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An Agro-Sylvo-Pastoral Approach to Desertification Control and Increased Productivity of the Sahel

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AN AGRO-SYLVO-PASTORAL APPROACH TO DESERTIFICATION CONTROL AND INCREASED PRODUCTIVITY OF THE SAHEL

by

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INTRODUCTION

The southern arid fringe of the Sahara Desert, called the Sahel, is progressively becoming less productive through a systematic deterioration of the environment. Population increases and technological advances have encouraged ecological degradation through man's normal activities for survival. The degradation process has been referred to as desertification, desertization, desert encroachment, and desert creep.

Agricultural development projects in this part of the world, for the most part, have been counterproductive in solving the long-range problems of the Sahelian ecosystem. There have been both technical and social reasons for these failures. Misapplied and inappropriate western technology is the root cause of the problem. A general lack of cooperation amongst the various development groups as well as a cultural and language gap between the donor and recipient has tended to impede the necessary coordination of development efforts. Years of development assistance to the Sahel have demonstrated that the complex problems of the Sahelian ecosystem cannot be met by single approaches, but rather require an integrated, unified effort on the part of the resource users and developers. This effort must take into account the long-term productivity of the ecosystem, which will often conflict with the immediate needs of the people and their governments.

An innovative rural development project in Chad described in this report offers a forum for discussion of the requirements for a potentially successful rural development project. This project proposes the application of a popular and easily understood concept of revegetation using a multi-purpose plant as a means to focus concern and unify efforts of the various agricultural development groups. The project focuses on the Acacia albida species because of its beneficial qualities for livestock, agricultural, and timber production. Although the immediate goal of the project is to plant and protect Acacia albida on marginal farmlands of the Sahel, this is not necessarily an end in itself. The project, once established with a network of nurseries, extension centers, and well trained extension agents, will serve not only to coordinate development efforts but also bridge the communications gap between the technical assistance agent and the villager. As the extension worker learns to understand the cultural constraints of the villager and as the villager gains confidence in the extension agent, a more complete land management program may evolve which could include all aspects of agricultural and livestock production development. The final objective would be a culturally acceptable, ecologically oriented program for integrated land management. This integrated development approach to ecological stability in the Sahel may be termed an agro-sylvo-pastoral approach, signifying a unification of efforts.

DESERTIFICATION IN THE SAHEL

The Sahelian countries of Mauritania, Senegal, Mali, Niger, Upper Volta, and Chad, and their 25 million inhabitants, are menaced by the process of environmental degradation called desertification. Desertification is a deteriorating transition from semi-arid to desert ecosystems with a concomitant reduction in biological productivity. Le Houerou (1975) considers the problem to be an encroachment of desert landscapes into areas that climatically should not be deserts.

The Sahelian droughts of 1968-1973 brought world attention to the critical nature of this problem when an estimated 250,000 people died and 50 percent of the livestock perished as a result of the decrease in crop and forage production associated with the accentuated degradation process (United Nations 1977). The severity of the situation is best reflected by the United Nations' (1976) statement that "if desert spreading is not stopped, two African countries will be completely destroyed within the next decade."

The rains have again returned to "normal" in the Sahel, the problems are not as critical, but the underlying element, the deterioration of a fragile arid ecosystem, is still there. This ecosystem deterioration is a very complex problem in serious need of world attention and assistance. In Lewis' (1969, p. 171) words, "Just as a nation is improvished by depleted range resources, so the entire world is poorer for every deteriorating acre of range."

Causes of Desertification

Most Sahelian ecosystem authorities agree that the basic cause of desertification is man's disruption of the otherwise balanced ecosystem, which is intensified by naturally occurring, periodic droughts (Delwaulle 1977, Eckholm and Brown 1977, Dregne 1977, Glantz 1977, Hare et al. 1977, Le Houerou 1977, Kassas 1970, United Nations 1977, Ware 1977). The principal disruptive effect man has on the land's resources is a systematic devegetation of the landscape. This results in a replacement of the stable perennial vegetation by the more transient annual vegetation, a decrease in litter and soil organic matter, an increase in soil erosion, and a generally more xeric, less productive ecosystem.

As populations increase in the arid areas of Africa, man's normal activities for survival place heavier burdens on the resource base, resulting in higher rates of devegetation. Man's land-use practices most affecting the devegetation process are 1) cultivation in marginal areas, 2) overgrazing, 3) uncontrolled range burning, and 4) firewood gathering and charcoal production.

Cultivation in Marginal Areas

The traditional cultivation method of the Sahel is bush fallowing whereby man cuts down the vegetation with an ax and machete, burns the brush, cultivates for about five years or until the soil is depleted of its fertility, and then leaves that particular depleted area in fallow to revegetate naturally while moving on to an adjacent area to continue the cycle. This method of cultivation is adapted to areas of greater than 400 mm annual rainfall (Le Houerou 1975) and where population densities allow for a minimum of 20 years fallow period for partial restoration of soil fertility and structure (Figure 1).

The problem, however, is that population trends and technical advances are encouraging a northward expansion of farming into the arid rangelands of the Sahel. These rangelands are too dry to support repeated cultivation. Population pressures are also limiting the amount of time land is left in fallow, thus bringing depleted land back into production.

Overgrazing

Traditionally, grazing patterns and herd sizes in the Sahel were controlled by the environment. Herds were moved according to rainfall distribution, trekking north during the wet season and returning in the dry months. This nomadic grazing provided the range vegetation with periodic relief from use and maintained an ecologically balanced vegetative cover and species composition. Current population trends, however, discourage this transhumant land use and grazing has become more concentrated. Political borders and taxation have placed limits on nomadic migrations; the northward expansion of farming is shrinking available rangelands which tends to concentrate wet season grazing farther north in the semi-arid zone; water developments have encouraged the year-long use of range areas that had otherwise been restricted due to water scarcity except during the wet season (Figure 2).

Figure 1. Traditional seedbed preparation.

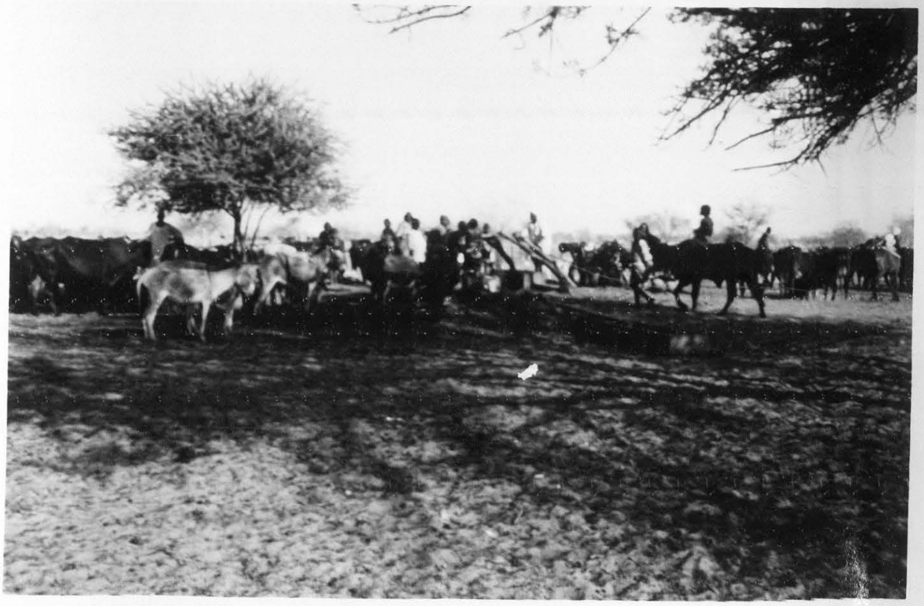


Figure 2. Overgrazing around borehole.

Herd sizes are also increasing. The growing population of the pastoralist and sedentary farmer is bringing about an expected increase in the number of support herds. These same pastoralists have learned from their experience of the last five year drought, which ended in 1973, that they can expect to lose at least 50 percent of their herd numbers during a drought period. They therefore feel encouraged to expand their herd size during favorable periods in order to assure themselves a larger number of surviving animals after a future drought. There is also the natural tendency on the part of the pastoralist to increase his herd size whenever possible as his wealth and prestige are measured in terms of number of animals and not the condition of his herd. It is an investment in the currency of animal units.

Improvements in veterinary services and water developments have helped make it possible for the pastoralist to increase his herd size by minimizing the natural control on numbers previously caused by disease and scarcity of water. These trends of increasing herd sizes and concentration of grazing are resulting in widespread overgrazing and range retrogression in the Sahel.

Uncontrolled Burning

Fire has traditionally been used in the Sahel for several purposes. Most important of these is the stimulation of green grass sprouts for livestock grazing at the onset of the dry season. Fire is widely used for hunting whereby the animals are chased in the direction of the waiting hunter. Burning of the range vegetation has also been used as a means of opening visibility around villages as a defense against the intrusion of dangerous animals and enemies. In Senegal there is a traditional belief that it is a good omen to set the first fire of the season (Figure 3).

Depending upon the timing, intensity and frequency of burning, this practice can be an important catalyst to the devegetation and resultant desertification process, as it reduces the protective perennial vegetation and litter cover. Le Houerou (1980) contends that the savannas of the Sahel are fire disclimaxes in which the perennial grasses have been replaced by annual grasses due to periodic burnings.

Firewood Gathering and Charcoal Production

Firewood gathering and charcoal production can be a highly destructive factor near population centers. Charcoal production is especially detrimental as it has developed into an important component of the rural economy whereby villagers supply urban centers with fuel (Figure 4). The combined consumption of firewood and charcoal is about 1 kg per day per family of five (Le Houerou 1977). This means that one family could theoretically destroy 1/2 hectare of woodland per year if there is no regeneration. But there is regeneration if land resources are properly utilized.

Figure 3. Burning of the range vegetation for the stimulation of green sprouts.

Figure 4. Bags of charcoal waiting to be transported by bush taxi to the city.

Social Complicating Factors--
Development Priorities

"Modernization", generally speaking, is a world goal which has negative repercussions on environmental equilibria. In the Sahel, modernization is encouraging migration to the cities and sedentarization of the nomads. This trend, along with improved medical services, is prompting an increase in localized population pressures with the consequent growing demands on the adjacent land resources.

To meet these expanding demands, development priorities are directed towards benefits that are immediately realized. These often preclude or at least ignore the preservation of long-term productivity of the land resources. Examples of agricultural development programs with immediate gratification as the primary objectives are:

1. Veterinarian practices applied to improve the health of livestock and increase numbers. (This is often done at the expense of a degrading range resource.)
2. Borehole development to provide a stable year-around water supply to livestock allowing an increase in animal numbers and limited migration. (This is also done at the expense of a degrading range resource.)
3. The use of European soil tilling techniques to improve crop production. (This may overlook potential damage to the soil structure and water relations.)
4. The use of expensive imported fertilizers to increase expectations of the capabilities of the land. (A continuous supply may not be guaranteed.)

5. The construction of irrigation systems which produce two or three crops per year rather than the usual one.

These types of development strategies share the common counter-productive feature of increasing expectations of the land's resource while providing no guarantee of sustained high productivity. The level of technology applied is rarely understood within the cultural context of the Sahelian villager and thus often not replicable by him. This may eventually be regarded, however, as the redeeming virture of misapplied western technology in the Sahel: a lack of permanency.

The agronomist and livestock producer do not commonly view the problems associated with environmental degradation as their responsibility, but rather it is an issue often relegated to the forester. As a consequence, major desertification control programming has been oriented toward the highly popular, however misdirected, "green belt" concept. This concept presupposes that desertification is a uniform process along a front and that a barrier of trees will be able to stop the "creep" (Le Houerou 1977). This approach only masks the real problem of resource overutilization involving farming and grazing pressures. Attention must be turned to the true causes of desertification, and emphasize preventative rather than corrective measures.

DESERTIFICATION CONTROL

An Integrated Approach to Land Management Within an Ecological Framework

Environmental degradation is a slow process, the causes of which are not immediately recognized by those concerned. Villagers and agricultural advisor alike, will find root causes that are compatible with their cultural traditions but may be ecological distortions. The Sahelian herder's reaction to the periodic droughts, that often kill a large proportion of his herd, is to increase the size of his herd during the better rainfall periods so that he will have more survivors in the event of another drought. The agricultural advisor, likewise, promotes higher productivity through the complete exploitation of the soil resource. Proper land management for long-term productivity is rarely a consideration of contemporary, between drought, recovery schemes.

Viewing the problem of desertification in its entirety reveals the prerequisite of coordinating resource availability and stability with resource utilization. This proper utilization of resources will only be possible when there is cooperation between the various users. The forester, the agronomist, the soil scientist, and the range manager must work together with the farmer and herder to obtain maximum long-term productivity from the land.

Mbithi (1974) suggests that the rural family is not neatly divided and categorized into departments as are government agencies and technical assistance agencies. Rather it looks at the world as being one and interrelated. What affects their crops can affect their livestock and visa versa. Rural development schemes on the other hand, by nature of bureaucratic structure, compartementalize food production activities. It would seem, therefore, that unification is most necessary at the rural extension level. This means unifying the interest of the various government ministries and foreign assistance programs involved with agricultural and livestock production. The question therefore becomes how to organize the foreign technical assistance into an ecologically sound unit, best understood by the rural villager.

Herein is proposed a development scheme for the Sahel which hypothesizes the unification of development activities by focusing attention upon a common goal of direct interest to all concerned. It is proposed that an ecologically sound, production oriented agro-sylvo-pastoral program may evolve from a central concept of revegetation with multi-purpose tree/shrub species. The *Acacia albida* is a good example of such a species because of its beneficial qualities relative to agriculture, livestock, and wood production. It is also one of the few protected species in the Sahel.

POTENTIAL OF *ACACIA ALBIDA* AS AN ECOLOGICALLY SOUND INTEGRATING AGENT

Description of the Species

Acacia albida Del is also known as the *Faidherbia albida* (Del.) A. Chev. In Arabic it is referred to as the harraz and the English common name is gao. It is a member of the legume family and of the subfamily Mimosoideae. The species is characterized by bipinnate leaves, orange curled seed pods, cream colored flowers, and thorns (Figure 5).

It is the fastest growing savanna tree in Africa (National Academy of Science 1975), reaching heights of 3-10 m in ten years depending upon the conditions (Wikens 1969). It may grow as a shrub if continually grazed (Wikens 1969), but usually develops into a tree with a large spreading crown. The mean maximum height is 25 m, with a girth of 5 m (UNDP and FAO 1968). It is a very long-lived species, with an average life span of 70-90 years in the Sudan and known to live more than 150 years in Zambia (Wikens, 1969).

Acacia albida has an extensive taproot system which develops rapidly to reach an adequate moisture layer. This characteristic makes the species relatively drought resistant. On coarse alluvial sands of the Sudan, a six month old seedling with 8 cm of areal growth had a taproot 70 cm long (Wikens 1969). A three-year-old seedling, excavated in northern Nigeria, produced a taproot in excess of 9.9 m (Weber 1978).

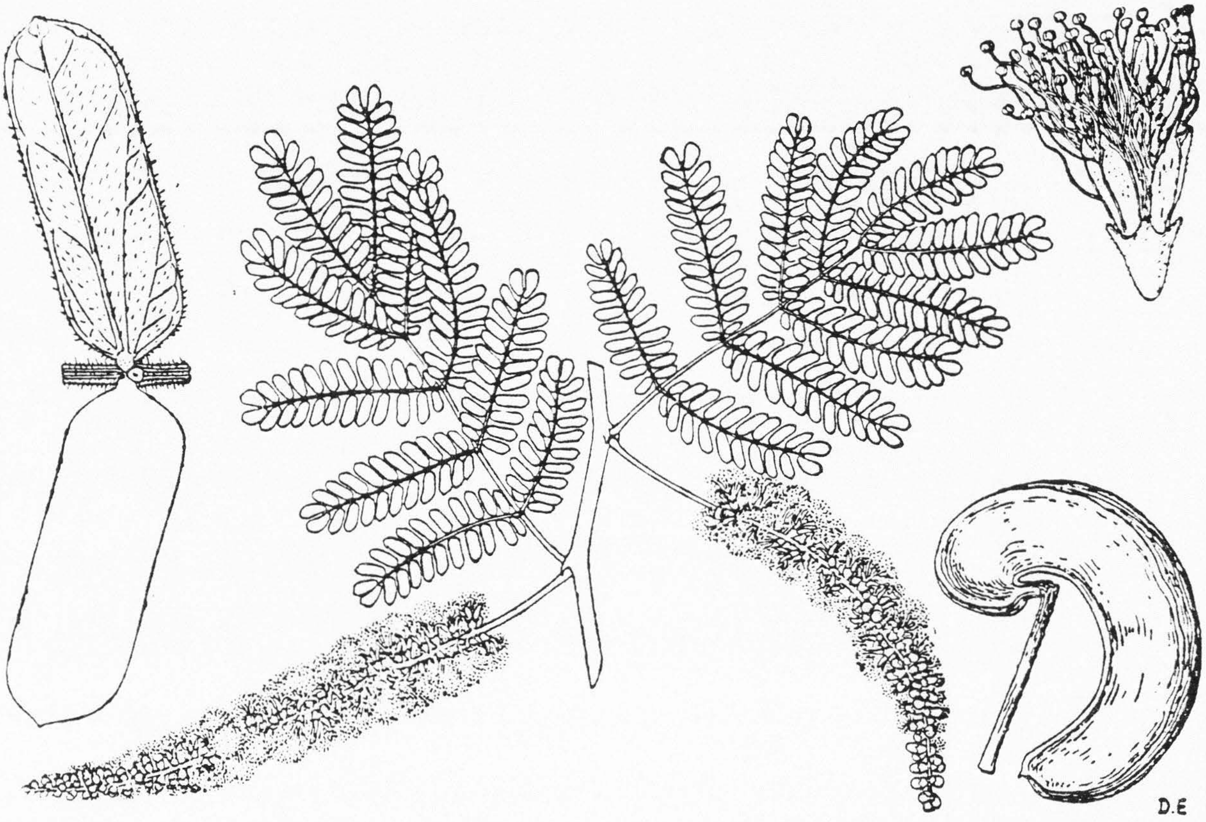


Figure 5. Botanical drawing of Acacia albido. From UNDP-FAO 1968.

The most unusual phenological characteristic of the species is the retention of the leaves during the dry season and the shedding of the leaves at the onset of the wet season. No other African savanna species is known to possess this unique reverse deciduous cycle (Wikens 1969, Weber 1978).

Acacia albida is located anywhere in Africa where there is a long dry season. This includes areas from south Algeria to Transvaal and from the Atlantic to the Indian Ocean (Giffard 1964). *Acacia albida* is an important component of the Sahel (Figure 6). It prefers a well drained sandy soil with a permanent water table, but will also grow on clay soils (Wikens 1969). Weber (1978) indicates that it is found anywhere millet can grow. Its present distribution appears to be related to man's activity. It is most typically found on cultivated land or land that is grazed by livestock. It is rarely found in natural woodlands that have not been exploited by man. Wikens (1969) suggests that this might indicate that *Acacia albida* is an alien species of uncertain origin.

Natural regeneration of the species is both stimulated and repressed by grazing animals. The seed pods are highly palatable and livestock can distribute the seed 100 miles from the source. The digestive juices of the ruminant stimulate seed germination (Weber 1978). Now, however, with increased grazing and cultivation pressures, natural regeneration is becoming more difficult for all perennials of the Sahel, including *Acacia albida*.

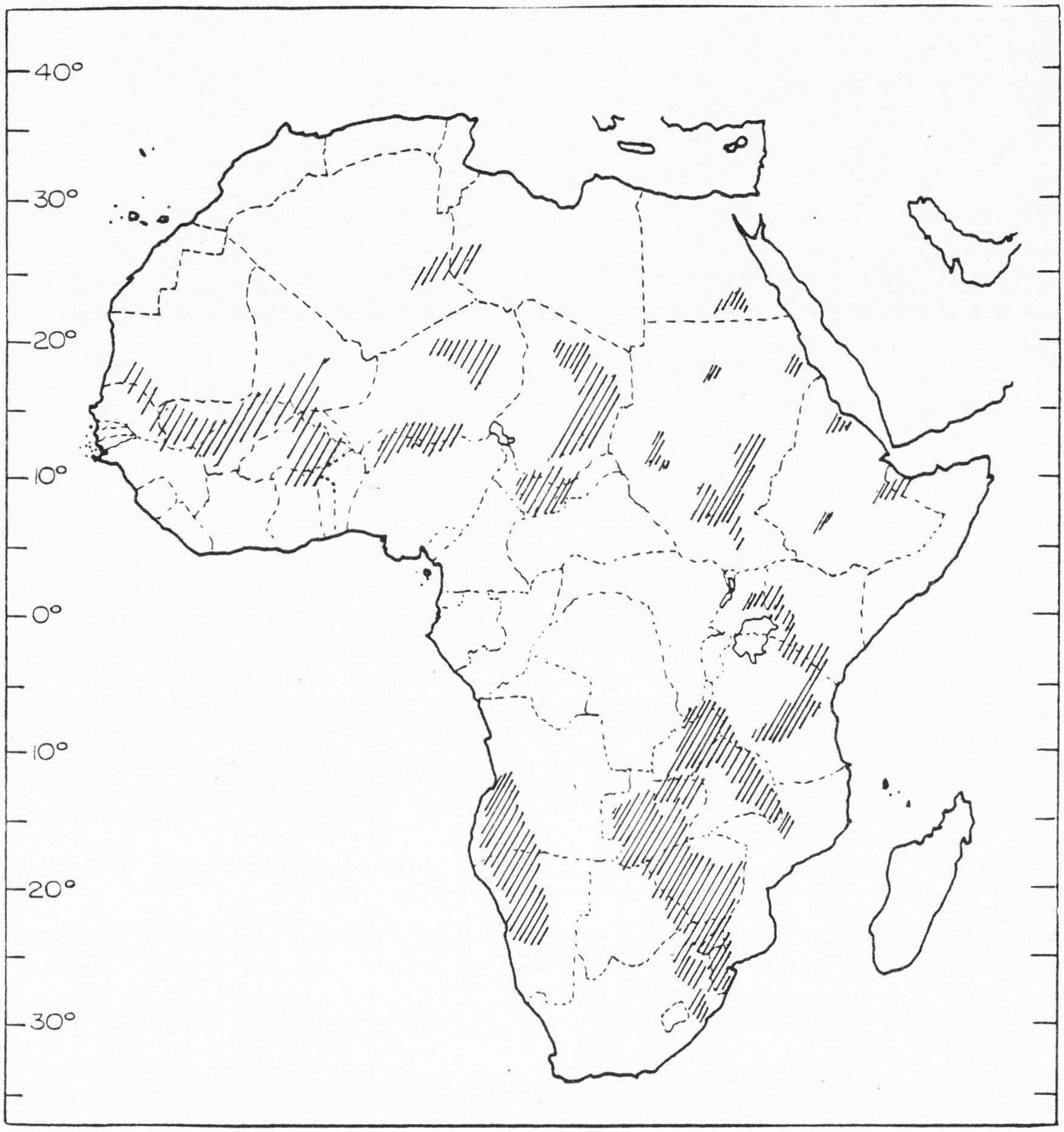


Figure 6. Distribution of Acacia albida. After: Wikens (1969).

Local Understanding of the Benefits of *Acacia albida*

It is a respected and well known species in most parts of the Sahel (Porteres 1952, Dancette 1968, Cationot 1974, Weber 1978). Local farmers recognize its benefit as an important dry season fodder, source of fiber, shade during the hot period of the year, and preferred location for crop production (McGahuey and Kirmse 1977). Because of its beneficial qualities it is a protected species in many parts of the Sahel, including Zinder of Niger, the Serere country of Senegal (Dancette 1968), and the Mora region of North Cameroon (personal interview with the Sultan of Mora).

Unfortunately, however, not all Sahelian tribes recognize the benefits of *Acacia albida*. This is especially true of areas recently settled by tribal members who have come from a region where the tree does not exist. A good example of this phenomenon is the recently settled (last 50-100 years) strip of land between latitudes 10 and 11 North, south of N'Djamena, Chad. Much of this woodland savanna is devoid of *Acacia albida* because it was traditionally a political no-man's-land; a tension zone between the Arabic speaking tribes of the north and the black tribes of the south. This area was without cropland that could provide suitable habitat. This compares to relatively heavy populations of *Acacia albida* to the north and south of this zone. This zone is now rapidly being settled by many different tribal groups including the Kotoko, Baguirmi, Banana, Toubouri, Moundan, Sare, Fulani, and Arabs. Some of these settlers do not have a traditional understanding of *Acacia albida*.

Production Advantages of Acacia albida

The production and ecological advantages of the Acacia albida as well as other tree and shrub vegetation types have been closely studied and well documented by French researchers in West Africa, primarily at Bambey, Senegal. Their findings over the last 25 years generally confirm the tribal African's perception of the beneficial qualities of the species in the Sahel.

Forage Values--Pods and Leaves

Blancou, Calvet, Friot, and Valenza (1977) have shown that browse is a very important component of the cattle's dry-season diet, providing the only source of protein and carotene. Their studies in the Ivory Coast show that 25 percent of the total dry season diet consists of browse.

The special phenological characteristic of Acacia albida of retention of the leaves during the dry season provides both shade and forage for livestock. The highly nutritious pods and leaves of Acacia albida (Tables 1, 2 and 3) are readily taken by all domestic and wild herbivores as they are highly palatable and offer some of the only relatively succulent forage during the dry season. Nomadic herdsmen typically lop the branches to provide browse for their stock while the seed pods fall to the ground in March and April which is a time of nutrient stress for Sahelian herbivores.

A single mature Acacia albida has been shown to produce up to 135 kg of pods per year. This amount of pods has been calculated to

Table 1. Chemical composition of leaves of *Acacia albida*. After: Wikens, 1969.

Chemical Composition	Young Green Leaflets with Stalks (Baynes 1940)	Mature Leaves (Dyer 1965)	Flowers (Baynes 1940)
Moisture content	63.7	8.6	82.2
Crude protein	17.1	14.2	19.0
Either extract	2.3	5.1	1.6
N-free extract	12.4	49.5	12.5
Crude fiber	59.7	14.7	57.2
Total ash	8.4	8.1	9.7
Silica	.6	-	1.9
Calcium	-	1.8	-
Phosphorus	-	0.1	-

Table 2. Chemical composition of pods of *Acacia albida*. After: Wikens 1969.

Chemical Composition	Pods (Codd 1951)	Pods (Baynes 1940)	Pods (Russel 1947)
Moisture content	8.0	6.0	9.2
Crude protein	10.4	15.5	10.6
Either extract	0.9	0.5	1.4
N-free extract	50.0	56.9	57.7
Crude fiber	27.4	22.9	26.7
Total ash	3.3	4.1	3.6
Silica	-	0.4	-
Calcium	-	-	0.7
Phosphorus	-	-	0.2

Table 3. Fodder value of pods of *Acacia albida* compared with peanut tops and mature native grass. Sources: Charreau and Nicou (1971) and Boudet and Riviere (1967).

	Total Yield Per Hectare	Digestible Protein Per Kg Dry Weight	Digestible Protein Per Hectare	Net Energy Per Kg Dry Weight	Net Energy Per Hectare
Acacia albida pods	2,500 Kg	70 g	175 g	1448 Kcal	3620 Mcal
Peanut foliage	3,000 Kg	60 g	180 g	725 Kcal	2256 Mcal
Grass, mature native	4,000 Kg	10 g	40 g	376 Kcal	1500 Mcal

be feed sufficient for the production of 90 liters of milk or 12.5 kg of meat (Charreau 1974) (Table 3). Dense populations of the tree can provide forage equivalence, from pods alone, greater than any other local forage on a per hectare basis (Charreau 1974). A wooded savanna in which *Acacia albida* is the dominant tree species is able to stock 20 animal units per square kilometer as compared with 10 animal units when *Acacia albida* is not present (Giffard 1964).

Agricultural and Soil-Enriching Values

Arid land shrubs and trees have been noted to be "islands of fertility" (Garcia-Moya and McKell 1970) due to their accumulation of litter and organic matter. Shrub and tree vegetation act to accumulate organic matter in several ways. Their configuration traps wind blown soil particles which contain organic matter. Leaf and other dead plant parts accumulate under the canopy more than outside the protection of the canopy. Animals seek out the cover and forage of the "islands", especially during the hot, dry season. Microbial decomposition of this concentrated organic matter is favored by the moderate temperatures and increased soil moisture retention under the shade of the canopy (Jung 1970, Giffard 1971, West and Klemmedson 1979). Soil moisture retention has been shown to be as much as 43 percent higher under the canopy of *Acacia albida* as compared with outside the canopy cover (Charreau and Vidal 1965).

Several researchers (Fireman and Haywood 1965, Richard 1965, Garcia-Moya and McKell 1970, Charley 1972) have described the mechanism by which the rooting volume acts as a sieve, absorbing inorganic nutrients from decomposed organic matter and recycling these elements back through the plant tissue. This mechanism provides a "reservoir" of plant nutrients which may be released to the plant community, adjacent to the tree or shrub, gradually through leaf fall and decomposition.

This accumulation of organic matter and recycling of plant nutrients has been found to create a horizontal and vertical distribution pattern of nitrogen and mineral elements under the canopy of shrub and tree species of arid ecosystems (Figure 7).

Symbiotic nitrogen fixation may also contribute to the available nitrogen pool of the soil adjacent to the arid land shrubs and trees but Garcia-Moya and McKell (1970) suggest that this is a minor component.

Extensive research on the soil-enriching properties of Acacia albida has been undertaken in Senegal by Charreau and Poulain (1964), Charreau and Vidal (1965), Jung (1967), Dancette and Poulain (1968), and Jung (1970), and in Niger by Dougain (1960). All soil nutrient properties were observed to be improved by the presence of the species. Most important increases were found in the nitrogen, available phosphorus, and exchangable calcium content of the soil. Increases from 20 to 100 percent in these soil nutrients were found (Table 4).

Studies by Dougain (1960) in Niger indicate that on a 10 cm depth basis, which represents about 1,500 tons of soil per hectare, the nutrient increases due to the presence of Acacia albida were

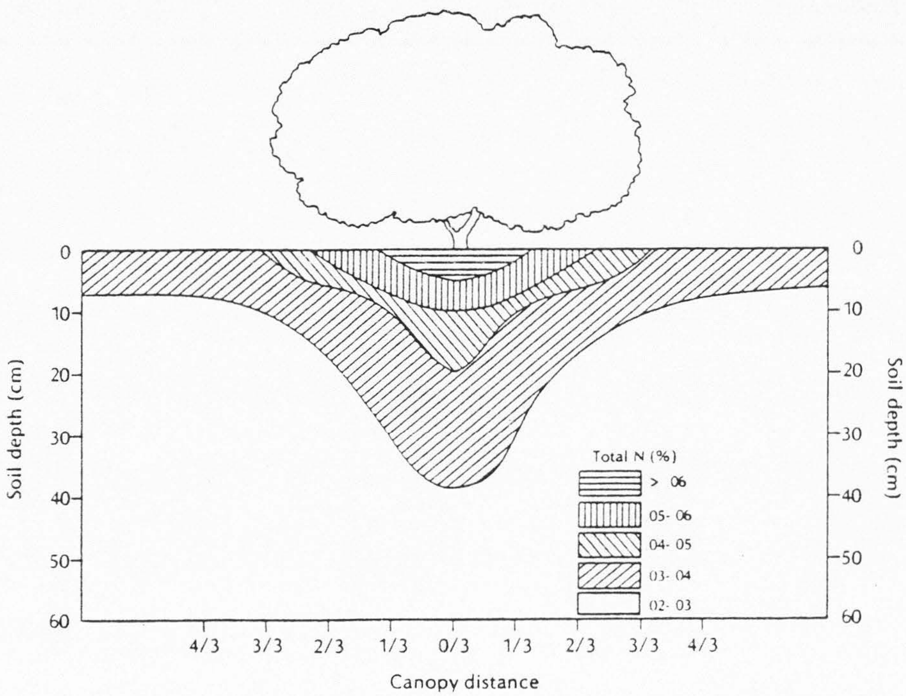


Figure 7. Horizontal and vertical distribution of nitrogen under <u>Prosopis juliflora</u>. From Klemmedson and Barth (1975).

Table 4. Elements returned to the soil from *Acacia albida*. After Jung, 1967.

Estimates Per Tree or Hectare	Dry OM kg	N kg	P205 kg	K20 kg	CaO kg	MgO kg
Per tree-mean surface under canopy: 231 m^2	267.5	4.3	0.2	2.1	7.2	1.6
Per ha-max stand density[1]	11,583	187	9	91	311	69
Per ha-mean stand density[2]	5,350	69	4	39	112	31

[1] Dense population (44 trees/ha); continuous cover; no removal.

[2] Medium population (20 trees/ha); partial removals.

equivalent to the following amounts of commercial fertilizers and amendments per year:

- 300 kg artificial nitrogen
- 31 kg P205
- 25 kg calcium
- 24 kg potassium
- 15 kg magnesium

The microclimatic conditions are also positive influenced by the presence of *Acacia albida*. The tree serves as a windbreak which protects crops and native vegetation from mechanical damage and excessive transporation (Dancette 1968) (Figure 8).

Charreau and Vidal (1965), with millet production studies in Senegal, have certified the Sahelian farmer's experience that crop production is in fact improved by the soil and microclimatic

Figure 8. Acacia albida tree. Note higher and darker vegetation (millet) growth under the crown.

influences of *Acacia albida*. They calculated that under the *Acacia albida* tree, grain production was 2.5 times that of crops grown in the open and protein content of the grain was up to four times greater (Table 5). Paulain and Dancette (1968) demonstrated that peanut production can be as high as 36.7 percent greater under the influence of *Acacia albida*.

In Senegal it has been documented that continuous cultivation without the usual requirement of long fallow periods is possible with a stocking rate of 10-20 *Acacia albida* trees per hectare (Giffard 1964).

The characteristic reverse deciduous cycle of the *Acacia albida* species is the key physiological property that allows satisfactory production of crops under a full stand of the species. The leaves are shed at the onset of the rainy season, allowing sunlight access to the crops during the growing season.

Timber Values

The wood of the *Acacia albida* tree is hard and favored locally for the construction of mortars and pestles as well as other light carpentry. Localized uses also include charcoal production and dugout canoe construction. In fact, in Chad, where trees old enough to have trunks that are no longer round, the stout taproot of the *Acacia albida* tree has been used for dugout canoes (personal conversation with fishermen). The bark can contain up to 28 percent tannin and is used for treating hides (UNDP and FAO 1968).

Table 5. Comparison of millet grain and protein production under the canopy of *Acacia albida* and outside the canopy. After: Charreau and Vidal, 1965.

	Average Number of Ears per Sample Bundle	Average Weight of Grain (g)				Protein Average	
		Total of Bundle	Per Bundle	Per Ear	Theoretical kg/ha[1]	Percent per Grain	Kg/ha
Sample bundles (25) taken from location near trunk	5.4	593	166.8	29.8	1,668	10.68	179.0
Sample bundles taken from limit of canopy	4.2	413	98.3	23.3	983	8.72	84.2
Sample bundles taken from outside canopy	2.9	255	66.0	26.6	660	8.10	52.2
General average	4.1	420	110.9	25.3	1,109	9.19	106.2

[1] Multiply by 10,000 bundles which is average number per hectare in Senegal.

Potential Negative Impacts of *Acacia albida* Propagation

The most commonly posed, potentially negative, impacts from the propagation of the *Acacia albida* concerns the attraction and increase of the grain feeding birds and tsetse fly. Any tree provides a habitat for the crop damaging birds of the region and farmers are justifiably concerned. Weber (1978) suggests that most of the complaints come from areas of heavy bird concentrations, such as the Lake Chad vicinity, where birds would be a problem whether or not the tree was present.

The tsetse fly that transmits the fatal trypanosoma disease to livestock is not a problem in the arid fringes of the desert in which tree planting is proposed, which is north of latitude 10°N where the fly is limited by the heat of the dry season (Glasgow 1963).

Acacia albida as an Appropriate Land Management Component

The above-mentioned multiple use qualities of *Acacia albida* indicate that the species would be of interest to 1) the agronomist for increasing crop production without the use of expensive fertilizers, 2) the livestock producer for the very critical supply of fodder during the dry season, as well as shade provided the animals, 3) to the watershed manager for the improvement in soil water holding capacity and decrease in erosion, 4) to the forester for timber uses, and 5) to the farmer as an improvement in his living standards without a change in cultural traditions. It is for these considerations that the _Acacia albida_ species can be a focal point of an agro-sylvo-pastoral land management program within an ecological framework.

Most authorities on the problem of desertization recommend the planting of the species as an appropriate land management component in the Sahel. Among these advocates are the Sahelian specialists Gilloteau (1953), Dancette (1968), Giffard (1971), Delwaulle (1973), Catinot (1974), and Weber (1977).

There have been initial attempts to organize land management programs using _Acacia albida_. Niger, Senegal, Nigeria and Chad had or have _Acacia albida_ programs. The Chad project is an interesting case study of the possibilities and problems of such a program.

A CASE STUDY

The *Acacia albida* Land Rehabilitation Project in Chad

The country

Chad is one of the poorest countries in the world, with a per capita income of $80. It is landlocked Sahelian country with all of the complex problems associated with an extremely fragile arid ecosystem and an economy based on small-scale subsistence farming and livestock grazing. It has a short growing season, poor soils, uneven rainfall patterns, and is subject to cyclical droughts. The country is currently recovering from its most recent and severe drought which occurred between 1970 and 1973. During this period agricultural production was reduced by approximately 62 percent (ASDA 1977).

Per capita food production, even before the drought, declined 32 percent from 1961-1970. The annual rate of growth per capita GNP from 1960 to 1970 was one of the lowest rates for all the Sahelian countries (USAID 1976). Paralleling the decline in per capita food production before the drought, the calorie supply, already sub-standard, declined from 94 percent of the basic requirements in 1960 to 86 percent in 1970 (World Bank 1976).

These trends may be indicative of two developments; an expanding population on a limited land resource or a degradation of the land's productivity. It is probably a combination of these two factors which results in a poor country getting poorer and less able to feed itself, much less protected its ecosystem from decay.

The problems of Chad typify those of all of the Sahelian countries. The local population growth, due in part to the improved medical services and the increasing sedentarization of nomadic herders, is progressively placing more pressure on the limited land resources. Land ownership, being communal, provides little incentive for proper land management.

Foreign assistance

Foreign assistance has only tended to compound the problem of environmental degradation in Chad by the introduction of inappropriate western technology. Technical assistance, as discussed earlier, has promoted highly visible projects which give immediate results, and most often does not calculate the ecological impacts. Some examples of development projects in Chad which fit this counter-productive category are animal traction tilling, borehole development, introduction of cash crops, and irrigation projects.

The introduction and promotion of animal traction tilling techniques is potentially the most destructive factor in soil degradation. The traditional method of seedbed preparation in Chad is the simple scratching of the soil surface and dropping the seed. Farmers have seen the higher first year crop yields resulting from soil tilling, and have been easily convinced. There is, in fact, a first year increase in crop yield because of the higher moisture infiltration rate immediately after plowing, while the soil structure is still intact. The turning over and exposure of this soil, however, leads to a more rapid depletion in soil structure and fertility as the fields are made vulnerable to wind erosion and the organic matter is exposed to the air for more rapid oxidation.

Plowing also destroys the perennial root systems which were preserved under the traditional seedbed preparation method. The perennials had provided an immediate vegetative cover after the fallow period begins. Without this means of immediate vegetative recovery by perennial plants, secondary succession progresses very slowly from a degraded, xeric soil condition. This requires a much longer fallow period to regain productivity, if productivity is retrievable after repeated cultivation. Once the land has reached such a poor condition, periodic burnings and grazing pressures may be sufficient disturbance to repress the restorative successional mechanism (Figure 9).

Water developments for the benefit of livestock production have had severe impacts on the ecosystem in Chad. The new water supply has led the herder to believe the size of his herd is not dependent upon the naturally slim water source, resulting in a growth of herd size. The heavy concentration of grazing around the water development has resulted in locally intense range retrogression. Boreholes with high discharge rates have been found to be able to support up to 25,000 to 50,000 animal units and created desert conditions in a radius of 15-20 kilometers around the borehole (Le Houerou 1980).

Figure 9. Animal traction tilling.

The introduction of cotton as a cash crop into Chad has compounded the problems of resource stress. Most of the suitable cropland is devoted to this "luxury crop". Cotton is now the first crop to be planted on a five year rotation with millet, sorghum, and peanuts. It requires a more fertile soil and, likewise, it removes more nutrients. The local government has supported cash crops because they bring in taxes and, in fact, the local government has been known to entice farmers into the production of cotton. Through personal experience I discovered Chadian government officials using foreign supplied disaster relief food to coax the farmers to plant the taxable cotton crop rather than the staple crops of millet and sorghum.

There are relics of irrigation projects that have folded soon after the foreign technican in charge left. The technology of irrigation, with the complex pumps that require imported parts and regular servicing, is simply out of place in Chad. The physical barrier to irrigation in Chad--the lack of an extensive, easily obtained water supply--restricts the impact (negative or positive) this technology could have on the economy and ecology. One should be aware of the consequences of substituting true desertification control efforts for this type of ephemeral treatment. As mentioned before, irrigation projects tend to build expectations that may be diaphanous.

Compounding the problems associated with the application of inappropriate western technology, agricultral development projects in Chad rarely cooperate for the optimization of resource utilization.

This lack of development cooperation is evident at both the local government and foreign assistance levels. The expatriate community is alive with reasons for this default in integrated cooperation. Some believe it is a result of intragovernmental jealousy, distrust, lack of communication, tribalism, or just a basic lack of interest to cooperate on the local ministerial level. These considerations could, and do, impede project cooperation, as all foreign assistance programs are subject to the control of a government ministry. The technical assistance community is also equally at fault for this deficiency in cooperation for many of the same reasons that apply to the host government offices.

The preceding represents a bleak picture of a so-called "developing" country with its critically misguided development priorities. Within this picture one should see a very poor country, very few natural resources, a fragile ecosystem, a virtually non-existent managerial infrastructure, and a very primitive level of technology. It is within this framework that a development agency must expect to work in order to "succeed". And success must be measured in terms of local values.

The following is a discussion of one such development project in which all efforts were made to utilize a technology appropriate for the cultural setting and goals set for the long-term stability of the ecosystem.

The Acacia albida Project

In June, 1976, CARE, with funding from the United States Agency for International Development (AID), set out to try an innovative approach to increase productivity and improve resource management in Chad. With the understanding that most agricultural development projects have been ecological as well as social failures due to the application of inappropriate technology, CARE undertook the advancement of local, "natural" technology. A technology, it was hoped, that would be socially acceptable and that could be replicated once the foreign advisor left the country. This technology involved the planting and protection of the Acacia albida species on marginal farmlands of Chad.

The actual planting and protection of the Acacia albida, although the central theme of the project, was not an end in itself. Rather, this conservation concept was to be a base of operations, understood by the people, from which a larger and all encompassing land management project could evolve. In other words, this popular and visible planting program would serve as a tool which could bridge the gap of communications amongst the various development agencies and the villages so that an integrated resource management program may develop.

The project proposed the planting of 100 seedlings of Acacia albida per hectare on 3,500 hectares of marginal farmland that was presently being cultivated by farmers. The 100 seedlings per hectare is five times the number of mature trees recommended by

Giffard (1964) as sufficient stocking to provide continuous cropping without the need of intermittent fallow periods. Due to the high mortality of seedlings this higher rate of stocking was considered necessary to insure the survival of the desired numbers of trees and proper distribution.

Cultivated fields were targeted for planting, rather than fallow fields, for three reasons:

1) The central concept of the project was to work with the local farmers and involve them as implementing agents. This follows Elkholm's (1976) reasoning that the local inhabitants must willingly participate and recognize their self-benefit before a conservation project will succeed.

2) Survival rates are much higher in cultivated fields than fallow land because of the extra protection the farmer provides against fire, grazing pressure, and grass competition (CARE 1978).

3) A third reasoning for planting in farmers' fields, and somewhat less probable, was related to one of the objectives of the project; to provide the farmer with a stable, high producing farmland (usually 2 hectares per family of five) so that he would no longer be obligated to clear additional land under the traditional shifting cultivation method.

This third reason is less logical because it takes Acacia albida 15 years to reach the stage of maturity whereby the soil is positively benefited. Since it takes only about five years for the depletion of soil fertility under the traditional cropping system, a farmer would abandon his Acacia albida-improved field ten years too early. Nevertheless, the tree would have had time, under his protection, to take root and would therefore eventually benefit the system.

Assumptions

Most foreign assistance projects concerned with agricultural or pastoral development in third world countries work on assumptions, both technical and social. The technological transfer process often assumes that the technology used in the developed country should work equally as well in the client country. Due to critical deficiencies of research and lack of expertise of western technicians in the Sahel, this assumption is often found to be faulty. A classical example of misapplication of technology is the use of western tilling methods on the fragile soil of the Sahel, as discussed earlier. The advantage of the agro-sylvo-pastoral program in Chad is that the "technology" of the *Acacia albida* is natural to the Sahel, time tested, and well studied by research scientists.

Assumptions concerning the social implications of rural development programming in the Sahel are yet more complicated as they deal with something as elusive as cultural nuances. It can hardly be expected that a technical expert can fully understand the cultural setting within which he is to operate. In fact, pretensions to understand often lead to the chronic problems of western ideas imposed upon unwilling villagers. This is not to imply that project designers and extension workers should ignore the cultural factors of development, but rather they should be sensitive to the needs of the villagers and include local level input into the planning processes as well as the implementation phases.

Mbithi (1974) lists five arguments for the need of local level involvement in the planning and implementation of rural development projects:

1) The change agent assumes he knows what is best for the client).
2) The change agent is often not familiar with the client's felt needs, perceptions, and resource constraints.
3) Change agents differ in socio-economic status and ethnic affilitation and therefore local people do not rely on their advice.
4) Under the strategy of land imposition, continuation depends upon the continued presence of the change agent.
5) Change agents see rural poor as homogeneous and do not recognize sub-groups and differences in cultures from one village to the next.

These are universal problems in rural development and the Chad project is no exception to the rule. The fact is that an idea--that of planting and protection of the Acacia albida species--was to be imposed with the critical assumption that the local inhabitants understood or could be taught the benefits provided by the presence of the species. This proved to be the weakest point of the project. Farmer understanding was so critical to the success of the program but yet was based on nothing more than western hope and expectations.

The program design included an initial questionnaire component in order to obtain some semblance of understanding of local needs, perceptions, and resource constraints. This quesionnaire sampled all locations of the project in order to canvass the various tribes and detect cultural differences. Time and language constraints rendered this endeavor practically worthless. The western oriented project managers (Americans) spoke in broken French, through a translation to Arabic, to the villagers whose mother tongue was any of a number of local dialects. The translators (French to Arabic) were Chadian Forest Service agents of the ruling class tribe (Sare) which was not trusted by the other tribal groups. Project managers could detect a sharp difference in response when comparing answers to questions by other members of the Sare tribe versus members of other tribes. The Sare tribal members were the most responsive to the project.

Therefore, out of necessity, and hopefully fairness to all tribal members, the program was standardized. One policy for operation was applied with all participants. This was done at the expense of adjusting to the various cultural differences.

Thus the project began with the ubiquitous assumptions that the local people could be trained to understand and appreciate the benefits of the planting and protection, and that three years later, in the absence of foreign technicians, the idea would live on. This point will be addressed in more detail below under the section "Interest Generated".

The Target Area

The target area consisted of marginal farmlands just north and south of the 400 mm rainfall belt. This land included the arid fringes of the desert between latitudes 10° and 13° north, with annual rainfall ranging from less than 200 mm in the north to 700 mm in the south. Annual rainfall variability ranges from 40 percent in the north to 25 percent in the south of this zone. Vegetation types in this zone included tree steppe, shrub savanna, and wooded savanna (refer to Appendix for vegetation and soil types).

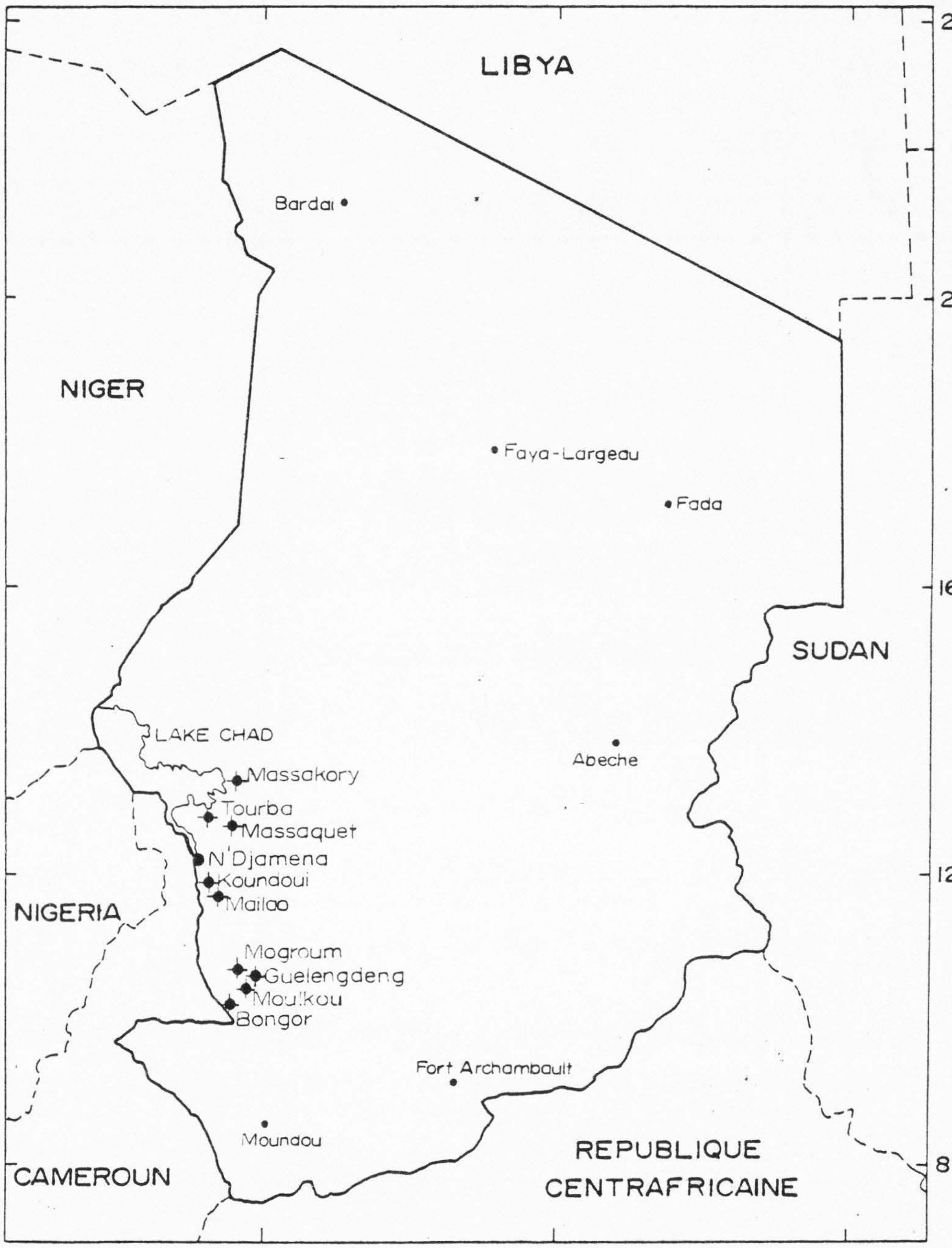
The land was inhabited by various tribes of sedentary farmers and pastoralists including the Sare, Moundan, Fulani, Arabs, Toubouri, Massa, Baguirmi, and Kotoko. Of these only the Sare, Moundan, Toubouri, and Massa had a traditional understanding of the Acacia albida. Cultivated crops included millet, sorghum, cotton, and peanuts. Grazing livestock included cattle, sheep, goats, and camels (for livestock production information refer to Appendix E). Elephants are also important in the higher rainfall areas.

This area was selected in order to demonstrate project technology in the most critically affected zone of the desertification process (Figure 10).

Project implementation

Eight nursery and extension centers were established in various locations ranging from 150 kilometers north and 250 kilometers south of N'Djamena (Figures 11 and 12). Local villagers were hired and trained to run the nursery operations. All efforts were made to establish nursery techniques of seedling propagation commensurate with locally obtained materials and understanding.

Approximately 2,500 farmers and their families participated in the revegetation effort. The targeted 3,500 hectares were all planted by the third growing season. The planting-out and nursery



✦ Nursery and extension center locations.

Figure 10. Chad: Project sites.

Figure 11. Nursery scene north Tourba. Note the fence construction of thorny branches.

Figure 12. Nursery scene south Bongor. Note grass matting fence and more humid conditions.

operations were critical steps in the success of the project. They required a well organized campaign to insure all seedlings were in the ground within a two week period at the onset of the rainy season. This planting-out component of the program proved to be clearcut in terms of social and environmental complications, especially in comparison with the truly difficult task of protecting the seedlings in the field. It is one thing to get the seedling in the ground, it is another keeping it there.

In the first year of operation, 54,000 seedlings were planted on 540 hectares of cropland. Within the course of the following year there was a mortality rate of 73 percent, resulting in only 14,500 saplings surviving the first season. In the second planting season the total number of seedlings planted was 285,500. During the course of the second year there was a 41 percent die-back bringing the total number of surviving saplings to 178,000. This decrease in mortality rate was in part due to a stepped-up protection program, and in part to the fact that second year seedlings have a much higher survival capacity. During the third planting season (1978), 292,000 seedlings were planted. It was projected that a combined first, second, and third year mortality rate of about 26 percent, of the total 470,000, would result in 350,000 seedlings surviving by the fourth year (Figure 13).

This rate of mortality is to be expected in the Sahel and is attributable to environmental and cultural factors. Grazing pressures caused the highest losses. Acacia albida is highly palatable to all herbivores, as mentioned earlier, and being one of

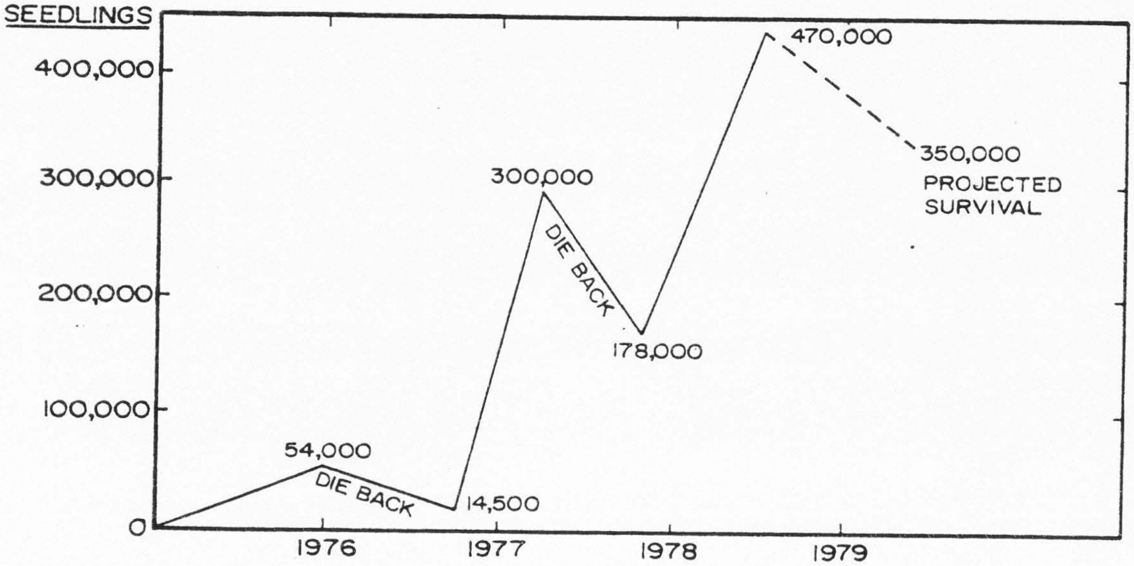


Figure 13. Acacia albida seedlings planted and survival rates.

the few plant species with green foliage during the dry season, it was readily taken if not protected. Perimeter fencing of the land was not possible or desired as this would disrupt the traditional grazing patterns of the nomadic herder. Furthermore, imported fencing materials that would resist the rigors of the environmental conditions were highly prized by the local villagers and rapidly disappeared. Instead, the laborious task of fencing each individual tree with locally obtained material, such as thorny branches, was undertaken (Figure 14).

Uncontrolled range fires also took a heavy toll of the young seedlings. Convincing the villagers and nomadic herders to refrain from their traditional burning habits was an exercise in futility. Here again, the only solution proved to be another major task; that of clearing fire lines, two meters in radius, around every seedling. This clearing of the native grasses also served to release available soil moisture competition in favor of the seedling.

Where termite infestation occurred, insecticides were applied on a tree-by-tree basis. It was also necessary to protect the fencing material from the ravaging termites by a crankcase oil and insecticide treatment. Crankcase oil was used because it was more easily obtained and less expensive than commercial wood preservatives.

There were, of course, environmental factors completely outside the control of project management. The periodic droughts could not be controlled. The rainy season normally lasts about two to three months in this part of Africa, leaving a pronounced dry period the rest of the year. For a seedling to take root before this long

Figure 14. Individual fencing with millet stock (treated).

intense dry period, it would have to be planted early during the rainy season, but only after the soil was moist 40 cm deep (CARE 1977). Correct calculation of the planting time was very critical to seedling survival, but unfortunately it was highly dependent upon luck. If there was a two-week dry period immediately after the seedling was planted, which was highly probable, chance of survival was greatly decreased. Another seedling mortality factor, beyond control of the project management, was elephant damage. Elephants selected out Acacia albida saplings as preferred browse (CARE 1977). The elephant's habitat has since been avoided as a matter of project policy.

Technology transfer problems in the rural setting

The overriding influence in seedling survival concerns the interest generated by the farmer who plants and protects the seedlings on his farmland. Survival depends upon the participant's understanding the purposes of establishing the tree on his land, and the benefits this promises to bring. In attempts to assure this village level understanding, where it wasn't already part of traditional knowledge, an intensive training and sensitization program was initiated. Films were made, talks were given, and demonstrations were presented. All of the conventional western extension tactics were employed to promote the idea of Acacia albida for proper land management. Interest was generated, although the reasons for this interest may not have been exactly the reasons one would have hoped for. One CARE employee paraphrases this sentiment well in saying that "we are the only show in town" (Figure 15).

Figure 15. Family members actively participating.

It was necessary to prop up the extension efforts with an incentive policy to allure the initial participation of local villagers into the revegetation scheme, and to encourage continuous protection of the planted fields. This incentive component involved the distribution of American-donated food commodities (called "food for work"). This, with reason, is a strongly criticized policy. Many will contend that giving of food will create a dependency and that the villagers will feel that they must be compensated for their efforts to help themselves. This can definitely be a major problem; however, project experience has demonstrated that initiation of participation is simply not possible without this food, or some other incentive. Actually, the Chadian Chief of the Forest Service suggested cash payments would be necessary.

This prerequisite of an incentive policy indicated that "willing participation" has not been obtained. Nevertheless, the project proceeded. Failure to obtain willing participation before project implementation has begun is not uncommon for rural development projects. A closer analysis and comparison of this program to the "traditional approach" to rural development as outlined by Mbithi (1974) might lend insight into the social factors of technological transfer failure.

Mbithi (1974) outlines four categories of neglect or miscalculation by which the traditional approach renders a rural development project culturally unacceptable. These are:

1) Local participation in the planning process is often neglected, thus neglecting local requirements such as

adapting introduced technology to the religious ritual and social constraints, so basic to the prescribed behavior of village life.

2) The traditional approach often neglects to identify, mobilize, and allocate local resources to their best potential. This would include the identification of sub-units of rural society such as age and sex groups, kinship groups, and neighborhood groups and then work through these groups.

3) Extension agents, government officials, and local progessive people are often separated from clan leaders, village notables and ritual experts due to differences in socio-economic status and ethnic affiliation. This disrupts the effectiveness by which change can be instituted.

4) Development programs are often imposed upon rural communities irrespective of expressed needs and abilities.

This project made an attempt to solicit local participation in the planning process in order to fit the project to local standards. The questionnaire stage of the project was discussed earlier. Basically, time constraints, ethnic incompatability, and communication problems limited the success of this component.

Time was a limiting factor because the project was forced to produce before the rainy season or lose funding credibility. Ethnic and language problems limited the free-flow communications with the various tribal groups. As a result, for all practical purposes, there was no effective local level planning in this program.

The project did identify and mobilize local subunits. In most cases the village chief (Blahma) or religious head (Sultan) was the instrument of administration. This element of the project was very effective and a most successful extension arrangement. The ethnic diversity of the area, as discussed earlier, presented insurmountable obstacles for complete coordination of activities, however. People of different tribes in this part of the Sahel (and probably others) simply do not work together.

This project was very heavily burdened by the traditional problem of incompatability between government extension agents and rural villagers. The extension agents, being mostly from the governing tribes, Sare and Moundan, were disliked and not trusted by other ethnic groups. These government agents, mostly from the Chadian Forest Service, assumed a paternalistic arrogance in their extension methods. They were well trained technically but poorly prepared to communicate ideas to the rural villagers. They could not motivate farmers to the idea of the agro-sylvo-pastoral program but rather could only pass on the message--and this, poorly. As desirable as it may seem, and as unavoidable as it is to have local government extension assistance in rural development, this was certainly another inherent barrier to project acceptance on the part of the rural villager.

Finally, as it has already been indicated, a rural development program is imposed upon a people, using food incentives where social integration and manipulation failed. Does this constitute failure of the project? A clear-cut answer is not apparent. The project was a partial success and a partial failure. It was a technical success in that it reached its goal of planting 3,400 hectares and involved over 2,000 farmers in this effort.

It was also successful in coordinating the interest of various technical assistant groups working in the country. Swiss Aid began to interplant *Acacia albida* on their agronomic demonstration plots, and rated the *Acacia albida* project as the best idea in agricultural and pastoral development in Chad (Charriere 1978). The United States Peace Crops assigned five volunteers to the project. Among others who participated were the French Development Agency, SATECA, the Catholic Church mission in Chad, the Cooperation Swiss, the local Lions Club, and the German agency, Bread for the World. The funding agency, AID, was interested in continuing the funding necessary for the protection of the young *Acacia albida* seedlings throughout the critical early years of growth. Local governmental officials demonstrated their interest by making periodic visits to the project and lending their support to the land management concept.

On the sociological scale the project may be considered a failure by some. This would be indicated by the requirement of an incentive to assure long-term participation. The 15-year delay before benefits are realized cannot be overlooked while evaluating the impact of this project on a people living on a subsistance economy. It has been observed that African languages often do not allow for a future tense (Mbiti 1970). This could definitely handicap a project with future goals. It would certainly appear, therefore, that the change agent (i.e., CARE) would be required to remain active in the project until benefits can be seen by the recipients.

If it is fundamentally agreed that the change agent should remain throughout the life of the project (which is not normally the case) another barrier is imposed by the funding agency. AID, as an example, will only fund a project for periods of three years at a time. At the end of each three year period continued funding is dependent upon proven success (i.e., increased animal production. increased agricultural output, increased rural jobs). This project, by nature of the biological time constraints, requires much more than three years to realize production gains or social changes. For this reason a program such as this is less likely to receive continued financial support than irrigation, veterinary improvement, fertilization projects, or other highly visible, short-term projects. It is imperative that a project with such far-reaching goals as this continues to be motivated by the extension agent until the participants see the results of the efforts and become "willing participants". If not, the project is a failure.

Unfortunately, this project did not continue. However, the reasons had nothing to do with the inherent problems of the traditional rural development programs. The sudden and unexpected end of the project due to the cou d'etat of 1979 underlines the ultimate prerequisite for a successful desertification control project--a stable governmental structure within which to work.

CONCLUSIONS

The desertification process is a complex web of environmental disturbances and its control is confounded by the layrinth of social and ecological complications. "Modernization" has reached a stage in the Sahel such that a return to traditional ways would not be possible, even if desirable, as a means to check the "desert creep". It is in the interest of the developed world to work with the affected countries to find an ecologically sound and socially acceptable solution to the degradation problem. The environmental understanding to apply conservative land management is available, but because of social and cultural differences, the framework within which it may be properly applied has not yet been developed.

A suitable framework for development and conservation of the Sahelian ecosystem must involve a unified effort on the part of all sectors of agricultural and livestock production to ensure proper utilization of the land's resources. Development efforts in the Sahel, however, do not have a history of such cooperation; coordination of efforts will only come with coordination of interests. The unique multi-use characteristics of *Acacia albida*, built into a rural development project, could be a device to focus related interests and forge cooperation between development efforts that have obvious ecological connections. This facilitation may ultimately be more helpful to the recipient country than the direct benefit of *Acacia albida* plantations to the agricultural and forage resources of the land.

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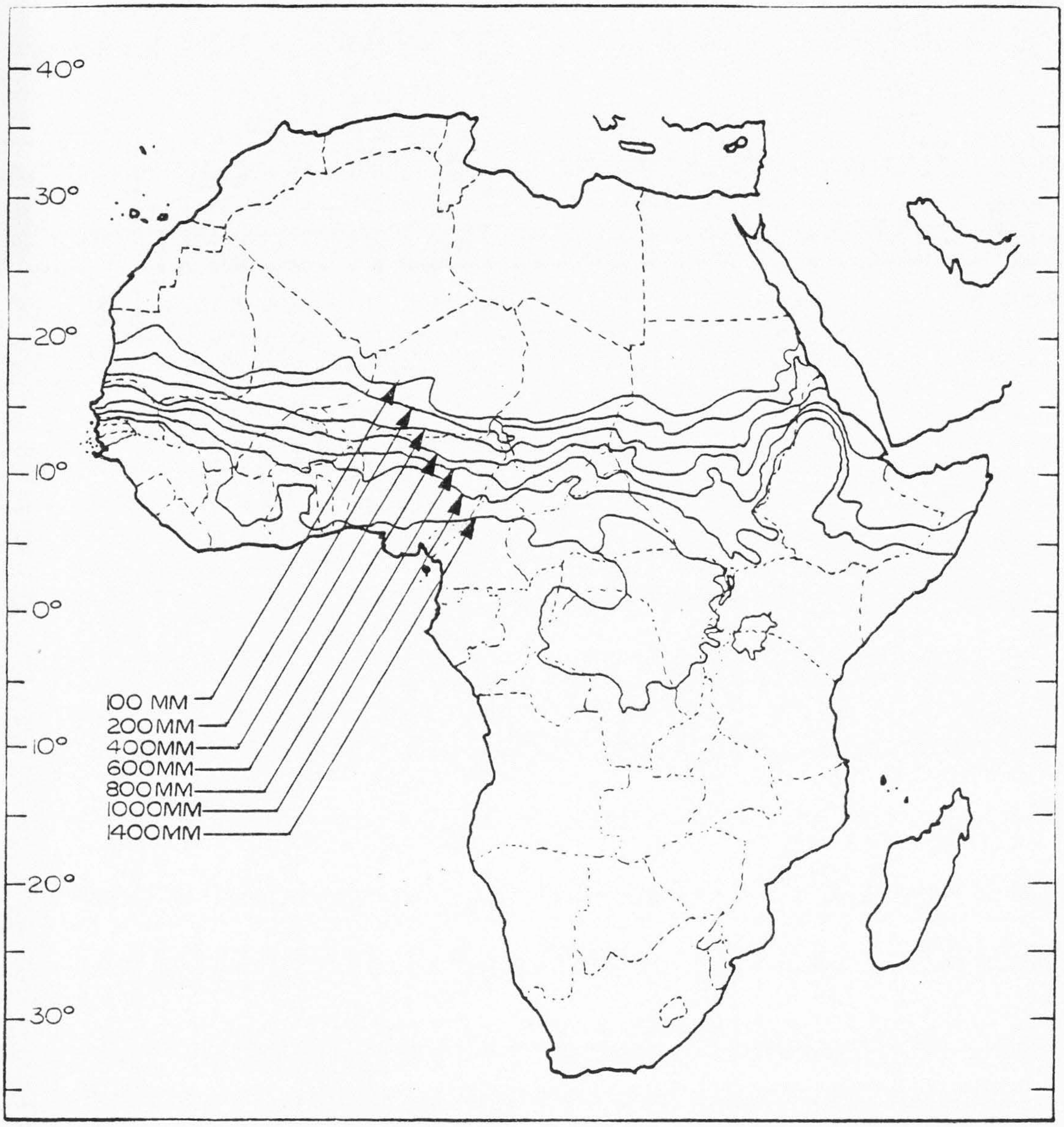
APPENDICES

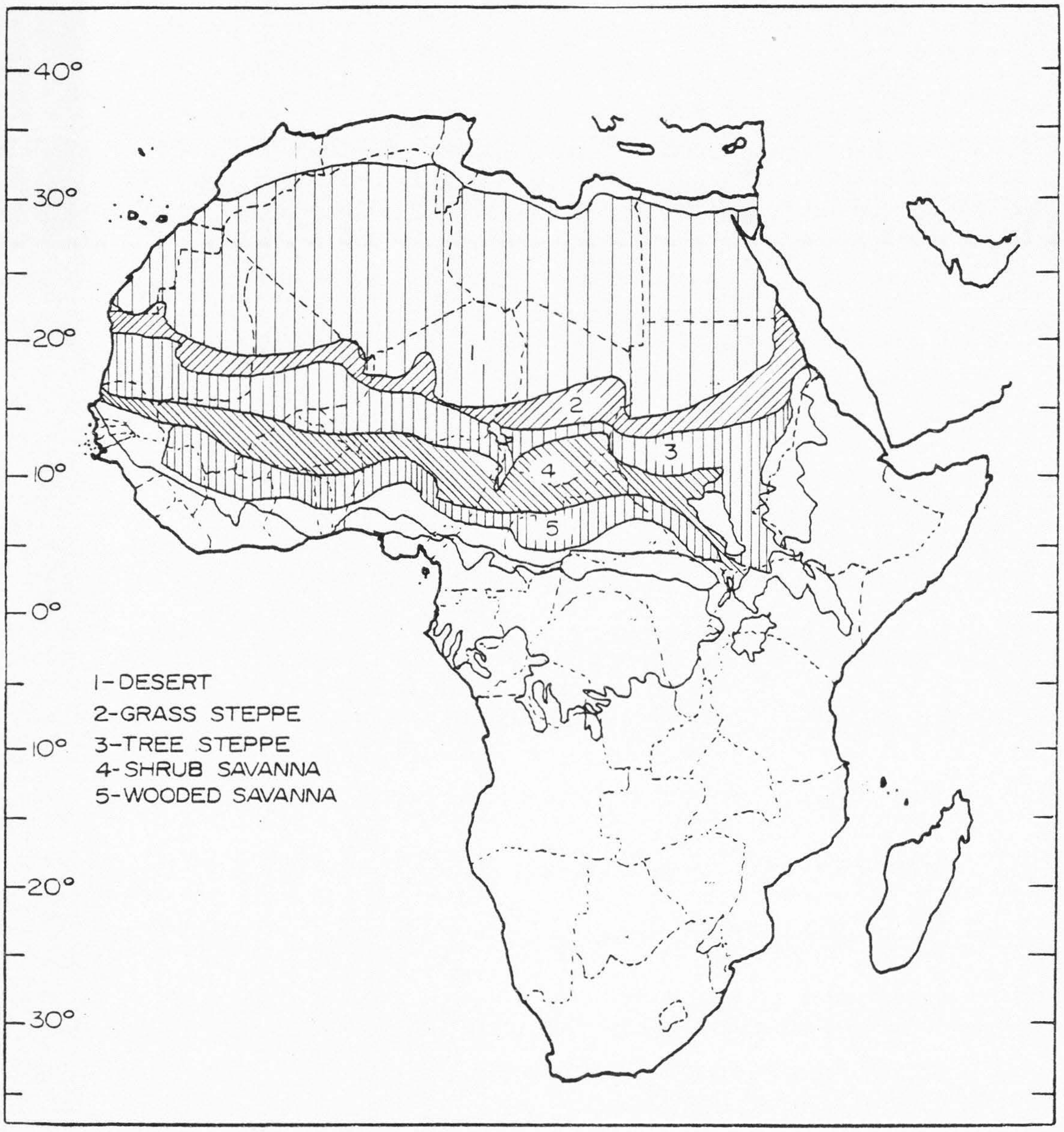
Appendix A

Climatic Map of the Sahel


40°
30°
20°
10°
0°
10°
20°
30°
100 MM
200MM
400MM
600MM
800MM
1000MM
1400MM

Appendix B

Vegetation Map of the Sahel


40°
30°
20°
10°
0°
10°
20°
30°
1
2
3
4
5
1-DESERT
2-GRASS STEPPE
3-TREE STEPPE
4-SHRUB SAVANNA
5-WOODED SAVANNA

Appendix C

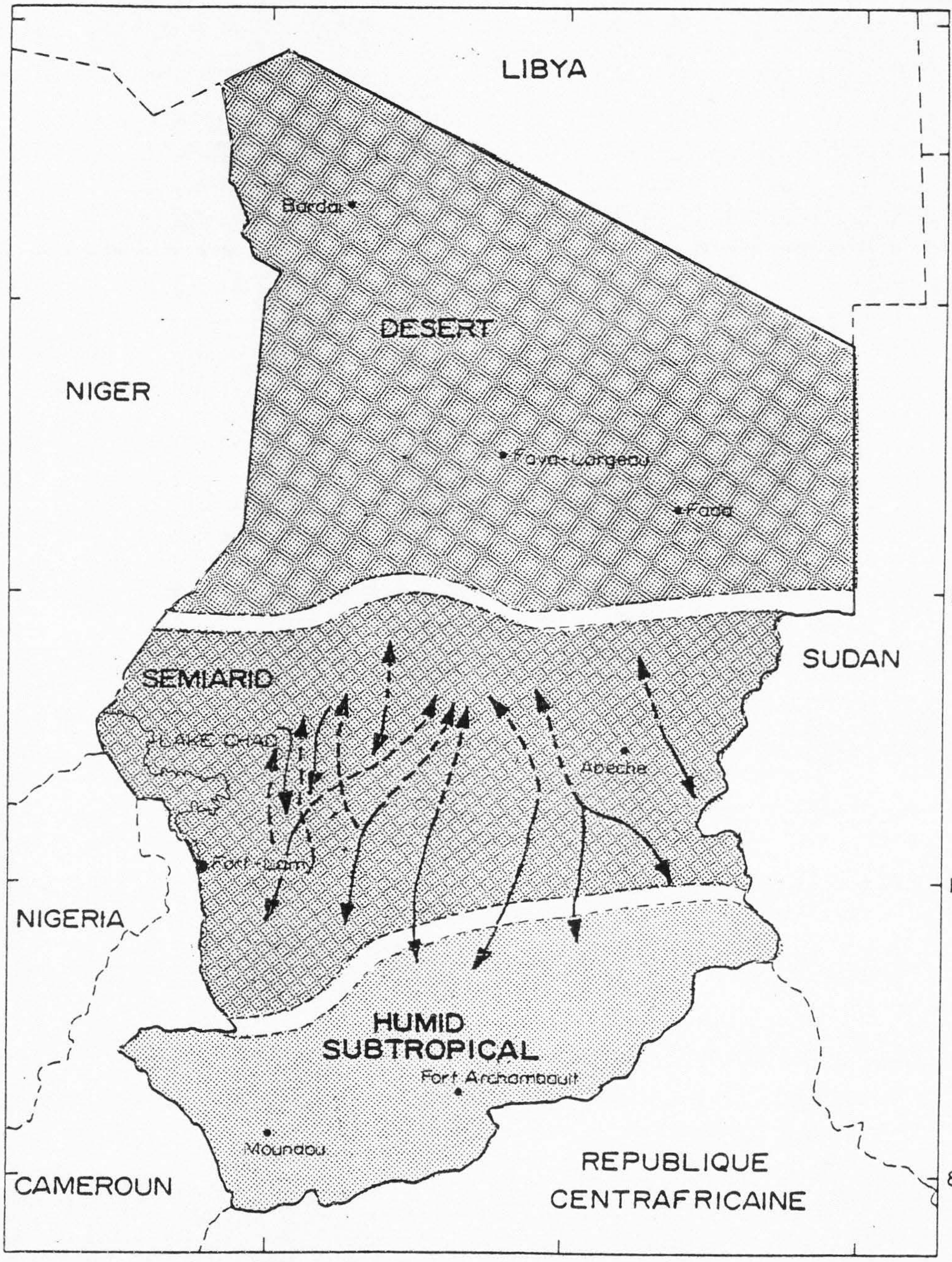
Vegetation Zones of the Sahel

VEGETATION ZONES

Rainfall mm/yr	Climatic Zones (Aubreville)	Vegetation Classification (Yangambi)	Active Period (M)	Herbaceous Cover	Woody cover	Soils
100–200	Sahelo-Saharian	Grass Steppe	1	Panicum turgidum	Acacia tortilis Acacia ehrenbergiana	aridisols (USDA) xerosols (FAO)
200–400	Sahelian	Tree Steppe	2-3	Aristida mutabilis Aristida siberana Schoenefeldia gracilis Echinochloa stagina	Acacia senegal Acacia tortilis Balanites aegyptica Commiphora africana	Brown soils Highly saturated nonkaolinitic clay complex OM well distributed throughout layer Abundant undecomposed OM
400–600	Sahelo Soudanien					
500–900		Shrub Savanna	3	Cenchrus biflorus Eragrostis tremula Loudetia togensis	Acacia albida Combretum glutinosum Sclerocarya birrea Acacia seyal Pterocarpus lucens	Ultisols and altisols Ferric luvisols (FAO) Ferruginous tropical soils on sandy parent material and on misc. rock. reddish brown in color OM confined in uppermost layer fair amnt undecomposed material
600–800	Soudaneo Sahelien					
800–1200	Soudanien					
900–1200		Wooded Savanna	4	Andropogon gayana Diheteropogon hageruppi	Anogessius Leiocarpus Combretum nigricans Butyrospermum paradoxum	

Appendix D

Climatic Map and Grazing Patterns of Chad



LIBYA
Bardai
DESERT
NIGER
Faya-Largeau
Fada
SEMIARID
SUDAN
LAKE CHAD
Abeche
Fort-Lamy
NIGERIA
HUMID SUBTROPICAL
Fort Archambault
Moundou
CAMEROUN
REPUBLIQUE CENTRAFRICAINE
24°
20°
16°
12°
8°
16°
20°
24°

Appendix E

Livestock Production Information of Chad

Cattle Production in Chad

Cattle Production

Calving rate: 50-55%
Age first calf: 3-4 years
Death loss: 30%
Age to reach market weight: 5-7 years
Market weight: 300-500 kg
Offtake: 7-10%
Annual herd increase: 3%

Diseases

Trypanosomiasis
Foot and mouth
Streptothricosis rabies
Tuberculosis
Contagious bovine pleuropneumonia
Rinderpest
Anthrax
Blackleg
Brucellosis

Cattle Breeds

Zebu (humped cattle)

A. Short-horned
   1. Azaouk or Adar
   2. Wadara or Shuwa Arab
   3. Sokoto Guadali

B. Medium-horned
   1. Adamawa or Ngaundere

C. Lyre-horned
   1. White Fulani or Bunaji
   2. Nigerian Fulani

D. Long-Lyre-horned
   1. M'Bororo, Rahaji or Red Fulani

Source: Carter & McLeroy (1968).

Appendix F

Research Needs and Recommendations

1. Acacia albida is a well studied species; however, there does not appear to be an agreement on the nitrogen fixation abilities of the species. The A. albida is a legume but the presence of nodules is a debated issue. Personally I have not seen nodules on young seedlings but this may be due to the fact that the growth medium was not inoculated. Whether or not seedlings require inoculation for optimum growth and development would be a worthwhile question.

2. Grazing or clipping studies to determine physiological reactions of the plant are needed. Interesting questions would be:

--when should A. albida be grazed to stimulate leaf growth?

--when should it be grazed, after planting, to maintain a shrub form for forage purposes?

--how should it be pruned by herders so as to avoid damage to the plant and stimulate maximum growth?

--what is the proper use factor?

3. Studies into the possibility of vegetative propagation are required. This may provide a means by which quality varieties may be maintained. Seed selection studies may also be a possibility of quality control. The Chad Acacia albida project did involve some rough demonstrations in seed selection. Seeds were collected from the northern sector of the project, Tourba, and planted in the more humid southern sector. Observation of the growth form indicated that the seedlings of northern arid zone seeds grow straighter and without branching while seedlings of southern seeds spread out in growth form.

4. Chemical protection (repellents) against grazing pressures in the early stages of development needs investigation. This could eliminate the costly and time consuming task of individual fencing and greatly expand the scope and impact of a revegetation project.

5. Long-term influences on the hydrologic balance should be studied on lands that have been aforested into *Acacia albida*. Special attention should be paid to the effect on the water table.

6. Water harvesting techniques should be studied in relation to their influence on survival rates of the *A. albida* seedling. An example of this technique is the herringbone dike (Weber 1978).

7. An interesting question not yet answered is why the *Acacia albida* loses its leaves during the rainy season, unlike any other species of the Sahel.

8. Sociological studies of methods by which farmers may be encouraged to participate in an *A. albida* related planning and protection program. Negative effects related to the use of food incentives should be weighed against the positive effects of the conservation program in general. A population's culture may be compromised by the use of food incentives while the land's capability to support the population may be in jeopardy if nothing is done to institute proper resource management techniques.

9. A new breed of resource managers to lend technical assistance to countries afflicted by deteriorating ecosystems is required. This new breed may be called human ecologists and should be trained in resource utilization for livestock and agricultural productivity within an ecological framework, while understanding and being sensitive to the cultural setting.