NETL Life Cycle Inventory Data
Process Documentation File

Process Name: Corn Grain, Cultivation, Operation

Reference Flow: 1 kg of Biomass Operation

Brief Description: This unit process includes operation of farming activities for cultivation of corn grain including inputs of combusted diesel, fertilizers, herbicides and water use, as well as emissions to air and water.

Section I: Meta Data

Geographical Coverage: US **Region:** Midwest

Year Data Best Represents: 2008

Process Type: Extraction Process (EP)

Process Scope: Cradle-to-Gate Process (CG)

Allocation Applied: No

Completeness: All Relevant Flows Recorded

Flows Aggregated in Data Set:

☒ Process	☒ Energy Use	☐ Energy P&D	☐ Material P&D

Relevant Output Flows Included in Data Set:

Releases to Air:	☒ Greenhouse Gases	☒ Criteria Air Pollutants	☐ Other
Releases to Water:	☒ Inorganic Emissions	☐ Organic Emissions	☐ Other
Water Usage:	☒ Water Consumption	☒ Water Demand (throughput)	
Releases to Soil:	☐ Inorganic Releases	☐ Organic Releases	☐ Other

Adjustable Process Parameters:

Corn yield (yield_ratio_y)	*Represents the weight of corn grain acre year.*

Tracked Input Flows:

Biomass Operation [Installation]	*This unit process is assembled with Land Preparation operations process in series.*
Diesel Combustion, Mobile Sources, Truck [Refinery products]	*Amount of diesel combusted within the mobile source*
Equipment Assembly per kg Biomass	*Amount of farm equipment required for*

[Valuable substances]	*1 kg of biomass.*
N Fertilizers [Inorganic intermediate products]	*Nitrogen fertilizer used in biomass cultivation operations*
P Fertilizers [Inorganic intermediate products]	*Phosphorus fertilizer used in biomass cultivation operations.*
K Fertilizers [Inorganic intermediate products]	*Potassium fertilizer used in biomass cultivation operations*

Tracked Output Flows:

Biomass Operation [Installation]	*This unit process is assembled with the biomass harvesting operation unit process therefore the reference flow is assumed to be 1 kg biomass operation.*

Section II: Process Description

Associated Documentation

This unit process is comprised of this document, as well as the data sheet (DS) *DS_Stage1_O_CG_Cultivation_2011.03.xlsx*, which provides additional details regarding calculations, data quality, and references as relevant.

Goal and Scope

The scope of this unit process covers the operation of farming activities used for cultivation for corn grain biomass in life cycle (LC) Stage #1. This unit process is based on the reference flow of 1 kg of biomass. The cultivation activities are described below and shown in **Figure 1**. The mass of diesel to power seeding equipment, mass of fertilizer and herbicides, and related emissions are calculated based on the reference flow. Impacts considered include the mass consumption of diesel, consumption of nitrogen, phosphorus and potassium (NPK) fertilizer, consumption of herbicides, particulate matter emissions associated with fugitive dust, water input flows required for biomass cultivation, wastewater flows including stormwater and runoff water, and emissions of criteria air pollutants. The energy and material flows for the upstream production and delivery of diesel as well as LC emissions of diesel production and combustion are not included in the boundary of this process.

Boundary and Description

The LC boundary of this unit process starts with the seeding of biomass and ends with corn grain ready for harvest. Operations of farming activities used for cultivation for corn grain are based on 1 kg of biomass operation of cultivation activities. Diesel is consumed by the tractor as it pulls the disc tiller and the seeding equipment. The diesel consumption rate for equipment used in farming cultivation activities was calculated based on specifications of a 1953 rpm tractor consuming 10.26 gal/hour of diesel fuel and a disc tiller of 188 inches width (John 2009a, John 2009b), and assuming that the tractor operates at 5.8 miles per hour (mph), an average operating speed (Tillage 2009).

By multiplying the width of the disk tiller, which is assumed to 15.7 feet, by the operating speed of the tractor, the land coverage rate is estimated at 11 acres per hour. Multiplying this land coverage rate by the fuel consumption rate, the estimated diesel consumption is 0.93 gal/acre cultivated. This calculation assumes that the tractor makes two passes over the site and the total diesel consumption is 1.86 gal/acre.

Similarly, the tractor seeder consumes an average of 10.26 gallons per hour (John 2009a). The seeder width is 12.19 m (40 ft) wide (John 2009c). It is assumed that tractor operates at 5 miles per hour (mph), an average operating speed, in seeding operations. The width of seeder and speed of the tractor translate to a land coverage rate of 24.24 acres per hour. The tractor seeder makes single pass of the land site. Multiplying the land coverage rate by the fuel consumption rate, the estimated diesel consumption is 0.42 gal/acre-pass.

The combined diesel consumption of the tractor disk tiller and tractor seeder is the sum of 1.86 gal/acre and 0.42 gal/acre, which equals 2.28 gal/acre-year. The emissions for the required amount of diesel combusted for this process are accounted for in an upstream diesel combustion process. That process is pulled as an input to this process. The impacts associated with the manufacturing of the tractor, disk tiller, and seeder are accounted for in a separate unit process. This process scales the manufacturing processes based on the amount of biomass demanded.

Fugitive dust emissions are generated by the disturbance of surface soil during the use of farm equipment. Fugitive dust emissions from cultivation are estimated using an emission factor specified by Western Regional Air Program (WRAP) (Countess Environmental 2004), which conducted air sampling studies on ripping and sub-soiling practices used for breaking up soil compaction. The emission factor for fugitive dust is 1.2 lb PM10/acre-pass. The tractor makes two pass of the site and thus has a fugitive dust emission factor of 2.4 lbs PM10/acre. The total emissions of fugitive dust are 1.081 kg PM10/acre-year, assuming one replanting per year (0.000284 kg/kg biomass). The ratio of PM2.5 to PM10 utilized for this study is 0.15 kg PM2.5/kg PM10.

Fertilizer use quantifies the amounts of nitrogen, phosphorous, and potassium required, while herbicide use is quantified in support of weed control. The mass of fertilizer was calculated, but upstream emissions were not included in this unit process (RAND 2009). It is assumed that approximately 10 percent (by weight) of applied nitrogen fertilizer volatilizes. Of that volatized nitrogen fertilizer, it is further assumed that one percent reacts to form nitrous oxide (N_2O) and five percent forms ammonia (NH_3) and nitrogen oxides (NO_x). Of the 90 percent of nitrogen fertilizer that does not volatize, soil processes release 0.0125 tons of N_2O per ton of nitrogen. An estimated 30 percent of non-volatized nitrogen is assumed to leach or runoff, forming 0.025 tons of N_2O per ton of nitrogen in leachate or runoff (Ney *et al*. 2002).

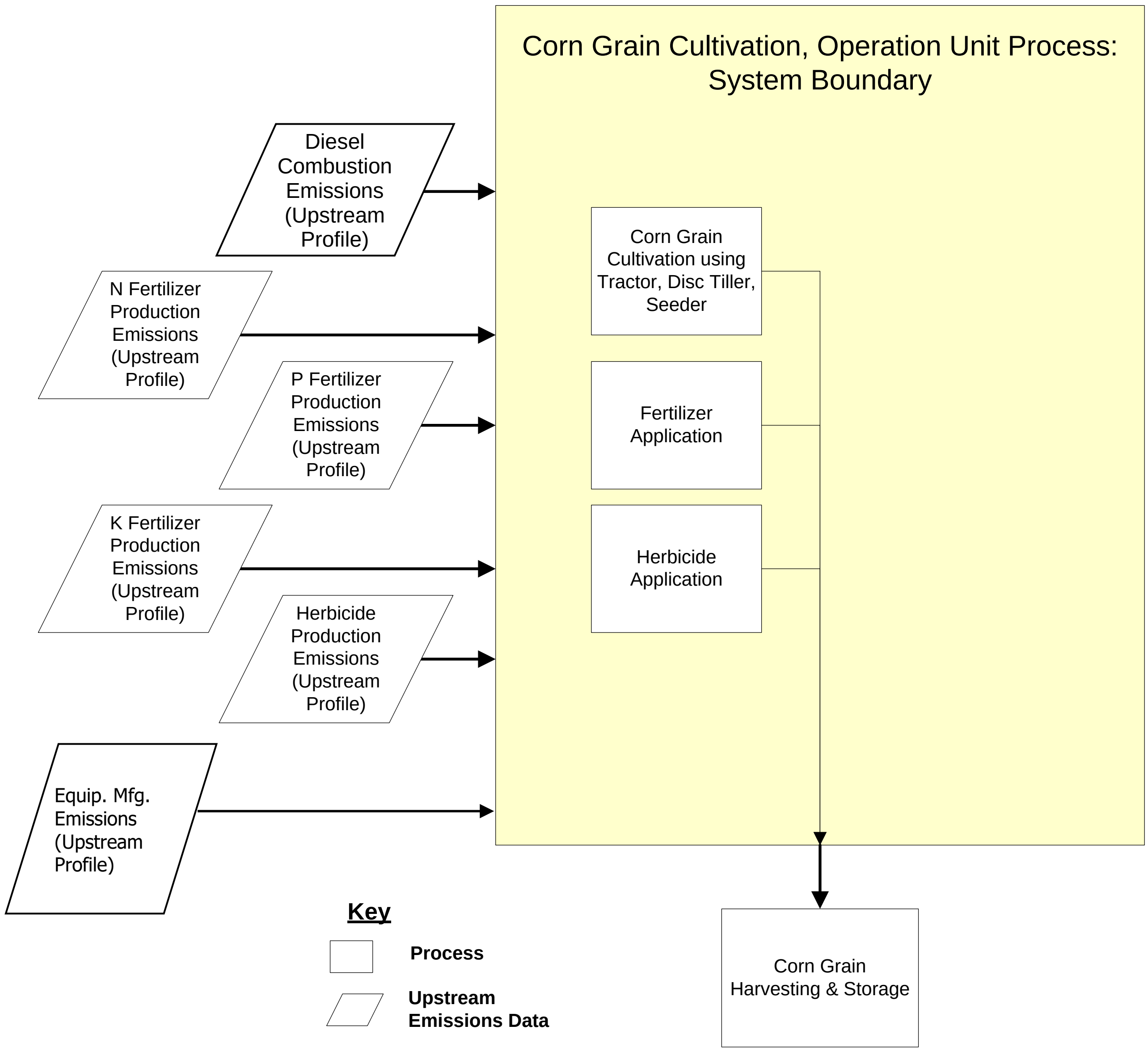
Biomass production for this study is assumed to occur in the Midwestern United States, a region where rain during the growing season contributes substantially to the water requirements of crops (DOC 2009). However, in many cases, supplemental irrigation water is also used to support increased yield and to relieve crop water stress during dry periods. As a result, quantifying water use and consumption for biomass crops grown in the Midwest is relatively complicated as compared to, for instance, biomass crops grown in the West, where growing season irrigation is the only significant source of water (SFP 2007). Water is applied as rainfall or as irrigation water from a combination of surface water and groundwater sources. Runoff water occurs as a result of excess rainfall, and agricultural pollutants, including nitrogen and phosphorous emissions, associated with stormwater runoff are quantified (USDA 2009).

Carbon dioxide (CO_2) uptake is quantified based on available carbon content data for corn stover, where CO_2 uptake is calculated stoichiometrically from the amount of carbon contained in the stover, assuming that all carbon was originally taken up as CO_2. The average carbon fraction of dry stover is assumed to be 46 percent, while the average carbon fraction of dry kernel is assumed to be 45 percent (DOE 2009, Wallace 1937). The low and high heating values of the kernel are assumed to be 6,643 and 6,970 Btu/lb, respectively (Pimentel *et al*. 2005, PSU 2009).

There is one major adjustable parameter in this unit process: the annual yield of corn grain. This adjustable parameter is designed to allow modeling flexibility, enabling the modeler to update the unit process to meet specific assumptions and study criteria, as relevant. Additionally, adjustable values may be updated as needed to incorporate newer or revised data sources. Corn grain yield per year indicates the annual yield of corn grain per acre and it is used to translate the values for diesel consumption and fugitive dust emissions from a basis of quantity per acre to a basis of quantity per kilogram of biomass production. NETL currently recommends a default value of 3,829 kg/acre-yr for this parameter based on a survey of national data from 2004 to 2009 (Iowa State 2009, USDA 2010).

Figure 1 shows the boundaries of this unit process, including a schematic of operations considered within the boundary of this unit process. The figure includes operations directly related to the growing of corn grain that account for fertilizer production, diesel production, water, and other agricultural inputs. Upstream processes may require energy or other ancillary substances, which are not shown here. Rectangular boxes represent relevant upstream processes, while trapezoidal boxes indicate upstream data that are outside of the boundary of this unit process. As shown, upstream emissions associated with the production and delivery of nitrogen, phosphorus and potassium (NPK) fertilizers and diesel fuel are accounted for outside of the boundary of this unit process.

Figure 1: Unit Process Scope and Boundary



Properties of corn grain biomass cultivation operation activities relevant to this unit process are illustrated in **Table 1**. **Table 2** provides a summary of modeled input and output flows. Additional details regarding input and output flows, including calculation methods, are contained in the associated DS sheet.

Table 1: Properties of Biomass Cultivation Operation Activities

Property	Value	Units
Corn grain yield	3829	kg/acre-year
HHV corn grain	6970	MJ/kg
HHV corn grain	14.6	Btu/lb
LHV corn grain	15.5	MJ/kg
LHV corn grain	6545	Btu/lb

Table 2: Unit Process Input and Output Flows

Flow Name*	Value	Units (Per Reference Flow)	DQI
Inputs			
Biomass Operation [Installation]	**1.00E+00**	**kg**	**2,3**
Diesel Combustion, Mobile Sources, Truck [Refinery products]	**1.91E-03**	**kg**	**2,2**
N Fertilizer [Inorganic intermediate products]	**1.96E-02**	**kg**	**2,2**
P Fertilizer [Inorganic intermediate products]	**3.03E-03**	**kg**	**2,2**
K Fertilizer [Inorganic intermediate products]	**6.77E-03**	**kg**	**2,2**
Herbicide Use (Atrazine) [Inorganic intermediate products]	**3.75E-04**	**kg**	**2,2**
Equipment Assembly per kg Biomass [Valuable substances]	**1.00E+00**	**Pieces**	**2,2**
Water (ground water) [Water]	1.33E+01	L	2,2
Water (surface water) [Water]	1.33E+01	L	2,2
Water (storm) [Water]	5.77E+02	L	2,2
Outputs			
Biomass Operation [Installation]	1.00E+00	kg	2,3
Nitrous oxide (laughing gas) [Inorganic emissions to air]	2.82E-04	kg	2,2
Ammonia [Inorganic emissions to air]	9.81E-04	kg	2,2
Nitrogen oxides [Inorganic emissions to air]	9.81E-04	kg	2,2
Carbon dioxide (biotic) [Inorganic emissions to air]	-1.49E+00	kg	1,1
Dust (PM10) [Particles to air]	2.84E-04	kg	2,3
Dust (PM2.5) [Particles to air]	4.26E-05	kg	2,3
Nitrogen [Inorganic emissions to fresh water]	6.71E-05	kg	1,2
Phosphorus [Inorganic emissions to fresh water]	2.50E-07	kg	1,2
Water (storm runoff) [Water]	1.84E+01	L	1,2

* **Bold face** clarifies the input is from the technosphere and *does not* include upstream environmental flows.

Inventory items not included are assumed to be zero based on best engineering judgment or assumed to be zero because no data was available to categorize them for this unit process at the time of its creation.

Embedded Unit Processes

None.

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Section III: Document Control Information

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Revision History:

13JUNE2012	Updated to revised parameter values.
24DECEMBER2014	Updated to reflect diesel combustion removal from process. Combustion is now an input. Added inventory item level DQI data to the data summary tab. Speciated PM emissions by size. Added NH_3 and NO_X emissions to air from N-fertilizer application.

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