**Product Carbon Footprint**

The carbon footprint of a product is the sum of all GHGs directly and indirectly emitted throughout the life cycle of the product (from cradle-to-grave). The life cycle of a product is composed of all the consecutive and interlinked stages, from raw material acquisition and extraction of natural resources to the disposal of the product at its end-of-life.

For a farm product that can supply various food or non-food end-use markets, the final use and distribution pattern are usually unknown. Therefore, to calculate its carbon footprint, a cradle-to-gate approach is more relevant. A cradle-to-gate approach is a partial life cycle inventory, where the use and the end of life of the product are not considered. Life cycle GHG emissions and removals are accounted for only up to the moment where the intermediate product leaves the reporting company’s gate (typically immediately following its production).

**Life cycle stages of miscanthus and switchgrass**

Handling and storage

Spray burning is preferred because it minimizes nutrient removal, reduces further drying costs, and improves fuel quality if biomass is combusted. Harvesting while the crop is still green for hay or bedding may harm regeneration. Usually, combine harvested miscanthus and switchgrass is baled and stored in the field or barn.

Main productive phase

Yield increases each year, reaching a maximum potential by year three or four. The plant’s efficient use of nutrients reduces further drying costs, and improves fuel quality if biomass is combusted. Harvesting while the crop is still green for hay or bedding may harm regeneration. Usually, combine harvested miscanthus and switchgrass is baled and stored in the field or barn.

Establishment phase

Land preparation

During the fall preceding establishment, fields can be sprayed with a broad-spectrum herbicide to control weed pressure from the stands. Furthermore, it is best to avoid fertilization before planting to minimize weed competition as it would commonly stimulate weed growth.

Establishment

Miscanthus and switchgrass are perennial crops, they don’t need to be replanted each spring. Unlike switchgrass, miscanthus produce no seed and must be established vegetatively by planting divides rhizome pieces or live plants. In the spring, planting and seeding should be performed after row crop planting.

**LIFE CYCLE ANALYSIS**

**Planting**

**AFC** is committed to working with industry partners. The opinions expressed in this document are those of the OFA and not necessarily those of AFC.

**Editing**

The carbon footprints of miscanthus and switchgrass have been assessed by the Inter-University Research Centre for Life Cycle of Products, Processes and Services (CIRAIG).

**Methodology**

To evaluate the carbon footprint of both products, the CIRAIG has referred to the international standards on life cycle assessment (ISO 14040:44) and to the Greenhouse Gas Protocol: Product Life Cycle Accounting and Reporting Standard supplemented with the Agricultural guideline.

**References**


**Acknowledgment**

Investment in this project has been provided by Agriculture and Agri-Food Canada through the Canadian Agricultural Adaptation Program (CAAP). In Ontario, this program is delivered by the Agricultural Development Council.

**Products description**

**Miscanthus**

Miscanthus is a warm-season grass but it is adapted to many soil conditions and can grow at relatively low temperatures. Miscanthus produces no seed, so it must be established vegetatively. However, it does not need to be reseeded each spring and it has lower input requirements than other row crops. Yield increases each year, reaching a maximum potential by year three or four. A miscanthus stand has a productive lifespan of 15 to 20 years.

**Switchgrass**

In North America, switchgrass grows naturally and in different environments like cold northern and warm southern areas. Switchgrass is relatively productive on medium to lower fertility soils, compared to most annual field crops. Establishment is by seeding and maximum production is first attained during the third growing season. Once established and properly maintained, a switchgrass stand can remain productive for up to 20 years.

**Use of miscanthus and switchgrass**

Many varieties of miscanthus have been bred and used ornamentally for over 100 years. In Japan, miscanthus varieties have been successfully cultivated and managed in prairie-like settings for use as forage and building material for thousands of years. In North America, switchgrass is an important component of tall grass prairie grasslands. Miscanthus and switchgrass can be used as a diversity of agricultural and energy markets. Producers are experimenting with their use as livestock bedding, as part of dairy feed, as a mushroom compost substrate, as a horticultural or roadside mulch, as biomaterials and as a combustion fuel for heat production.

Miscanthus and switchgrass can reduce greenhouse gas (GHGs) emissions by increasing the carbon stored naturally in soil through increased carbon capture and cycling in the plant material and the extensive root system. These crops provide an additional benefit by improving soil organic matter. They can also help to stabilize and improve soil properties, filter water and create wildlife cover. Miscanthus and switchgrass have been identified as a promising bioenergy and biomaterials feedstock through worldwide studies.

**Both miscanthus and switchgrass are being investigated as biomass crops for bioenergy.**
Why calculate the product carbon footprint?

Businesses have various reasons to evaluate the carbon footprint of their products. Understand product and value chain gives a better understanding of its production process and value chain, which helps to manage economic and environmental risks. Target cost reduction and environmental efficiency opportunities increases the level of understanding of where there are GHG-intensive processes and operations in the life cycle and helps in targeting where reduction efforts should be concentrated. Improve decision making provides a general framework for companies to make informed choices to reduce GHG emissions from the production (goods or services) they design, manufacture, sell, purchase, or use. Timely production positioning provides an incentive for increasing demands from major clients for carbon tracking on local and international markets. A strong tendency has been observed in various markets for a demand of more specific environmental product information. Accountability by tracking performance throughout the production cycle supports performance tracking of a product’s GHG inventory and emission reductions over time.

How is the carbon footprint calculated?

The six GHGs that are minimally accounted for are carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), sulfur hexafluoride (SF₆), perfluorocarbons (PFCs), and hydrofluorocarbons (HFCs). Each of these GHGs has a different global warming potential (GWP), a measure of their impact on climate change. The weighting of these GWP’s according to their GWP can bring different GHGs to a common denominator called carbon dioxide equivalent (CO₂e). Product carbon footprint is quantified in kg CO₂eq based on international methods. To account for all GHGs emitted during the product’s life cycle, primary data need to be collected on site (direct monitoring, physical measures of a process, etc.). When such data are not easily available, which is the case for most of the upstream processes not under the control of producers (i.e. fertilizer or diesel production), the experts can extract information from approved climate change databases (i.e. Agriculture Canada’s CIRIAIG database). The whole biomass life cycle is production, the experts can extract information from approved climate change databases (i.e. Agriculture Canada’s CIRIAIG database). The whole biomass life cycle is gigantic and involves many different processes and operations in the life cycle and helps in targeting where reduction efforts should be concentrated. Improve decision making provides a general framework for companies to make informed choices to reduce GHG emissions from the production (goods or services) they design, manufacture, sell, purchase, or use. Timely production positioning provides an incentive for increasing demands from major clients for carbon tracking on local and international markets. A strong tendency has been observed in various markets for a demand of more specific environmental product information. Accountability by tracking performance throughout the production cycle supports performance tracking of a product’s GHG inventory and emission reductions over time.

Functionality

This is the reference to which all input and output life cycle data inventory are normalised. It is defined here as “1 kg dry matter agricultural biomass, baled, at farm gate, produced in Ontario according to best management practices as of 2013”. Consequently, the carbon footprint will refer to kg of CO₂eq per kg dry matter of biomass harvested, baled, at farm, ready to deliver.

Life cycle stages contribution to the carbon footprint of biomass, excluding land use change (LUC) impact

Switchgrass

<table>
<thead>
<tr>
<th>Stage</th>
<th>CO₂eq/kg dry matter</th>
<th>Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swathing and Raking</td>
<td>0.15</td>
<td>36%</td>
</tr>
<tr>
<td>Baling and Bales handling</td>
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</tr>
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<td>Fertilizer</td>
<td>0.05</td>
<td>13%</td>
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<td>Other Inputs and Transport of Inputs</td>
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<td>17%</td>
</tr>
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<td>0.05</td>
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Miscanthus

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The contribution pattern for miscanthus biomass is slightly different, even though rhizome production and plantations contribute slightly higher to the impact than seeds and accounting for 95% of lifetime production. In fact, direct soil emissions contribute to 63% of the footprint, mostly from nitrification (N₂O) released from nitrogen inputs (urea fertilizer and crop residues). Urea production and supply accounts for over 17% of the impact. Fieldwork is also a larger contributor, with life cycle GHG emissions amounting to 18%, mainly as a result of direct GHG from field operations like the yearly baling process. Fieldwork during land preparation and seeding is the most important factor contributing to field operations GHGs, yet it has an impact on the total footprint, even when simulating larger establishment failure rates. The contribution pattern for miscanthus biomass is very similar, even though rhizome production and plantations contribute slightly higher to the impact than seeds and accounting for 95% of lifetime production. In fact, direct soil emissions contribute to 63% of the footprint, mostly from nitrification (N₂O) released from nitrogen inputs (urea fertilizer and crop residues). Urea production and supply accounts for over 17% of the impact. Fieldwork is also a larger contributor, with life cycle GHG emissions amounting to 18%, mainly as a result of direct GHG from field operations like the yearly baling process. Fieldwork during land preparation and seeding is the most important factor contributing to field operations GHGs, yet it has an impact on the total footprint, even when simulating larger establishment failure rates. The contribution pattern for miscanthus biomass is very similar, even though rhizome production and plantations contribute slightly higher to the impact than seeds and accounting for 95% of lifetime production. In fact, direct soil emissions contribute to 63% of the footprint, mostly from nitrification (N₂O) released from nitrogen inputs (urea fertilizer and crop residues). Urea production and supply accounts for over 17% of the impact. Fieldwork is also a larger contributor, with life cycle GHG emissions amounting to 18%, mainly as a result of direct GHG from field operations like the yearly baling process. Fieldwork during land preparation and seeding is the most important factor contributing to field operations GHGs, yet it has an impact on the total footprint, even when simulating larger establishment failure rates. The contribution pattern for miscanthus biomass is very similar, even though rhizome production and plantations contribute slightly higher to the impact than seeds and accounting for 95% of lifetime production. In fact, direct soil emissions contribute to 63% of the footprint, mostly from nitrification (N₂O) released from nitrogen inputs (urea fertilizer and crop residues). Urea production and supply accounts for over 17% of the impact. Fieldwork is also a larger contributor, with life cycle GHG emissions amounting to 18%, mainly as a result of direct GHG from field operations like the yearly baling process. Fieldwork during land preparation and seeding is the most important factor contributing to field operations GHGs, yet it has an impact on the total footprint, even when simulating larger establishment failure rates.

Swatchgrass and Miscanthus are low input crops. Biomass leaving Ontario farms displays a low carbon footprint.