INTERCROP VALUES

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D3.3 Infographic of the multicriteria value of intercrops in cropping sequences in a single global frame

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Abstract

Agricultural intensification has boosted global food production but has also resulted in biodiversity loss, environmental degradation, and reduced agroecosystem resilience. Diversifying cropping systems, particularly through intercropping, offers a promising pathway toward ecological intensification and sustainability. This task aimed to assess the multicriteria performance of intercropping systems compared to sole-cropping systems under real-farm conditions using data from the French DEPHY Ecophyto network (2009–2024). The Agrosyst database provided standardized data from approximately 2,000 farms engaged in pesticide reduction initiatives. Cropping systems including at least one intercropped field (n = 815) were identified and matched with comparable sole-crop systems (n = 1,606) based on agro-pedoclimatic and management criteria. Indicators related to synthetic nitrogen fertiliser input, pesticide use, water consumption, fuel use, soil tillage intensity (STIR), and workload were computed after data curation. Linear mixed models accounting for farming type (organic or conventional), climate, and year were applied to test the effects of intercropping. Results revealed that intercropping systems significantly reduced synthetic N fertiliser use by 8%, pesticide use by 12%, and water consumption by 29%, with a concurrent 8% decrease in workload. No overall effect on fuel consumption was detected, and STIR effects differed between systems, increasing in organic farms (+12%) but remaining unchanged in conventional ones. These findings confirm the potential of intercropping to enhance the environmental performance of arable systems without compromising efficiency. The study underscores the value of on-farm data for evidence-based policy and supports broader implementation of crop diversification strategies in European agriculture.

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1. Introduction

Agricultural intensification has greatly increased food production over the past century but has also led to major environmental degradation, biodiversity loss, and reduced system resilience. Simplified farming systems, largely driven by the widespread use of synthetic inputs, plant-breeding priorities, and European agricultural policies promoting specialisation, have decreased crop diversity and increased dependence on external resources. To counter these effects, diversification of cropping systems has emerged as a key strategy to enhance sustainability and resilience. Diversification, encompassing practices such as crop rotations, intercropping (crop associations or species mixtures), cover cropping, and agroforestry, increases the structural and functional complexity of agroecosystems. This complexity supports ecosystem services including pest and disease regulation, nutrient cycling, and improved soil and water quality, while enhancing carbon sequestration and buffering against climate variability—all without necessarily compromising yields.

Among diversification strategies, intercropping, particularly cereal–legume mixtures, has shown strong potential for ecological intensification. Numerous studies demonstrate that intercropping reduces weed and pest pressures, enhances soil biological activity, and improves yield stability due to species complementarity in resource use. However, adoption remains limited in Western countries, constrained by technical, economic, and logistical barriers, as well as unsuitable mechanization and post-harvest systems.

Despite extensive research highlighting the agronomic benefits of intercropping, few studies have conducted comprehensive multicriteria assessments of its performance. Moreover, existing evaluations are largely based on experimental station trials rather than on-farm conditions. To provide insights into the performance levels of such systems, we used data from the French Ecophyto (National plan to reduce pesticide use) network and identified cropping systems implementing intercropping practices. These systems were then compared with similar sole cropping systems operating under comparable agro-pedoclimatic conditions.

1.1 Data resources

An initial phase of the work consisted of identifying, at the European scale, the available datasets suitable for conducting a multicriteria performance analysis. It emerged that only the data collected within the framework of the French Ecophyto plan, centralised and structured in the Agrosyst database, could effectively support this cross-cutting performance assessment.

Following authorization for data use from the national coordination unit of the DEPHY Ecophyto network (https://ecophytopic.fr/dephy), the relevant datasets were retrieved and analysed.

1.2 Coordination team

The coordination team for this work included Gaëtan Seimandi-Corda, postdoctoral researcher for Task 3.3 of the IntercropVALUES project, Lionel Alletto (INRAE), and Maé Guinet (Institut Agro / INRAE), who was already involved in previous analyses of the Agrosyst data. Progress on this work was regularly presented within the WP3 coordination team and, more broadly, to the IntercropVALUES consortium during general assembly in order to share these original and unique results and discuss their significance.

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2. Materials and Methods

2.1 Presentation of the database

The DEPHY network is a farm network set up as part of the French Ecophyto action plan, which aims for French farmers to reduce pesticide use by 50%, if possible. The network has been active since 2010 and has included up to 3 000 farmers, although the number of participants varies annually, with a consistent participation of ca. 2 000 farmers in recent years. Farmers participate in the network on a voluntary basis without receiving financial compensation, and their common interest is to reduce pesticide use while maintaining farm profitability. Participants are organised in local groups of 10-15 farmers supported by an agronomist who provides guidance on adapting practices to reduce pesticide use. These agronomists also collect data on farming practices which are stored in the AGROSYST database. Farming practices are monitored annually using two approaches: 1) in individual fields and 2) in a synthetic way, in which each crop of the rotation is described as the mean of multiple fields cultivated with the same crop in a given year. We focused on arable farms or mixed arable-livestock farms, which represent approximately half of the farms monitored in the network.

2.2 Selection of the cropping systems

Cropping systems (defined as fields with the same crop rotation and decision rules on a single farm, on a specific year) that included at least one intercropped field were identified in the Agrosyst database. We defined intercrops as any mixture of plant species grown simultaneously, except for grasslands (temporary or permanent) and cover crops (crops providing ecosystem services grown between two main crops and not harvested or used for grazing). A set of sole-crop systems was then performed by looking for systems with sole crop only, located at a maximum of 60 km from a system with intercrops, sharing the same soil type (dominant soil type in the locality), the same type of system (conventional or organic), the same year, and the presence or not of irrigation. Systems in conversion from conventional to organic were categorised as organic systems. For this analysis only cropping systems with at least 8 different fields described were used to ensure sufficient crop diversity. Following this approach on 14 May 2024, 815 cropping systems with intercropping and 1606 systems with sole crops were identified in the dataset observed from 2009-2024.

2.3 Indicators computation

In Agrosyst different pieces of data were used to compute a set of indicators used for the multicriteria analysis. Because typing errors were frequent in a database, a data curation had to be performed. Data on the quantity of water used and the synthetic

N fertilisers were used directly from Agrosyst. Treatment Frequency Index (TFI, the total quantity of each active ingredient applied to each crop during a growing season based on standard doses for each use of the active ingredient) was computed to estimate the pesticide use. The computation was done using the quantity of product applied and the reference doses in Agrosyst. When no reference dose was available in Agrosyst, an average value from multiple target organisms was extracted from Ephy (the French catalogue of authorised pesticides). For the fuel consumption, the Soil Tillage Intensity Rating (STIR) and the workload another approach was used. Each farm operations of the selected cropping systems were categorised based on the names of the operations or the tools used available in Agrosyst (Table 1). For each category of operation, the workload (h/ha) and fuel consumption (L/ha) was defined based on a French abacus (Barème d'entraide 2024/2025 FMCUMA) and expert knowledge. For the few operations were no standard data were available for the workload (maize manual castration, garlic manual castration, manual weeding, stone removal, installation of irrigation, field observation, installation of animal grazing, trichogramme spreading), the median value in the database was used as a standard value. For each tillage operation, a Soil Tillage Intensity Rating (STIR) was computed, using an online tool developed by FiBL (https://www.progres-sol.ch/stir/ajouter-un-nouveau-calcul-du-stir.html). Once farm operation indicators were standardised, they were multiplied by the weight of the field in the rotation. This weight is available in Agrosyst for data collected in a synthetic way and represent the weight of the crop in the rotation taking into account multiple rotation paths. For data collected at the field level, the weight is the proportion of the field in the rotation (1 / total number of fields). The values of the indicators multiplied by the weight was then summed at the level of the cropping system.

To analyse the data and test the effect of the presence or not of intercropping on the different indicators, a linear mixed model was used. This model includes as fixed effect the presence or not of intercropping, the type of farming (organic or conventional), the climate type (based on Joly et al., 2010*), and the interaction between the presence of intercropping and the type of farming. As random effects, the year, the farm, and the reference set in interaction with the year were used. When residuals of the models were far from normality, the indicator was root squared transformed to improve their normality. The effects of the fixed effects were tested using a Type II Wald χ^2 test, and **mean estimated marginal means were extracted to represent the effect of the presence of intercropping in the infographic**. *We decided not to include the workload in the infographic to focus on indicators related to the sustainability of the cropping system, but results of this analysis including the workload will be disseminated in a future research paper.*

* Joly, Daniel, et al. (2010). "Les types de climats en France, une construction spatiale." Cybergeo: European Journal of Geography.

Table 1. List of the tools used to categorise farm operations and compute system workload, fuel consumption and STIR.

Tools	Performance (ha/h)	Fuel consumption (L/ha)	STIR
ATV-mounted sprayers	1	0.1	
Balers	35	0.48	
Ball wrapper	10	0.67	
Band speader	1.4	4.8	
Beet seeders & accessories	2.4	3.85	

Cereal seed drill	1.8	4.2	
Chisel	1.6	15.75	41
Combine harvester	1.5	30.87	
Cultivator	1.6	12.6	41
Cultivator with options	2.7	8.1	41
Detasseling (for maize)	2	6.2	
Disch harrow	2.5	10.08	48
Fertiliser spreader	10	0.84	
Flatbed trailers / Platforms	1	9.2	
Flax harvester	2	13.32	
Flax turner	0.8	11.03	
Forage wagon	1.75	16.32	
Furrower / Ridger	1.4	4.8	
Glypho-mulch system	1.7	11.86	
Harrows	3	4.48	13
Inter-row cultivartor	1.4	4.8	13
Manure spreader	1.92	7.44	
Market-garden seeder	2.4	5.25	
Mower options	2.4	8.4	
Mowers	2.5	3.02	
Mulcher	0.7	19.2	
Plough	1.1	19.85	51
Potato harvester	0.6	36.4	60
Potato planters	0.8	11.55	51
Potato ridger	0.9	18.67	51
Potato shredder	0.5	26.88	
Rollers	3	2.8	
Rotary hoe	6	1.68	13
Rotary spades	2.5	10.8	10
Rotary tillers	1.7	11.86	
Rotavator / Rotary tiller	0.8	18.9	20
Seed drill combination	1.8	14	
Seeders & accessories	1.8	14	
Self propelled forage harvester	2.5	29.4	
Self-loading trailers	1.25	16.13	
Self-propelled bean harvester	1	80	
Self-propelled sprayers	20	0.74	
Sprayers	5	1.51	
Spreaders & accessories	0.53	12.6	
Stone removal equipment	1	28.56	

Strip-till cultivator	3	10.64	5
Subsoilers / Deep rippers	0.4	33.6	13
Sugar beet harvester (decomposed)	0.9	35.47	40
Tedders and windrowers	4.5	1.87	
Thermal weeder	2.7	8.1	
Topper	4.5	1.87	
Trailer	5	10.1	
Verge mowers	1	20.16	
Vineyard cultivator	0.7	9.6	41
Vineyard subsoiler	0.6	28	13
Weeding machine plus sprayer	1.4	4.8	13

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3. Main objectives and main work steps

The main objective of this deliverable is to produce an infographic of the multicriteria analysis of cropping systems with intercropping.

To do so:

1) data from Agrosyst were extracted and curated;
2) a method was developed based on Guinet et al. (2023)* to create sets of systems with intercropping and reference systems without intercropping;
3) a statistical analysis was performed to compare different criteria (fertilisation, pesticide use, workload, water use, soil disturbance, fuel consumption) between systems including intercropping and systems with only sole crops;
4) results were synthesised and shared with a professional graphic designer to produce an infographic.

* Guinet, Maé, et al. "Fostering temporal crop diversification to reduce pesticide use." Nature Communications 14.1 (2023): 7416.

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4. Results of the multicriteria analysis and Infographics

A total of 815 cropping systems with intercropping were identified and compared to 1,606 systems in sole crop. Each system with intercropping was compared between 1 to 6 reference systems with sole crops only (median = 4). A total of 1,896 systems used for the analysis were conventional while 516 were organic.

The comparison of cropping systems with intercropping to systems with only sole cropping showed the following main results:

1. **A significant reduction** in synthetic N fertiliser (-8%), pesticide use (-12%), water use (-29%), and workload (-8%).
2. The effect on the STIR was **null overall**, but changed depending on the farm type with an increase of STIR in organic systems (+12%), and no differences in conventional systems. No significant effect was observed on the fuel consumption.

Improving farm sustainability with intercropping

Cropping systems that include intercropping exhibit better environmental performance than those relying on sole crop

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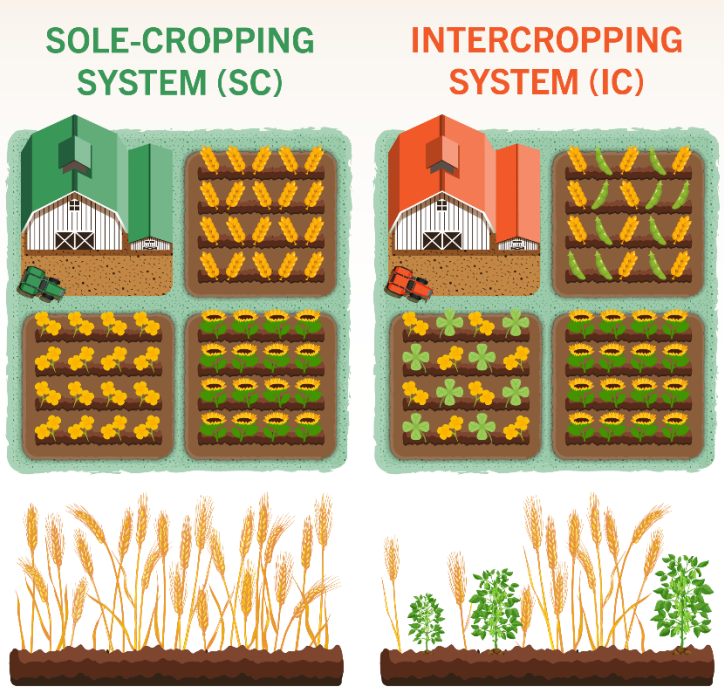
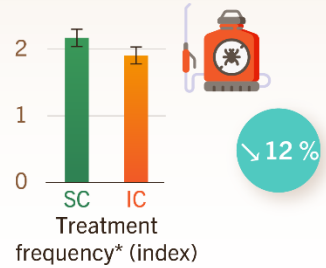
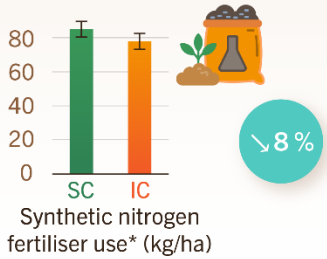
This may be due to the lower input requirements of intercropped plots, or to the greater frequency of adoption of intercropping by farms that are already more sustainable before its adoption.



Pesticide and fertiliser use

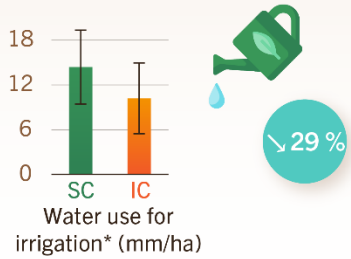


Treatment frequency* (index)



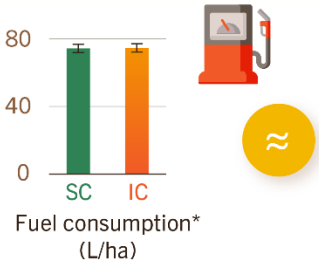
Synthetic nitrogen fertiliser use* (kg/ha)

Water managment

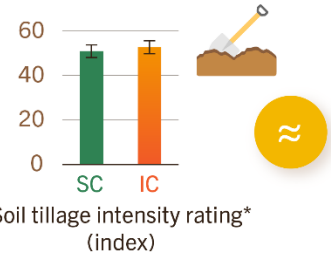


Water use for irrigation* (mm/ha)

Energy and soil work



Fuel consumption* (L/ha)



Soil tillage intensity rating* (index)

*Mean ± SE based on DEPHY farm data
Scales differ between indicators for clarity; all bars start at zero

Method: The DEPHY network is a nationwide farmer network that monitors around 2,000 farms in France each year, collecting detailed information on their agricultural practices. This monitoring program provides data on pesticide and synthetic fertiliser use, water consumption, soil management, and fuel use at the farm level. In total, 815 farm-years that included fields with multiple plant species (i.e. intercropping) were identified and used for analysis and compared to 1606 farm-years without intercrops located less than 40 km around, with similar farm type (conventional / organic)..

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5. Acknowledgments

We thank the farmers and agronomists who participated in the DEPHY network of the French Ecophyto Plan, as well as the AgroSyst team who collected, organised, pre-processed, and extracted the data. We also thank Romain Escassut-Nandillon, Nicolas Munier-Jolain, and Elodie Yan for their help with manipulating the AGROSYST database.

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