Water Sustainability and Climate
In the Yahara Watershed
UNIVERSITY OF WISCONSIN–MADISON

RESEARCH BRIEF

Crop yields benefit from shallow groundwater most in dry years and coarse soils

Summary

How sensitive crops are to water stress caused by drought or heavy rains is dependent on soil texture and groundwater depth, which vary across fields and ultimately affect yields. In particular, shallow groundwater can be advantageous to crops during dry conditions, especially those planted in coarse-grained soils, offering implications for how farmers can improve yield efficiency to meet rising global food demands, especially given climate change.

Background

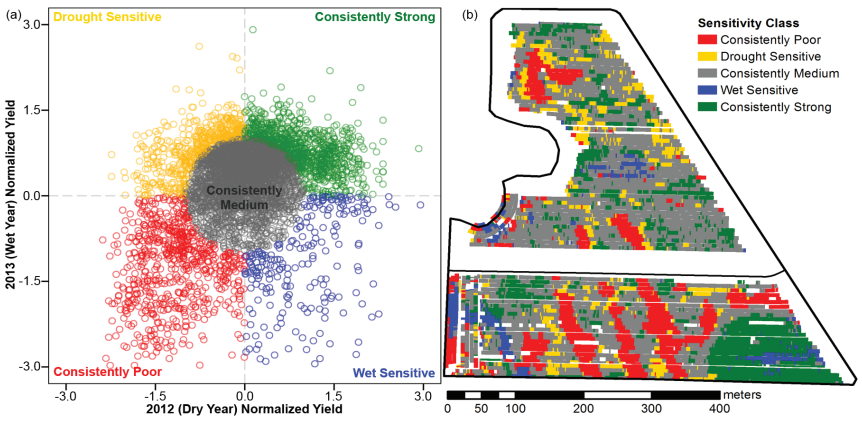
A significant roadblock to efficiently feeding the world's growing population is the "yield gap," when crop yields don't meet their full potential. Stress from either too much water or not enough is one of the factors that can lead to shortfalls.

Field variables such as soil texture and groundwater depth influence how vulnerable crops are to drought or flooding, which, in turn, affects yields. For example, crops planted in coarse-grained soils can be more vulnerable to drought, because precipitation flows quickly through the root zone, making it less available to the plants. But in coarse soils with a high water table, or shallow groundwater, crops can more easily tap into that water supply when rainfall is insufficient.

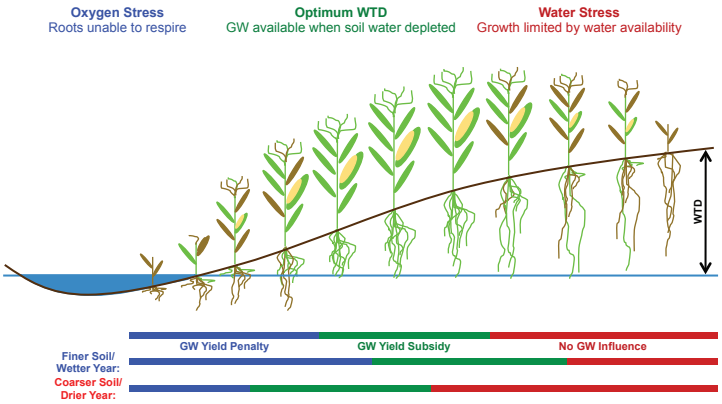
This research improves the knowledge of how soil texture, groundwater depth, and growing season weather interact with each other to affect crop yields across a field. A better understanding of these interactions and their effects on crops can help improve precision agricultural techniques to enable yields to reach their full potential. With this aim, this research sought to answer three questions: 1) how do different weather conditions, namely drought and excess rainfall, affect the water use and yields of corn across a field, 2) how do soil texture, shallow groundwater, and growing season weather conditions interact to determine year-end corn yields, and 3) how can the resulting water-use and yield patterns guide agricultural management?

Research Design

Using multiple methods, researchers collected data from two adjacent working cornfields in south-central Wisconsin over the course of the 2012 and 2013 growing seasons. The first study season was dry, and the second was wet. Researchers characterized the fields with on-the-ground measurements of crop water use, water stress, soil mois-



Researchers used data on yield patterns across the two fields to map crops' sensitivity to different weather conditions. Reproduced from Zipper et al. (2015)



This hypothetical model of the corn-groundwater-soil relationship shows how the optimum water table depth is shallower for crops in coarse soils and during drier growing seasons.

ture, groundwater levels, and soil texture. In cooperation with the Wisconsin Department of Natural Resources, they also took thermal images from a small plane to identify patterns in crop water use. They received yield data collected during harvest from the farmer who works the land. Finally, the researchers used computer model simulations to test how different combinations of soil texture and groundwater depth affect yields.

Findings

Comparing the growing seasons, how much water the plants used and their ultimate yield followed patterns determined by the soil texture and groundwater depth in their area of the field. Areas with fine-grained soils or shallow groundwater were protected from drought conditions, but were more vulnerable to yield losses during especially wet conditions.

Crops planted in coarse-grained soils, which have a harder time retaining water than fine-grained soils, benefited particularly from shallow groundwater, which provided the plants better access to water during drought. Shallow groundwater was also advantageous to crops late in the growing season. By then, the plants had used up stored soil moisture from snowmelt and precipitation, and the additional water source supported them during the critical growth stages of pollination and grain production. In fact, the benefits of shallow groundwater often outweighed the costs for crops in the coarse-grained soils and even many of the fine-grained soils in the study site, rendering higher crop yields, or "groundwater yield subsidies," even during the relatively wet 2013 growing season.

Implications

Understanding what factors cause crop yields to fall short of their full potential can inform both farm management practices and precision agricultural techniques, such as variable-rate irrigation and nutrient applications. These findings show that variations in soil texture and groundwater depth within a field can determine how yields respond to growing season weather conditions. Such information can help farmers identify areas of a field that are sensitive to dry or wet weather and tailor crop management to close potential yield gaps.

Moreover, this research reveals an opportunity for improving yields in areas with shallow groundwater. Though shallow groundwater may cause yield losses during wet years in some fields, it can also help protect crops during dry spells or drought, especially those planted in coarse-grained soils. Thus, in some cases, the common practice of draining fields could cause more harm than good. This knowledge can help farmers determine optimal field-draining depths based on soil texture, and invest their resources on areas that should perform well under different weather conditions, especially as drought or heavy rain become more frequent due to climate change.

Sources

Zipper, S.C., M.E. Soylu, E.G. Booth, and S.P. Loheide. "Untangling the effects of shallow groundwater and soil texture as drivers of sub-field-scale variability." *Water Resources Research* 51 (2015): 6338–58. doi:10.1002/ 2015WR017522

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Research sponsor

This material is based upon work supported by the National Science Foundation under grant DEB-1038759. Any opinions, findings, conclusions, or recommendations expressed in the material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Water Sustainability and Climate Project

The Water Sustainability and Climate Project (WSC) at the University of Wisconsin-Madison is an integrated effort to understand how water and the many other benefits people derive from nature could change over time. The five-year project (2011–2016) is focused on the Yahara Watershed in southern Wisconsin and funded by the National Science Foundation. Visit wsc.limnology.wisc.edu.