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PROXYLCA

A scalable proxy-based approach to closing life cycle inventory (LCI) data gaps of food imports

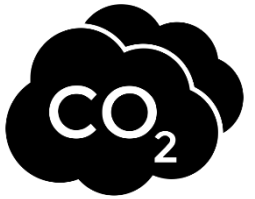
Clara Payró, Justine Brun, Maria Bystricky, Oliver Taherzadeh, Paul Behrens, Mélanie Douziech

Ökobilanz Plattform – May 5th 2026

Context: impacts of our food system

70% of global freshwater extraction[1]

50% of habitable land occupation[2]



25-35% of total global GHG emissions[3]

Sources: (1) Altobelli et al (2018) *; (2)* Rockström et al. (2026) *; (3)* Crippa et al. (2021)
Icon sources from the NounProject: Docktor Icon Shop, mynamepong, ProSymbols, HeadsOfBirds

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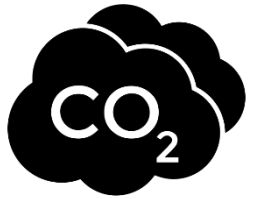

25-35% of total global GHG emissions

1/3 of agricultural emissions are linked to trade[1]

Sources: (1) Foong et al (2022)
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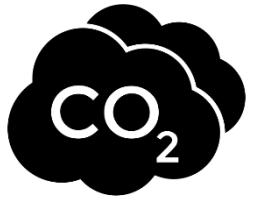

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➔ Importing country as a lever for environmental impact mitigation

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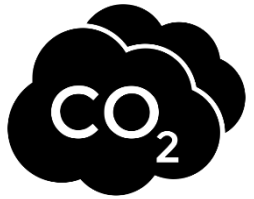


25-35% of total global GHG emissions

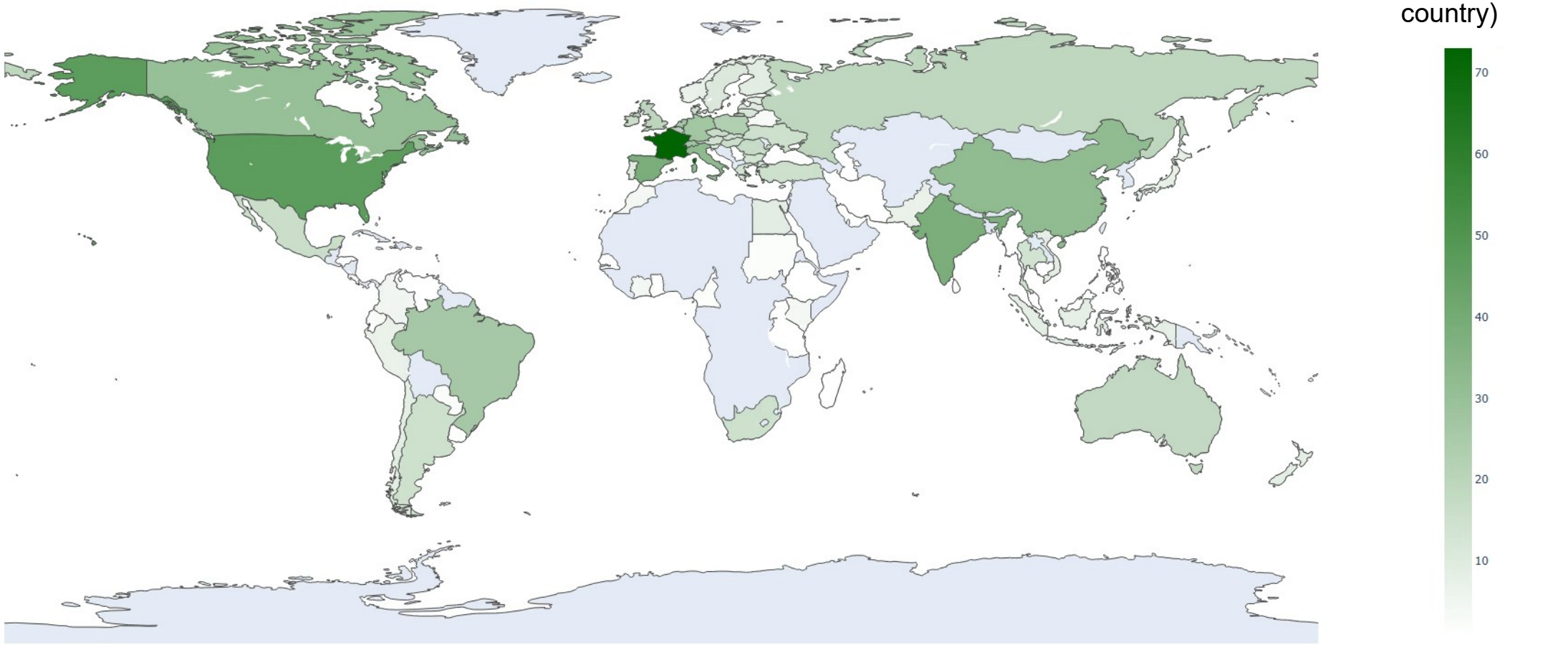
1/3 of agricultural emissions are linked to trade

➔ Importing country as a lever for environmental impact mitigation

➔ Life Cycle Assessment for the environmental impact assessment of products from around the world

Icon sources from the NounProject: Docktor Icon Shop, mynamepong, ProSymbols, HeadsOfBirds

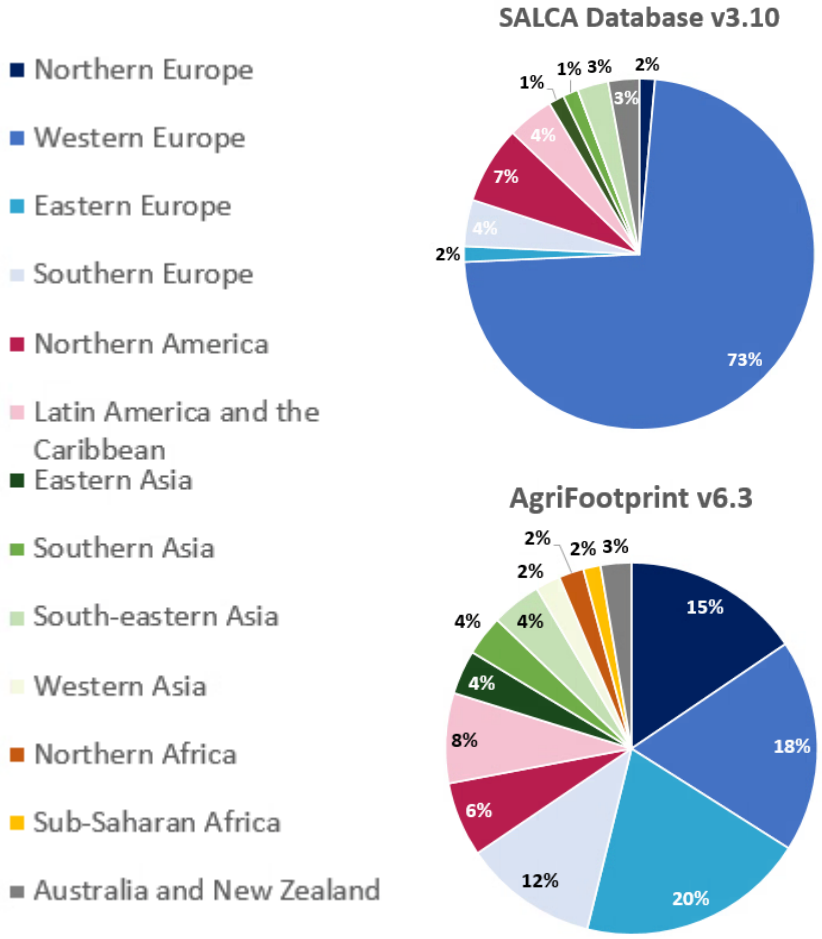
Problem: Environmental Impact Data of Food Products are missing



Limited geographical coverage of at-farm food products across 5 databases
(Agri-footprint, Agribalyse, World Food Life Cycle Database, SALCA, ecoinvent)

Problem: Choosing a single database is difficult

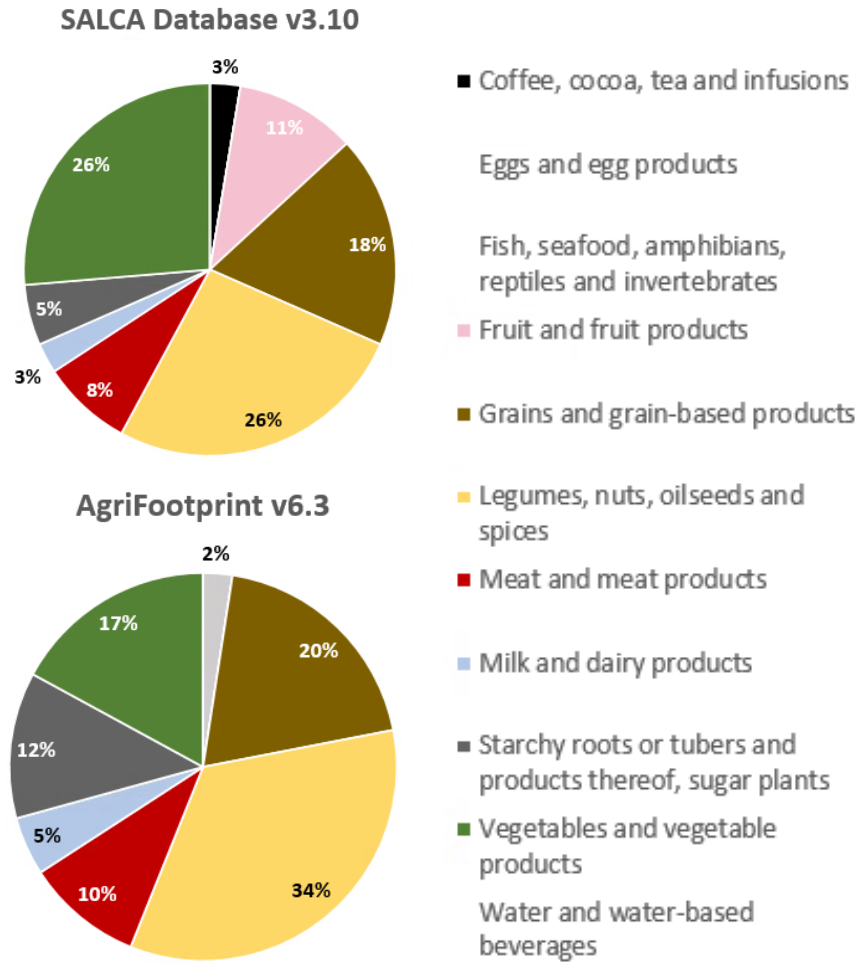
Geographical coverage



Data limited to Western Europe, more variety of products

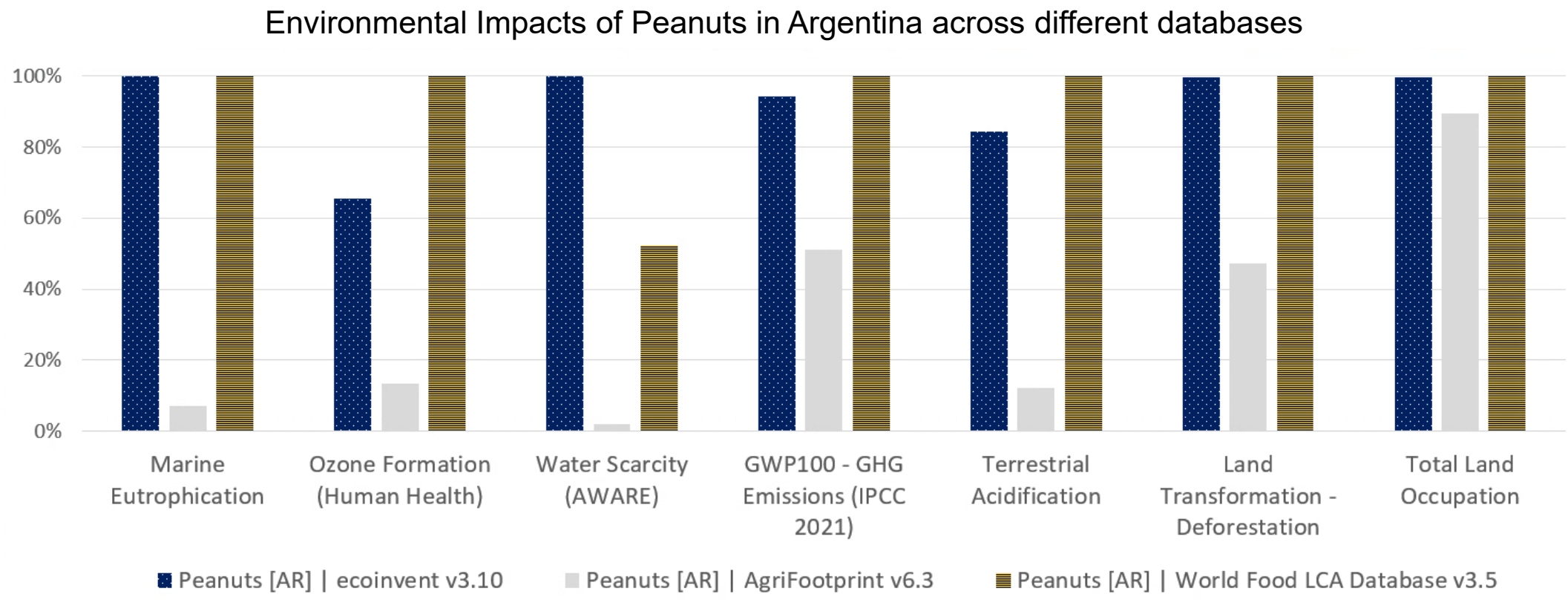
Broader geographical coverage, but no data on fruits

Product coverage



Problem: Sources of environmental impact data cannot be combined

Environmental Impacts for the same product and country can be widely different across LCI databases



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Solution: PROXYLCA Framework

- No single database currently provides comprehensive coverage of all countries and food products.

Sources: (1) Rimbaud et al. (2025)
Icon sources from the NounProject: Heztasia, HDM, Romaldon, Adrien Coquet

Solution: PROXYLCA Framework

- No single database currently provides comprehensive coverage of all countries and food products.

- Extrapolation methods exist but are not easily scalable for many inventories at once [1]

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- PROXYLCA = a standardised framework that can rapidly fill data gaps without modifying original inventories and their complex emission models

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- Extrapolation methods exist but are not easily scalable for many inventories at once [1]

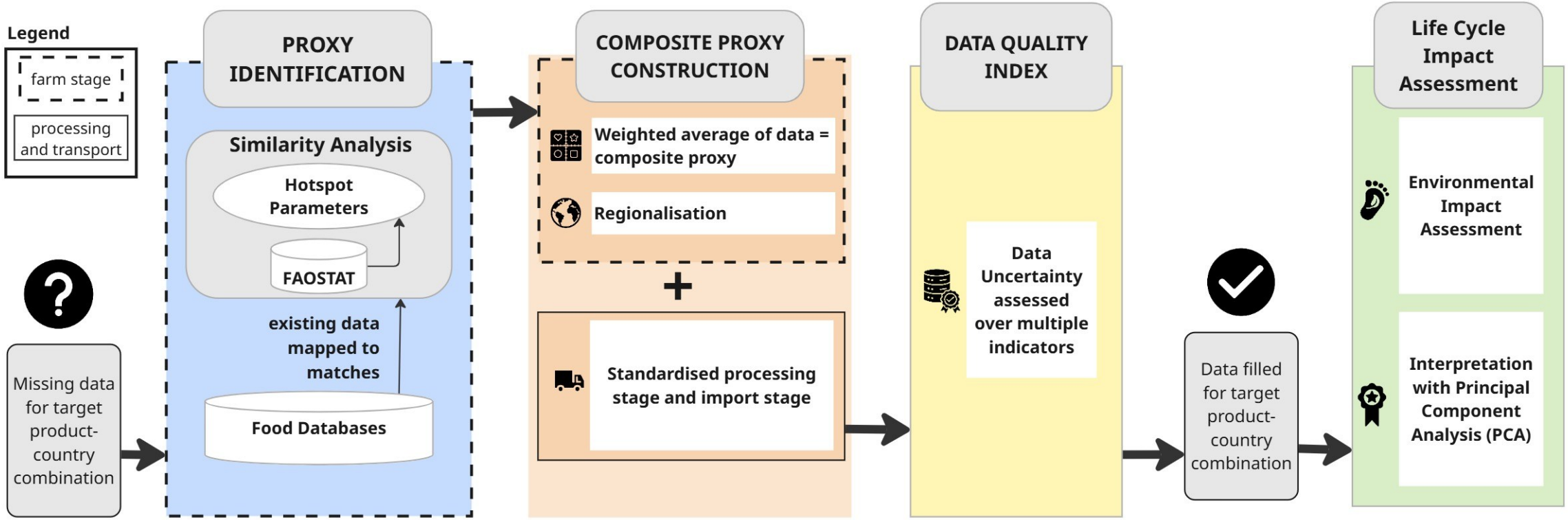
- PROXYLCA = a standardised framework that can rapidly fill data gaps without modifying original inventories and their complex emission models

- Using Apples imported to Switzerland as a case study

Sources: (1) Rimbaud et al. (2025)
Icon sources from the NounProject: Heztasia, HDM, Romaldon, Adrien Coquet

PROXYLCA:
methods behind the framework

PROXYLCA: methods structured around 4 pillars



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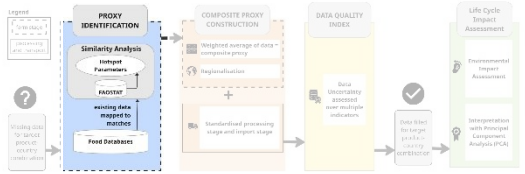
PROXYLCA: Proxy Identification



Number of data inventory per country for Apples across LCA databases

Database	# of countries represented per database
Agribalyse v3.1 - SimaPro	1
SALCA Database v3.10	2
ecoinvent v3.10 - SimaPro	5
World Food LCA Database v3.5 - SimaPro	4
All databases	*8*

1. Define a single database per target products
   - ➢ e.g. our target combination is Apples produced in Switzerland

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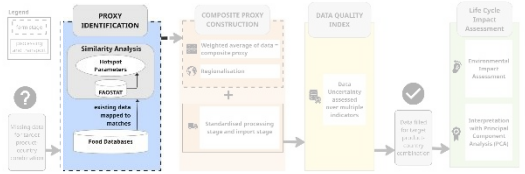
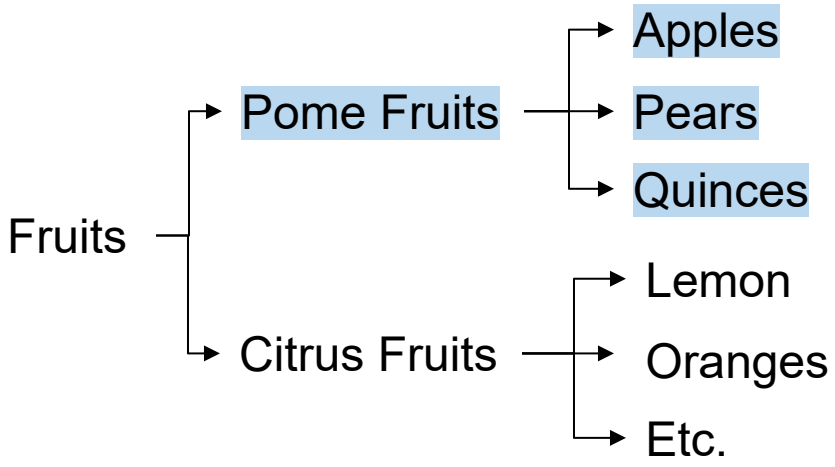
PROXYLCA: Proxy Identification

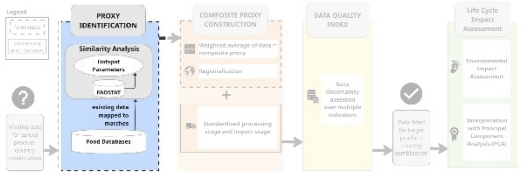


Case Description	Example target combination	Example identified proxy
Case “Perfect Match”: Same product & same country	Apples in Switzerland	Apples in Switzerland
Case 1: Same product & different country	Apples in Switzerland	Apples in France
Case 2: Substitute product, same country	Apples in Switzerland	Pears in Switzerland
Case 3: Substitute product, different country	Apples in Switzerland	Pears in France

2. Identify possible substitute products within same product category



PROXYLCA: Proxy Identification



Target Product	Target Country	Proxy Country	Proxy Product	Hotspot parameters		
				Yield (kg /ha)	Cropland nitrogen per unit area (kg/ha)	Total pesticides use per area of cropland (kg/ha)
Apples	**Switzerland**	**Switzerland**	**Apples**	**59305.94**	**145.90**	**4.83**
Apples	Switzerland	Switzerland	Quinces	59907.55	145.90	4.83
Apples	Switzerland	Switzerland	Pears	53755.52	145.90	4.83
Apples	Switzerland	Chile	Apples	49656.00	88.89	7.79
Apples	Switzerland	Albania	Quinces	56192.04	66.58	0.67
Apples	Switzerland	Italy	Apples	42455.24	71.13	5.43
Apples	Switzerland	New Zealand	Apples	57594.16	28.45	8.54
Apples	Switzerland	Austria	Apples	41574.02	67.87	3.98
Apples	Switzerland	Netherlands (Kingc	Apples	39963.70	170.68	8.89
Apples	Switzerland	New Zealand	Pears	52745.56	28.45	8.54
Apples	Switzerland	Netherlands (Kingc	Pears	37140.70	170.68	8.89
Apples	Switzerland	United Kingdom of	Apples	35293.58	120.97	2.82
Apples	Switzerland	South Africa	Apples	40990.94	25.75	3.29
Apples	Switzerland	United States of Ar	Apples	39059.46	38.31	2.96

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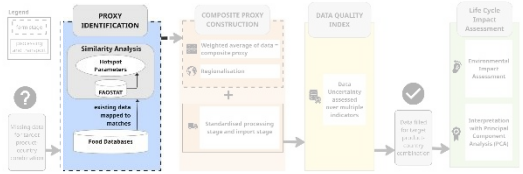
3. Hotspot parameters (defined by existing literature[1]) extracted from FAOSTAT for all countries

Sources: (1) Rimbaud et al. (2025)

PROXYLCA: Proxy Identification



				Hotspot parameters				
Target Product	Target Country	Proxy Country	Proxy Product	Yield (kg /ha)	Cropland nitrogen per unit area (kg/ha)	Total pesticides use per area of cropland (kg/ha)	Distance to Target (euclidean distance)	Rank
Apples	**Switzerland**	**Switzerland**	**Apples**	**59305.94**	**145.90**	**4.83**	**0.00**	**1**
Apples	Switzerland	Switzerland	Quinces	59907.55	145.90	4.83	0.06	2
Apples	Switzerland	Switzerland	Pears	53755.52	145.90	4.83	0.57	3
Apples	Switzerland	Chile	Apples	49656.00	88.89	7.79	1.55	4
Apples	Switzerland	Albania	Quinces	56192.04	66.58	0.67	1.70	5
Apples	Switzerland	Italy	Apples	42455.24	71.13	5.43	2.13	6
Apples	Switzerland	New Zealand	Apples	57594.16	28.45	8.54	2.17	7
Apples	Switzerland	Austria	Apples	41574.02	67.87	3.98	2.24	8
Apples	Switzerland	Netherlands (Kingc	Apples	39963.70	170.68	8.89	2.25	9
Apples	Switzerland	New Zealand	Pears	52745.56	28.45	8.54	2.26	10
Apples	Switzerland	Netherlands (Kingc	Pears	37140.70	170.68	8.89	2.50	11
Apples	Switzerland	United Kingdom of	Apples	35293.58	120.97	2.82	2.53	12
Apples	Switzerland	South Africa	Apples	40990.94	25.75	3.29	2.76	13
Apples	Switzerland	United States of Ar	Apples	39059.46	38.31	2.96	2.77	14

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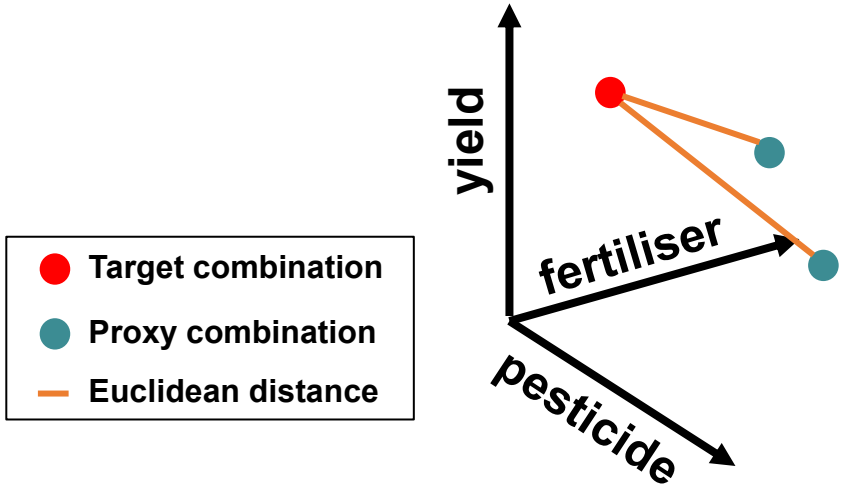
4. Similarity Analysis based on hotspot parameters to identify country-product combinations most similar to a target combination



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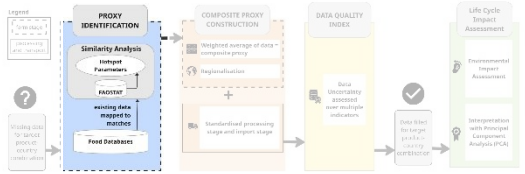
PROXYLCA: Proxy Identification



				Hotspot parameters					
Target Product	Target Country	Proxy Country	Proxy Product	Yield (kg /ha)	Cropland nitrogen per unit area (kg/ha)	Total pesticides use per area of cropland (kg/ha)	Distance to Target (euclidean distance)	Rank	Inventory Data Exisiting
Apples	**Switzerland**	**Switzerland**	**Apples**	**59305.94**	**145.90**	**4.83**	**0.00**	**1**	**No**
Apples	Switzerland	Switzerland	Quinces	59907.55	145.90	4.83	0.06	2	No
Apples	Switzerland	Switzerland	Pears	53755.52	145.90	4.83	0.57	3	No
Apples	Switzerland	Chile	Apples	49656.00	88.89	7.79	1.55	4	Yes
Apples	Switzerland	Albania	Quinces	56192.04	66.58	0.67	1.70	5	No
Apples	Switzerland	Italy	Apples	42455.24	71.13	5.43	2.13	6	Yes
Apples	Switzerland	New Zealand	Apples	57594.16	28.45	8.54	2.17	7	No
Apples	Switzerland	Austria	Apples	41574.02	67.87	3.98	2.24	8	No
Apples	Switzerland	Netherlands (Kingc	Apples	39963.70	170.68	8.89	2.25	9	No
Apples	Switzerland	New Zealand	Pears	52745.56	28.45	8.54	2.26	10	No
Apples	Switzerland	Netherlands (Kingc	Pears	37140.70	170.68	8.89	2.50	11	No
Apples	Switzerland	United Kingdom of	Apples	35293.58	120.97	2.82	2.53	12	No
Apples	Switzerland	South Africa	Apples	40990.94	25.75	3.29	2.76	13	Yes
Apples	Switzerland	United States of Ar	Apples	39059.46	38.31	2.96	2.77	14	Yes

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5. Mapping to available LCI in a single database

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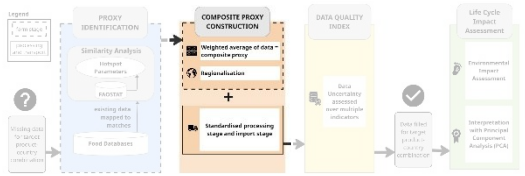
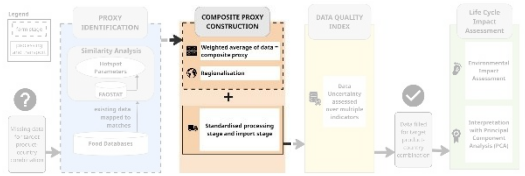
PROXYLCA: Composite Proxy Construction



- No single best proxy ➔ weighted average based on Euclidean distance
- Composite proxy construction is done at-farm gate only ➔ processed products and importing stages are added separately

				Hotspot parameters									
Target Product	Target Country	Proxy Country	Proxy Product	Yield (kg /ha)	Cropland nitrogen per unit area (kg/ha)	Total pesticides use per area of cropland (kg/ha)	Distance to Target (euclidean distance)	Rank	Inventory Data Exisiting	database	LCI Name	Weighted Average
Apples	Switzerland	Chile	Apples	49656.00	88.89	7.79	1.55	4	Yes	ecoinvent v3	Apple {CL}| app	20.0%
Apples	Switzerland	Italy	Apples	42455.24	71.13	5.43	2.13	6	Yes	ecoinvent v3	Apple {IT}| appl	14.6%
Apples	Switzerland	South Africa	Apples	40990.94	25.75	3.29	2.76	13	Yes	ecoinvent v3	Apple {ZA}| app	11.2%
Apples	Switzerland	United States of A	Apples	39059.46	38.31	2.96	2.77	14	Yes	ecoinvent v3	Apple {US}| app	11.2%
Apples	Switzerland	South Africa	Pears	36389.40	25.75	3.29	3.10	21	Yes	ecoinvent v3	Pear {ZA}| pear	10.0%
Apples	Switzerland	Belgium	Pears	34396.08	273.01	6.47	3.33	24	Yes	ecoinvent v3	Pear {BE}| pear	9.3%
Apples	Switzerland	Argentina	Pears	28774.38	21.40	5.24	3.74	29	Yes	ecoinvent v3	Pear {AR}| pear	8.3%
Apples	Switzerland	China	Apples	22128.72	154.46	2.03	3.85	33	Yes	ecoinvent v3	Apple {CN}| app	8.0%
Apples	Switzerland	China	Pears	19192.86	154.46	2.03	4.15	46	Yes	ecoinvent v3	Pear {CN}| pear	7.5%

PROXYLCA: Composite Proxy Construction



- No single best proxy ➔ weighted average based on Euclidean distance
- Composite proxy construction is done at-farm gate only ➔ processed products and importing stages are added separately
- Regionalisation (in progress)

Characterisation factors adapted to match the target country (here CH)

				Hotspot parameters									
Target Product	Target Country	Proxy Country	Proxy Product	Yield (kg /ha)	Cropland nitrogen per unit area (kg/ha)	Total pesticides use per area of cropland (kg/ha)	Distance to Target (euclidean distance)	Rank	Inventory Data Exisiting	database	LCI Name	Weighted Average
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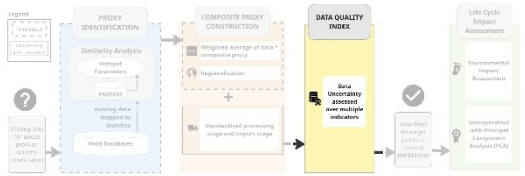
Apples	Switzerland	Italy	Apples	42455.24	71.13	5.43	2.13	6	Yes	ecoinvent v3	Apple ~~{IT}~~ appl	14.6%
Apples	Switzerland	South Africa	Apples	40990.94	25.75	3.29	2.76	13	Yes	ecoinvent v3	Apple ~~{ZA}~~ app	11.2%
Apples	Switzerland	United States of A	Apples	39059.46	38.31	2.96	2.77	14	Yes	ecoinvent v3	Apple ~~{US}~~ app	11.2%
Apples	Switzerland	South Africa	Pears	36389.40	25.75	3.29	3.10	21	Yes	ecoinvent v3	Pear ~~{ZA}~~ pear	10.0%
Apples	Switzerland	Belgium	Pears	34396.08	273.01	6.47	3.33	24	Yes	ecoinvent v3	Pear ~~{BE}~~ pear	9.3%
Apples	Switzerland	Argentina	Pears	28774.38	21.40	5.24	3.74	29	Yes	ecoinvent v3	Pear ~~{AR}~~ pear	8.3%
Apples	Switzerland	China	Apples	22128.72	154.46	2.03	3.85	33	Yes	ecoinvent v3	Apple ~~{CN}~~ app	8.0%
Apples	Switzerland	China	Pears	19192.86	154.46	2.03	4.15	46	Yes	ecoinvent v3	Pear ~~{CN}~~ pear	7.5%

PROXYLCA: Data Quality Index (DQI)



Every data quality indicator is ranked from a score of 1 (high data quality/low uncertainty) to 5 (low data quality/high uncertainty).

Target Product	Target Country	FoodEx2 Code	Average Rank	Similarity Score	# of LCI within composite proxy	Sample Size Score	Average Year of LCI	Temporal Score	Average DQI score of LCI	LCI with missing reported DQI	Precision Score	# of LCI in a different technological cluster	Technological Correlation Score	Overall DQI
Apples	Switzerland	A01DJ	21.11	1	9	2	2009.6	4	2.751	2	2	9	5	2.8

How similar are the selected proxies to the target country–product.

Number of proxies used to form a composite proxy

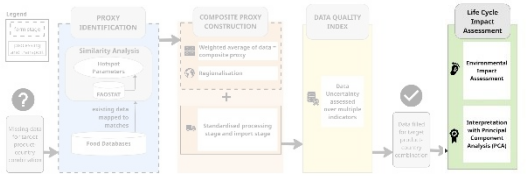
Weighted average age of proxies within a composite proxy

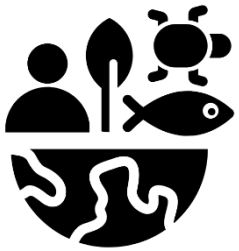
Average original data quality score of proxies

Alignment of proxy inventories with qualitative agricultural practices (types of pesticide, animal feed composition

Simple average of all the other scores

PROXYLCA: Life Cycle Impact Assessment (LCIA)





Comprehensive impact assessment

- With 20+ impact indicators (e.g., eutrophication, water scarcity, ecotoxicity, climate change).

Principal Component Analysis (PCA)[1]

- Identifies key impact categories that capture the strongest correlations
  - E.g. for ecoinvent v3.11 (food only): Water Use, Biodiversity, Terrestrial and Freshwater Ecotoxicity

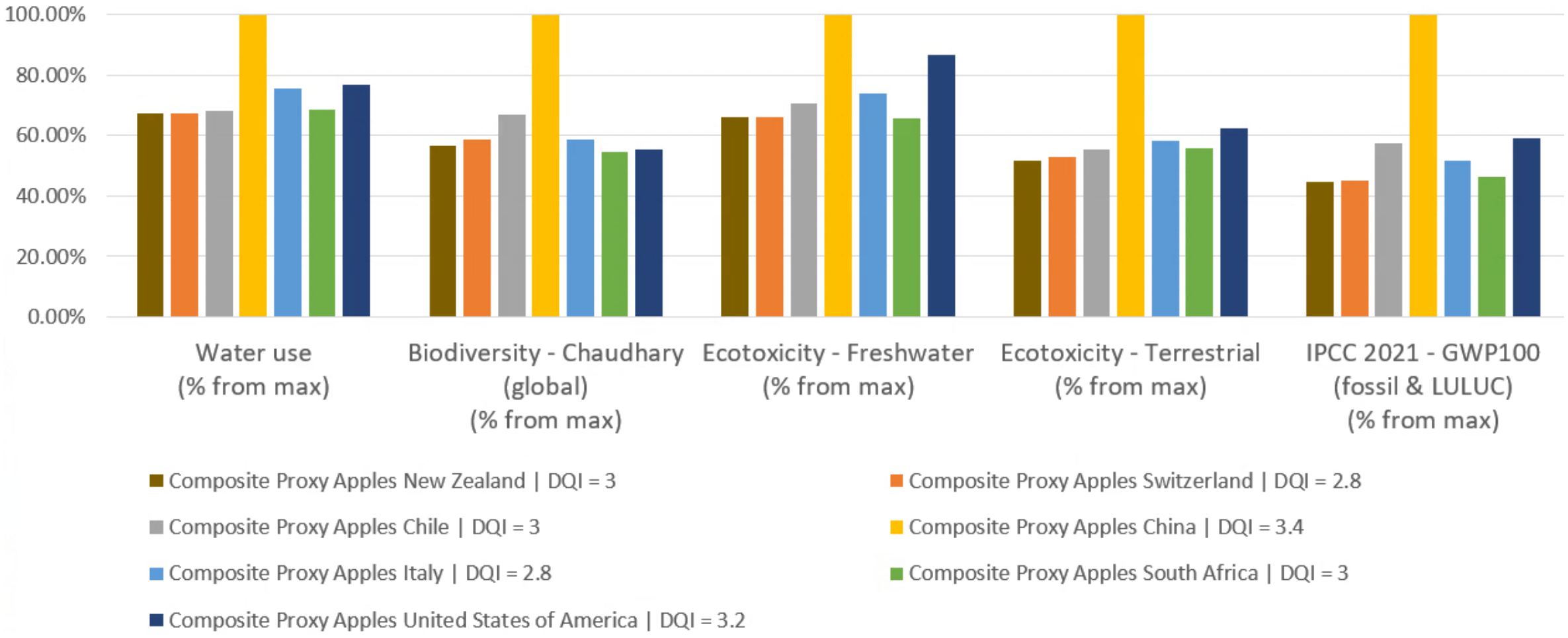
- Simplified interpretation but avoids subjective weighting

Sources: (1) Steinmann et al (2016)
Icons from the NounProject: Syaiful Khotam, Daisy

PROXYLCA:
Preliminary Results

PROXYLCA: Results Example for Apples

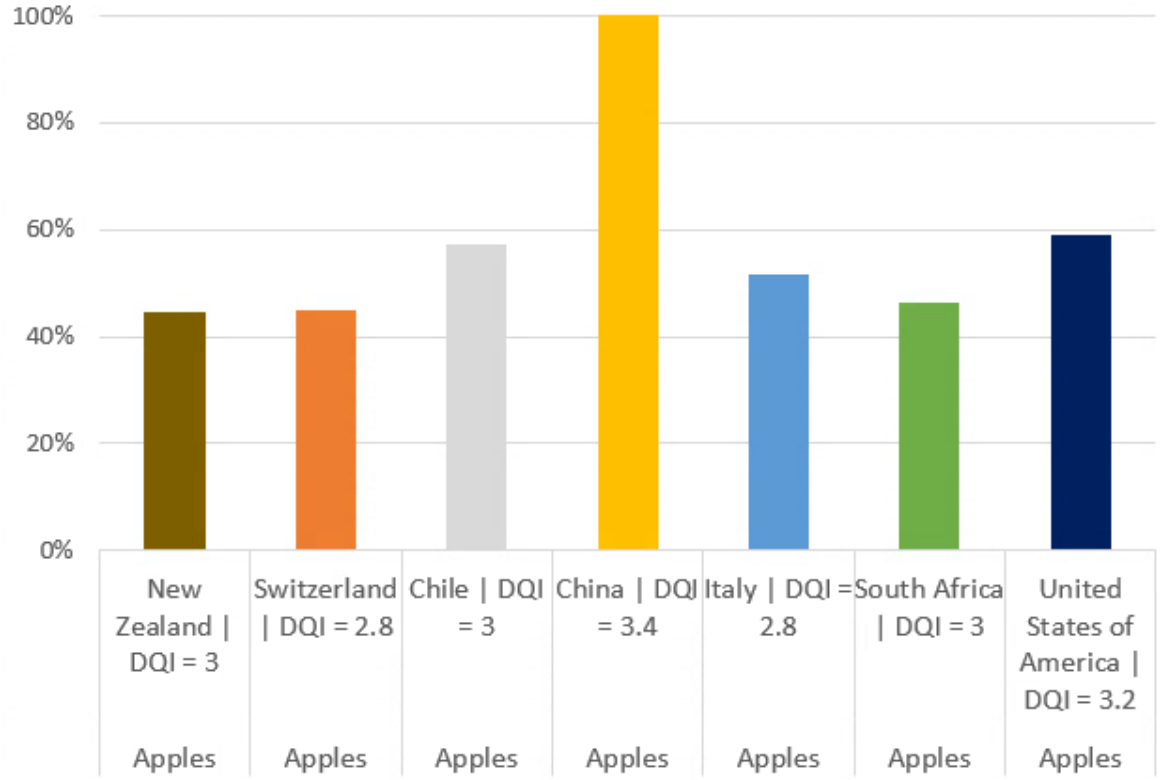
At-Farm environmental impacts for 1kg of apples produced in 7 different countries

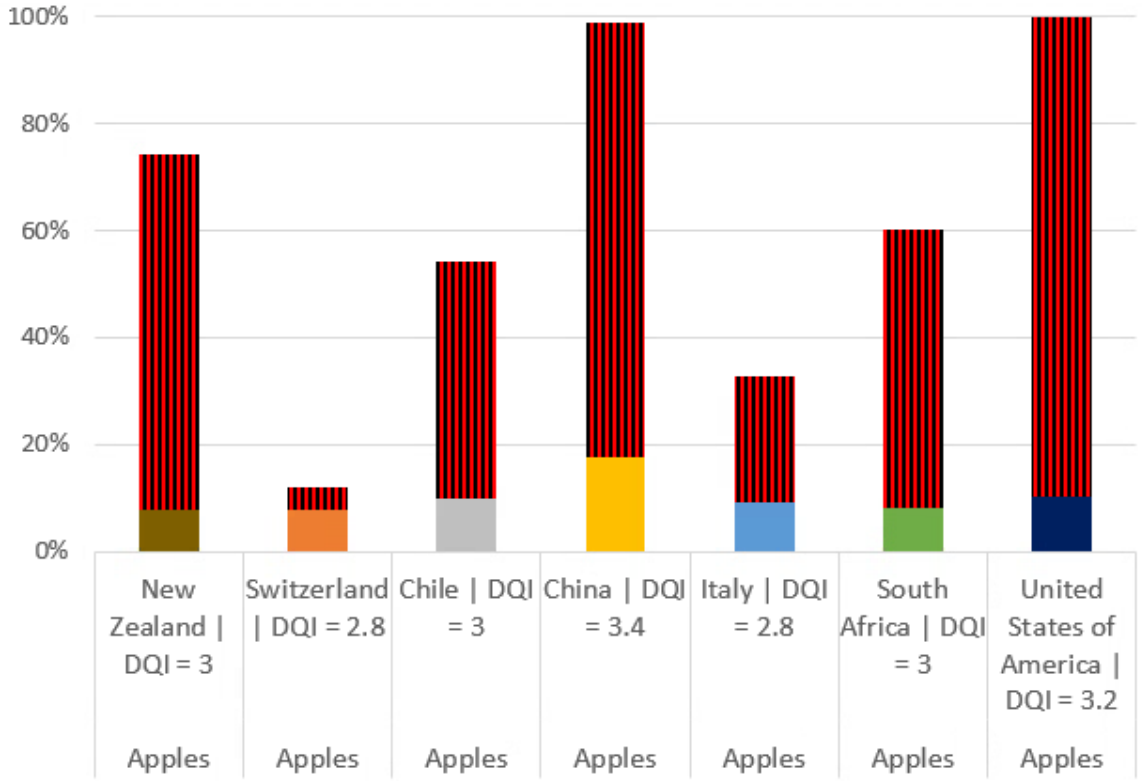


LCA impacts calculated with SALCA v2.03 for Apples in the ecoinvent v3.11 database

PROXYLCA: Import Stage Can Shift Environmental Performance

Carbon Footprint Impact for 1kg of Apples
(% from country with max impact)





Impacts from the at-farm stage per country of origin

Impacts from the importing stage to Switzerland per country of origin

LCA impacts calculated with SALCA v2.03 for Apples in the ecoinvent v3.11 database

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PROXYLCA:
Conclusion

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Conclusion

PROXYLCA:

- Rapidly estimates environmental impact for virtually any products across any countries
- Assesses environmental impacts beyond the carbon footprint
- Simplifies interpretation using principal component analysis

Icon sources from the NounProject: popcornarts, Creative Studio, WEBTECHOPS LLP

Conclusion

PROXYLCA:

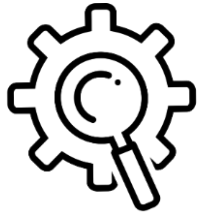
- Rapidly estimates environmental impact for virtually any products across any countries
- Assesses environmental impacts beyond the carbon footprint
- Simplifies interpretation using principal component analysis

Limitations:

- Inherits the same biases of current databases:
  - lack of representation for tropical climate for instance
  - Lack of representation for alternative production system (e.g. organic)

Icon sources from the NounProject: popcornarts, Creative Studio, WEBTECHOPS LLP

Conclusion



PROXYLCA:

- Rapidly estimates environmental impact for virtually any products across any countries
- Assesses environmental impacts beyond the carbon footprint
- Simplifies interpretation using principal component analysis

Limitations:

- Inherits the same biases of current databases:
  - lack of representation for tropical climate for instance
  - Lack of representation for alternative production system (e.g. organic)

Applications:

- Can compare the impacts of different food products produced in countries
- Can estimate the impact of trade as well as the impact of domestic production of food
- Can complement existing models such as CAPRI or SWISSFoodSys

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Thank you

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