GENERAL FICHE
INTERCROPPING

Data extracted in May 2021

Note to the reader: This *general fiche* summarises all the environmental and climate impacts of INTERCROPPING found in a systematic review of 25 synthesis research papers [1]. These papers were selected, according to our inclusion criteria, from an initial number of 111 yielded by 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 papers ranging from 11 to 180, the assessment of impacts relies on a large number of results obtained in field experiments (carried out in situations close to real farming environment).

In addition to this general fiche, *single-impact fiches* provide a deeper insight in each individual impact of INTERCROPPING (on Carbon sequestration, Nutrient use efficiency, Pest and disease control, Soil erosion, Soil nutrients, Water retention, and Crop yield), with more detailed information – medium part of the pyramid.

Finally, *individual reports* provide fuller 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 INTECROPPING is part of a set of similar fiches providing a comprehensive picture of the impacts of farming practices on climate and the environment.

1. DESCRIPTION OF THE FARMING PRACTICE

Description	<u>Intercropping</u> is a farming method that involves cultivating two or more crop species (i.e., crop mixture cropping) or genotypes (i.e., cultivar mixture cropping) in the same area and coexisting for a time so that they interact agronomically [3] [4].
Key descriptors	• This review **includes** different types of intercropping [2] [5]: - Mixed cropping: sowing multiple crop species or cultivars in the same field at the same time, in a mixture with a given seeding ratio but random spatial arrangement. - Row intercropping: sowing multiple crop species in the same field at the same time in alternate rows. - Strip intercropping: sowing two (or more) crop species in the same field at the same time in multi-row strips wide enough to allow independent cultivation. - Relay cropping: intercropping of two crop species in which the second species is under-sown in the first at a later point in the growing season.

[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] Vandermeer, J. H. (1992). The ecology of intercropping. Cambridge University Press.
[4] Brooker, Rob W., et al. "Improving intercropping: a synthesis of research in agronomy, plant physiology and ecology." New Phytologist 206.1 (2015): 107-117.
[5] Ditzler, Lenora, et al. "Current research on the ecosystem service potential of legume inclusive cropping systems in Europe. A review." Agronomy for Sustainable Development 41.2 (2021): 1-13.

	• This review **includes** intercropping applied to cash crops, fodder (one study) and cover crops [6] (one study). • This review **does not include** alley cropping, i.e., the cultivation of food, forage or specialty crops between rows of trees, and dual-purpose cropping, i.e. the cultivation of two or more crops used for grazing by livestock and for grain. These two practices are assessed in separate sets of fiches (link).

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

We reviewed the impacts of intercropping compared to monoculture, i.e., the cultivation of one crop or cultivar.

The table below shows the number of synthesis papers reporting positive, negative, no effect, or uncertain effects. For each impact, the effect with the higher score is marked in bold and the cell coloured. The numbers between parenthesis 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 25 synthesis papers selected, 18 reported studies conducted in Europe. None of the synthesis studies exploring the impacts of intercropping on Carbon sequestration, Soil erosion, Soil nutrients and Water retention included experiments conducted in Europe. All synthesis papers have a quality score higher than 50%. Some synthesis papers reported more than one impact.

		All studies				**Only studies including EU**			
Impact	**Intervention**	**Positive**	**Negative**	**No effect**	**Uncertain**	**Positive**	**Negative**	**No effect**	**Uncertain**
Increase Carbon sequestration	Crop mixture	**1 (1)**	0	0	0	0	0	0	0
Increase Nutrient use efficiency	Crop mixture	**5 (5)**	0	1 (1)	0	**4 (4)**	0	0	0
Increase Pest and disease control	Crop mixture	**5 (5)**	0	1 (1)	0	**1 (1)**	0	0	0
	Cultivar mixture	**3 (3)**	0	1 (1)	0	**3 (3)**	0	1 (1)	0
Reduce Soil erosion	Crop mixture	**2 (2)**	0	1 (1)	0	0	0	0	0
Increase Soil nutrients	Crop mixture	**1 (1)**	0	**1 (1)**	0	0	0	0	0
Increase Water retention	Crop mixture	**1 (1)**	**1 (1)**	0	0	0	0	0	0
Increase Crop yield *	Crop mixture	**14 (14)**	2 (2) **	2 (2)	0	**9 (9)**	1(1) **	1 (1)	0
	Cultivar mixture	**3 (3)**	0	1 (1)	0	**3 (3)**	0	1 (1)	0

* Nine out of 19 studies measured crop yield as land equivalent ratio (LER), i.e., the ratio of the area under sole cropping to the area under intercropping needed to give equal amounts of yield at the same management level. It is generally calculated as the sum of the fractions of the intercropped yields divided by the sole-crop yields.
** These studies considered crop yield from only the main crop, instead of all crops included in the intercropping.

[6] Cover crops are plants that are planted to cover (and protect) the soil rather than for being harvested.

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

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

Impact	Factors
Increase Nutrient use efficiency	Crop/cultivar combinations (ref. 5, 2, 6), Sowing time (ref. 7, 2), Geographical area (ref. 7), Soil texture (ref. 14), Previous crop (ref. 14), Growing degree days (Climate) (ref. 14), Fertiliser application (ref. 2, 6), Method used to quantify Nitrogen fixation (ref. 6)
Increase Pest control	Crop/cultivar combinations (ref. 1, 23, 20), Crop type (ref. 1), Sowing density (ref. 23), Disease severity (ref. 23), Type of herbivore pest (ref. 11), Season (ref. 8), Pathogen species (ref. 8)
Increase Water retention	Soil depth (ref. 3)
Increase Crop yield	Crop type (ref. 10, 3, 13, 25, 18, 9), Disease severity (ref. 10, 13), Trait heterogeneity (ref. 10), Fertiliser application (ref. 16, 13, 5, 4, 18, 19, 2, 9), Pesticide use (ref. 16), Tillage (ref. 16), Crop/cultivar combinations (ref. 16, 13, 12, 5, 4, 20, 25, 19, 17, 2, 21, 9), Herbicide use (ref. 16), Soil organic matter (ref. 13, 7), Soil pH (ref. 13), Latitude (ref. 13, 25), Crop spatial arrangement (ref. 5, 19, 17), Sowing time (ref. 18, 7), Crop density (ref. 18, 19), Geographical area (ref. 7, 19), Soil texture (ref. 14, 9), Previous crop (ref. 14), Growing degree days (ref. 14), Climate (ref. 9), Temporal treatment establishment (ref. 9), Row distance (ref. 9)

4. IMPLEMENTATION IN THE PERIOD 2014-2020

GAEC Cross compliance	
Greening	
Rural development measure – submeasure	

5. PICTURES

Mixed intercropping (oat and rye)[7]

Row intercropping (corn and climbing bean)[8]

Strip intercropping (maize-soybean)[9]

Relay cropping (maize-wheat)[10]

6. LINKS TO OTHER RELEVANT COMPLEMENTARY INFORMATION

[7] Source: Wikipedia.

[8] Source: Lithourgidis, A. S., et al. "Annual intercrops: an alternative pathway for sustainable agriculture." Australian journal of crop science 5.4 (2011): 396-410.

[9] Source: Du, Jun-bo, et al. "Maize-soybean strip intercropping: Achieved a balance between high productivity and sustainability." Journal of integrative agriculture 17.4 (2018): 747-754.

[10] Source: Tanveer, Mohsin, et al. "Relay cropping as a sustainable approach: problems and opportunities for sustainable crop production." Environmental Science and Pollution Research 24.8 (2017): 6973-6988.

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

Number	Author	Year	Title	Reference	doi
1	Gibson, AK; Nguyen, AE	2021	Does genetic diversity protect host populations from parasites? A meta-analysis across natural and agricultural systems	Evol. Lett. 5, 16-32	10.1002/evl3.206
2	Tang, XY; Zhang, CC; Yu, Y; Shen, JB; van der Werf, W; Zhang, FS	2021	Intercropping legumes and cereals increases phosphorus use efficiency; a meta-analysis	Plant Soil 460, 89–104	10.1007/s11104-020-04768-x
3	Daryanto, S; Fu, BJ; Zhao, WW; Wang, S; Jacinthe, PA; Wang, LX	2020	Ecosystem service provision of grain legume and cereal intercropping in Africa	Agric. Syst. 178, 102761	10.1016/j.agsy.2019.102761
4	Li, CJ; Hoffland, E; Kuyper, TW; Yu, Y; Li, HG; Zhang, CC; Zhang, FS; van der Werf, W	2020	Yield gain, complementarity and competitive dominance in intercropping in China: A meta-analysis of drivers of yield gain using additive partitioning	Eur J Agron. 113, 125987	10.1016/j.eja.2019.125987
5	Li, CJ; Hoffland, E; Kuyper, TW; Yu, Y; Zhang, CC; Li, HG; Zhang, FS; van der Werf, W	2020	Syndromes of production in intercropping impact yield gains	Nat. Plants 6, 653–660	10.1038/s41477-020-0680-9
6	Rodriguez, C; Carlsson, G; Englund, JE; Flohr, A; Pelzer, E; Jeuffroy, MH; Makowski, D; Jensen, ES	2020	Grain legume-cereal intercropping enhances the use of soil-derived and biologically fixed nitrogen in temperate agroecosystems. A meta-analysis	Eur. J. Agron. 118, 126077	10.1016/j.eja.2020.126077
7	Xu, Z; Li, CJ; Zhang, CC; Yu, Y; van der Werf, W; Zhang, FS	2020	Intercropping maize and soybean increases efficiency of land and fertilizer nitrogen use; A meta-analysis	Field Crops Res. 246, 107661	10.1016/j.fcr.2019.107661
8	Zhang, CC; Dong, Y; Tang, L; Zheng, Y; Makowski, D; Yu, Y; Zhang, FS; van der Werf, W	2019	Intercropping cereals with faba bean reduces plant disease incidence regardless of fertilizer input; a meta-analysis	Eur. J. Plant Pathol. 154, 931–942	10.1007/s10658-019-01711-4
9	Ashworth, AJ; Toler, HD; Allen, FL; Auge, RM	2018	Global meta-analysis reveals agro-grassland productivity varies based on species diversity over time	PloS One 13, e0200274.	10.1371/journal.pone.0200274
10	Borg, J; Kiaer, LP; Lecarpentier, C; Goldringer, I; Gauffreteau, A; Saint-Jean, S; Barot, S; Enjalbert, J	2018	Unfolding the potential of wheat cultivar mixtures: A meta-analysis perspective and identification of knowledge gaps	Field Crops Res. 221, 298-313	10.1016/j.fcr.2017.09.006
11	Koricheva, J; Hayes, D	2018	The relative importance of plant intraspecific diversity in structuring arthropod communities: A meta-analysis	Funct. Col. 32, 1704-1717	10.1111/1365-2435.13062
12	Martin-Guay, MO; Paquette, A; Dupras, J; Rivest, D	2018	The new Green Revolution: Sustainable intensification of agriculture by intercropping	Sci. Total Environ. 615, 767–772	10.1016/j.scitotenv.2017.10.024

Number	Author	Year	Title	Reference	doi
13	Reiss, ER; Drinkwater, LE	2018	Cultivar mixtures: a meta-analysis of the effect of intraspecific diversity on crop yield	Ecol. Appl. 28, 62–77	10.1002/eap.1629
14	Thapa, R; Poffenbarger, H; Tully, KL; Ackroyd, VJ; Kramer, M; Mirsky, SB	2018	Biomass production and nitrogen accumulation by hairy vetch-cereal rye mixtures: a meta-analysis	J. Agron. 91, 25–33	10.2134/agronj2017.09.0544
15	Xiong, M; Sun, R; Chen, L;	2018	Effects of soil conservation techniques on water erosion control: A global analysis	Sci. Total Environ. 645 753–760	10.1016/j.scitotenv.2018.07.124
16	Himmelstein, J; Ares, A; Gallagher, D; Myers, J	2017	A meta-analysis of intercropping in Africa: impacts on crop yield, farmer income, and integrated pest management effects	Int. J. Sustain. Agric. Res. 15, 1-10	10.1080/14735903.2016.1242332
17	Raseduzzaman, M; Jensen, ES	2017	Does intercropping enhance yield stability in arable crop production ? A meta-analysis	Eur. J. Agron. 91, 25–33	10.1016/j.eja.2017.09.009
18	Yu, Y; Stomph, TJ; Makowski, D; Zhang, LZ; van der Werf, W	2016	A meta-analysis of relative crop yields in cereal/legume mixtures suggests options for management	Field Crops Res. 198, 269–279	10.1016/j.fcr.2016.08.001
19	Yu, Y; Stomph, TJ; Makowski, D; van der Werf, W	2015	Temporal niche differentiation increases the land equivalent ratio of annual intercrops: A meta-analysis	Field Crops Res. 184, 133–144	10.1016/j.fcr.2015.09.010
20	Iverson, AL; Marin, LE; Ennis, KK; Gonthier, DJ; Connor-Barrie, BT; Remfert, JL; Cardinale, BJ; Perfecto, I	2014	Do polycultures promote win-wins or trade-offs in agricultural ecosystem services? A meta-analysis	J. Appl. Ecol. 51, 1593–1602	10.1111/1365-2664.12334
21	Pelzer, E; Hombert, N; Jeuffroy, MH; Makowski, D	2014	Meta-analysis of the effect of nitrogen fertilization on annual cereal-legume intercrop production	Agron. J. 106, 1775–1786	10.2134/agronj13.0590
22	Slattery, RA; Ainsworth, EA; Ort, DR	2013	A meta-analysis of responses of canopy photosynthetic conversion efficiency to environmental factors reveals major causes of yield gap	J. Exp. Bot. 12, 3723–3733	10.1093/jxb/ert207
23	Huang, C; Sun, ZY; Wang, HG; Luo, Y; Ma, ZH	2012	Effects of wheat cultivar mixtures on stripe rust: A meta-analysis on field trials	Crop Prot. 33, 52-58	10.1016/j.cropro.2011.11.020
24	Letourneau, DK; Armbrecht, I; Rivera, BS; Lerma, JM; Carmona, EJ; Daza, MC; Escobar, S; Galindo, V; Gutierrez, C; Lopez, SD; Mejia, JL; Rangel, AMA; Rangel, JH; Rivera, L; Saavedra, CA; Torres, AM; Trujillo, AR	2011	Does plant diversity benefit agroecosystems? A synthetic review	Ecol. Appl. 21, 9-21.	10.1890/09-2026.1
25	Kiaer, LP; Skovgaard, IM; Ostergard, H	2009	Grain yield increase in cereal variety mixtures: A meta-analysis of field trials	Field Crops Res. 114, 361–373	10.1016/j.fcr.2009.09.006