4. An experience in sand dune fixation: rehabilitating and extending the Nouakchott Green Belt

Between 1975 and 1992, the initial establishment of the 750-ha green belt around Nouakchott did not take account of the rapid growth in population, which now numbers almost 1 million, or of the immense pressure on the capital's urban and periurban space during recent decades.

Seeking to rectify this situation, in 1999 the Government of Mauritania sought the assistance of the Government of the Walloon Region of Belgium to launch a realistic programme to rehabilitate and extend the plantations already established around Nouakchott in order to protect its socio-economic infrastructure against sand encroachment.

On the initiative of Prince Laurent of Belgium, this assistance was provided between 2000 and the end of 2007, with the establishment of 800 ha under the Support for the Rehabilitation and Extension of the Nouakchott Green Belt Project, financed by the Walloon Region and executed by FAO in partnership with the Mauritanian Government. The World Food Programme (WFP) undertook to provide food incentives for the workers.

The development objective, as expressed in the project document, was to boost sand encroachment control and the protection of Nouakchott's socio-economic infrastructure by ensuring the permanence, extension and sustainable management of the capital's urban and periurban forest stands with the participation of cooperative groups, associations, NGOs and professional associations, in close coordination with administrative, municipal and technical authorities.

The immediate objectives were:

- to guarantee the permanence and renewal of the tree cover already established;
- to prepare, organize and maintain participation of local inhabitants and authorities in the protection, maintenance and extension of forest plantations;
- to design a medium- and long-term urban and periurban forestry programme for the city of Nouakchott;
- to adapt and carry out small-scale trials on fixation measures for coastal dunes.

During implementation of the project, 800 ha of inland dunes were fixed under government supervision northeast of the capital in order to back up the first reforestation activities undertaken between 1987 and 1992 by the Mauritanian Government and LWF.

A trial was also carried out on 7 ha in order to encourage renewal of the coastal dune belt to the west of the capital.

In rural areas of Trarza *wilaya*, the project intervened on the request of local authorities and communities to check the renewed sand encroachment that was threatening these areas, reduce degradation of their environment and protect their socio-economic infrastructure. With the active participation of the local population and technical support from the project, 50 ha were mechanically stabilized and planted.

Since its inception, the project has benefited from experience acquired by:

- the PLEMVASP project between 1983 and 1997;

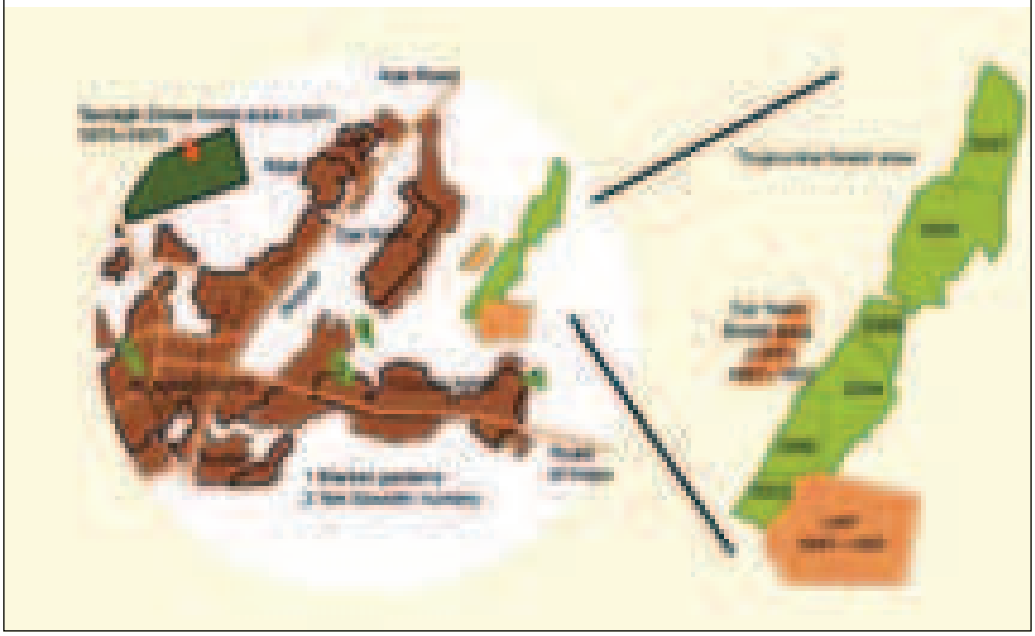
- LWF, which carried out the first dune fixation work around the capital between 1975 and 1992 under the Nouakchott Green Belt Project;
- studies carried out by FAO in 1984 on the dynamics of wind and sand and on the establishment of a sand encroachment map of the area around the capital.

PRELIMINARY STUDIES

Survey of forest and horticultural areas within project intervention zones

At its inception, the project carried out a survey in order to draw up a map of existing forest areas: 1 270 ha at Toujounine, Dar Naïm and Tavragh-Zeina, together with their extension of 857 ha during the 2000 to 2007 seasons at Toujounine (Figure 13), the Nouakchott coastal strip and at Tiguint and Tendghaïdsat in the Trarza *wilaya*.

FIGURE 13
The Toujounine intervention zone



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Dar Naïm horticultural zone

The main horticultural areas, totalling 150 ha on the outskirts of the capital, were also surveyed and mapped.

Thanks to intervention under the project, all the forested areas located in and around the capital were included by decree in urbanization plans for Nouakchott city in order to ensure their protection and guarantee the sustainable protection of socio-economic infrastructure against sand encroachment.

Analysis of meteorological data

The Nouakchott Airport Meteorological Station (18°05' north, 15°56' west) is situated some 5 km west of the Toujounine plantation. Data on temperature, rainfall, relative humidity, evaporation, hours of sunlight and wind speed were recorded between 1946 and 2007 – 62 years – and have now been collected, analysed and computerized (Table 1).

The Tiguint Meteorological Station in Trarza *wilaya* (17°15' north, 16°00' west) started to keep records of rainfall and the number of days of rain in 2002, the year of intervention under the project at Tiguint and Tendghaïdsat in Trarza *wilaya* (Table 2).

TABLE 1
Summary of meteorological data during the period of the project, Nouakchott Airport

Parameter	2000	2001*	2002	2003	2004	2005	2006	2007	Average 2000–2007
Temperature (°C)									
Average minimum	19.1	20.7	20.8	20.8	20.5	21.2	20.4	20.1	**20.4**
Average maximum	30.2	34.2	33.4	33.3	33.3	33.6	34.3	33.4	**33.2**
Overall average	24.6	27.5	27.1	27.1	26.9	27.4	27.3	26.7	**26.8**
Average absolute minimum	15.9	17.3	17.3	17.4	16.8	17.4	16.9	16.9	**17.0**
Average absolute maximum	36.9	41.0	40.4	40.1	40.2	40.4	42.3	39.4	**40.1**
Relative humidity (%)									
Average minimum	32.7	33.7	31.7	35.1	34.2	35.7	35.8	31.0	**33.7**
Average maximum	73.7	81.6	75.6	79.2	79.9	80.4	77.3	73.7	**77.7**
Overall average	53.2	57.6	53.6	57.1	57.0	58.1	56.6	52.3	**55.7**
Average absolute minimum	10.8	10.5	10.2	11.8	11.0	9.5	11.7	10.8	**10.8**
Average absolute maximum	90.6	98.3	96.7	96.1	97.4	98.0	94.1	95.5	**95.8**
Rainfall									
Total (mm)	75.9	127.7	32.5	45.4	25.8	184.2	64.9	15.5	**71.5**
Total number days of rain	9	9	7	7	9	17	13	7	**9.8**
Evaporation (Piche)									
Average (mm)	198.2	198.3	200.5	186.2	190.6	254.0	282.8	311.4	**227.8**
Sunlight									
Length (hours)	223.2	263.6	246.5	241.4	248.6	252.9	265.5	260.9	**250.3**
Wind speed (m/s)									
Average	4.5	4.4	4.7	4.5	4.6	4.1	4.4	4.5	**4.5**
Maximum	16.2	16.8	17.8	16.8	15.9	15.5	17.2	15.2	**16.4**

* No planting or restocking during this year.

TABLE 2
Rainfall at Tiguint

Rainfall	2002	2003	2004	2005	2006	2007	Average 2002–2007
Total mm	101.7	247.2	164.6	204.3	152.0	111.5	**163.6**
Total number days of rain	11	15	12	18	15	10	**13.5**

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Tendghaïdsat village nursery, Trarza wilaya

TREE NURSERIES

In general, the positioning of a permanent nursery to supply an area where reforestation work will be carried out over a relatively long period needs to take account of:

- the relief of the terrain: the ideal ground is flat, slightly sloping lengthwise, cleared, levelled and without stones;
- the quality of the soil, which must be of light or medium-textured loamy sand, easy to work, well drained and free of nematodes and dangerous cryptogams;
- a permanent supply of sufficient good-quality water;
- a central situation or proximity to reforestation areas;
- all-season ease of access;
- availability of sufficient labour;
- the capacity to obtain annual supplies of substratum to ensure the desired production.

The nursery area is protected against prevailing winds, runoff from rainfall or secondary buildups of water, livestock, fire, birds and plagues of locusts. It is also surrounded by a wire netting fence, lined on the inside with a preferably thorny life fence or with fences of plant or synthetic material. Permanent posting of guards is also advised.

Some nurseries have been set up and managed by communities. For example, the Tendghaïdsat village nursery in Trarza *wilaya*, covering 400 m² and with an annual production capacity of 25 000 seedlings, was set up using a participatory strategy with the rural community and the support and supervision of technical experts from the project.

An example: Ten Soueilim nursery

The nursery in the Ten Soueilim forest research station, Dar Naïm *moughataa* (prefecture), Nouakchott *wilaya*, meets all the criteria perfectly.

The plot selected for project activities covers an area of 1 500 m² and is intended to produce 60 000 seedlings each year for planting and restocking in the Toujounine reforestation zone, the Nouakchott coastal dune zone and the Tiguint reforestation zone in Trarza *wilaya*.

The area of the nursery was surveyed and mapped on a 1:200 scale at the start of the project, and the map was then updated each year. The map indicates the position

of seed beds depending on annual production and species for the storage of recipients (polyethylene pouches), raised beds for the production of bare roots, paths and supply points for irrigation water.

In this nursery, the seed beds are 1 m wide, 10 m long and 10 cm deep, and are separated by a 50-cm-wide path. They must always lie in an east-west direction in order to provide the young seedlings with the same length of daylight and thus ensure a uniform production. The beds are arranged on either side of the central path and each contains 1 000 seedlings.

The main modes of production are through sod seeding in black polyethylene pouches (with flat dimensions of 25 cm × 12.5 cm, giving a volume of 1 256 cm^3), cuttings in pouches and, as an experiment, bare roots in raised beds 10 m long, 1.1 m wide and 30 cm high.

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Ten Soueilim nursery

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Placing pouches in nursery beds

With a view to accustoming the seedlings to the sites where they will be planted, the substratum used is made up of dune sand and a small amount (10 to 15 percent) of organic fertilizer.

Before the pouches or raised beds are filled, the substratum is carefully mixed and sieved to produce a uniform texture and get rid of undesirable elements (wood, stones, etc.).

Sowing is one of the main nursery operations. It is important to:

- know the provenance and harvesting date of the seed;
- have healthy seed with a high germination rate (a germination test must be carried out for each species before sowing);
- water the recipients copiously prior to sowing in order to allow the germination of weeds and their removal, while avoiding any hardening of the substratum;
- soak the seeds in hot or cold water depending on the thickness of the cuticle prior to placing 2 to 3 of them in each recipient; the depth of sowing will depend on the size of the seed, but should be about 1.5 to 2 times its diameter; for the production of bare roots, the planting holes in the raised beds are arranged every 10 cm in lines 15 cm apart, making a density of 70 seedlings per square metre;
- sow slow-germinating species first;
- water by spraying after sowing and until emergence, making sure that the seeds are not ejected out of the seed beds;
- protect seeds against birds, insects and rodents with the aid of netting, insecticide and rodenticide;
- monitor the germination time of each species and if necessary resow in order to obtain seedlings of a uniform height.

Certain species, such as *Tamarix aphylla* and *T. senegalensis* used to fix coastal dunes, are multiplied in the nursery through cuttings. Taken from selected trees, the cuttings are 15 to 20 cm in height, with a diameter of 2 cm, and are pushed into the pouch at a slant, leaving one or two buds above the ground. The substratum is then pressed down around the cutting.

The following care is given to the young seedlings:

- Maintenance watering: This is carried out with a sprinkling can twice a day in the cooler hours, supplying 20 litres per square metre per watering; as the seedlings

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Bare-root production of Prosopis juliflora *in raised seed beds*

grow, they are watered less often in order to accustom them to their future environment.

- Thinning: If germination is very good, only the most vigorous seedling in each recipient is retained.
- Pruning and stripping of roots: When the seedling's root system starts to come out of the pouch, about four or five weeks after germination, the recipients are moved sideways to prevent the tap root and certain lateral roots from penetrating too deeply into the ground. This action encourages the development of radicles in the substratum and also results in good lignification of the aerial part of the seedling. The operation is carried out when the weather is not too sunny and takes place every two to three weeks until the seedlings are planted out; after the roots have been pruned, the treated seed beds are well watered. For the production of bare-rooted seedlings, regular pruning of the tap root and secondary roots is carried out to a depth of 25 to 30 cm with well-sharpened spades (with blades 30 to 35 cm long and 20 cm wide).

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Watering of seedlings in the nursery

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Pruning of bare roots

- Regular weeding of the seed beds.
- Shading of the beds: In order to protect the young seedlings from the sun, they have to be shaded in some climates; this protection is gradually removed as they grow.

The calendar of work is as follows for each growing season:

- March to April: repair of the general infrastructure of the nursery, addition of substratum, filling of pouches, preparation of nursery beds for the pouches and raised beds for the bare roots, installation of windbreaks, purchase of seed;
- April: pouch sowing of slow-growing local woody species (*Acacia raddiana, A. senegal, Leptadenia pyrotechnica, Nitraria retusa*) and grassy species (*Aristida pungens, Panicum turgidum*) and propagation by cuttings in pouches (*Tamarix aphylla, T. senegalensis*);
- May: pouch sowing and bare-root sowing in raised beds for *Prosopis juliflora*;
- July to October: watering, regular sideways shifting of pouches and monthly pruning of bare-root seedlings, pest and disease control, various types of maintenance and posting of guards until planting out.

If this calendar is followed, the best quality seedlings can be obtained for successful planting out.

The project gave priority to the production of indigenous woody and grassy species rather than non-indigenous species.

Throughout the project, stress was laid on ongoing practical training of staff, the production of healthy lignified seedlings with an orthotropous root system (neither spirally wrapped nor crooked) and a good quantity of secondary roots.

The transport of substratum, the filling of pouches and raised beds, and the installation of the pouches in their beds require 20 to 25 person-days for one month. Starting at sowing time, the daily staff at the nursery is made up of one team leader, two male workers and ten female workers, for an average annual production of 60 000 seedlings.

The average cost price per seedling is US$0.25.

MECHANICAL DUNE STABILIZATION

In the project intervention zones, the checkerboard wattling technique may be selected, taking account of the directions of the prevailing winds. On average, and depending on dune type and shape, 600 to 1 200 linear metres of fencing (around the edge, counter-dunes

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Nursery beds containing Panicum turgidum

perpendicular to the direction of prevailing winds, and interior wattling) were installed per hectare.

As stabilization material, the project decided on unwoven branches of *Leptadenia pyrotechnica* and *Prosopis juliflora*, which were placed directly in a previously dug trench, a method that proved much less arduous and time-consuming than that of the woven fences previously used. Sustainable extraction of plant matter in the form of pruning to improve mature stands near the areas to be stabilized had no negative effects on the growth of these stands.

When installing the plant matter, care is taken to ensure the permeability of the fences (30 to 40 percent left empty) and observe a height of 1 to 1.25 m. Cutting,

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Cutting with a saw

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Cutting with a chainsaw

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Transporting plant matter

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Installing plant matter

transporting and installing the plant matter takes two to three team-days' work by a 20-person team (1 leader and 19 workers).

Depending on the distance from the supply source, one person installs an average of 6 to 8 m of fencing per day. The cost price per linear metre installed is thus US$0.65.

BIOLOGICAL DUNE FIXATION

Once the dunes have been stabilized, they can then be fixed definitively by installing perennial grassy and woody vegetation.

For each planting season, planting and restocking start as soon as the first rains fall.

The ideal is to plant as soon as the new and residual soil moisture meet, which takes place a few days after good rain. A well-moistened soil means that the time taken in planting is reduced to a minimum and the seedlings take root well, thus reducing the planting costs per hectare. In the case of insufficient rainfall, supplementary water is given to each seedling in order to make up for the depth of residual moisture.

The positioning of species on the ground is a very important factor for successful planting.

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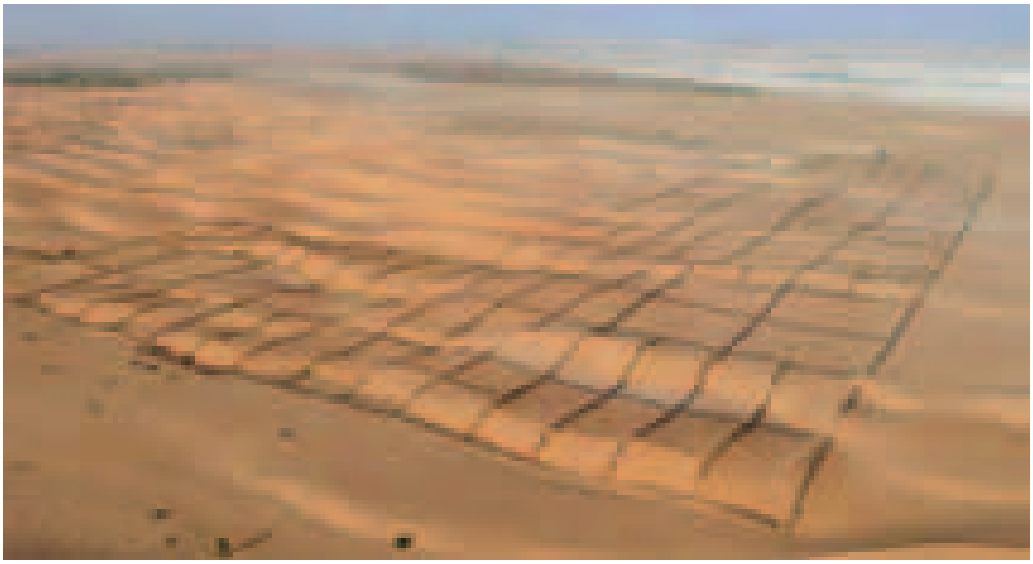
Installing a palisade or fence



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General view of a mechanically stabilized area


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Transporting water for watering


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Watering Acacia senegal *seedling after planting*


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Raising and planting the Nouakchott coastal strip

On inland dunes, three areas are considered: the accumulation zone, the deflation zone and the intermediate zone. The choice of species to be planted in each zone depends on their particular suitability. In the case of the project, *Prosopis juliflora* (the only woody species that has so far had any solid sustainable success on this type of soil) and *Aristida pungens* are planted on very mobile strip dunes in accumulation zones. Deflation zones are planted with *Leptadenia pyrotechnica, Aristida pungens* and *Panicum turgidum*, while other slow-growing woody species such as *Acacia raddiana* and *A. senegal* are planted in more stable intermediate zones. Broadcast direct sowing (of local grassy species) and pouch sowing (*Colocynthus vulgaris* of the Cucurbitaceae family) may be tried, but the success rate depends on rainfall.

On coastal dunes, planting concentrates on halophytic species, resistant to a high level of salinity, such as *Nitraria retusa, Tamarix aphylla* and *T. senegalensis*.

In the case of woody and grassy species produced in pouches, only well-lignified vigorous seedlings are selected. These are watered copiously immediately before being transported to the planting site, while rejected seedlings are disposed of. The selected seedlings are transported in a van with a tarpaulin cover to avoid exposure to wind and sun.

In the case of species produced with bare roots, the seedlings are sorted, and the roots are dressed and wrapped in well-moistened jute bags to protect them until they are planted.

Both woody and grassy species are planted at 5 × 5 m intervals in squares (making a density of 400 seedlings per hectare). With a view to encouraging development of the grassy cover and avoiding competition between trees in this ecosystem, which receives little rainfall, the distance between seedlings may be increased to 7 × 7 m in staggered rows (making a density of 235 seedlings per hectare) or even 10 × 10 m, also


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General view of the Toujounine plantation


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Natural regeneration of grassy cover


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Natural regeneration of Cyperus rotundus

in staggered rows (making a density of 115 seedlings per hectare) – although the latter density is increased on particularly mobile dunes.

The pouches are removed at the moment of planting in order to avoid spiral wrapping of the root system and gradual strangulation of the tap root. The pouches are collected up and destroyed to avoid polluting the environment with plastic rubbish.

Successful planting obviously depends on rainfall, the absence of parching sand-bearing winds and the organization and speed of field teams. During this period, the teams are closely supervised by technical experts from the project in order to ensure a maximum success rate for the seedlings.

On average, the mortality rate is lower than 30 percent for woody species planted in clods (after removal of the pouches), while the success rate is almost 80 percent for grassy species. However, bare-root planting of woody species will give good results only in zones with annual rainfall of more than 150 mm.

Restocking is carried out each year in sectors with a high mortality rate.

Thanks to intervention under the project, there has been major natural regeneration of the grassy cover, particularly with *Aristida pungens, Panicum turgidum, Cyperus rotundus, Elionorus elegans* and *Eragrostis* spp., in and around all the areas treated.

At planting time, three team-days' work by a 20-person team, evenly distributed on the ground, allows staking out (marking of lines where the seedlings are to be planted), the digging of holes, actual planting and the watering of seedlings.

One person plants an average of 15 seedlings per day, with a cost of US$0.3 per plant.

PROTECTION OF REFORESTED AREAS

The most appropriate solution is to post permanent guards for the intervention zones to prevent livestock (camels, sheep, goats and donkeys) from wandering from dedicated livestock corridors, while illicit human activities (collection of wood, cutting of fodder) are reduced to a minimum.

The guards are preferably recruited in villages near the planted areas. No wire netting fence is placed around the areas, for this method is too time-consuming and costly, and also lacks reliability in the short term.

The inhabitants are involved and made aware of the need to respect and preserve this forest asset, which will very quickly ensure the protection of their infrastructure

(dwellings, mosques, crops, market gardens, roads, etc.) against sand encroachment and more generally prevent degradation of their environment.

On average, one guard is responsible for 50 to 60 ha, although the number of guards is increased close to high-density grazing zones.

The annual cost of protecting planted areas in this way is US$15 per hectare.

MAIN CONSTRAINTS

Potential constraints on the success of reforestation in arid and semi-arid zones include:

- climatic factors: rainfall deficit, parching winds and major differences between daytime and night-time temperatures;
- the lack of involvement of the beneficiary rural population;
- the lack of technical support and training for national institutions and local communities for the effective implementation of forestry programmes;
- the choice and availability of material for mechanical dune stabilization;
- the selection of plant species, both woody and grassy, that are appropriate to the ecosystems in which the work is carried out;
- uncontrollable plagues of locusts.

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Plague of locusts on natural vegetation

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Prosopis juliflora *stand after desert locusts have passed*