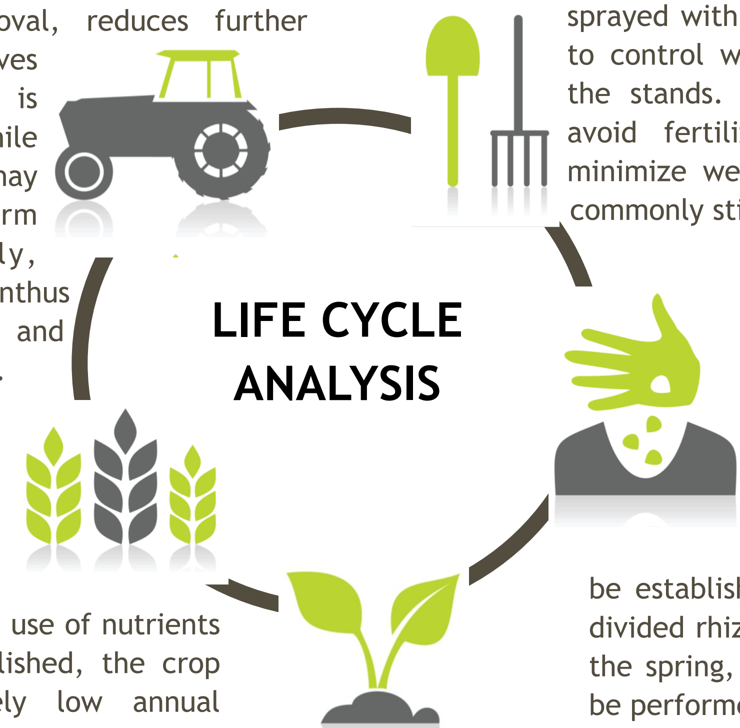
Product Carbon Footprint

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.

> The product carbon footprint assesses the impact of a product on climate change, throughout its complete life cycle.

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

Spring harvesting 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.

Land preparation

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

Planting

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

Main productive phase

Yield increases each year, reaching maximum potential by year three or four. The plant's efficient use of nutrients implies that, once established, the crop will require a relatively low annual fertilization rate.

Establishment phase

At establishment, weed control is critical as crops are slow to grow and weed pressure can affect their growth. Therefore, it is best to establish miscanthus and switchgrass on fields that have modest annual and perennial grass pressure. In the establishment years, a reduced yield is typically obtained.

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 Guidance.

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Agriculture and Agri-Food Canada — AAC agricultural adaptation council — OFA Ontario Federation of Agriculture

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

FACTSHEET

Ontario Federation of Agriculture

Miscanthus and switchgrass carbon footprints

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 in 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 feed stock 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 its 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 product (goods or services) they design, manufacture, sell, purchase, or use.

Timely production positioning
Prepares 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.

Study's goal and scope

The Ontario Federation of Agriculture (OFA) has taken steps to evaluate the cradle-to-gate carbon footprint of two purpose-grown biomass crops (miscanthus and switchgrass) based on best management production practices experimented among current biomass producers in Ontario, with the support of the Ontario Soil and Crop Improvement Association.

How is the carbon footprint calculated?

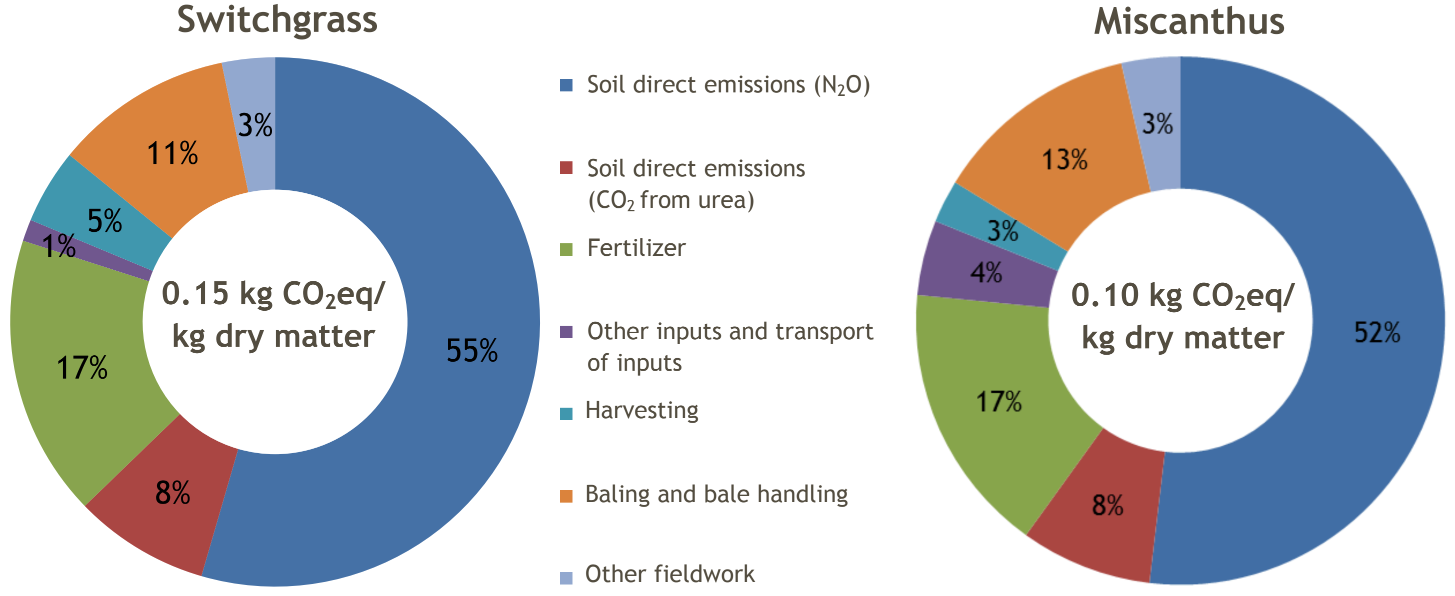
The six GHGs that are minimally accounted for are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), perfluorocarbons (PFCs), and hydrofluorocarbons (HFCs). Each of these GHGs has a different global warming potential (GWP), a measure of their impact on climate change. The weighting of GHGs according to their GWP can bring different GHGs to a common denominator called carbon dioxide equivalent (CO_2eq). Product carbon footprint is quantified in kg of CO_2eq based on international protocols.

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. *ecoinvent*). However, all GHG inventory guidance protocols suggest the use of primary data for farm operations as it improves the accuracy of the inventory and the robustness of the assessment. The whole biomass life cycle is considered for the inventory, assuming a lifespan of 15 years and including land preparation and establishment stages. The life cycle inventory is further allocated to the overall harvested material and reported according to the functional unit.

Functional unit

This is the reference to which all input and output life cycle data inventoried 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 CO_2eq 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



The productive years are by far the main contributor to the carbon footprint of the biomass. For switchgrass, around 91% of the impact is due to this phase which accounts for 95% of lifetime production. In fact, direct soil emissions contribute to 63% of the footprint, mostly from nitrous oxide (N_2O) 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 diesel combustion due to the yearly baling process. Fieldwork during land preparation and seeding is the most important factor contributing to field operations GHGs, yet it has a limited 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 plantation contributes slightly higher to the impact than seeds and seeding for switchgrass. On the other hand, no raking is involved when harvesting every year, whereas it is required for switchgrass (Fall cut and Spring harvested).

Since urea fertilizer supply and field emission of N_2O are, by far, the main contributors to the GHG emissions, a significant reduction of the impact could be achieved through reducing N fertilization rate (here assumed at 60 kg N/ha, from year 2) without sacrificing yield. Also, increasing lifetime of stands over 15 years could lead to a significant decrease of the carbon footprint in GHG per kg biomass harvested.

BIOMASS CARBON FOOTPRINT

	Switchgrass (kg CO_2eq/kg dry matter biomass)	Miscanthus (kg CO_2eq/kg dry matter biomass)
Land preparation, planting, and establishment year 1	0.004	0.006
Establishment year 2	0.009	0.006
Main Productive years (year 3-15)	0.134	0.087
Root system N_2O	0.004	0.005
Land use change (LUC)	0.084	-0.053
TOTAL	**0.24**	**0.05**

A comprehensive carbon footprint requires the consideration of LUC. Impact from LUC results from the change in soil organic carbon (SOC) stock and vegetation carbon stock when land is transformed from its previous use (assuming cropland for 75% and 90% for switchgrass and miscanthus, respectively; the rest split evenly among grassland and abandoned land). LUC is calculated according to the IPCC methodology, in compliance with international standards and certification schemes.

Including LUC impact, the biomass carbon footprint is 0.24 kg CO_2eq/kg dry matter for switchgrass and 0.05 kg CO_2eq/kg dry matter for miscanthus (see table). For miscanthus, the higher biomass yield, the different pattern of previous land use, and the higher carbon sequestration from vegetation, offset the soil carbon loss from land transformation and offer a net sequestration (0.2 tonne C/ha.year) which is credited to GHGs emitted from operations.

However, the scientific literature reveals there is a still a very large uncertainty related to field measurements and estimation of SOC change. The carbon footprint assessment study has evaluated different scenarios with possible higher carbon sequestration rates, resulting in negative and similar carbon footprints for both biomass products (CIRAIG, 2013).

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