Potential Effects of Structural Sunlight Obstruction
on
AAFC Research Plots

Theberge Homes Proposed Buildings

Prepared for:

Theberge Homes
205-1600 Laperriere Avenue
Ottawa, Ontario K1Z 8P5

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On behalf of Miller Engineering, Inc.
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December 19, 2023

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Theberge Homes Proposed Buildings

I. Introduction

Overview

Miller Engineering was asked on behalf of Theberge Homes to review the circumstances surrounding an application for a high-rise at 780 Baseline Road in Ottawa, Ontario, which is adjacent to the Central Experimental Farm (CEF).

The height of the proposed building is such that during certain periods of time, the adjacent research plots will be shadowed under various conditions of full and partial sunlight.

Questions from Agriculture and Agri-Food Canada (AAFC) have arisen with regards to the potential impact of shadowing and reduced sunlight affecting the conditions under which certain plants would be grown, and the attributes of adult plants and soil in that area.

Scope

Theberge Homes has requested that Miller Engineering, as an outside party, review the potential impact of the proposed development adjacent to the agronomy research station located within the city of Ottawa, Ontario. The Agriculture and Agri-Food Canada (AAFC) claims that the proposed structures will result in reduction in sunlight and the increased variability of sunlight could make its farmland “unusable for most field experiments.”

II. Background

Proposed Structures

The proposed development includes three structures to be located at 780 Baseline Road in Ottawa, Ontario. The proposed design consists of one tower that is 32 stories tall and two towers that are 24 stories tall. The buildings will be used for apartments as part of the City of Ottawa’s effort to provide more housing for its growing population.

Testing Facility

Ottawa Research and Development Center is located at 960 Carling Avenue in Ottawa, Ontario. It includes the Central Experimental Farm (CEF), spanning 1,055 acres a few kilometers from downtown Ottawa (AAFC, 2021). The CEF studies barley, oats, corn, soybean, spring wheat, and winter wheat (AAFC, 2022).

III. Potential for Sunlight Obstruction Shade Study

Miller Engineering was provided a letter from Agriculture and Agri-Food Canada (AAFC), addressed to the city planner of Ottawa, which outlined its concerns regarding the impact of the proposed structures on the CEF at Ottawa Research and Development Center. The letter included the results of a Shade Study ("AAFC study") done to quantify the potential reduction of sunlight that the proposed structures would impose on the CEF.

Conditions of Shade Study

The AAFC commissioned a graphical shade study relative to the proposed buildings and their location next to the AAFC plots. The conditions and assumptions associated with this shade study included:

- The growing season of April 1st to November 30th
- Cloudless conditions (full sunlight every day)
- Used the sun's position in the sky at one-minute intervals
- Created models using height and other exterior dimensions of the proposed structures
- The area of study was a four-kilometer squared block (400 hectares) centered on the location of the proposed structures
- The four square-kilometer block was divided into smaller 4 m^2 polygons

Conclusions from Shade Study

- 189,387 theoretical minutes of potential cloudless sunlight could be received at that latitude during the growing season.
- The shadowing would affect an area of the test plots that equaled about 0.19 km^2 of land (19 hectares) out of the 4 km^2 block (400 hectares) that was modeled.
- The amount of sunlight reduction varied from about 1% to about 20% depending on location in the plot and sun angles.
- Based on totally cloudless conditions, the theoretical lost minutes of sunlight would be in the range of 1,893 to 37,877 minutes during the growing season.

Miller Analysis of Cloud Considerations

Considering the expected cloud coverage from local Ottawa data, the following table was developed.

Table 1. Shade study adjusting for typical cloud coverage in Ottawa, Ontario

Variable	Calculation	Value
Unobstructed sunlight per season (AAFC study)	A	189,387 minutes
Cloud coverage per season (Canada Weather Stats, n.d.)	B	66,620 minutes
Estimated actual Sunlight per season adjusted for cloud coverage	A - B	122,767 minutes
"Shade Study" stated Sunlight reduction (AAFC study)	0.20 x 189,387	37,877 minutes
Actual Sunlight reduction (Miller Engineering)	0.20 x 122,767	24,553 minutes

Based on Miller analysis, the amount of sunlight reduction would be about 1/3 less than the value noted in the Shade Study itself. The significance of that loss will be explored in the following sections; however, the studies cited utilize a percent reduction as opposed to a particular quantitative value of loss in minutes. These studies will be utilized after a short overview of the Ottawa Research Development Center.

IV. Ottawa Research and Development Center

The Ottawa Research Development Center is one of four research and development centers in Ontario and one of 21 research and development centers in Canada.

We appreciate the role that the Central Experimental Farm (CEF) must serve to the province and country and are interested if there are unique roles it is serving which might not be duplicatable through other research centers. We do recognize that a small portion (~ 47 acres out of about 1000 acres) is involved in the present matter, and a portion of those acres would see minimal effect on their sunlight.

The national picture for research facilities and crop production in Canada is presented in the following tables. The commodities researched at the various centers are summarized in Table 2. The commodities researched in funded projects at Ottawa Research and Development Center are summarized in Table 3, to the best that we were able to discover online.

Table 2. Overview of Focus Areas of AAFC Research and Development Centers (AAFC, 2022)

	Research Commodity	**Number of Research Centers That Mention This Area on Their Website**
Areas of Research at Ottawa Research and Development Center	Wheat (Durum)	7
	Corn	5
	Oats	4
	Barley	3
	Soybeans	2
	Cereal (wheat, oats, barley)	2
	Oilseeds (canola, soybean, etc)	6
	Dairy/Manure	3
Areas of Research Not Emphasized at Ottawa Research and Development Center	Beef	8
	Fruits	6
	Vegetables	5
	Pulse (legumes -chickpeas, lentils, and peas)	4
	Swine	4
	Potatoes	3
	Peas	2
	High value crops	2
	Dry beans	1
	Rye	1
	Triticale (hybrid wheat and rye)	1
	Nuts	1
	Tomatoes	1
	Poultry	1

Table 3. Focus Areas of Funded Projects at Ottawa Research and Development Center with End Dates Ranging from 2022-2027 (AAFC, 2022)

Research Commodity / Focus Area	Number of On-going Funded Projects at Ottawa Research and Development Center
Barley	4
Wheat	3
Cereal (wheat, oats, barley)	3
Fungi	3
Pest Management	3
Sustainability	3
Crop response	3
Soil	2
Insects	2
Oats	1
Soybeans	1
Vegetables	1
Legumes	1
Weeds	1
Manure	1
Invasive Species	1
Fertilizer	1
Drought	1

Output from research centers is sometimes measured by publications. The list of publications from the Ottawa Center is shown in Table 4.

Table 4. Number of publications and presentations from Ottawa Research and Development Center by Focus Area (AAFC, 2023)

Research Commodity / Focus Area	Number of Publications/Presentations from Ottawa Research and Development Center in 2023
Soybeans	11
Manure	6
Wheat	5
Dairy	5
Methane	5
Fungi	4
Flax	3
Barley	2
Oilseeds (canola)	1
Livestock	1
Sustainability	1

We have not tried to correlate research center activity by quantity of production per province, but that could be done. However, interesting data from 2017-2021 was available for the primary province production areas. We see Ontario is a very substantial producer nationally in corn, soybeans, and winter wheat (USDA, n.d.). Southern Ontario, between Lake Huron and Lake Erie, dominate the production in that province. Production maps are available through United States Department of Agriculture Foreign Agriculture (Appendix A & B).

A study of the above data would reveal that multiple research and development centers throughout Canada are studying the same commodities as that of the CEF. Unique to the Ottawa facility funding is the emphasis on barley, but their publications emphasize soybeans, in one major project, as we read it. There are two other research and development centers in Ontario (e.g., London and Harrow) that undoubtedly contribute to the research of Ontario's primary crops as well.

Findings Based on Above Analysis of Canadian Agriculture Data

- Multiple research and development centers throughout Canada are studying the same crops that Ottawa Research and Development Center studies.
- Ontario contributes less than 1% of the national production of barley and oats.
- Ontario contributes over 50% of the national production of corn, soybeans, and winter wheat.
- Ontario's production of corn, soybeans, and winter wheat is concentrated in the southwest region of Ontario.

Application of Analysis to Ottawa Research and Development Center

- The Ottawa Research and Development Center does not appear to be unique in its areas of study.
- It is unclear why Ottawa Research and Development Center emphasizes barley and oats when Ontario does not contribute significantly to Canada's production of these crops.
- There are two research and development centers located in southwest Ontario (London and Harrow) that are more geographically appropriate for the study of corn, soybeans, and winter wheat.

V. Scientific / Agronomy Implications

Non-Crop Specific Studies

Touil et al., 2019

In a review of several studies evaluating the effect of partial shade caused by agrivoltaics, up to 25% sunlight reduction was found to have no significant effects on crop yield. Inhibitory effects on the production of crops occurred when sunlight reduction ranged from 50% to 100%.

Gommers et al., 2013

When plants are exposed to shade, they exhibit tactics known as "shade avoidance" and "shade tolerance" to mitigate the effects of the shade. All plants that experience a reduction in sunlight will adapt to the change by optimizing photosynthesis. Shade avoidance is displayed through stem elongation and reduced branching while shade tolerance is displayed through increased leaf area, lowered chlorophyll ratios, and higher photosystem ratios.

Crop Specific Studies

Corn – *Riska et al., 2022*

When studying four hybrid varieties of corn, shade had no statistically significant differences in dry weight, height, and leaf area for those grown with 25% sunlight reduction than those grown with 0% sunlight reduction. For the corn grown with 50% sunlight reduction, there was a significant difference in stem diameter than corn grown with 0% sunlight reduction. Two varieties of corn were able to produce high yields under a 50% reduction in sunlight.

Corn – *Ramos-Fuentes et al., 2023*

The partial shade of solar panels from the application of agrivoltaics can reduce the irrigation inputs of corn production by 19-47%, compared to unshaded plots of land.

Grass Species - *Semchenko, et al., 2011*

In a study of the effect of partial shading on grass species, grass species grown with 25% reduction in sunlight had no significant differences in dry mass than the grass species grown with no reduction in sunlight. When the reduction in sunlight was greater than 50%, there was a net facilitative effect on plant mass. At a reduction in sunlight of 90%, there was significantly lower dry mass than of that grown under full sunlight.

Soybean – *Fan et al., 2018*

When exposed to 8.7% and 31.1% reduction in sunlight due to intercropping with corn, the yield of soybeans decreased significantly. The soybeans showed many changes in features such as stem height, stem biomass, and leaf biomass to acclimate to the shaded environment.

Winter Wheat – *Weselek et al., 2021*

In southwest Germany, the impact of 30% sunlight reduction from being grown under a solar array was evaluated. The yield of winter wheat ranged from -19% to +3%. However, during a hot, dry summer, the yield of winter wheat increased by 2.7%.

Winter Wheat – *Tromsdorff et al., 2011*

During a hot, dry summer in Germany, a study of 40% sunlight reduction resulted in a 3% increase in yield for winter wheat.

Wheat – *Lakshmanakumar, 2018*

During winter in India, a study of four varieties of wheat where evaluated based on sunlight reduction. Conditions of 33% and 66% sunlight reduction here did result in a decreased grain yield.

Wheat and Barley – *Arenas-Corraliza et al., 2019*

The impact of 0%, 10%, and 100% sunlight reduction on wheat and barley was studied under Mediterranean conditions. A factor of 10% and 50% light reduction resulted in a 19% increase in yield for barley. Wheat had no significant change in yield at 10% reduction but a 19% increase in yield at 50% light reduction.

Specialized New Uses of Shaded Areas - Agrivoltaics

In the event of partial shading on the Ottawa research plots, the opportunity for novel research in the agrivoltaics sector and urban farming areas exists in the future. Agrivoltaics is the use of land for both agriculture purposes and energy generation through photovoltaics (i.e., solar panels). Ontario has about 94% of Canada's total cumulative installed capacity for photovoltaics (Baldus-Jeursen, 2019). Additionally, research has been ongoing to evaluate the potential for agrivoltaics in Ontario (Pearce, 2022).

Conclusions Based on Literature

- Corn and grasses (e.g., wheat and barley) were not significantly affected by 25% or less sunlight reduction.
- Soybean were significantly affected by as little as 8.7% sunlight reduction.

- For wheat grown in hot, dry climates, 30% sunlight reduction can have a positive effect on the yield of wheat. For wheat grown in cold climates, over 30% sunlight reduction can have an inhibitory effect on yield.

Application of Literature to Ottawa Research and Development Center

- Corn and grasses (e.g., wheat and barley) exposed to up to 20% reduction in sunlight, will not be significantly affected in terms of yield and other attributes.
- Soybean will be affected even by small amounts of sunlight reduction. Therefore, management practices should prevent soybeans from being grown in the potentially affected plots.
- With good management practices recognizing potential diminishing effects on certain crops, lightly shaded areas can be used to the benefit of various crop programs (e.g., agrivoltaics).

VI. Other Factors Affecting Experimental Plots

The factor of intermittent shade already exists at these research fields. Portions of its fields are exposed to shade from the tree belt along Fisher Road, as well as from developments that have already been built.

The factor of intermittent shade will actually become more prevalent given the recent approval of a similar high-rise building development at 1081 Carling Avenue.

Many of the fields adjacent to the CEF are even currently subjected to exhaust from cars that use the four-lane road that runs through and along the CEF, and chemicals that are used on the roadway and adjacent properties.

Finally, the city of Ottawa is planning to build a transit line along Baseline Road. This line will run along the CEF, impacting the farm through construction dust, increased traffic, and drainage.

Despite being exposed to these many variabilities for many years, the CEF has apparently continued to operate effectively, as evidenced by over forty publications and presentations in 2023. One can question why the additional effects from the proposed structures would be anything but "de minimis" (of little significant further influence).

VII. Opinions

1. Ottawa Research and Development Center is not unique in terms of the crops that they study. Many other research facilities throughout Ontario and Canada would seem capable of conducting similar research, and such research may be located closer to where a majority of production is occurring, i.e., research regarding oats and barley.
2. The AAFC shade study estimated a range of 1% to about 20% reduction in sunlight caused by the proposed structures. The potential area of concern appears to be about 47 acres out of an approximate 1000 acres for the CEF site. Within the potentially affected area, the ~20% reduction would likely be limited to less than two acres. The average expected impact across the 47 acres would likely be about 5% reduction in sunlight.
3. We acknowledge within the AAFC October 24, 2023, Development Application response, that the points made under #5-#11 of the Results section indicate reasonable concerns. Research reported again below indicates sunlight obstructions on certain crops can be a positive or

negative influence. Our overview findings suggest the effects across this acreage can be minimal. Additional tall structures on the perimeter or even planned in-field structures, which limit lighting, can be positive under the right management strategies, i.e., agrivoltaics.

4. In review, there has been substantial research relative to the effects of reduced sunlight on certain crops. Example findings are:
   - Corn and wheat are not significantly affected by 25% sunlight reduction.
   - Soybean is significantly affected by as little as 8.7% sunlight reduction.
   - For wheat grown in hot, dry climates, a 30% sunlight reduction can increase yield.
   - For wheat grown in cold climates, a 30% sunlight reduction can have a negative effect on yield.
5. One can conclude from the example studies that:
   - Corn and grasses (e.g., wheat and barley) exposed to up to 20% reduction in sunlight, will not be significantly affected in terms of yield and other attributes.
   - Soybean will be affected even by small amounts of sunlight reduction. Therefore, management practices should prevent soybeans from being grown in the potentially affected shaded plots.
   - Under certain management strategies, lightly shaded areas can be used to the benefit of various crop programs (e.g., study of agrivoltaics).
6. A number of plantings and buildings have already been allowed adjacent to the Central Experimental Farm. Given other tall structures in the area, there has been no evidence presented by AAFC that suggests shading from these other obstruction structures and plantings nearby have impacted the AAFC's programs at the CEF.
7. Test plots in urban areas will have the potential for sunlight obstruction and contaminants such as vehicle exhaust, road salt seepage, and manufacturing and process plant fumes. While less advantageous for crops intended for rural farming, there is a trend to promote "urban farming". In which case, these variations in conditions might be representative of what such urban farmers will experience, and which should be further researched. Should the CEF then focus some efforts on urban farming research, where partial sunlight obstruction will be a desired variable?
8. In the short term, the proposed structures would have little effect on future crop tests, given optimal management strategies on the part of AAFC. In the long term, the various other potential urban influences on the AAFC may cause concern regarding use of this location and choice of crops to test here, versus a more remote facility.
9. We would conclude that the impact of the proposed high structures relative to AAFC can be of a de minimis nature, and even of a benefit. Such benefit will depend on management's recognition that reduced sunlight can be a potential positive factor for some crop projects.

Respectfully submitted,

James Miller, PE, PhD
Helen Miller, EIT, M.S. Ag & Bio Engineering

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IX. Appendix

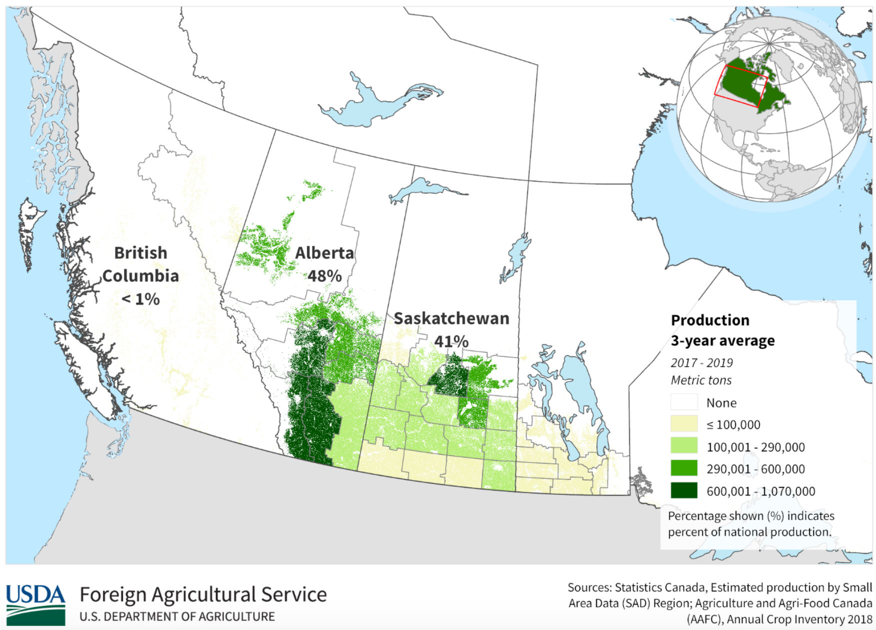
A. Three-year average of crop production by province in Canada ranging from 2017-2021 (USDA, n.d.)

Commodity	Province	Percent of Production
Barley	Alberta	48%
	Saskatchewan	41%
	British Columbia	<1%
Corn	Ontario	63%
	Quebec	26%
Oats	Saskatchewan	52%
	Manitoba	20%
	Alberta	19%
	British Columbia	<1%
Rapeseed	Saskatchewan	55%
	Alberta	28%
	Manitoba	16%
	British Columbia	<1%
Soybean	Ontario	55%
	Manitoba	24%
	Quebec	16%
	Saskatchewan	4%
Spring Wheat	Saskatchewan	41%
	Alberta	37%
	Manitoba	18%
Sunflower Seed	Manitoba	97%
	Alberta	2%
	Saskatchewan	1%
Wheat	Saskatchewan	45%
	Alberta	42%
	Manitoba	15%
	Ontario	6%
	Quebec	<1%
	Ontario	83%
	Saskatchewan	6%

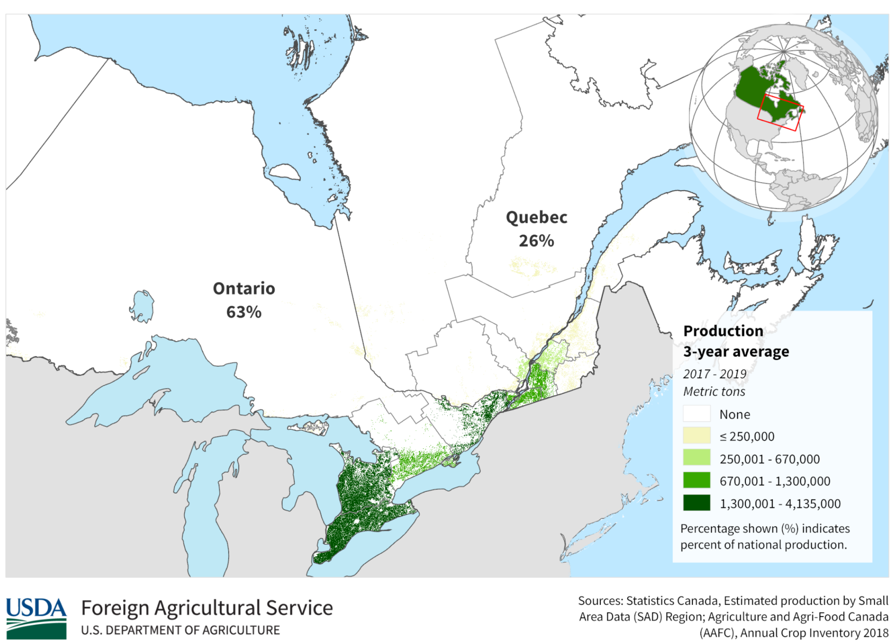
Winter Wheat	Alberta	5%
	Manitoba	3%
	Quebec	2%

B. Production Maps of Canada (USDA, n.d.)

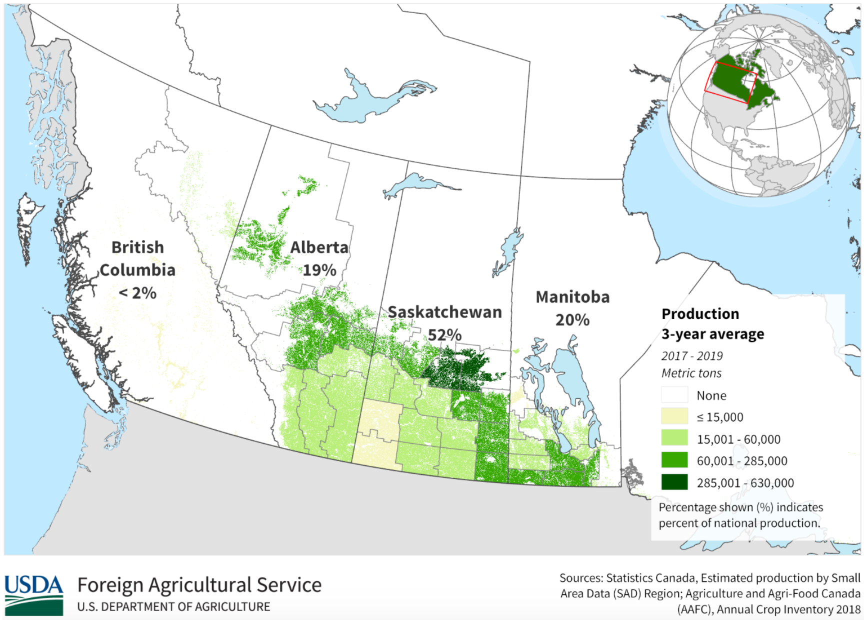
Canada: Barley Production



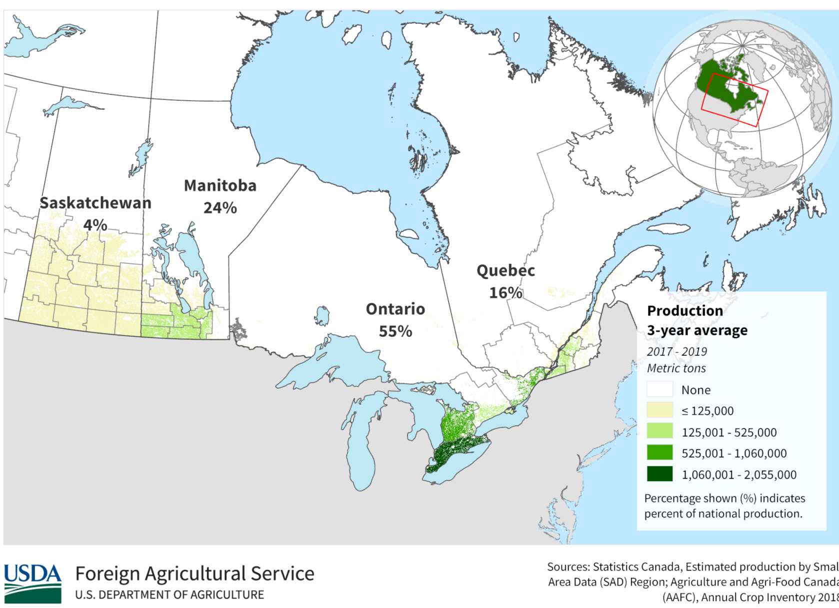
Canada: Corn Production



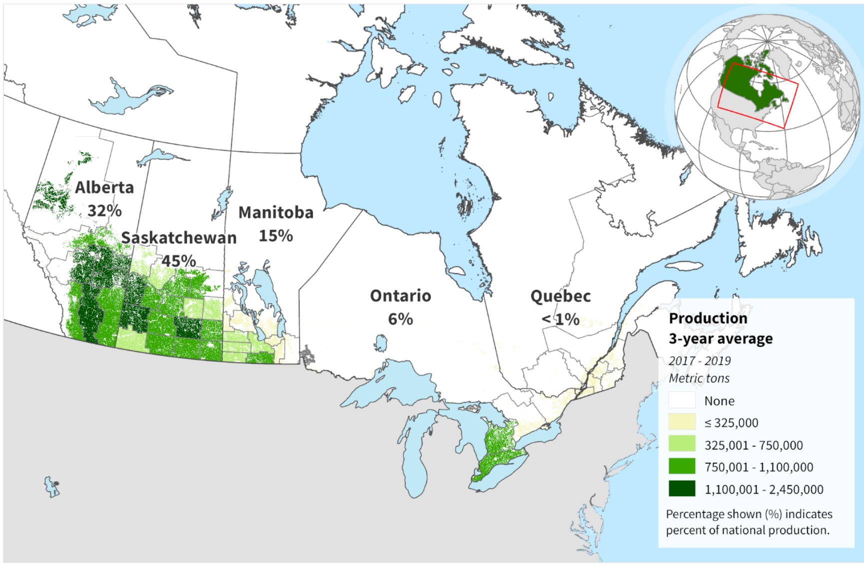
Canada: Oat Production



Canada: Soybean Production



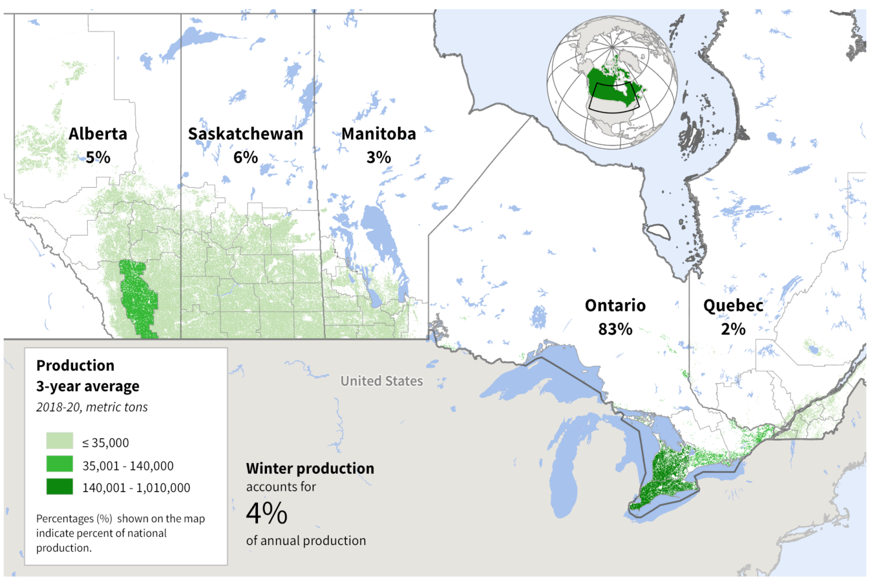
Canada: Wheat Production



USDA Foreign Agricultural Service
U.S. DEPARTMENT OF AGRICULTURE

Sources: Statistics Canada, Estimated production by Small Area Data (SAD) Region; Agriculture and Agri-Food Canada (AAFC), Annual Crop Inventory 2018

Canada: Winter Wheat Production



USDA Foreign Agricultural Service
U.S. DEPARTMENT OF AGRICULTURE

Sources: Statistics Canada, Estimated production by Small Area Data (SAD) Region; Agriculture and Agri-Food Canada (AAFC), Annual Crop Inventory 2018

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463 - Work Measurement
563 - Legal and Labor Issues in Engineering
639 - Engineering Safety Research
333 - Human Factors Engineering I
533 - Human Factors Engineering II
539 - Safety Design Engineering

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Master Business Administration, Ohio State University 1965
Bach. Mechanical Engineering, Ohio State University 1963

Professional Society Affiliations

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Human Factors and Ergonomics Society
American Society of Agricultural and Biological Engineers
American National Standards Institute
American Society for Testing and Materials
Society of Automotive Engineers
National Fire Protection Association
National Safety Council

PROFESSIONAL WORK EXPERIENCE SUMMARY

1997	Emeritus Professor, Industrial and Operations Engineering (IOE), The University of Michigan
1976 - 1997	Associate Professor of Industrial and Operations Engineering (IOE), The University of Michigan
1981 - present	President, J.M. Miller Engineering, Inc.
1978 - 1980	Special Assistant for Safety to Dr. Eula Bingham, U. S. Assistant Secretary of Labor, OSHA

OSHA responsibilities included:

- Directing promulgation and revision of construction, general industry, and maritime OSHA safety standards.
- Liaison activities between OSHA and NIOSH, U.S. Department of Transportation, Mine Safety and Health Administration, labor unions, trade associations, and industry organizations.
- Negotiation of agreements involving OSHA and U.S. Coast Guard.
- Research needs and project area definition and prioritization.
- Recruiting, staffing, and budgeting.

1977 - 1978	Acting Director of Safety Standards, Federal OSHA, Washington D.C.
1971 - 1976	Assistant Professor of IOE, University of Michigan
1964 - 1966	Corporate Methods Engineer, Owens-Corning Fiberglas, Toledo, Ohio

PUBLICATIONS

Books and Chapters

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Helen Miller, EIT

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Education

M.S. in Biosystems and Agricultural Engineering, Michigan State University, East Lansing, MI
Thesis: *A Decision Support System to Evaluate the Economic Feasibility of Solar Technology on Dairy Farms*
B.S. in Mechanical Engineering, Michigan State University, East Lansing, MI
Additional major in Psychology, minor in Agribusiness Management
Engineering Certification: Passed initial Engineer In Training examination December 2020

Relevant Experience

Project Engineer - Miller Engineering, Inc., Ann Arbor, MI (2019 – Present)
- Case experience regarding fermentation, farm vehicle road safety, agricultural equipment, generator testing, recreational vehicles, cranes, product recalls, etc.
- Studied lawsuits regarding product failure, warnings & regulations, and human factors engineering.
- Researching OSHA standards, applying engineering principles, and writing reports.

Research Assistant – Michigan State University, East Lansing, MI (5/21 – 5/23)
- Tractor newly converted to electric motor: Prepared formal plan for obtaining performance metrics.
- Tractor metrics: Included but not limited to tractor slip, hydrostatic pressure, and drawbar force.
- Agricultural Mechanization: Assisted with development of course.

Teaching Assistant – Michigan State University, East Lansing, MI (1/21 – 5/23)
- Over 50 biosystems & agricultural engineering undergraduate students.
- Agricultural and biosystems engineering junior design: Supervised and assisted creation of ag & bio design projects.
- Agricultural and biosystems engineering remote learning model: Developed for professor as well as ag and bio students.
- Agricultural engineering electronics lab: Set up agricultural related electrical and sensor components for monitoring.
- Instrumentation: Oscilloscopes, data acquisition systems, sensors, circuit boards, etc.
- Provided clear and effective feedback on technical writing to develop students into stronger technical writers.

ASABE International Conference, Volunteer Student Coordinator (7/21)
- Alliance for Modernizing African Agriculture: Lead the construction of the formal report, delegated tasks to a group of 12 agricultural engineering graduate students from other land-grant universities across the United States

Research Assistant – Mid Michigan Research, LLC, East Lansing, MI (1/20 – 4/21)
- Internal combustion engine modeling of cylinder fluid flow.
- For the above model: Compiled data for various variables and mended computer aid design (CAD) modeling errors on Converge CFD Software.

Property Management Intern - Kalajoki Farms, Clatskanie, OR (5/16 – 8/16)
- Rural Energy for America Program (REAP) government funded solar plant supervision of the installation.
- Prepared a home for rent through restoration, creative decision-making, and appliance installation.
- On farm equipment operation; tractors; irrigation systems; manual labor; weed control; electronic land surveying.

Presentations

ASABE International Conference: Alliance for Modernizing African Agriculture (7/21)
Title: The Potential of Solar Energy to Modernize African Agriculture
ASABE Global Initiative Conference: Sustainable Energy for a Sustainable Future (10/22)
Title: A Decision Support System to Evaluate the Economic Feasibility of Solar Technology on Dairy Farms

Relevant Skills

- Extensive experience with MS Office Suite, Slack, and other professional tools
- Extensive experience using: Camtasia, CONVERGE CFD, and Rstudio
- Moderate experience using: CSS, HTML, JavaScript, Matlab, NX 11 CAD, Altaire Inspire, SPSS, Minitab, Qualtrics
- Proven track record of effective time management with multiple projects, strong communication through several mediums to different groups, and systematic problem-solving of complex tasks.

Affiliations

American Society of Agricultural and Biological Engineers *2021 – Present*
American Society of Mechanical Engineers *2020 – Present*
Engineers Without Borders, Michigan State University *2019 – Present*
Tau Beta Pi, Engineering Honors Fraternity, Michigan State University *2018 – Present*
4H – Rabbitry, Western and English Horsemanship *2010 – 2016*

ABOUT MILLER ENGINEERING AGRICULTURAL EXPERTISE

We are more than engineering consultants as we actually manage the farming of 1000 acres of land in Idaho and Oregon. Also we have designed and operate a hydroelectric plant on the Snake River, and designed and built a solar farm to operate pressured pivot irrigation systems under a US Government Grant (REAP). The agricultural, academic, publications and forensic experience of our engineers in the allow us to act as experts in many of the warning, labeling, toxic material, vehicular accidents, animal safety, and other types of issues and incidents confronted in agricultural operations. We can assist with everything from agricultural accident analysis to systems design from simple individual pieces of equipment to complicated automatic irrigation, solar and hydroelectric systems.

On staff we also have a licensed applicator for herbicides, fertilizer, pesticides, insecticides, and restricted use chemicals. Below are examples of areas we have provided agricultural engineering expertise:

- Agricultural Safety Engineering
  - Tractor, Farm Implement, and Harvesting Safety (OSHA 29 CFR 1929)
  - Dairy and Food Processing Safety and Health
  - Cannabis and Hemp Processing Safety
  - Machine Guarding, Entrapment, & Entanglement
- Farm Tools, Vehicles, Equipment, and Machinery
  - Tractor Overturns/Rollovers
  - Irrigation & Hydroelectric Power Systems
  - All-Terrain Vehicle (ATV) Usage
- Farm Accident Analysis/Reconstruction
  - Hay, Crop and Grain Harvesting Accidents
  - Grain and Crop Conveyor and Elevator Storage and Accidents
  - Horse (Equine) and Cattle (Bovine) Accidents
- Agricultural Chemical Safety, Applications, and Exposure
  - Pesticide Use, Compliance, Disposal, and Contamination
  - Licensed Restricted Use and Chemigation Applicators
  - Wastewater
- Construction Safety, Training, and Accidents (OSHA 29 CFR 1926)
  - Building Materials
  - Building Codes

Our Working Farms and Ranches

Our 1,000 acres of ranch, farm and timberlands in Idaho and Oregon, as well as our solar farm and hydroelectric power plant on the Snake River (shown below), have the usual pieces on farm equipment: tractors, swathers, balers, rakes, planters, harvesters, tilling equipment, backhoes, skid steers, and ATV's. Crops produced include potatoes, alfalfa, sugar beets, barley for Coors and Budweiser, winter wheat, beans, carrots, and three types of corn: sweet, field, and silage corn. The ranch is also home to 300 registered black angus cattle.

These properties are available for various test or demonstration purposes of crops and equipment, and they are available for use by clients. We also use our contacts with our many local farmers to gather data about the equipment they buy and use. We are happy to make this connection to our farms available.