GLOWA — Jordan River

Variation of shoot mass of annual plants with rain pattern

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Abstract

We are using a spatially explicit, individual- and rule-based model for studying the consequences of climate change on the production and viability of annual plant communities in the Near East. The model comprises modules for the dynamics of soil water, seeds, and plants. We parameterized the model with germination requirements and drought tolerance for ten species occuring along a climatic gradient from arid to mesic Mediterranean. We tested first whether rain volume or rain pattern (number of days with rain >5, 10, 15, or 20 mm) better predicted shoot production in the ten species under current conditions. Second, using rainfall scenarios varying volume (100 – 800 mm mean annual precipitation) and pattern (arid to mesic Mediterranean) in a factorial way, we examined how the two factors affect shoot production of an average annual.

Shoot production of eight species was predicted better by rain pattern than volume than volume. The two exceptions were species that are most abundant in arid climate. Shoot production of the average annual increased significantly with rain volume, as expected. In addition, ANOVA on ln-transformed data indicated that shoot production increased significantly with rain pattern from arid to mesic Mediterranean independent of rain volume. The interaction between both factors was significant because any pattern for less than 400 mm rain resulted in low production (<20 g/m^2).

The results show that the production of annuals is likely to decrease not only if global warming decreases mean annual precipitation but also if rains fall more rarely. The greatest difference observed was for regions currently receiving 600 mm rain (arid pattern: 41 g/m^2 vs mesic Mediterranean pattern: 131 g/m^2). In the Near East, these regions are densely populated comprising major parts of Israel and the Palestinian Westbank.

Introduction

The rainfall patterns of Mediterranean and desert regions in Israel have become more similar since the 1930s (Ben-Gai et al. 1998). In the Mediterranean region, years with high rainfall (compared to the local mean) occur more often, whereas in the desert region, years with high rainfall (again compared to the local mean) have become rarer. How will this change affect the population dynamics of desert annuals?

Method

We compared the effect of rainfall pattern and volume on the simulated shoot production of populations of ten annual plant species that differ in the amount of rain required for germination and growth.

We systematically varied pattern (arid – mesic Mediterranean) and volume of annual rainfall (100 – 800 mm).

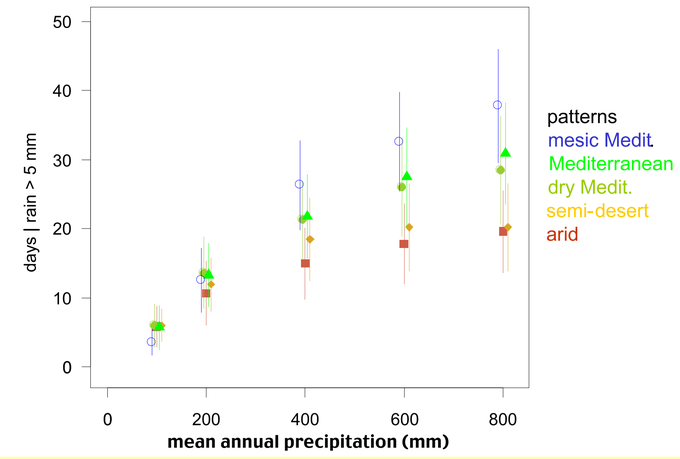
We selected the variable that predicted shoot production best, using linear regression including log and square-root transformations:

variables

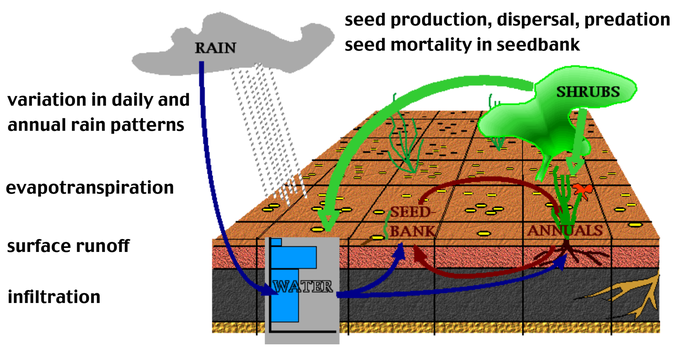
pattern: #days | $x \geq 0, 5, 10, 15, 20$ mm rain

volume: Σrain, days | $x \geq 0, 5, 10, 15, 20$ mm rain

Example: Variation of #days with ≥ 5 mm rain for all combinations of rain pattern and volume



The model: spatially explicit, individual-based

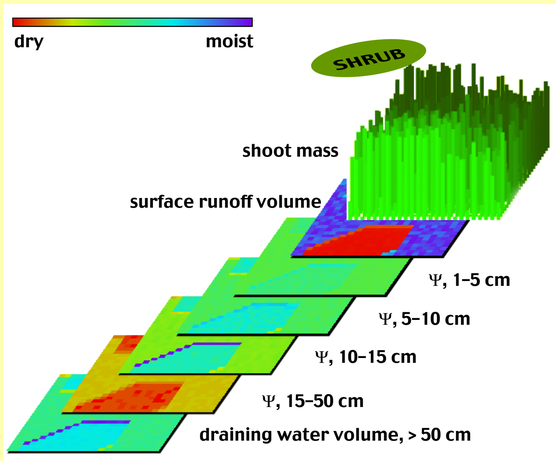


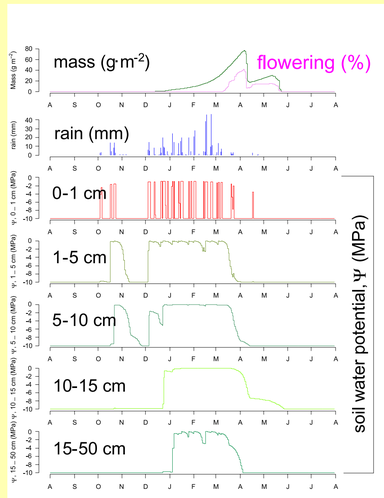
Grain: 4 cm^2, 1 d
Extent: 1 m^2, years

seed germination as a function of soil water potential and temperature

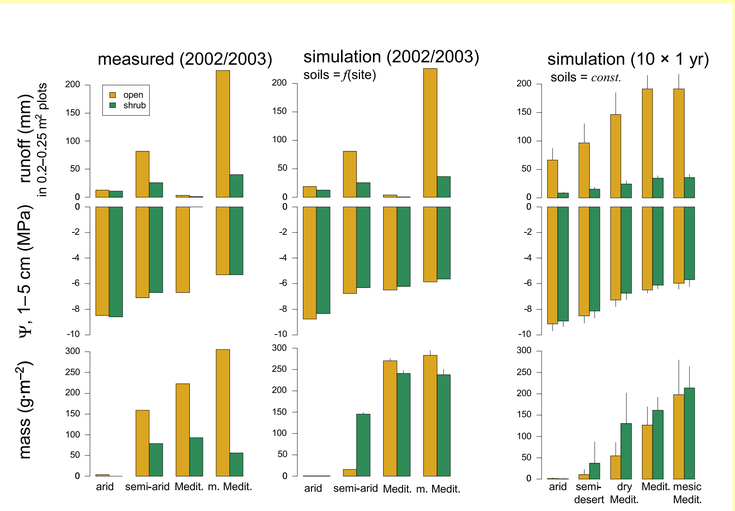
plant growth as a function of soil water potential, nutrients, light, and competition

Model out put (examples)



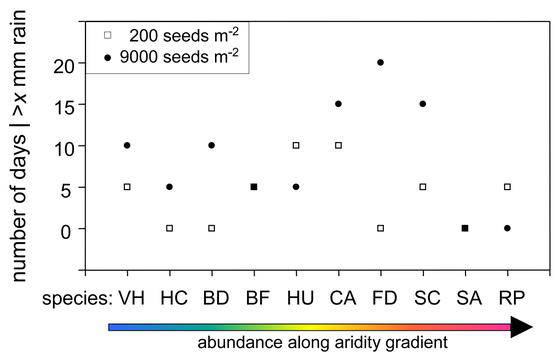


Model validation



RESULTS

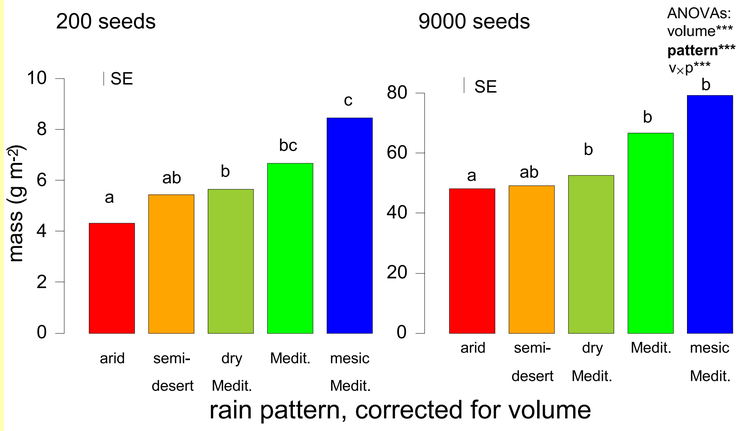
Best predictor variable for shoot mass of ten species



Valantia hispida R, *Hymenocarpos circinnatus* ℘, *Biscutella didyma* +, *Bromus fasciculatus* |, *Hippocrepis unisiliquosa* ℘, *Carrichtera annua* +, *Filago desertorum* *, *Schismus arabicus* |, *Stipa capensis* |, *Reboudia pinnata* +

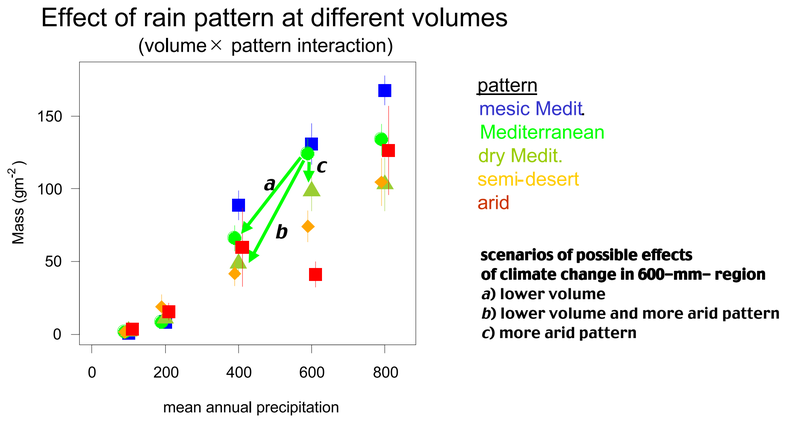
Rain pattern was generally a better predictor than rain volume. When a larger seedbank is present, fewer rain days are required for the best performance

Effect of rain pattern on shoot production for an "average" annual



More rain increases shoot production (results not shown).
In addition, more frequent rains further increase shoot production

Effect of rain pattern at different volumes



scenarios of possible effects of climate change in 600–mm– region
***a*) lower volume**
***b*) lower volume and more arid pattern**
***c*) more arid pattern**

Changes in rain pattern as observed during the last decades in the Near East could greatly reduce production of annuals (used as forage) despite unaltered annual precipitation.

Conclusions

The distribution of rainfall during the rainy season has a significant effect of plant performance in addition to rainfall volume. If trends observed 1930–1990 in Israel continue, i.e. towards a more normal distribution (more regular) of rain showers in the arid region and towards a more skewed distribution (more variable) of rain showers in the Mediterranean region, the total effect of climate change might be more severe than expected. The effect of rain pattern seems strongest in regions with about 600 mm of rain. This region is important for pastoral landuse, especially in the Palestinian subsistence economy.

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