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Deterioration of a sustainable agro-silvo-pastoral system in the Sudan: the gum gardens of Kordofan

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Abstract. The development and establishment of agroforestry systems is often suggested as a way to stabilize rural economies in developing countries [King, 1979]. At the same time, some traditional systems are being lost, due to an inability to protect the perennial or tree crop components of the system. These traditional systems and the forces that reinforce or destroy them should be carefully studied by those in the process of encouraging adoption of agroforestry systems in the developing world. The gum gardens of Western Sudan are a case in point. *Acacia senegal* (hashab*) and *Acacia seyal* (talh) are the two major marketable gum-producing trees found in the western region of Sudan. The *Acacias* are grown as part of an agro-silvo-pastoral system that has persisted for more than a hundred years in Kordofan Province, where 70% of Sudan's gum Arabic was once produced, as well as most of its grain and livestock products. After a lengthy drought lasting from 1979 to 1985 gum production in Sudan drastically decreased. It was reported that pest attacks and drought were major causal agents in the decline of gum production [Awouda, 1989; Sungar, 1986]. A survey executed in Northern Kordofan Province, starting in August of 1986, did uncover a great number of dead *Acacias* due to drought and pest attack, but from interviews with gum farmers we conclude that the decline in gum production is largely due to unfavorable socioeconomic relationships exacerbated by the drought, leading to the deterioration of the agroforestry system of production. An inability to get a fair price for gum at the local level and increasing emphasis on a cash economy led to the neglect of the tree components of the system. The gum gardens have long flourished with the intensive husbandry of small-scale farmers. Once these farmers were no longer able to care for them, the gum trees disappeared from the system, indicating that a lack of community stability can be fatal to even a well-developed agroforestry system.

Introduction

Gum Arabic, produced by gum *Acacia* trees, has been traded commercially for some 2000 years and is thought to have been used by the Egyptians to make inks, water colors, and dyes. It was traded to Medieval Europe through the Arabs, and came to be called gum Arabic [Awouda, 1989]. Although gum-producing trees are found worldwide, some of the finest gum in the world market is produced from *Acacia* stands well-adapted to the semi-arid zones of Western Sudan. Of the 36 varieties of gum-producing *Acacias* found in Sudan, the major producers of marketable gum are *Acacia senegal* (hashab) and *Acacia Seyal* (talh). Highly drought-resistant, they are grown as

* Common names are given in Arabic.

part of an agro-silvo-pastoral system that has proven sustainable for at least 200 years, and provided a natural buffer zone between the desert in the north and the agricultural tall grass savanna to the South [Awouda, 1989]. *Acacias* have a significant soil stabilizing effect, reducing or halting Desert-creep and sand dune movement [Sudan, 1976]. Nitrogen-fixing and valued for understory cropping, fodder, and mast, the *Acacias* are part of agro-forestry systems that are also major suppliers of Sudan's grain and livestock.

Sudan, one of the largest countries in Africa, was once among the biggest exporters of gum Arabic in the world [Flowerman, 1985]. The population of Sudan is predominantly rural and is primarily involved in subsistence agriculture. Industry is a distant second to agricultural production and most manufactured consumer products are imported. In the 1970's gum was one of Sudan's most important sources of foreign currency, third only to cotton and sesame exports, providing 80% of the world's supply [RAFI, 1986]. Gum Arabic production was once an important contributor to community stability: together with understory crop production, it provided a steady income for the sedentary agriculturist population [Forestry Department of Sudan, 1984]. But after a lengthy drought lasting from 1979 to 1984, gum production in Sudan drastically decreased.

Gum is used in textiles, confectionaries, paper, ink, rubber, glue, and for a variety of other products. Despite efforts to promote synthetic substitutes, worldwide demand for natural gum is increasing, stimulated by markets for 'natural' and biodegradable products [Jamal, 1989]. But after the drought, harvests from the rich gum gardens of Northern Kordofan continued to decline. The breakdown of the gum *Acacia* agroforestry system not only reduced gum production but threatens the stability of the Province's rich agricultural soils. Kordofan was one of two provinces termed the 'Grain Basket of the World' in 1961 [Khalid, 1985], and still furnishes Sudan with most of its grains. In addition, the region has enormous animal wealth, supporting up to about 20 million head of cattle, sheep, camels and goats [Awouda, 1989].

Because gum *Acacias* are highly resistant to drought, it was the conviction of government officials that pest attacks, stimulated by drought, were major causal agents in the decline of gum production. Sudan's Gum Arabic Company, which holds a monopoly over gum sales, contracted with the National Council for Research to investigate the main reasons for declining gum harvests. Beginning in August of 1986, a survey was carried out in the once-rich markets and production zones of the Gum Belt (Fig. 1). The survey included field surveys and collections of insects, but also a questionnaire administered to farmers, gum merchants, villagers, and the Central Market public officials who deal with classifying, distributing, and selling gum [Jamal, 1987]. While the survey did find that a great number of *Acacias* died in the region due to drought and pest attack [Jamal, 1987], based on the results of this questionnaire, interviews, and observations made during the survey, we conclude that the decline in gum production is largely due to unfavorable

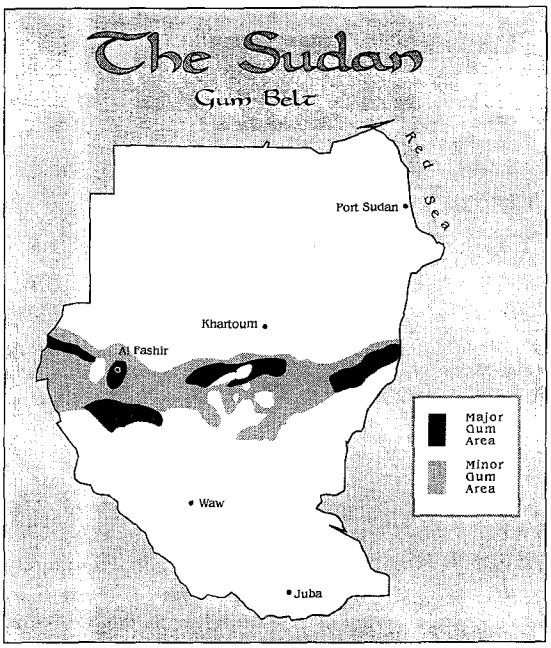

Fig. 1. The Gum Belt of Sudan.

socioeconomic policies and relationships that were only exacerbated by the environmental conditions. This paper discusses the decline of this once-sustainable agro-silvo-pastoral system and explores the interaction between socioeconomic and ecological conditions in driving this decline.

Study area and methods: the Kordofan Gum Belt

The bulk of gum-producing *Acacias* grow in an area known as 'the Gum Belt' stretching from the Ethiopian border through Central Sudan and across Chad into Senegal, where the main gum-producing trees were first identified by Lineaus in the eighteenth century (Fig. 1). The Gum Belt runs halfway along the North and South Provinces of both Kordofan and Darfur Provinces, from latitude 11° to 16°, which together produce the equivalent of 90% of Sudan's total yield. Kordofan Province alone furnishes more than 70% of national gum Arabic production. In Sudan, particularly in Kordofan and Darfur, the distribution of the species is relatively uniform, and the trees are found in pure stands, giving the Sudan area the distinction of not only being the most extensive gum-producing area but also the producer of the highest quality gum. In other gum-producing countries distribution is irregular, and the gum trees are often intermixed with other species. Another comparative advantage is that in Sudan gum Arabic trees occur over wide areas in both wild and cultivated conditions, allowing some economies of scale.

The soil types of Northern Kordofan, along which the Gum Arabic Belt runs, favors the Gum Arabic *Acacias*. These soils are mostly coarse alluvial sands and sandy soils on the plains at the foot of hills; face types are gravelly or red ferrous oxide. Many drought-resistant and arid soil-adapted tree species are found in these areas, such as *Ziziphus spinachristi, Leptidinia pyrotechnica, Pithecolobium dulce, Balannites aegyptica, Calotropis procera, Prosopis chilensis* (*P. julifora*), *Calatotrops* spp. and *Acacia* spp. The *Acacias* are the most common trees and, of these, the most valuable for rural communities are the gum Arabic-producing trees *A senegal* and *A. seyal.*

There are three major *Acacia*-growing soil types in the central part of Kordofan Province where most *Acacia senegal* and *Acacia seyal* is grown:

1. Sandy (*Goz*) areas. Found mostly in the north parts of the Gum Belt.
2. Rich sandy-clay soils (*Gardod*). Found near seasonal rivers (*Khors*).
3. The dark non-cracking clay soils (cotton soils) found mostly to the south of the Gum Belt [Shams, 1986].

Annual precipitation in the gum belt ranges from 300—600 mm in sands and 600—800 mm in clays [Smith, 1951], increasing from North to South. The 1986 survey itinerary began and ended in El Obeid and included routes leading to El Debeibat, Bara, Um Kiriadim, El Mazroub, El Khuwei, El Dallang and, finally, as far south in Kordofan as Kadugli (Fig. 2). El Dallang is outside the Gum Belt zone, but is becoming increasingly active in the production of lighter gum (*Tark-tark*) from *Boswellia papyrifera*, used mainly in incense burning during most occasions and ceremonies in Sudan. A study tour was also carried out in El Damokia Hashab Research Forest area, 50 miles south of El Obeid, and 20 miles east of Khor Takat. The Research Forest is a 24-ha reserve where stands of hashab and talh of a variety of provenances are grown and managed by the Western Sudan Research Project (WSARP)-Agricultural Research Corporation.

The vast size of the province, and the geographical differences among communities made it difficult to use any one set of standardized procedures for studying all the different gum gardens. All the gardens along the route were inspected and damage due to pest attack, over-tapping, overgrazing, and/or burning was recorded. The following methods were used to further explore the issues involved in gum production in Kordofan:

1. Open interviews with individual farmers and group interviews, totalling 120 farmers throughout Kordofan's gum-producing region.
2. A historical analysis of the experience of the farmers with gum trees and of the savanna communities with the agroforestry system. Information was gathered through dialogues with Central Market officials, Gum Arabic Company personnel, researchers and technicians from WASRP, the Forestry Department of Kordofan, the Central Government's Ministry of Agriculture and Natural Resources, and International NGOs involved in Agroforestry programs in Kordofan.

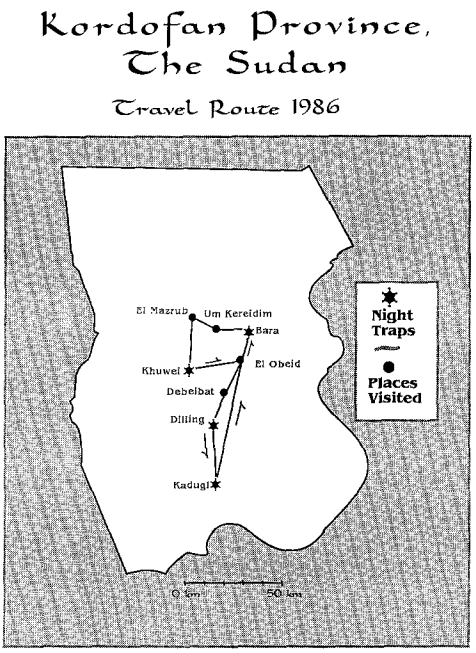

Fig. 2. Kordofan Province, Sudan.

3. Focused interviews with community individuals or groups to elicit criteria and preferences in gum production management. Interviewees were asked their reasons for various preferences and ranked their difficulties and priorities in production.

Gum Arabic production in a complex agroforestry system

Limited commercial gum Arabic production has been known in the western regions of Sudan since the last century, when farmers tapped *Acacia* mainly for medicinal purposes and other traditional handicrafts. It was not until the beginning of the twentieth century that farmers were approached by a French private company in view of supplying their industries in South of France with the globular crystals needed to produce glue, food additives, and other products [Salih, 1987]. From that time, until about 1984, internationally-based gum Arabic markets flourished every season. Arab merchants from central Sudan flocked to El Obeid Central Market, the capital of western Sudan, to buy gum to sell in the central markets of Khartoum (Fig. 2). From Khartoum the gum is transported to the Red Sea coastal city of Port Sudan, and then shipped to Europe.

The shift from gum production as a locally used product to a commercial

product in the world market did not significantly alter the pattern of growth and harvest by the farmers of western Sudan. Trees were abundant and the world market demand increased even as supply decreased (Fig. 3). Most of the commercial gum *Acacia* trees, especially *Acacia senegal* and *Acacia seyal*, grow and propagate naturally in farmer's plots [Awouda, 1986]. In addition, *Acacia senegal* may be sown with the last agricultural crop or they may re-sprout after old unproductive trees are coppiced [El Houri, 1989].

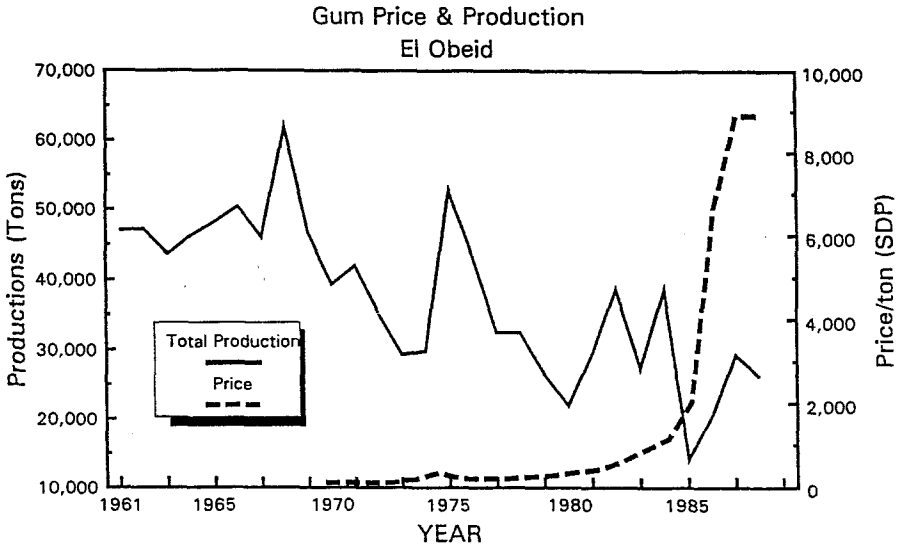

Fig. 3. Total production and price per ton of gum Arabic at El Obied, 1961—1988 (El Obeid Central Market records).

In the wet summer months, farmers in western Sudan reported that they grow cereals, mainly sorghum (*Sorghum vulgare*) and millet (*Pennisetum purpureum*) as food and fodder crops. These basic food grains are alternated with sesame (*Sesamum* spp.) or hibiscus (*Hibiscus* supp.) plantations as major cash crops. In the hot, dry climate of Kordofan, farmers stated that they appreciate the shade of the gum trees. But farmers indicated that the *Acacias* also serve a variety of other functions: fruits are used to make beverages for medicinal purposes, and mast and leaves provide nitrogen-rich fodder for domestic animals when grasses are dry and of little nutritional value. Finally the trees are tapped for their gum, a major source of cash income. The farmers interviewed were also aware of the stabilizing effect of the *Acacias* in reducing or halting Desert-creep and sand dune movement, and observed the enhanced fertility of the land underlying the nitrogen-fixing *Acacias*. The farmers are very motivated to keep a number of *Acacia* trees in their garden and indicated that gum trees are allowed to grow wherever they reproduce.

The role that livestock grazing management plays in the system is particularly interesting. Farmers may have camels, goats, sheep, and/or a few cattle, and report that they graze in the gum gardens when understory crops are fallow, making use of the grass and the fallen pods of gum trees. In addition, farmers stated that nomad camel caravans have some traditional grazing rights in the region. The caravans pass from north to south in the summer, from March to July, following the rains. In the fall, from August to September, they again pass through on their return north. They are often permitted to graze in the gum gardens when crops are fallow. Farmers protect *Acacia* seedlings and sprouts from browsing animals until they are out of reach, and they believe that the animal manure enhances soil fertility. But the farmer must manage all grazing to allow a good grass cover to remain into the dry, cold winter months, as the grass acts as an indicator, revealing when the gum is ready to harvest. When the grass understory around the trunks of the *Acacias* dries out, farmers begin tapping trees for gum. Interviewees excluded grazing from *Acacia* areas from late October through December.

Gum gardens

A commercially viable gum-producing plot is termed a 'garden'. Kordofan's gum gardens varied in the number of producing trees, ranging from at least five trees to a densely growing two hundred or more *Acacias*. It was difficult to assess the viable size of a garden, because of the complex land ownership patterns in the province. Land tenure is dominantly ethnic or tribal, with the highest in the communal hierarchy possessing most of the fertile lands, or those lands lying on plains. The minorities or marginalized adults of the tribe usually own either the poorest plots or the rocky and mountainous parts of the tribal land. For this reason the minimum extent of a viable garden is different in every locality. In general terms, however, the smallest size for a 'garden' was estimated by farmers to be 22 man-ropes or canes square. A man-rope, or cane, widely used in most of rural Africa, takes a fully grown man lifting his hands up as its unit. It is roughly one-sixth of a hectare.

Because the gum trees are allowed to regenerate naturally, their distribution varies greatly. Farmers stated they sometimes thin out low-quality trees, and tend to keep track of the gene lines of the best trees. In some plots there are widely spaced, irregular clumps of trees, where propagation has mainly taken place through cloning or sprouting. Another garden may have scattered individual trees. On occasion, trees have been planted, for example, on some community properties, and they may be found in rows. When the trees grow old and lose productivity, farmers remove them and plant in the revitalized soil.

Germinating *Acacia* trees develop a long tap root reaching 2 m in less than two months. The rooting habits of the species are specially adapted to make maximum use of available moisture. In the second or third year of

growth lateral roots develop that turn downward only after reaching out some distance from the tree. This branching and rooting habit enables the young seedling to continue to grow even after the rains have stopped. Most trees appear fully mature at 20—25 years of age, but there are many authenticated cases of trees over 40 years old still capable of producing gum. Growth and production seems to slow down considerably after the age of 25, and there are also the practical difficulties of tapping such old trees because of their size and height [Awouda, 1989].

Tapping and harvesting gum Arabic

Gum Arabic-producing *Acacias* are highly drought-resistant. The gum is tapped from the bark of the trees during winter dormancy, coinciding with the tree's largest accumulation of carbohydrate reserves from the previous wet summer season. The trees begin shedding their leaves and entering dormancy after the end of the rains, generally in early November. Exudation of gum is reduced during the coldest winter months, so the best time for tapping is in late fall and early spring. Trees are only tapped once per year.

Trees are first tapped when they reach a height of about 4—5 ft with a main stem of about 2 in or more in diameter — typically when they are 3—7 years old. Traditionally, a small bladed ax is used for tapping. A light blow is directed to the side of the branch and parallel to it so that the blade penetrates between the bark and the wood. The ax is then moved upwards and downwards to tear off the strip of bark, removing a strip of bark 3/4 inch to 1-1/4 inches in width and 2—4 ft in length. This is done for each main branch of the tree, tapping the young growing bark and not the main stem, because the bark soon becomes thick and fiberous and unfit for tapping. During the next year's tapping season, the opposite side of the branch is tapped [Awouda, 1989]. This gives the tree time to heal and re-grow its outer bark.

Once the branches are debarked or tapped the tree's reserve of carbohydrates rushes to seal the wounds in the form of liquid gum. The gum starts to solidify slowly as it comes in contact with oxygen, so the gum does not trickle as it does in latex or resins, but instead forms droplets at one or more points along the side of the stripped face. The gum exudes intermittently, forming a hard but slightly elastic skin on the outside. As more gum exudes the outer skin expands or cracks and the nodule grows in size to about 1—1-1/2 inches in diameter. When the outer skin becomes so hard that the liquid cannot force it to expand any further, the nodule ceases to grow in size and is ready for picking [Awouda, 1989]. The first harvest of gum, the one that will eventually bring home most of the return each season, usually occurs 40 days after tapping. New nodules form after the first are picked, and within 10—15 days a second picking is possible. An average of four to five pickings over two months is common, although some farmers stated that they may collect up to 15 times in six months.

The age and variety of the *Acacia* stand determines the quality and

structure of the gum that is formed. Farmers stated that the older trees, called *Cacao*, from 7 to 12 years in age and older, produce the best gum, while younger trees, *Shagaowa*, produce gum of a lower quality. The shapes and colors of the nodules vary greatly, ranging in shape from round compact masses to brittle, hexagonal crystals. The color of the gum varies from clear to all shades of brown, pink, or a dark opaque coloration. The best quality gum is found in solid, crystal-like spherical masses local farmers called *Nagaowa*, meaning crystal clear. The lowest quality gum is referred to as *Duka* or *Kas*, meaning crumbs. The residue is sifted and the portion caught by the sieve is known as 'gum sifting' while the portion passing through the sieve is known as 'gum dust'.

According to the farmers interviewed, activities in gum gardens are gender segregated. Men cater for the gum trees and do the tapping. Women usually harvest, clean, store and transport the produce.

The impact of drought on the western savanna

The sum total of gum production in this region has notably decreased over the last ten years (Fig. 3). Records from El Obeid Central Market, where all of Kordofan's gum Arabic is sold, show that production dwindled from an average of 9000 tons for the 1974 /75 season to a scanty harvest averaging a total of 750 tons for the 1984/85 season. This has drastically affected the well-being of farmers in Kordofan and limited motivation to produce gum or even care for gum trees.

The six years of drought from 1979 to 1986 was not the only factor that compromised *Acacia* abundance. The trees are so drought-resistant that drought alone cannot be blamed for the destruction of western Sudan's agroforestry systems. The effects of the drought were more indirect. As production of the main food crops underlying the gum trees declined, farmers reported that they started to use for food the grains found in their *Matamir*, the underground storage facilities where surpluses and seeds for the following year's field plantings are carefully stowed away.

Unfavorable weather conditions led to a reduction in food production, but poor distribution of available food resources eventually led to the week-known Sahel famine in the Region, as communities exhausted their food supplies. The deterioration of national socioeconomic conditions, combined with the failure of the central government to maintain peace and security and to distribute food to the famished population, eventually led to a *coup d'etat* in April 1984 [Legum, 1985].

Major reasons for breakdown of the system

The decline in Kordofan forests and in the production of gum Arabic can be explained by an examination of issues of equity, community needs and

environmental conditions. In 1986/87 Sudanese gum Arabic production sold at around 2,000 dollars a ton (Fig. 3) exported from Port Sudan. The farmers interviewed informed us that the price received by the farmer in Kordofan, on the other hand, was less than 10 dollars a ton, not really enough to justify labor-intensive gum production, particularly during the drought.

All of the 120 farmers interviewed considered tapping gum trees a strenuous and physically demanding activity, and without reasonable returns, farmers believed that they had few alternatives but to burn, fell and sell the wood for energy. In one typical case described by a farmer, prior to the drought a farmer's production averaged 75 lbs/tree in a garden but during the drought an average of 75 lbs for the entire garden was collected [Jamal, 1987]. With such low levels of production, returns simply fell below the level needed to justify maintaining the trees, as the price to the farmer was not tied to demand, but instead held at artificially low levels by a marketing monopoly. Financial hardships obliged many rural residents to migrate to urban areas [Gaitskell, 1959]. After exhausting their other resources, the remaining sedentary population sold logs or disposed of their gum gardens in return for cash.

Insect pest attack on gum-producing *Acacias* was enhanced by the disappearance of natural enemies. Over-tapping and bad husbandry practices also weakened trees, in turn attracting pests such as wood borers [Stebbing, 1914]. Many of these pests, with the exception of *Anacridium melanorhodon* Karny [Schmutterer, 1969] and termites [TDRI, 1983], are active in the breakdown of diseased wood and can be spread by the transport of logs. The law of 1942 that prohibits the transport of wood from the north to south of El Rosaries Dam did not seem adequately enforced. The law was primarily designed to prevent the spread of *Acacia* borers.

Conditions were so bad that the gum gardens and even the livestock, culturally the main source of status for rural residents, shared the same fate. In Kordofan, the size of herds determines the position of the head of the household in the community. Famished and thirsty animal stocks had to be disposed of due to severe shortages of water and lack of pastures. Flocks of sheep were given away or sold at less than one tenth of their value in return for food, water or forage. With even livestock being sold, the gum gardens, providing virtually no economic returns at the time, had no chance to be spared.

From Barra, El Mazroub, El Khuwei and up to El Obeid most of the gum gardens were destroyed. Along the roadside from El Mazroub to El Khuwei, piles of unsold logs of both hashab and talh were to be seen during the survey period. Desert creep and sand dune accumulation in all those regions were two of the most serious and obvious results of the overharvest of the trees. With the harvest sparing no particular species of trees, rapid and continuous desertification became a fact. In spite of community awareness of the role of trees in stabilizing sand dune movement and desert creep, farmers believed they had no alternative but to log and sell their *Acacias* in return for cash for staples.

On the other hand, in Kordofan south of the Gum Belt gum production was maintained and even enhanced during the same period because of the development of an underground marketing path. The farmers of Rashad and El Nihud indicated that they were able to get better returns for their gum than farmers to the north of the Gum Belt by smuggling gum across the border into Chad. Chad was listed as a major gum exporting country in 1986, although Chad's farmers possess no gum-producing *Acacias*. Southern farmers tapped gum less frequently than those to the north, got better returns, and as a result still have vigorous *Acacia* stands.

A comparison: El Damokia Forest in *Wadi Ashgar*

Comparing the results of the drought on a government-owned and managed gum garden allows us to separate the effects of drought and related pest damage from socioeconomic conditions affecting privately-owned gardens. The 2760 ha El Damokia Forest is approximately 50 miles south of El Obeid and 20 miles east of Khor Taket, in *Wadi* (valley) *Ashgar* (blond). The desert valley once belonged to tribal and ethnic groups of the Jamoayyah and Manasrah (lineage of extensive Bedyereah) tribes. The tribes abandoned the area after a long period of drought in 1958 during which the exceptionally deep wells in the area went dry. Modern drilling technologies allowed the tapping of deep underground water supplies in rock cavities, and in 1967 the Forestry Department of Sudan's Ministry of Agriculture began reforesting. In 1965—1966 the tribes were compensated for the land and Wadi Ashgar finally was registered as a public reserve.

The reserve was annexed to the Gum-Arabic Research Unit in 1975, following its detachment from the Department of Forestry. The main purpose of the reserve is to conduct research and develop an integrated agroforestry plan for 10 to 12 neighboring villages. As a pilot project, it was decided by the Ministry of Agriculture that 43 ha of the Preserve were to serve as a model for gum production in an agroforestry system. Around 14 ha of El Damokia were planted with hashab.

The site was chosen for a number of reasons. It is near the market of El Obeid, rainfall is in the middle of the range, with 400 mm typically falling from June to September, and the soil is typical Goz or deep desert sands, badly in need of stabilizing from wind erosion. El Damokia was hit hard by the drought: the annual rainfall in 1984 was 150 mm and in 1985, 75 mm. Despite the severe water shortages, El Damokia maintained vigorous, productive stands of *Acacias* through the drought period [WSARP, 1985—88].

Stands of different hashab, from various localities, were transported to El Damokia Forest. Trees were selected for production of high-quality gum and other beneficial characteristics. Tapping for gum and taxonomic studies are ongoing in El Damokia, although a fully developed agroforestry system is not yet in place. Until 1975, gum Arabic production amounted to an average of

6818 tons per season. Researchers stopped tapping during the drought, reducing stress on the trees, and the trees responded vigorously when the rains returned. Although Wadi Ashgar has not been particularly well managed in general, the contrast to farmers' trees in neighboring villages in Kordofan is striking.

Tree mortality at El Damokia was minimal. Some amount was probably due to limited drought tolerance in some individuals or provenances. In some cases uncontrolled livestock broke into the compound and damaged the trees. Insect pests were found tunneling under the bark layers of young trees, but causing no symptomatic problem. The older trees seemed to have escaped the attack either through a flow of rich phloem that totally submerged the mummified larvae, or through the presence of natural enemies in form of birds, generally, and wood-peckers, particularly. Most of the damage noticed was to the fallen seeds of *Acacias*. In and around El Damokia Forest at Wadi Ashgar deleterious sand dune accumulation was only noticeable at the edge of the Forest.

Conclusions

Agroforestry has become a popular idea in development and environmental circles throughout the world. It is a new word used to describe age-old land-use practices familiar to millions of farmers and herders in many parts of the world [Rocheleau et al., 1989]. The agroforestry system in Northern Kordofan had all the components of a successful sustainable system and lasted for at least two centuries. However, the structure of the system and its dynamics have been continually undermined in recent decades. The least flexible components of the system are those that were lost first: while farmers can change plant varieties after one season, decisions about woody plant resources and the soil are not so readily reversible [Wilson, 1987]. The vulnerability of the system became clear during the drought of the eighties as the *Acacias* disappeared.

The gum gardens were destroyed despite being valued by the rural population. Under less extreme economic and environmental conditions farmers probably would have maintained the trees even without any tapping for several years, in anticipation of future returns and to enjoy the benefits of fodder production, enhanced soil fertility, and the social status that gum garden ownership confers. During the drought of 1929, for example, the farmers of Kordofan preserved their gum savanna despite shortages. *Acacias* were left untouched and after 1930 good rainfall rewarded the farmers with an abundant harvest of more than five times the average production prior to 1929. Even during a far longer period of world market depression lasting from 1932 to 1939, gum tappers were unlikely to log *Acacia* trees. The price of gum during that period and for a while following World War II dropped

by a factor of ten, yet the agroforestry systems of Kordofan thrived and were preserved by the farmers [Salih, 1987].

Although the most recent drought was a severe one, the main reason for the failure of this agroforestry system and the subsequent deterioration of the environment can be tied to socioeconomic inequities, particularly in marketing. The low gum price paid to farmers removed any motivation to keep the trees through the drought, particularly in light of farmers increasing participation in a cash economy during recent decades. Logging was one of the few ways of obtaining the cash they have become dependent on.

Diversity in agricultural production, such as that represented by a viable agroforestry system, increases the availability of some type of edible, harvestable material throughout the year [Torres, 1983]. Agroforestry systems should be relatively resilient to variation in environmental and ecological conditions, such as in rainfall or temperature, because inherent crop variability ensures that some component of the system will still produce [Gliessman, 1984]. With no stress on the trees from over-tapping, overgrazing, burning, logging, or pest damage the agroforestry system was able to thrive through the critical long drought period, as at El Damokia. When socioeconomic conditions stimulated abuse of the system, the *Acacias* were the first to go, throwing the entire system out of balance.

Discussion and recommendations

A basic strategy for achieving sustainable development must solve the principal social problem in the southern hemisphere poverty: [Altieri, 1991]. The lack of options for income generation, weak market incentives, and limited alternatives to cutting gum-producing *Acacias*, contributed to the destruction of the gardens by desperate farmers in Kordofan. Sustainable agricultural development must attack the structural factors that underlie poverty, among them the economic policies which contribute to impoverishment of the population and, in large measure, encourage environmental degradation [Altieri, 1991]. Lack of marketing policies to sustain *Acacia* forests during the recession period, and inefficient transportation, resulted in bad husbandry practices in gum gardens and mismanagement of the whole ecosystem [Saeed et al., 1984]. The destruction of gum Arabic-producing *Acacias* in Kordofan led directly to the collapse of the entire desert-buffering agroforestry complex. This was mainly due to abusive national and corporate policies and the impact of international gum Arabic marketing policies at the local level [Jamal, 1988].

In the eighties, Kordofan and Darfur communities were some of the most affected by the famine, followed only by the war-stricken Southern Provinces. Drought and displacement drastically affected more than 500,000 people [Winter and Prendergast, 1990]. The delay in proclamation of the region as

an emergency zone, the subsequent delays in food aid and emergency fund mobilization, together with the general weakness of the State, led to a depletion of resources. A once sustainable system was exhausted and rapidly destroyed. For sustainable development to become a reality, it is necessary for the livelihood of the poor to be given priority [Barbier, 1987]. Improvement of the environment and poverty reduction deserve urgent and simultaneous attention.

Diversified production is an important basis for the survival of farmers in the harsh environmental conditions of Western Sudan. The gum *Acacia* agroforestry complex is a prime example of a resilient, diversified production system of the type that is looked to as a goal for many places in the developing world. Production of grain, livestock, and gum provides food and cash crops in a system that conserves soil fertility and minimizes erosion and desert creep. Some type of edible, harvestable material is available during the entire year. If there is variation in some ecological factor, such as rainfall or temperature, a diversity of crops ensures that some component of the system will still produce under most conditions [Gliessman, 1984].

Gum Arabic-producing *Acacias*, livestock, and wildlife disappeared not because the communities lacked alternatives, but because of the false hope of earning some cash from tapping and logging. During the drought period, sales should have been halted or slowed, perhaps by making funds or staples available to farmers, allowing them to survive the critical period. In the absence of all forms of security, the result was the deterioration of the whole environment and mass migration to urban areas.

On a national level, the state should strive to abolish inequity in the marketing system. Farmers and their children, the potential farmers of the future, are more aware of their conditions and the global situation. One means of empowering them to determine their own development might be through representation of the Gum Arabic Company Board in the Central Markets of both El Obied and Khartoum. By making farmers shareholders, they could have a direct role in the marketing situation.

It is evident that the process of environmental degradation associated with modern agriculture is not only an ecological process, but also an economic process [Altieri, 1991]. One option for improving the stability of gum garden communities would be for the International Gum Arabic Association (INGAR), formed of multi-national companies and scientists from industrialized countries that rely on Kordofan gum Arabic products in their industries, to contribute to a fund for research, extension, and emergency relief for farmers.

Kordofan is one of the wealthiest regions of Sudan. Its natural resources, history, and cultural diversity are among the richest in the world. It still remains as a potential 'Food Basket' of the African Continent. The preservation of traditional agriculture and the protection of the environment is a responsibility shared not only by Sudanese farmers but includes officials in the Central Government. The savanna agroforestry system will thrive only

with the careful husbandry of Kordofan farmers. Writing about rural Africa in 1970, D. Hapgood stated:

> Agricultural progress does not begin and end with a new tool or a different crop, for the way men work cannot be separated from other aspects of their lives. Agriculture is interwoven into the patterns of African society. Progress in rural Africa, therefore, depends on profound changes in the attitudes and ways of living of millions of villagers. But not on them alone. The new technology will be funneled through the tiny educated class that holds power in the capitals of independent Africa [Hapgood, 1970].

Unfavorable socioeconomic relationships that existed prior to the drought, particularly monopolies in the gum market that prevented farmers from getting the real value of the gum they produced, were exacerbated by the drought. This devaluation of one component of the agroforestry system, the trees that require the longest-term care, led to the deterioration of the entire agroforestry system of production, and ultimately, to increased risk of soil exhaustion and erosion. In general, modern agricultural policy tends to encourage the 'simplification' of agricultural systems. In the case of agroforestry systems such as the Sudanese gum gardens, this is often accomplished by neglect of the components of the system that need long-term protection and recovery time, in favor of annual crops producing short-term returns and conducive to mechanized agriculture on large holdings. Tree crops such as gum Arabic need the long term, conscientious involvement of concerned farmers to survive. Economic and educational programs should be oriented toward protecting small farmers in Sudan. While it is no doubt true that agroforestry systems offer opportunities for the stabilizing of rural communities, stable rural communities are also necessary for the survival of agroforestry systems.

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