Supplementary information 1

Growing local and circular: The potential of peri-urban agriculture in reducing imports and environmental impacts

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1. Production, import needs, and self-sufficiency

Figure SI1-1 presents a graphical representation of methodological step-by-step and datasets used to calculate the annual (2016) peri-urban and urban agriculture (UA) production, food consumption, fruits and vegetables self-sufficiency, and the import needs in the AMB.

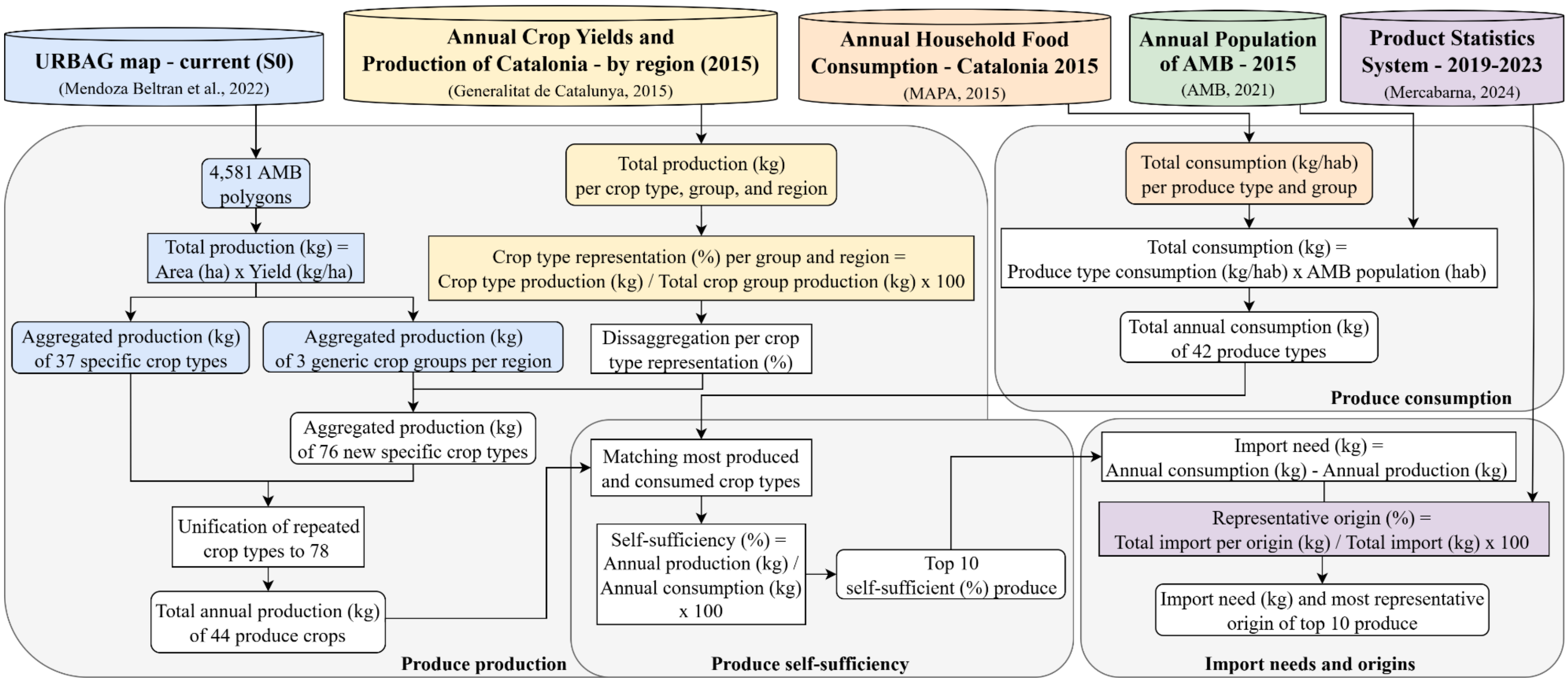

Figure SI1-1. Methodological step-by-step diagram of datasets and calculations used to determine UA production, food consumption, produce self-sufficiency, and import needs in the AMB. Colored boxes represent data and/or calculations from raw reference datasets. White boxes represent data and/or calculations after mixing datasets.

1.1. Local production

To refine estimates of local fruit and vegetable production in the AMB, we disaggregate generic crop groups into specific crops (e.g., 100 kg of vegetables into 60 kg of tomato, 30 kg of lettuce, and 10 kg of pepper). These generic groups – vegetables, non-citric fruits and herbaceous crops – represented 67% of the UA area (3,700 ha) and 81% of production (58,600 t) in the URBAG agricultural map (Mendoza Beltran et al. 2022) . First, we used the URBAG map to quantify the annual production of each generic crop group per the Catalonian regions within the AMB: Baix Llobregat, Barcelones, Maresme and Valles Occidental. We then used the 2015 official Crop Yields and Production by Region report of Catalonia (Generalitat de Catalunya 2015) to calculate the production share (%) of each specific crop within its corresponding crop group and region. We applied these shares to the region-specific production totals of the three generic groups from the AMB, disaggregating them into 76 specific crops. We merged crops already present among the original 37 categories and obtained a total of 78 specific crop types, of which 44 represented fresh produce (vegetables and fruits). We assume that all resulting production is consumed within the AMB. Table SI1-1 presents the full list of produce with their annual production.

Table SI1-1. Annual production of each fruit and vegetables produced in the AMB – 2016.

#	Crop	UA production (t yr^{-1}) - 2016	Produce type
1	Tomato	10,033.38	Vegetable
2	Onion	5,704.92	Vegetable
3	Peach trees	3,474.44	Fruit
4	Lettuce	3,269.49	Vegetable
5	Artichoke	3,168.12	Vegetable
6	Cucumber	2,271.69	Vegetable
7	Head cabbage	2,188.74	Vegetable
8	Cherry trees	1,938.59	Fruit
9	Celery	1,912.93	Vegetable
10	Pumpkin & zucchini	1,889.61	Vegetable
11	Plum trees	1,397.11	Fruit
12	Green beans	1,177.30	Vegetable
13	Chard	1,059.48	Vegetable
14	Apple trees	1,003.93	Fruit
15	Spinach	774.47	Vegetable
16	Leek	766.87	Vegetable
17	Potato	686.69	Vegetable
18	Cauliflower	559.13	Vegetable
19	Escarole/endive	520.08	Vegetable
20	Garlic	481.44	Vegetable
21	Pear trees	402.92	Fruit
22	Eggplant	386.07	Vegetable

23	Pepper	373.61	Vegetable
24	Apricot	266.38	Fruit
25	Fig tree	255.81	Fruit
26	Carrot	235.93	Vegetable
27	Radish	235.63	Vegetable
28	Watermelon	190.57	Fruit
29	Persimmon	186.21	Fruit
30	Quince	118.49	Fruit
31	Melon	115.50	Fruit
32	Other vegetables	100.72	Vegetable
33	Nectarine	92.60	Fruit
34	Peas	87.18	Vegetable
35	Mandarin	43.47	Fruit
36	Strawberry	39.95	Fruit
37	Kiwi	30.09	Fruit
38	Chili pepper	24.46	Vegetable
39	Asparagus	18.13	Vegetable
40	Orange tree	9.05	Fruit
41	Cardoon	3.44	Vegetable
42	Loquat/Medlar	2.93	Fruit
43	Turnip & others	0.45	Vegetable
44	Chicory, endive & others	0.21	Vegetable
	Total	**47,498.21**	

1.2. Produce consumption

The 2015 Annual Household Food Consumption report (MAPA 2015) lists 580 individual and aggregated food items consumed in Catalonia. We extracted 66 items corresponding to vegetables, fruits, dry fruits, and similar, of which 42 were fresh produce: 20 vegetables and 22 fruits. Table SI1-2 presents the full list of produce and their annual consumption (t).

Table SI1-2. Annual consumption of produce in AMB per specific food and type of produce.

#	Produce	AMB consumption (t yr^{-1}) - 2016	Produce type
1	Fresh potatoes	74,336.39	Vegetable
2	Oranges	70,604.76	Fruit
3	Tomatoes	56,050.12	Vegetable
4	Other vegetables	43,091.47	Vegetable
5	Apples	40,237.02	Fruit
6	Bananas	39,132.12	Fruit
7	Melon	28,890.67	Fruit
8	Watermelon	27,845.53	Fruit
9	Onions	27,218.39	Vegetable
10	Mandarins	26,367.86	Fruit
11	Pears	18,771.37	Fruit
12	Lettuce/Escarole/Endive	18,719.41	Vegetable
13	Peaches	17,687.12	Fruit

14	Other fresh fruits	16,954.86	Fruit
15	Peppers	15,881.52	Vegetable
16	Zucchini	13,793.55	Vegetable
17	Carrots	11,039.41	Vegetable
18	Green beans	10,321.40	Vegetable
19	Kiwi	9,761.05	Fruit
20	Grapes	8,662.30	Fruit
21	Strawberries	8,307.45	Fruit
22	Cucumbers	8,223.73	Vegetable
23	Lemons	8,125.85	Fruit
24	Eggplants	7,278.26	Vegetable
25	Nectarines	6,992.80	Fruit
26	Pineapple	6,559.73	Fruit
27	Cabbages	6,125.26	Vegetable
28	Leafy greens	4,933.72	Vegetable
29	Plums	4,383.79	Fruit
30	Cherries	4,361.20	Fruit
31	Asparagus	4,206.87	Vegetable
32	Apricots	3,043.15	Fruit
33	Garlic	2,554.97	Vegetable
34	Avocado	2,554.38	Fruit
35	Broccoli	0	Vegetable
36	Artichokes	0	Vegetable
37	Celery	0	Vegetable
38	Cauliflower	0	Vegetable
39	Leek	0	Vegetable
40	Grapefruit	0	Fruit
41	Cherimoya	0	Fruit
42	Mango	0	Fruit
	Total	**653,017.48**	

1.3. Import needs and origins

We used the calculated import needs to represent how much more of each fruit and vegetable crop is required to meet AMB total annual crop demand. Table SI1-3 presents the annual import needs, main origin selected, and representative share (%) for each crop based on the five-year analysis of Mercabarna imports (2019-2023). In Table SI1-4 we present assumed midpoint road distance to Mercabarna of each imported origin to estimate the total road exposure (tkm) for each imported crop.

Our five-year Mercabarna analysis shows that representative origins for imported crops can shift across crop varieties and years. In addition to "red apple" shifting from Lleida (ES) to Italy in 2022-2023, we found similar cases for lettuce, onion, pear, and potato. For lettuce, origin shifts from Murcia to Barcelona for "long lettuce "in 2022-2023. For onions, the representative origin shifts from Lleida to Valencia or Zaragoza when focusing on "soft onion" or "dry onion" in 2022, respectively. For pear, origin shifts from Lleida (ES) to South Africa for "summer pear" in 2019-2021. For potato, it shifts from France to Barcelona (ES) for "early potato" in 2021-2023. Figure SI1-2 presents the five-year (2019 – 2023) Mercabarna import analysis by produce variety and year for lettuce, apple, potato, pear, and onion.

Table SI1-3. Annual produce import needs, origin location, and import origin representation per produce.

#	Produce	Import needs (t yr^{-1})	Imports origin (2019-2023)	Import share (%)
1	Cherry	2,422.61	Zaragoza, ES	33%
2	Cabbage	3,936.52	Netherlands	52%
3	Plum	2,986.68	Badajoz, ES	55%
4	Cucumber	5,952.04	Granada, ES	46%
5	Onion	21,513.47	Lleida, ES	36%
6	Peach	14,212.68	Lleida, ES	30%
7	Garlic	2,073.53	Cuenca, ES	56%
8	Tomato	46,016.74	Almeria, ES	59%
9	Lettuce	15,449.92	Murcia, ES	61%
10	Zucchini	11,903.94	Granada, ES	53%
11	Green beans	9,144.10	Granada, ES	32%
12	Apricot	2,776.77	South Africa	42%
13	Eggplant	6,892.19	Almeria, ES	88%
14	Apple	39,233.09	Lleida, ES	58%
15	Pepper	15,507.91	Almeria, ES	80%
16	Pear	18,368.45	Lleida, ES	48%
17	Carrot	10,803.48	Segovia, ES	53%
18	Nectarine	6,900.20	Lleida, ES	41%
19	Potato	73,649.70	France	74%
20	Watermelon	27,654.96	Brazil	49%
	Total	**337,398.99**		

Table SI1-4. Import origin location, total exposure road distance, and share of land-only exposure per produce.

#	Produce	Import origin (2019-2023)	Assumed midpoint road distance to Mercabarna (km)	Total exposure road distance (tkm)	Share of land-only exposure road distance (%)
1	Cherry	Zaragoza, ES	300	726,782.31	0%
2	Cabbage	Netherlands	1500	5,904,775.57	3%
3	Plum	Badajoz, ES	950	2,837,348.85	1%
4	Cucumber	Granada, ES	880	5,237,795.08	3%
5	Onion	Lleida, ES	160	3,442,155.39	2%
6	Peach	Lleida, ES	160	2,274,029.21	1%
7	Garlic	Cuenca, ES	350	725,736.66	0%
8	Tomato	Almeria, ES	830	38,193,894.42	20%
9	Lettuce	Murcia, ES	600	9,269,954.83	5%
10	Zucchini	Granada, ES	880	10,475,464.77	6%
11	Green beans	Granada, ES	880	8,046,809.95	4%
12	Apricot	South Africa	Maritime transportation		0%
13	Eggplant	Almeria, ES	830	5,720,519.80	3%
14	Apple	Lleida, ES	160	6,277,294.24	3%

15	Pepper	Almeria, ES	830	12,871,561.86	7%
16	Pear	Lleida, ES	160	2,938,952.00	2%
17	Carrot	Segovia, ES	650	7,022,264.00	4%
18	Nectarine	Lleida, ES	160	1,104,031.68	1%
19	Potato	France	900	66,284,733.96	35%
20	Watermelon	Brazil	Maritime transportation		0%
	Total		**11,180.00**	**189,354,104.56**	

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94 Panel A

Lettuce - Import origin (%)

	2022	2023
Long lettuce		
Barcelona, ES	41%	53%
Granada, ES	24%	28%
Murcia, ES	16%	9%
Alicante, ES	14%	2%
Castellon, ES	6%	9%

Panel B

Apple - Import origin (%)

	2022	2023
Red apple		
Italy	42%	55%
Lleida, ES	30%	26%
Girona, ES	11%	8%
Murcia, ES	10%	2%
Almeria, ES	6%	9%

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Potato - Import origin (%)

	2021	2022	2023
Early potato			
Barcelona, ES	66%	63%	63%
Alicante, ES	34%	6%	26%
Girona, ES	0%	0%	4%
Almeria, ES	0%	3%	2%
France	0%	29%	3%

Panel D

Pear - Import origin (%)

	2019	2020	2021
Summer pear			
South Africa	46%	65%	35%
Murcia, ES	18%	16%	33%
Zaragoza, ES	16%	5%	5%
Lleida, ES	13%	7%	21%
Huesca, ES	7%	8%	6%

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98 Panel E

Onion - Import origin (%)

	2022
Dry onion	
Zaragoza, ES	32%
Lleida, ES	25%
Valencia, ES	18%
Barcelona, ES	15%
Cuenca, ES	10%
Soft onion	
Valencia, ES	37%
Barcelona, ES	18%
Alicante, ES	16%
Germany	15%
Zaragoza, ES	14%

Figure SI1-2. Five-year (2019 – 2023) analysis of Mercabarna's imports data per specific produce variety and years for lettuce (Panel A), apple (Panel B), potato (Panel C), pear (Panel D), and onion (Panel E).

2. Nutrient demand from local crops

For the six local crops selected, annual cultivated area (ha) was calculated from total annual production (t yr^{-1}) and corresponding crop yield (t ha^{-1}). We multiplied this area by the crop-specific fertilizer rates (kg N, P_2O_5, K_2O ha^{-1}) to estimate annual nutrient demand (kg yr^{-1}). We follow Arosemena Polo et al. (2024) and use N rates from Mendoza Beltran et al. (2022); P_2O_5 rates from López Bellido et al. (2010) when available, otherwise, from FAO (2013), López Bellido et al. (2010), and Ruralcat (2019) were combined with yields from MAPA (2016) and Mendoza Beltran et al. (2022); and K_2O rates from FAO (2013), López Bellido et al. (2010), and Ruralcat (2019). Table SI1-5 presents the input data of each crop and the annual area and nutrient demand.

Table SI1-5. Total annual production area and total nutrient-demand for the six selected crops.

Crop	Annual production (t yr^{-1})	Yield (t ha^{-1})	N rate (kg ha^{-1})	P_2O_5 rate (kg ha^{-1})	K_2O rate (kg ha^{-1})	Total area (ha)	Total N demand (kg yr^{-1})	Total P_2O_5 demand (kg yr^{-1})	Total K_2O demand (kg yr^{-1})
Peach	3,474.40	10.90	85.00	8.87	95.00	318.76	27,094.20	2,827.40	30,281.80
Tomato	10,033.40	41.60	220.00	75.00	220.39	241.19	53,061.10	18,089.00	53,155.20
Lettuce	3,269.50	20.70	165.66	79.96	121.84	157.95	26,165.70	12,629.40	19,244.20
Apple	1,003.90	24.10	100.00	50.00	110.00	41.66	4,165.70	2,082.80	4,582.30
Pepper	373.60	20.70	165.66	79.96	121.84	18.05	2,990.00	1,443.20	2,199.10
Pear	402.90	16.10	75.00	177.10	85.00	25.03	1,877.00	4,432.20	2,127.20

3. Local fertilization scenarios, including nutrient circularity

Four different fertilization scenarios were developed to assess (i) the environmental impacts of local crop production under current fertilization practices in the AMB and (ii) the potential benefits and trade-offs of increasing existing circular nutrient strategies (CNS) and/or implementing new ones. The scenarios include a *Reference scenario* (REF), and three circularity-oriented: *Compost scenario* (COM), S*truvite and ammonium salts scenario* (STA), and P*runing scenario* (PRU). For the circular scenarios (COM, STA, and PRU), increased use of circular nutrients is implemented along regulatory limitations that limit nutrient inputs from organic fertilizers and local availability constraints that reflect current and potential nutrient recovery capacities within the urban system. The following subsections (SI1-3.1 to SI1-3.4) provide assumptions, calculations, and constraints for each scenario.

3.1. Reference scenario (REF)

In this scenario, N inputs are based on Catalonia's Annual Nitrogen Declaration (DAN for its Catalan acronym) (RuralCat 2025), a mandatory reporting instrument in which crop farms declare the annual total N applied (kg), disaggregated by destination (crop type and municipality) and by N-based source categories: mineral fertilizer, manure, organic waste, commercial fertilizer with organic N, and irrigation water. We analyzed the last five years reported (2019-2023) to obtain, for each selected crop-municipality combination, the share (%) of total declared N of each of the five DAN source categories. We assume that the crop-specific annual N demand (see SI1-2) is met using this same N-based source distribution for the corresponding crop and municipality. Accordingly, the DAN-derived shares were applied to each crop annual N demand to allocate it across the five DAN categories, thereby representing the current composition of N-fertilization practices.

The municipality assigned to each crop (or crop group) was determined from the URBAG agricultural map (Mendoza Beltran et al. 2022) and corresponds to the municipality concentrating the largest cultivated area of that crop and/or crop group within the AMB. This allows the DAN-derived source shares to reflect local fertilization practices for the main municipalities producing each crop. Table SI1-6 presents the selected crop-municipality and the corresponding DAN-based N-source shares (%).

Table SI1-6. N-based fertilization shares for the six selected crops based on DAN (2019-2023).

Crop/crop group	Municipality	Mineral fertilizer	Manure	Organic waste	Commercial fertilizer with organic N	Irrigation water
Vegetables (tomato, lettuce and pepper)	Sant Boi de Llobregat	51%	26%	7%	9%	7%
Apple	Sant Vicençs dels Horts	5%	21%	0%	7%	67%
Peach	Santa Coloma de Cervelló	25%	11%	17%	2%	45%
Pear	Viladecans	57%	27%	0%	3%	13%

The annual N amount assigned to each DAN category was then converted into annual fertilizer input using the characterization of the representative fertilizer assumed for each category and expressed per FU by dividing by the corresponding annual crop production.

The assumed representative fertilizers follow the DAN category definitions and clarifications from office representatives. *Mineral fertilizer* refers to synthetic mineral fertilizers, for which we assume separated forms of synthetic mineral N, P_2O_5, and K_2O. M*anure* includes fresh and/or treated animal depositions applied to soil as fertilizer soil amendment, represented here by solid cattle manure as characterized by the official Fertilization and Treatment of Livestock Manure office (RuralCat – Oficina de Fertilització 2024). *Organic waste* refers to treated WWTP sludge and/or OMSW digestate applied as fertilizer or soil amendment; in the AMB context, office representatives report this category as mostly WWTP sludge compost, for which we used characterization parameters reported by ARC (2021). *Commercial fertilizer with organic N* refers to registered commercial organic fertilizers under Real Decreto 506/2013 (2013), represented here as AMB's OMSW compost, as characterized in Arosemena Polo et al. (2024). And *irrigation water* refers to nutrients contained in irrigation water, represented using assumed averages from Barcelona tap water concentrations (GenCat 2018). Table SI1-7 summarizes the characterization of each representative fertilizer and the implied conversion ratios in the back-calculations.

Table SI1-7. Representative fertilizers, characterization and back-calculation of P2O5 and K2O from DAN-declared N fertilization.

DAN source-category	**Assumed representative fertilizer**	**Key parameters**	**Effective N basis**	**Ratios for back-calculation**
Mineral fertilizer	Separated synthetic N, P_2O_5, K_2O fertilizers	N taken directly from DAN shares	N from DAN	P_2O_5 and K_2O computed by residual closure
Manure	Fresh cattle manure	Fresh basis; 8.8 kg N t^{-1}; 5.0 kg P_2O_5 t^{-1}; 7.8 kg K_2O t^{-1}	0.0088 kg N kg^{-1} manure	(P_2O_5 N^{-1}) = 0.568; (K_2O N^{-1}) = 0.088
Organic waste	WWTP sludge compost	Dry basis; 18.8% dry matter; 6.8% N; 4.6% P_2O_5; 0.6% K_2O	0.0127 kg N kg^{-1} WWTP sludge compost	(P_2O_5 N^{-1}) = 0.676; (K_2O N) = 0.088
Commercial fertilizer with organic N	OMSW compost	Dry basis; 72% DM; 2.5% N; 1.06% P; 1.38% K	0.0183 kg N kg^{-1} OMSW compost	After P and K conversions, (P_2O_5 N^{-1}) = 2.264; (K_2O N^{-1}) = 1.554
Irrigation water	Barcelona tap water	5 mg N-NO_3 L^{-1}; 1 mg P-PO_4 L^{-1}; 1 mg K L^{-1}	N concentration	After P and K conversions, (P_2O_5 N^{-1}) = 0.458; (K_2O N^{-1}) = 0.241

Because DAN explicitly reports N-based fertilization only (P_2O_5 and K_2O inputs are not requested and therefore not available), P_2O_5 and K_2O inputs from each DAN source category were estimated by back-calculation. For each crop and fertilizer source, we applied a single ratio-based approach derived from an assumed representative fertilizer for that DAN category (Eq. 1):

$$\mathbf{P_2O_5 = N_s \times (P_2O_5/N)_s}\text{; and analogous for } K_2O \quad (1)$$

where N_s is the N amount assigned to source *s* from DAN shares, and $(P_2O_5/N)_s$ and $(K_2O/N)_s$ are source-specific conversion ratios derived from the characterization of the representative fertilizer (basis, dry matter content, NPK composition, etc.). When fertilizer characterization was available as elemental P and K, these were converted to oxides using stoichiometric factors ($P \rightarrow P_2O_5 = 2.291$ and $K \rightarrow K_2O = 1.205$). After estimating P_2O_5 and K_2O supplied by the non-synthetic sources (manure, organic waste, commercial fertilizer with organic N, and irrigation water), the remaining amount required to meet crop demand was assigned as synthetic mineral P_2O_5 and synthetic mineral K_2O through a closure step (Eq. 2):

$$\mathbf{P_2O_{5\,mineral} = max\,(0, P_2O_{5\,demand} - \sum P_2O_{5s})}\text{; and analogous for } K_2O \quad (2)$$

If non-synthetic sources meet or exceed P_2O_5 or K_2O demand, the corresponding synthetic mineral input is set to zero, and any excess is tracked as oversupply. Because N demand is met by construction across all scenarios, oversupply applies only to P_2O_5 and K_2O. It may arise when these nutrients are co-delivered in fixed ratios with N-based fertilizer sources and meeting N demand already supplies P_2O_5 or K_2O beyond crop demand. We track this oversupply in REF and across the remaining scenarios. P_2O_5 oversupply occurs for peach under all four scenarios (see Figure SI1-3 and Table SI1-10).

3.2. Compost scenario (COM)

This scenario introduces an OMSW compost increment by substituting synthetic mineral fertilizers only, keeping the REF baseline of manure, WWTP sludge compost, and irrigation water unchanged. We assume the same OMSW compost as in the REF scenario; however, for the additional compost we consider an agronomic "effective nutrient availability" (i.e., assimilation factors) to represent the fraction of compost nutrients that can realistically displace synthetic nutrients in the year of application. Assimilation factors (40% for N; 95% for P and K) are taken from the compost characterization in Arosemena Polo et al. (2024). Although OMSW compost is P_2O_5-rich compared to N after assimilation consideration (1 kg supplies 2.3x more effective P_2O_5 than N), compost increment follows common practices, meeting N needs first, not P_2O_5, so is limited by an N-first substitution where effective N from compost cannot displace more synthetic mineral N than exists in REF. In this scenario, P_2O_5 oversupply occurs in all crops but pear, whereas K_2O oversupply arose slightly only in pear (see Figure SI1-3 and Tables SI1-10 to SI1-11).

The compost increment in this scenario is constrained by an organic-source N cap of 170 kg total N ha^{-1} yr^{-1} from all organic fertilizers, following the maximum applicable N regulation (RuralCat 2020). We define organic-source N as the total N applied per ha per year from REF organic fertilizers: manure + WWTP sludge compost + baseline OMSW compost. Because this scenario keeps these baseline organic sources unchanged, we limited the additional OMSW compost to the remaining N headroom before reaching the limit (170 kg N ha^{-1} yr^{-1}). We calculated this remaining headroom per crop from the REF baseline. We then enforced the cap on total organic-source N, including the total N content of the additional OMSW compost, rather than on effective N. Table SI1-8 presents the organic-source N cap use for REF and COM scenarios for each crop.

Table SI1-8. Organic-source N cap use for REF and COM scenarios, based on a maximum 170 kg total N ha^{-1} yr^{-1} from organic fertilizers.

Crop	REF organic-source N (kg N ha^{-1} yr^{-1})	Remaining N headroom to 170 (kg N ha^{-1} yr^{-1})	REF cap use (%)	COM organic-source N (kg N ha^{-1} yr^{-1})	COM cap use (%)
Peach	25.31	144.69	15%	79.49	47%
Tomato	91.91	78.09	54%	170	100%
Lettuce	69.21	100.79	41%	170	100%
Apple	28.36	141.64	17%	39.86	23%
Pepper	69.21	100.79	41%	170	100%
Pear	22.9	147.1	13%	129.42	76%

Moreover, OMSW compost application is also constrained by a compost production capacity of 5,000 t yr^{-1} in the AMB, following Arosemena Polo et al. (2024). If this availability is limiting, the compost increment is reduced proportionally across crops using a scaling factor. However, although the total OMSW compost mass across crops increased by 713% from REF to COM (436 t to 3,544 t), the production capacity cap is not reached, so no action is required. After applying these constraints, any remaining demand for N, P_2O_5, K_2O is met by synthetic mineral fertilizer as a closure.

3.3. Struvite and ammonium salts scenario (STA)

This scenario introduces recovered nutrients from WWTP as substitute for synthetic mineral fertilizers only, keeping the REF baseline of manure, WWTP sludge, OMSW compost, and irrigation water unchanged. We model two circular fertilizers recovered from WWTP: (i) struvite as P-rich that also contains N, and (ii) ammonium salts (ammonium sulfate salts – $NH_4{}_2SO_4$) as N-only fertilizer. We assume these fertilizers are already commercially available within the AMB so they can be declared as commercial fertilizers with organic N following DAN. In this scenario we reflect EU policies promoting nutrient circularity (European Parliament 2024a, 2024b) and recent state-of-the-art projects (WALNUT; Phos4You; ENRICH); and is based on Mendoza Beltran et al. (2026) adaptations for the AMB of the LIFE ENRICH project (Mayor et al. 2023), which implements a pilot-scale struvite and ammonium salts recovery in a WWTP in Murcia, Spain.

Struvite is characterized by 12.7% P and 5.7% N content, and ammonium salts by 18.8% N. No dry-matter or assimilation factors are considered (P_2O_5 and N from struvite and ammonium salts are assumed to be 100% assimilated). Because struvite is comparatively P-rich, it's used first to substitute the remaining synthetic mineral P_2O_5 from REF (P_2O_5-limited). The N co-supplied with struvite is then credited toward the total N demand, and ammonium salts are later introduced to substitute the remaining synthetic mineral N need. Because struvite substitutes the REF mineral P_2O_5 gap while keeping the REF baseline unchanged, this scenario avoids generating additional P_2O_5 oversupply but retains the baseline P_2O_5 oversupply already present for peach in REF (Figure SI1-3 and Table SI1-10).

The total struvite supply is constrained by a maximum annual recovery capacity of 275 t P yr^{-1} and the ammonium salts by a maximum recovery capacity of 530 t N yr^{-1} (Mendoza Beltran et al. 2026). In this scenario, these availability caps were not reached, so no action was required. In contrast to COM, this scenario does not apply the 170 kg total organic-N ha^{-1} cap. Neither fertilizer supplies K_2O, so the remaining K_2O demand is the same as in the REF baseline, met through synthetic mineral K_2O via the closure approach. After applying these constraints, any remaining demand for N and P_2O_5 is met by synthetic mineral fertilizer as a closure.

3.4. Pruning scenario (PRU)

This scenario is based on lessons learned from the Proof-of-Concept project "*Healthy Soil for Urban Agriculture through Nutrient and Carbon Circularity*" (NUTRISOIL (2024)), which compared the direct soil application of C-rich pruning residues with other CNS for soil regeneration and crop fertilization. According to empirical studies, a high-dose application of pruning residues to soil can stimulate soil microbial activity, increase soil C and N stocks, retain nutrients in soil, and promote nutrients recycling over subsequent crops (REGENSOL 2022; Pérez-Llorca et al. 2025; Evangelista et al. 2026; Fontana et al. 2023). However, the agronomic response remains crop- and timing-dependent due to limited nutrient release and short-term N limitation (Evangelista et al. 2026).

For this scenario, pruning residues are characterized by N, P, K, and C contents of 0.77%, 1.09%, 4.41%, and 46.9%, following experimental data from the NUTRISOIL (2024) project. We modelled pruning residues as a one-time application at 150 t ha^{-1} (15 kg m^{-2}, high-dose), with no re-application during the following 5 years. This reflects a "single application + legacy effect" approach, where part of the nutrients from pruning residues is retained in soil and can contribute to crop fertilization over multiple seasons (Fontana et al. 2023; Pérez-Llorca et al. 2025). This is consistent with experiences from AMB local farmers involved in NUTRISOIL (2024) project. Because REF, COM, and STA scenarios are reported on a one-year production basis, the pruning residues input is allocated over five years benefit horizon to preserve comparability with annual fertilizer inputs (this does not represent annual re-application).

Like in COM and STA scenarios, PRU displaces only synthetic mineral fertilizers, keeping the REF baseline inputs of manure, WWTP sludge compost, OMSW compost, and irrigation water unchanged. We adopt 45% replacement as the baseline case, assumed as a representation of partial mineral fertilizer replacement under favorable crop-soil responses. This assumption is based on the lower end fertilizer reductions (43-100%) observed in Pérez-Llorca et al. (2025) after the incorporation of pruning residues, where the 100% reduction is for N-fixing crops (e.g., sweet potato) and the 43% is for typical N-demanding vegetable (e.g., tomato), which we treat as representative of typical N demanding crop.

After accounting for the pruning nutrient inputs and the applied mineral fertilizer displacement, any remaining N, P_2O_5, and K_2O demand is met by synthetic mineral fertilizer as a closure. In this scenario, nutrients supplied by the one-time high-dose pruning application that are not required to meet the annual crop demand in the reporting year are not interpreted as oversupply, but as a nutrient legacy pool retained for the assumed five-year benefit horizon. Accordingly, Figure SI1-3 differentiates between the annual fertilization shares in PRU without the nutrient legacy pool (panel A) and with it (panel B).

To our knowledge, no regulation currently caps inputs of this residue type into soil, so no limitation associated with these is considered for this scenario. Moreover, we did not consider imposing availability constraint given the current underestimation of pruning generation potential by local authorities (NUTRISOIL 2024).

Table SI1-9. N fertilization shares for each crop's annual nutrient demand by scenario and crop type. REF represents current fertilization practices based on the Annual Nitrogen Declaration of Catalonia and reported for the most representative municipality of each crop according to UA production (t) in the AMB (SI1-3.1). OMSW, organic municipal solid waste; WWTP, wastewater treatment plant; NH_4, ammonium salts recovered from WWTP; REF, reference; COM, compost; STA, struvite and ammonium salts; and PRU, pruning scenarios.

Crop type		**Fertilization practice**	**Scenario - N shares**			
			REF	**COM**	**STA**	**PRU**
Vegetable	Tomato	Synthetic mineral fertilizer	51%	37%	0%	28%
		Manure	26%	26%	26%	26%
		WWTP sludge	7%	7%	7%	7%
		OMSW compost	9%	23%	9%	9%
		WWTP struvite + NH_4 salts	0%	0%	51%	0%
		Pruning	0%	0%	0%	23%

		Irrigation water	7%	7%	7%	7%
	Lettuce, pepper	Synthetic mineral fertilizer	51%	26%	0%	28%
		Manure	26%	26%	26%	26%
		WWTP sludge	7%	7%	7%	7%
		OMSW compost	9%	34%	9%	9%
		WWTP struvite + NH_4 salts	0%	0%	51%	0%
		Pruning	0%	0%	0%	23%
		Irrigation water	7%	7%	7%	7%
Fruit	Peach	Synthetic mineral fertilizer	25%	0%	0%	14%
		Manure	11%	11%	11%	11%
		WWTP sludge	17%	17%	17%	17%
		OMSW compost	2%	27%	2%	2%
		WWTP struvite + NH_4 salts	0%	0%	25%	0%
		Pruning	0%	0%	0%	11%
		Irrigation water	45%	45%	45%	45%
	Apple	Synthetic mineral fertilizer	5%	0%	0%	3%
		Manure	21%	21%	21%	21%
		WWTP sludge	0%	0%	0%	0%
		OMSW compost	7%	12%	7%	7%
		WWTP struvite + NH_4 salts	0%	0%	5%	0%
		Pruning	0%	0%	0%	2%
		Irrigation water	67%	67%	67%	67%
	Pear	Synthetic mineral fertilizer	57%	0%	0%	31%
		Manure	27%	27%	27%	27%
		WWTP sludge	0%	0%	0%	0%
		OMSW compost	3%	60%	3%	3%
		WWTP struvite + NH_4 salts	0%	0%	57%	0%
		Pruning	0%	0%	0%	26%
		Irrigation water	13%	13%	13%	13%

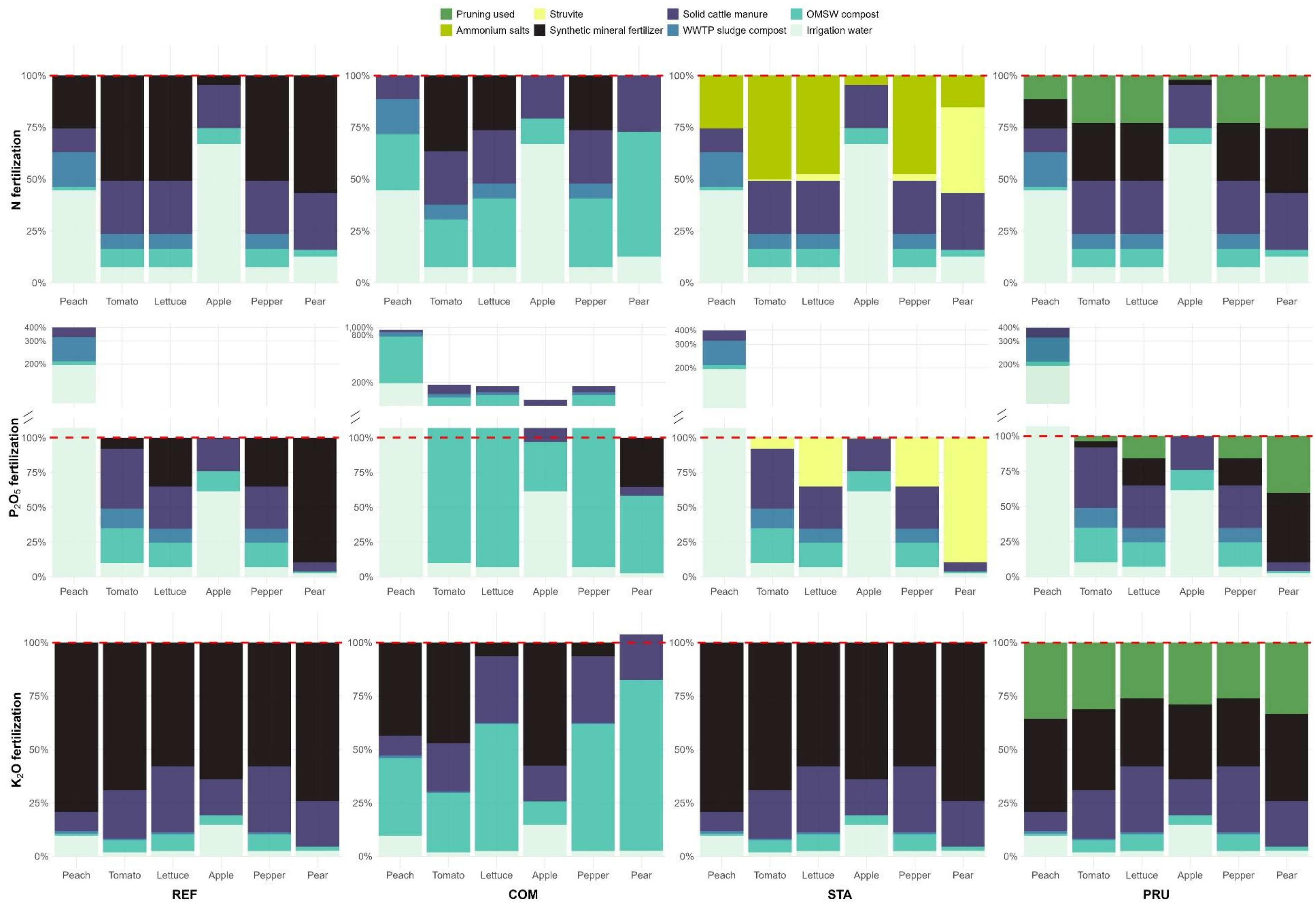
Table SI1-10. P_2O_5 fertilization shares for each crop's annual nutrient demand by scenario and crop type. All crops but pear present P_2O_5 oversupply in COM. For peach, fertilization shares in all scenarios sum to 381% due to P_2O_5 oversupply, shown as "(+%)". REF represents current fertilization practices based on the Annual Nitrogen Declaration of Catalonia and reported for the most representative municipality of each crop according to UA production (t) in the AMB (SI1-3.1). OMSW, organic municipal solid waste; WWTP, wastewater treatment plant; NH_4, ammonium salts recovered from WWTP; REF, reference; COM, compost; STA, struvite and ammonium salts; and PRU, pruning scenarios.

Crop type		Fertilization practice	Scenario - P_2O_5 shares			
			REF	COM	STA	PRU
Vegetable	Tomato	Synthetic mineral fertilizer	8%	0%	0%	4%
		Manure	43%	43%	43%	43%
		WWTP sludge	14%	14%	14%	14%
		OMSW compost	25%	33% (+86%)	25%	25%
		WWTP struvite + NH_4 salts	0%	0%	8%	0%
		Pruning	0%	0%	0%	4%
		Irrigation water	10%	10%	10%	10%
	Lettuce, pepper	Synthetic mineral fertilizer	35%	0%	0%	19%
		Manure	30%	30%	30%	30%
		WWTP sludge	10%	10%	10%	10%
		OMSW compost	18%	53% (+79%)	18%	18%
		WWTP struvite + NH_4 salts	0%	0%	35%	0%
		Pruning	0%	0%	0%	16%
		Irrigation water	7%	7%	7%	7%
Fruit	Peach	Synthetic mineral fertilizer	0%	0%	0%	0%
		Manure	62%	62%	62%	62%
		WWTP sludge	110%	110%	110%	110%
		OMSW compost	13%	13% (+553%)	13%	13%
		WWTP struvite + NH_4 salts	0%	0%	0%	0%
		Pruning	0%	0%	0%	0%
		Irrigation water	196%	196%	196%	196%
	Apple	Synthetic mineral fertilizer	0%	0%	0%	0%
		Manure	24%	24%	24%	24%
		WWTP sludge	0%	0%	0%	0%
		OMSW compost	15%	15% (+20%)	15%	15%
		WWTP struvite + NH_4 salts	0%	0%	0%	0%
		Pruning	0%	0%	0%	0%
		Irrigation water	61%	61%	61%	61%
	Pear	Synthetic mineral fertilizer	90%	35%	0%	49%
		Manure	7%	7%	7%	7%
		WWTP sludge	0%	0%	0%	0%
		OMSW compost	1%	56%	1%	1%
		WWTP struvite + NH_4 salts	0%	0%	90%	0%
		Pruning	0%	0%	0%	41%
		Irrigation water	2%	2%	2%	2%

Table SI1-11. K_2O fertilization shares for each crop's annual nutrient demand by scenario and crop type. Only pear in COM scenario presents an K_2O oversupply, shown as "(+%)". REF represents current fertilization practices based on the Annual Nitrogen Declaration of Catalonia and reported for the most representative municipality of each crop according to UA production (t) in the AMB (SI1-3.1). OMSW, organic municipal solid waste; WWTP, wastewater treatment plant; NH_4, ammonium salts recovered from WWTP; REF, reference; COM, compost; STA, struvite and ammonium salts; and PRU, pruning scenarios.

Crop type		Fertilization practice	Scenario - K_2O shares			
			REF	COM	STA	PRU
Vegetable	Tomato	Synthetic mineral fertilizer	69%	47%	69%	38%
		Manure	23%	23%	23%	23%
		WWTP sludge	1%	1%	1%	1%
		OMSW compost	6%	28%	6%	6%
		WWTP struvite + NH_4 salts	0%	0%	0%	0%
		Pruning	0%	0%	0%	31%
		Irrigation water	1%	1%	1%	1%
	Lettuce, pepper	Synthetic mineral fertilizer	58%	6%	58%	32%
		Manure	31%	31%	31%	31%
		WWTP sludge	1%	1%	1%	1%
		OMSW compost	8%	60%	8%	8%
		WWTP struvite + NH_4 salts	0%	0%	0%	0%
		Pruning	0%	0%	0%	26%
		Irrigation water	2%	2%	2%	2%
Fruit	Peach	Synthetic mineral fertilizer	79%	44%	79%	44%
		Manure	9%	9%	9%	9%
		WWTP sludge	1%	1%	1%	1%
		OMSW compost	1%	36%	1%	1%
		WWTP struvite + NH_4 salts	0%	0%	0%	0%
		Pruning	0%	0%	0%	35%
		Irrigation water	10%	10%	10%	10%
	Apple	Synthetic mineral fertilizer	64%	58%	64%	35%
		Manure	17%	17%	17%	17%
		WWTP sludge	0%	0%	0%	0%
		OMSW compost	5%	11%	5%	5%
		WWTP struvite + NH_4 salts	0%	0%	0%	0%
		Pruning	0%	0%	0%	29%
		Irrigation water	14%	14%	14%	14%
	Pear	Synthetic mineral fertilizer	74%	0%	74%	41%
		Manure	21%	21%	21%	21%
		WWTP sludge	0%	0%	0%	0%
		OMSW compost	2%	76% (+4%)	2%	2%
		WWTP struvite + NH_4 salts	0%	0%	0%	0%
		Pruning	0%	0%	0%	33%
		Irrigation water	3%	3%	3%	3%

Panel A



Pruning used
Struvite
Solid cattle manure
OMSW compost
Ammonium salts
Synthetic mineral fertilizer
WWTP sludge compost
Irrigation water
N fertilization
P2O5 fertilization
K2O fertilization
Peach
Tomato
Lettuce
Apple
Pepper
Pear
REF
COM
STA
PRU

Panel B

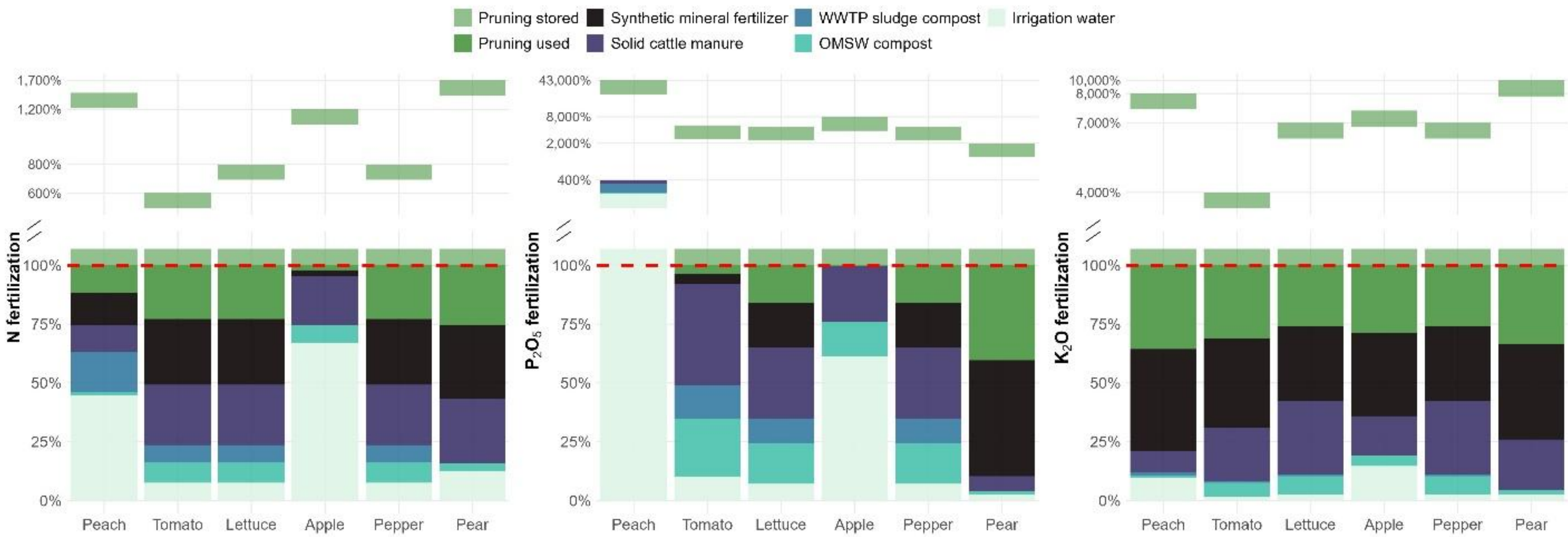


Figure SI1-3. N, P_2O_5, and K_2O fertilization shares of each crop's annual nutrient demand per scenario. Panel A (top) shows the annual fertilization shares for REF, COM, STA, and PRU, including P_2O_5 or K_2O oversupply where it occurs. Panel B (bottom) shows, for PRU, the nutrients not required to meet the year's crop demand and therefore interpreted as a nutrient legacy pool ("pruning stored") remaining available for the 5-year assumed horizon. The red dashed line at 100% marks the point at which nutrient demand is fully met. Values above 100% indicate nutrient oversupply and are displayed with a broken y-axis to show the full magnitude of the surplus. In panel B, this upper tier represents the nutrient legacy pool from pruning stored in PRU.

4. Life Cycle Assessment

4.1. Goal and scope

The function of each produce system is to supply (produce and distribute) fresh fruit and vegetables from the cultivation origin up to the wholesale market entry gate at Mercabarna. Given the two supply alternatives for each crop, local and imported, and the four local fertilization alternatives (scenarios), REF, COM, STA, and PRU, we define the reference flows as 1 kg of local crop produced under each fertilization scenario and 1 kg of imported crop.

4.2. Inventory analysis

Our cradle-to-market gate scope covers processes from material production used for crop cultivation to crop distribution from the cultivation origin to the wholesale market entry gate. We highlight three life cycle stages in our system boundaries: cultivation, packaging, and distribution. For cultivation, we included the following inputs: Infrastructure, agricultural machinery and diesel use, irrigation water (including irrigation system), fertilization (including the nutrient removal and recovery (NRR) technologies for recovered-fertilizer production in local crop production), and pesticides use. For packaging, we included plastic manufacturing and forming. And for distribution, we included road transport. For outputs, we included: Organic waste as food loss from cultivation in both crop systems (local and imported) and as food waste from distribution in imported crops only, plastic packaging waste, direct NH_3, NMVOC, N_2O, and CH_4 emissions to air from composting, and direct NH_3, NO_x, N_2O to air and NO_3^- and PO_4^{3-} to water from fertilizer use-on-land.

We adapted most of the crop-specific AMB data used to model local crop systems from previous and ongoing work with the URBAG agricultural map (Mendoza Beltran et al. 2022), including: N, P_2O_5, and K_2O fertilizers demand and N_2O emission factors from Mendoza Beltran et al. (2022), irrigation water requirements from Mendoza Beltran et al. (2026); and machinery use from Mendoza Beltran et al. (2023).

In the following subsections (SI1-4.2.1 to SI1-4.2.11) we describe sources, assumptions, and calculations used to build the LCIs for each crop, scenario, and fertilizers-CNS. Supplementary Information 2 (SI2) provides the complete LCIs for crops (Tables SI2-1 to SI2-6) and CNSs (Tables SI2-7 to SI2-9), including Table SI2-10 with LCI for food waste management (collection and treatment at an AMB facility) and Table SI2-11 with emission factors for direct emissions to air and water.

4.2.1.Cultivation typology, yield and infrastructure

For infrastructure inputs, we first assigned a site-specific cultivation typology to each local and imported crop based on the most representative cultivation practice identified for its corresponding origins. The origin of all local crops is the AMB, while for imported counterparts we used the main origin identified for each crop in the import analysis (SI1-1.3). We assumed all local crops to be predominantly cultivated in open-field on soil, as shown in the URBAG agricultural map of the AMB (Mendoza Beltran et al. 2022). For imported crops, we compiled LCIs specific to conventional production in the corresponding origins and treated the cultivation practice (production system and growing medium) reported in those sources as representative. We also used the crop yield reported in each source to scale and convert all inputs to the FU applied in this study. Table SI1-12 presents the origin and cultivation typology assumed for each local and imported crop, and Table SI1-13 presents the site-specific LCI data sources compiled to model them, including the corresponding yield.

Table SI1-12. Origin and cultivation typology assumed for each local and imported crop.

Crop system	**Produce type**	**Crop**	**Origin**	**Cultivation system**		**Cultivation medium**		**Orchard system**	
				Open-field	**Unheated greenhouse**	**Soil**	**Substrate**	**Free standing**	**Trellis**
Local	Vegetable	Tomato	AMB, ES	X		X		–	–
		Pepper		X		X		–	–
		Lettuce		X		X		–	–
	Fruit	Peach		X		X		X	
		Apple		X		X			X
		Pear		X		X			X
Imported	Vegetable	Tomato	Almeria, ES		X		X	–	–
		Pepper			X	X		–	–
		Lettuce	Murcia, ES	X		X		–	–
	Fruit	Peach	Lleida, ES	X		X		X	
		Apple		X		X			X
		Pear		X		X			X

Table SI1-13. Site-specific LCI data source and crop yield for each local and imported crop.

Produce type	**Crop**	**Site-specific LCI data source**		**Crop yield (kg m^{-2})**	
		Local	**Imported**	**Local**	**Imported**
Vegetable	Tomato	N, P_2O_5, and K_2O demand, agricultural machinery, and irrigation water from Mendoza Beltran et al. (2022, 2023, 2026), respectively	Torrellas et al. (2012)	4.16	16.50
	Pepper		Romero Gámez et al. (2018, 2023)	2.07	8.00
	Lettuce		Milà i Canals et al. (2008) and Martin-Gorriz et al. (2020)	2.07	2.65
Fruit	Peach		Vinyes et al. (2015, 2017)	1.09	3.61
	Apple		(Vinyes et al. 2017, 2018)	2.41	4.34
	Pear		CREDA-UPC-IRTA (2020)	1.61	2.50

For imported vegetables, we modelled tomato as unheated greenhouse production on substrate, using the reported greenhouse, substrate, substrate bed, and bed plastic inputs from Torrellas et al. (2012); pepper as unheated greenhouse production on soil, adapting the greenhouse input from Romero Gámez et al. (2018, 2023); and lettuce as open-field production, for which no infrastructure inputs were considered, following Martin-Gorriz et al. (2020). We modelled greenhouse input using an ecoinvent cut-off market dataset (Wernet et al. 2016) for greenhouses with plastic walls and roof, computed per FU (m^2 yr kg^{-1}) using crop yield as 1 ha divided by yield (kg ha^{-1}). For imported fruits, we modelled peach as a free-standing orchard system without trellis, consistent with common Catalan "vas català" cultivation system (IRTA 2022), for which we did not considered any infrastructure input. We modelled apple and pear as trellised orchard systems, consistent with intensive cultivation reported for these crops (CREDA-UPC-IRTA 2020; Vinyes et al. 2018), for which we estimate a trellis input. We modelled the trellis input using an ecoinvent cut-off market dataset (Wernet et al. 2016) for trellis system, computed per FU as ha kg^{-1} using crop yield as 1 ha divided by yield (kg ha^{-1}), corresponding to 1 ha of trellis service. For local crops, we did not consider infrastructure inputs for vegetables, consistent with the assumption of open-field cultivation on soil. For fruits, we assumed the same orchard systems as for the imported counterparts and scaled the corresponding infrastructure inputs to local crop yields.

We also include additional electricity inputs associated with greenhouse operation when these were reported, specifically for greenhouse ventilators in imported tomato, following Torrellas et al. (2012), and for the operation of windows in imported pepper, following Romero Gámez et al. (2018, 2023). These inputs were converted from kWh ha^{-1} to kg^{-1} using crop-specific yield.

4.2.2. Agricultural machinery and diesel

For each local crop, we model machinery manufacturing as a fixed machinery requirement per planted hectare using an ecoinvent cut-off dataset (Wernet et al. 2016) for planting as proxy – 1.17 kg agricultural machinery ha^{-1} – where the land requirement (ha) per FU (kg crop) was obtained from each crop yield (kg ha^{-1}) as ha/kg = 1/yield. Thus, machinery production per FU is (Eq. 3):

$$\textbf{Machinery}_{kg/kg} = \textbf{1.17 (kg/ha) x (ha/kg crop)} \qquad (3)$$

For imported crops, we take and/or adapt agricultural machinery needs (kg) from the site-specific inventory representing each import origin (SI1-4.2.1).

We represent burdens from fuel combustion by agricultural machinery separately from machinery manufacturing. For local crops, we take the total machinery use (h ha^{-1} yr^{-1}) by municipality and aggregated crop types from Mendoza Beltran et al. (2023). For each crop, we selected the machinery use corresponding to the municipality concentrating the largest cultivated area of that crop and to the crop type (see SI1-3.1), following the URBAG agricultural map dataset (Mendoza Beltran et al. 2022). Table SI1-14 presents the machinery use selected for each local crop.

Table SI1-14. Selected machinery use per local crop.

Crop type	Crop	Municipality	Machinery use ($h\ ha^{-1}\ yr^{-1}$)
Horta	Tomato	Sant Boi de Llobregat	35
	Lettuce		35
	Pepper		35
Altres fruiters regadiu / secà	Peach	Santa Coloma de Cervelló	21
	Apple	Sant Vicenç dels Horts	21
	Pear	Viladecans	20.05

For fruits, we compute the machinery hours as the average of the two reported fruit types: Irrigated fruits and non-irrigated fruits (*Altres fruiters regadiu / secà*), while vegetables use the Orchard (*Horta*) type. We translate the time intensities ($h\ ha^{-1}\ yr^{-1}$) of each crop into diesel use ($kg\ ha^{-1}\ yr^{-1}$) following the fuel consumption equation from Nemecek et al. (2007), calculated as (Eq. 4):

$$\mathbf{Diesel_{kg/ha} = (hours/ha) \times (L/h) \times 0.84\ (kg/L)} \qquad (4)$$

where diesel consumption is obtained from the total operation time, a fuel consumption rate, and then converted to mass using diesel density (0.84 $kg\ L^{-1}$). According to Mendoza Beltran et al. (2023), the aggregated machinery use for vegetables (Horta) is allocated as 50% walking tractor use and 50% regular tractor with plough/accessory, while for fruits as 100% regular tractor with plough/accessory. We use these machinery typologies to set fuel consumption rates to 4.2 $L\ h^{-1}$ for regular tractor (Nemecek et al. 2007) and 1 $L\ h^{-1}$ for walking tractor (assumed, consistent with lower-power machinery). We then convert diesel used from kg to MJ using 45 $MJ\ kg^{-1}$ diesel, heating value reported in an ecoinvent cut-off market dataset (Wernet et al. 2016) for diesel burned in agricultural machinery, and express it per FU by scaling to each local crop yield. For imported crops, we take and/or adapt the diesel burned by agricultural machinery (MJ) from the site-specific inventory representing each import origin.

4.2.3. Fertilizers and CNS

For imported crops, we took the N, P_2O_5, and K_2O fertilizer inputs per kg crop directly from the corresponding site-specific sources. We assumed that all imported crops are fertilized entirely with synthetic mineral fertilizers. To model these inputs, we used ecoinvent cut-off market datasets for Spain (Wernet et al. 2016), representing separate inorganic forms of N, P_2O_5, and K_2O.

For local crops, we calculated fertilizer inputs per kg crop for each scenario using the corresponding shares and fertilizer characterizations defined in SI1-3.1. We modelled synthetic mineral fertilizer as for imported crops, using the same separate ecoinvent cut-off market datasets for Spain (Wernet et al. 2016). We modelled solid cattle manure using ecoinvent cut-off market dataset for fresh, solid cattle manure. For WWTP sludge compost, we represented its burdens with a generic compost fertilizer dataset, using the ecoinvent cut-off market dataset for compost.

For CNS fertilizers, we included the nutrient removal and recovery (NRR) technologies considered in each local fertilization scenario and modelled them as described in the following subsections. Tables SI2-7, SI2-8, and SI2-9 provide complete LCIs for OMSW compost, struvite and ammonium salts, and pruning residues, respectively.

4.2.3.1. OMSW compost

For OMSW compost used in the REF and COM scenarios, we modelled the NRR technology as centralized industrial composting, using the LCI detailed in Arosemena Polo et al. (2024). This LCI models the AMB OMSW compost market using primary data from three centralized compost facilities: Mechanical-biological treatment (MBT; anaerobic digestion + in-vessel composting) at Zona Franca Ecoparc 1; in-vessel composting at the Sant Cugat composting plant; and open-air turned-windrow composting at the Torrelles composting plant. This LCI addresses multifunctionality in OMSW composting – recycling and co-production of compost and biogas – through substitution (i.e., avoided burdens). These include electricity cogenerated from biogas substituting conventional electricity production and composting substituting the mixed treatment of non-selectively collected OMSW. We maintained this approach to represent avoided activities that distinguish linear from circular fertilizers systems, as discussed in Mendoza Beltran et al. (2026).

We adapted this inventory to per 1 kg of compost and introduced two assumptions for the MBT facility based on current treatment at Zona Franca Ecoparc 1 (AMB 2022). First, we assume that all refused waste output from composting within the organic fraction line is incinerated rather than landfilled, while refused waste from composting in the RESTA line is landfilled. Second, we assume that the biostabilized output from OMSW treatment in the RESTA line is used as a soil amendment or in public construction and therefore leaves our system boundaries, rather than being modelled as CH_4 emissions from landfilling.

4.2.3.2. WWTP struvite and ammonium salts

For struvite and ammonium salts used in the STA scenario, we modelled the NRR technologies of crystallization for P recovery and ion exchange plus hollow-fibre membrane contactor for N recovery from WWTPs. We used the LCI detailed in Mendoza Beltran et al. (2026), which derives from the LIFE

ENRICH project (Mayor et al. 2023), a pilot-scale recovery process for struvite and ammonium salts in a WWTP in Murcia, Spain, and adapted to WWTP data from the AMB.

4.2.3.3. Pruning residues

For pruning residues, used in the PRU scenario, we modelled the NRR process as shredding followed by direct soil application. We built this LCI using experimental data from the NUTRISOIL (2024) project, as detailed in Evangelista et al. (2026) (see SI1-3.4). We included pruning shredding, modelled as wood chipping 15 t of fresh biomass per hour with an ecoinvent cut-off market dataset (Wernet et al. 2016), machinery use for direct soil application, and transport from shredding plant to fields, assumed to be 10 km, including return trip.

4.2.4.Irrigation water

For imported crops, we take the irrigation water input from the corresponding site-specific life cycle inventories. We model irrigation in all imported vegetables systems as drip irrigation, consistent with the inventories used for tomato (Torrellas et al. 2012), lettuce (Martin-Gorriz et al. 2020), and pepper (Romero Gámez et al. 2018, 2023). For imported fruits, we also assume drip irrigation based on CREDA-UPC-IRTA (2020), which reports that 70% of fruit cultivation in Catalonia uses drip systems. For local crops, we quantified foreground irrigation water use with the URBAG agricultural map (Mendoza Beltran et al. 2022) dataset and the water inventory approach described in Mendoza Beltran et al. (2026). For each agricultural polygon, we compute the annual water use ($m^3\ ha^{-1}\ yr^{-1}$) as irrigation demand adjusted for distribution and irrigation losses. Then, for each crop assessed, we aggregate the water use at polygon-level to the corresponding specific crop type/group and convert it to per-kg crop using the corresponding crop yields ($kg\ ha^{-1}$), yielding a direct water use ($m^3\ kg^{-1}$) intensity. Table SI1-15 presents the aggregated local irrigation demand and water use for each assessed crop. We assume all local crops are irrigated using surface irrigation (flooding), reflecting the dominant irrigation typology for UA in the AMB as characterized in the URBAG agricultural map (Mendoza Beltran et al. 2022) and corroborated through communication with local office representatives (*Parc Agrari Baix Llobregat*), which reported limited use of drip or sprinkler systems across AMB municipalities.

Table SI1-15. Aggregated irrigation demand and water consumption per local crop.

Crop	Total area (ha)	Irrigation demand ($m^3\ ha^{-1}\ yr^{-1}$)	Water consumption ($m^3\ ha^{-1}\ yr^{-1}$)
Peach	318.76	2,688.10	3,880.38
Tomato	241.19	3,866.14	5,605.90
Lettuce	157.95	5,606.26	8,102.02
Apple	41.66	609.58	883.89

Pepper	18.05	5,606.26	8,102.02
Pear	25.03	2,565.10	3,683.84

4.2.5. Pesticides

For imported crops, we take and/or adapt the pesticide inputs from site-specific references. For local crops, we assume the same pesticide application rate as the imported counterpart and scale it to each local crop yield. Then, we represent a partial adoption of integrated pest management (IPM) and lower-input practices by applying an IPM factor of 0.80 (20% reduction) to the resulting local pesticide intensity. This assumption is motivated by the rapid expansion of organic ("ecològica") farming in Catalonia (23% of utilized agricultural area and its measurable presence in Barcelona of 12% of cultivated area) (GenCat 2023), where production restricts synthetic pesticide use. However, uptake is not universal across peri-urban production in the AMB, so we apply a moderate reduction rather than modelling all local crops as fully organic.

4.2.6. Packaging

Plastic (HDPE) crates are a common packaging option for transporting fresh fruits and vegetables from farm to wholesale market (CREDA-UPC-IRTA 2020; Sanyé-Mengual et al. 2013), therefore we selected this option to represent packaging in the post-harvest stage for all local and imported crops. We assume plastic crates are reusable, with more reuses in local crops (50 uses) than in imported crops (20 uses), reflecting tighter packaging control in short supply chains and lower transport-related damage (Sanyé-Mengual et al. 2013). We adapt and/or compute the amount of HDPE (kg) representing the plastic crate for each imported crop as follows: For tomato, we adapt the per-kg HDPE amount from Sanyé-Mengual et al. (2013, 2015), which is tomato- and Almeria-specific, using a 0.9 kg reusable crate with a 6 kg load capacity for 20 uses; for lettuce, we compute the HDPE amount from the crate described in González Benavente García and López Marín (2003), which is lettuce- and Murcia-specific, assuming 12 loose heads of lettuce per crate and a default crate mass of 2.7 kg; for pepper, we assume the same crate as in tomato as proxy; and for fruits (peach, apple, and pear), we compute the HDPE amount from the crate characteristics reported in CREDA-UPC-IRTA (2020), which are crop- and Catalunya-specific. For local crops except tomato, we assume the same crate as the corresponding import crop, adapted to 50 uses; for local tomato, we take the value reported in Sanyé-Mengual et al. (2013), specific for a short supply chain of local tomato. We use the HDPE values as material input to model packaging manufacturing and forming, including associated transportation.

4.2.7. Distribution

We define distribution as the road transportation of fresh crops from the representative cultivation origin up to the wholesale market gate at Mercabarna. In this study, we model distribution as land-only road freight transport by vehicle or lorry, depending on the assumed road distance (km). For the road distances, we first defined a specific representative origin for each local and imported crop corresponding to the municipality or region concentrating the largest cultivated area of that crop. For local crops, we use the municipalities assigned to each crop or crop group in SI1-3.1, identified by analyzing the URBAG agricultural map (Mendoza Beltran et al. 2022). For imported crops except tomato, we refined the origins reported in SI1-1.3. by identifying a more specific origin proxy based on agricultural production information compiled from available web sources. For each origin, we then estimate a rounded road-distance proxy to Mercabarna. For imported tomato, we use the crop- and origin-specific road distance reported by Sanyé-Mengual et al. (2013). Table SI1-16 presents the refined representative origin selected for each local and imported crop and the corresponding assumed road-distance proxy to Mercabarna.

Table SI1-16. Refined representative origin and road distance proxy per local and imported crop.

Origin	Produce type	Crop	Specific representative origin	Road distance proxy to Mercabarna (km)
Local	Vegetable	Tomato Lettuce Pepper	Sant Boi de Llobregat, Barcelona (AMB), ES	8
	Fruit	Peach	Santa Coloma de Cervelló, Barcelona (AMB), ES	15
		Apple	Sant Vicenç dels Horts, Barcelona (AMB), ES	
		Pear	Viladecans, Barcelona (AMB), ES	
Imported	Vegetable	Tomato	Almeria, ES	850
		Lettuce	Torre-Pacheco, Murcia, ES	600
		Pepper	El Ejido, Almeria, ES	800
	Fruit	Peach	Aitona, Lleida, ES	175
		Apple	Corbins (Segrià), Lleida, ES	160
		Pear	Lleida, Lleida, ES	150

We use the above road distances (km) to calculate the transport demand for each crop in ton-kilometers per kg crop (tkm kg^{-1}). We assign the type of vehicle or lorry according to three road-distance ranges: Light commercial vehicle for up to 50 km; 16-32 t lorry for above 50 km and up to 500 km; and >32 t lorry for distances above 500 km. Because fresh fruits and vegetables are perishable, we assume imported crops are transported in refrigerated lorries to maintain freshness during long-distance transport. And because the modeled lorries do not include cooling, we include the burdens from reefer operation (for cooling) as a separate add-on to those lorries. For this, we use a reefer-operation value embedded in the ecoinvent cut-off dataset (Wernet et al. 2016) for cooled-lorry (0.926 kg day tkm^{-1}), which we converted and reported per kg crop in each crop inventory.

4.2.8. Food loss and waste

We follow Caldeira et al. (2019) and adopt the FUSIONS (2014) definition of food loss and waste (FLW) as food and associated inedible parts removed from the supply chain for valorization or disposal. We use "food loss" for FLW generated at the primary-production stage (cropping), while "food waste" for FLW generated during post-harvest stages – mainly packaging and distribution up to retail gate. We include FLW in the system boundaries to represent both: (i) upstream losses associated with distributing the FU (1 kg crop), meaning that more than 1 kg must be cultivated/distributed to deliver 1 kg crop (i.e., input multiplier), and (ii) the mass of organic waste requiring treatment at cropping and post-harvest stages.

We do not apply food loss as an additional multiplier to cropping inputs in either imported or local crops. For imported crops, we collected inventory data already reported per kg crop, so we assume upstream losses are embedded in those data. For local crops, we computed inventory data from per-ha datasets and converted to per-kg crop using marketable yields (t ha^{-1}), or adapted data from imported inventories already expressed per-kg crop; thus, we assume food loss is likewise embedded in the resulting inventories. Moreover, we only use food waste for post-harvest input scaling in imported crops. For local crops, we assume post-harvest food waste to be zero following a short supply chain (neighborhood-scale) Sanyé-Mengual et al. (2013), in which local crops are cultivated near the wholesale market (Mercabarna) and sold immediately, thus minimizing transport, handling, and food waste overall.

When available, we adopt crop- and site-specific FLW factors for each local and imported crop; otherwise, we assumed broader proxies. For local and imported fruits, we use the FLW factors from CREDA-UPC-IRTA (2020), which are suitable for both local and imported fruit systems because they are Catalunya- and crop-specific for peach, apple, and pear. For local vegetables, we adopt or adapt food loss factors as follows: Tomato from CREDA-UPC-IRTA (2021), which is Catalonia- and open-field tomato-specific; and lettuce and pepper from Tonini et al. (2022), which is Catalonia- and lettuce-specific in the former case, converting the reported factor of marketed product to a gross-production equivalent, and Catalonia-specific in the latter case, using the vegetable-basket average as proxy for pepper. For imported vegetables, we use the broad EU-level factors for fresh vegetables from Caldeira et al. (2019) for primary-production (food loss) and post-harvest distribution (food waste). Table SI1-17 summarizes the FLW factors adopted for each crop.

Table SI1-17. FLW factors for local and imported crops.

Stage	Crop	FLW factors (%)	
		Local	Imported
Primary production (food loss)	Peach	4.0%	4.0%
	Tomato	14.4%	15.8%

	Lettuce	32.4%	15.8%
	Apple	2.0%	2.0%
	Pepper	26.0%	15.8%
	Pear	2.8%	2.8%
Post-harvest, packaging + distribution (food waste)	Peach	0%	4.0%
	Tomato	0%	1.9%
	Lettuce	0%	1.9%
	Apple	0%	3.5%
	Pepper	0%	1.9%
	Pear	0%	3.8%

For imported crops, we use post-harvest food waste as an input multiplier for packaging and distribution processes occurring before the waste point. We calculate the amount entering the post-harvest stages required to distribute 1 kg crop as (Eq. 5):

$$\textbf{Post-harvest input}_{/\text{kg crop}} = 1 / (1 - L) \tag{5}$$

where L is the corresponding food waste factor. For local and imported crops, we use cultivation food loss as single gross-basis coefficient and post-harvest food waste as a single stage-entry coefficient. Thus, for 1 kg crop, we compute the mass of organic waste generated from food loss or food waste as (Eq. 6):

$$\textbf{FLW mass}_{\text{kg/kg crop}} = L / (1 - L) \tag{6}$$

where L is the corresponding food loss or food waste factor.

4.2.9. Waste treatment

In local and imported crops, we assume food loss generated at the cultivation stage is treated through on-farm composting, modelled as composting in heaps and containers as a proxy for open-air composting. For food waste generated at post-harvest stage in imported crops, we assume collection and management following Mercabarna's practice, in which nearly 10% is recovered through *Foodback* (on-site food recovery and redistribution program for unsold fruits and vegetables) and the remaining (90%) is treated as organic waste via industrial composting and biogas recovery (Mercabarna 2024). We model waste collection and industrial composting at the AMB MBT facility (Zona Franca Ecoparc 1) with the LCI for OMSW compost detailed in Arosemena Polo et al. (2024). We adapted the LCI to 1 kg of OMSW treated using the waste-to-compost ratio of 23.02 t OMSW t^{-1} compost specific for the MBT facility, reported in Arosemena Polo et al. (2024). Table SI2-10 presents this LCI for food waste management. Moreover, we assume plastic waste generated from packaging (plastic crate, see SI1-4.2.6) to be treated as 50% landfilled and 50% recycled.

4.2.10. Direct emissions to air and water

We adapted direct NH_3, NMVOC, N_2O, and CH_4 emissions to air from OMSW composting at three facilities representing AMB's compost market, using the compost LCI from Arosemena Polo et al. (2024). For fertilizer use-on-land, we calculated NH_3, NO_x, N_2O emissions to air, and NO_3^- and PO_4^{3-} to water, for each fertilizer, CNS, crop, and scenario using the corresponding fertilizer inputs (kg fertilizer kg^{-1} crop), nutrient content characterization, and selected fertilizer-specific emission factors. Table SI2-11 reports the emission factors used for each fertilizer and emission. These include Tier 2 crop-specific emission factors for N_2O in local crops from Mendoza Beltran et al. (2022), mitigation factors for struvite according to Wang et al. (2023), and Tier 3 emission factors for CO_2, CH_4, N_2O, and NH_3 from pruning residues, detailed in Evangelista et al. (2026) from experimental data measured in the NUTRISOIL (2024) project. We assumed ammonium salts have the same emission factors as synthetic mineral N fertilizer. For imported crops, we assumed default emission factors except for tomato and pepper, for which we used reported values from Torrellas et al. (2012) and Romero Gámez et al. (2018, 2023), respectively. We converted emissions to full compounds using the corresponding molecular factors.

4.2.11. Temporary biogenic CO_2 retention

We account for temporary biogenic CO_2 retention from the direct application of pruning residues to soil, as soil C storage from organic amendments can be considered in LCA when explicitly modelled over a defined time horizon (Martínez-Blanco et al. 2013). In a pruning-residue experiment used as one of the empirical bases for this CNS (see SI1-3.4), 22% of the applied C remained in the soil system after 14 months (Pérez-Llorca et al. 2025). We do not interpret this as permanent sequestration; instead, we treat it as temporary C storage that may be mineralized over time.

To project retained C to a 100-year time horizon consistent with the climate change impact category used in this LCA (GWP_{100}, kg CO_2-eq; ReCiPe 2016 v1.03 midpoint (H) (Huijbregts et al. 2016)), we start from the pruning rate applied to soil (150 t ha^{-1}) and convert it to C input using the C content (48% C) (NUTRISOIL 2024). We then applied the 14-month retention fraction (Pérez-Llorca et al. 2025) to define the retained C stock in year one (t_1) and project it to year 100 using a first-order decay with a RothC-based formulation (Coleman and Jenkinson 1996) as (Eq. 7):

$$\mathbf{C_{100} = C(t_1)\ exp\ [-k\ (100-t_1)]} \qquad (7)$$

where k is the RothC humified organic matter (HUM) decay constant (0.02 yr^{-1}) (Coleman and Jenkinson 1996), and we converted C_{100} to CO_2-eq using the 44/12 factor.

Although OMSW compost application has been associated with 2-16% of applied C sequestered over 100 years (Martínez-Blanco et al. 2013), we do not include a comparable long-term storage for compost in our case study because compost did not lead to a measurable soil organic carbon (SOC) stock increase in the reference experiment and, given our compost inputs, any potential 100-year storage would be negligible relative to pruning inputs.

4.3. Impact assessment

We highlight the following environmental issues captured by each selected impact category: Climate change (CC; GWP_{100} – kg CO_2-eq) captures GHG from energy use, fertilizer production and use-on-land, distribution transport, and waste treatment, as well as the temporary biogenic CO_2 retention in PRU (see SI1-4.2.11); Freshwater eutrophication (FE; FEP – kg P-eq) and marine eutrophication (ME; MEP – kg N-eq) capture P and N losses associated with fertilization, respectively, including differences in nutrient substitution and availability; mineral resource scarcity (MRS; SOP – kg Cu-eq) captures mineral resource extraction associated with fertilizer production, energy use, and transport; and water use (WC; WCP – m^3) captures irrigation demand differences across crops, yields, irrigation typologies and local/imported origins. Table SI1-18 reports the absolute LCIA results for each local and imported crop, including local under circular fertilization scenarios, for each impact category. Figure SI1-4 presents the relative life cycle impacts per FU of each local crop under circular scenarios compared to imports. Moreover, Tables SI2-12 and SI2-13 report detailed contribution analysis and full LCIA results scaled to the total annual demand, respectively.

Table SI1-18. Absolute LCIA results for 1 kg of imported and locally grown crops under fertilization scenarios. The color scale is applied independently within each impact category, from green for the lowest impacts or credits to red for the highest impacts. In the Local baseline crops are fertilized entirely with synthetic mineral fertilizers, allowing us to compare local crops with imports before introducing fertilization scenarios, including current practices under the REF scenario, which already entail some degree of circularity. CC, climate change (GWP_{100} – kg CO_2-eq kg^{-1}); FE, freshwater eutrophication (FEP – kg P-eq kg^{-1}); ME, marine eutrophication (MEP – kg N-eq kg^{-1}); MRS, mineral resource scarcity (MRS; SOP – kg Cu-eq); and WC, water use (WCP – m^3 kg^{-1}). Local represents the linear fertilization baseline using synthetic mineral fertilizer; REF, reference scenario; COM, compost scenario; STA, struvite and ammonium salts scenario; and PRU, pruning residues scenario

Impact category	Crop	Imported	Local	Local under fertilization scenarios				Unit
				REF	COM	STA	PRU	
CC	Apple	2.47E-01	1.82E-01	1.41E-01	1.42E-01	1.41E-01	-4.61E-02	kg CO_2-eq
	Peach	2.28E-01	2.44E-01	2.00E-01	2.06E-01	1.95E-01	-2.23E-01	
	Pear	2.76E-01	2.29E-01	2.11E-01	2.04E-01	1.84E-01	-8.98E-02	
	Lettuce	3.67E-01	2.37E-01	1.96E-01	1.88E-01	1.81E-01	-4.79E-02	
	Pepper	7.36E-01	2.29E-01	1.89E-01	1.80E-01	1.74E-01	-5.56E-02	
	Tomato	5.26E-01	1.96E-01	1.59E-01	1.51E-01	1.51E-01	2.15E-02	
FE	Apple	5.06E-05	3.97E-05	2.95E-05	2.39E-05	2.97E-05	3.55E-05	kg P-eq
	Peach	4.41E-05	5.08E-05	4.33E-05	-1.50E-05	4.55E-05	5.56E-05	
	Pear	5.30E-05	5.34E-05	4.84E-05	-3.60E-05	4.72E-05	5.13E-05	
	Lettuce	5.68E-05	3.35E-05	1.90E-05	-3.96E-05	2.30E-05	2.36E-05	
	Pepper	1.73E-04	3.43E-05	1.98E-05	-3.88E-05	2.38E-05	2.44E-05	
	Tomato	1.10E-04	2.21E-05	1.26E-05	-9.63E-06	1.55E-05	1.42E-05	
ME	Apple	1.36E-04	3.11E-04	7.65E-05	4.92E-05	7.62E-05	7.16E-05	kg N-eq
	Peach	2.39E-04	5.82E-04	3.82E-04	9.72E-05	3.80E-04	3.20E-04	
	Pear	2.13E-04	3.49E-04	2.89E-04	-9.12E-05	1.46E-04	2.04E-04	
	Lettuce	5.87E-04	5.86E-04	4.97E-04	2.17E-04	4.73E-04	3.66E-04	
	Pepper	6.75E-04	5.87E-04	4.98E-04	2.19E-04	4.74E-04	3.67E-04	
	Tomato	6.82E-04	3.88E-04	3.29E-04	2.22E-04	3.24E-04	2.43E-04	
MRS	Apple	7.37E-03	6.27E-03	5.38E-03	5.14E-03	5.46E-03	7.53E-03	kg Cu-eq
	Peach	5.89E-03	8.07E-03	7.15E-03	4.71E-03	7.97E-03	1.18E-02	
	Pear	7.60E-03	7.68E-03	7.18E-03	3.40E-03	9.66E-03	9.89E-03	
	Lettuce	6.89E-03	4.00E-03	2.85E-03	3.39E-04	4.71E-03	5.10E-03	
	Pepper	7.57E-02	4.55E-03	3.40E-03	8.89E-04	5.26E-03	5.65E-03	
	Tomato	3.90E-02	2.79E-03	2.03E-03	1.10E-03	3.15E-03	3.06E-03	
WC	Apple	1.51E-03	1.72E-03	9.67E-04	8.00E-04	1.01E-03	1.05E-03	m^3
	Peach	1.52E-03	2.45E-03	1.55E-03	-1.89E-04	1.98E-03	1.63E-03	
	Pear	1.77E-03	2.21E-03	1.81E-03	-7.03E-04	1.54E-03	1.65E-03	
	Lettuce	2.49E-03	2.15E-03	1.25E-03	-4.98E-04	2.03E-03	1.10E-03	
	Pepper	6.25E-03	2.12E-03	1.22E-03	-5.29E-04	1.99E-03	1.07E-03	
	Tomato	4.05E-03	1.37E-03	7.75E-04	1.15E-04	1.35E-03	6.32E-04	

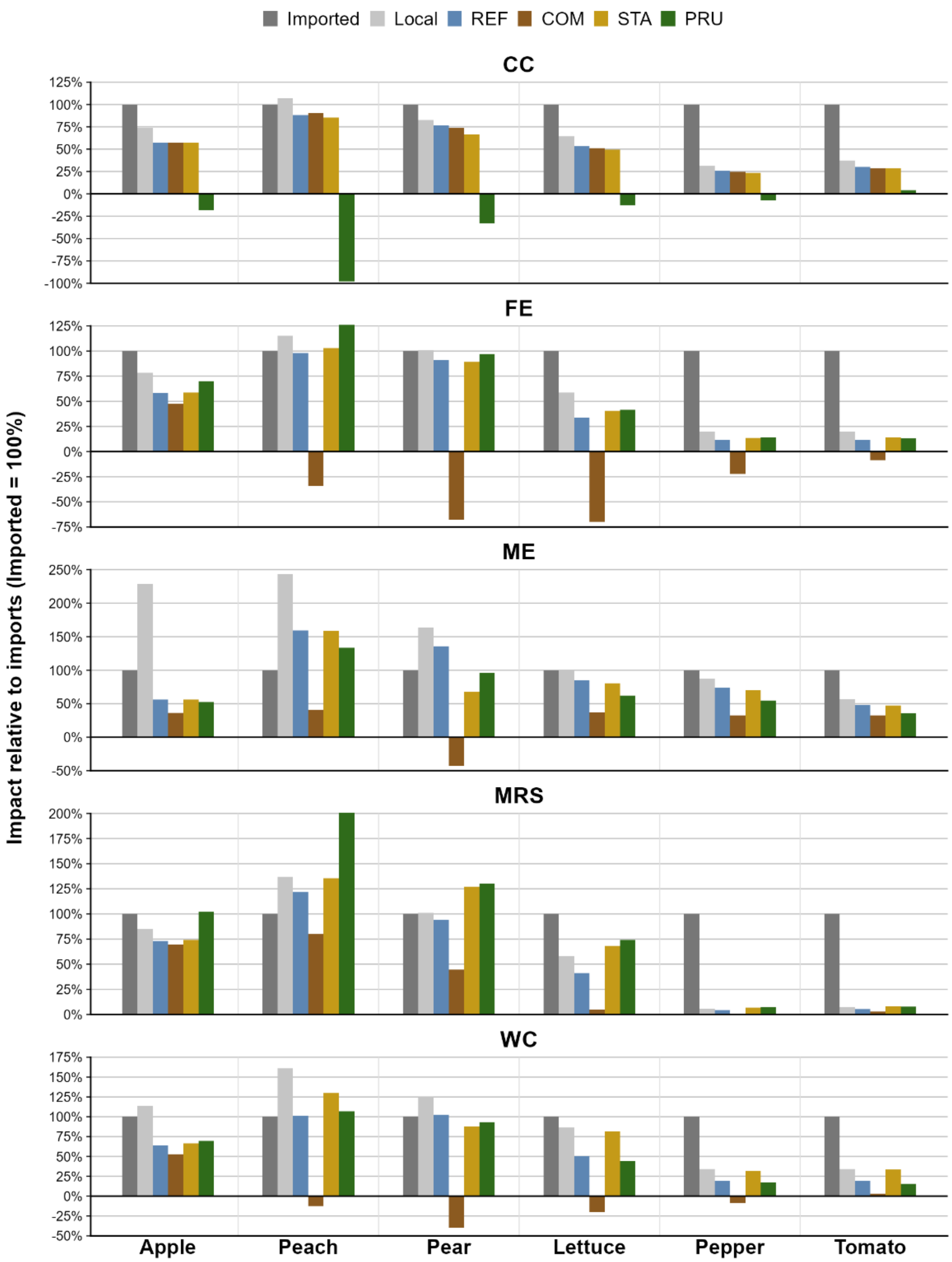
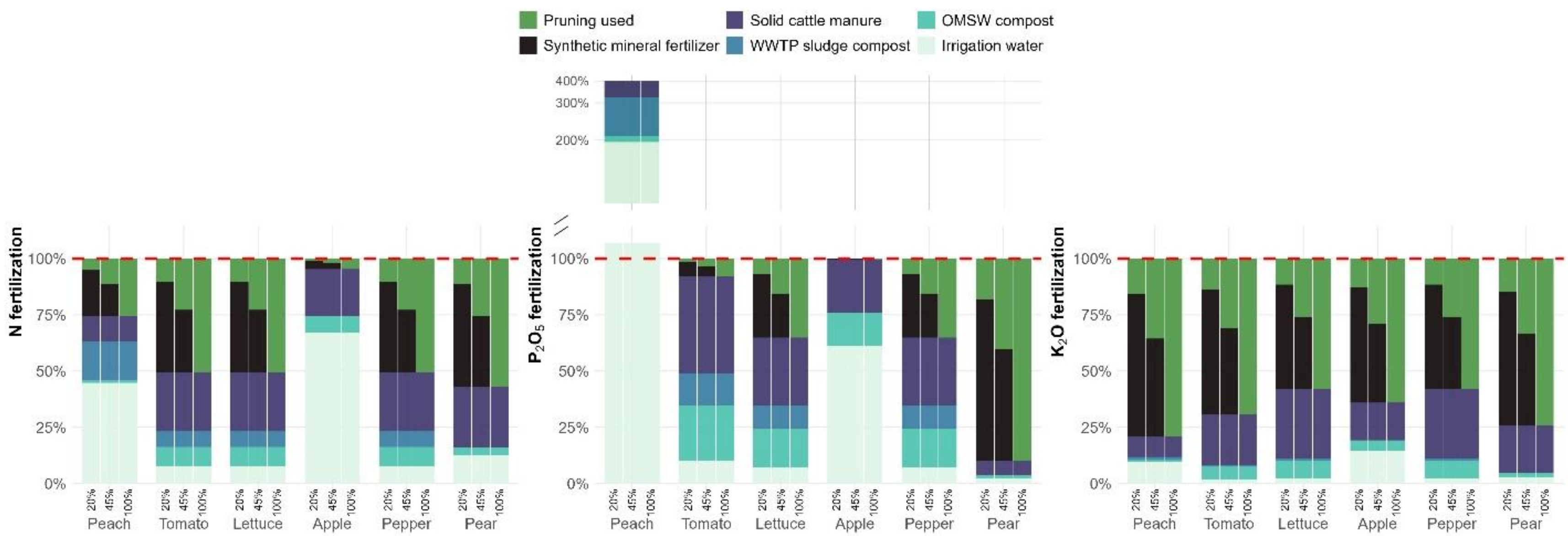


Figure SI1-4. Relative LCIA results for 1 kg of locally grown crops under fertilization scenarios compared with imported counterparts. Results are expressed relative to the imported counterpart for each crop and impact category, with Imported = 100%. In the Local baseline crops are fertilized entirely with synthetic mineral fertilizers, allowing us to compare local crops with imports before introducing fertilization scenarios, including current practices under the REF scenario, which already entail some degree of circularity. CC, climate change (GWP_{100} – kg CO_2-eq kg^{-1}); FE, freshwater eutrophication (FEP – kg P-eq kg^{-1}); ME, marine eutrophication (MEP – kg N-eq kg^{-1}); MRS, mineral resource scarcity (MRS; SOP – kg Cu-eq); and WC, water use (WCP – m^3 kg^{-1}). Local represents the linear fertilization baseline using synthetic mineral fertilizer; REF, reference scenario; COM, compost scenario; STA, struvite and ammonium salts scenario; and PRU, pruning residues scenario

4.4. Interpretation: Sensitivity analysis

For the 100% replacement, the upper bound of the 45% sensitivity, we represent full mineral fertilizer replacement under best practices following NUTRISOIL (2024) guidelines, including: pruning residues quality, crop selection (N-fixating), seasonality, and no-tillage (REGENSOL 2022; NUTRISOIL 2024; Evangelista et al. 2026). Figure SI1-5 presents the N, P_2O_5, and K_2O fertilization shares of each crop's nutrient demand under the PRU scenario and the sensitivity analysis applied to it (20%, representing a lower-bound replacement of synthetic mineral fertilizer, and 100%, representing an upper-bound).

Panel A



Panel B

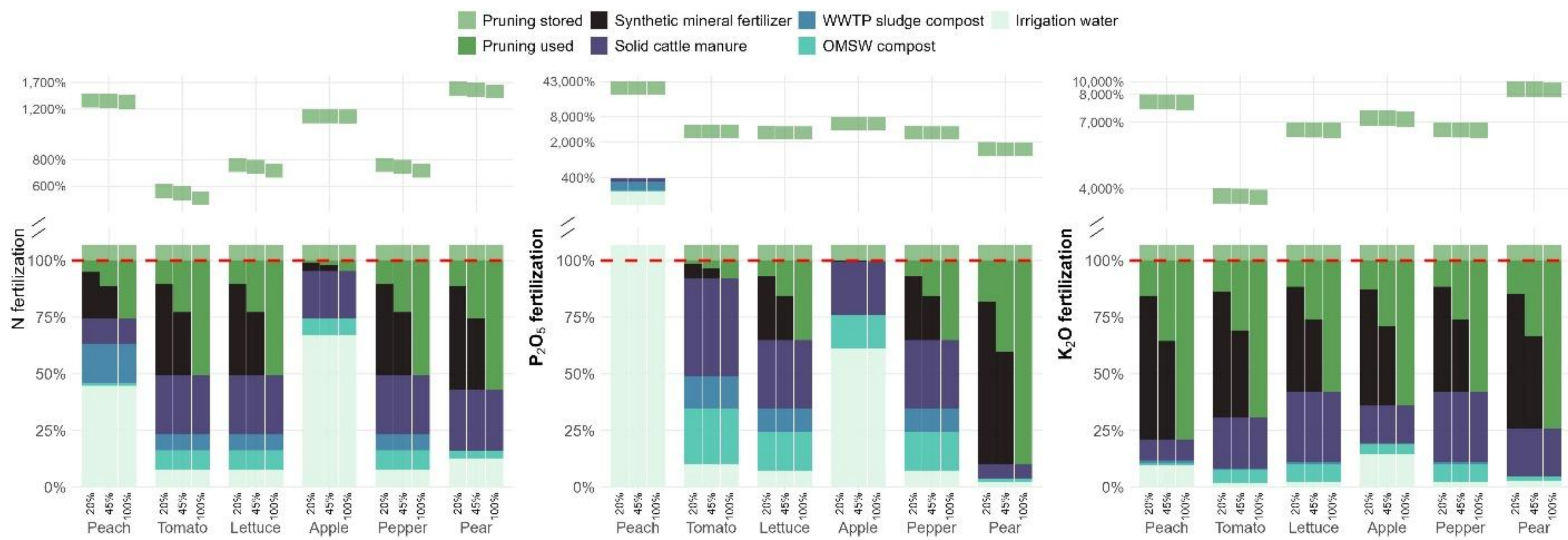


Figure SI1-5. N, P_2O_5, and K_2O fertilization shares of each crop's annual nutrient demand in PRU scenario under sensitivity analysis (20%-low, 45%-baseline, and 100%-full synthetic mineral fertilizer substitution), without stored pruning (panel A – top) and with stored pruning (panel B – bottom). The red dashed line at 100% marks the point at which nutrient demand is fully met. Whenever the scenario generates nutrient oversupply (i.e., total supply exceeds total annual demand), this surplus is displayed above the 100% mark using a broken y-axis. The upper tier (above the 100% mark) shows the true oversupply magnitudes resulting from the scenario calculation, including the nutrient legacy pool from the pruning stored in panel B.

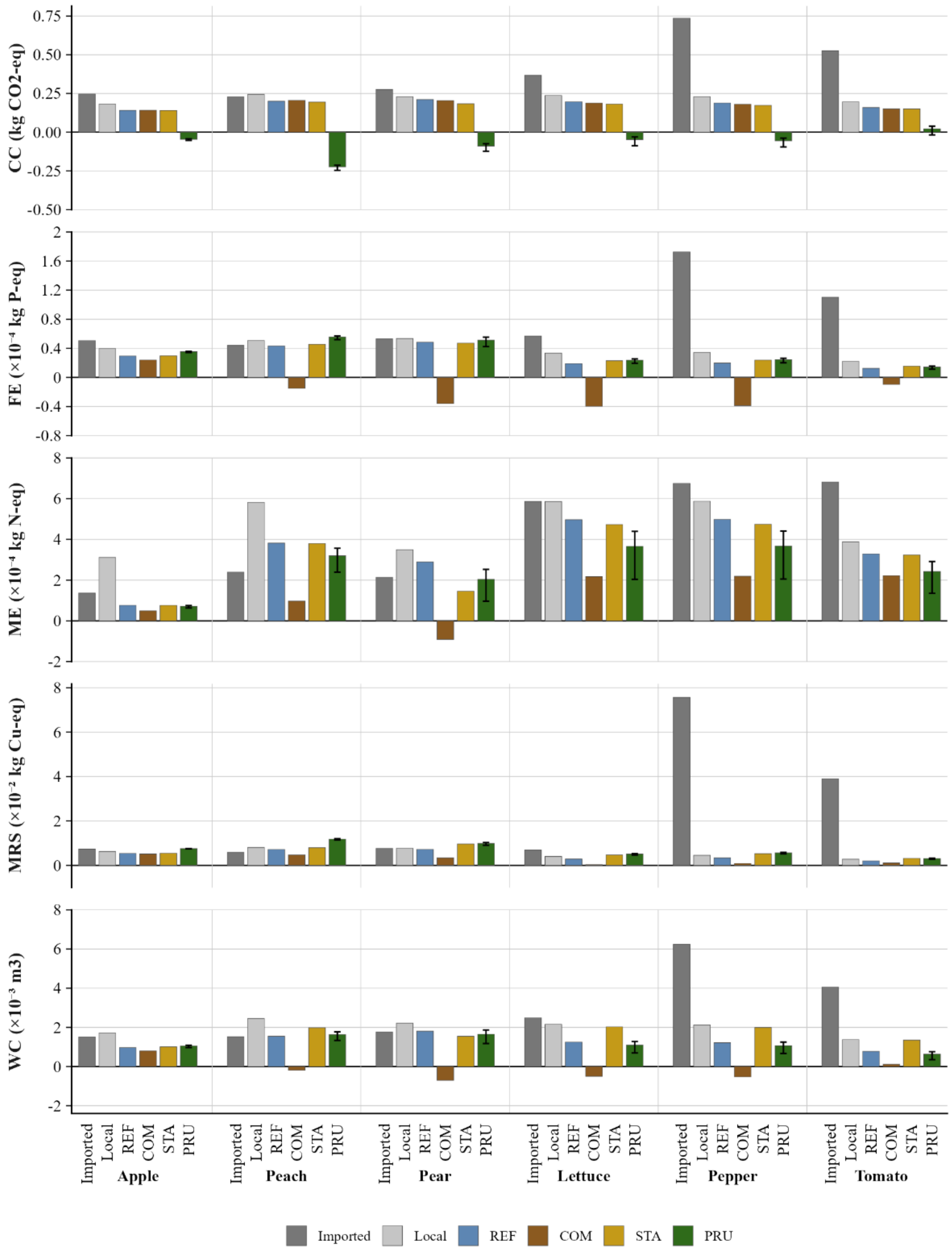


Figure SI1-6. Absolute life cycle impacts per FU for locally grown crops under fertilization scenarios and imports, and sensitivity analysis applied for crops under PRU scenario. The sensitivity range between the lower bound (20%) and upper bound (100%) is represented by the black error bars in the main PRU result. In the Local baseline crops are fertilized entirely with synthetic mineral fertilizers, allowing us to compare local crops with imports before introducing fertilization scenarios, including current practices under the REF scenario, which already entail some degree of circularity. CC, climate change (GWP_{100} – kg CO_2-eq kg^{-1}); FE, freshwater eutrophication (FEP – kg P-eq kg^{-1}); ME, marine eutrophication (MEP – kg N-eq kg^{-1}); MRS, mineral resource scarcity (MRS; SOP – kg Cu-eq); and WC, water use (WCP – m^3 kg^{-1}). Local represents the linear fertilization baseline using synthetic mineral fertilizer; REF, reference scenario; COM, compost scenario; STA, struvite and ammonium salts scenario; and PRU, pruning residues scenario

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