RADIANT-*Metrics*, state-of-the-art quantitative framework & decision support tool

Work Package Number: 4

Deliverable Number (D): 4.5

Lead Author(s): Marcela Porto Costa, David Styles

Date of Submission: 05.05.2025

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

Deliverable Description & Contributors

- **Due date**: 30.04.2025
- **Actual submission date**: 05.05.2025
- **Project start date**: September 1st 2021
- **Duration**: 48 months
- **Work package**: 4
- **Work package leader**: David Styles
- **Deliverable Title**: RADIANT-Metrics, state-of-the-art quantitative framework & decision support tool
- **Nature of deliverable**: Other
- **Dissemination level**: Public
- **Deliverable description:**

This deliverable consists of an MS Excel tool designed to present results from comparative case studies of underutilized crop (UC) value chains against conventional counterparts. The tool integrates sustainability and resilience indicators, capturing key field of metrics such as ecosystem services, economic indicators, life cycle assessment (LCA), and agricultural efficiency into an interactive dashboard. Users can customize the tool for various comparative analyses between UC and conventional crop value chains. Note that the tool does not support animal production comparisons. The methodology behind each evaluation pillar is detailed in this document, and case study results are summarised in an Appendix.

Contributors (Institution)

- Marcela Porto Costa (UoG)
- David Styles (UoG)
- Sophie Saget (UoG)
- Michael Williams (TCD)
- Chiara Flora Bassignana (Uni of Gastronomy, Pollenzo)
- Paola Migliorini (Uni of Gastronomy, Pollenzo)
- Yann de Mey (WUR)
- Marie-Fleur Bremaud (WUR)
- Marta Vasconcelos (UCP)

Keywords: Sustainability, resilience, farm level, value chain, economic performance, ecosystem services, life cycle assessment (LCA), environmental indicators.

Contents

Executive Summary

This deliverable includes four MS Excel files: The files consist of the *RADIANT-Metrics* tool applied to the four case studies comparing underutilized crops (UCs) to conventional alternatives (results summarised in Appendix 1). The *RADIANT-Metrics* decision support tool enables users to input data and analyse results via an interactive dashboard. It evaluates environmental impact through LCA (up to six environmental impact categories), environmental efficiency (three indicators), economic performance (six indicators), and ecosystem services (evaluated through eight indicators of agricultural practice). Indicators are measured at farm and/or value chain level and can be followed through to value chain (product) level.

The tool is intended for farmers, researchers, and policymakers to assess sustainability and resilience of UC products across these key areas. It supports comparisons of up to four alternatives simultaneously. The case studies provided in this deliverable include:

- Acorn (pickled) vs. olives as an appetizer (Portugal)
- Acorn flour vs. wheat flour (Portugal)
- Bere barley production vs. conventional barley, under conventional cropping and agroecological systems (Scotland)
- Salad leaves from conventional, UC agro-ecological, and hydroponic systems with grid- or renewable wind electricity (Spain and UK)

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

1. Overview

The *RADIANT METRICS* tool is an MS Excel file comprising six different tabs. The first tab, *Guidance*, provides users with instructions on how to navigate the tool effectively. Users can input data for their studies comparing underutilised cropping systems or value chains with traditional counterparts in the *Input Data* tab. This section includes fields for entering the names of the alternatives being compared, as well as the results or evaluation for each pillar evaluated: Life Cycle Assessment (LCA), Environmental Efficiency Indicators, Ecosystem Services, and Economic Indicators. These pillars are further explained in the subtopics below.

Once users have entered all the necessary data, they can view the results in the *Dashboard* tab. The *Dashboard* automatically calculates and presents results based on the *Input Data* and *Normalisation & Calcs* tabs. The *Normalisation & Calcs* tab facilitates intermediate calculations and normalisation based on user input. To maintain the integrity of calculations, users should not modify the *Dashboard*, nor the *Normalisation & Calcs* tabs. However, the latter remains accessible to view, ensuring methodological transparency. The normalisation steps are explained below according to the specific evaluation.

The *Dashboard* provides an overview of all analysed fields by offering a general analysis across four macro themes: LCA, Agricultural Efficiency, Ecosystem Services, and Economic Indicators. This is visually represented using a spider web graph, where lines closer to the edges indicate higher impacts and lower performance, as shown in Figure 1.

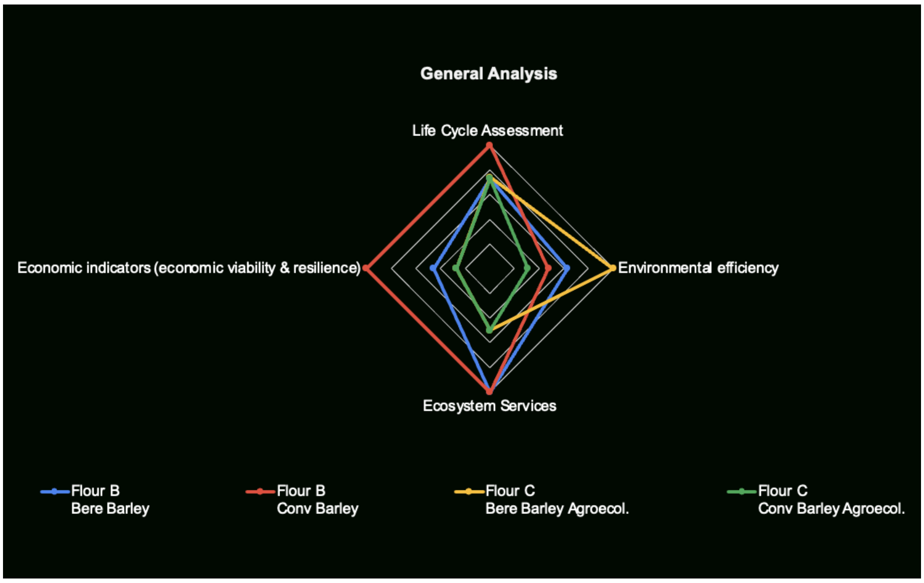


Figure 1: General Analysis of all investigated fields (LCA, Agricultural Efficiency, Ecosystem Services, and Economic Indicators) in the *RADIANT METRICS* tool.

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

Further analysis of each field is available through three elements:

1. A cobweb graph, where lines closer to the edges indicate higher impacts (lower performance). This representation is illustrated in Figure 2.
2. A consolidated single-score graph, which combines all indicators from the cobweb graph to represent the performance of each alternative in the respective field of analysis. In this visual, lower-positioned bubbles indicate better performance. This representation illustrated in Figure 2.
3. A summary table presenting the final normalised results that feed into the two graphs mentioned above.

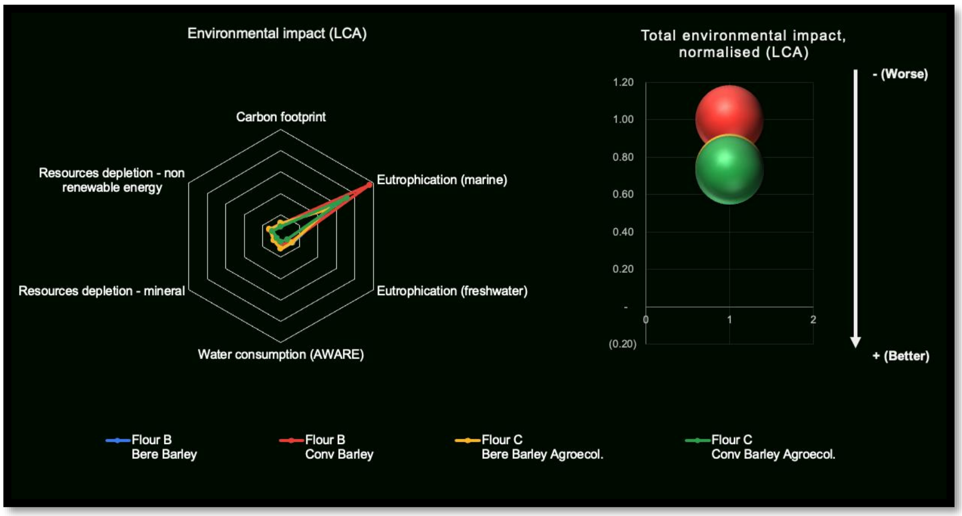


Figure 2: Life cycle Analysis graphics presented in the dashboard for Environmental Impact in the *RADIANT-Metrics* tool.

2. Methodology

2.1 Environmental Impact via Life Cycle Assessment

To analyse the environmental impact results, the user must have LCA results for each alternative under analysis. If an LCA has not been performed, users can utilise external tools (such as Hestia (2025) or Cool Farm Tool (2025)) to calculate LCA or carbon footprint – preferably following the EU Product Environmental Footprint impact assessment methodology (European Commission, 2018).

Once users have obtained these results, they should paste the relevant impact assessment data into the designated cells in the *Input Data* tab. The alternatives being compared must be aligned to the same functional unit, for example: "Alternative 1: Barley flour from UC system" vs. "Alternative 2: Barley flour from conventional cropping".

The categories analysed in LCA and their respective units of measurement are presented in Table 1 below.

Table 1: List of environmental impact categories and their units of measurement from the PEF methodology (European Commission, 2018) used in the *RADIANT-METRICS* tool.

Impact category	Unit of measurement
Carbon footprint	kg CO_2 eq. per Funcional Unit
Eutrophication (marine)	kg N eq per Funcional Unit
Eutrophication (freshwater)	kg P eq per Funcional Unit
Water consumption (AWARE)	m^3 depriv. per Funcional Unit per Funcional Unit
Resources depletion - mineral	kg Sb eq per Funcional Unit
Resources depletion - non renewable energy (Fossils)	MJ, net calorific value per Funcional Unit

Once the user has completed the *Input Data* tab, this information is processed in the *Normalisation & Calcs* tab, where a two-step normalisation occurs:

1. Initial Normalisation – The environmental impacts are normalised by dividing them by the default values (expressed in person/year) established by the PEF Framework (Table 2). The results are then displayed in the cobweb graph in the dashboard.
2. Final Normalisation – The values, now expressed in person-years, are summed into a single score per alternative and then further normalised against the highest value among them. This ensures that one alternative will always have the worst score (1), while the others are scaled accordingly. The single score results are presented in the bubble graph in the *Dashboard* tab.

Table 2: List of environmental impacts and their normalisation factors (in person-years) from the PEF Framework (European Commission, 2018) used in the *RADIANT-METRICS* tool.

PEF Normalisation values in person/years	
Carbon footprint (kg CO_2 eq)	8,097
Eutrophication (marine) (kg N eq)	19
Eutrophication (freshwater) (kg P)	1.61
Water consumption (AWARE) (m^3 depriv.)	11,469
Resources depletion – mineral (kg Sb eq)	0.06
Resources depletion - non renewable energy (MJ, net calorific value)	65,019

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

2.2 Environmental Efficiency via Environmental Indicators

These environmental efficiency indicators assess nitrogen (N) and phosphorus (P) use efficiency, as well as crop yields. Unlike LCA, these indicators evaluate efficiency on a per-hectare basis, focusing exclusively on cropping systems. Users can calculate these indicators at field- (or alternatively farm-) level, using input data such as compost or synthetic fertilisers, and outputs, including crop yields and crop residues left in the soil. The N and P balance data should be entered into the *Input Data* tab.

Once the data has been inputted, the normalisation steps are performed in the *Normalisation & Calcs* tab. The aim of nitrogen and phosphorus balance is to avoid both significant deficits, which could reduce soil fertility, and surpluses, which may lead to nutrient leakage (Costa et al., 2020). Therefore, N and P balances are normalised according to Table 3, with results expressed on a 0–1 scale, where 1 represents the worst case and 0 represents the best case.

The yield values are normalised comparatively among all alternatives, using the minimum value as a reference. The alternative that receives a score of 1, the worst scoring, is the one with the lowest yield. The normalised results are then visualised in the cobweb graph in the *Dashboard* tab.

To generate the single score displayed in the bubble graph (also in the *Dashboard* tab), an additional normalisation step is required. This step involves summing the normalised indicators for N and P balances and yields, followed by renormalisation against the highest value. As a result, the alternative that scores 1 represents the worst performance.

Table 3: Normalisation rules for N (Batool et al., 2022) and P balance (Batool et al. (2025) used in the RADIANT -Metrics tool.

N-Balance (kg/ha)	Rating	P-Balance (kg/ha)	Rating
x<=-50	1	x<=-10	1
-50<x<-30	0.5	-10<x<-5	0.5
-30<=x<=30	0	-5<=x<=5	0
30<x<50	0.5	5<x<10	0.5
>=50	1	>=10	1

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

2.3 Economic performance via Economic Indicators

In order to assess the economic performance of the alternatives, economic indicators were selected by experts from Wageningen University based on cumulative insights from the RADIANT project. The economic framework encompasses three indicators at the farm level (de Mey et al., 2024), and three indicators at the value chain level (Saget et al., 2024).

At the farm level, the following aspects are evaluated:

- Profit: sufficient profit is being made in order to sustain the business over time;
- Risk: volatility of profit should be acceptable over a period of time;
- Diversification: activities and revenue streams are sufficiently diversified in order to deal with changes.

At the value chain level, the framework assesses:

- **Value chain length**: value chains are dynamic and not overly complex and long;
- **Power/trust**: value chain actors trust each other and hence collaborate well, without significant power imbalance;
- **Autonomy**: the value chain is not overly reliant on external parties to ensure its survival.

Users rate each alternative on a scale of 1 to 5, where 1 represents the worst performance and 5 represents the best. A detailed description of each indicator, along with the rating scale, can be found in the *Econ. Rating* tab and in Table 4 below.

Once users have rated the alternatives under the economic pillar, the values are normalised in the *Normalisation & Calcs* tab, resulting in scores ranging from 0 to 1. As for the other indicators, a score of 1 represents the worst performance, as shown in Table 5.

The values for each indicator are then summed into a single score per alternative and renormalised against the maximum value. As a result, the final scores also range from 0 to 1, with the worst-performing alternative always scoring 1.

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

Table 4: Economic indicators framework used in the *RADIANT-METRICS* tool.

Indicator	Definition	Rating	Rating description
Profit	Sufficient profit is being made to sustain the business over time. When a comparison between structurally similar alternatives is being made, net pre-tax profit can be used (revenue - all costs). In the case of more diverse alternatives (e.g. marked differences in size or capital structure), EBITDA (earnings before interest, taxes, depreciation, and amortization) should be used instead to focus on operational profits before taking capital structure into account.	1	Highly unprofitable (losses are made, farm survival is at high risk)
		2	Poor profitability (farm is making marginal losses or breaking even)
		3	Moderate profitability (small profits are generated, but farm remains vulnerable)
		4	Good profitability (consistent and sufficient profit is generated)
		5	High profitability (strong financial performance by the farm, well above average)
Risk	Volatility of profit (as selected under economic indicator #1) is acceptable over a time-period. While some fluctuations are to be expected, these should be within reasonable and manageable bounds. Farmers can take risk management efforts to reduce their risk.	1	Extremely high risk (Profit volatility is severe and unpredictable)
		2	High risk (profit fluctuates significantly but remains somewhat manageable)
		3	Moderate risk (profit shows some expected fluctuations but remains within acceptable bounds)
		4	Low risk (profit is stable with minor, predictable fluctuations)
		5	Very low risk (profit is highly stable with minimal fluctuations)
Diversification	Acitivites and revenue streams are sufficiently diversified in order to deal with changes. Diversification could be either within the farm between different crops/varieties or between farm and non-farming activities. Diversification can help farms to reduce their economic vulnerability and enhance their economic resilience.	1	No diversification (farm relies on a single crop / revenue stream)
		2	Limited diversification (farm relies on a handful of main crops/activities)
		3	Moderate diversification (a small mix of crops and/or activities is present on the farm)
		4	Well diversified (multiple revenue streams exist across different crops and activities)
		5	Highly diversified (the farm has a wide variety of crops and income sources where no single source dominates)
Value chain length	Value chains are dynamic and not overly complex and long. Short value chains constitute an excellent way to gain higher added value, especially for small and	1	Long and complex (multiple intermediaries and low level of organisation)
		2	Long (long chain but some level of organisation emerging)

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

	medium size farms by removal of excessive middlemen.	3	Moderate (chain or reasonable length, balancing efficiency and reach)
		4	Short (short value chain with good organisation)
		5	Short and efficient (streamlined value chain with only key partners that coordinate well)
Power/trust	Value chain actors trust each other and hence collaborate well, without significant power imbalances. Equality within the value chain leading to more win/win scenarios.	1	Extreme power imbalance and no trust (one dominant actor controls the entire value chain)
		2	High power imbalance - low trust (large players exert significant control leaving smaller actors with limited negotiating power, leading to unfair value distribution
		3	Moderate trust - some power imbalances (larger players may still dominate, but negotiations are becoming more balanced leading to fairer contracts and cooperation)
		4	Good trust - balanced power (value chain actors collaborate effectively; trust is strong allowing for long-term partnerships)
		5	High trust and power balance (all value chain actors operate with mutual trust and transparency, with equal opportunities for all)
Autonomy	The value chain is not overly reliant on external parties to ensure its survival. Examples include government subsidies, debt through external financers, dependency or on global markets.	1	No Autonomy (the value chain heavily relies on external support to function, without external financing or aid it would collapse)
		2	High Dependence (the value chain still relies significantly on external support, but some internal mechanisms exist)
		3	Moderate Dependence (the value chain has a mix of internal and external dependencies with steps being taken to reduce reliance)
		4	Low Dependence (the value chain is largely self-sustaining, with minimal reliance on external forces)
		5	Fully Autonomous (the value chain operates independently and is considered self-sustaining)

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

Table 5: Economic indicators normalisation process used in the *RADIANT-METRICS* tool.

Economic Indicator rating	Normalisation value
1	1
2	0.75
3	0.5
4	0.25
5	0

2.4 Ecosystem Services via Agricultural practices

The Ecosystem Services approach has been proposed to capture the full value of (agri)ecosystems to humanity, including many non-market values missed by economic assessment. However, measuring Ecosystem Services ca be difficult, and is not well standardised. *RADIANT-Metrics* captures Ecosystem Services using the pragmatic Agricultural Practice Evaluation System (APES Framework), developed by Bassinga et al. (2025) as part of the of the RADIANT project. The agricultural indicators are rated on a scale from 0 to 3 (with 3 representing the best performance), based on farm-level practices. Users can rate these practices in the *Input Data* tab. Detailed descriptions of the ratings can be found in the *ES Rating* tab of the tool, as well as in Table 6 below. The correlation between the agricultural practices contributing to each ecosystem service is provided in the *Normalisation & Calcs* tab, and in Table 7.

Bassinga et al. (2025) developed a comprehensive framework that includes a large number of ecosystem services and agricultural practices. For *RADIANT-Metrics,* a selection of ecosystem services indicators from the framework was chosen. The main selection criterion was to represent ecosystem services that are not well represented by the Environmental Impact (LCA) and Efficiency indicator fields, thereby offering a complementary interpretation of the alternatives (Alejandre et al. (2019); Bergez et al., (2022)). Indicators related to animal practices were excluded, as the tool focuses solely on cropping systems and their value chains.

Once the user has rated the practices, a three-step normalisation process is applied. The first step involves calculating the average rating of the practices that contribute to each ecosystem service for each crop/value chain. In the second step, these values are normalised to a scale of 0-1, where 1 represents the worst performance. The normalisation logic is provided in Table 8, and these results are displayed in the cobweb graphic of the *Dashboard* tab. The third and final step is

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

to sum the normalised scores of all ecosystem services for each alternative and then normalise the total by the maximum value. The results, ranging from 0 to 1, display the worst alternative with a score of 1. These results are shown in the single-score bubble graphic on the *Dashboard* tab.

Table 6: Agricultural practices rating framework used in *RADIANT-METRICS* tool.

Indicator	Definition	Rating	Rating description
Conservation and no-tillage systems	The soil is disturbed minimally (no more than 3-5 cm deep) and with no inversion (soil 'cracking' up to 25 cm is allowed to de-com- pact the soil). The crop is seeded directly into a mulch or living crop (which is usually mown, rolled or tarped prior to seed), without any soil disturbance preceding.	0	Deep ploughing (more than 30 cm in depth) or rotavating one or more time per year
		1	Ploughing maximum 30 cm in depth and/or using power harrow once a year
		2	Reduced tillage up to 5 cm (e.g., superficial disc-harrowing g, wide-cutter or rotary hoe), strip tillage, ridge tillage
		3	No-till
Crop rotation	Long and diverse crop rotation, legume-based temporary grasslands in crop rotations, pulses in crop rotation	0	Mainly monocrop
		1	2-3 year rotation cycle
		2	4-5 year rotation cycle
		3	more than 6 years rotation cycle
Intercropping	Simple crop mixtures (e.g., cereal and pulse), polycultures with push-pull crops, permanent soil cover with companion species of the main crop(s), using allelopathic crops, Inter-row permanent crops on the uaa (utilised agricultural area)	0	0 intercropping on uaa
		1	30% uaa
		2	30-50 uaa
		3	>50
Cover crops	Mixtures of legume-based green manure, Cover crops, Soil fertility management with complex mixtures of green manures, Complex mixtures of green manures (cover crops), Main crop sown in green	0	The soil is covered with plants less than 6 months of the year on the total farmland
		1	The soil is covered for 6 to 8 months a year on the total farmland
		2	The soil is covered for 8 to 10 months a year
		3	The soil is covered at least 11 months of the year
Soil organic matter input	Compost tea, Green manure, composting, Balanced fertilisation, using organic manure - farmyard manure, recycled crop waste, Wood chips (or ramial wood chip (RWC), organic agro-industrial waste, biochar, straw mulching, inoculation with mycorrhiza	0	No organic matter inputs (the fertility management is completely based on synthetic fertilizers)
		1	Rarely used Organic inputs and/or only in a small part of the farm (up to 30% of used farmed land)
		2	Moderate use of practice and/or in up to one half of the farmed land
		3	Several strategies are implemented in at least 75% of the farmland
		0	Chemicals inputs, not include organic products

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

Organic pest and disease control	Organic Pest and disease control derived from plants and plant extract	1	30 % Organic pest control, purchased
		2	30% - 50% Organic pest control, purchased
		3	Only organic pest control and 50% self-produced
Water management practices	Drip irrigation, mulching, dryland farming, proper irrigation scheduling (e.g., irrigating at night), buried clay pot irrigation in market gardening, drainage	0	No implementation of techniques, practices and strategies for conserving water, noticeable inefficient water use in the farm
		1	Water conservation practices used rarely and/or only in a small part of the farm (up to 30% of the farmed land (on land where applicable)
		2	Moderate use of water conservation practices, in 31-50% of the farmed land
		3	Water conservation practices often used on more than 50% of the farmed land
Agroforestry	Windbreaks, use of shading trees, etc., Trees and other woody species can produce fruit, timber, firewood, forage, etc., Hedges, wooded strips, and tree lines, Traditional European agroforestry systems include the 'bocage' (hedge-row network) in livestock breeding regions, grazed traditional orchards, pollard tree rows, and the Mediterranean open forest associating several oak species and grazed by cattle, sheep and pig (Dehesa/Montado). Silvoarable systems. Silvopastoral systems. Forest farming.	0	Not implemented at all
		1	Rarely used and/or only in a small part of the farmed land (less than 25%)
		2	Moderate use, in up to one half of the farmed land (25-50%)
		3	Often used, in more than one half of the farmed land

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

Table 7: Agricultural practices and Ecosystem Services correlation developed by Bassinga et al. (2025), as used in *RADIANT-METRICS* tool.

		Ecosystem services (ES)					
		Carbon Sequestration	Increase N fixation	Minimise soil erosion	Pest and Disease Control	Pollination	Biodiversity
Agricultural indicators (AI)	Conservation and no-tillage systems	x	x	x	x		x
	Crop rotation	x	x		x	x	x
	Intercropping	x	x		x	x	x
	Cover crops	x			x	x	x
	Soil organic matter input	x	x				x
	Organic pest and disease control				x	x	x
	Water management practices	x			x		
	Agroforestry	x			x	x	x

Table 8: Normalisation steps for Ecosystem Services indicators *RADIANT-METRICS* tool.

AP rating	Normalisation value
0	1.00
1	0.67
2	0.33
3	0.00

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

3. Conclusions

The *RADIANT-Metrics* decision support tool provides a multi-faceted analysis to support decision making pertaining to sustainable and resilient crop value chains. The LCA indicators offer a perspective on the environmental performance of the value chain, with environmental impacts calculated in relation to a specific functional unit (environmental intensity per unit product). The environmental efficiency indicators, on the other hand, adopt an efficiency perspective at the field or farm level, with an area-based analysis. This provides complementary insight into the environmental intensity per hectare of fam land/landscape. Despite the differing analytical bases, both frameworks focus on production and resource efficiency. In contrast, the ecosystem services framework evaluates farm-level practices, not limited to one cropping system, and does not necessarily rate the most productive or efficient system (in terms of harvested output) as the best - but rather prioritises the system that is managed in a manner compatible with healthy and resilient ecosystems. The economic pillar provides a framework with indicators at both farm and value chain levels, complementing environmental performance assessment with economic performance assessment (e.g. profitability), but also indicating economic resilience (e.g. income and activity diversification).

The tool is deliberately designed not to generate absolute values for comparison against other studies. The normalisation steps used to enable benchmarking are based on a comparative approach. Therefore, they only apply to the alternatives under analysis, with the worst alternative always scoring 1. Additionally, to generate a single score for each field of analysis, it is assumed that all indicators hold equal importance (i.e., have the same weight). As such, the unique framework proposed by this tool should be interpreted with caution. Its main goal is to understand the relative performance of alternative systems across pillars pertinent to sustainability and resilience – indicating the relative strengths and weaknesses of (a) particular (innovative) crop value chain(s) when compared with (a) relevant (conventional) comparator value chain(s).

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

4. References

Alejandre, E.M; van Bodegom,, P.M; Guinee, J.B. Towards an optimal coverage of ecosystem services in LCA. Journal of Cleaner production. V. 231, 2019, p. 714-722https://doi.org/10.1016/j.jclepro.2019.05.284

Bassignana, C. F; Bruno, V; Migliorini, P (2025). APES Framework - Agroecological Practices for assessing Ecosystem Services. EU-H2020 funded project, “Realising Dynamic Value Chains for Underutilised Crops” (RADIANT), grant agreement No. 101000622. Available online at: www.radiantproject.eu. DOI:10.5281/zenodo.15197074.

Batool, M., Sarrazin, F.J., Attinger, S. et al. Long-term annual soil nitrogen surplus across Europe (1850–2019). Sci Data 9, 612 (2022). https://doi.org/10.1038/s41597-022-01693-9

Batool, M., Sarrazin, F. J., and Kumar, R.: Century-long reconstruction of gridded phosphorus surplus across Europe (1850–2019), Earth Syst. Sci. Data, 17, 881–916, https://doi.org/10.5194/essd-17-881-2025, 2025.

Bergez, J.-E. ; Béthinger,A; Bockstaller, C; Cederberg, C; Ceschia, E; Guilpart, N; Lange, S.; Müller, F; Reidsma,P; Riviere, C; Schader, C; Therond, O; van der Werf, H.M.G. (2022) Integrating agri-environmental indicators, ecosystem services assessment, life cycle assessment and yield gap analysis to assess the environmental sustainability of agriculture. Ecological Indicators, 141, 109107 doi.org/10.1016/j.ecolind.2022.109107.

Costa, M.P., Chadwick, D., Saget, S. et al. Representing crop rotations in life cycle assessment: a review of legume LCA studies. Int J Life Cycle Assess 25, 1942–1956 (2020). https://doi.org/10.1007/s11367-020-01812-x

Cool Farm Tool. (2025). Cool Farm Tool. https://app.coolfarmtool.org/

European Commission (2018). Product Environmental Footprint Category Rules Guidance.

Hestia (2025). Hestia Data and models for more sustainable agriculture. https://www.hestia.earth/

de Mey, Y., Bremaud, M.F., Meuwissen, M., Styles, D., Saget, S., Williams, M. (2024). D4.2 - Assessing farm level performance of Underutilized Crops for the EU-H2020 funded project, “Realising Dynamic Value Chains for Underutilised Crops” (RADIANT), grant agreement No. 101000622. Available online at: www.radiantproject.eu DOI: 10.5281/zenodo.10727246

Saget, S., Bremaud, M.F., Meuwissen, M., de Mey, Y., Styles, D., Williams, M. (2024). D4.3 – Underutilized crops value chain sustainability and resilience. EU-H2020 funded project – ‘Realising Dynamic Value Chains for Underutilised Crops (RADIANT)’, grant agreement No. 101000622. DOI: 10.5281/zenodo.13378390.

Saget, S., Styles, D., & Williams, M. (2024). Comparative Life Cycle Assessment of alternative winter salad value chains supplying the United Kingdom. *Science of The Total Environment*, *952*, 175870

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

Disclaimer

Copyright

Citation

Please cite this report as follows:
Costa, Marcela, P.; Saget, S.; Williams, M.; Bassignana, C.F.; Migliorini,P.; de Mey, Y.; Bremaud, M. Styles, D. (2024). D4.5 - RADIANT-Metrics, state-of-the-art quantitative framework & decision support tool, for the EU-H2020 funded project “Realising Dynamic Value Chains for Underutilised Crops” (RADIANT), grant agreement No. 101000622. Available online at: www.radiantproject.eu DOI:10.5281/zenodo.15346246.

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

Appendix 1: Preliminary case study application

This appendix summarises results from application of the *RADIANT-Metrics* tool to four case studies comparing UCs with conventional alternatives. Full results can be found in accompanying MS Excel files, and will be written up in a peer-reviewed article.

The *RADIANT-Metrics* decision support tool MS Excel files contain the case study input data, and present results via an interactive dashboard across the relevant dimensions described above: LCA (up to six environmental impact categories), environmental efficiency (three indicators), economic performance (six indicators), and ecosystem services (eight indicators of agricultural practice). Indicators are measured at farm and/or value chain level, and can be followed through to value chain (product) level in follow-up analyses where necessary. UC study case results are briefly described below.

Input data were obtained from different Work Packages (WP) of the *RADIANT* project. LCA and agricultural efficiency input data were sourced from LCA conducted by Trinity College Dublin and University of Galway in WP4. Ecosystem Services indicators were derived and assessed by University of Gastronomy of Pollenzo in WP3, and economic indicators were derived and assessed by Wageningen University in WP4.

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

1. Acorn (pickled) vs. olives as an appetizer (Portugal)

1.1. Input data for RADIANT-*Metrics* tool

The first comparison is pickled Acorns (UC) vs. Olives as a traditional appetizer. Input data can be observed on Table A1.

Table A1: Input data for the following indicators: LCA, Environmental Efficiency, Agroecological practices and Economic Indicators, for the comparison of appetizes types: Acorn (pickled) (UC) (Alternative 1) versus olives (Alternative 2).

Realizing dynamic value chains for underutilised crops		Alternative 1	Alternative 2
Indicator	Unit	Fermented Acorns (Focused approach)	Pickled Olives
Life Cycle Assessment and Life Cycle Inventory (environmental efficiency)			
Functional Unit:	**1 kg pickled food**		
Carbon footprint	kg CO2 eq. per Functional Unit	-2.70E+00	-7.10E-02
Eutrophication (marine)	kg N eq per Functional Unit	8.10E-02	1.00E-03
Eutrophication (freshwater)	kg P eq per Functional Unit	1.33E-04	3.00E-05
Water consumption (AWARE)	m3 depriv. per Functional Unit	2.00E-01	1.90E+00
Resources depletion - mineral	kg Sb eq per Functional Unit	4.80E-06	1.90E-06
Resources depletion - non renewable energy (Fossils)	MJ, net calorific value per Functional Unit	8.90E+00	1.40E+00
Environmental efficiency indicators			
N Balance	kg/ha	8.10E-02	1.31E-03
P Balance	kg/ha	1.33E-04	3.04E-05
Yields	kg/ha	387	5,020
Agroecological indicators (ecosystem Services & resilience)			
Conservation and no-tillage	Scale 0-3, 3 = best	3	1
Crop rotation	Scale 0-3, 3 = best	0	0
Intercropping	Scale 0-3, 3 = best	3	0
Cover crops	Scale 0-3, 3 = best	3	1
Soil organic matter input	Scale 0-3, 3 = best	3	1
Organic pest and disease	Scale 0-3, 3 = best	3	0
Water management practices	Scale 0-3, 3 = best	2	1
Agroforestry	Scale 0-3, 3 = best	3	2
Economic indicators (economic viability & resilience)			
Profit	Scale 1-5 , 5= best	5	3
Risk	Scale 1-5 , 5= best	4	4
Diversification of activities	Scale 1-5 , 5= best	5	2
Value chain lenght	Scale 1-5 , 5= best	5	3
Power/trust	Scale 1-5 , 5= best	5	2
Autonomy	Scale 1-5 , 5= best	5	3

1.2. Results from RADIANT-*METRICS* tool

Results show different comparative strengths and weaknesses for the two systems across different areas. Fermented Acorns (Alternative 1) display better results for Ecosystem services and Economic viability and resilience, while olives (Alternative 2) perform better on the LCA and on Environmental Efficiency Indicators. This can be observed in Figure A1 below. More details on each area can be found below.

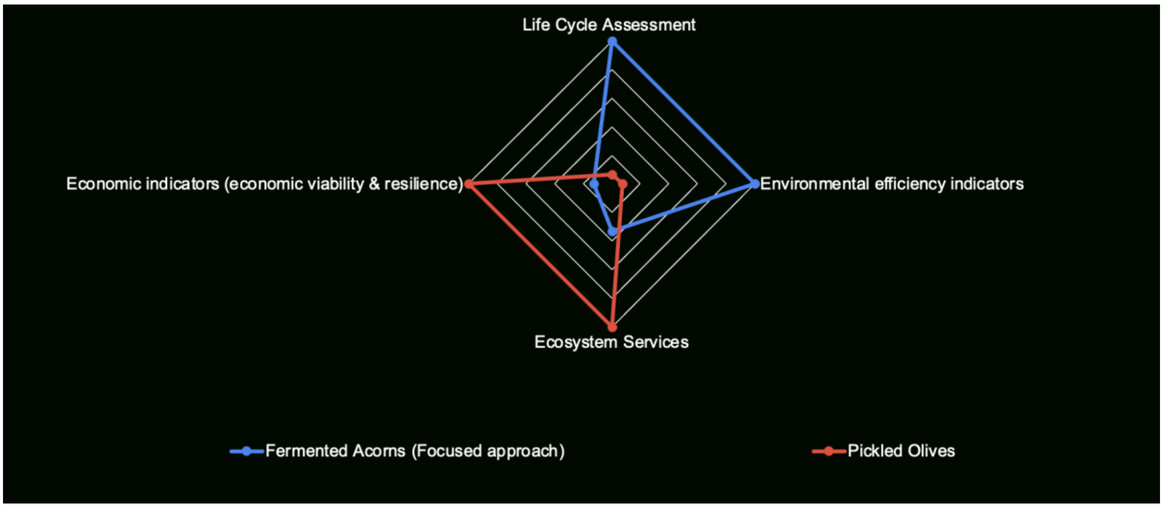
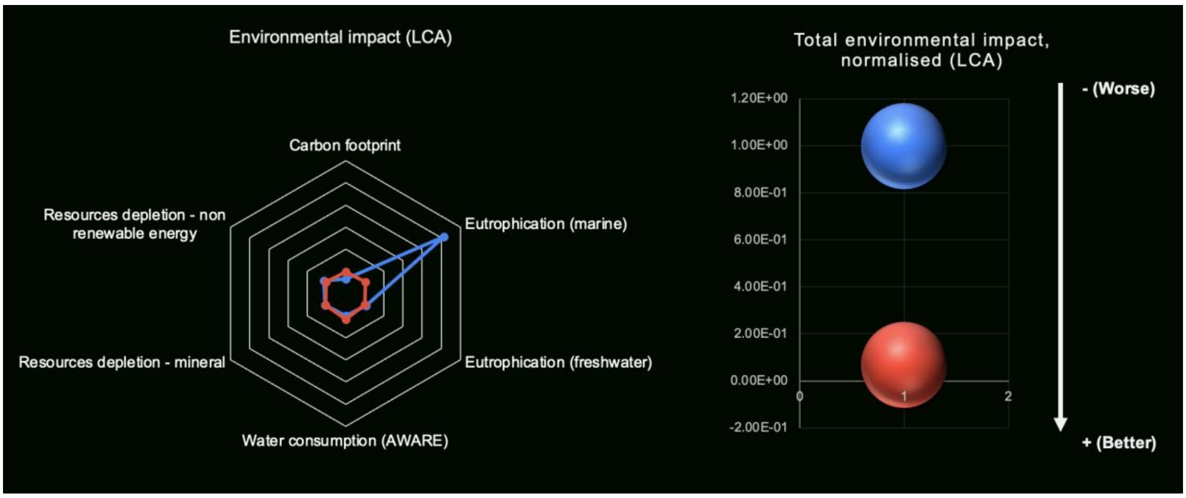


Figure A1: General results for the 4 areas evaluated in the *RADIANT-METRICS* tool for the Acorn (pickled) (Alternative 1) versus Olives (Alternative 2). Lines closer to the edge represent worse performance, whilst lines closer to the centre represent better performance.

Looking further into the LCA comparison, the pickled Acorns showed better results for the carbon footprint and water consumption while Olives ranked better across the other categories (Figure A2). A bigger discrepancy in results is observed in the marine eutrophication impact, where the olives ranked better. This was the determining weighted factor within the single score indicator that indicated Olives performed better overall.



Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

Figure A2: Specific results for the Life Cycle Assessment evaluated in the *RADIANT-METRICS* tool for pickled Acorn (Alternative 1) versus Olives (Alternative 2) study case. Lines closer to the edge represent worse performance in that area (left graphic), while the graphic on the right represents single score results for the LCA (higher location of the bubble, worse performance).

For the agricultural efficiency indicators, both alternatives ranked similarly for the N and P balance categories, without large nutrient deficit or surplus in either case. Therefore, the determining factor in this category was the yield. Olives achieve a higher yield, and therefore secure a higher performance overall (Figure A3).

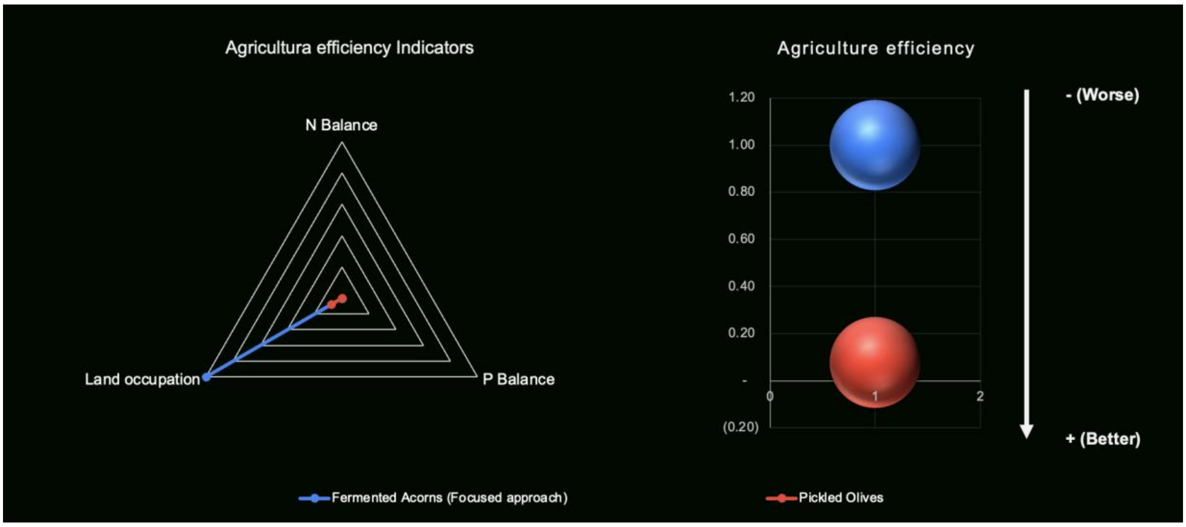


Figure A3: Specific results for the Agricultural efficiency indicators evaluated in the *RADIANT-METRICS* tool for the pickled Acorn (Alternative 1) versus Olives (Alternative 2). Lines closer to the edge represent worse performance in that area (left graphic), while the graphic on the right represents single score results (higher location of the bubble, worse performance).

In contrast to the LCA and Agricultural efficiency, ecosystem services assessment brings a different perspective, in which the Olives perform worse and pickled Acorns show an advantage (Figure A4). This is because the acorns, despite not being very efficient in terms of inputs and yield (outputs), are planted in agroforestry systems, promoting other benefits not captured in a business-as-usual LCA.

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

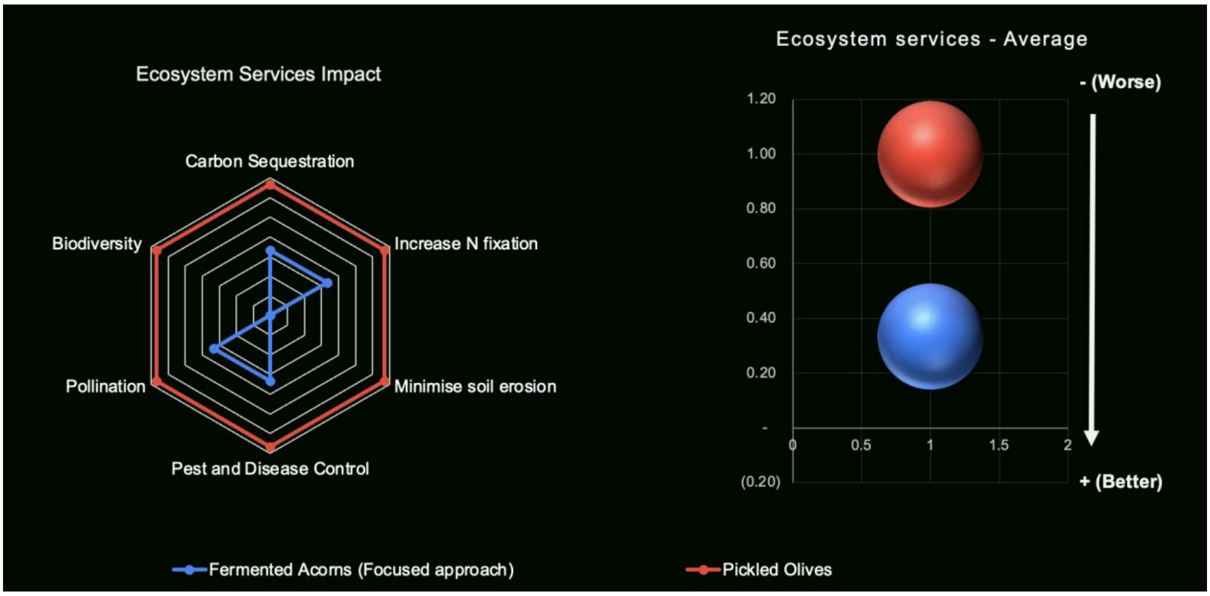


Figure A4: Specific results for the Ecosystem services evaluated in the *RADIANT-METRICS* tool for pickled Acorns (Alternative 1) versus Olives (Alternative 2). Lines closer to the edge represent worse performance in that area (left graphic), while the graphic on the right represents single score results (higher location of the bubble, worse performance).

Similarly for the economic indicators, the pickled Acorn alternative shows higher resilience compared to typical olive monocropping, ranking equally only on the risk category.

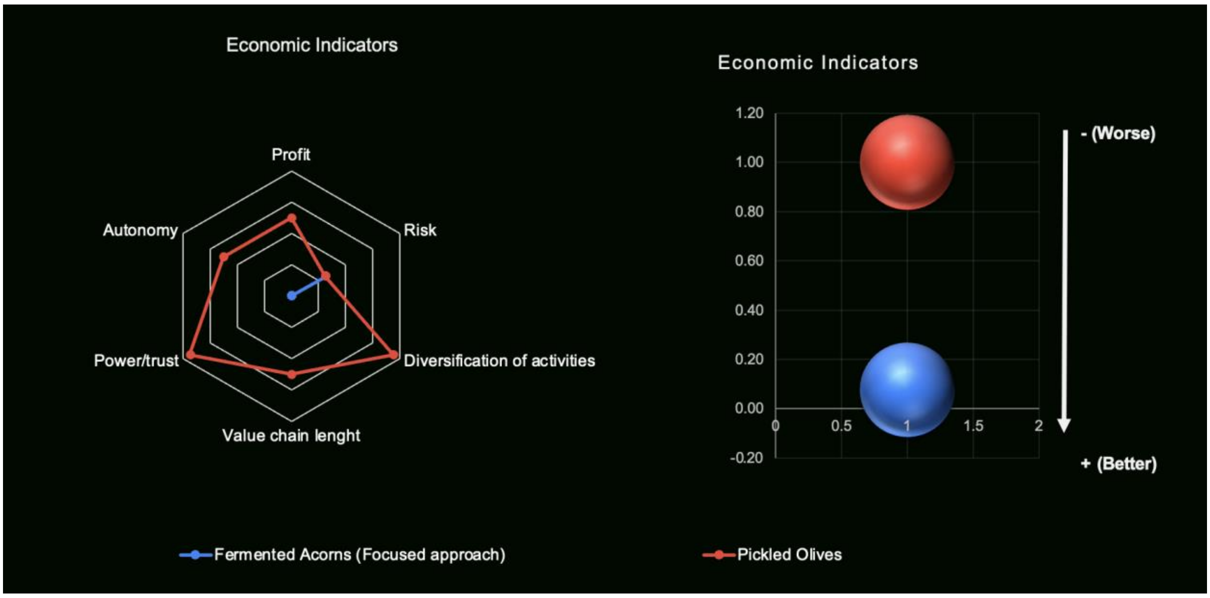


Figure A5: Specific results for Economic Indicators evaluated in the RADIANT-METRICS tool for pickled Acorns (Alternative 1) versus Olives (Alternative 2) study case. Lines closer to the edge represent worse performance in that area (left graphic), while the graphic on the right represents single score results (higher location of the bubble, worse performance).

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

2. Acorn flour vs. wheat flour (Portugal)

2.1. Input data for RADIANT-*Metrics* tool

This case study compares Acorn flour (Alternative 1) as the UC product vs traditional wheat flour (Alternative 2). Input for can be observed in Table A2.

Table A2: Input data for following indicators: LCA, Environmental Efficiency, Agroecological practices and Economic Indicators, for the comparison of flour types: Acorn flour (UC) (Alternative 1) versus traditional wheat flour (Alternative 2).

Realizing dynamic value chains for underutilised crops		Alternative 1	Alternative 2
Indicator	Unit	Acorn flour (Focused approach)	Organic wheat flour
Life Cycle Assessment and Life Cycle Inventory (environmental efficiency)			
Functional Unit:	**1 kg of flour**		
Carbon footprint	kg CO2 eq. per Functional Unit	-3.50E+00	5.00E-01
Eutrophication (marine)	kg N eq per Functional Unit	1.10E-01	2.00E-02
Eutrophication (freshwater)	kg P eq per Functional Unit	1.60E-04	2.00E-04
Water consumption (AWARE)	m3 depriv. per Functional Unit	2.00E-01	3.10E+00
Resources depletion - mineral	kg Sb eq per Functional Unit	5.20E-06	1.80E-06
Resources depletion - non renewable energy (Fossils)	MJ, net calorific value per Functional Unit	1.12E+01	3.40E+00
Environmental efficiency indicators			
N Balance	kg/ha	1.05E-01	2.45E-02
P Balance	kg/ha	1.57E-04	1.97E-04
Yields	kg/ha	387	4,069
Agroecological indicators (ecosystem Services & resilience)			
Conservation and no-	Scale 0-3, 3 = best	3	1
Crop rotation	Scale 0-3, 3 = best	0	3
Intercropping	Scale 0-3, 3 = best	3	2
Cover crops	Scale 0-3, 3 = best	3	1
Soil organic matter	Scale 0-3, 3 = best	3	2
Organic pest and	Scale 0-3, 3 = best	3	3
Water management	Scale 0-3, 3 = best	2	1
Agroforestry	Scale 0-3, 3 = best	3	0
Economic indicators (economic viability & resilience)			
Profit	Scale 1-5 , 5= best	4	3
Risk	Scale 1-5 , 5= best	4	3
Diversification of	Scale 1-5 , 5= best	5	2
Value chain length	Scale 1-5 , 5= best	5	2
Power/trust	Scale 1-5 , 5= best	5	3

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

Autonomy	Scale 1-5 , 5= best	5	3

2.2. Results from RADIANT-*Metrics* tool

Acorn flour (UC) option (Alternative 1) displays better results for Ecosystem services and Economic viability and resilience, while the organic wheat flour (alternative 2) performs better for LCA and Environmental Efficiency Indicators. This can be observed in below in Figure A6. More details on each area can be found below.

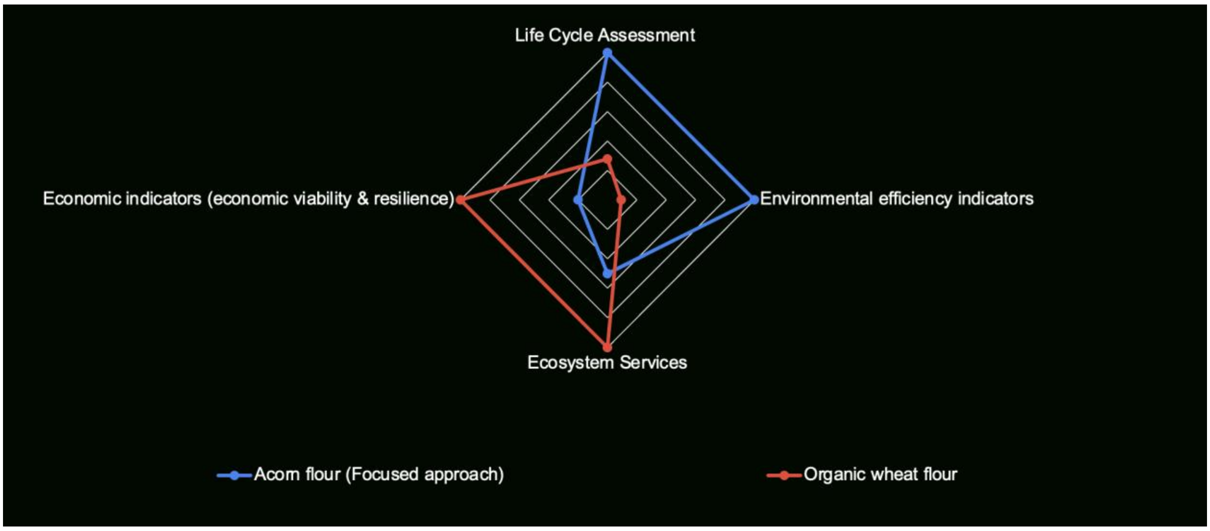


Figure A6: General results for the 4 areas evaluated in the *RADIANT-METRICS* tool for Acorn flour (UC) (Alternative 1) versus wheat flour (Alternative 2). Lines closer to the edge represent worse performance in that area.

Looking further into the LCA comparison, similarly to case study 1, the acorn flour showed better results for the carbon footprint and water consumption while the organic wheat flour ranked better across all other categories (Figure A7). A bigger discrepancy on is observed for the marine eutrophication impact, where the organic wheat flour ranked better. This was the determining weighted factor, making the organic wheat flour the better performer overall.

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

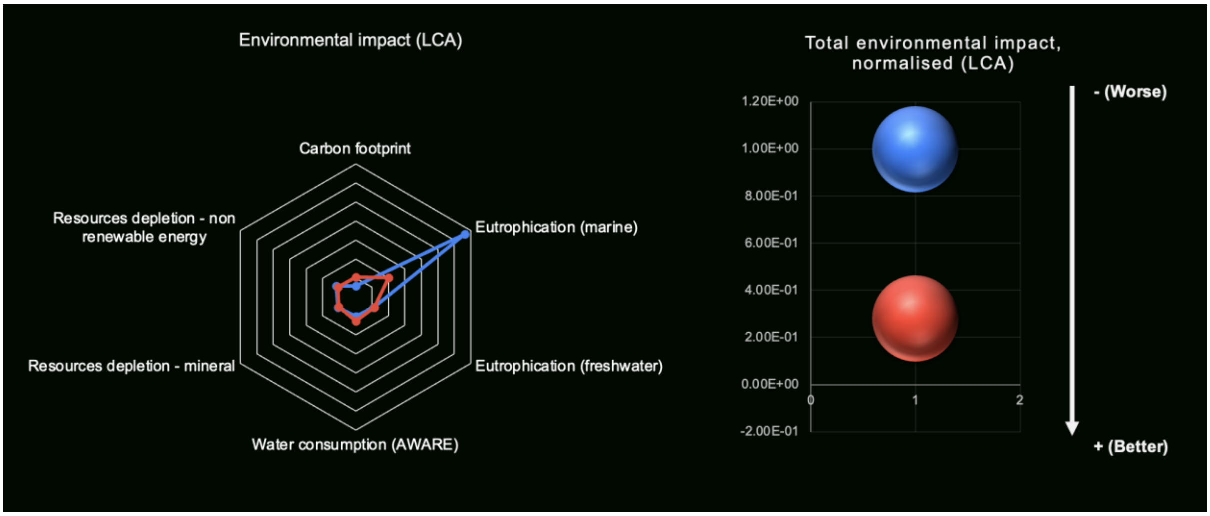


Figure A7: Specific results for the Life Cycle Assessment evaluated in the *RADIANT-METRICS* tool for Acorn (flour) (Alternative 1) versus organic wheat flour (Alternative 2). Lines closer to the edge represent worse performance in that area (left graphic), while the graphic on the right represents single score results for the LCA (higher location of the bubble, worse performance).

For the agricultural efficiency indicators, both alternatives ranked well for N and P balances. Therefore, the determining factor in this category was yield, which was higher (better) for organic wheat flour (Figure A8).

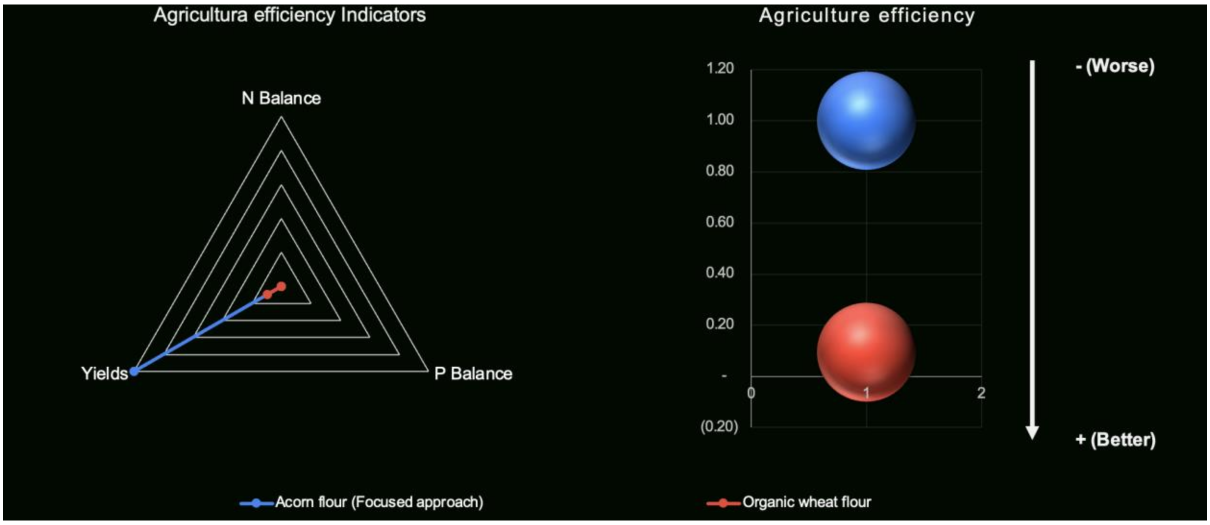


Figure A8: Specific results for the Agricultural efficiency indicators evaluated in the *RADIANT-METRICS* tool for Acorn flour (Alternative 1) versus organic wheat flour (Alternative 2). Lines closer to the edge represent worse performance in that area (left graphic), while the graphic on the right represents single score results (higher location of the bubble, worse performance).

In contrast to LCA and Agricultural efficiency scores, ecosystem services bring a different perspective, in which the organic wheat flour performs worse and the UC alternative (acorn flour) shows clear advantages across three of the six categories evaluated (Figure A9). This is because the acorns despite not being very efficient in terms of inputs and yield (outputs), they are planted in agroforestry systems, promoting other benefits do not capture in a business-as-usual LCA. Slightly different than the study case 1, this comparison shows a

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

lower contrast on performance for the compared alternative (organic wheat flour) in three out of six alternatives. This is because the alternative 2 is based on organic systems rather than just conventional wheat.

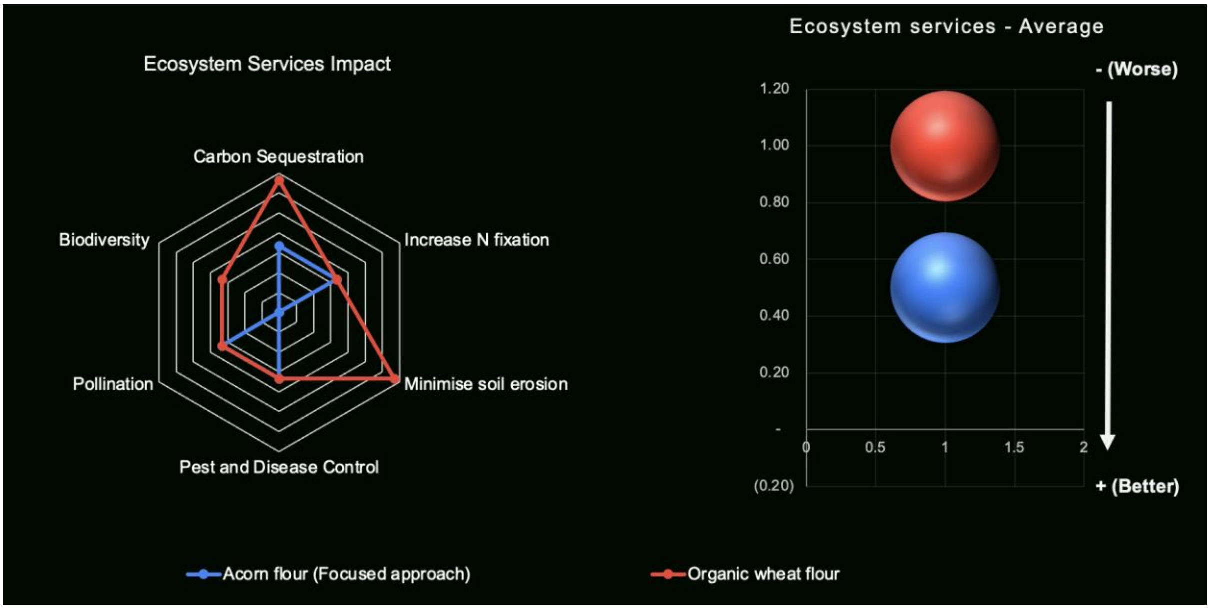


Figure A9: Specific results for Ecosystem Services evaluated in the *RADIANT-METRICS* tool for Acorn flour (Alternative 1) versus organic heat flour (Alternative 2). Lines closer to the edge represent worse performance in that area (left graphic), while the graphic on the right represents single score results (higher location of the bubble, worse performance).

Similarly to Ecosystem Services, the acorn flour (UC) alternative shows a better economic resilience towards its value chain compared to a typical olives monocropping across all areas evaluated (Figure A10).

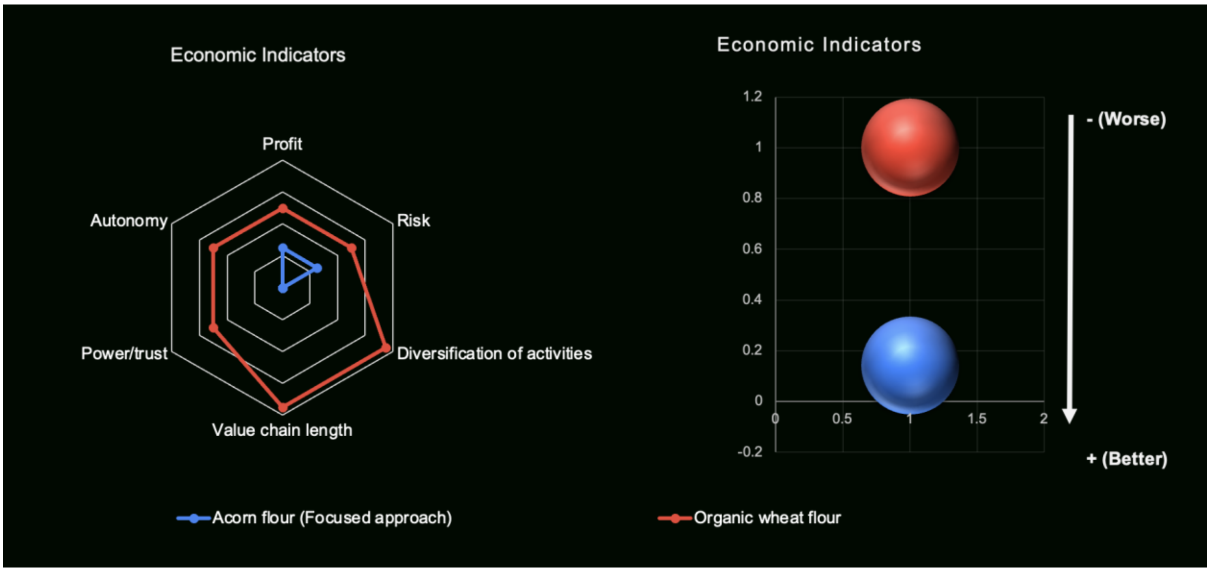


Figure A10: Specific results for Economic Indicators evaluated in the *RADIANT-METRICS* tool for Acorn flour (Alternative 1) versus organic wheat flour (Alternative 2). Lines closer to the edge represent worse performance

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

on that area (left graphic), while the graphic on the right represents a single score results (higher location of the bubble, worse performance).

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

3. Bere barley production vs. conventional barley, under conventional cropping and agroecological systems (Scotland)

3.1. Input data for RADIANT-*Metrics* tool

The third case study compares bere barley flour (UC) under conventional management (alternative 1) and agroecological management (alternative 3) versus traditional barley under conventional and agroecological management (alternatives 2 & 4). Input data for all alternatives can be found in the Table A3 below.

Table A3: Input data for following indicators: LCA, Environmental Efficiency, Agroecological practices and Economic Indicators, for the comparison of flour types: bere barley flour (UC) (Alternative 1), traditional barley flour (Alternative 2), bere barley flour from agroecological system (UC) (Alternative 3), and conventional flour from agroecological system (Alternative 4).

Realizing dynamic value chains for		Alternative	Alternative 2	Alternative 3	Alternative 4
Indicator	Unit	Flour B	Flour B	Flour C	Flour C
Life Cycle Assessment and Life Cycle Inventory (environmental efficiency)					
Functional Unit:	**1 kg of flour**				
Carbon footprint	kg CO2 eq. per Functional Unit	9.60E-01	9.20E-01	9.79E-01	7.05E-01
Eutrophication (marine)	kg N eq per Functional Unit	1.05E-02	1.87E-02	9.90E-03	1.39E-02
Eutrophication (freshwater)	kg P eq per Functional Unit	2.02E-04	1.69E-04	1.91E-04	1.06E-04
Water consumption (AWARE)	m3 depriv. per Functional Unit	9.80E-01	9.00E-01	1.38E+00	6.13E-01
Resources depletion - mineral	kg Sb eq per Functional Unit	4.73E-06	4.09E-06	5.05E-06	2.84E-06
Resources depletion - non renewable energy	MJ, net calorific value per Functional Unit	7.40E+00	7.97E+00	8.04E+00	5.89E+00
Environmental efficiency indicators					
N Balance	kg/ha	-0.98	-0.95	-0.98	-0.96
P Balance	kg/ha	-0.438	-0.443	-0.442	-0.451
Yields	kg/ha	3,750	4,940	2,350	7,680
Agroecological indicators (ecosystem Services & resilience)					
Conservation and no-	Scale 0-3, 3 = best	1	1	2	2
Crop rotation	Scale 0-3, 3 = best	2	2	3	3
Intercropping	Scale 0-3, 3 = best	0	0	2	2
Cover crops	Scale 0-3, 3 = best	2	2	3	3
Soil organic matter	Scale 0-3, 3 = best	1	1	2	2
Organic pest and	Scale 0-3, 3 = best	1	1	3	3
Water management	Scale 0-3, 3 = best	0	0	0	0
Agroforestry	Scale 0-3, 3 = best	0	0	0	0
Economic indicators (economic viability & resilience)					
Profit	Scale 1-5 , 5= best	4	2	4	4
Risk	Scale 1-5 , 5= best	4	3	4	4
Diversification of	Scale 1-5 , 5= best	3	3	4	4
Value chain length	Scale 1-5 , 5= best	4	1	5	5

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

Power/trust	Scale 1-5 , 5= best	5	2	5	5
Autonomy	Scale 1-5 , 5= best	3	2	4	4

3.2. Results from RADIANT-*Metrics* tool

Conventional barley (alternative 2) presented the worst overall performance, even though it ranked second best on agricultural environmental efficiency. The agroecological alternatives (alternatives 3 and 4) showed better overall performance across the 4 areas, even if alternative 3 (bere barley, agroecological) showed the worst performance on agricultural environmental efficiency. This can be observed in Figure A11. More details on each area can be found below.

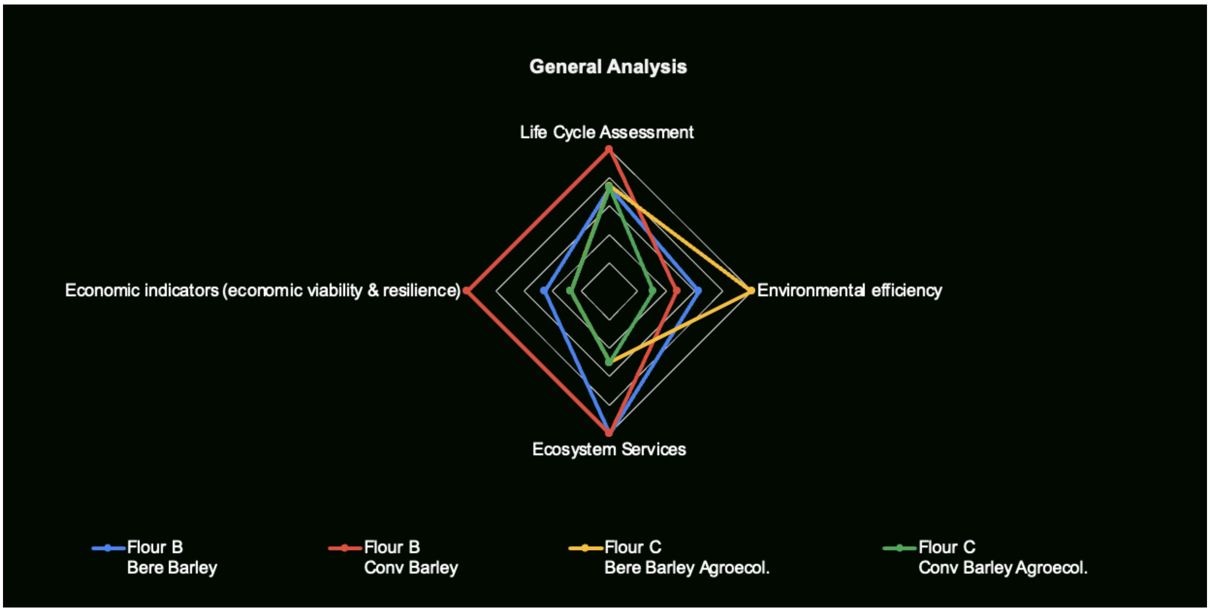


Figure A11: General results for the 4 areas evaluated in the *RADIANT-METRICS* tool for Acorn flour (Alternative 1 & 3) versus wheat flour (Alternative 2 & 4). Lines closer to the edge represent worse performance in that area.

Looking further into the LCA comparison, similarly to the case studies above, the marine eutrophication impact presented the largest discrepancy across the alternatives, driving final single score results. The worst performance was achieved by Alternative 2 (conventional barley) followed by Alternative 3 (bere barley, agroecological) and then by Alternatives 1 and 4 (bere barley, conventional management, and conventional barley, agroecological management, respectively. Performance differences between alternatives 3 ,1 and 4 were minimum. Interestingly, if the impact of marine eutrophication was not evaluated, the order of performance would change considerably, with conventional barley managed agroecologically (alt 4) ranking the best, followed by conventional barley managed conventionally (alt 2), bere barley managed conventionally (alt 1) and bere barley managed agroecologically (alt 3). These results can be found in Figure A12.

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

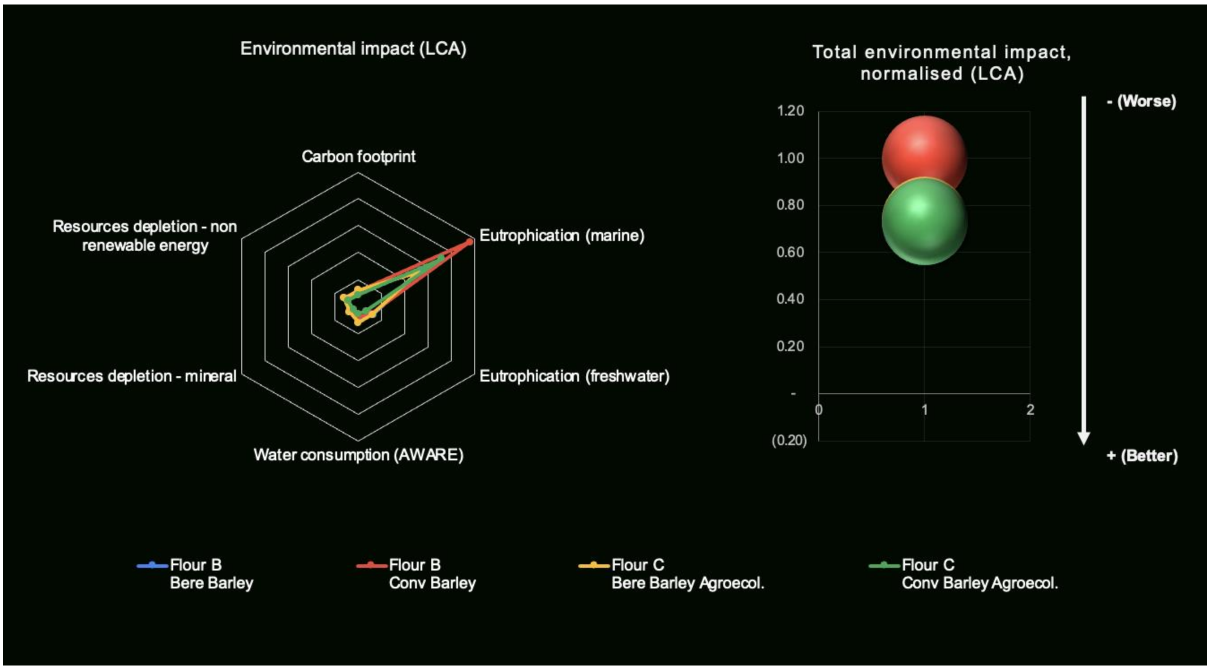


Figure A12: Specific results for the Life Cycle Assessment evaluated in the *RADIANT-METRICS* tool for the barley flour types. Bere barley flour is Alternative 1, conventional barley is alternative 2, bere barley from agroecological system is alternative 3 and conventional barley from agroecological system is alternative 4. Lines closer to the edge represent worse performance in that area (left graphic), while the graphic on the right represents single score results for the LCA (higher location of the bubble, worse performance).

For the agricultural efficiency indicators, all alternatives ranked well for the N and P balance. The determining factor in this category was again yield. Conventional barley from agroecological systems demonstrated the highest yields and therefore a higher performance overall, followed by conventional barley managed conventionally, bere barley managed conventionally and bere barley managed agroecologically (Figure A13).

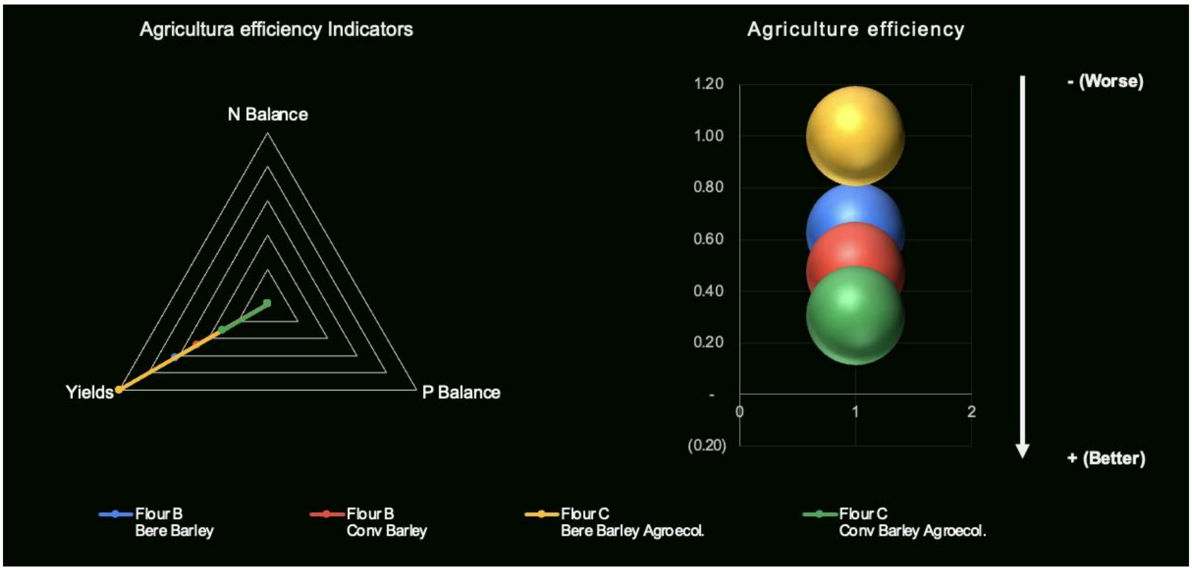


Figure A13: Specific results for Agricultural efficiency indicators evaluated in the *RADIANT-METRICS* tool for the barley flour types. Bere barley flour is Alternative 1, conventional barley is alternative 2, bere barley from agroecological system is alternative 3 and conventional barley from agroecological system is alternative 4. Lines

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

closer to the edge represent worse performance in that area (left graphic), while the graphic on the right represents single score results (higher location of the bubble, worse performance).

For ecosystem services, the alternatives from agroecological systems performed better (alternative 3 and alternative 4) compared to the alternatives from conventional systems (alternative 1 and 2) (Figure A14). There was no difference in performance between the UC and conventional barley variety when analysed under the same system (conventional or agroecological)

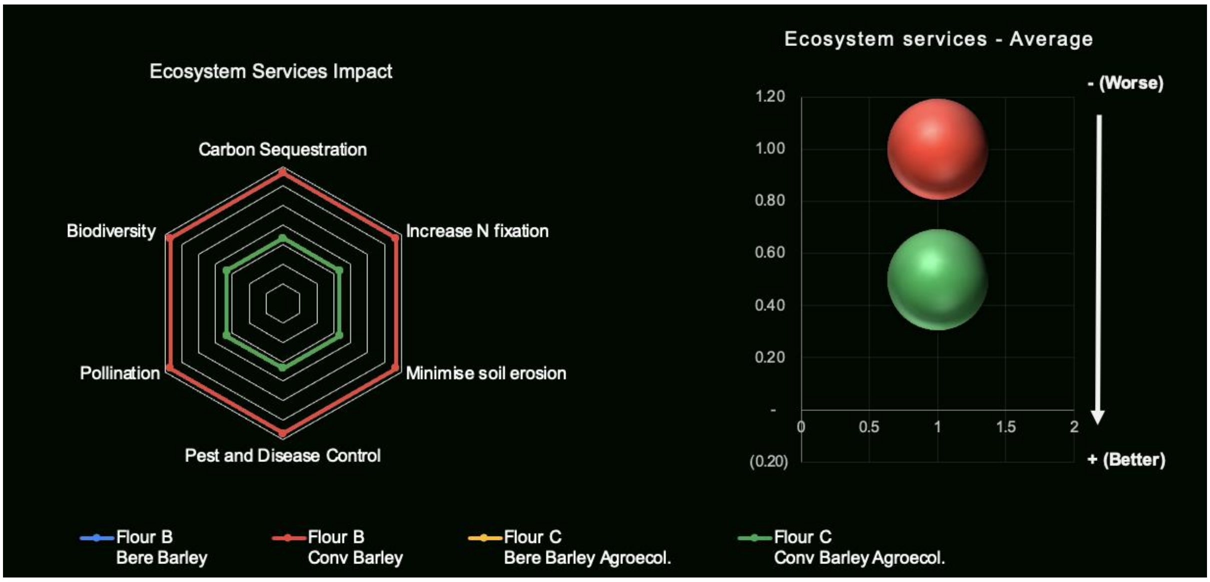


Figure A14: Specific results for Ecosystem services evaluated in the *RADIANT-METRICS* tool for barley flour types study case. Bere barley flour is Alternative 1, conventional barley is alternative 2, bere barley from agroecological system is alternative 3 and conventional barley from agroecological system is alternative 4. Lines closer to the edge represent worse performance in that area (left graphic), while the graphic on the right represents single score results (higher location of the bubble, worse performance).

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

For the economic indicators (Figure A15), the best performance was achieved by the agroecological options (bere barley, alt 3 and conv. Barley, alt 4), followed by the conventionally managed bere barley (alt 1) and the conventionally managed conventional barley (alt 2).

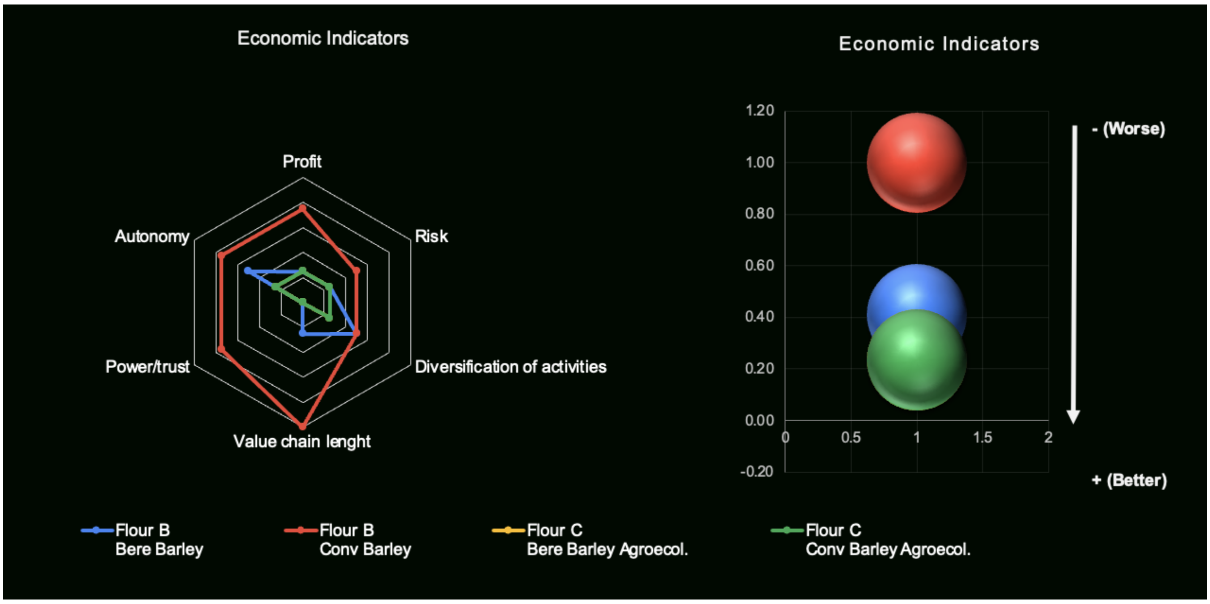


Figure A15: Specific results for the Economic Indicators evaluated in RADIANT-METRICS tool for the barley flour types study case. Bere barley flour (UC) is Alternative 1, conventional barley is alternative 2, bere barley from agroecological system (UC) is alternative 3 and conventional barley from agroecological system is alternative 4. Lines closer to the edge represent worst performance on that area (left graphic), while the graphic on the right represents a single score results (higher location of the bubble, worse performance).

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

4. Salad leaves from conventional, agro-ecological and hydroponic systems with grid- or renewable wind electricity (Spain & UK)

4.1. Input data for RADIANT-*Metrics* tool

The fourth case study compares conventional lettuce production from Spain (Alternative 1), Hydroponic lettuce from the UK (Alternative 2), Hydroponic lettuce from the UK with wind energy (Alternative 3) and finally the UC, mixed leaves under agroecological production on the Biofo farm in Portugal (Alternative 4). Input data are displayed in Table A4.

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

Table A4: Input data for following indicators: LCA, Environmental Efficiency, Agroecological practices and Economic Indicators, for the comparison of salad cultivation: Conventional lettuce from Spain (Alternative 1), Hydroponic lettuce from the UK (Alternative 2), Hydroponic lettuce from the UK with wind energy (Alternative 3), mixed leaf salad from Biofo farm in Portugal (Alternative 4).

Realizing dynamic value chains for underutilised crops		Alternative 1	Alternative 2	Alternative 3	Alternative 4
Indicator	Unit	Conventional Spain	Hydroponic UK	Hydroponic _ wind energy UK	Biofo, Portugal
Life Cycle Assessment and Life Cycle Inventory (environmental efficiency)					
Functional Unit:	**1 kg of salad leaves delivered to the UK**				
Carbon footprint	kg CO2 eq. per Functional Unit	6.27E-01	5.22E+00	5.74E-01	5.40E-01
Eutrophication (marine)	kg N eq per Functional Unit	2.58E-03	4.07E-03	5.96E-04	6.57E-03
Eutrophication (freshwater)	kg P eq per Functional Unit	1.03E-04	1.07E-03	2.09E-04	1.55E-04
Water consumption (AWARE)	m3 depriv. per Functional Unit	1.34E+01	5.22E-01	2.82E-01	1.18E+00
Resources depletion - mineral	kg Sb eq per Functional Unit	5.78E-06	6.12E-05	1.19E-05	3.39E-06
Resources depletion - non renewable	MJ, net calorific value per Functional Unit	8.96E+00	1.30E+02	6.71E+00	6.00E+00
Environmental agricultural efficiency					
N Balance	kg/ha	2.58E-03	4.07E-03	5.96E-04	7.22E-03
P Balance	kg/ha	1.03E-04	1.07E-03	2.09E-04	1.55E-04
Yields	kg/ha	71,900	1,558,500	1,558,500	36,500
Agroecological indicators (ecosystem Services & resilience)					
Conservation and no-tillage systems	Scale 0-3, 3 = best	0	0	0	3
Crop rotation	Scale 0-3, 3 = best	0	0	0	3
Intercropping	Scale 0-3, 3 = best	0	0	0	3
Cover crops	Scale 0-3, 3 = best	0	0	0	3
Soil organic matter input	Scale 0-3, 3 = best	1	0	0	3
Organic pest and disease control	Scale 0-3, 3 = best	0	0	0	3
Water management practices	Scale 0-3, 3 = best	1	1	1	3
Agroforestry	Scale 0-3, 3 = best	0	0	0	1
Economic indicators (economic viability & resilience)					
Profit	Scale 1-5 , 5= best	3	3	3	3
Risk	Scale 1-5 , 5= best	2	3	3	5
Diversification of activities	Scale 1-5 , 5= best	1	2	2	5
Value chain length	Scale 1-5 , 5= best	1	2	2	5
Power/trust	Scale 1-5 , 5= best	2	2	1	5
Autonomy	Scale 1-5 , 5= best	2	2	1	5

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

4.2. Results from RADIANT-*Metrics* tool

The Biofo mixed leaf salad from Portugal performed better across all areas, except for environmental efficiency in which it performed worst (Figure A16). The second best alternative was hydroponic lettuce from the UK with wind energy, followed by the hydroponic lettuce UK and last by the conventional lettuce from Spain. More details on each area can be found below.

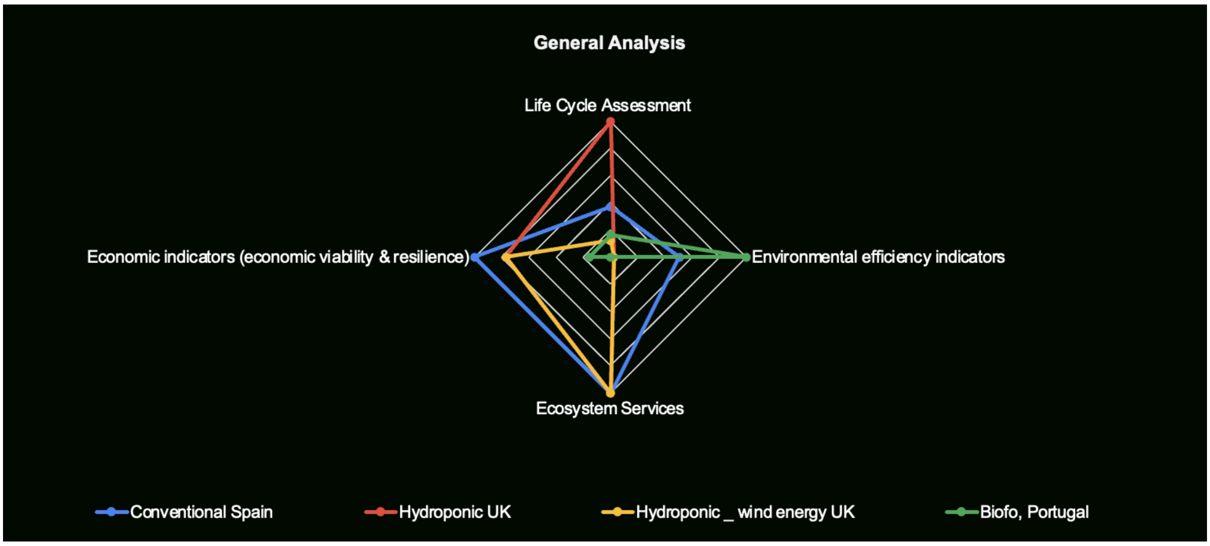


Figure A16: General results for the 4 areas evaluated in the *RADIANT-METRICS* tool for the lettuce systems (Conventional from Spain (Alternative 1), Hydroponic from the UK (Alternative 2), Hydroponic from the UK with wind energy (Alternative 3)) versus the mixed leaf UC salad from Biofo farm in Portugal (Alternative 4). Lines closer to the edge represent worse performance in that area.

Looking into the LCA comparison (Figure A17), it is possible to observe that the best ranked alternative was the Hydroponic system with wind energy in the UK, followed closely by the Biofo mixed leaf salad from Portugal (UC), then conventional lettuce in Spain and hydroponic lettuce with conventional energy in the UK. The Hydroponic system with conventional energy in the UK ranked worst for categories such as Resources depletion (renewables and non-renewables) and also on carbon footprint, while the conventional lettuce in Spain ranked worst for water consumption as the country is located in water scarcity region. The Biofo mixed leaf salad (UC) ranked worst only for marine eutrophication.

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

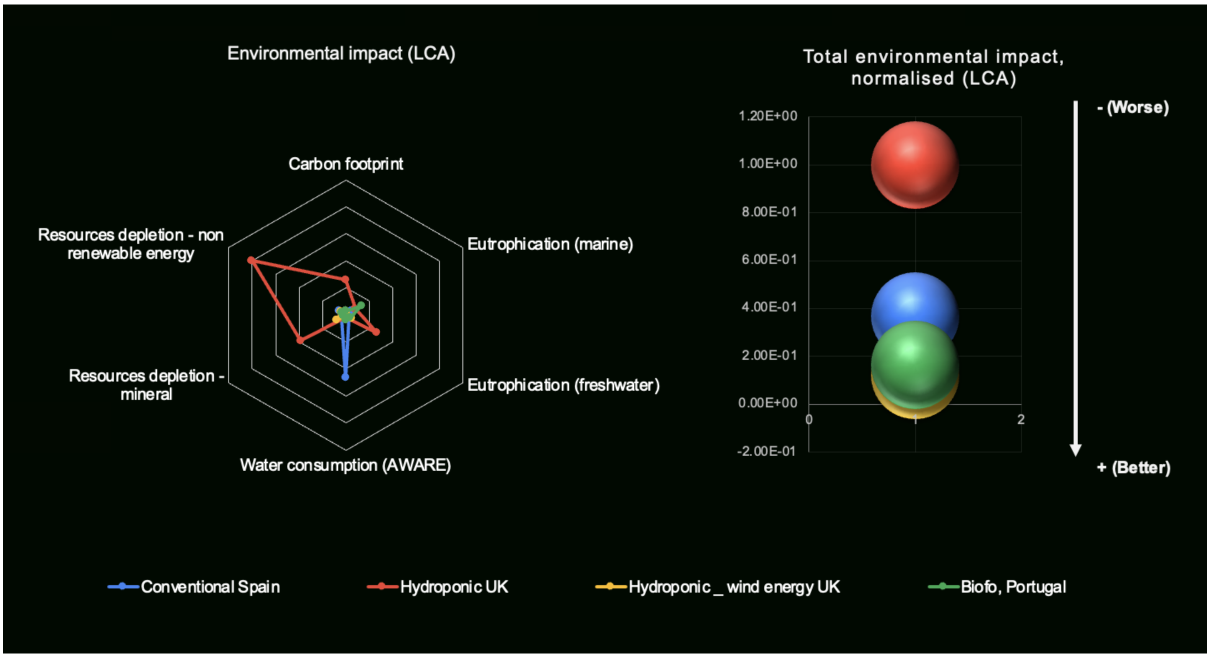


Figure A17: Specific results for Life Cycle Assessment evaluated in the *RADIANT-METRICS* tool for the lettuce systems (Conventional from Spain (Alternative 1), Hydroponic from the UK (Alternative 2), Hydroponic from the UK with wind energy (Alternative 3)) versus the mixed leaf salad from Biofo farm in Portugal (Alternative 4). Lines closer to the edge represent worse performance in that area (left graphic), while the graphic on the right represents single score results for the LCA (higher location of the bubble, worse performance).

For the agricultural efficiency indicators, (Figure A18), all alternatives ranked well for N and P balances. Again, the determining factor in this area was yield. The highest (best) yields were found for the UK Hydroponic lettuce production (2 and 3) followed by conventional Spanish production and then Biofo mixed leaf salad production in Portugal.

Figure A18: Specific results for Agricultural efficiency indicators evaluated in the *RADIANT-METRICS* tool for the lettuce systems (Conventional from Spain (Alternative 1), Hydroponic from the UK (Alternative 2), Hydroponic from the UK with wind energy (Alternative 3)) versus mixed leaf salad from Biofo farm in Portugal (Alternative 4). Lines closer to the edge represent worse performance on that area (left graphic), while the graphic on the right represents single score results (higher location of the bubble, worse performance).

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

For ecosystem services, the UC alternative (Biofo mixed leaf salad, Portugal) performed best compared with Hydroponic lettuce in the UK (alt 2 and 3) and Conventional lettuce from Spain (alt1) (Figure A19).

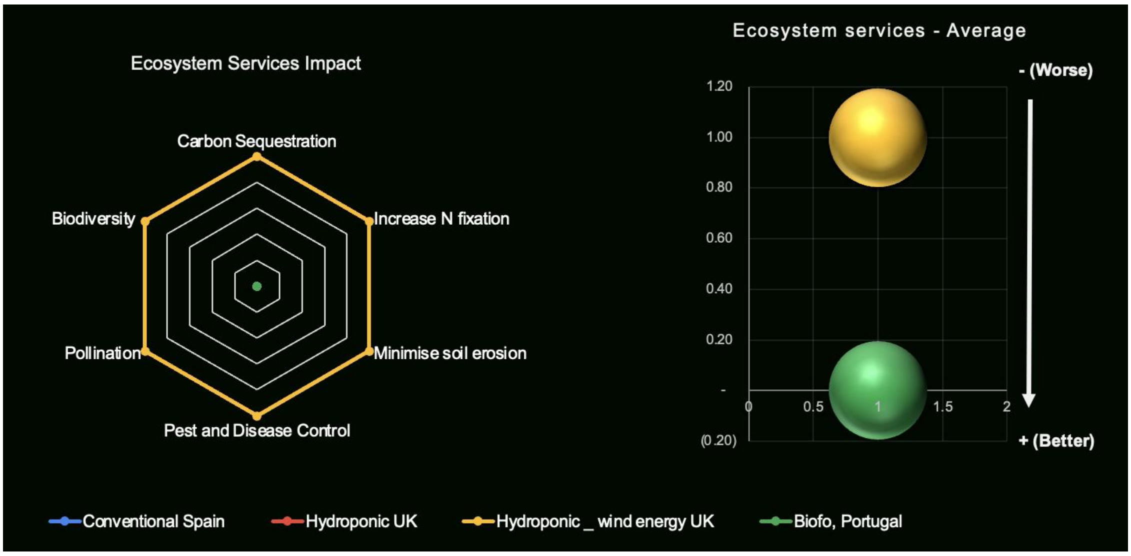


Figure A19: Specific results for Ecosystem services evaluated in the *RADIANT-METRICS* tool for the lettiuce systems (Conventional from Spain (Alternative 1), Hydroponic from the UK (Alternative 2), Hydroponic from the UK with wind energy (Alternative 3)) versus mixed leaf salad from Biofo farm in Portugal (Alternative 4). Lines closer to the edge represent worse performance in that area (left graphic), while the graphic on the right represents single score results (higher location of the bubble, worse performance).

Looking into the economic indicators, the best ranked alternative was Biofo mixed leaf salad (Portugal), followed by the Hydroponic UK lettuce with conventional and then with wind energy input, and then by the worst ranked alternative, Conventional lettuce from Spain. Results can be observed in Figure A20 below.

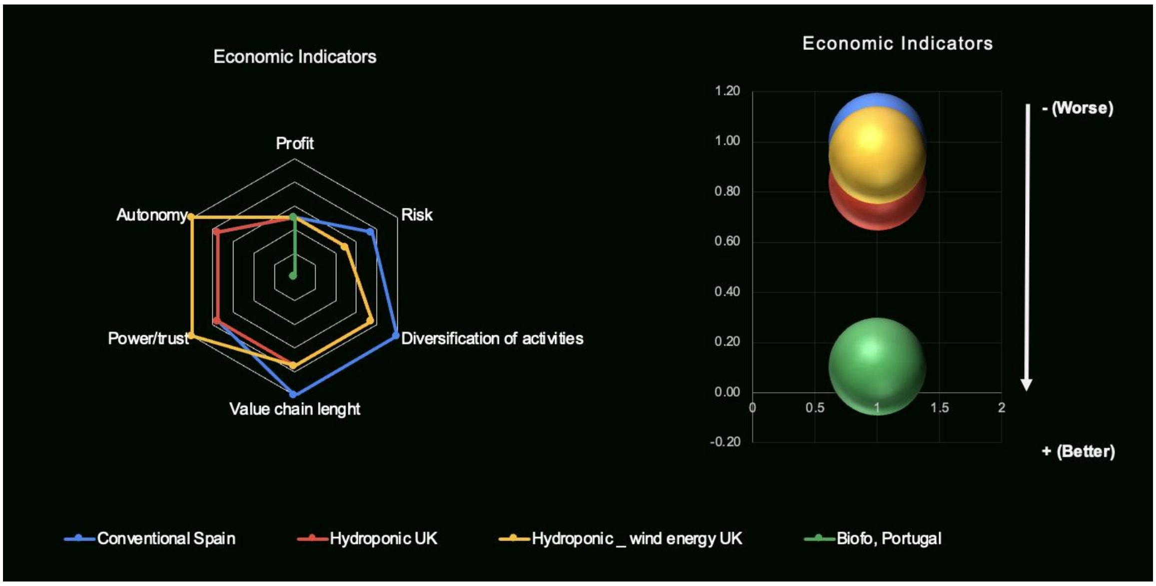


Figure A20: Specific results for Economic Indicators evaluated in the *RADIANT-METRICS* tool for the lettuce systems (Conventional from Spain (Alternative 1), Hydroponic from the UK (Alternative 2), Hydroponic from the UK with wind energy (Alternative 3)) versus mixed leaf salad from Biofo farm in Portugal (Alternative 4). Lines

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622

closer to the edge represent worse performance in that area (left graphic), while the graphic on the right represents single score results (higher location of the bubble, worse performance).

5. Final Considerations

For all case studies, the Ecosystem Services and Economic indicators provided different rankings to the LCA and Environmental Efficiency indicators, when comparing UC systems with conventional counterparts. This shows that evaluating a cropping system or a value chain through only one dimension can miss hotspots and lack wider perspective on important attributes of sustainable and resilient agri-food systems. The *RADIANT-Metrics* tool may lose some precision for each dimension (area) covered, but, by covering key dimensions, provides a more holistic and accurate perspective on sustainability and resilience of agri-food systems at different levels: field level (LCA and Environmental Efficiency Indicators), farm level (Ecosystem Services and Economic Indicators), and value chain level (LCA and Economic Indicators).

Realising Dynamic Value Chains for Underutilised Crops (RADIANT) is a Research & Innovation Action supported by European Commission's Horizon 2020 programme under Grant Agreement number 101000622