SINGLE-IMPACT FICHE
INTERCROPPING

IMPACT: NUTRIENT USE EFFICIENCY

Data extracted in May 2021

Note to the reader: This fiche summarises the impact of intercropping on NUTRIENT USE EFFICIENCY. It is based on 5 peer-reviewed synthesis research papers[1], each of them including from 17 to 132 individual studies.

1. WEIGHT OF THE EVIDENCE

- CONSISTENCY OF THE IMPACT:
  Intercropping of multiple crop species (i.e., crop mixture cropping), as compared to monoculture, resulted in an overall positive effect on nutrient (both nitrogen and phosphorous) use efficiency (i.e., increase in nutrient use efficiency). From a total of 6 results, 5 were positive and one showed no-effect (see **Table 1**).

  Among the 5 reviewed synthesis papers, 4 include data collected in Europe (see **Table 2**).

Table 1. Summary of effects. 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 the next section.

		All studies				Only studies including EU			
Impact	**Intervention**	**Positive**	**Negative**	**No effect**	**Uncertain**	**Positive**	**Negative**	**No effect**	**Uncertain**
Increase Nutrient use efficiency	Crop mixture	**5 (5)**	0	1 (1)	0	**4 (4)**	0	0	0

- QUALITY OF THE SYNTHESIS PAPERS: *The quality score summarises 16 criteria assessing the quality of three main aspects of the synthesis papers: 1) the literature search strategy and studies selection; 2) the statistical analysis; 3) the potential bias. Details on quality criteria can be found in this document* →.

As shown in the "Quality score" in **Table 2,** the quality level ranges from 69% to 88%. The least frequently satisfied quality criteria were "Number of studies at each step", "Publication_bias_analyzed" and "Search_string".

[1] Research synthesis papers include a formal meta-analysis or systematic reviews with some quantitative results

2. IMPACTS

The main characteristics and results of the synthesis papers are summarized in **Table 2**. Detailed results of each synthesis study are reported in the summary reports.

Table 2. Main characteristics of the synthesis papers reporting impacts of intercropping on nutrient use efficiency. The references are ordered chronologically with the most recent publication date first.

Reference	Population	Geographical scale	Num. papers	Intervention	Comparator	Metric	Conclusion	Quality score
Li, CJ; Hoffland, E; Kuyper, TW; Yu, Y; Zhang, CC; Li, HG; Zhang, FS; van der Werf, W 2020	Multiple crops	Global	132	Crop mixture cropping	Monoculture	Nitrogen fertilizer equivalent ratio (NFER) and phosphorus fertilizer equivalent ratio (PFER)	Intercropping saves nitrogen and phosphorus fertilizer compared with sole crop, offering opportunities for the sustainable intensification of both high- and low-input agriculture.	69%
Tang, XY; Zhang, CC; Yu, Y; Shen, JB; van der Werf, W; Zhang, FS 2021	Cereals and legumes	Global	17	Crop mixture cropping	Monoculture	Phosphorus use efficiency (Land equivalent ratio for P uptake, LERP; Net effect for P uptake, NEP)	Cereal/legume intercropping can increase the uptake of P and hence has the potential to increase P fertilizer use efficiency in agriculture.	75%
Rodriguez, C; Carlsson, G; Englund, JE; Flohr, A; Pelzer, E; Jeuffroy, MH; Makowski, D; Jensen, ES 2020	Cereals and legumes	Global	29	Crop mixture cropping	Monoculture	Dinitrogen (N_2) fixation and Soil-derived N acquisition	The meta-analysis confirms and highlights that intercropping consistently stimulates complementary N use between legumes and cereals by increasing N_2 fixation by grain legumes and increasing soil N acquisition in cereals. Cropping systems diversification via intercropping can be used for simultaneous production of both cereals and grain legumes, while increasing the use of N-sources and reducing external inputs of N fertilizers, thereby enhancing the sustainability of agriculture.	88%
Xu, Z; Li, CJ; Zhang, CC; Yu, Y; van der Werf, W; Zhang, FS 2020	Maize and soybean	Global	100	Crop mixture cropping	Monoculture	Nitrogen fertilizer equivalent ratio (FNER)	Exploiting species complementarities by intercropping maize and soybean enables major increases in land productivity with less fertilizer N use.	94%
Thapa, R; Poffenbarger, H; Tully, KL; Ackroyd, VJ; Kramer, M; Mirsky, SB 2018	Cover crops: hairy vetch (Vicia villosa Roth)–cereal rye (Secale cereale L.)	United States	21	Crop mixture cropping	Monoculture	Nitrogen content in the aboveground	Overall, the study suggests that legume–grass mixtures, in this case hairy vetch–cereal rye, have the potential to maximize cover crop nitrogen content, better synchronizing nitrogen release with nitrogen demand of the succeeding cash crop, than	75%

Reference	Population	Geographical scale	Num. papers	Intervention	Comparator	Metric	Conclusion	Quality score
						biomass of cover crops[2]	either monoculture species, accumulating as much nitrogen as pure hairy vetch.	

3. KNOWLEDGE GAPS

Li et al., 2020	Further research is needed to assess the environmental benefits of the high-input intercropping strategy compared with sole crops or reduced-input intercrops.
Xu et al., 2020	Further research is needed to identify optimal combinations of planting configuration, sowing dates and fertilizer to achieve high yields and high N use efficiency in intercropping, and exploit biological N fixation without driving the system to very resource poor low yielding conditions.
Thapa et al., 2018	Future studies evaluating cover crop mixtures over monocultures should consider the multiple factors that influence mixtures productivity, including soil N availability and precipitation during cover crop growth period. Future studies should also prioritize research on belowground biomass and N accumulation with cover crop mixtures relative to monocultures.

4. SYSTEMATIC REVIEW SEARCH STRATEGY

Keywords	TOPIC: (intercrop* OR "inter crop*" OR "mult* variet*" OR "mult* crop*" OR "Companion crop*" OR "Companion plant*" OR "polycultur*" OR "crop diversity" OR "mix* crop*" OR "crop* mix*" OR "cult* mix*"OR "variety mix*" OR "row crop*" OR "strip* crop*" OR "row crop*" OR "relay crop*") AND TOPIC: ("meta-analy*" OR "systematic* review*" OR "evidence map" OR "global synthesis" OR "evidence synthesis" OR "research synthesis")
Search dates	No time restrictions

[2] Authors consider Plant N content in cover crops as an indicator of nutrient use efficiency:
"Aboveground biomass and N content are proxies that indicate the potential value of cover crop monocultures or mixtures in terms of agroecosystem services provisioned. Cover crop biomass is positively correlated with weed suppression and retention of N against leaching loss in some regions. Cover crop N content is a key predictor of N supply to the subsequent crop, particularly in combination with cover crop C/N ratio. (…) Based on our findings, hairy vetch–cereal rye mixtures are recommended over monocultures when the goal is to maximize both cover crop biomass and N content, and better synchronize N release with N demand of the succeeding cash crop."

Databases	Web of Science and Scopus, run in May 2021
Selection criteria	The main criteria that led to the exclusion of a synthesis paper were if the paper: (1) does not deal with intercropping; (2) does not include results for cropland (e.g. pastures, forests); (3) deals with agroforestry (e.g. alley cropping); (4) experimental treatment included other practices as well (e.g. crop rotation); (5) intercropping treatment included non-cash crops (e.g. companion plants that were not harvested, dual-purpose cropping); (6) presents the same dataset as previous studies and similar analyses; (7) is a simple review or a non-quantitative systematic review. Synthesis papers that passed the relevance criteria were subject to critical appraisal carried out on a paper-by-paper basis. The search returned 109 synthesis papers potentially relevant for the practice object of our fiche. Searches for other farming practices added another 2 potentially relevant synthesis papers. From the 111 potentially relevant synthesis papers, 54 were excluded after reading the title and abstract, and 32 after reading the full text according to the above-mentioned criteria. Finally, 25 synthesis papers were selected for intercropping, from which 5 were relevant for this impact.