The effect of *Acacia Mearnsii* removal on water table fluctuations in the Tsomo valley Eastern Cape of South Africa

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Introduction

Invasive trees alter and utilize more water compared to indigenous trees because of their higher transpiration rates per unit leaf area (Enright 1999). Recent climate-soil-vegetation modeling suggests that, given the same soil type between forested and bare soil conditions, forested soils have higher moisture losses (about 30% more) from evapo-transpiration than bare soils (Zhang and Schilling 2006). This results in forested soils producing less groundwater recharge than bare soils.

Introduced vegetation changes the surface characteristics of habitats through altering plant to plant interactions (Dye and Jarmain 2004). They significantly influence soil water balance as they increase in dominance (Le Maitre *et al.* 2000); and alter soil water balance through shifts in phonological schedules (Luken and Thieret 1997).

In semi-arid savanna ecosystems, the suppressive effect of an increase in woody plant density on herbaceous plants, mainly grasses, is largely through competition for soil water (Smit and Rethman 1999). If a plant is introduced in an ecosystem, it will have seasonal pattern of canopy formation and physiological activity differing from the native species in the community (Enright 1999). Such differences lead to degradation of ecosystem resources. Invasives are very competitive as shown by Melaleuca quinquenervia which is a very prolific rooter regardless of competing vegetation in the Netherlands (Lopez-Zamora *et al.* 2004). *Melaleuca quinquenervia* develops root densities greater than many mature native species at an early age and in the soil surface during soil drying periods, even while competitive grasses are dying out (Lopez-Zamora *et al.* 2004).

Salt cedar (*Tamarix ramosissima*) is a great consumer of water in Russia; a single large plant can absorb 100 liters of water a day (Friedmanm 2000). This results in the lowering of the ground water, drying up of springs and marshy areas, as well as reduction in water yield of riparian areas. Experiments aimed at assessing the effects of clearing on groundwater have not been adequately integrated with other components of the hydrological cycle in modeling of groundwater dynamics (DWAF 1997).

The reasons for increased water use and whether such increases should be expected from all species of invading alien trees under all environmental conditions are not well understood (Calder and Dye 2001). The few South African catchments and evaporation studies that have yielded water use data so far are too few to provide an adequate foundation for the countrywide estimation of evaporation in invaded regions (Calder and Dye 2001). The objective of the study was to quantify the water table fluctuations due to presence of *Acacia mearnsii.*

Experimental layout and data collection

The field experiment was a complete randomized design with two replicates. Two treatments were tested: (a) presence of *Acacia mearnsii* trees (b) absence of *Acacia mearnsii* trees. There were a total of four experimental units. Four plots, measuring 20m x 10m each, were selected based on the presence of natural wells. The plots were largely dominated by clayey-loam soils. Clearing of *Acacia mearnsii* trees was done using chain-saws in September 2007 so as to start the recordings in November, when the rains start falling. In doing so a cyclic comparison in fluctuations would be obtained to compare between the wet and dry period. Infiltration rate, as affecting water seepage and water table level, was measured using the Double ring infiltrometer. Weather variables such as rainfall were monitored using a local weather station.

In each of the four plots, a Data Logger (HOBO Pro U20-001-03, 250-Foot Data Logger, Onset, 2005) machine was installed at a depth of 90cm to estimate the changes in the level of water table. The Data loggers were measuring daily temperatures, atmospheric pressure and the change in water storage from the natural wells in °C, KPa and meters respectively, within a radius of 20 meters. The data loggers were set up to record the above parameters every 15 minutes and the data was retrieved from the machines at two week intervals and then averaged over a month.

Data analysis

All data sets were subjected to normality test to ascertain compatibility with assumptions of analysis of variance. The F test was conducted as appropriate for randomized complete design with the generalized linear model of SAS (SAS 1999). Pearson's Correlation coefficient was used to establish the relationship between the variables with change in water storage. The data were split to wet and dry season. The equation adapted from Loheide *et al.* (2005), Dunne and Leopold (1978) was used to incorporate the variables that affected the water table fluctuations;

$dS = (dW \times \text{specific yield} - R) \times A$

Where change of water elevation (dW) represents the rise and fall in the level of the water table depth

dS= Change in storage

R=Rainfall

A=Watershed area

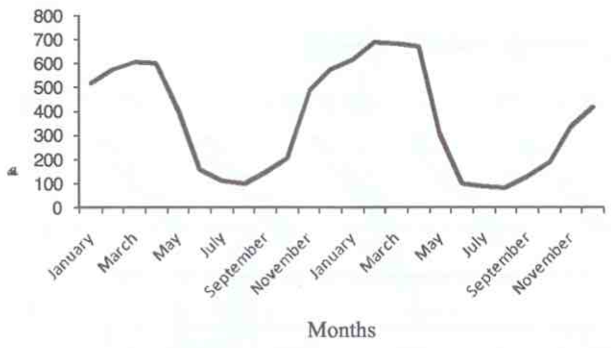
Specific yield is the volume of water released from storage per unit land surface area per unit drop in the water table. The specific yield can be estimated based on sediment texture of the soil when the depth to the water table is above 1 m (Loheide *et al.* 2005). These values are based on the assumptions that the water table is deeper than 1 m, and that the readily available specific yield is essentially independent of the magnitudeof the diurnal fluctuations and antecedent moisture conditions. The watershed area for Elliot was estimated from the digitalized elevation model.

Results

Effective management of groundwater resources requires information about all components of the water budget and the water table level is essential as it affects groundwater accessibility by vegetation. The water table is important because it provides moisture in the soil for vegetation to utilize readily. The closer the water table level is to the surface, the easier the access vegetation will have to the water. The proximity of the water table and the fluctuation of the water table over time, have a substantial influence on the type and productivity of plant communities.

As expected, rainfall during data collection constantly increased from November (2007) to February (2009), Rainfall received decreased gradually from February 2008 to June 2008 (Figure 1).

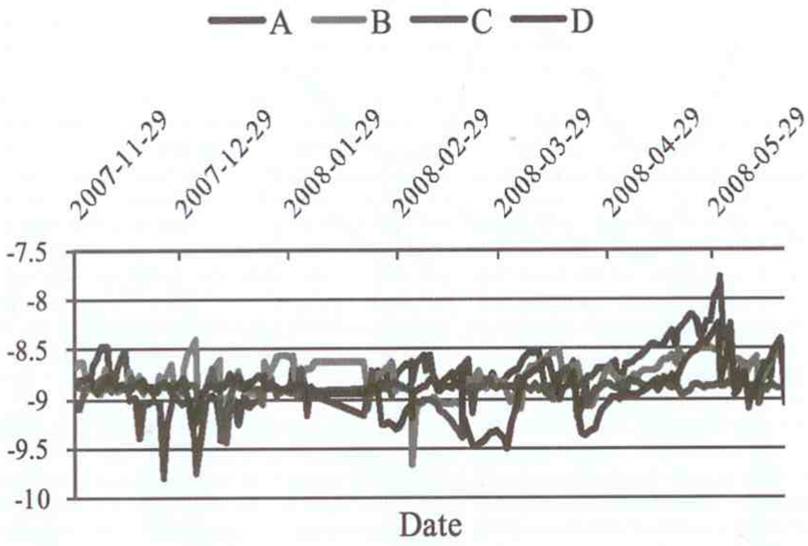
Figure 1: Rainfall amount received during data collection period (January 2007-December 2008)



In this study, the fluctuation of the change in water table storage from November (2007) to May (2008) did not vary significantly (Figure 2). The wet and the dry period recorded a significantly different change in water storage (-9.35 m and -8.8 m respectively), as expected, (Figure 2). The change in storage for the wet period showed a constant increase as the months progressed while a slight change in storage is seen between the first and third months only and, thereafter, a constant decrease occurred to the last month of the dry period (Figure 2.)

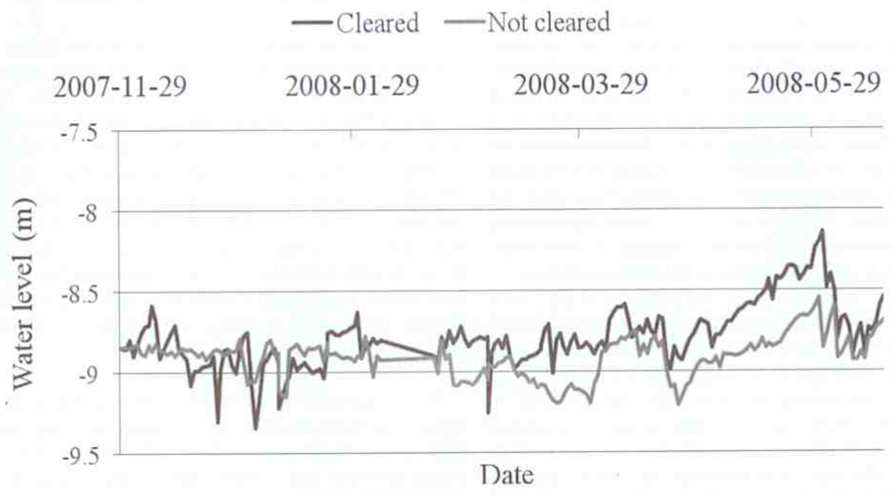
Water table fluctuations did not show significant differences when comparing the four data loggers (Figure 2). The data showed that cleared plots averaged higher (-9 m) than not cleared plots (-8.7 m) during the recording period (Figure 2). The fluctuations from the data loggers are more defined during the wet period of data collection (Figure 2).

Figure 2: Water table fluctuations from the four data loggers. A and D represent fluctuations measured in cleared plots while B and C represent fluctuations measured in non cleared plots.



Water table fluctuations are less defined during the initial months of the wet period but the difference between the fluctuations is however clearly defined and visible as the wet season approaches its end (February and March) (Figure 3). Water table recharge increases in the cleared plots as the water fluctuates towards positive levels compared to the not cleared plots (Figure 3). Differences between fluctuations are minimal during the initial stages of the wet period when comparing the cleared and not cleared plots but become clearer as the months progress, becoming clearer and, therefore, higher during the dry period (Figure 3).

Figure 3: Effects of clearing A. mearnsii on water level fluctuations



The water table fluctuation was positively correlated to the total biomass production in the plots ($r = 0.121$; $p > 0.05$), whilst water table fluctuation was also correlated to the basal cover ($r = 0.326$, $p < 0.05$). The infiltration rate was not correlated to the change in water table storage. Infiltration rate was significantly and positively correlated to the change in water storage ($r=0.56$, $p < 0.05$) for the cleared plots while infiltration rate was insignificantly correlated ($r=-0.93$, $p > 0.05$) to the change in water storage in the not cleared plots.

Discussion

Acacia mearnsii caused a reduction in water table in plots not cleared as it has high biomass production that in turn, leads to increased maintenance requirements for water and nutrients. Water table fluctuations in cleared plots increased water table recharge because clearing trees reduced water uptake by vegetation. These results are similar to Prinsloo and Scott (1999) in South Africa (Western Cape) where there was 12m-3day-1ha-1, 10.4 m-3day-1ha-1 and 8.8 m-3day-1ha-1 increase in stream flow after clearing Acacia mearnsii and Acacia longifolia in Knorhoek, Oaklands and Du Toitskloof in the Western Cape .

The invasive *Acacia mearnsii* reduced groundwater recharge through altering interception, infiltration, surface runoff, transpiration through the use of their deep rooting system. This also allowed A. mearnsii to utilize that water that would have ended up in rivers or streams instead. The presence of A. mearnsii affected water recharge by directly extracting groundwater from saturated strata and reducing the proportion of rainfall that eventually recharged by interfering with the passage of precipitation from the atmosphere to the water table in the soil.

Acacia mearnsii decreased water table recharge because it was extracting soil water in the unsaturated zone through its roots, to feed transpiration, thereby decreasing amount of percolating water that reached the saturated zone. Water tables can fluctuate considerably due to seasonal and annual changes in inflows of water and as expected the wet season had higher mean moisture water table recharge compared to the dry season due to the higher rainfall amounts received during the wet season. Plant water use varies within and between days, as well as within and between seasons. Therefore such a variation between seasons was expected for this study.

Tree harvesting, like the plots that had *A. mearnsii* cleared, changes the rate of transpiration as leaf area is reduced causing reduced water use by the tree. Therefore clearing *A. mearnsii* reduced total leaf area thus increasing water storage in the soil. *Acacia mearnsii* reduced water storage where there were trees and this may have been due to that *A. mearnsii* increased the bulk density of the soil, thereby reducing soil porosity. The less the soil was porous, as expected, the low the water quantity that would percolate.

The water received through rainfall was higher in the wet season than that utilised by the trees leading to an increased recharge of the water table. The results of this study are similar to those of Khanzada et al. (1998) when the water consumption by Acacia nilotica and Acacia ampliceps increased during the dry period of their study and was not significant in the wet season due to rainfall received. For most rainfall events there is a rise in water table level. Water infiltrates directly from the surface to the water table and rises in the water level, therefore, occur very quickly. Rainfall thus plays a critical part in evaluating the groundwater levels.

In the summer when most of the rainfall events occur, the trees are in a growth stage and the temperature is high the outflow will be positive. In winter months the contribution of these elements are minimal and it would be expected that with no, or very little, rainfall no outflow would occur but the fractured gneiss in the catchment slowly releases water into the system.

Infiltration rate was positively correlated to the change in water storage in the soil, most likely because a higher infiltration rate results in increased water percolation, thereby increasing the water table level. Infiltration rates from the cleared plots were higher than those from the not cleared plots due to the differences in soil porosity. The soil from the cleared plots was more porous as observed from its infiltration rate as compared to the not cleared plots. *Acacia mearnsii* bound the soil particles together in the plots not cleared thereby reducing the porosity of the soil.

A rise in water table increased the total biomass production in the plots that were cleared of *A. mearnsii* because clearing the plots reduced the amount of water loss through evapotranspiration and this water was instead utilized by the vegetation growing where *A. mearnsii* had previously grown. The basal cover also increased with an increase in water table recharge due to a reduction in water loss through evapotranspiration by trees, a similar observation to the total biomass observation.

Conclusion

Acacia mearnsii had a negative effect on water table recharge because the change in water storage was lower for the plots that had trees compared to the plots that did not have trees. The wet season recorded minimal water loss from the water table due to the rainfall received compared to the dry season. Invasion of rangelands by *Acacia mearnsii* therefore, causes serious threats to vegetation development because it converts water meant for utilization by native vegetation to its own use. The depression of water tables through consumptive use of water by invasive trees like *A. mearnsii* can lead not only to a reduction in available water, but also to a corresponding decrease in species diversity.

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