Prosopis juliflora for Irrigated Shelterbelts in Arid Conditions in Northern Sudan

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1.0 Introduction

The need for shelterbelts to protect homes and farmland in the arid areas of Northern Sudan is now established without doubt. The destruction of natural vegetation, coupled with the increase in population and the decrease in rainfall, has ensured that the effects of desertification have been felt over vast areas of the country. Although the monitoring of the broad spectrum of natural resources is only in its infancy in Sudan, it is possible to say that in many areas the livelihood of much of the population is threatened by the effects of desertification.

What are these effects? To those who live in the arid and semiarid zones the effects are clear and inescapable—decreasing productivity of the land, reducing cover of natural vegetation, less availability of timber and nontimber forest products, increasing aridity and desiccation, lower water tables. The list is a long one. The effects on the population are serious and long term—more poverty; poorer health through lack of nutritious food; and less resources for education, infrastructure, and improvements to agriculture and local industries. Migration, the traditional response to famine, war, and social upheaval, has become an accepted part of rural life. It involves not only the young but, increasingly, the older men and women, as less and less food is available first for export to other areas and, finally, for home consumption.

How important is the role of the environment in all of this? The answer is complex, but the dependency of both rural and urban populations on rural products is high. Food and fuel are perhaps the two most important individual items on every household budget, and although Sudan has many imported items of food and manufactured goods, the basic commodities are home grown and will always remain so. The production of these vital resources is crucially dependent on the state of the environment.

Food production is concentrated in a number of regions of Sudan. One of the most important is the Nile Valley north of Khartoum where irrigated crops of cotton, sorghum, Egyptian beans, wheat, onions, and other vegetables are produced for export to other parts of the country. The fields in which these crops are grown have been protected from the effects of desertification by centuries of growth of natural riverine forest. These forests have all but gone as the relentless pressure of increasing human and livestock populations has taken its toll. The result is sand everwhere—houses and hospitals buried and abandoned, fields inundated and rendered infertile, fruit trees and date palms blasted by sandstorms. And it is getting worse. Everywhere the dunes are gathering. Sand is whipped up by the wind and is carried for miles until it meets an obstacle that slows the wind. The sand is then deposited on or near to that obstacle, which it will eventually bury. Unless, of course, that obstacle is a tree.

But only certain sorts of trees can survive. Some species of tree have an extraordinary capacity to cope with extreme environmental conditions. The most important of these in northern Sudan is *Prosopis juliflora*, known also as mesquite.

This paper explores the utilisation of mesquite in northern Sudan.

2.0 People and Trees

People have always depended on trees and forests for housing, fuel, food, fodder, medicines, clothing and many other needs. In the distant past these needs were easily met, but since populations have grown, life expectancy has lengthened, pressure on land has increased, urban populations have increased faster than those in rural areas and, therefore, make larger fuelwood demands. Forests have not been able to cope with the pressures put upon them and are consequently being degraded—in a few cases they have virtually disappeared while in others there is hope that if action is taken soon, the forests can be brought under sustainable management.

Traditional forms of management are no longer appropriate for the nonreserved forests and, indeed, for many of the reserved forests as well.

The need is to recognise that people have always used forest resources and always will, and that foresters have to learn to work with the people, rather than seeing them as a threat that has to be controlled.

In the "old" days, rural communities utilised the forests in the vicinity of their villages—sheikhs allocated land and resources to individuals and families who were expected to manage them responsibly.

That sense of responsibility has now all but gone, leaving the forests open to anyone and everyone to exploit (the "if I don't take it, someone else will" syndrome). It is now essential to bring user groups into the process of forest management, however difficult this might appear.

This need has been recognised in the Forests Act 1989 which specifically provides for the establishment of community forests. These can be set up by individuals, village or other user groups, institutions and private companies, and, once a contract has been drawn up between the various parties and the Forests National Corporation (FNC), the users have the right to utilise that forest according to an agreed management plan. This legislation has tremendous potential to put responsibility back into the hands of the people and should result in improved environmental management.

Who are these user groups? The most important group is the sedentary farmers, of whom there are large numbers in the Nile Valley. Many have an interest in trees. Work carried out by SOS Sahel in collaboration with FNC since 1985 has enabled many communities and individuals to raise and plant trees for shelterbelts, windbreaks, shade and fodder. Many villages and much farmland are now protected from drifting sand, giving the people much greater security than they had before. Men, women, and children have been trained in all aspects of tree production and maintenance at the Village Extension Scheme (VES) in Shendi and at the Community Forestry Project (CFP) in Ed Debba. Both of these projects are situated in the Nile Valley north of Khartoum (Figure 1).

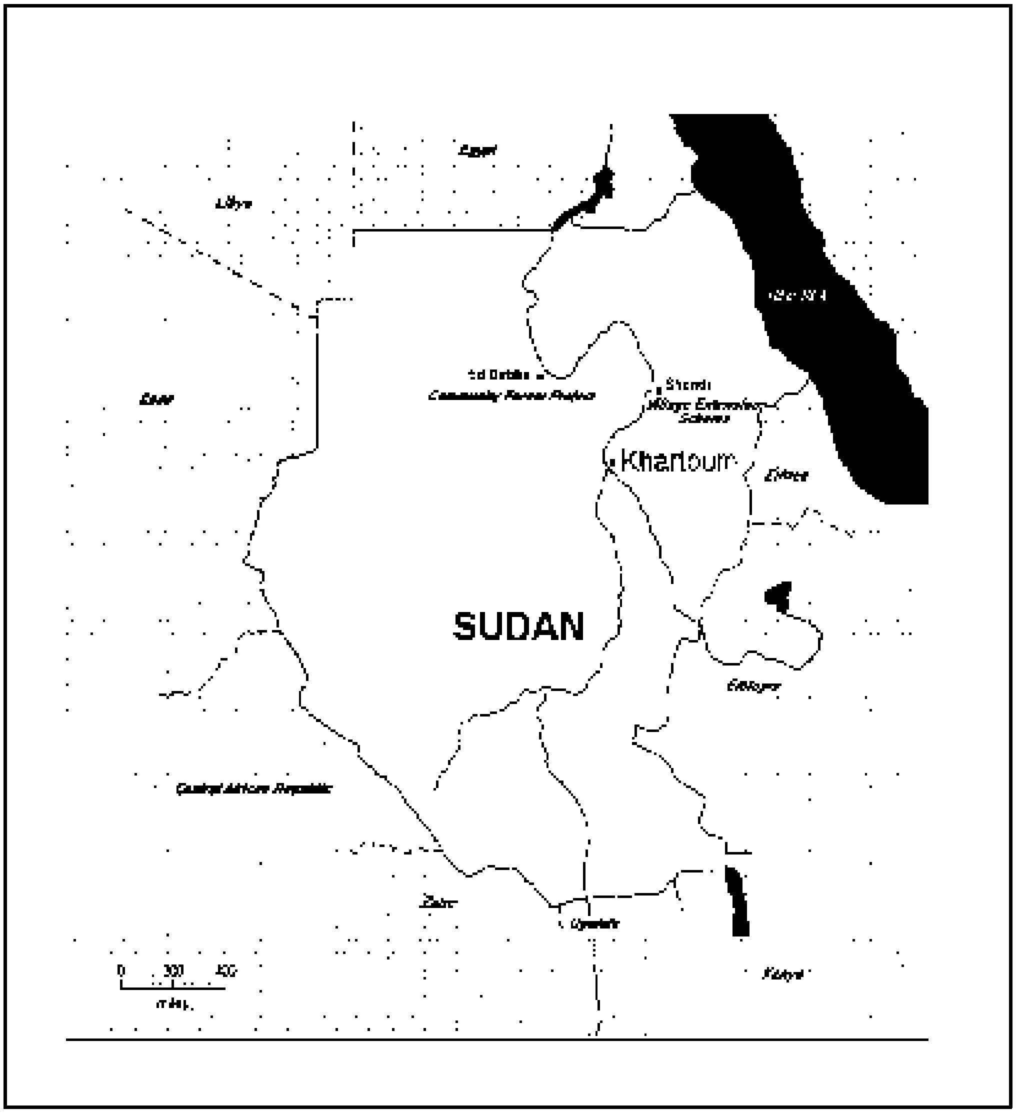

Figure 1. Two SOS Sahel Project Sites

2.1 Identifying a Need

The dependency of rural people on trees is well known. Less well known is how their forest resource has changed over the last few decades and how people have adapted to that change.

The most well known products from trees are, of course, timber for building and wood for fuel. They will only be replaced when other materials for building and fuel become available as acceptable substitutes. This is unlikely to happen in the near future. However, the resource is beginning to run out and alternatives are not easy to find.

A crucial role of trees is to protect soil and to reduce desertification. In the north, blown sand has become a major problem since the much of the natural forest has been destroyed. The results are well known—desert encroachment onto farmland, houses, schools and roads, leading to immense economic and social loss. Trees also improve the microclimate of an area, helping to increase crop yields and lowering air temperatures.

These uses of trees are not all found in one place at any one time, yet, throughout the northern state, trees play a vital role in the local economy and way of life.

But what are the main priorities when it comes to forestry? It is vital that the needs of local people are identified before any forestry activities start. Full involvement of the farming communities in planning and designing these programmes is essential if success is to be achieved.

3.0 Wind, Sand, and Trees

Air movement can be streamlined or turbulent. When wind flows over a flat smooth landscape, the air flow is more or less streamlined. If the air flow meets an obstacle, turbulence is set up and this effect may last for a relatively long distance downwind.

Sand is quite heavy, so light winds are not able to move it. But when wind speeds reach a certain critical level, the sand starts to move. First the grains start rolling along the surface and, as wind speed picks up, lighter grains start to lift. More and more grains take off until the air a few centimetres above the ground becomes saturated with sand. Grains tend to fly short distances, then land again (known as saltation), before being picked up and moved on again. The higher the wind speed, the higher the grains rise. In most sandstorms the majority of the sand can be found within 5 metres of the surface, but, in severe storms, sand can be lifted to great heights.

Sand is found in two main forms: sheets and dunes.

Sheet sand is the most common, and can be found over large areas of the Northern State. Sheets can be anything from 1 cm to 100 cm, or more, deep.

Dunes are more spectacular and are also more dangerous, as they can reach enormous sizes — up to 25 m high in the areas we are discussing. The one advantage of size for us is that the bigger they are, the slower they move, and dunes over 20 m high are very slow movers indeed. Smaller barchan (crescent shaped) dunes 2 m to 3 m high can, however, move 20 m to 30 m a year, burying everything in their path, except certain sorts of trees, such as *P. juliflora*.

4.0 Shelterbelts - When, Where, and How

SOS Sahel started its first Mesquite shelterbelt planting in 1986, and regular monitoring since then has provided a clear picture of what can and cannot be achieved using irrigation. There were some earlier plantings by a number of individual farmers who had the vision to appreciate that only trees could provide a solution to the problem of moving sand. However, little recording of these efforts has been made and we can only learn from what is visible today. The FNC carried out a number of plantings of shelterbelts in the North, including an extensive trial in the desert near Dongola. These unfortunately were abandoned and no useful data is available.

However, we have learned that some trees, especially mesquite, have the extraordinary ability not only to survive sandstorms, desiccation, and temperature extremes but to flourish sufficiently to keep pace with sand deposition. They can create a semipermeable barrier that can actually trap sand and cause it to build up into artificial dunes that remain more or less static, while the trees grow up faster than the sand can accumulate.

How can this be achieved?

Trees are permeable, and they get bigger as time goes on. This makes them far better at stopping sand than solid obstacles. This is because when wind hits a solid obstacle it is forced to change direction. This creates turbulence and airborne sand is dropped all in one place. A large heap can build up in a relatively short time. Trees filter the wind and do not create turbulence in the same way. Thus wind

is slowed but still passes through in the same direction. Airborne sand, instead of being deposited in one heap, is spread over a larger area, with the heavier grains dropping out first, usually in front of the trees, and lighter grains passing through the first rows to be deposited either inside the belt or on the leeward side. This has the effect of reducing the speed of sand buildup, which gives the trees a better chance to grow.

As sand piles up around the trees, they usually manage to grow to keep pace with the sand. In Ed Debba there are trees 9 m tall with sand built up to within 1m of their tops on the windward side.

5.0 Irrigation and Management of Mesquite Shelterbelts

5.1 Evaporation and Water Loss

The climate of arid and semiarid Sudan is far from ideal for plant growth. Most plants thrive best at a temperature of 22°C to 28°C, and a relative humidity (RH) of 75% to 90%. Such conditions are rarely found in Northern Sudan and it is more usual to find high temperatures and low RH. Shade temperatures in excess of 45°C are common in summer, and temperatures in the sun can reach 60°C to 70°C. Relative humidities go as low as 10%. In such conditions water is sucked out of plant material at an extraordinary rate and only plants with specialised water conservation systems can cope.

It is all the more strange that Mesquite can grow so well in these conditions as it has no obvious xeromorphic adaptions. Its leaves are thin and have a high surface area to volume ratio, there is little cuticle to prevent excessive transpiration, and the tree has no obvious water conservation strategy. Despite these apparent drawbacks Mesquite is the species of choice for shelterbelt work as it has a phenomenal ability not only to survive but also to flourish in the conditions found in the region, provided water is available in sufficient quantity and the young trees are protected from livestock.

Potential evapotranspiration (PET) can be more than 2500 mm per year and rainfall is often zero. This water deficit must be made up by irrigation and ground water. Young trees often require irrigation once a week to begin with, reducing to once a fortnight and then monthly. The time taken before the next reduction in watering depends on local factors such as soil type, topography, depth of ground water, time of year, windspeed, etc. Water loss from plants can be high where climatic factors are unfavourable and where the plant has no special xeromorphic characteristics. This limitation must be addressed if tree establishment is to occur as quickly as possible.

5.2 Plant Water Requirements

Irrigated Mesquite can reach a height of 4 m in nine months and can produce a crop of nutritious pods in the same period. Although it can survive with extremely small amounts of water, it needs considerable supplies in its early months if it is to grow at its full potential rate. This is particularly true if it is planted in summer. There is no critical planting season as the daytime temperature is nearly always sufficient for growth. Only in January and February in the north do day temperatures drop so low as to prevent growth occurring.

Water is traditionally applied through open furrows. This irrigation method, although requiring no special technology, does demand high volumes of water. For the first irrigation of a new shelterbelt near Shendi it was found that approximately 260 litres of water were being pumped for each tree in the belt. Such quantities are clearly unnecessary from the trees' point of view, but are inevitable with the open furrow system. Experiments with pipes show that trees can be successfully grown using as little as 9 litres at each watering. However, such a regime is unlikely to allow the tree roots to penetrate deeply into the soil, and they are, therefore, unlikely to reach ground water unless the latter is particularly near the surface. The aim must be not just to provide sufficient water to allow the tree to grow, but to encourage it to grow roots down into the soil towards the water table. This requires sufficient water to drain down to ground water level and to maintain a “damp cylinder” of soil below

the plant. It is very difficult to predict how much water this will take, and it will in any case vary with site conditions, soil type and topography.

Where conditions permit it is far more economical to use smaller quantities of water carefully directed to the individual trees than to use large quantities in open furrows of which the greater part is wasted. The former strategy however requires more equipment and materials and these may not always be available. Pipes of some sort, either semirigid alkathene, lay-flat woven nylon or reinforced polyethylene, are necessary and can be used in a variety of ways.

5.3 Irrigation Methods

5.3.1 Furrow

Furrows have already been mentioned. Although there are many different methods of irrigation, the use of furrows is well known and understood. It is a modification of the method that is most widely used for irrigating larger areas. In the Nile Valley there are thousands of wells that use diesel-powered pumps to irrigate farmland. The well discharges into a main canal which leads via smaller canals or furrows to basins in which a variety of crops is grown. In furrow irrigation the crops (trees in this case) are grown in furrows rather than in basins.

Advantages:
The system is well known and uses locally available technology. It depends on imported engines, pumps, and fuel, but these, and spare parts, are usually always in stock in the main towns. Ground water is independent of rainfall and river flow, and is reliable provided the installation is carried out correctly. Relatively large volumes of water can be pumped and made to flow considerable distances—up to 1000 m.

Disadvantages:
Topography:
Ground topography must be fairly level. If there are changes in level between the well and the trees then it can be very difficult to build a main canal that will carry water to the desired place. Large quantities of water can be lost—shelterbelts are often planted on freely draining sites and a great deal of water is lost through seepage. If the well is near the trees, it can be argued that seepage water contributes to the general field water content which will eventually be used by the trees. However, where the main canal is long (more than 25 m to the trees), seepage can be considered as a loss to the system. This can be compensated for by planting trees or other crops on the canal bank to utilise the water. However, land tenure and traditional user rights in the area will affect what can be done in this respect.

Fuel/spare parts:
Even though the technology is well known and relatively sustainable, any event that prevents fuel or spares reaching the area can cause serious problems. These can be severe enough to cause total failure of the programme.

Responsibility:
Ownership and responsibility for the equipment can also be a problem and needs sorting out at the beginning of the project. Ideally, the people benefiting from the shelterbelt should provide the equipment as there will then be no problem about who is responsible for its maintenance. However, not all communities will have the necessary resources and it may be necessary to provide some items of equipment on a credit basis through an arrangement with the local bank or directly with the project. In this case there should be a clear and unequivocal contract between the project or government department and the community. Failure to ensure this will result in endless problems.

Blown sand:
A major problem with the furrow system is that of blown sand. Shelterbelts are often planted for the main purpose of stopping blown sand, but this very sand can be a main cause of failure. Sand collects at any rough point or object on the surface, and furrows ploughed into a smooth surface are an ideal trap for moving sand. Depending on the site factors, the time of year and the depth of the water table, the furrows may need cleaning of sand prior to each watering. This is a very time consuming and laborious job, but is essential if proper irrigation is to be achieved. It is sometimes possible to plough some extra furrows to windward of the shelterbelt to trap the lowest levels of airborne sand, but large quantities are still carried on to the irrigation furrows and cleaning will almost certainly be necessary.

Where sand movement is severe, mechanical fences of any locally available material can be set up about 15 m to windward of, and parallel to, the belt. These fences, of date palm stems, brushwood or other material, will trap sand and create an artificial dune, helping to protect the furrows and young trees during their establishment phase.

The best solution is to try to get the trees' roots down into the ground water as quickly as possible—this will remove the need for irrigation and, hence, furrow cleaning. The time needed for this to occur depends mainly on the depth of the water table. In some cases it may be so deep that tree roots may never reach it, in which case irrigation, and hence furrow cleaning, will be needed permanently. However, once the most windward rows of trees are a reasonable height (1.5 m to 2 m), they will stop sand from reaching the next rows. Even if these most exposed trees die, they will, if left in place, continue to stop sand and, thereby, remove the need for furrow cleaning further to leeward. This sacrifice of possibly 2 or 3 rows of trees could be planned into the shelterbelt management programme as an effective method of reducing labour demand for furrow cleaning.

Salinity:
One last problem that needs mentioning is the possibility of finding saline water. When used for furrow irrigation the dissolved salts crystallise on the surface of the furrows and can build up to phytotoxic levels. Mesquite, fortunately, is salt tolerant, but there is a limit and too high a salinity level can eventually prevent successful establishment.

5.3.2 Pipe

The use of small-diameter pipes for irrigating trees is relatively new, depending as it does on the existence of a regular supply of low-pressure water. Such a supply is usually only available from the water storage tank of a village domestic supply, many of which have been installed only in the last few years.

Advantages:

The water source is usually reliable and of good quality, and no extra machinery is required for irrigation. The management of such a scheme is, therefore, very simple, involving only moving the pipe from one tree to the next and delivering the correct quantity of water at the correct period.

Disadvantages:

The length of pipe available, and the water pressure, will determine the length of shelterbelt and the distance of the farthest tree from the water source. Also, the amount of water that it is acceptable to take for each irrigation (assuming that the primary function of the supply is for domestic purposes) will be set by the community and will limit the size of the belt that can be irrigated at one time. Suitable pipe is not usually available locally and has to be imported, and the 2-inch lay-flat material that has been used successfully at several sites is prone to damage by thorns and stones.

5.3.3 Tanker

This is a well understood method for delivering water that has been used in forestry projects such as SOS Sahel's Community Forestry Project in Ed Debba where tanker-irrigated shelterbelts have been very successful. Water is delivered to individual trees according to a predetermined management program until their roots reach the water table. In another project in the same area a system of water transport with a tractor and trailer was used. This, however, was not as successful as the tanker.

Advantages:

Highly mobile tanker irrigation enables trees in any situation accessible to a vehicle to be irrigated regularly. Tankers can operate in all sorts of terrain and can carry water long distances, if necessary. Water sources can be a river, a matara well, a hand-dug well or a seasonal water course. Water can be delivered quickly and in considerable quantities. If Bedford TJ1090 trucks are used, the maintenance problems are greatly reduced as spares and know-how are locally available. It has been found that where shelterbelt establishment is attempted on dunes, the sand must not be deeper than about 4 m, otherwise, the trees do not survive even if they have sufficient water. This seems to be because there is insufficient fertility in the sand to enable the trees to grow down to the soil.

Disadvantages:

Any form of vehicle is likely to cause problems and these can sometimes be serious or even catastrophic. Fuel and oil supplies are often sporadic and a long interruption of supply could be fatal to young trees. Tankers cannot go everywhere — if the land is too steep or too sandy, the vehicle will be unable to reach the proposed planting area. Skilled staff are needed to operate and maintain the tanker.

5.4 Constraints and Problems

- First, the main constraint is a general lack of experience in implementing community forestry activities. This can cause problems as initiatives involving the voluntary participation of people require flexibility, compromise, and not a little psychology — skills which only come with experience. Too rigid an approach, or an unwillingness to meet the community on the same level, can result in no progress being made. On the other hand, too easygoing an approach or too great a willingness to compromise can lead to exploitation of the project by a village, resulting in too great a burden being placed on project resources.

On the technical side, problems of water management are considerable:

- **Too much water wastes valuable resources.**
- **Too little water causes stress and eventual death of the trees.**
- **Pumping equipment always needs regular maintenance and repair. Sand storms can bury pumpsets in a matter of an hour or two.**
- **Fuel supplies are often unpredictable.**
- **Water availability can vary and can diminish over time.**
- **Getting water to the trees can be difficult, whatever system is chosen.**
- **Water losses through seepage and evaporation can be very large.**
- **Water delivery systems invariably create problems which can sometimes prevent successful completion of the project.**

6.0 Species Selection

6.1 Mesquite and Other Exotics

Mesquite (*P. juliflora*) was introduced into Sudan from South America some time around 1940. It is in the legume family and fixes atmospheric nitrogen to assist in its growth. It does not look particularly drought resistant. In fact, there are many other tree species that will survive longer without water, but its major advantages for shelterbelt work are its rapid growth and its extraordinary ability to cope with heat, sandstorms, and sand buildup.

It is thorny (although there are thornless varieties available) but that does not stop its being eaten by livestock, especially goats, when there is no better forage around. It needs good water supplies if it is to perform well, but with sufficient water, good stock control, and no visits from locusts, it is possible to grow a substantial shelterbelt on a good site in two years.

Once mesquite trees have reached about 3 m height, goats are no longer a problem. The pods provide excellent fodder for goats, although the species can become a major weed problem if goats spread the seeds in their dung in areas of higher rainfall or irrigated farmland.

Its thorniness makes it difficult to manage, especially if irrigation furrows need to be cleaned regularly. On good sites it can be coppiced, but this should never be done if there is any chance that this will effect its value as a shelterbelt. General management of mesquite is relatively easy once it has grown through its first few months. It is pest and disease free on the whole, and can cope with extreme conditions, but is susceptible to drought. In difficult areas guards will be needed to keep livestock away.

To raise trees in the nursery, collect seed when it is ripe, and store in sacks. When needed, decorticate the seed and pretreat with sulphuric acid for 20 to 30 minutes before sowing.

The only places in northern Sudan where mesquite is unsuitable are irrigated farmland. As a boundary to farmland, mesquite is fine as long as the farmers look out for seedlings in their fields. However, there are plenty of farmers who do not clean their fields regularly and once mesquite gets a hold on irrigated land it is difficult to eradicate. In some areas of Sudan, such as the Tokar Delta and parts of

the Red Sea coast, mesquite has become a noxious weed. It should never have been introduced there. Careful site identification should prevent its introduction into areas where there is any danger that it might become a weed.

Other exotics, such as *Eucalyptus camaldulensis, E. microtheca, Parkinsonia aculeata* and *Pithecellobium dulce,* have all been tried in shelterbelts. However, none of these to date has been demonstrated to establish and grow better than Mesquite, nor do they have Mesquite's sand-stopping abilities.

6.2 Indigenous Species and Farmer Preference

Can indigenous species be used for shelterbelts? Several have been tried including *Leptadenia pyrotechnica, Acacia tortilis, A. nilotica,* and *Balanites aegyptiaca*. However, although these species can be grown with irrigation, they do not do particularly well, and cannot compete with Mesquite. In one trial, irrigation was stopped after some months, and the indigenous species survived a shorter time than Mesquite. This is probably because they developed shallow root systems under irrigation rather than the deep roots of naturally occurring trees. However, few species respond really well to irrigation, and it is not surprising that the indigenous species do not flourish in these conditions.

The advantages of indigenous species are that they have evolved within the ecosystem and should, therefore, be able to cope with the conditions better than introduced exotics. However, this advantage would only become apparent once the trees were mature and established, and it is doubtful whether this would ever be possible under irrigation.

Farmers have no doubt which species they prefer: mesquite for shelterbelts and *Eucalyptus camaldulensis* and *Pithecellobium dulce* for on-farm windbreaks. The latter two species are fast growing, produce strong poles, and *P. dulce* also produces edible fruit. Farmers also like *Azadirachta indica* for village planting (it is pest and disease resistant, very drought tolerant, can be pollarded, and is easy to grow). *Leucaena leucocephala* (very fast growing and nitrogen fixing) has been tried both on farms and in villages. Farmers do not want to plant indigenous trees, although they are happy to have big *Acacia tortilis, A. nilotica, A. seyal* and *Faidherbia albida* (syn. *A. albida*) around the villages.

7.0 VILLAGE EXTENSION SCHEME 1985–1996

7.1 Background

The Village Extension Scheme (VES) was set up in 1985 to help Nile-side villagers near the town of Shendi, 100 miles north of Khartoum, to combat desertification. Village tree nurseries and woodlots were established and protective mesquite shelterbelts and windbreaks planted. By the end of Phase One (October 1985 to September 1989), the project had set up 7 operational nurseries, 4 woodlots, and 10 village shelterbelts. During Phase Two (ended September 1993), seven new shelterbelts and three woodlots were established, by which time all the sites were under the management of village-elected committees. A third phase involving mesquite shelterbelts and an extended women's program ends in December 1996.

7.2 Mesquite Shelterbelts

The shelterbelt programme proved to be one of the most successful of the project's activities. So far, 19 village shelterbelts have been established, some of which are over 2 km in length.

A huge amount of sand has been trapped by the trees that would otherwise have reached the houses. At Goresh, it is estimated that approximately 50,000 tonnes of sand have been prevented from encroaching on the village and, at Taragma, at least 15,000 tonnes. Such an effect has profoundly impressed the villagers — new-house building is now taking place in the lee of the shelterbelts on land that was previously considered useless. Such long-term investment is happening at several shelterbelt sites including Goresh, Taragma, Rahamab, and Abdutab.

At many sites the shelterbelts are so valuable for their protection value that the villagers are unwilling to attempt to harvest them for firewood (Mesquite shelterbelts do not produce good straight poles, although strong forked poles can be found). Nevertheless, at sites where the shelterbelts can be relatively easily irrigated, to allow for rapid regrowth, they can also provide a valuable source of timber. To date, only one private shelterbelt has been coppiced to provide income. This is a desert farm about 2 km south east of Goresh where a single row of Mesquite was planted in 1987 and was cut and sold for £S 60,000 ($200). It was expected to regrow within two years. Such a return will become quickly known to other farmers in the area and more of this activity may well be seen in the future.

7.3 Women's Programme

Through the women's programme, over 6,800 women have been involved in forestry activities in 39 villages by growing trees in woodlots and in their home compounds. Women are now growing a wide variety of tree seedlings: Mesquite, lemon, guava, mango, henna, and arak as well as forestry species in their home nurseries. The working area has been expanded to incorporate new villages where women expressed interest in joining the programme. The women's programme has also started another training programme to show women how to build and use improved fuel-efficient stoves.

Subsequent to the success of the Women's Programme, a wider, low-input women's forestry project in the Northern State was proposed. Ten villages were studied, with the aim of establishing the most suitable areas for intervention. By the end of August 1993, 40 groups had already been set up, involving 460 women. The women began by growing forestry species, such as *P. juliflora*. The new extensionists then started to train women to grow fruit and ornamental trees and to build improved mud stoves.

7.4 Village Participation

Levels of enthusiasm and involvement in project activities varied considerably from village to village, and depended on a variety of factors, including the nature of the committee, the cohesiveness of the village, and the perceived benefits of the activity. Participation in implementation and in planning and decision making are discussed separately below.

7.4.1 Participation in Implementation

In each village, the committee would arrange for kafirs (community work days organized by local political structures) to carry out the physical work required, at which "everyone participated in the work." In some villages, women were allowed to work, in others they provided food and drink for the men working. Schoolchildren often helped in nursery work, for example filling polybags or planting out seedlings in the shelterbelts, particularly if their teachers were committee members.

Inevitably, those who benefited most from the project's activities, those whose houses were threatened by sand inundation in the case of the shelterbelts or those who benefited from the income in the case of the woodlots and nurseries, were most likely to be willing to contribute either their labour or their money.

In a village like Wad Killian, which is poor, small, and fairly homogeneous, the majority of the village felt affected by the sand movement. They regularly worked in nafirs to plant and tend their shelterbelt and still contribute financially to the running costs of the pump, each family according to its ability.

In El Hosh, which is a much larger settlement, the shelterbelt was managed from the start by the Popular Committee, most of whom lived in areas less directly affected by sand inundation, and were, therefore, not particularly motivated to make the belt a success. Those worst affected were the nomad communities that had settled recently on the outskirts of the village, but they were not an integral part of the village community, and were not involved in the project.

After handover, in many villages, the committee experimented with using hired labour instead of voluntary village labour. This seemed a sensible option for two main reasons. First, most of the village men are farmers; they complained that they were too busy working on their farms to have time to spare to devote to the project's activities. Second, much of the day-to-day work now required could be easily carried out by one or two people, and some of the tending tasks would be better performed by someone with some forestry experience.

7.4.2 Planning and Decision Making

After the initial meeting in which the committee was elected, the rest of the village tended not to be very involved in decisions taken regarding project activities. The committee and project forester often worked closely together and, in general, other villagers were not involved in their discussions or training sessions.

There was occasionally a strong feeling that the committee was operating on its own, without consulting the village as a whole about their decisions. It is not known whether this may be due to a lack of interest on the part of the village or because the committee did not invite their comments.

In some villages, such as Wad Killian, the whole community participated in the implementation of the shelterbelt, by offering their labour and financial contributions, and are more involved in decisions regarding it. However, even with full village participation on these levels, there was an additional responsibility, previously borne by the project staff, to be borne by someone or a small group of people (the committee): management and supervision of the activities on a daily basis. This responsibility remained regardless of whether the work itself was carried out by paid labourers or voluntarily.

7.5 Achievements

7.5.1 Shelterbelts

Most shelterbelts perform a useful protective role against the incoming desert sands. The main reason cited by the village representatives for joining the project was to stop sand inundation. According to the villagers, the benefits of the shelterbelts were that they kept the sand away; provided shade, fodder and some fuelwood and improved the view. Women were very clear about the benefits, saying, "Sand used to get everywhere before, in our food and our clothes and it gave people allergies and other health problems. It is much better now with the belt." There were also indications that some migration had been stemmed as a result of the belts, and there was evidence of new building in the lee of the belts. The peace of mind provided by the belt was also mentioned. "Before the belt, I knew if I didn't get the sand this year, I'd get it later on. It's different now," said one man from Taragma.

However, the belts can have some negative aspects: they can attract birds and children, a problem in areas where belts were located near to farmers' fields. Complaints about the evils of the invasive mesquite (the species with which all the belts are planted) often aroused heated debates. One man in Taragma summed up the situation by saying, "we accepted the mesquite in the shelterbelt as a lesser evil than the sand."

The two belts that were in poor condition, El Hosh and Goresh, had suffered different types of problems. At El Hosh, the problems seem to have resulted mainly from poor management and lack of motivation of the Committee who were in charge. Most of the Committee were not from the part of the village that was under threat. At Goresh, the village was extremely motivated — the belt had been planted out four times. The problems encountered were the result partly of bad luck and partly of insufficient technical experience.

7.5.2 Women's Programme

The women's programme consisted of three components: home seedling production and tree planting, improved stoves, and vegetable production. The improved stove component started late in Phase Two. Many women claimed that they used less firewood and produced less ash and mess. However, the coverage of the programme was fairly small.

Women extensionists also taught women how to grow seedlings to plant in their home compounds or to sell or give away. The scheme was popular in most villages. The benefits of the trees planted in home compounds were shade, fodder (from mesquite), toothbrushes (from Arak) and fruit (from lemons and guavas). Some women grew vegetables in their compounds or in the village woodlots or next to shelterbelts, but in almost all cases this stopped, in the woodlots and shelterbelts because irrigation was not frequent enough (now that the trees were better established) and in the case of home planting "because we are lazy."

Despite considerable efforts to explore marketing options for excess seedlings produced, these remained elusive. Selling seedlings was always difficult, especially so in villages where the home nursery programme was most successful. In Abdotab at one time there were 70 operational nurseries. With the restrictions imposed on women's movements in this traditional Moslem society, women could not easily travel beyond their village to market their seedlings. A small village such as Abdotab could not absorb the production of 70 nurseries. Therefore, it is not surprising that home nursery production ceased once women had grown sufficient seedlings for themselves and their friends and families.

The emphasis placed by the programme on self-sufficiency meant that women could usually obtain all the inputs they needed to raise their seedlings (including polybag alternatives), and knew how to collect and prepare seed. They were also often aware of the prices for which they could sell their seedlings and which species were most popular.

An important spin-off benefit of the women's programme was that the project had helped to raise women's status in some villages. When the women extensionists were first employed by the project and started working with women, other villagers were very dubious of their activities, and they suffered taunts and even accusations of being "loose women." However, when many of the village women succeeded in growing seedlings, and making some (small) income from them, the taunts stopped and people began to realise that they were serious. The extensionists are no longer working for the project, yet women still stop them in the street to ask their advice about their seedlings. The women's programme is perhaps in some way helping to change attitudes in these small conservative villages.

7.6 Evaluating Success

"Success" in a particular village was determined only partly by factors within the project staff's control, as so much depended on the villagers themselves. It also is very much determined by the time scale used for the assessment. It is worth noting that perhaps what could in some ways be judged to be the most and least successful villages, Wad Killian and El Hosh, were managed by the same forester. It is possible that the project should have been more willing to withdraw from unmotivated villages and invest the project's equipment and foresters' time at other sites.

7.7 Harvesting Belts

When a Mesquite shelterbelt is to be harvested to provide fuelwood, it should be cut in rows, in rotation, leaving approximately 1.5 years between cuts of the same row. In a belt of six rows, two rows could probably be harvested at one time. Cutting alternate rows means that the whole belt still offers some protection even after the cut. The prevailing wind direction at the time of the cut should be identified and the cut arranged so that the cut rows are those most protected from the wind. The cutting should be timed just before any possible rains, as this will help regeneration of the cut trees.

However, it should be noted that on each occasion when shelterbelt harvesting was discussed by the project with the villagers, they had categorically stated that they did not want to cut the belts in case it affected their efficiency as sand barriers.

7.8 Future Need

There is an increasing backlog of demand from villages for technical and financial assistance with shelterbelts which could not be met under the existing programme. A "Shelterbelt Office" based in Shendi would provide low-input support and technical advice for the establishment of shelterbelts in the area.

8.0 COMMUNITY FORESTRY PROJECT - 1988–1996

8.1 Background

Since 1988, SOS Sahel's Community Forestry Project has been working with agricultural communities in the Nile Valley around the town of Ed Debba, about 150 miles northwest of Shendi. Several of the highly fertile areas along the river are being gradually buried by encroaching desert sand. Mobile dunes creep foreward onto cultivated land, and windblown sand damages crops and machinery, fills wells and canals, and buries houses.

Although the desert has been nearby for a very long time, the stories of older local farmers suggest that until the late 1950s the Nile Valley was covered by a fairly dense vegetation of trees and shrubs for several kilometres on both sides of the river. In some places, large herds grazed the pastures and moving sand dunes were not present. Overgrazing and tree cutting are likely to have contributed to the devegetation of the valley.

Before 1945, no rainfall figures are available. But the rainfall figures for the Dongola station (about 100 km north of Ed Debba) show a drop from a yearly average of about 30 mm in the 1950s to 10.2 mm in the 1980s. Farmers say that before 1945 annual rains were substantially more important than in the last 40 years, and that until about 50 years ago some wadis used to flow into the Nile during the rainy season (for example near Abkor).

A possible drop in the ground-water table linked to the decrease in rainfall and decrease in the frequency of flooding of the Nile might have hampered tree regeneration. Major Nile floods in the project area have only occurred in 1946, 1954, 1975, and 1988, while, before 1945, floodings apparently occurred every two to three years.

Whatever the causes, at present the tiny fertile flood plains along the Nile are threatened by moving sands and dunes coming from the desert. Some small villages have already been buried. Moreover, the decreasing frequency and magnitude of the Nile floods badly affects the soil fertility of the agricultural flood basins. In comparison with the limited resources available, population density in the Nile valley has been relatively high for a long time.

The fertilising Nile floods were a safeguard against soil exhaustion and successive technological innovations ensured progressive intensification of agricultural production allowing increasing population densities.

However, the steady pressure of population growth has been squeezed between a chronic land shortage and the techno-economic endeavours to increase productivity on the limited natural resource base, resulting in successive waves of out-migration. The introduction some years ago of diesel-powered pumps for irrigation and more recently the use of these pumps to open up new land behind the flood basins are good examples of local efforts. Nevertheless, out-migration could not be stopped, and at present more than half of the population originally from the area now live elsewhere.

At present, farming systems have reached a relatively high level of sophistication, and it is estimated that two-thirds of the total income from crop production is used to cover production costs, for irrigation by diesel-powered pumps, fertilisers, mechanical land preparation etc., indicating that the bulk of the economy has been monetarised.

However, in recent years, agricultural profitability has decreased sharply. Costs of inputs (pumps, spare parts, fuel, fertilisers, mechanical land preparation) have increased more rapidly than the farm-gate value of production. For example, between 1985 and 1992, the price of fertiliser increased tenfold, while the selling price of beans went up only fourfold.

The aims of the first phase of the project were: to enable people to grow Mesquite shelterbelts and windbreaks and to stabilise mobile sand dunes in order to protect farmland and homes, to demonstrate to comunities that they can help themselves to protect their environment, and to research the most appropriate techniques for the establishement of trees on difficult desert sites.

During phase one, villagers from outside the orignal project area approached staff for assistance with seedling production and technical advice for shelterbelt establishment. Many of these villagers were already buying seedlings from the project, but lacked the technical expertise and inputs, such as seed and irrigation equipment, to produce a sufficient quantity and quality of seedlings to plant themselves. As a result a second phase of the project was planned, which began in January 1992, to extend activities to cover these new villages. This phase ends in December 1996.

8.2 Project Achievements

During the period 1988 to 1993 a total of 54.5 km of external shelterbelts, sand dune fixation, internal shelterbelts, and windbreaks were programmed (Table 1). The achieved total was 61.1 km.

Table 1. Targets and Achievements 1988–1993

Type of Activity	Targets		Project Output
	1988S1993 (km)	1988S1995 (km)	1988S1993 (km)
External Shelterbelts (ESB)	5.7	8.5	6.3
Sand-dune Fixation (SDF)	21.0	27.0	15.9
Internal Shelterbelts (ISB)	10.3	11.5	16.4
Private Shelterbelts (PS)	12.2	19.0	12.7
Windbreaks (W)	5.3	6.7	3.0
TOTAL	54.5	72.7	54.3

The total number of seedlings produced in the period 1988 to 1993 was 157,400. Approximately 56,750 seedlings were used for the activities coordinated by the project (including replacement of dead trees at 15%). The remaining 100,650 seedlings were sold, given to community members, or used outside the project area. The project produces seedlings from central nurseries run by project staff but also directly from private nurseries run independently by community members. These nurseries will have been established with the help of the project. Project-run nurseries produced 96,000 seedlings, which constitutes 61% of total production. Men from the community have

contributed a total of 430 working days and women contibuted 200 days toward the production of these seedlings. The remaining production was divided as follows:

- **Women's private nurseries, 45,900 (29% of total production and 3,094 working days)**
- **Men's nurseries 15,500 (10% of total production and 1370 working days).**

Assuming an annual prodiction at each private nursery of about 300 seedlings, the annual mean number of private nurseries over the last five years is about 30 for women and 10 for men.

By the end of 1994, the project had planted 93.3 km of shelterbelts. Severe floods in August and September 1994 destroyed some of the more recent shelterbelt plantings. Three kilometres of shelterbelts were lost as their trees were fully submerged by floodwaters for over two months. However, the project was also able to make good use of the flood waters collected in dune hollows and about 4 kms of shelterbelts were planted at sites which were previously categorised as inaccessible.

8.2.1 Seedling Production

Total seedling production during 1994 was 59,700, of which 23,800 were produced at the main project nurseries of Argi and Affad. The rest were produced by individuals in extension nurseries. Seedling production at extension nurseries in the Phase I sites of Affad and Argi decreased substantially as the demand for seedlings is dwindling.

Affad nursery was severely damaged by the Nile floods in September. Most of the young seedlings were lost, as well as the nursery buildings and the well. Production began again in March 1995 after the water table had subsided and the nursery rebuilding and repairs had been completed. Seedling production at Argi nursery and in the private extension nurseries has been increased to compensate for the loss of production from Affad.

8.2.2 Planting

During 1994, 10.612 km of shelterbelts were planted in the project area. Nearly all planting has taken place at Phase II sites. Irrigation at the external shelterbelt sites is proving to be difficult at all Phase I and Phase II sites due to sand burial and low community participation.

8.3 Extension and Women's Programmes

The male extension team have used puppet theatre as an extra tool for extension messages. This idea was pioneered at Shendi (Village Extension Scheme) and proved very effective there. Four shows were put on during the year which were well attended and were reported to be very popular.

The women's programme team began showing women how to construct improved fuel-efficient wood burning stoves, using techinques they had learnt during their visit to an FAO project in the Eastern State. Thirty women were trained in mud stove production.

8.4 Handover

The timetable for handing over the management of the project sites to the villagers has not yet been fully implemented, mainly due to the low participation at external shelterbelt sites, which are not yet fully established.

8.5 Effectiveness of the Mesquite Shelterbelts

Technically the shelterbelts are in excellent shape. The survival rate of planted seedlings is very high and the mere 15% of seedlings which do not survive have been replanted successfully.

Nearly all of the labour inputs needed for planting and watering of the shelterbelts have been provided by the local communities (almost exclusively by men) without any payments from the project. The project provides technical assistance, seedlings (or pays for them if locally produced), pumps for shallow wells or a water-tanker service for irrigation until the trees' roots reach soil moisture.

Physically, the shelterbelts are highly effective. They hold the sand back and will protect land and houses for some time. Some dunes that have built up behind the Mesquite shelterbelts are now 12 m high.

Due to the necessity of prolonged irrigation over more than a year, shelterbelt production is expensive. However, no alternative planting technique is available. Major project benefits are the protection of agricultural land against sand encroachment and the protection of houses.

Immediate (short-term) beneficiaries are a minority (about a quarter) whose land and houses are adjacent to the incoming moving sand and dunes. Medium-term beneficiaries can be estimated at more than half the total population. Longer term and indirect benefits affect the total population of the project area.

Monetary estimation of the benefits is very difficult, as the choice for those threatened with sand encroachment is between staying or leaving and loosing it all.

Internal and individual shelterbelts protect agricultural land, have an impact in the short-term and are "individually" planted by the adjacent farmers. They elicit the highest levels of participation and need a lower level of project "subsidies." External shelterbelts have more impact on homes (in the short-term) than on land (longer term) and have to be undertaken communally. Moreover, they are further off. As a result, the external shelterbelts, in the eyes of the villagers, have a lower priority and a lower cost/benefit ratio. They presented participation problems and required a higher level of project inputs. Participation in sand dune fixation work is somewhere between these two extremes.

The bulk of the seedling production for the project as well as women's and men's nurseries is *P. juliflora* with some *E. camaldulensis*.

Examples of the use of *Prosopis* are shown in Figure 2: Overview from the top of a sand dune fixed with *Prosopis (upper left)*, Camel by a shelterbelt with date palms in the background *(upper right)*, Villager beside irrigation canal for an external shelterbelt *(lower right)*, and Measuring the growth of mesquite *(lower left)*.

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Figure 2. Examples of the Use of Prosopis