PLEX

Plastic litter extension for ecoinvent

estimating plastic litter over the life cycle

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1 Introduction

This work builds on earlier work by Ciroth & Kuoame (2019) that aimed to support the modelling of plastic litter in life cycle inventories. Plastic pollution is a globally identified problem currently receiving much attention, yet it is still overlooked when performing life cycle analysis (LCA). The idea presented by Ciroth & Kuoame is that the plastic litter of a certain (unit) process is calculated by multiplying the total amount of expected plastic inflow to that process (by adding the plastic content of flows entering that process) with the littering probability (the expected amount of litter) of that process, see equation below.

$$PL_j = p_{litter} * \sum_{i=1}^{n} PC_i$$

Where:

- PL_j = plastic litter from process j [kg]
- P_{litter} = expected probability of litter from process j [%]
- PC_i = plastic content of flow i [kg]
- n = number of incoming flows for process j

The aim of this work is to create an extension of the ecoinvent database to be able to perform this calculation, i.e. add a new feature to the database to make this calculation possible. This includes to make an estimation of the plastic content of all flows as well as making estimations for the weight of flows in cases where the flow is not expressed in mass to be able to convert the unit to mass. It also includes estimating the littering probability of all processes. Important to keep in mind is that these are initial and rough estimations. Since the database contains over 3000 flows and more than 20 000 processes, they are estimated in groups. The content and probability are estimated according to classes further described in section 2, "Assumptions and extension of the database". Hence, the resulting output should not be taken as an accurate number, but rather be used to evaluate potential internal relationships (i.e. what flows imply a potentially high vs. low risk to create plastic pollution?) and hot-spot analysis. This is also an initial attempt to test a calculation method that could be further refined to give more accurate results.

2 Assumptions and extension of the database

Both plastic content of flows and the littering probability of processes were defined according to pre-defined classes.

For all flows, the plastic content is estimated as weight-% of that flow. Flows are evaluated as groups, e.g. all flows within the category "D: Electricity, gas, steam and air conditioning supply" are assumed to have 0% plastic content, and are not evaluated individually. All flows within the category "2013: Manufacture of plastics and synthetic rubber in primary forms" are assumed to have a 100% plastic content. The plastic content of flows is in general grouped as:

- all plastic 100% (example: primary plastic flows, e.g. polyethylene)
- very high 95% (example: plastic products, waste plastics)
- high 50% (example: paints)
- medium 10% (example: vehicles)
- low 0.1% (example: fibreboards, soaps)
- very low 0.0001% (example: most waste flows with no obvious plastic content)
- none 0% (example: metals, electricity)

In some exception cases, these classes are not used, e.g. when the plastic content could be generalized by another source. For example, the plastic content *of computer, electronic and optical products* was assumed to be 20%, based on the plastic content of e-waste (Sahajwalla & Gaikwad, 2018). The contents of flows in group A: Agriculture, forestry and fishing were estimated based on work by Richardson, Hardesty, & Wilcox (2019) and the report Sowing a plastic planet - how microplastics in agrochemicals are affecting our soils, our food and our future by Carlini & Drugmand (2022).
For all processes, the plastic litter-potential is estimated according to the same system and refers to the expected littered amount. Processes are also categorized as open (the pollution is directly released to the environment. e.g. tyre wear) or closed (the litter is kept within another system, such as inside an airplane), and based on what type of release it is; use, unforeseen disposal or accidental.

For all flows with another flow property than mass, the mass per unit is estimated. This is done in a similar way as the plastic content, i.e. in classes, for most flows. Most flows that haven't got mass as a property has “number of item(s)”, and the weight of these are estimated in classes according to the following list:

- very large > 100 000 000 kg, all objects in this category have the weight 5 000 000 000 (example: airport or reservoir for hydropower plant)
- large > 1 000 000 kg, = 50 000 000 kg (example: factories or smaller infrastructures, e.g. mining infrastructures)
- medium > 10 000 kg, = 500 000 kg (example: most buildings, airplanes, ships)
- small > 100 kg, = 5000 kg (example: vehicles and larger machines)
- very small < 100 kg, = 50 kg (example: domestic goods and everything smaller than that)

For other units (e.g. area, length or volume), the weight/unit was either defined in the description of the processes producing the flow and could be used directly, or the weight-class was estimated according to the list above. Hence, some numbers are very exact while others are more general.

3 Implementation and examples

Potential plastic litter is added to the database as a new exchange, i.e. as a new elementary output flow from all processes of concern (where the plastic litter > 0). It then appears as an output flow in openLCA, see Figure 1 .

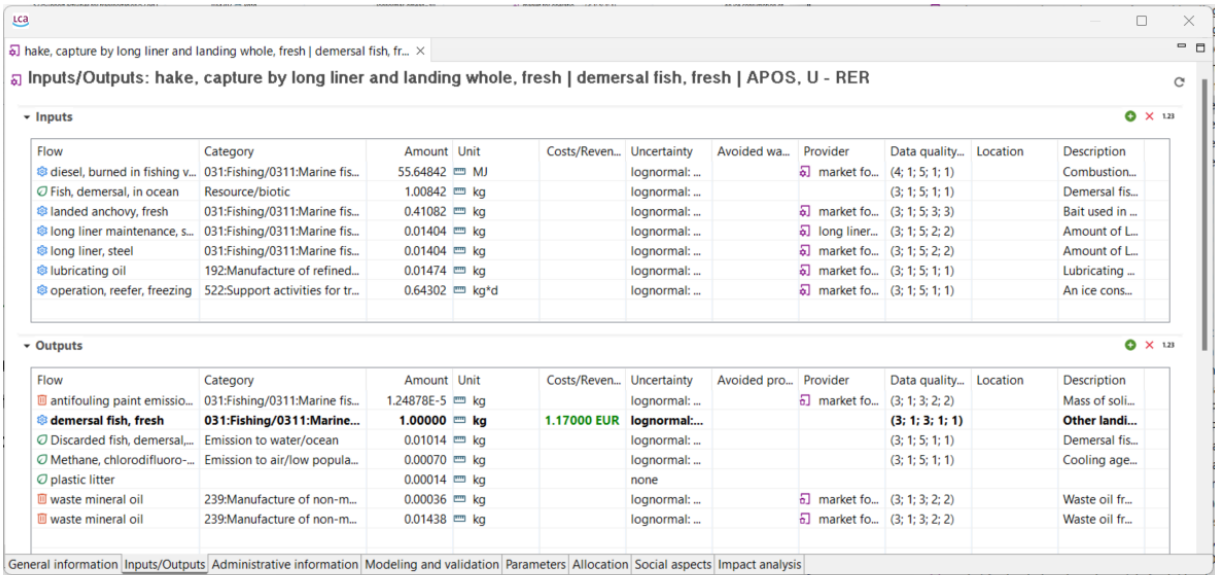

Figure 1: Demonstration of how plastic litter appear as an output flow in openLCA.

The total plastic litter of a full life cycle could be calculated by creating a new impact category that accounts for the plastic litter. See Figure 2 and Figure 3 for example calculations of two different processes.

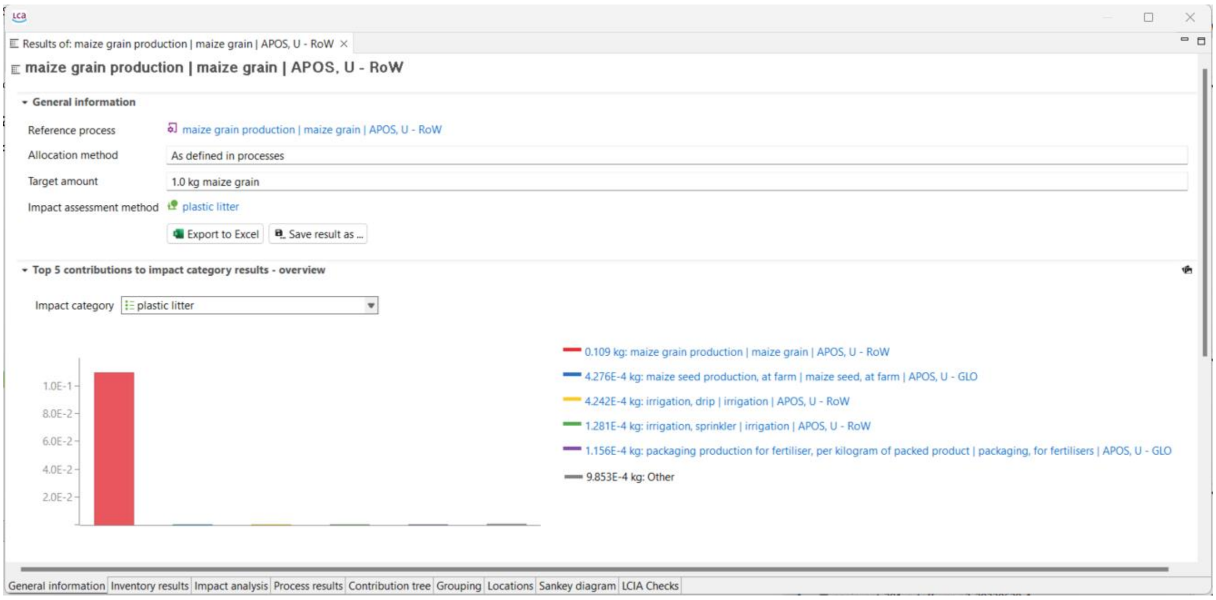

Figure 2: Example of plastic litter from process "maize grain production".

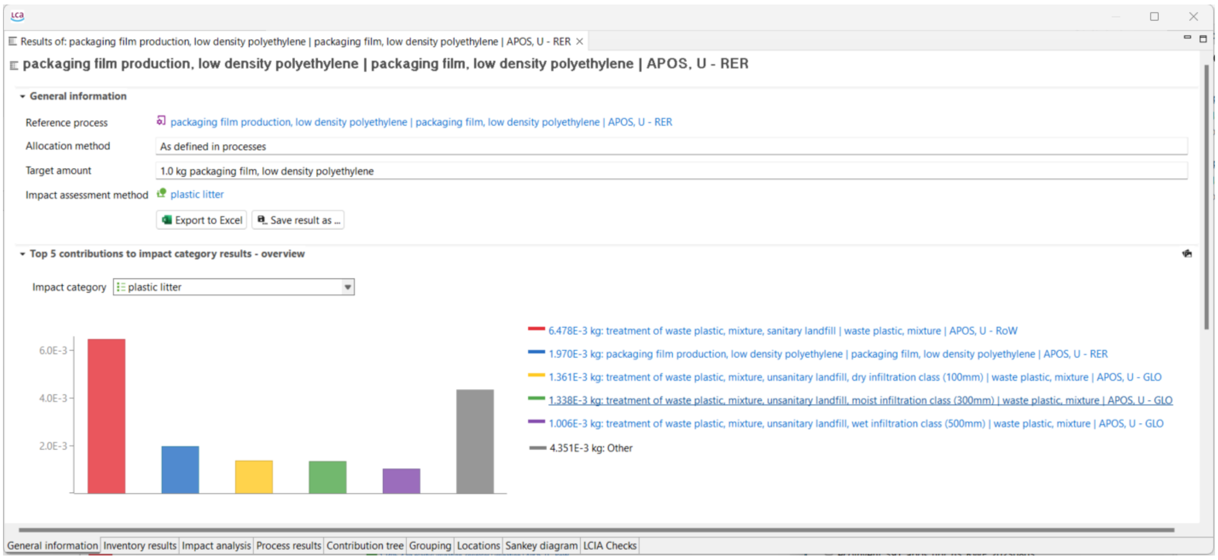

Figure 3: Example of plastic litter from process "packaging film production".

It is also possible to display the contribution of different processes connected to the studied process to its total plastic pollution, see Figure 4. In the "locations" tab, it is possible to see where the biggest impact occurs, see Figure 5. In Figure 6, the Sankey diagram produced when calculating the resulting plastic litter of “packaging film production” is displayed. The diagram shows how different processes contribute to the total plastic litter of the studied process.

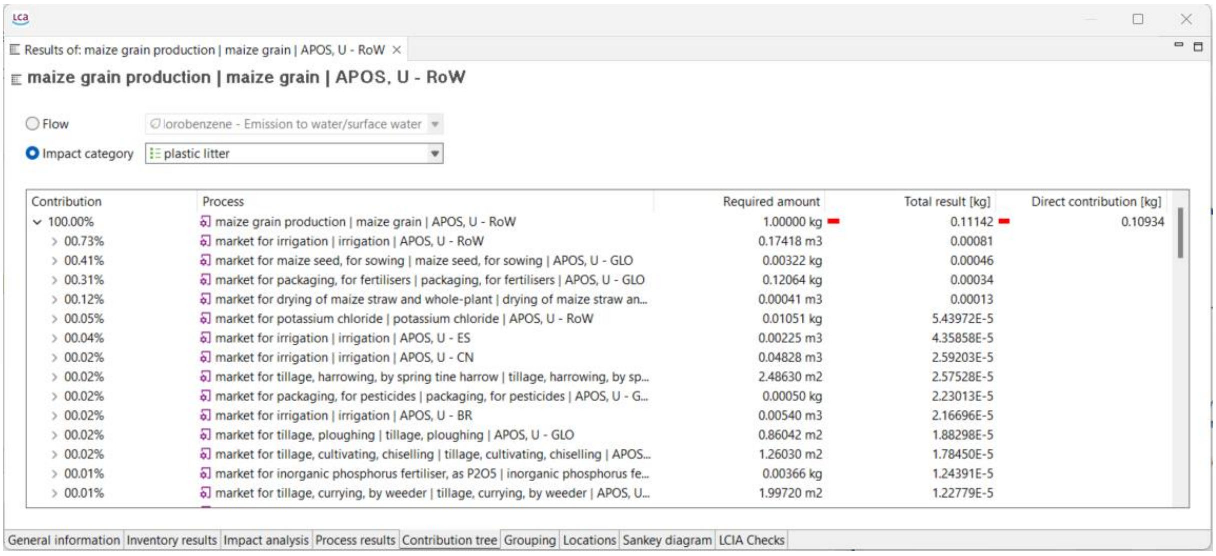

Figure 4: Contribution of other processes (contribution tree) to the plastic litter of "maize grain production".

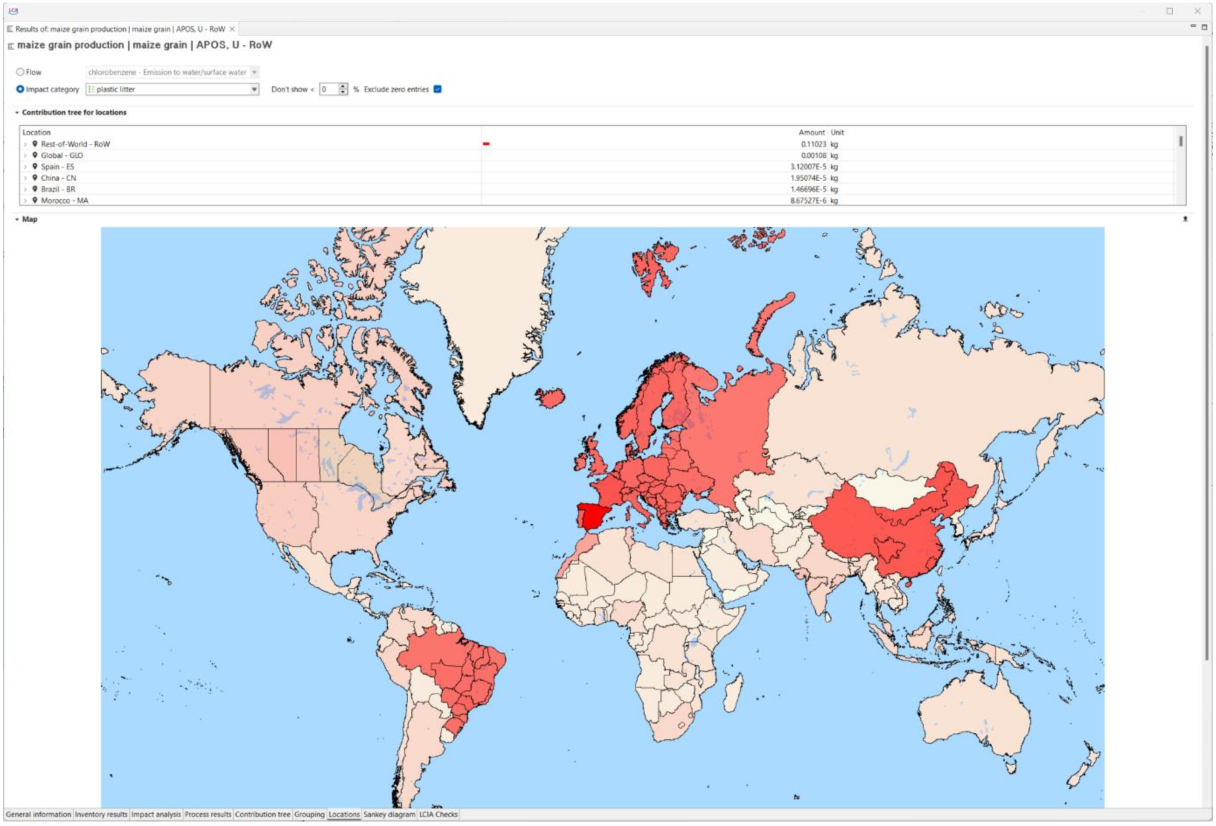

Figure 5: Locations of plastic litter occurring as a result of "maize grain production".

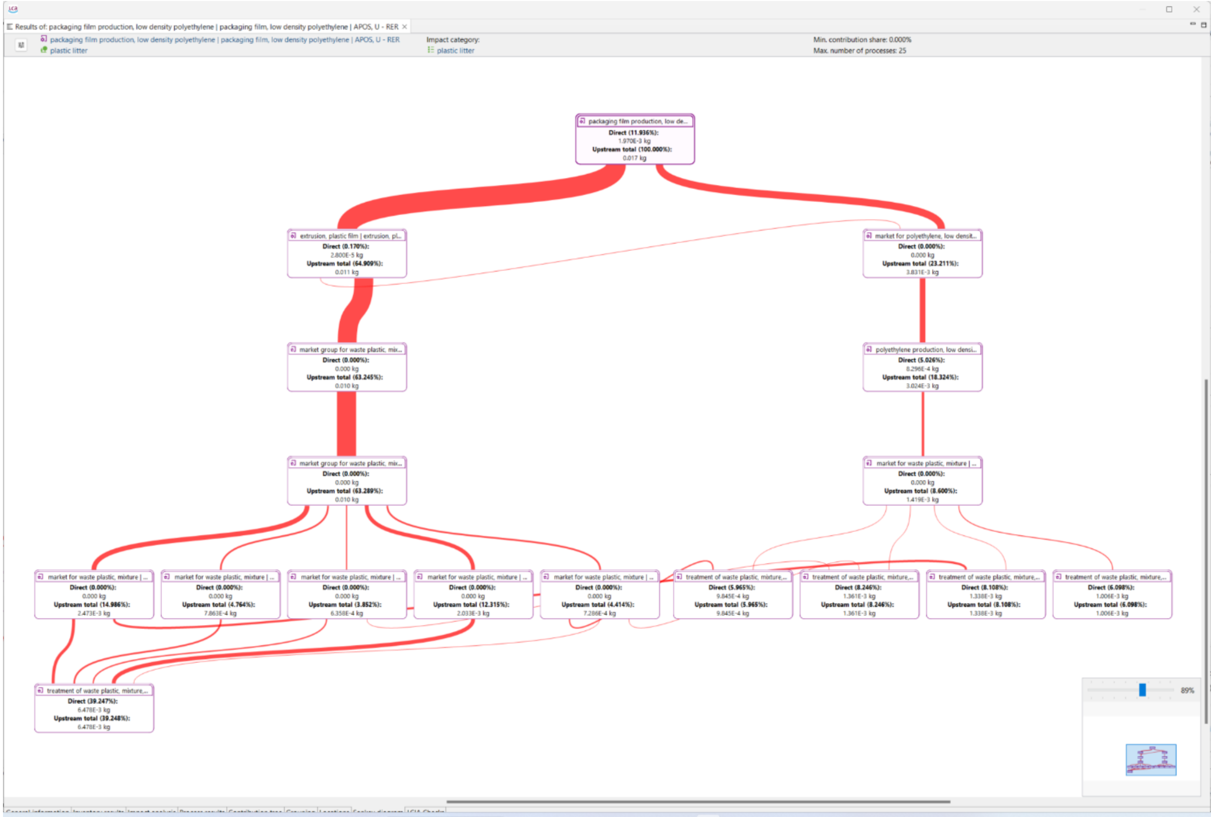

Figure 6: Sankey diagram showing different processes contribution to the total plastic litter from "packaging film production".

When reviewing all processes that now have a plastic output as a result of the extension, the highest plastic litter flows are found for large construction processes, such as airports or powerplants, which is understandable given the large amount of material entering such processes. The lowest plastic litter flows still larger than zero are found for e.g. production of cement, operation of mines and rock crushing.

3.1 Example of a product system

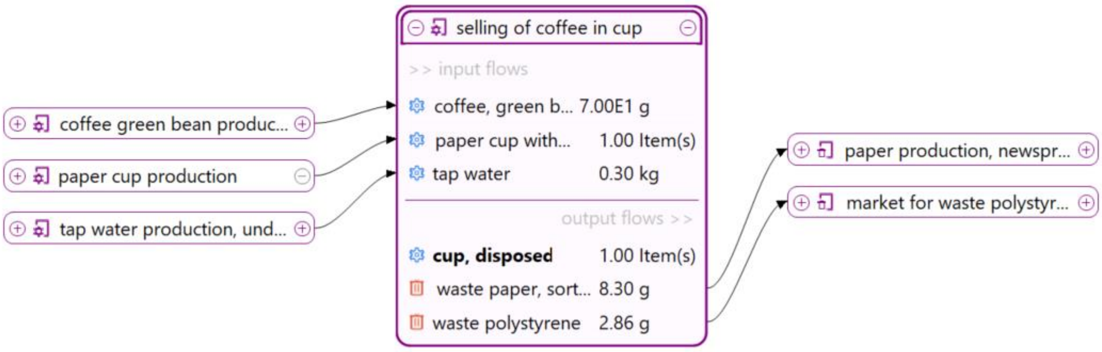

Figure 7: Example of a simplified product system.

If we construct a simplified product system (see Figure 7) based on a case study for selling coffee in a single-use paper cup (Martin, Bunsen, & Ciroth, 2018), taking only the materials and coffee into account (hence ignoring e.g. energy requirements and transport), we could calculate the total plastic litter from the entire system (0.05253 kg plastic/item) and also see where in the supply chain the litter appear, see Figure 8. The contribution and regionalization of the results are displayed in Figure 9 and Figure 10. What we could see in these is that the biggest contributor to the plastic litter in our example is the cultivation of coffee-beans (probably because it is accounted for that plastic coating is used for fertilizers and pesticides as described in Carlini & Drugmand, 2022), and consequently a big impact also appear in Colombia, one of the major coffee-producing countries (ICO, 2022).

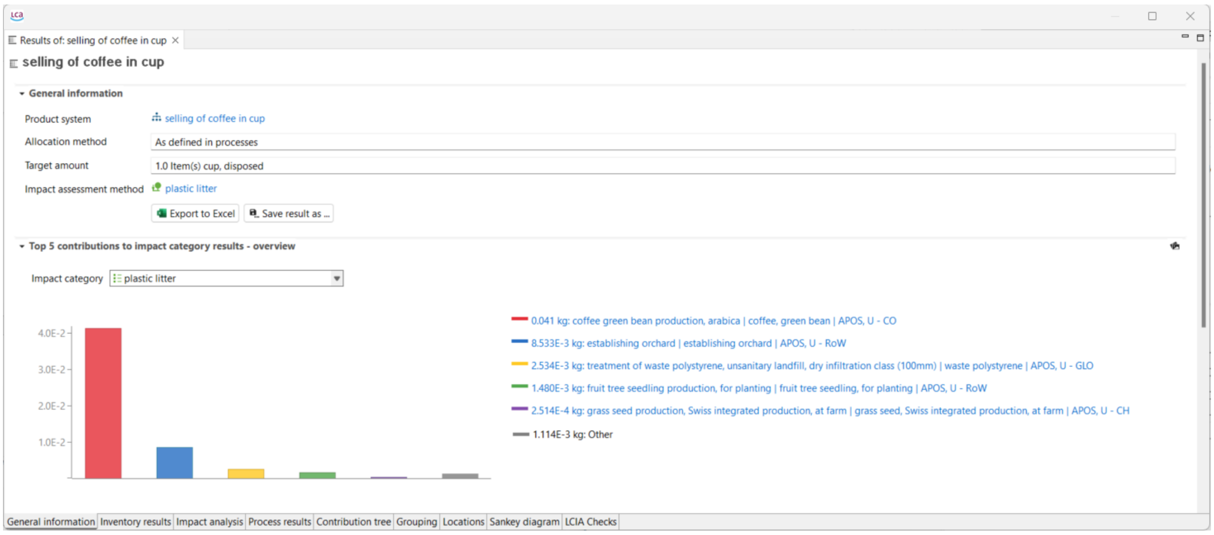

Figure 8: Top 5 contributing processes to plastic litter in the simplified product system.

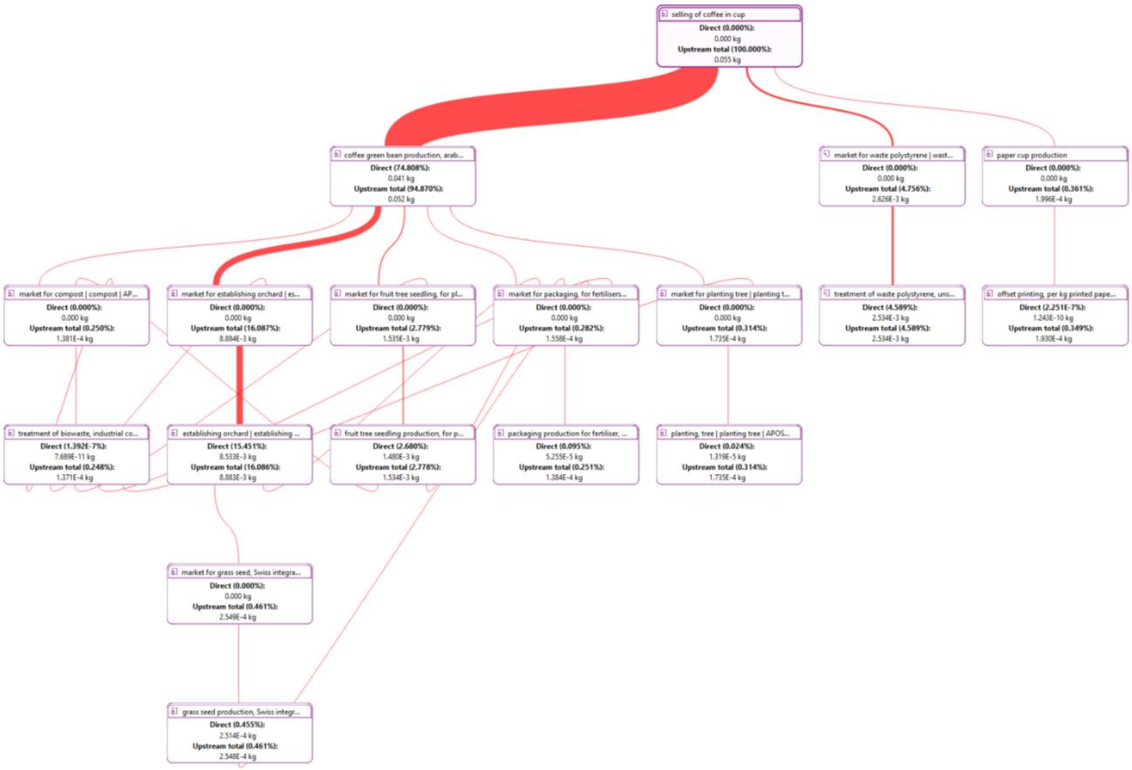

Figure 9: Sankey of the contribution distribution for our simplified example.

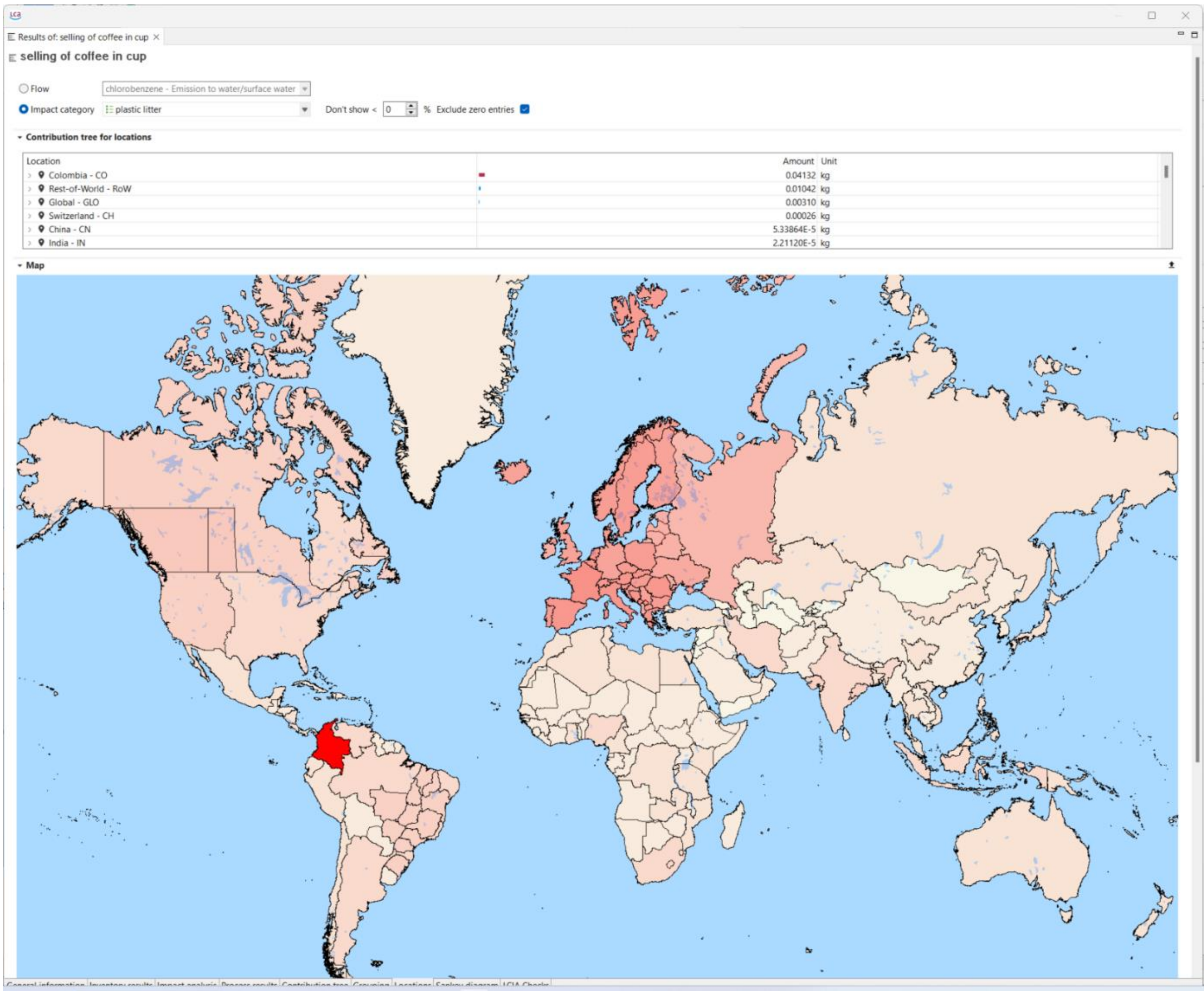

Figure 10: Regional distribution of the plastic litter impact for our simplified example.

4 Further work

There are many things that could be done to continue this work, for example:

1. As both flow plastic content and littering probability are rough estimates, these estimates could be refined. Initially the groups could be smaller and hence more accurate, and the classification could include more classes. Ideally, the plastic content is estimated individually for each specific flow, and the littering probability for each specific process.
2. The flows are not yet put in categories; it is not distinguished where the litter goes (e.g. to soils or marine waters).

3. Different geographical regions are expected to have different littering probabilities, based on that the flows of plastic litter are larger in some regions than in others (UNEP, u.d.), and hence a geographical differentiation would be preferable.
4. There is currently no differentiation of plastic type nor size of the litter (all plastic litter is accounted for as one impact category). Preferably, one could in the future differentiate between types (PET, PP, PE, PVS, etc) and sizes (macro, micro, or even specified sizes).
5. Supposedly, many flows of plastic litter are disregarded in the currently available databases, e.g. cigarette butts (Ciroth & Kuoame, 2019) or aspects of human behaviour.

5 Contact

The database extension will be made available on openLCA Nexus, https://nexus.openlca.org. For any feedback about use, bugs and implementation in openLCA as well as questions or other comments, please contact us:

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