Long-term effects of woodland planting in drylands on soil fertility and native vegetation productivity

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Introduction

Afforestation or tree planting in drylands have been investigated in terms of carbon sequestration[1], landscape restoration[2] and changes in rivers stream flows[3]. The effect of trees on the native vegetation and soil nutrient content was also explored but only at the subcanopy zone scale[4]. Little attention has been given to study the effects of trees planted in drylands on the native vegetation and soil fertility at large-spatial and long-term scales.

Here we evaluated the effects of woodland plantings (*Acacia victoriae*) in the degraded drylands of the Negev in 1993 on soil nutrients content and herbaceous vegetation after 20 years and its dynamics during the last 10 years. Herbaceous biomass, topsoil mineral-P, N and K, and soil organic matter were measured at the planted and an adjacent unplanted area (control). The satellite-derived Normalized Difference Vegetation Index (*NDVI*) from MODIS was used to expand the timespan of the analysis after calibration with field data.

A. Victoriae planted at the Negev drylands in 1993

Photos: A. Mussery

Data and Methods

MODIS-derived NDVI and Field sampling:

We decomposed MODIS-derived 250 m 16-day Normalized Difference Vegetation Index (*NDVI*) time series to their woody and herbaceous contributions (see details in Helman et al. 2014[5]). Planted and adjacent unplanted areas (control) were sampled for herbaceous biomass, soil nutrients (mineral-P, N and K) and soil organic matter (SOM) during 2008-2013.

Calibration and calculation of Rain Use Efficiency (RUE):

The *NDVI* of the herbaceous vegetation was regressed against herbaceous biomass measured in the planted and control sites for calibration (***Fig. 1***). Rainfall data from two stations were used to calculate *RUE (RUE = biomass / rainfall amount)* for both sites during 2000-2013.

Results

1. MODIS-NDVI correlations with herbaceous biomass:

The integral of the *NDVI* growing season ($NDVI_{GSI}$), which is the herbaceous contribution to the *NDVI* signal (see details in Helman et al. 2014[5]), was significantly correlated (R = 0.92, P<0.001) with herbaceous biomass in planted and control sites (green and black symbols, respectively in ***Fig. 1***).

2. Improved soil fertility and biomass in the planted area

Nutrients concentrations and SOM were significantly higher in planted area (***Fig. 2***). The *Acacia* trees had a facilitative effect on the herbaceous vegetation at the subcanopy zone, diminishing with distance from the tree bole (***Fig. 3***).

Figure 1

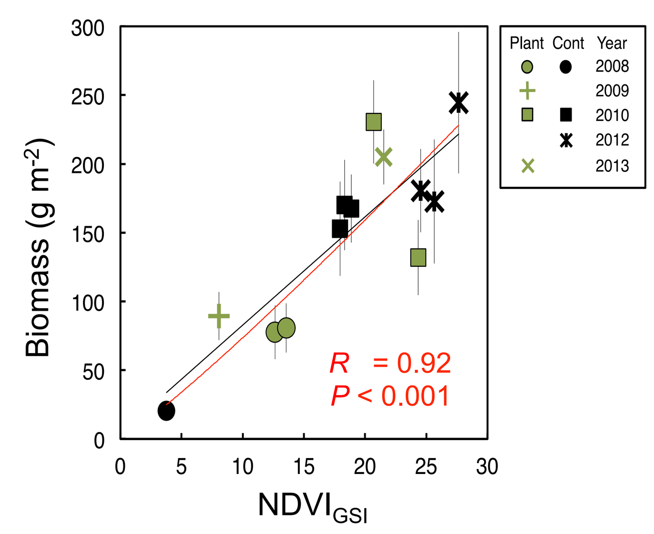


Figure 2

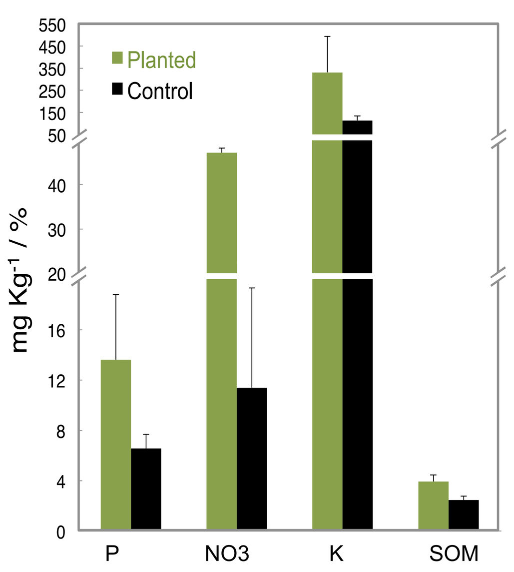
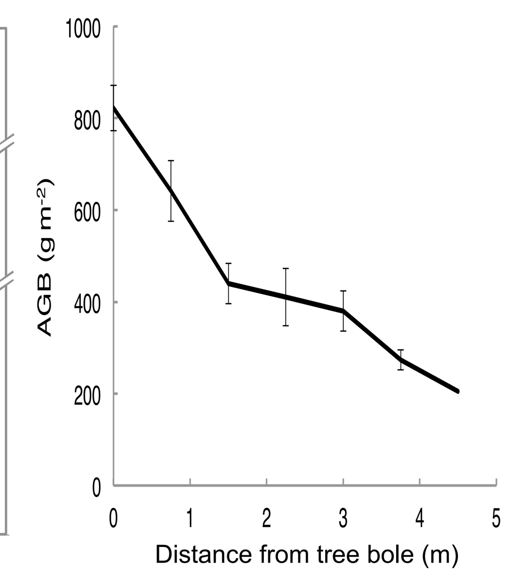


Figure 3



3. Biomass and RUE depend on annual rainfall amount

$NDVI_{GSI}$ (i.e. herbaceous biomass) and RUE_{NDVI} (the $NDVI_{GSI}$ to precipitation amount ratio) declined during 2000-2009 (***Fig. 3***). Such a decline was attributed to prolonged drought years as indicated from the $NDVI_{GSI}$ and rainfall amount linear relationship (R = 0.95, P<0.001; ***Fig. 4 and 5***). However, RUE_{NDVI} was maintained constantly higher in the planted area by 40% even in dry years (***Fig. 3b***).

4. Total biomass gained in the planted area for 1993-2013

For the entire period since plantation till date (1993 – 2013) mean annual ΔAGB in the planted area was ~60 g m^{-2} yr^{-1}. The total ΔAGB for the entire woodland islets area was estimated at ~360 t (i.e. 12 t ha^{-1}) for the last 20 years (***Fig. 5b***).

Figure 3

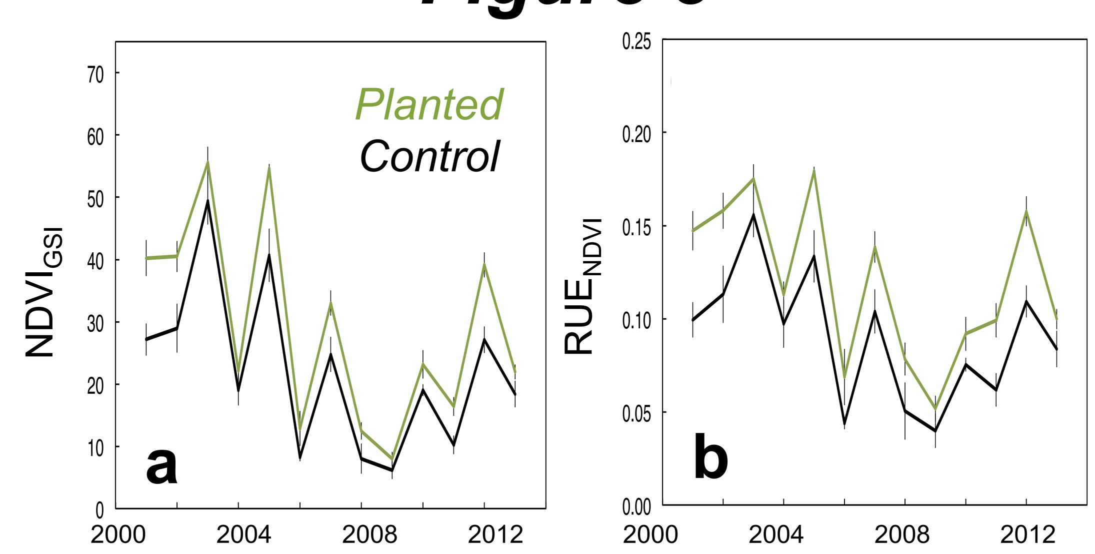


Figure 4

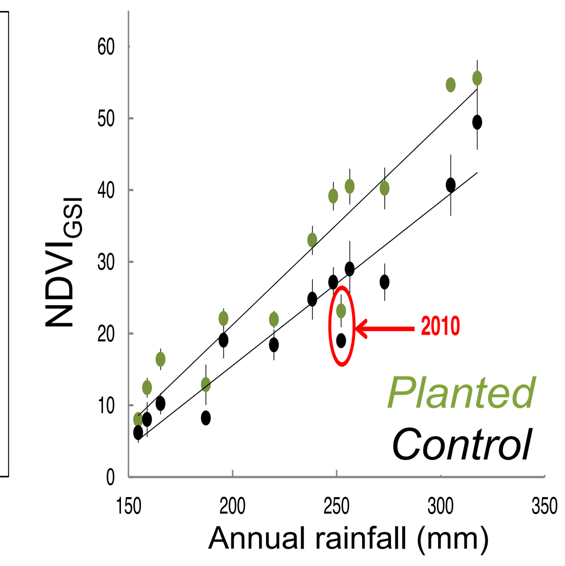
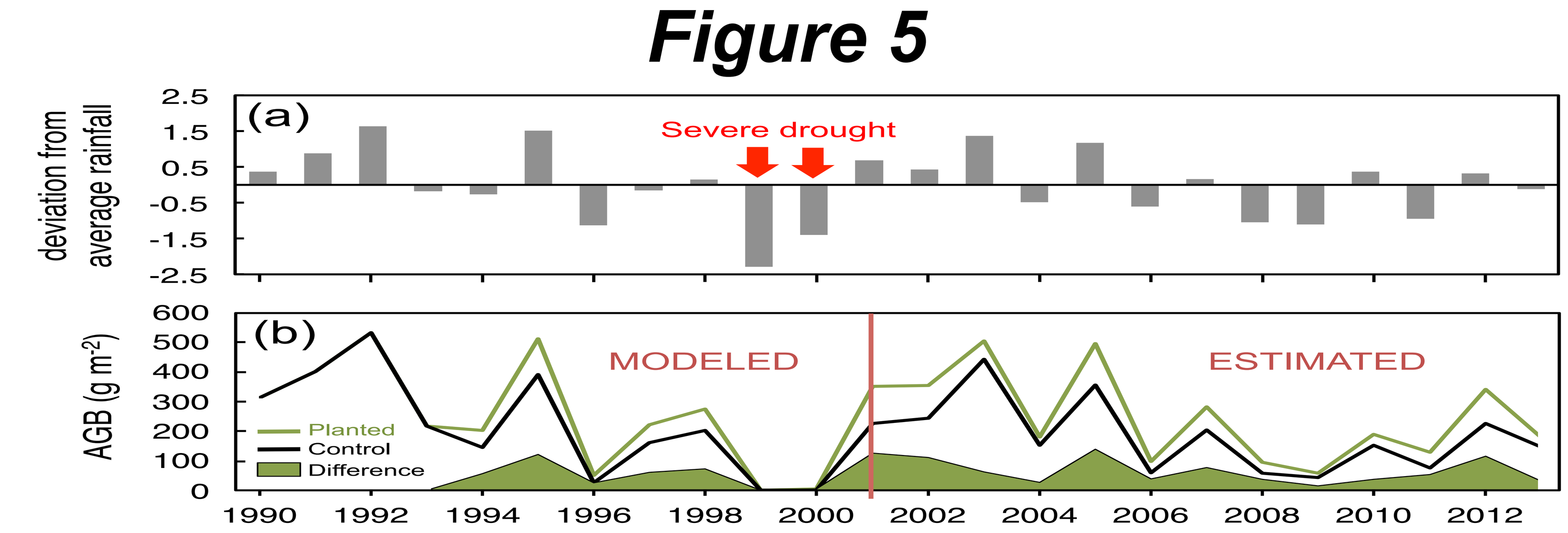


Figure 5



Conclusions

- Woodland planting in drylands improve soil quality and biomass productivity in a relatively short time.
- RUE and productivity was highly dependent on annual rainfall (R = 0.95).
- This improvement (40% in *RUE*) was maintained even in drought years.

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