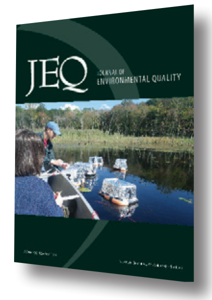
Published January 7, 2015

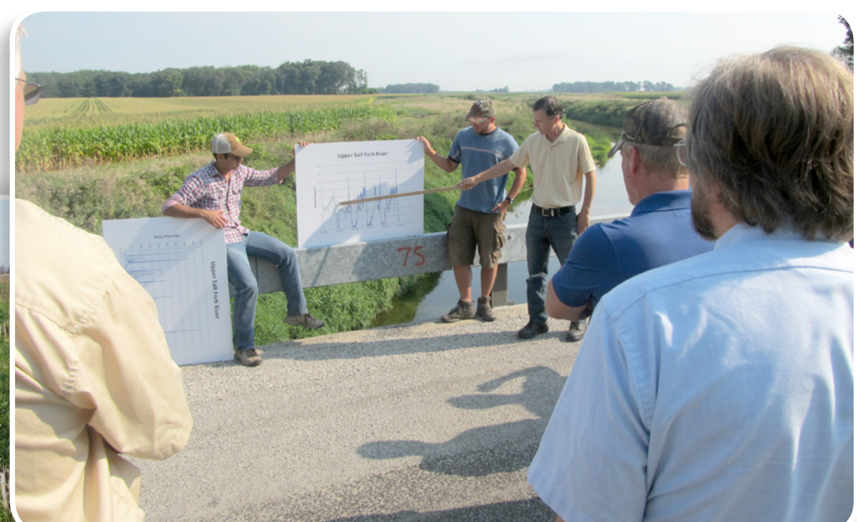
Many Practices Can Reduce Nitrate Losses from Fields, but Social Constraints Make Implementation Difficult

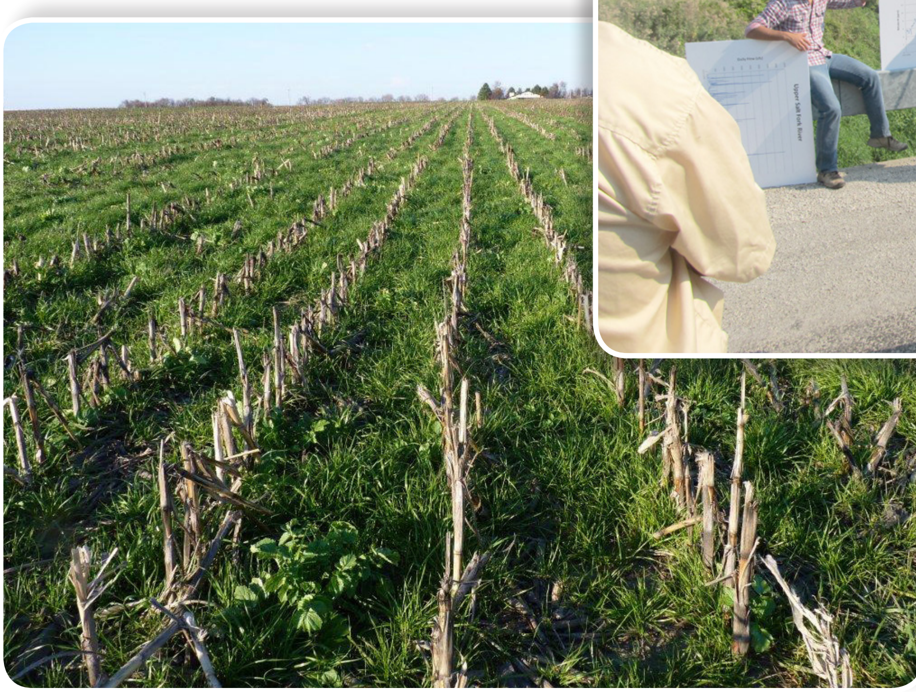


Watersheds in the upper Midwest Corn Belt are flat and extensively tile-drained, producing high yields of corn and soybeans on greater than 90% of the land. Corn production requires large inputs of nitrogen fertilizer, and there are extensive periods with no plant roots to take up available nitrate. Therefore, precipitation events during late fall through early summer lead to large losses of nitrate, typically about 20 to 30 kg N^{-1} ha^{-1} yr^{-1}. This nitrate is transported down the Mississippi River system and contributes to the hypoxic zone that forms each summer in the Gulf of Mexico. These watersheds are the focus of many federal and state programs to reduce these tile nitrate losses, with little success to this point.

In an upcoming issue of the *Journal of Environmental Quality*, researchers report on multi-year studies from two watersheds in east-central Illinois (Upper Salt Fork and Embarras River) where a range of nitrate reduction practices were evaluated on tile-drained fields, along with social science perspectives of the landowners and farmers. The article is part of a special section of papers on "Improving Nitrogen Use Efficiency in Crop and Livestock Production Systems." On-farm studies of fertilizer timing, cover crops, drainage water management, woodchip bioreactors, and constructed wetlands were used to evaluate the efficacy of reducing nitrate losses. All methods led to various levels of reductions in nitrate losses (30–80%), with the exception of drainage water management. The drainage water management fields were a retrofit of existing tile systems, and water flowed laterally from the managed tile to the free drainage system nearby.

The biophysical and social studies conducted on the Upper Salt Fork and Embarras River watersheds demonstrated a disconnect between field and stream measurements and water quality perspectives of farm operators as well as the complexity of reducing nitrate concentrations and loads in the river systems. Various in-field and edge-of-field techniques that could help to reduce nitrate loads had limitations and little social acceptance under our current policy and management systems. In addition, large-scale (nearly every field) adoption would be needed for substantial reductions in nitrate yields to occur. Interviews and surveys indicated that land owners and farmers had strong environ-





Left: Rye and radish cover crop growth following corn during the fall of 2012 in the Upper Salt Fork watershed in east-central Illinois. **Above:** Lowell Gentry explaining nitrate losses at the outlet of the Upper Salt Fork watershed in east-central Illinois during a 2013 field day for producers and landowners in the watershed.

mental concern and stewardship ethics, but financial and operational constraints limited their willingness to adopt conservation practices that specifically targeted nitrate losses but did not maintain or increase yields.

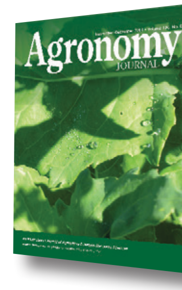
The researchers utilized their long-term data set for the Embarras River and did not observe a significant trend in river nitrate yields during the past 21 yr. It was possible that competing factors were at work and produced a virtual draw regarding improved water quality in the Embarras River watershed. For example, conservation benefits may have been offset by increased tile drainage installations, and gains in N use efficiency may have been offset by an increase in corn acreage. If USDA farm subsidy programs continue to reward only crop yield, then gains in N use efficiency will likely be nullified by increases in corn acreage and tile installations; improvements in surface water quality will go undetected in these watersheds.

Given the need for system-wide nitrate management practices to achieve results, cooperative programs to connect and coordinate farmers may be a valuable approach to increase conservation. However, with the policy and production systems currently in place on these corn- and soybean-dominated watersheds, results from this study suggest that large-scale nitrate reductions that are called for in nutrient loss reduction strategies for the Mississippi River Basin will be difficult to meet.

Adapted from David, M.B., C.G. Flint, L.E. Gentry, M.K. Dolan, G.F. Czapar, R.A. Cooke, and T. Lavaire. 2015. Navigating the socio-bio-geo-chemistry and engineering of nitrogen management in two Illinois tile-drained watersheds. J. Environ. Qual. 44(1). View the full article online at http://dx.doi.org/doi:10.2134/jeq2014.01.0036

doi:10.2134/csa2015-60-1-4

Analysis of Combined Experiments Revisited



Agronomic experiments are often replicated over time and space to evaluate how treatments perform over a range of environments. The analysis of experiments conducted over more than one growing season (years) and/or places (locations) is commonly referred to as analysis of combined experiments. Common analyses of these studies treat some effects as fixed and others as random and usually include interactions between fixed and random effects; thus, statistical models used in the analysis of combined experiments are mixed models.

When it is the intention of the researcher to make broad inferences over a geographical area, locations used in the experiment conceptually represent a sample of locations within the region. Location is sometimes considered to be fixed in combined experiments when the effects associated with it are predictable based on some intrinsic characteristic such as soil type, latitude, longitude, or some other variable that behaves as a fixed effect. Years are almost always considered to be random because they are completely confounded with weather, which is mostly unpredictable. Other treatments in a combined analysis are usually considered fixed because they relate to specific hypotheses about their effects. There are examples, however, where other random terms in addition to year and location are included in a model for a combined analysis. Despite these few exceptions, however, analysis of combined experiments usually involves a mixed-model approach.

There is a long-standing debate over how mixed interactions should be treated in the analysis of variance. Assuming these interactions to sum to zero within each level of a fixed effect historically has been the approach used in most agronomic studies. However, contemporary practice considers these effects to be mutually independent. This latter assumption is used to construct F-tests by many of the statistical analysis programs that are widely used to analyze data from agronomic experiments but is inconsistent with that presented in many texts and used in many previously published studies. One consequence of this shift in perspective is that conducting the hypothesis tests based on the sum-to-zero assumption can be difficult with modern software.

The assumptions made about mixed interactions in the analysis of variance can result in very different interpretations and potentially lead to different conclusions. This is because the assumption made with respect to mixed interactions affects the variance components included in expected mean squares on which F tests are based. Thus, the assumption made about mixed interactions can lead to different F tests and inferences. Also, there could be potential differences in variances calculated using the method of moments. That is, if a variance is estimated from a linear combination of mean squares and expectations of their variance components, the two assumptions may yield different estimates of the variance.

In the March–April 2015 issue of *Agronomy Journal*, there will be a special section dedicated to statistical concepts. In one of the articles, Ken Moore and Philip Dixon address the discrepancy between the analyses that were formerly recommended and those that are currently implemented by popular software programs and provides recommendations for analyzing data from combined experiments. SAS code for analyzing combined experiments under varying model assumptions is provided, and a rule-based method for assembling expected mean squares based on the independence assumption is presented.

Adapted from Moore, K.J., and P.M. Dixon. 2015. Analysis of combined experiments revisited. Agron. J. 107(2). View online at http://dx.doi.org/doi:10.2134/agronj13.0485

doi:10.2134/csa2015-60-1-5