Economic, Environmental, and Social Impacts on Agricultural Systems in Minnesota and the Republic of Georgia

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Introduction

Over the past century, global agriculture has experienced considerable intensification, with land converted to agricultural use, reduced crop diversity focusing on a small number of high-yielding varieties, and a reliance on low-cost synthetic fertilizer and pesticides (Matson, Parton, Power, & Swift, 1997). Collectivization in the 1930s in the Soviet Union followed this global trend of intensification, although the retention of small private plots maintained a certain level of diversity, especially in regards to livestock, fruit, and vegetables (Bell, 1961). Intensive agriculture has allowed crop production to increase steadily over time; however, it has lead to soil degradation and negative environmental effects (Foley et al., 2005; Matson et al., 1997). Among the environmental consequences of intensive agriculture are the contamination of groundwater by nitrates, which can cause "blue baby syndrome" in infants (Knobeloch, Salna, Hogan, Postle, & Anderson, 2000) and eutrophication and hypoxia in streams, lakes, and oceans caused by increased levels of sediment, phosphorus, and nitrogen from agricultural fields (Mitsch et al., 2001). In order for Minnesota to reach state and regional goals of nutrient loss reduction, it will be necessary to include significant cropping system changes which reduce the amount of time in which fields have no living plant cover (Minnesota Pollution Control Agency, 2014).

Cover cropping is one strategy that allows farmers to have growing plants on their fields in the fall after harvest and in the spring before planting. Cover crops have been shown to have numerous benefits including increasing soil organic matter levels and sequestering carbon (Jarecki & Lal, 2003; Poeplau & Don, 2015), improving water quality (Meisinger, Hargrove, Mikkelsen, Williams, & Benson, 1991; Qi, Helmers, Christianson, & Pederson, 2011; Quemada, Baranski, Nobel-de Lange, Vallejo, & Cooper, 2013; Tonitto, David, & Drinkwater, 2006), and reducing soil erosion (Basche et al., 2016). However, they have only been adopted on approximately 1.6% of Minnesota cropland (USDA, 2012) due to in part to difficulties in establishment, added costs and labor, nitrogen immobilization, and potential for yield loss in cash crops (MCCC, 2015; SARE & CTIC, 2016). The impact of cover crops on nitrogen cycling and cash crop yield is influenced by numerous factors, including species, C:N ratio, lignin and cellulose content, precipitation, temperature, length of growing season, tillage practices, termination type and timing, soil water holding capacity, and soil hydraulic properties

(Crandall, Ruffo, & Bollero, 2005; Jahanzad et al., 2016; Ketterings et al., 2015; Knorr, Frey, & Curtis, 2005; Meisinger et al., 1991; Poffenbarger et al., 2015; Tonitto et al., 2006; Wagger, 1989). A better understanding of the interactions between these variables will be necessary in order to make realistic recommendations to farmers for a given field and year.

Changing agricultural practices to improve environmental outcomes will require research and outreach that addresses grower concerns and meets their needs. In Minnesota, long experience with agricultural extension and surveys on farmer practices and information flows allow local researchers to effectively target research and outreach activities. We are leveraging our understanding of Minnesota growers' concerns about cover crops to conduct research which will improve our ability to make recommendations related to nitrogen requirements and yield of corn following cover crops. On the other hand, much less is known about current agricultural practices and grower concerns in the post-Soviet country of Georgia, where agricultural extension is only three years old (SRCA.gov.ge). In order to conduct research which will meet Georgian farmers' needs as well as larger goals related to environmental sustainability, a necessary first step is conducting a survey on agronomic practices, information flows, and grower motivations.

Methods

Minnesota:

Research is being conducted at three locations in southern Minnesota: Rosemount (Lindstrom silt loam soil), Lamberton (Normania loam and Webster clay loam soils), and Waseca (Canisteo clay loam soil). A soybean-winter cover crop-corn rotation was implemented beginning in 2015 and again in 2016 at each location. The study is a randomized complete block design with split plots and four replications. The main plot treatment is cover crop (medium red clover-*Trifolium pretense*, winter rye-*Secale cereal*; mix of winter rye and forage radish-*Raphanus sativus*; field pennycress-*Thalspi avense*; and no cover crop). The split plot treatment is six nitrogen rates (0-280 kg ha^{-1}). Cover crops were hand seeded before soybean harvest. In spring, they were spray terminated, left to desiccate for approximately one week, then disked. Plots were cultivated to approximately 10 cm just before corn planting.

Corn yield will be measured in each plot. Cover crop biomass will be sampled in fall and spring and analyzed for nitrogen content. Soil samples (0-90 cm depth) will be taken in two nitrogen rate plots (0 and 168 kg ha^{-1}) during soybean growth and shortly after spring cover crop termination and analyzed for total inorganic nitrogen content. Nitrogen availability will be measured throughout the corn-growing season using plant root simulator probes (which measure the soil's supply of plant available nitrogen over time) and 0-30 cm soil samples to measure total inorganic nitrogen content at eight sampling times. Mesh litterbags will be used to measure cover crop decomposition and nitrogen release. The mesh bags will be buried in the same plots as the plant root simulator probes, but with a modified study design (one year-2017, 3 replications, and 2 cover crop treatments-medium red clover and winter rye). Bags will be removed at 6 times during the corn-growing season and measured for total biomass remaining and analyzed for nutrient content (C,N,S by combustion and P,K, micronutrients by ICP-AES) and lignin and hemicellulose content (by NIR).

Georgia:

Surveys will be conducted in 2017 or 2018 of three key stakeholder groups: government and university officials; fertilizer retailer managers and employees; and rural residents of two regions: Imereti and Kakheti (the major maize and wheat growing regions). Surveys will be conducted in person, and questions will be designed and translated with Minnesota and Georgian social scientists. Research questions include: what agricultural research and outreach activities are currently ongoing; why have officials focused on these activities; what crop rotations are being used; which crops are receiving fertilizers or manure; what form and rates of fertilizer or manure are being used; what sources of information do growers have access to and which do they most trust; what factors most influence fertilizer or manure use; and what additional information on soil fertility would be growers most want to have.

Summary

Intensive agriculture has numerous negative environmental effects, including degrading water quality. Reducing these effects in Minnesota must include practices which lengthen the time in which crops are growing on fields. Cover crops can improve environmental outcomes, but a better understanding of the mechanisms impacting nitrogen availability and cash crop yields is necessary to improve farmer adoption. On the other hand, the collapse of intensive Soviet collective farming in the 1990s and resulting reduction in fertilizer use (FAO, n.d.) provides an opportunity for Georgia to rebuild its agricultural system in a more sustainable manner. In order to target the most effective areas for agricultural research and outreach, more data needs to be gathered on current practices and information flows.

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