Life cycle inventory data of agricultural tractors

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Data Article

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A B S T R A C T

Life Cycle Assessments (LCA) of agricultural systems are performed using inventory data from several databases. The inventory data used for agricultural machinery and especially agricultural tractors in these databases are based on old data (from 2002 and not updated since) using trucks (“lorry”) as a proxy for the manufacture of tractors. In consequences, they do not reflect the current technology used by farmers and do not allow comparison with new technologies in used in farms such as agricultural robots. The dataset proposed in this paper presents two updated Life Cycle Inventory (LCI) of an agricultural tractor. Data were collected based on the technical system of a tractor manufacturer, scientific and technical literature as well as expert opinion. Data on weight, composition, lifetime and maintenance hours of each tractor component as well as electronic parts, converter catalyst and lead battery are produced. The inventory is calculated based on the raw materials needed for the tractor manufacturing and maintenance over its lifetime as well as the energy and infrastructure needed for manufacturing. Calculations were made based on a tractor of 7300 kg with the following characteristics: 155 CV, 6 cylinders, four-wheel drive. The tractor modelled is representative of tractors from the same power category (i.e. between 100 and 199 CV and 70% of the annual sales in France). Two LCI are produced: a LCI for a 7200 h lifetime tractor, representative of an accounting depreciation, and a LCI for a 12000 h lifetime tractor, representative of the whole service life of the tractor (first use to

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final disposal). The functional unit is 1 kg of tractor (kg) or 1 piece (p) of tractor during its lifetime.

Specifications Table

Subject	Agricultural Sciences, Environmental Sciences, Engineering
Specific subject area	Agricultural machinery
Type of data	Table
How the data were acquired	Raw data were collected based on the technical system of a tractor manufacturer, scientific and technical literature as well as expert opinion. When data were not available in scientific and technical literature, the expert opinion from specialists in the field of electronics and agricultural machinery was used. Analysed data were calculated based on the raw data.
Data format	Raw Analysed
Description of data collection	Raw data on electronic component were obtained from the technical system provided by the tractor manufacturer. Raw data on GPS, camera, catalyst converter and lead battery were obtained from scientific literature. Raw data on the maintenance hours were obtained from the maintenance service of the tractor manufacturer. The composition of each tractor component and their weight were obtained from technical literature and expert opinion.
Data source location	Raw data were selected to be relevant in a French context. When available, data from France were selected. Raw and analysed data location are as follow: • Institution: INRAE Centre Clermont-Auvergne-Rhône-Alpes • City/Town/Region: Montoldre (Allier) • Country: France • GPS coordinates: 46.33905, 3.43486
Data accessibility	Repository name: Recherche Data Gouv Data identification number: https://recherche.data.gouv.fr/ Direct URL to data: https://doi.org/10.57745/JYXPHZ Licenses of use: etalab 2.0 (https://spdx.org/licenses/etalab-2.0.html)

Value of the Data

- This paper provides updated life cycle inventory data for an agricultural tractor representative of tractors manufactured since 2016.
- These data can be used by every person who wants to carry on a life cycle assessment of agricultural system using updated data for tractors, especially when the goal is to compare agricultural systems that involve new technologies such as agricultural robots.
- The information provided in this paper can be used to update generic or specific life cycle inventory databases.
- Four LCI of agricultural tractor are produced regarding the tractor lifetime (7200 h, representative of an accounting depreciation, and 12000 h, representative of the whole service life of the tractor) and the functional unit used (1 kg and 1 piece).

1. Objective

This paper aims at providing an updated Life Cycle Inventory (LCI) of agricultural tractors. Life Cycle Assessments (LCA) of agricultural systems are currently performed using inventory data from several databases. The inventory data used for agricultural machinery and especially agricultural tractors in these databases are based on old data (from 2002 and not updated since) using trucks ("lorry") as a proxy for the manufacture of tractors. In consequences, they do not reflect the current technology used by farmers and do not allow comparison with new technologies in used in farms such as agricultural robots as highlighted by [1]. This paper proposes two LCI for a standard agricultural tractor that represents tractors from the same power category (i.e. between 100 and 199 CV) and 70% of the annual sales in France [2]. This LCI includes all the electronic components (electronic cards, GPS, camera, electronically solenoid valves, on-board sensors…), the converter catalyst and the lead battery, data that are not included in LCI of agricultural tractor in the current databases.

2. Data Description

The dataset associated with this paper is available in the repository. It contains a total of 12 files of both raw and analysed data required to modelled the Life Cycle Inventory of an agricultural tractor regarding its lifetime (7200h or 12000h) and functional unit (1 kg or 1 piece).

2.1. Raw Data Files

Five raw data files are available in the repository. Each file description is listed here after:

- Composition.tab: this table presents for each type of tractor component the material used for its manufacturing (steel, plastic…).
- Maintenance hours.tab: this table presents for each tractor component their replacement interval in hours
- Piece replaced.tab: this table presents for each type of tractor component the number of times the component is replaced for the two modelled lifetimes (7200 h and 12000 h)
- Weight.tab: this table presents the weight, volume, number of piece or meter for each tractor component and the total weight of each component calculated based on the density (for liquid) or weight of each piece.
- Technical characteristics.tab: this table presents the technical characteristics of the tractor used for modelling. The technical characteristics are provided for the average weight of the tractor, the number of cylinders, the maximal and nominal power, the maximum torque, the tractor dimensions, the type of tyres and the tank capacities.

In addition to these files, Table 1 presents the raw data used to modelled the LCI of the electronic components of the agricultural tractor.

Table 1
Detail of the composition of the electronic components.

Name of the electronic component	Composition	Nb of elements	Unit weight (kg or m²)	Total weight (kg)
Control board n°1	Printed wiring board	1	3.26E+00	1.28E+00
	Fuse (small)	28	6.30E-04	1.76E-02
	Fuse (medium)	8	1.10E-03	8.80E-03
	Fuse (big)	3	5.08E-03	1.52E-02
	Relay (small)	14	3.36E-02	4.70E-01
	Relay (big)	2	6.18E-02	1.24E-01
	Diode	4	3.20E-05	1.28E-04
	Resistor	2	9.80E-06	1.96E-05
	3 wires clamp type connector	6	9.00E-03	5.40E-02
	Connector PCI bus (very large)	6	1.16E-02	6.96E-02
	Connector PCI bus (medium)	2	6.60E-03	1.33E-02
Control board n°2	Printed wiring board	1	3.08E+00	4.94E-02
	Fuse (small)	37	6.30E-04	2.33E-02
	Fuse (medium)	4	1.10E-03	4.40E-03
	Fuse (big)	1	5.08E-03	5.08E-03
	Relay (small)	9	3.36E-02	3.02E-01
	Relay (big)	4	6.18E-02	2.47E-01
	Diode	2	3.20E-05	6.40E-05
	3 wires clamp type connector	2	9.00E-03	1.80E-02
	Connector PCI bus (large)	7	8.10E-03	5.67E-02
Control board n°3	Printed wiring board	1	3.08E+00	4.99E-02
	Fuse (small)	3	6.30E-04	2.33E-02
	Connector PCI bus (small)	9	3.68E-05	3.31E-04
	Connector PCI bus (very small)	7	9.21E-06	6.45E-05
	Capacitor	6	7.00E-04	4.20E-03
	Diode	24	3.20E-05	7.68E-04
	Resistor	4	9.80E-06	3.92E-05
Control board n°4	Printed wiring board	1	3.08E+00	2.00E-01
	Fuse (small)	35	6.30E-04	2.21E-02
	Fuse (medium)	1	1.10E-03	1.10E-03
	Fuse (big)	1	5.08E-03	5.08E-03
	Relay (small)	9	3.36E-02	3.02E-01
	Relay (big)	1	6.18E-02	6.18E-02
	Diode	3	3.20E-05	9.60E-05
	Resistance	3	9.80E-06	2.94E-05
	Connector PCI bus (very small)	1	4.60E-06	4.60E-06
	Connector PCI bus (very small)	1	9.21E-06	9.21E-06
	Connector PCI bus (small)	3	3.68E-05	1.10E-04
	Connector PCI bus (large)	7	8.10E-03	5.67E-02
	Connector PCI bus (medium)	2	4.05E-03	8.10E-03
	3 wires clamp type connector	2	9.00E-03	1.80E-02
Solenoid valves	-	29	5.00E-01	1.45E+01
On-board sensors	Motor	37	1.40E-01	5.12E+00
	Hydraulic system	15	1.40E-01	2.14E+00
	Other location	29	1.10E-01	3.16E+00

2.2. Analysed Data Files

Seven analysed data files are available in the repository. Each file description is listed here after:

- LCI catalyst converter.tab: this table presents the life cycle inventory of the materials needed for the manufacturing of 1 kg of catalyst converter used to treat the exhaust gases of the tractor

- LCI electronics.tab: this table presents the life cycle inventory of the materials needed for the manufacturing of 1 kg or 1 piece of the following components: GPS, Camera, Control boards, Electronic controllers, Electronically controlled solenoid valves. This table uses the raw data presented in Table 1.
- LCI lead battery: this table presents the life cycle inventory of the materials needed for the manufacturing of 1 kg of lead battery
- LCI tractor 7200h (1kg).tab: this table presents the life cycle inventory of the materials, energy, infrastructure needed for the manufacturing and maintenance of a 7200 h lifetime tractor for a functional unit of 1 kg.
- LCI tractor 7200h (1p).tab: this table presents the life cycle inventory of the materials, energy, infrastructure needed for the manufacturing and maintenance of a 7200 h lifetime tractor for a functional unit of 1 piece (i.e. the total weight of the tractor).
- LCI tractor 12000h (1kg).tab: this table presents the life cycle inventory of the materials, energy, infrastructure needed for the manufacturing and maintenance of a 12000 h lifetime tractor for a functional unit of 1 kg.
- LCI tractor 12000h (1p).tab: this table presents the life cycle inventory of the materials, energy, infrastructure needed for the manufacturing and maintenance of a 12000 h lifetime tractor for a functional unit of 1 piece (i.e. the total weight of the tractor).

For each of these LCI, the reference product, the inputs from technosphere, the reference unit, the hypotheses made and the references used are detailed. A list of possible process names for each by-product and input from technosphere is proposed indicatively. These process names come from the ecoinvent v3.7 database (system modelling “Allocation, cut-off by classification”). Names for output to ecosphere are not proposed.

3. Experimental Design, Materials, and Methods

In order to build the LCI of the agricultural tractor, a description of all the components was done based on the technical system from the agricultural manufacturer [3]. For confidential reason, the manufacturer that provided the technical system will remain anonymous.

These components were classified in several modules such as electronics, filters, fluids, tyres, battery, cabin and main tractor structure.

The following sections describe the material and methods used for data collection and treatment, the assumptions made regarding the energy used for manufacturing and maintenance and the road vehicle factory needed for manufacturing.

3.1. Electronics Module

Each electronic component from the technical system was analysed. Fuse, relay and resistor were all modelled as resistor as no other process are available in current LCA databases. The weight for each electronic component comes from [4] and own measurements. The control boards n°1 and n°4 are surface-mounted while the other boards are through-hole mounted. It was assumed that the on-board sensors are composed of copper (10%), polyethylene (45%) and brass (45%) and the solenoid valves are composed of copper (40%), permanent magnet (i.e. neodymium) (40%) and stainless steel (20%). In addition to these electronic components, the tractor is equipped with i) 7 electronically controlled solenoid valves of 1 kg each, ii) 11 electronic commands used to control cabin climatization, panel control and autopilot embedded in a plastic box for a total weight of 4.86 kg, and (iii) 14 electronic commands used to control GPS, cabin climatization, motor, gear box, transmission, front and rear lift, isobus and brakes embedded in an aluminium box for a total weight of 7.54 kg.

Data for GPS and camera composition comes from [5] and weight from expert opinion. Data for alternator weight comes from the website agriconomie.com. Its composition is based on expert opinion and assumed to be copper (10%), steel (60%) and aluminium (30%). It was not possible to estimate the length of the electric cables in the tractor based on the technical system. An assumption of 10000 m length was done based on expert opinion but this value is highly uncertain as no data are available.

It was assumed that all the control boards as well as the GPS and camera were not replaced during the tractor lifetime. However, it was considered a replacement of 10% of component weight for the electronically controlled solenoid valves and the electronic controllers, a replacement of 2 on-board sensors and 2 solenoid valves during the tractor lifetime.

Energy for electronic components manufacturing, waste and outputs to ecosphere during manufacturing are not considered due to a lack of data.

The frequency of alternator replacement is calculated by dividing the tractor lifetime by the alternator lifetime.

3.2. Filters Module

In this module, the motor oil filter, gasoil filter, hydraulic primary and secondary filters, hydraulic filter front PTO, ADBlue® internal and external filters, cooling liquid filter, motor air filter, cabin filter, brake filter and catalyst converter were considered.

Data for catalyst converter weight comes from expert opinion and its composition comes from [6–8]. Data for other filters weight come from the website agriconomie.com, their composition comes from expert opinion.

Energy for filters manufacturing, waste and outputs to ecosphere during manufacturing are not considered due to a lack of data.

The frequency of each filter replacement is calculated by dividing the tractor lifetime by each filter replacement frequency.

3.3. Fluids Module

Tank capacity for each fluid comes from the maintenance service of the manufacturer. In order to simplify the lubrication oil modelling, it was assumed that the same oil is used by the motor and the hydraulic system. Data for the cooling liquid composition come from [9–11] and data for brake fluid composition come from [12].

The AdBlue® liquid composition is not specified in the composition table as it is not related to the tractor manufacturing but needed when assessing the tractor use in LCA of agricultural system. The AdBlue® is composed as pure urea (32.5%) and distillated water (67.50%). The amount of AdBlue® consumed during the tractor used is estimated between 3 and 10 % of fuel consumed by the tractor during the agricultural operation.

The weight of the hydraulic hoses was calculated assuming a density of 0.7 kg/m and a composition of synthetic rubber (75%) and steel (25%). A 10% replacement during the tractor lifetime was assumed for the hydraulic hoses.

Energy for fluids manufacturing, waste and outputs to ecosphere during manufacturing are not considered due to a lack of data.

The frequency of each fluid replacement is calculated by dividing the tractor lifetime by each fluid replacement frequency.

3.4. Tyres Module

The front and rear tyres were modelled based on technical characteristic on the tractor. The weight of the front and rear tyres is based respectively on a “16.9R28 MICHELIN AGRIBIB 141A8/138B TL” tyre [13] and a “20.8R38 MICHELIN AGRIBIB 153A8/150B TL” tyre [14].

Both rear and front tyre composition is assumed to be 76% synthetic rubber and 24% steel.

The frequency of tyre replacement is calculated by dividing the tractor lifetime by the tyre replacement frequency.

3.5. Battery Module

The life cycle inventory of the lead battery comes from [15]. The weight of the battery is calculated based on a mean for lead battery weight available on the website agriconomie.com. The energy for the battery manufacturing was included as well as the battery recycling. A value of 9.2 MJ is required to manufacture the battery [15]. The distribution between the type of energy comes from [16] and is as follow: 4.3% petroleum product, 30.9% natural gas, 0.6% heat, 63.6% electricity, 0.6% renewable energy (for electricity). It is assumed that only virgin material is used for the battery manufacturing.

Battery recycling is estimated to be around 95% [15].

The frequency of the lead battery replacement is calculated by dividing the tractor lifetime by battery replacement frequency.

3.6. Cabin Module

The tractor cabin is equipped with 3 LCD screens and a cabin seat. The weight of the LCD screen is estimated by expert opinion while the cabin seat weight comes from the website agriconomie.com. The cabin seat composition is assumed to be polyurethane foam (13%), steel (71%) and cotton (16%). The ratio between foam and cotton comes from [17]. It is assumed that the foam and cotton is replaced once in the tractor lifetime.

Energy for cabin seat manufacturing, waste and outputs to ecosphere during manufacturing are not considered due to a lack of data.

3.7. Main Tractor Structure

The tractor structure is composed of glass, steel, cast iron and alkyl paint. The weight of the glass comes from the website agriconomie.com based on the technical characteristic of the tractor.

The amount of paint needed during manufacturing is estimated at 5 litres per layer assuming 2 layers painting. The weight of the paint is calculated based on a 1.54 kg/L paint density. It is assumed that the tractor has a double layer painting during its whole lifetime.

The weight of the steel and cast iron is calculated based on the difference between the total weight of the tractor and the sum of the weights of filter and fluid, battery, tyres, electronic components, glass, and alkyd paint. The weight of steel and cast iron therefore represents 85.43% of the total tractor weight. The ratio between steel and cast iron comes from [17] and is respectively 66.6% and 33.4%. A 20% repair factor is assumed for steel, glass and cast iron [18].

3.8. Energy Used for Manufacturing and Maintenance

The energy used for manufacturing is calculated based on the energy for tractor manufacturing (27.63 MJ/kg) and the energy for tyre manufacturing (85.8 MJ/kg) [19]. The distribution between the type of energy comes from [16] and is as follow: 4.3% petroleum product, 30.9% natural gas, 0.6% heat, 63.6% electricity, 0.6% renewable energy (for electricity).

The energy used for the tractor maintenance is estimated to be 49% of the energy used for manufacturing [19].

3.9. Road Vehicle Factory Infrastructure

The amount of road vehicle factory is calculated based on a 50 years lifetime according to [20] and an annual production of 10,000 tractors of 7,300 kg average weight per year.

3.10. Waste Treatment

The waste treatment of lubricating oil, graphical paper from filters, aluminium, glass, synthetic rubber, steel, cast iron and used printed wiring board modelled for tractor maintenance and manufacturing are included in the LCI of agricultural tractor. It was considered that these materials are considered wastes at the tractor end-of-life (steel, cast iron, used wiring board, aluminium, glass) or once replaced after maintenance (lubricating oil, graphical paper). Specific considerations were done for steel and tyres for which the following specifications for waste treatment were considered: 83% of steel is recycled [21], 25.84% and 74.16% of tyres are respectively recycled and incinerated [22]. The other materials go into a single waste treatment stream.

Ethics Statements

The author assures that the work and manuscript follow and meet the ethical requirements of the journal. The work does not involve studies with humans or animals.

Declaration of Competing Interest

The author declares that she has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Life Cycle Inventory of agricultural tractors (Original data) (Dataverse).

CRediT Author Statement

Marilys Pradel: Conceptualization, Methodology, Resources, Validation, Visualization, Writing – original draft.

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References

[1] M. Pradel, M. de Fays, C. Seguineau, Comparative Life Cycle Assessment of intra-row and inter-row weeding practices using autonomous robot systems in French vineyards, Sci. Total Environ. 838 (Part 3) (2022) 156441.

[2] AXEMA, Immatriculations des Tracteurs Agricoles en 2022, 2023, p. 7. Available at https://www.axema.fr/index.php/actualite/communique-de-presse-immatriculations-des-tracteurs-agricoles-2022 .
[3] Tractor manufacturer, Technical Systems – Service & Parts. April 2022, 2022, p. 4680.
[4] R. Hischier, M. Classen, M. Lehmann, W. Scharnhorst, Life cycle inventories of electric and electronic equipement: production, USA and Disposa, in: Ecoinvent report n°18 Empa /Technology & Society lab, Swiss Cnetre for Life Cycle Inventories, Dübendorf, 2007, p. 200.
[5] Gawron, et al., Life Cycle Assessment of Connected and Automated Vehicles: Sensing and Computing Subsystem and Vehicle Level Effects, Environ. Sci. Technol. 52 (5) (2018) 3249–3256.
[6] Amatayakul, et al., Life cycle assessment of a catalytic converter for passenger cars, J. Clean. Prod. 9 (5) (2001) 395–403.
[7] Nazmul Islam, et al., Life cycle impacts of three-way ceramic honeycomb catalytic converter in terms of disability adjusted life year, J. Clean. Prod. 182 (2018) 600–615.
[8] Belcastro, Life Cycle Analysis of a Ceramic Three-Way Catalytic Converter, 2012, p. 87. Master report http://seeds4green.net/sites/default/files/Belcastro_EL_T_2012.pdf .
[9] HD Expert, Introduction to Coolant Technology, 2023, p. 3. pages. Available at https://hdexpert.com/wp-content/uploads/2020/03/Whitepapers_1.pdf .
[10] Coolant universityModule 2 – Coolant composition, 2023 Online video. Available at https://coolantuniversity.com/video/coolant-composition/ .
[11] Coolant universityModule 3 – Coolant inhibitors, 2023 Online video. Available at https://coolantuniversity.com/video/corrosion-inhibitors/ .
[12] RRS direct, ABC Book of Brake Fluid, 2023, p. 5. Available in French at https://rrs-direct.com/pub/media/notices/abecedaire-liquide-de-frein.pdf .
[13] Heuver website16.9R28 MICHELIN AGRIBIB 141A8/138B TL characteristics, 2023 Available at https://www.heuver.fr/product/b16900028mia8agr01/16-9r28-michelin-agribib-141a8-138b-tl .
[14] Heuver website20.8R38 MICHELIN AGRIBIB 153A8/150B TL Characteristics, 2023 Available at https://www.heuver.fr/product/b20800038mia8agr00/20-8r38-michelin-agribib-153a8-150b-tl .
[15] Sullivan, Gaines, A Review of Battery Life-Cycle Analysis: State of Knowledge and Critical Needs, 2010 45 pages. Available at https://publications.anl.gov/anlpubs/2010/11/68455.pdf .
[16] CERENDonnées 2016 Sur L'énergie dans L'industrie. Mise à jour, 2020 https://www.ceren.fr/publications/les-publications-du-ceren/.
[17] E.J. Mantoam, T.L. Romanelli, L.M. Gimenez, Energy demand and greenhouse gases emissions in the life cycle of tractors, Biosyst. Eng. 151 (2016) 158–170.
[18] T. Nemecek, T. Kägi, in: Life Cycle Inventories of Swiss and European Agricultural Production Systems. Final Report Ecoinvent v2.0 n°15a, Agroscope Reckenholz-Taenikon Research Station ART, Swiss Centre for Life Cycle Inventories, Zurich and Dübendorf CH, 2007, p. 308.
[19] W. Bowers, Agricultural field equipment, in: R C Fluck (Ed.), Energy in World Agriculture, Elsevier, Amsterdam, 1992, pp. 117–129.
[20] M. Spielman, C. Bauer, M. Tuchschimd, in: Transport Services. Ecoinvent Report n°14, Swiss Centre for Life Cycle Inventories, Dübendorf, 2007, p. 237.
[21] ArcelorMittal, Le Recyclage pour Stratégie. La Revue des Marques - n°104, 2018, pp. 24–27 https://www.ilec.asso.fr/uploads/media/5bbfb06d68358.pdf.
[22] In Extenso Innovation Croissance, Venice GRAF, Sarah PÉRENNÈS. ADEME, Thomas GRANDIN. Septembre 2021. Pneumatiques – Données 2020 – Rapport annuel - 58 pages. https://librairie.ademe.fr/dechets-economie-circulaire/5184-pneumatiques-donnees-2020.html