leaf retention, dark green leaf coloration, and yield (Griffiths, 1971). Thereafter, copper-based fungicides were applied increasingly to coffee to control coffee berry disease *(Collectotricum coffeanum Noack)* and leaf rust *(Hemileia vastatrix* Berk and Br.). The massive use of copper on coffee came to a peak in the sixties when coffee berry disease and leaf rust became a serious problem in Kenya. Copper fungicide was sprayed on coffee plants at the rate of 11 kg/ha of 50% Cu formulations otherwise called "Perenox" at 3 to 4 weekly intervals, resulting in a total of about eleven applications per year or 121, kg/ha of 50% Cu. It was soon shown that at this level, copper application negated the beneficial effects of fungicide application by exacerbating both leaf rust and coffee berry disease infections. It was found that soil copper accumulation increased from 3 ppm (6.7 kg Cu/ha) to 7 ppm (15.7 kg Cu/ha) in 5 years of continuous copper fungicide application

Following these findings, an attempt was made to simulate the effects of varying copper concentrations on plant growth (Aduayi, 1973). The results of these investigations using copper levels ranging from zero to 100 ppm Cu/ (224 kg Cu/ha) showed that copper levels above 5 ppm (11 kg Cu/ha) caused severe toxicity symptons in the foliage and roots and decreased stem diameter, shoot length and percent leaf retention when compared with plants receiving lower copper levels. The foliage of the coffee plant exhibited characteristic copper toxicity symptoms as observed in leaf yellowing, corrugation and necrosis and die-back of shoot. An anatomical study of the cells in the xylem tissues of plants receiving high copper levels showed irregularly shaped cell walls. Parenchyma cells of the leaves were dis-integrated and filled with large accumulation of starch grains with damaged cellular structure of the roots under excessive copper treatment. This phenomenon hindered the absorption and translocation of essential nutrient elements in the plant. These results showed that excessively high accumulation of copper in the soil through prolonged copper fungicide application could cause severe toxicity effects in plants. Based on the implication of the results just mentioned, there seems to be a parallel for cocoa in Nigeria where copper fungicide have been used extensively for the control of black pod disease.

On the same premise, I shifted my approach to the study of the activity of microfauna in predicting soil fertility. Towards this end, Professor A. O. Segun, a distinguished researcher and teacher in the Department of Zoology of this University and I initiated a series of studies supported by the University Research Committee, aimed at identifying African earthworm species as probable indicators of soil types and fertility in Nigeria. The ultimate goal of this study is to assess and recognise different soil types, their fertility potentials and their capacity to maintain the growth of various crops without actually going through the usually laborious physical and chemical analysis of the soil before deciding on the introduction of crops. Perhaps it may, in future, be possible to identify a specific earthworm species that can be bred and introduced to colonise the soil for the purpose of improving soil fertility (Segun and Aduayi, 1985). And, while still on earthworms, we should, at this stage, seriously consider the Chinese new [illegible] "[illegible] worms taste well in drinks". This [illegible] report from a local newspaper (*Punch*, [illegible]) [illegible] extracted from earthworms has been shown to be *high in nutrient*, and can be mixed in *alcoholic drinks, soft drinks*, and in *cakes*, to improve health. And, for the ladies, it may be interesting to note from the reports that the extracted liquid can also be used as skin cosmetics.

Diagnostic Criteria for Soil Fertility Evaluation

After ascertaining possible causes of nutrient deficiency, sufficiency and toxicity symptoms in plants, the next step of approach was to device simple diagnostic methods for detecting these symptoms. One simple diagnostic index is the pigmentation of the leaves.

Thus during growth, plant leaves exhibit various colour changes. The changes in colour are often related to specific nutrient stresses arising from the shortage or excesses of the essential elements in the region of the plant that most needs the element at a particular stage of growth. Thus, the leaves may turn yellow, brown, and purple whereas the entire vegetative portion of other plants may turn pale-yellow and become stunted with very short internodes. In the same way the leaves may develop chlorotic or necrotic patches intermingled with green tints in the veins.

These symptoms are easily identifiable in the field, and are easily used as qualitative indices of monitoring the nutrient status of the soil and plant. From these characteristic colours, it is often possible to diagnose deficiency symptoms of nitrogen as indicated in yellow coloration extending from the apex of the leaf to the base in a "V" shaped manner; phosphorus deficiency is observed as purple coloration; potassium as chlorosis or yellowing along the margin of the leaf; and magnesium as yellow and brown patches on leaf surface.

The severity of the symptoms I have just described depends on the mobility of the essential elements within the plant. Consequently, an element may either be *immobile* and move slowly, or *mobile* and move rapidly within the plant. The *immobile* elements (Ca, Fe, Mn, Cu, B, and Cl) accumulate in the lower parts of the plant such as the roots and older leaves, causing their deficiency symptoms to appear in the upper leaves when the elements are in short supply in the soil. On the other hand, the rapidly moving elements (N, P, K, Mg, Zn, Mo) often accumulate in the younger and upper parts of the plant resulting in deficiency symptoms appearing in the lower parts of the plants.

Also during growth, certain plants conceal nutritional *"hunger signs"* in them. The hunger signs are usually "hidden", thus posing a subclinical or incipient diagnostic *problem* to the soil scientist, a problem which induces the plant to assume a critical transitional state between nutrient deficiency and adequacy; and between adequacy and toxicity. As a result, a visual diagnosis through colour expression in the leaves becomes difficult. The only diagnostic option, therefore, is through chemical analysis of the plant in order to detect the actual level of the element.

In an analysis of soil and plant tissue samples from what I regard as "good" and "bad" farmland on the University of Ife campus, striking differences in chemical composition were observed. Whereas the "good" soil registered pH 6.7, organic matter of 2.2% NO_3–N of 77 ppm, phosphorus of 23 ppm, the "bad" soil had a pH of 5.8, organic matter of 6.0%, NO_3–N of 173 ppm and phosphorus 19 ppm. The plants in the "good" soil were healthy with green leaves, whereas those growing in the "bad" soil were stunted, severely yellow or chlorotic showing signs of acute nutrient deficiency symptoms. On a further chemical analysis of the maize plant tissue, we discovered that the healthy plants contained 3.4% nitrogen, 0.4% phosphorus, 3.3% potassium, 4.8% calcium and 0.26% magnesium. In contrast, the unhealthy plants had 0.7% nitrogen, 0.69% phosphorus (P–toxicity), 2.2% potassium, 2.0% calcium and 0.18% magnesium.

The soil and plant diagnostic guides I have just described should undoubtedly be useful to the career farmer as well as the "emergency" farmer who has taken more interest in farming as a result of recent government emphasis on food production.

Observation, Projections and Recommendations

I have been trying to portray the importance of providing adequate nutrition to the soil for plant growth. I have also tried to suggest means of reconditioning the soil for food production. The questions that may arise from my presentation so far are:

i. Why have we not succeeded in feeding ourselves?

ii. What practical contributions have our soil experts made to solve the perennial problems of food shortage in Nigeria ?

iii. Why can Nigeria not now produce enough food for export ?

The answers to these questions cannot all be satisfactorily provided in this lecture. However, I will attempt to highlight areas in our agricultural planning that we had neglected, and then reflect on what we ought to do next, and finally advance solutions for a sustained agricultural success through effective soil management.

I will however hasten to suggest here that a greater portion of the blame on the unimpressive progress in our agricultural endeavours revolves around the apparent lack of coordination among agricultural policy makers, such as, the governments of the federation, the soil scientists and the farmers. We have in my view, simply not made enough positive efforts to salvage the situation. We all seem to be working at cross purposes, by making individual approaches at problems of food production that can be best tackled collectively by all involved in the science of food production. What I am stressing here is that the responsibility for the management of the soil should be given to the soil scientist who is trained for the purpose. Anything short of this is a retrogressive move at food production.

It is, in fact, not the size of the farming area that dictates the success of an agricultural production. Rather, it is the ability to intensify agricultural inputs and the willingness to carry out regular 'check-up' of the land for food production. To buttress this view, we should consider the agricultural successes of the United States of America (U.S.A.), U.S.S.R., Israel, and Kenya, an African country whose land resources are not near what we have in Nigeria. These countries have at one stage or the other succeeded in feeding themselves.

An encouraging sign, however, seems to be appearing in Nigeria's agricultural horizon. This sign is reflected in the recent change in our outlook to farming and soil conservation. We are now frequently being reminded to "go back to the land". "Emergency farmers" are springing up daily. The memories of the philosophy of the "Operation Feed the Nation" and the "Green Revolution" appear to be returning to us. Slogans like: "Become a farmer, good things of life will follow", are being flashed on the screens of the Broadcasting Corporation of Oyo State T.V. (BCCS). And on the pages of some of our newspapers, we read of topics, such as "Rise in agricultural loan rate is a burden", *(Daily Sketch*, No. 6067, 6-8-85), "And Soil Testing Labs", "Strategies for Agricultural Development" (both in *Daily Times*, No. 278225 of 29-6-85), "Fertilizers come to Nigerian agriculture" and "who needs the fertilizer" *(The Guardian*, Vol. 2, No. 744, 1-7-85), to mention a few. From these developments, one feels proud as a soil scientist that agriculture which was once a noble profession but now neglected and relegated to the background in the nation's economic scene has suddenly resurrected. I hope this situation has now come to stay permanently.

With the agricultural stage being set for a take-off, we must ensure success through adequate and careful planning and execution of agricultural programmes. We seem to be in a hurry! Our agricultural plans are structured in such a way that not enough involvement is sought from those who have spent years studying the science of improving agricultural production in the field. Consequently, our programmes get aborted before maturation.

As we embark on a renewed approach to solving our food problems, we must be aware that haste is only successful when it is made slowly! The lecture by Professor Mabogunje, which appeared in *Daily Sketch* No. 6036 of July 1, 1985; captioned "Way out of the Mess, Let's do first things first" in his 1985 National Merit Award Winners Lecture titled "Last things first – a re-appraisal of fundamentals of Nigeria's Development Crisis", delivered in Enugu is appropriate here. Professor Mabogunje maintained that "the basis for most of the present crisis in Nigeria's development process is that governments have been doing the last things first". This view is also relevant to the nation's agricultural development efforts.

I strongly believe that there are enough indigenous and highly competent scientists in this country that can perform the task of revolutionalising our agriculture, rather than "foreign experts". Turning to the "foreign experts" should be the "last thing last"! For these "experts" are usually ignorant of the local conditions of the soil and climate in the country. In any case, one wonders how "expert" are the "foreign experts" who on assumption of their consultancy jobs troop daily to the offices and laboratories of indigenous soil scientists, seeking information on the history and conditions of our soils which they pass on to their clients. I believe that the indigenous soil scientist whose knowledge has been so tapped should be encouraged to deal directly with his clients, with less the remuneration the "foreign experts" enjoy. I am convinced that our indigenous soil scientists are committed and can do their assignments with dedication. They need to be recognised and trusted.

Nigeria's Third National Development Plan, 1975–80 placed the total agricultural land area in Nigeria as 93.3 million hectares, out of which about 71.2 million hectares are cultivable. This figure represents a large mass of land which, if properly controlled, should provide all the food we need with surplus for export. Hence, to develop our cultivable land space we must retrace and reflect on our glorious agricultural past, so as to correct omissions and errors of the present. We must work at our pace! We must learn again the act of applying simple and appropriate techniques, using easily adaptable implements which should be developed by our agricultural engineers. We must not rush to applying sophisticated machines we do not know how to operate and maintain. Experience from the present practice of utilizing these machines has been disappointing. Complaints from farmers applying them are mainly on shortage of spare parts, maintenance and operational problems leading to complete disuse. Our farms are being transformed daily into a grave yard of unusable machines. Under our present economic situation coupled with our desire to feed ourselves, we must not allow this situation to persist. More importantly, we must not be carried away by inovations from nations that are far more sophisticated than us! We have experienced cases in which heavy sophisticated machines were wrongly used to remove the top soil and degrade our farmland.

Perhaps, I should mention a recent advancement in foreign agriculture. This is mainly on the introduction of a highly sophisticated technology into agricultural research by scientists of the United States of America. The Americans are now researching into the use of the *Light Amplification by Stimulated Emission of Radiation techniques* popularly known as LASER to detect crop nutrient deficiencies *(New Nigeria* of June 18, 1985). Researchers at the U.S. Department of Agriculture's Beltsvile Agricultural Research Centre, the Goderd Space Fligh Centre of the U.S. National Aeronautics and Space Administration (NASA) and a private consultant applied the LASER technique to detect nutrient imbalances through changes in the leaves' fluorescence occuring primarily in the chlorophyll pigment. They were able to detect deficiencies of nitrogen, iron, potassium and phosphorus in maize plants *(Zea mays L)* and phosphorus, boron, sulphur, calcium, magnesium and potassium in soyabean *(Glycine max L)*. The deficiency symptoms were then corrected by the addition of the appropriate fertilizer.

These inovations, I agree, are great scientific feats. Nevertheless, we cannot now adopt them! It is not expedient to adopt a technique we cannot easily apply under the present state of our economic needs. As a nation anxious to feed itself, we should only aim at agricultural techniques that we fully understand, can apply, maintain and sustain. However, as our understanding improves and are able to ensure sufficiency in food production, we may then begin to look at techniques that can further ensure our needs for a long time.

There are, definitely, alternatives to the use of the LASER technique. The alternatives lie in our willingness and patience to go back to fundamentals and retrace efforts that would equally help in assessing nutrient deficiency and nutritiona' needs of plants without necessarily applying the LASER technique. We can achieve these by:

i. studying our soils and classifying them based on their fertility zones.

ii. carrying out an inventory of our arable land based on the concentration of agricultural crops.

iii. subdividing the country into agriculturally specific cash crop areas which may be identified as zones or belts for maize, plantain, banana, yam, cassava, cotton, sorghum, wheat, as it is now the case for coffee, kolanuts, tea, cocoa, and so on.

To ensure the success of crop zoning, the government should declare some of these crops and others as national crops and their cultivation financially supported and restricted to the ecological areas whose soils will best support their growth. There is, therefore no convincing reason for leaving fallow the large expanse of agriculturally fertile lands along our major roads. These lands contain mixed uneconomic vegetation that does not contribute much to our agricultural needs. Rather, the dense vegetation that infests the roads form safe abodes for criminals who from there move to the road sides to carry out their nefarious activities.

The mixed vegetation along our major roads should now be transformed into plantations of crops that are identified as naturally adapted to the soil types and climate subsisting in the area. For example, driving along our major expressways and highways, one observes agricultural products such as oranges, maize and yams along Ore–Benin expressway; tomatoes, yams and maize along the Ife–Akure, Ife–Ibadan highways; yams, tomatoes, mangoes, cassava and maize along the Benin–Asaba highway. Similar scenes can be observed along the Aba–Ikot Ekpene; Ikot Ekpene–Calabar; Calabar–Ogoja; Ibadan–Ilorin–Kaduna highways, et cetera.

What we need to do now is to convert the wasting forests in these areas into plantations of one of the identified economic crops, so that we can now *see* agriculture supported by agro-based industries as we drive round the country. The logistics of implementation of these ventures will, however, depend on a bold government policy on land tenure and agriculture.

Furthermore, to boost food production, urgent steps should be taken to establish a well coordinated *soil testing* and *plant* tissue analysis programme which will regularly monitor the soil and offer advice on its management. A *soil testing and plant tissue analysis programme* has supported soil management and conservation in most agriculturally advanced countries. It is a regular practice by government and commercial laboratories in the United States of America to carry out massive soil and plant tissue testing before and during land cultivation. For instance between 1968 and 1983, over 37 million soil, and 3 million plant tissue samples were analysed on routine basis before cultivation in state and commercial laboratories established all over the U.S.A. Kenya has a similar programme. But in Nigeria, until recently, there was no nationally supported soil testing and plant tissue analysis programme for farmers. The current effort by the federal government through the Department of Agricultural Land Resources to establish

four soil testing laboratories located in Ibadan, Jos, Kaduna, and Umudike, representing various ecological zones is therefore commendable. When fully operational, it should be possible to offer advice to farmers on:

i. type and rate of fertilizers to apply;
ii. method of application; and
iii. judicious and economic use of fertilizers.

A programme such as this should also advise farmers against the use of fertilizers for a specific period if it is found that the soil has sufficient nutrient reserves to support the season's growth of crops.

In addition to the zonal soil testing and plant analysis laboratories, it is necessary to encourage large scale successful farmers to establish miniature soil testing laboratories to monitor the nutrient status of their farmlands before cropping and possibly extend these services to rural farmers around them.

It goes without saying that the availability of soil testing laboratories would go a long way to improving farmers techniques in fertilizer use and application *(Daily Times,* No. 278, 225 of 29/6/85).

I will now devote a few minutes to the rationale for the use of fertilizers in agriculture. Arguments have been advanced on the rationale for the use of chemically manufactured and imported fertilizers to this country. Opponents of massive importation of fertilizers often hold the view that Nigeria can do without fertilizers since, as they claim, the country did not use fertilizers in the past when the country depended solely on agriculture to feed her population and that Nigeria should conserve foreign exchange. They also assume that our soils are permanently fertile! They, however, fail to carry out a comparative evaluation of the needs of the country then and now. They also fail to appreciate that agriculture as practised now is land intensive, whereby more crops are grown in an area much less than what farmers in the past cultivated. It has also been shown that the so-called permanent natural fertility status of the soil can only support about three years of intensive cropping. Thereafter, the soil often becomes severely depleted in plant food such that the only way to bring it to an adequate nutritional status is through the addition of fertilizers.

It is also clear that those who object to the use of fertilizers apparently seem obsessed by the magnitude of the amount imported into the country, particularly in 1977 when the government was reported to have spent about ₦300 million on fertilizers without noticeable possitive result in agricultural output. This position notwithstanding, it is still cheaper and more profitable in the long run to spend huge sums of money importing fertilizers to improve agricultural output than to spend similar amount of money on food importation. To a Nation like Nigeria gifted with fertile land, massive importation of foodstuffs should be discouraged as it kills incentive and motivation in farmers, and encourages laziness and such associated vices and fraud, gambling, and crime. It is with this view that the ban on the importation of rice and maize by the federal government on October 1st, 1985 is a welcome and bold attempt to exploit our hitherto untapped land resources and a challenge to agricultural experts and farmers.

The only possible alternative to the use of imported fertilizers however, may be the use of organic manures. And here again, there are obvious limitations to the use of organic manures. The major limitation lies in the difficulty in obtaining adequate amounts for large scale agriculture, and the delay in its release of nutrient elements for the immediate use of the plant. In fact, the availability of organic sources of manures, such as sawdust, poultry and cow dungs in this country is so low that it is not always sufficient even for backyard vegetable farming. On the other hand, chemically manufactured fertilizers release needed plant nutrient elements faster and in a more soluble form for the immediate use of the crop than the manure.

The question, therefore, is not in the amount of fertilizers imported or the foreign exchange involved but in the overall cost benefit such importation can add to the efforts to feed ourselves and the nation. In procuring fertilizers, there are precautions that must be taken to obtain results. These are the quality of the compound to be imported, the specific need of the soil and crops, the handling, including storage and the proper method and rate of application. In fact, records show that Nigeria's consumption of fertilizers is relatively low, and is estimated at 7 kg of nutrient per hectare of land under cultivation. This value contrasts sharply with the reported Africa average of 20 kg nutrient/ha (IFDC, 1984), with Kenya and Zimbabwe consuming over 35 and 58 kg nutrient/ha respectively, and Asia and the world averaging 68 kg and 78 kg nutrient/ha, respectively. Hence to stress the importance of fertilizers in our agricultural activities, Nigeria should promulgate a national policy on *fertilizer use and handling,* and take advantage of the "National Fertilizer Company of Nigeria" to promote the economic use of fertilizers for food production. Such a policy should aim at controlling the acquisition and importation of fertilizers into the country. It should provide that no fertilizer should be applied to the soil without reference to detailed soil tests to ascertain type, rate and frequency of application. It should also be mandatory for a soil chemist, analyst or fertility expert to confirm the correctness of the percentages of plant food shown on fertilizer bags before importation and distribution to farmers in the country.

Another area of policy guideline to ensure profitable agricultural productivity should be focussed on the roles of agricultural research stations and universities devoted to the study of the soil and crop. Whereas these institutions are independent of one another, they are often seen to perform complimentary roles, and in most cases, duplicating research efforts. To prevent duplication and wastage in their various roles there is need to promote collaboration and coordination of efforts of the research stations and university faculties of agriculture in the country. In view of these, I am proposing an integration of all agro-based research stations with faculties of agriculture of universities. In this framework, the research stations should be regarded as the practical experimental stations attached to the faculties. Thus, while the faculties of agriculture are engaged in their primary functions of manpower production in addition to the conduct of basic scientific research, the experimental stations should be engaged in practical research aimed at maximizing agricultural production. These stations should then join forces with the faculties of agriculture to evolve an effective agricultural extension service for farmers in the agricultural zones in which the research stations and universities are located. This arrangement will likely reduce the apparent confusion created by the multiplicity of extension services provided separately by the ministries of agriculture, universities and research stations to farmers.

These proposals are not entirely new. Part of the proposals suggested here are currently being practiced at the Ahmadu Bello University Faculty of Agriculture and the Institute of Agricultural Research; and to some extent, at Ife, by the University of Ife Institute of Agricultural Research and Training and the Faculty of Agriculture.

Furthermore, I believe that the University of Ife, through its Faculty of Agriculture can contribute more positively to food production in the country through a review of the funding of agricultural research projects. Subsequently, rather than allocate funds to individuals based on the strength of their proposals and justification, funding should be made on *programme basis* and, to *groups* of scientists with the sole objective of solving a specific national agricultural problem. Departments in the Faculty of Agriculture, and related faculties in the university should be made to identify one or two programmes that can attract collaborators from all relevant departments and the fund should be made directly to the programme or programmes with clear

mandate to achieve results. Broad programme objectives of local and national interests should be drawn up by the University Research Committee, to which groups of researchers should be invited to apply for funding. With group effort, and with every member of the group given a clearly defined assignment with instructions for time-dependent—results, there should be no reason for failure in our efforts to feed ourselves.

The soil is the pivot on which agricultural and indeed national developments revolve. How then can one discuss agriculture without the soil? The soil is one important endownment that nature has bestowed on Nigeria. The duty of the soil scientist is to protect, maintain and improve this precious gift of nature in order to sustain our agricultural needs.

On the importance of agriculture, General Olusegun Obasanjo, the former Head of State in his lecture at the 21st Annual Conference of the Agricultural Society of Nigeria at Ibadan, 1985 contended that "Agriculture must be *primus inter pares* with industry", warning that "if agriculture fails, other things are unlikely to succeed". This warning cannot be more appropriate at this stage of our agricultural development. I should also hasten to add that if we fail to *save our soils from destruction,* through failure to protect and manage it nutritionally, we will all fail to achieve self reliance in our agricultural pursuit.

We should strive to rely on the soil and make it nutritious to plants. I believe that with well fed plants, all other organisms including man that live on the surface of the soil will multiply and live happily in perpetual wealth. (See Fig. 8).

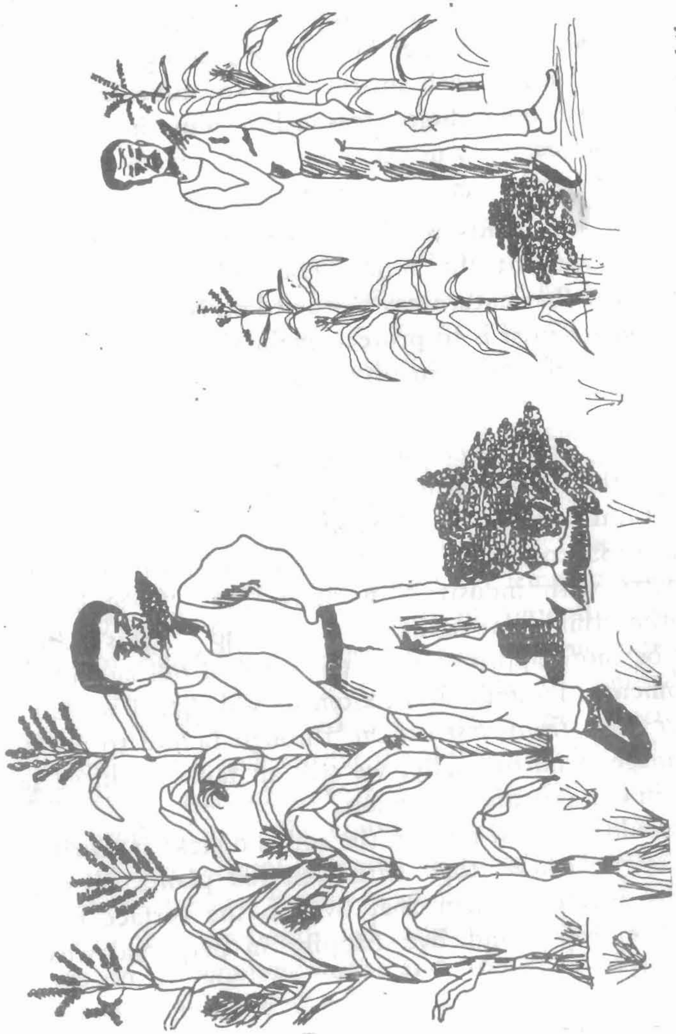

Figure 8: A Wise Farmer. He managed his soil well and applied enough Plant Food = Good harvest, healthy body and wealth.

Bad Farmer.. He neglected the soil = Poor harvest, hunger, sickness and poverty.

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