Perennial cropping systems improve environmental and human health

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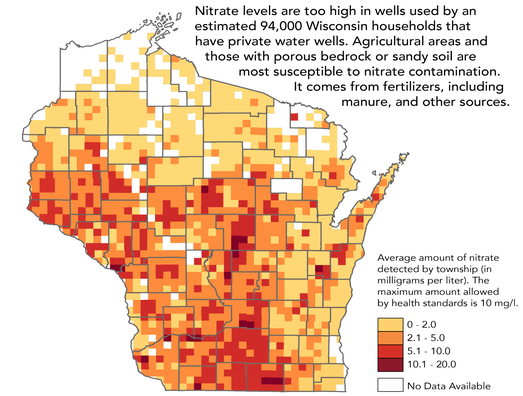
The problem

Nitrogen and phosphorous loss from agricultural systems significantly impacts natural ecosystems and human health in Wisconsin. Nitrate leaching through agricultural soils into groundwater wells poses a risk to pregnant women and newborn babies. Furthermore, the combined presence of these nutrients in lake ecosystems triggers annual algae blooms across the state, therefore reducing environmental services associated with the latter.[1]

Traditional annual crops like corn, soybeans and wheat are particularly problematic because of their low nutrient use efficiency. Around 50 to 60% of all applied fertilizer is lost through leachate, soil erosion, surface water runoff or tile drainage.[2]

Perennial cropping systems can solve these problems.

Nitrate in drinking water around Wisconsin



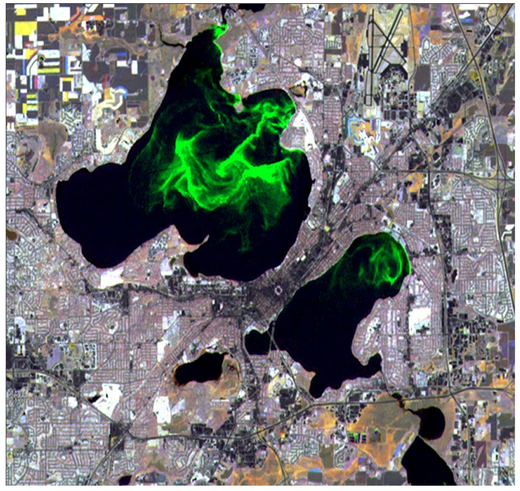
CREDIT: Katie Kowalsky/Wisconsin Center for Investigative Journalism

SOURCE: Well Water Quality Viewer, University of Wisconsin-Stevens Point's Center for Watershed Science and Education. Private Drinking Water Quality in Rural Wisconsin, Journal of Environmental Health, 2013.

Since the mid twentieth century, macro economics and policy trends have incentivized farmers to apply nitrogen and phosphorus fertilizers at increasing rates [7]. While yields have increased, the negative environmental externalities associated with higher inputs are observable in Wisconsin's groundwater resources and in its lake ecosystems.

Groundwater nitrate-nitrogen contamination poses a significant risk to human health. Excessive nitrates in private well drinking water increases the risk of a methemoglobinemia – a serious condition that that reduces the ability of hemoglobin to transport oxygen through the bodies of infants [8].

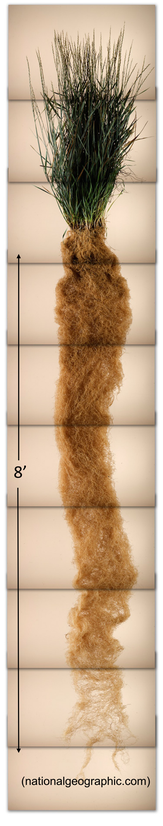
Furthermore, the combined presence of nitrogen and phosphorus in lakes and the resulting algae blooms significantly reduces the aesthetic and functional environmental services that are associated with freshwater lake ecosystems [1].



Digital representation of algal bloom in Lake Mendota and Lake Monona. Image courtesy of UW SSEC and WisconsinView

A potential solution

- KERNZA (Intermediate wheatgrass) is a recently developed perennial grain and forage crop.
- Provides year-round ground cover and living biomass protecting soil from erosion and runoff.
- It has dense and deep roots reaching for nutrients and water as far deep as 8 feet, reducing leachate of nutrients.
- Produces both food grade seeds and forage for ruminants (dairy and beef cattle).
- Patagonia's Long Root Ale is the first Kernza product on the market! (Pacific NW)



(nationalgeographic.com)

Material and methods

This poster is based on a literature review. Referenced papers are :

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2. Pourazari et al. 2015. Nitrogen use efficiency and energy harvest in wheat, maize and grassland ley used for biofuel – implications for sustainability.
3. Champan A et al, 2005. Sediment delivery from agricultural land to rivers via subsurface drainage.
4. Cox C, Hug A and Bruzelius N, 2001. Losing Ground
5. Nelson N et al,2015. Can cover crops reduce phosphorus loss from surface-applied fertilizer,.
6. Verbruggen et al, 2012. Mycorrhizal fungal establishment in agricultural soils: factors determining inoculation success. + national geographic.
7. Nehring, Richard. "Fertilizer Use and Price." *Econmic Research Service*. N.p., 12 Oct. 2016. Web. 12 Feb. 2017. <https://www.ers.usda.gov/data-products/fertilizer-use-and-price.aspx>.
8. Chern, Laura, George Kraft, and Jeff Postle. *Nitrate in Groundwater - A Continuing Issue for Wisconsin Citizens*. Madison: Wisconsin Department of Natural Resources, Mar. 1999. PDF.
9. Burke, Ingrid C., et al. "Regional and Temporal Variation in Net Primary Production and Nitrogen Mineralization in Grasslands." *Ecology*, vol. 78, no. 5, 1997, pp. 1330–1340.
10. Culman, Steve, Sieglinde Snapp, Bruno Basso, Mary Ollenburger, and Lee DeHaan. "Soil and Water Quality Rapidly Respondsto the Perennial Grain Kernza Wheatgrass." *Agronomy* 103.3 (2013): 735-44. Web.

Reducing Nitrogen (N)

Nitrogen is an essential component of biological systems. It is present throughout the terrestrial biosphere, and it is one of the key drivers of biological net primary production. Furthermore, nitrogen cycles continuously across multiple spatial and temporal scales [9]. Within the context of agricultural systems, mindful nitrogen management is crucial in order to optimize economic and environmental efficiency. Nitrogen loss from agricultural systems generally occurs by leaching through the soil profile, however it also volatilizes into the atmosphere when the environmental conditions permit. Research from Culman et al indicates that nitrate-nitrogen leaching is reduced in perennial Kernza Wheatgrass cropping systems compared to annual wheat cropping systems [10].

Cumulative Nitrate leached (Culman et al., 2013)

Plant Type	Management	Apr-Oct 2010	Apr- Oct 2011	Apr 2010 – Oct 2011
		Kg NO_3–N/ha^{-1}		
Annual (wheat)	High-N	24.3	69.8	148.3
	Mid-N	9.8	27.5	53.8
	Organic	11.3	17.7	45.1
Perennial (Kernza)	High-N	17.7	9.9	32.0
	Mid-N	12.7	0.5	15.0
	Organic	11.6	0.1	15.3

Reducing Phosphorous (P)

Phosphorus is essential for plant growth since it is a key component for photosynthesis, respiration and DNA-structure. It is also the first limiting factor for algae growth in surface water ecosystems[3]. Phosphorus transport therefore represents a major loss of field fertility and triggers algal blooms. It is transported via two different mechanisms:

Particulate transport: Phosphorus is poorly water-soluble and it is usually bound to soil particles. Therefore, sediment erosion and P-losses are highly correlated. Around 70% of all phosphorus transport happens via erosion[3]. By densely covering the soil year-round with its living stems and holding it together with its roots, Kernza has the potential to reduce sediment transport by more than 70%[4].

Advanced erosion in a newly planted corn field. (blog.nwf.org)

Ag. fertilizers contain water-soluble P (thatsfarming.com)

Leaching: Agricultural fertilizers, such as manure slurry or synthetic phosphate, contain soluble phosphorus that can easily leach through sandy or non-rooted soils[4].
Accounting for the other 30% of P-losses, phosphorus leaching is almost entirely reduced under perennial cropping systems[5]. Beneficial fungal associations reduce the need for P-fertilizer. Kernza's year-round, deep roots efficiently catch soluble nutrients[6].

Conclusion: Kernza perennial grain cropping systems have the potential to reduce nutrient transport through agricultural systems. Breeding, agronomic research, marketing, and supply chain optimization is be needed in order to increase the feasibility of Kernza as a complement to the major annual staple crops.