9.2 Result 2: Bush encroachment is controlled in an economically and ecologically sustainable way

9.2.1 Methods to control invader bush

Based on research results and on-farm experience in both humid and arid savannas of southern Africa, the methods to control or eradicate bush discussed here should be seen as guidelines only since their success cannot be guaranteed. These control methods include chemical, biological and mechanical applications. This section should be read together with Chapter 5, which is the source of some of the information here.

As proposed by Smit et al. (1999), the following options are available to the farmer as regards debushing:

> Before any woody plant control programme is embarked on, the two alternative approaches to the problem of increasing tree density in savanna areas need to be thoroughly assessed.
>
> One approach is to adapt the livestock system to the existing vegetation. Thus, where tree densities are high and the woody plants are palatable, browsers should form an important component of the livestock system.
>
> The second approach is one of modifying the vegetation to suit a particular livestock system (and particularly a system based on grazing animals). Here it is important to note that the establishment of woody plants is normally a continuing process in savanna areas and so control cannot be achieved with single thinning operations. Planning and implementation therefore needs to be ongoing.
>
> Where this option is adopted in areas of high tree density, the first operation should be the often drastic one of ***thinning*** down to some predetermined density, after which a ***post-thinning*** management programme will be needed to keep the area open. [Emphases added]

It is of utmost importance that a woodland management plan for each individual farm be devised in respect of the socio-economic environment (livelihoods, benefits and sharing, health and safety), the ecological environment (biodiversity, habitat diversity and landscape considerations), and linkages to main certification mechanisms.

For any given method, aftercare programmes are indispensable and, if they are neglected, it could lead to even worse problems.

A brief description of the methods proposed is given here.

9.2.1.1 Chemical methods

The herbicides recommended need to be applied in accordance with the quantities prescribed by the manufacturers. This in turn will mainly be influenced by the kind of problem species and the clay content of the soils. If the clay content is below 20%, the success rate of herbicides is fairly good, while higher clay contents require special attention to dosage and costs.

All remedies/chemical products used in Namibia are obliged to be registered with the Registrar of the Fertilizers, Farmfeeds, Agricultural Remedies and Stock Remedies Act, 1947 (Act 36 of 1947).

Not all herbicides are selective and care needs to be taken that desired fodder bushes and trees are not affected.

The application of certain chemicals is recommended under circumstances where (Smit 2002) –

- the woody component is very dense (beyond 2,000 bushes per hectare)
- the majority of the trees have grown out beyond the reach of browsing animals
- animal access is severely restricted by invader bushes
- the woody component is largely unpalatable
- it is not practical to incorporate browsers in the livestock system, and
- herbicides are available which will selectively affect the target woody species more severely than the palatable species.

9.2.1.2 Root-absorbent herbicides

Herbicides with Tebuthiuron, Ethidimuron or Bromacil as the active ingredient are applied on the soil surface and taken up by the roots of target bushes after effective rain. Products containing these ingredients are available as granules or pellets, wettable powders or in a liquid form. The ones in granular form that are suitable for manual application are applied under the canopy next to the stem. The dosage depends on the height of the tree/bush; it is recommended that larger dosages be applied in two to four portions around the stem. Some of the granular forms are also suitable for aerial application. With these, however, it should be emphasised that they are less selective and may damage desired plants too. Wettable powders, mixed with water and herbicides in liquid form, are sprayed onto the soil adjacent to the stem (Smit et al. 1999).

The application rate of the soil-applied formulations will vary according to the clay content, the soil's organic matter content and pH, the species of tree being treated, and its size. The higher the clay content, the greater the dose should be. All materials use tree height or some other measure of size on which to base the needed dosage (Smit et al. 1999). Soil type and, more specifically, the clay content of soils play an important role in the effectiveness of herbicides. If clay makes up more than 20% of the soil, chemical treatment is perceived to be much more expensive as a result of the need for higher dosages. Below 20% clay, applications on the soil are effective (Trollope et al. 1989; Dahl & Nepembe 2001). Some of the herbicides are not effective on soils with a clay percentage above 35% (Smit et al. 1999).

Various plant species also differ as far as their resistance to herbicides is concerned (Smit 1993). *Dichrostachys cinerea*, for example, will require double the dose (Quan, Barton & Conroy 1994) applicable to *Acacia mellifera*.

After application, these herbicides remain inactive until such time as rain carries the active ingredient (Tebuthiuron, Ethidimuron or Bromacil) into the soil, when it is taken up by the tree roots. Their action in the plant is to inhibit photosynthesis. The leaves become yellow and abscise. New leaves are formed, but also abscise. This process continues until the tree no longer has reserves to initiate re-growth and so it dies. These herbicides should be applied early in the growing season. If applied in the dormant season or late in the growing season, they will remain inactive on the soil surface for lengthy periods (Smit et al. 1999).

Aerial application is usually done when the plant is in an active growth stage, i.e. the leaves and the stoma are still open and able to absorb the remedies. Several researchers (e.g. Moore 1989) also found that the carbohydrate status of plant parts at the time chemical treatment was applied had a huge influence on the application's effectiveness. Thus, the carbohydrate status of the different plant parts during chemical application will influence the minimum dosage and, consequently, the economic viability of bush control. Chemical control will be the most effective during the translocation of carbohydrates to the roots, and when they are stored in the roots.

Aerial application of root-absorbent herbicides is also regarded as an effective method to combat bush and is probably the fastest way to clear bush.

Rhigozum trichotomum's root distribution covers a radius around the stem base of approximately three times the plant height. The specific nature of the root system favours broadcast application of chemicals and implies a possible low application rate. In any future strategy, drastic control measures will be needed to eradicate bush where densities are higher than 1,000 bush equivalents followed by very good rangeland (Moore 1989).

9.2.1.3 Foliar and stem-absorbent herbicides

Products in this group contain Picloram and Triclopyr as the active ingredients and are used in either an oil- or a water-base form (Smit n.d.). Herbicides are sprayed directly on the plant's above-ground growth. These chemicals will then be absorbed by the leaves.

Foliar and stem-absorbent herbicides are also applied where the stems of plants are cut off close to the soil surface. Until recently, the most common practice was to apply Picloram and Triclopyr (Tordon Super) mixed in diesel or old oil at a 1% concentration to the stem of the plant using a knapsack spray or a brush. A red oil-immiscible dye is available for adding to the mixture. Small trees with a stem diameter of less than 10 cm can be sprayed directly, while those with stem diameters of more than 10 cm need to be cut back before treatment. In the latter case, the tree should be cut off approximately 5–15 cm above the soil surface and be treated as soon as possible thereafter. The cut surface and the remaining stump as well as any exposed roots should be wet thoroughly. If only one side of the stump is treated, it will often grow out from the untreated side.

Although the manufacturers advise that the product should only be used during the active growing season, good results can be achieved at other times as well (Smit n.d.).

9.2.1.4 Advantages and disadvantages of using herbicides

(a) Soil-applied herbicides (Tebuthiuron, Ethidimuron and Bromacil)

(i) ADVANTAGES

- Treatment of individual trees is relatively fast (Bester 1985a; Smit et al. 1999).
- Application can be selective, particularly when applied by hand. There is little danger of untreated trees being exposed to the herbicide (Smit n.d.).
- The residual effect can suppress seedling regeneration for up to five years (Smit et al. 1999; Bester 1985a), and
- The manual application of herbicides is labour-intensive and provides ample opportunities for job creation (Van Eck, pers. comm.).

(ii) DISADVANTAGES

- Even with selective application, trees that have not been treated may die because their roots extend to the vicinity of application (Bester 1985a; Smit et al. 1999; Smit n.d.).
- The active ingredient may be slow to take effect because it only becomes active once rainwater has carried it into the soil profile. This means it can take up to two years to effectively kill target species (Bester 1985a; Smit et al. 1999).
- Trees that die remain standing and show a resistance to decay and decomposition when certain of these herbicides are applied. Nutrients contained in their wood remain unavailable for use by other plants for long periods of time (Bester 1985a; Smit et al. 1999). This is especially of concern in dense stands of bushes.
- The rate of application is dependent on the soil's clay and organic matter content, making this method very expensive in soils with a high clay content (Bester 1985a).
- Trees differ in respect of their sensitivity to herbicides. Some trees require a higher rate of application. Therefore, a person applying the herbicides without the necessary knowledge of trees and correct application rates may cause failures and substantial subsequent financial losses, and
- A large number of dead standing trees makes for an unattractive landscape (Smit et al. 1999).

(b) Foliar and stem-applied herbicides

(i) ADVANTAGES

- These are selective methods, as the leaf area of a specific tree is treated. There is little danger of untreated trees being exposed to the herbicide (Bester 1985a; Smit et al.1999).
- Chopped-down trees whose stems have been treated immediately, die immediately (Bester 1985a).
- One can establish very soon whether or not the appropriate number of trees has been retained (Smit et al. 1999).
- Dead plants can be harvested and utilised for the production of firewood or charcoal, for example. Income derived from such products can be used to retrieve some of the costs arising from bush clearing (Smit et al. 1999; International Development Agency 2003), and
- It is labour-intensive and can create job opportunities.

(ii) DISADVANTAGES

- The procedure is very time-consuming (Smit et al. 1999) and tedious (Bester 1985a), and
- With increasing bush densities, manual applications become increasingly expensive. For areas with more than 2,000 bushes per hectare, aerial application is the cheaper option.

(c) Aerial application

(i) ADVANTAGES

- Because of its uniform application, no individuals escape treatment (this can also sometimes be a disadvantage). Seedlings which are often missed in hand applications are usually killed by aerial applications (Smit et al. 1999).
- It is a cheaper method when bush densities exceed 2,000 per hectare.
- It is not time-consuming and large areas can be controlled within one season, especially where high bush densities occur (Bester 1985a).
- It is effective, with a mortality rate in the order of 70–90%. However, this still means that not all the bushes are killed (Bester, pers. comm.), and
- Very little labour is required (an advantage from a financial point of view, but less attractive from a socio-economic perspective).

(ii) DISADVANTAGES

- Valuable plants may be adversely affected by the herbicide due to the non-selective nature of aerial applications (Smit et al. 1999), and
- Landing strips for aircraft are not always available (Van Eck, pers. comm.).

Aerial application of Graslan 20P by aeroplane is usually recommended as a first treatment, especially when there are so many bushes that it is very difficult to penetrate the thickets manually. It becomes more cost-effective with bush densities beyond 2,000 tree equivalents per hectare. As an aftercare measure, this method is regarded as too expensive; other aftercare measures should be applied before densities become too high again.

Since 1,000 *Rhigozum trichotomum* bushes per hectare can reduce carrying capacity up to 93%, it is recommended that drastic control measures be introduced to eradicate bushes where densities are higher than 500 per hectare. Because of the extensive root system, broadcasting of chemicals may be the most efficient way of combating this particular species.
Tables 9.3 and 9.4 provide a summary of the available herbicides and their active ingredients.

Herbicide	Type	Active ingredient
Molopo SC	Liquid	Tebuthiuron (50%)
Molopo GG	Pellet	Tebuthiuron (20%)
Spike 5GR	Pellet	Tebuthiuron (5%)
Savanna 500	Liquid	Tebuthiuron (25%), Bromacil (25%)
Bushwacker	Wettable powder	Bromacil (80%)

Table 9.3: Soil-applied herbicides (non-selective)

Herbicide	Type	Active ingredient
Tordon Super (Cut stump or basal stem application)	Liquid (mixed with diesel)	Picloram 120 g per litre (12%) Triclopyr 240 g per litre (24%)
Access (Cut stump, basal stem or foliar application)	Liquid (mixed with water and Actipron)	Tebuthiuron 240 g per litre (24%)
Viroaxe (Foliar)	Liquid (mixed with diesel)	Triclopyr 480 g per litre (48%)
Touchdown Plus (Stump)	Liquid (mixed with water)	Glyphosate trimesium 480 g per litre (48%)

Table 9.4: Plant-applied herbicides (selective)

Source: *Smit (pers. comm.); Stoltsz (pers. comm.); Van Eck (pers.comm.)*

9.2.1.2 Biological methods

(a) *Browsers*

With the exception of tree seedlings, which can be impacted by small browsers, the use of browsers to exercise control on woody plants largely excludes game.

Provided that target bushes are within the 1.5 m utilisation zone, goats at high stocking rates can under certain circumstances be used as a short-term measure to reduce intruder bushes.

With high densities, however, the required stocking rates are so high that many benign fodder bushes and desired perennial grasses are eradicated before invader species are reduced to the level where the problem is solved.

It is doubtful, therefore, whether it is viable and environmentally sustainable to keep goats at a required stocking rate of two to three units per hectare on a commercial farm of several thousand hectares.

As a general rule, therefore, the use of browsers is not recommended to reduce bush density if it has already reached problematic dimensions (2,000 per hectare and more).

The value of browsers (goats and game) as an aftercare or preventative measure of bush control will be discussed under 9.2.2 below.

(b) *The use of fire*

Veld fires are not regarded as an effective means of combating bush.

Even with adequate amounts of grass the number of woody plants is not substantially reduced since –

- larger trees and shrubs do not die from fire, and often regrow strongly
- bushes up to 2 m high only suffer a top-kill and have the ability to regrow
- a suitably high fuel load is not always available: A minimum of 2,000 kg of grass per hectare is needed to ensure an effective top-kill resulting in an acceptable state for browsing animals. This amount of fuel is not available where bush densities are already a problem, i.e. more than 2,000 bushes per hectare. Under such circumstances a fire will do more harm than good, and
- grazing management is often in conflict with the use of fires.

Veld fires may, however, be used to modify the structure of the woody layer and they are most useful for this purpose as well as an aftercare treatment.

The following fire regime (season and frequency of burning) is recommended:

- A high-intensity fire (>2,000 kJ per second per metre) is required. This can be achieved with a fuel load of 2,000–4,000 kg of dry matter per hectare.
- The relative humidity should be below 30%.
- Air temperature should be above 25°C.
- Burn with the wind (i.e. a head fire), but the wind speed should not exceed 20 km an hour.
- The season is also important in respect of burning. The best time is during spring, when the woody plants have already started to grow, but the grasses are still dormant – usually just before the first rains.
- The frequency of burning is not fixed. In wetter savanna areas a fire every three to four years may be possible, while in drier areas it should be undertaken opportunistically depending on the rainfall and the presence of small woody plants that need to be controlled.

Controlled fires as an aftercare measure are discussed under 9.2.2 below.

(c) Fire-girdling/stem-burning

Fire-girdling (also known as *stem-burning*), in which a low-intensity fire burns or smoulders for an extended period around the stem of a woody plant, can be used to selectively kill individual trees.

In general, it was shown that fire-girdling is most effective if done as near to ground level as possible. Thus, a fire is made at the base of the tree, using either wood, cattle dung or rubber from tubes as fuel.

A minimum duration (of at least 3 minutes) and intensity of the fire needs to be achieved for fire-girdling to be effective.

Regrowth was lowest and mortality the highest for trees fire-girdled during the rainy season, i.e. between January and April.

This procedure is relatively inexpensive as any available fuel may be used, but it is labour-intensive and time-consuming. It is also not well-suited to trees with small stems or to multi-stemmed woody species.

Post -fire-girdling treatments, especially with browsers, are recommended since regrowth does occur.

(d) Use of fungi

Based on extensive research, the Council for Industrial and Scientific Research in Pretoria, South Africa, concluded that it would be very difficult to develop a control method for *Acacia mellifera* based on fungi, e.g. *Phoma glomerata*, *Phoma cava* or any fungal products.

The main difficulty with developing a novel herbicide based on fungi is the isolation and identification of the active ingredient. The alternative approach, namely using the fungus as a selective pathogen, is also unlikely since the fungus is possibly sensitive to environmental factors which cannot be controlled.

Moreover, knowledge concerning the magnitude and extent of mortalities caused by the fungus *Phoma glomerata* is still very meagre. Prospects of solving the bush encroachment problem through natural enemies is not known and needs further investigation. This includes the extent to which regrowth takes place, the role soil types play in this regard, and the extent to which the fungi affect intruder species other than *Acacia mellifera*.

Where mortalities as a result of *Phoma* activity occur, it should be seen as a bonus at this stage. A strategy built on the hope that this fungus will eventually solve the problem may end up in great disappointment and precious time lost. Other control methods should rather supplement the bonuses that there are.

The impact of fire on the presence/activity/mortality of the fungi is unknown and should be investigated.

(e) Use of bio-agents

The use of bio-agents is limited to alien species.

The vast majority of the farmers who experience *Prosopis* encroachment expressed the wish to eradicate them as soon as possible. Some farmers, however, place a high value on these trees as a source of nutrition. In this case there is a clear conflict of interests. Farmers who apply expensive techniques to combat *Prosopis* find that those who utilise it serve as a source of reinfestation. Pods are spread by animals and by water movement down river courses.

The introduction of natural enemies such as *Algarobius prosopis* and *Neltumius arizonensis* beetles could solve not only the encroachment problem as such, but also the conflict of interests. The following options should be considered:

- Introduce the mentioned bio-agents that will feed on the seeds of trees.
- Once the beetles are established, the *Prosopis*-infested areas should be withdrawn from grazing for at least eight months every year. This will allow the bio-agents to destroy the vast majority of the seed embryos, curb dispersal of seeds, and reduce the amount of follow-up work after clearing. Thereafter, the pods can still be used by grazing animals without significantly losing the nutritional value. Alternatively, the pods could be thoroughly harvested and crushed through a hammer mill.
- It should, however, be realised that there are many other *Prosopis* seed eaters that can utilise the pods and spread the seeds during the period of withdrawal.
- Since the bio-agents will not affect seeds already present in the soil, seedlings will still emerge from season to season and need to be controlled/eradicated by other methods, especially on farms where the pods are utilised. Once bush densities become too high, pod/seed production will drop substantially and it will become increasingly difficult for animals or harvesters to penetrate the thickets.

A firm decision needs to be taken, therefore, in terms of a manageable number of *Prosopis* trees per hectare (a density which will allow grass production too) and one should clear accordingly. For example, –

- clear a manageable amount of land each year, either chemically or mechanically as described above, or by means of a combination of the two. Aftercare measures will be imperative.
- establish a bio-agent breeding station from which point the beetles could be distributed to farmers who are interested in using them. Such a station could be managed and maintained by the Ministry of Agriculture, Water and Rural Development.
- undertake research on bio-agents that will attack and destroy *Prosopis* flowers. The release of such an agent will require a major policy decision.
- consider utilising the wood to recover some of the costs of clearing invader species. The possibility of establishing small enterprises in this regard should be investigated.

The whole process should be supported by formal policies and legislation. Such provision does not exist in Namibia and should be incorporated under an existing Act.

Because these bio-agents are not entirely effective when used alone, they should be used in combination with other methods.

(f) ***Rotational grazing and resting of veld***

Veld-resting, together with good rangeland management practices where serious bush invasion is encountered, seems to be ineffective. This method should rather be seen as an aftercare or preventative option (see 9.2.2 below).

9.2.1.3 Mechanical methods

(a) ***Bulldozers***

Clearing invader bush by means of bulldozers leads to soil surface disturbance. This in turn serves as a seedbed for the establishment of a variety of woody seedlings and other pioneer species of little forage value. *Dichrostachys cinerea* in particular is favoured in the process. Over time, this may result in a woody community which is more dense than the original one. It is also a very expensive practice.

Consequently, this method is not recommended for purposes of veld reclamation.

However, where bush is cleared for crop production, bulldozing is very suitable.

(b) Felling/stumping

Felling bush by means of axes, saws, chain saws, mattocks, etc. is only recommended if the bush is removed in such a way that the coppicing buds are destroyed or completely removed.

This method is totally unsuccessful with *Dichrostachys cinerea*.

Where coppicing does occur, the stumps can be treated with an appropriate herbicide, e.g. Access. This treatment will be effective for *Dichrostachys cinerea*, for example. Browsers or stem-burning are also recommended.

9.2.2 Aftercare measures

Practical experience has already shown that any delay or neglect in following up treatments to control regrowth and reinfestation leads to a worsening situation.

Farmers/land-users who are not willing to commit themselves to this principle should not even attempt to control problem bush.

At the same time, sound rangeland management practices are indispensable for long-term success (Bester 1985b).

One of the most important objectives with bush control is to reduce the problem plant to a near-juvenile stage of growth. This will result in the plant's inability to flower and produce seeds for a number of years, which in turn will influence the frequency of aftercare treatments and, consequently, a reduction in the soil's seed content.

9.2.2.1 Chemical

With this treatment, most bushes die within a year and the recovery of grass is good. Despite this, follow-up treatment is required because the increase of perennial grass species does not appear to suppress reinfestation. Other options include an occasional controlled burn, the removal of bush by hand, or the introduction of goats to browse the regenerating bush. Few farmers take the latter option because it is difficult to manage, it is expensive (in respect of herding or fencing), and there is the constant risk of theft and predators.

Whatever the method may be, aftercare treatment should continue indefinitely.

Any of the manually applied herbicides mentioned under 9.2.1.2 and 9.2.1.3 can be used effectively as an aftercare treatment. The frequency of treatment will be determined by the results obtained from meticulous monitoring activities.

9.2.2.2 Biological

(a) Browsers

As an aftercare measure, goats can be introduced successfully to utilise and control regrowth as a follow-up to other methods like the application of herbicides, felling/stumping, and controlled or accidental fires.

A strategic approach would be to prevent problem species from producing seeds.

In other words, the grazing pressure needs to be at a level where the growth is kept low. The only significant control the browsers have on woody plants is through their effect on seedling survival. Goats can be effective in preventing the establishment of seedlings. However, if seeds from invader species like *Acacia mellifera*, *Dichrostachys cinerea* and *Prosopis* are available in abundance, goats can play a major role in the distribution of seeds and subsequent seedling establishment.

As a general rule, goats should be used in combination with cattle. The stocking rate will depend on the amount of bush and regrowth, as well as the grass yield. Unfortunately, no definite carrying-capacity guideline can be given in this regard as circumstances will differ from farm to farm (or area to area) as well as within and between years. The use of indicator species to monitor stocking rates and vegetation changes will be essential to secure success.

Browsers are also found to be effective when used in tandem with fire to control bush thickening. As an alternative to goats, browsing game can also be introduced. Species should be selected according to different tree strata and available browse. For this purpose game species like giraffe, kudu and eland can be employed successfully to utilise and control regrowth. High management skills are required for this kind of venture, however, and special attention should be paid to marketing the animals timeously in order to control stocking rates. In this respect the impact of camels on invader bush should also be investigated.

Boer goats require a high degree of management if they are to be used to control woody plants and are, therefore, not popular among farmers. If they are given free range of an area, they are likely to have little impact on the woody plants. Standard stock fences are not adequate for goat control and goat herders are generally not able to keep goats in a specified area long enough to apply the required intensity of browsing to the woody plants. Electric fences may prove more useful to restrict the movement of the goats.

(b) *Controlled fires*

The role of fire to suppress growth and the establishment of young trees in arid and humid savannas is broadly recognised. All current theories indicate that fire can be successfully introduced as an aftercare measure, but at the same time there is very little experience about the practical implementation of this tool. On the one hand, more research into the biophysical effects of veld fires on bush encroachment in different ecological situations is needed, while on the other, socio-economic considerations are as important and need further investigation. The frequency at which burning is applied can play an important role in counteracting seed production and suppressing the growth and establishment of new seedlings. Clearly, such an operation needs proper control and cooperation between neighbours.

The use of fires as a management tool should be incorporated into a national woodland management policy. At the same time, proper legislation and fire management guidelines should be in place to direct and protect landowners and land-users.

During 2001/2, more than 1 million ha of rangeland were destroyed by uncontrolled fires. All these sites can serve as excellent opportunities where the long-term effect of fire on bush densities, mortalities, evapotranspiration, productivity, survival of *Phoma glomerata*, and soil structure can be monitored and researched through follow-up burning.

(c) *Fire-girdling/stem-burning*

This practice is regarded as a very effective aftercare measure, but should be executed with caution to prevent the ignition of wild fires (see 2.2.1 for more detail).

(d) *Rotational grazing and resting of veld*

The principle of rotational grazing is based on short grazing periods followed by a long rest. Desired perennial grasses are grazed selectively to ensure and maintain a vigorous grass cover that has the advantage in respect of moisture in the upper layers of the soil. Pastures in such a condition are able to suppress the establishment and growth of bush seedlings and, therefore, the intrusion of unwanted bush species.

Once intruder bushes have established themselves in high densities, the bounds of resilience of the natural state have been exceeded. Under these conditions it is not possible for grasses to compete successfully with the extensive network of roots belonging to bushes and trees in the upper layers of the soil. External intervention such as the removal of bush is needed to restore the grass's competitive edge. Sound rangeland management practices should, therefore, be regarded as a preventative measure and, during the first 20 years or more after bush clearing, should be used in combination with other aftercare methods to prevent reinfestation.

The establishment of artificial pastures of *Cenchrus ciliaris*, for example, can be of enormous value for the reclamation of natural rangelands. In this way, camps can be withdrawn from grazing during critical phenological and/or climactic stages in order to allow the maximum rest period for desired grass seedlings to establish.

9.2.3 Restoration technologies

Many technologies and approaches have been devised and applied by land-users to restore degraded land. These technologies are often based on indigenous knowledge and skills and are adapted to address specific problems and environmental conditions, and include the mechanical and/or biological reclamation of degraded rangelands. The challenge is to optimise and exchange these experiences and to disseminate them to as many land-users as possible. An effective way to do so is to capture information from these sources into computerised "expert systems" that can be consulted and serve as a Decision Support System (DSS) for future management application.

A DSS offers the means to facilitate knowledge transfer to extension workers, researchers, conservationists, decision-makers and land-users. For this purpose, the so-called Bush Expert was created at the University of Potchefstroom in South Africa on behalf of the project.

Once established in Namibia, the Bush Expert will be linked up with EcoRestore, a DSS in South Africa, which will be interlinked with websites such as the Agricultural Geo-reference Information System of the National Department of Agriculture in South Africa, the World Overview of Conservation Approaches and Technologies and other international databases, and so offer the user a wider range of technologies and advice. In due course, the Namibian experience should have been incorporated into a DSS.

Constant interaction between the Bush Expert (Namibia) and EcoRestore (South Africa) should be promoted.

9.2.4 Addressing research needs

All research gaps identified during Phase 1 of the project should be regarded as a Government responsibility and need to be followed up by the relevant Ministries. The project should consider standardising the methodology for field surveys and seek cooperation with the NRSC/Directorate of Forestry to undertake volume calculations of sample plots, applying user-friendly technology developed for the purpose.

The experience of the Living in a Finite Environment (LIFE) Program should be utilised in respect of developing natural resources planning and monitoring systems, and practice-oriented biodiversity monitoring. Efforts to involve jobless school-leavers and graduates in bush control programmes should also be pursued.

The most pressing issues to be researched are the following:

9.2.4.1 Research of an environmental nature

- Possible residual effects of arboricides and consequences for future marketing
- The occurrence and dynamics of bushes in relation to specific habitats/AEZs
- Natural die-off of problem species: magnitude, species affected and practical implications for farmers
- Frequency of seed production by different target species
- Age determination of different generations of intruder species versus year of establishment in relation to prevailing climatic conditions
- Quantification of the impacts of different densities of various woody species in the herbaceous layer. This would help in determining the extent of thinning required, as well as the bush species that should preferably be removed

- In relation to the invasion of *Prosopis* at an alarming rate in the Nossob, Auob and Olifants Rivers over the past two decades, the following urgently need to be researched:
  - Biological control of *Prosopis*
  - Water use and water-use efficiency
  - Cost-benefit analysis, including future management challenges and utilisation
  - Implementation of a long-term strategy
  - Geo-ecological analysis of *Prosopis*-infiltrated landscapes, and
  - Business plan for community development based on the utilisation of *Prosopis* products. The utilisation of *Prosopis* products such as wood and pods as well as involvement as workers in control programmes can create considerable employment opportunities for the rural poor.

9.2.4.2 Bush control methods

- Satellite imagery as a tool to monitor changes in woody composition and vegetation in general
- Fire as a management tool
- Camels as browsers
- The development of a bush control model, with all relevant biological and socio-economic indicators. Therefore, on-farm research to evaluate the applicability and consequences of any new technology in economic terms should be done before implementation of such a model. Research in general has not aimed at relating information to the level of the individual ranch or other agriculture-based businesses.
- Developing DSSs to facilitate information appraisal and dissemination to farmers using a non-prescriptive format. This will assist in solving bush management problems by using a modelling framework, involving the incorporation of simulation models within a DSS.
- The refinement of best practices of bush control through continuous surveys and case studies, and assessing the long-term effect of bush control programmes
- On-farm experience, together with research findings, should be stored in the Bush Expert database. A programme for this purpose is planned for Phase 2. It will be of no use to have the best technologies on bush control available if suitable and sustainable aftercare and rangeland management measures are neglected or not in place, and
- Investigate the possibility of manufacturing the active ingredients of the different arboricides in southern Africa or, alternatively, to import the herbicides or active ingredients directly from the manufacturing countries.

9.2.4.3 Industrial development

- Utilisation, processing and marketing of wood originating from problem species.

9.2.4.4 Addressing political aims

- The practical implications of bush control programmes for land reform.

9.3 Result 3: The integrated information and monitoring system is operational at national and farm level

9.3.1 Maintenance of a Bush Expert Decision Support System

The effectiveness and efficiency of the aforementioned methods, both bush clearing and aftercare, will be influenced by factors such as climate, soil type and clay content, topography, species composition and height classes, the level of management, and the level of knowledge of the different bush-clearing methods.

Apart from information obtained from research data and manufacturers, there was a dire need to record the results and experience of farmers who had applied these techniques. Thus, on-farm research was carried out on a number of farms in the affected areas. These findings are being processed and stored in the Bush Expert database developed for the project by the University of Potchefstroom in South Africa.