SOIL EROSION RISK AND MITIGATION THROUGH CROP ROTATION ON ORGANIC AND CONVENTIONAL CROPPING SYSTEMS

BY

ALISON G. NELSON

A Thesis
Submitted to the Faculty of Graduate Studies
in Partial Fulfillment of the Requirements
for the Degree of

MASTER OF SCIENCE

Department of Plant Science
University of Manitoba
Winnipeg, Manitoba

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ABSTRACT

Nelson, Alison G. M. Sc. University of Manitoba, April 2005. Soil Erosion Risk and Mitigation through Crop Rotation on Organic and Conventional Cropping Systems. Major Professor: Dr. Jane Froese

Organic cropping systems are often accused of increasing soil erosion risk through an increased use of tillage for weed control. However, little research has been conducted in Canada regarding soil erosion risk on organic farms. It is known that crop rotations can be used to ameliorate a variety of agronomic problems encountered in cropping systems, including soil erosion. Organic systems, which do not use synthetic pesticides and fertilizers, rely more heavily on crop rotations than conventional systems to solve agronomic problems such as weeds and insects. The objective of this study was to compare cropping practices (including crop rotations and tillage regime) on organic and conventional cropping systems, and examine the effect of crop rotation (annual-, biennial-, or perennial-containing rotations) and management (organic or conventional) on soil properties relating to wind and water erosion risk.

A mail-out survey was the source of data on soil conservation, crop rotation and tillage practices from 225 organic and conventional farmers in the study provinces of AB, SK, MB, ON, PEI, NB and NS. When compared to conventional farmers, organic farmers had more perennials and green manures in rotation, but fewer organic farmers had zero tillage practices on their farm. More organic farmers had other soil conservation practices (such as shelterbelts, contour tillage, ridge tillage and the use of composts) on their farm than conventional farmers.

Soil from three long-term rotation studies in the prairies (Lethbridge, AB; Scott, SK and Glenlea, MB) and 25 paired organic and conventional farms (in AB, SK, MB,

ON, PEI and NS) was sampled. The effect of management and rotation on dry and wet aggregate stability, as well as percent organic carbon (C) was determined. At the long-term studies, the biennial-containing rotation resulted in the highest wet and dry aggregate stability. Management significantly affected organic C in both the long-term studies and the farm pairs, with the organically managed soils having lower C contents than the conventionally managed soils. Despite the lowered organic C levels in the organic systems, aggregate stability remained higher, or equivalent to the conventional systems. This result indicates that aggregate stability in the organic systems is independent of total organic C levels at the current time (however, there are limitations to lowered levels of organic C, and at some point lower C will begin to affect soil properties). The organic soils may be higher in certain C compounds (such as polysaccharides) that stabilize the soil aggregates, but do not alter the total organic C levels.

Few differences in the measured soil properties of the paired organic and conventional farms were found. However, when farms were compared based on having an annual- or perennial-containing rotation, the farms with perennials in rotation were found to have higher wet aggregate stability. Rotation (annual- versus perennial-containing rotations) had a larger effect on wet aggregate stability and percent organic C than management in the farm pairs.

Organic management does not inherently lead to a higher risk of soil erosion than conventional management. While organic systems generally have higher intensities of tillage than conventional systems, organic farms also tend to have more perennials in rotation, which has been shown in this study to lower the risk of soil erosion.

FORWARD

This thesis has been written in manuscript style. The manuscripts were prepared in accordance with the style requirements of the Canadian Journal of Plant Science.

CHAPTER 1

GENERAL INTRODUCTION

Soil erosion has been a problem in Canadian agriculture since cultivation began and native ecosystems were converted to cropland. All cultivated land in Canada has been affected by, or has the potential for, soil degradation (Science Council of Canada 1986). Soil erosion by water (Shelton et al. 2000) and wind (Padbury and Stushnoff 2000) still pose a threat to the sustainability of Canadian agriculture today. The 1980's saw a large number of research agendas focused on the problem of soil erosion. Numerous publications and workshops occurred around this time (Soil Conservation Committee of the Agricultural Institute of Canada 1980; Science Council of Canada 1986; Prairie Farm Rehabilitation Administration 1983; van Vliet 1983). At this time, a number of soil conservation initiatives gained favor with farmers, such as reduced tillage practices and decreased use of summerfallow. Wind erosion risk was estimated to have decreased by seven percent in the Prairies between 1981 and 1991 due to conservation tillage practices and cropping system changes (Wall et al. 1995). Water erosion risk in Canada decreased by 11% during the same time period, also because of conservation tillage and cropping system changes (Wall et al. 1995).

The risk of soil erosion is affected by a number of soil properties, including dry aggregate stability, wet aggregate stability and organic carbon (C). These soil properties are affected by cropping system management practices, of which tillage and crop rotations are extremely important in determining soil erosion risk. Dry and wet aggregate stability indicate the soil's resistance to wind and water erosion, respectively (Lehrsch and Jolley 1992). Organic C helps to build soil structure and stability (Watson et al.

2002). Cropping practices such as including forages in rotation, applying manures, and using green manures have been found to increase organic C and aggregate stability levels (VandenBygaart et al. 2003; Biederbeck et al. 1998; Entz et al. 2002; Aoyama et al. 1999a; Aoyama et al. 1999b). All of the practices mentioned above are believed to be more common in organic systems compared with conventional systems, and these practices will help to decrease soil erosion risk.

Organic agriculture is increasing is popularity in Canada. Market sales of organic products have increased at a 15 to 20% annual rate of growth for the decade before 2003 (Haumann 2003). Consumers are increasingly demanding organic products because of concerns about food safety (genetically modified organisms, as well as pesticide, hormone and antibiotic residues) and negative environmental effects of conventional agriculture production (Klonsky 2000). On the production side, farmers are choosing to convert their production to organic for many reasons, including: reduction of input costs and a possible increase in profits (Willick 2004), increased farmer independence (Entz et al. 2001), as well as a concern about the negative health or environmental impacts of synthetic chemical use (Henning 1994).

There are many claimed benefits and limitations to organic agriculture, yet few of these claims have been confirmed through scientific investigation. One of the alleged limitations of organic agriculture is that it increases the risk of soil erosion through an increased use of tillage for weed control; however, few studies have compared soil erosion risk in organic and conventional systems in Canada (Moulin et al. 2001; unpublished data, Alan Moulin), and none have compared soil erosion risk on organic and conventional farms.

This study examined current organic cropping systems in Canada and how they compared to non-organic systems with respect to soil erosion prevention. The research was undertaken on a large geographic scale, encompassing ecozones in Alberta, Saskatchewan, Manitoba, Ontario and Prince Edward Island. There were three major objectives to the study. The first objective was to characterize cropping practices related to soil erosion risk on organic and conventional farms in certain Canadian provinces, and identify differences (if any) between organic and conventional systems. Secondly, the soil properties affecting erosion risk were compared on organic and conventional systems for various combinations of rotations involving annual, biennial and perennial crops using long-term organic versus conventional studies located in the prairie provinces. The final objective was to compare the soil properties related to erosion risk on organic and conventional systems in the study provinces using soil samples obtained from paired comparisons of organic and conventional farms of similar crop rotations.

CHAPTER 2

LITERATURE REVIEW

Introduction

The negative environmental impacts of modern industrial agricultural practices are receiving increasing attention by both the general public and the agricultural industry itself. For this and food safety reasons, environmentally sustainable agricultural initiatives such as organic farming are becoming more popular (Klonsky 2000). Organic agriculture is one of the more commonly known alternative agricultural systems that attempts to attain environmental sustainability. Despite the increasing popularity of organic agriculture (as evidenced by an increasing number of certified organic farms and organic food sales in Canada, (Haumann 2003)), there is a lack of information regarding these systems and their environmental impact on the Canadian agricultural resource.

Soil Erosion

EFFECTS OF SOIL EROSION. Soil erosion refers to the wearing away of the earth's surface. This is a natural phenomenon that both helps to form soil and also, more commonly, cause soil loss. Particular agricultural practices, such as field enlargement, the removal of perennial crops and vegetation and lack of soil cover in the winter (Baudry and Papy 2001), can accelerate the rate of soil loss through erosion to unsustainable levels (McRae et al. 2000).

Soil is a critical resource to both plants and animals. Soil functions include serving as the biological habitat and gene reserve for numerous organisms; a filter, buffer or detoxifier of compounds between air, water and plant roots; as well as the medium for production of biomass, which provides food, fodder and energy for animal life (Blum 1998). The loss of soil through erosion is, therefore, an important issue on many levels. For agricultural systems, the loss of soil can mean the loss of productive land and the restriction of crop types grown in rotation to lower valued crops (e.g., substituting forages for cash crops in rotation). This restriction of crop types can come either through legislation (Ketcheson 1977) or through a loss of soil quality and, therefore, soil productivity (Verity and Anderson 1990).

Soil erosion degrades the quality of soil through the loss of organic matter, soil structure and nutrients (Soil Conservation Committee of the Agricultural Institute of Canada 1980). Bauer and Black (1994) found that soil erosion decreased soil productivity because the lowered soil organic matter content resulted in a decline in soil fertility. Larney et al. (2000) found that a removal of 20 cm of topsoil lead to declines between 36 to 71% of the soil organic carbon levels in the top 7.5 cm of soil at four research sites in Alberta. These effects have social, economic and ecological consequences.

HISTORY OF SOIL EROSION IN CANADA. Significant soil losses have occurred on agricultural land in Canada since cultivation began. During the 1980's, some researchers attempted to quantify the tolerable rates of soil loss, the total amount of soil lost through erosion in Canada, and the economic impact of erosion. A soil loss rate of less than 6 t ha^{-1} $year^{-1}$ has been identified as a tolerable or sustainable for most agricultural areas, meaning that this rate of soil loss is generally offset by the rate of soil formation (Shelton et al. 2000). Using the 1981 agriculture census, and a soil loss value of 10 or more t ha^{-1}

$year^{-1}$ indicating moderate or severe rates of erosion, Dumanski et al. (1986) estimated the area of land affected by water and wind erosion. They concluded that in Canada, 5.84 million hectares of arable land had been affected by moderate or severe water erosion levels while 6.36 million hectares had been affected by wind erosion levels that were either moderate or severe. The estimates of the on-farm economic impact of these erosion figures ranged from 266-424 million dollars for water erosion and 218-283 million dollars for wind erosion.

The prairies have been greatly affected by both wind and water erosion, with moderate or severe (i.e., over 10 t ha^{-1} $year^{-1}$ of soil loss) water and wind erosion levels occurring on 4.64 million hectares and 6.31 million hectares of land, respectively (Dumanski et al. 1986). In the grain growing areas of the prairies, 14% of improved farmland has lost significant amounts of topsoil through erosion (Science Council of Canada 1986). De Jong and Kachanoski (1988) estimated that organic carbon levels have declined by 40-50% in the Chernozemic soils over the past 80 years, and that 70% of organic carbon losses in a Black Chernozemic soil after 50 years of cultivation are due to erosion. The same study found that erosion was the major factor affecting organic carbon losses on study sites in Saskatchewan between the mid-1960's and the early 1980's.

SOIL CONSERVATION. Soil conservation refers to all practices that reduce or prevent the degradation of soil, including preventing erosion, salinization and compaction of soil.

Changes in cropping and tillage practices within the last two decades have combined to decrease the overall wind and water erosion risk in the majority of Canadian provinces. Cropping practices have shifted towards a reduction in the amount of