Science Societies

Through the lens of phosphorus

Celebrating influential scientist Andrew Sharpley's legacy and work on the Phosphorus Index

By Kaine Korzekwa

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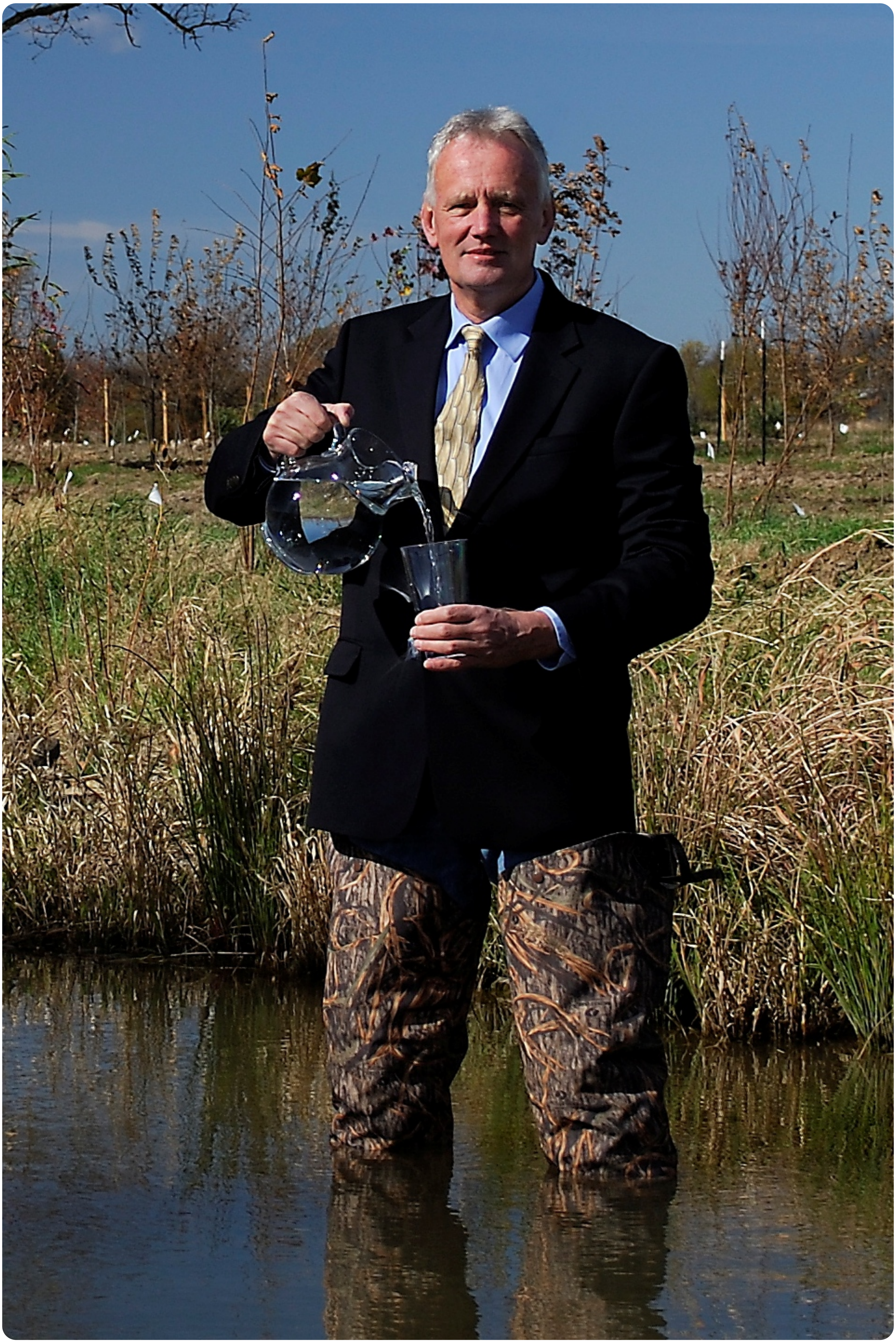


Sharpley poses for a photo to illustrate his commitment to clean waterways and drinking water, coupled with the importance of agriculture. Photo courtesy of Deanna Osmond.

> Renowned researcher Dr. Andrew Sharpley had a nearly 45-year career focused on addressing agricultural phosphorus management, particularly its impact on water quality. Sharpley, known for his expertise in nutrient chemistry, soil physics, systems biology, and more, played a pivotal role in developing the Phosphorus Index (P Index), a tool designed to assess and mitigate phosphorus runoff from agricultural fields. His leadership, marked by consensus-building, mentorship, and intellectual collaboration, was key to the creation of the Phosphorus Index and its adoption across the United States. An upcoming special section in Journal of Environmental Quality honors Sharpley's legacy.

The halls of history are filled with one-of-a-kind scientists and once-in-a-generation leaders, but even more rare is when these unique qualities are found in a single individual. Andrew Sharpley is widely viewed as being among those esteemed ranks. A true multidisciplinary scholar and leader, he is not only skilled in all facets of soil science—nutrient chemistry, systems biology, soil physics, computational modelling, and more—but also leadership, communication, and consensus-building. And throughout his nearly 45-year career, he aimed these talents at a single wicked problem: the management of agricultural phosphorus.

An upcoming special section in the *Journal of Environmental Quality* titled "Through the Lens of Phosphorus—Honoring the Legacy of Andrew Sharpley" will celebrate the work and scholarship of Professor Andrew Sharpley, who retired in 2021, and the ways in which he inspired and influenced his colleagues and students.

Born and raised in urban Manchester, England post-World War II, colleagues say his classically British "stiff upper lip" was an asset to overcoming adversity and conflict, even if he didn't fit the traditional mold of a scientist doing applied research on an American rural issue. What few knew is how much he thoroughly enjoyed the sights, sounds, and even smells of childhood trips to farms and dairies outside Manchester. While studying soil science at the University College of North Wales, he was introduced to agricultural science and saw the field as a path to making a difference.

Recruited to New Zealand for graduate school, he was introduced to the power of watershed science and to the importance of collaboration and teamwork in making an impact, in addition to learning from great minds in phosphorus research. It was in New Zealand that Sharpley began to amass a scientific understanding and publication record that followed him throughout his career. His discoveries as a young scientist, such as those related to the mechanisms of dissolved phosphorus mobilization and its transport to and from tile drains, would stand the test of time. As his colleagues say was often the case with Sharpley's early work, his ideas would be rediscovered in other settings by those who had yet to fully appreciate his foundational research.

Sharpley as a graduate student in the 1970s in New Zealand. His time in New Zealand was very formative and set the stage for the impact he would have on managing agricultural phosphorus. Photo courtesy of Andrew Sharpley.

Intellectual persuasion and the Phosphorus Index

What followed graduate school was a career tour of the United States many Americans themselves do not experience. After a brief stint at the University of California–Davis, he moved to rural Durant, OK in 1979 as a postdoc and then research scientist in a USDA-ARS lab through Oklahoma State University. Roughly two decades later, he transferred through ARS to Pennsylvania State University and later made a final career move more firmly into academia at the University of Arkansas. A longtime member of the Soil Science Society of America (SSSA) and American Society of Agronomy (ASA), he would become an influential journal editor and ultimately president of SSSA.

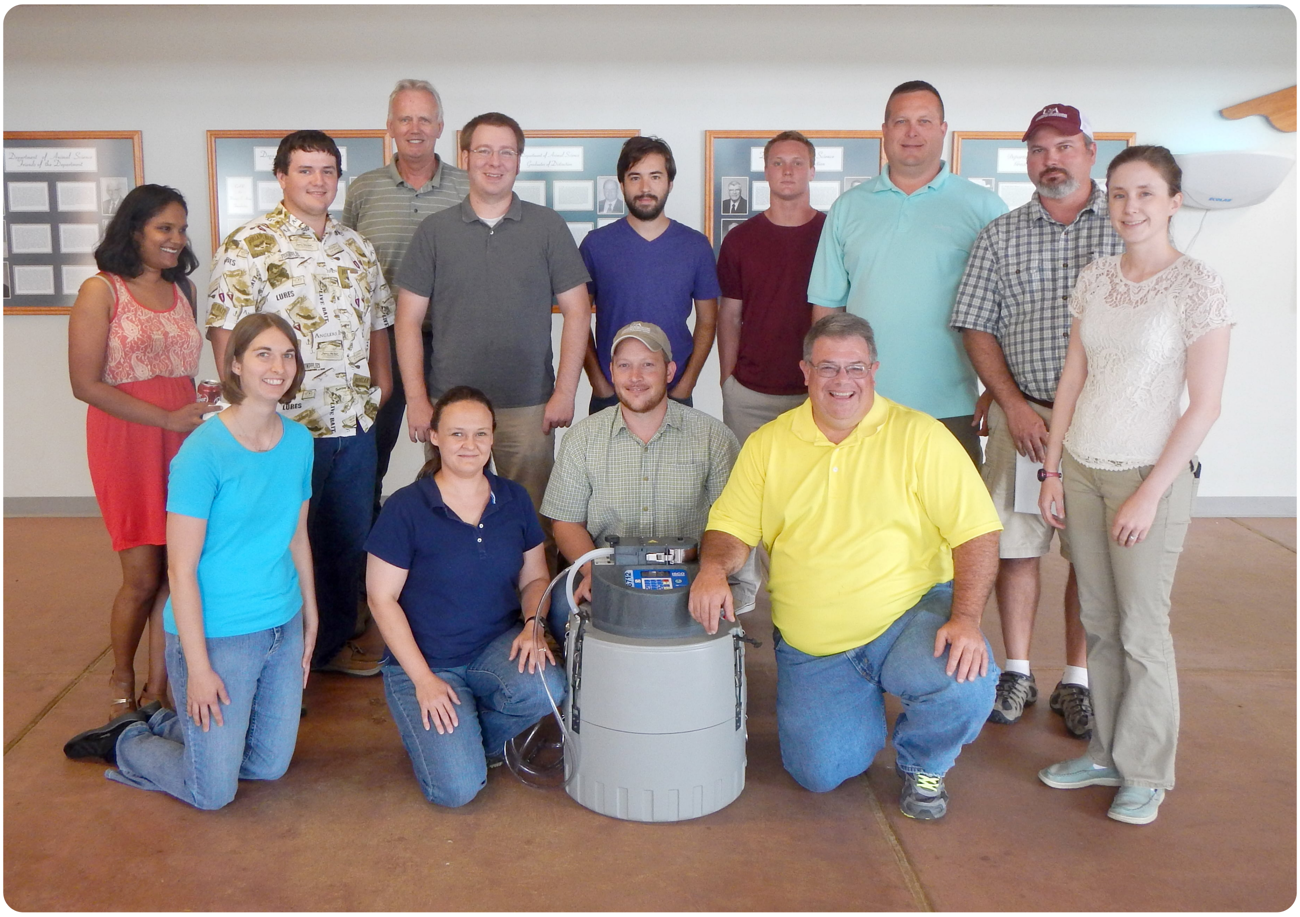
“Dr. Sharpley worked across disciplines from basic soil chemistry to watershed processes and, within 10 years of starting his career, had identified almost all the major concepts around agricultural phosphorus loss,” explains Deanna L. Osmond, a professor emerita in the Department of Crop and Soil Sciences at North Carolina State University who worked extensively with Sharpley over the years. “This range of expertise combined with his extraordinary intellectual keenness, kindness, and politeness drew people to work with him.”

Osmond, who is also an ASA and SSSA member, adds that Sharpley provided the intellectual framework of phosphorus cycling and its multiple pathways of use and loss relative to conservation practices. In addition, he developed the critical source area concept, which is that in some watersheds, the majority of phosphorus loss comes from a minority of the land area.

The critical source area concept became the foundation of one of Sharpley’s most seminal contributions—the Phosphorus Index (P Index)—which began to take shape starting in 1990. That year, USDA-NRCS asked leading scientists to make recommendations to reduce surface water eutrophication due to agricultural phosphorus. Sharpley worked to champion the idea of using a set of factors influencing phosphorus loss to make recommendations for farm management, which would ultimately be known as the P Index.

It was through these meetings that Sharpley's leadership style came to the fore. He became renowned for his ability to resolve conflict, build consensus, mentor others, give credit where due, and provide strong leadership from multiple angles within a group.

"He led from behind, which meant he worked with others to find consensus," Osmond says. "He worked through intellectual persuasion. Additionally, he could easily change roles from team leader to team member."



Andrew Sharpley and his water quality team pose for a photo shortly after starting at the University of Arkansas. Photo courtesy of Andrew Sharpley.

Pete Kleinman, a research leader and soil scientist at the USDA-ARS and a member of ASA and SSSA, was Sharpley's former postdoc. He remembers clearly how Sharpley guided his career and that of many others. While getting his Ph.D. at Cornell, Kleinman began to notice Sharpley was the author on nearly every influential paper that he was reading in the library's stacks.

Kleinman recalls Sharpley's leadership style being on display when he organized a trip to meet Sharpley in Pennsylvania. Upon arrival, another USDA scientist led the discussion, who Kleinman assumed was Sharpley—only to realize Sharpley had elevated a colleague to the head role for the visit rather than himself.

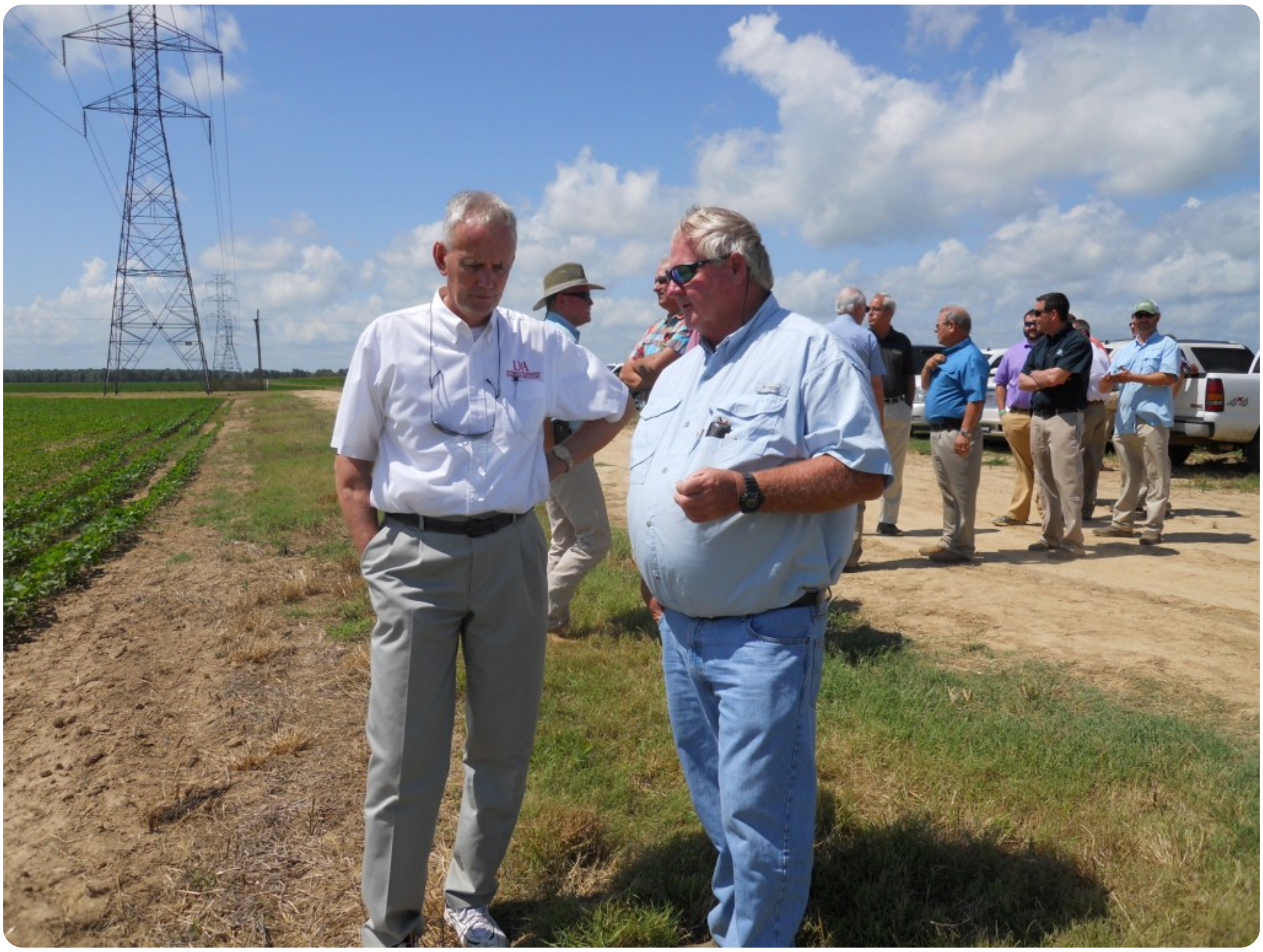
"Andrew was very good at four fundamental leadership qualities," Kleinman says. "First, he could identify the problem and help everyone understand the common objective. Second, he understood that recognition and acknowledgment is the currency of academia and foundation of scientific integrity. He routinely would stop a great presentation to highlight the contribution of colleagues, often pointing them out in the audience. His third step was understanding that concepts need flexibility so common protocols could be adapted and adopted by local experts. Lastly, he knew how to integrate diversity perspectives, often including disagreements, into something that is useful and would have real impact."

These principles helped make the ideas of Sharpley and others into a fully developed P Index, as Osmond and Kleinman explore in their paper in the special section, "A short history of the Phosphorus Index and Andrew Sharpley's contributions from inception through development and implementation." This first P Index was added to the USDA-NRCS 590 Nutrient Management Standard around 2000, after significant scientific collaboration and outreach to policymakers and even briefings to members of Congress. It took into account site characteristics like soil erosion, phosphorus fertilizer application rate and method, and organic phosphorus source application rate and method. The goal of the index was to help producers and others understand potential non-point source phosphorus runoff from their fields and help prioritize conservation efforts.

Osmond explains how the NRCS writes generic national standards so they can be adapted by states to account for environmental and agricultural differences across the country. The NRCS provided states a certain amount of time to develop their own indices, and ultimately 48 states adopted their own P Index. Sharpley helped develop them for several states as well as coordinated research across 20 states to carry out standardized studies to continually improve the index.
A way to describe Sharpley is as a scientific detective—inherently curious and driven to research clues using various tools, combining them into a cohesive viewpoint focused on translating findings into impact.

“He has this ability to endure even when early conclusions are not simplistic and tidy, but instead seem to unravel,” Kleinman explains.

“And his stewardship of the work, of revisiting initial clues and products over time, was central to his ethos and something he felt was incredibly important.”



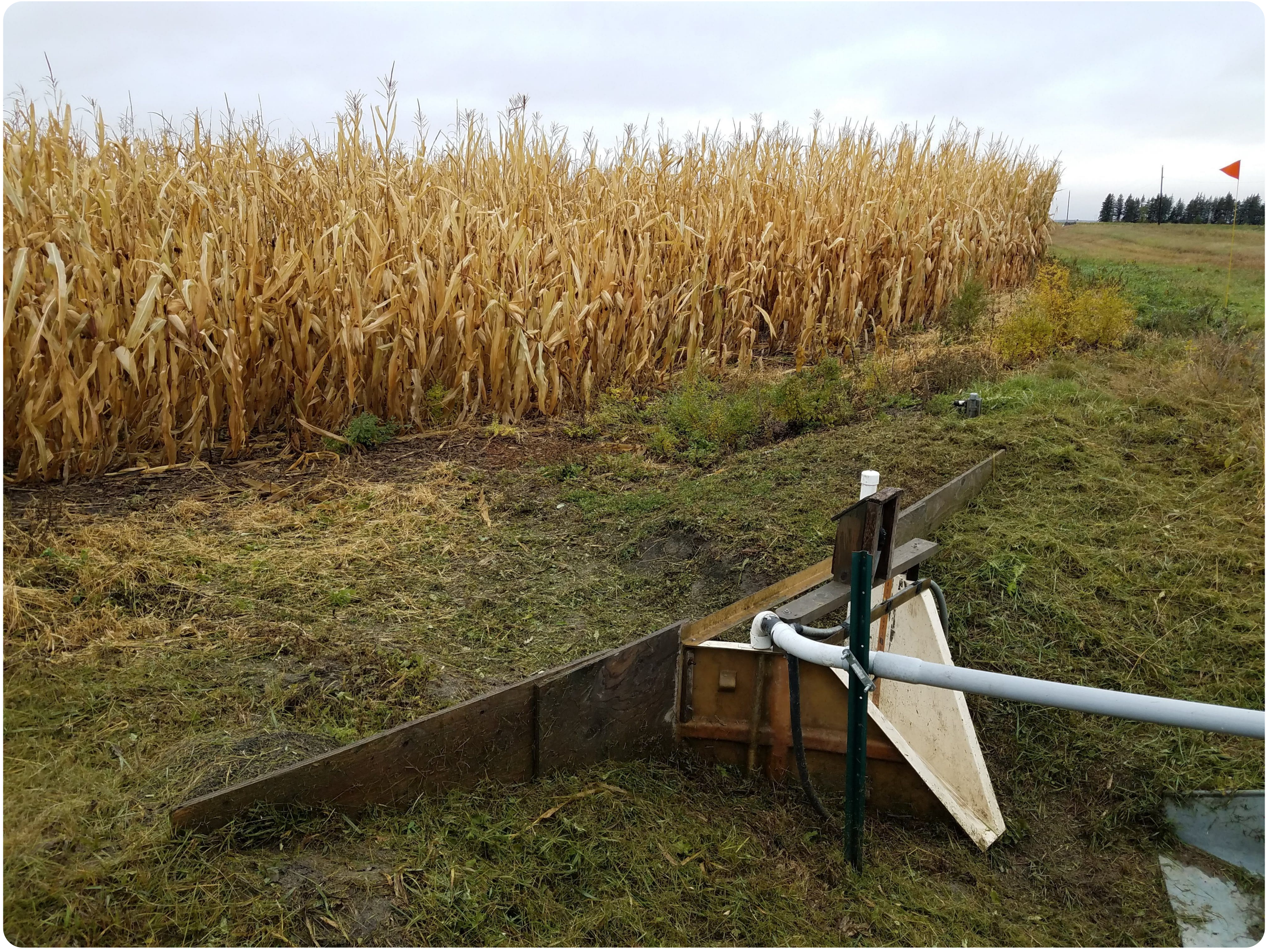
Andrew Sharpley hosting a field day in Arkansas. Photo courtesy of Andrew Sharpley.

Evaluating the P Index in Minnesota

This idea of continually returning to past findings is embodied in a paper in the special section titled "Evaluation of Minnesota Phosphorus Loss Index Performance." Originally supported by a large research project led by Sharpley, Minnesota developed its Minnesota P Loss Index (MNPI). It has not been revised since 2006. Public concern over eutrophication of public waters has more recently brought the issue of phosphorus runoff into the public consciousness, also motivating the researchers to return to the MNPI.

Lindsay Pease, an assistant professor at the University of Minnesota specializing in nutrient and water management, served as an author on the paper. Minnesota's P

Index is considered a weighted and additive model that provides a sense of phosphorus loss potential by considering three forms of edge-of-field phosphorus loss, Pease explains. These include sediment-bound P in rainfall runoff, known as particulate P; soluble P in rainfall runoff, known as soluble P; and soluble P in snowmelt runoff, known as snowmelt P. The researchers wanted to test if the MNPI was both "directionally and magnitudinally correct."



Edge-of-field monitoring helps capture and analyze field runoff continuously, rather than readings being taken periodically. Photo courtesy of Lindsay Pease.

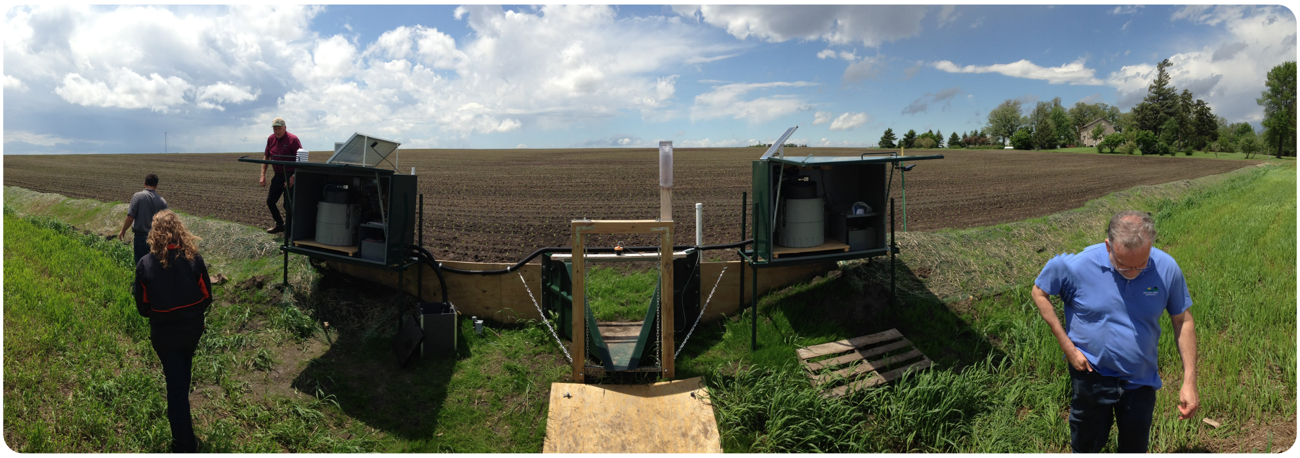
"Directionally" refers to whether the predicted and observed losses increase and decrease at the same time. On the other hand, "magnitudinally" is a check on whether the amount of phosphorus loss predicted matches what was observed. Their study included 67 site-years where they observed phosphorus loss using annual edge-of-field data and compared this with MNPI-predicted loss.

“We wanted to know if the sites with high observed losses match with the highest predicted losses and appropriately rank loss across sites,” says Pease, a member of ASA, CSSA, and SSSA. “We found that the Minnesota index is indeed directionally correct, which was a great finding because the main goal of the tool is to help prioritize sites and resources. However, according to our findings, the MNPI was not magnitudinally correct because it was often not predicting the correct amount of P loss—it was typically much greater than what we observed.”

The researchers’ analysis found two areas of the MNPI they recommend addressing. First, it overpredicted phosphorus lost via snowmelt. In addition, the equation it uses to predict sediment loss—called Revised Universal Soil Loss Equation Version 2, or RUSLE2—was greatly overpredicting sediment loss for sites without subsurface drainage.

“The region of Minnesota where this calculation was developed is very different from other parts of the state in terms of topography, soils, and climate,” Pease explains. “We have not done enough snowmelt runoff studies in Minnesota to have a good idea how to calculate these losses. Over time, we may be able to add this component back in, but it seemed that predictions were actually better without it than with it. When it comes to RUSLE2, this is something that the original model review may have missed due to infrequent samplings. Scaling back those predictions by about one-third brought those numbers into alignment with what we observed.”

Key to this study was the use of accurate and frequent edge-of-field runoff measurements from real farms in Minnesota. A large portion of the data for this study was provided by a program called Minnesota Discovery Farms, which is managed by the nonprofit Minnesota Agricultural Water Resources Center and works to collect credible data that can be used for research and educational purposes to help farmers deal with water quality challenges.



Fields are monitored using surface water and tile drainage monitoring stations, such as this one in Dodge County, Minnesota. Automated monitoring equipment is shown in the green boxes. Photo by Tim Radatz.

Discovery Farms Coordinator Tim Radatz served as an author on the paper and notes how the inclusion of Discovery Farms and connections with real-life producers is another example of Sharpley's philosophy on display.

"It is much easier to study and apply these models on [a] larger scale, but you have to balance that with the understanding that a management practice that works well in one region may not work in another," Radatz says. "And so you have to do actual on-the-ground partnering for farmers for monitoring."

Radatz remembers meeting Sharpley when a group of researchers from Arkansas visited Minnesota Discovery Farms and were interested in starting their own similar program. As a result, Sharpley served as a lead investigator implementing the program in Arkansas.

“It was always clear that he had the most knowledge in the room but would not flaunt it in front of others,”

Radatz says. “He is a very nice and generous person, but if you were paying attention, you could tell he was the real driver behind a lot of the work then that has only continued.”

Pease, the young faculty member at the University of Minnesota, never worked directly with Sharpley. However, she, like Sharpley’s former postdoc Kleinman felt she got to know him through reading his countless papers as a graduate student and postdoc. As she notes in her paper, this study of Minnesota’s P Index is a testament to Sharpley’s decades-long commitment to improve and revise the P Index as the science and management of agricultural phosphorus continues to advance.

“Sharpley was a key researcher in the initial development of these P Indices, and he advocated returning to these metrics over time and re-evaluating them to take stock of how we are doing,” Pease says. “That is something that had not been done with the Minnesota P Index, and that was really the spirit that I was hoping to capture with this work.”

Dig deeper

Check out the research cited in this article:

Osmond, D. L., Kleinman, P. J. A., Coale, F., Nelson, N. O., Bolster, C. H., & McGrath, J. (2024). A short history of the phosphorus index and Andrew Sharpley's contributions from inception through development and implementation. *Journal of Environmental Quality*. https://doi.org/10.1002/jeq2.20535

Reitmeier, H., Pease, L., Loss, P., & Radatz, T. (2024). Evaluation of Minnesota Phosphorus Loss Index performance. *Journal of Environmental Quality*. https://doi.org/10.1002/jeq2.20635
