# The Environmental Impacts of Regional Agriculture and Food Systems in Southern Ontario

**Submitted to**

**The Friends of the Greenbelt Foundation,**
**George Cedric Metcalf Charitable Foundation, and**
**The J. W. McConnell Family Foundation**

**Submitted by**


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# 1. Introduction

This report is one of three separate reports prepared for the Friends of the Greenbelt Foundation, George Cedric Metcalf Charitable Foundation, and The J. W. McConnell Family Foundation. It focuses on the estimation of the environmental impacts of regional agricultural and food systems in Southern Ontario.

The local and regional agricultural and food supply chains in Southern Ontario are well established. They continue; however, to face a few challenges that have constrained their development potential, dynamic growth, capacity to adequately meet local demand and anchor local food security. There still exist a few inhibitors that have precluded in the past and continue to inhibit the wider participation of local food producers in meeting local demands. Removing these constraints would support local agricultural development, local economic growth, and job creation and reduce the negative environmental impacts of food consumption when it and other agricultural products are transported from distant markets. Removing these constraints may also lead to raising the proportion of healthy and organic food, relative to the total food supply, available to Ontario consumers and processors, and raise the potential for realizing local food security.

While it is difficult to disentangle the environmental impacts of agriculture and food systems from their economic and social impacts, this report will highlight some of the specific environmental impacts of food and agricultural production and consumption, the direct and total environmental impacts of production and consumption of food and will integrate environmental issues with food security issues.

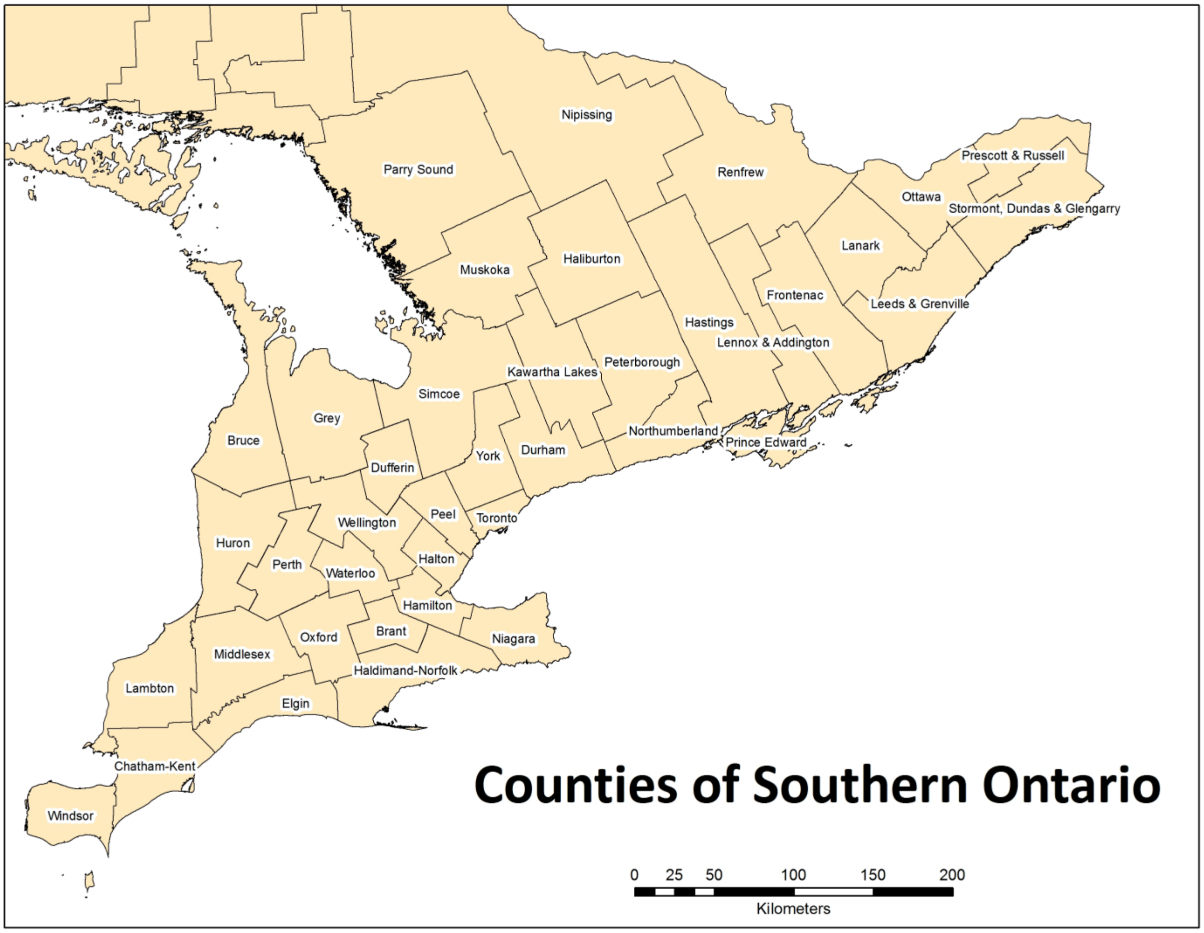
Two related approaches will be used in this analysis. First, we benchmark the impacts of production, consumption and transportation of food and agriculture, followed by constructing a number of scenarios that evaluate these impacts relative to incremental changes from the base case (benchmark) situation. While many interesting scenarios can be formulated, we will limit the analysis to those that deal with different production structures (commodity composition) and alternative sourcing of food from different regions.

# 2. Background

Most of the agricultural activity is concentrated in Southern Ontario, a region identified to include all areas of Ontario south of the Canadian Shield as depicted in Figure 1 below.

The environmental impacts of agricultural production are organized by County because the data is available at this geographical resolution. Emissions and transportation impacts within the supply chain network are also organized at the county level. There is no published data, however, on food manufacturing by county. Some of this data was constructed using provincial averages but their accuracy and reliability are subject to some limitations.

**Figure 1 – Counties of Southern Ontario**




It is difficult to imagine a sustainable economy that does not gauge the environmental impacts of its different production, consumption and transportation systems. There is no single or collection of standard and generally accepted environmental indicators that adequately capture the environmental impacts of the three systems. We have singled out a set of indicators as representative of the nature and magnitude of these impacts in Ontario. These indicators are estimated within the same platform of the economic impact model.

# 3. Approach and Methodology

The impact model is based on an inter-industry accounting framework that is described in detail in the economic impact report. In summary, the input-output analysis used here to quantify the environmental impacts generates these impacts simultaneously with the determination of the output and value added effects.

The specific environmental indicators generated by the model from the agricultural and food production and consumption systems include the following:

- Water Demand/Balances
- Air Emissions/Pollutant
- Energy Demands
- Solid Waste
- Contaminants
- Green GDP
- Greenhouse Gases

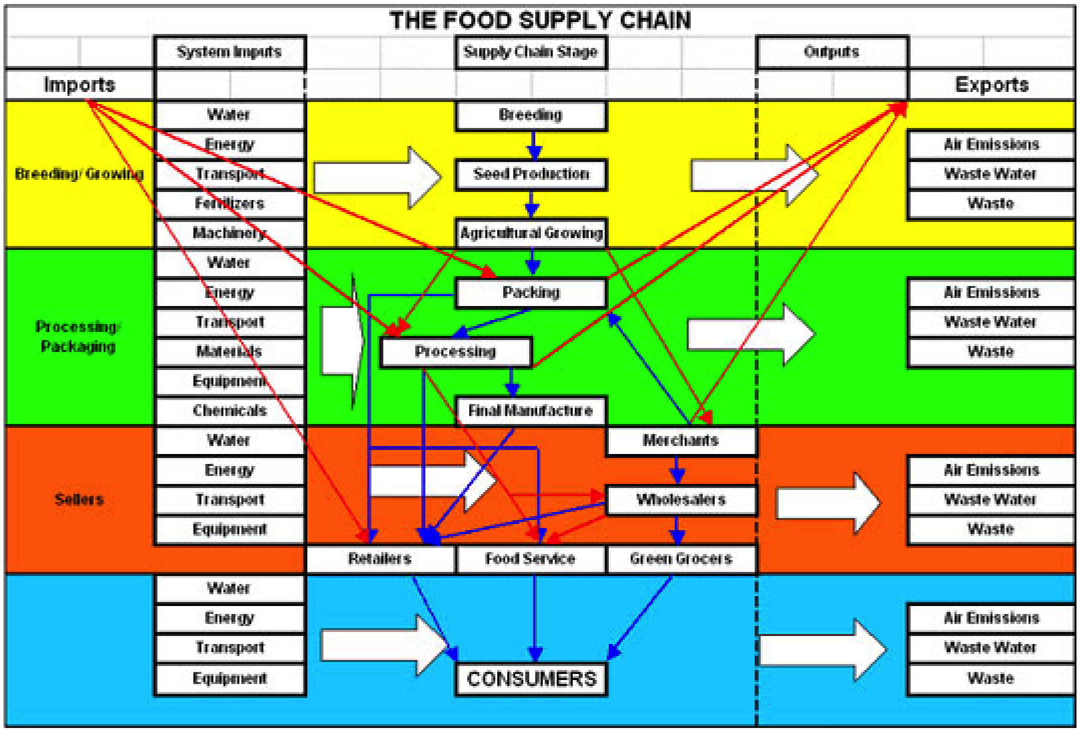
Beside these production impacts, we present the environmental impacts of the food supply chains as food and agricultural products are moved through the transportation grid.

The food producing sector includes a myriad of products but generally the following general subsets of crops, fruits, vegetables and meat:

- Dairy cattle and milk production
- Beef cattle and feedlots
- Hog and pig
- Poultry and egg
- All other animal production
- Field crops
- Fruit and vegetables
- Flowers, herbs and other speciality

The food supply chain is a system of organizations, people, technology, activities, information and resources involved in moving food products or services from supplier to customer. Supply chain activities transform natural resources, raw materials and components into a finished product that is delivered to the end customer. This system is captured in Figure 2 below that provides a more complex display as it integrates the environment into the chain as supplier of inputs and as a sink.

**Figure 2 – An Economic and Environmental Integrated Schema of the Food Supply Chain**




*Source: http://www.foodwaterstorage.com/index.php?s=food+supply+chain*

# 4. The Environmental Impacts of Agriculture in Southern Ontario by County

The presentation of the agricultural environmental impact results is organized by the 40 counties in Southern Ontario. These are also grouped into three major sub-regions of Southern Ontario – Southwestern, South-Central and Southeastern.

The environmental impacts by the set of indicators enumerated above are generated by the generalized impact model. They capture, therefore, not only the direct environmental impacts but the total impacts as indirect and induced effects are also estimated.

For each sub-region we present the environmental impact results in two separate tables except for South-Central Ontario where we have four tables because of the large number of counties in this region.

The annual environmental impact results associated with agriculture production in the Southwestern Ontario sub-region reveal a specific pattern as shown in tables 1 and 2 below.

**Table 1**
**The Province Wide Environmental Impacts of Agriculture by County, Southwestern Ontario**

| | Hamilton | Niagara | Haldimand | Brant | Oxford | Elgin | Chatham | Essex | Lambton | Middlesex |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Demand for Water (MCM)*** | | | | | | | | | | |
| Intake | 201.2 | 593.6 | 541.5 | 140.4 | 502.4 | 247.5 | 362.7 | 675.7 | 309.7 | 453.5 |
| Discharge | 199.0 | 587.0 | 535.5 | 138.9 | 496.9 | 244.7 | 358.5 | 667.8 | 306.2 | 448.4 |
| Net Usage | 2.3 | 6.6 | 6.1 | 1.6 | 5.5 | 2.8 | 4.2 | 7.9 | 3.5 | 5.1 |
| ***Air Emissions (Tonnes)*** | | | | | | | | | | |
| Particulates | 193.1 | 583.6 | 536.4 | 138.4 | 491.7 | 256.8 | 391.6 | 769.6 | 345.6 | 469.3 |
| Sulphur Oxides | 553.0 | 1,567.7 | 1,450.9 | 381.8 | 1,160.4 | 676.3 | 1,099.6 | 2,459.4 | 852.9 | 1,151.9 |
| Nitrogen Oxide | 166.1 | 477.4 | 440.3 | 115.3 | 367.8 | 204.6 | 324.2 | 705.4 | 257.8 | 354.9 |
| Volatile Organic C | 956.0 | 2,630.8 | 2,735.5 | 754.1 | 2,094.5 | 1,348.1 | 2,307.5 | 4,448.7 | 1,718.2 | 2,250.9 |
| Carbon Monixide | 581.6 | 1,651.7 | 1,622.0 | 436.0 | 1,376.9 | 769.9 | 1,220.8 | 2,103.4 | 969.3 | 1,358.4 |
| ***Energy Used (terajoules)*** | | | | | | | | | | |
| Coal | 1,029.4 | 3,058.3 | 2,695.8 | 698.5 | 2,323.7 | 1,217.0 | 1,904.6 | 3,386.1 | 1,534.9 | 2,234.2 |
| Crude Oil | 2,699.0 | 7,683.5 | 7,064.2 | 1,851.9 | 5,606.0 | 3,310.2 | 5,443.7 | 13,484.9 | 4,200.1 | 5,540.7 |
| Natural Gas | 1,565.5 | 4,599.3 | 4,117.4 | 1,079.8 | 3,440.0 | 1,860.4 | 2,984.2 | 5,159.6 | 2,313.2 | 3,377.1 |
| Electricity | 631.9 | 1,896.1 | 1,654.9 | 427.2 | 1,444.5 | 743.7 | 1,158.7 | 2,023.6 | 939.7 | 1,379.5 |
| Nuclear Steam | 216.2 | 590.3 | 681.5 | 194.6 | 529.5 | 349.3 | 606.6 | 816.4 | 452.3 | 600.6 |
| Total | 6,141.9 | 17,827.5 | 16,213.9 | 4,252.0 | 13,343.7 | 7,480.6 | 12,097.7 | 24,870.6 | 9,440.2 | 13,132.1 |
| ***Greenhouse Gases (Tonnes)*** | | | | | | | | | | |
| Carbon Dioxide | 325,927.3 | 941,050.4 | 865,765.2 | 227,197.7 | 717,137.6 | 405,475.9 | 659,657.4 | 1,414,754.8 | 518,018.9 | 704,856.7 |
| Methane | 354.0 | 1,023.9 | 945.0 | 248.5 | 787.7 | 443.0 | 721.3 | 1,482.7 | 566.1 | 775.6 |
| Nitrous Oxide | 465.7 | 1,354.2 | 1,242.6 | 325.7 | 1,049.3 | 581.3 | 938.8 | 1,900.1 | 745.5 | 1,026.4 |
| ***Green GDP ('000 Dollars)*** | | | | | | | | | | |
| GDP | $381,821 | $1,130,230 | $963,886 | $258,307 | $846,050 | $430,634 | $633,166 | $1,219,999 | $523,696 | $778,743 |
| Green Cost | $22,673 | $65,028 | $61,361 | $16,264 | $50,391 | $29,049 | $47,540 | $96,654 | $37,114 | $50,384 |
| Green GDP | $359,148 | $1,065,202 | $902,525 | $242,043 | $795,659 | $401,585 | $585,626 | $1,123,345 | $486,582 | $728,359 |
| Percent of GDP | 94.1% | 94.2% | 93.6% | 93.7% | 94.0% | 93.3% | 92.5% | 92.1% | 92.9% | 93.5% |

Source: Econometric Research Limited and Partners

- Net usage of water is highest in Essex and lowest in Brant, but regardless of county, water consumption in agriculture is relatively high compared to industrial and residential uses.

- A different set of air emission categories is revealed by each county. In the City of Hamilton carbon monoxide represents the largest emission category. In Niagara Region, VOC is the largest emission category and it is so in Haldimand-Norfolk County (henceforth only Haldimand), Brant County, Oxford County, Elgin County, the Municipality of Chatham-Kent (henceforth only Chatham), Essex and Middlesex counties. These differences arise on account of the different local industrial bases.

- Large amounts of particulates are produced in Essex County and Niagara Region, whereas the largest emissions of sulphur oxides are in Niagara Region and Haldimand County. Nitrogen oxide emissions are largest in Essex County and Niagara Region.

- The largest energy usage is in Niagara Region and Essex County. All counties in Southwestern Ontario depend most heavily on crude oil followed by natural gas and then coal. Electricity does not account for a major share of the energy bill in agriculture in Southwestern Ontario.

- Carbon dioxide is produced in abundance in every county of the sub-region. Relatively high amounts of nitrous oxide are produced.

- Green GDP, which is nominal GDP less environmental mitigation costs (such as planting trees to absorb carbon), as a fraction of GDP is highest in Niagara Region and Oxford County. The differences in these shares among counties are small. They are lowest in Essex County and Chatham-Kent Municipality.

**Table 2**
**The Province Wide Environmental Impacts of Agriculture by County, Southwestern Ontario**

| | Hamilton | Niagara | Haldimand | Brant | Oxford | Elgin | Chatham | Essex | Lambton | Middlesex |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Waste Generated (Tonnes)*** | | | | | | | | | | |
| ONP | 377.9 | 1142.5 | 998.7 | 255.8 | 910.7 | 455.0 | 698.8 | 1157.8 | 582.0 | 852.2 |
| Fine Paper | 791.1 | 2392.2 | 2091.1 | 535.5 | 1906.8 | 952.7 | 1463.0 | 2424.2 | 1218.6 | 1784.3 |
| Boxboard | 732.1 | 2213.6 | 1935.0 | 495.5 | 1764.5 | 881.6 | 1353.9 | 2243.3 | 1127.7 | 1651.2 |
| OCC | 968.3 | 2927.7 | 2559.3 | 655.4 | 2333.7 | 1166.0 | 1790.6 | 2966.9 | 1491.4 | 2183.8 |
| Mixed Paper | 177.1 | 535.6 | 468.2 | 119.9 | 426.9 | 213.3 | 327.5 | 542.7 | 272.8 | 399.5 |
| Magazines | 283.4 | 856.9 | 749.0 | 191.8 | 683.0 | 341.3 | 524.1 | 868.4 | 436.5 | 639.2 |
| Tel. Books | 11.8 | 35.7 | 31.2 | 8.0 | 28.5 | 14.2 | 21.8 | 36.2 | 18.2 | 26.6 |
| Glass Cont. | 129.9 | 392.7 | 343.3 | 87.9 | 313.1 | 156.4 | 240.2 | 398.0 | 200.1 | 293.0 |
| Plastic | 224.4 | 678.4 | 593.0 | 151.9 | 540.7 | 270.2 | 414.9 | 687.5 | 345.6 | 506.0 |
| Alumin. Cans | 35.4 | 107.1 | 93.6 | 24.0 | 85.4 | 42.7 | 65.5 | 108.5 | 54.6 | 79.9 |
| Tinplate | 59.0 | 178.5 | 156.1 | 40.0 | 142.3 | 71.1 | 109.2 | 180.9 | 90.9 | 133.2 |
| Used Tires | 188.9 | 571.3 | 499.4 | 127.9 | 455.4 | 227.5 | 349.4 | 578.9 | 291.0 | 426.1 |
| Yard Waste | 248.0 | 749.8 | 655.4 | 167.8 | 597.7 | 298.6 | 458.6 | 759.8 | 382.0 | 559.3 |
| Food Waste | 1074.5 | 3249.0 | 2840.1 | 727.3 | 2589.9 | 1294.0 | 1987.1 | 3292.6 | 1655.1 | 2423.5 |
| Wood Waste | 3176.4 | 9604.3 | 8395.6 | 2150.0 | 7655.8 | 3825.0 | 5874.0 | 9733.0 | 4892.6 | 7164.0 |
| Demol. Waste | 283.4 | 856.9 | 749.0 | 191.8 | 683.0 | 341.3 | 524.1 | 868.4 | 436.5 | 639.2 |
| Diapers | 11.8 | 35.7 | 31.2 | 8.0 | 28.5 | 14.2 | 21.8 | 36.2 | 18.2 | 26.6 |
| Foundry Sand | 779.3 | 2356.5 | 2059.9 | 527.5 | 1878.4 | 938.5 | 1441.2 | 2388.0 | 1200.4 | 1757.7 |
| Other | 2231.7 | 6748.0 | 5898.8 | 1510.6 | 5379.0 | 2687.4 | 4127.1 | 6838.5 | 3437.6 | 5033.4 |
| Total | 11784.5 | 35632.4 | 31148.0 | 7976.8 | 28403.4 | 14190.8 | 21792.8 | 36109.9 | 18151.9 | 26578.6 |
| ***Contaminants (Tonnes)*** | | | | | | | | | | |
| Ammonia-N | 5.177 | 13.705 | 16.052 | 4.613 | 11.843 | 8.217 | 14.483 | 20.680 | 10.480 | 13.777 |
| Oil & Grease | 4.177 | 11.063 | 12.864 | 3.692 | 9.528 | 6.570 | 11.549 | 16.916 | 8.373 | 11.001 |
| TSS | 75.724 | 209.007 | 221.187 | 60.992 | 168.587 | 109.200 | 186.078 | 280.274 | 138.528 | 187.334 |
| Phosphorus | 0.605 | 1.600 | 1.953 | 0.565 | 1.415 | 1.017 | 1.816 | 2.313 | 1.303 | 1.711 |
| Cyanide | 0.151 | 0.421 | 0.410 | 0.110 | 0.324 | 0.194 | 0.318 | 0.582 | 0.243 | 0.334 |
| Phenolics | 0.085 | 0.237 | 0.228 | 0.061 | 0.182 | 0.107 | 0.173 | 0.285 | 0.134 | 0.187 |
| Copper | 0.055 | 0.148 | 0.166 | 0.047 | 0.125 | 0.084 | 0.146 | 0.228 | 0.107 | 0.141 |
| Lead | 0.096 | 0.240 | 0.327 | 0.098 | 0.230 | 0.176 | 0.322 | 0.391 | 0.226 | 0.290 |
| Zinc | 0.427 | 1.198 | 1.126 | 0.297 | 0.903 | 0.523 | 0.840 | 1.409 | 0.653 | 0.919 |

Source: Econometric Research Limited and Partners

- Large total amounts of solid waste are generated by agricultural production. They are highest in Essex County and Niagara Region. The largest category of solid waste is wood waste in all counties.

- Total suspended solids (TSS) are the largest contaminant produced by agriculture in every county in this sub-region, followed by ammonia-N.

- Small amounts of phosphorous, cyanide and phenolics, copper, lead and zinc contaminants are associated with agricultural production in Southwestern Ontario.

The environmental impact results associated with agriculture production in the South-Central Ontario sub-region reveal another interesting pattern as shown in tables 3-6 below.

**Table 3**
**The Province Wide Environmental Impacts of Agriculture by County, South-Central Ontario**

| | Peel | Dufferin | Wellington | Halton | Waterloo | Perth | Huron | Bruce | Grey | Simcoe | Hastings |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Demand for Water (MCM)*** | | | | | | | | | | | |
| Intake | 74.3 | 105.8 | 453.1 | 104.4 | 313.7 | 497.0 | 579.2 | 261.9 | 226.8 | 296.0 | 76.5 |
| Discharge | 73.5 | 104.6 | 448.1 | 103.3 | 310.2 | 491.6 | 572.7 | 259.0 | 224.3 | 292.7 | 75.7 |
| Net Usage | 0.8 | 1.2 | 5.0 | 1.2 | 3.4 | 5.5 | 6.5 | 2.9 | 2.5 | 3.3 | 0.9 |
| ***Air Emissions (Tonnes)*** | | | | | | | | | | | |
| Particulates | 71.6 | 112.2 | 494.2 | 97.3 | 356.0 | 519.1 | 680.4 | 309.8 | 247.5 | 302.2 | 71.6 |
| Sulphur Oxides | 194.9 | 272.5 | 1,088.7 | 306.6 | 741.1 | 1,175.4 | 1,494.6 | 712.1 | 565.1 | 825.8 | 202.9 |
| Nitrogen Oxide | 59.4 | 83.9 | 341.6 | 91.0 | 232.3 | 370.0 | 459.9 | 215.8 | 175.2 | 248.3 | 61.8 |
| Volatile Organic C | 349.1 | 525.0 | 1,953.0 | 517.0 | 1,260.6 | 2,158.3 | 2,844.2 | 1,326.3 | 992.1 | 1,582.1 | 358.1 |
| Carbon Monixide | 214.2 | 312.3 | 1,247.7 | 297.8 | 849.5 | 1,389.8 | 1,698.2 | 774.5 | 627.6 | 903.5 | 216.2 |
| ***Energy Used (terajoules)*** | | | | | | | | | | | |
| Coal | 359.7 | 513.7 | 2,145.0 | 525.5 | 1,627.1 | 2,410.5 | 2,945.3 | 1,320.1 | 1,083.5 | 1,426.6 | 320.6 |
| Crude Oil | 949.3 | 1,340.5 | 5,346.8 | 1,562.6 | 3,538.7 | 5,670.9 | 7,361.7 | 3,539.1 | 2,779.3 | 4,087.8 | 1,015.3 |
| Natural Gas | 543.1 | 769.5 | 3,104.1 | 805.5 | 2,347.3 | 3,558.5 | 4,316.9 | 1,926.0 | 1,567.6 | 2,167.6 | 473.6 |
| Electricity | 220.4 | 317.2 | 1,334.3 | 321.0 | 1,024.4 | 1,504.2 | 1,833.9 | 814.2 | 670.7 | 866.9 | 191.6 |
| Nuclear Steam | 82.6 | 135.2 | 491.2 | 102.2 | 329.3 | 564.5 | 751.3 | 332.9 | 240.8 | 385.8 | 76.4 |
| Total | 2,155.2 | 3,076.2 | 12,421.4 | 3,316.9 | 8,866.8 | 13,708.6 | 17,209.0 | 7,932.2 | 6,341.8 | 8,934.7 | 2,077.6 |
| ***Greenhouse Gases (Tonnes)*** | | | | | | | | | | | |
| Carbon Dioxide | 115,683.9 | 166,390.2 | 677,132.3 | 178,496.5 | 470,212.1 | 738,511.6 | 935,617.6 | 437,965.1 | 345,971.2 | 487,737.6 | 117,304.3 |
| Methane | 125.9 | 181.8 | 740.2 | 191.4 | 518.6 | 814.3 | 1,025.5 | 477.0 | 376.6 | 528.9 | 125.9 |
| Nitrous Oxide | 165.9 | 240.4 | 989.4 | 249.2 | 699.9 | 1,087.5 | 1,366.6 | 633.5 | 502.4 | 692.8 | 164.9 |
| ***Green GDP ('000 Dollars)*** | | | | | | | | | | | |
| GDP | $125,622 | $166,009 | $743,331 | $206,500 | $575,064 | $860,489 | $998,048 | $426,944 | $346,318 | $488,236 | $99,630 |
| Green Cost | $8,122 | $11,819 | $47,435 | $12,216 | $32,766 | $52,003 | $66,180 | $30,807 | $24,160 | $34,597 | $8,174 |
| Green GDP | $117,500 | $154,190 | $695,897 | $194,284 | $542,298 | $808,486 | $931,868 | $396,136 | $322,158 | $453,638 | $91,456 |
| Percent of GDP | 93.5% | 92.9% | 93.6% | 94.1% | 94.3% | 94.0% | 93.4% | 92.8% | 93.0% | 92.9% | 91.8% |

Source: Econometric Research Limited and Partners

- Net usage of water is highest in Huron, Perth and Wellington counties, and relatively low in the other counties.
- Volatile organic compounds (VOC) are the highest air emissions amounts associated with agriculture in each county within South-Central Ontario.
- Large amounts of carbon monoxide and sulphur oxide are produced by agriculture in the various counties of the sub-region.
- Large amounts of particulates are produced in Huron, Perth and Wellington. Similarly the large emissions of sulphur oxides are also produced in these counties as well as Simcoe and Waterloo.
- The largest energy usage is also in Huron, Perth and Wellington counties. All counties in South-Central Ontario depend most heavily on crude oil followed by natural gas and then coal. Electricity does not account for a major share of the energy bill in agriculture in South-Central Ontario.
- Carbon dioxide is produced in abundance in every county of this sub-region.
- Green GDP as a fraction of GDP is highest in Prince Edward County and lowest in Haliburton County. It is interesting to note that the counties that produce the largest agriculture output are not those with the highest proportion of Green GDP to nominal GDP.

**Table 4**
**The Province Wide Environmental Impacts of Agriculture by County, South-Central Ontario**

| | Peel | Dufferin | Wellington | Halton | Waterloo | Perth | Huron | Bruce | Grey | Simcoe | Hastings |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Waste Generated (Tonnes)*** | | | | | | | | | | | |
| ONP | 135.6 | 197.6 | 858.3 | 187.5 | 659.0 | 962.1 | 1164.2 | 519.7 | 429.6 | 528.0 | 121.2 |
| Fine Paper | 284.0 | 413.8 | 1797.1 | 392.7 | 1379.7 | 2014.3 | 2437.5 | 1088.1 | 899.4 | 1105.5 | 253.8 |
| Boxboard | 262.8 | 382.9 | 1662.9 | 363.4 | 1276.7 | 1864.0 | 2255.6 | 1006.9 | 832.3 | 1023.0 | 234.9 |
| OCC | 347.5 | 506.4 | 2199.4 | 480.6 | 1688.6 | 2465.3 | 2983.2 | 1331.7 | 1100.7 | 1353.0 | 310.7 |
| Mixed Paper | 63.6 | 92.6 | 402.3 | 87.9 | 308.9 | 451.0 | 545.7 | 243.6 | 201.4 | 247.5 | 56.8 |
| Magazines | 101.7 | 148.2 | 643.7 | 140.7 | 494.2 | 721.5 | 873.1 | 389.8 | 322.2 | 396.0 | 90.9 |
| Tel. Books | 4.2 | 6.2 | 26.8 | 5.9 | 20.6 | 30.1 | 36.4 | 16.2 | 13.4 | 16.5 | 3.8 |
| Glass Cont. | 46.6 | 67.9 | 295.0 | 64.5 | 226.5 | 330.7 | 400.2 | 178.6 | 147.7 | 181.5 | 41.7 |
| Plastic | 80.5 | 117.3 | 509.6 | 111.4 | 391.3 | 571.2 | 691.2 | 308.6 | 255.0 | 313.5 | 72.0 |
| Alumin. Cans | 12.7 | 18.5 | 80.5 | 17.6 | 61.8 | 90.2 | 109.1 | 48.7 | 40.3 | 49.5 | 11.4 |
| Tinplate | 21.2 | 30.9 | 134.1 | 29.3 | 103.0 | 150.3 | 181.9 | 81.2 | 67.1 | 82.5 | 18.9 |
| Used Tires | 67.8 | 98.8 | 429.1 | 93.8 | 329.5 | 481.0 | 582.1 | 259.8 | 214.8 | 264.0 | 60.6 |
| Yard Waste | 89.0 | 129.7 | 563.3 | 123.1 | 432.4 | 631.4 | 764.0 | 341.0 | 281.9 | 346.5 | 79.6 |
| Food Waste | 385.7 | 562.0 | 2440.8 | 533.3 | 1873.9 | 2735.9 | 3310.6 | 1477.8 | 1221.5 | 1501.5 | 344.7 |
| Wood Waste | 1140.1 | 1661.2 | 7215.0 | 1576.5 | 5539.4 | 8087.3 | 9786.3 | 4368.6 | 3610.9 | 4438.4 | 1019.1 |
| Demol. Waste | 101.7 | 148.2 | 643.7 | 140.7 | 494.2 | 721.5 | 873.1 | 389.8 | 322.2 | 396.0 | 90.9 |
| Diapers | 4.2 | 6.2 | 26.8 | 5.9 | 20.6 | 30.1 | 36.4 | 16.2 | 13.4 | 16.5 | 3.8 |
| Foundry Sand | 279.7 | 407.6 | 1770.2 | 386.8 | 1359.1 | 1984.3 | 2401.1 | 1071.8 | 885.9 | 1089.0 | 250.0 |
| Other | 801.0 | 1167.2 | 5069.3 | 1107.7 | 3892.0 | 5682.2 | 6875.9 | 3069.4 | 2537.0 | 3118.4 | 716.0 |
| Total | 4229.8 | 6163.1 | 26768.0 | 5848.9 | 20551.4 | 30004.3 | 36307.5 | 16207.6 | 13396.6 | 16466.6 | 3780.8 |
| ***Contaminants (Tonnes)*** | | | | | | | | | | | |
| Ammonia-N | 1.955 | 3.082 | 10.737 | 2.523 | 6.910 | 12.456 | 16.522 | 7.480 | 5.344 | 9.198 | 1.882 |
| Oil & Grease | 1.574 | 2.475 | 8.662 | 2.057 | 5.567 | 10.005 | 13.254 | 6.018 | 4.318 | 7.387 | 1.528 |
| TSS | 27.998 | 41.671 | 153.232 | 36.724 | 104.523 | 176.752 | 227.256 | 103.740 | 77.496 | 123.735 | 26.509 |
| Phosphorus | 0.233 | 0.375 | 1.273 | 0.279 | 0.819 | 1.510 | 2.018 | 0.901 | 0.627 | 1.111 | 0.216 |
| Cyanide | 0.054 | 0.077 | 0.298 | 0.078 | 0.206 | 0.331 | 0.418 | 0.195 | 0.153 | 0.230 | 0.054 |
| Phenolics | 0.030 | 0.042 | 0.165 | 0.042 | 0.117 | 0.186 | 0.228 | 0.108 | 0.086 | 0.127 | 0.030 |
| Copper | 0.021 | 0.032 | 0.114 | 0.028 | 0.074 | 0.130 | 0.172 | 0.078 | 0.057 | 0.095 | 0.020 |
| Lead | 0.038 | 0.064 | 0.206 | 0.044 | 0.125 | 0.246 | 0.338 | 0.150 | 0.100 | 0.191 | 0.036 |
| Zinc | 0.152 | 0.205 | 0.820 | 0.211 | 0.591 | 0.926 | 1.127 | 0.532 | 0.427 | 0.621 | 0.150 |

Source: Econometric Research Limited and Partners

- Large total amounts of solid waste are generated by agricultural production, particularly in the three prominent agriculture counties -- Huron, Perth and Wellington counties. It is to be noted that agriculture in Waterloo Region produces large amounts of solid waste. The largest category of waste is wood waste in all counties.

- Total suspended solids (TSS) are the largest contaminant produced by agriculture in every county in this sub-region, followed by ammonia-N.

- Small amounts of phosphorous, cyanide and phenolics, copper, lead and zinc contaminants are associated with agricultural production in South-Central Ontario.

**Table 5**
**The Province Wide Environmental Impacts of Agriculture by County, South-Central Ontario**

| | Prince Edward | North-umberland | Peterborough | Kawartha Lakes | Durham | York | Muskoka | Haliburton | Parry Sound |
|---|---|---|---|---|---|---|---|---|---|
| ***Demand for Water (MCM)*** | | | | | | | | | |
| Intake | 82.5 | 121.8 | 70.6 | 101.6 | 232.8 | 224.2 | 9.3 | 1.9 | 13.1 |
| Discharge | 81.5 | 120.4 | 69.9 | 100.5 | 230.2 | 221.7 | 9.2 | 1.8 | 13.0 |
| Net Usage | 0.9 | 1.4 | 0.8 | 1.1 | 2.6 | 2.5 | 0.1 | 0.0 | 0.1 |
| ***Air Emissions (Tonnes)*** | | | | | | | | | |
| Particulates | 67.7 | 118.3 | 63.0 | 102.1 | 209.3 | 208.9 | 6.9 | 1.4 | 10.4 |
| Sulphur Oxides | 202.4 | 306.3 | 173.4 | 269.7 | 594.5 | 578.9 | 22.9 | 4.4 | 31.8 |
| Nitrogen Oxide | 62.7 | 94.7 | 54.1 | 82.5 | 182.6 | 177.5 | 7.1 | 1.4 | 9.9 |
| Volatile Organic C | 364.0 | 571.9 | 298.1 | 490.7 | 1,064.6 | 1,044.6 | 34.0 | 7.0 | 49.2 |
| Carbon Monixide | 234.2 | 351.0 | 191.0 | 289.8 | 663.7 | 641.4 | 24.4 | 4.4 | 33.4 |
| ***Energy Used (terajoules)*** | | | | | | | | | |
| Coal | 383.6 | 572.6 | 282.9 | 435.1 | 1,087.4 | 1,096.1 | 41.2 | 5.0 | 47.7 |
| Crude Oil | 963.9 | 1,497.1 | 861.5 | 1,363.8 | 2,887.9 | 2,836.5 | 107.6 | 24.1 | 158.8 |
| Natural Gas | 594.0 | 864.0 | 414.1 | 638.6 | 1,655.9 | 1,674.5 | 62.0 | 7.0 | 68.8 |
| Electricity | 235.1 | 352.3 | 169.9 | 262.1 | 664.8 | 676.1 | 24.8 | 2.9 | 28.1 |
| Nuclear Steam | 87.1 | 142.0 | 62.9 | 109.5 | 248.9 | 248.1 | 6.2 | 0.9 | 8.3 |
| Total | 2,263.8 | 3,428.2 | 1,791.2 | 2,809.1 | 6,544.8 | 6,531.3 | 241.8 | 39.9 | 311.8 |
| ***Greenhouse Gases (Tonnes)*** | | | | | | | | | |
| Carbon Dioxide | 118,364.5 | 184,499.7 | 100,816.7 | 158,489.8 | 349,848.9 | 344,821.2 | 12,963.1 | 2,410.4 | 17,825.0 |
| Methane | 129.4 | 201.4 | 108.4 | 170.2 | 380.6 | 375.4 | 14.1 | 2.5 | 18.9 |
| Nitrous Oxide | 169.9 | 265.7 | 142.6 | 223.4 | 500.2 | 493.7 | 18.5 | 3.2 | 24.8 |
| ***Green GDP ('000 Dollars)*** | | | | | | | | | |
| GDP | $148,879 | $203,886 | $91,531 | $128,152 | $399,170 | $405,508 | $14,555 | $1,404 | $13,644 |
| Green Cost | $8,350 | $13,044 | $7,008 | $11,094 | $24,573 | $24,197 | $887 | $162 | $1,214 |
| Green GDP | $140,530 | $190,842 | $84,523 | $117,058 | $374,597 | $381,311 | $13,668 | $1,242 | $12,430 |
| Percent of GDP | 94.4% | 93.6% | 92.3% | 91.3% | 93.8% | 94.0% | 93.9% | 88.5% | 91.1% |

Source: Econometric Research Limited and Partners

**Table 6**
**The Province Wide Environmental Impacts of Agriculture by County, South-Central Ontario**

| | Prince Edward | North-umberland | Peterborough | Kawartha Lakes | Durham | York | Muskoka | Haliburton | Parry Sound |
|---|---|---|---|---|---|---|---|---|---|
| ***Waste Generated (Tonnes)*** | | | | | | | | | |
| ONP | 138.8 | 218.5 | 109.2 | 167.2 | 402.6 | 409.4 | 15.7 | 1.8 | 18.1 |
| Fine Paper | 290.7 | 457.5 | 228.7 | 350.1 | 842.9 | 857.1 | 33.0 | 3.8 | 37.8 |
| Boxboard | 269.0 | 423.3 | 211.6 | 323.9 | 780.0 | 793.2 | 30.5 | 3.5 | 35.0 |
| OCC | 355.8 | 559.9 | 279.9 | 428.4 | 1031.6 | 1049.0 | 40.4 | 4.6 | 46.3 |
| Mixed Paper | 65.1 | 102.4 | 51.2 | 78.4 | 188.7 | 191.9 | 7.4 | 0.8 | 8.5 |
| Magazines | 104.1 | 163.9 | 81.9 | 125.4 | 301.9 | 307.0 | 11.8 | 1.4 | 13.6 |
| Tel. Books | 4.3 | 6.8 | 3.4 | 5.2 | 12.6 | 12.8 | 0.5 | 0.1 | 0.6 |
| Glass Cont. | 47.7 | 75.1 | 37.5 | 57.5 | 138.4 | 140.7 | 5.4 | 0.6 | 6.2 |
| Plastic | 82.4 | 129.7 | 64.8 | 99.3 | 239.0 | 243.1 | 9.3 | 1.1 | 10.7 |
| Alumin. Cans | 13.0 | 20.5 | 10.2 | 15.7 | 37.7 | 38.4 | 1.5 | 0.2 | 1.7 |
| Tinplate | 21.7 | 34.1 | 17.1 | 26.1 | 62.9 | 64.0 | 2.5 | 0.3 | 2.8 |
| Used Tires | 69.4 | 109.2 | 54.6 | 83.6 | 201.3 | 204.7 | 7.9 | 0.9 | 9.0 |
| Yard Waste | 91.1 | 143.4 | 71.7 | 109.7 | 264.2 | 268.6 | 10.3 | 1.2 | 11.9 |
| Food Waste | 394.8 | 621.4 | 310.6 | 475.5 | 1144.8 | 1164.1 | 44.8 | 5.1 | 51.4 |
| Wood Waste | 1167.1 | 1836.8 | 918.1 | 1405.5 | 3384.0 | 3441.3 | 132.4 | 15.2 | 151.9 |
| Demol. Waste | 104.1 | 163.9 | 81.9 | 125.4 | 301.9 | 307.0 | 11.8 | 1.4 | 13.6 |
| Diapers | 4.3 | 6.8 | 3.4 | 5.2 | 12.6 | 12.8 | 0.5 | 0.1 | 0.6 |
| Foundry Sand | 286.3 | 450.7 | 225.3 | 344.8 | 830.3 | 844.3 | 32.5 | 3.7 | 37.3 |
| Other | 820.0 | 1290.5 | 645.1 | 987.5 | 2377.6 | 2417.8 | 93.0 | 10.7 | 106.7 |
| Total | 4329.8 | 6814.5 | 3406.2 | 5214.3 | 12554.8 | 12767.2 | 491.1 | 56.3 | 563.6 |
| ***Contaminants (Tonnes)*** | | | | | | | | | |
| Ammonia-N | 2.103 | 3.294 | 1.534 | 2.616 | 5.966 | 5.822 | 0.166 | 0.025 | 0.218 |
| Oil & Grease | 1.690 | 2.648 | 1.248 | 2.121 | 4.803 | 4.702 | 0.136 | 0.021 | 0.181 |
| TSS | 29.528 | 45.363 | 22.300 | 36.075 | 84.910 | 81.485 | 2.889 | 0.362 | 3.471 |
| Phosphorus | 0.249 | 0.396 | 0.175 | 0.304 | 0.708 | 0.684 | 0.018 | 0.002 | 0.023 |
| Cyanide | 0.058 | 0.086 | 0.046 | 0.071 | 0.165 | 0.160 | 0.006 | 0.001 | 0.008 |
| Phenolics | 0.033 | 0.047 | 0.026 | 0.039 | 0.093 | 0.088 | 0.004 | 0.000 | 0.005 |
| Copper | 0.022 | 0.034 | 0.016 | 0.027 | 0.063 | 0.062 | 0.002 | 0.000 | 0.002 |
| Lead | 0.041 | 0.066 | 0.028 | 0.051 | 0.115 | 0.113 | 0.002 | 0.000 | 0.003 |
| Zinc | 0.161 | 0.234 | 0.130 | 0.193 | 0.462 | 0.434 | 0.020 | 0.002 | 0.024 |

Source: Econometric Research Limited and Partners

The environmental impact results associated with agriculture production in the Southeastern Ontario sub-region reveal another interesting pattern as shown in tables 7 and 8 below.

- Net usage of water is highest in Stormont, Dundas and Glengarry United Counties, followed by Prescott County and the City of Ottawa. The remaining counties show relatively low net water usage.

- Volatile organic compounds (VOC) are the highest air emissions amounts associated with agriculture in each county within Southeastern Ontario.

- Large amounts of carbon monoxide and sulphur oxide are produced by agriculture in the various counties of the sub-region.

- Large amounts of particulates are produced in Stormont, Dundas and Glengarry United Counties, Prescott County and the City of Ottawa. Similarly the large emissions of sulphur oxides are also produced in these counties as well as in Leeds and Grenville United Counties.

- The largest energy usage is also in Stormont, Dundas and Glengarry United Counties, Prescott County and the City of Ottawa. All counties in Southeastern Ontario depend most heavily on crude oil followed by natural gas and then coal. Electricity does not account for a major share of the energy bill in agriculture in South-Central Ontario.

- Carbon dioxide is produced in abundance in every county of this sub-region.

- Green GDP as a fraction of GDP is highest in Lennox County and lowest in Lanark County. It is interesting again to note that the counties that produce the largest agriculture output are not those with the highest proportion of Green GDP to nominal GDP. Meaning that the mitigation costs of agriculture are quite significant.

**Table 7**
**The Province Wide Environmental Impacts of Agriculture by County, Southeastern Ontario**

| | Stormont | Prescott | Ottawa | Leeds | Lanark | Frontenac | Lennox | Renfrew | Nippissing |
|---|---|---|---|---|---|---|---|---|---|
| ***Demand for Water (MCM)*** | | | | | | | | | |
| Intake | 267.4 | 210.7 | 160.7 | 111.9 | 46.1 | 35.7 | 55.1 | 74.8 | 14.2 |
| Discharge | 264.4 | 208.4 | 158.9 | 110.7 | 45.6 | 35.3 | 54.5 | 74.0 | 14.0 |
| Net Usage | 3.0 | 2.3 | 1.8 | 1.2 | 0.5 | 0.4 | 0.6 | 0.8 | 0.2 |
| ***Air Emissions (Tonnes)*** | | | | | | | | | |
| Particulates | 258.9 | 193.4 | 157.3 | 102.2 | 41.4 | 31.2 | 49.0 | 70.7 | 12.0 |
| Sulphur Oxides | 697.1 | 506.8 | 462.8 | 269.5 | 122.9 | 91.7 | 129.4 | 204.9 | 35.9 |
| Nitrogen Oxide | 213.0 | 158.4 | 138.2 | 83.9 | 37.4 | 28.2 | 40.8 | 61.9 | 11.1 |
| Volatile Organic C | 1,342.8 | 938.6 | 857.6 | 458.5 | 208.9 | 151.5 | 223.0 | 349.2 | 61.9 |
| Carbon Monixide | 803.0 | 596.9 | 482.8 | 305.9 | 127.6 | 95.1 | 148.0 | 209.3 | 38.7 |
| ***Energy Used (terajoules)*** | | | | | | | | | |
| Coal | 1,240.7 | 922.2 | 763.3 | 500.6 | 188.2 | 139.1 | 238.6 | 311.1 | 53.9 |
| Crude Oil | 3,371.7 | 2,444.9 | 2,334.3 | 1,288.1 | 618.2 | 466.2 | 630.3 | 1,035.2 | 179.6 |
| Natural Gas | 1,884.0 | 1,382.9 | 1,165.7 | 740.4 | 277.3 | 202.7 | 354.1 | 454.9 | 79.6 |
| Electricity | 753.9 | 562.6 | 461.6 | 305.7 | 111.8 | 82.7 | 146.2 | 184.7 | 31.9 |
| Nuclear Steam | 338.9 | 231.3 | 192.9 | 105.8 | 41.3 | 28.2 | 50.7 | 69.3 | 12.4 |
| Total | 7,589.2 | 5,543.9 | 4,917.7 | 2,940.7 | 1,236.8 | 918.8 | 1,419.9 | 2,055.2 | 357.4 |
| ***Greenhouse Gases (Tonnes)*** | | | | | | | | | |
| Carbon Dioxide | 415,131.0 | 302,734.8 | 270,579.6 | 160,080.1 | 70,262.2 | 52,211.7 | 77,041.4 | 117,495.4 | 20,333.4 |
| Methane | 453.8 | 330.8 | 291.5 | 174.7 | 75.0 | 55.5 | 83.7 | 125.4 | 21.7 |
| Nitrous Oxide | 596.7 | 436.8 | 379.7 | 231.8 | 98.1 | 72.6 | 110.8 | 164.1 | 28.3 |
| ***Green GDP ('000 Dollars)*** | | | | | | | | | |
| GDP | $447,911 | $334,689 | $279,645 | $169,239 | $58,252 | $46,729 | $83,877 | $99,931 | $16,220 |
| Green Cost | $29,601 | $21,433 | $18,956 | $11,169 | $4,854 | $3,583 | $5,370 | $8,109 | $1,413 |
| Green GDP | $418,310 | $313,256 | $260,689 | $158,070 | $53,398 | $43,146 | $78,507 | $91,822 | $14,807 |
| Percent of GDP | 93.4% | 93.6% | 93.2% | 93.4% | 91.7% | 92.3% | 93.6% | 91.9% | 91.3% |

Source: Econometric Research Limited and Partners

- Large total amounts of solid waste are generated by agricultural production, particularly in the three prominent agriculture counties – Stormont, Dundas and Glengarry United Counties, Prescott County and the City of Ottawa. It is also true that agriculture in Leeds produces large amounts of solid waste. The largest category of waste is wood waste in all counties.

- Total suspended solids (TSS) are the largest contaminant produced by agriculture in every county in this sub-region, followed by ammonia-N.

- Small amounts of phosphorous, cyanide and phenolics, copper, lead and zinc contaminants are associated with agricultural production in Southeastern Ontario.

**Table 8**
**The Province Wide Environmental Impacts of Agriculture by County, Southeastern Ontario**

| | Stormont | Prescott | Ottawa | Leeds | Lanark | Frontenac | Lennox | Renfrew | Nippissing |
|---|---|---|---|---|---|---|---|---|---|
| ***Waste Generated (Tonnes)*** | | | | | | | | | |
| ONP | 472.1 | 354.8 | 277.7 | 194.2 | 70.5 | 52.5 | 91.9 | 117.1 | 20.0 |
| Fine Paper | 988.5 | 742.8 | 581.5 | 406.6 | 147.5 | 109.8 | 192.5 | 245.1 | 41.9 |
| Boxboard | 914.7 | 687.4 | 538.1 | 376.3 | 136.5 | 101.6 | 178.1 | 226.8 | 38.8 |
| OCC | 1209.8 | 909.1 | 711.6 | 497.7 | 180.6 | 134.4 | 235.6 | 300.0 | 51.3 |
| Mixed Paper | 221.3 | 166.3 | 130.2 | 91.0 | 33.0 | 24.6 | 43.1 | 54.9 | 9.4 |
| Magazines | 354.1 | 266.1 | 208.3 | 145.7 | 52.8 | 39.3 | 68.9 | 87.8 | 15.0 |
| Tel. Books | 14.8 | 11.1 | 8.7 | 6.1 | 2.2 | 1.6 | 2.9 | 3.7 | 0.6 |
| Glass Cont. | 162.3 | 122.0 | 95.5 | 66.8 | 24.2 | 18.0 | 31.6 | 40.2 | 6.9 |
| Plastic | 280.3 | 210.6 | 164.9 | 115.3 | 41.8 | 31.1 | 54.6 | 69.5 | 11.9 |
| Alumin. Cans | 44.3 | 33.3 | 26.0 | 18.2 | 6.6 | 4.9 | 8.6 | 11.0 | 1.9 |
| Tinplate | 73.8 | 55.4 | 43.4 | 30.3 | 11.0 | 8.2 | 14.4 | 18.3 | 3.1 |
| Used Tires | 236.1 | 177.4 | 138.9 | 97.1 | 35.2 | 26.2 | 46.0 | 58.5 | 10.0 |
| Yard Waste | 309.8 | 232.8 | 182.3 | 127.5 | 46.2 | 34.4 | 60.3 | 76.8 | 13.1 |
| Food Waste | 1342.6 | 1008.9 | 789.8 | 552.3 | 200.4 | 149.2 | 261.4 | 332.9 | 56.9 |
| Wood Waste | 3968.7 | 2982.3 | 2334.5 | 1632.7 | 592.3 | 440.9 | 772.7 | 984.0 | 168.3 |
| Demol. Waste | 354.1 | 266.1 | 208.3 | 145.7 | 52.8 | 39.3 | 68.9 | 87.8 | 15.0 |
| Diapers | 14.8 | 11.1 | 8.7 | 6.1 | 2.2 | 1.6 | 2.9 | 3.7 | 0.6 |
| Foundry Sand | 973.7 | 731.7 | 572.8 | 400.6 | 145.3 | 108.2 | 189.6 | 241.4 | 41.3 |
| Other | 2788.4 | 2095.4 | 1640.3 | 1147.1 | 416.2 | 309.8 | 542.9 | 691.4 | 118.3 |
| Total | 14724.1 | 11064.5 | 8661.3 | 6057.2 | 2197.5 | 1635.8 | 2866.9 | 3650.8 | 624.5 |
| ***Contaminants (Tonnes)*** | | | | | | | | | |
| Ammonia-N | 8.070 | 5.446 | 4.708 | 2.502 | 1.045 | 0.712 | 1.189 | 1.740 | 0.315 |
| Oil & Grease | 6.464 | 4.377 | 3.801 | 2.019 | 0.851 | 0.586 | 0.964 | 1.419 | 0.257 |
| TSS | 109.659 | 75.529 | 64.099 | 37.333 | 15.232 | 10.390 | 17.340 | 25.102 | 4.526 |
| Phosphorus | 0.988 | 0.654 | 0.555 | 0.293 | 0.117 | 0.076 | 0.137 | 0.194 | 0.036 |
| Cyanide | 0.199 | 0.143 | 0.124 | 0.074 | 0.032 | 0.023 | 0.035 | 0.053 | 0.009 |
| Phenolics | 0.113 | 0.081 | 0.068 | 0.044 | 0.018 | 0.013 | 0.020 | 0.030 | 0.005 |
| Copper | 0.082 | 0.056 | 0.049 | 0.026 | 0.011 | 0.008 | 0.013 | 0.018 | 0.003 |
| Lead | 0.168 | 0.109 | 0.094 | 0.045 | 0.019 | 0.012 | 0.022 | 0.031 | 0.006 |
| Zinc | 0.557 | 0.402 | 0.333 | 0.219 | 0.090 | 0.064 | 0.099 | 0.149 | 0.027 |

Source: Econometric Research Limited and Partners

# 5. The Sub-Regional Comparative Environmental Impacts of Agriculture in Southern Ontario by County

Agriculture in Southwestern Ontario accounts for most of the environmental impacts of agriculture, followed closely by South-Central Ontario. The following general characteristics are evident from the results in tables 9 and 10.

- Net water usage of agriculture exceeds 45.4 MCM in Southwestern Ontario, about 42.8 MCM in South-Central Ontario and about 10.9 MCM in Southeastern Ontario.

- Volatile organic compounds generated by agriculture exceed 21,244 tonnes in Southwestern Ontario, 17,790 tonnes in South-Central Ontario and only 4,592 tonnes in Southeastern Ontario.

- Total energy usage is over 124,800 terajoules in Southwestern Ontario, 110,002 terajoules in South-Central and 26,980 terajoules in Southeastern Ontario.

- Crude oil usage is over 56,884 terajoules in Southwestern Ontario, 47,893 terajoules in South-Central and 12,368 terajoules in Southeastern Ontario.

- Agriculture produces large amounts of greenhouse gases with carbon dioxide exceeding 6,779,842 tonnes in Southwestern Ontario, 5,961,062 tonnes in South-Central Ontario and 1,485,870 tonnes in Southeastern Ontario, but still below the emission levels of most industrial activities. Direct agricultural emissions in Canada have typically been around 8% of all emissions.[1]

- There are no significant sub-regional differences in the proportion of green GDP to GDP. It is 93.5% in South-Central Ontario, 93.4% in Southwestern Ontario and 93.2% in Southeastern Ontario.

[1] Desjardins, R. et al. 2010. Agricultural greenhouse gases. In: Eilers, W., R. MacKay, L. Graham and A. Lefebvre (eds). Environmental Sustainability of Canadian Agriculture: Agri-Environmental Indicator. Report Series — Report #3. Agriculture and Agri-Food Canada, Ottawa, Ontario. Pp. 110-117.

**Table 9**
**Comparative Environmental Impacts of Agriculture by Sub-Region**

| | South-Western | South-Central | South-Eastern |
|---|---|---|---|
| ***Demand for Water (MCM)*** | | | |
| Intake | 4,028.3 | 3,846.4 | 976.6 |
| Discharge | 3,982.9 | 3,803.7 | 965.7 |
| Net Usage | 45.4 | 42.8 | 10.9 |
| ***Air Emissions (Tonnes)*** | | | |
| Particulates | 4,176.1 | 4,049.9 | 916.1 |
| Sulphur Oxides | 11,353.9 | 9,764.0 | 2,521.0 |
| Nitrogen Oxide | 3,413.8 | 3,011.7 | 772.9 |
| Volatile Organic C | 21,244.3 | 17,789.9 | 4,592.0 |
| Carbon Monixide | 12,090.0 | 10,964.6 | 2,807.3 |
| ***Energy Used (terajoules)*** | | | |
| Coal | 20,082.5 | 18,629.2 | 4,357.7 |
| Crude Oil | 56,884.2 | 47,893.2 | 12,368.5 |
| Natural Gas | 30,496.5 | 27,558.6 | 6,541.6 |
| Electricity | 12,299.8 | 11,514.9 | 2,641.1 |
| Nuclear Steam | 5,037.3 | 4,406.1 | 1,070.8 |
| Total | 124,800.2 | 110,002.3 | 26,979.6 |
| ***Greenhouse Gases (Tonnes)*** | | | |
| Carbon Dioxide | 6,779,841.9 | 5,961,061.7 | 1,485,869.6 |
| Methane | 7,347.8 | 6,507.0 | 1,612.1 |
| Nitrous Oxide | 9,629.6 | 8,634.5 | 2,118.9 |
| ***Green GDP ('000 Dollars)*** | | | |
| GDP | $7,166,532 | $6,442,920 | $1,536,493 |
| Green Cost | $476,458 | $418,808 | $104,488 |
| Green GDP | $6,690,074 | $6,024,112 | $1,432,005 |
| Percent of GDP | 93.4% | 93.5% | 93.2% |

Source: Econometric Research Limited and Partners

**Table 10**
**Comparative Environmental Impacts of Agriculture by Sub-Region**

| | South-Western | South-Central | South-Eastern |
|---|---|---|---|
| ***Waste Generated (Tonnes)*** | | | |
| ONP | 7431.4 | 7244.1 | 1650.8 |
| Fine Paper | 15559.5 | 15167.5 | 3456.2 |
| Boxboard | 14398.4 | 14035.4 | 3198.3 |
| OCC | 19043.1 | 18563.0 | 4230.1 |
| Mixed Paper | 3483.5 | 3395.7 | 773.8 |
| Magazines | 5573.6 | 5433.0 | 1238.0 |
| Tel. Books | 232.2 | 226.4 | 51.7 |
| Glass Cont. | 2554.6 | 2490.0 | 567.5 |
| Plastic | 4412.6 | 4301.0 | 980.0 |
| Alumin. Cans | 696.7 | 679.2 | 154.8 |
| Tinplate | 1161.2 | 1131.9 | 257.9 |
| Used Tires | 3715.8 | 3621.9 | 825.4 |
| Yard Waste | 4877.0 | 4754.0 | 1083.2 |
| Food Waste | 21133.1 | 20600.2 | 4694.4 |
| Wood Waste | 62470.7 | 60895.1 | 13876.4 |
| Demol. Waste | 5573.6 | 5433.0 | 1238.0 |
| Diapers | 232.2 | 226.4 | 51.7 |
| Foundry Sand | 15327.4 | 14940.7 | 3404.6 |
| Other | 43892.1 | 42785.0 | 9749.8 |
| Total | 231769.1 | 225922.4 | 51482.6 |
| ***Contaminants (Tonnes)*** | | | |
| Ammonia-N | 119.027 | 99.833 | 25.727 |
| Oil & Grease | 95.733 | 80.395 | 20.738 |
| TSS | 1636.911 | 1406.019 | 359.210 |
| Phosphorus | 14.298 | 11.921 | 3.050 |
| Cyanide | 3.087 | 2.695 | 0.692 |
| Phenolics | 1.679 | 1.496 | 0.392 |
| Copper | 1.247 | 1.049 | 0.266 |
| Lead | 2.396 | 1.957 | 0.506 |
| Zinc | 8.295 | 7.422 | 1.940 |

Source: Econometric Research Limited and Partners

- Total solid waste produced by agriculture is 231,769 tonnes in Southwestern Ontario, 225,922 tonnes in South-Central Ontario and 51,483 in Southeastern Ontario.

- Total suspended solids are about 1,637 tonnes in Southwestern Ontario, 1,406 tonnes in South-Central Ontario and 359 tonnes in Southeastern Ontario.

- Total ammonia-N contaminants associated with agriculture are relatively small with 119 tonnes in Southwestern Ontario, 100 tonnes in South-Central Ontario and 26 tonnes in Southeastern Ontario.

- Other contaminants associated with agricultural production in Southern Ontario sub-regions including oil & grease, phosphorus, cyanide, phenolics, copper, lead and zinc are relatively small and insignificant.

# 6. Total Environmental Impacts of Agriculture in Southern Ontario

Aggregating all of the environmental impacts by indicator for all of Southern Ontario reveals a set of interesting results as displayed in tables 11 and 12.

- The water intake associated with agriculture in Southern Ontario is about 9 billion cubic metres per year with a net usage of only 100 billion cubic metres.
- Large amounts of emissions are generated by agriculture production but particularly of VOC, sulphur oxides and carbon monoxide, but generally far below emissions of industrial activities.
- Total direct, indirect and induced energy consumption exceeds 261,782 terajoules. To put this in proportion, in 2007, Ontario households consumed 515,166 terajoules of energy in total.[2]
- Crude oil remains the dominant energy source in agriculture with 117,146 terajoules.
- A total of 14,226,773 tonnes of greenhouse gases are generated by agriculture production in Southern Ontario.
- Green GDP is 93.4% of nominal GDP.
- A total of $1 billion dollars is the estimated green cost of agriculture production.
- A total of 509,174 tonnes of solid waste are generated by agriculture in Southern Ontario with 137,242 tonnes of wood waste.
- More than 46,427 tonnes of food waste are associated with agriculture production in Southern Ontario.
- Total suspended solids produced by agriculture in Southern Ontario exceeded 3,402 tonnes.
- Total ammonia-N contaminants associated with agricultural production in Southern Ontario exceeded 244 tonnes.

[2] Households and the Environment: Energy Use, 2007, Statistics Canada, Catalogue no. 11-526-S.

**Table 11**
**The Province Wide Environmental Impacts of Agriculture**
**Southern Ontario**

| | Total |
|---|---|
| ***Demand for Water (MCM)*** | |
| Intake | 8,851.34 |
| Discharge | 8,752.24 |
| Net Usage | 99.09 |
| | |
| ***Air Emissions (Tonnes)*** | |
| Particulates | 9,142.1 |
| Sulphur Oxides | 23,638.9 |
| Nitrogen Oxide | 7,198.4 |
| Volatile Organic C | 43,626.2 |
| Carbon Monixide | 25,861.9 |
| | |
| ***Energy Used (terajoules)*** | |
| Coal | 43,069.4 |
| Crude Oil | 117,145.9 |
| Natural Gas | 64,596.7 |
| Electricity | 26,455.8 |
| Nuclear Steam | 10,514.2 |
| Total | 261,782.1 |
| | |
| ***Greenhouse Gases (Tonnes)*** | |
| Carbon Dioxide | 14,226,773.2 |
| Methane | 15,466.9 |
| Nitrous Oxide | 20,383.0 |
| | |
| ***Green GDP ('000 Dollars)*** | |
| GDP | $15,145,945 |
| Green Cost | $999,754 |
| Green GDP | $14,146,191 |
| Percent of GDP | 93.4% |

Source: Econometric Research Limited and Partners

**Table 12**
**The Province Wide Environmental Impacts of Agriculture**
**Southern Ontario**

| | |
|---|---|
| ***Waste Generated (Tonnes)*** | |
| ONP | 16,326.3 |
| Fine Paper | 34,183.2 |
| Boxboard | 31,632.1 |
| OCC | 41,836.2 |
| Mixed Paper | 7,653.0 |
| Magazines | 12,244.6 |
| Tel. Books | 510.3 |
| Glass Cont. | 5,612.1 |
| Plastic | 9,693.6 |
| Alumin. Cans | 1,530.7 |
| Tinplate | 2,551.0 |
| Used Tires | 8,163.1 |
| Yard Waste | 10,714.2 |
| Food Waste | 46,427.7 |
| Wood Waste | 137,242.2 |
| Demol. Waste | 12,244.6 |
| Diapers | 510.3 |
| Foundry Sand | 33,672.7 |
| Other | 96,426.9 |
| Total | 509,174.1 |
| | |
| ***Contaminants (Tonnes)*** | |
| Ammonia-N | 244.6 |
| Oil & Grease | 196.9 |
| TSS | 3,402.1 |
| Phosphorus | 29.3 |
| Cyanide | 6.5 |
| Phenolics | 3.6 |
| Copper | 2.6 |
| Lead | 4.9 |
| Zinc | 17.7 |

Source: Econometric Research Limited and Partners

# 7. The Environmental Impacts of Agriculture and Agri-Food Manufacturing in Southern Ontario and Regions

The environmental impacts of agri-food manufacturing are not much different qualitatively and quantitatively from agriculture production. Among the most significant differences are the following:

- Total water intake associated with agri-food is higher than that of agriculture – 9.3 billion cubic metres with a net water usage of over 115 million cubic metres.
- Total air emissions are also higher, with agri-food generating 25,951 tonnes of VOC, 24,833 tonnes of carbon monoxide and 18,649 of sulphur oxide.
- Total energy use in the agri-food production is 249,271 terajoules with natural gas accounting for the largest energy consumption with 91,493 terajoules.
- Green GDP in the agri-food sector is a higher proportion of nominal GDP, with a 94.9% ratio.
- The total green cost in the agri-food sector is slightly higher at about $1.1 billion.
- Almost three times (2.8) as much solid waste is produced by the agri-food sector than the agricultural sector.
- Total suspended solids are significantly higher in the agri-food manufacturing sector than in agriculture.
- There is a noticeable difference in the contaminants generated by the agri-food manufacturing sector compared to agricultural production. The agri-food manufacturing sector produces less ammonia-N and lower amounts of oil & grease but much more phosphorous.
- The agri-food manufacturing sector produces more cyanide, phenolics, and zinc but less copper and lead than agriculture.

**Table 13**
**The Province Wide Environmental Impacts of Agri-Food Production in Southern Ontario**

| | |
|---|---|
| ***Demand for Water (Cubic Meters)*** | |
| Intake | 9,328,334,146 |
| Discharge | 9,213,205,544 |
| Net Usage | 115,128,050 |
| ***Air Emissions (Tonnes)*** | |
| Particulates | 7,133 |
| Sulphur Oxides | 18,649 |
| Nitrogen Oxide | 6,024 |
| Volatile Organic C | 25,951 |
| Carbon Monixide | 24,833 |
| ***Energy Used (terajoules)*** | |
| Coal | 55,029 |
| Crude Oil | 62,760 |
| Natural Gas | 91,493 |
| Electricity | 32,880 |
| Nuclear Steam | 7,108 |
| Total | 249,271 |
| ***Greenhouse Gases (Tonnes)*** | |
| Carbon Dioxide | 14,823,281 |
| Methane | 18,407 |
| Nitrous Oxide | 24,715 |
| ***Green GDP (Millions of Dollars)*** | |
| GDP | $21,345 |
| Green Cost | $1,090 |
| Green GDP | $20,255 |
| Percent of GDP | 94.9% |

Source: Econometric Research Limited and Partners

**Table 14**
**The Province Wide Environmental Impacts of Agri-Food Production in Southern Ontario**

| | |
|---|---|
| ***Waste Generated (Tonnes)*** | |
| ONP | 45,202 |
| Fine Paper | 94,641 |
| Boxboard | 87,579 |
| OCC | 115,830 |
| Mixed Paper | 21,188 |
| Magazines | 33,901 |
| Tel. Books | 1,413 |
| Glass Cont. | 15,538 |
| Plastic | 26,839 |
| Alumin. Cans | 4,238 |
| Tinplate | 7,063 |
| Used Tires | 22,601 |
| Yard Waste | 29,664 |
| Food Waste | 128,543 |
| Wood Waste | 379,978 |
| Demol. Waste | 33,901 |
| Diapers | 1,413 |
| Foundry Sand | 93,229 |
| Other | 266,973 |
| Total | 1,409,733 |
| ***Contaminants (Tonnes)*** | |
| Ammonia-N | 216.0 |
| Oil & Grease | 164.3 |
| TSS | 6424.6 |
| Phosphorus | 44.9 |
| Cyanide | 6.8 |
| Phenolics | 5.3 |
| Copper | 2.1 |
| Lead | 2.8 |
| Zinc | 31.3 |

Source: Econometric Research Limited and Partners

# 8. The Environmental Impacts of the Food Supply Chain in Southern Ontario and Regions

In this section, we first describe the methodology used to assess emissions from trucks transporting agricultural products in Southern Ontario. We then describe the aggregate results obtained. More detailed results are provided in the Appendix to this document.

## *8.1 Estimating Food Commodity Flows and Truck Emissions*

For this analysis, we consider Southern Ontario divided into 40 counties as shown in the map of Figure 1. We start with the production and consumption of commodities at a county level in terms of tonnage and, as a first step, we determine the flows of commodities between origin and destination counties. We then translate the commodity into truck flows. Following that, using truck flows we derive emissions of pollutants using the software package Mobile 6.2c, a version of the MOBILE6 Vehicle Emission Modeling Software, developed by the US Environmental Protection Agency and customized for the Canadian fleet of vehicles.[3] The results of the analysis provide, for each commodity, the average weekday trips and the contribution towards environmental emissions.

## *8.2 Commodity Production/Consumption*

We start with the production and consumption data for three categories of food commodities - Cereal, Fruits/Vegetables, and Livestock - for the 40 counties within Southern Ontario. While the estimated production data were available at the county level, consumption was only available on an estimated national per/capita basis. This required converting the consumption data to county level using the total population for each county. To balance the production and consumption totals for all counties, we assigned the deficit and surplus for each commodity to an external zone. For example, as the total production of wheat in the 40 counties is greater than the total consumption, we assigned the surplus as consumption to the external zone. The latter is defined as the rest of the world outside the boundaries of Southern Ontario study area. For each county, the general balance is defined as:

Consumption + Exports = Production + Imports

Further, we uniformly converted the commodity data into tonnes to serve as inputs to the development of origin-destination matrices.

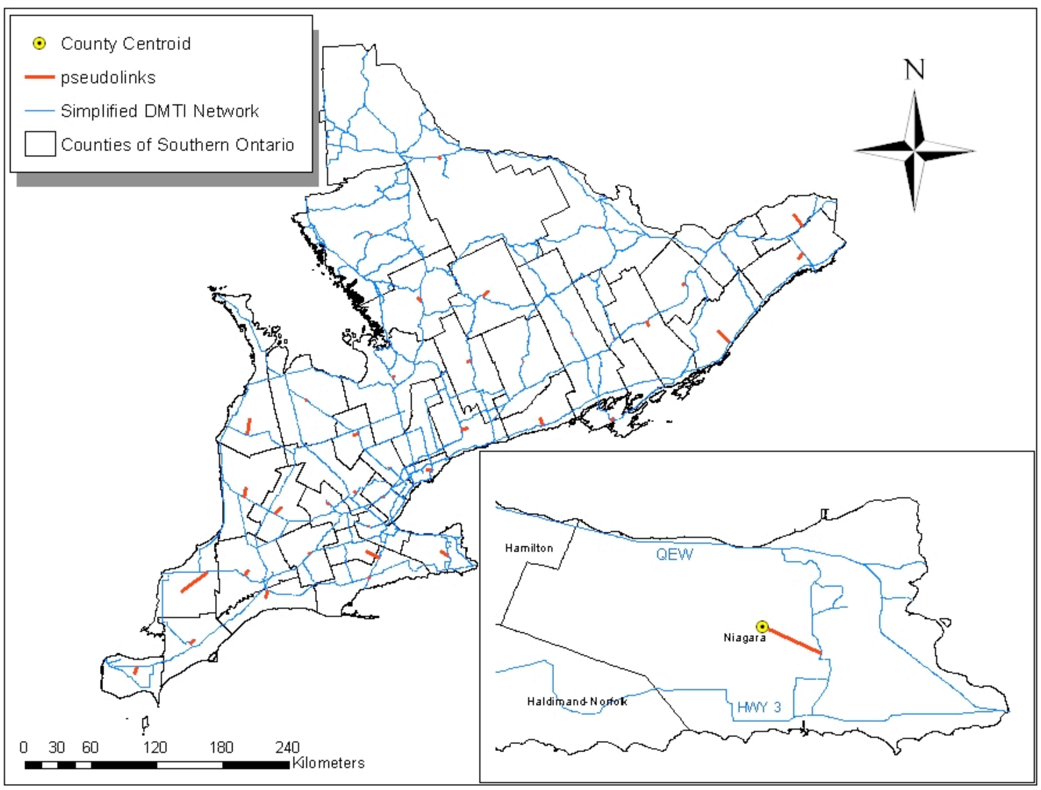
## *8.3 GIS-Based Road Network and Zonal System*

In a Geographical Information System (GIS), we developed a vector road network for Southern Ontario as a shape file consisting of arterial roads and highways. We processed further this shape file to obtain the network as a graph consisting of links and nodes suitable for traffic assignment modelling. This

[3] The Canadian Transit Company (2007),CEAA Environmental Impact Assessment, Ambassador Bridge Enhancement Project, pp 21.

entailed identifying the topological relationships between the various links to define the connectivity of the network. Furthermore, we used the DMTI road class[4] to determine the posted travel speeds [km/hour] on each road link. The design capacity on each road link was based on estimating the number of lanes per link. We derived the latter from the GEOBASE GIS road network produced by Natural Resources Canada.[5] We used standard information from the Highway Capacity Manual 7 to determine the passenger car per lane per hour (PCPLPH) values on each link of the network.[6] The product of the PCPLPH value and number of lanes of each link provided the design capacity measure needed when performing the traffic assignment (see below for description). We calculated the length of each link in km using GIS. This information is used in conjunction with the posted speeds during simulations to determine the time required to traverse a given link in a free flow situation.

**Figure 3 – Southern Ontario Road Network**




A county-level zone system was also developed to represent the origins and destinations for the 40 counties within Southern Ontario, as shown in Figure 1. An additional zone to represent flows from the external zone was also created. These zones serve as the basis for the development of origin-destination matrices using production and consumption for each commodity. In order to connect origins and destinations to the network we created pseudo links connecting the geometric centroid of each county to

[4] DMTI Spatial Inc. (2005) CanMap Major Roads and Highways, User Manual Version 2005.3, pp 23.
[5] http://www.geobase.ca/geobase/en/news/2013/nrn-on.html.
[6] Highway Capacity Manual 2010 (HCM2010). Transportation Research Board. National Academy of Sciences.

the network, as shown in red in Figure 3. The assumption here is that any commodity flows out of a county emanate from the centroid of the county.

### *8.4 Developing Origin/Destination Commodity Flows*

We used a doubly-constrained gravity model to estimate the commodity flows produced at an origin county and attracted to a destination county. This is a method that takes as input the marginal totals in a table, in this case county productions and consumptions, and optimally fills all the cells of the table. The basic premise is that the flow of a commodity between an origin county and a destination is proportional to the production of the origin and the consumption of the destination and inversely proportional to some function of the distance between the origin and the destination, which is typically referred to as friction. We run a separate model for each one of the commodities. The model balances both production and consumption for a commodity between the counties based on supply and demand. The basic assumption here is that the flows produced at an origin and attracted to a destination are proportional to the total production at the origin and the total attraction at the destination.

We obtained a travel-time matrix representing the free-flow travel times between origin-destination pairs using the Southern Ontario road network. To estimate the parameters of the gravity model, we developed a friction factor matrix. These factors represent the resistance to flows as the travel time or travel distance increases. We developed the factors using the calibration parameters specified in the NCHRP Report-365.[7]

The application of the gravity model results in a commodity flow-matrix after the production and consumption totals are balanced, i.e., when the total production matches the total consumption for all counties. Using the flow data for the commodities, we created separate trip matrices for each commodity for assigning to the road-network.

### *8.5 Development of Truck Trip Matrices*

The Commodity Flow Survey (CFS) is a comprehensive nationwide goods movement data source on freight shipments by establishment in the United States,[8] and provides flow information in terms of the tonnage and value of commodities between origins and destinations. Using this resource, we converted the origin/destination commodity flows into truck trips for the purposes of assignment onto the transport network. In what follows in this section we discuss briefly the procedure of converting commodity flows measured in tons into the equivalent number of trucks for the development of truck O-D matrices.

The first step in the process is to identify the primary truck configurations and major truck body types. There are five truck configuration categories and nine body types (for example: dry van, flat bed, bulk, reefer, etc). The primary truck configuration categories are:

1. Single Unit Trucks

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[7] Transportation Research Board (1998) NCHRP Report-365, Travel Estimation Techniques for Urban Planning, pp 41.
[8] http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/commodity_flow_survey/index.html.

2. Truck plus Trailer Combination
3. Tractor plus Semitrailer Combination
4. Tractor plus Double Trailer Combination
5. Tractor plus Triple Trailer Combination

The second step involves allocating the tonnage for each commodity to truck configurations used to transport the commodity. We used separate allocations for five distance ranges (0-50 miles, 51-100 miles, 101-200 miles, 201-500 miles, and 501-10000 miles).

In the third step, we developed truck equivalency factors. For this, we established the mean payloads by truck type, body type, and commodity type using the Vehicle Inventory and Use Survey (VIUS) 2002 database.[9]

We then applied the mean payloads to the percent allocations by body type to convert the commodity volume in tons to an equivalent number of trucks. This step converts the flows allocated for each truck configuration to create a disaggregated dataset describing the total number of loaded trucks required to move the freight between the zones. The loaded truck traffic estimates were disaggregated by commodity type, truck configuration, and body type.

In the fifth step, we adjusted the number of truck trips estimated in step four to account for empty-backhauls based on the percentage for a given truck and body type configuration.

A detailed discussion on converting the commodity flows from tons to truck trips is provided in the FAF Freight Traffic Analysis draft report.[10]

### *8.6 Assignment of Trips*

Our next step was to determine the routes trucks will follow on the actual transport network. This was accomplished with TRAFFIC, an in-house software package for travel demand modeling and forecasting. It accepts as input a set of origin/destination matrices for the different types of trucks, such as those described in the previous subsection. TRAFFIC is based on the Stochastic User Equilibrium (SUE) algorithm, which simulates how travelers choose their paths to go from a given origin to a given destination. To determine emissions from trucks, hourly flow estimates are needed by vehicle class for a typical weekday of the year.

For this project, we modified the TRAFFIC algorithm to assign truck trips for the primary truck configuration categories discussed in the previous section. Since TRAFFIC allows a maximum of four vehicle classes to be assigned simultaneously, two categories 'Tractor plus Double Trailer Combinations' and 'Tractor plus Triple Trailer Combinations' were combined into one class: Tractor plus Double/Triple Trailer Combinations. We preserved the first three configuration categories in their original format.

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[9] http://www.census.gov/prod/ec02/ec02tv-us.pdf.
[10] USDOT, Federal Highway Administration (2011) FAF3 Freight Traffic Analysis, Final Draft Report.

### 8.7 Estimating Link-Based Emissions

LINK EMISSIONS is an in-house software package that we used to extract and display the results of calculations from TRAFFIC for on-road mobile sources. The software makes use of the assigned traffic volume on a link of the network and combines it with emission factors to calculate emissions for several pollutants. The emission factors used are derived from Mobile 6.2C, a version of the USEPA MOBILE6 Vehicle Emission Modeling Software[11] that has been calibrated for the Canadian car fleet. LINK EMISSIONS generates either tabular information or a spatial output for emissions in the form of GIS shape files on the link. The traffic emission pollutants that we considered in this study are:

- Hydrocarbons (gaseous)
- Oxides of nitrogen (gaseous)
- Carbon monoxide (gaseous)
- Particulate matter (PM2.5 and PM10)
  - $SO_4$ - sulfate portion of exhaust particulate
  - OCARBON - organic carbon portion of diesel exhaust particulate
  - ECARBON - elemental carbon portion of diesel exhaust particulate
  - GASPM - total carbon portion of gasoline exhaust particulate
  - Lead - Lead Portion of Exhaust Particulate
  - $SO_2$ - Sulfur Dioxide (gaseous)
  - $NH_3$ - Ammonia (gaseous)
  - Brake - Brake Wear Particulate
  - Tire - Tire Wear Particulate
- Air Toxics
  - Benzene
  - 1,3-Butadiene
  - Formaldehyde
  - Acetaldehyde
  - Acrolein
- Carbon dioxide

# 9. Results

The process described above generates spatially detailed results at the level of the transportation link. Figures 4, 5 and 6 indicate the highways 401, 403 and QEW are prominent in moving agricultural

[11] http://www.epa.gov/otaq/m6.htm.

produce and products in southern Ontario. As a result, CO, NOx and PM10 emissions on them are high. Figures for other pollutants are similar, so they are not included in this report. In terms of a breakdown of emissions by region, Table 15 indicates that in Southwestern Ontario emissions are about twice as high as South-central and Eastern Ontario combined. The reason for that is the relatively heavier agricultural production in Southwestern Ontario and the movement of the produce to the more heavily populated South-central and to Eastern Ontario. Although the values in Table 15 refer to the peak hour of 8:00am, the summation over all hours of a typical weekday provide a similar order of magnitude in pollutants.

**Figure 4 – CO Emissions, Total Food Commodity Flows, 8:00 am, Average Weekday (2011)**

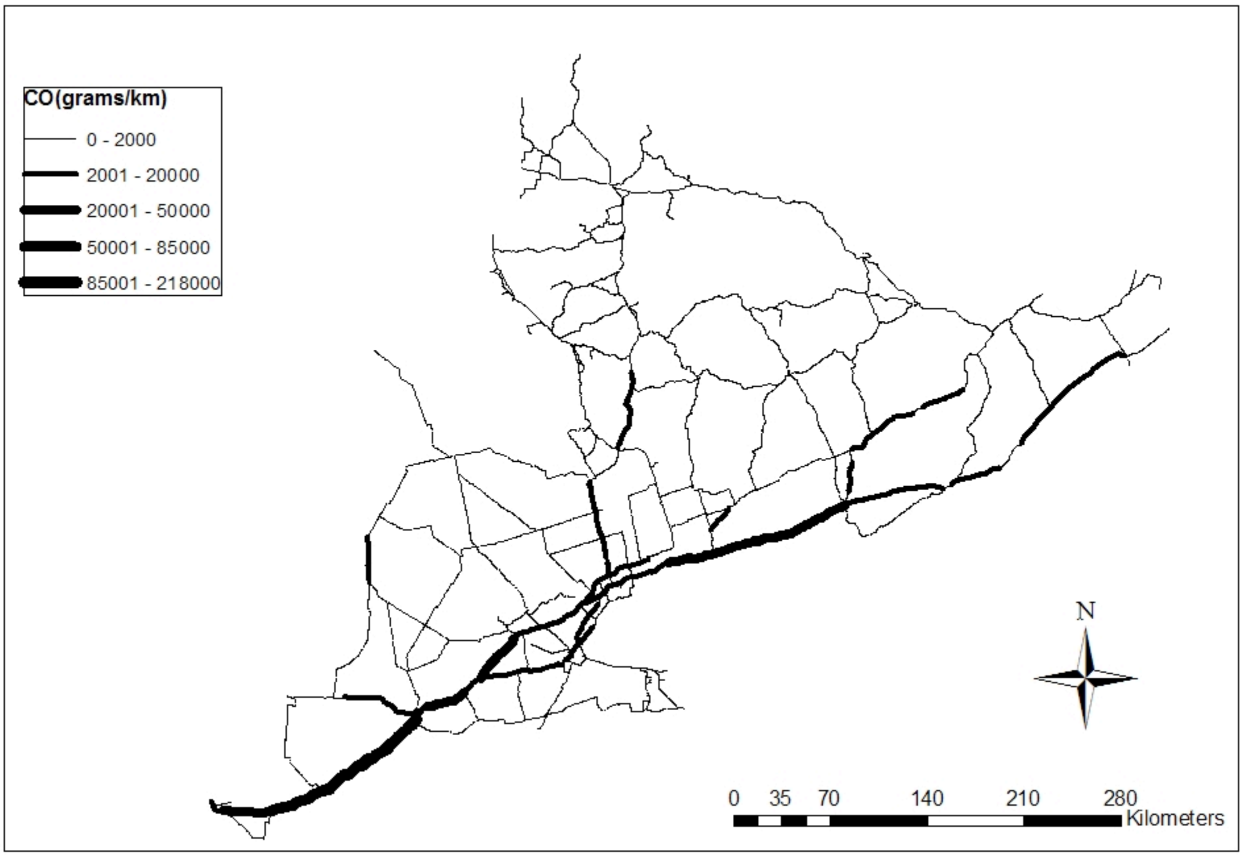

**Figure 5 – Nox Emissions, Total Food Commodity Flows, 8:00 am, Average Weekday (2011)**

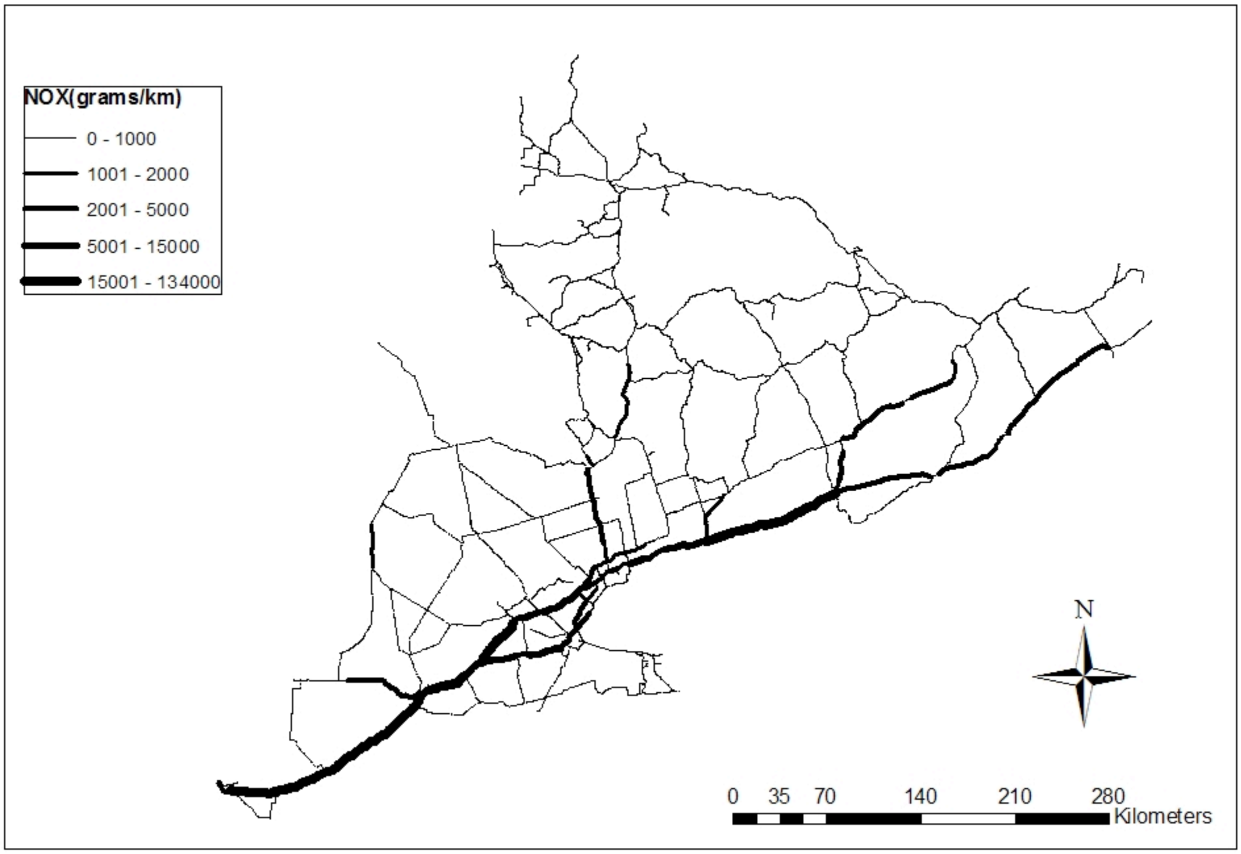

**Figure 6 – Particulate Matter (PM10) Emissions, Total Food Commodity Flows, 8:00 am, Average Weekday (2011)**

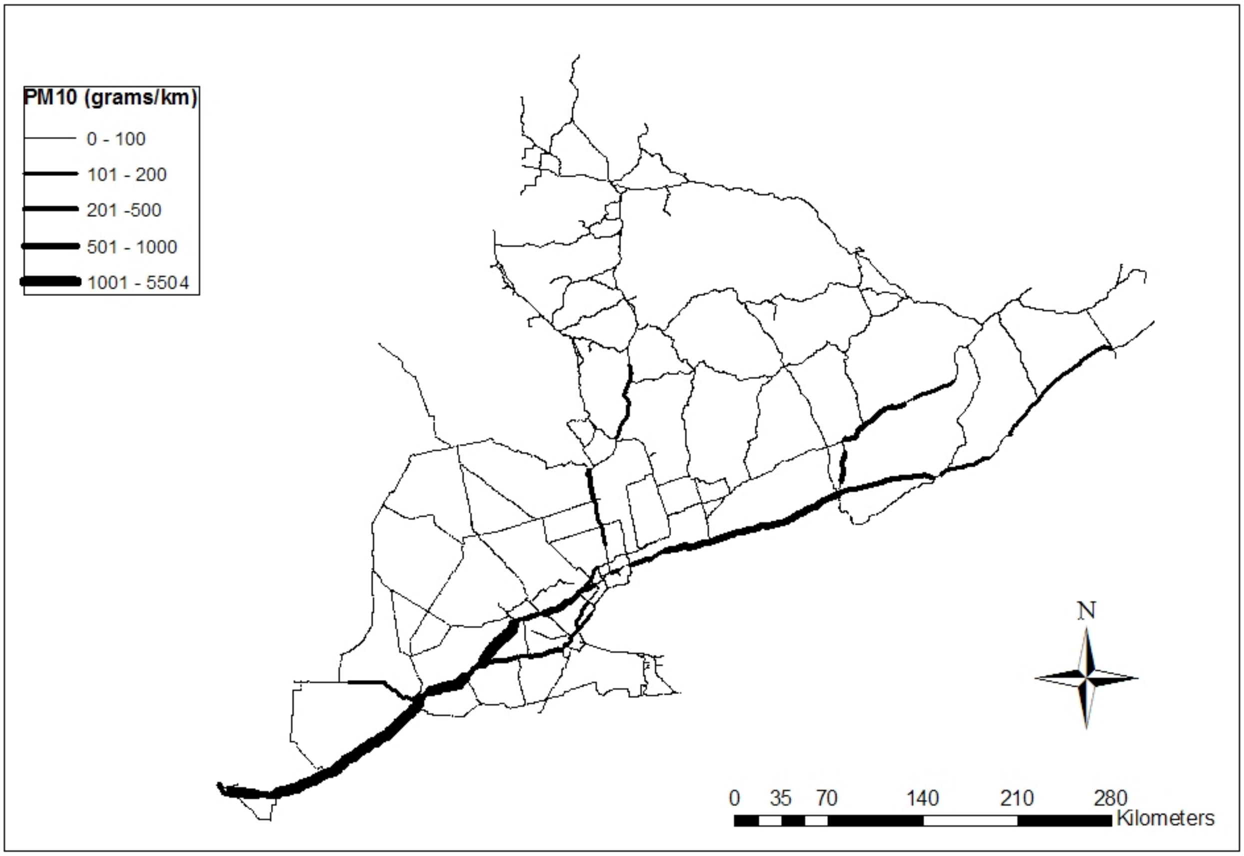


**Table 15**
**2011 Average Weekday Emissions (kg/km) for Total Food Commodity Flows, 8:00 am**

| | CO | NOx | PM10 |
|---|---|---|---|
| Southwestern ON | 606 | 368 | 20 |
| South Central ON | 263 | 160 | 9 |
| South Eastern ON | 56 | 34 | 2 |
| Total | 926 | 562 | 31 |

Table 16 provides a summary of the emissions for all pollutants by commodity. The series of tables in Appendix 1 provides a more detailed description of the emissions by commodity. From the aggregate results, it is clear that:

- Most of the emissions are generated from the movement of cereals (over 83.6%), followed by fruit/vegetables and livestock. This is mainly due to the high tonnage of cereal, mostly grain corn and wheat, transported between the counties and locations outside the study area (imports and exports).

- Counties in the Southwestern part of the province generally produce more cereal than the Eastern and Central regions. Due to a large amount of cereal being transported outside the study area, including the USA, the emissions within this region are considerably higher.

- The allocation of tonnage to heavier truck types (e.g., combination semitrailer, combination double/triple) as opposed to the lighter ones (e.g., single unit) increases with trip distance. For example, a combination semitrailer that is allocated 13% of the tonnage for travel distance of 80km-160km is allocated 75% of the tonnage for a distance of 320km to 800km. Consequently, the emissions increase with increases in truck payload. A detailed description of the tonnage allocation to different types of truck is described in more detail in the section of this report entitled Development of Truck Trip Matrices.

- Emissions are also affected by the total distance travelled by commodities weighted by their tonnage. For example, the total network travel distance weighted by tonnage (i.e., the sum of the products and distances between origin-destination counties and corresponding tonnage) for Wheat, Grapes and Beef are 608.4 tonne-km, 24.6 tonne-km, and 11.0 tonne-km, respectively. Also, the average trip length for these commodities is 261.8km (Wheat), 84.6km (Grapes), and 243.1km (Beef).

- From the cereals over 81% of pollutants and in some cases, such as $SO_4$ and PM10, and over 90% of pollutants are generated from the movement of grain corn.

- Corn and wheat movement is responsible for almost all the emissions from cereals.

- From within the fruits/vegetables group, movement of potatoes is most prominent (over 51%) followed by tomatoes (over 10%).

- From the livestock category, chicken movement is most prominent, followed by eggs, beef and pigs.

## Table 16
## 2011 Total Annual Emissions for Commodity Flows in Southern Ontario (Tons) - Base Case

| Commodity | HC | CO | NOX | CO2 | SO4 | PM10 | PM2.5 | BENZENE | BUTADIENE | FORMALDEHYDE | ACETALDEHYDE | ACROLEIN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cereal** | | | | | | | | | | | | |
| Wheat | 80.05 | 1,519.60 | 500.94 | 57,050.81 | 0.24 | 29.39 | 25.87 | 1.51 | 0.56 | 3.71 | 1.07 | 0.30 |
| Oats | 0.48 | 13.11 | 7.33 | 759.89 | 0.00 | 0.40 | 0.35 | 0.01 | 0.00 | 0.02 | 0.01 | 0.00 |
| Barley | 5.31 | 94.92 | 43.10 | 4,401.58 | 0.02 | 2.30 | 2.03 | 0.08 | 0.03 | 0.18 | 0.05 | 0.01 |
| Grain Corn | 371.20 | 9,848.20 | 5,843.93 | 691,546.83 | 2.97 | 343.01 | 301.52 | 6.91 | 2.79 | 20.94 | 6.40 | 1.53 |
| **Total** | **457.04** | **11,475.83** | **6,395.30** | **753,759.10** | **3.23** | **375.10** | **329.78** | **8.52** | **3.38** | **24.86** | **7.53** | **1.84** |
| **Fruits/Vegetables** | | | | | | | | | | | | |
| Apple | 8.08 | 213.16 | 111.53 | 11,705.97 | 0.05 | 6.35 | 5.60 | 0.14 | 0.06 | 0.36 | 0.11 | 0.03 |
| Strawberry | 0.26 | 7.51 | 4.14 | 428.55 | 0.00 | 0.23 | 0.20 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |
| Peach | 0.12 | 3.99 | 2.19 | 223.58 | 0.00 | 0.12 | 0.11 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |
| Grapes | 0.01 | 0.27 | 0.14 | 14.23 | 0.00 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Tomatoes | 8.97 | 137.37 | 51.98 | 5,283.63 | 0.02 | 2.88 | 2.54 | 0.13 | 0.04 | 0.28 | 0.08 | 0.02 |
| Carrots | 1.40 | 34.08 | 17.18 | 1,833.62 | 0.01 | 1.01 | 0.89 | 0.02 | 0.01 | 0.06 | 0.02 | 0.00 |
| Cabbage | 0.34 | 9.84 | 5.30 | 567.61 | 0.00 | 0.31 | 0.27 | 0.01 | 0.00 | 0.02 | 0.01 | 0.00 |
| Sweet Corn | 1.84 | 39.58 | 19.16 | 1,977.24 | 0.01 | 1.07 | 0.95 | 0.03 | 0.01 | 0.07 | 0.02 | 0.01 |
| Green Wax Beans | 0.12 | 3.94 | 2.23 | 228.70 | 0.00 | 0.12 | 0.11 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |
| Peppers | 0.24 | 7.05 | 3.83 | 410.19 | 0.00 | 0.22 | 0.20 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |
| Dry Onions | 0.27 | 7.49 | 3.79 | 460.39 | 0.00 | 0.26 | 0.23 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 |
| Potatoes | 43.36 | 765.66 | 234.27 | 26,271.05 | 0.11 | 13.86 | 12.22 | 0.78 | 0.28 | 1.80 | 0.51 | 0.15 |
| **Total** | **65.01** | **1,229.93** | **455.74** | **49,404.77** | **0.21** | **26.45** | **23.32** | **1.13** | **0.42** | **2.64** | **0.76** | **0.21** |
| **Livestock** | | | | | | | | | | | | |
| Chicken | 17.85 | 395.68 | 178.76 | 19,935.48 | 0.08 | 11.40 | 10.07 | 0.31 | 0.13 | 0.71 | 0.21 | 0.05 |
| Beef | 2.31 | 41.77 | 17.55 | 1,878.53 | 0.01 | 1.05 | 0.93 | 0.04 | 0.01 | 0.08 | 0.02 | 0.01 |
| Sheep_Lamb | 0.02 | 0.81 | 0.47 | 49.74 | 0.00 | 0.03 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pigs | 1.23 | 26.26 | 11.89 | 1,298.09 | 0.01 | 0.73 | 0.65 | 0.02 | 0.01 | 0.05 | 0.01 | 0.00 |
| Turkey | 0.17 | 2.92 | 1.17 | 125.65 | 0.00 | 0.07 | 0.06 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |
| Eggs | 3.30 | 96.55 | 49.95 | 5,451.31 | 0.02 | 3.06 | 2.70 | 0.06 | 0.03 | 0.16 | 0.05 | 0.01 |
| **Total** | **24.88** | **563.99** | **259.79** | **28,738.79** | **0.12** | **16.34** | **14.43** | **0.43** | **0.18** | **1.00** | **0.30** | **0.07** |
| **TOTAL** | **546.94** | **13,269.75** | **7,110.82** | **831,902.66** | **3.55** | **417.89** | **367.53** | **10.09** | **3.98** | **28.50** | **8.59** | **2.12** |

# 10. Alternative Scenarios of Production and Transportation of Food

To test the impacts of incremental changes from the base case (benchmark) scenario, we developed alternative scenarios of production and transport of food. Specifically, we formulated two scenarios as discussed below. For consistency, in implementing the scenarios, we used the same procedure described in the “Estimating Food Commodity Flows and Truck Emissions” section of the report. For this purpose, however, we developed new origin-destination truck trip matrices using the production/consumption data that were pertinent to the scenarios.

## *10.1 Scenario 1 – The Optimal Food Bundle*

This scenario quantifies the impact of food consumption based on the estimated optimal nutrition requirements in the 40 counties of Southern Ontario. To estimate the origin-destination truck trips for the counties, the optimal level (kg/capita) of food was used, as described in the economic report of this project. While the production of food is maintained at current levels, consumption is varied to reflect the optimal food requirements.

## *10.2 Scenario 2 – Import (Export) Substitution*

In this scenario, the impact of replacing imports with domestic production is tested, as well as exporting excess production over consumption. Here, we formulated two alternatives.

- The first case involves a generalized 10% reduction in the top ten imports of edible fruits and vegetables. For the purposes of this scenario, we developed the origin-destination truck-trip matrices for the counties using per capita reductions of imports as specified in tables S3-18 and S3-19 of the “Local Food and Economy Report”.

- In the second case, the impact of a reduction in imports and/or an expansion of exports of peppers and tomatoes are tested. The concept here is that we align consumption with what we are able to produce domestically, import or export. Here, we developed the origin-destination truck-trip matrices for the counties by reducing consumption and reducing imports (increasing exports). In Ontario, the total production of peppers is 83.13 kilo tons and the consumption is 52.69 kilo tons. The excess production of peppers in Ontario is decreased by increasing exports (83.13 – 52.69) proportionally from the counties where there is a surplus. For Tomatoes, the total production in Ontario is 701.66 kilo tons and the total consumption is 403.08 kilo tons. For all those counties where there is a food deficit for Tomatoes, the consumption is reduced to match production levels. However, since total production is greater than consumption for Ontario, the reduced consumption in Ontario is allocated as exports to the external zone to preserve the balance of trips.

## 10.3 Environmental Impacts

Tables 17 to 19 present the estimated emissions for scenarios 1 and 2. The results from the scenarios reflect the variations in total truck-trips related emissions across Southern Ontario and the external zone. In the optimal food bundle scenario, the total emissions generally increase with respect to the base case for cereals and fruits/vegetables. This is particularly true for Oats, Apples, Strawberries, Tomatoes, Carrots, Cabbage, Sweet Corn, Green and Wax Beans and Potatoes. However, this scenario does not incorporate reductions in wheat and grain corn consumption and production that might be associated with land use shifts to production required for the optimal food basket scenario. From the Desjardins et al. analysis,[12] land use shifts in the order of 10% are likely which would produce net reductions in emissions associated with transport.

In the first case of import substitution scenario involving a generalized 10% reduction in the top ten imports of edible fruits and vegetables, total emissions generally decrease with respect to the base case. For $CO_2$ production, for example, 10% reduction in imports from eight of the top ten import crops (comparing tables 16 and 18) resulted in an overall 57% reduction in emissions. The largest savings are associated with tomatoes. However, for Grapes, the total emissions increase as the reduced consumption per capita leads to higher exports.

In the second case of import substitution scenario involving a simultaneous reduction in imports or increase in exports of peppers and tomatoes, the total emissions for peppers increases whereas the total emissions for tomatoes decreases. This is because of the total increase in the exports of tomatoes and some increase in the exports of peppers. A reduction in consumption of peppers leads to consequent reduction in imports. In the case of Tomatoes, however, the total production is much higher than total consumption in Southern Ontario. Therefore, a reduction in consumption of tomatoes, leads to a major increase in exports.

[12] Desjardins, E., R. MacRae and T. Schumilas. 2010. Meeting future population food needs with local production in Waterloo Region: linking food availability and optimal nutrition requirements. Agriculture and Human Values 27(2):129-140.

**Table 17**

**2011 Total Annual Emissions for Commodity Flows in Southern Ontario (Tons) –Optimal Food Bundle**

| Commodity | HC | CO | NOX | CO2 | SO4 | PM10 | PM2.5 | BENZENE | BUTADIENE | FORMALDEHYDE | ACETALDEHYDE | ACROLEIN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cereal** | | | | | | | | | | | | |
| Wheat | - | - | - | - | - | - | - | - | - | - | - | - |
| Oats | 0.64 | 17.61 | 9.85 | 1,020.86 | 0.00 | 0.54 | 0.47 | 0.01 | 0.00 | 0.03 | 0.01 | 0.00 |
| Barley | - | - | - | - | - | - | - | - | - | - | - | - |
| Grain Corn | - | - | - | - | - | - | - | - | - | - | - | - |
| **Total** | **0.64** | **17.61** | **9.85** | **1,020.86** | **0.00** | **0.54** | **0.47** | **0.01** | **0.00** | **0.03** | **0.01** | **0.00** |
| **Fruits/Vegetables** | | | | | | | | | | | | |
| Apple | 17.21 | 453.78 | 237.44 | 24,920.61 | 0.10 | 13.51 | 11.92 | 0.31 | 0.13 | 0.77 | 0.23 | 0.05 |
| Strawberry | 0.47 | 13.35 | 7.36 | 761.97 | 0.00 | 0.41 | 0.36 | 0.01 | 0.00 | 0.02 | 0.01 | 0.00 |
| Tomatoes | 9.04 | 138.43 | 52.38 | 5,324.15 | 0.02 | 2.90 | 2.56 | 0.13 | 0.04 | 0.28 | 0.08 | 0.02 |
| Carrots | 29.30 | 711.77 | 358.76 | 38,290.31 | 0.16 | 21.15 | 18.66 | 0.51 | 0.21 | 1.25 | 0.37 | 0.09 |
| Cabbage | 1.13 | 32.61 | 17.57 | 1,881.04 | 0.01 | 1.02 | 0.90 | 0.02 | 0.01 | 0.05 | 0.02 | 0.00 |
| Sweet Corn | 3.37 | 72.57 | 35.13 | 3,625.04 | 0.02 | 1.97 | 1.74 | 0.05 | 0.02 | 0.13 | 0.04 | 0.01 |
| Green Wax Beans | 6.50 | 209.12 | 118.21 | 12,149.02 | 0.05 | 6.54 | 5.77 | 0.12 | 0.05 | 0.34 | 0.10 | 0.02 |
| Potatoes | 90.97 | 1,606.38 | 491.52 | 55,117.73 | 0.23 | 29.09 | 25.63 | 1.63 | 0.59 | 3.78 | 1.08 | 0.31 |
| **Total** | **157.98** | **3,238.01** | **1,318.36** | **142,069.87** | **0.59** | **76.59** | **67.54** | **2.79** | **1.06** | **6.62** | **1.93** | **0.51** |
| **Grand Total** | **158.62** | **3,255.62** | **1,328.21** | **143,090.74** | **0.60** | **77.13** | **68.01** | **2.80** | **1.06** | **6.65** | **1.94** | **0.51** |

**Table 18**
**2011 Total Annual Emissions for Commodity Flows in Southern Ontario (Tons) –Import Substitution**

| Commodity | HC | CO | NOX | CO2 | SO4 | PM10 | PM2.5 | BENZENE | BUTADIENE | FORMALDEHYDE | ACELDEHYDE | ACROLEIN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Fruits/Vegetables** | | | | | | | | | | | | |
| Apple | 1.15 | 26.47 | 13.32 | 1,456.03 | 0.01 | 0.79 | 0.70 | 0.02 | 0.01 | 0.05 | 0.01 | 0.00 |
| Strawberry | 0.09 | 5.86 | 3.40 | 343.72 | 0.00 | 0.18 | 0.16 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |
| Grapes | 1.04 | 30.11 | 16.81 | 1,688.61 | 0.01 | 0.89 | 0.79 | 0.02 | 0.01 | 0.05 | 0.01 | 0.00 |
| Tomatoes | 5.33 | 70.75 | 22.72 | 2,398.76 | 0.01 | 1.31 | 1.16 | 0.08 | 0.03 | 0.15 | 0.04 | 0.01 |
| Carrots | 1.06 | 25.09 | 12.39 | 1,285.73 | 0.01 | 0.70 | 0.62 | 0.02 | 0.01 | 0.04 | 0.01 | 0.00 |
| Cabbage | 0.24 | 7.45 | 4.21 | 442.00 | 0.00 | 0.23 | 0.21 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |
| Peppers | 0.19 | 6.22 | 3.60 | 373.11 | 0.00 | 0.19 | 0.17 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |
| Dry Onions | 0.26 | 8.01 | 4.21 | 467.04 | 0.00 | 0.26 | 0.23 | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 |
| **TOTAL** | **9.36** | **179.96** | **80.66** | **8,455.00** | **0.04** | **4.55** | **4.04** | **0.15** | **0.06** | **0.33** | **0.07** | **0.01** |

**Table 19**
**2011 Total Annual Emissions for Commodity Flows in Southern Ontario (Tons) – Simultaneous Reduction in Imports and Exports of Peppers and Tomatoes**

| Commodity | HC | CO | NOX | CO2 | SO4 | PM10 | PM2.5 | BENZENE | BUTADIENE | FORMALDEHYDE | ACELDEHYDE | ACROLEIN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Fruits/Vegetables** | | | | | | | | | | | | |
| Tomatoes | 5.88 | 74.95 | 23.02 | 2,419.37 | 0.01 | 1.32 | 1.16 | 0.09 | 0.03 | 0.16 | 0.05 | 0.01 |
| Peppers | 0.10 | 3.37 | 1.91 | 203.33 | 0.00 | 0.11 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **TOTAL** | **5.98** | **78.32** | **24.93** | **2,622.70** | **0.01** | **1.43** | **1.26** | **0.09** | **0.03** | **0.16** | **0.05** | **0.01** |

# 11. Conclusions

The environmental impacts of agriculture and agri-food manufacturing were estimated for tw
First, the embedded environmental impacts of agriculture and food manufacturing were esti
then the environmental impacts of the Ontario food supply chain.

Aggregating all of the environmental impacts by indicator for all of Southern Ontario revea
interesting results that include the following:

- The water intake associated with agriculture in Southern Ontario is about 9 billion cu per year with a net usage of only 100 billion cubic metres.
- Large amounts of emissions are generated by agriculture production but particularly sulphur oxides and carbon monoxide, but generally far below emissions of industrial ac
- Total direct, indirect and induced energy consumption exceeds 261,782 terajoules. To proportion, in 2007, Ontario households consumed 515,166 terajoules of energy in tota
- Crude oil remains the dominant energy source in agriculture with 117,146 terajoules.
- A total of 14,226,773 tonnes of greenhouse gases are generated by agriculture pro Southern Ontario.
- Green GDP is 93.4% of nominal GDP.
- A total of $1 billion dollars is the estimated green cost of agriculture production.
- A total of 509,174 tonnes of solid waste are generated by agriculture in Southern Or 137,242 tonnes of wood waste.
- More than 46,427 tonnes of food waste is associated with agriculture production ir Ontario.
- Total suspended solids produced by agriculture in Southern Ontario exceeded 3,402 tor
- Total ammonia-N contaminants associated with agricultural production in Souther exceeded 244 tonnes.

By comparison with the environmental impacts of agriculture, the environmental impacts oi
manufacturing generates environmental impacts that are qualitatively and quantitatively simil
the most significant differences are the following:

[13] Households and the Environment: Energy Use, 2007, Statistics Canada, Catalogue no. 11-526-S.

- Total water intake associated with agri-food is lower than that of agriculture -- 6.5 billion cubic metres with a net water usage of about 80 million cubic metres.

- Total air emissions are also lower, with agri-food generating 17,966 tonnes of VOC, 17,192 tonnes of carbon monoxide and 12,911 of sulphur oxide.

- Total energy use in the agri-food production is 172,574 terajoules with natural gas accounting for the largest energy consumption with 63,342 terajoules.

- Green GDP in the agri-food sector is a higher proportion of nominal GDP, with a 94.9% ratio.

- The total green cost in the agri-food sector is only $754 million.

- Almost twice as much solid waste is produced by the agri-food sector than the agricultural sector.

- Total suspended solids are significantly higher in the agri-food manufacturing sector than in agriculture.

- There is a noticeable difference in the contaminants generated by the agri-food manufacturing sector compared to agricultural production. The agri-food manufacturing sector produces less ammonia-N and lower amounts of oil & grease but slightly more phosphorous.

- The agri-food manufacturing sector produces less cyanide but more phenolics, and less copper and lead but more zinc than agriculture.

Over and beyond the 40 counties we considered one additional geographical zone that represents the world outside of Southern Ontario. That latter zone allowed us to take into account imports and exports. We started with the production and consumption of commodities at a county level in terms of tonnage. As a first step, we determined the flows of commodities between origin and destination counties. We then translated the commodity into truck flows. Following that, using truck flows on the transport network we derived emissions of pollutants using the software package Mobile 6.2c, a version of the MOBILE6 Vehicle Emission Modeling Software, developed by the US Environmental Protection Agency and customized for the Canadian fleet of vehicles.[14] The results of the analysis provided, for each commodity, the average weekday trips and the contribution towards environmental emissions.

The results indicate that highways 401, 403 and QEW are prominent in moving agricultural produce and products in southern Ontario and are associated with high emissions for all the pollutants. In terms of a breakdown by region, South-Western Ontario emissions are about twice as high as South-Central and Eastern Ontario combined. The reason for these high emissions is the relatively heavier agricultural production in South-Western Ontario and the movement of the produce to the more heavily populated South-Central and to Eastern Ontario.

[14] The Canadian Transit Company (2007),CEAA Environmental Impact Assessment, Ambassador Bridge Enhancement Project, pp 21.

A breakdown of emissions by commodity indicates that the movement of cereals generates over 83.6% of the emissions. This is mainly due to the high tonnage of cereal, mostly grain corn and wheat, transported between the counties and locations outside the study area (imports and exports). From the cereals over 81% of pollutants and in some cases, such as CO2, over 91% of pollutants are generated from the movement of grain corn. Counties in the South-Western part of the province generally produce more cereal than the Eastern and Central regions. Due to a large amount of cereal being transported outside the study area, including the USA, the emissions within this region is considerably higher. From within the fruits/vegetables group, movement of potatoes is most prominent (over 51%) followed by tomatoes (over 10%). From the livestock category, chicken movement is most prominent, followed by eggs and beef.

**Emissions under Alternative Scenarios of Food Production and Distribution**

To test the impacts of incremental changes from the base case (benchmark) scenario, we developed alternative scenarios of production and transport of food. Specifically, we formulated two scenarios:

*The Optimal Food Bundle Scenario:*

This scenario quantifies the impact of food consumption based on the estimated optimal nutrition requirements in the 40 counties of Southern Ontario. While the production of food is maintained at current levels, consumption is varied to reflect the optimal food requirements, as defined in the detailed economic report of this study.

*Import Substitution Scenario:*

In this scenario, the impact of replacing imports with domestic production is tested. Here, we formulated two alternatives:

- The first case involves a generalized 10% reduction in the top ten imports of edible fruits and vegetables.

- In the second case, the impact of a simultaneous reduction in imports and exports of peppers and tomatoes is tested. The concept here is that we align consumption with local production.

Results indicate that in the optimal food bundle scenario, the total emissions generally increase with respect to the base case for cereals and fruits/vegetables. However, for Tomatoes and Sweet Corn, the total emissions decrease. This is because, for these two commodities, the current total production is much higher than consumption in Southern Ontario, as a consequence of which, higher local consumption leads to reduced exports. However, this scenario does not incorporate reductions in wheat and grain corn consumption and production that might be associated with land use shifts to production required for the optimal food basket scenario. Given that the majority of emissions in the baseline scenario are associated with wheat and grain corn exports, a modest shift of a few percentage points out of wheat and grain corn production and export would cancel out the very small increases associated with increased oat and white bean distribution within Ontario. From the Desjardins et al. analysis,[15] land use shifts in the order of 10% are likely, which would produce net reductions in emissions associated with transport.

In the first case of scenario 2, involving a generalized 10% reduction in the top ten imports of edible fruits and vegetables, total emissions generally decrease with respect to the base case. For $CO_2$ production, for example, 10% reduction in imports from eight of the top ten import crops (comparing tables 16 and 18) resulted in an overall 59% reduction in emissions of $CO_2$. The largest savings are associated with tomatoes. However, for Grapes, the total emissions increase as the reduced consumption per capita leads to higher exports

In the second case of scenario 2 involving a simultaneous reduction in imports and exports of peppers and tomatoes, the total emissions for peppers increases whereas the total emissions for tomatoes decreases. A reduction in consumption leads to reduction in imports. In the case of Tomatoes, however, the total production is much higher than total consumption for Southern Ontario. Therefore, a reduction in consumption of tomatoes, leads to a large increase in exports.

[15] Desjardins, E., R. MacRae and T. Schumilas. 2010. Meeting future population food needs with local production in Waterloo Region: linking food availability and optimal nutrition requirements. Agriculture and Human Values 27(2):129-140.

# APPENDIX 1: Total Emissions (Base Case Scenario)

## CEREAL

**2011 Average Weekday Emissions (Kg) for Wheat**

| | | | | | | PM10 | | | | | | | PM2.5 | | | | | | | AIR TOXICS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vehicle Type | HC | CO | NOX | CO2 | SO4 | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | BENZENE | BUTADIENE | FORMALDEHYDE | ACETALDEHYDE | ACROLEIN |
| Combination Double/ Triple | 4.05 | 112.42 | 62.81 | 4538.17 | 0.019 | 1.084 | 3.432 | 0.178 | 0.298 | 0.107 | 0.037 | 0.107 | 0.997 | 3.157 | 0.131 | 0.298 | 0.107 | 0.016 | 0.027 | 0.062 | 0.029 | 0.212 | 0.062 | 0.017 |
| Truck Trailers | 1.35 | 47.94 | 5.33 | 1215.95 | 0.002 | 0.355 | 0.247 | 0.046 | 0.045 | 0.137 | 0.028 | 0.018 | 0.326 | 0.227 | 0.034 | 0.045 | 0.137 | 0.012 | 0.004 | 0.039 | 0.019 | 0.051 | 0.015 | 0.002 |
| Combination Semitrailers | 206.86 | 3864.26 | 1288.60 | 146752.75 | 0.629 | 18.792 | 21.569 | 13.061 | 9.456 | 4.706 | 1.664 | 1.761 | 17.289 | 19.841 | 9.917 | 9.456 | 4.706 | 0.706 | 0.440 | 3.898 | 1.397 | 9.689 | 2.785 | 0.793 |
| Single Unit Trucks | 7.05 | 138.68 | 15.71 | 3796.73 | 0.010 | 0.511 | 1.811 | 0.153 | 0.191 | 0.480 | 0.156 | 0.087 | 0.470 | 1.666 | 0.112 | 0.191 | 0.480 | 0.066 | 0.022 | 0.151 | 0.083 | 0.213 | 0.061 | 0.008 |

**2011 Average Weekday Emissions (Kg) for Oats**

| | | | | | | PM10 | | | | | | | PM2.5 | | | | | | | AIR TOXICS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vehicle Type | HC | CO | NOX | CO2 | SO4 | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | BENZENE | BUTADIENE | FORMALDEHYDE | ACETALDEHYDE | ACROLEIN |
| Combination Double/ Triple | 0.03 | 1.42 | 1.02 | 71.03 | 0.000 | 0.017 | 0.054 | 0.003 | 0.005 | 0.002 | 0.001 | 0.002 | 0.016 | 0.049 | 0.002 | 0.005 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.001 | 0.000 |
| Truck Trailers | 0.02 | 0.62 | 0.07 | 15.61 | 0.000 | 0.005 | 0.003 | 0.001 | 0.001 | 0.002 | 0.000 | 0.000 | 0.004 | 0.003 | 0.000 | 0.001 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 |
| Combination Semitrailers | 1.12 | 30.94 | 18.66 | 1915.21 | 0.008 | 0.245 | 0.281 | 0.170 | 0.123 | 0.061 | 0.022 | 0.023 | 0.226 | 0.259 | 0.129 | 0.123 | 0.061 | 0.009 | 0.006 | 0.019 | 0.007 | 0.054 | 0.016 | 0.004 |
| Single Unit Trucks | 0.15 | 2.95 | 0.33 | 80.05 | 0.000 | 0.011 | 0.038 | 0.003 | 0.004 | 0.010 | 0.003 | 0.002 | 0.010 | 0.035 | 0.002 | 0.004 | 0.010 | 0.001 | 0.000 | 0.003 | 0.002 | 0.005 | 0.001 | 0.000 |

**2011 Average Weekday Emissions (Kg) for Barley**

| | | | | | | PM10 | | | | | | | PM2.5 | | | | | | | AIR TOXICS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vehicle Type | HC | CO | NOX | CO2 | SO4 | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | BENZENE | BUTADIENE | FORMALDEHYDE | ACETALDEHYDE | ACROLEIN |
| Combination Double/ Triple | 0.20 | 9.19 | 6.42 | 458.28 | 0.002 | 0.109 | 0.347 | 0.018 | 0.030 | 0.011 | 0.004 | 0.011 | 0.101 | 0.319 | 0.013 | 0.030 | 0.011 | 0.002 | 0.003 | 0.004 | 0.002 | 0.015 | 0.005 | 0.001 |
| Truck Trailers | 0.13 | 4.78 | 0.54 | 120.97 | 0.000 | 0.035 | 0.025 | 0.005 | 0.004 | 0.014 | 0.003 | 0.002 | 0.032 | 0.023 | 0.003 | 0.004 | 0.014 | 0.001 | 0.000 | 0.004 | 0.002 | 0.005 | 0.001 | 0.000 |
| Combination Semitrailers | 13.57 | 232.94 | 109.63 | 11131.55 | 0.048 | 1.425 | 1.636 | 0.991 | 0.717 | 0.357 | 0.126 | 0.134 | 1.311 | 1.505 | 0.752 | 0.717 | 0.357 | 0.054 | 0.033 | 0.198 | 0.065 | 0.461 | 0.135 | 0.037 |
| Single Unit Trucks | 0.66 | 13.14 | 1.48 | 348.31 | 0.001 | 0.047 | 0.166 | 0.014 | 0.018 | 0.044 | 0.014 | 0.008 | 0.043 | 0.153 | 0.010 | 0.018 | 0.044 | 0.006 | 0.002 | 0.014 | 0.008 | 0.020 | 0.006 | 0.001 |

# FRUITS/VEGETABLES

**2011 Average Weekday Emissions (Kg) for Apple**

| | | | | | | PM10 | | | | | | | PM2.5 | | | | | | | AIR TOXICS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vehicle Type | HC | CO | NOX | CO2 | SO4 | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | BENZENE | BUTADIENE | FORMALDEHYDE | ACETALDEHYDE | ACROLEIN |
| Combination Double/ Triple | 0.54 | 27.39 | 19.68 | 1395.05 | 0.006 | 0.333 | 1.055 | 0.055 | 0.091 | 0.033 | 0.011 | 0.033 | 0.307 | 0.971 | 0.040 | 0.091 | 0.033 | 0.005 | 0.008 | 0.010 | 0.006 | 0.044 | 0.013 | 0.003 |
| Truck Trailers | 0.74 | 25.95 | 2.89 | 660.61 | 0.001 | 0.193 | 0.134 | 0.025 | 0.024 | 0.075 | 0.015 | 0.010 | 0.177 | 0.123 | 0.018 | 0.024 | 0.075 | 0.006 | 0.002 | 0.021 | 0.011 | 0.028 | 0.008 | 0.001 |
| Combination Semitrailers | 17.32 | 462.78 | 275.29 | 28104.82 | 0.121 | 3.599 | 4.131 | 2.501 | 1.811 | 0.901 | 0.319 | 0.337 | 3.311 | 3.800 | 1.899 | 1.811 | 0.901 | 0.135 | 0.084 | 0.288 | 0.107 | 0.813 | 0.247 | 0.061 |
| Single Unit Trucks | 3.53 | 67.87 | 7.71 | 1910.67 | 0.005 | 0.257 | 0.911 | 0.077 | 0.096 | 0.242 | 0.079 | 0.044 | 0.236 | 0.838 | 0.056 | 0.096 | 0.242 | 0.033 | 0.011 | 0.075 | 0.041 | 0.106 | 0.030 | 0.004 |

**2011 Average Weekday Emissions (Kg) for Strawberries**

| | | | | | | PM10 | | | | | | | PM2.5 | | | | | | | AIR TOXICS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vehicle Type | HC | CO | NOX | CO2 | SO4 | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | BENZENE | BUTADIENE | FORMALDEHYDE | ACETALDEHYDE | ACROLEIN |
| Combination Double/ Triple | -0.03 | -1.58 | -1.14 | -79.67 | -0.0003 | -0.0190 | -0.0603 | -0.0031 | -0.0052 | -0.0019 | -0.0007 | -0.0019 | -0.0175 | -0.0554 | -0.0023 | -0.0052 | -0.0019 | -0.0003 | -0.0005 | -0.0006 | -0.0003 | -0.0025 | -0.0008 | -0.0002 |
| Truck Trailers | -0.03 | -1.13 | -0.13 | -28.57 | -0.0001 | -0.0083 | -0.0058 | -0.0011 | -0.0011 | -0.0032 | -0.0007 | -0.0004 | -0.0077 | -0.0053 | -0.0008 | -0.0011 | -0.0032 | -0.0003 | -0.0001 | -0.0009 | -0.0004 | -0.0012 | -0.0003 | -0.0001 |
| Combination Semitrailers | -0.82 | -23.84 | -14.58 | -1491.03 | -0.0064 | -0.1909 | -0.2191 | -0.1327 | -0.0961 | -0.0478 | -0.0169 | -0.0179 | -0.1757 | -0.2016 | -0.1008 | -0.0961 | -0.0478 | -0.0072 | -0.0045 | -0.0141 | -0.0053 | -0.0412 | -0.0126 | -0.0030 |
| Single Unit Trucks | -0.14 | -2.77 | -0.31 | -73.70 | -0.0002 | -0.0099 | -0.0351 | -0.0030 | -0.0037 | -0.0093 | -0.0030 | -0.0017 | -0.0091 | -0.0323 | -0.0022 | -0.0037 | -0.0093 | -0.0013 | -0.0004 | -0.0030 | -0.0016 | -0.0042 | -0.0012 | -0.0002 |

**2011 Average Weekday Emissions (Kg) for Peaches**

| | | | | | | PM10 | | | | | | | PM2.5 | | | | | | | AIR TOXICS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vehicle Type | HC | CO | NOX | CO2 | SO4 | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | BENZENE | BUTADIENE | FORMALDEHYDE | ACETALDEHYDE | ACROLEIN |
| Combination Double/ Triple | 0.0117 | 0.6366 | 0.4638 | 32.0025 | 0.0001 | 0.0076 | 0.0242 | 0.0013 | 0.0021 | 0.0008 | 0.0003 | 0.0008 | 0.0070 | 0.0223 | 0.0009 | 0.0021 | 0.0008 | 0.0001 | 0.0002 | 0.0002 | 0.0001 | 0.0010 | 0.0003 | 0.0001 |
| Truck Trailers | 0.0148 | 0.5552 | 0.0627 | 14.0178 | 0.0000 | 0.0041 | 0.0028 | 0.0005 | 0.0005 | 0.0016 | 0.0003 | 0.0002 | 0.0038 | 0.0026 | 0.0004 | 0.0005 | 0.0016 | 0.0001 | 0.0001 | 0.0004 | 0.0002 | 0.0006 | 0.0002 | 0.0000 |
| Combination Semitrailers | 0.2225 | 8.0239 | 5.1858 | 515.8758 | 0.0022 | 0.0661 | 0.0758 | 0.0459 | 0.0332 | 0.0165 | 0.0058 | 0.0062 | 0.0608 | 0.0697 | 0.0349 | 0.0332 | 0.0165 | 0.0025 | 0.0015 | 0.0041 | 0.0016 | 0.0129 | 0.0040 | 0.0009 |
| Single Unit Trucks | 0.0753 | 1.5126 | 0.1700 | 39.7871 | 0.0001 | 0.0054 | 0.0190 | 0.0016 | 0.0020 | 0.0050 | 0.0016 | 0.0009 | 0.0049 | 0.0175 | 0.0012 | 0.0020 | 0.0050 | 0.0007 | 0.0002 | 0.0016 | 0.0009 | 0.0023 | 0.0007 | 0.0001 |

**2011 Average Weekday Emissions (Kg) for Grapes**

| | | | | | | PM10 | | | | | | | PM2.5 | | | | | | | AIR TOXICS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vehicle Type | HC | CO | NOX | CO2 | SO4 | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | BENZENE | BUTADIENE | FORMALDEHYDE | ACETALDEHYDE | ACROLEIN |
| Combination Double/ Triple | 0.0009 | 0.0443 | 0.0320 | 2.2393 | 0.0000 | 0.0005 | 0.0017 | 0.0001 | 0.0001 | 0.0001 | 0.0000 | 0.0001 | 0.0005 | 0.0016 | 0.0001 | 0.0001 | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0001 | 0.0000 | 0.0000 |
| Truck Trailers | 0.0012 | 0.0436 | 0.0049 | 1.1039 | 0.0000 | 0.0003 | 0.0002 | 0.0000 | 0.0000 | 0.0001 | 0.0000 | 0.0000 | 0.0003 | 0.0002 | 0.0000 | 0.0000 | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Combination Semitrailers | 0.0180 | 0.5346 | 0.3273 | 32.7117 | 0.0001 | 0.0042 | 0.0048 | 0.0029 | 0.0021 | 0.0010 | 0.0004 | 0.0004 | 0.0039 | 0.0044 | 0.0022 | 0.0021 | 0.0010 | 0.0002 | 0.0001 | 0.0003 | 0.0001 | 0.0009 | 0.0003 | 0.0001 |
| Single Unit Trucks | 0.0055 | 0.1091 | 0.0123 | 2.9393 | 0.0000 | 0.0004 | 0.0014 | 0.0001 | 0.0001 | 0.0004 | 0.0001 | 0.0001 | 0.0004 | 0.0013 | 0.0001 | 0.0001 | 0.0004 | 0.0001 | 0.0000 | 0.0001 | 0.0001 | 0.0002 | 0.0000 | 0.0000 |

**2011 Average Weekday Emissions (Kg) for Tomatoes**

| | | | | | | PM10 | | | | | | | PM2.5 | | | | | | | AIR TOXICS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vehicle Type | HC | CO | NOX | CO2 | SO4 | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | BENZENE | BUTADIENE | FORMALDEHYDE | ACETALDEHYDE | ACROLEIN |
| Combination Double/ Triple | 0.426 | 17.046 | 11.319 | 790.782 | 0.0034 | 0.1889 | 0.5980 | 0.0309 | 0.0518 | 0.0187 | 0.0065 | 0.0187 | 0.1738 | 0.5502 | 0.0229 | 0.0518 | 0.0187 | 0.0028 | 0.0047 | 0.0071 | 0.0037 | 0.0283 | 0.0085 | 0.0022 |
| Truck Trailers | 0.337 | 12.377 | 1.387 | 312.075 | 0.0006 | 0.0910 | 0.0633 | 0.0117 | 0.0115 | 0.0353 | 0.0071 | 0.0046 | 0.0838 | 0.0582 | 0.0087 | 0.0115 | 0.0353 | 0.0030 | 0.0011 | 0.0097 | 0.0049 | 0.0129 | 0.0038 | 0.0006 |
| Combination Semitrailers | 22.566 | 321.744 | 126.882 | 12711.082 | 0.0547 | 1.6277 | 1.8682 | 1.1313 | 0.8190 | 0.4076 | 0.1441 | 0.1525 | 1.4975 | 1.7186 | 0.8589 | 0.8190 | 0.4076 | 0.0611 | 0.0381 | 0.3171 | 0.0983 | 0.6772 | 0.1939 | 0.0558 |
| Single Unit Trucks | 1.255 | 25.197 | 2.826 | 661.757 | 0.0017 | 0.0890 | 0.3156 | 0.0266 | 0.0333 | 0.0837 | 0.0272 | 0.0151 | 0.0819 | 0.2904 | 0.0195 | 0.0333 | 0.0837 | 0.0115 | 0.0038 | 0.0269 | 0.0149 | 0.0382 | 0.0109 | 0.0014 |

**2011 Average Weekday Emissions (Kg) for Carrots**

| | | | | | | PM10 | | | | | | | PM2.5 | | | | | | | AIR TOXICS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vehicle Type | HC | CO | NOX | CO2 | SO4 | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | BENZENE | BUTADIENE | FORMALDEHYDE | ACETALDEHYDE | ACROLEIN |
| Combination Double/ Triple | 0.0308 | 1.472 | 1.047 | 76.261 | 0.0003 | 0.0182 | 0.0577 | 0.0030 | 0.0050 | 0.0018 | 0.0006 | 0.0018 | 0.0168 | 0.0531 | 0.0022 | 0.0050 | 0.0018 | 0.0003 | 0.0005 | 0.0006 | 0.0003 | 0.0024 | 0.0007 | 0.0002 |
| Truck Trailers | 0.0366 | 1.278 | 0.142 | 32.568 | 0.0001 | 0.0095 | 0.0066 | 0.0012 | 0.0012 | 0.0037 | 0.0007 | 0.0005 | 0.0087 | 0.0061 | 0.0009 | 0.0012 | 0.0037 | 0.0003 | 0.0001 | 0.0010 | 0.0005 | 0.0014 | 0.0004 | 0.0001 |
| Combination Semitrailers | 0.8199 | 19.575 | 11.202 | 1165.828 | 0.0050 | 0.1493 | 0.1714 | 0.1038 | 0.0751 | 0.0374 | 0.0132 | 0.0140 | 0.1373 | 0.1576 | 0.0788 | 0.0751 | 0.0374 | 0.0056 | 0.0035 | 0.0132 | 0.0048 | 0.0359 | 0.0108 | 0.0027 |
| Single Unit Trucks | 0.1518 | 2.919 | 0.334 | 83.397 | 0.0002 | 0.0112 | 0.0398 | 0.0034 | 0.0042 | 0.0105 | 0.0034 | 0.0019 | 0.0103 | 0.0366 | 0.0025 | 0.0042 | 0.0105 | 0.0015 | 0.0005 | 0.0032 | 0.0018 | 0.0046 | 0.0013 | 0.0002 |

**2011 Average Weekday Emissions (Kg) for Cabbage**

| | | | | | | PM10 | | | | | | | PM2.5 | | | | | | | AIR TOXICS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vehicle Type | HC | CO | NOX | CO2 | SO4 | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | BENZENE | BUTADIENE | FORMALDEHYDE | ACETALDEHYDE | ACROLEIN |
| Combination Double/ Triple | 0.0262 | 1.3546 | 0.9807 | 69.2468 | 0.0003 | 0.0165 | 0.0524 | 0.0027 | 0.0045 | 0.0016 | 0.0006 | 0.0016 | 0.0152 | 0.0482 | 0.0020 | 0.0045 | 0.0016 | 0.0002 | 0.0004 | 0.0005 | 0.0003 | 0.0021 | 0.0007 | 0.0002 |
| Truck Trailers | 0.0347 | 1.2328 | 0.1379 | 31.2836 | 0.0001 | 0.0091 | 0.0063 | 0.0012 | 0.0012 | 0.0035 | 0.0007 | 0.0005 | 0.0084 | 0.0058 | 0.0009 | 0.0012 | 0.0035 | 0.0003 | 0.0001 | 0.0010 | 0.0005 | 0.0013 | 0.0004 | 0.0001 |
| Combination Semitrailers | 0.6910 | 20.8283 | 13.0018 | 1354.8338 | 0.0058 | 0.1735 | 0.1991 | 0.1206 | 0.0873 | 0.0434 | 0.0154 | 0.0163 | 0.1596 | 0.1832 | 0.0916 | 0.0873 | 0.0434 | 0.0065 | 0.0041 | 0.0121 | 0.0047 | 0.0363 | 0.0111 | 0.0026 |
| Single Unit Trucks | 0.1851 | 3.5473 | 0.4021 | 99.7443 | 0.0003 | 0.0134 | 0.0476 | 0.0040 | 0.0050 | 0.0126 | 0.0041 | 0.0023 | 0.0123 | 0.0438 | 0.0029 | 0.0050 | 0.0126 | 0.0017 | 0.0006 | 0.0039 | 0.0022 | 0.0056 | 0.0016 | 0.0002 |

**2011 Average Weekday Emissions (Kg) for Sweet Corn**

| | | | | | | PM10 | | | | | | | PM2.5 | | | | | | | AIR TOXICS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vehicle Type | HC | CO | NOX | CO2 | SO4 | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | BENZENE | BUTADIENE | FORMALDEHYDE | ACETALDEHYDE | ACROLEIN |
| Combination Double/ Triple | 0.0457 | 2.1841 | 1.5418 | 108.6862 | 0.0005 | 0.0260 | 0.0822 | 0.0043 | 0.0071 | 0.0026 | 0.0009 | 0.0026 | 0.0239 | 0.0756 | 0.0031 | 0.0071 | 0.0026 | 0.0004 | 0.0006 | 0.0008 | 0.0004 | 0.0035 | 0.0011 | 0.0003 |
| Truck Trailers | 0.0476 | 1.7168 | 0.1920 | 43.4691 | 0.0001 | 0.0127 | 0.0088 | 0.0016 | 0.0016 | 0.0049 | 0.0010 | 0.0006 | 0.0117 | 0.0081 | 0.0012 | 0.0016 | 0.0049 | 0.0004 | 0.0002 | 0.0014 | 0.0007 | 0.0018 | 0.0005 | 0.0001 |
| Combination Semitrailers | 1.6630 | 34.2952 | 18.1182 | 1840.5903 | 0.0079 | 0.2357 | 0.2705 | 0.1638 | 0.1186 | 0.0590 | 0.0209 | 0.0221 | 0.2168 | 0.2489 | 0.1244 | 0.1186 | 0.0590 | 0.0088 | 0.0055 | 0.0255 | 0.0087 | 0.0642 | 0.0191 | 0.0050 |
| Single Unit Trucks | 0.1848 | 3.6602 | 0.4121 | 98.2008 | 0.0002 | 0.0132 | 0.0468 | 0.0040 | 0.0049 | 0.0124 | 0.0040 | 0.0022 | 0.0121 | 0.0431 | 0.0029 | 0.0049 | 0.0124 | 0.0017 | 0.0006 | 0.0040 | 0.0022 | 0.0056 | 0.0016 | 0.0002 |

**2011 Average Weekday Emissions (Kg) for Green and Wax Beans**

| | | | | | | PM10 | | | | | | | PM2.5 | | | | | | | AIR TOXICS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vehicle Type | HC | CO | NOX | CO2 | SO4 | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | BENZENE | BUTADIENE | FORMALDEHYDE | ACETALDEHYDE | ACROLEIN |
| Combination Double/ Triple | 0.0037 | 0.1975 | 0.1435 | 9.9875 | 0.0000 | 0.0024 | 0.0076 | 0.0004 | 0.0007 | 0.0002 | 0.0001 | 0.0002 | 0.0022 | 0.0069 | 0.0003 | 0.0007 | 0.0002 | 0.0000 | 0.0001 | 0.0001 | 0.0000 | 0.0003 | 0.0001 | 0.0000 |
| Truck Trailers | 0.0039 | 0.1416 | 0.0159 | 3.5838 | 0.0000 | 0.0010 | 0.0007 | 0.0001 | 0.0001 | 0.0004 | 0.0001 | 0.0001 | 0.0010 | 0.0007 | 0.0001 | 0.0001 | 0.0004 | 0.0000 | 0.0000 | 0.0001 | 0.0001 | 0.0001 | 0.0000 | 0.0000 |
| Combination Semitrailers | 0.0931 | 3.1870 | 2.0409 | 205.4807 | 0.0009 | 0.0263 | 0.0302 | 0.0183 | 0.0132 | 0.0066 | 0.0023 | 0.0025 | 0.0242 | 0.0278 | 0.0139 | 0.0132 | 0.0066 | 0.0010 | 0.0006 | 0.0017 | 0.0007 | 0.0052 | 0.0016 | 0.0004 |
| Single Unit Trucks | 0.0232 | 0.4582 | 0.0518 | 12.4114 | 0.0000 | 0.0017 | 0.0059 | 0.0005 | 0.0006 | 0.0016 | 0.0005 | 0.0003 | 0.0015 | 0.0054 | 0.0004 | 0.0006 | 0.0016 | 0.0002 | 0.0001 | 0.0005 | 0.0003 | 0.0007 | 0.0002 | 0.0000 |

**2011 Average Weekday Emissions (Kg) for Peppers**

| | | | | | | PM10 | | | | | | | PM2.5 | | | | | | | AIR TOXICS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vehicle Type | HC | CO | NOX | CO2 | SO4 | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | BENZENE | BUTADIENE | FORMALDEHYDE | ACETALDEHYDE | ACROLEIN |
| Combination Double/ Triple | 0.0183 | 0.9538 | 0.6920 | 48.8261 | 0.0002 | 0.0117 | 0.0369 | 0.0019 | 0.0032 | 0.0012 | 0.0004 | 0.0012 | 0.0107 | 0.0340 | 0.0014 | 0.0032 | 0.0012 | 0.0002 | 0.0003 | 0.0003 | 0.0002 | 0.0015 | 0.0005 | 0.0001 |
| Truck Trailers | 0.0237 | 0.8361 | 0.0934 | 21.2605 | 0.0000 | 0.0062 | 0.0043 | 0.0008 | 0.0008 | 0.0024 | 0.0005 | 0.0003 | 0.0057 | 0.0040 | 0.0006 | 0.0008 | 0.0024 | 0.0002 | 0.0001 | 0.0007 | 0.0003 | 0.0009 | 0.0003 | 0.0000 |
| Combination Semitrailers | 0.4704 | 14.8423 | 9.3975 | 978.6044 | 0.0042 | 0.1253 | 0.1438 | 0.0871 | 0.0631 | 0.0314 | 0.0111 | 0.0117 | 0.1153 | 0.1323 | 0.0661 | 0.0631 | 0.0314 | 0.0047 | 0.0029 | 0.0084 | 0.0033 | 0.0256 | 0.0079 | 0.0019 |
| Single Unit Trucks | 0.1388 | 2.6731 | 0.3037 | 75.1257 | 0.0002 | 0.0101 | 0.0358 | 0.0030 | 0.0038 | 0.0095 | 0.0031 | 0.0017 | 0.0093 | 0.0330 | 0.0022 | 0.0038 | 0.0095 | 0.0013 | 0.0004 | 0.0030 | 0.0016 | 0.0042 | 0.0012 | 0.0002 |

**2011 Average Weekday Emissions (Kg) for Dry Onions**

| | | | | | | PM10 | | | | | | | PM2.5 | | | | | | | AIR TOXICS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vehicle Type | HC | CO | NOX | CO2 | SO4 | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | BENZENE | BUTADIENE | FORMALDEHYDE | ACETALDEHYDE | ACROLEIN |
| Combination Double/ Triple | 0.02 | 0.85 | 0.61 | 48.26 | 0.000 | 0.012 | 0.036 | 0.002 | 0.003 | 0.001 | 0.000 | 0.001 | 0.011 | 0.034 | 0.001 | 0.003 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 |
| Truck Trailers | 0.04 | 1.38 | 0.15 | 36.11 | 0.000 | 0.011 | 0.007 | 0.001 | 0.001 | 0.004 | 0.001 | 0.001 | 0.010 | 0.007 | 0.001 | 0.001 | 0.004 | 0.000 | 0.000 | 0.001 | 0.001 | 0.002 | 0.000 | 0.000 |
| Combination Semitrailers | 0.42 | 13.74 | 9.09 | 1032.89 | 0.004 | 0.132 | 0.152 | 0.092 | 0.067 | 0.033 | 0.012 | 0.012 | 0.122 | 0.140 | 0.070 | 0.067 | 0.033 | 0.005 | 0.003 | 0.008 | 0.003 | 0.026 | 0.008 | 0.002 |
| Single Unit Trucks | 0.25 | 4.54 | 0.53 | 144.09 | 0.000 | 0.019 | 0.069 | 0.006 | 0.007 | 0.018 | 0.006 | 0.003 | 0.018 | 0.063 | 0.004 | 0.007 | 0.018 | 0.003 | 0.001 | 0.005 | 0.003 | 0.007 | 0.002 | 0.000 |

**2011 Average Weekday Emissions (Kg) for Potatoes**

| | | | | | | PM10 | | | | | | | PM2.5 | | | | | | | AIR TOXICS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vehicle Type | HC | CO | NOX | CO2 | SO4 | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | BENZENE | BUTADIENE | FORMALDEHYDE | ACETALDEHYDE | ACROLEIN |
| Combination Double/ Triple | -2.0333 | -57.3357 | -32.2420 | -2379.2471 | -0.0102 | -0.5683 | -1.7993 | -0.0931 | -0.1560 | -0.0563 | -0.0195 | -0.0562 | -0.5228 | -1.6553 | -0.0689 | -0.1560 | -0.0563 | -0.0083 | -0.0141 | -0.0311 | -0.0150 | -0.1086 | -0.0319 | -0.0087 |
| Truck Trailers | -1.0534 | -36.6424 | -4.0555 | -932.6964 | -0.0017 | -0.2721 | -0.1891 | -0.0350 | -0.0345 | -0.1054 | -0.0213 | -0.0137 | -0.2503 | -0.1739 | -0.0260 | -0.0345 | -0.1054 | -0.0091 | -0.0034 | -0.0300 | -0.0152 | -0.0398 | -0.0118 | -0.0017 |
| Combination Semitrailers | -92.0162 | -1578.9206 | -489.2680 | -54549.8640 | -0.2340 | -6.9854 | -8.0176 | -4.8550 | -3.5151 | -1.7493 | -0.6185 | -0.6547 | -6.4265 | -7.3753 | -3.6862 | -3.5151 | -1.7493 | -0.2623 | -0.1637 | -1.6348 | -0.5646 | -3.8490 | -1.0945 | -0.3204 |
| Single Unit Trucks | -3.6593 | -71.1649 | -8.0782 | -1980.0170 | -0.0050 | -0.2663 | -0.9443 | -0.0797 | -0.0996 | -0.2503 | -0.0814 | -0.0452 | -0.2450 | -0.8688 | -0.0584 | -0.0996 | -0.2503 | -0.0345 | -0.0113 | -0.0780 | -0.0428 | -0.1102 | -0.0315 | -0.0042 |

# LIVESTOCK

**2011 Average Weekday Emissions (Kg) for Chicken**

| | | | | | | PM10 | | | | | | | PM2.5 | | | | | | | AIR TOXICS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vehicle Type | HC | CO | NOX | CO2 | SO4 | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | BENZENE | BUTADIENE | FORMALDEHYDE | ACETALDEHYDE | ACROLEIN |
| Combination Double/ Triple | 1.4129 | 63.7421 | 44.8080 | 3345.1305 | 0.0143 | 0.7989 | 2.5297 | 0.1309 | 0.2193 | 0.0792 | 0.0275 | 0.0790 | 0.7350 | 2.3273 | 0.0968 | 0.2193 | 0.0792 | 0.0116 | 0.0198 | 0.0250 | 0.0138 | 0.1080 | 0.0331 | 0.0080 |
| Truck Trailers | 2.6192 | 87.7500 | 9.6323 | 2250.2086 | 0.0041 | 0.6564 | 0.4562 | 0.0843 | 0.0832 | 0.2544 | 0.0515 | 0.0330 | 0.6039 | 0.4196 | 0.0627 | 0.0832 | 0.2544 | 0.0218 | 0.0082 | 0.0741 | 0.0375 | 0.0984 | 0.0292 | 0.0042 |
| Combination Semitrailers | 35.9032 | 762.6150 | 415.8092 | 44065.0028 | 0.1899 | 5.6428 | 6.4766 | 3.9219 | 2.8393 | 1.4131 | 0.4996 | 0.5288 | 5.1913 | 5.9577 | 2.9777 | 2.8393 | 1.4131 | 0.2119 | 0.1322 | 0.5609 | 0.1962 | 1.4581 | 0.4362 | 0.1115 |
| Single Unit Trucks | 8.9683 | 169.9512 | 19.5079 | 4957.4096 | 0.0124 | 0.6668 | 2.3643 | 0.1995 | 0.2493 | 0.6268 | 0.2038 | 0.1131 | 0.6133 | 2.1752 | 0.1463 | 0.2493 | 0.6268 | 0.0864 | 0.0283 | 0.1902 | 0.1039 | 0.2679 | 0.0770 | 0.0104 |

**2011 Average Weekday Emissions (Kg) for Beef**

| | | | | | | PM10 | | | | | | | PM2.5 | | | | | | | AIR TOXICS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vehicle Type | HC | CO | NOX | CO2 | SO4 | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | BENZENE | BUTADIENE | FORMALDEHYDE | ACETALDEHYDE | ACROLEIN |
| Combination Double/ Triple | 0.1584 | 6.5207 | 4.4043 | 318.5192 | 0.0014 | 0.0761 | 0.2409 | 0.0125 | 0.0209 | 0.0075 | 0.0026 | 0.0075 | 0.0700 | 0.2216 | 0.0092 | 0.0209 | 0.0075 | 0.0011 | 0.0019 | 0.0027 | 0.0014 | 0.0110 | 0.0033 | 0.0008 |
| Truck Trailers | 0.1817 | 6.4024 | 0.7111 | 162.7069 | 0.0003 | 0.0475 | 0.0330 | 0.0061 | 0.0060 | 0.0184 | 0.0037 | 0.0024 | 0.0437 | 0.0303 | 0.0045 | 0.0060 | 0.0184 | 0.0016 | 0.0006 | 0.0052 | 0.0026 | 0.0069 | 0.0020 | 0.0003 |
| Combination Semitrailers | 5.4025 | 90.0653 | 41.6613 | 4345.9138 | 0.0187 | 0.5565 | 0.6388 | 0.3868 | 0.2800 | 0.1394 | 0.0493 | 0.0522 | 0.5120 | 0.5876 | 0.2937 | 0.2800 | 0.1394 | 0.0209 | 0.0130 | 0.0788 | 0.0256 | 0.1823 | 0.0532 | 0.0145 |
| Single Unit Trucks | 0.5892 | 11.4553 | 1.3022 | 319.5046 | 0.0008 | 0.0430 | 0.1524 | 0.0129 | 0.0161 | 0.0404 | 0.0131 | 0.0073 | 0.0395 | 0.1402 | 0.0094 | 0.0161 | 0.0404 | 0.0056 | 0.0018 | 0.0126 | 0.0069 | 0.0177 | 0.0051 | 0.0007 |

**2011 Average Weekday Emissions (Kg) for Sheep and Lambs**

| | | | | | | PM10 | | | | | | | PM2.5 | | | | | | | AIR TOXICS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vehicle Type | HC | CO | NOX | CO2 | SO4 | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | BENZENE | BUTADIENE | FORMALDEHYDE | ACETALDEHYDE | ACROLEIN |
| Combination Double/ Triple | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Truck Trailers | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Combination Semitrailers | 0.0494 | 1.8810 | 1.2435 | 125.9871 | 0.0005 | 0.0161 | 0.0185 | 0.0112 | 0.0081 | 0.0040 | 0.0014 | 0.0015 | 0.0148 | 0.0170 | 0.0085 | 0.0081 | 0.0040 | 0.0006 | 0.0004 | 0.0009 | 0.0004 | 0.0031 | 0.0009 | 0.0002 |
| Single Unit Trucks | 0.0183 | 0.3374 | 0.0392 | 10.2824 | 0.0000 | 0.0014 | 0.0049 | 0.0004 | 0.0005 | 0.0013 | 0.0004 | 0.0002 | 0.0013 | 0.0045 | 0.0003 | 0.0005 | 0.0013 | 0.0002 | 0.0001 | 0.0004 | 0.0002 | 0.0005 | 0.0002 | 0.0000 |

**2011 Average Weekday Emissions (Kg) for Pigs**

| | | | | | | PM10 | | | | | | | PM2.5 | | | | | | | AIR TOXICS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vehicle Type | HC | CO | NOX | CO2 | SO4 | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | BENZENE | BUTADIENE | FORMALDEHYDE | ACETALDEHYDE | ACROLEIN |
| Combination Double/ Triple | 0.0961 | 4.2837 | 2.9806 | 216.8491 | 0.0009 | 0.0518 | 0.1640 | 0.0085 | 0.0142 | 0.0051 | 0.0018 | 0.0051 | 0.0476 | 0.1509 | 0.0063 | 0.0142 | 0.0051 | 0.0008 | 0.0013 | 0.0017 | 0.0009 | 0.0071 | 0.0022 | 0.0005 |
| Truck Trailers | 0.1466 | 5.0438 | 0.5574 | 128.7616 | 0.0002 | 0.0376 | 0.0261 | 0.0048 | 0.0048 | 0.0146 | 0.0029 | 0.0019 | 0.0346 | 0.0240 | 0.0036 | 0.0048 | 0.0146 | 0.0012 | 0.0005 | 0.0042 | 0.0021 | 0.0055 | 0.0016 | 0.0002 |
| Combination Semitrailers | 2.6064 | 52.8343 | 27.9049 | 2930.1333 | 0.0126 | 0.3752 | 0.4307 | 0.2608 | 0.1888 | 0.0940 | 0.0332 | 0.0352 | 0.3452 | 0.3962 | 0.1980 | 0.1888 | 0.0940 | 0.0141 | 0.0088 | 0.0401 | 0.0138 | 0.1016 | 0.0302 | 0.0078 |
| Single Unit Trucks | 0.5111 | 9.7902 | 1.1201 | 280.6637 | 0.0007 | 0.0378 | 0.1339 | 0.0113 | 0.0141 | 0.0355 | 0.0115 | 0.0064 | 0.0347 | 0.1231 | 0.0083 | 0.0141 | 0.0355 | 0.0049 | 0.0016 | 0.0109 | 0.0059 | 0.0153 | 0.0044 | 0.0006 |

**2011 Average Weekday Emissions (Kg) for Turkey**

| | | | | | | PM10 | | | | | | | PM2.5 | | | | | | | AIR TOXICS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vehicle Type | HC | CO | NOX | CO2 | SO4 | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | BENZENE | BUTADIENE | FORMALDEHYDE | ACETALDEHYDE | ACROLEIN |
| Combination Double/ Triple | 0.0112 | 0.4439 | 0.2961 | 21.5353 | 0.0001 | 0.0051 | 0.0163 | 0.0008 | 0.0014 | 0.0005 | 0.0002 | 0.0005 | 0.0047 | 0.0150 | 0.0006 | 0.0014 | 0.0005 | 0.0001 | 0.0001 | 0.0002 | 0.0001 | 0.0008 | 0.0002 | 0.0001 |
| Truck Trailers | 0.0123 | 0.4309 | 0.0478 | 10.9605 | 0.0000 | 0.0032 | 0.0022 | 0.0004 | 0.0004 | 0.0012 | 0.0003 | 0.0002 | 0.0029 | 0.0020 | 0.0003 | 0.0004 | 0.0012 | 0.0001 | 0.0000 | 0.0004 | 0.0002 | 0.0005 | 0.0001 | 0.0000 |
| Combination Semitrailers | 0.4118 | 6.3904 | 2.7862 | 291.2407 | 0.0013 | 0.0373 | 0.0428 | 0.0259 | 0.0188 | 0.0093 | 0.0033 | 0.0035 | 0.0343 | 0.0394 | 0.0197 | 0.0188 | 0.0093 | 0.0014 | 0.0009 | 0.0059 | 0.0019 | 0.0132 | 0.0038 | 0.0011 |
| Single Unit Trucks | 0.0379 | 0.7383 | 0.0838 | 20.5032 | 0.0001 | 0.0028 | 0.0098 | 0.0008 | 0.0010 | 0.0026 | 0.0008 | 0.0005 | 0.0025 | 0.0090 | 0.0006 | 0.0010 | 0.0026 | 0.0004 | 0.0001 | 0.0008 | 0.0004 | 0.0011 | 0.0003 | 0.0000 |

**2011 Average Weekday Emissions (Kg) for Eggs**

| | | | | | | PM10 | | | | | | | PM2.5 | | | | | | | AIR TOXICS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vehicle Type | HC | CO | NOX | CO2 | SO4 | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | OCARBON | ECARBON | GASPM | SO2 | NH3 | BRAKE | TIRE | BENZENE | BUTADIENE | FORMALDEHYDE | ACETALDEHYDE | ACROLEIN |
| Combination Double/ Triple | 0.3071 | 15.6202 | 11.3060 | 818.8676 | 0.0035 | 0.1956 | 0.6193 | 0.0320 | 0.0537 | 0.0194 | 0.0067 | 0.0194 | 0.1799 | 0.5697 | 0.0237 | 0.0537 | 0.0194 | 0.0028 | 0.0048 | 0.0056 | 0.0032 | 0.0252 | 0.0078 | 0.0018 |
| Truck Trailers | 0.5594 | 19.3748 | 2.1466 | 494.5333 | 0.0009 | 0.1443 | 0.1003 | 0.0185 | 0.0183 | 0.0559 | 0.0113 | 0.0072 | 0.1327 | 0.0922 | 0.0138 | 0.0183 | 0.0559 | 0.0048 | 0.0018 | 0.0159 | 0.0080 | 0.0211 | 0.0063 | 0.0009 |
| Combination Semitrailers | 5.9395 | 186.9869 | 118.5367 | 12399.0255 | 0.0535 | 1.5878 | 1.8224 | 1.1035 | 0.7989 | 0.3976 | 0.1406 | 0.1488 | 1.4607 | 1.6764 | 0.8379 | 0.7989 | 0.3976 | 0.0596 | 0.0372 | 0.1056 | 0.0413 | 0.3239 | 0.0997 | 0.0235 |
| Single Unit Trucks | 2.2248 | 42.5308 | 4.8697 | 1222.6604 | 0.0031 | 0.1645 | 0.5831 | 0.0492 | 0.0615 | 0.1546 | 0.0503 | 0.0279 | 0.1513 | 0.5365 | 0.0361 | 0.0615 | 0.1546 | 0.0213 | 0.0070 | 0.0473 | 0.0259 | 0.0666 | 0.0191 | 0.0026 |