Environmental thresholds controlling earthworm distribution and impact

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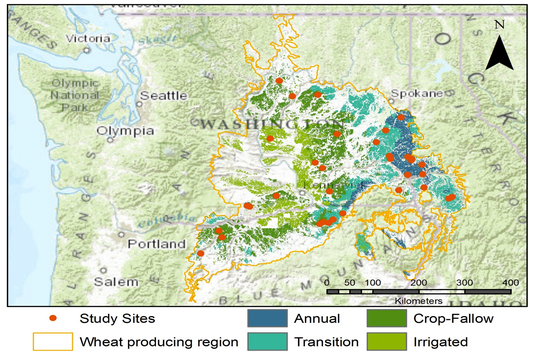
Introduction

Greenhouse experiments have shown that, under ideal soil conditions and high densities, earthworms have the potential to increase wheat yields by improving nutrient cycling, water infiltration and soil structure. In reality, climatic thresholds limit the distribution of earthworms and the period of the growing season during which they remain active. This research aims to connect laboratory studies of earthworm environmental thresholds and impacts on wheat yield to real-world conditions, climate variation and regional distribution across the Inland Pacific Northwest (IPNW) wheat producing region.

Sample Sites and Cropping System Distribution



Materials and Methods

Sites within the study region were classified into three cropping system types, annual, transition, and crop-fallow using the CropLand data layer (NAS) based on the proportion of crop to fallow land in the surrounding acreage. Earthworms were collected using hand sorting techniques from two pits at each site. Earthworms were weighed to determine fresh weight and adults were identified to species. Earthworms were considered to be aestivating if found curled up in a spherical chamber (see below).

Aestivating earthworm

Aporrectodea trapezoides

Results

Figure 1: Mean annual precipitation by cropping system 1980-2010

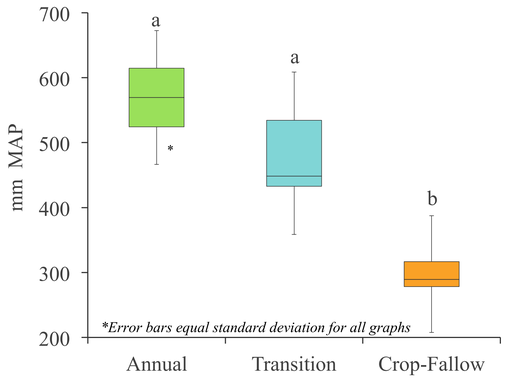


Figure 2: Spring earthworm density by cropping system 2011-2013

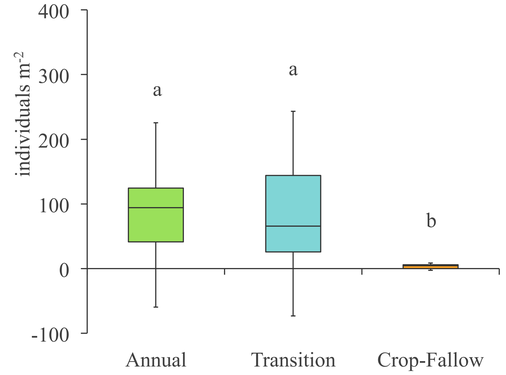


Figure 3: Earthworm presence/absence by mean annual precipitation

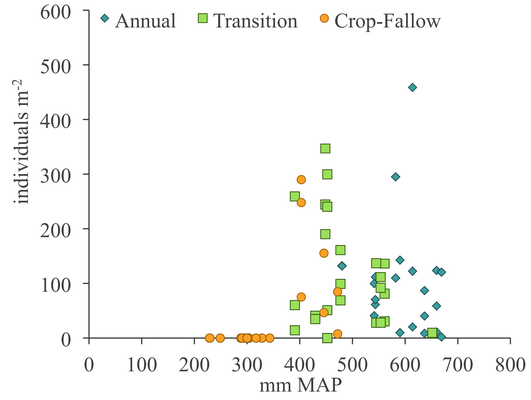
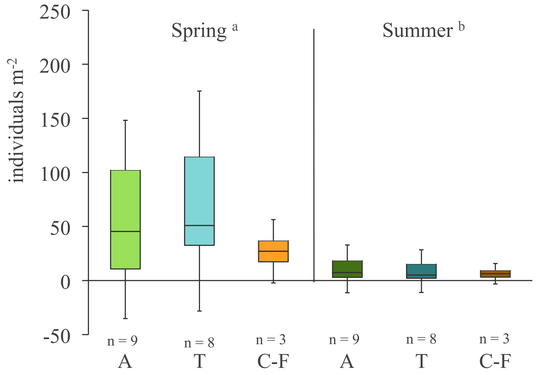


Figure 4: Earthworm density by cropping system in Spring and Summer 2013



What species of earthworms are currently present in IPNW crop fields?

The European invasive species *Aporrectodea trapezoides* accounted for 85% of adult specimens collected over the three year period. The remaining 15% of earthworms were other closely related *Aporrectodea* spp. Juveniles of *Lumbricus* spp. were also collected at a small number of sites in the higher rainfall zones but could not be identified to species.

What role does climate play in determining earthworm distribution?

There are significant differences between cropping systems for mean annual precipitation (MAP) (figure 1). In turn, cropping system was significant for earthworm density ($p<0.0001$), with densities highest in the annual and transition cropping systems and lowest in crop-fallow systems (figure 2). There were significant differences between years for spring (March-June) precipitation ($p<0.0001$), with spring precipitation highest in 2011 and lowest in 2013. There was a corresponding but non-significant decrease in earthworm density from 2011 to 2013.

Earthworms are generally distributed in a patchy manner across landscapes making precise estimates of earthworm density difficult to determine without intensive sampling. Because of this high degree of biological variation it is difficult to correlate earthworm densities with climatic and environmental variables. However, when looking at earthworm presence/absence by MAP a clear threshold can be seen between 350 and 400 mm of annual rainfall, below which earthworms are not likely to be present (figure 3).

How does climate affect earthworm active periods?

Sites with earthworms present in May/June of 2013 were resampled in June/July of 2013. Between the spring and summer sampling dates the mean soil moisture for the top 30 cm dropped an average of 11.1% ($p<0.001$) and the mean soil temperature rose 3.6°C ($p<0.001$), across all zones. Significantly warmer and drier soil was accompanied by a significant decrease in mean earthworm density across zones (figure 4) from 69.8 to 7.2 earthworms m^{-2} ($p<0.001$). At the spring sampling date aestivating earthworms were found at 2 of the 20 sites, at the summer date earthworms were aestivating at an additional 3 sites. Positive effects on wheat production have been reported in greenhouse experiments with earthworm densities equivalent to 300-415 individuals m^{-2}, earthworm densities in the region ranged from zero to 460 individuals m^{-2}, with most sites having fewer than 300 individuals m^{-2}.

Conclusions

- *A. trapezoides* is the dominant species in IPNW wheat fields.
- Earthworm densities vary significantly between cropping systems and seasons, decreasing with increasing temperature and decreasing MAP and soil moisture.
- There appears to be a threshold between 350 and 400 mm MAP below which earthworms are unlikely to be found.
- Low densities of earthworms and limits on active periods due to environmental thresholds may limit the potential positive impact of earthworms on wheat production, however research evaluating the impact of real-world earthworm densities is limited.
- Future studies will include (a) field surveys at a finer temporal scale, at a subset of sites, to obtain a more accurate estimate of active periods and (b) a greenhouse study to measure the effect of realistic earthworm densities and active periods on wheat production.

Impact

This research will link data from an in-progress greenhouse study measuring the impact of earthworms on wheat yields and a more detailed seasonal earthworm field survey to our current field-based knowledge of earthworm distribution across the region. The results of this work will be used to establish environmental and climatic thresholds that determine earthworm distribution, active periods and potential effect on wheat. Once quantified, earthworm impacts on wheat yield may be incorporated into cropping systems models parameterized for use in the IPNW wheat production region.

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