Case study: Too many, too few or the wrong trees – a region-wide challenge

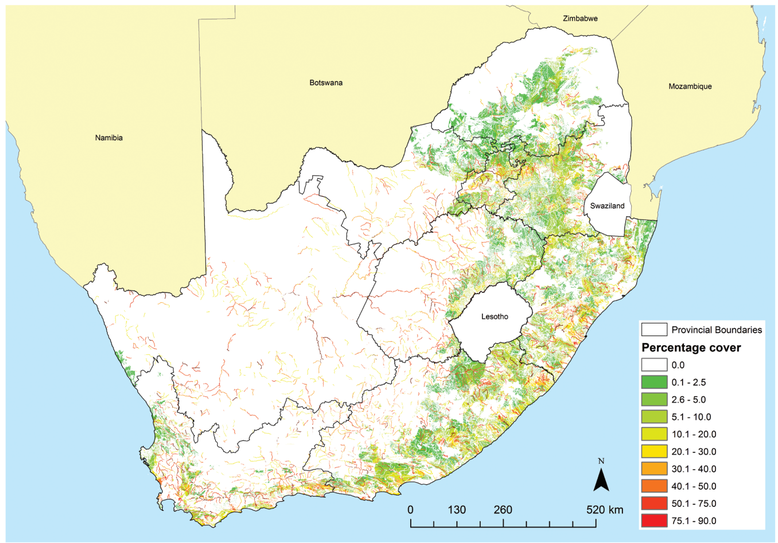
Southern Africa

Background

Deforestation and forest degradation is a major concern over much of southern Africa, however it is actually an increase in tree cover that is the major form of degradation in many areas. Invasive alien plant species (IAPs) are displacing indigenous vegetation in some areas, not only changing species composition but in some cases totally altering the vegetation structure and function and the flow of ecosystem services. Southern African savannas and woodlands are also following the global trend of woody plant densification (locally termed 'bush encroachment'), where areas that were historically relatively open woodlands or grassland are becoming near-impenetrable woody thickets of predominantly indigenous woody species. All three of these processes occur throughout southern Africa and, although overlapping, the causes and consequences are typically spatially separated in response to differing sets of environmental and human drivers. This case study considers each process in terms of where it occurs, our best understanding of the drivers of the change and the implications on the flow of ecosystem services.

The spread of invasive alien trees in South Africa

The spread of exotic invasive alien trees and shrubs (IAPs) into the natural indigenous vegetation has been identified as one of the most severe environmental problems in South Africa. Many of these plants are species purposefully introduced in the country in support of commercial forestry, sand dune stabilisation or the provision of fuelwood, shade or garden ornamental trees. Some arrived through accidental introduction as a consequence of global trade. These species have now spread into the surrounding vegetation, where they have become naturalised. Some are still actively grown for their initial intended purpose, despite their destructive nature as IAPs. Although IAPs are found through most of the sub-region, there are areas where their rate and intensity of spread is of particular concern. This includes much of the fynbos biome, where a number of Australian species are particularly well adapted, and grasslands where, in some locations, exotic tree species have replaced the local vegetation with dense woody jungles. Even arid areas are affected, with Prosopis species displacing natural vegetation in desert riverbeds in the Northern Cape (1 470 million ha impacted) and Namibia[1, 2]. It is estimated that about 20 million ha of South Africa are infested with IAPs. Aliens impact on water resources, grazing and agricultural land, natural biodiversity, and catchment stability and resilience. In biomes such as the fynbos, where many plants are endemic and have small ranges, this is a particular threat. In addition to the plant species displaced, there are impacts on pollinators and other species dependent on the original biodiversity. Furthermore, the alien species promote different fire regimes, and in fire-dependent habitats (such as fynbos, savannas and grasslands) this can have many secondary effects, including more intense fires that destroy soils, changing water infiltration and promoting erosion. It is estimated that aliens have reduced the value of just the fynbos by US$ 11.5 billion (Higgins et al., 1997), with the annual South African national reduction in the value of ecosystem services estimated at US$ 464 million[3].



Proportion of area under invasive alien plants in South Africa, Swaziland and Lesotho[22] This map excludes the known invasion of Prosopis species in the more arid areas.
Source: Kotzé, J. et al. 2010[22].

In South Africa IAPs have long been recognised as having significant impacts on the flow of ecosystem services. Areas of high rainfall, the source areas of major river systems, tend to be worst affected by IAPs. These invasives have been shown to substantively reduce streamflow, in some cases turning perennial streams into annual streams. It is estimated that South Africa loses 2.95 % of its run-off as a direct consequence of plant invasions. In a water-scarce country, where demand exceeds available water in almost all catchments, this added stress is a major concern[4].

To counter these impacts the South African government has established an ambitious publics works programme, called 'Working for water'. Since 1995 it has spent approximately US$ 715 million and employed over 227 000 person-years of labour, with the 2016 expenditure being approximately US$ 130 million. This high level of investment has helped contain the level of invasions, yet the problem continues to grow. One necessary shortcut is the introduction of biological controls, and here there have been some marked successes.

Squared timber at the Okavango river crossing between Namibia and Angola at Rundu (Namibia).
Source: Hill, J.

Bush encroachment in southern Africa

Woody plant densification, locally known as 'bush encroachment', is a common global phenomenon in savannas and woodlands[5]. This densification is often dominated by shrub-like vegetation, and the term 'bush thickening' would be more appropriate as, unlike the problem of IAPs, this increased woody plant density is mostly of indigenous species that are already in the area[6]. In some cases areas that were historically open grassland are becoming wooded thickets dominated by indigenous woody species (though IAPs may also be present).

The causes of bush encroachment are multiple and complex[7]. Overgrazing has generally been seen as the main driver. Heavy grazing not only removes the grass, hence reducing competition for woody species, but also reduces the fire load that historically would have destroyed trees, and in particular young establishing trees[8, 9]. Very obvious fence-line contrasts observed between areas with differing grazing histories provide strong support for this mechanism of bush encroachment. Bush encroachment has, however, also been observed in areas with light grazing. Research suggests that the global increase in CO_2 is an additional factor, and there is growing evidence that the increasing CO_2 levels and the different ways in which trees and grasses respond to this change give trees a competitive advantage over grasses[10]. Furthermore, the increased global temperature is potentially expanding the savanna biome into areas where cold winter temperatures previously favoured grasslands[11].

Employed under the Working for Water (WfW) programme, workers are ready for cutting invasive species to re-establish stream flows.
Source: Montgomery Kay.

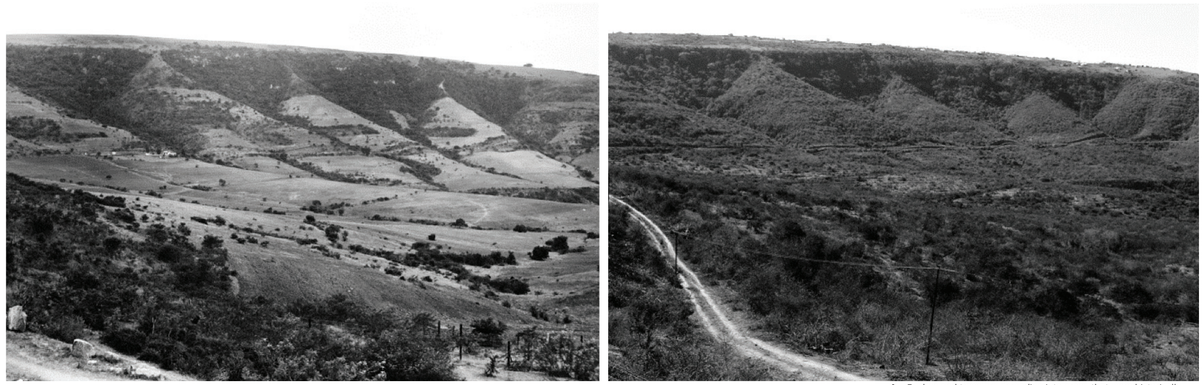
In Namibia bush encroachment is seen as a relatively recent phenomenon that has become more obvious since the early 1960s[9].

Bush encroachment has a profound impact on the flow of ecosystem services. It can be devastating to cattle management, reducing the carrying capacity by as much as 90 %[12, 13]. Bush encroachment in Namibia is estimated to occur over 260 000 km^2[13] and has been estimated to have reduced the national cattle herd by 50 %, with an annual economic cost of US$ 170 million[14]. The total economic value to be gained from the clearing of bush in Namibia was estimated at US$ 4.7 billion over 45 years based on a 67 % debushing[14].

Bush encroachment changes biodiversity. Tree species are favoured over grass and forb species, and the structure of the habitat is fundamentally altered. There is evidence that birds that favour more open grasslands, such as secretary birds, have shifted their range. In Namibia the endangered cheetah, which favours open savanna, is being displaced, as are open grazers such as zebra and wildebeest. The dense bush hinders both human and animal movement, which makes animal management difficult and reduces the tourism potential in conservation areas.

Bush encroachment changes the hydrology of the area, leading to lowered groundwater tables[15]. Bush encroachment can also have devastating financial consequences from a cattle or game farmer's perspective. Past studies have shown that, in arid areas with low livestock-carrying capacity, the costs involved in clearing invasive bush cannot be justified through the revenue gains from livestock production[16, 17]. However, changes in the economics of beef production suggest that this situation may be changing.

Alternative revenue streams have been developed based on invasive bush, the principal one being charcoal production[18, 19], with Namibia estimated to produce between 85 000 and 100 000 tonnes of charcoal per year[20]. Use of bush for electricity production is also being considered, and a study found that there would be more than enough biomass in the country to run several biomass power stations, generating a total of 20 MW on a sustainable basis[21]. The increased carbon storage from bush is also being proposed by Namibia as an offset to anthropogenic carbon emissions, and Namibia now considers itself to be a carbon-neutral country.



Bushes and trees are spreading into areas that were historically grassland. This matched pair of photographs, the first taken in 1954 and repeated in 2010 near the Kei River in the Eastern Cape Province, South Africa illustrates a wide-scale trend throughout the region of areas once predominantly grassland and now increasingly dominated by trees and shrubs. This has major impacts on the potential of the land to provide grazing for cattle and can drastically reduce the streamflow of rivers.
Source: Original: Denzil Edwards; Repeat: James Puttick and Timm Hoffman.

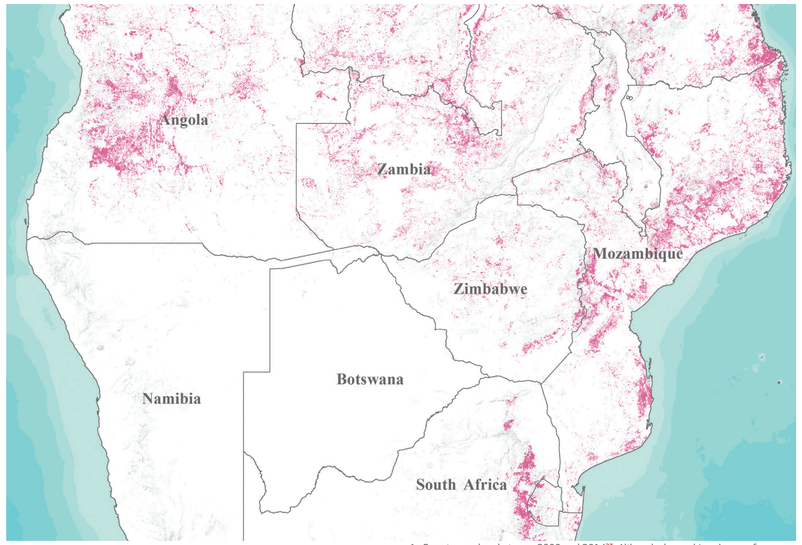
Changing CO_2 levels have profound impacts on tree growth
Acacia karroo (sweet thorn) was subjected to differing levels of CO_2 ranging from 150 ppm (~ minimum ice-age levels) to 260 ppm (~ pre-industrial levels), 375 ppm (approximate levels from 2010) and 450 ppm (estimates for the mid 2030s). Increased CO_2 results in huge increases in root growth, and root starch stores allow seedlings to grow rapidly, escaping fire and browsing, to become established trees in areas they would have struggled to colonise at low ambient CO_2 levels[10, 23].
Source: Kgope, B.

Case study: Too many, too few or the wrong trees – a region-wide challenge (cont'd)

Southern Africa (cont'd)

Deforestation and forest degradation

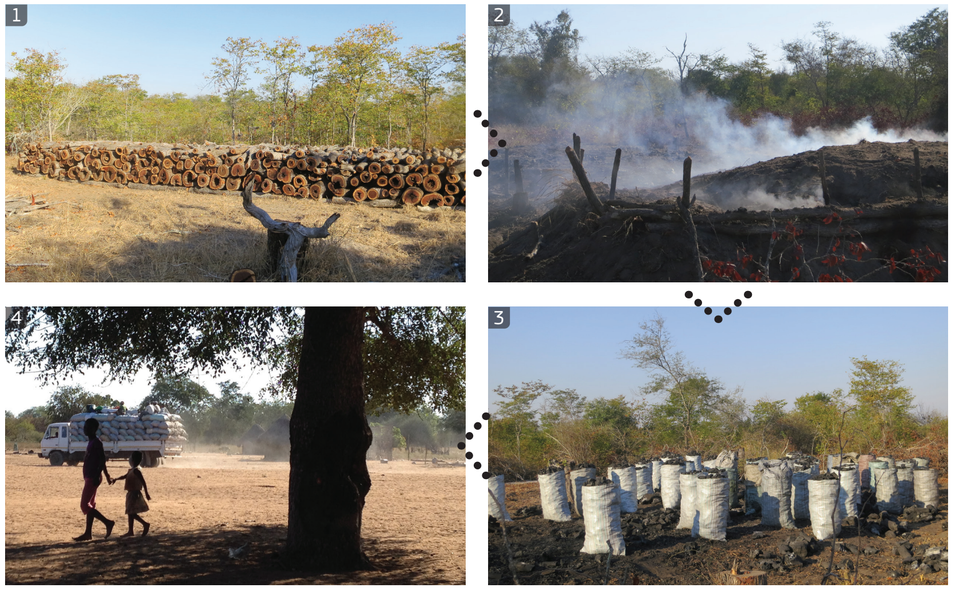
Deforestation and forest degradation are widespread across southern Africa's forest areas. There is a net reduction in forest area in many locations[23, 24, 25], but even when forest areas are not fully lost, they are being degraded resulting in a significant net biomass losses[26, 27]. Deforestation and forest degradation are largely driven by agricultural expansion, shifting cultivation and woody resource extraction for both economic gains and for charcoal production[28, 29]. They reduce the extent and quality of forest and woodland by changing forest structures. This can impact on biodiversity, fire regimes and the availability of natural resources and ecosystem services. Rural communities are particularly at risk, as they rely on forests and woodlands to provide ecosystem services and livelihood benefits[30, 31], with forest resources estimated to support approximately 30% of rural incomes[32].



Forest cover loss between 2000 and 2014[23]. Although charcoal is only one of many causes of deforestation its impact is growing in line with the growth in urban demand.
Source: Hansen/UMD/Google/USGS/NASA, Sources:Esri, ISGS, NOAA.

Country	Total forest 1990 (Thousand hectares)	Rate of loss 1990-2000	Rate of loss 2005-2015	Total forest 2015 (Thousand hectares)
Angola	60 836	0.20%	0.21%	57 731
Zambia	52 740	0.32%	0.33%	48 571
Zimbabwe	22 010	1.47%	1.85%	13 957
Namibia	8 762	0.83%	1.00%	6 919
Mozambique	43 340	0.50%	0.55%	37 856
Botswana	13 718	0.86%	0.92%	10 840
Malawi	3 764	1.05%	1.25%	2 728
South Africa	7 615	0.12%	0.02%	7 478

Annual rate of forest loss, In most countries the rate is high and increasing.
Source: Food and Agriculture Organization of the United Nations (FAO).



Large mature Mopani trees are cut and stacked (photo 1) as the basis for a simple and inefficient mud-covered kiln, smouldering near the completion of the combustion phase (photo 2). The final product, charcoal sacks of up to 90 kg, is ready for pick-up (photo 3). A charcoal truck collects sacks of charcoal from a village in the Mabalane district of Mozambique for transport to the larger urban centres of Maputo, where an estimated 80% of households are reliant on charcoal as their primary energy source for the cooking of food (photo 4). Only about 20% of the final sales value of charcoal finds its way back to the producers, and the trees used to make the charcoal are in effect a free resource to the charcoal makers, costing them only their labour and a small charcoal-licensing fee. The high demand for charcoal, coupled with loss of resources near the town, means that charcoal for Maputo is being imported from ever-increasing distances away from the city centre, with reports of some production sites now more than 300 km away.
Source: photo 1-3, Baumert, S., photo 4 Ryan, C.

Charcoal case study: Mabalane district, Gaza province, Mozambique

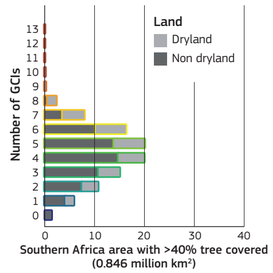
Charcoal production is a major economic activity in sub-Saharan Africa, with a value in most southern African countries of around 2-3% of GDP[33]. Charcoal provides affordable energy to 70-90% of the urban population[34]. In Mozambique wood fuels account for 81% of energy consumption[35], with charcoal the dominant fuel in urban centres[36]. Charcoal production in Mozambique employs an estimated 214 000 people, supporting 1.2 million dependents — equivalent to 5% of the country's population[33]. Despite the importance of charcoal to rural economies and the wide extent of participation, very little is known of the impacts of charcoal production on other ecosystem services, nor on rural livelihoods[37]. Charcoal production has the potential to severely degrade, or even deforest, woodlands if intensities are high[29, 38].

To address the need for studies on the impact of charcoal production on other ecosystem services and on rural populations, a large-scale interdisciplinary study (for example the ACES project: https://miomboaces.wordpress.com) was conducted in the Mabalane district of Gaza province, southern Mozambique, collecting biophysical and social data in seven villages across a charcoal 'boom and bust' frontier.

Gaza province is currently one of the major supply areas of charcoal to the capital Maputo, and is at the edge of the expanding charcoal frontier. Most of the charcoal from this area is produced from the tree species *Colophospermum mopane*. High demand for good-quality charcoal drives this selectivity, given the high-density timber for the species.

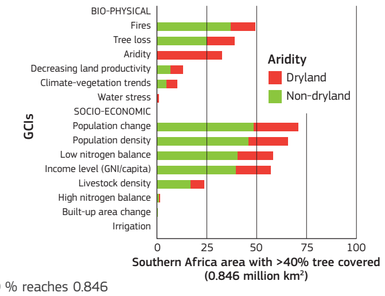
Using biophysical data on woodland structures and species composition, in combination with social data on ecosystem services uses and preferences, the study found that charcoal production was most likely to impact on firewood and woody construction material availability, and to reduce the carbon stocks and storage potential of the woodlands[39].

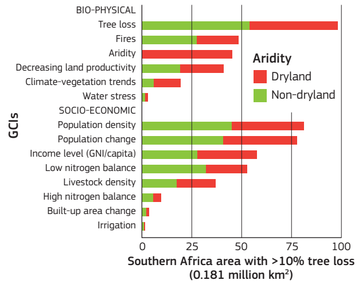
Villages with longer histories of charcoal production had already experienced decreases in one or more of these services. However, even under intense charcoal-production scenarios, all of the ecosystem services assessed were still available to some degree at the local scale. Villages where ecosystem services availability and biodiversity were low will be more vulnerable to further degradation of woodlands in future, and reducing the impacts of further charcoal production or woodland degradation is becoming a key challenge.

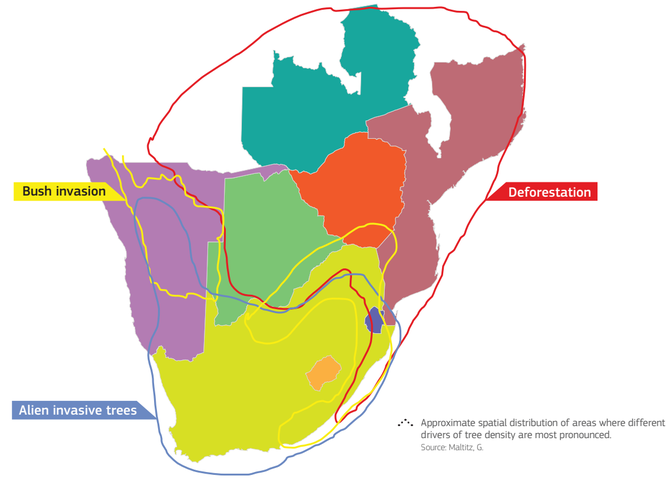


Convergence of evidence

The area with tree cover of more than 40 % reaches 0.846 million Km² in Southern Africa and about 28 % of the forested area is dryland. On about 32 % 1 to 3 Global Change Issues (GCIs, see page 144) are at coincidently at play, while 4 to 7 GCIs accumulate over about 65 % od the forested area. On about 5% more than 7 GCIs exist simultaneously. Population change is the most frequent GCI (72 %), followed by population density (65 %), In about 60 % of the forest area, agro-forestry activities are low-input land use (low nitrogen balances show over 60 % of the area) and fire occurs over 50 %. Tree loss is reported in about 38 % of this forested area. Decreasing land productivity is mapped over 13 %, equally in dryland and non-drylands. In 'tree loss' areas (see most right graph), fire occurs in nearly 50% and land productivity decline reaches nearly 40 %. Drought was a factor in about 20 % of the tree loss area.







Approximate spatial distribution of areas where different drivers of tree density are most pronounced.
Source: Maltitz, G.

If wood extraction for charcoal production were to become less selective in future, further trade-offs with other ecosystem services and greater losses of ecosystem services availability can be expected. Therefore, charcoal production must remain selective in nature, or risk further degradation or even loss of woodlands and associated ecosystem services. However, avoiding non-selective charcoal extraction is difficult if the demand for charcoal remains high, with increasing prices and incentives to make charcoal[29]. It will require coordination of the charcoal licensing regime at provincial level to ensure the frontier keeps moving away from Maputo, rather than becoming more intensive. Enforcement is still a major challenge.

The majority of the villages in the district are involved in charcoal production, generating much-needed income for rural households with few alternative income sources. However, the study found that the majority of the charcoal-production income did not remain with local communities[40]. This is due to governance challenges in the forestry sector and a lack of support for community management initiatives. The real income is accrued by large-scale migrant producers. Providing alternatives to charcoal production and supporting local management initiatives is therefore a key challenge in southern Mozambique.

Conclusions

Major changes in tree density are being experienced across southern Africa. The vast savannas and woodlands that dominate much of the region are under strong threat from deforestation. This results in a loss of many other ecosystem services that are of importance to local livelihoods, though grazing may be enhanced. Drivers of deforestation are largely linked to agricultural expansion, but clearing of woodlands and forest for charcoal production is a large and growing problem.

Ironically, whilst vast parts of the region are experiencing deforestation, for some areas an increasing density of bush, shrubs and trees has become the key driver of reduced productivity. Some of this is the result of introduced exotic invasives, but, over vast areas and especially in arid zones, it is indigenous species that are invading grasslands and changing the tree density of what were previously open grasslands or woodlands. The type of degradation is largely related to the levels and types of human intervention, for instance over-harvesting or over-grazing, but climate and vegetation type also play a role. Increased levels of global CO_2 appear to be favouring woody species growth over grasses.

Source: Hill, J.