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Exploring agricultural advice networks, beneficial management practices and water quality on the landscape: A geospatial social-ecological systems analysis

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ABSTRACT

Agricultural practices have been linked to detrimental effects on ecosystems, with water quality of particular concern. Research has been devoted to understanding uptake of beneficial, or best, management practices (BMPs) in agriculture; however, sources of advice and subsequent effects on the landscape have not been elucidated. This study set out to understand (1) what sources of information agricultural producers rely on when making land-management decisions; (2) the characteristics of their advice networks; and (3) how the advice network linked spatially to water quality on the landscape. A watershed in Alberta was used as a case study and respondents identified that regional advisors were relied upon most often for advice and these advisors had the most influence on the adoption of BMPs. Results indicate that respondents with connections to regional actors implemented more BMPs that those without. Regional government actors had a greater effect than regional non-governmental actors. Local actors played a lesser role in advice networks related to BMP adoption. A 3D geovisualization was used to explore linkages among advisors, BMPs, and water quality. This technique may be useful for other scenarios and can contribute to policy development and enhanced practices.

1. Introduction

The intensification and industrialization of agriculture has led to apprehension about the myriad of potential impacts on the environment, the need for continuous improvement of practices, and the overarching imperative of sustainability. Potentially serious detrimental effects on ecosystems have accompanied marked gains in productivity (Tilman, 1999; Tilman et al., 2002; Plummer et al., 2008). These effects are not restricted to large or intense operations. Small and moderate sized farms may also cause environmental damage, and in some instances, their practices may have a greater environmental impact due to lack of capital, absence of technologies, and less stringent reporting requirements (FitzGibbon et al., 2002). While soil erosion and sedimentation are longstanding effects associated with agriculture, the adverse effects from modern practices have grown in terms of diversity and extent (see Stoate et al., 2009; Gomiero et al., 2011 for examples of reviews).

The effects on water quality from agricultural practices are pervasive, a growing issue of public concern, and a challenge to policy makers. Drawing upon data from water bodies surveyed in the National Water Quality Inventory, the United States Environmental Protection Agency (USEPA, 2002) reported that nonpoint source pollution from agriculture was the leading cause of degradation of water quality in rivers and lakes, the second greatest contributor to wetland impairments, and a major contributor to groundwater and estuary contamination. Within the Organisation for Economic Co-operation and Development countries, "... agriculture is often the main source of water pollution" and attempts to address it costs billions of dollars (OECD, 2012, p. 9).

Pollution from agricultural activities is almost exclusively nonpoint source in nature (Weersink et al., 1998). Nonpoint sources of pollution are diffuse as opposed to originating from a single identifiable source. Nonpoint sources are also complicated. In specific reference to agriculture as a nonpoint source of water pollution, (1) the point of origin is typically 'invisible' or low in concentration

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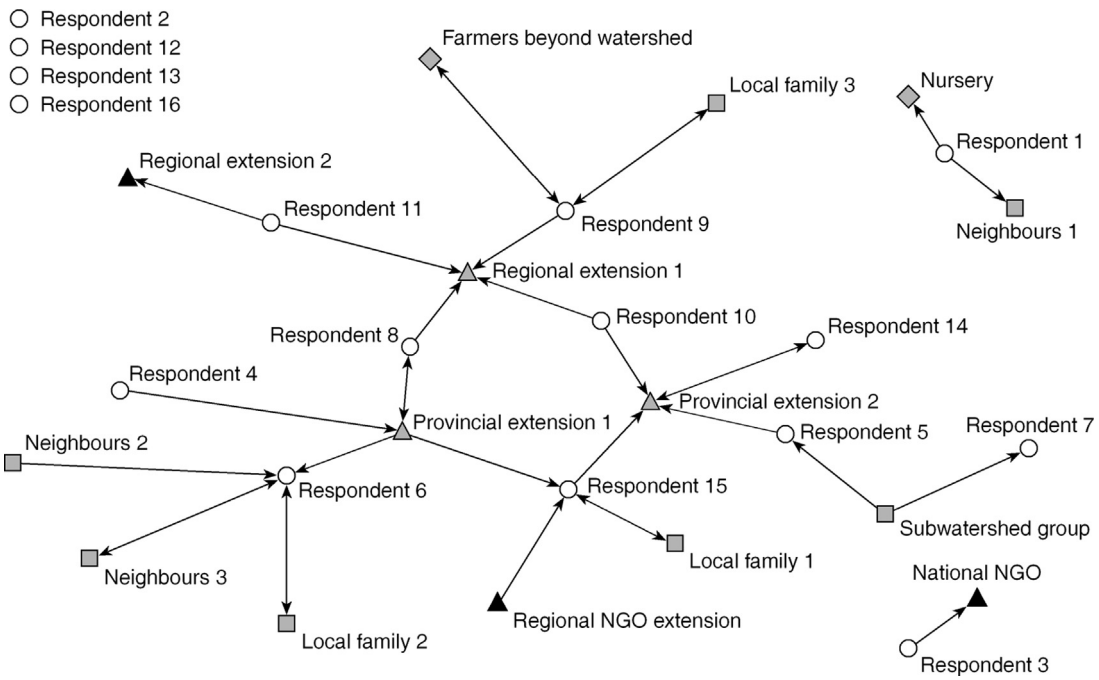

Fig. 1. Respondent advice network. White circle nodes represent respondents and grey and black nodes represent non-respondents (grey triangle = governmental regional actor; black triangle = non-governmental regional actor; square = local actor; diamond = other business).

and the paths by which pollution enters water systems are complex; (2) the impact from diffuse sources over a large area tend to have a cumulative impact; and (3) the impacts are influenced not only by farm activities on the land but also stochastic events and physical properties (Baird, 2012; OECD, 2012).

Effectively addressing nonpoint sources of pollution is a substantive challenge. Agriculture is emblematic of the limitations associated with the regulatory approach due to the volume and diffuseness of sources, technical complexities and costs of monitoring, uncertain causal relationships and difficulties in assigning attribution, and cumulative effects (Weersink et al., 1998; Plummer et al., 2008). The effectiveness and efficiency of traditional regulations as a way to garner compliance regarding agriculture pollution has been critically questioned (Young and Karkosky, 2000; Pretty et al., 2001; Dowd et al., 2008; Plummer et al., 2008). Dowd et al. (2008) reviewed the agricultural nonpoint source pollution policy literature and categorized it into voluntary programs, command and control programs, and economic instruments. Beneficial management practices (or 'best management practices' in the United States) (BMPs) can apply to all three categories and are integral to mediating environmental degradation effects from agricultural practices.

The application of BMPs in the United States grew out of the Soil and Conservation District movement of the mid 1930s (see Ice, 2004 for a history). A BMP is generally considered "a farming method that minimizes risk to the environment without sacrificing economic productivity" (Hillard et al., 2002 p. i). Agricultural BMPs to protect water quality encompass on-field improvements, edge of field sinks, and multiple BMPs at watershed scales (see USDA, 2013 for examples). While the characteristics of nonpoint source pollution make it challenging to document their effectiveness (Mulla et al., 2006), insights are being gained into their effects on water quality at different spatial and temporal scales (Chaubey et al., 2010; Meals et al., 2010; Lam et al., 2011).

Adoption of BMPs has been used as an indicator of the sustainability and resilience of the agricultural sector (MacKay and Hewitt, 2010). Despite ongoing extension efforts and financial support for adoption of BMPs, uptake has been relatively low –40% throughout Canada (Eilers et al., 2010) and 56% in Alberta in 2014 (IPSOS REID, 2014). To the authors' knowledge, similar broad assessments of agricultural BMP uptake have not been conducted in other countries; however, a commodity-specific assessment in Australia revealed approximately 60% of land area devoted to cotton production had been registered in a BMP auditing program (WWF Australia, 2005).

Research has been devoted to understanding how and why BMPs and conservation practices are adopted. From their analysis of more than 2500 research reports on this subject in 2006, the United States Department of Agriculture Natural Resources Conservation Service highlights that producers most commonly go through six stages associated with the adoption-diffusion model (awareness, interest, evaluation, trial, adoption, and adaptation) when implementing conservation (American Farmland Trust, 2013). Investigating variables that influence the adoption of conservation practices in agriculture have been the subject of several reviews (e.g., Pannell et al., 2006; Knowler and Bradshaw 2007; Prokopy et al., 2008). Given methodological limitations and relative insignificance of findings from previous reviews, Baumgart-Getz et al. (2012), (p. 17) conducted a meta-analysis of 46 studies on BMP adoption in the United States from 1982 to 2007 and found that the largest impact on adoption was from "... access to and quality of information, financial capacity, and being connected to agency or local networks of farmers or watershed groups."

Accessibility of information is one of the main reasons BMP adoption is limited (Brethour et al., 2007; Bjornlund et al., 2009) and the pathways by which agricultural producers access information and advice regarding their land management decisions remains unclear. It is important to understand whom farmers are relying on for information and/or advice regarding land management practices to potentially influence decision-making at the individual scale (Prell et al., 2009; Knoot and Rickenbach 2011) and to promote continual improvement and development of new practices by researchers (Council of Canadian Academies, 2013). The effectiveness of formal government information pathways may be limited as agricultural producers often mistrust these agencies and/or find the costs to outweigh the benefits in gaining access