Impacts of bush encroachment on groundwater recharge:

Evidence from 9 years of soil hydrological monitoring in the Namibian thornbush Savanna

Namibia increasingly faces challenges to sustain the livelihood of the people due to worsening environmental conditions. In a country were the annual potential evapotranspiration typically exceeds the annual rainfall largely, the potential to recharge groundwater is generally very low and limited to years with extraordinary rainfall or to those parts of the landscape, where water can rapidly infiltrate in the deep underground or where water is concentrated due to runoff.

Groundwater recharge is further reduced by bush encroachment which currently affects more than 30 million hectares of Namibia's land surface or 30% of the country size.

Groundwater reserves have a high ecological and economical value, with over 80% of Namibia's rural population and main economic activities such as mining, industry and agriculture dependent on local underground water resources.

Aiming at adding value to the yielded woody biomass, the Ministry of Agriculture, Water and Forestry (MAWF) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) Support to De-bushing Project (now called Bush Control and Biomass Utilisation) conducted studies to quantify the benefits for ecosystem services under different bush thinning scenarios at national and regional level using Otjozondjupa region as a case study. In view of this, observations in groundwater recharge on bush encroached and bush thinned areas were assessed and are presented in this brief.

1 Background

The general opinion is that bush encroachment impacts negatively on soil water hydrology and on groundwater recharge. However, there is a lack of scientific evidence on the topic. Research is often vague, with Namibian research often based on individual rainfall events while international research often takes place in regions with different environmental conditions. The Southern African Science Centre for Climate Change and Adaptive Land Management (SASSCAL[1]), in collaboration with the University of Hamburg, carried out a study on soil moisture covering the period of 2007-2016 (9 years) in the thornbush savanna of central Namibia. This data set has been interpreted with regards to potential of groundwater recharge in relationship to vegetation cover. Limitations are acknowledged such as systematic errors of the equipment and lack of proper understanding of plant ecohydrology (which may depend on tree species). However, as this research is based on a long term data set, it offers substantial insights on how bush encroachment influences soil water dynamics.

2 Objectives

Observations were made in terms of soil water dynamics of bush-encroached areas as well as bush thinned areas for a period of 9 years with automatic field monitoring techniques. The research aimed to understand the influence of different vegetation cover on the processes of soil water uptake and losses and thus to understand the water consumption patterns of different vegetation types.

1 www.sasscal.org

Observations allowed for three specific objectives:

1. Impact of bush encroachment on water infiltration process
2. Impact of bush encroachment on consumption of soil moisture (evapotranspiration)
3. Impact of bush encroachment on potential deep percolation

3 Materials and methods

Measurements were conducted at three experimental plots on a commercial farm about 110 km north of Windhoek in central Namibia. Each plot consisted of two soil profiles of about 5 m distance equipped with sensors and a rain gauge to measure soil water content and soil water potential at different depths.

The main comparisons were done between:

A. Open grassland (at one plot)
B. Intercanopy[2] (grasses, dwarf shrubs; at two plots) and
C. Under-canopy[3] patches (large shrubs to trees; at two plots).

4 Results

4.1 Impact of bush encroachment on the water infiltration process

Excluding effects of run-on, the average infiltration of rainwater for intercanopy profiles was 88%, indicating a 12% loss of rainwater. This is in contrast to infiltration under canopy of 58%, and thus a rainwater loss of 42%. The results suggest that **infiltration is higher under intercanopy and grassland conditions, and lower for under-canopy conditions**.

The loss of rainwater results from evaporation of the topsoil above moisture sensors (20 cm) and of the impact that trees have on rainfall events. Besides, the influence of run-off and stem flow could also have played a role.

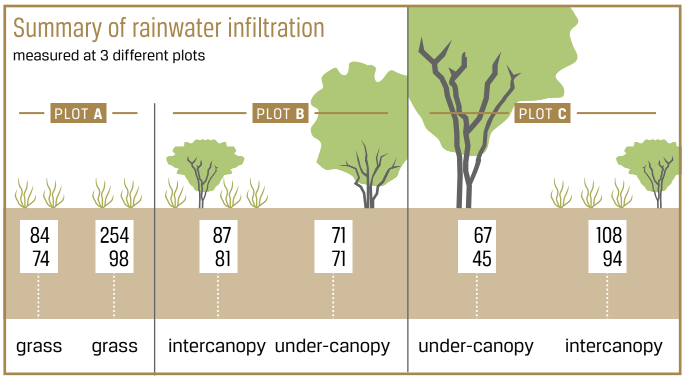

Figure 1. Summary of the proportion of rainfall infiltration (%): Upper value: all events. Lower value: without minimum estimate of run-on[4]

Table 1: Summary of average rainwater infiltration

Plant cover units	Infiltration%	Loss%
Intercanopy	88	12
Under-canopy	58	42
Grassland	86	14

2 Represents conditions of open savannas

3 Represents conditions of bush encroached areas

4 Values excl. estimated run on. Some of the figures are extremely skewed due to run off figures and hence provide a distorted result, (run-on: the amount of water that ponds on the soil surface at rain events and runs to the measuring position)

4.2 Impact of bush encroachment on consumption of soil moisture through evapotranspiration (ET)

If the soil was moistened by rainfall, a subsequent decrease in soil moisture indicates both the evaporation from the soil surface and the root water uptake and transpiration through leaves (evapotranspiration). The measurements taken found that the daily root water uptake reduces strongly with ongoing desiccation of the soil.

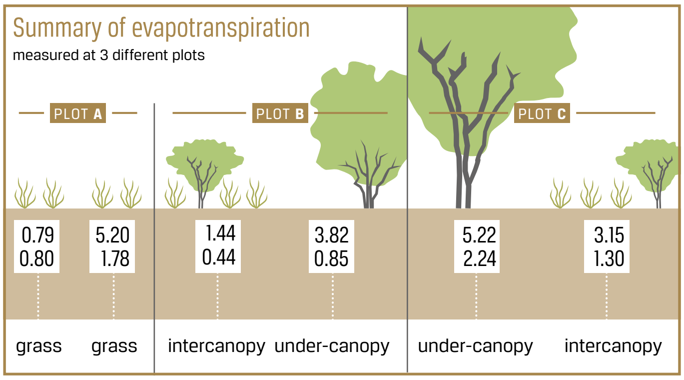

Figure 2. Summary of daily water losses by evapotranspiration (ET, mm d^{-1}): Upper value median ET at moist soil condition; Lower value: median ET at intermediate dry soil condition

Table 2: Summary of the extent of evapotranspiration

	Median Evapotranspiration (mm/d)	
Plant cover units	**moist soils**	**intermediate dry soils**
Intercanopy	2.4	0.9
Under-canopy	4.5	1.5
Grassland	3.0	1.3

If the soils are dry the ET is rather similar and low irrespective of vegetation cover. However, **by comparison of all days with moist soils, the evapotranspiration for under-canopy profiles is 1.9 fold compared to intercanopy sites,** or in other words approximately twice as high as under intercanopy conditions. ET under large bushes/ trees is approximately 40% higher than under small bushes, i.e. more pronounced. Soil moisture below canopies is consumed in higher daily rates than in the respective intercanopies.

4.3 Impact of bush encroachment on potential deep percolation, i.e. potential groundwater recharge

In the 9 years of observation, the **potential for deep percolation, i.e. potential for groundwater recharge, for intercanopy profiles was found to be about 2.7 times higher than for undercanopy profiles**. The higher potential for groundwater recharge under intercanopy sites is attributed to above dynamics: higher infiltration rates and lower evapotranspiration rates. For complete data sets (7 years), the mean deep percolation for the intercanopy profiles was calculated with 389 mm and for the belowcanopy profiles with 172 mm, respectively. Deep percolation was restricted to the rare moments of intensive rainfall on deeply moistened soils. This was especially the case in the seasons 2010/11 and 2011/12 with about 750 mm rainfall each. Under canopies, no deep percolation was observed in years with less than 500 mm rainfall. In contrast, even in years with lower rainfall some rain events may result in minor rates of deep percolation in the intercanopy conditions.

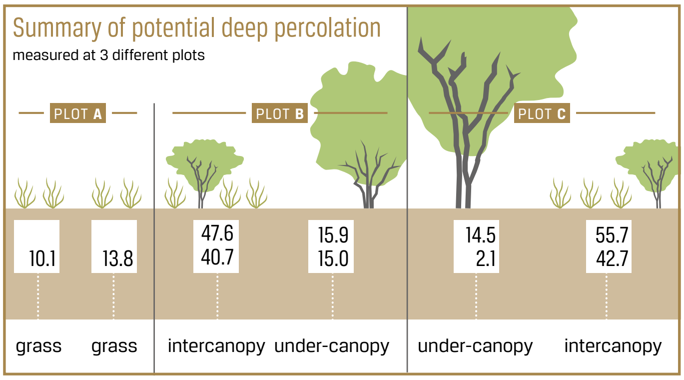

Figure 3. Summary of potential deep percolation (weighed frequencies/ (%* mm d^{-1}): Upper row from period 10/2007 – 10/2016; Lower row from period 4/2011 – 10/2016

Table 3: Summary of potential for deep percolation (groundwater recharge)

Plant cover units	Potential deep percolation (% mm)
Intercanopy	41.7 (9 years)
Under-canopy	15.2 (9 years)
Grassland	11.9 (5.5 years)

5 Conclusions

The analysis of the impact of bush encroachment on groundwater recharge, based on a 9 years soil water data history in central Namibia, suggests that **severe bush encroachment reduces the probability of groundwater recharge to approximately one third in comparison with non-encroached or bush thinned areas**.

Although the study had its methodological limitations, it provided **strong empirical evidence that bush encroachment impacts negatively on soil water dynamics, affecting water infiltration, reducing soil moisture and groundwater recharge**. In an arid to semi-arid environment like Namibia, this is a **strong incentive for bush thinning of heavily encroached landscapes**.

It is thus recommended that more in-depth research into groundwater dynamics is conducted in combination with other studies such as an analysis of various tree species water consumption patterns in order to fully understand the complexity of groundwater dynamics.

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