LCA Digital Commons Unit Process Data: field operations/ work processes and farm implements

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Executive Summary

This document describes the preparation of datasets for the *LCA Commons* that represent unit process/ gate-to-gate operations for field operations (a.k.a. work processes e.g., soil preparation and planting for conventional tillage, applying fertilizer with incorporation) and farm implements (e.g., operation of moldboard plows, broadcast sprayers) used in the production of field crops. The data cover 49 types of field operations and 104 types of farm implements for 9 crops in 36 US states, resulting in the development of almost 19,000 unit process datasets. The field operation and farm implement datasets described herein fall between the field crop production and the aggregated fleet equipment datasets already in the Commons.

Field operation datasets represent the use of farm implements for soil preparation and planting (by crop and tillage type); nutrient, pesticide, and micro-compound applications, as well as harvest. Whereas the key information source used for the development of the field operation datasets representing soil preparation and planting is the Energy Estimator for Tillage, developed by the USDA Natural Resources Conservation Service (NRCS), the remaining field operation datasets (i.e., application and harvest operations) are based on a review of related literature and input from the peer reviewers. For the farm implement datasets, estimates of implement work, storage, construction, maintenance, and retirement are based on a review of crop budget and economic analysis tools and ASAE D497.7 from the American Society of Agricultural and Biological Engineers (ASABE).

As is the case for all the Commons datasets, the intended audiences are those interested in using the field crop data and those interested in building field crop production life cycle inventories. All data are coupled with meta data conforming to the submission guidelines for the Commons and details concerning raw data and calculations (the parameterization). Also, critical review of the datasets engaged one panel of subject area and LCA experts who met twice by teleconference during the preparation of the data.

1. Background

1.1. Project background, goal, intended audience, and critical review

Life Cycle Assessment (LCA) is an accounting and evaluation of the inputs, outputs, and potential environmental impacts of a product system throughout its life cycle. Standardized by the International Standards Organization (ISO 2006a and 2006b), LCA describes the life cycle as consecutive and interlinked stages of a product system extending from the acquisition of raw materials (e.g., agriculture, mining, residuals management) through materials processing, technology manufacturing/ construction, technology use/maintenance/upgrade, and the technology retirement.

In an LCA, data are collected at the *unit process* level, intended to represent a single industrial activity such as the activities on a farm or in a crude oil refinery. Each single industrial activity (a) produces product (e.g., cotton lint or diesel fuel) and sometimes co-products[1] (e.g., cotton seeds or naphtha); (b) uses resources from the environment (e.g., carbon dioxide (CO_2) from the air, crude oil from the ground); (c) uses resources from other unit processes in the *technosphere* (a.k.a. the industrial sector) (e.g., ammonium nitrate produced at a fertilizer production plant or electricity generated in a power plant); and (d) generates emissions to the environment (e.g., ammonia (NH_3) emissions from fertilizer application or fuel combustion emissions). In an LCA, the inventory analysis combines unit process data for the life cycle and the impact assessment estimates the impact associated with activities and flows to and from the environment for the inventory.

The unit process data described here have been developed for the *LCA Digital Commons*[2]. The *LCA Digital Commons* is an open access database and toolset built by the United States Department of Agriculture (USDA) National Agricultural Library in response to a national need for data representing US operations for use in LCAs. The *LCA Digital Commons* database will ultimately be seeded with unit process data representing a wide range of industrial production practices and developed by researchers throughout the US at all stages of the life cycle. The tool set, being developed using the open source OpenLCA code[3], will then allow unit process data to be combined into life cycle inventories so that life cycle environmental impacts to be estimated.

Given this, the goal of this work is to generate unit process datasets representing field operations and farm implements for the US field crop production data largely based on the USDA annual Agricultural Resource Management Survey[4] (ARMS) and already in the *LCA Digital Commons* and described in Cooper, Kahn, and Noon (2012). Field operations datasets essentially present the mix of drawn and self-propelled implements used for soil preparation and planting, nutrient and pesticide applications, and harvest. Subsequently, implement

[1] The product of interest is called the reference product and any additional valuable products are called co-products. It is in the mathematical treatment of co-products in an LCA that manifests *credits* in attributional LCA and many of the indirect market responses studied in consequential LCA.

[2] See http://riley.nal.usda.gov/nal_display/index.php?info_center=8&tax_level=1&tax_subject=757

[3] See http://www.openlca.org/index.html

[4] See http://www.ers.usda.gov/data-products/arms-farm-financial-and-crop-production-practices

datasets quantify the work to be performed by fleets of agricultural equipment (e.g., tractors and balers) and the storage, construction, maintenance, and retirement of the implement used.

As is the case for all the Commons datasets, the intended audiences are those interested in using the field crop data and those interested in building field crop production life cycle inventories. Also, critical review of the datasets engaged one panel of subject area and LCA experts by teleconference. The panel reviewed initial data estimation methods and preliminary results in June 2014 and final methods and results in September of 2014. The panel members are listed in Table 1.

Table 1. Critical review panel

Panelist	Organization
Marty Matlock, panel chair	Office for Sustainability, Center for Agricultural and Rural Sustainability, and Biological and Agricultural Engineering, University of Arkansas, Fayetteville, AR
Giulio Ferruzzi	USDA Natural Resources Conservation Service, Portland, OR
Alvin Womack	Biosystems Engineering and Soil Science, University of Tennessee, Knoxville, TN
William Lazarus	Department of Applied Economics, University of Minnesota, St. Paul, MN
C. Alan Rotz	USDA-Agricultural Research Service-Pasture Systems and Watershed Management Research Unit, University Park, PA
Greg Thoma	Chemical Engineering and the Applied Sustainability Center University of Arkansas, Fayetteville, AR

1.2.Scope and dataset naming convention

The datasets described in this document represent unit process/ gate-to-gate operations for field operations and farm implements. Each dataset includes:

- **A reference product,** as *1 hectare (ha)* representing the area over which crop production work is performed and
- **Flows from the technosphere (a.k.a. intermediate flows or industry flows),** which specify the specific types of activities occurring in the area defined by the reference flow.

Each field operation dataset identifies the mix of drawn and self-propelled implements used for soil preparation, planting, applications, and harvesting crops on 1 hectare (ha). The related farm implement datasets provide estimates of work by tractors and self-propelled implements and related implement storage, construction, maintenance, and retirement. Data representing the tractors and self-propelled implements link to the aggregated fleet datasets already in the Commons and described in Cooper et al. (2014). These datasets combine *self-propelled fleet datasets* (which divide work among the fuels, input power populations, and model years of equipment in a fleet) and *self-propelled equipment datasets* (which provide estimates of fuel and lubricant transport, use, and emissions and equipment storage, construction, maintenance, and retirement for the individual self-propelled equipment in a fleet). This means that the field operation and farm implement

datasets described herein are essentially the links between the field crop and the aggregated fleet datasets already in the Commons.

Each dataset is identified by a name that conforms to the Commons naming convention based on the four components listed in Table 2. Note that the crop name is included in each dataset name and "for growing" or "for harvesting" is included in the farm implement dataset name because this allows the operating temperatures to be identified for aggregated fleet datasets (already in the Commons) and used for the estimation of gasoline engine operating emissions. For example, whereas the aggregated fleet datasets for harvesting corn that use tractors in North Dakota operate at an average temperature of 4.5 ^{o}C (34 ^{o}F, during October and November), tractors in Georgia operate at an average temperature of 6.2 ^{o}C (76 ^{o}F, during August and September). More information concerning the specification of seasonal operating temperatures is provided in Cooper et al. (2014).

Table 2. Dataset naming convention

	Commons field description	**Field operation dataset example**	**Farm implement dataset example**
Base name	General descriptive name of the product produced.	soil preparation and planting	operation of Chisel plow (Chisel, st. pt.)
Treatment / standards / routes	Qualitative information about the product produced, specifically: treatment received, standard fulfilled, product quality, use information, production route name, educt name, primary / secondary etc.	for conventional till, corn	for growing corn
Location type	A description of the location type of availability.	at farm	at farm
Quantitative product or process properties	Quantitative information about the product produced.	<15% residue	155HP tractor, 20 ft wide
Resulting dataset name	The components of the name are combine, as separated by semicolons.	soil preparation and planting; for conventional till, corn; at farm; <15% residue	operation of Chisel plow (Chisel, st. pt.); for growing corn; at farm; 155HP tractor, 20 ft wide

Names preceded by the word "CUTOFF" are indicative of farm implement datasets that are not being submitted to the Commons at this time and do not already exist within the Commons (i.e., they are left for future work). Herein, datasets that are cutoff are listed in Table 3.

Table 3. Cutoff farm implement datasets

storage time; farm equipment; at farm	Additive tank, for micro-compound application system
production; <implement name>; at farm	Controls, for micro-compound application system
maintenance; <implement name>; at farm	operation of Pump, for micro-compound application system
equipment retirement; <implement name>; at farm	Anti-siphon device; for chemigation[5]
operation of Aerial seeding	Backflow device; for chemigation
operation of Graze, stubble or residue 50 pct	Pressure sensor; for chemigation
operation of Water mulch	operation of Injection pump; for chemigation, for corn
operation of Aerial application; by airplane	Interlock; for chemigation
operation of Aerial application; by helicopter	

Table 4 lists the types of field operations and farm implements considered herein: there are 49 types of field operations and 104 types of farm implement datasets covering soil preparation and planting (by crop and tillage type), nutrient and pesticide applications, and harvest. Each of the datasets listed in Table 4 are developed as applicable to 9 crops (corn, cotton, oats, peanuts, rice, soybeans, as well as durum, other spring, and winter wheat) produced in 36 US states, resulting in the development of almost 19,000 unit process datasets. Details such as what is included in datasets and how estimates are made follows.

Table 4. Field operation and farm implement datasets described in this document

Types of field operation datasets (each by crop and state)	**Types of farm implement datasets** (each by crop, for growing or harvest, and state)	
1. soil preparation and planting; for conventional till	1. Bed shaper	53. Drill or airseeder, offset double disk openers
2. soil preparation and planting; for mulch till	2. Bedder, hipper, disk hiller	54. Drill, air seeder, sweep or band opener
3. soil preparation and planting; for no till	3. Bedder, hipper, hiller 12 in high	55. Drill, deep furrow 12 to 18 in spacing
4. soil preparation and planting; for ridge till	4. Chisel, st. pt.	56. Drill, heavy, direct seed, dbl disk opnr
5. soil preparation and planting; for strip till	5. Chisel, st. pt. 12 in deep	57. Planter, double disk opener on 8 inch high beds
6. apply gypsum; using a spreader and tandem disks	6. Chisel, st. pt. 15 in deep	58. Planter, double disk opnr
7. apply gypsum; using a spreader and chisel plow	7. Chisel, st. pt. 5 in deep	59. Planter, double disk opnr w/fluted coulter
8. apply liming materials; using a spreader and tandem disks	8. Chisel, sweep shovel	60. Planter, in-row subsoiler
9. apply liming materials; using a spreader and chisel plow	9. Chisel, twisted shovel	61. Planter, in-row subsoiler low disturbance
10. apply pesticide; using foliar application equipment	10. Cultipacker, roller	62. Planter, in-row subsoiler w/ residue mgr.
11. apply pesticide; using directed spray application equipment	11. Cultivator, field 6-12 in shovels C	63. Planter, narrow slot w/smooth or rippled coulter
12. apply pesticide; using banded or side-dressed application equipment	12. Cultivator, field 6-12 in sweeps	64. Planter, ridge till
13. apply pesticide; using broadcast with incorporation application equipment	13. Cultivator, field w/ spike points	65. Planter, strip till
14. apply pesticide; using broadcast without incorporation application equipment	14. Cultivator, off bar w/disk hillers on beds	66. Planting, broadcast seeder
15. apply pesticide; using chiseled or injected/knifed in application equipment	15. Cultivator, rotary	67. Band sprayer
16. apply pesticide; using in seed furrow application equipment	16. Cultivator, row - 1st pass ridge till	68. Broadcast sprayer
17. apply pesticide; using in irrigation equipment	17. Cultivator, row - 2nd pass ridge till	69. Directed sprayer
18. apply pesticide; as broadcast by air	18. Cultivator, row 1 in ridge	70. Dry spreader
19. apply sewage sludge; using drawn broadcast spraying application equipment	19. Cultivator, row 3 in ridge	71. Spot sprayer
	20. Cultivator, row between beds	72. Boll buggy
	21. Disk, offset, heavy	73. Combine w/ corn head (operated with a cart)
	22. Disk, tandem heavy primary op.	74. Combine w/ corn head (operated without a cart)
	23. Disk, tandem light finishing	75. Combine w/ grain head
	24. Disk, tandem secondary op.	
	25. Do all	
	26. Do all, on beds	
	27. Furrow diker	

[5] Chemigation equipment were identified at http://www.ag.ndsu.edu/irrigation/chemigation

Types of field operation datasets (each by crop and state)	**Types of farm implement datasets** (each by crop, for growing or harvest, and state)	
20. apply sewage sludge; using self-propelled broadcast spraying application equipment	28. Furrow shaper, torpedo	76. Combine w/ grain head (operated with a cart)
21. apply micronutrients; using micronutrient systems on other application equipment	29. Harrow, coiled tine	77. Combine w/ grain head (operated without a cart)
22. apply fertilizer; using application and incorporation equipment	30. Harrow, heavy	78. Combine w/ pickup head (operated with a cart)
23. apply fertilizer; using application equipment without incorporation	31. Harrow, spike tooth	79. Combine w/ pickup head (operated without a cart)
24. apply fertilizer; using no broadcast application equipment	32. Harrow, tine, on beds	80. Combine w/ soybean head (operated with a cart)
25. harvest; using a drawn combine and grain cart	33. Land plane	81. Combine w/ soybean head (operated without a cart)
26. harvest; using a self-propelled combine and grain cart	34. Lister, 40 in	82. Corn grain cart
27. harvest; using a drawn combine	35. Para-plow or para-till	83. Cotton module builder
28. harvest; using a self-propelled combine	36. Plow, moldboard	84. Cotton picker
29. harvest; using a drawn forage harvester	37. Plow, moldboard 10 inch depth	85. Cotton picker/ module
30. harvest; using a self-propelled forage harvester	38. Rodweeder	86. Cotton stripper/ buggy
31. harvest; using a drawn picker	39. Roller, corrugated packer	87. Cotton stripper/ module
32. harvest; using a self-propelled picker	40. Roller, smooth	88. Forage harvester
33. harvest; using a picker/module builder	41. Rotary hoe	89. Header-Corn (operated with a cart)
34. harvest; using a stripper with a drawn module builder	42. Subsoiler	90. Header-Corn (operated without a cart)
35. harvest; using a stripper with a self-propelled module builder	43. Subsoiler bedder (ripper/hipper)	91. Header-Draper
36. harvest; using a drawn stripper/module builder	44. Sweep plow 20-40 in wide	92. Header-Rice (operated with a cart)
37. harvest; using a combine with a cart	45. Sweep plow wider than 40 in w/ mulch treader	93. Header-Rice (operated without a cart)
38. harvest; using a header with a cart	46. Sweep plow, wider than 40 in	94. Header-Soybean (operated with a cart)
39. harvest; using a draper header with a cart	47. Drill or air seeder single disk openers 7-10 in spac.	95. Header-Soybean (operated without a cart)
40. harvest; using a swather and combine with a cart	48. Drill or air seeder single disk openers, + fert. opnrs 7-10 in spac.	96. Header-Wheat-sorghum
41. harvest; using a swather and combine	49. Drill or air seeder, hoe/chisel openers 6-12 in spac.	97. Peanut Dig/Invertor
42. harvest; using a combine	50. Drill or airseeder, double disk	98. Peanut dump cart
43. harvest; using a digger/ inverter	51. Drill or airseeder, double disk opener, w/ fert openers	99. Peanut harvester
44. harvest; using a lifter	52. Drill or airseeder, double disk, w/ fluted coulters	100. Peanut lifter
45. harvest; using a rice header with a cart		101. Rice grain cart
46. harvest; using a rice header		102. Soybean grain cart
47. harvest; using a soybean header with a cart		103. Swather
48. harvest; using a soybean header		104. Wheat-sorghum grain cart
49. harvest; using a wheat header with a cart		

1.3. Meta data

The meta data are described in Appendix A: LCA Digital Commons meta data. Note that datasets are assigned International Standard Industrial Classification (ISIC) codes that also identify datasets in the Commons and select other databases (e.g., ISIC codes by ecoinvent). Also, the data are parameterized such that raw data and formulas used are included in the dataset as described by Cooper, Noon, and Kahn (2012).

1.4.Data variability and uncertainty

Uncertainty (referring to the degree of precision in quantities) and variability (referring to heterogeneity) are not modeled in the field operation or farm implement datasets but should be considered for future work.

1.5.Data quality

The 2-tiered data quality analysis method used by the Commons is described in Cooper and Kahn (Cooper and Kahn 2012) and presented in Table 5. The "2-tiers" define flow data as either meeting a minimum criteria

(receiving a score of A) or not (receiving a score of B). In each dataset, scores are listed presented parenthetically in the order presented in Table 5 (as e.g., (A,B,A,A,A,B,B) intended to represent a score of A for reliability and reproducibility, a score of B for flow data completeness, and so on. The data quality results are presented in Section 3.

Table 5. LCA Digital Commons flow data quality scoring criteria

Category	Requirements for a data quality score of A
1. Reliability and reproducibility	The **flow data** were based on measurements using a specified and standardized measurement method **OR** the **flow data** were estimated using methods and data described in specified archival or other consistently publically available sources.
2. Flow data completeness	The **flow data** were collected over at least 3 years for agricultural (crop, livestock, forest, range) processes or other processes in which the data point varies for uncontrolled annual conditions (e.g., weather) **AND** the **flow data** balance the mass and energy in and out of the unit process.
3. Temporal coverage	The **flow data** represent operations that occurred between the unit process start and end dates without forecasting.
4. Geographical coverage	The **flow data** represent operations that occurred within the location of the unit process, including non-agricultural process data that have been adapted to reflect logistics and market shares for the unit process location.
5.Technological coverage	The **flow data** represent the process(es) and/or material(s) specified without surrogacy or aggregation with other technologies.
6. Uncertainty	The **flow data** either include estimates of the first quartile, mean, median, and third quartile values **OR** data or probability distribution from which these values can be estimated.
7. Precision	The relative standard error of the **flow data** is less than or equal to 25% **OR** the interquartile range divided by the median is less than or equal to 50% **OR** for a triangular distribution, the minimum **flow data** value is ≥ 75% and maximum **flow data** value is ≤125% of the most likely value **OR** For a uniform distribution, the minimum **flow data** value is ≥ 75% and maximum **flow data** value is ≤125% of the average of the minimum and maximum values.

Field operation datasets essentially present the number of passes for the farm implements used for soil preparation and planting, nutrient and pesticide applications, and harvest.

2. Field operation dataset development

2.1. Soil preparation and planting

Farm implements for soil preparation and planting were identified by crop, tillage method, and Crop Management Zone (CMZ) from the *Energy Estimator for Tillage* (ecat), developed by agronomists at the USDA

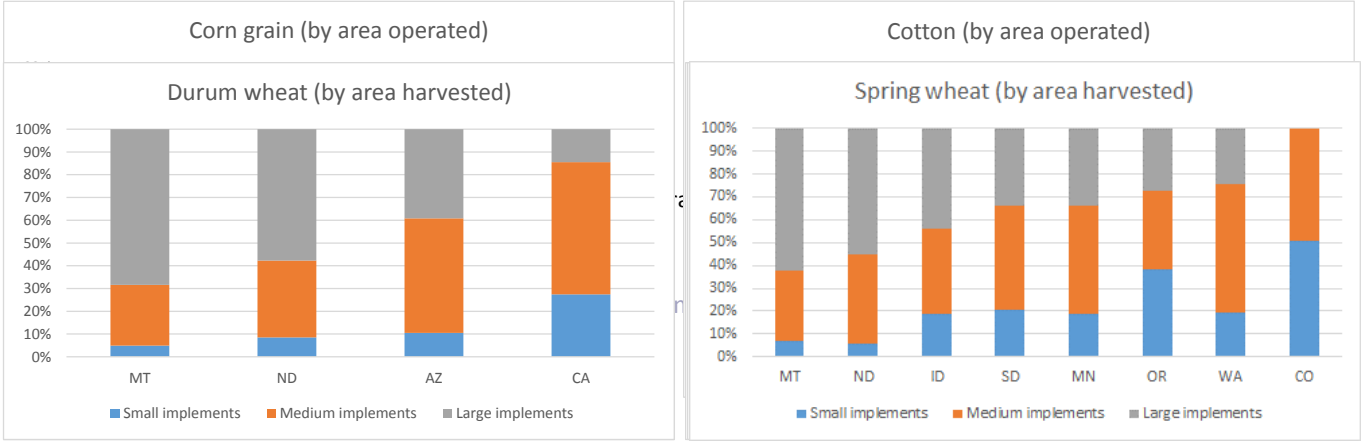
NRCS[6]. ecat is an on-line tool to estimate diesel fuel use and costs for typical implement sets in the production of key crops. The tool covers 78 CMZs and compares potential energy savings between conventional tillage and alternative tillage implement sets. Data contained within ecat were developed from the Land Management and Operations Database (LMOD). Future versions of the field operation datasets should use data directly from LMOD as it is in the process being developed for public access with the capability of directly accessing state data.

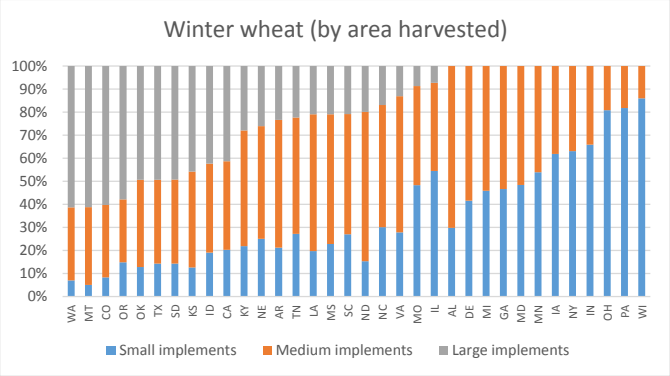
ecat covers the farm implements for 5 tillage systems: conventional, mulch, ridge, strip, and no till. Also, the tillage systems cover implements for 15 crop situations: corn, corn silage, cotton, ultra-narrow-row cotton, oats, peanuts, rice, soybeans, narrow-row soybeans, wide-row soybeans, soybean silage, spring wheat, spring wheat with fallow, winter wheat, and winter wheat with fallow as applicable.

For soil preparation and planting, the number of passes (or the times over the planted or harvested area) by a given implement was quantified in three steps. First, ecat lists tillage systems as applied over 1, 2, or 3 years. When a system is applied over 1, 2, or 3 years, the number of passes for an individual implement was assumed to be 1, 0.5, or 0.33 passes respectively in a given growing season. Second, some implements are listed in ecat multiple times for a single tillage system/crop situation/CMZ combination. In these cases, the number of passes for the individual implement (in step 1) were summed over the multiple listings of the implement. Third, the data were aggregated to the state level using the fraction area covered by each CMZ in each state. These fractions were estimated as a spatial join using the US states base map from the National Atlas[7] overlaid by the CMZ basemap in ArGIS. The area percentage is then estimated as the area of the CMZ laying within the state, divided by the total area of the relevant tillage system/ crop situation/CMZ combinations for the state.

Next, the number of passes are divided into the fractions of passes using small, medium, and large implements. Fractions were estimated on the basis of farm size as a surrogate for implement size using publically available Agricultural Census Data (representing 2012, the latest available). Specifically, the fraction of crop production was estimated for 0-259 acres, 260-999 acres, and 1,000 or more acres for the harvested area for durum, other spring, and winter wheat[8] and for the area of operation for all other crops. The resulting implement size fractions are depicted in Figure 1. The corn data were found to compare well with those described in Lazarus (2012).

Figure 1 Fractions of small, medium, and large farm





implement use by crop and state

2.2. Applications and harvest

Application field operation datasets cover fertilizer, pesticides, gypsum, liming materials, sewage sludge, and micro-compounds (nutrient inhibitors, sulfur, sulfuric acid, and zinc compounds) and harvest datasets cover harvest of the 9 field crops. Implement selection has been based on a review of related literature and input from the peer reviewers with the number of passes presented in Appendix B: Implement types for applications and harvest.

3. Farm implement dataset development

Implement datasets quantify the work to be performed by fleets of agricultural equipment (e.g., tractors and combines) and the storage, construction, maintenance, and retirement of the implement to be used.

3.1. Characterization of implements

The datasets representing field operations identify 61 categories of draw and self-propelled implements listed in Table 6 for which estimates of work, storage, construction, maintenance, and retirement requirements are needed for the farm implement datasets. Supporting data for these estimates were compiled from 10 crop budget or economic analysis tools or related documentation (Farmdoc (2014), Gay and Grisso (2009), Griffith (2002), Lazarus (2013), Eberly (2007), Murphy et al. (2010), Fletcher (2007), Lacy (2014), Texas A&M (2014), and Laughlin and Spurlock (2008)) and from ASAE D497.7 from the American Society of Agricultural and Biological Engineers (ASABE). Within each category, implements from the 10 references were listed with the data they contain including a drawn or self-propelled designation, the horsepower requirement, the implement width (ft),

the speed (mph), the field efficiency[9] (%), the number of rows (for implements preparing soil, planting, applying material, or harvesting crops in rows), the capacity (bushels, for carts), and the expected ownership period (years). In Table 6, an entry represents a specific implement within a category (e.g., a 15 foot wide chisel plow drawn by a 130 HP tractor at a speed of 5.5 mph and a field efficiency of 85% in the chisel plow category from Lazarus (2013)). Note that implement storage space data were taken from the range of values for similar equipment specified by Gay and Grisso (2009) as supplemented for the boll buggy[10] and the digger inverter[11]. Expected implement lifetime data were taken from the range of values for similar equipment specified by Griffith (2002) as largely based on the ASABE standard.

Table 6. Implement categories

Implement category	Drawn or SP	# of entries in the implement table	Implement category	Drawn or SP	# of entries in the implement table
Band sprayer	drawn	5	Header-Corn	drawn	6
Bedder	drawn	1	Header-Draper	drawn	6
Bed-Disk-Hipper	drawn	10	Header-Rice	drawn	10
Bed-Paratill	drawn	8	Header-Soybean	drawn	4
Boll Buggy	drawn	6	Header-Wheat-sorghum	drawn	3
Broadcast seeder	drawn	1	Land plane	drawn	1
Broadcast sprayer	drawn	24	Lister	drawn	2
Broadcast sprayer	self-propelled	11	Mintill row planter	drawn	59
Chisel plow	drawn	28	Moldboard plow	drawn	7
Chisel-Harrow	drawn	4	No-till drill	drawn	21
Combine w/ corn head	self-propelled	5	Offset or heavy disk	Drawn	13
Combine w/ grain head	self-propelled	3	Peanut Dig/Invertor	Drawn	3
Combine w/ pickup head	self-propelled	1	Peanut dump cart	Drawn	1
Combine w/ soybean head	self-propelled	3	Peanut harvester	Drawn	3
Corn grain cart	drawn	3	Peanut Lifter	Drawn	1
Cotton module builder	drawn	6	Rice grain cart	Drawn	3
Cotton module builder	self-propelled	7	Ridge cultivator	Drawn	4
Cotton picker	drawn	8	Rodweeder	Drawn	1
Cotton picker	self-propelled	21	Roller/Stubble	Drawn	2
Cotton picker/ module	self-propelled	8	Rotary hoe	Drawn	5
Cotton stripper/ buggy	drawn	10	Row cultivator	Drawn	29
Cotton stripper/ module	drawn	9	Row planter	Drawn	65
Cultipacker	drawn	7	Soybean grain cart	Drawn	3
Directed sprayer	drawn	5	Spot sprayer	Drawn	5
Do all	drawn	4	Strip till planter	Drawn	4
Dry spreader	drawn	6	Subsoiler	Drawn	14
Field cultivator	drawn	28	Swather	self-propelled	1
Forage harvester	drawn	1	Sweep plow	Drawn	2

[9] Field efficiency is the ratio between the productivity under field conditions and the theoretical maximum productivity. For example, it accounts for failures to use the full operating width, operator time losses, and field characteristics.

[10] Boll buggy storage space is estimated as 115% dimensions from http://www.crustbuster.com/boll-buggys and http://www.crustbuster.com/boll-buggy-super-20

[11] Peanut digger inverter storage space is estimated as Digger inverter 115% of the dimensions at from http://www.fergusonmfgco.com/peanut_digger.htm

Implement category	Drawn or SP	# of entries in the implement table	Implement category	Drawn or SP	# of entries in the implement table
Grain drill	drawn	32	Tandem disk	Drawn	12
Harrow	drawn	7	Wheat-sorghum grain cart	Drawn	3
Harvester w/ pickup head	self-propelled	2			

Given the tabulated data and starting with the horsepower requirement, within each implement category the closest horsepower lower than the 1st quartile, the closest horsepower lower than the median, and the closest horsepower lower than the 3rd quartile for all the entries in the category were identified for the small, medium, and large implements respectively. For tillage or seeding implements identified as "major" in ASAE D497.7, the horsepower requirements were adjusted using the average operation depths presented in RUSLE2 (see USDA Agricultural Research Service (2013) and ftp://ftp-fc.sc.egov.usda.gov/ID/technical/rusle/operations_1-9-06.xls and note that the RUSLE2 implements map to the ecat implements). For the adjustment, the horsepower is multiplied by the ratio of category median RUSLE2 depth to the depth for each specific implement, mimicking the adjustment in the typical draft requirement relationship presented in ASAE D497.7 (section 4.1.1). Finally, all results are rounded to the nearest 5 horsepower.

Also within each implement category, the closest implement operating width, number of rows, or cart capacity lower than the median for each of the 3 horsepower values (for the small, medium, and large implements) versions of each implement) is used. The spacing between rows is taken as crop specific: a row spacing of 8 inches is used for oats, rice, wheat, and ultra-narrow-row (UNR) cotton; 30 inches for corn and wide-row soybeans; 15 inches for other soybeans; and 38 inches for peanuts and other cotton.

Finally, median speed and field efficiency data are similarly identified with one exception for combines used without carts. It is assumed here that the field efficiency of combines used without carts are associated with a 10% increase in the field efficiency (adapted from the data presented in Table 6 of Schnitkey and Lattz (2008)).

The resulting implement characterization is presented in Appendix C: Supporting data for the farm implement dataset parameterization. Over 350 types of implements are covered in the appendix, with data presented for the identification of the power unit (T = tractor, SP= self-propelled); the identification of any implement or add on; the lifetime of the implement or add on (hours); the expected ownership period (years); the width, row, or capacity data; the depth adjusted horsepower, the implement speed (mph), the field efficiency (%), and the applicability to small, medium, and large implements.

3.2. Work estimates

Given the implement characterization, estimation of the implement work to be performed using a tractor or by a self-propelled implement is based on the following equations and the data in Appendix C: Supporting data for the farm implement dataset parameterization. Starting with the hours each implement takes to complete 1 pass over 1 acre, Zoz and Grisso (2003) and Grisso et al. (2007) assume:

$$hours/acre = \frac{8.25}{(sW_{imp})\frac{f_e}{100}} \quad \text{<equation 1>}$$

where:

8.25 = factor to convert units of measure

s = speed (mph)

w_{imp} = the implement width (ft)

f_e = the field efficiency

Carts (e.g., grain carts used with combines) are an exception to the use of equation 1. For carts, the hours per acre were taken from Laughlin and Spurlock (2008). Other than for the carts, the implement width is either specified for the implement in the supporting data (e.g., a 40 ft wide bed shaper) or is a function of the number of planted rows and the row widths:

$$\text{For row implements, } w_{imp} = \frac{(row_{num})(row_{space})}{12} \quad \text{<equation 2>}$$

where:

row_{num}= the number of rows the implement prepares or treats

row_{space}= the spacing between rows (inches)

12 = conversion factor from inches to feet

Given the hours per acre estimated using equations 1 and 2, the hours each implement takes to complete 1 pass over 1 hectare is estimated as:

$$hours/hectare = 2.471054(hours/acre) \quad \text{<equation 3>}$$

where:

2.471054 = conversion factor (acres/ha)

Finally, the work required for the implement to complete 1 pass over 1 hectare is estimated as:

$$MJ/hectare = \frac{(HP_{depth\ adjusted})(\text{hours/hectare})(3600)}{1341} \quad \text{<equation 4>}$$

where:

$HP_{depth\ adjusted}$ = depth adjusted horsepower (HP)

3600/1341 = conversion factor (MJ/HP-hr)

Supporting data for these relationships are presented in Appendix C: Supporting data for the farm implement dataset parameterization.

For each implement, the depth adjusted horsepower is used to identify the appropriate aggregated tractor fleet or self-propelled equipment fleet dataset (e.g., combines or swathers) already in the Commons as described in Cooper et al. (2014). These fleet datasets divide work among the fuels and model years of the fleet and link to equipment datasets which provide estimates of fuel and lubricant transport, use, and emissions and equipment storage, construction, maintenance requirements, and retirement for the fleet. **It is very important to note that**

all aggregated fleet datasets are specified for a 2014 operating year irrespective of the field crop production year specified for the crop production datasets already in the Commons. This is because both the Commons and current LCA software are unable to manage the very large numbers of datasets that would result from maintaining all field operation, implement, and aggregated fleet datasets at all crop production operating years (from 1996-2009). Thus, these data are likely not appropriate for use in studies comparing operations over time.

3.3. Implement storage, construction, maintenance, and retirement

For the farm implement datasets, estimation of the storage, construction, maintenance, and retirement requirements for implements used with tractors or heads added to combines is based on the following equations using the hours/ hectare estimated using equation 3 and the data in Appendix C: Supporting data for the farm implement dataset parameterization. First, the fraction of the implement life used in 1 pass over 1 hectare is estimated as:

$$life\ fraction = \frac{hours/hectare}{life\ hours} \quad \text{<equation 5>}$$

where:

life hours = implement life (hours)

This estimate is used to represent production, maintenance, and retirement of the implement or add-on and are accounted using the unit of measure "item(s)." All of these datasets are cutoff (as noted in Table 3) meaning that the datasets ultimately developed to quantify production, maintenance, and retirement energy and materials should cover the entire life of the implement or add-on. Also, note that any lubricating oils used to maintain implements need to be accounted within the maintenance datasets.

Next, the hours the implement is owned is estimated as:

$$hours\ owned = (365.25)(24)(years\ owned) \quad \text{<equation 6>}$$

where:

365.25 = days per year

24 = hour per day

years owned = implement ownership period (years)

Given this, the hours the implement is stored is estimated as the ownership hours less the life hours is estimated as:

$$hours\ stored = hours\ owned - life\ hours \quad \text{<equation 7>}$$

such that the hours the implement is stored per the hours used can be estimated as:

$$hours\ stored/hours\ used = \frac{hours\ stored}{life\ hours} \quad \text{<equation 8>}$$

Finally, the hours stored for 1 pass over 1 hectare is estimated as:

$$storage\ hours/hectare = (hours\ stored/hours\ used)(hours/hectare) \quad \text{<equation 9>}$$

4. Data quality results

At the dataset level, both the field operation and farm implement datasets are complete. At the flow level, the data quality results are presented in Table 7 and Table 8.

Table 7. Field operation dataset flow data quality scores

Category	USDA LCADC data quality= (A, B, A, A, A, B, B)
1. Reliability and reproducibility	A: The flow data were estimated using methods and data described in specified archival or other consistently publically available sources.
2. Flow data completeness	B: For all soil preparation and planting field operations, ecat does not provide documentation indicating the number of years over which implement data were collected. It is only noted that the data were "developed by agronomists at the USDA NRCS." For the applications and harvest datasets, implement selection has been based on a review of related literature and input from the peer reviewers and has not been validated for multi-year applicability.
3. Temporal coverage	A: The flow data represent operations that occurred between the unit process start and end dates without forecasting (all data are assumed to represent operation in 2014).
4. Geographical coverage	A: The flow data represent operations that occurred within the location of the unit process. For the soil preparation and planting field operations specifically, this is true assuming that the CMZ data can be aggregated to the state level.
5.Technological coverage	A: The flow data represent the processes specified without surrogacy or aggregation with other technologies.
6. Uncertainty	B: Uncertainty data are not included in the datasets.
7. Precision	B: Precision data are not included in the datasets.

Table 8. Farm implement dataset flow data quality scores

Category	USDA LCADC data quality= (A, B, A, A, A, B, B)
1. Reliability and reproducibility	A: The flow data were estimated using methods and data described in specified archival or other consistently publically available sources.
2. Flow data completeness	B: It is assumed that without variation in the speed and field efficiency, the data do not represent data collected over at least 3 years to capture uncontrolled annual conditions (e.g., weather).
3. Temporal coverage	A: The flow data represent operations that occurred between the unit process start and end dates without forecasting (all data are assumed to represent operation in 2014).
4. Geographical coverage	A: The flow data represent operations that occurred within the location of the unit process.
5.Technological coverage	A: The flow data represent the processes specified without surrogacy or aggregation with other technologies.
6. Uncertainty	B: Uncertainty data are not included in the datasets.
7. Precision	B: Precision data are not included in the datasets.

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Appendix A: LCA Digital Commons meta data conventions

	Meta data field	**Data Type**	**LCA Digital Commons Convention**
General Information	Base name	text	General descriptive name of the product produced.
	Treatment / standards / routes	text	Qualitative information about the product produced, specifically: treatment received, standard fulfilled, product quality, use information, production route name, educt name, primary / secondary etc. Separate each treatment, standard, or route by commas.
	Location type	text	A description of the location type of availability (LCADC). Include only the location types of availability if the process is not a mix.
	Mix type	text	Information on whether the process is a production mix or consumption mix, if applicable.
	Quantitative product or process properties	text	Quantitative information on the reference flow if applicable: constituent contents, energy-content per unit, etc.
	Description	text	A description of the process, its technical scope (e.g. gate-to-gate or cradle-to-grave), and any aggregation. Describe the technology that was used, its operating conditions, and the process's general temporal and geographic representativeness.
Categorization	Category - level 0	text	The class name corresponding to the top level ISIC code(the first name in the hierarchy, noted with a single letter) in the following format: "Class name"
	Category - level 1	text	The 4-digit ISIC code and its corresponding class name (the final name in the hierarchy) in the following format: "ISIC XXXX: Class name"
	ISIC 4 digit code	text	The 4-digit ISIC code
Quantitative reference	Quantitative reference	text	The name of the quantitative reference flow.
Time	Start date	mm/dd/yyyy	Start date for the time period that the data represent.
	End date	mm/dd/yyyy	End date for the time period that the data represent
	Time Comment	text	Description of the data's temporal characteristics, including the time period they refer to and for which they are valid, and any temporal aggregation and incongruence of supporting data.
Geography	Location	text	ISO 3166-2 code indicating the dataset's geographic location (US state).
	Geography Comment	text	Description of the dataset's geographic representativeness and any geographic aggregation methods.
Technology	Technology Comment	text	A short, general description of the process's technical scope. This description should inform users of the data's technical relevance. Includes a list of processes/ activities (anthropogenic or natural) included in the dataset, including a description of any fate and transport modeling.
Administrative information	Intended application	text	A description of the intended application for the data including the larger context within which the data were developed and the objectives of the research. The intended application may differ due to project scope or system boundaries, data aggregation methods, and/or data gaps.
	Data set owner	text	The name of the person or entity that owns this dataset. The dataset owner is not necessarily the copyright holder, if the dataset is copyrighted.
	Data generator	text	The name of the person or entity responsible for generating the dataset
	Data documentor	text	The name of the individual or entity that documented the dataset. Documentation activities include entering information into an LCA modeling program or database.
	Publication	text	Reference to an APA (American Psychological Association) formatted citation of a foundational publication that illustrates how the data were used.
	Access and use restrictions	text	A clear statement about how the data and metadata may be used.
	Project	text	Information about the project in which the data were generated.
	Version	xx.xx.xxx	The dataset version number. The first two digits refer to major updates, the second two digits refer to minor revisions and error corrections, and the final three digits are used for automatic and internal version counting during dataset development. (ILCD)
	Copyright	true/false	A flag indicating whether or not the dataset is copyrighted.
Modeling and Validation	Process type	text	Indication of whether the data represent a unit or system process, where a system process is an LCI result.
	Modeling constants	text	The primary assumptions used to create this unit process

	Meta data field	**Data Type**	**LCA Digital Commons Convention**
	Data completeness	text	A description of (1) Treatment of missing intermediate flow data, (2) Treatment of missing data to or from the environment, and (3) Mass balance.
	Mass balance	text	Either (1) Quantifies and describes the mass imbalance or (2) Describes the mass balance as unknown.
	Data treatment	text	Detailed description of the methods and assumptions used to transform primary and secondary data into flow quantities through recalculating, reformatting, aggregation, or proxy data. Also includes a description of the data quality according to LCADC convention.
Data source information	Sampling procedure	text	Detailed description of how boundary conditions were defined, how data were collected, and how uncertainty is estimated.
	Data collection period	text	Time period in which the data were collected.
Process evaluation and validation	Reviewer	text	Name of the individual or entity who reviewed the dataset.
	Data set other evaluation	text	Name of the individual or entity who reviewed the dataset.
Sources	Sources	text	The primary and secondary resources used to compile the data.

Appendix B: Implement types for applications and harvest

Values in the table represent the number of passes noting that carts and the cotton buggy are ultimately sized on a per pass basis. Not listed is "apply pesticide; as broadcast by air, all crops" at 0.9375 and 0.0625 for "Aerial application, by airplane (self-propelled)" and "Aerial application, by helicopter (self-propelled)" respectively.

	Chisel, st. pt. (drawn)	Disk, tandem heavy primary op. (drawn)	Disk, tandem secondary op. (drawn)	Furrow diker (drawn)	Dry spreader (drawn)	Broadcast sprayer (drawn)	Broadcast sprayer (self-propelled)	Spot sprayer (drawn)	Directed sprayer (drawn)	Band sprayer (drawn)	Additive tank, for micro-compound application system	Controls, for micro-compound application system	Pump, for micro-compound application system	Anti-siphon device; for chemigation	Backflow device; for chemigation	Pressure sensor; for chemigation	Injection pump; for chemigation, for corn	Interlock; for chemigation	Combine w/ corn head (self-propelled)	Corn grain cart (drawn)	Header-Corn (drawn)	Forage harvester (drawn)	Forage harvester (self-propelled)	Cotton picker (drawn)	Boll buggy (drawn)	Cotton module builder (drawn)	Cotton picker (self-propelled)	Cotton module builder (self-propelled)	Cotton picker/ module (self-propelled)	Cotton stripper/ buggy (drawn)	Cotton stripper/ module (drawn)	Swather (self-propelled)	Combine w/ pickup head (self-propelled)	Rice grain cart (drawn)	Combine w/ grain head (self-propelled)	Peanut Dig/Invertor (drawn)	Peanut harvester (drawn)	Peanut dump cart (drawn)	Peanut lifter (drawn)	Header-Rice (drawn)	Combine w/ soybean head (self-propelled)	Soybean grain cart (drawn)	Header-Soybean (drawn)	Wheat-sorghum grain cart (drawn)	Header-Wheat-sorghum (drawn)	Header-Draper (drawn)
apply gypsum; using a spreader and tandem disks, all crops		1	1		1																																								
apply gypsum; using a spreader and chisel plow, all crops	1				1																																								
apply liming materials; using a spreader and tandem disks, all crops		1	1		1																																								
apply liming materials; using a spreader and chisel plow, all crops	1				1																																								
apply pesticide; using foliar application equipment, all crops								1																																						
apply pesticide; using directed spray application equipment, all crops									1																																					
apply pesticide; using banded or side-dressed application equipment, all crops										1																																			
apply pesticide; using broadcast with incorporation application equipment, all crops	1					1																																							
apply pesticide; using broadcast without incorporation application						1																																							

	Chisel, st. pt. (drawn)	Disk, tandem heavy primary op. (drawn)	Disk, tandem secondary op. (drawn)	Furrow diker (drawn)	Dry spreader (drawn)	Broadcast sprayer (drawn)	Broadcast sprayer (self-propelled)	Spot sprayer (drawn)	Directed sprayer (drawn)	Band sprayer (drawn)	Additive tank, for micro-compound application system	Controls, for micro-compound application system	Pump, for micro-compound application system	Anti-siphon device; for chemigation	Backflow device; for chemigation	Pressure sensor; for chemigation	Injection pump; for chemigation, for corn	Interlock; for chemigation	Combine w/ corn head (self-propelled)	Corn grain cart (drawn)	Header-Corn (drawn)	Forage harvester (drawn)	Forage harvester (self-propelled)	Cotton picker (drawn)	Boll buggy (drawn)	Cotton module builder (drawn)	Cotton picker (self-propelled)	Cotton module builder (self-propelled)	Cotton picker/ module (self-propelled)	Cotton stripper/ buggy (drawn)	Cotton stripper/ module (drawn)	Swather (self-propelled)	Combine w/ pickup head (self-propelled)	Rice grain cart (drawn)	Combine w/ grain head (self-propelled)	Peanut Dig/Invertor (drawn)	Peanut harvester (drawn)	Peanut dump cart (drawn)	Peanut lifter (drawn)	Header-Rice (drawn)	Combine w/ soybean head (self-propelled)	Soybean grain cart (drawn)	Header-Soybean (drawn)	Wheat-sorghum grain cart (drawn)	Header-Wheat-sorghum (drawn)	Header-Draper (drawn)
equipment, all crops																																													
apply pesticide; using chiseled or injected/knifed in application equipment, all crops	1					1																																							
apply pesticide; using in seed furrow application equipment, all crops				1						1																																			
apply pesticide; using in irrigation equipment, all crops														1	1	1	1	1																											
apply pesticide; as broadcast by air, all crops																																													
apply sewage sludge; using drawn broadcast spraying application equipment, all crops	1					1																																						
apply sewage sludge; using self-propelled broadcast spraying application equipment, all crops	1						1																																						
apply micronutrients; using micronutrient systems on other application equipment, all crops											1	1	1																															
apply fertilizer; using application and incorporation equipment, all crops	1					1																																						
apply fertilizer; using application equipment without incorporation, all crops						1																																						

	Chisel, st. pt. (drawn)	Disk, tandem heavy primary op. (drawn)	Disk, tandem secondary op. (drawn)	Furrow diker (drawn)	Dry spreader (drawn)	Broadcast sprayer (drawn)	Broadcast sprayer (self-propelled)	Spot sprayer (drawn)	Directed sprayer (drawn)	Band sprayer (drawn)	Additive tank, for micro-compound application system	Controls, for micro-compound application system	Pump, for micro-compound application system	Anti-siphon device; for chemigation	Backflow device; for chemigation	Pressure sensor; for chemigation	Injection pump; for chemigation, for corn	Interlock; for chemigation	Combine w/ corn head (self-propelled)	Corn grain cart (drawn)	Header-Corn (drawn)	Forage harvester (drawn)	Forage harvester (self-propelled)	Cotton picker (drawn)	Boll buggy (drawn)	Cotton module builder (drawn)	Cotton picker (self-propelled)	Cotton module builder (self-propelled)	Cotton picker/ module (self-propelled)	Cotton stripper/ buggy (drawn)	Cotton stripper/ module (drawn)	Swather (self-propelled)	Combine w/ pickup head (self-propelled)	Rice grain cart (drawn)	Combine w/ grain head (self-propelled)	Peanut Dig/Invertor (drawn)	Peanut harvester (drawn)	Peanut dump cart (drawn)	Peanut lifter (drawn)	Header-Rice (drawn)	Combine w/ soybean head (self-propelled)	Soybean grain cart (drawn)	Header-Soybean (drawn)	Wheat-sorghum grain cart (drawn)	Header-Wheat-sorghum (drawn)	Header-Draper (drawn)
apply fertilizer; using no broadcast application equipment, all crops										1																																		
harvest; using a drawn combine and grain cart, for corn																				1	1																								
harvest; using a self-propelled combine and grain cart, for corn																			1	1																								
harvest; using a drawn combine, for corn																					1																								
harvest; using a self-propelled combine, for corn																			1																										
harvest; using a drawn forage harvester, for corn																						1																							
harvest; using a self-propelled forage harvester, for corn																							1																						
harvest; using a drawn picker, for cotton																								1	1	1																			
harvest; using a self-propelled picker, for cotton																									1		1	1																
harvest; using a picker/module builder, for cotton																													1															
harvest; using a stripper with a drawn module builder, for cotton																										1				1														
harvest; using a stripper with a self-propelled module builder, for cotton																											1			1														

	Chisel, st. pt. (drawn)	Disk, tandem heavy primary op. (drawn)	Disk, tandem secondary op. (drawn)	Furrow diker (drawn)	Dry spreader (drawn)	Broadcast sprayer (drawn)	Broadcast sprayer (self-propelled)	Spot sprayer (drawn)	Directed sprayer (drawn)	Band sprayer (drawn)	Additive tank, for micro-compound application system	Controls, for micro-compound application system	Pump, for micro-compound application system	Anti-siphon device; for chemigation	Backflow device; for chemigation	Pressure sensor; for chemigation	Injection pump; for chemigation, for corn	Interlock; for chemigation	Combine w/ corn head (self-propelled)	Corn grain cart (drawn)	Header-Corn (drawn)	Forage harvester (drawn)	Forage harvester (self-propelled)	Cotton picker (drawn)	Boll buggy (drawn)	Cotton module builder (drawn)	Cotton picker (self-propelled)	Cotton module builder (self-propelled)	Cotton picker/ module (self-propelled)	Cotton stripper/ buggy (drawn)	Cotton stripper/ module (drawn)	Swather (self-propelled)	Combine w/ pickup head (self-propelled)	Rice grain cart (drawn)	Combine w/ grain head (self-propelled)	Peanut Dig/Invertor (drawn)	Peanut harvester (drawn)	Peanut dump cart (drawn)	Peanut lifter (drawn)	Header-Rice (drawn)	Combine w/ soybean head (self-propelled)	Soybean grain cart (drawn)	Header-Soybean (drawn)	Wheat-sorghum grain cart (drawn)	Header-Wheat-sorghum (drawn)	Header-Draper (drawn)
harvest; using a drawn stripper/module builder, for cotton																														1															
harvest; using a combine with a cart, for durum wheat																																		1									1		
harvest; using a header with a cart, for durum wheat																																											1	1	
harvest; using a draper header with a cart, for durum wheat																																											1		1
harvest; using a swather and combine with a cart, for oats																															1	1	1											
harvest; using a combine with a cart, for oats																																	1	1										
harvest; using a swather and combine, for oats																															1	1												
harvest; using a combine, for oats																																		1										
harvest; using a digger/ inverter, for peanuts																																			1	1	1							
harvest; using a lifter, for peanuts																																				1	1	1						
harvest; using a combine with a cart, for rice																																	1	1										
harvest; using a rice header with a cart, for rice																																	1								1			
harvest; using a combine, for rice																																		1										
harvest; using a rice header, for rice																																									1			

	Chisel, st. pt. (drawn)	Disk, tandem heavy primary op. (drawn)	Disk, tandem secondary op. (drawn)	Furrow diker (drawn)	Dry spreader (drawn)	Broadcast sprayer (drawn)	Broadcast sprayer (self-propelled)	Spot sprayer (drawn)	Directed sprayer (drawn)	Band sprayer (drawn)	Additive tank, for micro-compound application system	Controls, for micro-compound application system	Pump, for micro-compound application system	Anti-siphon device; for chemigation	Backflow device; for chemigation	Pressure sensor; for chemigation	Injection pump; for chemigation, for corn	Interlock; for chemigation	Combine w/ corn head (self-propelled)	Corn grain cart (drawn)	Header-Corn (drawn)	Forage harvester (drawn)	Forage harvester (self-propelled)	Cotton picker (drawn)	Boll buggy (drawn)	Cotton module builder (drawn)	Cotton picker (self-propelled)	Cotton module builder (self-propelled)	Cotton picker/ module (self-propelled)	Cotton stripper/ buggy (drawn)	Cotton stripper/ module (drawn)	Swather (self-propelled)	Combine w/ pickup head (self-propelled)	Rice grain cart (drawn)	Combine w/ grain head (self-propelled)	Peanut Dig/Invertor (drawn)	Peanut harvester (drawn)	Peanut dump cart (drawn)	Peanut lifter (drawn)	Header-Rice (drawn)	Combine w/ soybean head (self-propelled)	Soybean grain cart (drawn)	Header-Soybean (drawn)	Wheat-sorghum grain cart (drawn)	Header-Wheat-sorghum (drawn)	Header-Draper (drawn)
harvest; using a combine with a cart, for soybeans																																							1	1				
harvest; using a soybean header with a cart, for soybeans																																								1	1				
harvest; using a combine, for soybeans																																								1					
harvest; using a soybean header, for soybeans																																										1			
harvest; using a combine with a cart, for spring wheat																																			1								1		
harvest; using a wheat header with a cart, for spring wheat																																											1	1	
harvest; using a draper header with a cart, for spring wheat																																											1		1
harvest; using a combine with a cart, for winter wheat																																			1								1		
harvest; using a wheat header with a cart, for winter wheat																																											1	1	
harvest; using a draper header with a cart, for winter wheat																																											1		1
harvest; using a drawn forage harvester, for corn																						1																								
harvest; using a drawn forage harvester, for cotton																						1																								
harvest; using a drawn forage harvester, for durum wheat																						1																								
harvest; using a drawn forage harvester, for oats																						1																								

	Chisel, st. pt. (drawn)	Disk, tandem heavy primary op. (drawn)	Disk, tandem secondary op. (drawn)	Furrow diker (drawn)	Dry spreader (drawn)	Broadcast sprayer (drawn)	Broadcast sprayer (self-propelled)	Spot sprayer (drawn)	Directed sprayer (drawn)	Band sprayer (drawn)	Additive tank, for micro-compound application system	Controls, for micro-compound application system	Pump, for micro-compound application system	Anti-siphon device; for chemigation	Backflow device; for chemigation	Pressure sensor; for chemigation	Injection pump; for chemigation, for corn	Interlock; for chemigation	Combine w/ corn head (self-propelled)	Corn grain cart (drawn)	Header-Corn (drawn)	Forage harvester (drawn)	Forage harvester (self-propelled)	Cotton picker (drawn)	Boll buggy (drawn)	Cotton module builder (drawn)	Cotton picker (self-propelled)	Cotton module builder (self-propelled)	Cotton picker/ module (self-propelled)	Cotton stripper/ buggy (drawn)	Cotton stripper/ module (drawn)	Swather (self-propelled)	Combine w/ pickup head (self-propelled)	Rice grain cart (drawn)	Combine w/ grain head (self-propelled)	Peanut Dig/Invertor (drawn)	Peanut harvester (drawn)	Peanut dump cart (drawn)	Peanut lifter (drawn)	Header-Rice (drawn)	Combine w/ soybean head (self-propelled)	Soybean grain cart (drawn)	Header-Soybean (drawn)	Wheat-sorghum grain cart (drawn)	Header-Wheat-sorghum (drawn)	Header-Draper (drawn)
harvest; using a drawn forage harvester, for peanuts																						1																						
harvest; using a drawn forage harvester, for rice																						1																						
harvest; using a drawn forage harvester, for soybeans																						1																						
harvest; using a drawn forage harvester, for spring wheat																						1																						
harvest; using a drawn forage harvester, for winter wheat																						1																						
harvest; using a self-propelled forage harvester, for corn																							1																						
harvest; using a self-propelled forage harvester, for cotton																							1																						
harvest; using a self-propelled forage harvester, for durum wheat																							1																						
harvest; using a self-propelled forage harvester, for oats																							1																						
harvest; using a self-propelled forage harvester, for peanuts																							1																						
harvest; using a self-propelled forage harvester, for rice																							1																						
harvest; using a self-propelled forage harvester, for soybeans																							1																						
harvest; using a self-propelled forage harvester, for spring wheat																							1																						
harvest; using a self-propelled forage harvester, for winter																							1																						

	Chisel, st. pt. (drawn)	Disk, tandem heavy primary op. (drawn)	Disk, tandem secondary op. (drawn)	Furrow diker (drawn)	Dry spreader (drawn)	Broadcast sprayer (drawn)	Broadcast sprayer (self-propelled)	Spot sprayer (drawn)	Directed sprayer (drawn)	Band sprayer (drawn)	Additive tank, for micro-compound application system	Controls, for micro-compound application system	Pump, for micro-compound application system	Anti-siphon device; for chemigation	Backflow device; for chemigation	Pressure sensor; for chemigation	Injection pump; for chemigation, for corn	Interlock; for chemigation	Combine w/ corn head (self-propelled)	Corn grain cart (drawn)	Header-Corn (drawn)	Forage harvester (drawn)	Forage harvester (self-propelled)	Cotton picker (drawn)	Boll buggy (drawn)	Cotton module builder (drawn)	Cotton picker (self-propelled)	Cotton module builder (self-propelled)	Cotton picker/ module (self-propelled)	Cotton stripper/ buggy (drawn)	Cotton stripper/ module (drawn)	Swather (self-propelled)	Combine w/ pickup head (self-propelled)	Rice grain cart (drawn)	Combine w/ grain head (self-propelled)	Peanut Dig/Invertor (drawn)	Peanut harvester (drawn)	Peanut dump cart (drawn)	Peanut lifter (drawn)	Header-Rice (drawn)	Combine w/ soybean head (self-propelled)	Soybean grain cart (drawn)	Header-Soybean (drawn)	Wheat-sorghum grain cart (drawn)	Header-Wheat-sorghum (drawn)	Header-Draper (drawn)
wheat																																														

Appendix C: Supporting data for the farm implement dataset parameterization

	Power unit (T = tractor, SP= self-propelled)	Implement or add on lifetime (hours)	Expected ownership period (years)	Width, row, or capacity data for hours/acre estimate	Depth Adjusted HP	Speed (mph)	Field efficiency (%)	Applies to small implements	Applies to medium implements	Applies to large implements
Bed shaper	T	2500	10.0	40 ft wide	135	5	80	x	x	x
Bedder, hipper, disk hiller	T	2500	10.0	6 rows, 30 in spac (R6-30)	135	5	80	x		
Bedder, hipper, disk hiller	T	2500	10.0	6 rows, 38 in spac (R6-38)	135	5	80	x		
Bedder, hipper, disk hiller	T	2500	10.0	6 rows, 8 in spac (R6-8)	135	5	80	x		
Bedder, hipper, disk hiller	T	2500	10.0	6 rows, 15 in spac (R6-15)	135	5	80	x		
Bedder, hipper, disk hiller	T	2500	10.0	8 rows, 30 in spac (R8-30)	150	5	80		x	
Bedder, hipper, disk hiller	T	2500	10.0	8 rows, 38 in spac (R8-38)	150	5	80		x	
Bedder, hipper, disk hiller	T	2500	10.0	8 rows, 8 in spac (R8-8)	150	5	80		x	
Bedder, hipper, disk hiller	T	2500	10.0	8 rows, 15 in spac (R8-15)	150	5	80		x	
Bedder, hipper, disk hiller	T	2500	10.0	10 rows, 30 in spac (R10-30)	180	5	80			x
Bedder, hipper, disk hiller	T	2500	10.0	10 rows, 38 in spac (R10-38)	180	5	80			x
Bedder, hipper, disk hiller	T	2500	10.0	10 rows, 8 in spac (R10-8)	180	5	80			x
Bedder, hipper, disk hiller	T	2500	10.0	10 rows, 15 in spac (R10-15)	180	5	80			x
Bedder, hipper, hiller 12 in high	T	2500	10.0	6 rows, 30 in spac (R6-30)	205	5	80	x		
Bedder, hipper, hiller 12 in high	T	2500	10.0	8 rows, 30 in spac (R8-30)	230	5	80		x	
Bedder, hipper, hiller 12 in high	T	2500	10.0	10 rows, 30 in spac (R10-30)	270	5	80			x
Chisel, st. pt.	T	2500	11.0	20 ft wide	155	5	85	x		
Chisel, st. pt.	T	2500	11.0	28 ft wide	225	5	85		x	
Chisel, st. pt.	T	2500	11.0	36 ft wide	310	5	85			x
Chisel, st. pt. 12 in deep	T	2500	11.0	20 ft wide	265	4	85	x		
Chisel, st. pt. 12 in deep	T	2500	11.0	28 ft wide	385	4	85		x	
Chisel, st. pt. 12 in deep	T	2500	11.0	36 ft wide	530	4	85			x
Chisel, st. pt. 15 in deep	T	2500	11.0	20 ft wide	330	4	85	x		
Chisel, st. pt. 15 in deep	T	2500	11.0	28 ft wide	480	4	85		x	
Chisel, st. pt. 15 in deep	T	2500	11.0	36 ft wide	665	4	85			x
Chisel, st. pt. 5 in deep	T	2500	11.0	20 ft wide	110	5	85	x		
Chisel, st. pt. 5 in deep	T	2500	11.0	28 ft wide	160	5	85		x	
Chisel, st. pt. 5 in deep	T	2500	11.0	36 ft wide	220	5	85			x
Chisel, sweep shovel	T	2500	11.0	20 ft wide	155	5	85	x		
Chisel, sweep shovel	T	2500	11.0	28 ft wide	225	5	85		x	
Chisel, sweep shovel	T	2500	11.0	36 ft wide	310	5	85			x
Chisel, twisted shovel	T	2500	11.0	20 ft wide	155	5	85	x		
Chisel, twisted shovel	T	2500	11.0	28 ft wide	225	5	85		x	
Chisel, twisted shovel	T	2500	11.0	36 ft wide	310	5	85			x
Cultipacker, roller	T	2500	12.0	11 ft wide	55	6	85	x		
Cultipacker, roller	T	2500	12.0	21 ft wide	130	6	85		x	
Cultipacker, roller	T	2500	12.0	24 ft wide	150	6	85			x
Cultivator, field 6-12 in shovels C	T	2500	10.3	25 ft wide	150	6	85	x		
Cultivator, field 6-12 in shovels C	T	2500	10.3	37 ft wide	225	6	85		x	
Cultivator, field 6-12 in shovels C	T	2500	10.3	42 ft wide	260	6	85			x
Cultivator, field 6-12 in sweeps	T	2500	10.3	25 ft wide	150	5	85	x		
Cultivator, field 6-12 in sweeps	T	2500	10.3	37 ft wide	225	5	85		x	
Cultivator, field 6-12 in sweeps	T	2500	10.3	42 ft wide	260	5	85			x
Cultivator, field w/ spike points	T	2500	10.3	25 ft wide	150	6	85	x		
Cultivator, field w/ spike points	T	2500	10.3	37 ft wide	225	6	85		x	
Cultivator, field w/ spike points	T	2500	10.3	42 ft wide	260	6	85			x
Cultivator, off bar w/disk hillers on beds	T	2500	10.3	25 ft wide	95	5	85	x		
Cultivator, off bar w/disk hillers on beds	T	2500	10.3	37 ft wide	140	5	85		x	
Cultivator, off bar w/disk hillers on beds	T	2500	10.3	42 ft wide	165	5	85			x

	Power unit (T = tractor, SP= self-propelled)	Implement or add on lifetime (hours)	Expected ownership period (years)	Width, row, or capacity data for hours/acre estimate	Depth Adjusted HP	Speed (mph)	Field efficiency (%)	Applies to small implements	Applies to medium implements	Applies to large implements
Cultivator, rotary	T	2500	10.7	17 ft wide	75	4	80	x		
Cultivator, rotary	T	2500	10.7	22 ft wide	105	4	80		x	
Cultivator, rotary	T	2500	10.7	28 ft wide	140	4	80			x
Cultivator, row - 1st pass ridge till	T	2500	12.0	8 rows, 30 in spac (R8-30)	150	5	80	x		
Cultivator, row - 1st pass ridge till	T	2500	12.0	8 rows, 38 in spac (R8-38)	150	5	80	x		
Cultivator, row - 1st pass ridge till	T	2500	12.0	8 rows, 8 in spac (R8-8)	150	5	80	x		
Cultivator, row - 1st pass ridge till	T	2500	12.0	8 rows, 15 in spac (R8-15)	150	5	80	x		
Cultivator, row - 1st pass ridge till	T	2500	12.0	8 rows, 30 in spac (R8-30)	170	5	80		x	
Cultivator, row - 1st pass ridge till	T	2500	12.0	8 rows, 38 in spac (R8-38)	170	5	80		x	
Cultivator, row - 1st pass ridge till	T	2500	12.0	8 rows, 8 in spac (R8-8)	170	5	80		x	
Cultivator, row - 1st pass ridge till	T	2500	12.0	8 rows, 15 in spac (R8-15)	170	5	80		x	
Cultivator, row - 1st pass ridge till	T	2500	12.0	12 rows, 30 in spac (R12-30)	190	5	80			x
Cultivator, row - 1st pass ridge till	T	2500	12.0	12 rows, 38 in spac (R12-38)	190	5	80			x
Cultivator, row - 1st pass ridge till	T	2500	12.0	12 rows, 8 in spac (R12-8)	190	5	80			x
Cultivator, row - 1st pass ridge till	T	2500	12.0	12 rows, 15 in spac (R12-15)	190	5	80			x
Cultivator, row - 2nd pass ridge till	T	2500	12.0	8 rows, 30 in spac (R8-30)	150	5	80	x		
Cultivator, row - 2nd pass ridge till	T	2500	12.0	8 rows, 38 in spac (R8-38)	150	5	80	x		
Cultivator, row - 2nd pass ridge till	T	2500	12.0	8 rows, 8 in spac (R8-8)	150	5	80	x		
Cultivator, row - 2nd pass ridge till	T	2500	12.0	8 rows, 15 in spac (R8-15)	150	5	80	x		
Cultivator, row - 2nd pass ridge till	T	2500	12.0	8 rows, 30 in spac (R8-30)	170	5	80		x	
Cultivator, row - 2nd pass ridge till	T	2500	12.0	8 rows, 38 in spac (R8-38)	170	5	80		x	
Cultivator, row - 2nd pass ridge till	T	2500	12.0	8 rows, 8 in spac (R8-8)	170	5	80		x	
Cultivator, row - 2nd pass ridge till	T	2500	12.0	8 rows, 15 in spac (R8-15)	170	5	80		x	
Cultivator, row - 2nd pass ridge till	T	2500	12.0	12 rows, 30 in spac (R12-30)	190	5	80			x
Cultivator, row - 2nd pass ridge till	T	2500	12.0	12 rows, 38 in spac (R12-38)	190	5	80			x
Cultivator, row - 2nd pass ridge till	T	2500	12.0	12 rows, 8 in spac (R12-8)	190	5	80			x
Cultivator, row - 2nd pass ridge till	T	2500	12.0	12 rows, 15 in spac (R12-15)	190	5	80			x
Cultivator, row 1 in ridge	T	2500	12.0	8 rows, 30 in spac (R8-30)	150	5	80	x		
Cultivator, row 1 in ridge	T	2500	12.0	8 rows, 38 in spac (R8-38)	150	5	80	x		
Cultivator, row 1 in ridge	T	2500	12.0	8 rows, 8 in spac (R8-8)	150	5	80	x		
Cultivator, row 1 in ridge	T	2500	12.0	8 rows, 15 in spac (R8-15)	150	5	80	x		
Cultivator, row 1 in ridge	T	2500	12.0	8 rows, 30 in spac (R8-30)	170	5	80		x	
Cultivator, row 1 in ridge	T	2500	12.0	8 rows, 38 in spac (R8-38)	170	5	80		x	
Cultivator, row 1 in ridge	T	2500	12.0	8 rows, 8 in spac (R8-8)	170	5	80		x	
Cultivator, row 1 in ridge	T	2500	12.0	8 rows, 15 in spac (R8-15)	170	5	80		x	
Cultivator, row 1 in ridge	T	2500	12.0	12 rows, 30 in spac (R12-30)	190	5	80			x
Cultivator, row 1 in ridge	T	2500	12.0	12 rows, 38 in spac (R12-38)	190	5	80			x
Cultivator, row 1 in ridge	T	2500	12.0	12 rows, 8 in spac (R12-8)	190	5	80			x
Cultivator, row 1 in ridge	T	2500	12.0	12 rows, 15 in spac (R12-15)	190	5	80			x
Cultivator, row 3 in ridge	T	2500	12.0	8 rows, 30 in spac (R8-30)	150	5	80	x		
Cultivator, row 3 in ridge	T	2500	12.0	8 rows, 38 in spac (R8-38)	150	5	80	x		
Cultivator, row 3 in ridge	T	2500	12.0	8 rows, 8 in spac (R8-8)	150	5	80	x		
Cultivator, row 3 in ridge	T	2500	12.0	8 rows, 15 in spac (R8-15)	150	5	80	x		
Cultivator, row 3 in ridge	T	2500	12.0	8 rows, 30 in spac (R8-30)	170	5	80		x	
Cultivator, row 3 in ridge	T	2500	12.0	8 rows, 38 in spac (R8-38)	170	5	80		x	
Cultivator, row 3 in ridge	T	2500	12.0	8 rows, 8 in spac (R8-8)	170	5	80		x	
Cultivator, row 3 in ridge	T	2500	12.0	8 rows, 15 in spac (R8-15)	170	5	80		x	

	Power unit (T = tractor, SP= self-propelled)	Implement or add on lifetime (hours)	Expected ownership period (years)	Width, row, or capacity data for hours/acre estimate	Depth Adjusted HP	Speed (mph)	Field efficiency (%)	Applies to small implements	Applies to medium implements	Applies to large implements
Cultivator, row 3 in ridge	T	2500	12.0	12 rows, 30 in spac (R12-30)	190	5	80			x
Cultivator, row 3 in ridge	T	2500	12.0	12 rows, 38 in spac (R12-38)	190	5	80			x
Cultivator, row 3 in ridge	T	2500	12.0	12 rows, 8 in spac (R12-8)	190	5	80			x
Cultivator, row 3 in ridge	T	2500	12.0	12 rows, 15 in spac (R12-15)	190	5	80			x
Cultivator, row between beds	T	2500	10.1	8 rows, 38 in spac (R8-38)	140	5	80	x		
Cultivator, row between beds	T	2500	10.1	8 rows, 8 in spac (R8-8)	140	5	80	x		
Cultivator, row between beds	T	2500	10.1	8 rows, 38 in spac (R8-38)	190	5	80		x	
Cultivator, row between beds	T	2500	10.1	8 rows, 8 in spac (R8-8)	190	5	80		x	
Cultivator, row between beds	T	2500	10.1	12 rows, 38 in spac (R12-38)	225	5	80			x
Cultivator, row between beds	T	2500	10.1	12 rows, 8 in spac (R12-8)	225	5	80			x
Disk, offset, heavy	T	2500	10.3	12 ft wide	105	5	85	x		
Disk, offset, heavy	T	2500	10.3	12 ft wide	140	5	85		x	
Disk, offset, heavy	T	2500	10.3	15 ft wide	155	5	85			x
Disk, tandem heavy primary op.	T	2500	10.4	11 ft wide	90	5	80	x		
Disk, tandem heavy primary op.	T	2500	10.4	15 ft wide	145	5	80		x	
Disk, tandem heavy primary op.	T	2500	10.4	26 ft wide	210	5	80			x
Disk, tandem light finishing	T	2500	10.4	11 ft wide	45	5	80	x		
Disk, tandem light finishing	T	2500	10.4	15 ft wide	70	5	80		x	
Disk, tandem light finishing	T	2500	10.4	26 ft wide	105	5	80			x
Disk, tandem secondary op.	T	2500	10.4	11 ft wide	75	5	80	x		
Disk, tandem secondary op.	T	2500	10.4	15 ft wide	120	5	80		x	
Disk, tandem secondary op.	T	2500	10.4	26 ft wide	175	5	80			x
Do all	T	2500	10.0	17 ft wide	175	4	80	x		
Do all	T	2500	10.0	24 ft wide	225	4	80		x	
Do all	T	2500	10.0	30 ft wide	260	4	80			x
Do all, on beds	T	2500	10.0	17 ft wide	205	5	80	x		
Do all, on beds	T	2500	10.0	24 ft wide	255	5	80		x	
Do all, on beds	T	2500	10.0	30 ft wide	300	5	80			x
Furrow diker	T	2500	10.0	40 ft wide	135	4	80	x	x	x
Furrow shaper, torpedo	T	2500	10.0	40 ft wide	100	5	80	x	x	x
Harrow, coiled tine	T	2500	12.0	21 ft wide	190	6	85	x	x	
Harrow, coiled tine	T	2500	12.0	27 ft wide	225	6	85			x
Harrow, heavy	T	2500	10.0	21 ft wide	150	4	85	x		
Harrow, heavy	T	2500	10.0	24 ft wide	190	4	85		x	x
Harrow, spike tooth	T	2500	12.0	21 ft wide	190	6	85	x	x	
Harrow, spike tooth	T	2500	12.0	27 ft wide	225	6	85			x
Harrow, tine, on beds	T	2500	12.0	21 ft wide	190	5	85	x	x	
Harrow, tine, on beds	T	2500	12.0	27 ft wide	225	5	85			x
Land plane	T	2500	10.0	16 ft wide	190	4	85	x	x	x
Lister, 40 in	T	2500	11.0	20 ft wide	75	5	80	x	x	x
Para-plow or para-till	T	2500	12.0	6 rows, 38 in spac (R6-38)	225	3	80	x	x	x
Para-plow or para-till	T	2500	12.0	6 rows, 8 in spac (R6-8)	225	3	80	x	x	x
Plow, moldboard	T	2500	10.7	9 ft wide	115	5	85	x		
Plow, moldboard	T	2500	10.7	10 ft wide	140	5	85		x	
Plow, moldboard	T	2500	10.7	12 ft wide	190	5	85			x
Plow, moldboard 10 inch depth	T	2500	10.7	9 ft wide	145	5	85	x		
Plow, moldboard 10 inch depth	T	2500	10.7	10 ft wide	180	5	85		x	

	Power unit (T = tractor, SP= self-propelled)	Implement or add on lifetime (hours)	Expected ownership period (years)	Width, row, or capacity data for hours/acre estimate	Depth Adjusted HP	Speed (mph)	Field efficiency (%)	Applies to small implements	Applies to medium implements	Applies to large implements
Plow, moldboard 10 inch depth	T	2500	10.7	12 ft wide	240	5	85			x
Rodweeder	T	2500	11.0	8 rows, 38 in spac (R8-38)	100	5	80	x	x	x
Rodweeder	T	2500	11.0	8 rows, 8 in spac (R8-8)	100	5	80	x	x	x
Roller, corrugated packer	T	2500	12.0	11 ft wide	55	4	85	x		
Roller, corrugated packer	T	2500	12.0	21 ft wide	130	4	85		x	
Roller, corrugated packer	T	2500	12.0	24 ft wide	150	4	85			x
Roller, smooth	T	2500	12.0	20 ft wide	50	4	85	x	x	x
Rotary hoe	T	2500	10.7	17 ft wide	75	10	80	x		
Rotary hoe	T	2500	10.7	22 ft wide	105	10	80		x	
Rotary hoe	T	2500	10.7	28 ft wide	140	10	80			x
Subsoiler	T	2500	12.4	16.7 ft wide	305	5	80	x	x	
Subsoiler	T	2500	12.4	17 ft wide	355	5	80			x
Subsoiler bedder (ripper/hipper)	T	2500	12.4	16.7 ft wide	145	5	80	x	x	
Subsoiler bedder (ripper/hipper)	T	2500	12.4	17 ft wide	165	5	80			x
Sweep plow 20-40 in wide	T	2500	11.0	23 ft wide	140	5	85	x	x	x
Sweep plow wider than 40 in w/ mulch treader	T	2500	11.0	23 ft wide	140	4	85	x	x	x
Sweep plow, wider than 40 in	T	2500	11.0	23 ft wide	140	4	85	x	x	x
Drill or air seeder single disk openers 7-10 in spac.	T	1200	8.6	13 ft wide	130	5	70	x		
Drill or air seeder single disk openers 7-10 in spac.	T	1200	8.6	16 ft wide	150	5	70		x	
Drill or air seeder single disk openers 7-10 in spac.	T	1200	8.6	18 ft wide	170	5	70			x
Drill or air seeder single disk openers, + fert. opnrs 7-10 in spac.	T	1200	8.6	13 ft wide	130	5	70	x		
Drill or air seeder single disk openers, + fert. opnrs 7-10 in spac.	T	1200	8.6	16 ft wide	150	5	70		x	
Drill or air seeder single disk openers, + fert. opnrs 7-10 in spac.	T	1200	8.6	18 ft wide	170	5	70			x
Drill or air seeder, hoe/chisel openers 6-12 in spac.	T	1200	8.6	13 ft wide	130	5	70	x		
Drill or air seeder, hoe/chisel openers 6-12 in spac.	T	1200	8.6	16 ft wide	150	5	70		x	
Drill or air seeder, hoe/chisel openers 6-12 in spac.	T	1200	8.6	18 ft wide	170	5	70			x
Drill or airseeder, double disk	T	1200	8.6	13 ft wide	130	5	70	x		
Drill or airseeder, double disk	T	1200	8.6	16 ft wide	150	5	70		x	
Drill or airseeder, double disk	T	1200	8.6	18 ft wide	170	5	70			x
Drill or airseeder, double disk opener, w/ fert openers	T	1200	8.6	13 ft wide	130	5	70	x		
Drill or airseeder, double disk opener, w/ fert openers	T	1200	8.6	16 ft wide	150	5	70		x	
Drill or airseeder, double disk opener, w/ fert openers	T	1200	8.6	18 ft wide	170	5	70			x
Drill or airseeder, double disk, w/ fluted coulters	T	1200	8.6	13 ft wide	130	5	70	x		
Drill or airseeder, double disk, w/ fluted coulters	T	1200	8.6	16 ft wide	150	5	70		x	
Drill or airseeder, double disk, w/	T	1200	8.6	18 ft wide	170	5	70			x

	Power unit (T = tractor, SP= self-propelled)	Implement or add on lifetime (hours)	Expected ownership period (years)	Width, row, or capacity data for hours/acre estimate	Depth Adjusted HP	Speed (mph)	Field efficiency (%)	Applies to small implements	Applies to medium implements	Applies to large implements
fluted coulters										
Drill or airseeder, offset double disk openers	T	1200	8.6	13 ft wide	130	5	70	x		
Drill or airseeder, offset double disk openers	T	1200	8.6	16 ft wide	150	5	70		x	
Drill or airseeder, offset double disk openers	T	1200	8.6	18 ft wide	170	5	70			x
Drill, air seeder, sweep or band opener	T	1200	9.0	12 ft wide	130	5	70	x	x	
Drill, air seeder, sweep or band opener	T	1200	9.0	30 ft wide	175	5	70			x
Drill, deep furrow 12 to 18 in spacing	T	1200	8.6	13 ft wide	130	5	70	x		
Drill, deep furrow 12 to 18 in spacing	T	1200	8.6	16 ft wide	150	5	70		x	
Drill, deep furrow 12 to 18 in spacing	T	1200	8.6	18 ft wide	170	5	70			x
Drill, heavy, direct seed, dbl disk opnr	T	1200	8.6	13 ft wide	130	5	70	x		
Drill, heavy, direct seed, dbl disk opnr	T	1200	8.6	16 ft wide	150	5	70		x	
Drill, heavy, direct seed, dbl disk opnr	T	1200	8.6	18 ft wide	170	5	70			x
Planter, double disk opener on 8 inch high beds	T	1200	8.6	6 rows, 38 in spac (R6-38)	150	5	65	x		
Planter, double disk opener on 8 inch high beds	T	1200	8.6	6 rows, 8 in spac (R6-8)	150	5	65	x		
Planter, double disk opener on 8 inch high beds	T	1200	8.6	15 rows, 38 in spac (R15-38)	190	5	65		x	x
Planter, double disk opener on 8 inch high beds	T	1200	8.6	15 rows, 8 in spac (R15-8)	190	5	65		x	x
Planter, double disk opnr	T	1200	8.4	8 rows, 30 in spac (R8-30)	170	5	65	x		
Planter, double disk opnr	T	1200	8.4	8 rows, 38 in spac (R8-38)	170	5	65	x		
Planter, double disk opnr	T	1200	8.4	8 rows, 8 in spac (R8-8)	170	5	65	x		
Planter, double disk opnr	T	1200	8.4	8 rows, 15 in spac (R8-15)	170	5	65	x		
Planter, double disk opnr	T	1200	8.4	15 rows, 30 in spac (R15-30)	190	5	65		x	
Planter, double disk opnr	T	1200	8.4	15 rows, 38 in spac (R15-38)	190	5	65		x	
Planter, double disk opnr	T	1200	8.4	15 rows, 8 in spac (R15-8)	190	5	65		x	
Planter, double disk opnr	T	1200	8.4	15 rows, 15 in spac (R15-15)	190	5	65		x	
Planter, double disk opnr	T	1200	8.4	16 rows, 30 in spac (R16-30)	215	5	65			x
Planter, double disk opnr	T	1200	8.4	16 rows, 38 in spac (R16-38)	215	5	65			x
Planter, double disk opnr	T	1200	8.4	16 rows, 8 in spac (R16-8)	215	5	65			x
Planter, double disk opnr	T	1200	8.4	16 rows, 15 in spac (R16-15)	215	5	65			x
Planter, double disk opnr w/fluted coulter	T	1200	8.4	8 rows, 30 in spac (R8-30)	170	5	65	x		
Planter, double disk opnr w/fluted coulter	T	1200	8.4	8 rows, 38 in spac (R8-38)	170	5	65	x		
Planter, double disk opnr w/fluted coulter	T	1200	8.4	8 rows, 8 in spac (R8-8)	170	5	65	x		
Planter, double disk opnr w/fluted coulter	T	1200	8.4	8 rows, 15 in spac (R8-15)	170	5	65	x		
Planter, double disk opnr w/fluted coulter	T	1200	8.4	15 rows, 30 in spac (R15-30)	190	5	65		x	
Planter, double disk opnr w/fluted coulter	T	1200	8.4	15 rows, 38 in spac (R15-38)	190	5	65		x	
Planter, double disk opnr w/fluted coulter	T	1200	8.4	15 rows, 8 in spac (R15-8)	190	5	65		x	
Planter, double disk opnr w/fluted	T	1200	8.4	15 rows, 15 in spac (R15-15)	190	5	65		x	

	Power unit (T = tractor, SP= self-propelled)	Implement or add on lifetime (hours)	Expected ownership period (years)	Width, row, or capacity data for hours/acre estimate	Depth Adjusted HP	Speed (mph)	Field efficiency (%)	Applies to small implements	Applies to medium implements	Applies to large implements
coulter										
Planter, double disk opnr w/fluted coulter	T	1200	8.4	16 rows, 30 in spac (R16-30)	215	5	65			x
Planter, double disk opnr w/fluted coulter	T	1200	8.4	16 rows, 38 in spac (R16-38)	215	5	65			x
Planter, double disk opnr w/fluted coulter	T	1200	8.4	16 rows, 8 in spac (R16-8)	215	5	65			x
Planter, double disk opnr w/fluted coulter	T	1200	8.4	16 rows, 15 in spac (R16-15)	215	5	65			x
Planter, in-row subsoiler	T	1200	8.6	6 rows, 30 in spac (R6-30)	150	3	65	x		
Planter, in-row subsoiler	T	1200	8.6	6 rows, 38 in spac (R6-38)	150	3	65	x		
Planter, in-row subsoiler	T	1200	8.6	6 rows, 8 in spac (R6-8)	150	3	65	x		
Planter, in-row subsoiler	T	1200	8.6	6 rows, 15 in spac (R6-15)	150	3	65	x		
Planter, in-row subsoiler	T	1200	8.6	15 rows, 30 in spac (R15-30)	190	3	65		x	x
Planter, in-row subsoiler	T	1200	8.6	15 rows, 38 in spac (R15-38)	190	3	65		x	x
Planter, in-row subsoiler	T	1200	8.6	15 rows, 8 in spac (R15-8)	190	3	65		x	x
Planter, in-row subsoiler	T	1200	8.6	15 rows, 15 in spac (R15-15)	190	3	65		x	x
Planter, in-row subsoiler low disturbace	T	1200	8.4	8 rows, 30 in spac (R8-30)	170	3	65	x		
Planter, in-row subsoiler low disturbace	T	1200	8.4	8 rows, 38 in spac (R8-38)	170	3	65	x		
Planter, in-row subsoiler low disturbace	T	1200	8.4	8 rows, 8 in spac (R8-8)	170	3	65	x		
Planter, in-row subsoiler low disturbace	T	1200	8.4	8 rows, 15 in spac (R8-15)	170	3	65	x		
Planter, in-row subsoiler low disturbace	T	1200	8.4	15 rows, 30 in spac (R15-30)	190	3	65		x	
Planter, in-row subsoiler low disturbace	T	1200	8.4	15 rows, 38 in spac (R15-38)	190	3	65		x	
Planter, in-row subsoiler low disturbace	T	1200	8.4	15 rows, 8 in spac (R15-8)	190	3	65		x	
Planter, in-row subsoiler low disturbace	T	1200	8.4	15 rows, 15 in spac (R15-15)	190	3	65		x	
Planter, in-row subsoiler low disturbace	T	1200	8.4	16 rows, 30 in spac (R16-30)	215	3	65			x
Planter, in-row subsoiler low disturbace	T	1200	8.4	16 rows, 38 in spac (R16-38)	215	3	65			x
Planter, in-row subsoiler low disturbace	T	1200	8.4	16 rows, 8 in spac (R16-8)	215	3	65			x
Planter, in-row subsoiler low disturbace	T	1200	8.4	16 rows, 15 in spac (R16-15)	215	3	65			x
Planter, in-row subsoiler w/ residue mgr.	T	1200	8.6	6 rows, 30 in spac (R6-30)	150	3	65	x		
Planter, in-row subsoiler w/ residue mgr.	T	1200	8.6	6 rows, 38 in spac (R6-38)	150	3	65	x		
Planter, in-row subsoiler w/ residue mgr.	T	1200	8.6	6 rows, 8 in spac (R6-8)	150	3	65	x		
Planter, in-row subsoiler w/ residue mgr.	T	1200	8.6	6 rows, 15 in spac (R6-15)	150	3	65	x		
Planter, in-row subsoiler w/ residue mgr.	T	1200	8.6	15 rows, 30 in spac (R15-30)	190	3	65		x	x

	Power unit (T = tractor, SP= self-propelled)	Implement or add on lifetime (hours)	Expected ownership period (years)	Width, row, or capacity data for hours/acre estimate	Depth Adjusted HP	Speed (mph)	Field efficiency (%)	Applies to small implements	Applies to medium implements	Applies to large implements
Planter, in-row subsoiler w/ residue mgr.	T	1200	8.6	15 rows, 38 in spac (R15-38)	190	3	65		x	x
Planter, in-row subsoiler w/ residue mgr.	T	1200	8.6	15 rows, 8 in spac (R15-8)	190	3	65		x	x
Planter, in-row subsoiler w/ residue mgr.	T	1200	8.6	15 rows, 15 in spac (R15-15)	190	3	65		x	x
Planter, narrow slot w/smooth or rippled coulter	T	1200	8.4	8 rows, 38 in spac (R8-38)	170	5	65	x		
Planter, narrow slot w/smooth or rippled coulter	T	1200	8.4	8 rows, 30 in spac (R8-30)	170	5	65	x		
Planter, narrow slot w/smooth or rippled coulter	T	1200	8.4	8 rows, 8 in spac (R8-8)	170	5	65	x		
Planter, narrow slot w/smooth or rippled coulter	T	1200	8.4	8 rows, 15 in spac (R8-15)	170	5	65	x		
Planter, narrow slot w/smooth or rippled coulter	T	1200	8.4	15 rows, 38 in spac (R15-38)	190	5	65		x	
Planter, narrow slot w/smooth or rippled coulter	T	1200	8.4	15 rows, 30 in spac (R15-30)	190	5	65		x	
Planter, narrow slot w/smooth or rippled coulter	T	1200	8.4	15 rows, 8 in spac (R15-8)	190	5	65		x	
Planter, narrow slot w/smooth or rippled coulter	T	1200	8.4	15 rows, 15 in spac (R15-15)	190	5	65		x	
Planter, narrow slot w/smooth or rippled coulter	T	1200	8.4	16 rows, 38 in spac (R16-38)	215	5	65			x
Planter, narrow slot w/smooth or rippled coulter	T	1200	8.4	16 rows, 30 in spac (R16-30)	215	5	65			x
Planter, narrow slot w/smooth or rippled coulter	T	1200	8.4	16 rows, 8 in spac (R16-8)	215	5	65			x
Planter, narrow slot w/smooth or rippled coulter	T	1200	8.4	16 rows, 15 in spac (R16-15)	215	5	65			x
Planter, ridge till	T	1200	8.6	6 rows, 30 in spac (R6-30)	150	5	65	x		
Planter, ridge till	T	1200	8.6	6 rows, 38 in spac (R6-38)	150	5	65	x		
Planter, ridge till	T	1200	8.6	6 rows, 8 in spac (R6-8)	150	5	65	x		
Planter, ridge till	T	1200	8.6	6 rows, 15 in spac (R6-15)	150	5	65	x		
Planter, ridge till	T	1200	8.6	15 rows, 30 in spac (R15-30)	190	5	65		x	x
Planter, ridge till	T	1200	8.6	15 rows, 38 in spac (R15-38)	190	5	65		x	x
Planter, ridge till	T	1200	8.6	15 rows, 8 in spac (R15-8)	190	5	65		x	x
Planter, ridge till	T	1200	8.6	15 rows, 15 in spac (R15-15)	190	5	65		x	x
Planter, strip till	T	1200	10.0	10 rows, 30 in spac (R10-30)	225	5	65	x		
Planter, strip till	T	1200	10.0	10 rows, 38 in spac (R10-38)	225	5	65	x		
Planter, strip till	T	1200	10.0	10 rows, 15 in spac (R10-15)	225	5	65	x		
Planter, strip till	T	1200	10.0	12 rows, 30 in spac (R12-30)	280	5	65		x	
Planter, strip till	T	1200	10.0	12 rows, 38 in spac (R12-38)	280	5	65		x	
Planter, strip till	T	1200	10.0	12 rows, 15 in spac (R12-15)	280	5	65		x	
Planter, strip till	T	1200	10.0	16 rows, 30 in spac (R16-30)	305	5	65			x
Planter, strip till	T	1200	10.0	16 rows, 38 in spac (R16-38)	305	5	65			x
Planter, strip till	T	1200	10.0	16 rows, 15 in spac (R16-15)	305	5	65			x
Planting, broadcast seeder	T	1200	10.0	20 ft wide	75	5	70	x	x	x
Band sprayer	T	2000	8.0	50 ft wide	170	7	65	x	x	x
Broadcast sprayer	SP			60 ft wide	125	12	65	x		

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Broadcast sprayer	SP			90 ft wide	250	12	65		x	x
Broadcast sprayer	T	2000	8.6	37 ft wide	60	7	65	x		
Broadcast sprayer	T	2000	8.6	51 ft wide	150	7	65		x	
Broadcast sprayer	T	2000	8.6	55 ft wide	170	7	65			x
Directed sprayer	T	2000	8.0	8 rows, 30 in spac (R8-30)	170	7	65	x	x	x
Directed sprayer	T	2000	8.0	8 rows, 38 in spac (R8-38)	170	7	65	x	x	x
Directed sprayer	T	2000	8.0	8 rows, 8 in spac (R8-8)	170	7	65	x	x	x
Directed sprayer	T	2000	8.0	8 rows, 15 in spac (R8-15)	170	7	65	x	x	x
Dry spreader	T	1200	9.7	31 ft wide	190	7	70	x		
Dry spreader	T	1200	9.7	38 ft wide	240	7	70		x	
Dry spreader	T	1200	9.7	44 ft wide	280	7	70			x
Spot sprayer	T	2000	8.0	40 ft wide	170	7	65	x	x	x
Boll buggy	T	2500	10.0	4 rows, 38 in spac (R4-38)	190	4	70	x	x	x
Boll buggy	T	2500	10.0	4 rows, 8 in spac (R4-8)	190	4	70	x	x	x
Combine w/ corn head (operated with a cart)	SP	2000	12.0	20 ft wide	275	3	70	x		
Combine w/ corn head (operated without a cart)	SP	2000	12.0	20 ft wide	275	3	65	x		
Combine w/ grain head	SP	2000	12.0	20 ft wide	220	3	70	x		
Combine w/ grain head	SP	2000	12.0	20 ft wide	275	3	70		x	x
Combine w/ grain head (operated with a cart)	SP	2000	12.0	20 ft wide	220	3	70	x		
Combine w/ grain head (operated with a cart)	SP	2000	12.0	20 ft wide	275	3	70			
Combine w/ grain head (operated without a cart)	SP	2000	12.0	20 ft wide	220	3	65	x		
Combine w/ grain head (operated without a cart)	SP	2000	12.0	20 ft wide	275	3	65			
Combine w/ pickup head (operated with a cart)	SP	2000	12.0	23 ft wide	275	3	70	x		
Combine w/ pickup head (operated without a cart)	SP	2000	12.0	23 ft wide	275	3	65	x		
Combine w/ soybean head (operated with a cart)	SP	2000	12.0	15 ft wide	220	3	70	x		
Combine w/ soybean head (operated with a cart)	SP	2000	12.0	18 ft wide	275	3	70			
Combine w/ soybean head (operated without a cart)	SP	2000	12.0	15 ft wide	220	3	65	x		
Combine w/ soybean head (operated without a cart)	SP	2000	12.0	18 ft wide	275	3	65			
Corn grain cart	T	2500	12.0	500 bu (at 0.032 hr/acre)	190	NA	NA	x		
Corn grain cart	T	2500	12.0	700 bu (at 0.025 hr/acre)	190	NA	NA		x	
Corn grain cart	T	2500	12.0	1000 bu (at 0.025 hr/acre)	225	NA	NA			x
Cotton module builder	SP			18 ft wide	150	4	70	x		
Cotton module builder	SP			17 ft wide	165	4	70		x	
Cotton module builder	SP			16 ft wide	190	4	70			x
Cotton module builder	T	2500	10.0	4 rows, 38 in spac (R4-38)	190	4	70	x	x	x
Cotton module builder	T	2500	10.0	4 rows, 8 in spac (R4-8)	190	4	70	x	x	x
Cotton picker	SP			4 rows, 38 in spac (R4-38)	255	4	70	x		

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Cotton picker	SP			4 rows, 8 in spac (R4-8)	255	4	70	x		
Cotton picker	SP			5 rows, 38 in spac (R5-38)	330	4	70		x	
Cotton picker	SP			5 rows, 8 in spac (R5-8)	330	4	70		x	
Cotton picker	SP			5 rows, 38 in spac (R5-38)	350	4	70			x
Cotton picker	SP			5 rows, 8 in spac (R5-8)	350	4	70			x
Cotton picker	T	3000	8.0	4 rows, 38 in spac (R4-38)	325	4	70	x	x	
Cotton picker	T	3000	8.0	4 rows, 8 in spac (R4-8)	325	4	70	x	x	
Cotton picker	T	3000	8.0	6 rows, 38 in spac (R6-38)	330	4	70			x
Cotton picker	T	3000	8.0	6 rows, 8 in spac (R6-8)	330	4	70			x
Cotton picker/ module	SP			6 rows, 38 in spac (R6-38)	365	4	70	x	x	
Cotton picker/ module	SP			6 rows, 8 in spac (R6-8)	365	4	70	x	x	
Cotton picker/ module	SP			6 rows, 38 in spac (R6-38)	500	4	70			x
Cotton picker/ module	SP			6 rows, 8 in spac (R6-8)	500	4	70			x
Cotton stripper/ buggy	T	2500	10.0	5 rows, 38 in spac (R5-38)	150	4	70	x	x	x
Cotton stripper/ buggy	T	2500	10.0	5 rows, 8 in spac (R5-8)	150	4	70	x	x	x
Cotton stripper/ module	T	2500	10.0	4 rows, 38 in spac (R4-38)	150	4	70	x	x	x
Cotton stripper/ module	T	2500	10.0	4 rows, 8 in spac (R4-8)	150	4	70	x	x	x
Forage harvester	SP	2000	12.0	12 ft wide	315	3	70	x	x	x
Forage harvester	T	2000	8.0	6 ft wide	100	3	70	x	x	x
Header-Corn (operated with a cart)	T	2000	8.0	19 ft wide	265	3	65	x		
Header-Corn (operated with a cart)	T	2000	8.0	25.3 ft wide	325	3	65			x
Header-Corn (operated without a cart)	T	2000	8.0	19 ft wide	265	3	60	x		
Header-Corn (operated without a cart)	T	2000	8.0	25.3 ft wide	325	3	60			x
Header-Draper	T	2000	8.0	30 ft wide	325	3	65	x	x	x
Header-Rice (operated with a cart)	T	2000	8.0	25 ft wide	325	3	65	x		x
Header-Rice (operated without a cart)	T	2000	8.0	25 ft wide	325	3	60	x		x
Header-Soybean (operated with a cart)	T	2000	8.0	22 ft wide	265	3	65	x		
Header-Soybean (operated with a cart)	T	2000	8.0	25 ft wide	325	3	65			x
Header-Soybean (operated without a cart)	T	2000	8.0	22 ft wide	265	3	60	x		
Header-Soybean (operated without a cart)	T	2000	8.0	25 ft wide	325	3	60			x
Header-Wheat-sorghum	T	2000	8.0	22 ft wide	265	3	65	x		
Header-Wheat-sorghum	T	2000	8.0	25 ft wide	325	3	65		x	x
Peanut Dig/Invertor	T	2500	15.0	4 rows, 38 in spac (R4-38)	190	5	60	x	x	x
Peanut dump cart	T	2500	20.0	6 rows, 38 in spac (R6-38)	190	3	65	x	x	x
Peanut harvester	T	2500	20.0	4 rows, 38 in spac (R4-38)	225	3	70	x	x	x
Peanut lifter	T	2500	20.0	6 rows, 38 in spac (R6-38)	225	5	60	x	x	x
Rice grain cart	T	2500	12.0	500 bu (at 0.063 hr/acre)	190	NA	NA	x		
Rice grain cart	T	2500	12.0	700 bu (at 0.055 hr/acre)	190	NA	NA		x	
Rice grain cart	T	2500	12.0	1000 bu (at 0.046 hr/acre)	190	NA	NA			x
Soybean grain cart	T	2500	12.0	500 bu (at 0.026 hr/acre)	190	NA	NA	x		
Soybean grain cart	T	2500	12.0	700 bu (at 0.021 hr/acre)	190	NA	NA		x	
Soybean grain cart	T	2500	12.0	1000 bu (at 0.021 hr/acre)	190	NA	NA			x
Swather	SP			14 ft wide	80	5	80	x		
Swather	SP			14 ft wide	115	5	80		x	
Swather	SP			14 ft wide	165	5	80			x
Wheat-sorghum grain cart	T	2500	12.0	500 bu (at 0.026 hr/acre)	190	NA	NA	x		

	Power unit (T = tractor, SP= self-propelled)	Implement or add on lifetime (hours)	Expected ownership period (years)	Width, row, or capacity data for hours/acre estimate	Depth Adjusted HP	Speed (mph)	Field efficiency (%)	Applies to small implements	Applies to medium implements	Applies to large implements
Wheat-sorghum grain cart	T	2500	12.0	700 bu (at 0.021 hr/acre)	190	NA	NA		x	
Wheat-sorghum grain cart	T	2500	12.0	1000 bu (at 0.021 hr/acre)	190	NA	NA			x