Analysis of Long-Term Crop Water Use Efficiency under Different Management Practices in the Upper Midwest

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Summary

- The Systems Approach to Land Use Sustainability (SALUS) model was used to simulate maize-soybean-winter wheat rotation under conventional, no-till and reduced-input treatments.
- Water Use Efficiency (WUE) was linearly correlate to the grain yield ($p < 0.005$).
- WUE was greater in No-Till (T2)(14 out of 22 years), compared to Conventional (T1) and Reduced Input (T3).
- Seasonal ET values did not differ among treatments but the partition between soil evaporation (E) and plant transpiration (T) was different.

Objective

To evaluate the impact of agronomic management on crop WUE in maize-soybean-winter wheat rotation.

Methodology

The study was carried out at the Long Term Ecological Research site, Kellogg Biological Station (KBS, 42º24''N, 85º23''W, 288m a.s.l) at Michigan State University.
We present the results of 22 years of a maize-soybean-winter wheat rotation under three treatments.
The climate features of the study site was shown in Figure 1.

Treatments:

Conventional treatment (T1):
- Chisel plow and subsoiler at 20 cm
- Applied N-, P- and K- fertilizer, pesticide and herbicide

No-tillage treatment (T2):
- No-Till, then same as T1

Reduced-input treatment (T3):
- 33% less N-fertilizer applied compared to T1 and T2
- Less herbicide but more tillage events
- Cover crops planted between the main crops: vetch, red clover and rye grass

WUE was calculated based on the following equation:

WUE (kg/mm/ha) = (Grain Yield)/Evapotranspiration

Maize, soybean and wheat grain yield was measured from 1989 to 2015.
Crop evapotranspiration (ET) was estimated by the validated SALUS model (Fig. 2).

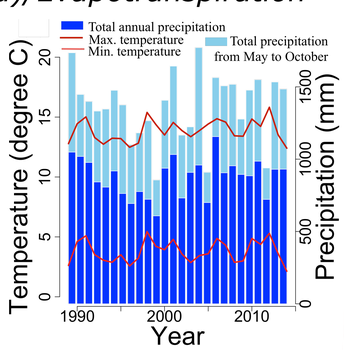

Fig. 1 Average temperature and precipitation in 1989-2014 at KBS (http://lter.kbs.msu.edu/data/)

Results

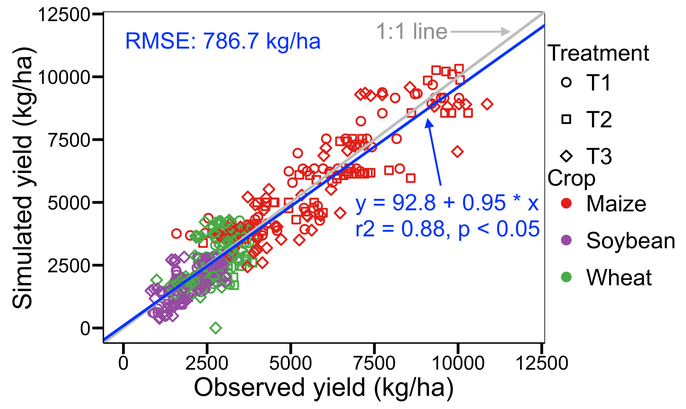

Fig. 2 Comparisons between the observed and SALUS-simulated grain yield

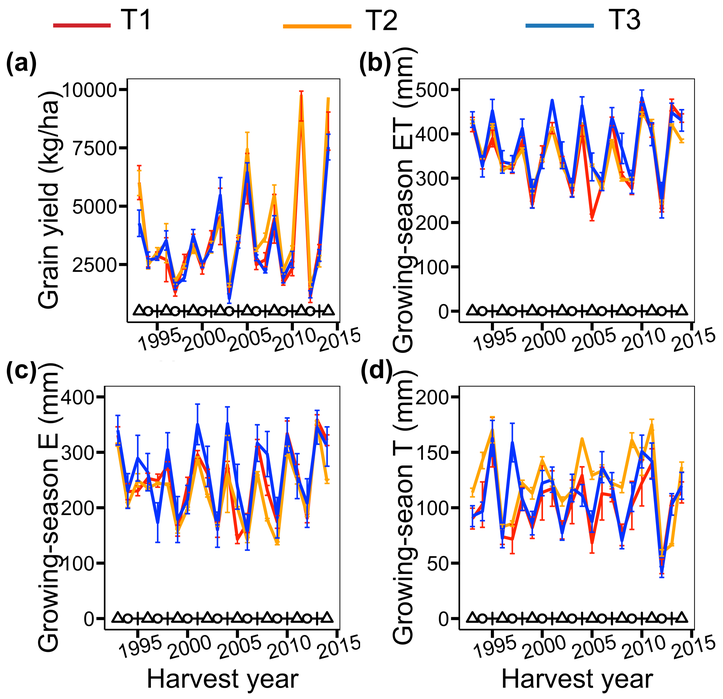

Fig. 3 (a) Observed grain yield, (b) growing-season ET, (c) growing-season evaporation (E), (c) growing-season transpiration (T) by each treatment at KBS in 1993-2014 (the shape in the bottom denotes the crop harvested in the year. Δ: maize, ○: soybean, +: winter wheat)

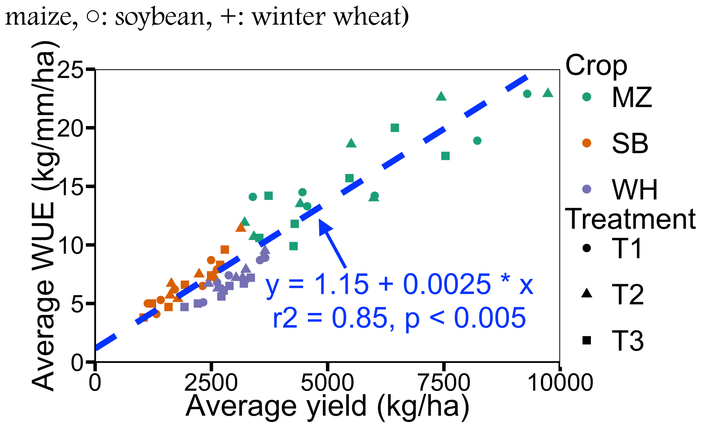

Fig. 4 Correlation between grain yield and crop water use efficiency (WUE)

Table 1 Mean (±standard deviation) of the observed grain yield, estimated ET, evaporation (E), transpiration (T) and WUE in 1993-2014⁝ by crop and treatment

	T1 (Conventional)	T2 (No-till)	T3 (Reduced-input)
Grain yield (kg/ha)			
Maize	5601.9 a* (± 2313.7)	6296.4 a (± 2461.1)	5659.9 a (± 2168.6)
Soybean	1856.9 b (± 600.5)	2199.6 a (± 550.3)	1963.5 ab (± 692.4)
Winter wheat	2994.0 a (± 518.4)	3129.7 a (± 462.1)	2720.6 b (± 508.3)
ET (mm)			
Maize	336.4 a (± 78.7)	347.4 a (± 55.2)	363.4 a (± 59.5)
Soybean	294.6 a (± 42.1)	302.9 a (± 55.49)	301.2 a (± 37.8)
Winter wheat	420.2 b (± 31.8)	409.7 b (± 47.4)	452.8 a (± 30.1)
E (mm)			
Maize	246.0 ab (± 64.7)	225.6 b (± 46.0)	269.9 a (± 57.7)
Soybean	201.0 a (± 36.9)	183.0 b (± 35.6)	189.3 ab (± 41.6)
Winter wheat	298.3 b (± 41.2)	280.0 c (± 44.0)	327.0 a (± 38.4)
T (mm)			
Maize	90.4 b (± 24.7)	121.8 a (± 25.7)	93.5 b (± 25.6)
Soybean	93.6 b (± 29.5)	119.9 a (± 34.0)	111.9 a (± 36.2)
Winter wheat	122.0 b (± 21.6)	129.7 c (± 36.4)	125.8 a (± 24.0)
WUE (kg/ha/mm)			
Maize	16.9 a (± 6.7)	17.7 a (± 5.47)	15.6 a (± 5.2)
Soybean	6.3 b (± 1.7)	7.4 a (± 1.9)	6.5 ab (± 2.1)
Winter wheat	7.2 a (±1.4)	7.7 a (± 1.4)	6.0 b (± 1.0)

⁝1989-1992 were not included in the analysis due to different crops grown on T3 from T1 and T2
*letters indicate detectable differences at significance level of 0.05

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