Review on "Bush encroachment in Namibia" by JN de Klerk (2004)

What is bush encroachment?

Before discussing aspects of the report of de Klerk, I think it is necessary to elucidate the concept of bush encroachment.

De Klerk defines bush encroachment as follows:

"Bush encroachment is the invasion and / or thickening of aggressive undesired woody species, resulting in an imbalance of the grass:bush ratio, a decrease in biodiversity, a decrease in carrying capacity and concomitant economic losses."

This definition is essentially a definition by pasturalists – farmers, extension workers, agriculturists and pasture scientists, thus the emphasis on the *decreasing carrying capacity and economic losses.* With this definition it is also clear why bush encroachment is regarded as a form of land degradation and thus desertification – a concept many have a problem with ("How can an increase in woody plants be equalled to the forming of a desert?"), but with which I wholeheartedly agree.

Essentially, bush encroachment is characterised by:

- A change in composition of savanna-type ecosystems, **favouring** woody species.
- This is a result of a number of factors, including a decreased abundance of grasses, but also **leads to a further reduction** of grass abundance.
- Because of the changed composition, the functioning of the ecosystem changes.
- And because of the changed ecosystem functioning, the ecosystem services are changing.

Because grass abundance is reduced (both as cause of, and as a result of bush encroachment), we are experiencing a loss in grazing capacity – thus less animals we can keep on a unit area, i.e. less food (milk, meat, etc.) we can produce per unit area.

This loss in grass production is **NOT COMPENSATED** by increased bush densities – most are unpalatable (thorny shrubs, high tannin content of the leaves[1]) to animals (or potentially out of reach), and in most cases the increased woody component also does not mean that we have more timber resources. As a matter of fact, I estimate that at least 60 % of all encroaching woody plants are even too small to be used for charcoal production, never mind other timber products. Due to the aridity of the country and the slow growing rate of the shrubs, we are also not an effective carbon sink in terms of global increasing CO_2 levels in the atmosphere.

Decreased grass cover of the soil means the forming of a soil crust, and more run-off. Two types of soil crusts are recognised: Biological soil crusts are often welcomed, because these are often formed by cyanobacteria binding nitrogen. Their effect on water infiltration are however disputed. More significantly in this case are however physical crusts formed by the impact of rain drops falling directly on the soil surface. Grass cover breaks the fall of the raindrops, scattering these into small droplets with a fraction of the compacting impact as the original rain drops. See Strohbach (2000)[2] for a complete explanation. More run-off fills our dams – until the water is lost

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[1] According to Strydom & Smith (1994), *Rhus marlothii, Acacia karroo, Terminalia sericea* and *Ozoroa paniculosa* have an extreme high tannin content, whilst *Combretum apiculatum* and *Albizia anthelmintica* show also a high Protein Precipitation Capacity associated with tannins. Various other species show either a high phenolic content, concentrated tannin content or Protein Precipitation Capacity. For more information, see Strydom, P. J. & Smith, W. A. 1994. Effect of inherent polyphenolics on the nutritional value of Namibian browse. *Dinteria* 24:19-27.

[2] Strohbach, B. J. 2000. Soil Erosion - causative factors, extent and prevention. *Agri-Info* 6(1):8-14.

to evaporation in any case. Run-off **DOES NOT** recharge our aquifers. Shrubs **DO NOT** prevent soil erosion – through collecting raindrops in their twigs, and these big drops having a stronger spatter effect on the soil, they actually increase the occurrence of soil erosion.

Overall the condition of the land is deteriorating through bush encroachment – what we call land degradation. Loss of productivity of the land is what has been described as desertification – thus we can equal bush encroachment with desertification.

Causes of bush encroachment

De Klerk 2004 gives an excellent overview of relevant literature on the topic. If this chapter is difficult and confusing to read, it just illustrates the complexity of factors leading to bush encroachment. One has to remember that bush encroachment is a dynamic process in nature – it happened without the interference of mankind. But: it happened on a far smaller scale, and less dramatic, and is, over time, likely to be reversible. As with many other human interferences, we are causing bush encroachment to happen at a scale which is at a too large scale and far too fast, resulting in often irreversible changes – at least irreversible within a human comprehensible timeframe.

(Examples of bush encroachment without human intervention are rare – we do not know how the vegetation looked like before being settled by the Herero people during the 18th and 19th century. De Klerk quotes Anderson complaining about dense bush between the Omatako mountains and Lake Oshikoto in 1856. The battle of the Waterberg was nearly lost because a relief company of german soldiers got lost in the dense bush at the foot of the Waterberg[3]. Think of present day Etosha Park – large expanses can be classified as being bush encroached, even though no cattle farming happened here. In both latter cases some form of human intervention can be argued, though.)

The main causes of bush encroachment identified by various authors are grouped around two *determinants*:

Primary determinants are the habitat, as defined by the climate (rainfall, to a lesser extend temperature and humidity ranges), the soils and the topography. The habitat determines the species composition of the vegetation – both i.t.o. species occurring in the area as well as the density / abundance of these species.

As example: The deep sands of the Kalahari basin result in a dominance of Terminalia – Combretum savannas, especially in the eastern Otjozondjupa region. As rainfall increases to the north, these shrublands are replaced by broad-leafed woodlands; as the rainfall decreases to the south, the Terminalia-Combretum savannas are replaced again by camelthorn-type trees and shrubs.

As the soil climatic conditions become more arid to the west (through less rainfall, but also through heavier soils, stonier and shallower soils, even soils with a high base status), the Terminalia-Combretum savannas are replaced by Thornbush savannas proper or even mopane savannas.

Secondary determinants are those factors influencing the ecosystem dynamics within a given habitat. No single one factor results in bush encroachment, it is always a combination, often even a sequence of happenings that result in bush encroachment.

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[3] Jankowitz, W. J. 1983. *Die plantekologie van die Waterberg Platopark*. Ph.D. thesis, Universiteit van die Oranje Vrystaat, Bloemfontein.

- A decrease in grass biomass (through utilisation or overutilisation) is generally accepted as the major cause of bush encroachment. Grasses are fast growers and thus efficient users of especially water resources. (Over)utilisation of grasses leads to a decreased competitive advantage of the grass sward, and an increased competitive advantage of shrub species. Shrub species generally have a stronger ability to extract water from the soil, from a larger soil volume, and can easily outcompete grasses for this resource. This is also why grasses generally become less and less once bushes have established. Most of our grasses are also C4-grasses. The C4 photosynthetic pathway is specially adapted to hot, sunny conditions – even though the water availability might not be ideal. These grasses do not like shade[4]. Once trees and shrubs have established, the increased soil fertility (as a positive feedback from bush encroachment) and the slightly better soil moisture conditions (through stemflow[5] by the shrubs / trees) do not favour the bulk of the grass sward. The few plants (including some grass species) growing in the shade of encroachers are (a) of the C3-type, (b) annual, (c) weedy and (d) often unpalatable or otherwise unsuitable for grazing (think of the burrs of *Setaria verticilata, Pupalia lappacea* or even *Bidens* or *Tagetes* species).

- Exclusion of regular hot fires in large parts of our grazing areas. Although it is general knowledge that a single fire event does not kill a shrub or tree, a series of fire events does. This has been clearly demonstrated in the Kruger National Park and various other fire trials in southern Africa. This can also be seen along the Namibian / Botswana border, there the border cutline forms an effective firebreak. The flames are blown towards Namibia by generally easterly winds during the fire season (late winter to early summer), but blocked at the border. Thus the shrub is denser within Namibia than in Botswana. It is also true that fires are less frequent in our

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[4] The C4 photosynthetic process is adapted to high temperatures and high levels of light intensity as experienced in the tropics. The C4 process takes place at an optimum between 30 and 40 C, whilst C3 often has an optimum of between 15 and 25 C only. This is however highly species dependent. Photosaturation (the point at which more light will not increase the photosynthetic rate) takes place at a total irradiance of about 750 Wm^{-2} in cotton (as C3 plant), whilst Maize (as C4 plant) did not show any signs of photosaturation yet at 1000 Wm^{-2}. Wheat (a temperate zone C3 plant) show photosaturation already at under 500 Wm^{-2}. (Salisbury, F. B. & Ross, C. W. 1985. *Plant Physiology*. Third Edition. Wadsworth Publishing Company, Belmont, California.)

In practical terms – it has been found that *Panicum maximum* (a C3/C4 grass) increases in veld with a moderate increase in shrub density. However, as soon as the density of shrubs goes beyond a certain limit, *Panicum maximum* also starts decreasing in abundance (Smit, G. N. & van Romburgh, K. S. 1993. Relations between tree height and the associated occurence of Panicum maximum in sourish mixed Bushveld. *African Journal of Range and Forage Science* 10(3):151-153). Typical C4 grasses (e.g. *Stipagrostis uniplumis* are never found in shade, whilst some palatable grasses (e.g. *Digitaria* seriata) find refuge from grazing in low shrub species – but grow to such height what their photosynthesising leaves are above the shrub canopy – own observations.

[5] Stemflow" refers to the effect there raindrops are collected in the branches of trees and shrubs and are "funneled" along the stem into the soil. This is mainly the main reason many of our tree species have an umbrella-like canopy. For further info, see:

Strohbach, B. J. 1990. Bosverdigting: 'n Onomkeerbare proses?. *Agri-Info* 3(1):11-13.

Dunkerley, D. L. 2002. Infiltration rates and soil moisture in a groved mulga community near Alice Springs, arid central Australia: evidence for complex internal rainwater redistribution in a runoff-runon landscape. *Journal of Arid Environments* 51:199-219.

Martinez-Meza, E., W.G. 1996. Stemflow, throughfall and channelization of stemflow by roots in three Chihuahuan desert shrubs. *Journal of Arid Environments* 32:271-287.

Pressland, A. J. 1973. Rainfall partitioning by an arid woodland (*Acacia aneura* F. Muell.) in south-western Queensland. *Australian Journal of Botany* 21:235-245.

Whitford, W. G., Anderson, J. & Rice, P. M. 1997. Stemflow contribution to the 'fertile island' effect in creosotebush, *Larrea tridentata*. *Journal of Arid Environments* 35:451-457.

arid country (ca 5 to 9 years cycle) than in the more mesic eastern half of the subcontinent, yet a hot fire after a good rainy season (like in the Okahandja district in 2000) can do wonders to kill seedlings and small shrub – even big trees. De Klerk reports on personal observations at Sachinga Station nearby Katima Mulilo – a similar thing has been observed at Mile 46 Livestock Development Centre in central Kavango, where the eastern fence serves as a first firebreak for fires coming from the east, and the central passage as a second fire break. The shrubby undergrowth is virtually non-existent to the east outside Mile 46, prominent in the eastern half of Mile 46 and very dense in the western half of the station – all within the same Woodland system of central Kavango.

Excessive fires will also kill trees, resulting in a landscape of coppice.

- A sequence of favourable years for seedling establishment is often quoted in the latest literature as cause of episodic bush encroachment events. If such sequences of good years follow poor rainfall years, the effect is much more dramatic because there is virtually no competition for shrub seedling establishment.

- Socio-economic / political / administrative factors forcing farmers to overutilise their resources – ranging from prohibiting the transport (and thus selling) of animals because of diseases, ineffective marketing possibilities, or even plain simple economic considerations.

It is speculated that one of the main encroachment phases happened in the early sixties, when three of the above factors applied:

Foot-and-mouth disease broke out in 1960, and government quarantined all animals on the farms – right through a severe drought phase. Farmers were forced to over-utilise their pastures for 1 ½ years – they could not destock or reduce cattle numbers other than culling animals. After the end of the foot-and-mouth period, followed two good rainfall years, making seedling establishment in a virtual void of grass species possible. The effect of seedling establishment would however only become noticeable 10 to 20 years later, once the established seedlings became full-grown shrubs.

A number of other causes (and effects countering bush encroachment) are discussed in the report – all cited from knowledgeable sources. At present much focus in research is given to the mechanisms of bush encroachment – de Klerk hinted at these, but because most are not published yet, these could not be discussed. It is beyond the scope of this short review to go into detail of each causing factor.

Extend of bush encroachment

Chapter 4 generally deals with the extend of bush encroachment. Mapping of bush densities using remote sensing techniques failed due to a variety of reasons, one of the major factors however being the complexity of the problem – we know too little of our own resources to be able to adequately delimit the primary determinants of habitat (climate and soils). In this regard, Bester's map from 1999 is one of the best approximations of the extend and severity of bush encroachment we have. Bester's map has a flaw – it is oversimplified. I would like to see:

- Unit 7 to mention both *Dichrostachys cinerea* **and** *Terminalia prunioides* as problem species
- Unit 3 to join up with Unit 2 around Windhoek (there is some unexplained border)
- Unit 9 to extend far more east- and northwards, right up to the border of the Kavango woodlands south of Tsumkwe
- Unit 10 to extend further eastwards into the southern Kalahari, with extensive patches to the west and the north linking up with Unit 3.

An attempt has been made to illustrate bush encroachment using some 1909 sample plots and overlaying these to a number of GIS layers. The only clear pattern emerging from this analysis is that increased rainfall to the north-east results in increased shrub densities. Yet, when analysing rainfall vs. bush encroachment, the authors used rainfall as a dependant variable rather than being the independent variable – being the main primary determinant. The regression lines on figures 4.25 and 4.26 are, to my mind, non-sensical.

Prof Nico Smit, renowned bush encroachment expert in southern Africa, made a Rule of Thumb, stating that optimal bush densities (in ETTE) should **NOT EXCEED** twice the annual rainfall in mm. This Rule of Thumb should have been used in the analysis of rainfall vs. bush densities as an indicator of what is encroached, what not. Accordingly, I would estimate that at least 80 % of all plots indicated in Figure 4.29 are above this limit and should be classed "encroached". (Here, the 3rd order polynomial regression line indicates the trend very well.)

The analysis of geology vs. bush encroachment is non-sensical – many geological features coincide with rainfall patterns (e.g. the limestone sediments of the Karstveld with the high rainfall of the Karstveld area). The analysis of soil types vs. bush encroachment would have made sense if more habitat-indicative factors would have been used rather than soil names – which for the uniformed reader is a lot of gobbledygook. Sensible variables would have been soil texture (sorted from loose sand to heavy clay), soil depth and possibly pH. What would have also made sense would have been a multiple regression using rainfall, soil texture, soil depth and pH as the various independent variables.

Mapping the species distribution patterns just confirmed the correctness of the map of Bester (1999).

Using NDVI images to attempt mapping bush encroachment areas proved only partially successful. This again proves that attempts to estimate annual biomass / grazing production for Namibia will be difficult also in future, as long as no adequate stratification system is available. The research into NDVI characteristics to determine bush encroachment areas (on a very broad scale) should however not be abandoned. Especially methods like those employed by Hoare & Frost 2004[6] might hold some promise for future success.

Severity, impact and cost of bush encroachment

As with the extend, the severity of bush encroachment is often difficult to determine. We have very little evidence of the composition of the veld in various parts of the country before the 1950's. Available documentation, in the form of photos, very little compositional data, is mostly limited to the central, western and southern savanna areas (thornbush savannas, dwarfshrub savannas). The evidence available does indicate that in especially the thornbush savannas bush encroachment is widespread. Using Smit's Rule of Thumb (ETTE = 2 x annual rainfall), the presently measured bush densities are far higher than should be the case. Very clearly documented from the field studies done for this project was the decline in veld condition (e.g. the decreasing number of perennial grasses) with the increase in bush densities.

Water use efficiency

Donaldson's figures on water use are much quoted and used in the bush encroachment literature. Unfortunately, concepts like ETTE and BTE (by Smit) were only developed later, meaning that

[6] Hoare, D. & Frost, P. 2004. Phenological description of natural vegetation in southern Africa using remotely-sensed vegetation data. *Applied Vegetation Science* 7:19-28.

comparison is often difficult. Also Donaldson does not give figures for a large range of species – a fact which needs to be corrected in future research.

But let us assume some hypothetical veld composition:

Typical "good veld" in Namibia consists of 10 % climax grasses (*Anthephora pubescens* and *Schmidtia pappophoroides*), 80 % subclimax grasses (typically *Stipagrostis uniplumis*, but as Donaldson has no figures on this species, assumed to be the same as *Eragrostis lehmanniana*) and a neglible 10 % pioneer grasses. Let's also assume that the pioneer species use about as much water as the subclimax species. Such veld typically has a bush density of about 500 shrubs/ha, whilst grass density is about 5 tufts per $1m^2$. Such a veld would produce an estimated 2000 kg grazable material /ha per year.

This results in the following calculation for good veld:

Species	% contribution	Transpiration per plant (l/day)	Transpiration per m2 (l/day)	Transpiration per ha (l/day)
Anthephora pubescens	1	0.344	0.00344	34.4
Schmidtia pappophoroides	9	0.116	0.01044	104.4
Eragrostis lehmanniana	80	0.075	0.06	600.0
Pioneer species	10	0.075	0.0075	75.0
Shrubs (*Acacia mellifera*)	500/ha	64.8	3.24	32,400.0
Total water use (l/ha/day)				33,213.8

Lets also assume a "poor veld" with typically 20 % subclimax species (*Eragrostis lehmanniana*) and 80 % pioneer grasses. Lets also assume that the density is similar – ca 5 tufts per m^2. This is typically achieved through the larger number of seedlings of annual pioneer-type grasses. Typically, the shrub density in such veld will exceed 2000 plants/ha. According to the data of Snyman and van Rensburg (1990), this veld will produce a tenth of the grazable material /ha as climax veld (a VERY REALISTIC figure!) – i.e. only 200 kg /ha!

Species	% contribution	Transpiration per plant (l/day)	Transpiration per m^2 (l/day)	Transpiration per ha (l/day)
Anthephora pubescens	0	0.344	0	0.0
Schmidtia pappophoroides	0	0.116	0	0.0
Eragrostis lehmanniana	20	0.075	0.015	150.0
Pioneer species	80	0.075	0.06	600.0
Shrubs (*Acacia mellifera*)	2000/ha	64.8	12.96	129,600.0
Total water use (l/ha/day)				130,350.0

The above figures speak for themselves:

For four times more water, encroached veld produces ten times less grazing. The water goes into the (very slow) production of woody biomass – not even justifiable i.t.o. timber production norms!

To take the calculation one step further – lets assume that our samples are situated in the Okahandja district with an annual rainfall of 350 mm and a growing period of about 60 days (AEZ data). That means, over a 60 day period, evapotranspiration in good veld is 1,992,828 l per ha, whilst in encroached veld it is 7,821,000 l per ha. Typically, such veld gets 350 mm rain annually – i.e. 350 l per m^2 per year. This amounts to 3,500,000 l per ha per year. That means, good veld uses 56 % of the water received per year – the remaining water is available for aquifer recharge and/or runoff. Encroached veld, however, uses 223% of the water received per year – drawing on underground resources. This is highly unsustainable!

One qualifier: These figures may sound unbelievable. Yet these figures by Donaldson are widely accepted, and at this stage (even 35 years after publication) the only such figures available for such calculations. Here is definitely a need for further verification. Circumstantial evidence however show that these trends are applicable:

- Reduced cattle population. Figure 2.11 illustrates clearly that the Namibian cattle population has reduced by over 50 % over the last five decades since the peak cattle population during the 1950's.
- This is due to the fact that the grazing capacity of the land has reduced from less than 10 ha per Large Stock Unit (LSU) to over 25 ha/LSU (Figure 2.12). Especially the Karstveld area, which used to have the highest potential also due to high rainfall, is most severely affected. The reduced grazing capacity is a sure sign of land degradation, of which (as discussed earlier) bush encroachment is a typical form.
- A reduced ground water table is widely reported by farmers. This could be partially because of increased water extraction, but also due to reduced infiltration and recharge.

Trees and shrubs also have a positive feedback on the environment: next to providing habitats for a host of animals (birds, insects, lizards, even some mammal species), they also contribute to the fertilisation of the soil through nutrient cycling and the fixation of nitrogen. Especially in our harsh climate the latter is a constant constraint. But – it also has been shown that this positive feedback reaches a limit at between 500 and 1000 ETTE/ha – any increase of shrub beyond this limit will adversely affect the grass production! Dense bushveld is also not contributing to faunal biodiversity – the shrub becomes too dense for most animals to move through.

Trends over time

A view into the crystal ball is difficult at best of times. In the report it is indicated that bush encroachment in the commercial farming areas and the eastern communal areas is likely to increase in the near future due to already present high number in small plants.

Bester has been monitoring the die-back of problem bush (specifically *Acacia mellifera*) due to *Phoma glomerata*, *Phoma cava* and over fungi species over the past years. The fungi seem to have impacted on large areas in the Thornbush savanna, yet, its impact can only be considered as drastic in the central areas between Okahandja and Otjiwarongo (Figure 1)[7]. On many photos showing die-off effects the smaller shrubs are clearly visible. Smaller shrubs are generally fast growing and have less stress due to their lesser need for resources. It is thus likely that the *Phoma* infestation is unlikely to affect this upcoming generation of problem plants.

Predicted scenarios for the effect of global change also favour further bush encroachment. Through the increasing CO_2 content in the atmosphere, the present C4-dominated savannas are to be replaced by C3-dominated vegetation. Most herbaceous C3-plants are not well adapted to arid conditions, leaving woody C3 species as the only potential plant functional type replacing the

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[7] Bester, F.V.; Van Eck, J.A.J.; Kölling, H.; Van Rooyen, B. & Prinsloo, R. 2002. Bush encroachment: with reference to the occurrence, die-back and regeneration of *Acacia mellifera* subspecies *detinense* in Namibia. In: Proceedings of the Annual Research Reporting and Farming Systems Research and Extension (FSRE) Implemenation Conference, October 2002.

at present still dominating C4 species (Midgley et al. 2004[8]). (I personally don't understand why C3 replaces C4 – maybe because shrubs can extract water better than grasses – and Midley et al. also don't give an explanation.)

Although there is evidence of some reduction in bush encroachment through *Phoma* species, the prognosis is bleak – further, more intense bush encroachment is yet to come.

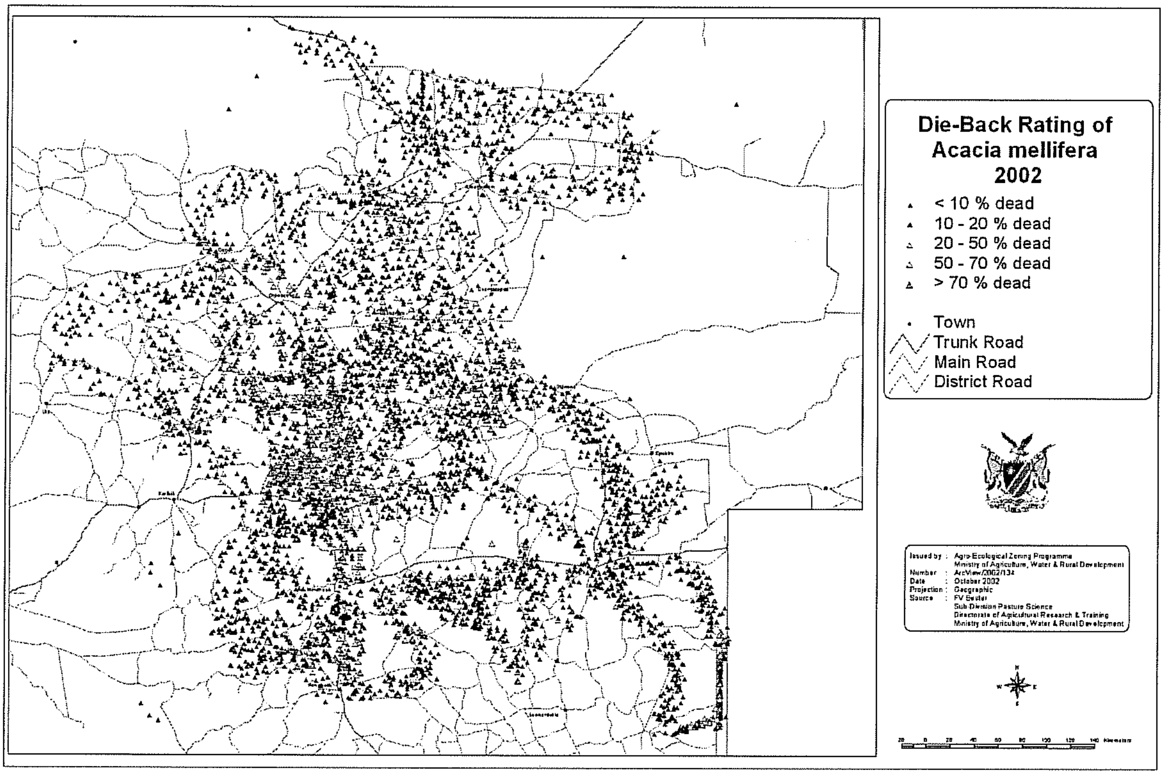

Figure 1: The incidence of die-back of *Acacia mellifera* due to *Phoma glomerata* infestation. Map from Bester et al. (2002).

In general

The report of de Klerk has been prepared using the inputs of various experts from Namibia and South Africa. Extensive literature reviews have been done. I think that this report is well prepared and as good a review of the topic as is possible at present. The report gives a large number of facts – occasionally even contradicting facts. Unfortunately, many such contradicting facts exist in nature. Making a complete, coherent picture out of such facts is an art.

The weakest part of the report is the attempt to map the extend of bush encroachment – understandably, considering the high number of variables determining bush encroachment. This necessitates a huge number of ground truth points – from personal experience I estimate at least 10 times as many ground truth points (>20 000) as used in the present study would have been needed to properly map bush densities.

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[8] Midgley, G.; Hughes, G.; Thuiller, W.; Drew, G. & Foden, W. 2004. Assessment of potential climate change impacts on Namibia's plant species biodiversity, and ecosystem structure and function. 1st draft of an unpublished report for the Namibian National Biodiversity Programme.

Because mapping and monitoring by remote sensing techniques is so difficult, it is necessary to urgently implement the monitoring programme suggested by de Klerk.