GENERAL FICHE – ORGANIC SYSTEMS

Data extracted in October 2021

Note to the reader: This *general fiche* summarises all the environmental and climate impacts of organic systems and specifically on organic livestock systems, found in a review of 30 synthesis research papers[1]. These papers were selected, according to our inclusion criteria, from an initial number of 220 obtained through a systematic literature search strategy[2].

The general fiche provides the highest level of synthesis – symbolised by the top of the pyramid. As each synthesis research paper involves a number of individual research papers ranging from 7 to 164 (often around 50), the assessment of impacts relies on a large number of results obtained mainly from real farms, field experiments (carried out by scientists in situations close to real farming environment), and sometimes from model simulations (e.g. by life cycle analysis including accounting for all 'cradle-to-farm gate' activities). In addition to this general fiche, *single-impact fiches* provide a deeper insight in each individual impact of organic systems (e.g. on carbon sequestration, on biodiversity, etc.), with more detailed information – medium part of the pyramid. Finally, *individual reports* provide thorough information about the results reported in each synthesis paper, in particular about the modulation of effects by factors related to soil, climate and management practices – base of the pyramid .

This general fiche on organic systems is part of a set of similar fiches providing a comprehensive picture of the impacts of farming practices on climate and environment.

1. DESCRIPTION OF THE FARMING PRACTICE

Description	Organic production is an overall system of farm management and food production that combines best environmental and climate action practices, a high level of biodiversity, the preservation of natural resources and the application of high animal welfare standards and high production standards in line with the demand of a growing number of consumers for products produced using natural substances and processes. [3]
Key descriptors	• Organic farming systems are production systems which avoid or largely **exclude** the use of synthetically compounded fertilizers, pesticides, growth regulators and livestock feed additives [4].Unlike the other farming practices, discussed in the other fiches, organic systems do not consist of a single practice, but of a combination of several "elementary" farming practices, which need to be respected together. Organic systems are defined by the REGULATION (EU) 2018/848 [3]. • To the maximum extent feasible, organic systems (significantly more frequently than conventional farming according to a recent meta-analysis by Alvarez, 2021 [5]) **rely on**

[1] Synthesis research papers include either meta-analysis or systematic reviews with quantitative results.
[2] For further details on the search strategy and inclusion criteria, see section 4 in single-impact fiches.
[3] REGULATION (EU) 2018/848.
https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32018R0848&from=EN
[4] https://doi.org/10.1016/B0-12-227050-9/00235-0 and https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/organic-farming-system
[5] https://doi.org/ 10.1080/03650340.2021.1946040

	crop rotations, multicropping, crop residues retention, no/minimum tillage, animal manures, green manures, off-farm organic wastes and aspects of biological pest control to maintain soil productivity and tilth, to supply plant nutrients and to control insects, weeds and other pests [4].
	• This review **compares** the impacts of organic and conventional farming systems. The following types of results are included:
	  o Results of field experiments designed by researchers, comparing plots under organic and conventional management.
	  o Results of field data or farm-scale surveys on organic and conventional systems, designed and managed by farmers.
	  o Results of life-cycle assessments, typically considering a cradle-to-farmgate model.
	• Results were grouped into two categories:
	  o Organic cropping systems (including all different types of organic systems), excluding results reported specifically on livestock production.
	  o Organic livestock systems, reports specific results where livestock production is the focus, including farms with forage/fodder production dedicated to in-farm livestock production and mixed farming systems (co-production of cash crops and forage/fodder/livestock in the same farm).
	• In all reviewed synthesis papers, results are expressed in two different units:
	  o per unit of cultivated area (e.g., per ha)
	  o per unit of product (e.g., per kg of grain).
	Since organic systems generally result in lower yields than conventional systems, the effects per unit of product may be different to those per unit of area. Consequently, where available, both types of results are reported in the Table 1.

2. DESCRIPTION OF THE IMPACTS OF THE FARMING PRACTICE ON ENVIRONMENT AND CLIMATE

The table below shows the number of synthesis papers reporting positive, negative or no effect, based on the statistical comparison of the intervention and the control. In addition, we include the number of synthesis papers reporting relevant results, but without statistical test of the effects (here labelled as uncertain). For each impact, the effect with the higher score is marked in bold and the cell coloured. The numbers between parentheses indicate the number of synthesis papers with a quality score of at least 50%. Details on quality criteria can be found in this document →.

Out of the 30 synthesis papers selected, 28 reported studies conducted in Europe and 26 have a quality score higher than 50%. Some synthesis papers reported more than one impact.

Impact	Metric	Impacts per unit of agricultural land				Impacts per unit of product			
		Positive	Negative	No effect	Uncertain	Positive	Negative	No effect	Uncertain
Organic cropping systems									
Increase Acidification						0	1 (1)	1 (1)	1 (1)
Decrease Ammonia emission		0	0	1 (1)	0	0	0	1 (1)	0
Increase Biodiversity		9 (9)	1 (1)	1 (1)	1 (0)				
Increase Carbon sequestration		7 (6)	0	0	2 (1)				
Decrease Energy use						3 (3)	2 (1)	2 (1)	1 (1)
Decrease Eutrophication						0	1 (1)	2 (2)	1 (1)
Decrease GHG emissions	Aggregated* GHG emissions					1 (1)	0	3 (2)	1 (1)
	CH_4 emission	1 (1)	0	0	1 (1)	1 (1)	0	0	1 (1)
	N_2O emission	2 (2)	0	0	1 (1)	0	1 (1)	1 (1)	1 (1)
Decrease Nutrients loss	Nitrogen	2 (2)	0	0	0	0	1 (1)	1 (1)	0
	Phosphorous	0	0	2 (2)	0				
Increase Pest and disease control	Natural enemies of pests	2 (2)	0	0	0				
	Pests per unit of area	0	2 (2)	0	0				
Improve Soil biological quality		1 (1)	0	0	1 (0)				
Increase Soil nutrients		0	0	0	1 (0)				
Increase Crop yield	Main cash crop yield **	0	9 (9)	2 (2)	1 (1)				
	Crop yield stability along years	0	1 (1)	2 (2)	0				
Decrease Agricultural land use per unit of product***						0	3 (3)	0	1 (1)
Organic livestock systems									
Decrease Acidification						0	1 (1)	1 (1)	1 (1)
Increase Carbon sequestration		2 (2)	0	1 (1)	0				
Decrease Energy use						1 (1)	0	2 (1)	1 (1)
Decrease Eutrophication						0	1 (1)	1 (1)	1 (1)
Decrease GHG emissions	Aggregated GHG emissions	1 (1)	0	0	0	0	1 (0)	3 (2)	1 (1)
	CH_4 emission	1 (1)	0	0	0				
	N_2O emission	1 (1)	0	0	0				
Decrease Nutrients loss	Nitrogen	0	0	1 (1)	0				
Decrease Agricultural land use per unit of product***						0	2 (2)	0	1 (1)

* Emissions (including contributions of all GHG emissions sources, as CO_2-equivalents) are typically accounted for all 'cradle-to-farm gate' activities, using life cycle analysis (LCA), to assess the performance of organic systems in comparison to conventional systems.
** Crop yield is typically measured for cash crops only, as total biomass or target crop produce harvested per hectare per year. Research studies typically do not account for co-productions of fodder/forage through crop diversification techniques (rotations, multicropping, cover crops), which were found to be significantly more frequent in organic farming systems (Alvarez, 2021, ref. 30). One study (Ponisio et al, 2015, ref. 13) reports that yield gaps of organic versus conventional farming drop from -25% to -8%, when considering full productivity of diversification techniques (multi-cropping and crop rotations, respectively).
*** Agricultural land use per unit of product (also called Agricultural land use efficiency) is calculated (typically by LCA approaches) as the ratio between the total land used and the total amount of target food products obtained along the whole production chain. For crops production systems only, this impact is nearly equivalent to crop yield.

3. DESCRIPTION OF THE KEY FACTORS INFLUENCING THE SIZE OF THE EFFECT

Only the factors explicitly studied in the reviewed synthesis papers are reported below. Details regarding the factors can be found in the *individual reports* following the hyperlinks (→ or refX).

IMPACTS	FACTORS
Increase biodiversity →	Landscape structure and heterogeneity (ref 28),Taxon (ref 20),Pest management strategies (ref 2),Herbicide application (ref 2),Addition of compost (ref 2),Diversity of cover crops (ref 2),Experiment scale (ref 14),Crop field size (ref 1),Organism group (ref 16),Proportion of arable land in the surrounding landscape (ref 16),Crop type (ref 16).
Increase carbon sequestration →	C input (ref 18),Soil disturbance (ref 18),Fertilisation intensity (ref 5),Climate (ref 5),External C input (ref 22),Clay concentrations in soils (ref 22),Mean annual temperature (ref 22),Mean annual precipitation (ref 22),External C inputs (ref 22),Crop rotation (ref 22),External N input (ref 22),Legume forages (ref 22),Plough depth (ref 27),Organic input (ref 27),Crop residues incorporation (ref 27),Land use type (ref 27),Region (or certification guidelines) (ref 4),Crop type (ref 4),Input of organic matter (ref 24),Presence of leys in the rotation (ref 24)
Decrease eutrophication →	Quantity and type of fertilizer (ref1)
Reduction of energy use →	Type of product (ref 12),Cropping pattern (ref 12),Data sample size (ref 12),Production of mineral fertilisers (ref 24)
Decrease of GHG emissions →	Product/area unit (ref 12),Per unit of field area: Positive; Per unit of product: Negative. (ref 15)
Decrease nutrient loss →	Fertilisation regime (ref 27),Crop diversification strategies (ref 27),C/N ratio of fertilisers (ref 27),Livestock density (ref 27),Nitrogen input (ref 24)
Increase pest- and disease- control →	Pests type (ref 25),Crop type (ref 25 7),Presence of pest management (ref 25),Experiment scale (ref 25),Study type (ref 7)
Improve soil biological quality →	Fertilisation (ref 29),Diversification strategies (ref 29),Pesticides use (ref 29),Tillage (ref 29)
Increase crop yield →	Fertilisation regime (ref 6),Crop diversification strategies (ref 13),Multicropping, crop rotations and the use of cover crops reduce the yield gaps of organic farming. (ref 13),Nitrogen input (ref 23),Water management (ref 23),Type of crop (ref 23),Soil pH (ref 23),Best practices (ref 23),Negative effect (ref 1),Fertilisation (ref 30)

4. PREVIOUS IMPLEMENTATION

GAEC Cross compliance	
Greening	
Rural development measure – submeasure	

5. PICTURES

Pictures are not relevant in this case.

6. LINKS TO OTHER RELEVANT COMPLEMENTARY INFORMATION

We include in this section the links to other complementary sources of information (not peer-reviewed meta-analyses or systematic reviews), provided by AGRI or other stakeholders.

7. LIST OF SYNTHESIS PAPERS INCLUDED IN THE REVIEW OF THE FARMING PRACTICE IMPACTS

Authors	Year	Article Title	Source Title	DOI
Crowder, DW; Northfield, TD; Gomulkiewicz, R; Snyder, WE.	2012	Conserving and promoting evenness: organic farming and fire-based wildland management as case studies.	Ecology 93: 2001–2007.	10.1890/12-0110.1
Garcia-Palacios, P; Gattinger, A; Bracht-Jorgensen, H; Brussaard, L; Carvalho, F; Castro, H; Clement, JC; De Deyn, G; D'Hertefeldt, T; Foulquier, A; Hedlund, K; Lavorel, S; Legay, N; Lori, M; Mader, P; Martinez-Garcia, LB; da Silva, P; Muller, A; Nascimento, E; Reis, F; Symanczik, S; Sousa, J; Milla, R.	2018	Crop traits drive soil carbon sequestration under organic farming	Journal of Applied Ecology 30, 1–10.	10.1111/1365-2664.13113
Gattinger A; Muller A; Haeni M; Skinner C; Fliessbach A; Buchmann N; Mäder P; Stolze M; Smith P; El-Hage Scialabba N; Niggli U.	2012	Enhanced top soil carbon stocks under organic farming	PNAS 109 (44), 18226-18231.	10.1073/pnas.1209429109
Katayama, N; Bouam, I; Koshida, C; Baba, YG	2019	Biodiversity and yield under different land-use types in orchard/vineyard landscapes: A meta-analysis.	BIOLOGICAL CONSERVATION 229, 125-133	10.1016/j.biocon.2018.11.020
Lichtenberg, EM; Kennedy, CM; Kremen, C; Batary, P; Berendse, F; Bommarco, R; Bosque-Perez, NA; Carvalheiro, LG; Snyder, WE; Williams, NM; Winfree, R; Klatt, BK; Astrom, S; Benjamin, F; Brittain, C; Chaplin-Kramer, R; Clough, Y; Danforth, B; Diekotter, T; Eigenbrode, SD; Ekroos, J; Elle, E; Freitas, BM; Fukuda, Y; Gaines-Day, HR; Grab, H; Gratton, C; Holzschuh, A; Isaacs, R; Isaia, M; Jha, S; Jonason, D; Jones, VP; Klein, AM; Krauss, J; Letourneau, DK; Macfadyen,	2017	A global synthesis of the effects of diversified farming systems on arthropod diversity within fields and across agricultural landscapes.	23, 11, 4946-4957.	10.1111/gcb.13714

S; Mallinger, RE; Martin, EA; Martinez, E; Memmott, J; Morandin, L; Neame, L; Otieno, M; Park, MG; Pfiffner, L; Pocock, MJO; Ponce, C; Potts, SG; Poveda, K; Ramos, M; Rosenheim, JA; Rundlof, M; Sardinas, H; Saunders, ME; Schon, NL; Sciligo, AR; Sidhu, CS; Steffan-Dewenter, I; Tscharntke, T; Vesely, M; Weisser, WW; Wilson, JK; Crowder, DW.				
Smith, OM; Cohen, AL; Reganold, JP; Jones, MS; Orpet, RJ; Taylor, JM; Thurman, JH; Cornell, KA; Olsson, RL; Ge, Y; Kennedy, CM; Crowder, DW	2020	Landscape context affects the sustainability of organic farming systems	PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA 117 6, 2870-2878	10.1073/pnas.1906909117
Smith, OM; Cohen, AL; Rieser, CJ; Davis, AG; Taylor, JM; Adesanya, AW; Jones, MS; Meier, AR; Reganold, JP; Orpet, RJ; Northfield, TD; Crowder, DW	2019	Organic Farming Provides Reliable Environmental Benefits but Increases Variability in Crop Yields: A Global Meta-Analysis	FRONTIERS IN SUSTAINABLE FOOD SYSTEMS 3	10.3389/fsufs.2019.00082
Tuomisto HL; Hodge ID; Riordana P; Macdonald DW	2012	Does organic farming reduce environmental impacts? – A meta-analysis of European research	Journal of Environmental Management 112, 309-320	10.1016/j.jenvman.2012.08.018
Ugarte, CM; Kwon, H; Andrews, SS; Wander, MM.	2014	A meta-analysis of soil organic matter response to soil management practices: An approach to evaluate conservation indicators	Journal of soil and water conservation 69, 422-430	10.2489/jswc.69.5.422
Knapp, S; van der Heijden, MGA.	2018	A global meta-analysis of yield stability in organic and conservation agriculture.	NATURE COMMUNICATIONS 9, 3632	10.1038/s41467-018-05956-1
Ponisio, LC; M'Gonigle, LK; Mace, KC; Palomino, J; de Valpine, P; Kremen, C	2015	Diversification practices reduce organic to conventional yield gap	Proc. R. Soc. B 282, 20141396	10.1098/rspb.2014.1396
Muneret, L; Mitchell, M; Seufert, V; Aviron, S; Djoudi, E; Petillon, J; Plantegenest, M; Thiery, D; Rusch, A.	2018	Evidence that organic farming promotes pest control	Nature Sustainability 1, 361-368	10.1038/s41893-018-0102-4
Seufert, V; Ramankutty, N; Foley, JA	2012	Comparing the yields of organic and conventional agriculture	NATURE 485, 229–232.	10.1038/nature11069
Wilcox, JC; Barbottin, A; Durant, D; Tichit, M; Makowski, D.	2013	Farmland Birds and Arable Farming, a Meta-Analysis.	Sustainable Agriculture Reviews 13: 35-63.	10.1007/978-3-319-00915-5_3
Doring, J; Collins, C; Frisch, M; Kauer, R	2019	Organic and Biodynamic Viticulture Affect Biodiversity and Properties of Vine and Wine: A Systematic Quantitative Review	AMERICAN JOURNAL OF ENOLOGY AND VITICULTURE 70 3, 221-242	10.5344/ajev.2019.18047
de Ponti T., Rijk B., van Ittersum M.K.	2012	The crop yield gap between organic and conventional agriculture.	AGRICULTURAL SYSTEMS 108, 1–9	10.1016/j.agsy.2011.12.004
Kaschuk, G; Alberton, O; Hungria, M.	2010	Three decades of soil microbial biomass studies in Brazilian ecosystems: Lessons learned about soil quality and indications for improving sustainability.	Soil Biology & Biochemistry 42: 1–13.	10.1016/j.soilbio.2009.08.020
Montañez, MN; Amarillo-Suárez, A.	2014	Impact of organic crops on the diversity of insects: a review of recent research.	Revista Colombiana de Entomología 40: 131 - 142.	NA
Aguilera, E; Lassaletta, L; Gattinger, A; Gimeno, BS.	2013	Managing soil carbon for climate change mitigation and adaptation in Mediterranean cropping systems: A meta-analysis	AGRICULTURE ECOSYSTEMS & ENVIRONMENT 168, 25-36.	10.1016/j.agee.2013.02.003
Bengtsson, J; Ahnstrom, J; Weibull, AC.	2005	The effects of organic agriculture on biodiversity and abundance: a meta-analysis.	Journal of Applied Ecology 42: 261-269.	10.1111/j.1365-2664.2005.01005.x
Garratt, MPD; Wright, DJ; Leather, SR.	2011	The effects of farming system and fertilisers on pests and natural enemies: A synthesis of current research	AGRICULTURE ECOSYSTEMS & ENVIRONMENT 141, 261-270.	10.1016/j.agee.2011.03.014
Kopittke, PM; Dalal RC; Finn D; Menzies NW	2016	Global changes in soil stocks of carbon, nitrogen, phosphorus, and sulphur as influenced by long-term agricultural production.	Global change biology 23, 2509-2519	10.1111/gcb.13513
Lee K.S., Choe Y.C., Park S.H.	2015	Measuring the environmental effects of organic farming: A meta-analysis of structural variables in empirical research	JOURNAL OF ENVIRONMENTAL	10.1016/j.jenvman.2015.07.021

			MANAGEMENT 162, 263-274.	
Lesur-Dumoulin, C; Malezieux, E; Ben-Ari, T; Langlais, C; Makowski, D.	2017	Lower average yields but similar yield variability in organic versus conventional horticulture. A meta-analysis.	Agronomy for Sustainable Development 37, 45	10.1007/s13593-017-0455-5
Mondelaers, K; Aertsens, J; Van Huylenbroeck, G.	2009	A meta-analysis of the differences in environmental impacts between organic and conventional farming	BRITISH FOOD JOURNAL 111 10, 1098-1119	10.1108/00070700910992925
Skinner, C; Gattinger, A; Muller, A; Mader, P; Fliessbach, A; Stolze, M; Ruser, R; Niggli, U.	2014	Greenhouse gas fluxes from agricultural soils under organic and non-organic management - A global meta-analysis	Science of the Total Environment 468–469, 553–563	10.1016/j.scitotenv.2013.08.098
Tuck, SL; Winqvist, C; Mota, F; Ahnstrom, J; Turnbull, LA; Bengtsson, J.	2014	Land-use intensity and the effects of organic farming on biodiversity: a hierarchical meta-analysis.	Journal of Applied Ecology 51: 746-755.	10.1111/1365-2664.12219
Puissant, J; Villenave, C; Chauvin, C; Plassard, C; Blanchart, E; Trap, J	2021	Quantification of the global impact of agricultural practices on soil nematodes: A meta-analysis	SOIL BIOLOGY & BIOCHEMISTRY, 161, 108383	10.1016/j.soilbio.2021.108383
Alvarez, R	2021	Comparing Productivity of Organic and Conventional Farming Systems: A Quantitative Review	ARCHIVES OF AGRONOMY AND SOIL SCIENCE	10.1080/03650340.2021.1946040
Clark, M; Tilman, D.	2017	Comparative analysis of environmental impacts of agricultural production systems, agricultural input efficiency, and food choice.	ENVIRONMENTAL RESEARCH LETTERS 12 6	10.1088/1748-9326/aa6cd5