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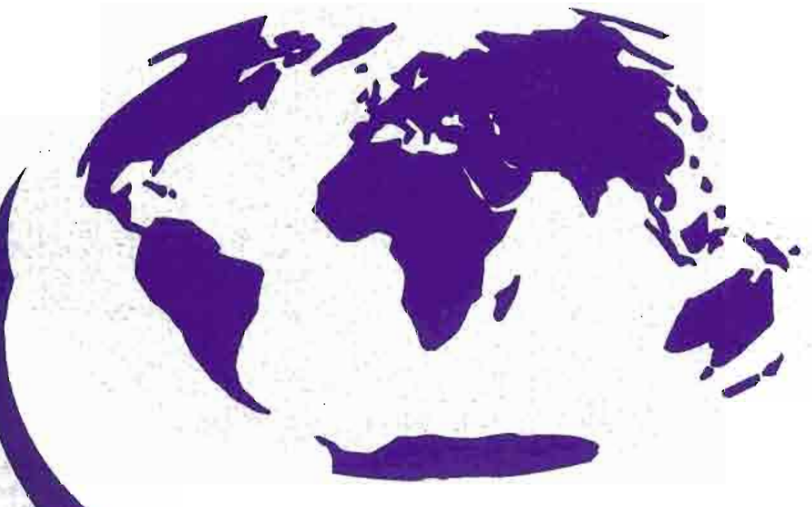

DESERTIFICATION IN AFRICA

The Lessons it Provides for Arid and Semi-Arid Regions

by Professor Edward S. AYENSU

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DESERTIFICATION IN AFRICA :

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I. INTRODUCTION

The pressing problems associated with desertification and therefore famine in many parts of Africa, require extraordinary initiatives. For much the same reasons that the U.S. weather service gives the name of a man or woman to a destructive hurricane (such as David in 1979), the famines which periodically hit the Sahel semi-arid regions are given local Tuareg names. Two such famines were named "The Sale of Children" and "Forget Your Wife" - and the names indicate the desperate state of deprivation of the victims of famine (Dresch, 1977).

National and international organizations are currently calling for multilateral technical assistance programmes, drawing on a pool of knowledge and skills, to provide the latest methodologies of environmental assessment. Studies to determine the extent to which, for example, the land and its natural resources, the water resources and the climate can be turned to the best advantage, using the techniques of applied systems analysis, are the types of programme needed.

During the past few years the International Institute for Applied Systems Analysis (IIASA), in collaboration with the Food and Agriculture Organization (FAO) has undertaken a series of studies aimed at obtaining a comprehensive understanding of desertification and its relation to food production in many parts of Africa. A clear understanding of the ecological and technical limits of the agricultural production potential, population supporting capacity and above all the soil degradation hazards in Africa are among the insights being sought.

For it is clear that the past two decades or so have witnessed a substantial growth of food production in all continents with the exception of Africa. Food production, especially grains, in Latin America and Asia has increased substantially. The only continent lagging drastically behind in overall production in grains is Africa. It is this concern that has prompted various international organizations to engage in serious soul-searching on the best ways for increasing food production in Africa. The news that the Rockefeller Foundation, for example, has very recently decided to focus special attention on Africa with respect to food production is most welcome. Among the techniques being seriously considered for implementation in its programmes included the latest techniques of biotechnology, including genetic engineering.

It is therefore regrettable that the Organization of African Unity (OAU), after producing the laudable document—the "Lagos plan of action for the economic development of Africa" (1981), has systematically frustrated its own objectives by not being able even to meet in order to discuss, *inter alia,* the major problems of desertification, food and energy production on the continent of Africa. It is obvious that these problems cannot be solved unless and until the African governments accord them the highest priority and therefore take pragmatic and practical steps to help themselves.

In this presentation I will attempt to share my views with you on some of the following areas : a) the phenomenon of desertification, b) marginal lands utilization, c) agroforestry, d) fuelwood and firewood, e) aerial seeding, f) types of plant resources, g) crop genetic resources, h) improved crop productivity, and i) desert wildlife resource utilization.

II. MAJOR CONSIDERATIONS

A. The Phenomenon of Desertification

In Africa, millions of people are living in conditions of poverty at subsistence levels in the arid zones. The situation has been aggravated by the widespread process of desertification. The term "desertification" — a purist will use "desertization" (Le Houerou, 1977) — was coined to describe desert encroachment and land degradation in arid and semi-arid zones of Africa, where ecological changes deprive the land of its ability to sustain agriculture and human existence. Uncontrolled methods of grazing and the use of marginal lands, combine with climatic fluctuations to extend the desert conditions into nearby areas (Paylore, 1976).

Essentially, one-third of Africa suffers from desertification (Karrar, 1981). Twenty-seven countries are involved. Of the total arid and semi-arid areas of those countries, which cover 12.38 million sq. km., 86 percent (10.68 million sq. km.) are affected by desertification. Approximately 1 1/2 million hectares of productive land are lost annually.

In addition to the 6,178,000 sq. km. of natural desert in Africa, which cover 20.4 percent of the continent, there are approximately 10,316,000 sq. km. of land (34.7 percent of the continent) suffering from desertification hazards of moderate to high degrees of intensity.

A study presented to the General Assembly of the United Nations in 1980 indicates that, "in the arid and semi-arid regions of Africa, 17.3 percent of the irrigated lands (1.34 million ha.), 82.5 percent of the rained crop land (39.63 million ha.), and 87.5 percent of the range lands (1,029.76 million ha.) are affected by desertification" (Karrar, 1981).

The areas affected by desertification are :

1. North Africa (Algeria, Egypt, Libya, Morocco, Tunisia).
2. Sudano-Sahelian region (Cape Verde, Chad, Djibouti, Ethiopia, Gambia, Kenya, Mali, Mauritania, Niger, Nigeria, Senegal, Somalia, Sudan, Uganda, Cameroon, Upper Volta).
3. Subequatorial (Botswana, Madagascar, Namibia, South Africa, Tanzania, Zimbabwe).

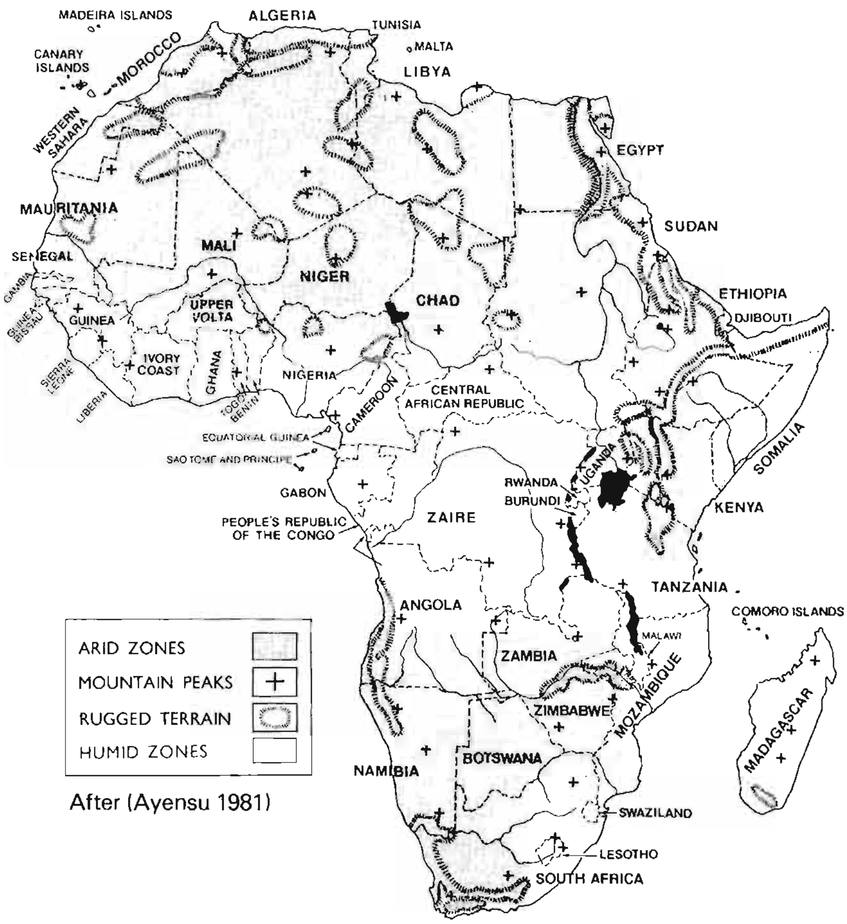

Figure 1. Countries and Topography of Africa

It has been estimated that during the past one hundred years, the Sahara Desert has extended to over one million square kilometers of land originally suitable for grazing and farming, and that at least 100 km2 of arable land are lost to the desert in North Africa every year. Approximately 2.6 percent of the land area of Africa is highly threatened by desert encroachment. The Sahel region of sub-Saharan Africa, encompassing parts of the Sudan, Chad, Niger, Mali, Algeria, and Mauritania, is particularly prone to the encroachment of the desert (Quigg, 1976; Hazelton, 1979).

Youdeowei (1981) has noted that one of the most important aspects of ecological deterioration in arid and semi-arid zones is soil erosion, which happens both during dry and rainy seasons. During extenuated dry periods, the soils crack and become disintegrated, and are blown about by dust storms, sand storms, and whirlwinds. The soil particles carried by the wind tend to clog up water-wells, but the major effect is to carry away a great deal of fertile topsoil, and to create sand dunes by wind action.

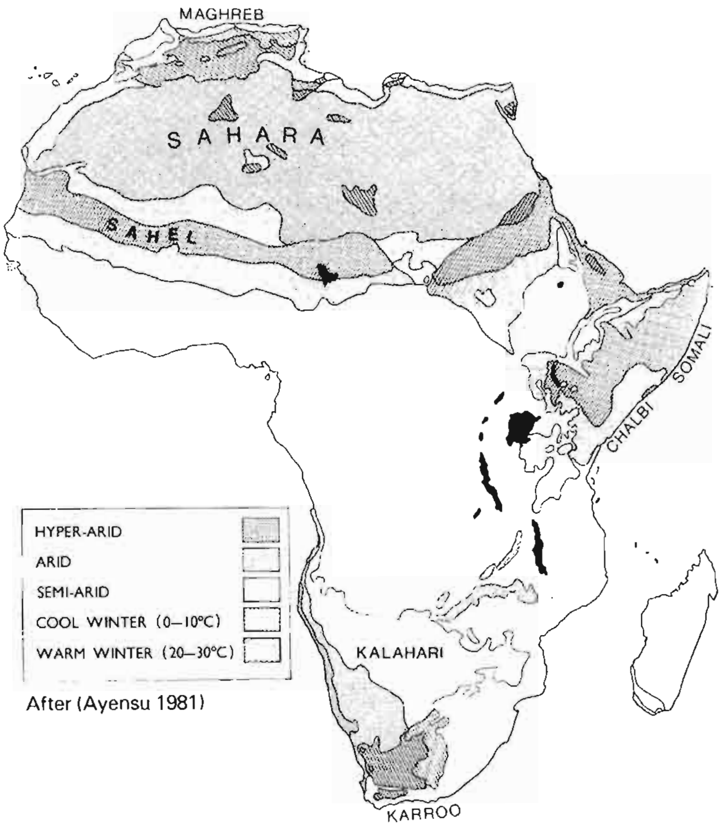

Figure 2. Arid Zones of Africa

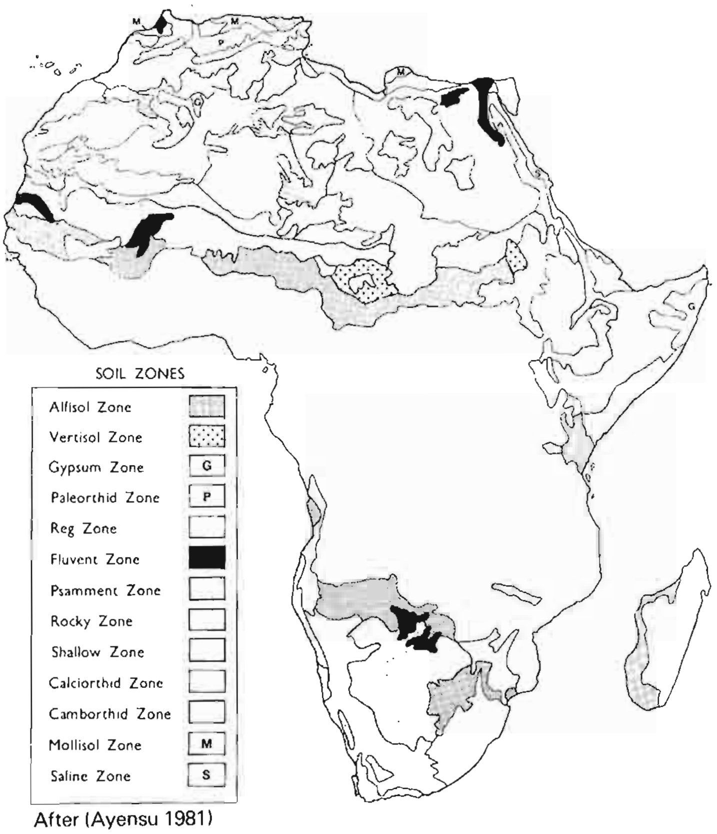

Figure 3. Characteristic Arid Soils

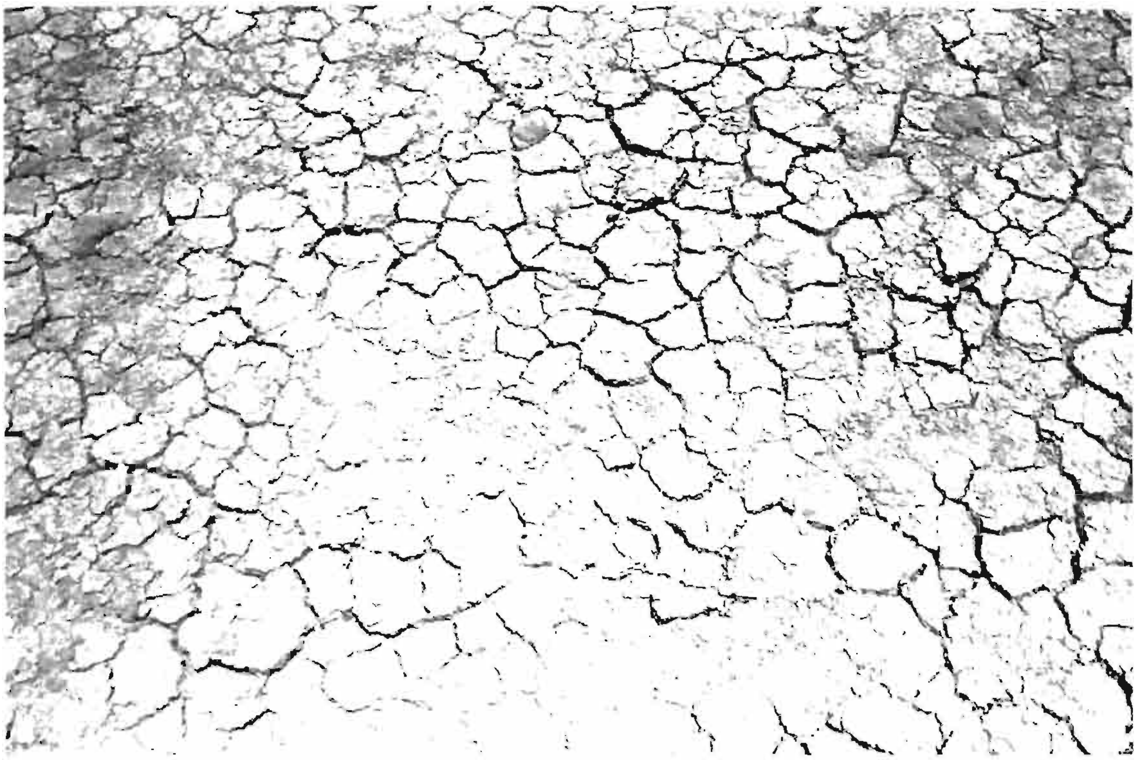

Plate 1. Showing the fracturing of what is left of the topsoil after severe erosion and prolonged drought. Photo taken in the Sahelian zone of Senegal. (E.S. Ayensu).

Alternating with this are the fluctuating rains, which, when they finally arrive, do encourage growth of the vegetation and increases in the livestock, but also cause population explosions of rats, rabbits, and locusts. Grazing animals crowd the edges of newly-filled water holes and eat all the plants surrounding them. The force of the falling rain causes erosion of various kinds, such as splash-erosion, sheet-erosion, rill-erosion and gully-erosion. The sparse vegetation is not enough of a protective and absorptive cover over the soil.

Modern technology is finding ways to monitor the pace of desertification, for example, by studying the patterns and directions of shifting sands which are a threat to the fertile soil on the banks of the Nile River in Egypt (El-Baz, 1977). This has been accomplished by ground-verification of Apollo-Soyuz photographs taken by astronauts in 1975. Along the Mediterranean coast to the west of the Nile delta, it was possible to locate a potentially arable strip of desert, up to 30 km. wide in parts, which has clayey particles in the soil. Dr. Farouk El-Bas, formerly of the Smithsonian Institution and now with NASA, who made the discovery with a team of geologists from Ain Shams University in Cairo, noted that it was the first instance of space photographs being utilized "to point out and outline the extent of reasonably arable land where soil is reclaimable from the desert".

Space photo comparisons have also been used to calculate the area of land which has been reclaimed from the desert in Egypt. It is interesting to note that 686 square kilometers of vegetated land were reclaimed between the taking of the photos by the Gemini 5 astronauts in 1965 and the Apollo-Soyuz astronauts in 1975. This is a particularly welcome figure since only 4 percent of Egypt is fertile, the remaining 96 percent being, for the most part, desert wasteland. Even so, irrigated land on reclaimed sections of the Egyptian desert has been plagued with problems of salinity, alkalinity, rising of the water table, and industrial and chemical pollution caused by fertilizers and pesticides. Although land reclamation is possible, the solution lies in the development of proper land use and proper management of water (Biswas, 1978).

B. Marginal Lands Utilization

Over the past century, mankind has helped to create a great deal of dry marginal land in Africa. As the Director General of UNEP, Dr. Mostafa Tolba has said, the pressures of subsistence living may force farmers to cultivate marginal lands intensively, year after year. Such poverty-induced and environmentally imprudent farming practices will in time turn once productive soils into barren lands (Tolba, 1982). The people from these degraded lands have often moved to over-crowded cities

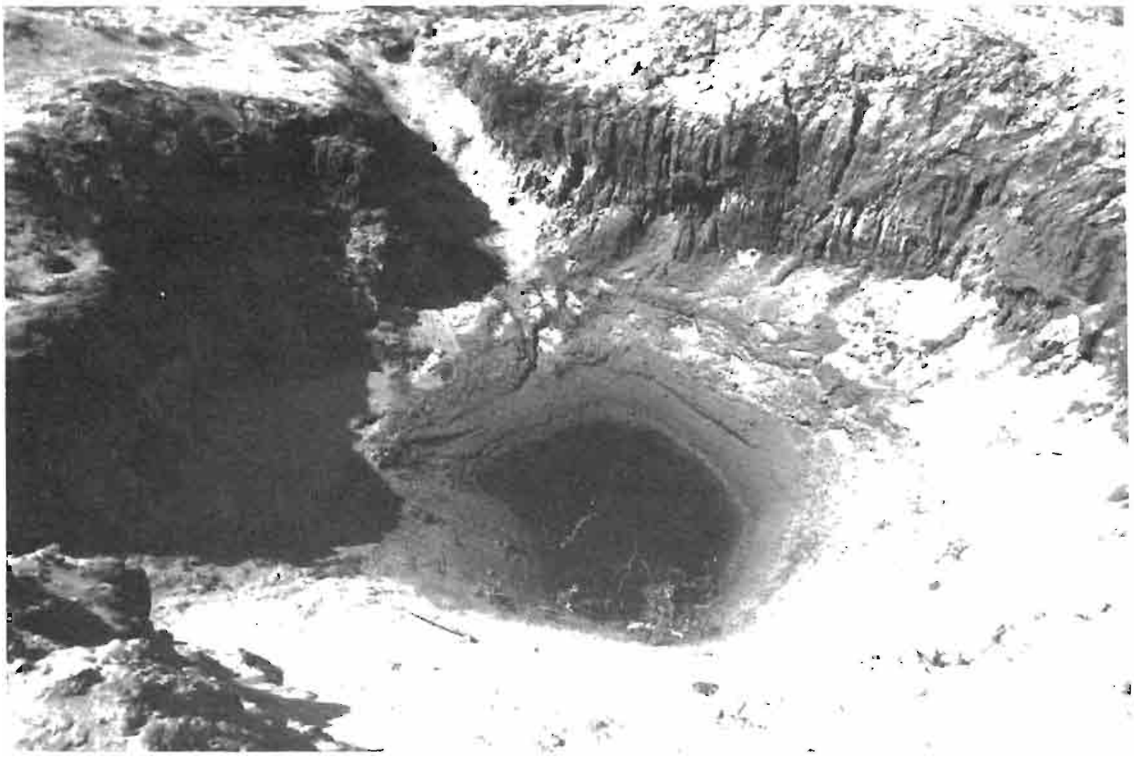

Plate 2. Exhibiting the attempts to extract deep ground-water for irrigation in many of the arid and semi-arid regions of West Africa. Such waters usually very salty and turbid. (E.S. Ayensu).

in search of a livelihood, and they thus have been called "ecological refugees" in the *Global 2000* study (Ayensu, 1981). In fact, as of today, in North Africa as a whole there is an annual loss of at least 100,000 ha (247,000 acres) of land due to "desert-creep" (Galal, 1977). It has been recorded also that in the past 20 years, in the region south of Khartoum (Sudan), the acacia scrub zone has marched southward a distance of 90 km (56 miles). The southern limit of the Sahara Desert is now 199 km further south than it was in 1963 (Anonymous, 1982).

In July of 1982, an immense cloud of hot dust from the Sahara travelled across the Atlantic Ocean and settled over most of Florida, in what scientists called the most significant outbreak of Saharan air to have reached this part of the United States since 1972. The cloud dramatically raised the air pollution level, but it was predicted that the dust would only cause some irritation to people who are not already in the best of health (Anonymous, 1982A). The point here is that the dust cloud was 1,000 miles long, extending from Florida eastward over the Atlantic, but fortunately it dissipated before reaching the danger level of pollution. It should remind us that, in the long run, as more land becomes converted into marginally productive soil, the more dust is likely to be contributed to these clouds which wander far from their genesis.

Before we even contemplate encroaching on the remaining forests, it would make for sound business sense to examine the marginal land we have created in various African countries and try rapidly to restore a vegetative cover. This can now be done; we have a collective knowledge of the kinds of trees and shrubs to grow in order to bring marginal lands into the productive sector of the economy. I am optimistic that we can restore marginal lands while studying and researching the potential of natural areas.

I had the pleasure of chairing an international panel for the U.S. National Academy of Sciences which produced a valuable report on *Firewood Crops : Shrub and Tree Species for Energy Production* (U.S. National Academy of Sciences, 1980), and I would urge its amalgamation into local and national efforts to restore marginal lands to utility. Local plant species are always preferable to exotic species in replanting schemes, but in many cases the only choice available is the exotic species. A telling observation impinging on this has been made with reference to South Africa (Anonymous, 1980) : "Try to tell a man on the Cape Flats the evils of alien vegetation when he is using that vegetation for fuel and shelter and see what he thinks of conserving the *fynbos.*" The *fynbos* is the fastest disappearing land habitat in South Africa, yet it contains the richest flora of the world, with c. 6,000 species, most of which are endemic members of Proteaceae, Ericaceae and Restionaceae (Huntley, 1978).

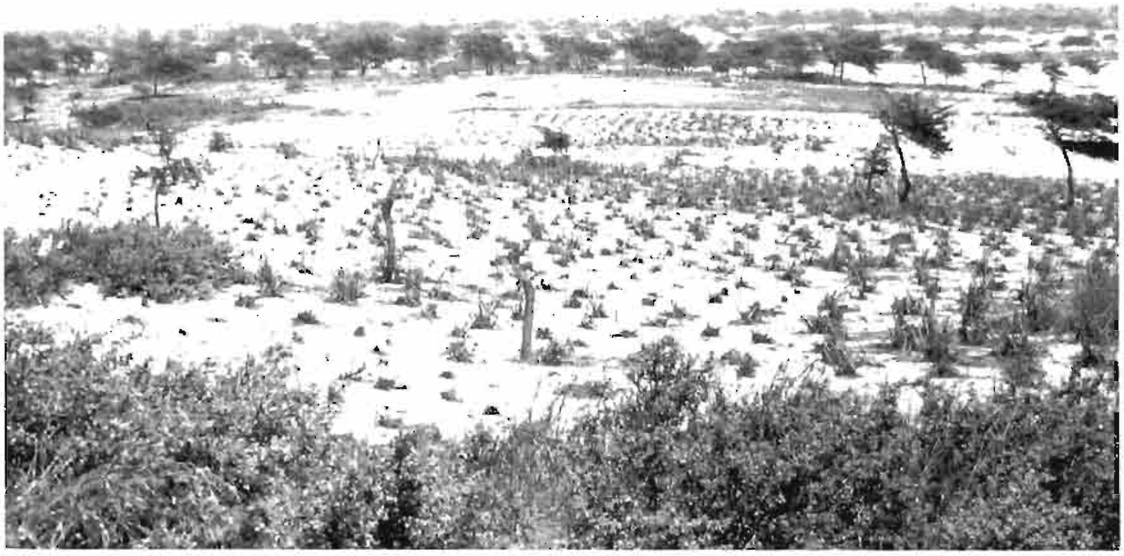

Plate 3. Attempts at providing vegetation cover for many of the marginal lands that have been created as a result of prolonged drought. Photo taken in Senegal. (E.S. Ayensu).

In regard to South Africa's marginal land, a report by the Wildlife Society of Southern Africa (Anonymous, 1980A) has attempted to explain that "the real cause is the lack of an appreciation of conservation principles by most of the country's 77,000 white farmers who control 71 percent of the nation's land, while overgrazing in black homelands — where some 33 percent of the country's 25 million people occupy 12 percent of the land area — has reduced many areas to virtual deserts."

South African government statistics indicate the present ownership of land in that country, as follows (Anonymous, 1980B) :

White farmes	- 72.7 %
Black areas	- 12.2 %
Nature reserves	- 2.7 %
Urban areas	- 1.3 %
Roads, railways, airports	- 0.9 %
State owned	- 8.9 %

One hopes that, using all of the ingenuity and capabilities at the disposal of African governments, measures will continue to be taken to restore worthless and marginal land to some measure of productivity and equilibrium with the environment.

These poor lands are spreading up to the very boundaries of many national parks and nature reserves, steadily encroaching as game animals and vegetation are plundered by poverty-stricken individuals for their daily needs. I can only conclude that such parks may in the future no longer be sanctuaries solely for the benefit of the affluent.

C. Agroforestry

It has been estimated that in both the Sahelian grass steppe and tree steppe, the proportionate factors contributing to desertification are : overgrazing for forage (75 %), overcutting for firewood (10 %), agricultural expansion for farmland (10 %), and burning for various reasons (5 %) (National Research Council, 1982).

Agroforestry has been called in to help make restitution for this degradation. The conservation techniques embodied in agroforestry help to increase soil fertility through the introduction of such plants as *Acacia albida* (Leguminosae) into farm fields and the introduction of tree crops and better farm management through rotation. Agroforestry also helps to control wind erosion by means of windbreaks and live fencing with trees, and to control water erosion through contour planting for the control of sheet erosion, vegetation strips, and bank and slope protection to reduce channel erosion.

Plate 4. High concentrations of cattle often result in the destruction of the vegetation as well as the topsoil. Photo taken in the dry savannas of Ghana. (E.S. Ayensu).

Agroforestry basically is the (old) practice of growing woody plants together with agricultural crops and/or livestock on the same land. It serves to help solve the demands of local people for food (by supplying edible fruits and leaves, as well as fodder); it contributes to improvement of the scarce water resources; and it helps with their energy requirements, which in the Sahel averages 1 kg. of firewood (including charcoal) per person per day.

Agroforestry techniques help to serve the demands of people for renewable raw materials, in addition. These raw materials include wood for fencing, agricultural and household implements, and furniture; gum arabic from *Acacia senegal* (Leguminosae); and "tannins from barks and pods of many tree species, fibers for binding materials, basketry and stuffing material, various gums, resins and waxes, dyes, stains and inks, saponines, poisons and antidotes, and drugs for medicinal and veterinary uses". (National Research Council, 1982).

Agroforestry is compatible with traditional Sahelian land use practices which try to maintain the human ecological carrying capacity. The two traditional agroforestry systems of the Sahel are nomadic pastoralism, and sedentary rain-fed agriculture. Characteristics of nomadic pastoralism include extensive utilization of vast areas for grazing; year-long engagement in land use; mobility of the people and livestock; multiple exploitation of plant cover, but no cultivation of plants; and the fact that animals (i.e. cattle, camels, donkeys, goats and sheep) are at the center of the peoples' lives.

In the case of sedentary rain-fed agriculture, there is intensive utilization of small favorable sites; a short season of concentrated agricultural efforts, depending on the rains which fall from June-July to October; an immobile population; the cultivation of only a few plant species for specific products; and only a few small animals being kept, largely for household use (National Research Council, 1982). The crops grown in the Sahel include beans, cotton, and groundnuts; fruit trees, e.g. mangoes, citrus, guava, papaya; cereals, e.g. millet, sorghum, maize; and indigenous tree crops which supply protein, such as the shea butter tree *(Butyrospermum parkii,* Sapotaceae) and nere *(Parkia biglobosa,* Leguminosae). The local protein-supplying trees, as well as the tamarind trees and acacias, grow well in farm fields and near gardens, and in many cultivated Sudanian zone areas, sizable fully-grown trees are scattered among farm fields.

The main necessity is thus not principally to bring trees, as a new concept, to the Sahel. Rather, the principal need is to reestablish and protect seedlings against increasing animal pressure and poor cultivation practices which happen as the lands degrade through human pressures. This technology is being tested in various ways, including field trials of trees for various uses. It must be recalled that the Sahel is not forest land and that the growing of large, closed forests would perhaps cause severe disturbance to the ecological balance. However, planting trees singly or in small groups on soils which are suitable for their specific requirements, will produce excellent results. The specific use of irrigation schemes to sustain tree growth in the arid Sahelian climates will in most cases be a rather new concept for the local farmers to embrace, in concert with their traditional methods of agroforestry.

The National Research Council of the U.S. National Academy of Sciences in collaboration with other organizations is studying the feasibility of establishing agroforestry in the Sahel. The Academy is sponsoring screening trials on 12 *Acacia* species, 6 *Prosopis* species, *Leucaena leucocephala,* and *Parkinsonia aculeata.* It was decided to focus entirely on legumes because of the importance of increasing nitrogen availability in Sahelian agro-sylvo-pastoral systems, and because legumes are easily germinated and offer relatively rapid initial growth, among other reasons.

The sites selected for the species trials are within the (rain-fed) 100-500 mm precipitation zone of the Sahel, including locations in Cape Verde, Mali, Mauritania, Niger and Senegal. The U.S. Agency for International Development (USAID) will be the major participant in the trials, which will be done on a "randomized complete block" design prepared by the Commonwealth Forestry Institute at the University of Oxford.

Dr. P.K.R. Nair has characterized agroforestry as "a sound land-use system that integrates trees with crops and/or animals so as to get higher productivity, more economic returns, and better social benefits on a sustained basis, than are obtainable from monoculture on the same unit of land. Even for marginal areas and under conditions of low levels of technological inputs." Agroforestry land management systems can have great relevance to agricultural production and environmental rehabilitation in the semi-arid West African Sahel.

D. Fuelwood and Firewood

According to the FAO *Map of the Fuelwood Situation in the Developing Countries of the World* (1981), based on 1980 figures, approximately 2,000 million people, equivalent to three-quarters of the entire population of the developing countries, depend on fuelwood and other traditional fuels of their daily domestic energy requirements. A fuelwood *scarcity* situation exists when fuelwood consumption is below their minimum needs, and wood is depleted to the point where people cannot obtain sufficient fuelwood even through overcutting. Increasingly, in rural situations there is often a *deficit* of wood, causing the minimum needs of the people to be met at the cost of depleting the existing resources.

The degree to which the "firewood crisis" is taking its toll in Africa may be discerned from the FAO's categorization of the areas in question, with a few examples from each type. Firstly, there are desert and sub-desert areas having a *scarcity* situation with very few resources and with low population, such as the Sahara Desert, Somalia, and South West Africa (Namibia). Secondly, areas of *acute scarcity* include central Ethiopia. Thirdly, the areas where a *deficit* situation prevails include Niger, central and western Madagascar, and parts of Angola.

Plate 5. The search for firewood to cook a simple meal often results in many miles of walking to a possible source. The picture shows a Ghanaian villager carrying a baby at her back and a full load of firewood. (E.S. Ayensu).

In addition to these is a fourth category, made up of areas having a *prospective deficit* of fuelwood and evolving into a crisis situation by the year 2000. Examples of prospective fuelwood deficit regions include coastal North Africa, Mali, central Sudan, southern Chad, Tanzania, and Zimbabwe.

There are, of course, some places in the world where fuelwood simply does not exist at all. Animal dung is burned as a wood substitute in parts of Africa. More than 400 million tons of dung is burned annually around the world, excrement which in better times was used to fertilize the worn-out soils from which people scratched out a living. Soil fertility is diminishing as a result of the absence of this fertilizer.

Natural regeneration of locally growing, native firewood trees and shrubs is of course prevented by overcutting (as well as by fires in the savannas). In order to minimize these pressures, the Man and the Biosphere Programme (MAB) of Unesco has suggested several alternative measures to conserve wood resources. These include the use of energy-efficient ovens, such as "closed" ovens which can save up to 50 percent of the wood consumed by cooking over open fires. Instead of wood, alternative fencing and building materials used in humid tropical zones can be inexpensively employed and the techniques of their use can be taught to the arid zone dwellers. Such materials include bamboo, straw, and the stalks of sorghum and millet.

Rather than turning livestock loose to graze on any woody plant in sight, supplementary alternative fodder crops such as spineless cactus and atriplex can be used to lower the grazing pressures. Very importantly, woodlots and afforestation programmes should be initiated to serve families, villages and towns. Woodlots will reduce the time needed to travel to obtain fuel, and of course the local cost of fuel. Some West Africans must walk fifteen miles to locate wood. In Niamey, Niger, manual laborers spend one-quarter of their income on fuelwood; 25 percent is typical of the amount of the average Sahelian villager's budget which is spent on wood.

In Africa, 85 Percent of the total energy used comes from trees and shrubs. It has been predicted that tree planting in the Sahel of Africa must increase 50-fold if the firewood demands by the year 2000 are to be fulfilled.

Much basic research is still required in order to choose and develop the correct tree species for replanting in a given region. Faster-growing trees need to be introduced, but they may have a tendency to over-reproduce and become invasive weeds. The local species are better adapted to local ecological conditions, but they often seem to grow at intolerably slow rates which cannot meet the overwhelming demand for their limbs and shoots. The FAO suggests intensive studies of seed germination, breeding experiments, and calorific value studies of prospective species must be done before the genetic and biological values of the semi-arid trees will be known well-enough for confident planting in many regions.

Plate 6. The quest for fuel often ends in disappointment, as exhibited by this young Senegalese girl who has travelled several miles without obtaining any firewood. (E.S. Ayensu).

Some provenances of the very species that have been proposed as new firewood crop plants are themselves endangered and vulnerable to extinction. The FAO and cooperating countries are now trying to conserve specific provenances of, for example, the Sudanese variants of *Acacia tortilis* and *Acacia nilotica* (Leguminosae).

Plate 7. The establishment of woodlots can often result in bounty harvests, as shown by these stacks of neem stems and branches alongside a highway in Ghana. (E.S. Ayensu).

Plate 8. In many West African countries where firewood is in short supply, vendors often obtain packing cases as well as scaffoldings as a substitute for natural fuel. (E.S. Ayensu).

a. Plantations

Firewood plantations will not only help to alleviate the cremation of African tree resources but will provide employment for producers and distributors of the wood, and give shade, shelter, beauty, wildlife, food, soil stability, and watershed amenities to the environment.

In a plantation, fuel is produced by plants which "harvest" and store solar energy. The chief objective of energy plantations is to produce biomass from selected tree and shrub species in the shortest possible time and at minimal cost, so as to satisfy local energy requirements in a decentralized manner, and thereby relieve pressure on the consumption of fossil fuel (e.g. kerosene) and prevent wanton destruction of the earth's plant cover (Khoshoo, 1982).

Because of the fact that plant cover is one of the primary components of our life-support system, our plant-based energy needs, ideally, should not be filled from natural stands, a procedure which further reduces the areas under plant cover. In addition, yields from natural stands are low compared to plantations since natural stands are a mixture of species having different rates of growth. The plantation, on the other hand, is formed of species which are suited to particular locations, and the selected species are known to produce high yields of plant material. In addition, plantations are the only areas where management conducive to high yields of plant material is possible.

There are some constraints inherent in choosing a site for an energy plantation. It should be done on marginal *but* cultivable land, for it is indeed erroneous to assume that firewood/fuelwood plantations can be raised where nothing grows. It has been shown that the poorer the site, the higher the cost of cultivation. The rainfall should be available during the growing season, and not when the plants are dormant.

Speaking of constraints, it may be surprising to some of us that in actual fact, the utilization of fuelwood is known to possess some generally undesirable characteristics. These can be noted as follows (Khoshoo, 1981):

1. since fuelwood contains about 50 percent moisture, it is not utilizable immediately after harvesting;
2. drying of wood is rather slow;
3. plantations accelerate the removal of nutrients and organic matter from the soil;
4. it burns with a long flame (and smoke) and there is a loss of combustion efficiency;
5. when it becomes necessary to move the harvested wood, transportation is often costly due to its high weight and volume;
6. smoke from the wood is a pollutant (it contains 37 pollutants, carcinogens, and toxic agents), and is regarded by villagers as a "necessary evil" since it also discourages insect infestations in thatched roofs.

The potential advantages accruing from properly made plantations, however, far outweigh any negative aspects. Fuelwood plantations, if fully embraced to their potential, could release millions of tons of dung (presently used as fuel) which could then be used as organic fertilizer, or perhaps also used in anaerobic fermentation to generate methane and fertilizer-rich sludge.

The publication by the U.S. National Academy of Sciences, *Firewood Crops : Shrub and Tree Species for Energy Production* (1980) has recommended that great attention should be placed on plants with the following characteristics:

1. nitrogen-fixing ability;
2. rapid growth;
3. ability to coppice;
4. ability to produce wood of high calorific value that burns without sparks or toxic smoke;
5. ability to grow successfully in a wide range of environments, including different altitudes, soil types, rainfall regimes, amounts of sunlight, and terrain.

b. Research Needed on Firewood and Fuelwood Plantations

There are a number of research problems to be solved with regard to the maintenance of energy plantations, which can be summarized as follows (Khoshoo, 1982).

1. Test plantations need to be established involving various different tree and shrub species on fallow marginal lands in different agroclimates. Data must be obtained on their performance in order to arrange for balanced silviagricultural use of such lands, and for the long term management of energy plantations along sound economic lines.
2. Nutritional problems, including salt tolerance, should be investigated for the availability of minerals in sodic and other poor soils, and for use of the data as an index of the adaptation potential of various species.

3. The entire nutritional recycling system needs detailed investigation. In a short rotation biomass plantation, there is an unusually large depletion of nutrients from the soil as trees are felled at short intervals of 2 to 4 years and density is many times higher than in conventional plantings. As a result, the amount of nutrients returned to the soil is not large enough to replenish the loss of nutrients by way of litter-fall, and the soil does not get enough time to build its exchange capacity for sustained tree growth. Under these circumstances the use of petroleum-based inorganic fertilizers would be contrary to the basic objective of plantations. The use of woody legumes with high nitrogen—fixing capacity would be a good solution, and the actual amount of nitrogen made available to the individual species should be determined.
4. The subject of microbial systems, utilizing mycorrhizal and rhizobial associations with energy species.
5. Selection and improvement of appropriate tree and shrub species needs to be intensified, using conventional genetic and genetic engineering methods.
6. In plantations, due to the high population density and the usage of elite clones, methods of mass multiplication, including tissue culture techniques, need to be applied to selected species.
7. An entire plantation system needs to be viewed in terms of the costs of inputs and returns, together with the intangible benefits such as improvement to the soil and environment. Economic analyses of plantations are necessary with regard to the type of seeds, fertilizer, irrigation water, pesticides, and all other operations which in fact consume energy.

E. Aerial Seeding

Approximately one million hectares of forest have been successfully seeded from the air in Australia, New Zealand, Canada, and the United States. Although seeding from an airplane or helicopter is not presently being done to any appreciable extent in the developing countries, it has been recommended that experimentation should go forward in those areas (National Research Council, 1981). The current pace of deforestation is outstripping the rate of forest regeneration around the world, and therefore any of the newer technologies are deemed worthwhile to investigate.

A number of good fuelwood and plantation species have been sown successfully from the air, including *Eucalyptus camaldulensis* (Myrtaceae) and seven other eucalyptus in Australia : *Leucaena leucocephala* (Leguminosae) in the Pacific Islands; and twelve species of *Pinus* in the United States, Canada and New Zealand. Aerial seeding has become a viable alternative or supplement to conventional seeding largely due to the coating of the seeds with a bird-repellant and insecticide.

The aerial method is advantageous for large areas where a sparse human population makes the planting of seedlings by hand a difficult proposition. While aerial seeding has, in principle, an exceptional potential for use in arid lands, it has actually been reported only a few times to have been successfully attempted. In the 1950's *Prosopis juliflora* (Leguminosae) was seeded for the stabilization of sand dunes in Gujarat, India, and in the 1960's a trial involving seeds of neem *(Azadirachta indica,* Meliaceae) sown over arid Nigeria was made. The neem seeds germinated readily, but because it was the wrong season, only those shaded by the scrub vegetation survived.

Since, by tradition, acacias, neem and cashews are direct-seeded from the ground in the Sudan and the Sahel, it offers hope that indeed aerial seeding could prove to be successful as well in similar dry areas. In general, seeds for aerial dissemination should be of fast growing, almost "pioneer" species, which is a trait also looked for in fuelwood species. A great number of the same fuelwood crop species proposed by the U.S. Academy of Sciences also appear in the list of possible candidates for aerial seeding in developing countries (National Research Council, 1981), including *Prosopis* for semi-arid zones.

Before doing aerial seeding, sites are chosen and inspected at least eight months in advance, taking note of the following factors :

1. extent of grazing by livestock and wildlife;
2. infestations of ants, rodents, and seed-eating birds;
3. areas where trees are adequately reproducing naturally;
4. conditions of the seedbed and need for burning the site;
5. advantageous ridges from which aircraft can be guided.

Several of the specific characteristics that make a particular plant appropriate for aerial seeding are also welcomed traits of fuelwood and plantation species which can be discerned from the following requirements for aerially-sown seeds :

1. small or medium-sized seed;
2. frequent and prolific seed availability;
3. ability of the seed to germinate on the soil;

4. fast germination and rapid seedling growth;
5. ability to withstand temperature extremes and prolonged dry periods;
6. ability to tolerate a wide range of soil conditions;
7. high light tolerance;
8. seed that is easy to collect in large quantities and to store for long periods;
9. suitability of seed for handling with mechanical seeding devices;
10. rapid development of a deep taproot by seedlings to enable them to withstand adverse climatic conditions in the period following germination.

Notwithstanding the fact that aerial forestation offers little control over the density and spacing of the trees produced, and often requires ten times the amount of seed as reforestation with nursery-grown seedlings, the technique of aerial seeding should be pursued in the world's semi-arid and arid regions. And, when we consider that from an ever-dwindling supply of wood, the countries of the Sahel must derive an average of 82 percent of their total national energy needs (94 percent in Upper Volta, 93 percent in Mali, 89 percent in Chad, 88 percent in Niger, etc.) (Ki-Zerbo, 1981), the days of aerial seeding experiments should not be delayed.

III. PLANT AND ANIMAL RESOURCES

A. Types of Plant Resources

In comparison to the tropics, the arid and semi-arid zones would seem to have rather fewer plants as natural resources that can be relied upon on a continuous basis. Resources of this harsh environment are ever at the mercy of severe pressures, and some of the species survive only precariously.

The following data, adapted from Ayensu (1983), indicate the extent to which plant resources are utilized in African and semi-arid zones :

Use	Number of Plant Species Utilized	% of Total
Human Food	40	20.4
Fuel		
1. Firewood	10	5.1
2. Oil	3	1.5
Medicine	28	14.5
Animal Food	58	29.6
Construction		
1. Sand binding	11	5.6
2. Buildings and other construction	21	10.7
Dyes	1	0.5
Shade	2	1.02
Gum Production	2	1.02
Fibre	12	6.1
Wax Production	1	0.5
Tannin Production	7	3.6

a. Economic Plants

Medemia argun (Palmae) and *Cyperus papyrus* subsp. *hadidii* (Cyperaceae) have both been greatly depleted for their fibrous qualities, and are further threatened by habitat destruction. *Dracaena ombet* (Liliaceae), the Nubian Dragon Tree, another good source of fiber, is succumbing to the demands for firewood, and is also overgrazed. *Olea laperrinei* (Oleaceae, close relative of the cultivated olive), *Euphorbia cameronii* (Euphorbiaceae), a potential fodder crop, and *Wissmannia carinensis* (Palmae), a potential ornamental plant, are all similarly threatened by the pressures of livestock.

The protein level of the marama bean *(Tylosema esculentum,* Leguminosae), at 30-39 percent, is equal to that of soybeans, and yet this food of the Kalahari Desert and adjacent parts of southern Africa is exploited by few other than the Kung Bushmen.

A famine food from the dry savannas of Somalia and Ethiopia known as the yeheb nut, *Cordeauxia edulis* (Leguminosae), has only 13 percent protein but has a 24 percent sugar content, and was relied upon during recent warfare in the Ogaden desert region to the extent that it became highly endangered; a few plots of it have now been protected and research into its qualities is underway. These are only a few of the potentially economic species awaiting investigation.

b. Medicinal Plants

The arid zones of Africa contain a multitude of plants having proven and potential medicinal and drug uses, which await the elucidation of their chemical properties and manufacture by drug companies located in developing countries of the continent.

For example, this year (1983) we will see the publication of *Medicinal Plants of North Africa,* an important book by the respected taxonomist Dr. Loutfy Boulos of the National Research Centre in Cairo. It is one of the series on *"Medicinal Plants of the World",* of which I am the editor, and to date I have written treatments for *West Africa* (Ayensu, 1978) and the *West Indies* (Ayensu, 1981 A). The traditional herbal drugs and medicines utilized in North Africa include numerous human abortifacients, aphrodisiacs, female weight-inducing drugs, and even some medicinal plants used otherwise as Saharan war poisons by local tribes.

Several years ago I visited the medicinal plant "farm" maintained by the Suez Canal University (Ismailia) in the Sinai desert. A modest but effective irrigation system provides the life-support for a number of species being grown there. Egypt normally imports material to the Cairo drug markets, and this medicinal farm indicates their intention to provide domestic sources of such plants.

I have published a compilation of *Plants for Medicinal Uses with Special Reference to Arid Zones* (Ayensu, 1979), giving the chemical constituents and uses for approximately 443 species in 64 flowering plant families from various world arid regions. A great number of these species are represented in Africa. The international conservation venture known as "Year of the Plant" is stressing the value of wild medicinal plants in efforts to keep many of their ecosystems intact.

c. Endangered Plants

The arid and semi-arid regions of Africa are the homeland of many highly vulnerable plant species.

Cupressus dupreziana (Cupressaceae), the Saharan Cypress, is a living legacy from the more humid past of the Sahara; some individuals are 2000 years old. One of the most drought-resistant species known, this shade tree is seriously threatened by browsing livestock that consume new growth, and the indiscriminate cutting of branches for firewood.

Succulent members of the Euphorbiaceae have evolved to a position analagous to the Cactaceae of the New World. These xerophytes have spongy tissues in the stem which store water, and the leaves are often reduced to sharp spines. These morphological adaptations to the arid environment often result in oddly-shaped, caudiciform and arborescent types which are widely sought by commercial and private collectors. All arborescent euphorbs are currently protected under provisions of the CITES treaty against exportation without a permit.

In southern Africa, the Kalahari and Namib Deserts have evolved strange succulents which have figured prominently in international commerce in endangered species. The Namib Desert in Angola, South West Africa (Namibia) and South Africa, receives less than two inches of rain per year, but receives 40 to 50 mm of moisture from dew coming from the sea fogs. The spectacular gymnosperm *Welwitschia bainesii* (Welwitschiaceae) (Went Babu, 1978) is nurtured in this manner, as are the few grasses and halophytes on the dunes. Succulent plants of the Namib include *Mesembryanthemum, Sesuvium* and *Lithops* (all in Aizoaceae), *Cotyledon* (Crassulaceae), *Aloe* (Liliaceae), *Euphorbia* (Euphorbiaceae), and tree-succulents such as *Cissus* (Vitaceae) and *Pachypodium namaquanum* (Apocynaceae), which reaches 5m tall.

The Kalahari Desert of Botswana and eastern Namibia specializes in gourds (Cucurbitaceae), *Stapelia* (Asclepiadaceae) and *Aloe,* as well as *Euphorbia* and *Mesembryanthemum* (McGinnies, 1967). In arid Madagascar, peculiar endemic families such as Didiereaceae are now protected by the CITES treaty. All species of cycads (Cycadaceae) are also protected, including the *Encephalartos* of the South African veldt, a localized "treeless savanna" primarily dominated by grasses.

Proper husbandry of these endangered species and all natural resources should be a cardinal consideration in the management of arid and semi-arid regions. Where possible, species should be protected, *in situ,* and also cultivated in botanic gardens in order to preserve genetic material. These species are magnificently adapted to their environment, and with judicious management many can be commercially utilized on a sustained-yield basis.

B. Crop Genetic Resources

In 1978 a workshop on *Crop Genetic Resources in Africa* was held at Ibadan, Nigeria (International Institute of Tropical Agriculture, 1980), in order to create awareness at the national and continental levels of the need to conserve the invaluable crop genetic resources of Africa. From the proceedings, we learn of the important work being conducted by ICRISAT, which is the International Crops Research Institute for Semi-Arid Tropics, based in India (Van der Maesen, 1980). The institute has a major involvement in assembling germplasm collections in Africa of the following crops : sorghum *(Sorghum bicolor),* pearl millet *(Pennisetum americanum),* chickpea *(Cicer arietinum),* pigeon pea *(Cajanus cajan),* and peanut or groundnut *(Arachis hypogaea).*

The above crops are of great importance in Sahelian and other dry countries of Africa, as may be indicated by the following figures (1975 data) on the number of hectares grown in Africa as a whole :

Sorghum	13,687,000
Millet	16,415,000
Chickpea	154,000
Pigeon pea	561,000
Peanut	6,882,000

In a number of the 27 African countries in which desertification is occurring, more germplasm accessions are needed on a priority basis to fill geographical gaps. In the case of pigeon peas, for example, India is the area of origin but Africa is the area of diversity. The following table, from data in Van der Maesen (1980), indicates the present degree of necessity to collect germplasm of three selected crops in arid and semi-arid Africa, reflecting the number of samples already possessed by ICRISAT as well as the richness of crop genetic resources in a given country.

	Sorghum	Pearl Millet	Pigeon Pea
North Africa			
Algeria	Urgent	Urgent	—
Libya	Urgent	Needed	—
Morocco	Needed	Urgent	—
Sudano-Sahelian			
Chad	Very Urgent	Very Urgent	Needed
Gambia	Urgent	Urgent	Urgent
Kenya	Needed	Urgent	Urgent
Mali	Very Urgent	Urgent	Needed
Mauritania	Urgent	Urgent	—
Niger	Very Urgent	Very Urgent	Urgent
Senegal	Urgent	Urgent	Urgent
Sudan	Very Urgent	Very Urgent	Very Urgent
Uganda	Needed	Very Urgent	Very Urgent
Upper Volta	Urgent	Very Urgent	—
Subequatorial			
Botswana	Very Urgent	Urgent	Urgent
Namibia	Urgent	Very Urgent	Urgent
Tanzania.	Very Urgent	Very Urgent	Very Urgent

C. Improved Crop Productivity

Temperature, radiation, soil nutrients and soil type, carbon dioxide and water are important factors for biological productivity in warm climates. In arid and semi-arid zones, the primary limited factor for biological production is water; temperature, radiation and carbon dioxide are rarely limiting. Cocheme and Franguin (1968) have shown that in the Sahel, the yield of millet increases with the amount of precipitation. This is because of the stomatal control mechanism in plants, since no production takes place if the plant is not transpiring, and it is also important to the nitrogen cycles which further encourages plant growth (Warren and Maizels, 1977). Water supply is very important for plant yields, and a very complex relationship exists between the amount of water available, the timing of water supply, frequency of availability and the gross yield and quality of various parts of plants.

Ayensu (1983) provides a detailed account of the soils of arid and semi-arid lands of Africa. Arid soils have a pH of 7 or higher and many of the soil types coincide with atmospheric date. Some of the soils are poor in mineral nutrients such as phosphorus, but many dryland soils are fertile, patchily distributed and support a limited variety of plant life. Biological activity is close to the soil surface and highly intense during the short wet periods.

An important factor in the biological productivity of dry lands is salinity. In many drylands, excess salt is leached from geological deposits or brought in by winds from the ocean. The excess salts are poorly flushed away from the soils and so they accumulate to levels where only a few tolerant wild or cultivated plant species can survive and produce; in some cases plant growth is totally prevented. Animal production is also affected by saline vegetation and drinking water. Many dryland animals have become genetically adapted to a large salt intake while other animals become acclimatized. In both cases, the animals have to considerably increase their water intake in order to flush excess salts through their systems (Warren and Maizels, 1977).

Steps need to be taken immediately by the responsible African governments to alleviate the vulnerable position in which their people find themselves. It is mandatory that very imaginative and innovative programs have to be designed to help arrest further dislocations of people and resources due to desertification. There are certain basic research projects in crop sciences that have to be given serious consideration. The first, in my judgement, is to conduct research on the adaptation of major crop plants to drought stress. Currently, very little information exists on the morphological, physiological, genetic and biochemical pathways inherent in drought resistance in some of the important food crops in the African arid and semi-arid regions. For example, climatic behavioural models covering some of the major farming systems will have to be simulated in such experiments, in order to evolve alternative cropping strategies to suit different growing conditions.

Another activity that requires investigation to raise the yield potential of crops in arid and semi-arid regions is the exploitation of heterosis or hybrid vigor, namely the modification of plant architecture and growth rhythm, so that the response of the genotype to irrigation and fertilizer (be it organic or chemical) application may be enhanced. Similarly intensive experiments on raising the ceiling to yield without affecting stability of performance are by and large yet to be tried in rainfed crops grown in arid and semi-arid regions. Such experiments could achieve early seedling vigor and rapid root growth through heterosis. Suitable F_1 hybrids may help to elevate and stabilize yields in rain-fed crops through early seedling establishment as well as early maturity.

In this regard, it is imperative that the collection and preservation of both crop and animal genotypes which are adapted to drought stress conditions be undertaken before they become extinct in the irrigated areas. It will also be most useful for the relatively few well-equipped facilities in Africa to use radioisotope techniques in estimating heterosis for root growth. Because of the importance of legumes in the diet in the arid and semi-arid regions of Africa, it is necessary that the bio-energetics of plant mass production as well as microbiological and physiological aspects of nitrogen-fixation be encouraged in the laboratories that are equipped to undertake such studies.

The production of high yielding crops should not be the only major concern in these areas. Problems relating to post-harvest crop conservation should be given equal attention. It seems most unfortunate that because of the lack of expertise, large quantities of crops go to waste after harvest in these regions. This is largely due to the lack of attention to the chemical composition of the harvested crops, and the seed anatomy and physiology as they affect the nutritional qualities of the produce. It has been repeatedly demonstrated that little data comparable to that known about the composition and structure of wheat exists to guide plant breeders in the selection of high-yielding cultivars of millet, sorghum and dryland legumes that combine nutritional and functional properties of such crops. In addition, there is little understanding of the biochemical and biophysical characteristics that influence the useful properties of grains and how these are affected during storage. Surely, in order to change the current unsatisfactory situation, research in these areas of post-harvest food conservation should be given the highest priority.

D. Desert Wildlife Resource Utilization

Desertification often transcends national boundaries, and the arrest of its ecological effects may well involve joint action by two or more countries (Tolba, 1982). In the harsh habitats of the African desert and subdesert, antelopes such as the addax, oryx and gazelles are good resources for converting the coarse grasses into excellent meat without destroying the environment upon which they subsist, in contrast to destructive goats and cattle (Curry-Lindahl, 1974). It is difficult to establish efficient nature reserves for nomadic antelopes which wander great distances in irregular patterns following the paths of the erratic rainfall. The best way to save the wild desert herbivores, in an effort to maintain ecological balances in the region, would be inter-African cooperation, chiefly by Mauritania, Mali, Niger and Chad, with regard to strict hunting regulations, and education and information programmes.

Wildlife is the only natural resource that thrives in the arid lands of the Sahara and most of the Sahel, since the land is mostly unsuitable for agriculture or permanent stock-rearing. But there is currently a lack of willingness to look at the wildlife in parks and reserves as a useful, exploitable natural resource for meat, hides, hunting and tourism. Not least among the people who need to be convinced of the natural benefits of maintaining and eventually using the wildlife resources of dry, marginal lands are the major international funding and development agencies (e.g. World Bank, European Development Fund, U.S. AID), whose policies and money virtually dictate the way in which Sahelian development is going (Newby, *pers. comm.)*.

There is a very urgent need for pilot projects to demonstrate once and for all that wildlife can be a valid alternative source of income, and may well be the best form of land use in the long run, considering the environmental factors of desertification and capricious climate. It has been noted that if we are to succeed in the Sahel, we must get away from the concept of traditional national parks and nature reserves, and into the realms of natural resource management units and multiple purpose land-use zoning (see also Myers, 1972). This conforms to the *World Conservation Strategy* principle of judiciously linking conservation and development (IUCN, 1980).

Protected areas must become dynamic in nature, capable of changing their objectives with an evolving community of natural resources, and responding to the current requirements of the human population. From the beginning, it must be emphasized that the animals could be grown as a harvestable crop, rather than overly pursuing the practice of isolating these vanishing animals in open-air museums which are increasingly more threatened by poaching and habitat destruction.

To begin action, we need to create good protected areas in African arid and semi-arid zones where wildlife still exists in viable quantities : such key zones include (Newby, *pers. comm.)* :

1. the Majabat of Mauritania and Mali;
2. the Air/Termit zone of Niger;
3. the Hoggar and surrounding Tassilis of Algeria;
4. the Ouadi Rime-Ouadi Achim area in Central Chad.

Norman Myers (1973, 1981) has been an advocate of the concept that surplus (excess) wild animals in national parks should be sacrificed to provide food, hides, and beneficial revenue, and also of the concept of game ranching. In the Sahara and Sahel, this could certainly be explored from an international viewpoint in an attempt to solve the problems of this starving part of the African land.

IV. SUMMARY AND CONCLUSIONS

Approximately one-third of the African land suffers from the hazards of desertification, wherein desert encroachment and land degradation in the arid and semi-arid zones cause ecological changes which deprive the land of its ability to sustain agriculture and human existence. Uncontrolled methods of grazing, overcutting for fuelwood and injudicious expansion into marginal lands have combined with climatic phenomena causing wind — and rainfall — erosion of the soil. Food shortages are ever present, and the twenty-seven nations in which desertification is now occurring must give priority to increasing food production, so that famine will not recur as it has in the past.

Fortunately the Rockefeller Foundation has recently decided to help Africa by finding methods to increase food production using some of the latest technologies. The combined efforts of IIASA and FAO are directed to using techniques of applied systems analysis to help gain a comprehensive understanding of the desertification process. Natural resources of biological, pedological and hydrological importance must be more diligently utilized, managed and conserved.

The great amount of marginal land which mankind has created over the last century will have to be restored as much as possible, using the techniques of agroforestry and fuelwood plantation management. Agroforestry, which is the cultivation of woody plants together with agricultural crops and/or livestock on the same land, will help to sustain the human ecological carrying capacity for the local people who practice both traditional nomadic pastoralism and sedentary rain-fed agriculture. Through irrigation and intensified trials on the re-establishment of seedlings on worn out land, the basic needs of the people for food (especially protein from edible fruits) and firewood will be substantially fulfilled.

In Africa, 85 percent of the total energy used comes from trees and shrubs. Tree planting in the Sahel must be increaed 50-fold above the present rates if the projected firewood demands by the year 2000 are to be satisfied. Supplies of fuelwood and firewood can be increased by growing plantations of rapid growth plants under a management scheme conducive to high yields, with emphasis on woody legumes for their nitrogen-fixing abilities. Much research is required on numerous aspects of fuelwood plantations, such as on the performance of various species, the nutritional problems of salt tolerance, and the entire recycling system as regards soil nutrient depletion. The use of conventional genetic methods as well as genetic engineering, and the use of tissue culture technology for propagating elite clones of the trees, will require investigation.

Aerial seeding of fuelwood species having a fast growth rate shows potential. Trials made in certain arid regions are showing great promise. In the African arid and semi-arid zones, acacias and neem *(Azadirachta indica,* Meliaceae) represent the most obvious candidates because of their high seed viability.

The local plant resources exhibit a variety of often underexploited characteristics making them useful for food, fiber and fodder. The marama bean of the Kalahari and yeheb nut of the Horn of Africa are legumes containing high amounts of protein and sugar respectively. Numerous medicinal plants have active chemical constituents which must be further studied. Endangered species of commercially valuable cycads, euphorbs, and arborescent Liliaceae abound in the arid and semi-arid zones, and could be commercially propagated to earn income if their numbers in the wild are first stabilized by adequate conservation procedures. Many countries in the regions affected by pockets of desertification possess a rich variety of crop genetic resources, especially of sorghum, pearl millet and pigeon peas. Germplasm accessions of these crops are urgently required by ICRISAT collectors in semi-arid Africa.

Innovative programmes are required to help improve crop productivity. More research is needed on the adaptation of the major species of crop plants to drought stress including the biochemical pathways inherent in drought resistance; on the exploitation of heterosis for root-growth using radioisotope techniques; on climatic behavioural models which simulate some of the major farming systems, in order to evolve alternative cropping strategies; and for the prevention of post-harvest food loss, which happens when the physiology of the harvested produce in storage is not well understood.

The wildlife resources, such as gazelles and other antelopes, are the best animals for converting the coarse grasses of semi-arid regions into excellent meat without destroying the environment, as compared to domesticated cattle and goats. The wild animals in excess of the carrying capacity of protected national parks and reserves should more often be harvested by controlled hunting, and used for the provision of meat and hides for local people.

In conclusion, it is hoped that the African governments will draw upon these recommendations to help arrest desertification. Furthermore, other arid lands outside the continent may learn from the African experience in the search for their own solutions.

V. POSTSCRIPT

At the time of going to press, the following feature, "Desertification and Famine Hit Ethiopia", was released by the United Nations Environment Programme (UNEP) on 4 March 1983. This represents a case study from which many lessons can be drawn.

Drought and desertification are hitting Ethiopia again and millions of people are threatened with famine by the worst drought in 10 years. Ethiopian officials compare it to the 1972-1974 disaster which led to famine and the death of over 200,000 people. The situation is made worse by land degradation and desertification—often the real culprit behind hunger and famine.

Ethiopia's Relief and Rehabilitation Commission (RRC) says that in several regions the drought is as severe as in 1974. The most seriously affected are the rugged northern Administrative Regions of Wollo, Tigrai and Gondar, the same regions which were hit hardest by the 1972-1974 drought.

Relief and Rehabilitation Commissioner Shimelis Adugna, has appealed for urgent relief aid to stave off famine in the drought areas. As early as last November, the RRC warned of impending disaster when it reported the failure of the July-August rains in 13 of the country's 14 regions, posing a threat to some five million people. Now, tens of thousands of people are leaving the drought-striken areas for relief centres in search of food and the *Ethiopian Herald* reports that 44 people already died in Wollo and Gondar along with over 50,000 head of livestock.

The drought is only the trigger for the famine situation. The real problem goes much deeper. The worn-out lands of these northern regions are no longer able to maintain their population on more than a marginal level of survival due to chronic food shortage. Even a relatively slight drop in food production can lead to famine and the periodic droughts which hit the region often have this result.

Abebech G. comes from one such area, Wegel Tena, almost 12,000 feet (3,500 m) up on the Delanta Plateau in western Wollo. She is still pretty, but at 25 she looks 35. When Wegel Tena is mentioned, her eyes turn sad. She survived the 1974 famine-her family did not.

Wegel Tena and the countryside along the precarious 138 km. mountain road from Dessie, the regional capital, has all the basic problems that lead to famine in the northern highlands — deforestation, land degradation, soil-erosion and loss of fertility — while the population keeps increasing.

Most of Ethiopia used to be covered with forests. Even 10 years ago, 16 percent of the land was under forest cover. Now, it is only 3.1 percent. With deforestation, the soil lost much of its capacity to retain moisture, and consequently, its productivity and resistance to drought conditions. It also reduced the capacity of the mountain catchments to absorb the rainwater and release it gradually. The result is quick run-off and flash floods, while formerly permanent streams now stop flowing in the dry season and periods of drought.

Most of the rainfall is concentrated in three months of the year. This, and the rugged nature of the landscape, makes it highly vulnerable to erosion once the forest cover is removed. Most of the rainfall runs off quickly, taking the fertile top-soil with it.

More that 70 percent of Ethiopia's population lives in the highlands, along with 80 percent of the country's 77 million head of livestock. Population pressure has led to such destructive land-use practices as cultivation of steep slopes until the soil is washed away, clearing of forests for firewood and building timber — now there is virtually no wood in the northern highlands — and overgrazing of steep mountainsides and semi-arid rangelands to support the increasing animal population.

These practices, together with erratic rainfall have caused severe soil-erosion over more than 50 percent of the country. In some areas, annual soil-loss runs as high as 20 metric tons per hectare, with national soil-loss estimated at more than one billion tons-the equivalent of stripping away a one-metre deep layer of top-soil from 79,000 hectares.

Erosion is only one of the problems destroying the fertility of northen Ethiopia. In much of the countryside, firewood supplies have run out and animal dung and the straw from the harvest are being used for domestic fuel. Very little organic matter is returned to the soil, which is therefore becoming poorer, more exhausted and less capable of supporting its human and animal population.

In the lowlands, the rangelands-erosion is less severe, but there is also less water. In these semi-arid regions the pastoralists have expanded their herds to support the growing human population — and as a sort of insurance — so that in case of drought or disease, they will have enough animals left for a viable herd. Increase in herd size, however, is leading to overgrazing, and range degradation. When drought hits, drastically reducing the carrying capacity of the rangelands, overgrazing becomes intense until the vegetation cover is destroyed and disaster becomes inevitable.

The Ethiopian Authorities recognize the present drought situation as a manifestation of deeper problems — soil-exhaustion, soil-erosion and desertification. They know that food relief can only be a temporary expedient and they are determined to find permanent solutions.

In fact, they are finding them. The RRC has started a programme to resettle more than 100,000 peasant families from the most degraded areas, in the more fertile lowlands of the south and west. Eventually, up to 300,000 families may have to be resettled. The programme aims at reducing population pressure in the nothern highland to permit the land to recover. Some 16,000 families from those areas have already been resettled, but RRC Commissioner Shimelis Adugna says that more resources are needed to make the programme a success.

Another key strategy is improved land-use planning. The Sirinka Pilot Catchment Rehabilitation Project has already made significant progress towards its goal of finding "ways and means of raising rural productivity while keeping soil-erosion to an acceptable level". The 355 km2 project set up by the Land-use Planning Authority, together with the RRC and the Extension and Project Implementation Department (EPID), is developing improved land-use patterns, agricultural techniques and crop varieties to rehabilitate the land and raise productivity without evacuating the population and which can be replicated elsewhere in the region.

At the same time, a large-scale reforestation and a land and water conservation effort is under way in six regions of northern and eastern Ethiopia, aimed at rehabilitating key watersheds, controlling soil-erosion and restoring soil fertility. Like Sirinka, it has already had some success — enough to prove that success is possible, that desertification in the region can be controlled — and even reversed — if the resources are availabe.

This, of course, is one of the problems. Ethiopia, like most developing countries lacks the resources needed to reverse the desertification process. However the problem is not only Ethiopia's. It's a global threat. Desertification, the loss of scarce arable land anywhere in the world, eventually affects, economically or otherwise, the rest of the world.

Last year's special session of the United Nations Environment Programme's (UNEP) Governing Council identified desertification and soil loss as the single most important aspect of environmental degradation. The world is losing 20 m. hectares of arable land a year and UNEP's Executive Director, Dr. Mostafa Tolba said in 1982 that the rate was accelerating. Unless desertification can be halted by the year 2000, he warned, it would be out of control.

UNEP says that an additional $ 1.8 billion a year is needed to control desertification. It looks like one of the best investment opportunities going — for mankind.

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