The use and impacts of glyphosate and pyraclostrobin in soybean and sugar beet farming: selected socio-ecological issues in Michigan's Huron, Sanilac, Lapeer and Tuscola counties, USA

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Abstract
Huron, Sanilac, Lapeer and Tuscola counties, Michigan, USA, currently cultivate eighty-seven percent of the land largely in soybeans, sugar beets, corn and winter wheat. Both glyphosate and pyraclostrobin are regularly applied in the region to manage pests. A public discussion emerged in the region regarding the long-term effects on soil quality and the future viability of agriculture.This research seeks to identify and discuss the inter-related socio-ecological dimensions of the long-term use of glyphosate and pyraclostrobin on soybean and sugar beet production in Michigan's Thumb region using a multidisciplinary approach. In-depth interviews with farmers will identify the social and cultural pressures of farm management in the region, and commonly referenced soil quality indicators. Potential synergies and/or long-term effects of glyphosate and pyraclostrobin on soil quality will be examined using a data-driven meta-analysis of previously conducted soil quality and pesticide research. This type of analysis encompasses an array of researches and determines if insignificant results of single experiments are statistically significant across multiple experiments. Results of this research will not only benefit the Michigan agricultural community, but also raise critical questions regarding the long-term viability of many agricultural practices.

Key Words
Genetically modified, agriculture, soil quality, Ethnopedology, multidisciplinary.

Introduction

Current situation

Eighty-seven percent of the land in Michigan's Huron, Sanilac, Lapeer and Tuscola counties, Michigan's Thumb region, is cultivated largely with soybeans, sugar beets, corn and winter wheat (NASS 2007). In this region, eighty-five percent of the land is farmed conventionally where it is common to grow soybeans (*Glycine max* (L.) Merr.) that are genetically modified to resist glyphosate, a broad spectrum herbicide. Fungicides with the active ingredient pyraclostrobin (a broad spectrum fungicide), e.g. BASF's Headline fungicides, are also used on the same farms to eliminate pathogenic fungi. Approximately 1.3% of the cultivated area in the region, or 18,500 acres, is farmed organically (NASS 2007). The organic farms do not use genetically modified seeds or apply glyphosate and pyraclostrobin. Given the close proximity of these different crop management strategies, questions regarding the region's soil health and quality are frequent and controversial topics of discussion in the region.

The region's loamy till parent materials and relatively fine soil texture creates a rich landscape for the production of a variety of crops, as long as the soils are provided with ample subsurface drainage. But the more than ten years of glyphosate applications and five years of pyraclostrobin applications may be compromising the soil health in this region, and consequently the future of the region's economic well-being. A growing public discussion about the relationship between the long-term use of glyphosate and pyraclostrobin and observed changes in the region's soil quality inspired this research. Are these crop management technologies, often promoted as sustainable, undermining the viability of the region's soils and the livelihoods of its farmers? This research seeks to identify and discuss the inter-related socio-ecological dimensions of the long-term use of glyphosate and pyraclostrobin on soybean and sugar beet production in Michigan's Thumb region.

Literature review and research issues

Agriculture in the United States changed significantly when genetically engineered varieties of soybeans, corn and cotton became commercially available in the late 1990's. Genetically engineered, or genetically modified (GM), crops undergo alterations to their DNA to make, modify, improve or develop the crop for production and management purposes (ERS 2009). GM-varieties became increasingly popular in the US as

farmers learned more about the perceived benefits associated with these varieties. GM-seeds, in particular, are touted for their ability to increase crop yields, efficiently manage pests, tolerate climatic variation, and decrease labor and input costs (Monsanto Company 2009). From a peak of 87% in 2007, the percentage of GM soybeans planted in Michigan in 2008 and 2009 declined from 84% and 83% respectively (ERS 2009).

The attractive qualities of GM-crops accelerated farmers' willingness to accept and cultivate these varieties. Rapid integration into the agricultural system across the United States spurred research on various ecological implications including: the likelihood of cross contaminations; the impacts on non-target species; the emergence of superweeds; and, the loss of seed biodiversity. Farm management decisions are dependent on how farmers interpret the benefits and drawbacks of cultivating GM-varieties.

There is little question that the market value of the harvested crop weighs heavily on the farmers' decision to use a seed. At the same time, several researchers have identified how farmers vary in their motivations ranging from purely economic gains to valuing environmental and social incentives (Sall *et al.* 2000). Guehlstorf (2008) concludes that farmers integrate, rather than mutually exclude, economic prosperity, environmental health and social well-being. Overall, these results show that each farmer individually decides what is important and then chooses a management strategy. In short, farmers identify with the phrases "appropriate farm management" and "healthy soils" differently because each farmer is socially, politically, and philosophically situated. This means that the way farmers assess and monitor soil quality also varies. Romig et al. (1995) studied the various ways farmers in Wisconsin assess soil health and quality in the field. After consulting farmers, they identified the natural indicators farmers commonly use to identify a healthy soil. This work is also one of the few ethnopedological studies on modern conventional farmers. This variability in how farmers make soil management decisions creates challenges for studying soil health issues and for developing practical solutions, including ways for dealing with the long-term impacts of glyposate and pyraclostrobin.

The available research results on the impacts of glyphosate and pyraclostrobin on soil quality further complicate studies on soil health. To date no studies have examined the combined effect of applying both glyphosate and pyraclostrobin to the same field, as commonly practiced by farmers. Application of these pesticides in the same field may have synergistic effects, especially on microbial communities, which actively breakdown these chemicals in the soil (Bartlett *et al.* 2002; Duke *et al.* 2003). Reliance on these biotic communities to remove both glyphosate and pyraclostrobin from the soil may, in the long-term, have deleterious effects on the soil's quality.

The following experimental results are separated based on the effects each pesticide has on the soil. With GM glyphosate-resistant crops, glyphosate is often applied over the top of the field accounting for the more than six-fold increase in use between 1992 and 2002 (Gianessi and Reigner 2006). Glyphosate absorbs quickly into soil particles and is rapidly degraded by soil microbial communities (Duke *et al.* 2003). Exposure to glyphosate for numerous years increases plant propagules and rates of microbial activity, measured through soil respiration concentrations, without adverse effects (Cerdeira and Duke 2006). Glyphosate also directly and indirectly influences the number of fungi present because it affects how fungi and microorganism's interact (Wardle and Parkinson 1990). Overall, these studies show that in the short- and long-term, glyphosate increases the rate of activity in soil microbial communities.

BASF Corporation's pyraclostrobin, a broad spectrum strobilurin fungicide, became commercially available in 2002. Resistance to pyraclostrobin can occur through a single point mutation in both basidiomycetes and ascomycetes (Grasso *et al.* 2006). Pyraclostrobin readily forms mobile metabolites with decreased toxicity and it is absorbed by microbes and through photolysis (Bartlett *et al.* 2002). Ragsdale and Koch (2008) compiled scientific references that demonstrate how pyraclostrobin adversely affects entomopathogenic fungi, naturally occurring host specific bioinsecticides, and how it encourages the development of aphid populations by eradicating fungal disease within the population. This adverse effect mitigates soil microbial interactions which imbalances biotic communities.

This research will explore three dimensions of the future status of the soil quality and agricultural viability of Michigan's Thumb region. First, the social and cultural pressures farmers navigate to make farm management decisions. Secondly, how modern farmers assess soil quality and perceive the region's future with consistent use of glyphosate and pyraclostrobin. Lastly, this research will explore ecological impacts

and potential synergies that exist with joint use of these chemicals in the scientific literature. In summary, our working hypothesis is that farmers in Michigan's Thumb region rely on soil quality indicators to make farm management decisions because they want to maximize productivity without depleting the rich soils. In addition, this research may find that while farmers have observed adverse affects from using glyphosate and pyraclostrobin, they are socially influenced to use new synthetic chemicals rather than rebuilding natural ecological services within the system. Ultimately, the lack of scientific evidence on the long-term use of these pesticides inhibits farmers from diversifying their farm management tactics.

Methods

This research will be conducted November 2009 - May 2010 to fulfill part of L. Atwood's Master's of Science degree. To examine these inter-related socio-ecological relationships, a multidisciplinary approach utilizing both qualitative and quantitative methods will be used. Efforts will be made to interview farmers who have previously participated in soil test research so that relationships between these data sets can be analyzed. In-depth interviews will be used to document farmers' farm management decisions, pesticide usage, and soil quality observations. During the in-depth interviews, farmers will be asked to describe their current farming practices, why they decided to farm this way, and what they perceive as the benefits and drawbacks of their management practices. Farmers will also be asked to describe what environmental impacts, if any, they have observed in the field and if they relate these adverse affects to the long-term use of glyphosate and pyraclostrobin. Finally, farmers will be asked to describe the relationship between the region's current soil quality and the future of agriculture in the region. All interviews will be taped, transcribed and analyzed using a thematic content analysis. Emergent concepts and themes from the interviews will be compiled and coded using NVivo, a coding and qualitative management program.

To determine if there are interactions and/or long-term effects of glyphosate and pyraclostrobin on soil quality, data from previously conducted soil quality and pesticide research will be compiled and analyzed using an emergent technique similar to a meta-analysis. Data-driven meta-analyses of published, peer-reviewed literature can reveal significant results that are often concluded as insignificant within a single experiment, but can be statistically significant across multiple experiments. This method was previously used to analyze laboratory experiments on the impacts of GM plants on arthropod natural enemies to determine if result summaries influence conclusions and future research (Lovei *et al.* 2009). This type of comprehensive quantitative analysis will provide a more holistic and inclusive look at the potential impacts of glyphosate and pyraclostrobin. Relevant peer-reviewed and Michigan State University Extension research will be compiled. Data-driven data analysis of these experiments will then be conducted.

Significance

Inter-related socio-ecological issues are common in today's societies, but academics often research these issues independently. Since Michigan's Thumb region is economically dependent on agriculture, this type of research will aide in their efforts to sustain agricultural viability, which also involves conservation of the region's soils. Overall, these results will not only benefit Michigan's agricultural community, but also raise critical questions regarding the long-term viability of many agricultural practices.

References

Bartlett DW, Clough JM, Godwin JR, Hall AA, Hamer M, Parr-Dobrzanski B (2002) The strobilurin fungicides. *Pest Management Science* **58**, 649-662.

Cerdeira AL, Duke SOJJoEQ (2006) The current status and environmental impacts of glyphosate-resistant crops: a review. **35**, 1633.

Duke SO, Baerson SR, Rimando AM (2003) Herbicides: Glyphosate. In 'Encyclopedia of Agrochemicals'. (John Wiley & Sons: New York).

Economic Research Services (ERS) (2009) Adoption of Genetically Engineered Crops in the U.S.: Soybeans Varieties. United States Department of Agriculture.

Gianessi L, Reigner NJCLFWDC (2006) Pesticide use in US crop production: 2002.

Grasso V, Palermo S, Sierotzki H, Garibaldi A, Gisi U (2006) **Cytochrome** gene structure and consequences for resistance to Qo inhibitor fungicides in plant pathogens. *Pest Management Science* **62**, 465-472.

Guehlstorf NP (2008) Understanding the Scope of Farmer Perceptions of Risk: Considering Farmer Opinions on the Use of Genetically Modified (GM) Crops as a Stakeholder Voice in Policy. *Journal of Agricultural*

& Environmental Ethics **21**, 541-558.

Lövei GL, Andow DA, Arpaia SJEE (2009) Transgenic insecticidal crops and natural enemies: a detailed review of laboratory studies. **38**, 293-306.

Monsanto Company (2009) Benefits of Our Products. http://www.monsanto.com/products/benefits.asp

National Agricultural Statistical Services (NASS) (2007) The Census of Agriculture. United States Department of Agriculture.

Ragsdale DW, Koch KAJPotICPTC (2008) Fungicides: Do They Adversely Affect Beneficial Insect Pathogens in Multiple Cropping Systems?

Romig DE, Garlynd MJ, Harris RF, McSweeney K (1995) How farmers assess soil health and quality. *Journal of Soil and Water Conservation* **50**, p229(228).

Sall S, Norman D, Featherstone AM (2000) Quantitative assessment of improved rice variety adoption: the farmer's perspective. *Agricultural Systems* **66**, 129-144.

Sandor JA, WinklerPrins AMGA, Barrera-Bassols N, Zinck JA (2006) The Heritage of Soil Knowledge Among the World's Cultures. In 'Footprints in the Soil: People and Ideas in Soil History'. (Ed. BP Warkertin) pp. 43-84. (Elsevier: Boston, MA).

Wardle D, Parkinson D (1990) Influence of the herbicide glyphosate on soil microbial community structure. *Plant and Soil* **122**, 29-37.

Williams BJ, Ortiz-Solorio CA (1981) Middle American Folk Soil Taxonomy. *Annals of the Association of American Geographers* **71**, 335-358.