

THÈSE DE DOCTORAT

Évaluation environnementale des systèmes alimentaires territoriaux :

Apports de l'analyse du cycle de vie territoriale à la construction et à l'évaluation des processus de reterritorialisation durables des systèmes agroalimentaires en France

Annexes

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TABLE DES MATIERES

Annexe I. Inventaire des données Finistère

Annexe I. Inventaire des données Mouans-Sartoux

Annexe II. Article n°1

Annexe II. Article n°2

Annexe II. Article n°3

Annexe III. Analyses de sensibilité et d'incertitude supplémentaires

Annexe IV. Questionnaires

ANNEXE I. INVENTAIRE DES DONNEES FINISTERE

Catégorie d'activité	Activité inventoriée	Descripteur d'activité	Valeur	Unité	Source de	Processus ACV	ICV
Production agricole majeure	Artichaut	Volume annuel	20 690	tonnes	(Chambres d'agriculture de Bretagne, 2020)	Artichoke FR	Agribalyse V3.0
	Pomme de terre		225 404			Ware potato, conventional, for fresh market, at farm gate/FR F	
	Chou-fleur		108 943			Cauliflower, national average, at farm gate/FR F	
	Ble		70 716			Soft wheat grain, conventional, breadmaking quality, 15% moisture, at farm gate/FR	
	Tomate		84 333			Tomato, production mix, greenhouse production, national average, at greenhouse/FR	
	Epinard		6			Spinach (GLO) production	
	Aubergine		4 900			Zucchini (GLO) production	
	Carotte		24 963			Carrot, conventional, national average, at farm gate/FR F	
	Salade		1 685			Lettuce, conventional, national average, at farm gate/FR F	
	Fraise		2 508			Strawberry, national average, at farm gate/FR U F	
	Brocoli		4			Broccoli (GLO) production	
	Haricot		13			French bean, conventional, national average, at farm gate/FR U F	
	Oignon		19			Onion, national average, at farm/FR U F	
	Bovin (viande)		26 000			Beef cattle, national average, at farm gate/FR F	
	Porc		427 700			Pig, conventional, national average, at farm gate/FR F	
	Veuil		4 700			Veal, conventional, fattening system, calves from lowland milk system, at farm gate/FR F	
	Thon		189 118			Yellowfin Tuna, ECA, Seine, average, at landing/CI F	
	Poulet		16 346			Broiler, broiler feed, conv prod, at farm gate/FR U F	
	Canard		948			Duck, duck feed, conv prod, at farm gate/FR U F	
	Dinde		6 396			Turkey, turkey feed, conv prod, at farm gate/FR U F	
Bovin lait, conventionnel	1 114 950	Cow milk, conventional, lowland milk system, silage maize more than 30%, at farm gate/FR U F1					
Bovin lait, biologique	53 924	Cow milk, organic, system mix, at farm gate/FR U					
Industrie agroalimentaire	Distribution & transformation alimentaire	Consommation annuelle de gaz	1 874 070	MWh	GRDF Open data	Heat, district, or industrial, natural gas (Europe without Switzerland) market for	Ecoinvent
		Consommation annuelle d'électricité	567 900	MWh	Enedis Open data	Electricity, low voltage (FR) market for	Ecoinvent
Transport	Transport des agriculteurs locaux	Volume transporté annuellement sur une distance	Extrapolation à partir de	kokm	Moyenne	Transport, freight, lorry 16-32 metric ton, euro (RER) market for transport, freight, lorry 16-32 metric ton, EURO6	Ecoinvent
	Transport des consommateurs au	Distance parcourue par les habitants	701 142 000	km	Enquête locale	Transport, passenger car, medium size, diesel, EURO 3 (RoW) market for transport, passenger car, medium size, diesel, EURO6	Ecoinvent
Fruits, légumes, noix importés annuellement	Artichaut	46	Artichoke, consumption mix/FR				
	Aubergine	408	Aubergine (GLO) production				
	Beterave	1 162	Beetroot, consumption mix/FR				
	Brocoli	470	Broccoli, consumption mix/FR				
	Carotte	1 969	Carrot, consumption mix/FR				
	Celeri	154	Celery, consumption mix/FR				
	Courgette	899	Courgette or zucchini, pulp and peel, raw, processed in FR				
	Concombre	650	Cucumber, consumption mix/FR				
	Fenouil	58	Fennel, consumption mix/FR				
	Tomate	6 981	Fresh tomato, consumption mix/FR				
	Ail	51	Garlic, consumption mix/FR				
	Cornichon	227	Gherkin, consumption mix/FR				
	Légumes grillés	2 338	Grilled vegetables pan-fried, Mediterranean-style, frozen, raw, processed in FR				
	Porreau	534	Leek, consumption mix/FR				
	Légumes mix	823	Mixed vegetables, frozen, raw, processed in FR / Frozen				
	Champignon	480	Mushroom, consumption mix/FR				
	Oignon	465	Onions, consumption mix/FR				
	Persil	11	Parsley, fresh, consumption mix/FR				
	Poivron	288	Pepper, green, consumption mix/FR				
	Courge	157	Squash, consumption mix/FR				
	Mais	162	Sweet corn, canned/FR				
	Patate douce	12	Sweet potato, consumption mix/FR				
	Tomate paste	119	Tomato paste, concentrated, canned, processed in FR				
	Navet	41	Turnip, consumption mix/FR				
	Légumes rotis	1 111	Vegetable rosti, pre-fried, frozen, at plant/FR				
	Légumes pâtée	4 394	Vegetables (3-4 types), mashed, processed in FR				
	Aubergine	103	Asparagus, consumption mix/FR				
	Chou-fleur	930	Cauliflower, national average, at farm gate/FR				
	Ratatouille	3 59	Ratatouille cooked, processed in FR				
	Salsifis	112	Salsify, consumption mix/FR F				
	Radis	370	Radish, consumption mix/FR F				
	Salade verte	6 283	Green salad, consumption mix/FR F				
	Pinats	38	Parsnip, consumption mix/FR F				
	Petit pois	525	Garden peas, consumption mix/FR F				
	Melon	2 093	Melon, consumption mix/FR				
	Noisette	105	Chestnut, consumption mix/FR				
	Amande	90	Almond, consumption mix/FR				
	Sesame	26	Sesame seed, consumption mix/FR				
	Noix	137	Walnut, dried, husked, processed in FR				
	Pistache	31	Pistachio nut, grilled, salted, processed in FR				
	Cacahuete	300	Peanut, consumption mix/FR				
	Pomme	20 355	Apple, production mix, national average, /FR				
	Abricot	758	Apricot, consumption mix/FR				
	Cerise	287	Cherry, conventional, national average/FR				
	Figue	40	Fig, consumption mix/FR				
	Fruits compote	9 086	Fruits compote, miscellaneous, FR				
	Confiture	2 896	Jam, strawberry, processed in FR				
	Nectarine	1 887	Nectarine, consumption mix/FR				
	Pêche	1 871	Peach, consumption mix/FR				
	Poire	3 054	Pear, consumption mix/FR				
	Prune	901	Prune, consumption mix/FR				
	Fraise	1 222	Strawberry, consumption mix/FR				
	Raisin	650	Table grape, consumption mix/FR				
	Framboise	322	Raspberry, raw, processed in FR				
	Rhubarbe	21	Rhubarb, consumption mix/FR				
	Banane	4 727	Banana, consumption mix/FR				
	Panpanmousse	1 323	Grapenfruit (inc. panicles), consumption mix/FR				
	Kivi	1 091	Kiwi, consumption mix/FR				
	Citron	268	Lemon, consumption mix/FR				
	Mandarine	4 43	Mandarin, consumption mix/FR				
	Mangue	93	Mango, consumption mix/FR				
	Orange	3 73	Orange, consumption mix/FR				
	Ananas	739	Pineapple, consumption mix/FR				
	Grenade	78	Pomegranate, consumption mix/FR				
	Algue	4	Algae (Laminaria), dried, consumption mix/FR				
	Avocat	459	Avocado, consumption mix/FR				
	Olives	108	Olives, consumption mix/FR				
	Œuf	2 565	Chicken egg, raw, consumption mix/FR				
	Œuf blancs	265	Egg white, raw, processed in FR				
	Œuf jaune	31	Egg yolk, cooked, processed in FR				
	Omelette	2 011	Omelette, with herbs, processed in FR				
	Aioli	12	Aioli sauce (garlic and olive oil mayonnaise), prepacked, at plant/FR SR				
	Beaufort	10	Beaufort cheese, from cow's milk, processed in FR				
	Bechamel	53	Bechamel sauce, prepacked, processed in FR				
	Blue	95	Blue cheese, from cow's milk, processed in FR				
	Brie	413	Brie cheese, from cow's milk, processed in FR				
	Beurre	2 803	Butter, 80% fat, lightly salted, processed in FR				
	Camembert	2 114	Camembert cheese, from cow's milk, processed in FR				
	Cantal	77	Cantal, Salers or Laguiole cheese, from cow's milk, processed in FR				
	Fromage de pâtisserie	210	Cheese in puff pastry, processed in FR				
	Scouffle	83	Cheese soufflé, processed in FR				
	Buche	423	Cheese buche, from goat's milk, processed in FR				
	Comté	438	Comté cheese, from cow's milk, processed in FR				
	Edam	19	Edam cheese, from cow's milk, processed in FR				
	Emmental	893	Emmental cheese, from cow's milk, processed in FR				
	Feta	19	Feta cheese, from ewe's milk, processed in FR				
	Fromage frais	2 912	Fresh cream cheese, plain, around 3% fat, processed in FR				
	Gouda	62	Gouda cheese, from cow's milk, processed in FR				
	Gruyère	663	Gruyère cheese, from cow's milk, processed in FR				
	Crème	624	Liquid cream 30% fat, UHT, processed in FR				
	Livarot	42	Livarot cheese, from cow's milk, processed in FR				
	Maroilles	70	Maroilles cheese, from cow's milk, processed in FR				
	Mayonnaise	3 876	Mayonnaise, processed in FR				
	Mayonnaise (70% gras)	493	Mayonnaise (70% fat and more), processed in FR				
	Lait	30 126	Milk, semi-skimmed, pasteurised, processed in FR				
	Mimolette	6	Mimolette cheese, from cow's milk, processed in FR				
	Mozzarella	242	Mozzarella cheese, from cow's milk, processed in FR				
	Ossau-Iraty	19	Ossau-Iraty cheese, from ewe's milk, processed in FR				
	Parmesan	127	Parmesan cheese, from cow's milk, processed in FR				
	Fromage fondu	1 322	Processed cheese, double cream, around 31% fat, processed in FR				
Raclette	85	Raclette cheese, from cow's milk, processed in FR					
Reblochon	95	Reblochon cheese, from cow's milk, processed in FR					
Roquefort	67	Roquefort cheese, from ewe's milk, processed in FR					
Saint-Felicien	173	Saint-Felicien cheese, from cow's milk, processed in FR					
Tartiflette	743	Tartiflette (cheese fondue), processed in FR					
Tomme	258	Tomme cheese, from cow's milk, processed in FR					
Fromage à tartiner	2 912	Uncured soft cheese, spreadable, around 25% fat, in a tub, processed in FR					
Yogurt	23	Yogurt, fermented milk or dairy speciality, flavoured, with sweetener, fat free, processed in FR					
Yogurt	23	Yogurt, fermented milk or dairy speciality, plain, processed in FR					
Morbier	146	Morbier cheese, from cow's milk, processed in FR					
Onchelle	114	Spanish-style tortilla with onions (omelette with potatoes and onions), processed in FR					
Salers	10	Salers cheese, from cow's milk, processed in FR					
Absoudance	29	Absoudance cheese, from cow's milk, processed in FR					
Munster	29	Munster cheese, from cow's milk, processed in FR					
Selles-sur-Cher	38	Selles-sur-Cher cheese, from goat's milk, processed in FR					
Sainte-Maure	10	Sainte-Maure cheese, from goat's milk, processed in FR					
Rocamadour	10	Rocamadour cheese, from goat's milk, processed in FR					
Pouilly-Saint-Pierre	12	Pouilly-Saint-Pierre cheese, from goat's milk, processed in FR					

Produits importés

Viande & poissons importés annuellement

Epoisses	19
Epinard et crème fraîche	263
Fromage dur	34
Crottin	48
Pétoncle	4
Hareng	4
Morue	22
Limande	2
Sol	2
Merlu braise	1
Merlu	3
Huître	4
Sardine	2
Poisson	12
Dorade	2
Bar	2
Moule	3
Homard	10
Paëlla	9
Lieu jaune	3
Rillettes	7
Saumon	14
Truite de mer	1
Terrine de fruits de mer	2
Calmar	2
Sushi	2
Esadon	1
Taramasalata	0
Merlan	0
Thon albacore	5
Escargot	0
Surimi	5
Rouleau de printemps	1
Rais	0
Sauce noix main ou sauce poisson	0
Eglefin	0
Flétan de l'Atlantique	1
Escargot	1
Burger de poulet	279
Tajine au poulet	168
Poulet au curry et sauce au lait de coco	125
Poitrine de poulet	3 108
Cuisse de poulet	2 937
Viande de poulet	578
Nugget de poulet	494
Galette de canard	148
Canard	460
Escalope	497
pintade	36
Paupiette de volaille	47
Lapin	78
Dinde	135
Dinde rôtie	1 311
Vol-au-vent	155
Pigeon	126
Faisan	62
Lard	4
Jambon cuit	31
Pâté de campagne	12
Foie gras	2
Saucisse merguez	13
Mortadelle	0
Saucisse de Strasbourg	13
Saucisse	13
Salami	0
Saucisson sec, Rosette	1
Rillettes	2
Coppa	0
Boudin noir	3
Graisse de porc	2
Filet mignon de porc	4
Porc à la sauce caramel	2
Côtelette de porc	19
Longe de porc	2
Épaule de porc	26
Ragoût de bœuf aux carottes	22
Joué de Bœuf	48
Bœuf braise	554
Bavette de bœuf	171
Steak haché de bœuf	3 132
Entrecôte de bœuf	89
Rôti de bœuf	474
Rumsteck de bœuf	128
Steak de sauterie de bœuf	24
Steak de bœuf ou steak de bœuf	1 859
Viande à ragoût de bœuf	472
Cheeseburger	422
Chili con carne	173
Hamburger	1 791
Gigot d'agneau	156
Côtelette d'agneau	199
Épaule d'agneau	273
Lasagnes ou cannellonis à la viande	14
Boulettes de viande	549
Tajine de mouton	154
Mésan de bœuf	35
Langue	123
Filet de veau	461
Veau	205
Samoussas au bœuf	247
Poivre noir	81
Bouillon	3 542
Hariots	33
Chéri	466
Moutarde	152
Vinaigrette	1 534
Sel	139
sauce	53
Préparation "crème" de soja	76
Dessert au soja	76
Bouillon au soja	109
Sucre	1 579
Vinaigre	80
Falafel	97
Café expresso	65 442
Infusion	12 375
Mélange de chicorée et de café	12 355
Smoothies	428
Eau du robinet	264 677
Thé	34 715
Bouillon instantané au cacao	23 990
Nouilles asiatiques	706
Sarrasin	51
Couscous	2 461
Croûtons	53
Frites ou chips	5 653
Gnocchi	401
Muesli	2 612
Avoine	147
Polenta	21
Quinoa	174
Riz	6 754
Boulgour de blé	140
Farine de blé	66
Pâte sablée	16 308
Blé	132
Pain	37 667
Fajitas	327
Hariots	4 462
Pest chiches	75
Haricot flageolet	231
Lentilles	929
Bière	9 391
Champagne	699
Cidre	2 156

tonnes

INCA 3 Brittany (2017)

Epoisses cheese, from cow's milk, processed in FR	
Spinach w cream sauce, processed in FR	
Semi-hard cheese, from ewe's milk, processed in FR	
Crottin cheese, from goat's milk, processed in FR	
American or Canadian sea scallop, consumption mix/FR	
Atlantic herring, smoked, fillet, processed in FR	
Cod, consumption mix/FR	
Common dab, consumption mix/FR	
Common sole, consumption mix/FR	
European hake, braised, processed in FR	
European hake, consumption mix/FR	
European oyster, raw, processed in FR	
European pilchard or sardine, consumption mix/FR	
Fish, breaded, fried, processed in FR	
Freshwater bream, consumption mix/FR	
Mediterranean bass, consumption mix/FR	
Mediterranean mussel, raw, processed in FR	
Norway lobster, consumption mix/FR	
Paëlla, processed in FR	
Pollack, consumption mix/FR	
Rillettes, mackerel, processed in FR	
Salmon, canned, drained, processed in FR	
Sea trout, consumption mix/FR	
Seafood terrine, with or without fish, processed in FR	
Squid, consumption mix/FR	
Sushi or maki with seafood products, processed in FR	
Swordfish, consumption mix/FR	
Taramasalata, prepacked, processed in FR	
Whiting, steamed, processed in FR	
Yellowfin tuna, consumption mix/FR	
Snail, consumption mix/FR	
Surimi, on sticks, in slices or grated, crab flavour, processed in FR	
Spring roll, processed in FR	
Ray, consumption mix/FR	
Noise main sauce or fish sauce, prepacked, processed in FR	
Haddock, consumption mix/FR	
Atlantic halibut, consumption mix/FR	
Snail in parsley butter, cooked, processed in FR	
Chicken burger - fast foods restaurant, processed in FR	
Chicken tagine, processed in FR	
Chicken with curry and coconut milk, sauce, processed in FR	
Chicken, breast, meat and skin, roasted/baked, processed in FR	
Chicken, leg, meat and skin, roasted/baked, processed in FR	
Chicken, meat and skin, roasted/baked, processed in FR	
Chicken, nugget, breaded croquette, processed in FR	
Duck fat, processed in FR	
Duck, magret, cooked in pan, processed in FR	
Escalope cordon bleu (topped with a ham slice and Gruyère sauce), processed in FR	
Guinea fowl, raw, processed in FR	
Poultry paupiette, processed in FR	
Rabbit, meat, cooked, processed in FR	
Turkey, meat, raw, processed in FR	
Turkey, meat, roasted/baked, processed in FR	
Vol-au-vent with meat/poultry/sage, processed in FR	
Pigeon, meat, roasted/baked, processed in FR	
Pheasant, meat, roasted/baked, processed in FR	
Bacon, back, processed in FR	
Cooked ham, choice, processed in FR	
Country-style rigatoni with mushrooms, processed in FR	
Foie gras, duck's liver, whole, cooked, at plant/FR	
Merguez sausage, raw, processed in FR	
Mortadella, processed in FR	
Strasbourg sausage, processed in FR	
Sausage, dried, processed in FR	
Salami, processed in FR	
Rosette dry sausage, processed in FR	
Rillettes, poultry, processed in FR	
Coppa, processed in FR	
Black pudding (blood sausage), sautéed/pan-fried, processed in FR	
Lard or pork fat, processed in FR	
Pork fillet mignon, cooked, processed in FR	
Pork with caramel sauce, processed in FR	
Pork, chop, grilled, processed in FR	
Pork, loin, roasted/baked, processed in FR	
Pork, shoulder, cooked, processed in FR	
Beef stew with carrots, processed in FR	
Beef, cheek, braised or boiled, processed in FR	
Beef, chuck, braised or boiled, processed in FR	
Beef, flank steak, raw, processed in FR	
Beef, minced steak, 15% fat, cooked, processed in FR	
Beef, rib steak, lean, grilled/pan-fried, processed in FR	
Beef, roast beef, roasted/baked, processed in FR	
Beef, rump steak, grilled, processed in FR	
Beef, sirloin steak, roasted/baked, processed in FR	
Beef, steak or beef steak, raw, processed in FR	
Beef, stewing meat, raw, processed in FR	
Cheeseburger, double, from fast foods restaurant, processed in FR	
Chili con carne, processed in FR	
Hamburger, from fast foods restaurant, processed in FR	
Lamb, leg, roasted/baked, processed in FR	
Lamb, rib chop, grilled/pan-fried, processed in FR	
Lamb, shoulder, roasted/baked, processed in FR	
Lasagna or cannelloni with meat (bolognese sauce), processed in FR	
Meat balls, beef, with tomato sauce, processed in FR	
Mutton tagine, processed in FR	
Ox mizale in salad dressing sauce, processed in FR	
Tongue, beef, cooked, processed in FR	
Veal fillet, roasted/baked, processed in FR	
Veal, shoulder, raw, processed in FR	
Beef samosas or samosas, processed in FR	
Black pepper, powder, processed in FR	
Broth, stock or bouillon, vegetables, dehydrated and reconstituted, processed in FR	
Hariots (fast spicy sauce), prepacked, processed in FR	
Honey, consumption mix/FR SR	
Mustard sauce prepacked, processed in FR	
Salad dressing, prepacked, processed in FR	
Salt, white, for human consumption (sea, igneous or rock), no enrichment, processed in FR	
Sauce, pesto, prepacked, processed in FR	
Soy "cream" preparation, processed in FR	
Soy dessert, flavoured, refrigerated, processed in FR	
Soy drink, plain, at plant/FR SR	
Sugar, white, processed in FR	
Vinegar, processed in FR	
Falafel, processed in FR	
Espresso coffee, not instant coffee, without sugar, ready-to-drink, processed in FR	
Infusion, brewed, without sugar, processed in FR	
Mix of chicory and coffee, instant, without sugar, ready-to-drink (reconstituted with water), processed in FR	
Smoothie, processed in FR	
Tap water (Europe without Switzerland)	
Tea, brewed, without sugar, processed in FR	
Instant cocoa or chocolate beverage, with sugar, ready-to-drink FR	
Asian noodles, plain, cooked, unsalted, processed in FR	
Buck-wheat, consumption mix/FR U SR	
Couscous (durum wheat semolina pre-cooked with steam), cooked, unsalted, processed in FR	
Croûtons, plain, prepacked, processed in FR	
French fries or chips, frozen, roasted/baked, processed in FR	
Gnocchi, from potato, cooked, processed in FR	
Muesli, flakes (Bircher-style), processed in FR	
Oat, consumption mix/FR U SR	
Polenta or maize semolina, cooked, unsalted, processed in FR	
Quinoa, consumption mix/FR U SR	
Rice, cooked, unsalted, processed in FR	
Wheat bulgur, raw, processed in FR	
Wheat flour, type 55 (for pastry), processed in FR	
Shortbread dough, cooked, processed in FR	
Wheat, whole, pre-cooked, raw, processed in FR	
Bread, French bread, baguette, processed in FR	
Fajitas, processed in FR	
Beans, consumption mix/FR SR	
Chick peas, consumption mix/FR SR	
Flageolet bean, consumption mix/FR SR	
Lentils, consumption mix/FR SR	
Beer, regular (4-5° alcohol), processed in FR	
Champagne, processed in FR	
Cider, processed in FR	

tonnes

Agribalyse V3.0

		Cocktail	1 638		Cocktail, punch type, 16% alcohol, processed in FR
		Kir	103		Kir (Cocktail of white wine with red fruit liqueur), processed in FR
		Liqueur	21		Liqueur, processed in FR
		Pastis	1 039		Pastis (anise-flavoured spirit), processed in FR
		Vin rosé	15 556		Red wine, consumption mix FR U SR
		Whisky	290		Whisky, processed in FR
		Sangria	219		Sangria, processed in FR
		Limonade	3 485		Lemonade, without sugar, with artificial sweetener(s), processed in FR
		Jus de fruits mélangés	32 776		Mixed fruits juice, reconstituted from a concentrate, multivitamin, processed in FR
		Boisson non-alcoolisée	24 429		Soft drink, carbonated, without fruit juice, with sugar, processed in FR
		Sirup	129		Syrup, with sugar (to be diluted), processed in FR
		Crumble aux pommes	724		Apple crumble, processed in FR
		Tarte aux pommes avec crème anglaise	307		Apple pie with custard (flour, eggs, cream, sugar, apple alcohol), processed in FR
		Lutin	943		Brownie (chocolate cake), processed in FR
		Crème anglaise caramélisée	104		Caramelized custard cream (crème brûlée), refrigerated, processed in FR
		Gâteau au chocolat	1 801		Chocolate cake, processed in FR
		Pâte à choux	173		Chou pastry with praline flavoured cream, processed in FR
		Brioche de Noel	3 586		Christmas brioche with candied fruits, prepacked, processed in FR
		Crêpe	3 22		Crêpe, plain, prepacked, room temperature, processed in FR
		Tarte flan aux oeufs	1 288		Flan tart with eggs, processed in FR
		Tarte aux fruits	3 383		Fruit tart, processed in FR
		Mousse	1 266		Mousse, chocolate, refrigerated, processed in FR
		Queselle	296		Queselle, plain, raw, processed in FR
		Baba au rhum	46		Rum baba, prepacked, processed in FR
		Gâteau moelleux	219		Soft cake, plain, sponge cake type, processed in FR
		Génoise	285		Sponge cake filled and covered with chocolate, processed in FR
		Tiramisu	237		Tiramisu, refrigerated, processed in FR
		Pudding aux fruits	4 653		Fruits batter-pudding, refrigerated, processed in FR
		Gâteau au yaourt	1 801		Yogurt cake, processed in FR
		Gâteau basque	186		Basque cake (shortbread), with custard, processed in FR
		Cheesecake	351		Cheesecake, refrigerated, processed in FR
		Crème fouettée	80		Whipped cream or Chantilly cream, under pressure, UHT, processed in FR
		Huile d'olive	151		Olive oil, extra virgin, processed in FR
		Graisse végétale	798		Vegetable fat (margarine type), 70% fat, unsalted, processed in FR
		Huile de tournesol	971		Sunflower oil, processed in FR
		Biscuit	108		Biscuit (puff pastry), palmier, from bakery, processed in FR
		Biscuit (biscuit)	3 316		Biscuit (cookie), assortment of miniature sweets and biscuits, processed in FR
		Chewing-gum	90		Chewing gum, without sugar, processed in FR
		Barre de chocolat	943		Chocolate confectionery or bar, with dairy filling, processed in FR
		Donut	504		Doughnut, plain, processed in FR
		Gâteaux de fruits	96		Fruit jelly, processed in FR
		Grisini ou gressin	265		Grisini or bread stick, processed in FR
		Bonbons durs et sucettes	774		Hard candy and lollipop, processed in FR
		Glace	1 879		Ice cream, cone (normal size), processed in FR
		Ketchup	677		Ketchup, processed in FR
		Macaron	38		Macaroon, processed in FR
		Biscuits madeïnes	668		Madéïne biscuit, with chocolate, prepacked, processed in FR
		Pizza à base de viande	2 877		Pizza, ham and cheese, processed in FR
		Pizza sans viande	1 918		Pizza, vegetables or pizza 4 seasons, processed in FR
		Pop-corn ou maïs soufflé à l'huile	25		Pop-corn or oil popped maize, salted, processed in FR
		Chips de pommes de terre et produits connexes	591		Potato crisps and related, reduced fat, processed in FR
		Quiche lorraine	2 497		Quiche Lorraine (eggs and lardons quiche), processed in FR
		Gaufre	291		Soft waffle (Brussels-style), plain or with sugar, prepacked, processed in FR
		Rouleau de printemps	316		Spring roll, processed in FR
		Taboulet	871		Tabbouleh, prepacked, processed in FR
		Pain croustillant	274		Crispbread, extruded and grilled, processed in FR
		Milk-shake	71		Milkshake, from fast food restaurant, processed in FR
		Muffin	143		Muffin, with blueberry or chocolate, at plant FR F
		Tablette de chocolat au lait	437		Milk chocolate bar, processed in FR
		Tablette de chocolat noir	427		Dark chocolate bar, more than 70% cocoa, processed in FR
		Salade César (salade)	4 797		Caesar's salad (salad, chicken, croûtons, sauce), processed in FR
		Tarte au fromage	1 391		Cheese tart, at plant FR SR PROXY CAKE
		Crêpe ou crêpe au sarrasin	3 891		Crêpe or buckwheat crêpe, filled with cheese, ham, mushrooms and bechamel sauce, processed in FR
		Croissant	597		Croissant, ordinary, from bakery, processed in FR
		Gratin de pommes de terre dauphinoises	3 474		Dauphiné-style creamed potatoes "au gratin", processed in FR
		Pâtes fraîches	1 138		Fresh pasta, stuffed with cheese (e.g. ravioli), raw, processed in FR
		Risotto	227		Risotto, w cheeses, processed in FR
		Sandwich au jambon grillé	1 294		Toasted ham sandwich topped with grated cheese and a fried egg, processed in FR
		Sandwich au jambon grillé garni de fromage râpé	4 888		Toasted ham sandwich topped with grated cheese, processed in FR
		Soupe de légumes	26 055		Soup, mixed vegetables, prepacked, to be reheated, processed in FR
		Plat de légumes pour bébé	6 916		Vegetable dish for baby, w meat/fish and starch, from 12 months, processed in FR
		Beouillon	1		Broth, stock or bouillon, meat and vegetables, dehydrated and reconstituted, processed in FR
		Soupe à l'asiatique	438		Soup, Asian-style with noodles, prepacked, to be reheated, processed in FR
		Soupe de poisson	14		Soup, fish and/or crustacean, prepacked, to be reheated, processed in FR

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ANNEXE I. INVENTAIRE DES DONNEES MOUANS-SARTOUX

Catégorie d'activité	Activité inventoriée	Description d'activité	Valeur	Unité	Source de	Processus ACV	ICV
Production agricole majeure	Tomate	Volume annuel	0,6	tonnes	Enquête agriculteurs	Fresh tomato, consumption mix FR U SR	Agribalyse V3.0
	Framboise de bêche		4			Goat cheese from raw milk, processed in FR (Chilled / LDPE / No preparation at consumer) FR (Causal code: 12807)	
	Melou AB		2			Melon, organic, at farm gate/FR U SR BIO	
	Pomme de terre		11			Potato, consumption mix FR U	
	Tomate AB		11			Tomato, organic, greenhouse production, national average, at greenhouse/FR U SR BIO	
	Course AB		11			Squash, springtime, under tunnel, organic, at farm gate/FR SR BIO	
	Pomme de terre AB		11			Potato, organic (CHI) production /Cut-off/ S MS	
	Chou fleur AB		7			Cauliflower, winter, organic, at farm gate/FR U SR BIO	
	Course AB		11			Carrot, organic, Lower Normandy, at farm gate/FR U SR BIO	
	Course		2			Squash, consumption mix FR U SR	
Chou fleur	2	Cauliflower, consumption mix FR U SR					
Course AB	2	Carrot, consumption mix FR U SR					
Industrie agroalimentaire	Distribution agroalimentaire	Consommation annuelle d'électricité	1330	MWh	Enedis Open data (Enedis, 2022)	Electricity, low voltage [FR] / market for	Ecovint 3
	Transport des agriculteurs locaux	Volume transporté annuellement sur une distance	2 988	kgkm	Enquête agriculteurs	Transport, freight, lorry 3.5-7.5 metric ton, eu06 [RER] / market for transport, freight, lorry 3.5-7.5 metric ton, EURO6 / Cut-off, S Mozans	Ecovint 3
Transport	Transport des consommateurs au supermarché	Distance parcourue par les habitants	1 755 360	km	Enquête consommateurs	Transport, passenger car, medium size, diesel, EURO3 [RoW] / transport, passenger car, medium size, diesel, EURO	Ecovint 3
	Fruits, légumes, noix importés annuellement	Algue (Laminaires)	157			Algae (Laminaria), dried, consumption mix	
Pomme AB		159 272			Apple, organic, national average, at orchard		
Abricot		11 510			Apricot, consumption mix		
Arcanaut		10 049			Atrichole, consumption mix		
Aubergine		7 574			Aubergine (GLO) production /Cut-off/ U - Couped from Ecovint SR conso		
Avocat		6 540			Avocado, consumption mix		
Banane asiatique		408			Banana plantain, consumption mix		
Banane		60 191			Banana, consumption mix		
Basilic		127			Basil, dried, consumption mix		
Betula		6 185			Betula, consumption mix		
Myrtille		198			Blueberry, raw, processed in FR / Ambient (average) / No packaging / No preparation at consumer		
Brocoli		7 379			Broccoli, consumption mix		
Carotte		31 963			Carrot, organic, Lower Normandy, at farm gate		
Celeri		2 156			Celery, consumption mix		
Cerise		13 006			Cherry, conventional, national average, at orchard		
Courgette		25 474			Courgette or zucchini, pulp and peel, raw, processed in FR / Ambient (average) / No packaging / No preparation at consumer		
Concombre		11 302			Cucumber, consumption mix		
Date		367			Dates, dried, consumption mix		
Fenouil		3 733			Fennel, consumption mix		
Finon		3 308			Fry, consumption mix		
Tomate AB		104 843			Tomato, organic, greenhouse production, national average, at greenhouse		
Connote de fruits		118 277			Fruits composites, miscellaneous, at plant		
Fil		1 509			Garlic, consumption mix		
Coriandre		3 219			Chefkin, consumption mix		
Pamplemousse (y compris romélos)		16 500			Grapefruit (inc. pomelos), consumption mix		
Légumes à feuilles potées		7 448			Grilled vegetables pan-fried, Mediterranean-style, frozen, raw, processed in FR / Frozen / LDPE / Microwave / at consumer		
Kiwi		70 768			Kiwi, strawberry, processed in FR (Chilled / Glass) / No preparation at consumer		
noisau		6 904			Kiwi, consumption mix		
Chion		3 228			Leek, consumption mix		
Mandarine		26 989			Lemon, consumption mix		
Mangue		3 409			Mandarin, consumption mix		
Melon		24 662			Mango, consumption mix		
Légumes melonnés		32 163			Melon, organic, at farm gate		
Champignon		8 293			Mixed vegetables, frozen, raw, processed in FR / Frozen / PP / No preparation at consumer		
Nectarine		18 736			Mushroom, consumption mix		
Olives		5 082			Nectarine, consumption mix		
Oignon		8 390			Olives, consumption mix		
Orange		43 771			Onions, consumption mix		
Péral		469			Orange, consumption mix		
Pêche AB		28 656			Parsley, fresh, consumption mix		
Poire AB		25 508			Peach, organic, national average, at orchard		
Poire		9 854			Pear, organic, at farm gate		
Kaki		1 638			Pepper, green, consumption mix		
Ananas		6 883			Peppers, consumption mix		
Prune		9 662			Pineapple, consumption mix		
Saumons		264 553			Prune, consumption mix		
Sauvage		780			Soup, mixed vegetables, dehydrated and reconstituted, processed in FR / Ambient (low) / Cardboard / at distribution		
Fraise		34 585			Squash, springtime, under tunnel, organic, at farm gate		
Mais doux		4 967			Strauberry, consumption mix		
Pomme de terre		1 677			Sweet corn, canned		
Raisin		11 362			Sweet potato, consumption mix		
Légume		4 685			Tapenade (a puree of capers, mixed black olives, anchovy and herbs, with olive oil and lemon juice), processed in FR (Chilled / Glass) at supermarket		
Pâté de tomates		1 026			Tomato rust, concentrated, canned, processed in FR (Ambient average) / Steel / at supermarket		
Navet		1 570			Turnip, consumption mix		
Plat de légumes pour bébé		68 042			Vegetable dish for baby, w meat		
Roti de légumes		9 337			Vegetable root, pre-fried frozen, at plant		
Légumes (3-4 types)		53 170			Vegetables (3-4 types), mashed, processed in FR (Chilled / PP / at supermarket		
Chou blanc		7 375			White cabbage, consumption mix		
Asperges		12 184			Azparagus, consumption mix		
Framboise		958			Raspberry, raw, processed in FR / Ambient (average) / No packaging / No preparation at consumer		
Chou-fleur		4 397			Cauliflower, winter, organic, at farm gate		
Pomme		159 272			Cauliflower, winter, organic, at farm gate		
Pêche		28 656			Apple, production mix, national average, at orchard		
Poire		25 508			Pear, consumption mix		
Nectarine		2 089			Almond, consumption mix		
Noix de cajou		3 329			Cashew nut, consumption mix		
Châtaigne		126			Chestnut, consumption mix		
Sésame		253			Sesame seed, consumption mix		
Sauce soja (moyennement à faible et à haute)		645			Soi sauce (garlic and olive oil mayonnaise), prepackaged, at plant		
Framboise Beaufort		1 089			Beaufort cheese, from cow's milk, processed in FR (Chilled / LDPE / No preparation at consumer		
Sauce béchamel		677			Béchamel sauce, prepackaged, processed in FR / Chilled / PVC / at supermarket		
Framboise bleu		4 244			Blue cheese, from cow's milk, processed in FR / Chilled / LDPE / No preparation at consumer		
Framboise bleu		3 355			Brie cheese, from cow's milk, processed in FR / Chilled / LDPE / No preparation at consumer		
Beurre		19 990			Butter, 80% fat, lightly salted, processed in FR (Chilled / PP / No preparation at consumer		
Camembert		18 523			Camembert cheese, from cow's milk, processed in FR / Chilled / LDPE / at distribution		
Canal		571			Canal, Salers or Laporte cheese, from cow's milk, processed in FR (Chilled / LDPE / at distribution		
Framboise chabichou		504			Chabichou cheese, from goat's milk, processed in FR / Chilled / LDPE / at distribution		
Framboise en robe feuilletée		2 727			Cheese in puff pastry, processed in FR (Chilled / Cardboard / Oven at consumer		
Soufflé au fromage		3 363			Cheese soufflé, processed in FR (Chilled / Cardboard / at distribution		
Framboise		4 378			Cheese, buche, from goat's milk, processed in FR (Chilled / LDPE / No preparation at consumer		
Foie de poule		38 873			Chicken egg, raw, consumption mix		
Framboise, coute		7 025			Camé cheese, from cow's milk, processed in FR / Chilled / LDPE / at distribution		
Petit choux/streusel au fromage		1 141			Crotin cheese, from goat's milk, processed in FR (Chilled / LDPE / No preparation at consumer		
Framboise Fdam		858			Edm cheese, from cow's milk, processed in FR (Chilled / LDPE / No preparation at consumer		
Blanc d'oeuf		1 957			Egg white, raw, processed in FR / Ambient (average) / Cardboard / No preparation at consumer		
Laine d'oeuf		1 129			Egg yolk, cooked, processed in FR / Chilled / Cardboard / Pan frying at consumer		
Framboise Fdam		11 159			Emmental cheese, from cow's milk, processed in FR / Chilled / LDPE / No preparation at consumer		
Feta		492			Feta cheese, from cow's milk, processed in FR / Chilled / LDPE / at distribution		
Framboise fraie à la crème		20 489			Fresh cream cheese, plain, around 31% fat, processed in FR / Chilled / PP / at distribution		
Framboise Gorgonzola		988			Gorgonzola cheese, from cow's milk, processed in FR / Chilled / PP / at distribution		
Framboise Gouda		1 638			Gouda cheese, from cow's milk, processed in FR / Chilled / LDPE / at distribution		
Gruyère		3 308			Gruyère cheese, from cow's milk, processed in FR / Chilled / LDPE / No preparation at consumer		
Crème liquide 30% de matière grasse		42 517			Liquid cream 30% fat, UHT, processed in FR (Chilled) / PP / No preparation at consumer		
Framboise Livarot		309			Livarot cheese, from cow's milk, processed in FR (Chilled / LDPE / No preparation at consumer		
Framboise Maquilles		704			Maquilles cheese, from cow's milk, processed in FR (Chilled / LDPE / at distribution		
Mayonnaise (70% de matière grasse et sel)		36 188			Mayonnaise (70% fat and meal), processed in FR (Chilled) / PVC / at packaging		
Lait		539 772			Milk, semi-skimmed, pasteurised, processed in FR / Ambient (average) / HDPE / No preparation at consumer		
Framboise mimollette		704			Mimollette cheese, from cow's milk, processed in FR / Chilled / LDPE / No preparation at consumer		
Framboise mozzarella		2 858			Mozzarella cheese, from cow's milk, processed in FR (Chilled / LDPE / No preparation at consumer		
Omelette		17 929			Omelette, with herbs, processed in FR (Chilled / LDPE / Microwave at consumer		
Framboise Ossau-Iraty	408			Ossau-Iraty cheese, from ewe's milk, processed in FR / Chilled / LDPE / No preparation at consumer			
Parmesan	4 014			Parmesan cheese, from cow's milk, processed in FR (Chilled / LDPE / No preparation at consumer			
Framboise Jond	314 270			Processed cheese, double cream, around 31% fat, processed in FR (Chilled / LDPE / No preparation at consumer			
Framboise à raclette	1 523			Raclette cheese, from cow's milk, processed in FR (Chilled / LDPE / No preparation at consumer			
Reblochon	1 162			Reblochon cheese, from cow's milk, processed in FR / Chilled / LDPE / No preparation at consumer			
Framboise Roufflet	1 402			Roufflet cheese, from ewe's milk, processed in FR / Chilled / PP / at distribution			
Framboise Saint-Etienne	3 831			Saint-Etienne cheese, from cow's milk, processed in FR / Chilled / LDPE / No preparation at consumer			
Fondue suisse (fromage vin et pain)	2 408			Savoy-style fondue (cheese wine and bread), processed in FR (Chilled / Cardboard / Microwave at consumer			
Petit choux/streusel au fromage	1 141			Small cheese cloverleaf puff, processed in FR (Chilled / Cardboard / at supermarket			
Tartiflette (fromage au fromage)	3 543			Tartiflette (cheese fondue), processed in FR (Chilled / Cardboard / at distribution			
Tomme	4 472			Tomme cheese, from cow's milk, processed in FR (Chilled / LDPE / No preparation at consumer			
Framboise à milk milk non affiné	20 848			Unaged soft cheese, ripenable, around 55% fat, in a tub, processed in FR (Chilled / LDPE / at distribution			
Yogurt faitif	159 244			Yogurt, fermented milk or dairy specialty, flavoured, with sweetener, fat free, processed in FR (Chilled) / PP / No preparation at consumer			
Yogurt	139 245			Yogurt, fermented milk or dairy specialty, plain, processed in FR / Chilled / PP / No preparation at consumer			
Framboise Moberg	748			Moberg cheese, from cow's milk, processed in FR (Chilled / LDPE / No preparation at consumer			
Beuf, usé, braisé	523			Beef, chest, braised or boiled, processed in FR (Chilled) / PS / at supermarket			
Ragoût de boeuf aux carottes	6 867			Beef stew with carrots, processed in FR / Chilled / PP / at supermarket			
Beuf, ragoût, braisé	4 119			Beef, chuck, braised or boiled, processed in FR / Chilled / PS / at supermarket			
Beuf, bavette	3 041			Beef, flank steak, raw, processed in FR (Chilled) / PS / No preparation at consumer			
Beuf, haché	2 764			Beef, flank steak, raw, processed in FR (Chilled) / PS / No preparation at consumer			
Beuf, steak haché	43 217			Beef, minced steak, 15% fat, cooked, processed in FR (Chilled / LDPE / at supermarket			
Beuf, entrecôte	4 553			Beef, rib steak, lean, grilled			
Beuf rôti de boeuf, rôti/cuit au four	4 240			Beef, roast beef, roasted			
Beuf, mince	873			Beef, rump steak, grilled, processed in FR (Chilled) / PS / at supermarket			
Beuf, autogre	723			Beef, sirloin steak, roasted			
Beuf, steak ou steak de boeuf, cru	29 848			Beef, steak or beef steak, raw, processed in FR (Chilled) / PS / No preparation at consumer			
Beuf, filet	9 097			Beef, stewing meat, raw, processed in FR (Chilled) / PS / No preparation at consumer			
Beuf, viande à ragoût	1 884			Beef, stewing meat, raw, processed in FR (Chilled) / PS / No preparation at consumer			
Cheesburger	6 412			Cheesburger, double, from fast foods restaurant, processed in FR (Chilled) / PS / Oven at consumer			
Chili con carne	953			Chili con carne, processed in FR (Chilled) / PP / Microwave at consumer			
Pâtes fraîches	628			Fresh pasta, stuffed with meat (e.g. bolonese-style ravioli), raw, processed in FR (Chilled / LDPE / Microwave at consumer			
Hamburger	10 018			Hamburger, from fast foods restaurant, processed in FR (Chilled / LDPE) / Oven at consumer			
Rein	628			Kidney, lamb, braised, processed in FR (Chilled) / PS / at supermarket			
Agneau gigot	4 862			Lamb, leg, roasted			
Côte d'agneau	14 768			Lamb, rib chop, grilled			
Agneau ragoût	4 082			Lamb, shoulder, roasted			
Lassano ou camelloni à la viande (sauc)	17 372			Lassano or camelloni with meat (bolonese sauce), processed in FR (Chilled) / PP / Microwave at consumer			
Boulettes de viande	4 547			Meat balls, beef, with tomato sauce, processed in FR / Chilled / PP / Microwave at consumer			
Viande de porc	816			Mutton tagine, processed in FR (Chilled) / PP / Microwave at consumer			
Museau de boeuf à la sauce salade	314			Ox muzzle in salad dressing sauce, processed in FR (Chilled) / PS / No preparation at consumer			
Lamproie	1 524			Tomato, beef, cooked, processed in FR (Chilled) / PS / at supermarket			
Filet de veau	2 245			Veal filet, roasted			
Veau	10 285			Veal, shoulder, raw, processed in FR (Chilled) / PS / No preparation at consumer			
Lard	1 538			Bacon, back, processed in FR (Chilled) / PS / No preparation at consumer			
Jambon cuit	24 568			Cooked ham, shcice, processed in FR (Chilled / Ambient packed) / PE / No preparation at consumer			
Pâté campagne au chamois	1 068			Country-style pâté, with mushrooms, processed in FR (Chilled / Steel) / No preparation at consumer			
Pâté de gibier	7 005			Foie gras, duck's liver, whole, cooked, at plant			
Herdin	1 570			Game pâté, processed in FR (Chilled / Steel) / No preparation at consumer			
Sausse mecouze	890			Hot-dog, processed in FR (Chilled) / LDPE / at supermarket			
Hot-dog	19 240			Merguez sausage, raw, processed in FR (Chilled) / PS / at supermarket			
Moradilla	314			Moradilla, processed in FR (Chilled) / PS / Oven at consumer			
Sausse de Strasbourg	10 240			Strasbourg sausage, processed in FR (Chilled) / PS / at supermarket			
Burger de poulet	968			Chicken burger - fast foods restaurant, processed in FR (Chilled) / PS / Oven at consumer			

Table with 3 columns: Product Name, Quantity, and Unit. Lists various food items like Taigne au rosel, Poulet au curry, and various pastries and breads.

Table with 3 columns: Product Name, Quantity, and Unit. Lists various food items like Chicken tagine, Chicken with curry, and various pastries and breads.

ANNEXE II. ARTICLE N°1

Use of territorial LCA framework for local food systems assessment:
Methodological developments and application

**Use of territorial LCA framework for local food systems
assessment: Methodological developments and
application**

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Abstract

Purpose

Reducing the environmental impacts of food systems has become a growing concern for public authorities. This study aims to adapt the territorial LCA framework (T-LCA) to local food systems assessment to identify territorial hotspots of a food system in relation to its land use functions. To achieve this goal, the T-LCA must be enhanced by overcoming previously exposed limitations.

Methods

Deriving from the T-LCA framework, the methodology used in this paper assesses all territorial food-producing, processing, and consuming activities. The methodological developments suggest addressing its three principal methodological limitations by: (i) using agricultural statistics to estimate the local consumption and thus account for intra-territorial flows, (ii) proposing novel agri-food land use functions related to a local food system and (iii) developing a simplified framework for sensitivity analysis (SA) through detection of the most uncertain and influential data followed by a once-at-a-time (OAT) approach to improve the uncertainty related to the substantial number of data involved in meso-level LCAs. The methodology is applied to a case study in France using the Environmental Footprint (EF) 3.0 method.

Results and discussion

The results indicate that intra-territorial flow analysis effectively distinguishes between local and imported flows, identifying their primary environmental hotspots. Despite the significant impact of imported flows, export-oriented livestock production emerges as the principal hotspot of the studied food system. Integrating agri-food land use functions into LCA is crucial for linking the activities with higher environmental impact contributions and their territorial functions. This is the case of animal husbandry which is the main environmental hotspot and one of the principal local economic activities. Finally, the sensitivity analysis reveals a low sensitivity of the overall results to the most influential and uncertain parameters.

Conclusions

These findings confirm the interest in further developing territorial LCA methodologies and adapting them to various contexts to determine the principal environmental burdens of local systems and improve territorial land planning. This study also proposes various research perspectives to confirm and enhance the robustness of T-LCA frameworks, including the development of regional life cycle inventories.

Keywords: *local food planning, agri-food system, territorial life cycle assessment (T-LCA), sustainable food, land use function, sensitivity analysis, case study*

1 Introduction

Over the past decade, local public bodies in the Global North have been progressively applying local food policies to mitigate the environmental impacts of food systems (Clancy and Ruhf 2010; Kremer and DeLiberty 2011; Benis and Ferrão 2016; Chiffolleau and Dourian 2020). These policies aim not only to relocate agriculture but also to encourage the adoption of more sustainable farming practices and local food habits (Lulovicova and Bouissou 2023). Yet, such local planning strategies either neglect environmental assessment (Kremer and DeLiberty 2011; Freedgood et al. 2011) or lack systemic and multi-impact perspective, often focusing primarily on the climate change indicator, leaving room for burden shifting (Cremer et al. 2020). Such a dearth of holistic assessment at the territorial scale hinders the ability of local authorities to measure the environmental impact from a systemic point of view and thus prevents them from designing effective mitigation strategies. To address this gap, this study assesses the environmental impacts of local food systems (LFS) to enhance local food planning. LFS, as defined in this paper, include all activities from food production to food consumption located in a delimited geographical area (Schönhart et al. 2009). While the definition of ‘local’ varies widely across the literature, within the European context, we consider ‘local’ as any sub-national level, including regions, municipalities, or rural areas.

The LCA method, which has become an internationally recognized environmental assessment method over the past two decades, was originally developed as a spatially and temporally independent method for assessing the impact of products or services (Udo de Haes 1996). To enable a meso-level and systemic assessment of local activities, scholars progressively develop territory-scale LCA frameworks (Loiseau 2014; Nitschelm et al. 2016; Benis and Ferrão 2016; Maihac et al. 2016; Albertí et al. 2019a; Mirabella et al. 2019; Qi et al. 2019; Cremer et al. 2020). While most studies focus on a city level (Goldstein et al. 2013; Petit-Boix et al. 2017; Mirabella et al. 2019; Qi et al. 2019; Cremer et al. 2020), the general territorial perspective is adopted by Loiseau et al. (2013).

Even though LCA is a well-established method for agriculture and food systems assessment (Roy et al. 2009; Poore and Nemecek 2018; Rouault et al. 2020), territorial LCA studies of food systems are recent (Lulovicova and Bouissou 2023) and its latest developments concern mostly agricultural regions (Nitschelm et al. 2016; Avadí et al. 2016; Borghino et al. 2021; Ding et al. 2021; Rogy et al. 2022), generally neglecting consumer-related activities. Consumer-related activities include the food consumed in the territory that can be both produced locally or imported, but also other inhabitants’ activities such as their transport to supermarkets. Omitting such consumer activities can lead to carbon or other impact leakages by overlooking upstream processes situated outside of the territorial boundaries (Larsen and Hertwich 2009; De Laurentiis et al. 2019). Previous studies demonstrate for

instance that food imported to urban territories constitutes more than 90 % of the cumulative local food system's impact (Lulovicova and Bouissou 2023). They also show that dietary preferences have the highest potential for GHG mitigation in urban food mitigation strategies (Benis and Ferrão 2016) or that cities influence around two-thirds of food emissions (Mohareb et al. 2018). Altogether, these findings reinforce the need to include consumption-based activities in territorial assessments.

Out of the proposed territory-based LCA frameworks, in their extensive review, Mirabella et al. (2019) demonstrate that territorial LCA (T-LCA) developed by Loiseau (2014) is one of the most comprehensive frameworks. T-LCA and its adaptations assess geographically defined systems or subsystems, taking into account all activities located within the studied territory while defining its multifunctionality. The territory is considered not only as a geographical space, but also as the interactions between local actors including decision-makers, producers, and consumers and their environment. T-LCA thus constitutes an appropriate framework to assess LFS as it can be applied to any territory, and its industrial sub-categories, and includes both producer and consumer-based activities (Qi et al. 2019; Lulovicova and Bouissou 2023).

Despite the T-LCA potential, multiple methodological limitations persist when moving from product-oriented LCA to processes-oriented assessment, especially related to boundaries and allocation systems, functional unit (FU) definition, and uncertainty analyses (Goldstein et al. 2013; Loiseau et al. 2013; Albertí et al. 2019a; Mirabella and Allacker 2021). Applied to food systems, we distinguish three main limitations: double-counting issue, lack of multifunctionality definition of LFS, and lack of uncertainty assessment.

The first unresolved limitation to be primarily addressed in agri-food T-LCA is the definition of local food flows (Loiseau 2014). In general, the scope includes the entire responsibility of the territory in terms of environmental impact including all consumption and production activities, which might generate potential double-counting, especially for the agri-food sector. Life cycle inventories of food-consuming activities include the impact at the farm gate which creates a supply-chain overlap meaning that food produced and consumed within the same geographical borders are automatically double-counted. For that reason, Loiseau et al. (2013) divided all activities into two categories: production and consumption categories and accounted for their impact separately. Such an approach avoids double-counting but prevents identifying overall territorial hotspot activities and thus remains to be improved.

The second barrier to overcome is related to the FU definition which for Albertí et al. (2019a) is the principal shortcoming related to territory-based LCAs and should be addressed by future research (Goldstein et al. 2013).

For a single metric FU enabling benchmarking between different territories, Mirabella and Allacker (2021) suggest applying a population-equivalent unit, and Albertí et al. (2019a) develop the City Prosperity Index. Yet determining a unique FU is insufficiently adapted for territorial LCA (Loiseau et al. 2013; Cremer et al. 2020). Territory and its system provide a variety of functions to its inhabitants, economic actors, and ecosystems. The definition of the multifunctionality of the territory through land use functions, assessing its societal, economic, and environmental functions, is thus one of the significant evolutions developed in T-LCA (Loiseau et al. 2013). These functions are assessed through a set of indicators as a vector of the territorial land use functions and a comparison between territories. This multi-indicator approach is further adapted by Qi et al. (2019) by adding regional characteristic functions. Other propositions of multifunctional FU are made in agricultural T-LCA (Nitschelm et al. 2016; Rogy et al. 2022) such as assessment per land occupation or economic benefit. Yet no advancement is proposed for local food systems including consumer activities. The definition of land use functions in food systems is consequently to be developed to allow a better interpretation of the LCA results.

Finally, one of the most important limitations of territory LCA is the uncertainty related to its results. The uncertainties in LCA studies stem from a) parameters, b) models, and c) choice uncertainty (Huijbregts 1998). T-LCA includes the entire responsibility of the territory and its activities, which involves hundreds of life cycle inventory (LCI) processes. In most cases, the approach requires the use of heterogeneous sources, proxy data, the use of regional or national statistics, and extrapolation. The use of such data is profoundly uncertain (Avadí et al. 2018) as they do not precisely describe the local specificities (Fuchs et al., 2011). The parameter uncertainty in T-LCA is thus high and can be a source of under- or over-estimation.

A multitude of methods has been developed to assess uncertainties in LCA, with Monte Carlo simulation being the most dominant method (Barahmand and Eikeland 2022). In addition to the uncertainty range analysis, the ISO standard 14040/44 (ISO 14040 2006) recommends the application of sensitivity analysis (SA), which aims to understand the principal sources of uncertainty. Yet these practices are still not generalized even in classic LCA studies (Igos et al. 2019). In territory-based LCA application, Loiseau et al. (2014) test the sensitivity of the results by changing LCA methods and comparing the results of ReCiPe (Huijbregts et al. 2017) and IMPACT World+ (Bulle et al. 2019) methods. In the work of Heinonen and Junnila (2011), sensitivity analysis is conducted by normalization of the key parameters. More efforts are to be engaged in developing SA in meso-level LCA to increase the reliance on the outcome.

Based on the identified limitations, this paper aims to adapt the T-LCA method for LFS assessment and evaluate the novel framework on French administrative territory. Three major adaptations are developed: i) including the local consumption by accounting for intra-territorial flows, ii) proposing novel agri-food land use functions, and iii) developing a simplified framework for identifying uncertainty and conducting sensitivity analysis in a meso-level LCA.

The main objective is twofold, to explore the adequacy of the proposed adaptations to the overall LCA result, and to characterize the most impact-contributing processes of local food systems. The paper is structured as follows: section 2 describes the selected case study and the adapted methodology used. Section 3 illustrates the main findings linked to the proposed methodological advancements. Finally, section 4 discusses the advantages of the novel approach employed and its principal implications for local planners, followed by a conclusion in section 5.

2 Methods

The methodology used in this paper consists of four classic LCA steps following the T-LCA approach (Loiseau 2014). It consequently assesses the impact of the entire local food system (reference flow) and its production and consumption-related activities. Parallely, the multifunctionality of the territory is assessed through agri-food land use functions (ALUFs) and interpreted in relation to LCA results.

The modifications introduced in this study deal with (1) adjusting the definition of the territorial activities and its intra-territorial flows, (2) creating a set of indicators for territorial agri-food functions and (3) assessing the sensitivity of the results to the data used. Such evolutions ensure a more robust understanding of territorial impact-generating activities in comparison with territorial functions measured through ALUFs (Fig.1).

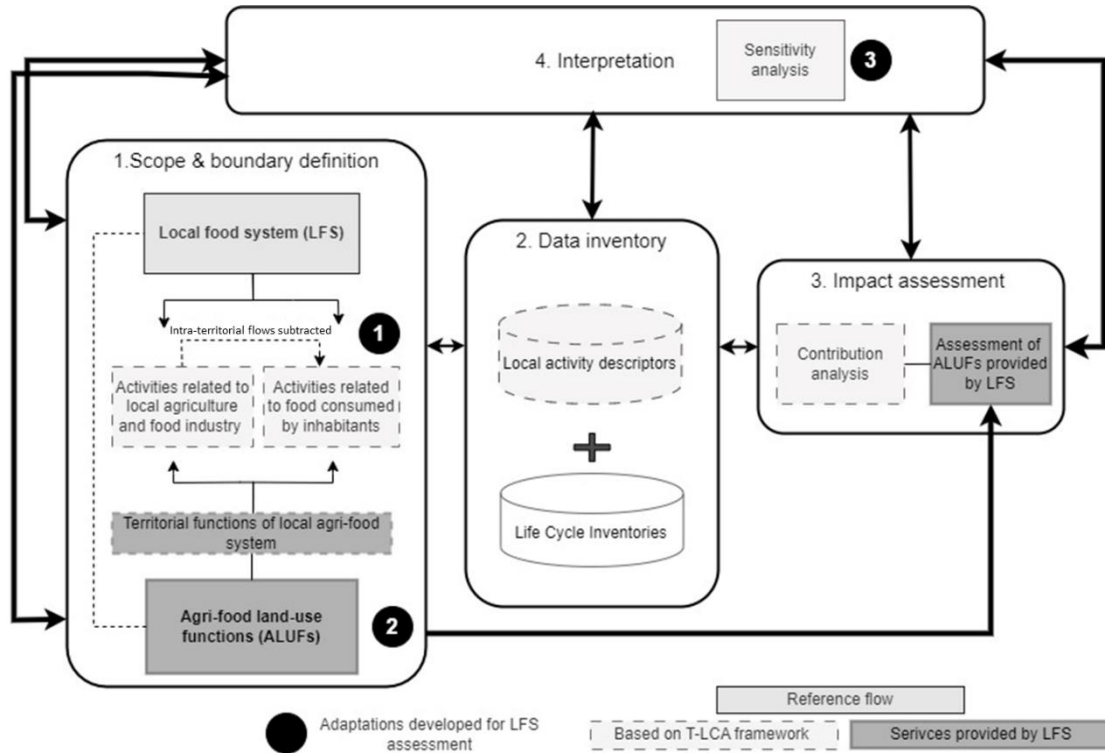


Fig.1 T-LCA framework for local food system assessment and the three major adaptations consisting in the definition of 1) the local food system and its intra-territorial flows, 2) the multifunctionality of the territory, and 3) the sensitivity of the results.

2.1 Case study presentation

For multiple reasons, French regions establish suitable study areas to assess the adapted methodological framework. Primarily, France is a major European food producer, as well as a leader in encouraging the local governments to relocate agriculture and promote sustainable LFS (Ministry of Agriculture 2017). Furthermore, multiple life cycle inventories of French farming systems and food products have been recently modeled thanks to the development of the Agribalyse database (Colomb et al. 2015).

The French Department of Finistere is consequently used as a case study. Geographically, the department is a coastal area of 900,000 inhabitants in Western France. It is one of the principal French farming regions, especially for animal husbandries such as swine, and dairy production. Despite its cold climate, it is also one of the principal producers of artichokes, cauliflowers, and tomatoes. Its industry is equally centered on tuna, poultry, and beef exportations (Agreste Bretagne 2019).

The territory is chosen due to the importance of farming and local food policies for local authorities. Increasingly, the local government implements policies to decrease the emissions and energy use in farming. Relocating policies

are equally encouraged by Finistère's public bodies with a focus on developing sustainable eating habits (Conseil départemental du Finistère 2017).

2.2 Goal & scope definition

The goal of this LCA study is to (1) adapt an existing T-LCA framework to the local food system's assessment, including both local producing and consuming activities, and thereby develop a comprehensive, reliable, and easy-to-conduct LCA framework for local food planning, (2) identify major hotspots related to territorial agri-food functions.

2.2.1 System boundary

Scope and boundary selection in territorial LCA approaches is a difficult feature to determine due to their vast background system (Petit-Boix et al. 2017). In this work, we opted for the most extensive system boundary selection including the territory's integral (global) responsibility (Loiseau et al. 2013; Mirabella and Allacker 2021). Consequently, all local food system activities related to agriculture, food industry, and food consumption are assessed allowing us to accurately define the principal environmental burdens of the entire system. This implies allocating the impact of all food production or consumption-related activities to their geographical and administrative territory (Albertí et al. 2019b). Four major activity categories are addressed: local farming, local agro-industry, local agri-food transport, and imported food. The term “*local*” relates to the administrative department scale. The activities are composed of the *foreground* and *background* systems following the definition in the International Reference Life Cycle Data System (ILCD) handbook (European Commission 2010). The *foreground* system is comprised of activities described by data specific to the territorial system such as the volume of farming production. The *background* system consists of sub-activities or processes that support the foreground system and are based on average or generic data from LCI databases that are representative of the local activities such as the use of fertilizers or pesticides. In some territorial LCA adaptations, the distinction of foreground system is used to model the direct local impacts such as local emissions or pollutants to distinguish between direct (in-site) and indirect (off-site) burdens (Azapagic et al. 2007; Loiseau et al. 2013). This distinction is not developed in this study.

In this paper, the foreground system for local farming includes the local production of major crops, livestock, and fish. The related background processes are all farm-gate activities such as soil preparation, farming inputs production, or animal feed. For the local agro-industry, the foreground system is limited to energy use in food

outlets and agri-food processing industries. For agri-food transport, the foreground system includes local farmers' and consumer journeys to supermarkets. The background processes in both cases include energy and fuel use as well as the related infrastructure. The foreground system of imported food activity is composed of food products imported for local consumption including categories such as plant-based (cereals, potatoes, vegetables, and fruits), animal-based (red meat, poultry, pork, seafood, dairy, eggs), and ultra-processed (ready-to-eat, confectioneries, snacks, beverages) that are not produced locally. Those contain background processes linked to their entire life cycle such as farm gate, processing, transport, and disposal. The consumer-based activities are enclosed in the overall food consumption by local inhabitants included in the *local farming* category (for locally consumed products) and the *imported food* category, and in the consumer journey to the supermarket included in *agri-food transport*. (Fig.2)

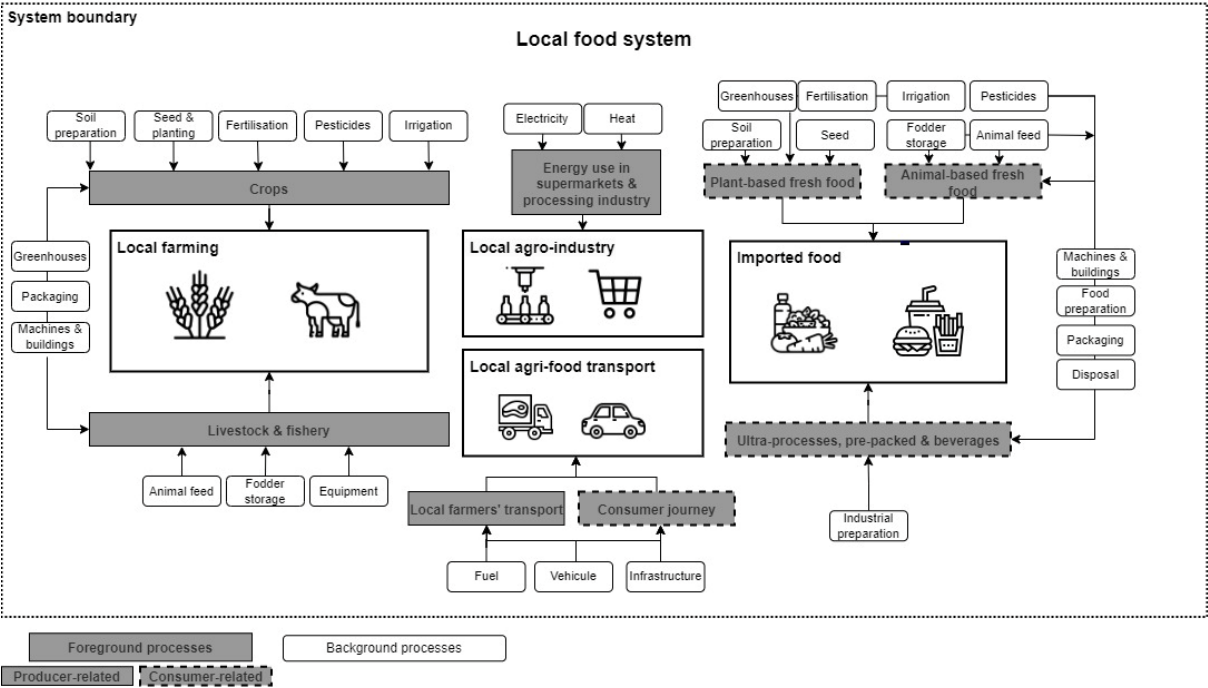


Fig.2 System boundary of the revised territorial food planning LCA with major foreground and background processes. The term *local* refers to the Department of Finistere but could be related to other territorial scales ranging from municipality to region depending on the case study. Credits: flaticom.com

2.2.2 Intra-territorial flows consideration

The classic T-LCA framework divides producing and consuming activities to avoid double-counting some activities such as local consumption or waste management (Loiseau et al. 2018). Such a division prevents understanding the proportion of the impact derived from local production and local or imported consumption.

This study bypasses the double-counting issue by under-allocating the impact of food products that are both locally produced and consumed to the farming industry for the farm gate, and to the local agri-food industry and transport for the other downstream activities related to processing and transportation. The impact of locally produced and consumed goods is consequently subtracted from the data related to all food consumed locally creating the *imported food* category. It can be assumed that local data about farming, energy consumption, and transport are more precise and site-specific than the general processes used in food products consumption assessment mostly based on national statistics which increases the overall LCA precision. Yet implementing this approach requires knowledge of intra-territorial flows. While no meticulous data or modeling approaches exist to this day, a regional agricultural census conducted every 10 years is used for this first estimation (Chambres d’agriculture de Bretagne 2020). This regional database provides information about the number and profile of farmers selling their products through a short supply chain. By French administrative definition, a short supply chain involves direct sales on farms or sales including a maximum of one intermediary usually implying a geographical proximity compared to long supply chains based on multiple intermediaries and long distances (Ministère de l’Economie 2022). While a short supply chain does not necessarily imply that the products are consumed locally and conversely, a long supply chain does not confine the product to be sold outside the department’s border, such an assumption can provide a reasonable initial estimate. According to the 2020 Finistere data, 18.6% of local farmers sell their products through a short supply chain (Chambres d’agriculture de Bretagne 2020). Yet, in most cases, the entire production is not sold in short supply chains and disparities exist among farming sectors. Percentages are thus calculated per major farming sector including solely the proportion of goods sold through short supply chains. The evaluation is further pursued by determining the quantities consumed by the local population through the downscaling of regional INCA3 data (Anses 2017) which provides a quantitative assessment of regional diets. This allows us to estimate the percentage of local consumption produced in the department per major farming sector. The percentage of the local food consumption considered to be produced within the department is consequently subtracted from the local diet consumption data to account solely for the imported products and avoid double-counting with local activities including farming, processing, or transport. For sectors such as swine production, due to its consequent local production, it is estimated that 99% of the local consumption originates within the department, representing solely 3.4% of the department’s swine production in volume. For other sectors, despite their important production capacities, less than 20% of the local consumption is estimated to come from the territory. For the cereals intended for human consumption, the percentage sold locally is negligible. (Table 1)

<i>Farming sector</i>	Overall local production (volume in tons)	% of farms selling through SSC	% of local production sold through SSC	Quantities consumed annually by the local population (in tons)	% of local food consumption estimated to be produced locally
Cereals		1.37%	negligible		
Vegetables	250,051	9.51%	6.07%	83,173	18.26%
Fruits	2,508	68.93%	44.43%	44,671	2.49%
Milk products	114,440	5.94%	2.37%	56,196	4.83%
Eggs & Poultry	23,690	5.83%	3.17%	11,553	6.51%
Beef & veal	30,700	7.48%	3.44%	15,57	6.78%
Swine	427,700	7.48%	3.44%	14,838	99.16%

Table 1. Estimates of local food production and consumption overlap for the Finistere department based on (Chambres d’agriculture de Bretagne 2020) and (Anses 2017) data

Despite the estimates using the most recent and detailed data, significant uncertainty may still be associated with these assumptions due to the aforementioned reasons. This uncertainty should be accordingly considered in the interpretation stage through sensitivity analyses assessing the influence of the data used.

2.3 Agri-food land use functions (ALUFs)

The land use function assessment defined in T-LCA represents a shift from a single FU to a set of indicators based on the reference flow defined by the land planning scenario. It involves identifying appropriate functions of the territory based on societal, economic, and environmental criteria (Paracchini et al. 2011). Concerning an agricultural territory, three main functions found in the literature are economic profit and food production, land occupation, and biodiversity preservation (Nemecek et al. 2011b; Tendall and Gaillard 2015; Nitschelm et al. 2016; Rogy et al. 2022) with no proposition related to consumers and their diets. The *agri-food* land use indicators assessed in this study reflect both, the functions of the local farming industry as well as food consumption. While these indicators can be defined by local decision-makers (Loiseau et al. 2013; Nitschelm et al. 2016), we suggest an indicator framework based on previous agri-food LCA literature and studies assessing local food systems (Landert et al. 2017; Allen et al. 2019; Greniers d’abondance 2020). Most of these studies consider the capacity of food production as a key LFS function associated with potential food autonomy. Similarly, farming’s ability to preserve local biodiversity is largely developed. Other indicators related to social well-being, health, and economy are more varied ranging from the proportion of organic and local production to food quality, or economic resilience. We thus selected the most recurrent indicators that are comparable between varied territories and comprehensively assessed (Qi et al. 2019).

For each societal, economic, and environmental criterion, we selected between three to four representative indicators that are complementary to each other. The environmental section includes indicators describing the functions of the local food system and farmland such as landscape protection (by preventing or accelerating erosion), prevention of toxic exposure, preservation of ecosystem quality (especially aquatic), and farmland biodiversity. The local farming capacity to preserve surrounding ecosystems is evaluated through the pesticide use and nitrogen surplus, considered as the major local environmental issues related to agri-food systems (Srivastav 2020; Rani et al. 2021). The farmland biodiversity is assessed through the indicator High Nature Value (HNV), available for all French areas and giving a score to a territory based on its farmland features beneficial for biodiversity including crop diversity, extensivity of practices, and presence of landscape elements (Pointereau et al. 2010).

The societal indicators concern the function of the territory to offer locally produced and diverse food products, guaranteeing potential food autonomy in case of crisis, and promoting organic and healthy products leading to sustainable diets. They are measured through both, the offer (local organic production) but also through consumer data such as obesity rate. Potential food autonomy is assessed by comparing the local supply of food products with local demand. It does not consider whether such products are in practice exported or consumed locally.

Lastly, economic indicators concern partly the consumer side through the function of guaranteeing financial and physical access to food and secondly the farming industry through the function of territory to maintain farmland and farming population. Financial access to food is apprehended through the poverty rate, being one of the major markers of food shortage. The data used for collecting the ALUF indicators are taken from publicly available data and national institutes such as INSEE, ADES, or BRGM or existing studies on the subject such as the French obesity study (Fontbonne et al. 2023) (details in Table 2)

Function category	Function	Indicator	Unit	Data source
Environmental	Protecting landscape	Soil erosion hazard	Scale (low-strong hazard)	(BRGM 2000)
	Preventing toxic exposure	Pesticide use	Number of unit doses	(Eau France 2020)
	Preserving ecosystems quality	Nitrogen concentration (groundwater)	mg.L ⁻¹	(ADES 2021)
	Maintaining biodiversity	High nature value (HNV) farmland	Score (0-30)	(Solagro 2017)
Societal	Being able to satisfy hypothetical local food demand	Potential food autonomy (ratio of local production vs global demand)	%	(Anses 2017; Chambres d'agriculture de Bretagne 2020;)

	Supporting local offer for organic products	organic surfaces in global farmland	%	(Agence Bio 2021)
	Guaranteeing healthy diets	Prevalence rate of obesity	%	(Fontbonne et al. 2023)
Economic	Guaranteeing financial access to food	Poverty rate	%	(INSEE 2020a)
	Guaranteeing physical access to food	Population dependent on the car for food shopping (> 2 km)	%	Aggregation by (Greniers d'abondance 2022) based on (INSEE 2015, 2020b; OpenStreetMap 2021) data
	Protecting farming population	Farmers in the overall population	%	(INSEE 2019)
	Protecting farmland	Farmland surface in global surface area	%	(RPG 2019)

Table 2. Indicators used to measure the agri-food land use functions of the territory

2.4 Data collection & life cycle inventories

The undertaken T-LCA is a process-LCA that collects data defining territorial food consumption and production activities referred to as “*activity descriptors*” and connects them to existing LCI processes. Activity descriptor data can be collected through either bottom-up approaches, i.e., using local statistics or surveys, or top-down approaches, using national data and downscaling them to the studied territory (Loiseau et al. 2013). In this paper, the bottom-up collection (specific data) is privileged as it provides more accurate estimates than the top-down approach (Browne et al. 2011).

The activity descriptor data about farming production are provided by the regional chamber of the Ministry of Agriculture (Chambres d'agriculture de Bretagne 2020). The latter provides the annual volumes of major crop and livestock production and production types (organic or conventional). The data about the local agri-food industry are provided by the INSEE inventory of local businesses (INSEE 2021) and their energy consumption is taken from Enedis and GRDF open data platform (Enedis 2022; GRDF 2022). The transportation data of local farming activities are extracted from Agribalyse of which models are based on national statistics (Colomb et al. 2015). The consumer journey is modeled using a local survey providing information about car use and distance for food shopping by local inhabitants (Master GTDL 2020). For food consumption activity data, the regional INCA3 database is used (Anses 2017). The database provides a detailed description of food consumed (i.e., daily volume by food product or specific meals eaten) by a representative sample of inhabitants for each French region. These data are further downscaled and extrapolated to the sub-population of the Finistere Department. While this extrapolation technique might introduce sampling bias due to potential differences in participants' diets compared to the studied territory, it is the most exhaustive food database available for French regions. Locally produced and consumed data are subtracted from the downscaled INCA3 data to account solely for the imported goods.

The *activity descriptor* data are further connected to existing LCIs. The processes related to farming and food consumption are taken from the French food database Agribalyse V3.0 (Colomb et al. 2015). The database includes processes modeling each French national average farming production at the farm gate as well as the life cycle of food products consumed in France. For energy and transport processes, Ecoinvent 3.0 inventory is used (Wernet et al. 2016). The regional soil and climate characterization factors are not considered. Similarly, the specific data about background processes, such as the composition of animal feed, quantities, types of fertilizers, etc. are not adjusted in existing LCIs, thus relying on generic data. For imported food, market mix processes are used if specific information is not available in the INCA3 database. (Table 3)

Local activity category	Activity descriptors (foreground processes annual data)	Units	Data source	LCI processes
Local production	Farming production per product	t	Agricultural surfaces (RPG 2019) Volumes produced (Chambres d'agriculture de Bretagne 2020)	Agribalyse V3.0
Agri-food industry (Processing & retail)	Electricity & heat consumption	MWh	Industry data (INSEE 2021) Energy consumption (Enedis 2022; GRDF 2022)	Ecoinvent 3
Transportation	Farmers transport	Kg.km	National data estimation based on local production (RPG 2019)	Ecoinvent 3
	Consumer journey to the supermarket	km	Local surveys	Ecoinvent 3
Imported food	Imported goods from other national or international territories to be consumed by the local population	kg	Downscaling of regional INCA 3 databases (Anses 2017)	Agribalyse V3.0

Table 3. Inventory data including the local activity descriptors and related LCIs (Colomb et al. 2015; Wernet et al. 2016)

The precise data used in the case study can be found in Table S1 in the Supplementary material.

2.5 Impact assessment

In the impact assessment phase, we assess and identify the hotspot activities of the local food system and estimate their contribution to the overall impact by means of a contribution analysis. The assessment is conducted using SimaPro 9.2 Software (PreConsultants, 2015). The EF 3.0 method is employed (Fazio et al. 2018). The method's usage is encouraged by the European Commission and is equally supported by the Agribalyse database (Colomb et al. 2015; EC-JRC 2018). All sixteen impact categories are modeled including climate change, ozone depletion,

ionizing radiation, photochemical ozone formation, particulate matter, human toxicity (non-cancer and cancer), acidification, eutrophication (freshwater, marine, and terrestrial), ecotoxicity (freshwater), land and water use as well as fossil, mineral, and metal resource. This comprehensive approach aims to fully illustrate the consequences of the LFS as well as to avoid burden-shifting.

The identification of the LCA hotspots is consequently linked to the assessment of agri-food land use functions (ALUFs). The values for the selected ALUF indicators are calculated and attributed a score from 1 to 10 and compared to the national level. The contribution analysis is equally used for uncertainty identification by recognizing the most contributing and uncertain processes to undergo a sensitivity analysis.

2.6 Uncertainty and sensitivity analysis

Sensitivity analysis (SA) is a crucial tool used in LCA to study the robustness of the results and determine parameters of which data quality is to be improved (Wei et al. 2015). It is thus conjointly used with uncertainty analysis (UA). The sources of uncertainty can be linked to each life cycle stage such as scope or scenario definition, inventory phases linked to parameters used in processes, or to impact assessment mostly through model uncertainty characterization, normalization and weighting methods used, etc. (Lo Piano and Benini 2022).

Due to the recentness of meso-level LCA frameworks, the use of UA and SA is not a well-established practice. Besides, the sources of uncertainties in such studies can vary considerably from classic LCA. According to the ILCD handbook (European Commission 2010), the efforts for uncertainty treatment should focus on low-quality elements with an increased significance for LCA results. Due to ever-increasing model inputs, flows and hypotheses in T-LCA, parameter uncertainty emerges as the primary source of uncertainty that should be identified and quantified. Parameter uncertainty relates to a large amount of data needed in the inventory phase and might stem from the empirical accuracy of imprecise local data or the unrepresentativity of the selected processes from LCIs (Huijbregts 1998).

The T-LCA framework used in this study thus focuses on examining parameter uncertainty by identifying the most impactful parameters associated with high uncertainty. These parameters can be categorized into two groups: specific and generic parameters or data. Specific (territorial) parameters encompass the data describing the activities in the studied territory, referred to as activity descriptor data. Generic parameters refer to the average data used in existing life cycle processes following the definition outlined by Modahl et al. (2013). The purpose of the proposed SA framework is to first, identify the most influential input parameters related to both specific and

generic data, second, assign them an uncertainty score (DQR), and third, evaluate their sensitivity. If the sensitivity of an influential parameter is demonstrated to be significant, more accurate data are required.

Firstly, to identify the most uncertain parameters, diagnostic diagrams are used for both specific and generic data (Maurice et al. 2000; Van Der Sluijs et al. 2005; Pye et al. 2018; Baldowska-Witos et al. 2020; Lo Piano and Benini 2022). The diagnostic diagrams rely on identifying parameters to be assessed according to their contribution to the overall impact of the activities they describe, and the uncertainty of data used for their characterization. The y-axis represents the measure of the significance of the local activity based on its contribution to cumulative results and the x-axis represents the uncertainty score attributed to their data. They thus divide the diagram into four quadrants and classify the activities into the most or less uncertain and influencing LCA components (Fig.3). This is done firstly through contribution analysis, which determines the territorial activities and the related life cycle processes with the greatest influence on the overall impact. The contribution is calculated through the EF coefficient which aggregates all sixteen impact categories using the weighting proposed by the European Commission and used in the Agribalyse database (Colomb et al. 2015). We then obtain an aggregated percentage of the global contribution of each activity. Secondly, to identify uncertain activity descriptors data, mainstream quantitative analysis based on stochastic simulation such as Monte-Carlo, cannot be used due to the multiplicity of unquantifiable assumptions exceeding the quantifiable ones (Van Der Sluijs et al. 2005). We thus employ a qualitative dimension of the Pedigree matrix published by (Weidema and Wesnæs 1996). The data quality is assessed through five aspects (reliability, completeness, temporal acquisition, geographic accuracy, and technological correlations). A rating score between 1-highest quality and 5-lowest quality to each data input aspect is attributed to each activity descriptor data. Based on those, an aggregated data quality indicator DQR (or pedigree score) is calculated according to the weighting proposed by (Maurice et al. 2000) attributing 0.25 to geographical and technological correlation and 0.167 to the three remaining indicators. While the indicators in the Pedigree matrix should not be aggregated (Weidema and Wesnæs 1996), the use of aggregation is only used as an intermediate indicator for sensitivity analysis and is not transformed into a probability distribution (Maurice et al. 2000). This first diagram thus assesses the uncertainty related to the specific (activity descriptor) data.

For generic or inventory data uncertainty, we analyze the uncertainty of life cycle processes used to describe activities identified in the first step, such as a specific farming activity or types of food consumed with an increased contribution to the overall results. Their data quality is assessed using the data quality information provided in the Agribalyse DQR based on European Commission recommendations and equally corresponding to a score from 1

to 5 as in the classic Pedigree matrix (Colomb et al. 2015). An elevated score for process uncertainty typically arises from the use of proxies and dummies with a score exceeding 3 being subject to a precautionous interpretation. The diagnostic diagram consequently allows the identification of parameters that must (Q4) or might (Q2 and Q3) undergo sensitivity analysis. (Fig.3)

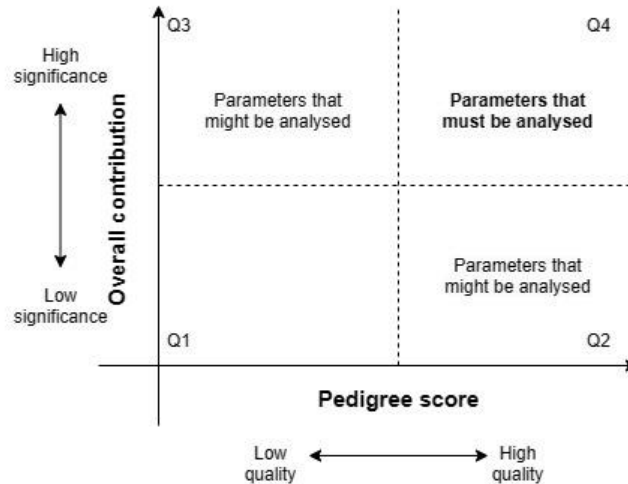


Fig. 3 Diagnostic diagram used for qualitative uncertainty analysis to identify activities and their processes suitable for sensitivity analysis based on (Maurice et al. 2000)

To analyze the influence of these parameters on the results, multiple SA methods can be considered, including local or global SA. While local SA (LSA) examines a change in a single parameter, global SA evaluates a change to the entire parameter distribution and their interaction (Wei et al. 2015; Barahmand and Eikeland 2022). LSA is thus privileged in this work as it is the most straightforward method for more complex LCA frameworks including a high number of uncertain parameters (Wei et al. 2015). The OAT approach (one-at-a-time) of LSA is applied to calculate the relative sensitivity of each uncertain parameter identified through the diagnostic diagram. This is done by varying each parameter by a certain percentage one by one and observing the consequences on the final LCA output (Wei et al. 2015; Ding et al. 2021). Various strategies can be applied when varying the inputs in OAT either by using quantified uncertainty ranges or applying arbitrary variations for a more simplified analysis (e.g., ± 10 or 20%) (Igos et al. 2019). The latter is employed in this study. If variations demonstrate to be high, the data used to describe the local activity or the life cycle processes selected should be revised.

3 Results

3.1 Assessment of agri-food land use functions (ALUFs)

The radar chart in Fig.4 illustrates the assessment of agri-food land use functions of the studied local food system. The territorial values are normalized on a dimensionless 0-10 scale, where a score of 10 indicates full fulfillment

of the function, while a score of 0 represents absence or low fulfillment. The local scores are further compared to the average national values.

In general, Finistere’s ALUFs, similarly to the national level, are oriented towards economic functions. This is due to an important level of farming population and farmland preservation. The scores for financial and physical access to food are similar to national levels. However, locally, a major proportion of the territory is affected by agricultural pollution. Despite being slightly lower than the average frequency of use in France, pesticide use remains high, with an average of three treatments applied at their maximum authorized dosage. The average nitrogen concentration is twice the natural threshold of 10 mg.L⁻¹ posing a threat to local ecosystems. Despite this, the farming biodiversity score is better than the national average due to a higher presence of ecological farm infrastructures such as hedgerows, forest edges, and higher crop diversity. For the societal functions, the overall scores are similar to the national level, reflecting comparable levels of obesity, high potential food autonomy, and low organic offer. (Fig.4)

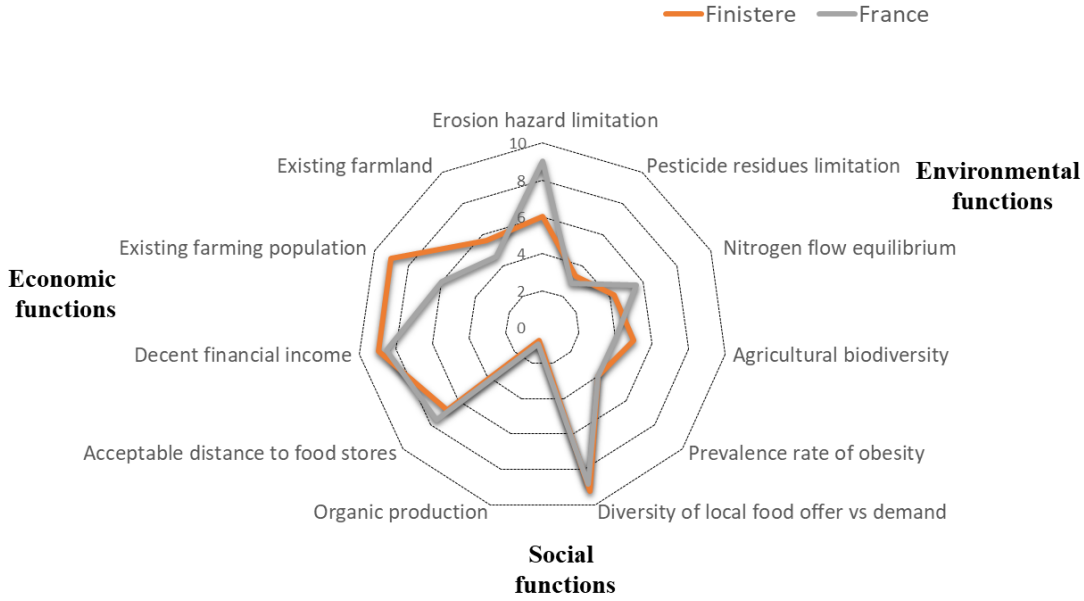


Fig.4 Radar charts of agri-food land use functions assessed through indicators defined in Table 2. The highest values (10) indicate better function fulfillment, while low values (0) represent unfulfilled functions

3.2 Environmental impact assessment and contribution analysis

Fig.5a illustrates the contribution of major local food system activities to its overall impact allowing constraining activities that require more attention in local food planning. Fig.5b and 5c further demonstrate the impact of the two most impactful activity categories: local farming and imported food.

Due to the presence of farming in Finistere, the farming activities generate between 18-77% of the local food system’s impact (Fig.5a) mostly due to livestock including swine and dairy production as well as tuna fisheries for photochemical ozone formation and minerals and metals resource use indicators (Fig 5b). These three major farming productions (swine, milk, tuna) contribute over 70% of the local farming impact for all indicators. Despite significant local production, the contribution of locally produced and consumed food is low ranging from 0.7 to 3.8%. On the contrary, imported food generates a non-negligible proportion of the global impact ranging from 14-51% of the cumulative local food system impact. An increased contribution (50%) of imported food is demonstrated in the water use indicator related to the types of imported products such as exotic fruits or beverages like coffee and their production countries' practices. While the local consumption of locally produced meat, especially pork, is high, meat and dairy products constitute a major contribution of the imported food category impact ranging up to 55% for the terrestrial eutrophication indicator (Fig.5c). The second most impactful imported food category consists of ultra-processed food products, and predominantly chocolate confectionery, accounting for impacts ranging between 16-32% of the imported food impact. Following closely behind is the impact of beverages, some of which are equally ultra-processed such as sodas. The fossil, mineral, and metal resource use and ionizing radiation indicators have a higher contribution to the local agri-food industry and transport related to the use of heat and electricity as well as personal vehicle use. The impact of the agri-food industry on these indicators is influenced by the prevalence of nuclear power use in French electricity production (Fig.5a)

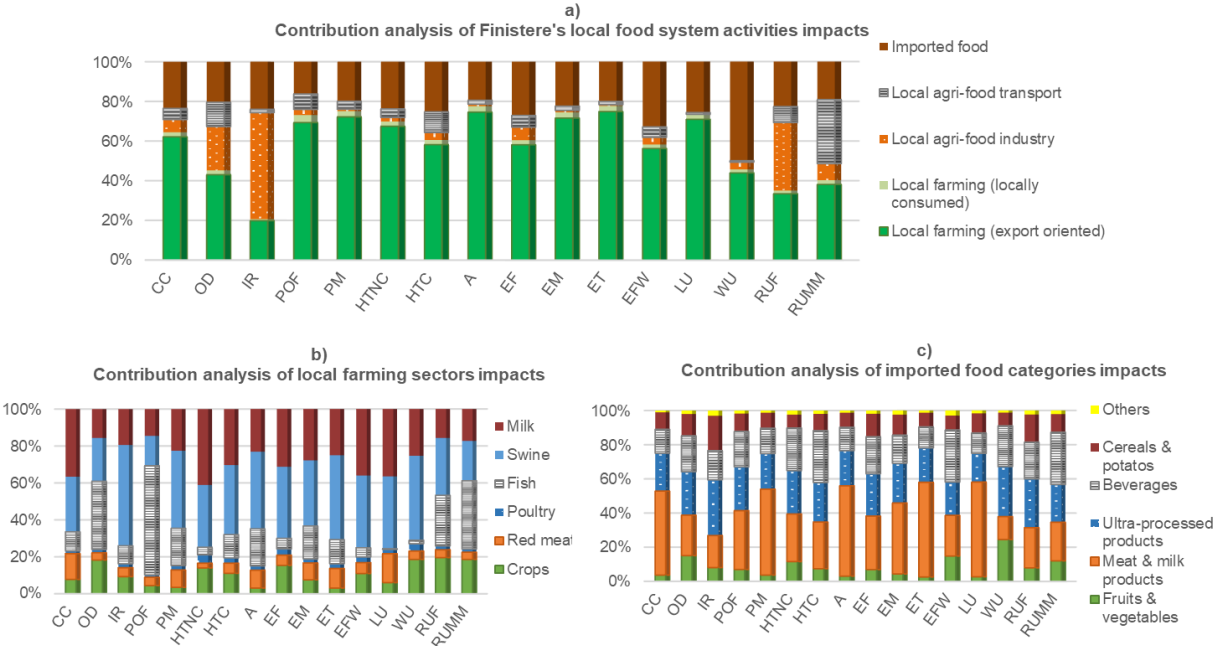


Fig. 5 Contributions made by a) local food subsystem activities, b) local farming, and c) imported food categories to sixteen impact categories using the EF 3.0 method for the Finistere case study. Abbreviations: CC = Climate

change; OD = Ozone depletion; IR = Ionizing radiation; POF = Photochemical ozone formation; PM = Particulate matter; HTNC = Human toxicity, non-cancer; HCT = Human toxicity, cancer; A = Acidification; EF = Eutrophication, freshwater; EM = Eutrophication, marine; ET = Ecotoxicity, terrestrial; EFW = Ecotoxicity, freshwater; LU = Land use; WU = Water use; RUF= Resource use, fossils; RUMM = Resource use, minerals and metals.

3.3 Sensitivity analysis

The most uncertain and influential parameters are identified through the diagnostic diagram (Fig.6). Two types of diagrams were undertaken. The first aims to identify the most uncertain specific or activity data, while the second focuses on the most uncertain generic data taken from existing inventories. Both diagrams are classified based on the overall contribution of the territorial activity they describe to LFS and their data quality ratio (DQR). A high value of overall contribution measures the influence of the local activity on the cumulative LCA results of the system in % using an aggregated EF coefficient. A high value in DQR indicates high data uncertainty with a score of 2 representing medium quality and 3 representing mediocre quality. The most critical activities are situated in Q4.

Fig.6a demonstrates that local farming and especially the livestock contribution outweighs other local activities, yet their specific data quality is rated as satisfactory. The data on imported food and their precision is medium or weak not only because these data are based on extrapolating the consumption INCA 3 database, but mostly since the imported food volumes are based on assumptions of intra-territorial flows, which might be an important source of uncertainty. Any imprecision in intra-territorial flow modelling can influence the volumes of local and imported food resulting in a need for sensitivity analysis related to these factors.

Concerning the most influential sub-activities of local farming and imported food categories, Fig.6b demonstrates that local swine and dairy productions contribute up to 20% of the overall impact and the generic data quality for the processes used is situated between 2 and 3. The most impactful and uncertain imported food processes concern red meat and beverages like coffee, yet their influence is lower than 5% of the overall LCA impact. Considering the substantial contribution of the local swine industry to the global impact, sensitivity analysis should be considered.

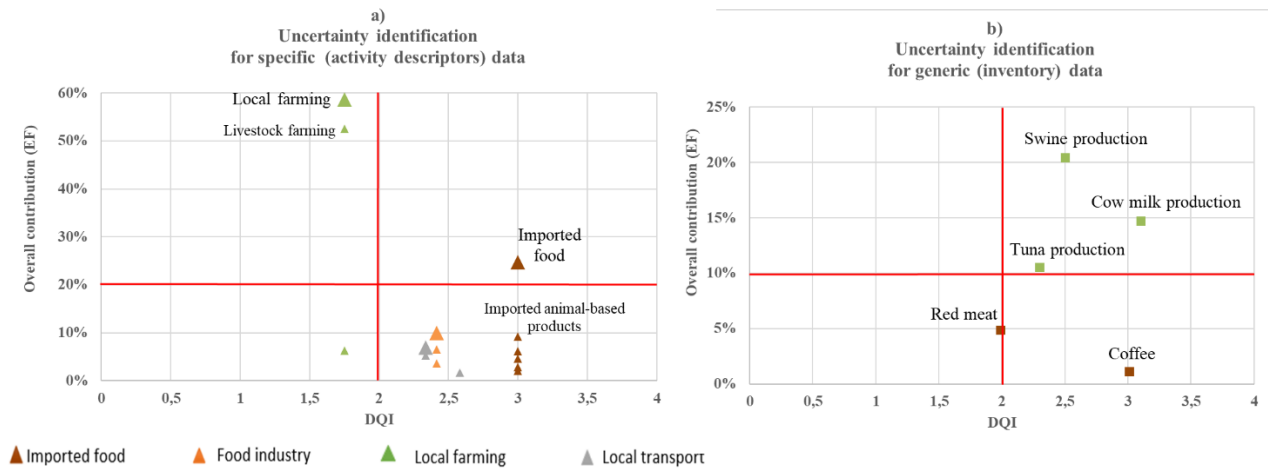


Fig.6 Diagrams (a) related to specific (activity descriptor) data, (b) to generic (inventory) data used in major corresponding processes

Based on the key parameter identification in Fig.6, sensitivity analyses examining the impact of the selected activity descriptor data and generic life cycle processes data on the overall sensitivity of the model, i.e., cumulative LCA results are conducted. The selected parameters to test are those identified in the danger zone Q4, as well as those with either high contribution or great uncertainty, which are part of Q2 and Q3. While those include multiple SA, only a sample of the most two uncertain examples is demonstrated in Fig.7.

Firstly, Fig.7a illustrates the sensitivity of the activity descriptor data for the imported food on the cumulative impact of the LFS. This example is chosen due to a substantial uncertainty associated with intra-territorial flow estimation and its influence on the imported food data quality. This is made by varying the hypotheses about the % of intra-territorial flows by a 20, 40, and 60% increase and decrease in local consumption on the overall impact and consequently influence the volumes of imported food categories. The results demonstrate that even an important hypothesis error such as an overall 60% increase or decrease in local consumption, influences the overall results by a maximum of 10% for the climate change indicator. A more realistic assumption of a 20% decrease or increase change illustrates an error ranging from 1-5% in cumulative results.

Regarding the uncertainty in the generic data, the sensitivity of the selected swine farming process is assessed due to the considerable contribution of this activity to the global impact. The Agribalyse database offers multiple choices to describe French swine production which might influence the overall results. The sensitivity analysis is consequently conducted by comparing the overall impact using each of the three swine production systems (based on on-farm animal feed, local French feed (mostly rapeseed), and major imported soybean feed) with the national average system used (Fig.7b). The findings demonstrate that the farm system processes selection does not significantly influence the results, apart from the water use and human non-cancer toxicity indicators, especially

between rapeseed or soybean feed and on-farm feed models, representing 14 points increase for water use in on-farm feed supply. The differences are related to the increased use of maize grain for the on-farm feed system requiring more water and mineral fertilizers during its entire life cycle. Comparing the chosen alternative processes and the initially used process (based on national average data), findings show less than a 10% decrease for soybean and rapeseed animal food for water use and a 4-10 % decrease for human toxicity indicator. For the rest of the indicators, differences are marginal.

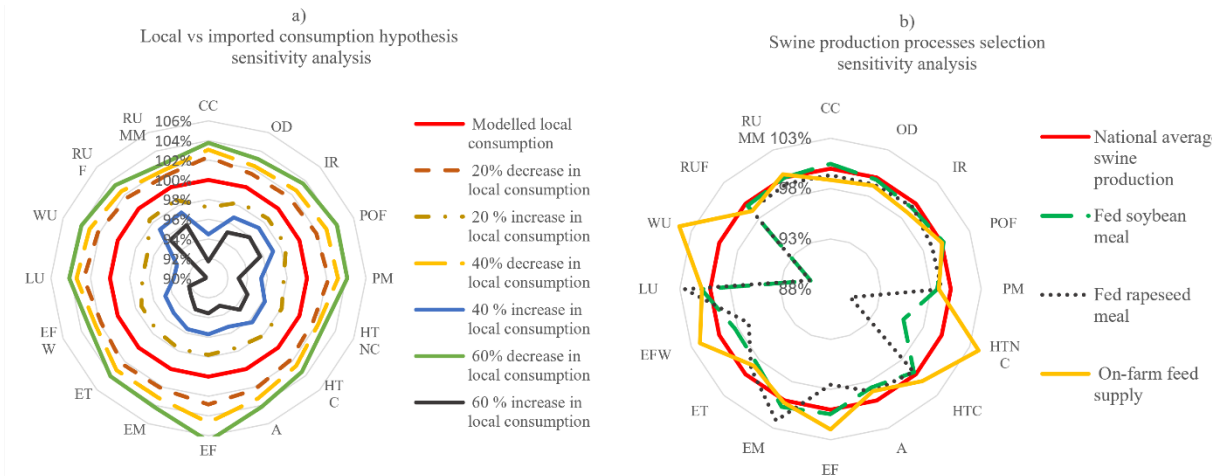


Fig.7 Sensitivity analyses of the most influential (a) specific (activity descriptor) data – example of local and imported food consumption (b) generic (inventory) data: example of swine production processes. Abbreviations: CC = Climate change; OD = Ozone depletion; IR = Ionizing radiation; POF = Photochemical ozone formation; PM = Particulate matter; HTNC = Human toxicity, non-cancer; HCT = Human toxicity, cancer; A = Acidification; EF = Eutrophication, freshwater; EM = Eutrophication, marine; ET = Ecotoxicity, terrestrial; EFW = Ecotoxicity, freshwater; LU = Land use; WU = Water use; RUF= Resource use, fossils; RUMM = Resource use, minerals and metals.

In this case study, the sensitivity analyses demonstrate that, for an initial territorial macro-analysis, more accurate data is not necessary.

4 Discussion

4.1 LCA of an entire local food system for improved local planning

The methodological innovations of this study provide new insights to overcome several shortcomings of the territory-based LCAs related to the agri-food sector (Loiseau et al. 2013; Albertí et al. 2019a; Mirabella and Allacker 2021) and contribute to enhanced environmental planning at the local level.

Firstly, by utilizing the principle of global responsibility, including both producer and consumer activities as well as estimating intra-territorial flows, the study confirms that even in regions with intensive agricultural production,

such as the Finistere Department, the impact of imported food is considerable. This underscores the necessity to evaluate upstream processes linked to local consumer practices as previously highlighted by scholars (Larsen and Hertwich 2009; Benis and Ferrão 2016; Albertí et al. 2019a; Mirabella et al. 2019). Despite the substantial impact of imported food, the primary hotspots include local livestock production and mostly export-oriented pork and dairy industries. At the same time, meat and dairy products emerge as hotspots among imported food categories. These findings underscore the imperative for local authorities to address both the production and consumption of animal-based food to mitigate the environmental impact of their local food systems. This aligns with prior research emphasizing the role of reducing animal protein consumption in transitioning to a more sustainable food system (Poore and Nemecek 2018; Springmann et al. 2018; Billen et al. 2021). While local policies in Finistere set actions to promote more sustainable dietary habits, primarily through public canteens (Conseil départemental du Finistère 2017), more widespread and ambitious actions may be required to significantly influence local diets. Regarding local livestock production, authorities could promote sustainable practices in identified hotspot industries or support a shift of local livestock farming towards less resource-dependent productions, such as pulses. Future studies are needed to identify more precise solutions for reducing local impacts such as prospective scenario analyses.

Despite the advantages of employing the global responsibility approach (Eder and Narodoslawsky 1999; Loiseau et al. 2013; Mirabella and Allacker 2021), which accounts for the impact of all regional activities, such an approach is not suitable for broader national or international carbon and environmental accounting due to the risk of double-counting. This implies that if each region assesses the impacts of all of its production and consumption activities, double-counting will necessarily occur between the regions. Nonetheless, the results obtained in this case study demonstrate the importance of including consumer-based activities in regional environmental assessments, especially in developed and highly interconnected global economies, for more systemic and efficient local policies.

4.2 Multifunctionality in LCA

The development of territorial ALUFs emphasizes the need to improve functional unit (FU) in territorial LCA studies to reflect the multifunctionality of territories and their sub-systems as suggested by Loiseau et al. (2013) and reinforced by Qi et al. (2019) rather than unique FU as promoted by (Benis and Ferrão 2016; Albertí et al. 2019a; Mirabella and Allacker 2021). While a unique FU is suitable for a straightforward benchmark between territories, it does not acknowledge the territory's capacity to guarantee various functions to local populations and ecosystems. The ALUFs assessment combined with LCA results in this study demonstrates that whereas local farming in the Department of Finistere secures important economic and societal functions, such as the capability

of feeding almost its entire population, it is the major territorial environmental hotspot activity and especially its exported food production. This underscores the challenge of balancing local economic imperatives with the need to address the identified environmental concerns, suggesting the need for further investigation in future research. Yet the utilization of the environmental indicators in the selected ALUFs might be partially redundant with LCA which is demonstrated through low environmental functions associated with local farming hotspots. Nonetheless, the chosen indicators allow us to account for the environmental consequences tied to the spatial-temporal dynamics of local polluting activities such as pollutant accumulation leading to threshold breaches or violations of ecosystem carrying capacities. Such considerations are often overlooked in conventional LCA studies (Reap et al. 2008; Liu et al. 2019). This includes precise local information about the pesticides or nitrogen surpluses, particularly prevalent in highly intensive farming regions. Similarly, while LCA methods address impacts on biodiversity through indicators such as land use, toxicity, or eutrophication, most LCA studies do not incorporate critical facets of biodiversity or the ecosystem services provided by agricultural landscapes (Nemecek et al. 2011a; Boone et al. 2019; van der Werf et al. 2020; Wittwer et al. 2021; Boschiero et al. 2023). In the selected ALUF's indicators, the presence of ecological structures such as hedgerows is thus considered through the indicator of High Nature Value.

Such parallel functions assessment ensures a more comprehensive interpretation of LCA results and facilitates a feasible comparison between territories. In future research, these functions could be used to calculate the eco-efficiency of different land planning scenarios. This means identifying scenarios that minimize environmental impacts and maximize territorial functions, such as potential local food autonomy, thereby indicating their environmental efficiency.

4.3 Treatment of uncertainties

Despite the recognized significance of assessing LCA uncertainties, uncertainty and sensitivity analyses remain an isolated exercise in LCA studies (Lo Piano and Benini 2022) with less than 20% of studies published since 2014 reporting any kind of such assessment (Bamber et al. 2020). In the case of territorial or other meso-level LCA, multiple limitations, principally related to parameter and epistemic uncertainty requiring the use of statistical data, proxies, or simplification of model assumptions, may hinder the robustness of the LCA results. The precision of territorial LCA results thus remains a major limitation in existing studies, proving the importance of establishing a simplified framework and thus accelerating the use of SA.

The SA framework used in this study is based on confining the most significant and uncertain parameters and testing their sensitivity toward the entire model outcome. Such a framework avoids the time-consuming processes of full quantitative uncertainty analysis and the selection of statistical functions applied in LCA. It also bypasses the need to determine the uncertainty range for processes for which uncertainty information is missing. As pointed out by other scholars (Björklund 2012), local authorities do not have sufficient resources for an extensive assessment. The detection of key parameters through SA proposed by this work constitutes a straightforward and rapid decision-support tool that improves the credibility of the cumulative results.

The SA results demonstrate, for instance, that despite the uncertainty surrounding the imported food data due to the shortcomings of intra-territorial flow estimation, even a significant error would not increase the overall results by more than 10% for most indicators. Similarly, the variations in different swine production processes do not significantly impact the overall results, except for indicators such as water use and human toxicity (cancer). Consequently, the identified uncertain parameters do not influence the overall conclusion presented in this case study.

However, the developed simplified SA framework contains several shortcomings. Firstly, the assessment of data quality is based on qualitative aspects through DQR, which might represent limits related to their completeness. Furthermore, the aggregated EF score for the diagnostic diagrams uses a weighting approach that might privilege some indicators and thus modify the overall results. In the future, quantitative and global sensitivity analyses could be adapted and tested for meso-level LCAs. Additionally, the development of specific regional LCA inventories or precise data related to intra-territorial flows could confirm the conclusions of this study.

5 Conclusions

This work introduced multiple enhancements to the T-LCA framework to be applied in local food planning. The findings demonstrate that developments made in the framework including intra-territorial flow consideration and assessment of agri-food land use functions allow for a more precise analysis of local food systems. Similarly, a simplified procedure for conducting a sensitivity analysis proves to efficiently identify key parameters to be surveyed. Such results can be of use to local planners wishing to assess and decrease the impact of local food systems while protecting or improving their territorial functions. The findings reveal that local authorities should focus on decreasing the impact of local livestock export-oriented production as well as the impact of animal-based and ultra-processed imported food. Further advancements are to be pursued to confirm the robustness of territory-based food LCAs, for instance, by developing regional life cycle inventories.

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Data Availability Statement

All data generated or analyzed during this study are included in this published article [and its supplementary information files].

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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ANNEXE II. ARTICLE N°2

Environmental Assessment of Local Food Policies through
a Territorial Life Cycle Approach

Article

Environmental Assessment of Local Food Policies through a Territorial Life Cycle Approach

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Abstract: Sub-national governments play a vital role in achieving food-related sustainability goals through the re-territorialization of agriculture. While the environmental impact of such policies cannot be reduced to decreased food miles, multiple methodological bottlenecks prevent seizing their entire potential. In this paper, a territorial life cycle analysis is adapted and used to comprehend the cradle-to-grave impact of local food policies. This is conducted by assessing the impact of a territory's food-producing and consuming activities before and after the local food policies implementation. To evaluate the feasibility of the methodology, the municipality of Mouans-Sartoux (southeast France), engaged in local food policies for twenty years, is chosen. Four impact categories are modeled: global warming, fossil resource depletion, water consumption, and land use. The findings show that local food policies drive direct and indirect changes in farming and retail practices, but a more significant transformation is achieved by inhabitants, mostly by decreasing meat and ultra-processed product consumption. All actions summed up decrease the local food system's impact by between 7 and 19%. These results demonstrate the efficiency of the method to provide a holistic environmental assessment at a mesoscale as well as the environmental efficacy of the local authority's intervention in food-related matters.

Keywords: sustainable assessment methodology; local food systems; food policy analysis; environmental impact; short supply chain



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1. Introduction

The conditions used to produce, transport, and process our food have important consequences on the environment. Agriculture and the food industry are major contributors to anthropogenic pressures such as climate change, biodiversity loss, and water and soil quality deterioration [1–6].

In response to the consequent environmental degradation, governments worldwide are trying to build policies to curb this current trend. The European Union in particular set multiple regulations such as the European Green Deal, its recent Farm to fork and Biodiversity strategies, the Circular Economy action plan, and more ancient Nitrate Directive. Those aim to cut food-related greenhouse gas emissions, improve the quality of aquatic and terrestrial biodiversity, or reduce the impact of food waste.

Yet the environmental outcome of these policies is difficult to seize on the European or national scale. Each country's indicators are highly variable to regional differences due to diverse pedoclimatic profiles, infrastructure, agriculture, local culture, or social welfare levels [7].

Many authors thereby believe that a local level is a more appropriate scale to rectify and assess the negative externalities of the globalized food system [8,9], and thus, contribute to achieving sustainable development goals [10,11].

In practice, hundreds of municipalities have already signed collective international agreements such Milan Urban Food Policy Pact or Glasgow Food and Climate Declaration aiming to put local sustainable food policies at the heart of their ecological transition [12,13].

In the case of France, the largest agricultural producer in the EU, the recent political ambitions aim to redirect food production closer to consumers and cut agricultural-related greenhouse gas emissions by 50% by 2050 [14]. National policies encourage cities to relocate agriculture and promote sustainable territorial food organization through regulatory tools such as the Food territorial project (Projet Alimentaire Territorial PAT) created in 2014 by the French Ministry of Agriculture [15]. These projects enlarge the strategies undertaken by sub-national governments and regroup the globality of local agri-food policies. Administered by municipalities, food territorial projects aim to anchor the sustainable food economy into local tissue through public procurement, sustainable land policies, support to local farmers, implementation of urban agriculture, awareness-raising about sustainable diets, and other actions [16]. Such projects, thereby, surpass simple relocation policies based solely on developing a short supply chain by including both producer and consumer-based initiatives.

Despite such rising enthusiasm for a more locally organized food system, their environmental efficiency is yet to be proven. The literature has been extensively developed on the impact of a short food supply chain over the past two decades [17–28], but there is a research gap related to the consequences of more comprehensive and integrated local food policies [18]. The most recent meta-analyses and studies demonstrate heterogeneous outcomes concerning shorter supply chains with prevalent findings showing little or no significant environmental advantage if only the transport part is considered [18,19,21,22,29,30]. Yet when the entire life cycle of the supply chain is considered including agricultural practices or consumer habits, such as protecting landscape biodiversity or eating seasonally, the short supply chain and locally organized food system might present considerable environmental benefits [18,31]. Previous research shows that reconnecting production and consumption can positively affect sustainable production and consumption patterns [32,33]. To encourage and amplify such changes, the municipalities engaged in international treaties such as Milan Urban Food Policy Pact increasingly include actions such as encouraging organic agriculture development or changing diet habits in their reterritorialization policies. The academic literature proves that similar actions can have a vast impact-reducing potential [34–38]. Yet studies considering systemic impact, and the indirect consequences of developing local food organizations and integrated food policies are scarce [8,18]. When addressed, the latter is measured by descriptive indicators or frameworks rather than impact assessment [17,39,40]. More systemic and impact assessment studies of local policies exist but there are either action-specific such as improving the sustainability of public procurement in school canteens [41] and developing urban agriculture [42] or they analyze hypothetical transformations such as the environmental potential of changing local diets or reducing transportation distances [43].

While this previous research on agri-food assessment and local food initiatives shows mostly positive environmental impacts, its sectorial approach disregards the impact on the entire territorial system and its complex interdependencies. For instance, for methodological reasons, the existing studies led at the municipal level employ either producer or consumer-based perspectives [44,45]. This is mostly due to the methodological difficulty of assessing territorial policies including a high variety of actions, ranging from urban farming to food waste reduction, and the difficulty of understanding the causal link. Yet it has been proved that local consumption patterns are influenced by the local food supply [46]. Neglecting such connections lead to an underestimation of the interrelations of the processes involved in the whole food systems from farm to fork and hence of their environmental impact. There is, therefore, a need for a territorial, systemic, and longitudinal assessment based on the entire life cycle of food supply chains monitoring farmers' and consumers' practices to better comprehend the impact of local initiatives [18].

Concerning food supply chain, agriculture, and land planning environmental assessment (EA), the most used systemic method including the whole life cycle in the current worldwide research is by far life cycle assessment (LCA) followed by Material Flow Analysis (MFA), Input-Output Analysis (IOA) and Ecological Footprint (EF) [47–52]. The LCA

method [53] has a promising potential for assessing the impact of complex decision-making as its systemic approach avoids burden-shifting between life cycle stages and impact categories [54]. It has also been proven to be an efficient tool for urban planning [55,56].

To be able to use the LCA approach at a territorial scale and consequently include all local activities, the territorial life cycle assessment (TLCA) method was created [57]. TLCA assesses the eco-efficiency of all production and consumption activities located in the territory while defining the functions provided by those activities. The reference flow is defined by the land planning scenario implemented in the studied geographical territory. The upstream processes linked to local activities are included in the scope. The inventory is carried out by collecting the data related to local activities and linking them to existing LCA databases. The territorial hotspot activities are further identified by considering the land-use functions the corresponding territory provides [58].

The TLCA methodology was first developed to assess all territorial activities including every industry sector [57] but was later declined to evaluate an agricultural territory [59–61]. These existing studies reveal that most of the analyzed impact comes from outside of the studied territory. This confirms the advantage of a lifecycle-based methodology that prevents underestimating the local policies' impact by focusing solely on the locally visible indicators. This is particularly true in the case of developed countries or urban food systems environmental assessment as the average food autonomy of the main French cities is estimated to be two percent [62].

Despite its potential, to our knowledge, the use of the TLCA-based method has not been implemented in food policy assessment and requires several adaptations. This is what we propose to do in this study. The main objective is to reply to the research question of whether the LCA method is an efficient methodology to be used for systemic and territorial assessment of food policies. Secondly, it aims to examine the cradle-to-grave impact of integrated local food policies going far beyond the short supply chain and sectorial actions. It consequently addresses the research question about the impact of systemic food planning and its contribution to sustainability goals. The paper thus fills in a research gap on systemic assessment methods for local policy evaluation, the impact of locally organized food systems, and its contribution to sustainable development.

Three principal hypotheses are investigated in this research. First, it stipulates that the TLCA-based methodology is an adequate assessment method for understanding the enlarged impact of a more locally organized food system and relevant local food policies. Secondly, it assumes that local food policies emerging in the Global North have significantly positive consequences on the local actors, their practices, and their habits. Finally, the third hypothesis supposes that the positive changes triggered by local policies generate important environmental benefits contributing to the achievement of national and European sustainability targets.

The hypotheses are assessed by applying the adapted TLCA approach to the municipality of Mouans-Sartoux engaged in food policies in the past twenty years. The structure of the paper is as follows: it first describes the study area and the methodology used. This is followed by results chapter describing the findings obtained through questionnaires and interviews conducted in the study area as well as the calculated environmental impact reduction stemming from the local policies and their contribution to international and national targets. Finally, the discussion and conclusion chapters address the added value of the used LCA methodology to the literature on the integrated policies assessment, the impact triggered by local authorities, and its implications for further research and policymakers.

2. Materials and Methods

2.1. Study Area

Mouans-Sartoux is a town of 9500 inhabitants located in the suburban area of the city of Nice in the southeast of France.

For the past 20 years, sustainable food policies have been part of the town's Agenda 21, intending to improve local food self-sufficiency and engage in food transition, from both, the producer, and consumer sides. The elected officials are involved in food challenges, and in 2012, the municipality converted to 100% organic and local food public procurement for municipal schools' canteens [63]. The transition was conducted without any increase in price thanks to the reduction of food waste. The school canteens weighed leftover food and consequently adjust the quantities cooked, which caused a 75% decrease in food waste [64].

The town equally bought four hectares of an agricultural plot to supply the public canteens with organic vegetables. Today the plot was extended to six hectares, employs three farmers (municipal workers), and provides more than 80% of the vegetables served in the canteen. In addition, 50% of the dishes served in the canteen are vegetarian [65]. The impact of this action went beyond the pupils and influenced the surrounding environment. For instance, according to the municipality's survey, 85% of parents of pupils eating in municipal canteens declared changing their eating habits [66]. Moreover, this initiative has been a lever for sustainable food policies that followed. The municipality increased the agricultural protected land from 40 to 112 hectares in urbanism documents and created an association of collective gardens [67]. At the same time, the municipality supports organic grocery stores, such as grocery stores selling in bulk to reduce waste, and helps to supply social grocery stores* (*selling productions with 70–90% reduction for precarious population) with organic products and products from community gardens and set a weekly marketplace for local producers [68].

In 2016, the town implemented the Food territorial project which led to the creation of the House of Sustainable Food Education MEAD (Maison d'éducation à l'alimentation durable) which is a municipal service dedicated to the development of sustainable local food policies [64]. The scope of its actions includes the settlement and assistance to farmers and raising awareness of sustainable food through education for all stakeholders, including families, visitors, elected officials, and pupils (Ibid.). Every year since 2017, the MEAD organizes the Challenge "Families with Positive Diet" FAAP (Famille à l'Alimentation Positive) to engage a dozen households in revisiting their diets and reorienting them to more sustainable, organic, and local food without increasing their food budget [63]. This is carried out through farm visits, cooking classes, gardening, etc. Other events are equally organized by the municipality each year such as "The Honey festival" or the "Marché gourmand" annual market to spread awareness of sustainable diets and give place to local producers (Ibid.).

Yet due to its localization, the reconquest for local food sovereignty is hindered by real estate speculation, artificialization pressure, and soaring prices which results in a small proportion of existing farms. Despite this, local production is overwhelmingly sold in local organic shops, which constitute around half of the food stores situated in the municipality (Figure 1).

As a result of the broad range of actions that have taken place over the past 20 years, the impact of the territorial food policies stays difficult to measure. The municipality already assessed the impact of the local food supply, food waste reduction, and vegetarian menu implemented in the public canteens, which all together lead to the annual economy of 100 tons of CO₂-eq [69]. Yet, it can be assumed that the years of awareness-raising and sustainable territorial initiatives have a direct and indirect impact on the entire local food system, including local farmers and food retailers taking part in the project as well as on the diets of inhabitants. The main assumptions are the following:

- Farmers are encouraged to implement more sustainable farming practices and sell locally
- Industries are encouraged to environmental management practices concerning local supply chain, store waste, and energy management
- Inhabitants are encouraged to modify their diets towards less processed and more organic, local, and plant-based food

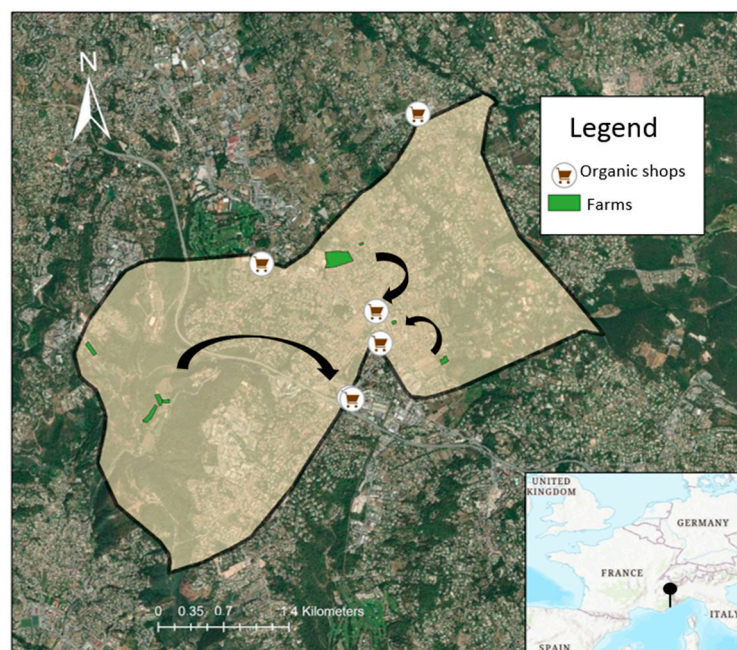


Figure 1. The map of the studied area, its farming surface, and organic stores.

Despite that, such assumptions and their environmental consequences have never been ascertained due to the methodological complexity it presents. In this study, we propose to use local quantitative data collection and statistical analysis to study the changes triggered by local food policies, and the adapted territorial LCA to calculate their environmental impact.

2.2. Territorial LCA-Based Assessment of Local Food Policies

2.2.1. Goal and Scope Definition

The goal of this assessment is to evaluate the impact of a wide range of actions of local planners on the territorial food system including food producer and consumer activities of Mouans-Sartoux municipality. To achieve this ambition, the adapted territorial LCA is used. The employed methodology consists of classic four LCA steps (scope definition, inventory, impact assessment, and interpretation) while considering a territory and its food activities as a product or service to be assessed.

The scope is limited by the geographical and administrative boundaries of the municipality based on Alberti et al. [70]. Compared to conventional LCAs, characterized by a unique functional unit, in the TLCA, the reference flow is the entire food territorial system including major producing or consuming-related activities. This means that the system includes both, food produced and processed locally (that can be either consumed locally or exported) and food imported for local consumption (Figure 2).

The territorial activities assessed are as follows: local agricultural production at the farm gate, processing, and retail industries' energy use, generated local food transport, consumption activities including the entire life cycle of the locally imported food, and finally local waste treatment. The burdens included in each activity type are allocated based on the individual responsibility of each actor, i.e., the local farmers are responsible for the production at the farm gate and the consumers are responsible for the production, processing, and transport of imported goods. Transportation activity type includes only local transportation comprising farmers' transport (not included in the production activity) and the consumer's travel (not included in the consumption activity). Freight transport for imported goods is accounted for in the consumption activity. To avoid double-counting, we precisely retrace the part of the local production consumed within the municipal borders through local interviews conducted.

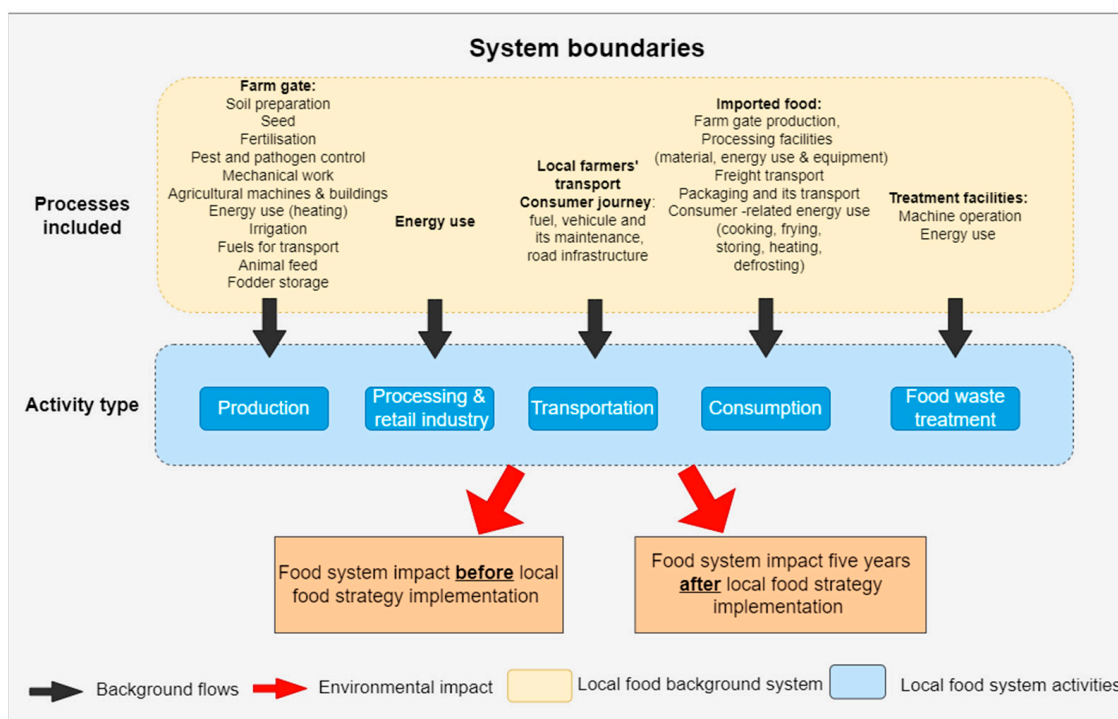


Figure 2. System boundaries and processes allocation related to each local food activity type.

The system boundaries comprise background processes that can be influenced by territorial actors. This means for instance that the construction of already existing agri-food or retail buildings is not considered in the scope.

The entire system's impact is assessed two times: before and after the implementation of territorial food policies. The comparison between these two assessments allows modeling of the impact of food-related changes during the period under interest from both the producer and consumer sides. The link between these changes and the local policies is studied during the questionnaire phase.

Despite the engagement of the municipality during the past 20 years, the period of the previous five years was retained for the assessment. A longer period makes it difficult to characterize the initial state. Furthermore, from the municipality representatives' point of view, this period particularly marked the acceleration of the food policies due to the implementation of a food territorial project and the creation of the MEAD in 2016.

2.2.2. Data Collection & Life-Cycle Inventory

Preliminary data related to local food system activities are obtained from open data sources (RPG data for local farmers, INCA3 for local diets, and INSEE for local distribution). In addition, precisions about the data related to local distribution and farmers were given by the municipality representatives. Further precisions and the changes taking place over the past five years, necessary for the policy assessment, were obtained through interviews and questionnaires. More specifically, three types of questionnaires were conducted:

- Semi-structured interviews with four local farmers (e.g., 70% of the local farmers)
- Semi-structured interviews with 13 local food retail managers (e.g., 60% of the local industries)
- Online and direct survey with a representative sample of the municipality population of 218 respondents (e.g., 5% of households).

For the interviews with professional actors, all voluntary participants were chosen to be interviewed.

The municipality population survey divided the population into two sub-samples:

1. the respondents who participated or benefited from diverse activities of the MEAD and municipality's local food policies (schools, companies . . .),
2. the respondents who did neither participate nor are implicated in any form of those policies.

Both sub-samples are of the same size and were selected to be representative of the population in terms of age groups and socio-professional categories. An online version of the questionnaire was sent by the municipality to the mailing list of all parents of children in local schools benefiting from the local and organic canteen and other participants of food-related initiatives such as urban gardening or sustainable diet challenges. For the overall population, the questionnaire was shared on municipal social networks and in public buildings such as libraries. To equilibrate the representativity of the sample, the group of researchers interrogated dozens of individuals in publicly available places. Thanks to the sample representativeness in terms of the age groups and socio-professional groups, representing 5% of households, the data obtained through the population survey are extrapolated to the municipality population for the result analysis.

During the survey, the professional respondents (farmers or local retail managers) were asked about the changes they undertook including the possible conversion of local farmers to organic production, energy decrease or renewable source in food retail, and decreased transport. For the consumer respondents, the questions were devoted to characterizing changes related to travel to a supermarket and diet composition. It includes collecting quantitative data related to the volume of food produced by local farmers, their farming practices, their transport, the energy consumed by local food industries, and the volume and character of food consumed by the local population.

The participants were equally asked about the degree of the influence of the local food strategy on their behavior change. The local food policies with potential influence on local actors include essentially the protection of agricultural land for local farmers, providing a local marketplace, setting up urban farming, and raising awareness about sustainable diets in schools and companies or through challenges such as FAAP and other events dedicated to the general population. Full surveys and interview guides are available in Supplementary Material Section SII.

Based on the principles of territorial LCA, the locally collected data (called activity descriptors) are afterward linked to existing LCA databases such as Ecoinvent 3 [71] and Agribalyse V3.0 [72] to incorporate the data of all background processes which are unable to be locally collected due to the magnitude of data needed (Table 1).

Table 1. Data sources for activities of the local food system and corresponding LCIs for background data.

Activity Type	Activity Descriptors	Units	Public Data Sources	Precisions about the Data	Background Data LCI
Production	Annual production	t	RPG data (RPG, 2019) [73]	Municipal agricultural board Farmers' interview	Agribalyse V3.0
Processing & retail industry	Annual electricity consumption	MWh	Industry identification: SIRENE database (INSEE, 2021) [74]	Municipal electives Retail managers' interview	Ecoinvent 3
			Annual consumption: Enedis Open data (Enedis, 2021) [75]		
Transport	Annual farmers transport	kg-km	Agribalyse data on the transport of French food products	Farmers' interview	Ecoinvent 3
	Consumer trips to the shopping	km	NA	Population survey	Ecoinvent 3
Consumption	Annual food consumption by the local population	kg	Local food diets: INCA3 database (Anses, 2017) [76]	Population survey	Agribalyse V3.0

Note: The data inventory related to the case study and a more detailed data description can be found in Supplementary Material Section SI.

Regarding the choice of the LCI databases for background data, the existing modeled processes found in Ecoinvent 3 and Agribalyse 3 databases are considered comparable to the processes observed in the territory. Yet, an exception involves the organic products datasets which are at this point still nascent. To be able to include organic production, the Agribalyse database is selected despite its use not being advised for the comparison of organic and conventional agriculture. This is mostly due to the limited sample of farms which increases the data uncertainty [72]. Despite its drawbacks, we decided to use the database as it is the most accurate available database. Yet its limits will be discussed during the interpretation.

2.2.3. Impact Assessment

The impact of different food system activities in the territory before and after the launch of the Food territorial project in 2016 is modeled on four indicators:

- Global warming: characterizing global warming potential in yr kg CO₂-equivalent affecting the entire world ecosystems
- Land use: characterizing the amount of natural agricultural and urban land transformed and occupied in m²·yr measuring their degradation and consequent biodiversity loss
- Water consumption: characterizing freshwater depletion in m³ considering its scarcity in selected world regions
- Fossil resource scarcity: characterizing the amount of extracted fossil fuel (coal, oil, natural gas) based on the lower heating value in kg oil equivalent (having a lower heating value of 42MJ)

The selection was based on the leading contribution of the food system activities on the determined indicators [1,2,77–79] which consequently allows studying the possible contribution of local food policies to global sustainable dynamics.

The empirical data related to the impact of the local food policies on the environmental practices of local actors is obtained through questionnaires and interviews. The participants provided quantitative replies related to the changes in farming practices, transport, energy consumption, or the volumes of distinct types of food consumed for the population survey. The questionnaires are translated to an LCA by modifying the activity descriptors or inventory background data used for the two time periods. For instance, if a farmer converted a part of apple production to organic agriculture, the background database of conventional apples is replaced by organic one or if inhabitants decrease their consumption of red meat by 10% the activity descriptors of the annual consumption of red meat are modified.

The analyses are conducted in SimaPro9.2.0.2 software using Recipe Midpoint 2016 [80,81] and its hierarchist perspective, considered the most relevant approach for European agri-food assessment [82].

2.2.4. Interpretation

In the interpretation phase, we analyze the changes undertaken by local actors (producers and consumers) in the past five years and their contribution to environmental impact reduction. To further confirm whether the local policies are influencing the local actors or whether it is a societal trend, the results of the local changes in consumption practices are compared to national changes over the same period. Similarly, we compare the magnitude of changes in the two sub-samples (the survey participants that benefited from local food policies and those who did not) to analyze the possible influence of local institutions. This analysis, and in particular differences between the two sub-samples, were based on statistical analysis (Z-test and Khi2 tests) to select solely statistically significant results.

Consequently, we compare the environmental impact of the entire life cycle of the local food system before and after the launch of the food territorial project on selected impact categories to seize a cradle-to-grave impact reduction between the two time periods.

A more precise analysis is conducted for the global warming indicator to estimate the ability of local food policies to fight climate change. To do so, we observe the mean degree

of changes for the two sub-samples and estimate a generated reduction in their carbon footprint in kg CO₂-eq.

The findings are used to formulate recommendations for local, national, and international policymakers. (Resume of the methodology in Figure 3).

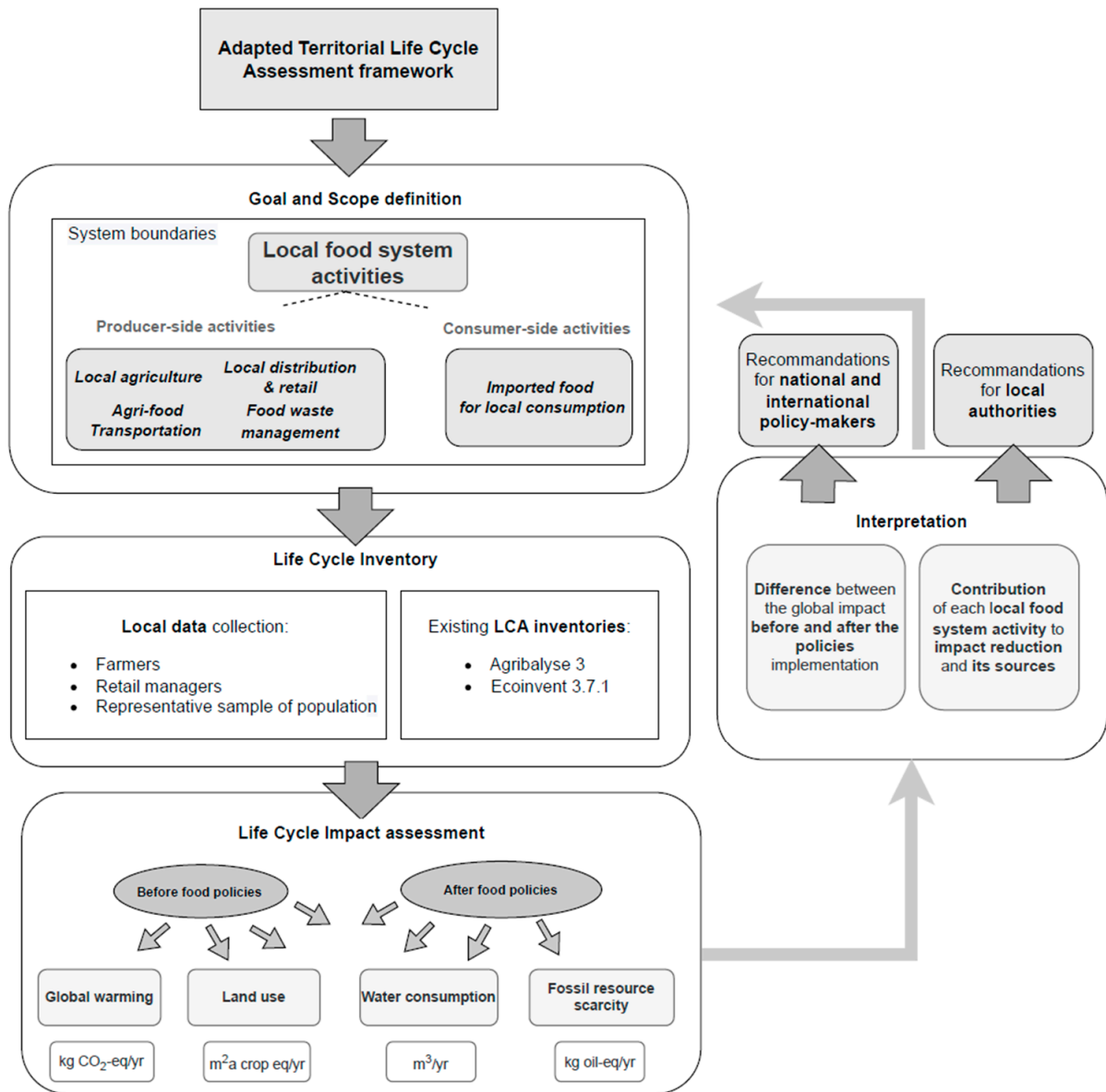


Figure 3. Framework chart of the methodology used in this research based on territorial life cycle assessment (TLCA) adapted to the environmental impact assessment (EIA) of local food policies.

2.2.5. Adaptations to Territorial LCA: System Functions

Compared to the TLCA methodology developed by Loiseau et al. [83], the first part of the methodology used in this paper is simplified, but the steps included are more detailed and adapted for policy assessment.

More precisely, the land-use functions assessment (e.g., economic, societal, and environmental functions of the territory) and the division of on-site and off-site impacts are not included in this research per se. For agricultural systems TLCA, three main functions can be economic profit, food production, and land occupation [61]. Our analysis of the related function indicators revealed little or no change in the territorial circumstances during the two studied periods. For instance, despite the efforts to increase the number of farmers and protect agricultural land, in the past five years, only two additional hectares were used

to produce food within the municipality's borders. Despite a consequent slight increase in food production, this does not significantly influence the local self-sufficiency potential. The current agricultural production based on organic horticulture engenders negligible pollution with little evolution in the past decade. This results in the overwhelming part of the impact being off-site for both periods. It can be therefore considered that the functionality of the territory remains intact which implies that any impact reduction improves the eco-efficiency of the territory.

To adapt TLCA to policy assessment we included a longitudinal dimension by looking at the dynamics of the entire food system of the territory in parallel with policy implementation and global trends. This is conducted by collecting detailed data about specific territorial practices and monitoring their evolution (farming practices, agri-food industry energy consumption, and diet preferences).

3. Results

3.1. Changes Driven by the Municipal Food Strategy

The field study reveals that during the past five years, and partially under the impulsion of the local food policies, several changes occurred. From the producer side, one farmer converted to organic production indirectly being influenced by the municipal services, and two organic shops moved to the territory thanks to its reputation or engaged actions in energy reduction and renewable energy consumption. Yet due to the profile of the municipality (suburban area, small farmer population) and the activities of the MEAD, which focuses principally on awareness-raising and access to sustainable food, the positive impact of the studied food territorial project is predominantly due to the consumption activities, i.e., individual changes in eating habits. The questionnaire's results demonstrate that globally 14% of the respondents changed the way to go to the supermarket from car to bike, 46% reduced their food waste, and 59% changed their diets (reducing meat, ultra-processed food, eating more organic, seasonal, and local food).

Two-thirds of all participants state that their behavioral shift was influenced by the municipality's activities. The findings equally show that the respondents of the sub-sample benefiting from the local food policies were two to three times more likely to change their behavior than the other sub-sample (Table 2).

Table 2. The degree of changes in the Mouans-Sartoux population for the two sub-samples (%).

Studied Change (2017–2022)	Evolution of Implicated Sub-Sample	Evolution of Non-Implicated Sub-Sample	Average Evolution of Mouans-Sartoux Inhabitants	National Evolution
Consumption of ultra-processed food	−40%	−20%	−30%	On the increase (precise % NA)
Consumption of meat	−32%	−14%	−23%	+0.7%
Consumption of organic products (% of the consumption of organic products on regular basis)	39%	18%	28%	15%
Use of bike to the supermarket	+21%	+6%	+14%	NA
Food waste reduction	−4%	−1.5%	−2.7%	NA

Note: Those implicated or benefiting from local food policies include the parents of pupils consuming food from municipal plots, participants of sustainable diet challenges, or inhabitants involved in urban farming amongst others.

The behavioral changes evoked cannot be entirely attributed to local policies and are multifactorial. Despite this, the implicated sub-sample demonstrates significantly far-reaching transformation. In addition, the changes observed in our case study counter the current trends in France or are more pronounced. For instance, the respondents globally decreased the consumption of ultra-processed food by 30%, which is an increase in France [76], and they decreased the overall meat consumption by 23%, which is on the

increase of 0.7% per habitant per year [84]. Similarly, 28% of inhabitants consume organic products on an everyday basis compared to 15% in France [85] (Table 2).

3.2. Environmental Impact Reduction

Figure 4 provides the results of the annual decrease or increase of the food system's environmental impacts per change that occurred between 2017 and 2022 and can be linked to local food policies. The positive impacts correspond to a reduction while the negative impacts to an augmentation over the five years. By analyzing the contribution of each change, the findings reveal that the diet composition change undeniably influences the overall impact reduction (ranging from 45% to 95 % of the overall impact reduction). This includes the reduction of meat and ultra-processed food consumption, and an increase in fruits, vegetables, legumes, and nuts. Approximately 60% of this reduction is due to the decrease in the consumption of animal protein and another 40% is thanks to the decrease in ultra-processed food and beverages, including desserts and alcohol. Solely changing the inhabitants' diet results in a reduction of 2880 tCO₂-eq, 2,870,000 m² crop-eq of soil, 20,800 m³ of water, and 140 tons of oil equivalent.

While the overall food waste reduction of the population is inferior to 3%, its impact reduction potential is substantial. It is the second most important source of the impact decrease, especially for the indicators of water and fossil energy scarcity, decreasing by 17,700 m³ of water and 60 tons of oil equivalent respectively.

For climate change and fossil energy indicators, changing the transport mode from food shopping to biking is the third most important change to initiate, counting for 4% and 16% of the global impact reduction respectively representing economies of 150 tCO₂-eq and 44 tons of oil eq.

The use of renewable electricity in local organic stores, consumption of seasonal products, and buying in bulk or composting generated only a marginal impact diminution compared to other studied activities (0–4% of the overall impact reduction).

The increase in the consumption of organic products significantly decreased the use of fossil energies and greenhouse gases but slightly increased the use of water and land (Figure 4).

The increase in water use due to the consumption of organic food stems from the consumption of organic apples, responsible for a 64% increase in water consumption, followed by organic peaches. Both products consume 60% more water per kg produced than their conventional equivalent. Contrary to what might be believed, most of the water footprint does not come from irrigation on farms, but from industrial processes such as electricity or diesel production used on farms for harvest, trellising, or trimming. It is relevant to mention that the increase of 18,440 m³ of water used represents only a 2.66% increment in global impact and is entirely compensated for by other changes.

This result should be interpreted precisely due to the limits of the Agribalyse database. The functional unit of kg/produced is disadvantageous for organic systems that are more extensive and produce lower crop yield. In the database, the average yield considered for organic apples is 22,041 kg ha⁻¹ yr⁻¹ compared to the average conventional yield of 46,160 kg ha⁻¹ yr⁻¹ (+52%) which might not reflect local real-life conditions.

The impact of consuming more local food could not have been measured due to the diversity and multiplicity of existing supply chains as well as insufficient regional data. The fruits and vegetables produced within municipal borders do not represent more than 3% of the local vegetable consumption and are partly exported to neighboring municipalities. The environmental efficiency of local supply chains was found similar to conventional chains (accounting only for the transport part) and any advantage to decreased travel distance was found apart from the exception of the municipal agricultural plot. The delivery of the vegetables from the municipal plot to school canteens shortened the food miles to 3 km but its positive impact is negligible in the entire life cycle of the local food system.

Figure 5 shows the global impact reduction in percentage over the five years analyzed for the four same impact categories. The reduction of the environmental impact ranges

from 7 to 19% of the whole life cycle of the local food system depending on the impact category. The reduction is more pronounced for the indicators of land use (m² a crop-eq) and climate change (kg CO₂-eq), 18% and 19% respectively. The impact categories of water (m³) and fossil resource scarcity (kg oil-eq) display a reduction inferior to 10%. This leads to an overall decrease in 20,192 m³ of freshwater, 308,247 kg of oil-equivalent, 3.02 million m² of land, and 3.66 million CO₂-eq for all changes combined. Such a decrease diminishes the local food system’s dependency on external inputs, reinforcing its resilience (Figure 5).

Annual impact reduction per change

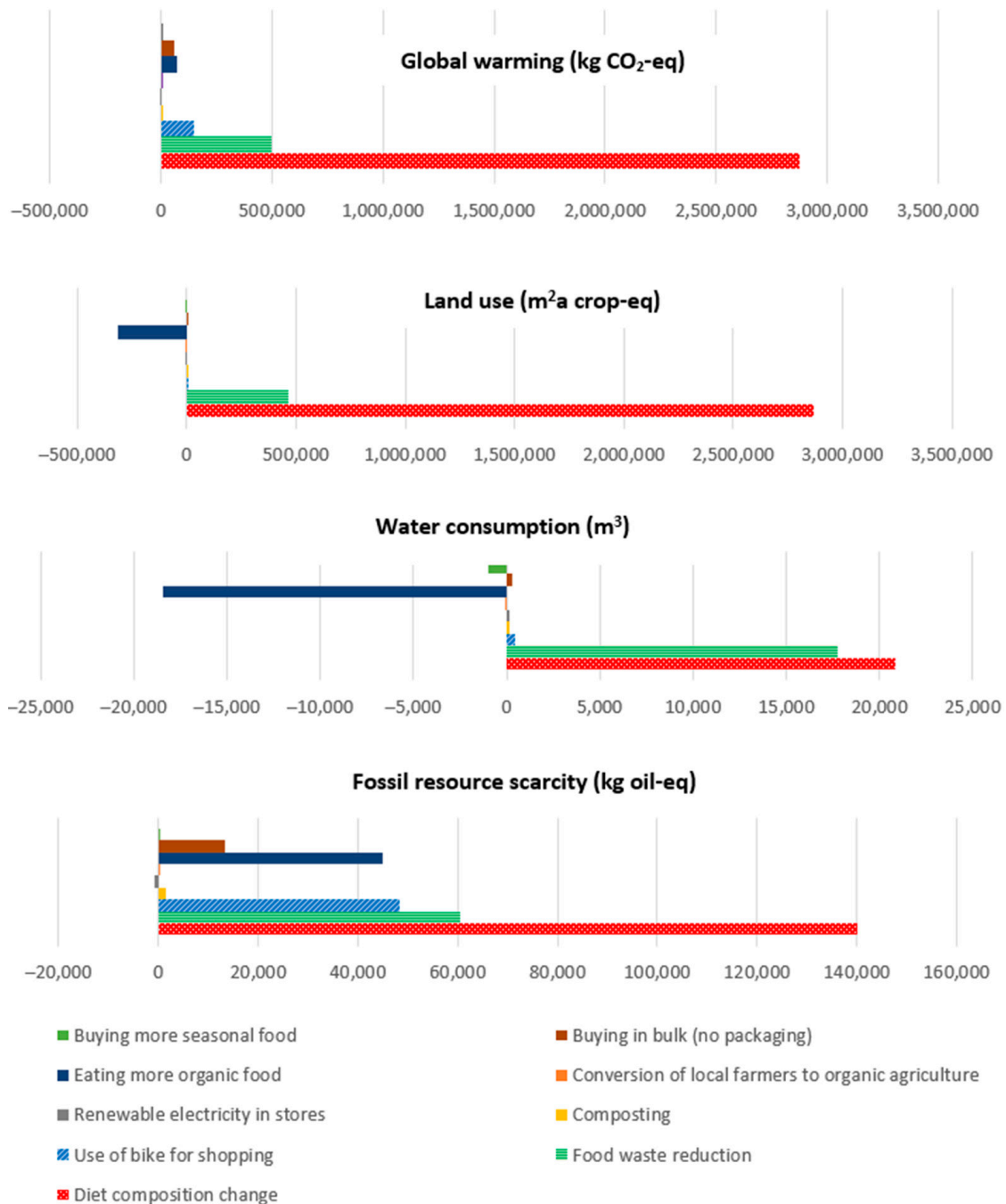


Figure 4. Environmental impact reduction per changes partially or directly driven by the food territorial project of Mouans-Sartoux.

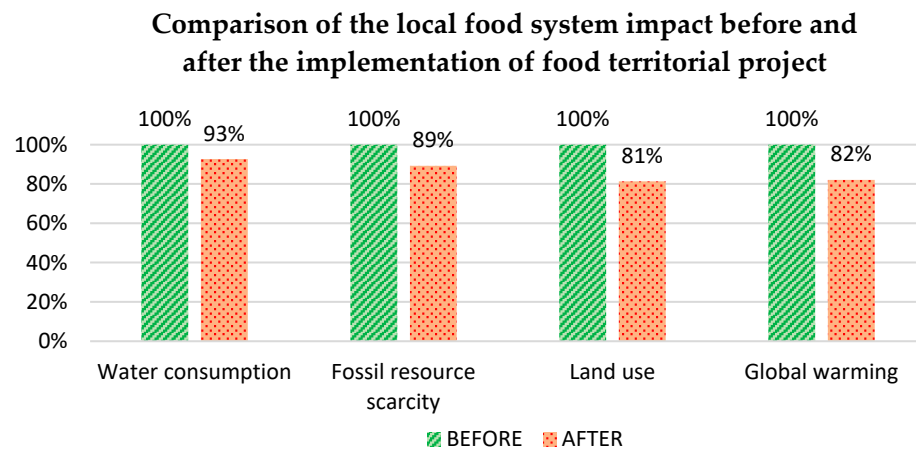


Figure 5. Comparison of the environmental impact of the entire local food system of Mouans-Sartoux before and after the initiation of its food territorial project (2017–2022).

The analysis of the ability of consumer-based changes to contribute to the climate change fight indicates significantly positive results as illustrated by Figure 6. For the sub-sample that is implicated or benefiting from local food policies (a), the average impact reduction sums up to the decrease of 515 kg CO₂-eq yr⁻¹ pp which is equivalent to a 26% reduction of the average food carbon footprint of a French citizen being 2000 kg CO₂-eq yr⁻¹ pp. The diet composition change is the principal driver of this reduction (413 kg CO₂-eq yr⁻¹ pp). The sub-sample that has not benefited from local food policies equally displays an impact reduction (b), but the latter is less consequent with the overall average reduction of 236 kg CO₂-eq yr⁻¹ representing a 12% decrease in their food carbon footprint (Figure 6).

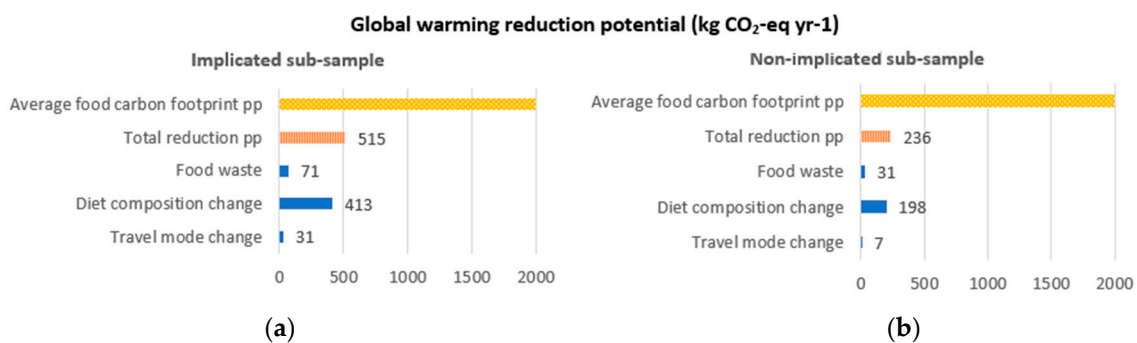


Figure 6. The mean contribution of changes of Mouans-Sartoux inhabitants to their food carbon footprint reduction. (a) The sub-sample implicated or benefiting from local food policies; (b) the sub-sample that has not benefited from local food policies.

4. Discussion

4.1. Application of Adapted Territorial LCA to Policy Assessment

Despite the results based on a well-defined and specific area of Mouans-Sartoux, that cannot be considered representative of other French or European territories, the insights derived from this experiment contribute to an understanding of the dynamics of environmental impact stemming from local policy implementation. Interrogating the changes taking place in the entire local food system and coupling producer and consumer-based approaches allows accounting for indirect consequences offering thereby a holistic vision of the impact reduction.

The findings demonstrate that the environmental consequences of local food policies reach far beyond the reduced food miles, the modifications of the menu of school canteens, or the observed local indicators. This proves that a life-cycle-based assessment of local food

policies allows for seizing an enlarged positive environmental potential of territorialized food systems. As an example, before the present assessment, the estimated GHG reduction of local food strategy obtained by adding separate initiatives was approximately 100 tCO₂-eq [69], which seems negligible compared to the results of more than 3660 tCO₂-eq thanks to the applied methodology. Such a systemic vision affirms the benefit of the deployment of lifecycle-based methodology at the meso-level [86] and confirms the research hypothesis assuming the enlarged benefits related to the application of TLCA-based assessment on the local food system and policies.

The study provides a novel methodological framework for the assessment of integrated environmental policies at the local level replying to emerging environmental research related to local food issues, especially in the Global North [8,10]. While this approach might still disregard certain local changes, it proposes a more comprehensive view of local food strategies' direct and indirect impact. As such, this TLCA-based framework can be used as a basis for further research of local food systems at a wider level and to enlarge the research on the benefits of shorter and more local supply chains currently based predominantly on evaluating transport efficiency [18,19,21,22].

Benefiting from the favorable political context in some European countries [87], such as in France [32], the framework and its results can be used as a foundation for local food planning adding an empiric impact evaluation to already-existing frameworks [40,88]. More precisely, it can be used to assess the implementation of food policies at the sub-national level such as Food territorial projects (PAT) or similar integrated policies. It can also be used to understand the dynamics of local food systems and their link to institutional changes and thus serve as a basis for regional, national, or international planners.

4.2. Positive Impact of Local Food Policies & Policy Implications

The positive potential of diminishing the food system's environmental impact through local food policies emerging in numerous European and French regions was confirmed using the TLCA-adapted methodology. This confirms the determinant role of local authorities in shaping sustainable food systems as well as the positive externalities of reconnecting producers and consumers as suggested by previous research [10,32,89,90]. It thus validates the hypothesis claiming the positive consequences of local food policies on the local actors and their environmental practices. Globally, the changes partially or directly influenced by the Mouans-Sartoux local food strategy contributed to the reduction of up to one-fifth of the environmental impact of the entire life cycle of the local food system. Meanwhile, this impact reduction did not weaken the potential food autonomy. Similarly, the food policies reinforced the resilience of its system by decreasing its dependence on external inputs such as fossil resources.

The contribution of each action to the impact reduction is highly variable, with the individual diet change absorbing the major part. In our case study, the environmental advantage of a more territorialized food organization is therefore predominantly due to the changes it drives in consumer habits rather than diminished food miles as initial studies assumed. This result is consistent with other food impact studies exposing dietary changes as having the highest mitigation potential [35,41,43]. It means that while policies supporting local farmers are essential, awareness-raising actions with local schools, industries, and inhabitants encouraging a shift to a more plant-based and fresh diet are identified as the most beneficial environmental actions in the given context.

The impact reduction is greater for the sub-population directly benefiting from local food policies, leading to a one-fourth decrease in their food carbon footprint. They thereby participate in achieving national climate objectives coherent with the targets presented in future scenarios such as Afterres2050 [91] or TYFA [92] as well as with the National Low-Carbon Strategy [14] and European objectives [93] conceiving a more sustainable food system by 2050. It thereby validates the final hypothesis formulated by this paper assuming a positive environmental contribution of local food policies to national and European climate targets.

Considering policy implications, the outcome of this analysis proves the relevance of consumer-based educational actions in municipal agendas and prompts urban planners to include similar strategies in their local food agenda. Considering their impact reduction potential, national governments should dedicate sufficient financial and methodological resources to sub-national governments' food strategies. Internationally, the results of this study advocate for more national and local authorities' intervention in food systems, encouragement of plant-based and fresh diets through policy implementation, and protection and development of territorialized food systems. The introduction of integrated sustainable policies aiming to transform both producers and consumers, such as French food territorial projects, should be promoted.

4.3. Lack of Appreciation for Alternative Farming Systems in LCA

In our results, the increased consumption of organic food raised water consumption mostly due to organic apple production. These findings correspond to already existing LCA studies of organic orchard systems [94]. Yet similar studies analyzing organic and low-input production of apples revealed a positive impact if the functional unit per hectare is used [95]. That is why the major limitation of the used methodology is its insufficient recognition of the benefits of organic farming systems. The LCA and its existing databases are conceived on the efficiency logic using a functional unit of 1 kg of produced food. This results in a more optimized and intensive system having a better environmental score than an extensive organic system, especially for livestock farming [96]. The French institute of organic agriculture denounces this major drawback of the Agribalyse database and alerts on its use for the assessment of organic systems. It shows for instance that out of eight different farming systems for egg production, the three organic systems display the worst environmental score contrary to the most efficient caged egg production [97].

Apart from this productivist aspect of LCA being unfavorable to extensive production, LCA only models indicators that have negative consequences on the environment. Existing meta-analyses demonstrate that organic farming systems provide numerous ecosystem services such as improving water infiltration, precluding soil erosion, and maintaining more diversified and resilient ecosystems with greater landscape diversity [98,99]. Yet many of those impacts are not accounted for in traditional LCA studies or are poorly modeled such as ecotoxicity or biodiversity indicators [100] despite research and projects being initiated on their improvement [101,102].

Despite these shortcomings, and as proved by this study, the LCA approach and Agribalyse database allow us to provide an enlarged vision of the benefits of local food systems, which could be hardly achievable by any other method. In its application in territorial assessment for highly agricultural regions, a complementary method could be used to assess farming systems such as the method *Clim'agri* [103], *Dialecte* [104], or ecosystem services-based assessment methods [105].

5. Conclusions

This paper empirically demonstrates the positive environmental consequences partially or entirely induced by local food policies through the adaptation of territorial life-cycle assessment. It thereby broadens the research debate on the environmental benefits of local food systems and shorter supply chains. The research question interrogating the environmental potential of integrated local food policies has been addressed by confirming significant direct and indirect environmental benefits. The globality of the changes triggered under the local food policies over five years generated annual economies of 20,192 m³ of freshwater, 308,247 kg of oil-equivalent, 3,015,406 m² of land, and 3,660,702 kg CO₂-eq for 9500 inhabitants. The awareness-raising institutional policies proved to generate the greatest proportion of the impact reduction.

This positive outcome reinforces the need for future institutional, methodological, and financial support to local food projects to magnify their efficiency and encourage their emergence. Such support is not only needed to be able to implement this sort of policy

but also to engage in proper impact assessment and initiate more relevant policies. The imperative to modify dietary patterns to engage in ecological transition and achieve the 2050 sustainability targets is also proven.

The adapted TLCA framework used in this study has proved relevant for assessing complex local food policies and can be used in other environmental meso-level assessment studies. It, therefore, fills in a gap related to the assessment of systemic territorial policies. The paper exposes the need for more lifecycle-based thinking in policy assessment to include the externalities taking place outside of the territory lenses, especially for urban areas or industrialized countries. Yet, the necessity to better account for the benefits of agroecological farming should be explored in further research.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/su15064740/s1>. Table S1. Local agri-food activities considered in the scope. Table S2. Data sources and background LCI databases used for each activity descriptor. Table S3. Foreground data for Mouans-Sartoux case study including years 2017 and 2022. File S1. Interview guides & questionnaires. References [71–76,96,97,106] are cited in the Supplementary Materials.

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ANNEXE II. ARTICLE N°3

Life cycle assessment as a prospective tool for sustainable agriculture and food planning at a local level

Life cycle assessment as a prospective tool for sustainable agriculture and food planning at a local level

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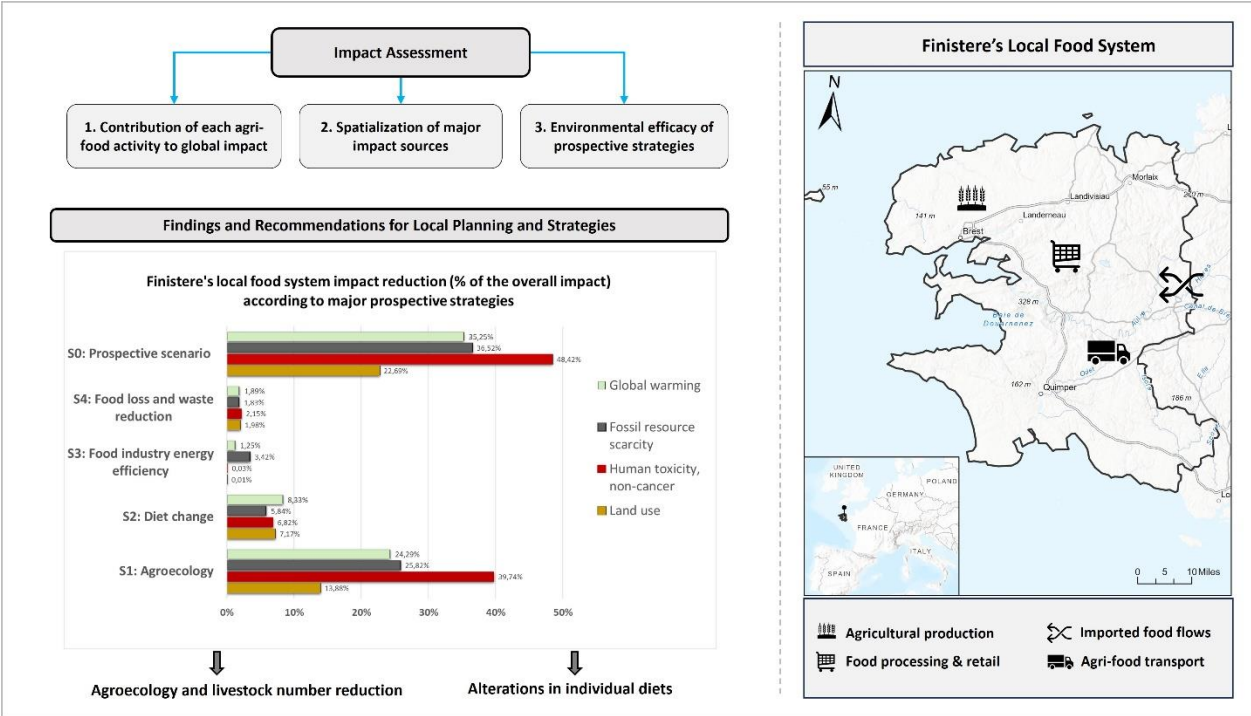
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Graphical abstract



Abstract

Owing to the far-reaching environmental consequences of agriculture and food systems, such as their contribution to climate change, there is an urgent need to reduce their impact. International and national governments set sustainability targets and implement corresponding measures. Nevertheless, critics of the globalized system claim that a territorial administrative scale is better suited to address sustainability issues. Yet, at the sub-national level, local authorities rarely apply a systemic environmental assessment to enhance their action plans. This paper employs a territorial life cycle assessment methodology to improve local environmental agri-food planning. The objective is to identify significant direct and indirect environmental hotspots, their origins, and formulate effective mitigation strategies. The methodology is applied to the administrative department of Finistere, a strategic agricultural region in North-Western France. Multiple environmental criteria including climate change, fossil resource scarcity, toxicity, and land use are modeled. The findings reveal that the primary environmental hotspots of the studied local food system arise from indirect sources, such as livestock feed or diesel consumption. Livestock reduction and organic farming conversion emerge as the most environmentally efficient strategies, resulting in a 25% decrease in the climate change indicator. However, the overall modeled impact reduction is insufficient following national objectives and remains limited for the land use indicator. These results highlight the innovative application of life cycle assessment led at a local level, offering insights for the further advancement of systematic and prospective local agri-food assessment. Additionally, they provide guidance for local authorities to enhance the sustainability of planning strategies.

Keywords: Environmental analysis; Territorial life cycle assessment; Prospective scenario; Agri-food planning, Local food system

1 Introduction

Agriculture and food (agri-food) systems play a pivotal role in addressing multiple Sustainable Development Goals (SDGs) by meeting nutritional needs, guaranteeing income to local communities, and protecting natural ecosystems. However, the sector currently faces challenges associated with climate change, biodiversity loss, or the impending peak oil crisis (Atallah et al., 2014; FAO, 2012; Godfray et al., 2010). Failure to address these challenges not only jeopardizes the achievement of United Nations sustainability objectives but also undermines the fundamental functions of agri-food systems. By 2100, unless drastic changes occur, median global temperatures may increase by 3.2°C. This poses threats to farming ecosystems, global food supply chains, and the subsistence of populations (Shukla et al., 2022).

Over the last six decades, the organization of agri-food systems and the scale of food exchanges have undergone radical transformations (Robinson and Carson, 2015). In the early 20th century, cities relied on local and peri-urban production for most of their food supply. However, post-World War II, international trade surged, leading regions and countries to specialize in specific crops and livestock to enhance their agricultural comparative advantage. This trend accelerated in recent decades, with global trade volumes doubling since 1995 (FAO, 2020a). Such transformation disrupts the traditional link between the territory and its hinterland fostering an industrialized agriculture. The latter is characterized by standardized production, homogenized practices, increased yields, and mass consumption. This shift spurred mechanization, and the widespread use of synthetic fertilizers and pesticides (Rastoin, 2007). The resulting globalization and industrialization of the agri-food sector contribute to an exacerbation of the same environmental pressures that make it more vulnerable, including factors such as climate change and biodiversity loss. The current agri-food system is responsible for between 21-37% of anthropogenic greenhouse gases (Mbow et al., 2019), and its energy consumption ranges between 15-20% of the global demand (Usubiaga-Liaño et al., 2020). Moreover, it is the main driver of deforestation, threatening local and global ecosystems (Kissinger et al., 2012). Owing to its excessive impact and vulnerabilities, addressing the environmental impact of the agri-food system sector is a strategic prerogative to achieve a sustainable and carbon-neutral future.

The European Union (EU) is a global leader in agri-food trade and positions itself as a frontrunner in sustainable and environmental development. To address environmental burdens related to its agri-food production, the EU has implemented policies aimed at reducing the use of synthetic inputs and the emissions of the farming sector, such as the introduction of the "green payment" in the Common Agricultural Policy (CAP) in 2014 and the recent Farm to Fork strategy (European Parliament, 2022;

European Commission, 2023). However, the effectiveness of these measures remains highly questionable. At the European level, since 2010, the usage of mineral fertilizers has increased, and pesticide use has remained stable (Eurostat, 2022b). Some countries, like Bulgaria, increased the consumption of pesticides by more than 60% during this period (European Environment Agency, 2019). In contrast, the greenhouse gas (GHG) emissions from the EU agricultural sector have decreased since 1990, mainly due to the reduction in the beef cattle herd driven by economic circumstances. Yet, national GHG calculations do not consider imported emissions related to the European food supply. These imports contribute an additional 40% to domestic agricultural emissions and have been rising over the past 20 years (IDH, 2020).

Given the hypothesis that the intensification of environmental impacts in the agri-food system is linked to the globalization of the food chain, such inefficient outcomes are not surprising. The European Union, driven by its CAP, is the world's top exporter and importer of agri-food products in terms of economic value (FAO,2022). The Union's commercial strategy is based on the promotion of free trade and the opening of new markets. Partly due to the accentuating international competition, the European farming workforce has been decreasing sharply in the past two decades, replaced by industrial machines or workers in countries outside the EU with lax regulations. Since 2005, the number of farms has decreased by 37%, while agricultural land surfaces have remained almost unchanged (Eurostat, 2022a). This is attributed to a substantial reduction in small-sized farms, which have been absorbed by existing large-scale farms, resulting in further farmland concentration. Farmland enlargement, encouraged by CAP subsidies per hectare, fosters industrialization and reinforces energy and input use, contributing to environmental degradation.

Many scholars thus believe that local or regional food organization is more suitable for addressing environmental externalities than a globalized system, enabling local communities to regain control over their agricultural production (Chiffolleau and Dourian, 2020; Clancy and Ruhf, 2010; Dansero and Puttilli, 2014; Delgado, 2023; Kremer and DeLiberty, 2011; Morgan and Santo, 2018). Such movements refer to the concept of food "reterritorialization" as a re-creation of the relationship between food and territory, in contrast to deterritorialization driven by globalization (Dansero and Pettenati, 2018). The concept goes beyond the simple relocation of food chains and considers the empowerment of local authorities to shape the entire food system to increase sustainability. Local food organization, related to any sub-regional scale, implies a more comprehensive management of local food resources and the establishment of policies related to local farming or food supply.

Despite the EU's export-led and free trade orientation, food reterritorialization initiatives are flourishing and being encouraged by the Member States. These initiatives are primarily promoted through public procurement but also include measures developing sustainable farming and food

supply practices (Morgan and Morley, 2002; Mansfield and Mendes, 2013; Stefanovic, 2022). France is a notable example of institutional encouragement for food relocation (Kneafsey et al., 2013). The development of a short supply chain has been endorsed by law since 2013 (Wallet and Bouroullec, 2021). The government also subsidizes French municipalities to implement specific programs called "Food Territorial Projects," aiming to encourage relocation and sustainable agri-food policies. More than 430 such projects have been initiated across France since 2014 (Ministry of Agriculture and Food, 2023). These projects align with environmental and carbon-neutral programs such as the National Low Carbon Strategy (SNBC), aiming to decrease the agriculture and food industries' impact. France's objective is to reduce the farming sector's emissions by 46% by 2050 compared with 1990 levels (Ministry of Ecological Transition, 2020). To achieve this, the national low-carbon strategy involves measures including agroecological transformation, awareness campaigns for sustainable diets, and the relocation of agriculture through the development of Food Territorial Projects.

However, the efficacy of such local agri-food strategies, including reterritorialization, remains underexplored, particularly in terms of their environmental potential. Some initiatives led by local authorities have already proven their positive environmental effects, specifically contributing to mitigating climate change and reducing energy consumption (Perez-Neira et al., 2021; Lulovicova and Bouissou, 2023). Yet, at present, most territories employ reterritorialization policies solely through organic public procurement and shortening of the supply chain (Terres en ville, 2020), potentially limiting their environmental benefits. While acknowledging the positive repercussions of such initiatives, local authorities oversee numerous aspects, enabling them to shape their food organization to a greater extent (Pothukuchi and Kaufman, 2000). Specifically, in many European countries, local governments can influence not only the agricultural sector but also other food-related industries, including supermarkets, restaurants, fast-food establishments, and canteens. They also manage land use and planning decisions, directly impacting farmers and food infrastructures. Additionally, they administer food-related waste disposal and address agricultural water pollution within the territory. Simultaneously, local policies influence consumer choices not only through educational institutions but also by managing healthcare facilities and authorizing the development of food chains and promotional activities.

To analyze comprehensively the potential environmental impact of these numerous local strategies, a systemic assessment at the local scale is imperative, encompassing not only on-site agricultural impacts, such as pesticide residues, but also the broader environmental consequences throughout the entire food supply chain. Within the scope of systemic land-use and agri-environmental assessments, Life Cycle Assessment (LCA) emerges as the internationally recognized and most widely used method (van der Werf et al., 2011; Loiseau et al., 2012; Park et al., 2016; Perminova et al., 2016; Avadí et al.,

2018; Cucurachi et al., 2019; Rouault et al., 2020). The LCA method is a multi-criteria method that accounts for direct and indirect inputs and outputs during the entire life cycle of a product or service and translates them into an environmental impact, following the guidelines outlined in ISO 14040 (2006). The methodology provides the identification of the critical life cycle activities responsible for the greatest impact and thus determines the most efficient strategies to target (Vidergar et al., 2021). The application of the methodology for urban planning assessments has been developed recently (Dias et al., 2018; Heinonen and Junnila, 2011; Oliver-Solà et al., 2011), but the conceptualization of the LCA application on an entire territory is recent and subject to methodological challenges. Most importantly, LCA was initially an aspatial method, based on the assumption of spatial and temporal homogeneity of the environment (François et al., 2021). Recently, several authors (Loiseau et al., 2013; Mirabella et al., 2019; Nitschelm et al., 2016; Qi et al., 2019) included the spatial dimension and local characteristics in LCA methodology enhancing its territorial application. One of its most comprehensive adaptations, Territorial Life Cycle Assessment (TLCA) developed by Loiseau et al. (2018) enables quantifying the global impact of all local production and consumption activities. The TLCA methodology has since been employed to assess potential strategies of the local agricultural sector, proving to be a promising approach for prospective planning at a local level (Borghino et al., 2021). Its application for prospective local agri-food planning, including both local production and external food supply, has never been conducted and is developed in this paper. The purpose is to understand the environmental impact of a local food system, its sources, and assess potential consequences of various local strategies. Ultimately, the aim is to improve prospective local agri-food planning by adding environmental and life cycle perspectives. To validate the methodology, the French department of Finistere is used as a study area. The subsequent section provides an overview of the study area, followed by a description of the employed assessment methodology.

2 Materials and methods

2.1 Study area

France is the largest agricultural producer in Europe, contributing 18 % to European production (FAO, 2020b). The administrative department of Finistere, located in the French western Brittany region, with over 900,000 inhabitants, is a strategic agricultural area in France. Its farmland constitutes 56 % of the department's global surface (**Fig. 1**).

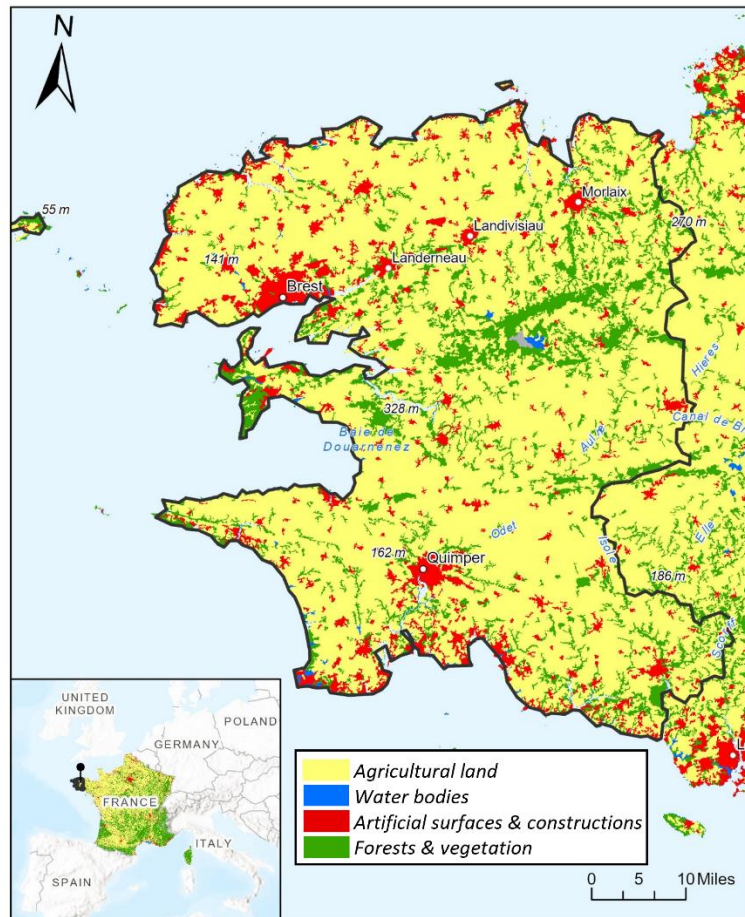


Fig. 1. Map of Finistere’s land type surfaces based on Corine Land Cover 2018 data (European Environment Agency, 2020).

Local agriculture primarily focuses on conventional export-led livestock farming, but also contains vegetable production in the north of the department. Despite Finistere covering only 1% of the national surface, its farming industry contributes 21% to France's total pig production, occupying an important part of the west coast. Local farming also contributes to 56% and 42% of national artichoke and cauliflower production, respectively, in terms of dedicated surface for these crops (Finistere Departmental Council, 2017a). This makes the department the premier pig and vegetable producer. The department’s farmers produce more than one billion liters of milk and one-third of French tuna production. Concerning more alternative approaches to production and distribution, around 19% of this local farming turnover is sold through a short supply chain, mostly through direct sales on farms. Approximately 13% of farms are organic, experiencing a remarkable 150% increase since 2010 (Chamber of Agriculture Brittany, 2020).

The food industry is a major employer, with more than 1,000 establishments dedicated to processing, transporting, or selling food items (INSEE, 2021). It is estimated that 39% of industrial workers are employed by the agri-food industry (Agreste Brittany, 2016). Similar to other French regions, Finistere’s

inhabitants consume excessive amounts of animal proteins and ultra-processed food in comparison to national nutritional recommendations (Anses, 2017).

Over the past two decades, farmland in the department has remained relatively stable. It experienced a modest decrease of 3.1% between 2000 and 2010, and a further 1% reduction between 2010 and 2020, amidst an exponential trend in farm enlargement. In 1970, Finistere counted almost 400,000 farms, a number that declined to 6,267 by 2020 (Chamber of Agriculture Brittany, 2020). The average farm size surged from 12 hectares in 1970 to 61 hectares in 2020. As of 2020, farms exceeding 100 hectares, which were nonexistent 40 years ago, now constitute over 40% of all farms, cover 60% of the total surface area, and contribute to 85% of the gross output value. Between 2010 and 2020, 20% of farms ceased operations, and the average farm size increased by 23%. Regarding the pig industry, the dedicated surface decreased by 9%, with one in three pig farms ceasing activity during this period (*Ibid*). In 1961, Finistere bred 353,000 pigs (Flatrès, 1963), compared to the current count of 4.8 million (Finistere Departmental Council, 2017a).

The decline in farm numbers and diversity illustrates the trend of landscape homogenization linked to major environmental issues, as previously outlined. Finistere's soils exhibit excess nitrogen, phosphorus, potassium, and copper levels due to the intensive use of pesticides, fertilizers, and animal feces. In the north of the department, NO₂ concentration in groundwater surpasses 50 mg/l (GIS SOL, 2022), a level that leads to water eutrophication and toxicity for ecosystems. Annually, approximately 800 tons of pesticides are sold in Finistere, with fluctuating levels and no substantial decrease over the past decade (Eau France, 2020). Farming stands out as the primary source of emissions, contributing to 39% of local greenhouse gas emissions (Air Breizh, 2020). In terms of energy consumption, the agricultural sector accounts for approximately 8% of direct energy usage (Region Brittany, 2020).

The Regional Sustainable and Territorial Planning Strategy (SRADDET) (Region Brittany, 2021) aims to reduce regional GHG emissions by 34% by 2040 and decrease the energy use in the farming sector by 7% by 2050. Yet this strategy considers solely direct impacts (scope 1), or indirect impacts associated with the energy use (scope 2) for GHG inventories. It consequently overlooks other consequences related to food supply such as imported animal feed or farming inputs. Regarding the inputs used in agriculture and the diffuse pollution they cause; the regional plan aims towards zero use of synthetic pesticides by 2040. The main actions to develop include the promotion of organic agriculture and other agroecological practices.

At the local level, the Finistere department launched the Food Territorial Project which incorporates measures to promote short supply chain distribution, foster local sustainable production and consumption patterns through consumer awareness, minimize food waste, provide support to local farmers, and enhance organic industries (Finistere Departmental Council, 2017a). Another eight

municipalities within the department initiated their own Food Territorial Projects with similar objectives, all aiming to improve local sustainability and diminish environmental impact. However, the lack of environmental assessment or any prospective targets at this sub-regional level hampers the ability to anticipate, measure, and adjust the environmental consequences of various strategies. Recognizing this knowledge gap, the adoption of territorial LCA methodology emerges as a compelling solution tailored to address the expanded environmental aspects of the local food system.

2.2 Territorial LCA methodology

The evaluation of the local food system of Finistere and its potential strategies is based on the territorial LCA methodology (Loiseau et al., 2013), which has been adapted for the local food planning context. The adapted methodology comprises four pivotal steps, rooted in the classical LCA method (Fig. 2).

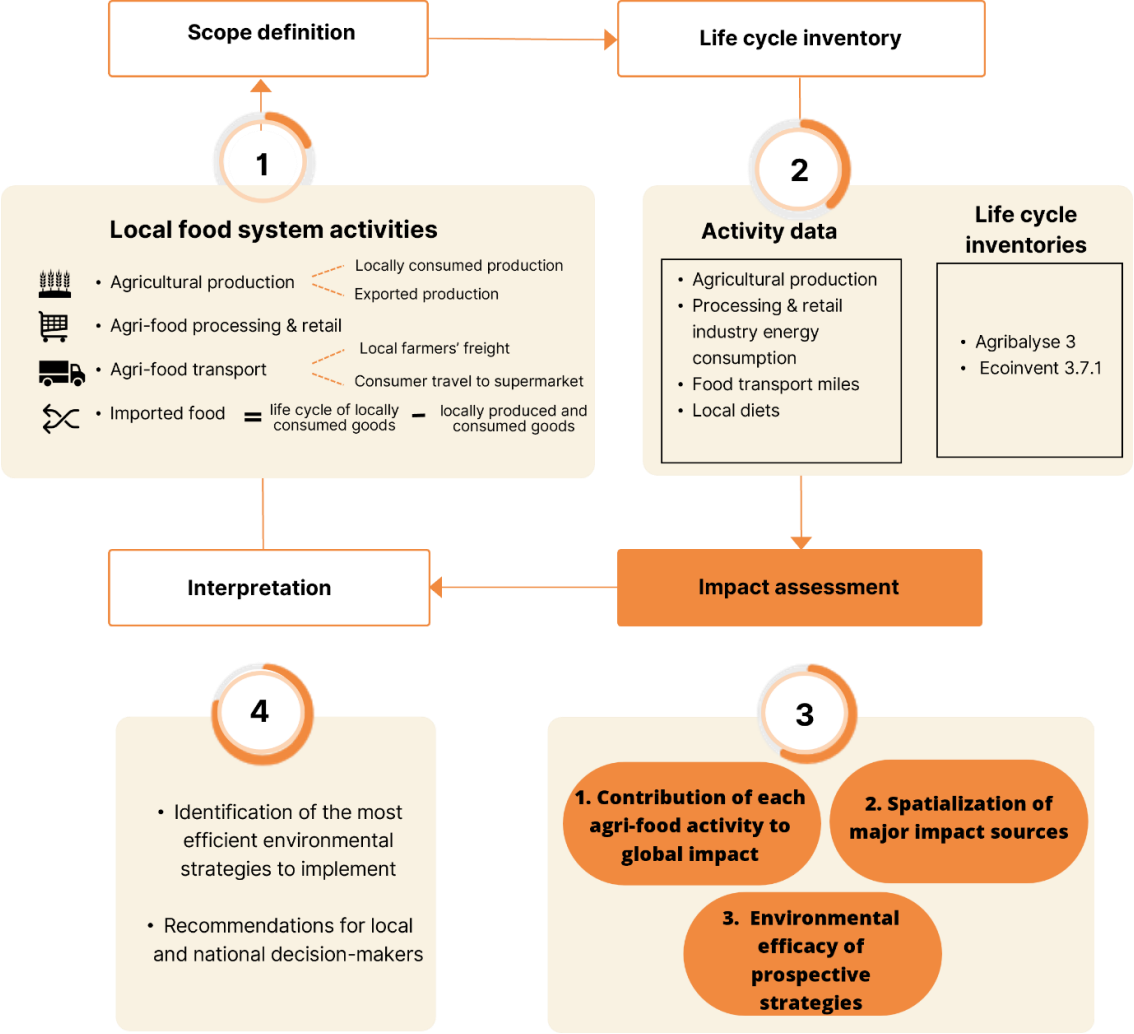


Fig. 2. LCA methodology employed in this study to assess the impact of various sustainable strategies at the local level and improve regional and local agri-food planning.

Scope definition

In this initial step, the primary focus is on delineating all agri-food production and consumption activities occurring within the Finistere's local food system to be assessed. The term "local" relates to the analyzed administrative sub-national scale (Finistere department). The assessed activities encompass:

- **Agricultural production:** covers locally consumed and exported goods
- **Agri-food processing & retail industry:** includes the energy consumption of the sector
- **Agri-food local transport:** involves the local farmer's freight and consumer travel to supermarkets
- **Imported food:** represents goods imported for inhabitants of the department and their entire life cycle.

Life cycle inventory

Proceeding to the life cycle inventory step, local data on assessed agri-food activities are compiled from publicly available resources. These data include the annual farming production volumes measured by the Regional Agricultural Direction Office DRAFF (Agreste Brittany, 2016), a list of agri-food industries from the SIRENE industry database (INSEE, 2021), their energy consumption through Enedis electricity and GRDF gas Open data (Enedis, 2022; GRDF, 2022) and transportation statistics from local surveys (Charles and Charles, 2020). The data on imported food products use the INCA 3 regional food consumption database extrapolated to the Finistere population (Anses, 2017). The food items produced locally are deducted from the consumption data to estimate the imported food flow supply. The reliability and geographical and temporal correlations of data are considered satisfactory in light of the paper's objectives.

These activity data are further linked to existing life cycle inventories, which include background data necessary to assess the impact of the selected activities throughout their entire life cycle. The employed life cycle inventories are Agribalyse 3 (Colomb et al., 2015) for all farming and food goods and the Ecoinvent 3 database (Wernet et al., 2016) for energy and transportation-related activities.

(Table 1)

Table 1

Data sources and LCA databases used for the activities considered in the assessment.

Local agri-food activity	Activity data	Units	Data sources	LCA database
Agricultural production	Annual volume per product type	t	(Agreste Brittany, 2019)	Agribalyse V3.0

Processing & retail industry	Annual energy consumption	MWh	(Enedis, 2022; GRDF, 2022; INSEE, 2021)	Ecoinvent 3
Transport	Annual local farmers' freight for distribution	Kgkm	(Charles and Charles, 2020)	Ecoinvent 3
	Annual inhabitants travel to supermarkets			Ecoinvent 3
Imported food	Annual imported food consumption by inhabitants	t	(Anses, 2017)	Agribalyse V3.0

Note: More precision related to the activity and inventory data employed can be found in the Supplementary material.

The quantity of food produced and consumed locally is estimated based on data from the Agricultural Census 2020 (Chamber of Agriculture Brittany, 2020). This database provides details regarding the number and types of farms selling their production through a short supply chain, along with the proportion of production distributed through this channel. As presented in **Table 2**, the findings highlight a significant level of potential food autonomy, juxtaposed with a modest portion of local food flows sold in a short supply chain. Notably, in the pig and fish industries, agricultural production surpasses local demand by up to 2,882% and 1,516%, respectively. Conversely, for products like fruits, the potential autonomy is approximately 5%. Despite representing a mere 3.4% of the total local pig production in volume, nearly 99 % of local pork meat consumption is estimated to originate within the department. For all other sectors, less than 20% of local consumption is evaluated to be procured through short supply chains within the department, despite the substantial production volumes.

Table 2

Quantities in kilograms of major production and consumption considered, the estimations of potential autonomy, and the proportion of local production and consumption produced locally based on data from the Agricultural Census 2020.

Major productions in Finistere	Quantity produced in Finistere	Quantity sold locally	% of local production sold locally	The quantity consumed by local inhabitants	Potential local food autonomy	% of local diets produced locally
Vegetables	250,051,000	15,189,938	6.07%	83,173,172	300.6%	18.26%
Fruits	2,508,000	1,114,320	44.43%	44,671,021	5.6%	2.49%
Dairy	114,440,000	2,716,601	2.37%	56,195,895	203.6%	4.83%
Poultry	23,690,000	751,696	3.17%	11,552,800	205%	6.51%
Beef & veal	30,700,000	1,055,691	3.44%	15,575,756	197%	6.78%
Pig	427,700,000	14,712,880	3.44%	14,838,030	2,882%	99.16%
Fish	189,118,000	NA	NA	12,477,283	1,516%	NA

Impact assessment

The third pivotal step in our analysis centers around the impact assessment, which involves a comprehensive examination through three analyses, each generating distinct results. The initial analysis aims to discern the influence of each local agri-food activity, defined in the initial scope definition step, on crucial environmental indicators. These indicators encompass climate change (kgCO₂eq), fossil resource scarcity (kg oil eq), human non-cancer toxicity (kg 1,4-DCB), and land use (m²a crop eq). A deliberate choice was made to avoid a singular focus on the climate change indicator, a common approach in global strategies and research papers, to prevent potential environmental burden-shifting. The selected indicators represent critical issues for sustainable development studies (Fu et al., 2021). In addition to climate change, we employ the ReciPe 2016 method (Huijbregts et al., 2017) to model the impact on fossil resource scarcity, encompassing the depletion of coal, natural gas, crude oil, and peat. To assess the toxic impact of pesticides and other substances, the USEtox method is employed, focusing on the analysis of the human toxicity (non-cancer) indicator (Fantke et al., 2017). Biodiversity loss, a significant concern in agriculture, is addressed using the land use indicator through the Ecological scarcity 2013 method (Frischknecht and Büsler Knöpfel, 2014). This method incorporates regionalized eco-factors across 14 diverse biomes, capturing the impact of land use on plant and animal biodiversity. Despite its advantages, the method lacks consideration for the positive impact of diversified agriculture on biodiversity (Nitschelm et al., 2020; van der Werf et al., 2020), not included in this assessment. The primary objective of this initial phase in the impact assessment is to identify major local hotspot activities generating environmental impact, such as local farming, food retail industry, or imported food flows. Identifying these activities and their principal impact sources, including livestock, transport, or energy use, serves as a prerequisite for subsequent assessments.

The second phase of the impact analysis involves spatializing a subset of the major impact sources identified. This entails selecting the most impactful background activities and investigating their potential origins. The aim is to evaluate the geographical extent of environmental consequences tied to the organization of the study area's food system. This second phase enables us to leverage the full potential of local strategies and understand their implications on a global scale.

The final phase of the impact assessment involves evaluating the efficiency of prospective local strategies. This involves the selection of major strategies from existing scenarios (elaborated further in Section 2.3) and an assessment of their environmental potential at a local level. The impact assessment modeling is executed through SimaPro 9.2 software.

Interpretation

The ultimate interpretation methodological step follows each of the three impact analyses, interpreting results to highlight major impact sources. The aim is to identify efficient strategies for local planning and suggest recommendations for decision-makers.

2.3 Prospective agri-food strategies

In the final phase of the third impact assessment step (**Fig. 2**), we explore the potential impact of diverse agri-food and land management strategies in the study area by creating a prospective scenario. The scenario's development is inspired by existing studies and scientific reports, showcasing the growing interest of academic and institutional entities in identifying effective measures to mitigate the impacts of food systems through prospective scenarios (Ambler-Edwards et al., 2009; Couturier et al., 2021; Hauck et al., 2019; Qu et al., 2020). To summarize the existing assessments, the agronomic specialist organization Solagro conducted a comparative analysis of sixteen land-use agriculture and food prospective scenarios intending to achieve a sustainable and carbon-neutral economy. These scenarios encompass technological bets, such as increased yield and smart farming, as well as more systemic approaches like the Ten Years of Agroecology (TYFA) scenario, focusing on dietary changes, agroecology, and supply chain decarbonization (Poux and Aubert, 2018). In the French context, two principal studies have emerged recently including the macroeconomic carbon-neutral scenarios of the French environmental agency ADEME (Barbier et al., 2022) and the French agricultural and food scenario Afterres 2050 (Solagro, 2016). In all studies and reports, scenarios emphasizing systemic changes, including transformations in agricultural and dietary practices, demonstrate more certain and increased environmental potential compared to technocentric approaches.

Drawing from this existing literature, an explorative scenario comprising four major strategies is generated for the study area. These strategies are consistent with the measures included in the French ADEME transition(s) 2050 (Barbier et al., 2022), the French agricultural Afterres 2050 (Solagro, 2016), and the European agroecology TYFA (Poux and Aubert, 2018) scenarios. The selected strategies are grounded in systemic and structural changes related to transforming local agriculture, modifying local food diets, optimizing energy use in the agri-food industry, and reducing food waste. The four strategies are detailed as follows:

1. **Agroecology (S1):** This strategy S1 centers on fostering local agroecological principles. An agroecological transformation is the principal basis of each studied scenario and is at the top of the national, regional, and local action lists. While agroecology encompasses various definitions, our analysis focuses on transitioning to organic farming and adopting grassland farming for cattle. Organic farming stands out as the sole agroecologically certified practice

adhering to precise regulatory specifications enabling a specific LCA assessment. Aligned with objectives from scenarios like Afterres 2050, this strategy examines the impact of converting 40% of local conventional production to organic farming. However, organic or grassland livestock farming, characterized by more extensive practices, necessitates additional land, thereby calling for a reduction in livestock numbers. We maintain the hypothesis of a 40% reduction in current livestock levels, consistent with scenarios such as TYFA or Afterres 2050.

2. **Diet change (S2):** The second strategy revolves around altering the dietary habits of the local population towards patterns that are both healthier and more sustainable. This shift is a prevalent theme in local political agendas, lacking specific objectives, and is a recurring element in all analyzed scenarios and sustainability-focused food research that deems existing food regimes as unsustainable (Poore and Nemecek, 2018). The adjustments in consumption correspond to the national Afterres 2050 diet change scenario (Solagro, 2016), incorporating nutritional recommendations. This involves an augmentation in the intake of fruits, vegetables, whole grain products, and nuts, coupled with a reduction in animal-based products, particularly red meat, and beverages, including alcohol. Despite not being explicitly outlined in the Afterres scenario, a decline in the consumption of ultra-processed food is also modeled in our strategy. The specific quantities of increase or decrease are detailed in **Table 3**.
3. **Food industry energy efficiency (S3):** This strategy delves into optimizing and enhancing efficiency in the food processing and retail sector. The reduction of 20% in energy consumption is retained mirroring the scenario of ADEME Transition(s) 2050.
4. **Food losses and waste reduction (S4):** The last strategy focuses on addressing food losses and waste, a solution consistently featured in every analyzed existing prospective scenario. At the same time, the management of food waste is subject to comprehensive regulations in France and constitutes a primary focus in Food Territorial Projects. In the French context, food losses and waste account for approximately 18% of total food production, with a higher percentage attributed to fruits and vegetables and a lower proportion to animal products (ADEME, 2016). Consistent with scenarios such as ADEME Transition(s) 2050, TYFA, and Afterres 2050, this strategy examines the potential impact of reducing global food waste by 50%.

The hypotheses of the scenario and the quantitative targets of each strategy are summarized in **Table 3**.

Table 3

Strategies and hypotheses included in the prospective scenario assessing the implementation of national-based structural strategies on a local level.

STRATEGY CODE	STRATEGY	HYPOTHESES USED	HYPOTHESES OBJECTIVES	SCENARIO MODEL/ BASIS
S1	Agroecology	Conversion to organic or grassland systems	+40%	Afterres 2050 TYFA
		Livestock and fish reduction	-40%	Afterres 2050 TYFA
S2	Diet change	Whole foods, fruits, and vegetables	+20%	Afterres 2050
		Pulses and nuts	+300%	
		Fish and seafood	-70%	
		Animal-based food	-50%	
S3	Food industry energy efficiency	Ultra-processed food	-50%	ADEME Transition(s) 2050
		Decrease in electricity and gas consumption	-20%	
S4	Food losses and waste reduction	Reduction in food losses throughout the entire supply chain	-50%	ADEME Transition(s) 2050

These strategies undergo individual analysis to assess their respective contributions to impact reduction. Subsequently, they are integrated into the overall prospective scenario to model their cumulative effects. The selected strategies incorporate the most recurring elements found in existing scenarios and align with both national and local targets, allowing for an estimation of their environmental contributions to national and regional sustainability policies. In addition to the analyzed strategies, previous scenarios considered technological or agronomic advances and the shortening of the supply chain. However, the present assessment excludes these elements due to challenges in modeling cutting-edge technologies and uncertainties regarding their environmental benefits. Similarly, the shortening of the supply chain is omitted due to the diversity of existing forms, preventing generalization, and its marginal potential impact compared to other strategies (Majewski et al., 2020). Despite the limitations associated with excluding such strategies, the chosen ones encompass the most prevalent components of existing scenarios, providing an initial estimate of their environmental potential through life cycle assessment.

3 Results and discussion

3.1 Contribution of each agri-food activity to global impact

Applying the territorial life cycle impact assessment for the Finistere's agri-food system yields three distinct sets of outcomes, as detailed in Methods Section 2.2. These results include the assessment of

the environmental impact of each local activity and its sources, their partial spatialization, and, lastly, the evaluation of the prospective scenario environmental efficacy.

The results of the first impact assessment part are illustrated in **Fig. 3**. They encompass the contribution of each territorial agri-food activity and its major sources in an absolute percentage to the overall impacts of Finistere's entire food system, covering a) climate change b) fossil resource scarcity c) human non-cancer toxicity, and d) land use indicators.

Overall, local agricultural production is identified as the primary environmental hotspot across all indicators, constituting 47% to 76% of the total local food system's impact. Livestock farming, specifically pig and dairy cattle production, is a significant contributor, with the pig industry alone accounting for 10% to 32% of the global impact. Such an outcome is not surprising due to the significant livestock production in the study area (**Table 2**). Yet, despite substantial vegetable production, exceeding local demand threefold, locally cultivated crops exert a negligible impact. The food imported from other departments and countries is the second most impactful activity across all categories, accounting for up to 38% of the total impact. This is noteworthy, considering the significant potential food autonomy of the territory. The primary contributors to this imported food impact are animal-based products, particularly red meat, and dairy. Despite being produced locally in quantities twice as high as the actual demand (as demonstrated in **Table 2**), these products are predominantly directed towards the export market, implying a decreased local offer and a need for imports. In contrast, the impact of the local agri-food-related retail and processing industry, as well as transportation, proves secondary. Their impact is driven by heat usage in supermarkets and the use of vehicles for consumer travel to supermarkets in the case of transportation.

While these findings are consistent across all examined environmental indicators, distinct background impact sources are identified for each indicator, emphasizing the necessity of tailored strategies. Regarding the climate change indicator, major background sources include biogenic methane from livestock, the production of animal feed, and the heat use related to greenhouse tomato production (**Fig. 3a**). This highlights the imperative to modify local farming practices to reduce the carbon footprint, especially in addressing livestock and its methane emissions. Over the past two decades, national and local policies have predominantly focused on decarbonizing the supply chain, with insufficient attention to interventions in livestock practices and methane emissions mitigation, potentially hindering the local climate objectives (French General Accounting Office, 2023). Comparable hotspot impact sources are identified for the imported food, primarily driven by red meat consumption.

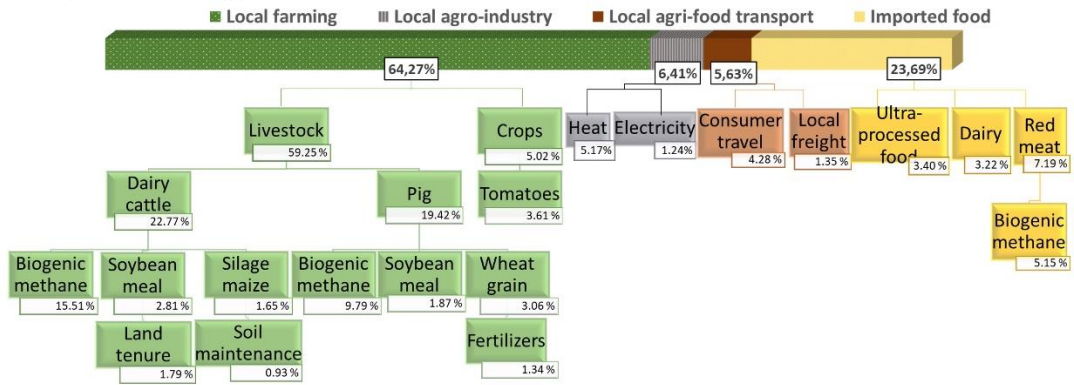
For the fossil energy indicator, the contribution of each agri-food activity is more evenly distributed. Hotspot impact sources include diesel combustion and gas production for farm use, synthetic fertilizer

production, and transportation, encompassing both freight and consumer travel (**Fig. 3b**). These findings underscore the environmental repercussions of the industrialization of food supply chains. Notably, diesel usage in marine engines for the local fishing industry accounts for over 15% of the global impact, diesel combustion by private cars used for shopping for 7.31%, and the impact of plastics on imported food packaging for 3.58% of the global impact. To diminish the local dependence on fossil fuels, local authorities thus have the potential not only to address direct energy use at farms but also to implement policies that reduce mineral fertilizer usage, gas heating in food retail, or consumer travel.

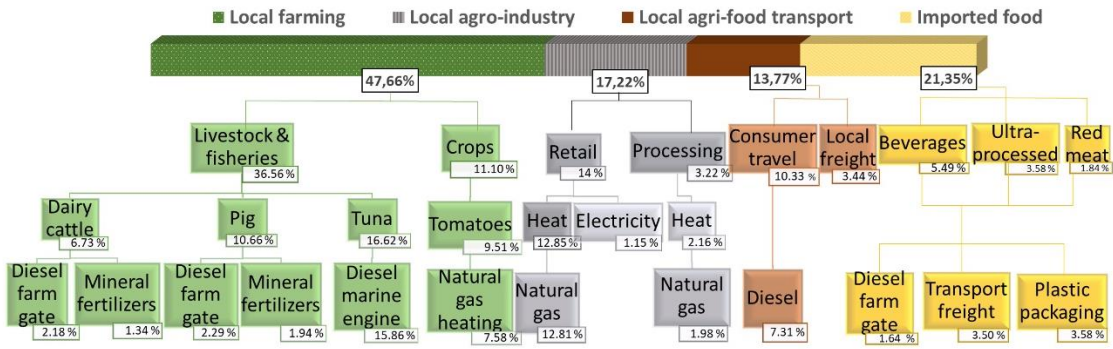
The human toxicity non-cancer indicator primarily results from various pesticides employed in animal feed crop production, such as soybean and wheat grain for the pig and cattle industries (**Fig. 3c**). These crops can be either locally produced or imported due to the limited surface of the study area compared to the significant volumes of local meat and dairy production. Approximately one-third of the global impact arises from imported animal-based products and highly processed items, such as red meat, milk, confectionery, or ultra-processed beverages. This impact stems partly from industrial substances used in processing, like formaldehyde as a preservative, contributing to more than 9% of the entire local food system's impact. These hidden toxicity impacts, absent from local strategies, significantly contribute to negative health and ecosystem pressures in production sites. In addition to addressing local pesticide usage following the regional sustainability plan, local planning can also encompass initiatives aimed at reducing the importation and consumption of ultra-processed foods by promoting the development of local and sustainable alternatives.

Concerning the land use indicator, the cultivation of crops for animal feed, such as wheat and maize for the cattle and pig industry, stands out as the primary source of impact. This impact primarily arises from the occupation of land for annual crops, with pastures contributing to only ~10% of the entire land use impact (**Fig. 3d**). The cultivation of these crops using industrial inputs poses a threat to biodiversity. To address this issue, local authorities should prioritize food products that demand reduced land use or employ techniques less damaging to ecosystems through subsidies and local agri-food strategies.

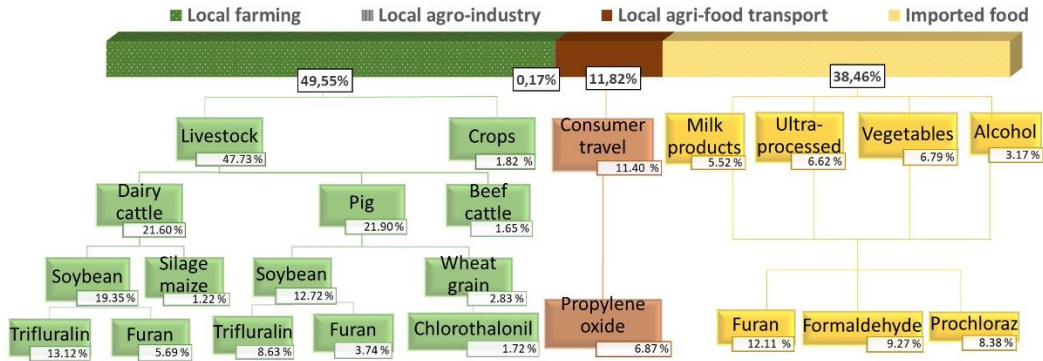
a) Climate change



b) Fossil resource scarcity



c) Human toxicity, non-cancer



d) Land use

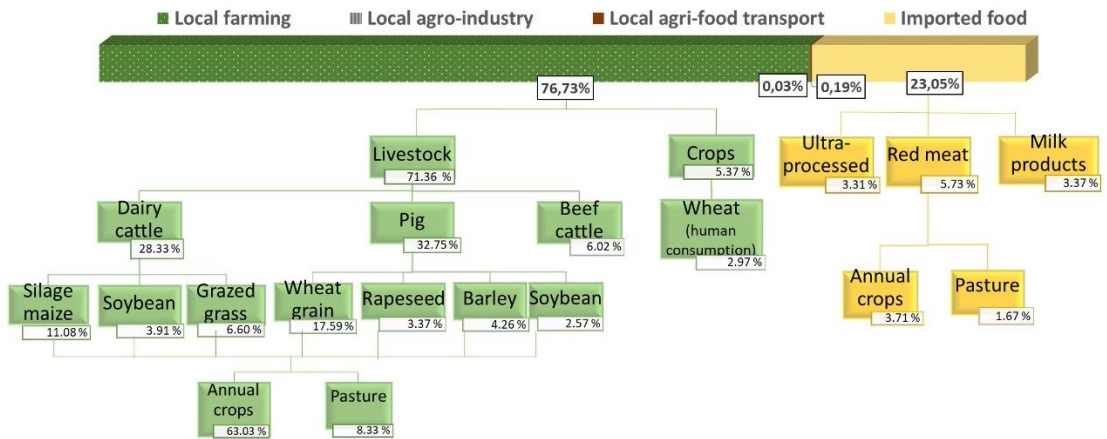


Fig. 3. Distribution of the environmental impact of Finistère's agri-food activities and the principal hotspot background activities in absolute % of their global contribution. The background activities with a contribution lower than 1 % are not displayed.

In conclusion, to achieve climate and environmental targets in the study area, local planning strategies must first focus on addressing the impact sources associated with local livestock farming and their inputs, particularly those related to animal feed. These critical areas, often overlooked by local and national environmental policies (Marcadet, 2021), highlight the advantages of employing a life cycle methodology in local assessments.

However, the comprehensive nature of using Life Cycle Assessment (LCA) for local assessments introduces limitations linked to the background data, which may not always be fully representative of reality. This implies, for instance, that the employed data do not represent the specific volumes of pesticides or fertilizers used by local agriculture but are derived from national average data. Future research could address this by incorporating more precise data or including local characteristics such as soil types to enhance result precision (Nitschelm et al., 2016). Despite these limitations, the integration of a global perspective in this assessment provides a more profound basis for developing sustainable agri-food policies in the context of a globalized economy. This first impact source identification can further be used to illustrate partially the geographical origins of the identified sources in the second impact assessment phase.

3.2 Spatialization of major impact sources

Resulting from the first part of the impact assessment, it can be deduced that the most prevalent hotspot impact sources include pesticides, animal feed, diesel and gas use, and production. Some of these impacts, such as a portion of local crops used for animal feed, occur within the department, yet most of these activities involve imported inputs. While precise data about Finistère's imports are unavailable, we can analyze national importation data. By leveraging national-level data, we can gain insights into the potential geographical extent of Finistère's food system impacts, particularly as some of its impact sources are tied to food imported from other regions of France. This includes analyzing the data related to national statistical data on pesticides (OEC, 2020), animal feed (FAO, 2020c), crude oil, and gas imports (Ministry of Ecological Transition, 2021). **Fig. 4** illustrates this second part of the impact assessment. The findings underscore that the impact sources related to Finistère's food system extend far beyond the French borders.

More specifically, despite France ranking among the leading global exporters of pesticides, these substances are largely imported. Major exporting countries include other European nations, notably

Germany (529 million dollars worth of pesticides/year), followed by the United States. Meanwhile, France produces twice as much in terms of economic value (Fig. 4a). These pesticides are used not only in local agriculture but also in the production of imported food, including animal feed. Their use is not only toxic for on-site application but can also cause environmental and health issues for factory workers in the producing countries (Van Maele-Fabry et al., 2006).

Concerning feed for livestock, soy is consistently identified as having a significant contribution to the overall impact. This observation holds for both local livestock farming and imported meat into the territory. The cultivation of soy, particularly in the form of soybean meal, remains insufficient in France, producing only approximately 400,000 tons. This necessitates the import of 3 million tons per year primarily from Latin America, specifically from Brazil and Argentina (Fig. 4b). The importation of animal feed and soybeans is a major cause of deforestation in the world's most precious forests, contributing to biodiversity loss and soil degradation (Martínez-Valderrama et al., 2021).

As for fossil fuels such as crude oil or gas, these are almost entirely imported from other countries (Fig. 4c and 4d). France imports 51.5 Mtoe per year of crude oil, mostly from Northern Africa, the Arabian Peninsula, and the Russian Federation, and produces less than 1 Mtoe (Fig. 4c). A similar pattern is noted for natural gas imports, primarily originating from Norway or Russia (Fig. 4d). In addition to being a source of global threats such as climate change, fossil energy extraction poses a threat to local ecosystems and their biodiversity (Butt et al., 2013). These fossil inputs are closely implicated in a significant portion of the impacts for all the studied activities.

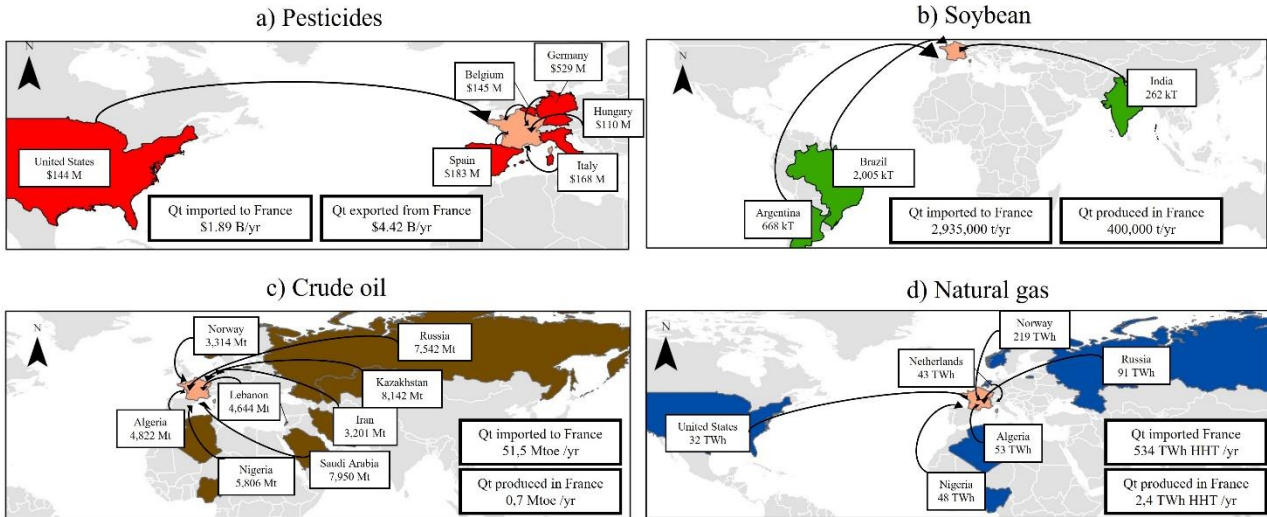


Fig. 4. Origins of the hotspot background activities identified in Finistere’s agri-food system based on national data on importations of a) Pesticides, b) Soybean meal, c) Crude oil, d) Natural gas (FAO, 2020c; Ministry of Ecological Transition, 2021; OEC, 2020).

Such imports not only reveal a high dependency on external sources but also generate distant and less controllable environmental pressures, contributing to pollution and ecosystem damage in exporting countries. Consequently, local sustainability strategies must adapt to address both local and imported threats. This involves estimating the potential direct and indirect impact of local strategies, as explored in the following section.

3.3 Environmental efficacy of prospective strategies

The last step of the impact assessment is dedicated to assessing the potential environmental benefits of strategies based on international and national sustainability plans and scenarios. To assess the potential efficacy of various prospective strategies from a life cycle perspective, we modeled the impact of a prospective scenario composed of four strategies outlined in Section 2.3. The impact of each strategy is individually evaluated for the same environmental indicators: climate change potential, fossil resource scarcity, human non-cancer toxicity, and land use. The results demonstrate positive impact reductions for all analyzed indicators and all strategies, as illustrated in **Fig. 5**.

The obtained environmental reductions vary significantly based on the targeted strategy. This variability is mainly due to the local activities' impact contribution, the majority of which comes from local agricultural production. Consequently, the agroecology strategy S1 displays the most substantial environmental benefits, accounting for between 61% to 82% of all decreases. The greatest reduction is observed for the human toxicity indicator, followed by fossil resource scarcity and climate change indicators. The reductions in land use and climate change indicators result from the considered livestock number decrease and the diminished human toxicity indicator mainly due to the conversion to organic practices excluding synthetic pesticides. While local plans and measures are consistent with addressing the hotspots identified in this assessment by supporting organic and local production, the prospective analysis indicates that the most efficient measures should also involve livestock reduction, particularly in the pig industry. Currently, there are no policies targeting livestock reduction at the local or national levels. Although implementing such policies may present challenges, the Netherlands serves as a noteworthy example of their feasibility. The country aims to decrease its pig herd by 25% by 2030 and has initiated the process by subsidizing affected farmers (Flach and Selten, 2021).

The diet change strategy (S2), entailing the substitution of imported meat and ultra-processed food with fresh, plant-based alternatives, exhibits the second most notable impact on all indicators. The impact reduction ranges from 5.8% to 8.3% across various impact categories, with the most significant reductions observed in land use and climate change. This decrease is attributed to the lowered consumption of red meat, impacting climate change through methane emissions and land use through

animal feed crops. This impact reduction specifically applies to the imported food supply. It thus underscores the influential role of dietary shifts in affecting environmental pressures in exporting countries, even in agriculturally intensive regions with a high level of potential food autonomy. Consequently, it emphasizes the necessity of incorporating strategies related to dietary choices into local planning efforts.

The strategies S3 (Food industry energy efficiency) and S4 (Food loss and waste reduction) result in an impact decrease of less than 3.5% across all impact categories. Energy efficiency strategy contributes to reducing dependency on fossil resources, and food waste reduction strategy primarily impacts the human toxicity indicator. This modest decrease in impact can be attributed to these activities having a relatively low contribution to the overall agri-food impact in Finistere (Section 3.1). Despite their marginal contribution, consistent with previous research (Barbier et al., 2022), energy efficiency and food waste are extensively addressed in environmental policies. However, our findings suggest that simultaneously, there should be an increased focus on agricultural and dietary practices.

The global scenario considers all four strategies and their interactions. For instance, the diet change strategy incorporates modifications from other strategies, such as food waste reduction, among others. Consequently, the impact of the global scenario does not correspond to the sum of the impacts of the strategies analyzed individually. Overall, the scenario demonstrates a significant decrease for all studied indicators. The most significant reduction in the global scenario (48.42%) is observed in the human toxicity indicator, primarily due to a substantial decrease in pesticide use in the agroecological strategy and the reduction of cropland for animal feed. This reduction closely corresponds to regional and national targets of decreasing the use and toxicity of synthetic pesticides by at least 50%. The indicators of fossil resource scarcity and climate change demonstrate a reduction of 35-36%, approaching the target of a 46% reduction in greenhouse gas emissions set by the French government. The land use indicator decreased by 22.69%. The relatively minor decrease in land use results from an increase in agricultural surfaces for the agroecological strategy, which generally employs more extensive practices, such as grassland systems. Despite the significant decrease observed in all indicators and their alignment with local and national objectives, a more substantial reduction is necessary to address these environmental issues and reply to the ambitious targets defined. Yet, this limited reduction can also be attributed to the restricted number of strategies considered in this analysis. Finally, local authorities should also consider the indirect consequences of their food system, the contribution of which is revealed to be significant and is rarely addressed in national or regional policies.

Finistere's local food system impact reduction (% of the overall impact) according to major prospective strategies

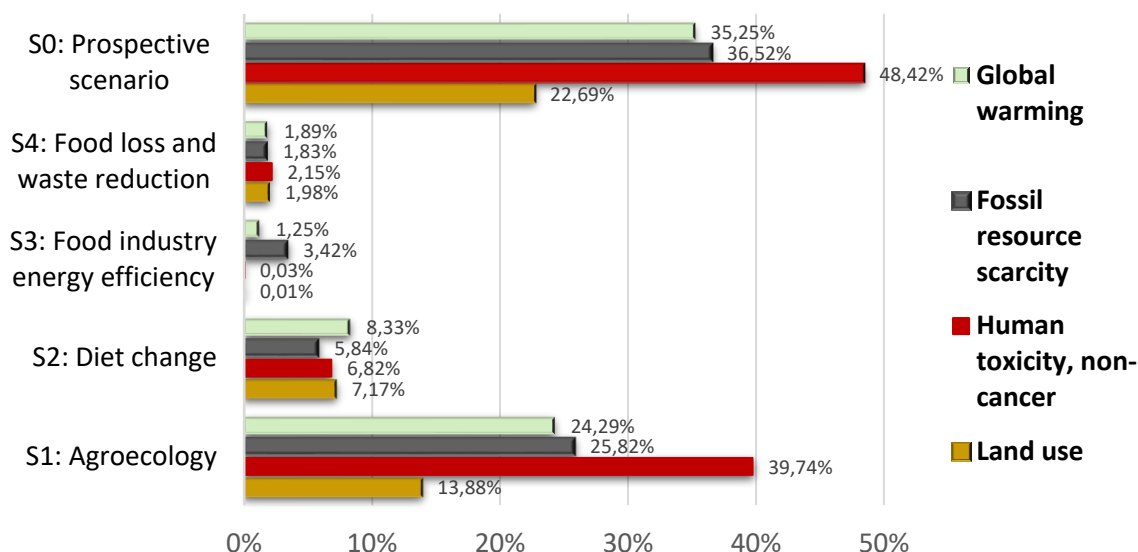


Fig. 5. The reduction of the global Finistere’s agri-food system impact for the prospective scenario (S0) combining the four strategies (S1-S4) and for each strategy individually.

The achieved reduction in environmental impact raises questions about the prospective scenario's effects on the department's productive capacities. The results indicate that under the scenario, the potential food autonomy remains highly sufficient for both the local demand and the export. This is illustrated in **Table 4**, which presents the new quantities produced and consumed. Specifically, the decrease in livestock numbers does not affect the department's potential food autonomy, nor does it significantly alter its exporting potential, given that the produced quantities remain high. Conversely, the reduction in local consumption of certain products in the Diet change strategy (S2) results in an increased potential autonomy for all livestock sectors. For instance, despite the reduction in pig production (-40%), the quantities produced under the scenario are 34 times higher than the newly estimated local consumption (**Table 4**).

Table 4

Volumes in kilograms estimated to be produced and consumed in the tested scenarios compared to the volumes produced and consumed.

Major productions in Finistere	Actual situation		Scenario		
	Potential local autonomy		New quantity produced in Finistere	New quantity consumed by local inhabitants	New % of potential local autonomy
Vegetables	300,64%		250,051,000	99,807,806	250,53%

Fruits	5,61%	2,508,000	53,605,225	4,68%
Dairy	203,64%	69,431,115	28,097,948	247,10%
Poultry	205,06%	14,071,860	5,776,400	243,61%
Beef & veal	197,10%	18,235,800	7,787,878	234,16%
Pig	2882,46%	254,053,800	7,419,015	3424,36%
Fish	1515,70%	112,336,290	3,743,185	3001,09%

The realism of the selected strategies is to be discussed. Contrary to the ambitious targets set by national and local authorities, the observed evolution is less remarkable. In 2022, soaring inflation prices led to a decreased demand for organic products in Finistere, slowing down the conversion of farms (Ministry of Agriculture and Food, 2023). Similarly, despite national and local awareness campaigns, the proportion of ultra-processed food in diets is on the rise (Anses, 2017). The primary aim of this assessment was to evaluate the efficacy of such measures. While there is a risk that the objectives of the scenario, derived from international and national reports, may not be achieved, the results emphasize the need to accelerate policies and engage in even more ambitious interventions. For instance, despite significant changes in farming and diet practices, the tested scenario does not surpass a 40% reduction in greenhouse gas emissions. Current Finistere's food policies focus on shortening the supply chain and promoting local, sustainable, and organic products (Finistere Departmental Council, 2017a, 2017b). Yet they do not question the industrial and export-led farming model, which is the primary potential source of impact reduction. Based on the paper's findings, and prior research (Loiseau et al., 2020; Majewski et al., 2020), the current efforts thus may have only a limited positive impact on environmental issues. Additionally, the local policy roadmap includes mostly communication and educational actions at schools, raising questions about their efficacy compared to the necessary changes. Finally, the ability of local authorities to exert influence and effectively implement the tested strategies is uncertain, given the prevailing dominance of international and national policies centered around trade liberalization and industrialization.

Nevertheless, the results of the prospective LCA methodology offer a macroscopic and multicriteria perspective on the potential impacts of the evolution of the studied local food system and its environmental externalities. Consequently, it provides a guideline for local authorities outlining the essential changes leading towards increased sustainability. While the paper models only four strategies, the life cycle methodology used enables the analysis of a vast number of strategies, scenarios, and environmental indicators at every geographical scale. This potential could be explored in future research.

4 Conclusions

Over the past six decades, the elongation of the food supply chain has contributed to the dilution of responsibility for the impact of food production and consumption. The relocation of production and the implementation of local food policies can play a pivotal role in restoring the accountability of a territory and its stakeholders for the impact it generates. Despite the implementation of various local policies over the last ten years, indicating the commitment of local governments to regain control over the food organization, there is an urgent need to formulate a systematic vision for more environmentally sustainable local measures in food production and consumption.

The innovative application of territorial life cycle assessment methodology for food planning enhances the understanding of principal sources of environmental impact within a local food system and the consequences of diverse planning strategies. It thus offers an expanded view of environmental indicators not accessible through assessments based solely on local indicators related for instance to water or soil pollution, providing insights for local planners and decision-makers. The findings of the prospective analysis underscore that strategies focusing solely on energy and food waste efficiency have a marginal effect on environmental impact. In contrast, the conversion to agroecological practices, involving livestock reduction, and alterations in individual diets represent a greater potential for impact decrease. This emphasizes the need to incorporate such strategies more effectively into territorial planning. Deploying a life cycle assessment in prospective local agri-food planning allows for the integration of territorial aspects into LCA methodologies and improves local assessments with a global perspective. We argue that such a vision is essential in a globally interconnected economy, particularly in industrialized countries. While the development of regional and spatialized LCA models could offer more precise and detailed prospects, this paper serves as an initial step toward territorializing and aligning national sustainability targets and systematic assessments.

5 Declaration of Competing Interests

The author declares that there are no known competing financial interests or personal relationships that influenced the work reported in this paper.

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ANNEXE III. ANALYSES DE SENSIBILITE ET D'INCERTITUDE SUPPLEMENTAIRES

Cette annexe illustre une partie des analyses menées en complément des résultats présents dans le manuscrit. Cela concerne i) des analyses OAT (once-at-time) pour une partie des processus des deux cas d'étude, ii) une comparaison des méthodes de modélisation pour le cas de Mouans-Sartoux et iii) une analyse de Monte-Carlo pour une partie des données d'entrée pour l'exemple de Mouans-Sartoux.

Analyses OAT supplémentaires

Pour Mouans-Sartoux, en raison de l'importance et de l'incertitude liées aux produits importés, la majorité des analyses ont porté sur la sensibilité des différents processus pouvant être sélectionnés à partir de la base des données Agribalyse et de leur éventuelle influence sur le résultat global (Figure 1). Cela concerne notamment les produits nécessitant une transformation (industrielle ou par le consommateur). Ces analyses montrent une incertitude relativement faible qui ne nécessite pas une caractérisation plus précise.

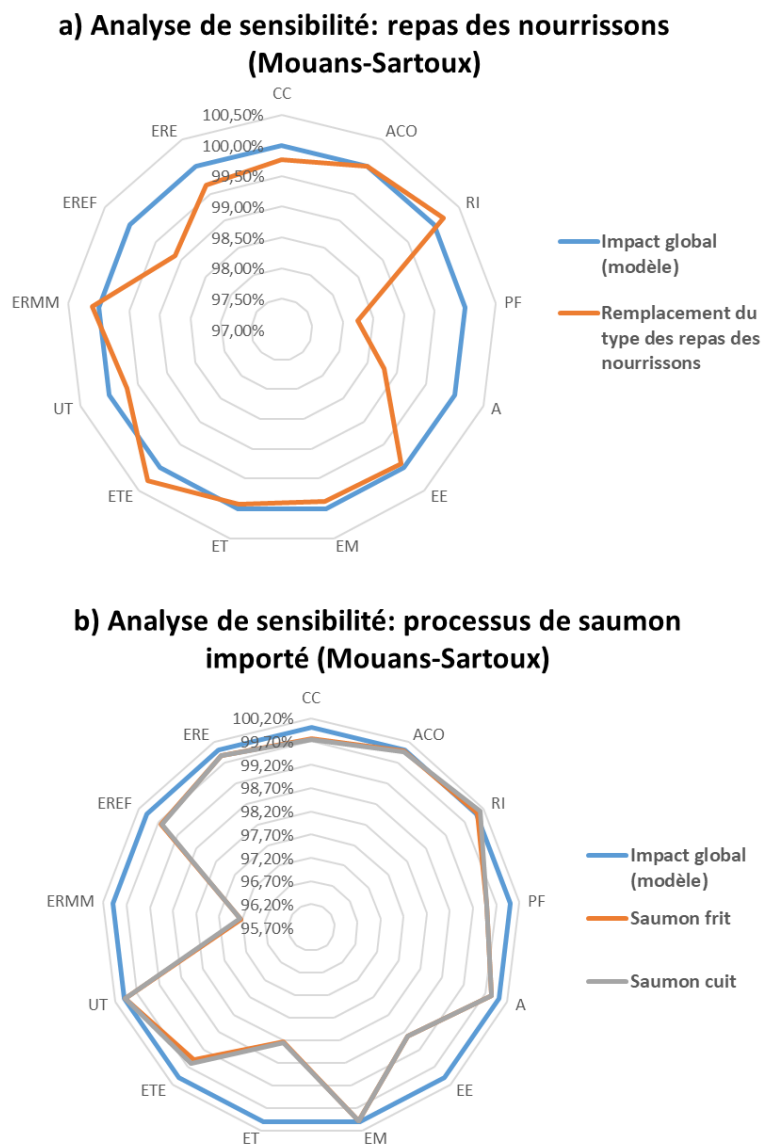


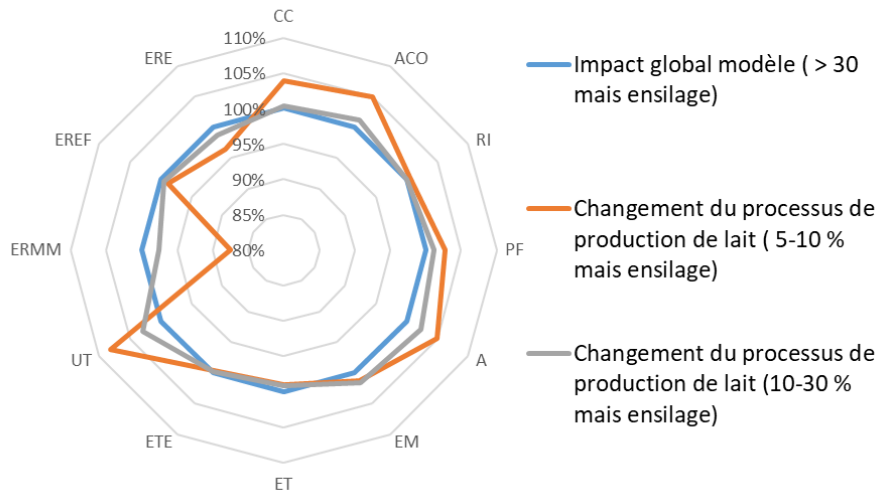
Figure 1. Exemples des analyses de sensibilité pour les processus d'Agribalyse utilisés dans la modélisation de produits importés de Mouans-Sartoux. Exemple de : a) repas des nourrissons, b) types de cuisson de saumon. Abréviations : CC = Changement climatique ; ACO = Appauvrissement de la couche d'ozone ; RI = Radiation ionisante, effet sur la santé ; FOP = Formation photochimique d'ozone ; PF = Particules fines ; A = Acidification ; EE = Eutrophisation, eau douce ; EM =

Eutrophisation, marine ; ET = Eutrophisation, terrestre ; ETE = Ecotoxicité d'eau douce ; UT = Usage des terres ; EREF= Épuisement des ressources énergétiques fossiles; ERMM = Épuisement des ressources minérales et des métaux ; ERE = Épuisement des ressources en eau

En ce qui concerne le cas du Finistère, l'accent est principalement mis sur l'évaluation de la sensibilité des processus liés à la production locale. La Figure 2 illustre des exemples liés au processus de production de lait de vache (en fonction du pourcentage de maïs ensilage dans l'alimentation) et au processus de l'élevage de thon (type de thon pêché). En général, ces derniers révèlent une sensibilité faible, à l'exception des indicateurs d'épuisement des ressources minérales et de toxicité. Plus de caractérisation serait nécessaire dans les futurs travaux en se concernant spécifiquement sur le type de production locale en lien avec ces indicateurs.

D'autres analyses portant sur l'ensemble des descripteurs d'activités et des processus étudiés démontrent une faible sensibilité en termes de leur impact sur les conclusions majeures de l'étude.

a) Analyse de sensibilité: processus de production de lait (Finistère)



b) Analyse de sensibilité: processus du thon (Finistère)

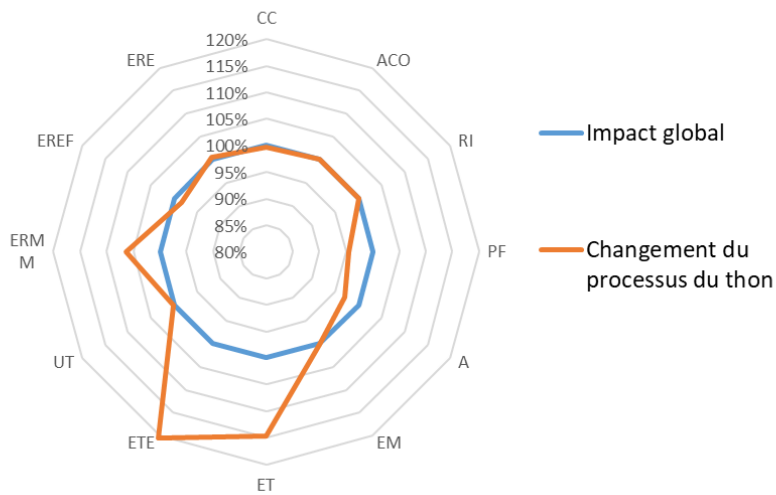


Figure 2. Analyses de sensibilité pour les processus d'Agribalyse utilisés dans la modélisation de la production agricole du Finistère. Exemple de : a) production du lait de vache, b) pêche du thon.
 Abréviations : CC = Changement climatique ; Appauvrissement de la couche d'ozone ; RI = Radiation ionisante, effet sur la santé ; FOP = Formation photochimique d'ozone ; PF = Particules fines ; A = Acidification ; EE = Eutrophisation, eau douce ; EM = Eutrophisation, marine ; ET = Eutrophisation, terrestre ; ETE = Ecotoxicité d'eau douce ; UT = Usage des terres ; EREF= Épuisement des ressources énergétiques fossiles ; ERMM = Épuisement des ressources minérales et des métaux ; ERE = Épuisement des ressources en eau

Comparaison des méthodes de modélisation

Outre les incertitudes liées aux données utilisées, les modélisations d'ACV varient en fonction du modèle appliqué. Il convient donc d'analyser si les conclusions majeures formulées dans le cadre de ce diagnostic des systèmes alimentaires territoriaux analysés sont modifiées en fonction de la méthode employée, notamment en comparaison avec la méthode EF 3.0 (Environmental Footprint) utilisée dans notre premier diagnostic. Une autre méthode récemment mise à jour et fréquemment utilisée pour les produits agroalimentaires est la méthode ReCiPe 2016. ReCiPe 2016 Midpoint comprend presque les mêmes indicateurs que la méthode EF, avec deux indicateurs supplémentaires. En effet, l'indicateur de formation photochimique de l'ozone a été divisé en deux (impact sur la santé humaine et les écosystèmes), et en plus de l'indicateur d'écotoxicité d'eau douce, elle inclut l'indicateur d'écotoxicité marine. Outre ces différences, les dénominations utilisées pour certains indicateurs varient selon les modèles employés. À titre d'exemple, la méthode EF 3.0 inclut l'impact de l'épuisement des ressources en eau, tandis que ReCiPe 2016 inclut la consommation d'eau. Les deux méthodes n'utilisent pas les mêmes modèles d'impact pour chaque catégorie d'impact, à quelques exceptions près, tels que l'indicateur du changement climatique basé sur le modèle d'IPPC (2013) ou l'appauvrissement de la couche d'ozone basé sur le modèle du WMO (2011) pour les deux méthodes. Leur comparaison revêt ainsi une importance cruciale pour confirmer les résultats obtenus.

La comparaison des deux méthodes (Figure 3a et c) a été effectuée pour le cas de Mouans-Sartoux et ses analyses détaillées de contribution d'impact. Les résultats montrent des différences mineures sur la distribution globale, avec quelques exceptions pour les indicateurs de toxicité et d'épuisement des ressources fossiles et minérales. Plus précisément, la contribution du transport fluctue selon la méthode utilisée. En ce qui concerne les produits importés (Figure 3b et d), des différences sont observées pour ces mêmes indicateurs, avec une augmentation de la contribution des produits ultra-transformés et des desserts pour la méthode ReCiPe 2016.

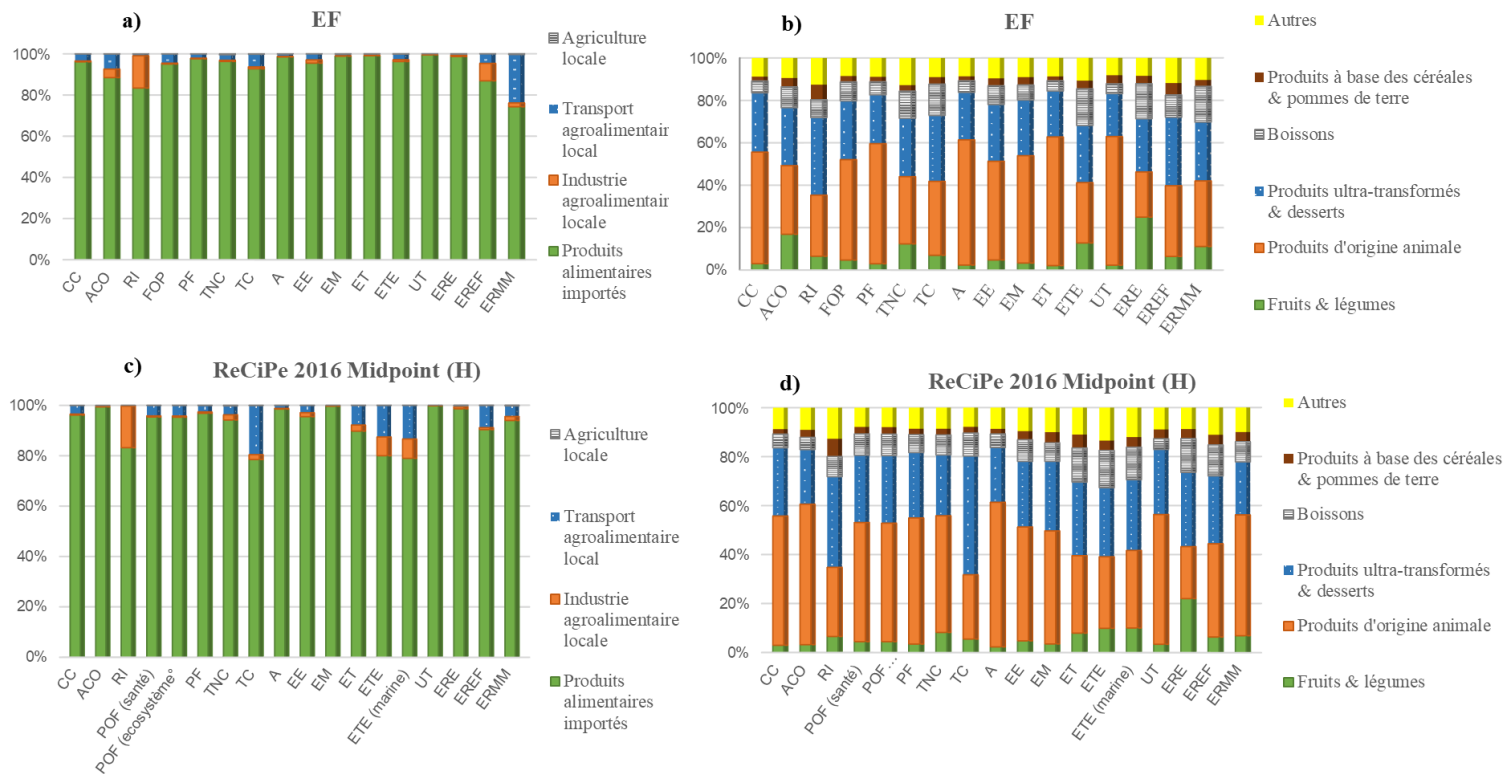


Figure 3. Comparaison de la méthode de modélisation utilisée entre la méthode ReCiPe 2016 (c et d) et méthode EF 3.0 (a et b) sur la contribution des activités majeures à l'impact global (a et c) et la contribution des catégories alimentaires à l'impact des produits importés (b et d). Abréviations : CC = Changement climatique ; ACO = Appauvrissement de la couche d'ozone ; RI = Radiation ionisante, effet sur la santé ; FOP = Formation photochimique d'ozone ; PF = Particules fines ; TNC = Effets toxicologiques sur la santé humaine : substances non-cancérogènes ; TC = Effets toxicologiques sur la santé humaine : substances cancérogènes ; A = Acidification ; EE = Eutrophisation, eau douce ; EM = Eutrophisation, marine ; ET = Eutrophisation, terrestre ; ETE = Ecotoxicité d'eau douce ; UT = Usage des terres ; ERE = Épuisement des ressources en eau ; EREF = Épuisement des ressources énergétiques fossiles ; ERMM = Épuisement des ressources minérales et des métaux

Monte-Carlo

La mise en œuvre de l'analyse de Monte-Carlo, visant à quantifier les incertitudes des résultats, demeure compliquée pour l'ACV-T en raison du manque des données d'incertitude relatives à l'ensemble des paramètres. Elle peut néanmoins être menée pour définir l'incertitude globale pour une partie des données d'entrée. Cela se fait uniquement avec les données d'incertitude présentes au sein des bases d'ACV utilisées. Bien qu'une grande partie de données n'ait pas été examinée, cette analyse permet toutefois d'identifier des indicateurs d'ACV dont l'incertitude est trop élevée, nécessitant une interprétation prudente.

La Figure 4 présente les intervalles d'incertitude calculés par la méthode Monte-Carlone pour l'impact global du système alimentaire de Mouans-Sartoux, pour chaque indicateur et pour les deux méthodes testées : a) EF 3.0 et b) ReCiPe 2016. Pour les deux méthodes, l'incertitude pour l'indicateur « effets toxicologiques des substances non-cancérogènes » est élevée. En effet, pour la méthode ReCiPe 2016, la valeur de l'impact global varie de -350 % à +550 % par rapport à la valeur initiale. Cet indicateur doit donc être utilisé avec précaution. Pour la méthode EF 3.0, les indicateurs d'épuisement des ressources d'eau et des ressources minérales fluctuent dans un intervalle entre -20 % et +20 %, et +10 % pour l'indicateur d'usage des terres. Pour la méthode ReCiPe 2016, l'incertitude est similaire pour la consommation d'eau, mais légèrement plus basse pour les indicateurs d'épuisement des ressources minérales et d'usages des terres (+-10 %). Pour les analyses détaillées des indicateurs sélectionnés dans le manuscrit, la méthode ReCiPe 2016 a ainsi été utilisée en complément de la méthode EF 3.0.

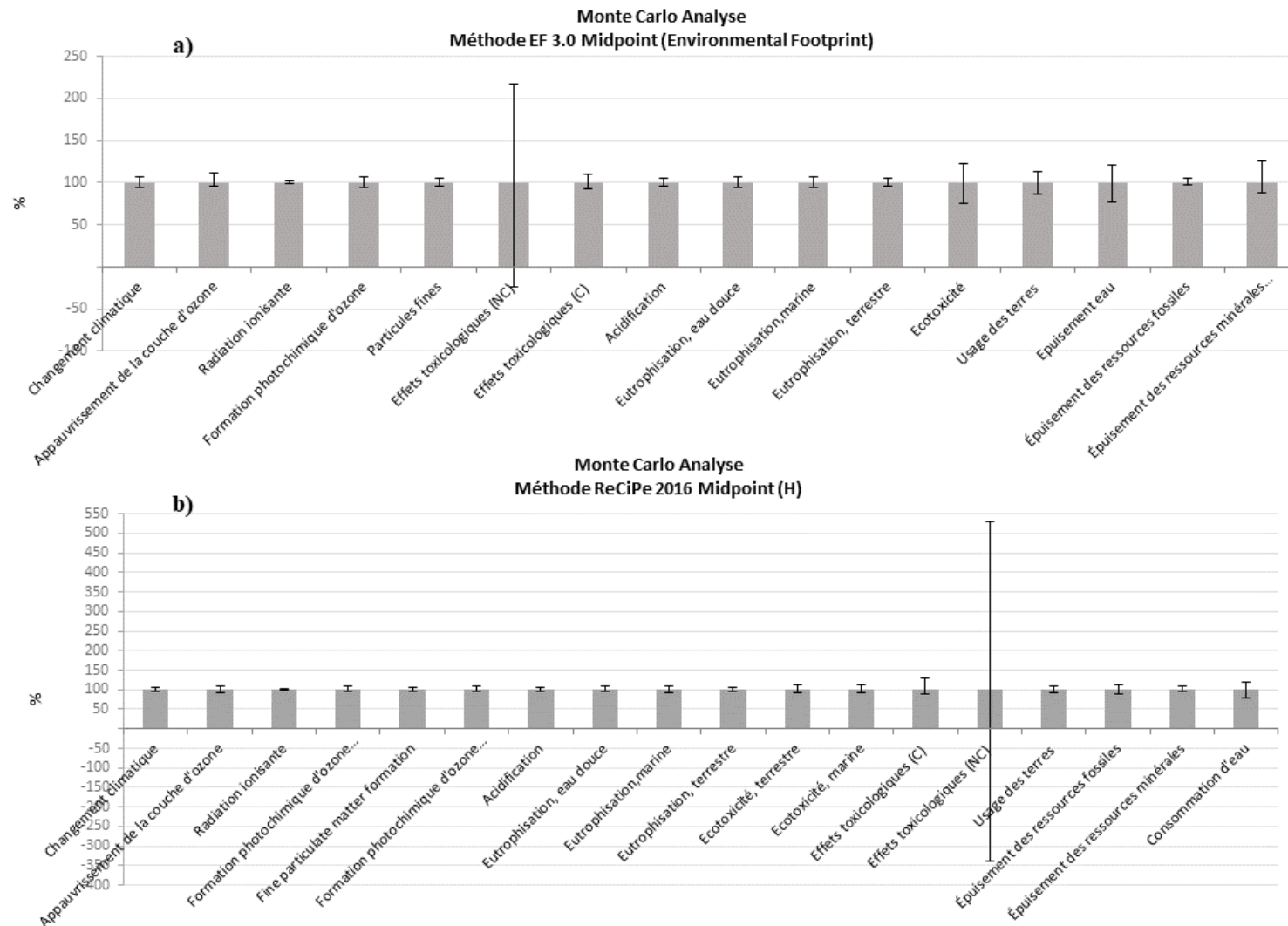


Figure 4. Analyse Monte-Carlo pour les résultats globaux de l'impact du système alimentaire de Mouans-Sartoux pour a) la méthode EF 3.0 et b) la méthode ReCiPe 2016 Midpoint

ANNEXE IV. QUESTIONNAIRES

Impact de la politique alimentaire de la ville sur les agriculteurs du territoire

Votre lien avec les actions de la ville de Mouans-Sartoux

1. Avez-vous participé à certaines actions portées par la Ville de Mouans-Sartoux ?

Plusieurs réponses possibles.

- La ville m'a aidé à trouver ou à aménager le foncier agricole
- Je travaille pour la régie agricole
- Je participe au marché de producteurs de la ville
- La ville m'a aidé à trouver des débouchés (AMAP, l'épicerie Boomerang...)
- La ville communique sur mon activité et mes produits
- La ville a sollicité mon expertise/ mes connaissances ou mon expérience
- Aucune de ces actions

2. Plus spécifiquement, pouvez vous nous présenter rapidement les activités liées au(x) projet(s) avec la MEAD/ ville de Mouans-Sartoux?

Votre exploitation

3. Pouvez-vous présenter rapidement votre exploitation, vos ateliers ?

SAU par atelier, type et nb de cultures majoritaires, d'élevage, date d'installation, surface...

4. Pouvez-vous estimer le volume moyen produit annuellement (par culture si possible)

5. Certains de vos produits sont-ils certifiés ?

Plusieurs réponses possibles.

- Oui, par une indication géographique (AOP, AOC, IGP)
- Oui, par un label de qualité (Label Rouge, etc.)
- Oui, en agriculture biologique ou équivalent (AB, Nature & Progrès, etc.)
- Oui, en biodynamie (Déméter, etc)
- Oui, Haute Valeur Environnementale, niveau I ou II
- Oui, Haute Valeur Environnementale, niveau III option A
- Oui, Haute Valeur Environnementale, niveau III option B
- Autre : _____

6. Si oui, depuis quand êtes-vous engagé(e) dans ces certifications ?

Pratiques au champs

7. Vos pratiques au champ ou post-récolte ont-elles évolué ces 5 dernières années ? De quelle manière ?

Pratiques pouvant être concernées : fertilisation, traitements phytos, gestion de l'eau, longueur des rotations, travail du sol, espèces/varieties semées, santé animale, alimentation des animaux, plantation de haies, etc.

8. Ces changements ont-ils été influencé par les projets en lien avec la ville ou par sa politique en général?

Sinon, qu'est-ce qui a influencé votre changement?

Impact de la politique alimentaire de Mouans-Sartoux

9. Grâce au(x) projet(s) avec la ville, vous sentez-vous plus concerné(e)/investi(e) par :

Plusieurs réponses possibles.

- Le changement climatique
- Le bien-être animal
- Les impacts sur l'environnement
- Les conditions de vie de votre famille ou de vos employés
- La santé
- Protection de l'eau
- Les impacts de la pollution chimique
- Pollution diffuse
- Je ne me sens pas plus concerné qu'avant

10. En bilan, pensez-vous que la politique alimentaire de la ville ont eu une influence sur l'évolution de vos pratiques?

Plusieurs réponses possibles.

- Oui, sur le développement des pratiques plus respectueuses de l'environnement
- Oui, sur le mode de valorisation de mes produits
- Oui, sur les pratiques d'adaptation au changement climatique
- Oui, sur ma résilience vis-à-vis des aléas climatiques ou économiques
- Oui, sur ma capacité à produire
- Oui, sur mon autonomie (vis-à-vis des services, intrants, main d'oeuvre)
- Oui, sur la prise de conscience des enjeux sociaux et environnementaux mondiaux
- Oui, sur mon implication dans le tissu social et économique local
- Non, je ne le pense pas

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Impact de la politique alimentaire de la ville sur les acteurs économiques du territoire

Pour commencer...

1. Précisez votre entreprise et votre poste/métier :

2. En particulier, avez-vous participé à/bénéficié des projets suivants en lien avec la ville de Mouans-Sartoux:

Plusieurs réponses possibles.

- J'ai un partenariat avec la ville/ la MEAD/ CCAS..
- Je livre à la restauration collective (cantine des écoles primaires ou des crèches...)
- Je participe au projet "Alimentation durable dans l'entreprise" mené par le club d'entrepreneurs du Pays de Grasse
- La ville communique sur mon activité et mes produits
- La ville m'a aidé à trouver des débouchés/ des fournisseurs (contact agriculteurs...)
- Je n'ai participé à aucune de ces actions

3. La participation à cette action a-t-elle eu l'influence sur votre activité professionnelle?

Démarche environnementale

4. Votre entreprise possède-t-elle un label d'engagement pour l'environnement, le climat ou la biodiversité ? (ex : une certification ECOCERT)

Une seule réponse possible.

- Oui, grâce à la participation à un des projets avec la ville
- Oui, mais sans lien avec la ville
- Non

5. Si oui, pouvez vous préciser la/les certification(s) en question:

6. Avez-vous mis en place un programme dédié à l'optimisation énergétique ou à la diminution des émissions des gaz à effet de serre ?

Une seule réponse possible.

- Oui
- Non

7. Avez vous réussi à diminuer vos consommations d'énergie depuis ces dernières années ?

Une seule réponse possible.

Oui

Non

8. Pouvez-vous indiquer vos consommations énergétiques annuelles (ou estimations) en MWh/ an ou en euro pour la consommation d'électricité et le chauffage ainsi que le fournisseur ou la source d'énergie associée?

9. Pouvez-vous préciser s'il existe d'autres actions en faveur de l'environnement menées par votre établissement

10. Approvisionnez-vous par des produits bio et locaux? Si oui, pouvez-vous développer (fournisseurs, distances...)

Influence de la ville

11. Diriez-vous que la politique alimentaire de la ville a-t-elle eu l'influence sur un de ces composants:

Plusieurs réponses possibles.

- Oui, sur mon installation sur le territoire
 - Oui, sur le changement en faveur de la durabilité (consommations énergétiques, labels...)
 - Oui, sur le choix de produits (produits biologiques ou locaux)
 - Oui, sur ma résilience face à différents chocs et menaces
 - Peut-être
 - Non, du tout
-

Ce contenu n'est ni rédigé, ni cautionné par Google.

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Manger à Mouans-Sartoux

1. Quel âge avez-vous ?

Une seule réponse possible.

- Moins de 15 ans
- Entre 15 à 24 ans
- Entre 25 à 34 ans
- Entre 35 à 49 ans
- Entre 50 et 64 ans
- Plus de 65 ans

2. Vous êtes :

Une seule réponse possible.

- un homme
- une femme
- Autre : _____

3. Vous êtes :

Une seule réponse possible.

- Agriculteur exploitant
- Artisan, commerçant, chef d'entreprise
- Cadre ou profession intellectuelle supérieure
- Profession intermédiaire
- Employé
- Ouvrier
- Retraité
- Etudiant
- Sans activité professionnelle

Déplacements pour faire les courses alimentaires

4. Où avez-vous l'habitude de faire vos courses alimentaire ?

Plusieurs réponses possibles.

	Supermarché ou hypermarché	Epicerie, alimentation générale, magasin spécialisé (poissonnerie, boucherie, etc)	Magasins alimentaires bio	AMAP et autres systèmes de paniers	Marchés	A la ferme	Autre
Principalement	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Régulièrement	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
ça m'arrive	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

5. Comment allez-vous principalement faire vos courses alimentaires?

Une seule réponse possible par ligne.

	En voiture/ moto	En transport en commun	A vélo / pied
Il y a 5 ans	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Aujourd'hui	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

6. A quelle fréquence utilisez-vous ce mode de transport pour aller faire vos courses alimentaires?

Une seule réponse possible par ligne.

	Moins d'1 fois toutes les 2 semaines	1 fois toutes les 2 semaines	1 fois par semaine	2 fois par semaine	Plus de 2 fois par semaine
Il y a 5 ans	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Aujourd'hui	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

7. Quelle distance (approximative)* parcourez-vous pour aller faire vos courses alimentaires (aller-retour)?

*si vous effectuez vos courses alimentaires sur votre chemin au travail/école etc. veuillez indiquer la distance EN PLUS que vous parcourez pour aller au magasin

Une seule réponse possible par ligne.

	< 3 km	3-6 km	6-10 km	10-15 km	> 15 km
Il y a 5 ans	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Aujourd'hui	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

8. Comment définissez-vous l'évolution de votre régime au cours des 5 dernières années ?

Une seule réponse possible par ligne.

	Il y a 5 ans	APRES le changement
Omnivore, et grand consommateur de viande (l'équivalent de + d'1 steak haché par jour)	<input type="radio"/>	<input type="radio"/>
Omnivore et consommateur modéré de viande (l'équivalent d'un demi à 1 steak haché par jour)	<input type="radio"/>	<input type="radio"/>
Omnivore, et mangeur de viande occasionnel (moins d'un demi steak haché par jour)	<input type="radio"/>	<input type="radio"/>
Je suis pescétarien : Je ne consomme pas de viande mais du poisson et des produits animaux : lait, crème, beurre, oeuf...	<input type="radio"/>	<input type="radio"/>
Je suis végétarien : Je ne consomme pas	<input type="radio"/>	<input type="radio"/>

**de viande ni de
poisson, mais des
produits animaux :
lait, crème, beurre,
oeuf...**

**Je suis végétalien : Je
ne consomme pas de
viande, ni poisson, ni
produits animaux**

10. Mangez vous des produits bio ? Si oui, pour quelle catégorie d'aliments ?

Une seule réponse possible par ligne.

	Oui, parfois bio mais cela reste minoritaire	Oui, majoritairement bio	Très peu ou pas du tout
Viande	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Produits laitiers & oeufs	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Légumes & fruits	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Céréales (pâtes, riz.) & pommes de terre	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

11. Votre consommation de ces produits bio a-t-elle évolué au cours des 5 dernières années?

Une seule réponse possible.

- J'en consomme au moins deux fois moins
- J'en consomme un peu moins
- Non elle n'a pas changé
- J'en consomme un peu plus qu'avant
- J'en consomme au moins deux fois plus qu'avant

12. Y-a-t-il des produits que vous achetez en VRAC ? (sans emballage)

Plusieurs réponses possibles.

- Fruits & Légumes
- Céréales (pâtes, riz..)
- Fromages (à la coupe plutôt que déjà emballé)
- Viandes (à la boucherie plutôt que déjà emballé)
- Je bois l'eau du robinet au lieu d'acheter les bouteilles d'eau
- D'autres boissons/liquide (vin, huile...)
- Je n'achète pas des produits en vrac

13. Quelle est la proportion de ces produits achetés en vrac il y a 5 ans et aujourd'hui?

Plusieurs réponses possibles.

	Très minime	Petite (environ 1/4 des produits achetés)	Environ la MOITIE des produits achetés	Importante (plus de 3/4 des produits achetés)
Il y a 5 ans	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Aujourd'hui	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

14. Quelle est la proportion des produits de saison dans votre panier alimentaire il y a 5 ans et aujourd'hui? (légumes d'été, d'hiver..)

Plusieurs réponses possibles.

	Très minime	Petite (environ 1/4 des produits achetés)	Environ la MOITIE des produits achetés	Importante (plus de 3/4 des produits achetés)
Il y a 5 ans	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Aujourd'hui	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Gaspillage alimentaire

15. Comment gérez-vous vos déchets alimentaires (le reste de repas, les épluchures, les produits périmés, ...) ?

Une seule réponse possible.

- Compost individuel
- Compost collectif
- Poubelle ordinaire
- Collecte de biodéchets par la collectivité

16. Le gaspillage alimentaire moyen par français représente environ 30% de la nourriture achetée ! Concernant votre ménage, vous diriez qu'entre les produits périmés, les fruits oubliés et les restes des repas non consommés, la part d'aliments jetée à la poubelle s'élève à (approximativement) à quelle proportion avant et après votre changement (lors ces 5 dernières années) ?

Une seule réponse possible par ligne.

	>10 %	10 - 30%	environ 30%	30 - 50%	Plus de la moitié de la nourriture achetée (ou reçue) est jeté
Avant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Après	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

17. Quels sont les produits qu'aujourd'hui vous gaspillez moins qu'il y a 5 ans?

Plusieurs réponses possibles.

- Fruits & légumes
- Produits laitiers /poisson / viande
- Produits transformés (pain, chocolat, plats préparés...)

Influence de la politique alimentaire de la ville

18. Pensez-vous que les actions de la ville et sa politique alimentaire ont eu une influence sur l'évolution de vos habitudes alimentaires (courses, menus, gaspillage, etc) ?

Plusieurs réponses possibles.

- Oui, sur le lieu d'achat (grande surface, marché...)
- Oui, sur le transport (mode/distance de déplacement)
- Oui, sur le changement des régimes alimentaires (plus ou moins de viande, de légumes..)
- Oui, sur la consommation des produits bio
- Oui, sur l'achat des produits en vrac
- Oui, sur l'achat des produits de saison
- Oui, sur le compostage
- Oui, sur le gaspillage alimentaire
- Oui, sur mes connaissances sur l'alimentation durable
- Non, je ne pense pas être influencé par les actions de la ville

19. Avez-vous participé aux actions listées ci-dessous ? (cochez toutes celles qui vous concernent de près ou de loin)

Plusieurs réponses possibles.

- Votre ou vos enfant(s) fréquente(nt) ou ont fréquenté la cantine scolaire d'une école de la ville
- Vous ou un membre de votre famille fréquente l'épicerie sociale
- Vous ou un membre de votre famille a participé au défi Foyer à Alimentation Positive
- Vous fréquentez le marché des producteurs de la ville du mercredi soir
- Vous participez au projet "Le citoyen nourrit la ville"
- Vous avez participé à un évènement du projet "Alimentation durable en entreprise"
- Vous avez participé à un évènement organisé par la Maison de l'Education à l'Alimentation Durable (MEAD) : Printemps des possibles, Festival Alimenterre...