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DISPLACEMENT OF FERTILIZERS AND PESTICIDES IN WHEAT CULTURE IN NORTH AMERICA

prepared for

Commission for Environmental Cooperation of North America

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1 INTRODUCTION

The Commission for Environmental Cooperation (CEC) continues to deepen understanding of the environmental effects of free trade and related market integration, at the sector-specific level. Future work will continue to build on previous analyses of the effects of liberalization in the energy and agricultural sectors, as well as related institutional issues. Other projects have shown that at the aggregate level the environmental effects of free trade are marginal. However, when disaggregated, analysis suggests a concentration of some environmental impacts in specific geographic regions and sectors of the economy, as well as the presence of peak and troughs in key environmental indicators, justifying an 'environment-first' approach.

The agriculture sector has experienced rapid changes over the last 10 years and will be experiencing further liberalization under the WTO Doha Round negotiations and possibly the Free Trade Area of the Americas. While embarking on these changes, the question is how to ensure North Americans (and the world) have an affordable and abundant supply of food while maintaining environmental and health objectives.

Agro-chemical inputs into agricultural production have been demonstrated to have large environmental impacts that are hard to address after the inputs have been used in agricultural production since these inputs become non-point sources, diffuse in nature and not easily observable or controllable in the same way that 'end-of-pipe pollution' is. It thus follows that intercepting or avoiding those synthetic fertilizers and pesticides, before their release into the environment, could be an effective strategy for reducing the presence of these substances in the environment, and improving public and ecosystem health. The focus of this project is to document the 'displacement' of these fertilizers and pesticides which results from a more sustainable, and less chemical-intensive agriculture.

Because no standard emission levels exist for agriculture as exist for other sectors, such as the electricity or manufacturing sectors, measuring displacement of agricultural fertilizers and pesticides is more involved. However, this exercise is intended to be a starting point that will allow for the identification of areas of scientific uncertainties and unknowns that could help to prioritize research in areas that are most vital for the health of our ecosystems.

The purpose of this study is to quantify fertilizers and pesticides which could be prevented from being released to consumers and the environment through an 'organic portfolio standard.' The notion of 'organic portfolio standard' comes from the use in many States in the United States, which are considering or have adopted renewable energy portfolio standards. These standards set a minimum proportion of electricity that is required to be generated from ‘renewable,’ or cleaner sources in a given jurisdiction. Generally they determine both a proportion of electricity generation or consumption that is required to be renewable, as well as what sources of electricity qualify as ‘renewable.’ The notion of the organic portfolio standards is similar in that it would determine the proportion of agricultural production or consumption that would have to be produced ‘organically,’ within a given jurisdiction. Though organic agriculture is one among various ‘sustainable agricultural methods,’ pollutant displacement is more easily quantifiable using organic practices, given that specific standards for what qualifies as organic already exist, with respect to what inputs can and cannot be used (e.g. US Organic Standard, CODEX Organic Standard, National Standards of Canada for Organic Agriculture, etc.).

Regional trends will be described. In addition data gaps and questions meriting further study will be noted. The focus is on wheat systems as distinct from other crop systems, but the information presented at this stage relates to just the wheat portion; an extension of this work, to include the other crops in rotation with wheat would treat the wheat system as a whole.

2 APPROACH

The concept for this report is to compile the rates of application of potentially polluting substances used in wheat systems - first for mainstream agricultural practice and then for organic practice[1]. Also, plausible scenarios of wheat areas shifting from mainstream to organic practice are presented. Given that rates of application of these substances are lower or zero in organic practice[2] than in mainstream practice, estimates are made of the amounts of fertilizers and pesticides which are now, and could be in future, ‘displaced’

[1] A summary of the requirements for organic certification in Canada:
To be certified organic the grower must make no use of chemical fertilizers or herbicides, and submit their land and produce to strict testing to meet the requirements of the Canadian General Standards Board (CGSB), which sets standards for many types of industries.

Principles of organic production as stated by the CGSB are as follows:
- Protect the environment, minimize soil degradation and erosion, decrease pollution, optimize biological productivity, and promote a sound state of health.
- Replenish and maintain long-term soil fertility by optimizing conditions for biological activity within the soil.
- Maintain diversity within and surrounding the enterprise and protect and enhance the biological diversity of native plants and wildlife.
- Recycle materials and resources to the greatest extent possible within the enterprise.
- Provide attentive care that promotes the health and behavioural needs of livestock.
- Maintain the integrity of organic food and processed products from initial handling to point of sale.

[2] ‘Almost all pesticides believed to have potentially negative health impacts on humans are not permitted in organic production.’, A National Strategy for the Canadian Organic Food and Faming Sector. McCrae, R., et al, Organic Agriculture Centre of Canada, Truro, Nova Scotia, B2N 5E3.

from the environment by organic practice. This exercise is conducted for the Central Grasslands in Canada, USA and Mexico.

The potential ‘pollutants’ considered are eroded soil (and degraded soil organic[3] matter), synthetic fertilizers, herbicides, insecticides and fungicides. To illustrate the amount of fertilizers and pesticides applied or displaced, we present maps and tables for fertilizers, herbicides, insecticides and fungicides. The principal results are shown in maps of: a) the mainstream wheat area, for reference, and the mass of a particular pollutant applied in this practice, and b) the organic wheat area and the mass of that pollutant *not applied in / displaced by* this practice, assuming that the average rate of application would have matched the average rate for that state/province in mainstream practice.

For future scenarios, estimates of the area under organic stewardship in 2002 and in 2007 are tabulated, together with the amounts of fertilizer or pesticide which would be displaced given estimated trends. Note that this partial analysis does not take into account the distribution of these changes across provinces based on their comparative advantages and instead assumes changes in production are equally divided among jurisdictions. Results presented here would certainly be different if general equilibrium modeling were used to allocate changes in production to each state or province, and if the impacts on prices and consumption of these production changes were modeled. We have chosen this simpler approach to present clearer displacement results. A third scenario considers the year 2007 with the additional assumption that domestic demand for domestic wheat rises by 3%, causing corresponding increases in mainstream area and in the fertilizers and pesticides applied, The question addressed in the latter scenario is: In terms of the amount of pollutant released, would a 3% expansion of domestic demand for mainstream wheat lead to more fertilizers and pesticides being used incrementally than are expected to be displaced via organic stewardship?’

For context we present a map developed by the CEC under its work to identify ecosystems of common concern in North America (Figure 2.1) showing the Central Grasslands of North America in green (CEC, forthcoming). Superimposed on the states and provinces of the Central Grasslands are bars indicating hectares of mainstream and organic wheat currently grown. Comparison of mainstream to organic areas in wheat systems can be read directly from this map, providing a perspective on the mix of these two stewardship options in the states/provinces, regions and countries.

[3] The adjective, organic, in this context, stands in distinction to mineral components of the soil. In the context of organic farming or stewardship, organic refers to the approach described in the previous footnote emphasizing biological processes.

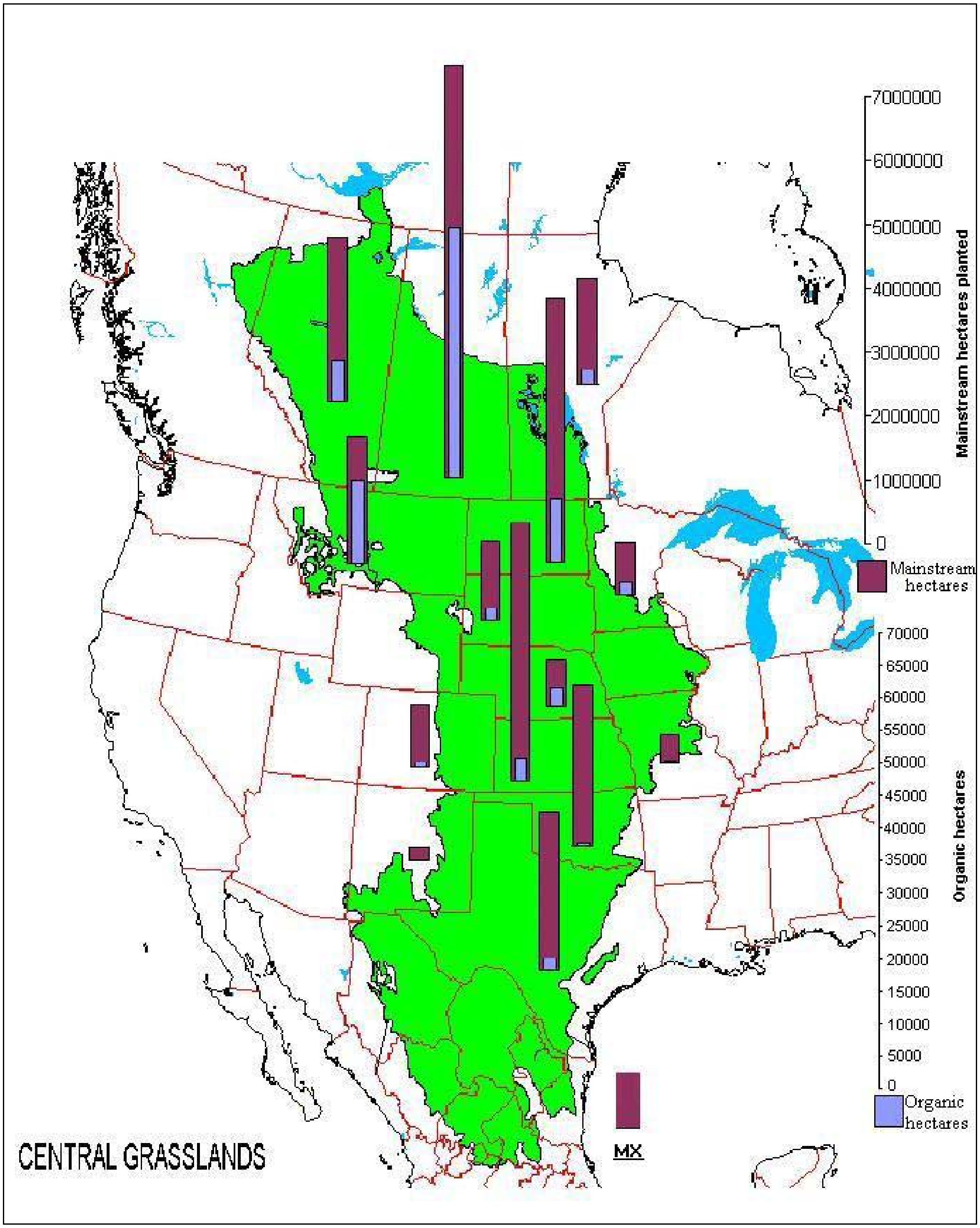

Figure 2.1. Areas in mainstream and organic wheat systems in the Central Grassland region. The bars are anchored in the corresponding state/province. Note the adjustment in scales – organic areas are shown 100 times expanded relative to mainstream areas. Source: Adapted from CEC (forthcoming).

Figure 2.1 shows the mainstream and organic wheat system areas[4] [5] [6] [7] [8] [9]by state/province for the three NAFTA countries. The area under organic practice is in every case still a small fraction of the area under mainstream practice. The chart bars are scaled so that if the organic wheat area were 1% of mainstream wheat area for a state/province, the organic bar (blue) would reach the same height as the mainstream bar (maroon). The map shows that in every case areas of organic wheat systems amount to less than 1% of areas in mainstream wheat. The present displacement of fertilizers and pesticides as a percentage of the total quantities applied is indicated approximately by the percentage of organic to mainstream wheat area.

From Figure 2-1, for Canada in 2000, Saskatchewan had the largest area in wheat with 0.6% of its wheat area in organic wheat . For the US in 2000, North Dakota, Kansas, Oklahoma and Texas had the largest areas in wheat. Montana, Nebraska and North Dakota exhibited relatively high proportions of wheat land under organic practice[10], reaching as high as 0.7%. For Mexico we know the total (mainstream) wheat area to be 913,000 ha. in 1990, with an average of 237,000 ha in Sonora in the 1990's, but we do not know how the remainder is distributed among the other states. Our initial information is that there are no organic wheat areas.

In total the three countries have approximately 30 million ha in wheat production in the central grassland region, less than 1% being in organic production.

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[4] USA areas in mainstream wheat are taken from USDA, , National Agricultural Statistics Service May 2001. Agricultural Chemical Usage 2000 Field Crops Summary.

[5] Canadian areas in mainstream wheat by province were taken from the Potash and Phosphate Institute of Canada report, Western Canada Region Crop Production Area and Average Yields – 2001, based on the Statistics Canada November 2001 estimate of production of principal field crops.

[6] Mexican areas in mainstream wheat were 913,000 ha. (North America Fertilizer Situation, International Fertilizer Development Centre, November, 2001)

[7] USA areas in organic wheat for 1997 appear in USA Economic Research Service report, Harmony between agriculture and the environment: current issues, US Organic Agriculture, Table 6. Certified organic grain crop acreage, by State, 1997. The total area was estimated at 96,100 acres (39,000 ha) in 1995 and 125,700 acres (51,000 ha) in 1997. Fitting a power law and extrapolating to 2002 yields, as an extrapolation, an estimate of 100,700 ha ± 30% ; and for 2007, 198,100 ha ± 40%.

[8] Canadian areas in organic wheat for 2000 were obtained from Alberta Department of Agriculture, Food and Rural Development, the Organic Directorate of Saskatchewan Department of Food and Agriculture, and the Organic Producers Association of Manitoba.

[9] Our information is that there is no organic wheat land in Mexico.

[10] The data for US organic wheat refers to the year, 1997; data for mainstream wheat refers to the year, 2000.

2.1 Basic Calculations

The representative rate of application in kilograms per hectare was calculated for each pollutant as a state/province aggregate: the total amount of pollutant applied divided by the total area of wheat system lands in the state/province.[11]

If information was not available at the level of state/province, we used region- or country-scale aggregates.

Application rates of the various types of fertilizers were lumped into one representative rate of active ingredients per hectare – producing an indicator. Similarly, two other indicators were produced; all the herbicide rates were lumped into one representative rate, as were all the insecticides and fungicides together.

2.2 Uncertainties in Areas

We assumed that the total areas in wheat from Statistics Canada and the U.S.National Agriculture Statistics Service are accurate within 10%, and include those areas in organic wheat. If the latter assumption – including organic areas - is incorrect, this error is less than 1% because the organic areas are comparatively small.

2.3 Uncertainties in Rates of Application (ROA)

We are not certain in all cases whether total amounts of fertilizers and pesticides applied to wheat for a state/province are calculated using records of sales from suppliers or questionnaires from farmers about amounts applied, or both, as a check. We also note that if the total amount of pollutant were estimated as the product of average wheat area (on a farm) and average rate of application, and if the actual wheat areas and ROAs were correlated, this would introduce an error known as aggregation error.

We judge uncertainties for ROAs to be ±30%. Consistent with this, the uncertainty of the total mass of pollutant, area x ROA, is judged to be ±35%.

[11] For herbicides in Alberta, Saskatchewan and Manitoba, the only information available to us was an average application rate for herbicides over all agricultural uses in Alberta – 0.72 kg ai/ha (after correction for insecticides and fungicides). Fact Sheet Alberta Environment: Pesticide use in Alberta (1998).

3 RESULTS

3.1 Soil Erosion

Soil erosion constitutes a degradation of soil productivity and, as well, eroded soil is a pollutant in streams. What is the relationship between the farming regime and soil erosion? There is evidence that no-till and organic farming[12] are more effective than conventional tillage in reducing soil erosion and therefore in maintaining soil productivity. It appears that there is little distinction, in terms of soil erosion, between no-till and organic; the advantages in no-till of surface crop residues and soil binding by roots are similar to the advantages in organic farming of amendments such as composted manure and cover crops.

3.2 Soil Organic Carbon

Soil organic carbon is an indicator of soil productivity. Specific practices acting to increase the level of soil organic carbon include rotation with sod crops[13], reduced tillage, reduced row cropping, green manure crops, and importing manure. These practices can be part of mainstream and organic wheat systems. We do not have information available on the average state of soil organic carbon in wheat systems with organic stewardship compared to those with mainstream stewardship. We have found reports where yields of wheat from compost treatments were 6.5% and 42% lower than synthetically fertilized wheat, depending on the location, and 33% higher when the crop experienced severe drought.[14]

3.3 Synthetic Fertilizers and their Displacement

Figure 3.1 shows mainstream wheat areas together with the amount of fertilizer applied, by state/province.[15] [16] Bars of equal height reflect an ROA of 100 kg fertilizer active ingredient[17] per hectare - a fertilizer bar reaching the same height as the area bar indicates that 100 kg fertilizer per hectare per year are applied. Rates of application (ROA) vary from 73 kg/ha-y in Texas to ~200 kg/ha-y in Missouri and Sonora.

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[12] Cramer, Nancy G., 2002. Myth versus Reality, Information Bulletin, Summer 2001, Organic Farming Research Foundation, and Langdale et al, Cover crop effects on soil erosion by wind and water, in Hargrove, WI., Cover Crops for Clean Water, 1991, Soil and Water Conservation Society..

[13] Sod crops include pasture and hay, and are made up of a variety of grasses, legumes, and forbes.

[14] Gagnon, B., Simard, R., Robitaille, R., Goulet, M., and Rioux, R. 1997. Effect of composts and inorganic fertilizers on spring wheat growth and N uptake. *Can J. Soil Sci*. **77**:487-495.

[15] The total amount of fertilizer used for wheat in Canada in 1993 is given in Table 30A of the International Fertilizer Development Center's report, North America Fertilizer Situation, November 2001. Amounts of fertilizer (active ingredient) used for mainstream wheat systems in Alberta, Saskatchewan and Manitoba were pro-rated from the total for Canada based on area.

[16] US fertilizer statistics for 2000 taken from National Agricultural Statistics Service, USDA.

[17] N, P_2O_5 , and K_2O

Figure 3.2 shows organic wheat areas and the amount of fertilizer displaced there by state/province, assuming that no chemical fertilizers[1] are used in organic agriculture, and that chemical fertilizer is displaced at a rate equal to the average ROA for that state/province. Amounts displaced are shown as negative quantities. For the three countries, the amount of fertilizer displaced (Figure 3.2) amounts to at least ten thousand tonnes in total (Table 3.1).

Table 3.1 Fertilizer displaced under estimated organic areas for 2002, 2007 and 2007 plus 3% increase in domestic demand for mainstream wheat.

Scenario	Estimated Organic Wheat Areas (hectares ±30%)			Fertilizer Displaced (thousands of tonnes ±35 to 40%)			
	US	Mexico	Canada	US	Mexico	Canada	TOTAL
2002	100,700	0	67,500	-6.8	0	-4.1	**-10.9**
2007	198,000		168,000	-13.5		-10.1	**-23.6**
2007 + 3% increase in supply	198,000		168,000	+42.9[18]		+8.8	**+51.7**

Under Scenario 2002, where organic wheat areas are estimated to have reached 100,000 ha[19] in the US and 67,500 ha[20] in Canada, the total amount of fertilizer predicted to be displaced amounts to -10.9± 3.8 thousand tonnes annually.

Under Scenario 2007, where organic wheat areas are estimated to have reached 198,000 ha [6] in the US and 168,000 ha in Canada, the total amount of fertilizer predicted to be displaced amounts to -23.6± 9.4 million kilograms.

Under Scenario 2007 + 3% increase in domestic demand, mainstream areas are increased by 3% with concomitant increase in fertilizers. In this case, we estimate that the displacement would be overwhelmed and that there would be a net increase of 51.7 million kilograms of fertilizers applied. It would take a three-fold increase in organic area to compensate for a 3% increase in domestic supply produced conventionally.

[18] net increase in fertilizer applied
[19] a factor of two times1997 organic wheat areas by extrapolation of a fitted power law.
[20] The prediction for 2002 area based on the actual area in 2000 and an increase of 20% per year for organic foods in general, from: Organic grain and Oilseeds Enterprise, Alberta Agriculture, Food and Rural Development, 2000.

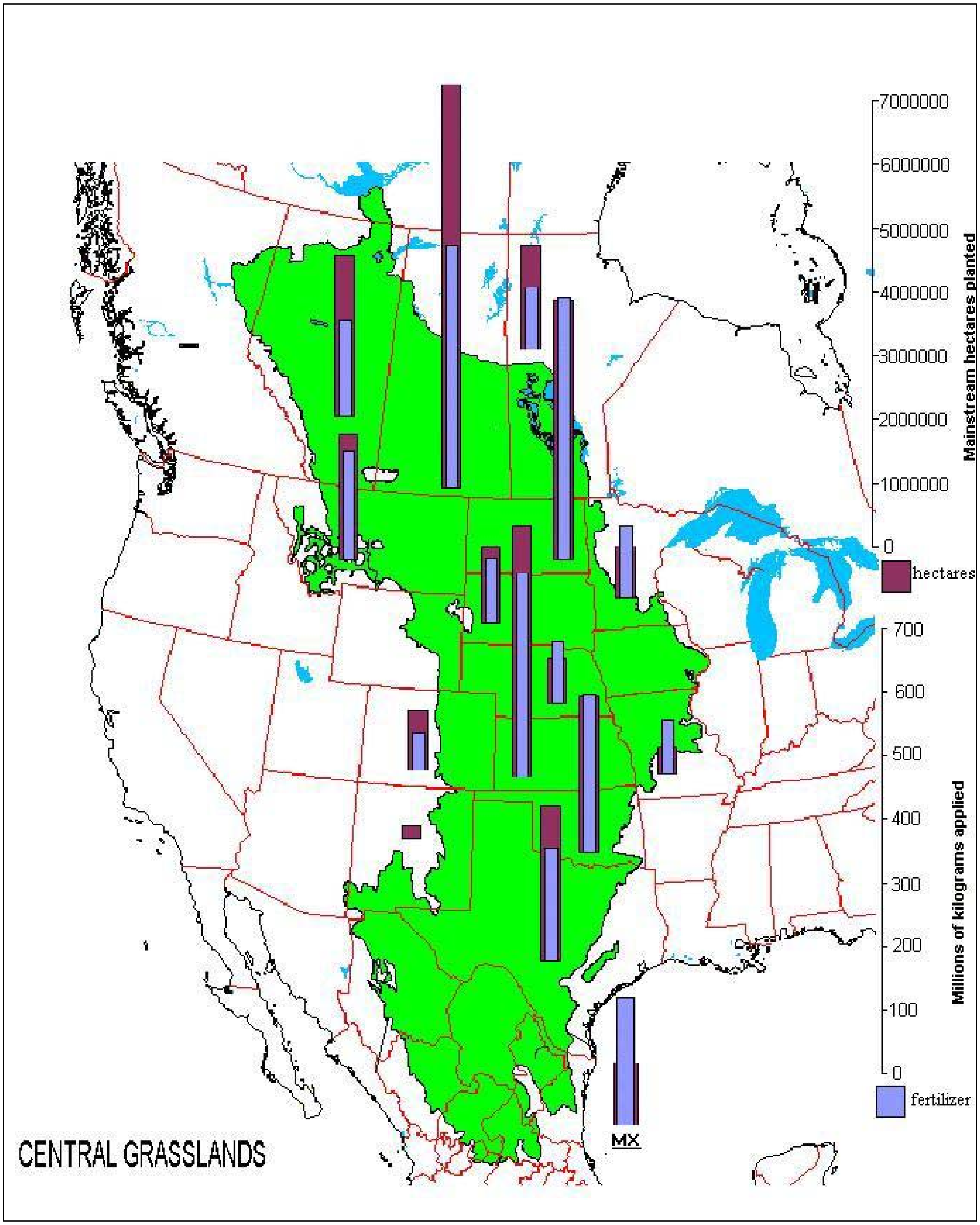

Figure 3.1. Total wheat areas and fertilizers applied in mainstream practice. A fertilizer bar reaching the same height as the area bar indicates that 100 kg fertilizer per hectare per year are applied.

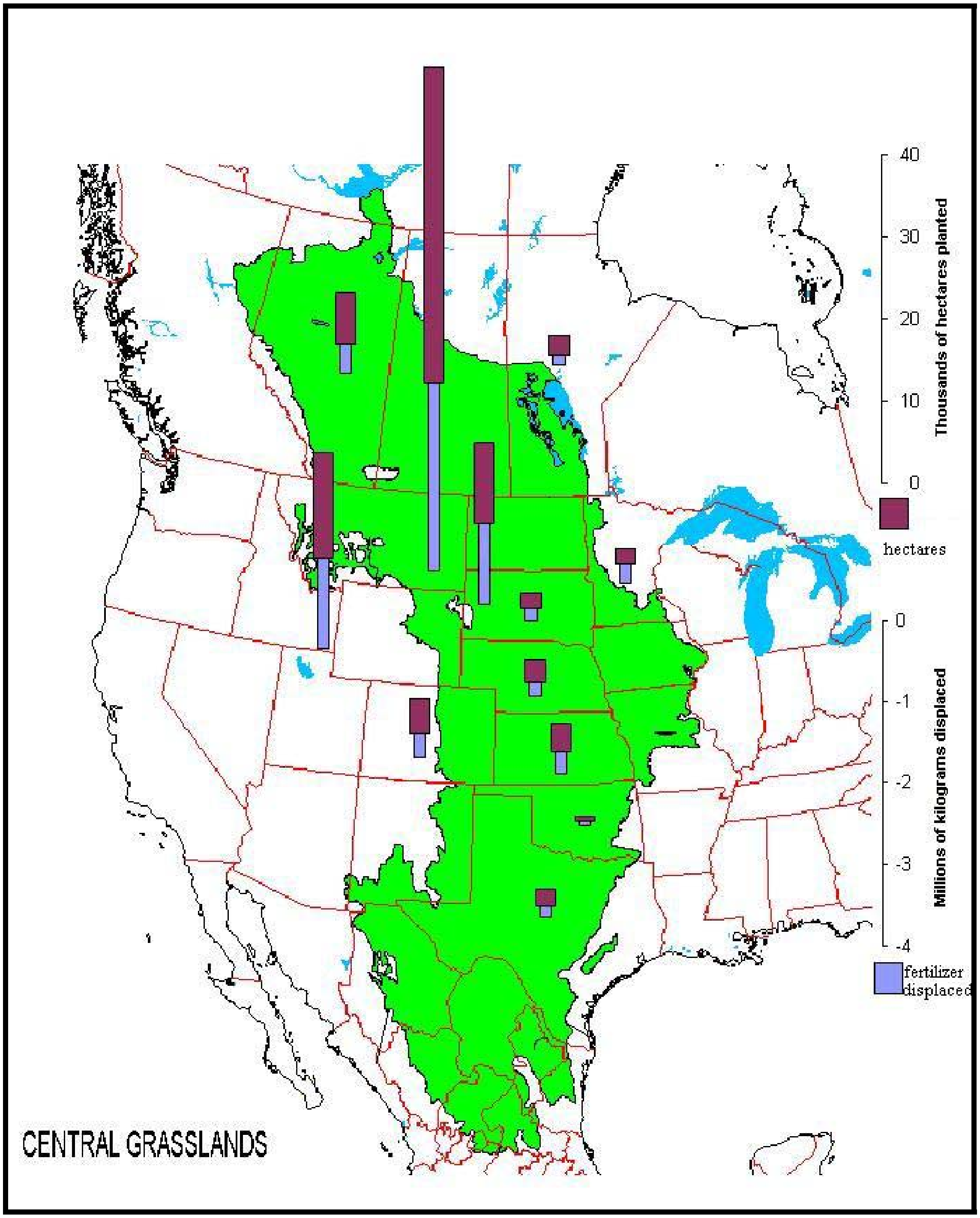

Figure 3.2. Organic area and amount of fertilizers 'displaced' in 1997-2000.
Bars of equal (opposite) height reflect displacement of 100 kg fertilizer/ha.

3.4 Herbicides and their Displacement

Figure 3.3 shows mainstream wheat areas, for reference, and the amount of herbicide applied by state/province.[21] [22] Bars of equal height reflect an ROA of 1 kg herbicide active ingredient per hectare. Average rates of application (ROA) vary from 0.01 kg/ha-y in Missouri to 0.83 kg/ha-y in Montana. The distribution of ROA by state appears to be bi-modal. States with highest ROA tend to treat their lands more than once per year while other states do not. This may be related to adoption of no-till.

Figure 3.4 shows organic wheat areas and the amount of herbicide[23] displaced there by state/province, assuming that organic farmers use no herbicides and that herbicide is displaced at a rate equal to the average ROA for that state/province. Bars of equal (but opposite) heights reflect a rate of displacement of 1 kg herbicide active ingredient per hectare.

The amount of herbicide displaced annually in 2000 amounts to at least 30 tonnes in total.

Results for plausible future scenarios for displacement of herbicide are shown in Table 3.2.

Table 3.2 Herbicide displaced under estimated organic areas for 2002, 2007 and 2007 plus 3% increase in domestic demand for mainstream wheat.

Scenario	**Estimated Organic Wheat Areas (hectares ±30%)**			**Herbicide Displaced (tonnes active ingredient ±35 to 40%)**			
	US	**Mexico**	**Canada**	**US**	**Mexico**	**Canada**	**TOTAL**
2002	100,700	0	67,500	-44.3	0	-48.6	**-93**
2007	198,100		168,000	-88.1		-121	**-210**
2007 + 3% increase in supply	198,100		168,000	+90.2		+106	**+200**

[21] Herbicide ROA's for the US are found in USDA. May 2001. Agricultural Chemical Usage 2000 Field Crops Summary, National Agricultural Statistics Service.

[22] Herbicide ROA's for Canadian prairie provinces are extrapolated from the year 2000 value for Alberta for all agriculture, 0.72 kg ai/ha. Pesticide use in Alberta (1998), Factsheet Pesticides, Alberta Department of Environment, October 2001.

[23] For wheat the herbicides displaced are chiefly 2,4-D, glyphosate, MCPA and triallate.

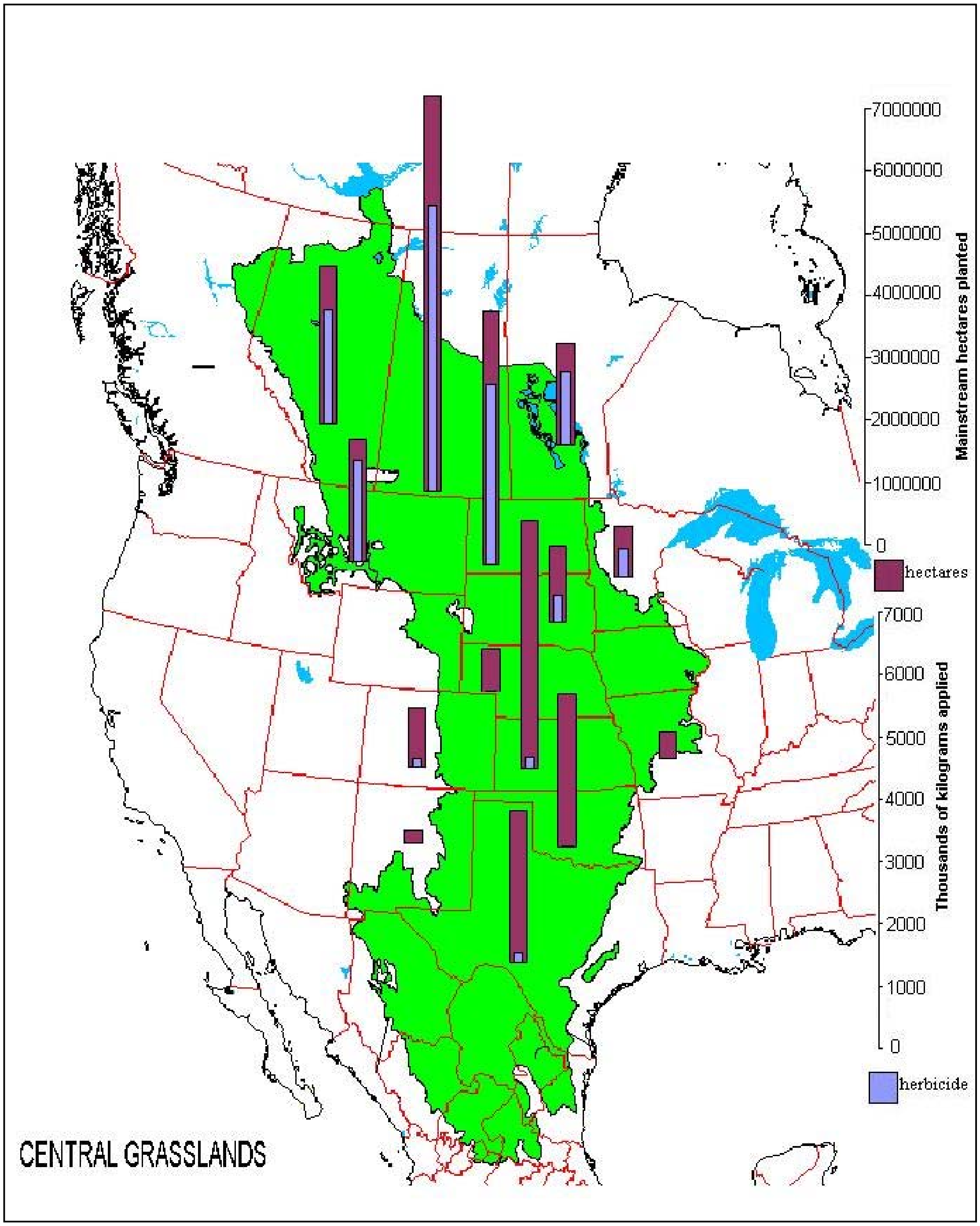

Figure 3.3. Total wheat areas and herbicides applied on average in mainstream wheat production. Bars of equal height reflect an ROA of 1 kg herbicide active ingredient per hectare.

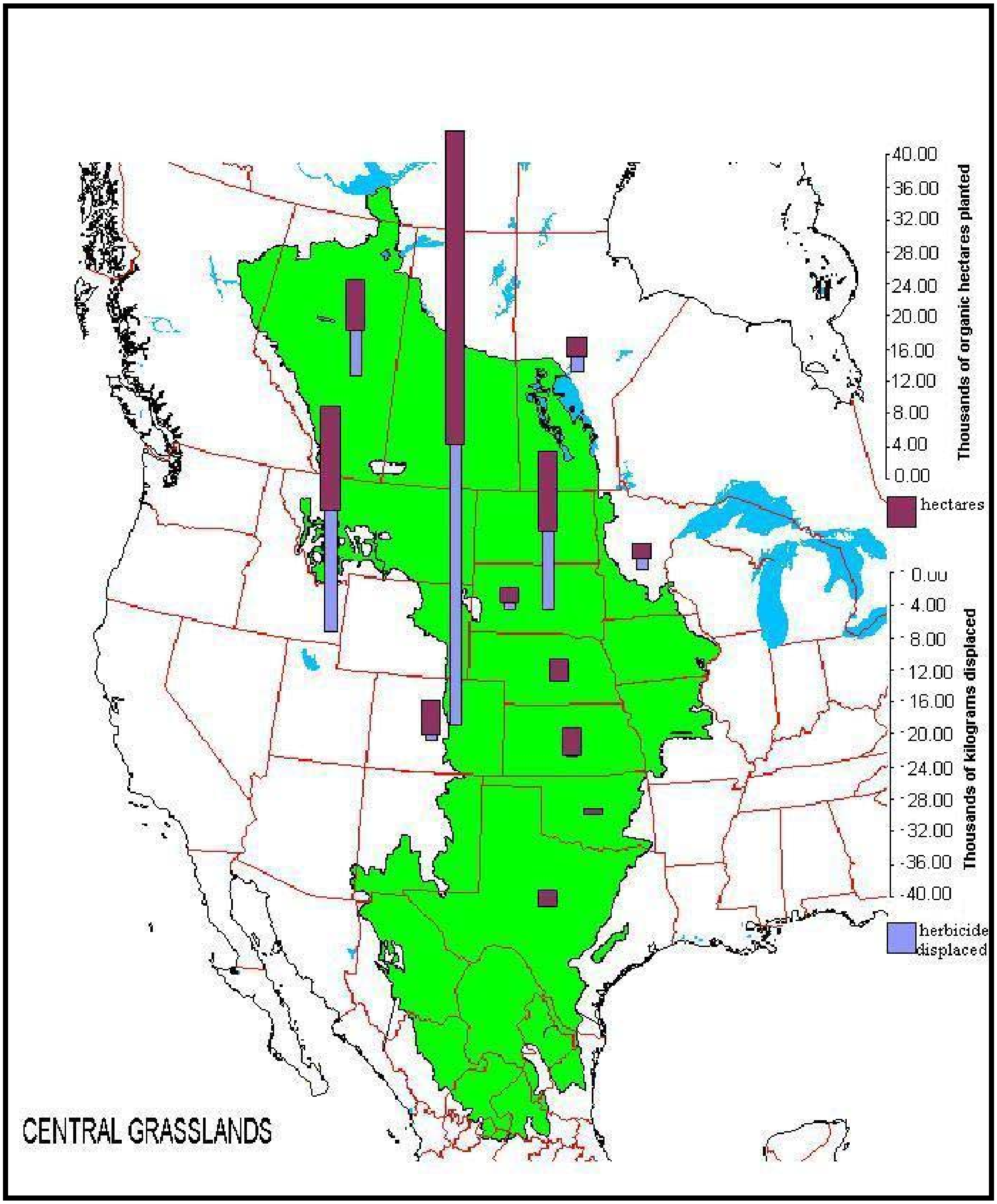

Figure 3.4. Organic wheat areas and herbicide displaced. Equal (opposite) bars indicate a displacement of 1 kg herbicide per hectare.

Under Scenario 2002, the total amount of herbicide predicted to be displaced amounts to -93 ± 33 tonnes active ingredients.

Under Scenario 2007, where organic wheat areas are projected to have increased markedly, the total amount of herbicide predicted to be displaced amounts to -210 ± 80 tonnes active ingredients.

Under Scenario 2007 + 3% increase in domestic demand, the amount of herbicide displaced would be offset by increased applications in mainstream wheat systems.

This analysis assumes proportional distribution of converted organic area among jurisdictions within each country. If organic areas were to increase disproportionally in states with higher application rates of herbicides then these results for displacement of herbicides would be underestimated (and vice-versa).

3.5 Insecticides and fungicides and their Displacement

Insecticides[24] and fungicides[25] find application in mainstream wheat systems both in wheat fields and in storage bins and elevators. Estimates of amounts used are shown in Table 3.3[26].

Table 3.3 Estimated amounts of insecticides and fungicides applied in mainstream wheat systems in the Central Grasslands and displaced with organic wheat.

Country	**USA**	**Mexico**	**Canada**
Estimated amounts of insecticides and fungicides applied (kg active ingredient)	645,000		840,000
ROA (kg ai/ha	0.03		0.08
1997 area of organic wheat systems in Central Grasslands (hectares)	36,000		47,000
Estimated amounts of insecticides and fungicides displaced in 1997 (kg ai)	1000		3800

[24] Some specific insecticides used are Chlorpyrifos and Dimethoate.
[25] Some specific fungicides used are Tebuconazole and Propiconazole.
[26] Pesticides include herbicides as well as insecticides and fungicides.

4 DISCUSSION

In Mexico and Canada, data were not generally available at the state/province level; available data were either aggregated to region or country level. These estimates of rates of application of synthetic fertilizers and pesticides in wheat systems can be upgraded, in terms of assessing present levels for each state/province, including applications to any crops rotated with wheat in the wheat systems, and evaluating trends in mainstream and organic practices. A similar survey could be conducted for other crops common to the three countries, such as fruits and vegetables and corn, which are also produced in the three countries and are larger users of external inputs than wheat. Future studies could also use modelling to allocate the potential increase in demand for organic products to states and provinces to arrive at finer predictions of displacement.

The estimated total amounts of synthetic fertilizers and pesticides *currently* being displaced by verifiably sustainable agriculture and prevented from being released into the environment in North America amount to 6,300 metric tonnes of fertilizer active ingredients and 61 metric tonnes of pesticide active ingredients. These constitute less than 1% of the quantities applied in wheat systems in the Central Grasslands of North America. The widest ranges of rates of applications and potential displacements of synthetic fertilizers and pesticides are shown for 2007 in Table 4.1.

Table 4.1 Ranges of rates of application and the corresponding potential for displacement.

Potential Pollutants	**Rates of Application (kg/ha)**		**Area of Organic Wheat (ha)**	**Total Displacement (tonnes/y)**
	Main-stream wheat systems	Organic wheat systems		
Synthetic Fertilizers	60 to 245	0	168,000	10,000 to 40,000
Herbicides	0.01 to 0.83	0	168,000	1.7 to 139
Synthetic insecticides and fungicides	0.03 to 0.08	0	168,000	5 to 13

Projecting into the future, demand for organic food is anticipated to increase 20% per year. If this demand is met through domestic or regional supply (since this is a shared ecosystem), the environmental and health side-benefits could be substantial.

It is worth noting that these displacements are market-based and not the result of government policies (no special treatment in agricultural policies exist in any of the three

NAFTA countries). Farmers instead rely on their personal convictions, non-governmental organization programs (such as community supported agriculture projects) and the price premium that producing organic brings. In the US, for instance, organic wheat in 2000 and 2001 brought a price premium of 103 and 94% over the conventional price. It is clear however that policies can help foster this sector through clear labeling rules, public education of the environmental benefits of organic agriculture, and ensuring that organic farmers are not discriminated against in program implementations. More farmers may also adopt this production method (or similar ones) if the costs of certification were lower and the risk of losing a certification were reduced. (For instance, for organic crops planted near transgenic varieties, the flow of genes and their introgression into organic crops would automatically void the organic certification and thus the associated premium.)

Finally, obviously if organic or more sustainable agriculture does not use commercial fertilizers, herbicides, insecticides and fungicides, they do use other materials (often natural such as compost), methods (e.g., more labor to control weeds, insects and fungus) and values (e.g., flavor) to create livelihoods. If agriculture is to meet society's demands for improved environmental quality, rural landscape amenities, wildlife habitat, wetlands, and improved water and air quality—along with food, fiber, and timber production - the distributed benefits of more sustainable approaches or organic approaches must be taken into account – from job creation for the continuity of rural communities to environmental health through displacement of pollutants.