Fertility Trends in 20 Years of Nutrient Drawdown and Best Management Practices at the Wisconsin Cropping Systems Trial

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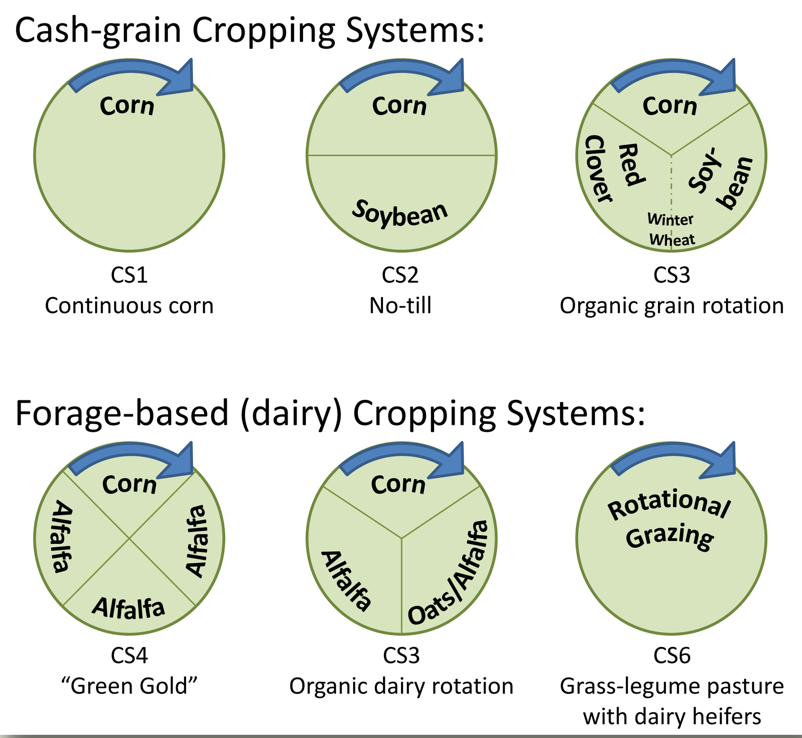
The Wisconsin Integrated Cropping Systems Trial (WICST)

Introduced in 1990, the WICST studies productivity, profitability, and environmental impact in six cropping systems (CS; Fig. 1), broken into two enterprises; cash grains (including continuous corn and no-till corn/soybean) and dairy forage (including corn/alfalfa/alfalfa/alfalfa and rotational grazing). The experimental design included four-block randomized complete blocks and four replicate plots of 0.3ha per rotation phase.

Figure 1: Cropping Systems in the WICST



Nutrient Drawdown Study

Excessively high soil test P and K at the inception prompted a nutrient drawdown objective. The nutrient drawdown was determined by two methods: analyzing the nutrient balance of the systems and by soil testing. Best management practices were followed as outlined in UWEX Publication A2809[1]. Manufactured fertilizers were applied in all systems, with manure applications in the dairy forage systems. Records were kept of all nutrient additions, and manure analysis was used when possible.

Method 1: Nutrient Balance

Inputs

Cumulative inputs were calculated and plotted against year to determine input rates in each replicate plot, as well as for the system as a whole. Nutrient inputs were recorded as kg ha^{-1}, on an elemental basis.

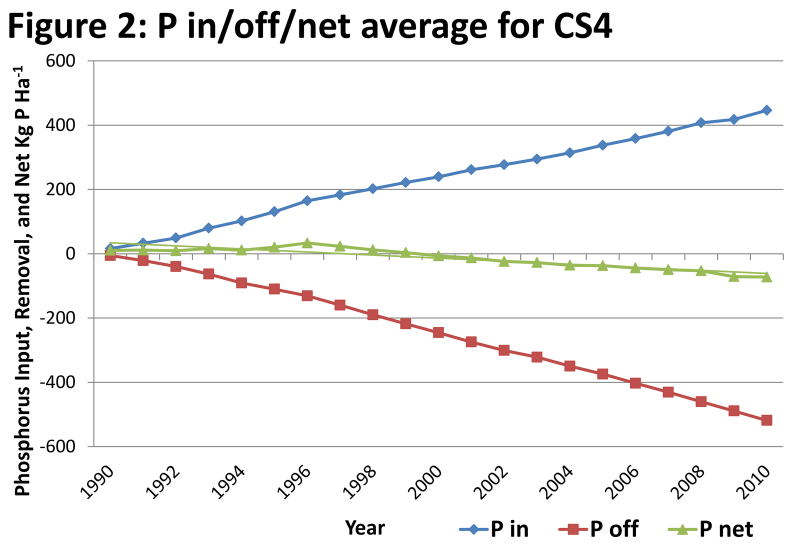
Outputs

Nutrient removals were determined by analyzing the harvested portion of the plant for total P and K. Results were paired with yield to determine kg ha^{-1} of P and K removed in a cropping year. Cumulative removals were plotted against year to determine removal rates in kg ha^{-1} y^{-1}.

Net

The net nutrient balance was calculated as the cumulative inputs minus cumulative removals.

Figure 2: P in/off/net average for CS4



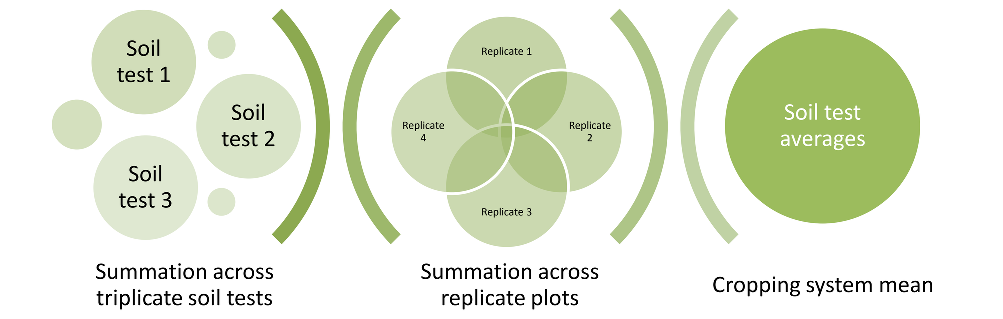
Drawdown Calculation

Nutrient drawdown rates were determined by calculating the slope of the net nutrient balance with respect to time. Figure 2 shows the in, off, and net graphically for CS4 over the 20y of this study.

Method 2: Soil Test

Triplicate soil tests were sampled at a 20-cm depth post-harvest and averaged within replicates. Results were then averaged across replicates to yield soil test results for each cropping system (Figure 3).

Figure 3: Summarizing soil test data



Analytical methods[1]

1:10 Bray-1 P & K, 1:1 H_2O pH,
Loss-on-ignition organic matter

For reference, Bray-1 K results correlate well (r^2=0.933) with ammonium acetate extraction, which will extract ~25% more K.

Drawdown Calculation

Summarized soil test data was plotted against year and the resulting slope was the nutrient drawdown rate for each cropping system.

Results and Conclusions

Both soil testing and nutrient balance show that the WICST has been running in a nutrient deficit over this 20-y period of data collection. This was the intended result, as the system was found to have excessive fertility at onset and was intentionally operating with nutrient drawdown. However, the two methods of determining nutrient drawdown rate do not agree upon how quickly nutrients are leaving the system. Table 1 shows the 20-y P and K removal rates for each cropping system, based on the soil surface nutrient balance and 20-cm soil test. Periodic deep soil sampling events also occurred. These data were also analyzed with respect to time to determine whether the subsoil held answers to the discrepancies. It did not, and the resulting rates are also listed in Table 1.

Table 1: Nutrient Removal Rates per Cropping System Within the WICST

	20-y Phosphorus removal rate (kg ha^{-1} y^{-1})			20-y Potassium removal rate (kg ha^{-1} y^{-1})		
Cropping System	Nutrient Balance	Soil Test	Deep Soil Test	Nutrient Balance	Soil Test	Deep Soil Test
1	-15.9	-3.9	-10.4	-9.6	-4.7	-11.1
2	-18.3	-4.7	-2.1	-29.7	-12.1	-20.0
3	-15.9	-3.4	-2.1	-42.2	-15.4	-17.4
4	-5.3	-1.3	8.4	-53.7	-10.6	-7.3
5	-8.5	-1.5	-3.5	-66.9	-14.0	-22.0

Figure 3: Soil Test Removal Rates vs Nutrient Balance Removal Rates Phosphorus, All replicates, CS1-CS5

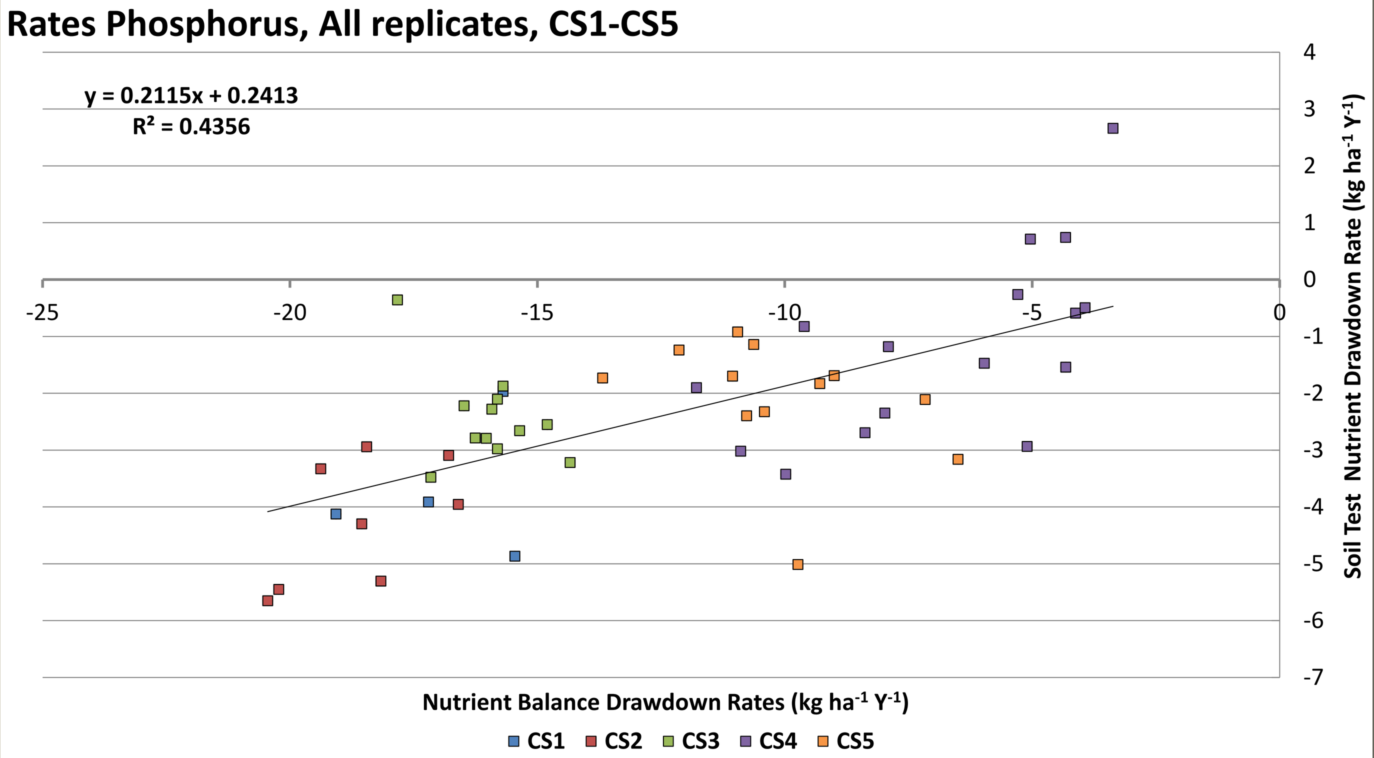
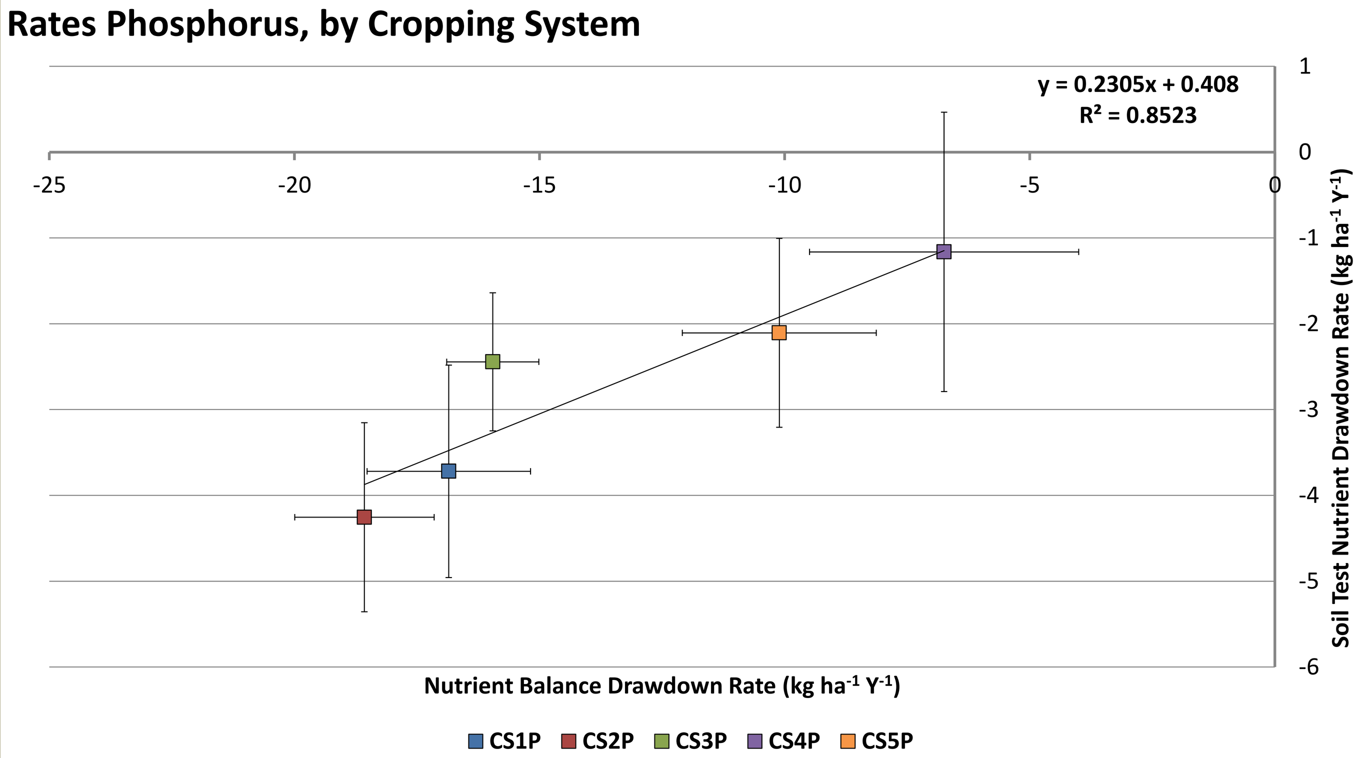


Figure 4: Soil Test Removal Rates vs Nutrient Balance Removal Rates Phosphorus, by Cropping System



Phosphorus

Considerable scatter exists across replicates of cropping systems, as seen in Figure 4. Summarizing the removal rates by cropping system (Figure 5) greatly increases the correlation between the drawdown rates.

These data suggest that the Bray-1 soil test can, on average, account for 23% of the actual nutrient removal with 85% accuracy. Given a soil density of 1.47 Mg m^{-3}, we can use this information to estimate that a 1 ppm y^{-1} drop in Bray-1 soil test P in the plow layer equates to an actual nutrient removal of 9.32 kg ha^{-1} y^{-1}.

Figure 6: Soil Test Removal Rates vs Nutrient Balance Removal Rates for Potassium, by Cropping System

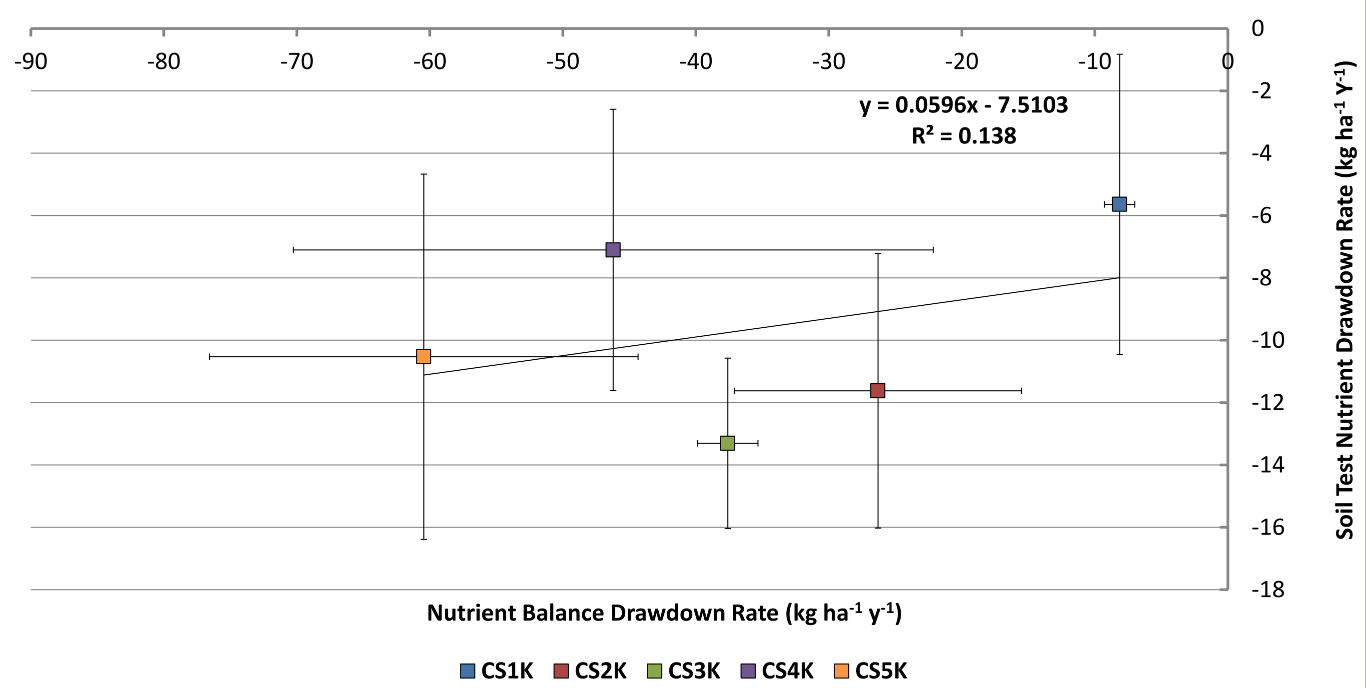
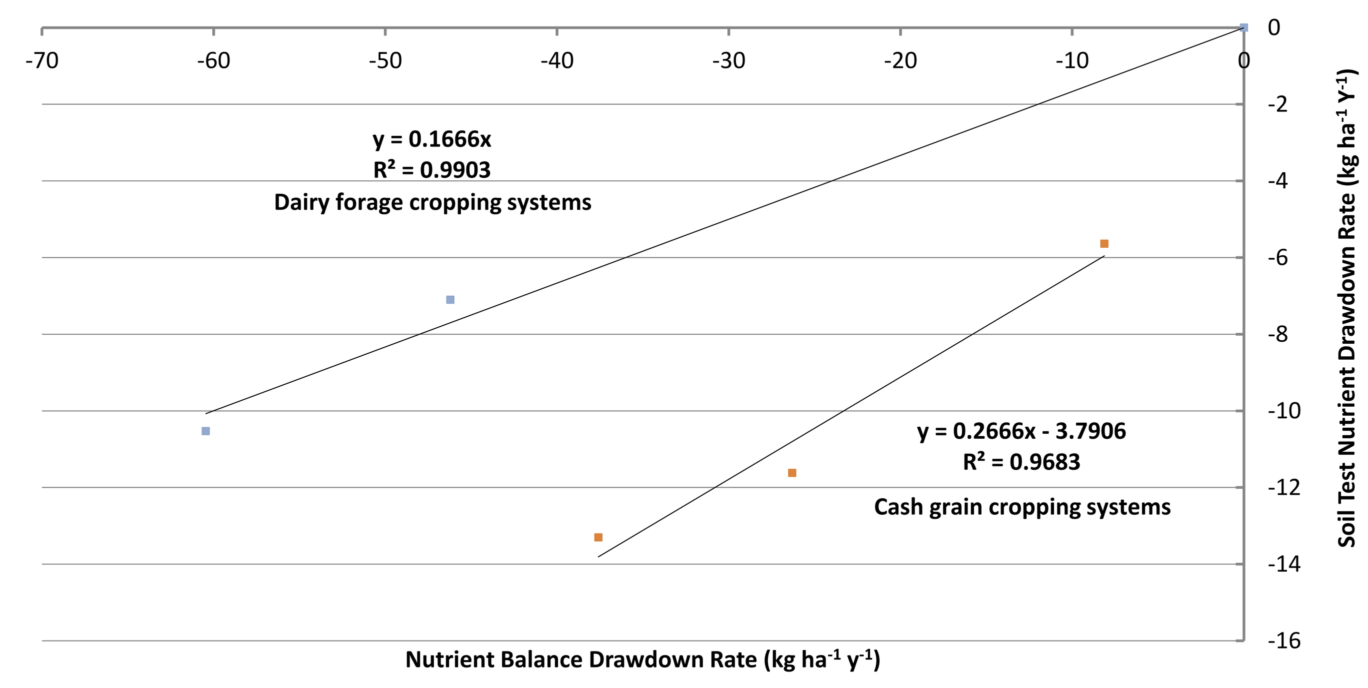


Figure 7: Soil Test Removal Rates vs Nutrient Balance Removal Rates for Potassium, by Enterprise



Potassium

These data suggest that the relationship between nutrient balance and soil testing is poorly correlated across all cropping systems (Figure 6). However, when the data is divided by cropping enterprise, correlations become very strong (Figure 7).

This suggests that potassium soil testing alone does not tell the entire nutrient balance story. Complex relationships among the soil, plant, and microbial communities have an impact that we are not accounting for. The dairy forage systems exhibited more plot-to-plot variation and soil testing accounted for less of the nutrient removal than in the cash grain operations.

Acknowledgements

Joshua Posner, Professor of Agronomy at the UW-Madison, died on April 3, 2012 at age 64. He was the leader of the WICST until his death and devised the research plan, handing off these research data to us as his co-authors, discussing these results, and obliging us to publish to the larger world.

Reference cited:

[1] Laboski, C. A. et al., Nutrient Application Guidelines for Field, Vegetable, and Fruit Crops in Wisconsin, University of Wisconsin Cooperative Extension Publication A2809