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A Review of Bush Encroachment in Namibia: From a Problem to an Opportunity?

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Abstract. Bush encroachment leads to land degradation in semiarid to arid regions. Over 45 million hectares of agricultural land in Namibia are affected. This is worrisome as nearly 70% of the Namibian population depends on agricultural activities and the beef industry is the mainstay of the farming communities. This study employed secondary data sources to provide a review of the problems and benefits of bush encroachment in Namibia. The phenomenon has led to decreased biodiversity, degradation of the functions and structures of ecological ecosystems, lowering the grasslands' carrying capacity, displacement of wildlife, as well as impacting groundwater recharge. Encroachers include species such as *Senegalia erubescens*, *Senegalia fleckii*, *Vachellia nilotica*, *Vachellia luederitzii*, *Vachellia reficiens*, *Colophospermum mopane*, *Rhigozum trichotomum*, *Terminalia prunioides*, *Terminalia sericea*, *Senegalia mellifera* and *Dichrostachys cinerea*. In 2018, the beef industry made at least US$ 184 million dollars. This amount could have been more, if the carrying capacity of the grazing lands was not reduced. On the other hand, the encroachers offer extra income from de-bushed wood material, including income from charcoal industry, which currently flourishing. Namibia is presently one of the main charcoal exporters and made close to US$34 million during the year 2018, putting the country on a first 1st position in Africa and 11th position worldwide. This brings a dilemma in managing the encroachers, as to whether to eliminate them and improve the grasslands or to allow them to grow for other benefits. The study concludes that while trying to improve the ecosystems by de-bushing, managing de-bushing needs to be sustainable. There is also a need for research to largely focus on evaluating the trade-offs between the problem and opportunities.

Key words: Bush encroachment, Problems, De-bushing benefits, Value chains, Namibia

Introduction

Bush encroachment is described as a process of thickening and or expanding of woody species in open savanna and woodland vegetation types, which ultimately results in loss of rangelands and grazing carrying capacity (Eldridge *et al*., 2011; Van Auken, 2009). The process is predominantly intense in arid to semiarid regions which are characterised by grassland and savanna ecosystems, occupying nearly 40% of the world's pastorable land and at least 50% of it is used for rangelands (Lukomska *et al*., 2010; Huang *et al*., 2018;). The structures and functions of the world's ecosystem have been altered by the rapid expansion of bush encroachers in the last couple decades (Eldridge, *et al.,* 2011; Van Auken, 2009), and that has consequently adversely affected 20% of the world's population (Archer *et al*., 2001; Ayelew and Mulualem, 2018). Rangeland degradation has not only led to several losses of grazing land for livestock, it has also reduced arable land and hunting grounds for animals in African savanna ecosystems (de Klerk, Nesongano, 2018), leading to major financial losses for commercial farmers, especially in non-migratory ranches in the Southern Africa region (DRFN, 2009). Countries such as South Africa, Bostwana, Uganda, Zimbabwe, Ethiopia and Namibia are among some of the African countries that are currently affected by bush encroachment (Ayelew and Mulualem, 2018; Charis *et al*., 2019).

In the last century, bush encroachment has become a major problem in Namibia, and it is described as one of the most extensive contributors towards land deterioration and is a critical problem in Namibian rangelands (Ayelew and Mulualem, 2018; Schroter *et al.*, 2009). Around 70% of Namibia's land surface is characterised by arid to semiarid regions (National Drought Task Force, 1997) and close to 84% is covered by Karooid, savanna grassland and woodland vegetation types, which are prone to bush encroachment (MAWF, 2014). Currently, encroachers have dominated about 32% of the country's land surface, affecting nearly 45 million hectares of savanna ecosystems (Uchezuba *et al*., 2019).

Among the negative impacts of bush encroachment observed in Namibia are the reductions of the grassland carrying capacity, reductions in agricultural production, decreases in botanical diversity, production of dull and monotonous scenes leading to a reduction in tourism activities, and ground water recharge (Birch *et al*., 2017; NNF, 2016). Despite the negative impacts, the encroachers have also provided positive ecological and economic important impacts to Namibia. These include the protection of soil against soil erosion due to their strong root systems and bigger canopy, the enrichment of the soil with nitrogen as they are leguminous, and with leaf debris as they are deciduous, an addition of some vitamins, proteins and minerals from foraging, the various uses of wood, and the chain values from the wood products (DECOSA, 2016; MAWF, 2017a). There are a number of unpublished reports on bush encroachment in Namibia, however, a holistic overview of problems and benefits is lacking. This paper thus aims at providing a review drawn mostly from various literature sources not in the public domain of bush encroachment in Namibia. The review is significant as it gives a synopsis of the role that bush encroachment is currently playing on the very unique forms of survival in the environment, and the possibility of doing the same to the regions that are experiencing a similar problem worldwide.

Materials and methods

Methods

The methodology employed in this paper was to collect all relevant material on the problems and the opportunities of bush encroachment in the country and provide a review of the relevant literature. First, we present an overview of the problem of bush encroachment and spatial distribution scales, densities and the biomes affected in the study area. As part of the results, our review focused on presenting information and interpretations of bush encroachment in relation to land use, its causes and effects and overall impact on ecosystem services. The information on degradation of the ecosystems services is crucial to Namibia as the majority of the population depends on agriculture related resources. The researchers also reviewed the value chains, with a specific focus on the energy industry (charcoal) and agriculture benefits (animal fodder and beef industry). The effects of climate change on the natural resources are projected to worsen in the near future, especially in semiarid to arid regions (IPCC, 2007). Consequently, our discussion draws on the link between the bush encroachment problems and climate change. The implications of managing encroachers and an overview of legal entities involved are also discussed.

Regional settings

Namibia lies between latitudes 17˚ and 29˚S, and longitudes 11˚ and 26˚E. It has a surface area of 824 268 km^2 and it is bordered by Angola to the north, Zambia and Botswana to the east, South Africa to the south and the Atlantic Ocean to the west. Namibia has a coastline of 1500km characterised by the cold Benguela current, and that results in little or no rainfall. Even though the country appears to be relatively large, nearly half of the country is covered by surface bedrock and at least 20% is a desert region, 33% is arid; 37% is semiarid and 8% is a sub-humid region (National Drought Task Force, 1997; UNFCCC, 2010). The country is one of the driest countries in Sub-Saharan Africa (Fig. 1a), with annual average temperature ranges that from 20 ˚C – 36 ˚C (Mendelsohn *et al*., 2002) and almost half of the country receives an annual rainfall of less than 250mm (Fig. 1a). Rainfall is highly variable, spatially and temporally, and concurrent droughts poses several challenges to agricultural activities (Sweet and Burke, 2000).

The limited annual amount of rainfall is one of the factors influencing the extent of bush encroachment. The majority of the encroachers thrive between areas with an average annual rainfall of 300 - 450mm (Fig. 1a). This area falls under the tree and shrub savanna biome, one of the five biomes in Namibia (Fig. 1b). Others include Namib Desert, Nama Karoo, Succulent Karoo and lastly the lakes and salt pans biome (Mendelsohn *et al*., 2002; NAU, 2010; UNFCCC, 2010). Encroachers are classified into three groups based on their invasiveness. *Acacia erubescens* (*Senegalia erubescens*), *Acacia fleckii* (*Senegalia fleckii*) and *Acacia nilotica* (*Vachellia nilotica*) are considered to be less invasive encroachers, *Acacia luederitzii* (*Vachellia luederitzii*), *Acacia reficiens* (*Vachellia reficiens*), *Colophospermum mopane*, *Rhigozum trichotomum*, *Terminalia prunioides*, and *Terminalia sericea* are regarded as main encroachers, while *Acacia mellifera* (*Senegalia mellifera*) and *Dichrostachys cinerea* are classified as aggressive encroachers as they account for 40% of the encroached area (Bester, 1999; Hauwanga, McBenedict, & Strohbach, 2018; MAWF, 2017b).

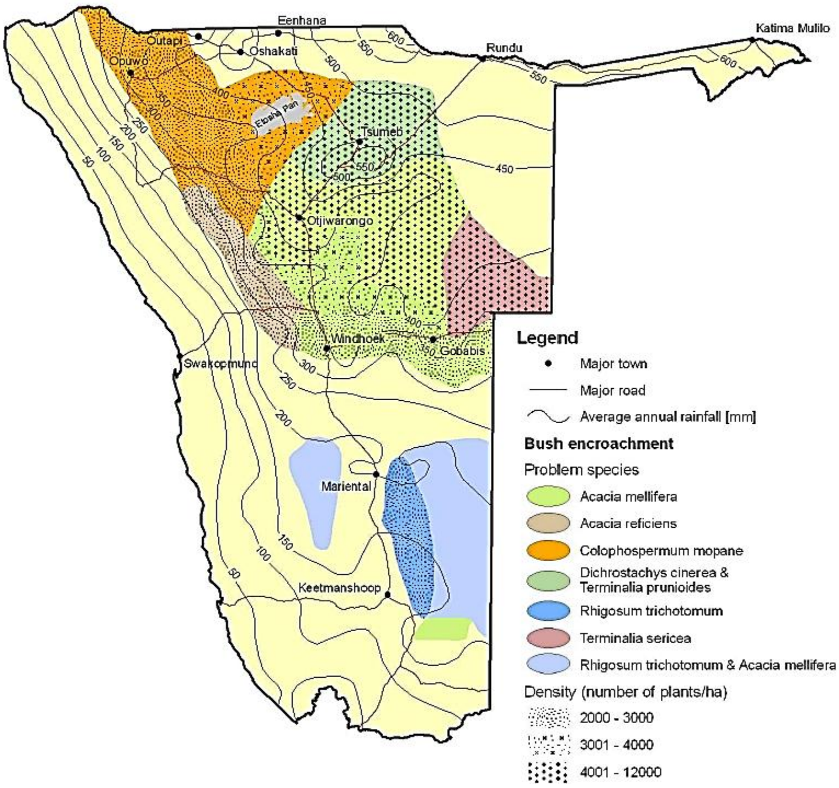

Fig. 1a: Bush-encroached areas & densities (NAU, 2010; Birch *et al*., 2017)

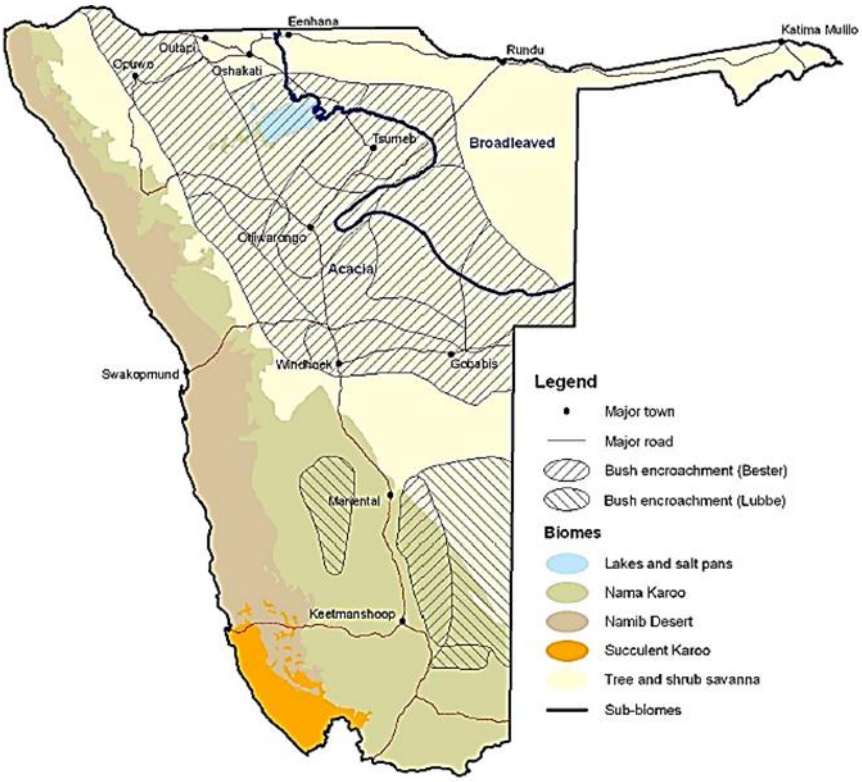

Fig. 1b: Bush-encroached areas in biomes (NAU, 2010; Birch *et al*., 2017)

Bush encroachments dynamics in Namibia

Bush encroachment and land use

Most of the land in Namibia is used by commercial farmers (freehold land) and communal lands (non-freehold land) that take up 43% and 30% respectively (Table 1a & b). The latter supports up to 68% of the Namibian population and up to 41% of the land is used for subsistence farming of rain fed crop production (UNDP, 2019). Agriculture is the main source of livelihoods in Namibia, and about 71% of the Namibian population practices diverse farming activities (Mendelsohn *et al.*, 2002; Sweet and Burke, 2006), therefore their well-being directly and indirectly depends on the productivity of agriculture sector. According to Mendelsohn *et al.* (2002), nearly 65% of the national agricultural output is produced by commercial farms, however, about 50% of 71 million hectares of commercial land and at least 15 million hectares of communal land are affected by bush encroachment (de Klerk, 2004; de Wet, 2015). As a result of bush encroachment species, land productivity has been reduced and reported to have occurred more rapidly in recent years (MITSMED, 2016; Temmerman, 2016). This has resulted in lower food security and nutrition in communal farms (NAU, 2010; MAWF, 2012), and in reduced carrying capacity to half of its original value (de Klerk, 2004; Charis *et al.*, 2019; MAWF, 2012). Furthermore, the encroachment has resulted in competition with vegetation that feeds livestock, and subsequently led to N$1.4 - 1.6 billion dollars national financial loss (NAU, 2010; MAWF, 2012).

Table 1a: Major land uses in Namibia (UNDP, 2019)

Types of land use	**Area (km^2)**	**Total area (%)**	**Dominant location**
Agriculture and tourism on freehold land	356,700	43.3	South/ Central Namibia
Small-scale agriculture on communal land	250,700	30.4	North with exception of West Caprivi; east; patches in the south.
State protected areas	136,000	16.5	Along Atlantic Coast / Namib Desert; east Mahango / West Caprivi / Khaudum); north central (Etosha)
Large-scale agriculture on communal land	48,600	5.9	North with exception of West Caprivi, east; patches in south.
Other gover./parastatal uses	12,400	1.5	Various
Urban areas	7,200	0.9	Scattered
Resettlements	7000	0.8	Small patches across the country
Government agriculture	5,400	0.7	Kavango; Caprivi
TOTAL	**824,800**	**100**	

Table 1b: Estimated lands encroached (Honsbein *et al*., 2009; NNF, 2016)

Zones	**Categories of thickening bush**		**Affected land (million ha)**		
(Fig. 2)	**Main bush species**	**Bush density (avg.no./ha)**	**Commercial land**	**Communal land**	**Total**
1	*Colophospermum mopane*	2500	1.451	2.986	4.437
2	*Acacia mellifera*	3000	1.676	0.691	2.367
3	*Acacia mellifera*	2000	3.360	0.195	3.555
4	*Colophospermum mopane*	4000	0.484	1.090	1.572
5	*Acacia mellifera*	8000	2.067	0.013	2.080
6	*Acacia mellifera*	4000	2.692	0.210	2.902
7	*Dichrostachys cinerea*	10000	2.513	1.220	3.733
8	*Acacia mellifera*	5000	0.950	2.453	3.403
9	*Terminalia sericea*	8000	0.586	1.624	2.210
10	*Rhigozum trichotomum,*	2000	-	-	-
TOTAL			15.779	10.482	26.259

Drivers of bush encroachments

In Namibia, factors including climate change, veld fire suppression, overgrazing, lack of adequate dew to seedlings and reduced browsing pressure are among those leading to the problem of bush encroachment (Birch *et al.*, 2017; de Klerk, 2004; MAWF, 2017b). Increased temperature favours the encroachers such as *S. mellifera* as they are able to tap to deep moisture with their tap roots, giving them better survival mechanisms as compared to grasses that are likely to die during drought periods (Liu *et al*., 2013; Nesongano, 2018). In spite of an average of 43% of Zambezi and 34% of Kavango region being burnt annually (Mendelsohn and El Obeid, 2005), the supressing of high intensity fires for cattle farming reduces the possibility of killing the seedling and the saplings of the encroachers. The increased carbon dioxide concentration in the atmosphere also favours bush encroachment. The C_4-photosynthetic vegetation such as grass is effective in fixing carbon at low atmospheric CO_2 concentrations and reducing water loss through transpiration (Bond, 2008; Nesongano, 2018). The C_3-photosynthetic plants such as *Vachellia* and *S. mellifera* are effective in fixing carbon in elevated CO_2 conditions (Bond *et al.,* 2002; MAWF, 2014) and as a result of the little lost energy through photorespiration, these plants grow fast and recuperate successfully in a short period of time after damages (Bond and Midgley, 2000; Nesongano, 2018).

The displacement of browsers is found to result in putting pressure on grasslands and also bigger animals such as elephants and rhinos which tend to stunt the development of woody saplings, reducing seed production; while other animals such as kudus, impala, rabbits and domestic goats prevent the transitions of weakened savanna landscapes from growing to a full maturity (MAWF, 2017b). The weakened grass swards lead to mass growth of encroachers of both soft coated seeds (*S. mellifera*, *V. reficiens*, *V. luederitzii*, *S. erubescens*) and hard coated seeds (*D. cinerea*, *V. erioloba*, *V. hebeclada*) (MAWF, 2017b). Over grazing weakens the roots of grasses, impeding the grass to efficiently take up the water and nutrients, reducing the grass layer and creating the favourable conditions for encroachers. This is particularly true mostly for the non-perennial grass because the perennial grass gets affected greatly and in many cases they are unable to recover from the impacts of over grazing (NNF, 2016).

Impacted ecosystem services

Regardless of the causes, bush encroachment has an influence on ecosystems and their services. Most of the ecosystem services have moderate densities of encroachers, ranging from 3000 - 4000 bushes per hectare (Fig. 2), and only some parts of the Karstveld and of the Northern Woodlands have very high densities (up to 10 000 bushes per hectare) while Nama Karoo Shrubs have a low density (2000 bushes per hectare) of encroachers (Birch *et al.*, 2017; Harper-Simmonds *et al.*, 2015; NNF, 2016; Fig. 2).

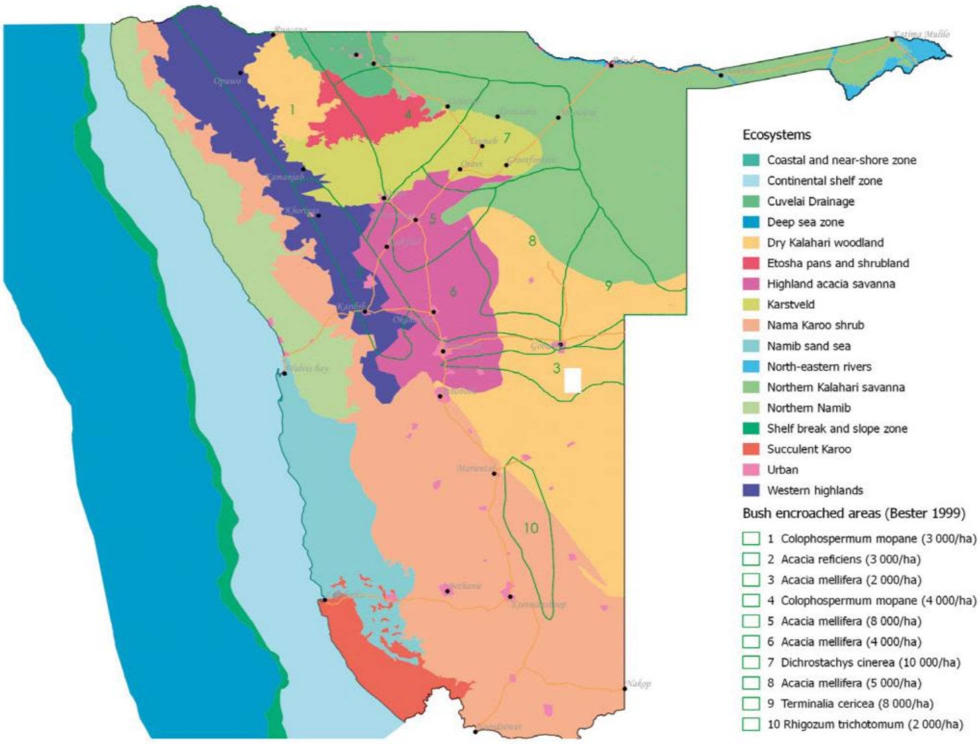

Fig. 2: Encroachment and ecosystems (Birch *et al*., 2017)

Due to the importance and value of various ecosystem services to the economy of the country and to the livelihoods of the majority of the Namibian population, managing the problem of bush encroachment has become one of the key priority areas to the farmers and the Namibian government. Bush encroachment control (de-bushing) is practiced through manual means (i.e. the use of axes, *pangas* and spade), semi-mechanised (i.e. the use of bush cutter and chain saw), mechanical / physical (i.e. the use of heavy machined cutters, bulldozers & bush rollers), chemical and biological methods and planned fires (de Wet, 2015; MAWF, 2017b). De-bushing is not aimed at completely eradicating the encroachers but at reducing the excessiveness of the woody biomass, with the purpose of enabling the regrowth of the grass, thus aftercare is also applied where necessary (Lukomska *et al.*, 2010; MAWF, 2017b; Temmerman, 2016). Table 2 provides some of the identified ecosystems services that are found to be have been impacted by de-bushing in Namibia (Birch *et al.*, 2017; Harper-Simmond *et al.*, 2015; NNF, 2016). The services are classified into three categories of Common International Classification of Ecosystem Services (CICES) as recognised by the UN System of Environmental - Economic Accounting and the Inventory of Ecosystem Services in Namibia (NNF, 2016). These categories of services are defined by Haines-Young and Potschin (2013) as: (i) provisioning (all nutritional, material and energetic outputs from living systems), (ii) regulation and maintenance (cover all the ways in which living organisms can mediate or moderate the ambient environment that affects human performance), and (iii) cultural (cover all the non-material, and normally non-consumptive, outputs of ecosystems that affect physical and mental states of people) (Birch *et al.*, 2017; NNF, 2016).

Table 2: Namibian ecosystem services impacted by de-bushing (adapted from NNF, 2016)

Type of services	**Types of impacts**	**Ecosystem services**
Provisioning	Positive	Reared animals and their outputs; groundwater for drinking and non-drinking uses; plant-based resources (charcoal and firewood production, electricity generation); cultivated crops; wild plants, algae and their outputs; fibres and other construction materials for direct use or processing; and animal-based resources (energy production from fat etc.).
	Both ways	Wild animals and their outputs (depending on the species); surface water for drinking and non-drinking uses (depends on use of de-bushed land); and materials for agricultural use such as animal feed supplements (overall supply depletes).
	Negative	Both water and air pollution might increase due to lack of filtering and less fixation of carbon from the atmosphere.
Regulation and Maintenance	Positive	Mass stabilisation and control of erosion rates by improvement of grass; buffering and attenuation of mass flows; hydrological cycle and water flow maintenance; and weathering processes (restoration of soils).
	Both ways	Pollination and seed dispersal (depending on the location); Maintaining nursery populations and habitats (may be conflicting impacts based on species); decomposition and fixing processes (depends on species of bush and extent of de-bushing); and chemical condition of freshwaters (depends on the use after de-bushing).
	Negative	Global climate regulation by reduction of greenhouse gas concentrations; flood protection; and ventilation & transpiration.
	Unknown	Bio-remediation by microorganisms, algae, plants and animals (detoxification, decomposition and mineralisation); filtration and sequestration of pollutants in soil; pest and diseases control, and micro & regional climate regulation (local climate, air quality, regional precipitation).
Cultural	Positive	Experiential use of plants, animals & landscapes (wildlife viewing); physical use (trophy hunting); entertainment (ex-situ viewing); symbolic identification of landscape features; aesthetic; existence; and bequest.
	Both ways	Scientific research and education (change in land cover restricts some potential for scientific research and increases others); and heritage & cultural use (depends on the use of land).
	Unknown	Scares practices of communities.

Impacts with specific to the groundwater

All the above-mentioned impacted services are valued in Namibia; however, the main influencing factor of bush encroachments is water. Considering the aridity of the country and the effects of climate change, water is important in all aspects. The amount of water lost caused by the encroachers through transpiration is estimated to be around 12 million m^3 on a 10 000ha (NAU, 2010). Currently, around 33% of 476 548 km^2 of the low groundwater potential, 52% of 323 333 km^2 of the moderate and 89% of 24 247 km^2 of the high groundwater potential are encroached (NAU, 2010; Fig. 3a). Figure 3a shows only boreholes with reliable information, hence not all the boreholes in the area were considered. However, the trends are considered to be representative (NAU, 2010). This could be worrisome to an arid country, as 83% of the rainfall evaporates, 14% returns to the atmosphere through evapotranspiration, and only 2% is surface overflow and 1% goes to groundwater recharge (NamWater, 2018).

During periods of drought, groundwater is the most important water source in Namibia and close to 80% of the country depends on this source (NAU, 2010; UNFCCC, 2010). Five (5) out of the ten (10) zones invaded by bush encroachment are dominated by *S. mellifera* (Fig.1), covering at least 14 307 000 hectares (Table 1b). Plants generally transpire up to 45 – 80% (Larcher, 1983), however with *S. mellifera*, the situation could be worse off, transpirations is at least 6 times more than other bushes and shrubs, which results in *mellifera* using around 2000 litres in 8 hours a day (Donalson, 1969; NAU, 2010). At farm Aiams, Otavi district, it has been observed that the species has an extensive root system with a length of over 30m deep and have an impacted on the level of water table (NAU, 2010). Around the Platveld aquifer area, some of the farmers' boreholes were initially 7m deep in 1940 and this decreased to an average of 85m in depth by 1990 (Fig. 3b). The number of boreholes were increased in the hope of getting more water at all times. The increase in the number of boreholes did not improve the diminishing depth levels of boreholes, but led to decreased stocking rates which was necessitated by bush encroachment (NAU, 2010). In other parts of the world, de-bushing has improved the water table over a long period of time, with 11 m in Kwazulu-Natal and 20m over 30 years in Thabazimbi, South Africa (NAU, 2010; Vegter, 1993). Even though this has not been well researched in Namibia, estimations have been made (Honsbein *et al.*, 2009; NNF, 2016; Table 3).

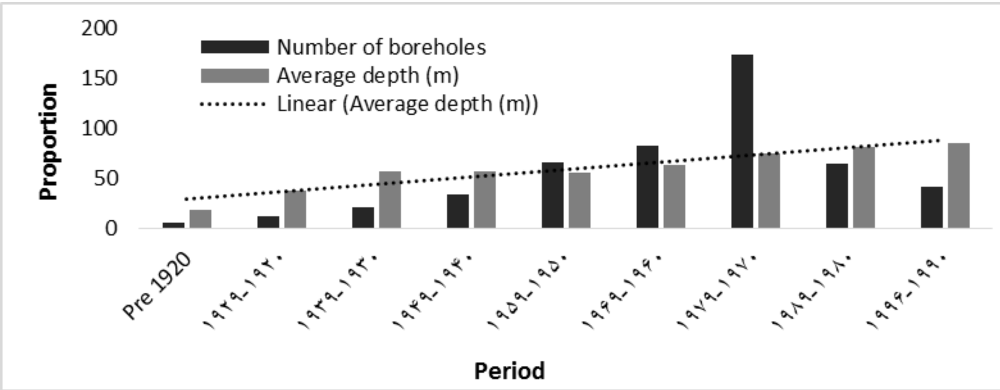

Fig. 3a: Groundwater: Boreholes and their depths (Carr Barbour Associates, 1996)

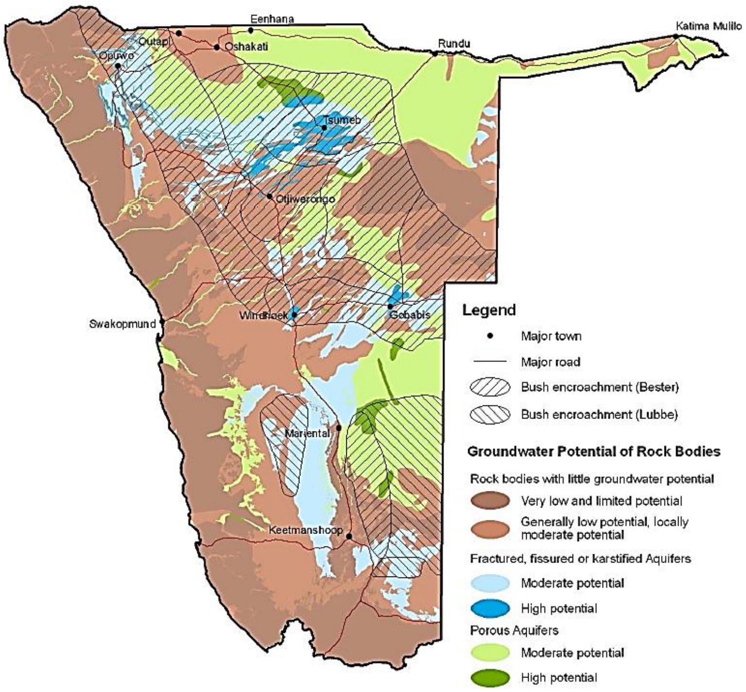

Fig. 3b: Groundwater: Hydrogeological map (Bester, 1999; DWA & GSN, 2001)

Table 3: Estimated recharge after de-bushing (Honsbein *et al*., 2009; NNF, 2016)

Zones (Fig. 2)	Total Farmlands (million m^2)	De-bushed Farmlands (60% of total) (million m^2)	Rainfall (m.p.a)	Total rainfall on de-bushed farmlands (million m^3 p.a)	Ground water inflow at 1% recharge (million m^3 p.a)	Ground water inflow at 2% recharge (million m^3 p.a)	Potential increase in ground water inflow (million m^3 p.a)
1	44370	26622	0,325	8652	87	173	87
2	23670	14202	0,225	3195	32	64	32
3	35550	21330	0,325	6932	69	139	69
4	15720	9432	0,425	4009	40	80	40
5	20800	12480	0,425	5304	53	106	53
6	29020	17412	0,375	6530	65	131	65
7	37330	22398	0,500	11199	112	224	112
8	34030	20418	0,425	8678	87	174	87
9	22100	13260	0,425	5636	56	113	56
10	-	-	0,150	-	-	-	-
Total	**262 590**	**157 554**		**60 134**	**601**	**1 203**	**601**

De-bushing benefits

Value chains of bush encroachers in Namibia are classified into the large scale and small scale uses. The large scale uses are further categorised into residential wood fuel (fire, compressed wood and charcoal); industrial heat and power generation (chips, pellets, bio-oil and bio-ethanol); construction (timber, poles, wood-cement bricks, wood-charcoal bricks and wood-clay bricks); boards/panels (wood-cement boards, wood-sand boards, particle boards, oriented stranded boards, medium density fibre boards, medium fibre boards, gypsum-bonded fibre boards, wood-plastic composites, block boards and furniture); agriculture (animal feed, compost and bio-char) and paper products while the small-scale uses include parquet, shingles, wooden frames, kitchen boards, transport boxes, carving, tooth picks, spatulas, ice cream sticks, sosatie sticks, stick/ handles for tools, wood glue, traditional medicine, smoking/ aromatic material and mulch for gardening (Birch *et al.*, 2017; MAWF, 2014).

Many of the products from de-bushed products have been only fully operational since 2004, charcoal has been practiced for more than 60 years (de Klerk, 2004; MAWF, 2014). Presently, there are at least 650 charcoal producers and around 6000 workers in Namibia (Factsheet, 2018). The charcoal industry appears to be currently thriving in both domestic and international markets (Factsheet, 2018; MITSMED, 2016; Fig. 4). According to Workman (2019), Namibia is currently one of the world's top 12 charcoal exporting countries and the highest in Africa, exporting at least 2.6% of the world's percentage (in 2018 it exported $34.1 million). South Africa is the 18th (1.5%) and Ghana the 20th (1.3%), making them second and third highest charcoal exporters in Africa, respectively. Charcoal is also used as a method of rehabilitating the degraded land (Factsheet, 2018) and it can also be used in the livestock diet to reduce the anti-nutritional effects of secondary compounds in the animal feeds (Poage *et al.*, 2000). Furthermore, with continuous de-bushing, the industry of charcoal is expected to grow, increasing with 25% by 2020 compared to the 2016 of exportation (Factsheet, 2018).

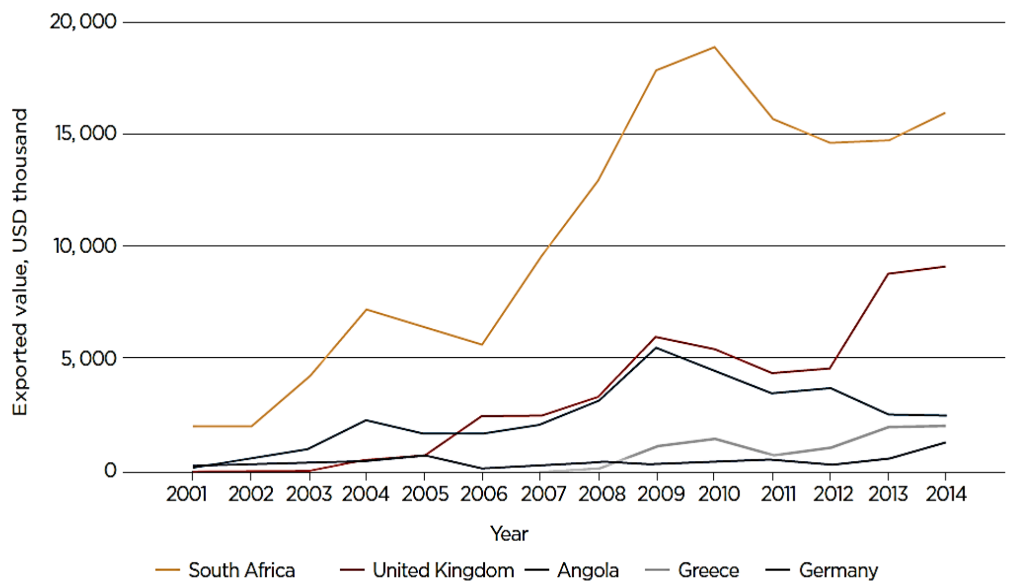

Fig. 4: International sales of charcoals (MITSMED, 2016)

Bush encroachment and animal feed

The biomass of the de-bushed encroachers is used as animal fodder and largely benefiting the rangeland farmers in Namibia. Moore (1989) argues that the leaves, fruits and seeds are the only digestible parts of the encroachers and the rest might not be digestible due to the high content of lignin. Nonetheless, using bush for animal fodder has been practiced by a few since 1980 and increasingly growing since 2012 (MAWF, 2017a). Encroachers such as *Senegalia mellifera* and *Dichrostachys cinerea* are part of the largely used bushes, but, *Rhigozum trichotomum*, *Terminalia prunioides* and *Terminalia sericea* are also found to be suitable (MAWF, 2017a; Table 4). While de-bushing is becoming a viable business for income to the farmers, many have practiced it as a drought relief solution for livestock, ensuring higher fibre content nutrition (fat, protein and energy) (Table 4). Table 4 shows that the most aggressive encroachers *Senegalia mellifera* and *Dichrostachys cinerea*, are also the most nutritious on the dry season. The digestibility and tastefulness of the materials (palatability) is improved by adding additional materials (Lucerne, *Vachellia eriobola*, *Prosopis pods*, bran, cotton seeds) and or chemicals (ammonium chloride, urea, phosphorus and calcium) (MAWF, 2017a). With the use of encroachers as animal fodder, the country appears to have slightly and turned around the situation involving billions of dollars in financial losses.

Livestock is estimated to contribute up to 75% to the total agricultural output, with beef production being the largest contributor, followed by sheep and goat production (Sweet and Burke, 2000). In 2018, the beef industry brought in N$ 2.7 billion while in 2017 it brought in at least N$2 billion (i.e. from the 85% of meat production exported), of which 37 tonnes of beef is exported to South Africa and at least 9500 tonnes are exported to European countries including the European Union, United Kingdom, Reunion, and Norway (The Meat Corporation, 2017).

Table 4: Percentages (%) of chemical composition of analysed plants (adapted from MAWF, 2017a)

Month Sampled	Species	Moist	Ash	Fat	CP	CF	ADF	NDF	OMD	ME	Ca	P
	*Grass**	7.93	10.02	1.32	5.03	38.15	42.70	72.08	-	-	-	0.24
April 2016 (end of rainfall)	*Senegalia mellifa*	4.66	5.31	2.66	12.4	36.92	47.17	55.66	46.4	6.5	1.113	0.046
	Combretum collinum	4.64	7.49	3.17	13.00	29.34	33.21	45.86	39.4	5.3	1.656	0.063
	Dicrostachy Cinerea	4.61	4.74	2.24	10.50	29.96	35.3	46.67	35.0	4.8	0.759	0.090
	Grewia flava	4.69	5.96	4.93	11.55	29.54	40.06	51.61	43.8	6.6	0.636	0.198
	Grewia flavensis	5.02	4.89	3.47	8.62	32.00	44.47	53.90	43.9	6.4	0.821	0.037
	Terminalia sericea	4.76	8.80	2.56	11.95	24.15	34.54	45.04	38.2	4.9	2.054	0.068
Sept./Oct. 2016 (dry period)	*Senegalia mellifera*	3.42	4.31	2.45	9.55	40.03	49.78	63.11	38.1	5.4	-	-
	Combretum collinum	3.03	11.14	1.21	5.75	32.01	44.34	51.17	37.5	4.5	-	-
	Dichrostachy cinerea	3.78	4.23	1.77	9.09	35.90	52.28	55.36	38.9	5.4	-	-
	Grewia flava	3.49	5.33	1.03	5.75	38.56	53.79	65.2	36.0	4.8	-	-
	Grewia flavensis	3.13	5.33	1.11	4.95	41.42	56.87	64.43	33.3	4.4	-	-
	Terminalia sericea	3.12	7.57	1.01	5.85	30.21	44.03	49.58	39.4	5.1	-	-
Dec 2016 (beginning of rainfall)	*Senegalia mellifa*	5.59	6.56	2.75	15.50	31.79	40.76	54.53	-	-	1.585	0.024
	Combretum collinum	5.23	7.17	3.24	11.10	26.87	34.18	43.33	-	-	1.775	0.022
	Dicrostachy Cinerea	6.15	4.76	2.24	13.6	30.85	41.38	55.99	-	-	1.034	0.016
	Grewia flava	5.99	6.10	1.78	8.70	32.24	47.09	58.72	-	-	1.508	0.015
	Grewia flavensis	6.12	5.27	1.84	8.63	35.83	48.47	58.79	-	-	1.281	0.016
	Terminalia sericea	6.25	6.44	2.75	9.95	26.89	32.41	44.84	-	-	1.658	0.019
March 2017	Grass*	7.73	11.55	1.84	10.65	27.16	31.09	54.49	-	-	-	0.17

Moist = % Moisture; Ash = %Ash; Fat = % Fat; CP = % Crude Protein; CF = % Crude Fibre; ADF = % Acid Detergent Fibre; NDF=%Neutral Detergent Fibre; OMD = % Organic Matter Digestibility; ME = Metabolizable Energy (MJ/Kg); Ca = % Calcium; P=%Phosphorus.

*The grass indicated in the Table was a composite sample of grasses in a grazing camp. The majority of the species were annuals.

Discussion

Bush encroachment and climate change

World climate is expected to become drier, not too far in the future. For Namibia, rainfall is expected to decline with 10% in the south and northern part of the country, with 15% in the central areas of the country by the year 2015 (IPCC, 2001; UNDP, 2019). The mean decadal temperature increase is estimated to be 0.2˚C, which is three times the projected mean temperature increase of the global for the 20th century (IPCC, 2001; Midgley *et al.*, 2005). Studies have shown that the encroachers modify the ecosystem functions and possibly their ecohydrological processes, and one of the direct consequences of climate change is the increase of favourable conditions to bush encroachment.

As result of climate change, where an increase in temperature and decrease in rainfall has occurred, encroachers have rapidly colonised the Namibian savanna landscapes, thereby decreasing groundwater as a result of their long tap root system. As a result of the increasing encroachers that have long tap root systems, and their interception of the rainfall water available to other species, the availability of water decline. This leads to a magnified vulnerability to drought for humans, animals and ecosystems, affecting the carrying capacity of the farming lands, and worsening the shortage of grass for the livestock which results in a dire scarcity of animal feed in Namibia. A continuous control of these encroachers is critical and therefore the consequent production of animal feed that transforms the potential for agriculture during the drought periods for the livestock industry.

Management challenges

When de-bushing was introduced, it was with an expectation that it would improve the impacted services and increase agricultural production (NNF, 2016), on the other hand the practise also provides an opportunity for value chains that include building materials, products which are sources of income, energy production materials such as charcoal, and meat for the export market (Charis *et al.*, 2019; Uchezuba *et al.*, 2019). This shows that de-bushing of encroachers adds substantial socio-economic and ecological benefits. This brings a challenge in managing the encroachers, whether or not encroachers should be encouraged for the purpose of de-bushing and consequently forgo the natural ecosystems affected, or de-bushing should be done effectively regardless of the economic benefit. Using encroachers as fodder is not only for economic value, it is a drought relief strategy and it is viewed as an essential strategy to mitigate the expected effects of climate change as specified by Sustainable Development Goal 13 (MAWF, 2012). Furthermore, the practice has far-fetching effects on the survival of the population in terms of meat, milk, and income at local and national scales, and it is in line with the current National Development Plan (NDP5) for Namibia, the National Rangeland Management Policy and Strategy of 2012, the National Industrial Policy of 2012 and the Growth at Home Strategy, in supporting the domestic value addition for local resources.

The questions here are: with the increase in evidence of the problems and benefits of de-bushing, are the positive effects outweighing the negative effects for arid country of Namibia? Has the problem become an opportunity? Is this a climate resilient adaption strategy that Namibia should focus on? Is it a short term solution or are encroachers going to be allowed to grow for specific purposes, despite the negative ecological effects? To what extent can this be taken as a sustainable trade off?

Relating projects and legal entities

De-bushing is highly encouraged, despite Namibia not having a regulating laws (MAWF, 2014). There are several projects either supporting and or promoting the value chains production from bush encroachments. Examples include the Ministry of Agriculture, Water and Forestry (MAWF) which promotes the sustainable management of forest resources to improve socio-economic development and environmental stability; the De-bushing Advisory Service (DAS) which is the focal point for information relating to bush encroachment, bush thinning and value addition to bushes; Namibia Biomass Industry Group that represents the Namibian biomass sector; Sustainable Management of Namibia Forested Land which is aimed at strengthening and enhancing community forests by encouraging communities to take ownership of local level forest resources, and the MAWF-GIZ Bush Control and Biomass Utilisation which aims at improving the capacities of the regulators in the biomass industry.

De-bushing requires a forestry permits (harvesting, transport, export and marketing permit) for forestry products and environmental clearance certificates (Birch *et al.*, 2017; DECOSA, 2016; MAWF, 2014; MAWF, 2017b), depending on the amount of the products. The permits are dealt with by the Forestry Act 2001 and its regulations (2015), and the certificates are handled by the Environmental Management Act number 7 of 2007 and its 2012 regulations which are part of the Ministry of Agriculture, Water and Forestry (MAWF, 2017b). This works hand in hand with other ministries such as the Ministry of Environment and Tourism. Other instruments that provide guidance in de-bushing include the Development Forestry Policy (2001), Draft Bush Encroachment Management Policy (2004), Environmental Assessment Policy for Sustainable Development and Environmental Protection (1995), Forest Act (2001) as amended by Act No 13 (2005), National Agricultural Policy (1995), National Drought Policy and Strategy (1997), Nature Conservation Amendment Act (1996), Nature Conservation Ordinance (1975) and Soil Conservation Act (1969), (Birch *et al.*, 2017; DECOSA, 2016; MAWF, 2014).

Conclusion

Bush encroachment affects agricultural productivity. Although the process poses many challenges that lead to long lasting rangeland degradation, through de-bushing it is providing many value chains that are useful to livelihoods, and also provide a drought resilience solution to the meat industry, and therefore contributing to the country's economy. The opportunities are mainly in three sectors; namely: in the construction sector, the energy sector and the agricultural sector. However, if de-bushing is not controlled and managed in a sustainable way, it could still negatively impact the environment in a different manner. It could lead to problems such as increased soil erosion (depending on the type of land) which in turn will increase the vulnerability of groundwater resources, in terms of recharge and contamination. Moreover, de-bushing could also decrease the amount of carbon sequestered in the soil as well as the rate and amount of CO_2 fixed by C_3 photosynthetic encroachers, which not only consequently contribute to global warming, but the elevation of CO_2 disadvantage the C_4 vegetation that is needed, such as grass.

Therefore, while trying to improve the ecosystems by de-bushing, managing de-bushing needs to be sustainable. For these reasons, there is a great need to determine the stage at which the encroachers are best de-bushed, such as age, stem diameter and height, so that de-bushing can be selective for each species or on rotational plots. There is also a need for research to largely focus on evaluating the trade-offs between the problem and opportunities. One way of ensuring sustainability at the moment is, for instance, to concentrate on using the mechanical way of controlling the encroachers, as this means leaves the root systems in place for future growth and not upsetting the ecological functions while at the same time also creating jobs needed and income. Other methods such as the use of chemicals might be ecologically lethal. Other research efforts could be directed at the effects of the encroachers (especially the treated fodder) on animal health, on the quality of milk and meat, and consequently on human health as consumers.

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