Fertility Trends in 20 Years of Nutrient Drawdown Practices at the Wisconsin Integrated Cropping Systems Trial

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The Wisconsin Integrated Cropping Systems Trial (WICST)

Established in 1990, WICST was designed to compare six common Midwestern cropping systems in terms of productivity, profitability, and environmental impact. The cropping systems (shown in Figure 1) include both organic and conventional dairy forage and cash grain systems and represent both no-till and conventional tillage practices.

The experiment is located within the University of Wisconsin's Agricultural Research Station in Arlington, Wisconsin, USA (43.3048, -89.3308) and has relatively deep (1 M) well-drained Plano silt loam (fine-silty, mixed, superactive, Mesic Typic Argiudolls). The experimental design included four-block randomized complete blocks and four replicate plots of 0.3ha per rotation phase, resulting in 56 total experimental units (EU).

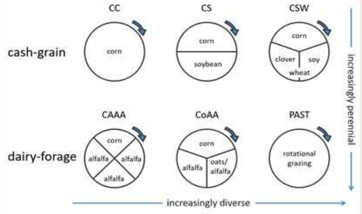

Figure 1: Visual depiction of the cropping systems at WICST

Excessively high soil test P and K at inception prompted a nutrient drawdown objective following the best management practices outlined by the University of Wisconsin's "build and maintain" strategy. Detailed records were kept of nutrient inputs and offtakes, and soil fertility tests were conducted every Autumn, post-harvest.

The objective of this study is to use these ancillary data to quantify the rates of P and K removal as determined by the soil tests and contrast to the P and K removal rates as determined by the nutrient budget (ΔPST, ΔKST, ΔPNB, and ΔKNB respectively). The relationship between soil testing and the nutrient budget provides a mechanism to effectively quantify the nutrient "buffering capacity" of the soil and investigate whether the cropping system plays a role in that buffering capacity.

Method 1: Nutrient Balance (ΔNB) [Figure 2]

Inputs

Depending upon the cropping system, inputs consisted of a combination of dairy manure and manufactured fertilizers. In all cases, inputs were recorded in elemental form on an area basis (kg ha^{-1}). Inputs were accumulated year over year and plotted against time for each EU.

Outputs

Nutrient outputs 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 elemental P and K removed in a cropping year. Cumulative removals were plotted against year just as inputs were.

Nutrient Net

Cumulative outputs were subtracted from cumulative inputs to determine the nutrient net. The slopes of the P and K nutrient nets are defined as ΔPNB and ΔKNB, respectively.

Method 2: Soil Test (ΔST) [Figure 3]

Triplicate soil samples were collected to a 15 cm depth every Autumn and analyzed for available P and K using the 1:10 Bray-1 extractant.* Soil tests within an experimental unit were converted from ppm to kg ha^{-1} using previously determined bulk densities of the soil. Triplicate values were averaged and plotted against time and the average value of each EU within a cropping system and year was combined into a single data set and simple linear regression was used to determine the slope of soil test data over time for the cropping system. These slopes are defined as ΔPST or ΔKST.

*Official UW soil test methods use Bray-1 (1:10) for K determination. A separate study determined that using Mehlich III (1:10) as the extractant did not significantly impact the findings of this study.

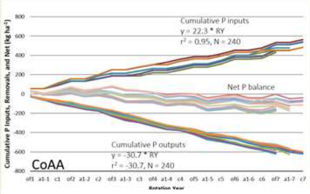

Figure 2: Nutrient balance data for all EUs in CoAA from 1990 to 2008

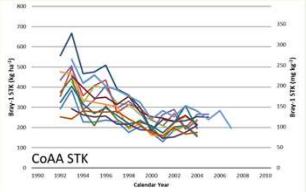

Figure 3: STK values for all EUs in CoAA from 1990 to 2008

Results and Discussion

Data analysis showed ΔPST, ΔKST, ΔPNB, and ΔKNB to be negative, meaning that both methods of analysis agree that P and K are leaving the system. This is important to note, as that was the intent of the fertilization strategy. Significant differences exist, however, in the average rate at which P and K are leaving when we compare the nutrient balance and soil test methods (Table 1).

Table 1: Nutrient Removal Rates per Cropping System Within WICST (kg ha^{-1} yr^{-1})

System	ΔNBP	ΔSTP	ΔNBK	ΔSTK
CC	-15.8	-3.7	-9.6	-4.4
CS	-18.4	-4.0	-37.0	-7.4
CSW	-16.4	-3.0	-40.5	-10.4
CAAA	-6.2	-1.4	-79.2	-9.8
CoAA	-9.2	-1.5	-96.5	-17.3
Cash Grain	-17.1	-3.4	-27.2	-6.3
Dairy Forage	-7.5	-1.4	-86.7	-13.1
All	-10.6	-2.0	-46.3	-8.3

The relationship between ΔNB and ΔST was variable depending upon the cropping system, though the data show that the soil test values are decreasing at a slower pace than the nutrient balance in all cases. Figures 4 and 5 illustrate the nature of the relationships with ΔST plotted against ΔNB for each EU in WICST, color coded according to cropping system. Potassium soil testing tracked well with the nutrient budget but differed at the enterprise level, providing the following relationships: ΔSTK = 0.26 * ΔNB-K ($p = 0.0002$, $r^2 = 0.48$), and ΔSTK = 0.16 * ΔNB-K ($p = 0.0095$, $r^2 = 0.23$) for cash grain and dairy forage systems, respectively. ***This suggests that the cropping system played a role in the potassium buffering capacity of the soil.*** Differences between enterprises were likely driven by stover removal and manure applications in the forage operations.

Phosphorus soil testing tracked well for WICST as a whole as well as at the enterprise level, but the enterprises were not different from one another. The best relationship was at the WICST level and was defined as ΔSTP = 0.22 * ΔNBP ($P<0.0001$, $r^2 = 0.52$).

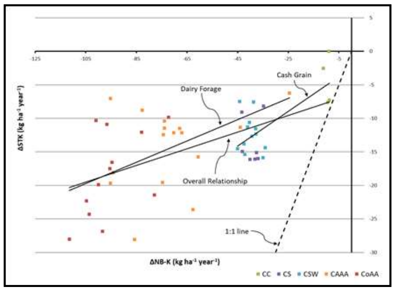

Figure 4: ΔSTK vs. ΔNB-K for all plots in WICST, color coded by cropping system. A 1:1 dashed line is provided for reference, and regression lines are displayed for enterprise type and WICST as a whole.

Nutrient additions appear to have a serious impact on the variability and reliability of soil testing through time, when compared to the nutrient budget. However, even if soil tests do not track nutrient budgets perfectly, they may still provide an accurate depiction of the labile nutrient pool which is essential information when determining the risk of nutrient loading. As the use and interpretation of soil tests continue to evolve in the agricultural community, it is incumbent upon the soil science community to keep pace with these popular uses of soil testing so that we can provide guidance and manage expectations. As such, it is important that the soil science community continue to maintain and learn from long term soil experiments such as WICST. They are fundamental to our research.

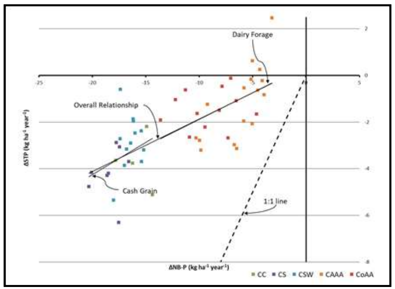

Figure 5: ΔSTP vs. ΔNB-P for all plots in WICST, color coded by cropping system. A 1:1 dashed line is provided for reference, and regression lines are displayed for enterprise type and WICST as a whole

Acknowledgements

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