A benchmark to diagnose and improve water productivity in maize cropping systems

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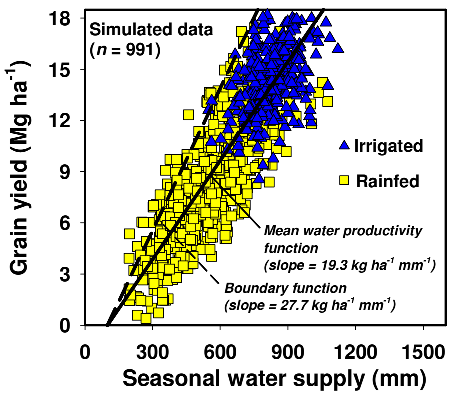
Introduction: **Useful benchmarks are best estimated from biophysical processes that determine crop productivity responses to environment x management interactions. The challenge is translating these complex processes into decision-support tools useful to farmers, consultants, and policy-makers. The central USA accounts for 35% of global maize production and includes one of the largest irrigated areas in the world. Rising demand for food, livestock, and biofuels will require greater yields on existing cropland and with limited water supply.**
Objectives: **To develop a benchmark to diagnose and improve water productivity (WP; kg grain mm^{-1} water supply) in maize systems of the Western U.S. Corn Belt.**

Methodology: 4 steps

- **STEP 1: WP benchmarks were derived from the relationship between simulated grain yield and seasonal water supply (stored soil water + rainfall + irrigation). Irrigated and rainfed yields were simulated at 18 locations in the Western U.S. Corn Belt using the Hybrid-Maize model and site-specific (20-y) weather data, soil properties, and management practices [1].**
- **STEP 2: benchmarks were validated against actual data from rainfed and irrigated maize field studies in the Western U.S. Corn Belt where crops received optimal management [3].**
- **STEP 3: benchmarks were used to diagnose WP in irrigated fields using on-farm yield data collected over 3 years in the Tri Basin Natural Resources District (NRD), central Nebraska. Water supply was estimated using interpolated rainfall from nearby rainfall monitoring sites, actual applied irrigation amounts, and estimated available soil water at planting [2, 3].**
- **STEP 4: analysis of farmers management practices identified opportunities to increase on-farm WP. Variables evaluated in the analysis were: type of irrigation system, irrigation and nitrogen management, crop rotation, tillage system, sowing date, plant population density, and hybrid maturity [2, 3].**

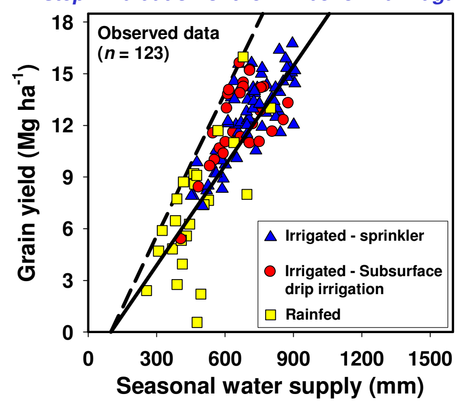
1st step: Development of the WP benchmark using simulated data



Whereas the *boundary function* defines an upper frontier for WP, the *mean WP function* is a more meaningful benchmark because it accounts for the variation in grain yield at any level in water supply due to solar radiation, temperature, and distribution of water supply

Fig. 1. Simulated yields as a function of seasonal water supply (stored soil water + rainfall + irrigation). Dashed and solid lines are WP benchmarks with x-intercept = 100 mm.

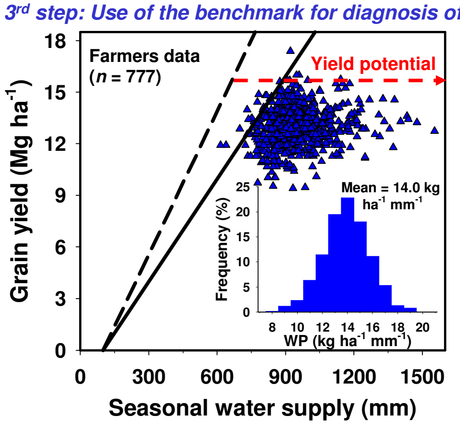
2nd step: Evaluation of the WP benchmark against observed data



Yields from fields with optimal management practices under rainfed and irrigated conditions approached the *boundary function*. Most observations were distributed around the *mean WP function* except for a few rainfed sites exposed to severe water deficit around silking.

Fig. 2. Observed yields in maize fields with near-optimal management as a function of seasonal water supply. Dashed and solid lines are WP benchmarks shown in Fig. 1.

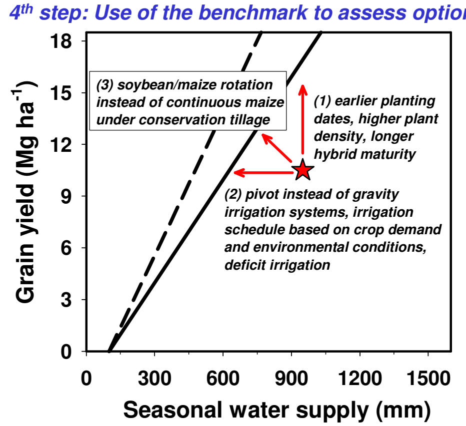
3rd step: Use of the benchmark for diagnosis of WP in farmers fields



Mean on-farm WP was 73% of the attainable WP derived from the slope of the mean WP function. Yield potential estimated for this region (15.4 Mg ha^{-1}) requires 900 mm of water supply according to the *mean WP function*. However, 55% of the irrigated fields had water supplies > 900 mm.

Fig. 3. Farmers irrigated yields in central Nebraska as a function of seasonal water supply. Inset shows frequency distribution of water productivity (WP) in farmer fields.

4th step: Use of the benchmark to assess options for improvement of WP



On-farm data analysis allowed identification of management practices that improve WP by increasing yield at the same level of water supply (1), maintaining the same yield level with less water supply (2), or both (3). Results for the Tri-Basin NRD showed that up to 32% of total annual water volume allocated to irrigated maize could be saved without yield loss.

Fig. 4. Opportunities to improve WP through changes in crop and irrigation practices derived from analysis of farmers data.

Conclusions

- **Benchmarks defined in this study are useful tools to diagnose and improve WP in rainfed and irrigated maize fields of the Western U.S. Corn Belt. The approach can be applied in other cropping systems to quantify yield gaps and resource-use efficiency.**
- **Benchmarking performance of individual fields and aggregated regional or watershed averages based on high quality, farmer-provided data is an efficient and effective way to identify constraints and prioritize investments in research and extension to improve productivity, profitability, and environmental performance of cropping systems.**

References

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