Water Quality/Quantity Issues for Sustainable Agriculture in Canada

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Abstract: Intensification of agriculture, with growing use of fertilizers and pesticides, and the increasing separation between animal and crop production, are creating problems for water quality in Canada. Excessive nitrate content is observed in many water bodies, and pathogens may also occur as a result of manure disposal. Climate change is expected to increase the pressure on the water resource, both from the quantitative and qualitative points of view. Environmental sustainability is a major concern for policy-makers, and maintaining the health of the natural resources is increasingly part of programs and policies. Research is supporting these efforts through the development of cropping systems and best management practices that will help alleviating the pressure on the soil and water resources.

1 Introduction

The contribution of agriculture to Canada=s Gross Domestic Product from the primary production sector amounts to 29%, and it is second to mining and energy, and before forestry (AAFC, 2000a). Extensive efforts are therefore made by the federal and provincial governments in collaboration with the industry, to ensure that the sector operates and grows in a sustainable manner. Agricultural production implies the addition of inputs, e.g. nutrients, pesticides, technology, capital, labor, solar energy, to the natural capital, i.e. soil, water, air and genetic resources, to produce crops, livestock, fibre, landscape management, and waste. The export of a large percentage of the production from the production site, with a decline in the biomass content of the soil, is a characteristic of the agroecosystems.

The transformation of natural ecosystems to agroecosystems and the structural changes in agricultural production that occured over the years, i.e. fewer but larger farms, greater farm specialization, more intensive crop and livestock production, put much pressure on the environment and have extensive impacts on soil and water quality. The decline of the organic matter content level by 15-30 % in many agricultural soils, and changes in the soil structure and biological activity following the clearing of the land for cultivation (Gregorich *et al*, 1995), reduce the ability of the soil to fulfill its functions of storing water for plant use and filtering the water flowing through the soil (De Kimpe and Warkentin, 1998).

Agriculture is the most important water consuming sector in Canada: it withdraws some 9% of the water used for human activities, but returns only 30% to the source, the remaining being lost to the atmosphere through evapo-transpiration. This situation will not improve in the future considering the potential effects of climate change. The objective of this paper is to discuss the interactions between agriculture and water in Canada, and examine some solutions that are proposed to address these environmental issues.

Context of Canadian agriculture

With over 90% of the total land area being rural, Canada is also an Aurban@ country (AAFC, 2000b). In 1991, 56% of the population lived in cities of more than 500,000 inhabitants. In 1996, the rural population declined to about 31%, and the population actively engaged in agriculture was approximately 3%, a percentage similar to several other industrialized countries. Non-agricultural rural residents are expressing concerns about the environment, especially about the presence of intensive animal production units, and the odor and manure disposal issues.

On a relative basis, Canada has only a small share of land available to agriculture: it represents some 7% of the land area, compared to an average of 58% in Western Europe and 47% in the United States. Over the last 25 years, the total farmland remained relatively constant, with about 83% in the semi-arid Prairies, and some 13% in Quebec and Ontario. Only half of the 68 million ha available to agriculture is considered prime agricultural land. Between 1901 and 1996, the cultivated land, i.e. the area under crops and summer fallow, expanded five-fold, while the amount of dependable land decreased by about 16% over this period because of the conversion to urban and non-agricultural uses (McGregor and McRae, 2000). Since the 1980s, the area under cultivation exceeds the area of prime land. The apparent stability of the agricultural land base masks another reality: the continuing loss of prime farmland to urban development prompts farmers to use environmentally sensitive lands for crop production, with impacts on farm productivity, yield and the environment. In the central provinces, Ontario and Quebec, the conflict between the agricultural and non-agricultural uses of the land is more acute and is growing because this region, an area of about 80,000 km^2, supports over 60% of the Canadian population. Urban pressure on the land is even more severe in southwestern Ontario, that lost some 60,000 ha of prime agricultural land in the last 20 years.

The need to increase food production prompted the development of new and improved varieties designed to maximize yields, facilitate multiple cropping, and resist diseases. New management practices, integrated pest management and rotations were introduced. A chemical revolution helped achieving the potential yield of these improved varieties: fertilizer use increased by nine-fold between 1950 and 1985, and pesticide use by thirty-two-fold (Hopper, 1995). The growth in fertilizer use in Canada was also a consequence of the former approach of using existing soil nutrients and /or under-fertilizing the crops, which resulted in a decrease of soil quality and fertility.

2 Water quality

The report on agri-environmental indicators (McRae *et al*., 2000) was the first step towards a comprehensive assessment of the agroecosystem sustainability, using indicators to measure the performance of the agricultural sector in relation to specific environmental objectives. One indicator addressed water contamination. The risk of water contamination was preferred to absolute values of water quality, that are difficult to define as the concept of water quality is related to the intended subsequent uses of the water. In this report, the risk of water contamination was developed from the perspective of N (MacDonald, 2000a) and P (Bolinder *et al*., 2000) loading. However, agricultural activities contribute to impairing water quality in several other ways:

$ Sediments result from soil erosion by wind or water: from 1981 to 1996, the risk of water erosion exceeding a tolerable level decreased by amounts varying from 2 to 25% in the Prairies, Ontario and New Brunswick; wind erosion on the prairie cropland fell by 30%; and tillage erosion dropped by 22%. Introduction of no-till and conservation tillage contributed largely to the protection of the soil resource.

$ Nitrogen surpluses and residual nitrogen: about 3.5 million tonnes of chemical fertilizers and 2 million tonnes of sewage sludge are applied to the agricultural land every year. Livestock produce some 300 million tonnes of manure per year, and most of it is disposed of on the cropland. As a result of crop intensification, the amount of fertilizer applied to the field has been growing, which is probably the most important source of concern for water quality in Canada (Chambers *et al*., 2001). The accumulation of residual nitrogen under the root zone in the Prairies may be a long-term threat for water quality, as an increase in rainfall would release this nitrate to groundwater.

$ Pesticides can wash off farmland and enter surface water with surface runoff, or leach through the soil and contaminate groundwater. Pesticides may also be transported as aerosols following spraying, and reach water bodies with rainfall. Pesticides and their residues are commonly detected in surface waters, but most often at a concentration below the drinking water quality guidelines (CCME, 1999). Concentration sometimes exceeds the recommendations for aquatic life and irrigation water. However, the situation has improved in recent years. For example, between 1992 and 1995, the frequency of atrazine concentration exceeding water quality guidelines for drinking water and aquatic life decreased from 22 and 43% to 6 and 16%, respectively, in four rivers of Quebec draining intensive corn-producing areas (Giroux *et al*., 1997).

Table 1 Change of nitrogen status in agricultural land between 1981 and 1996 (MacDonald, 2000a and b)

Province	Farmland (M ha)*	% of farmland where nitrogen content changed			% of farmland where residual nitrogen changed		
		decrease	no change	increase	decrease	no change	increase
British Columbia	1.5	51	31	12	51	22	27
Alberta	17.7				7	51	42
Saskatchewan	23.0				2	45	53
Manitoba	6.7				1	19	80
Ontario	4.2	2	30	68	0	31	69
Quebec	1.9	1	22	77	1	28	71
Atlantic Provinces	0.4	2	36	62	2	44	53

* Farmland area is the sum of all 1996 Census of Agriculture land classes except All Other Land. The British Columbia land base for change in N content is 0.1 Mha, which corresponds to the South coastal region only.

$ Endocrine Disruptive Compounds (EDC): the agriculture sector has been identified as a potential source of environmental EDCs through pesticides and land-applied sewage sludge, and natural EDCs present in livestock wastes. Research so far indicates that farming operations are not a significant source of EDCs

(E. Topp, personal communication, 2001).

$ Pathogens: the presence of fecal coliform bacteria may indicate that water has been contaminated by human or animal waste. Pathways for water contamination by bacteria is with runoff and also following application of manure to no-tilled soil: bacteria can rapidly reach the tile drainage network through the main soil pores, especially in well structured heavy soils. The ABest Management Practice@ is to break up the soil surface before applying manure to these soils.

Other toxic substances such as heavy metals: the risk of water contamination following application of municipal sewage sludge will be minimal when observing the guidelines for application. However, the mobility of heavy metals may be enhanced by soil microorganism activity (De Kimpe, 2002)

Regional impacts of agricultural production on water quality can be summarized as follows:

In the humid regions of British Columbia, Ontario, Quebec and the Atlantic Provinces, the percentage of farmland at increasing risk of water contamination varies between 57 and 67%, whereas in the Prairies, 53% of farmland shows increasing residual nitrogen. Water quality is decreasing in areas with high livestock production, as shown by the number of wells that contain contaminants. Several aquifers, such as the Abbotsford-Sumas aquifer in British Columbia, are contaminated by nitrate. This regional analysis was further documented by Environment Canada (Chambers *et al.*, 2001). Nutrient addition to low-nutrients waters stimulates aquatic plant and animal productivity, and increases biodiversity. However, prolonged nutrient addition results in excessive aquatic plant growth, loss of plant species, depletion of oxygen, and deleterious changes in abundance and diversity of aquatic invertebrates, fish and possibly birds and mammals depending upon these habitats. There is evidence that nutrients are damaging the environment in Canada, although the severity and geographic extent of nutrient-induced problems are less important than in countries with a longer history of settlement or agricultural production.

It is simplistic and not scientifically correct to say that the increasing use of fertilizers *per se* is responsible for water contamination. Contamination may be attributed only in part to improper management of nutrients. Other factors, e.g. high intensity rainfall events, the precipitation distribution pattern over the year, as well as the climatic conditions prevailing in the areas that support agricultural activities, must be considered to interpret the effects of nutrients on water quality. Most of the cropland in the Prairies is in the semi-arid region with less than 250 mm of annual rainfall in the driest part, and less than 600 mm in the remaining part (A. Bootsma, personal communication, 2002), and a mean annual snowfall between 50 and 150cm. Annual rainfall is more abundant in the eastern part of Canada, where it ranges between 600 and 1,250 mm, with an excess of precipitation over the amount of water used by the crops, and snowfall between 150 and 350 cm. Finally, annual rainfall is highest in coastal British Columbia, where it ranges between 1,250 and 2,250 mm. When the snow melts in the spring, it may contribute to leach some of the residual nitrogen not used by the crop in the preceding year (MacDonald, K.B. 2000 b).

Processes controlling an efficient nutrient cycling within the root zone are not fully understood (De Kimpe, 2002). For example, there is a need for understanding better the role of microorganisms in the mineral nutrition of plants. Better synchrony between the processes linking mineralization of N and P with plant N and P uptake is desirable. Addressing such fundamental questions will help minimizing the losses of N and P in the environment.

3 Water quantity

Dry regions in the interior of British Columbia and the southern Prairies have severe soil moisture deficits during most summers and can also suffer from long-term drought conditions.. These areas hold most of the 1 million ha of irrigated land in Canada, especially in Alberta, where water for irrigation is more available. Despite more favorable conditions prevailing in central Canada, drought periods may also exist in southwestern Ontario: in the summer of 2001, corn yield was much affected in some areas. Corn grew well in April-June with rainfall being 70%—100% of the average, but later growth was limited in soils with low water holding capacity by a lack of moisture in July-August, when rainfall was 30-50 % of the average (Stewart, 2001). Irrigation is used sometimes in Ontario for high-value crops. Where available, municipal effluent is also used for irrigation, and this provides an additional source of nutrients. Extension of irrigation in Canada will depend upon the availability of water. Use of groundwater for irrigation is in direct competition with other uses, and withdrawals would not exceed the recharge rates. Competition for water among users is expected to grow as water supplies become less available, giving rise to conflict in some cases. Effective solutions involve the management of the demand and the development of improved irrigation techniques that will make better use of the water available, e.g. trickle irrigation for fruit trees.

4 Policy approaches and prospect for the future

- Water quality and quantity issues were identified in the June 1990 federal/provincial report on environmental sustainability (Anonymous, 1990). This resulted in a National Soil and Water Conservation program
  - In 1997, Agriculture and Agri-Food Canada published its first Sustainable Development Strategy that contained a strategic direction on the promotion of environmental and resource stewardship (AAFC, 1997). Focus was on the impact of agriculture on off-farm water quality. The strategy called for an ecosystem approach and the need to identify vulnerable areas, especially with respect to water quality.
  - In 2001, the second Sustainable Development Strategy (AAFC, 2001) renewed the commitment for the environmental sustainability of the natural resources. It recognized also the need to enhance the sector=s capacity to reduce the risk of water contamination by manure and nutrients.
  - In June 2001, the federal and provincial ministers of agriculture agreed to work towards a comprehensive plan for accelerated environmental action, fully covering all farms, that will help achieving measurable and meaningful environmental results and management goals in the areas of water, air and soil quality, and bio-diversity.
  - One of the business lines of Agriculture and Agri-Food Canada is directed towards the Health of the Environment, with a commitment to use the environmental resources in a manner that ensures their quality and availability for present and future generations.
  - Several tools are used in the areas of policies, programs and research, and by producers, to improve water quality:

— environment farm plans: such a program was initiated in Ontario, and it is proposed to extend it to all farms across the country. The objective is to have farm families identifying the environmental strengths and weaknesses of their operations, and developing an action plan that can help them farm more sustainably.

- nutrient management plans are proposed to help farmers achieve optimal crop yields and product quality, manage input costs, while protecting soil and water resources (De Kimpe and MacDonald 1998). Nutrient management plans take manure into account, and amounts of chemical fertilizer to be applied are reduced accordingly.

— water table management: in the humid regions with sub-surface drained land, the drainage system eliminates the excess of water, but it may also provide sub-irrigation in the summer if a water source exists. Alleviating crop water stress enables the crop to take up more nutrients and reduce the amount of residual nitrate at the end of the growing season. Controlled drainage-irrigation systems allowed to reduce nitrate losses by 40-55 %.

— IPM techniques are being developed as alternatives to pesticides in the control of pests and diseases.

— the conservation of riparian areas, using a permanent vegetative cover, with or without limited agricultural activities and no access to livestock, allows to improve the filtering capacity of the soil and to create a barrier between the field and the streams.

— reduced tillage (no-till was used on 14% of the cropland area in 1996) and crop residue management contribute to reduce the erosion and sediment loading to the water bodies.

— water conservation and irrigation management contribute to reduce the amount of water used by the agri-food sector.

— NLWIS: the National Land and Water Information Service is designed to assist farmers and decision-makers in proposing the best use of the natural resources.

— Codes of practices are being developed in several areas: they provide guidelines that producers can follow to ensure that their management practices are environmentally sustainable.

— research is working on the understanding of the factors responsible for water contamination, and on the protection of the vulnerable recharge areas of aquifers in order to protect public health.

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