Applicazione del LCA alle filiere agro-alimentari

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Agroecological practices to increase farm resilience: A measurement of economic-environmental sustainability through a life cycle approach

Giacomo Falcone, Emanuele Spada, Nathalie Iofrida, Anna Irene De Luca
Department of Agraria, University Mediterranea of Reggio Calabria

ASSOCIAZIONE RETE ITALIANA LCA

UNIVERSITÀ DEGLI STUDI DI MILANO

MUR

CONSIGLIO DELL'ORDINE NAZIONALE DEI DOTTORI AGRONOMI E DEI DOTTORI FORESTALI

Ministero della Giustizia

WP 3.3 - Evaluation and demonstration for stakeholder engagement and innovation exploitation
GOAL: Assess and communicate the environmental and socio-economic impact of developed innovations through large demonstrators

T3.3.2 Multidisciplinary technology assessment

Life Cycle Sustainability analysis of developed agricultural innovations agritech

Main objective of activities: This activity aims to carry out **integrated analysis and sustainability measurement** of the new solutions for smart agricultural systems implemented within WP 3.2 (UNIRC-Task 3.2.2 and UNIRC-Task 3.2.4) to compare and evaluate different practices for soil management in organic farming, as well as for wastewater reuse from the agri-food industries. The activities will entail the implementation of specific Life-Cycle based methodologies for stressing and quantifying the **potential environmental, economic, and social impacts** derived from the **innovative solutions fulfilment**.

UNIRC TASK 3.2.4 = efficient management of organic fertilisation to provide assimilable forms of nutrients (N and P) to sustain crop yields and limit losses.

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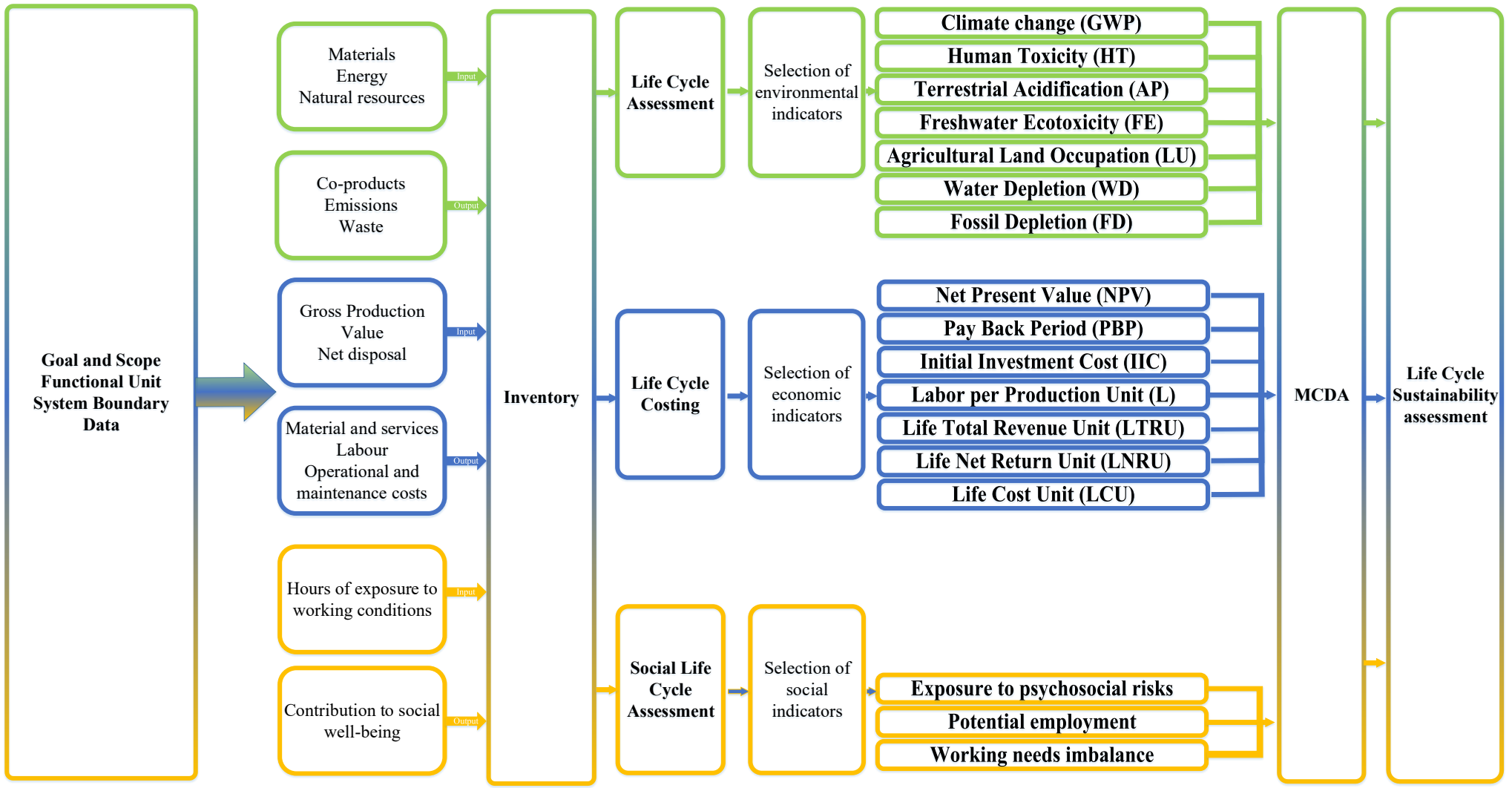
Objective: Use of intercropping with functional groups of crops (e.g. leguminous crops) to improve complementarity and facilitation of nutrient (N) and rhizospheric (P) utilisation in cereals. Use of biofertilisers to investigate the benefits and limitations on soil functioning and temporary growth and yield of intercropped cereals.

A temporary seeding of fava beans/ durum wheat was carried out in November 2022 and 2023. Soil incorporation of broad beans (March 2023 and March 2024). Monitoring of crop growth in the experimental field and biomass and soil sampling.


Goal and Scope
Functional Unit
System Boundary
Data
Materials
Energy
Natural resources
Input
Co-products
Emissions
Waste
Output
Gross Production Value
Net disposal
Input
Material and services
Labour
Operational and maintenance costs
Output
Hours of exposure to working conditions
Input
Contribution to social well-being
Output
Inventory
Life Cycle Assessment
Selection of environmental indicators
Climate change (GWP)
Human Toxicity (HT)
Terrestrial Acidification (AP)
Freshwater Ecotoxicity (FE)
Agricultural Land Occupation (LU)
Water Depletion (WD)
Fossil Depletion (FD)
Life Cycle Costing
Selection of economic indicators
Net Present Value (NPV)
Pay Back Period (PBP)
Initial Investment Cost (IIC)
Labor per Production Unit (L)
Life Total Revenue Unit (LTRU)
Life Net Return Unit (LNRU)
Life Cost Unit (LCU)
Social Life Cycle Assessment
Selection of social indicators
Exposure to psychosocial risks
Potential employment
Working needs imbalance
MCDA
Life Cycle Sustainability assessment
I
II
III
IV
V

Data collection

QUESTIONARIO PER LA RILEVAZIONE DI DATI PRIMARI DI COLTURE ERBACEE SUGLI ASPETTI AMBIENTALI ED ECONOMICI

Per questa tipologia di rilevazione dati, l'intervistato dovrebbe essere un consulente tecnico / agronomo dell'azienda, oppure il proprietario o il responsabile dell'azienda,

I DATI DOVRANNO ESSERE RIFERITI AD 1 ETTARO DI SUPERFICIE

Identificazione dell'azienda agricola	

SEZIONE 1. Dati generali dell'azienda e della coltivazione

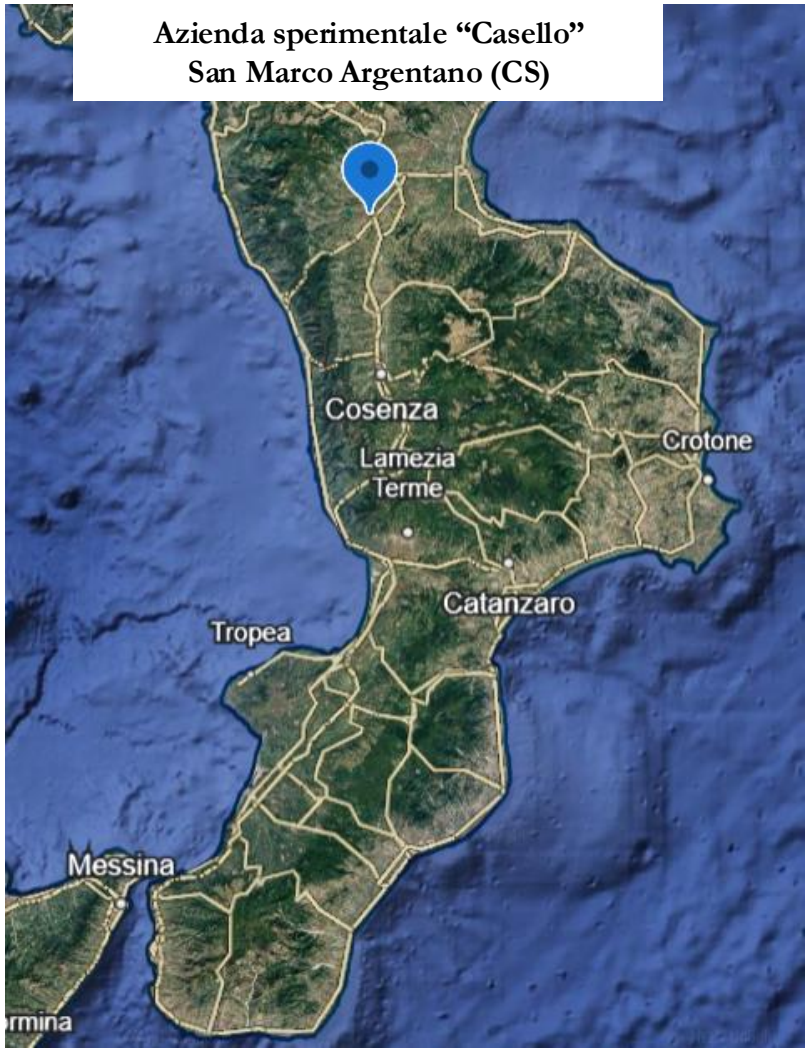
1.1) Rispondere alle domande spuntando la casella corrispondente con una X.
Se l'azienda presenta per tutti gli appezzamenti caratteristiche uniformi, selezionare solo una categoria, nel caso di scenari diversi all'interno della stessa azienda, inserire la percentuale specifica relativa alla superficie interessata da quella caratteristica (esempio 80% pianura, 20% collina).

Localizzazione (comune)			
Superficie aziendale (ha)			
Superficie aziendale destinata alle colture oggetto di studio (ha)			
		Percentuale %	Numero di ettari
SUPERFICIE	X PIANURA		
	☐ COLLINA		
	☐ MONTAGNA		
TIPO DI COLTIVAZIONE	X In pieno campo		
	☐ Coltura protetta		
SISTEMA DI ALLEVAMENTO	☐ TRADIZIONALE		

Production process modelling

Year	Business As Usual (BAU)	Temporary Intercropping (TI)
1°	Durum wheat	Durum wheat
2°	Broad beans for green manure for 100% of the area	Durum wheat 50 % of the area and Broad beans 50 % of the area (Temporary intercropping)
3°	Durum wheat	Durum wheat

Azienda sperimentale "Casello"
San Marco Argentano (CS)



Main technical features

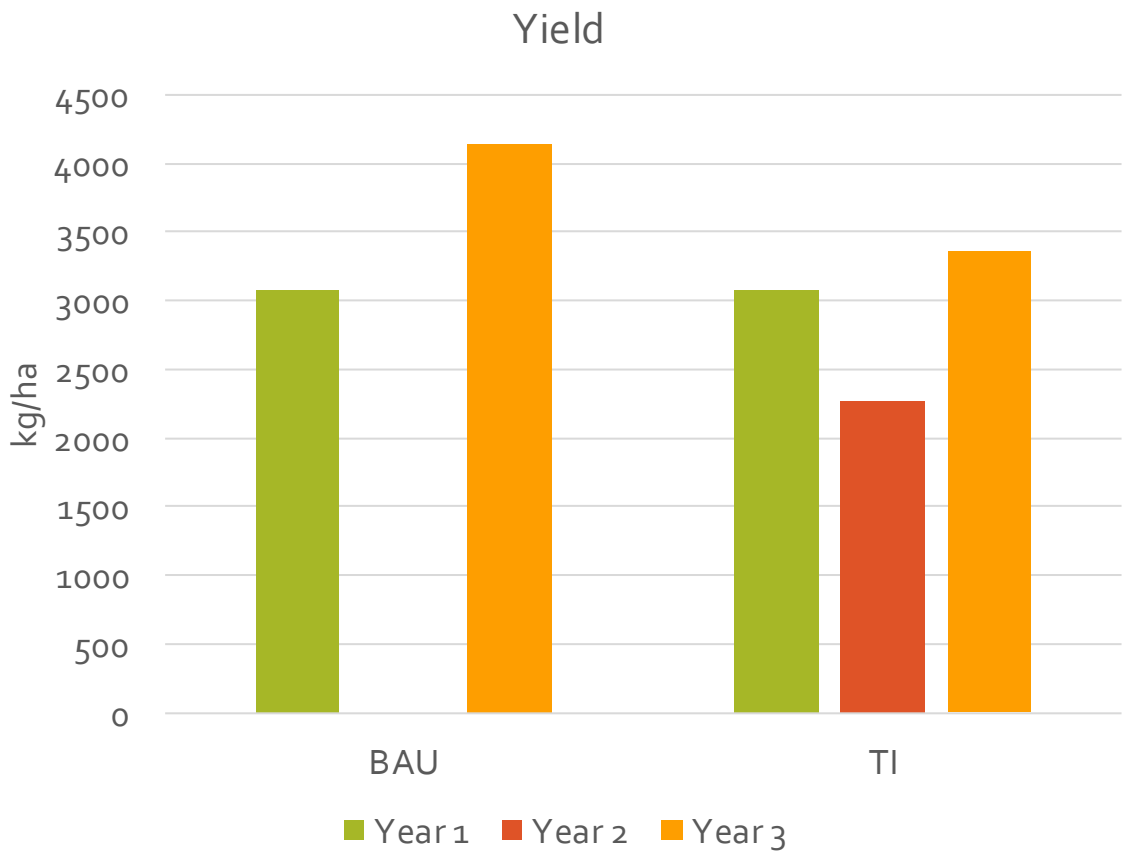
Main technical characteristics		BAU	TI
Cultivar		Senatore Cappelli	
Irrigation		Without irrigation	
Level of mechanisation		Medium	
Cultivation system		Organic	
Yield	1° Year	**Durum wheat 3.075 kg ha $^{-1}$**	
	2° Year	**Broad beans for green manure 100%**	**Durum wheat 2.375 kg ha $^{-1}$**
	3° Year	**Durum wheat 4.140 kg ha $^{-1}$**	**Durum wheat 3.360 kg ha $^{-1}$**
Variables adopted	*Unit*		
Farm area	ha	48	
Wheat price	€ kg $^{-1}$	0,5	
Straw price		0.08	
Labour cost	€ h $^{-1}$	10,00	
Harvesting cost	€ kg $^{-1}$	0.07	

In the TI scenario, wheat and field beans are seeded at the same time with the same seeder.

Inventory

Process	Input	Unit	Business as usual	€ kg^{-1}	Temporary intercropping	€ kg^{-1}
Technical operations	Ploughing diesel	kg	0.0192	0.0173	0.0233	0.0209
	Harrowing diesel	kg	0.0117	0.0106	0.0133	0.0120
	Seeding diesel	kg	0.0117	0.0106	0.0133	0.0120
	Leguminous management	kg	0.0079	0.0071	0.0068	0.0061
	Engine oil	kg	0.0006	0.0117	0.0007	0.0133
	Grease	kg	0.0003	0.0023	0.0003	0.0027
	Seed	kg	0.1976	0.0585	0.3013	0.1706
Work	Ploughing	h	0.0013	0.0130	0.0027	0.0068
	Harrowing	h	0.0010	0.0098	0.0020	0.0068
	Seeding	h	0.0010	0.0098	0.0020	0.0068
	Leguminous management	h			0.0014	0.0068
	Moving and various	h	0.0007	0.0065	0.0014	0.0031
Agricultural products	Durum wheat	kg	1.0	-	2.	-
	Straw	kg	1.5	-	3.	-
Work	Surveillance	h	0.003	0.022	0.003	0.022

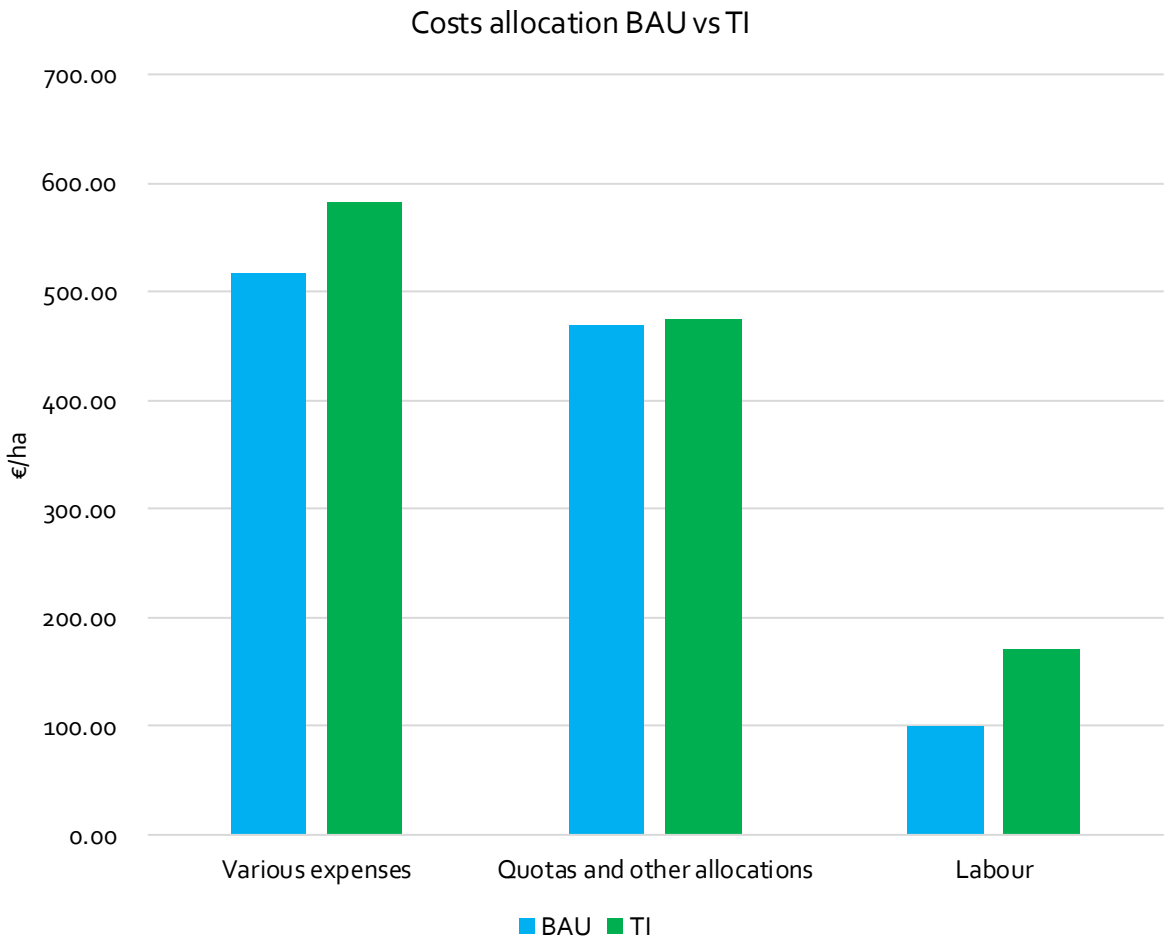
Technical-economic results

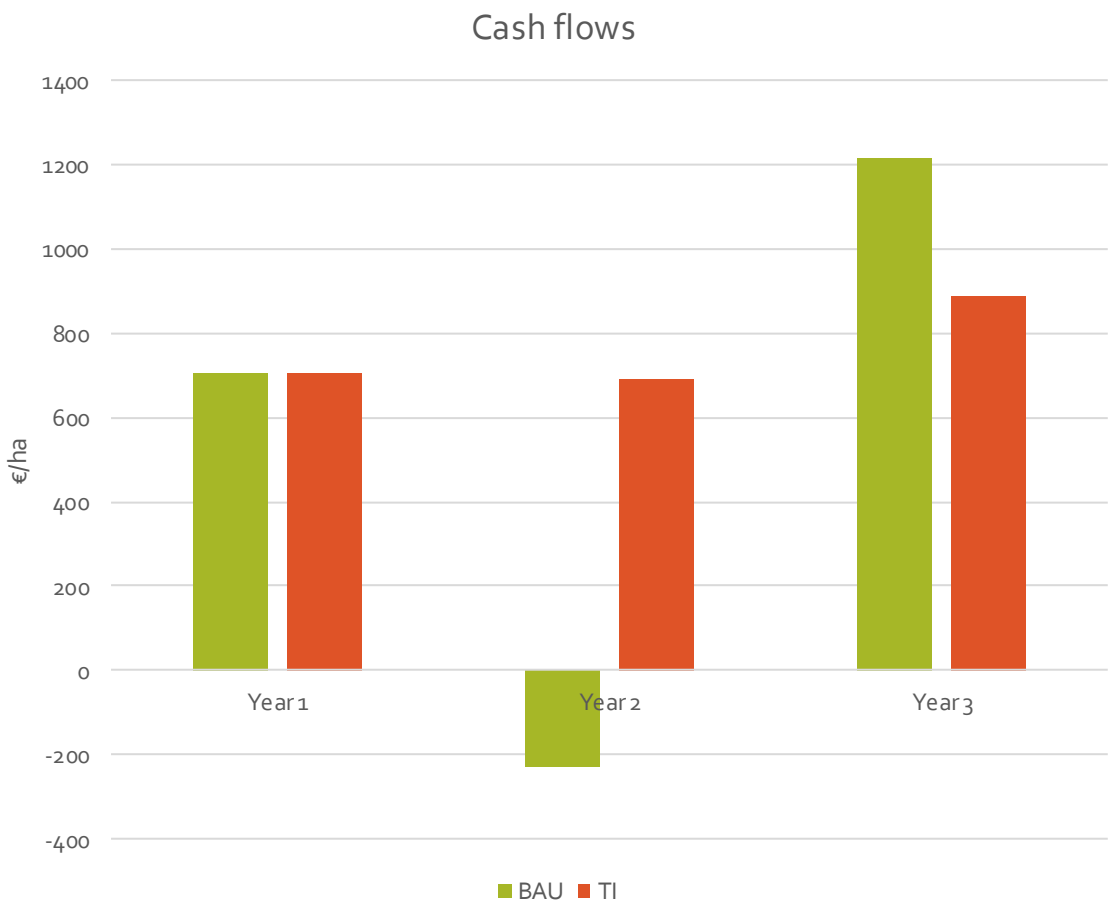


In the TI scenario, wheat production in the second year is 80 per cent of that of the first year, while in the BAU scenario, wheat production is completely nullified as the entire area is devoted to green manure beans.

In the TI scenario, higher costs are recorded due to the higher quantity of seed (wheat + broad bean) and operations related to green manure of leguminous plants.

Technical-economic results





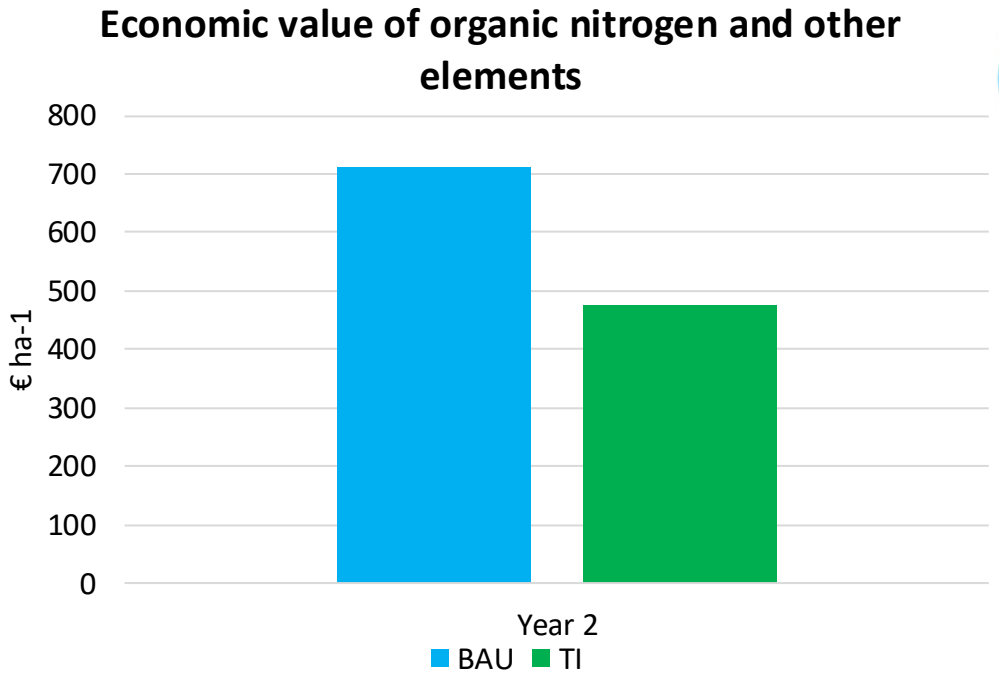
Technical-economic results

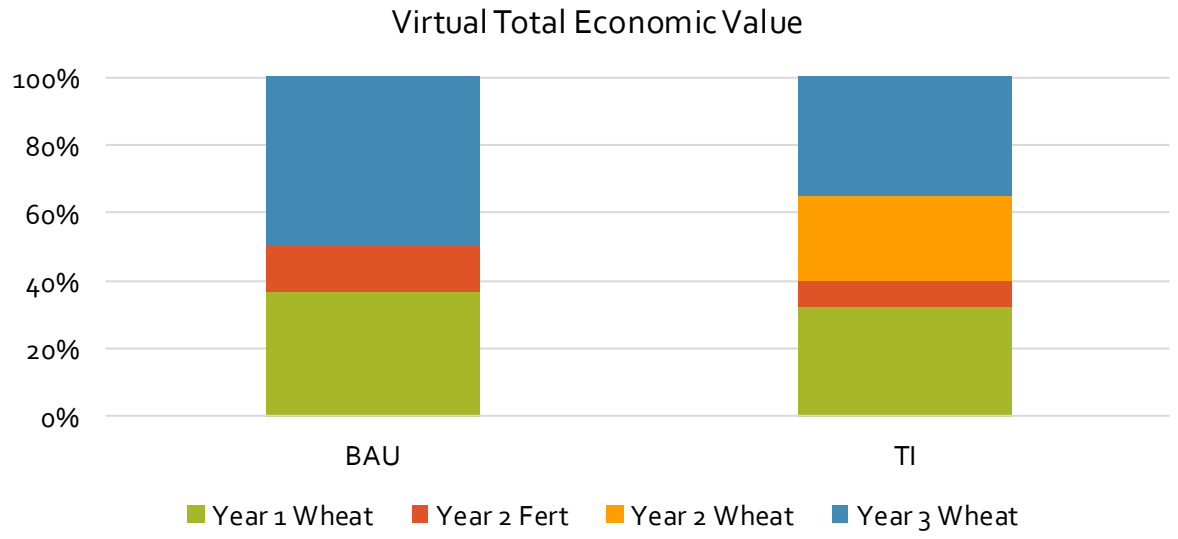
Organic Nitrogen and Organic Phosphorus contained in test field beans

Anno	BAU	TI
1	-	-
2	**N: 114 kg* P: 131 kg***	**N: 76 kg P:88 kg**

*Estimated
In the BAU scenario, there is less accumulation per unit area of N and P due to intraspecific competition. The legume-cereal symbiosis allows the amount stored to be increased.

The average N and P removals for durum wheat are 30 and 15 kg t^{-1}





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Year	Business As Usual (BAU)	Temporary Intercropping (TI)
1°	Durum wheat	Durum wheat
2°	Broad beans 100% of the area	Durum wheat 50 % of the area and broad beans 50 % of the area(Temporary intercropping)
3°	Durum wheat	Durum wheat

- In the experimental period, when considering only wheat production, the TI scenario performs better economically. However, if we also consider the value of fertilising elements delivered to the soil, the two scenarios become almost equivalent.
- The TI scenario, in addition to the N and P fixed by the legume, can provide other benefits to the ecosystem in terms of biodiversity and diversification.
- The BEP of the TI scenario corresponds to about 1,800 kg of wheat, so a reduction in production in the following years would keep the scenario economically positive up to a 23% decrease.
- The quantity of nitrogen (N) and phosphorus (P) stored by the leguminous crop and made available to the next crop is equivalent to the amount removed under typical Mediterranean production conditions. Given the volatility of the fertilizer market, temporary intercropping can enable a partial or total reduction of fertilizer use
- In the CAP 2023-2027, adherence to Eco-scheme 4 obliges crop diversification (rotation), with a contribution per hectare of 120 euros per year; however, in the dry Mediterranean areas, the lack of alternatives to leguminous crops does not allow the cultivation of other cash crops.
- The TI scenario could provide a solution to the crop diversification proposed by Ecoscheme 4 of the CAP 2023–27, enabling the farm to continue producing cereals such as wheat annually and benefit from crop rotation. Currently, for the Mediterranean area, adherence to this Ecoscheme takes place within the BAU scenario. However, this leads to a significant reduction in profits, despite a contribution of around 120 euros per hectare, which does not compensate for economic losses.
- In the Calabrian territory, about 65 thousand hectares of arable land out of the 100 thousand hectares used for cereal and fodder production adhered to Ecoscheme 4 in 2024, which had a direct effect on production balances.

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Life Cycle Assessment – Goal and scope

- Systems under study: BAU rotation VS Temporary Intercropping
- Function of the systems: Wheat production
- Functional Unit: 1 kg of wheat
- System boundaries: From cradle to gate of rotation
- Allocation rules: Cut-off allocation to wheat
- Data quality: Primary foreground data, Ecoinvent background data, Estimation models emissions
- LCIA method: ReCiPe 2016 midpoint (H)

Results of the characterization of environmental impacts per kg of wheat – LCIA Method ReCiPe 2016 midpoint (H)

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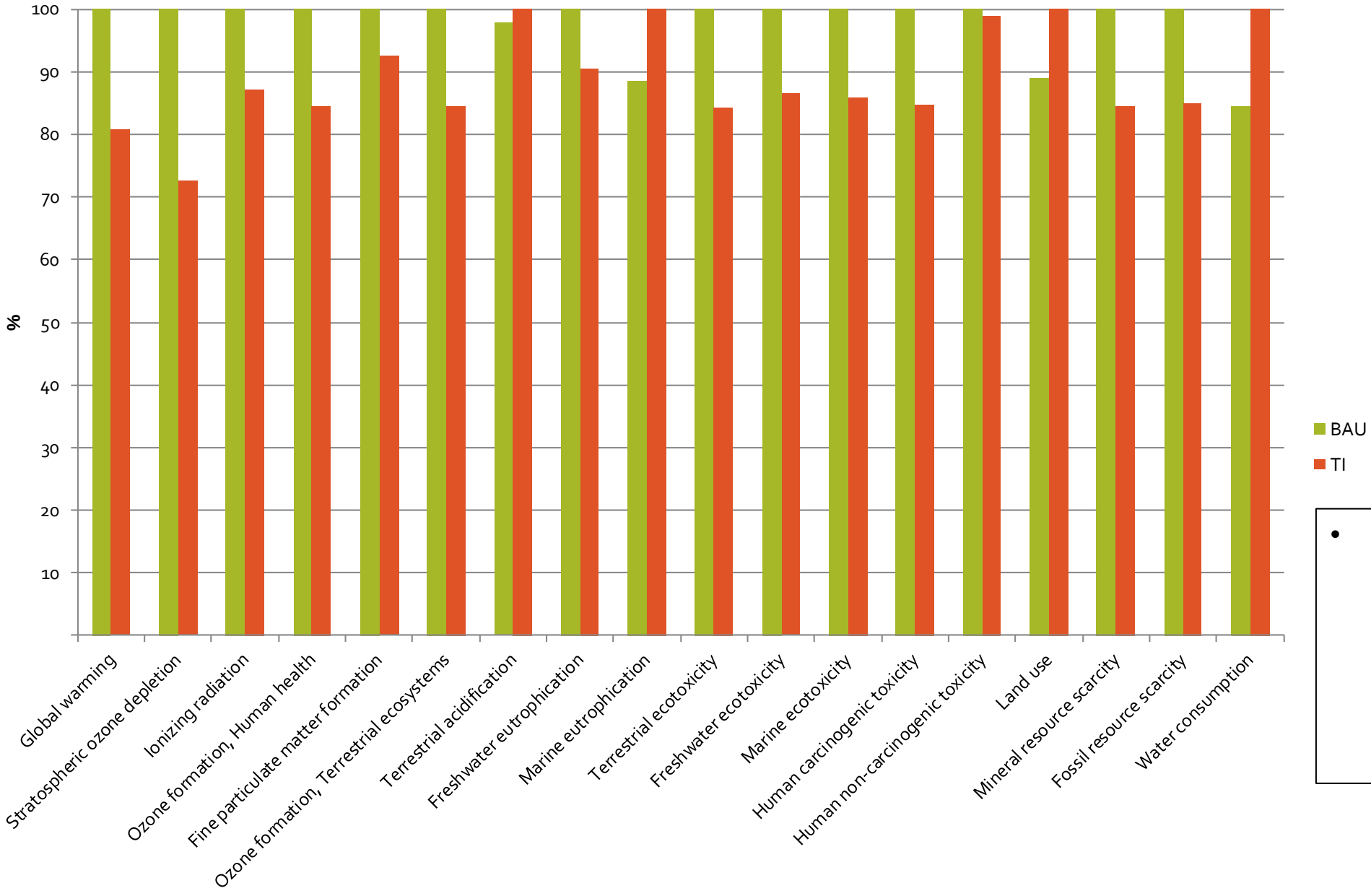
Impact category	Unit	BAU	TI
Global warming	kg CO2 eq	0,345037868	0,278669442
Stratospheric ozone depletion	kg CFC11 eq	4,2772E-06	3,10336E-06
Ionizing radiation	kBq Co-60 eq	0,004195203	0,003653484
Ozone formation, Human health	kg NOx eq	0,001747871	0,00147734
Fine particulate matter formation	kg PM2.5 eq	0,000733953	0,000678577
Ozone formation, Terrestrial ecosystems	kg NOx eq	0,001795444	0,001517537
Terrestrial acidification	kg SO2 eq	0,002619399	0,002678149
Freshwater eutrophication	kg P eq	7,76642E-05	7,02796E-05
Marine eutrophication	kg N eq	0,000681921	0,000771013
Terrestrial ecotoxicity	kg 1,4-DCB	5,289122271	4,460203924
Freshwater ecotoxicity	kg 1,4-DCB	0,013180209	0,011398228
Marine ecotoxicity	kg 1,4-DCB	0,022218874	0,01908283
Human carcinogenic toxicity	kg 1,4-DCB	0,069113169	0,058504327
Human non-carcinogenic toxicity	kg 1,4-DCB	1,399567115	1,384571374
Land use	m2a crop eq	0,52582839	0,591608655
Mineral resource scarcity	kg Cu eq	0,001481288	0,001253592
Fossil resource scarcity	kg oil eq	0,063834415	0,054211934
Water consumption	m3	0,004354764	0,005153246

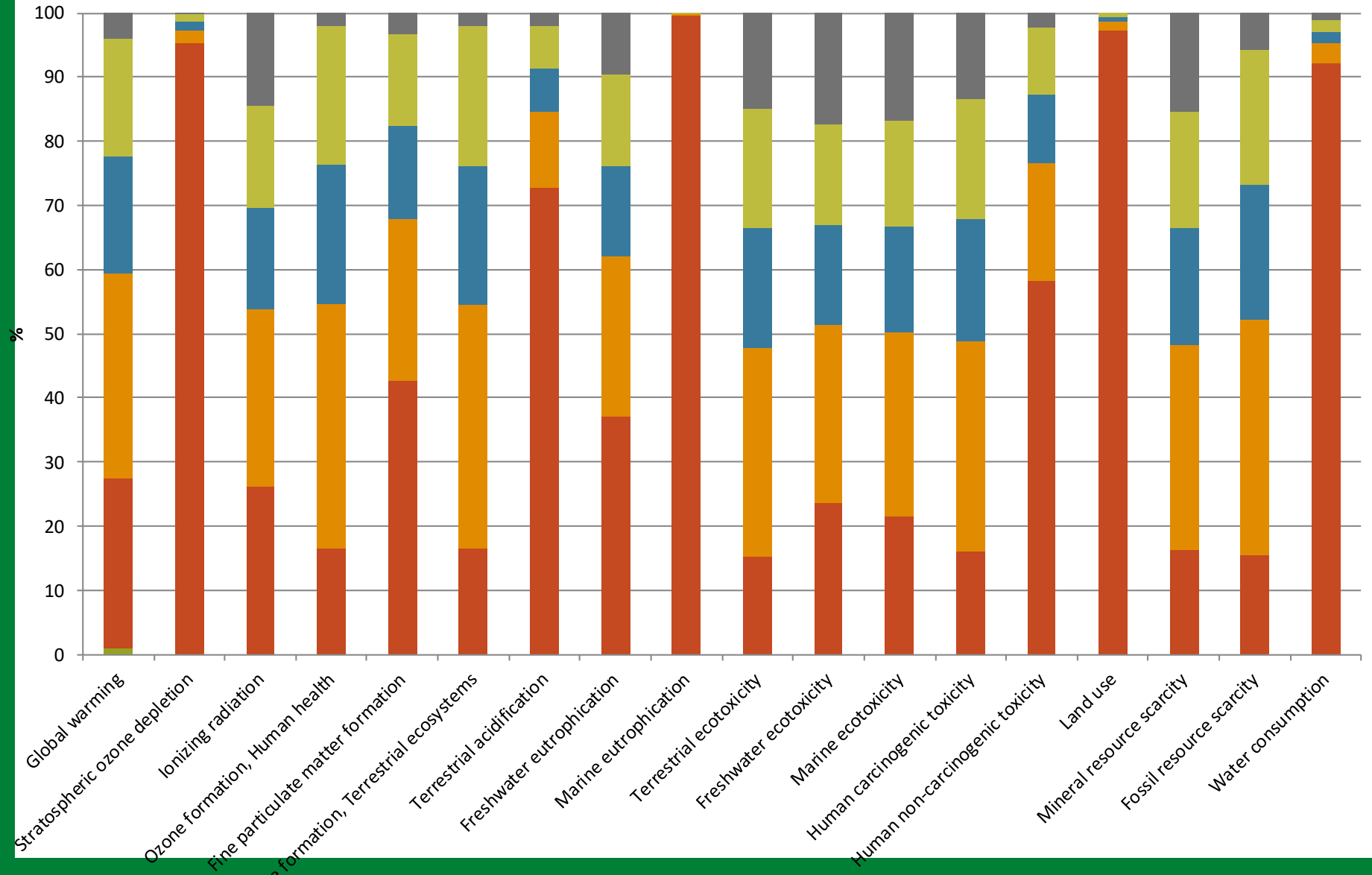
- The scenario with intercropping in the second year is better from an environmental point of view in almost all impact categories.
- This is because in the BAU scenario in the second year we have no production while in the TI scenario we have production, although reduced.
- Classical green manure releases more nitrogen and phosphorous while green manure with intercropping achieves about 70% of both elements.
- Despite the higher number of operations and the larger amount of seeds the scenario with intercropping is still more profitable.

Comparison of environmental impacts per kg of wheat – LCIA Method ReCiPe 2016 midpoint (H)



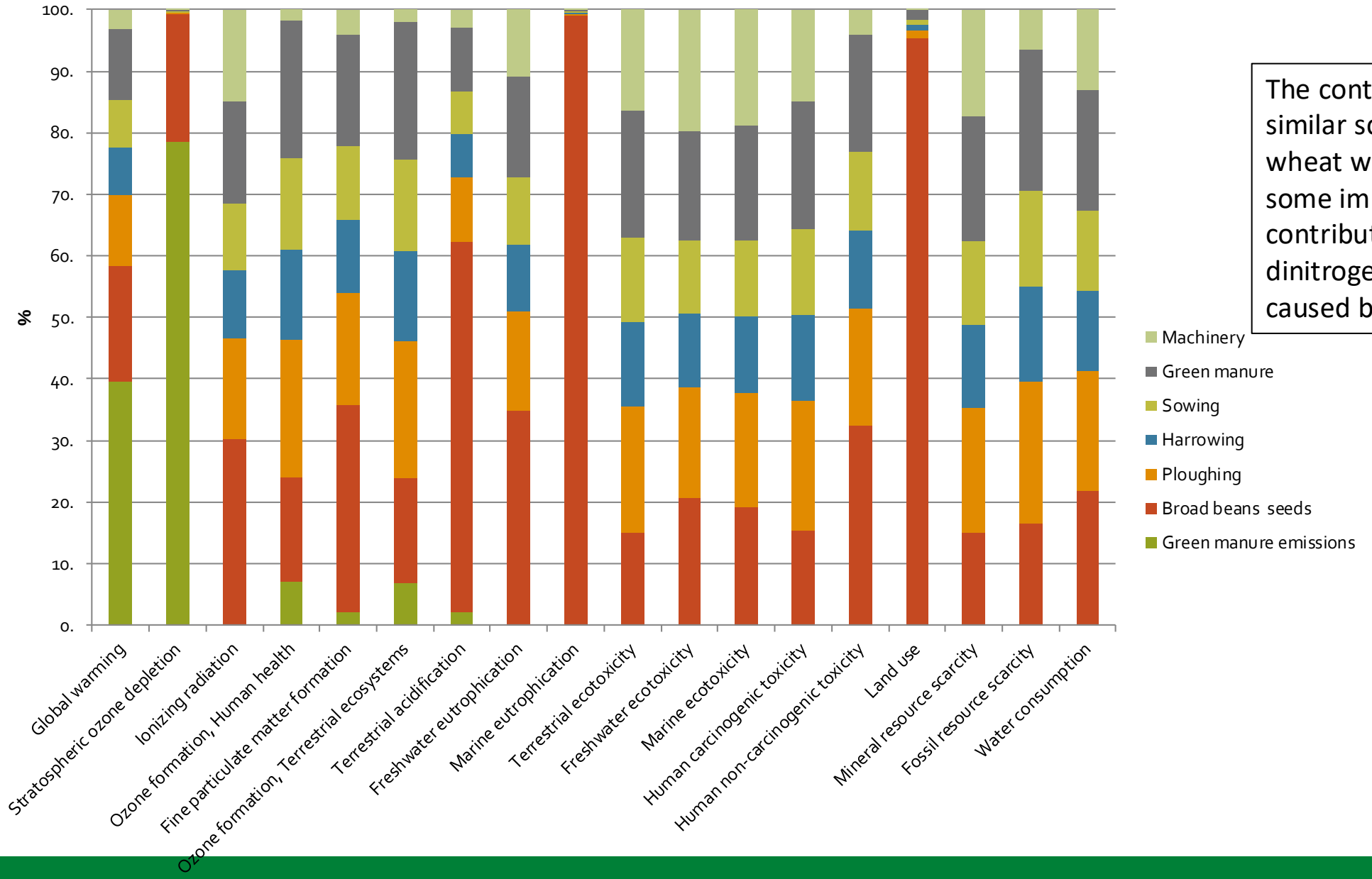
- Impacts are on average 10% lower in the IT scenario with the exception of water consumption, Terrestrial acidification, Marine eutrophication, Land use and Water consumption

Contribution analysis wheat cultivation – LCIA Method ReCiPe 2016 midpoint (H)



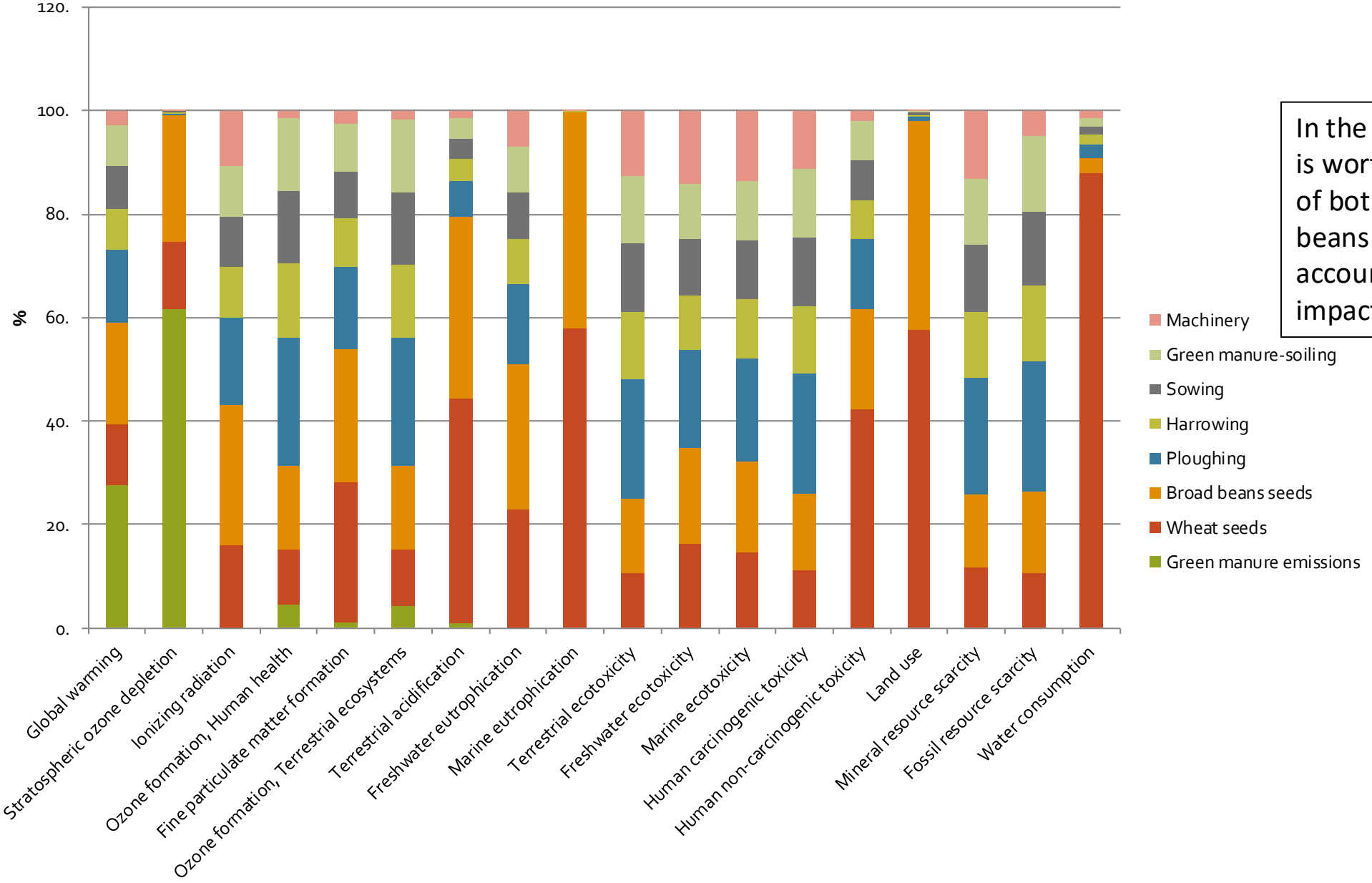
In the contribution analysis of wheat cultivation, it can be seen that seed has a very important weight, second only to diesel consumption, which shows an impact in the various operations proportional to consumption

Contribution analysis Broad beans cultivation – LCIA Method ReCiPe 2016 midpoint (H)



The contribution analysis shows a similar scenario to that seen for wheat with the difference that on some impact categories the contributions of nitrogen oxide and dinitrogen monoxide emissions caused by leguminous green manure

Contribution analysis intercropping cultivation – LCIA Method ReCiPe 2016 midpoint (H)



In the inter-cropping scenario, it is worth highlighting the weight of both wheat seeds and Broad beans , which in absolute terms account for almost 50% of the impacts on average

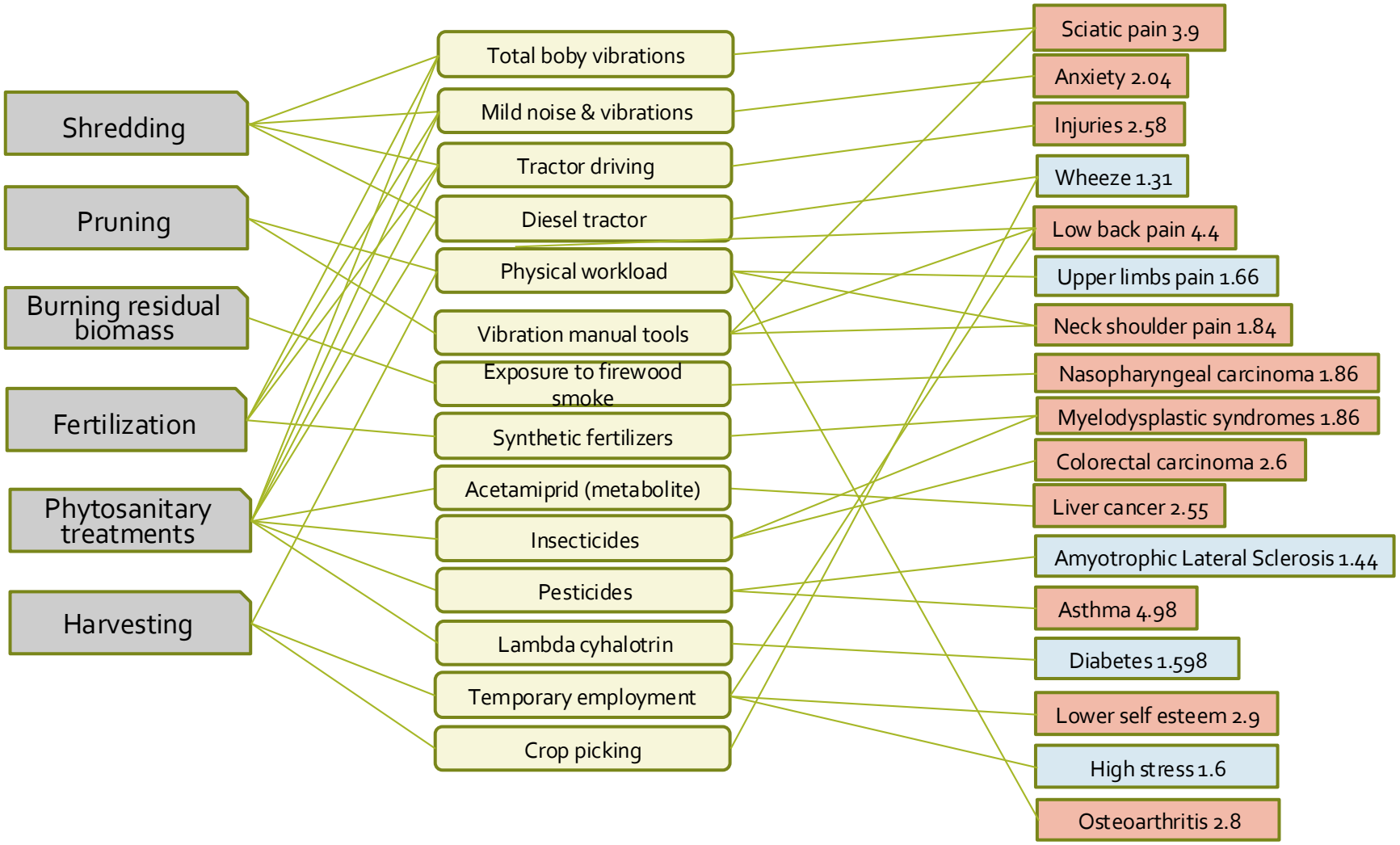
SLCA Type II – Psychosocial Risk Factors Impact Pathway

OBJECTIVES

Characteristics	Reference Scale Approach (Type I)	Impact Pathway Approach (Type II)
Aim for users	Assessment of the product system in terms of its social performance or social risk.	Assessment of consequences resulting from the product system, with a focus on potential social impacts.
Relation between activity and potential social impacts [a/b]	Relation assumed. Analysis focuses on activity and its direct evaluation, more specifically on their positioning with regards to performance reference points.	Cause-effect relations established through 1) developed and justified characterization models or 2) qualitative descriptions of existing relations along an impact pathway.

- ✓ Attributing social impacts to the product or service life cycle
- ✓ Characterization of short- and long-term cause-effect relations
- ✓ Distinguishing impacts per each life cycle phase
- ✓ Generalizable
- ✓ Results are comparable to environmental LCA (FU, SB, objectivity)
- ✓ Quantifyable indicators
- ✓ Integration with software

PSYCHOSOCIAL RISK FACTORS (PRF) are "*those aspects of work planning and management – and their relative social and environmental contexts – that can POTENTIALLY lead to physical or psychological damages*"
(Cox and Griffiths, 1995:69)


Shredding
Pruning
Burning residual biomass
Fertilization
Phytosanitary treatments
Harvesting
Total boby vibrations
Mild noise & vibrations
Tractor driving
Diesel tractor
Physical workload
Vibration manual tools
Exposure to firewood smoke
Synthetic fertilizers
Acetamiprid (metabolite)
Insecticides
Pesticides
Lambda cyhalotrin
Temporary employment
Crop picking
Sciatic pain 3.9
Anxiety 2.04
Injuries 2.58
Wheeze 1.31
Low back pain 4.4
Upper limbs pain 1.66
Neck shoulder pain 1.84
Nasopharyngeal carcinoma 1.86
Myelodysplastic syndromes 1.86
Colorectal carcinoma 2.6
Liver cancer 2.55
Amyotrophic Lateral Sclerosis 1.44
Asthma 4.98
Diabetes 1.598
Lower self esteem 2.9
High stress 1.6
Osteoarthritis 2.8
Operations
Working conditions
Health risks

Meaning of Odds Ratio

- The OR is a statistical measure of the intensity of the association between two variables
- It's the ratio between the odds of exposure for people with a disease and the odds of exposure for healthy people.
- It's a retrospective study

		Dependent Variable		
		disease	*no disease*	
Independent Variable	*exposure*	***a***	***b***	a + b total exposed
	no exposure	***c***	***d***	c + d total not exposed
		a + c total cases	b + d total controls	

$$ODDS\ RATIO = \frac{a \times d}{b \times c}$$

Example: an OR of 2 means there is a 100% increase in the odds of an outcome with a given exposure.

Negative association	No association	Weak	Moderate	Strong	Very strong
0<OR<1	OR=1	1<OR<1.3	1.3<OR<1.7	1.7<OR<8	OR>8

METHODOLOGY

Example of Social Life Cycle Inventory

Process	Input	Unit	Sample STS scenario	Sample nSTS scenario
Work	Tillage	h	0.002	0.002
	Shredding pruning residues	h	0.003	
	Spreading leaves and twigs	h	0.003	0.002
	Pomace spreading	h	0.002	
	Fertilization	h	0.001	0.001
	Pest-control	h	0.001	0.001
	Pruning	h	0.012	0.012
	Arrangement of pruning residue	h	0.011	0.010
	Transportation and handling	h	0.007	0.007
	Rolling pre-harvest	h	0.002	0.002
	Cleaning borders with brush cutter	h	0.003	0.003
	Harvest shaker	h	0.010	0.010
	Moving nets for harvesting	h	0.010	0.010

Psychosocial Risk Factors Impact Pathway

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EVALUATION MATRIX

Stakeholder group	Category of working condition	Working conditions	Category of health risk	Health risk	Odds Ratio	Reference
Workers	Chemicals exposure	Bleach exposure	Respiratory	Asthma	1.41	Lemire et al., 2020
Workers	Chemicals exposure	Deltamethrin exposure	Cancers	Myelodysplastic syndromes	1.67	Avgerinou et al., 2017
Workers	Chemicals exposure	Dyeing clothes	Cancers	Bladder cancer	4.63	Risch et al., 1988
Workers	Psychological conditions	Effort reward imbalance	Metabolic	Metabolic syndrome	1.14	Schmidt et al., 2015
Workers	Dusts exposure	Exposure to organic textile dusts	Respiratory	Asthma	1.5	Zhang et al., 2019
Workers	Chemicals exposure	Exposure to trichloroethylene	Cancers	Renal cancer	1.3	Moore et al., 2010
Workers	Chemicals exposure	Herbicides exposure	Cancers	Myelodysplastic syndromes	2.27	Avgerinou et al., 2017
Workers	Others	Night shift work	Deficiencies	Vitamin D deficiency	1.4	Park et al., 2020
Workers	Chemicals exposure	Organophosphates insecticides exposure	Neurological	Parkinson Disease	1.8	Elbaz et al., 2009
Workers	Chemicals exposure	Organophosphates insecticides exposure	Cancers	Non-Hodgkin's lymphoma	2.11	Fritschi et al., 2005
Workers	Economic	Poor incomes	Cardiovascular	Stroke	2.45	Min et al., 2017
Workers	Economic	Poor incomes	Cardiovascular	Myocardial infarction	2.68	Min et al., 2017
Workers	Physical conditions	Sedentary posture	Musculoskeletal system	Low Back Pain	1.34	Gupta et al., 2015
Workers	Physical conditions	Standing posture	Musculoskeletal system	Neck - shoulder pain	1.15	Hildebrandt et al., 2001
Workers	Psychological conditions	Temporary employment	Psychological	High level of stress perceived	1.6	Domenighetti et al., 1999
Workers	Psychological conditions	Temporary employment	Musculoskeletal system	Back or low back Pain	2.00	Domenighetti et al., 1999
Workers	Psychological conditions	Temporary employment	Psychological	Lower self esteem	2.9	Domenighetti et al., 1999
Workers	Others	Textile and tayloring workers	Neurological	Systemic sclerosis	2.00	Bovenzi et al., 2004
Workers	Others	Textile factory work	Respiratory	Breathless	9.4	Zele et al., 2020
Workers	Physical conditions	Total body vibrations	Musculoskeletal system	Sciatic Pain	3.9	Bovenzi and Betta, 1994
Workers	Physical conditions	Uncomfortable postures	Musculoskeletal system	Low Back Pain	2.49	Hildebrandt et al., 2001
Residential population	Chemicals exposure	Maternal residential exposure to agricultural pesticides	Birth defects	Atrial septal defects	1.7	Rappazzo et al., 2016
Residential population	Chemicals exposure	Maternal residential exposure to agricultural pesticides	Birth defects	Hypertrophic pyloric stenosis	1.71	Rappazzo et al., 2016
Residential population	Chemicals exposure	Maternal residential exposure to agricultural pesticides	Birth defects	Tracheal esophageal fistula/ esophageal atresia	1.98	Rappazzo et al., 2016
Residential population	Chemicals exposure	Maternal residential exposure to agricultural pesticides	Birth defects	Hirschsprung's disease	2.22	Rappazzo et al., 2016
Residential population	Chemicals exposure	Residential (maternal) agricultural neonicotinoid exposure	Birth defects	Anotia/ microtia	3.00	Carmichael et al., 2015
Residential population	Chemicals exposure	Residential proximity to pesticide application (high exposure): azole antifungals	Cancers	Childhood Acute Lymphoblastic Leukemia	3.9	Rull et al., 2010
Residential population	Chemicals exposure	Residential proximity to pesticide application (moderate exposure): organophosphates	Cancers	Childhood Acute Lymphoblastic Leukemia	1.6	Rull et al., 2009
Residential population	Others	Rural residence	Neurological	Amyotrophic Lateral Sclerosis	1.25	Kang et al., 2014
Consumers	Chemicals exposure	Non organic food diet during pregnancy (Fruits)	Birth defects	Hypospadias in offspring	1.08	Schultz Christensen et al., 2013
Consumers	Chemicals exposure	Non organic food diet during pregnancy (Vegetables)	Birth defects	Hypospadias in offspring	1.1	Schultz Christensen et al., 2013

PRF impact pathway Method: PRF *beta*

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- Substances
  - Raw materials
  - Airborne emission
  - Waterborne emiss
  - Final waste flows
  - Emissions to soil
  - Non material emis
  - Social issues
  - Economic issues

Substance	Default unit
00-2,4-D (herbicide) - high use	hr
00-Chlorpyriphos & Deltamethrin on olive trees	hr
00-Citrus chemicals exposure (fertilizers and pesticides)	hr
00-Copper Oxicloride exposure	hr
00-Deltamethrin exposure	hr
00-Effort-reward imbalance	hr
00-Farming occupation	hr
00-Fertilizers exposure	hr
00-Fungicides exposure 1	hr
00-Fungicides exposure 2+	hr
00-Glyphosate and sun exposure	hr
00-Glyphosate exposure > 10 days/year	hr
00-Glyphosate exposure > 2 days/year	hr
00-Herbicides exposure	hr
00-Herbicides exposure 1	hr
00-Herbicides exposure 2-4	hr
00-Herbicides exposure 5+	hr
00-High exposure to pesticides ($15 years; (>0.018 mg/m3)	hr
00-High physical demand and heavy manual labour	hr
00-High psychological demand (quantity of work, intellectual requirements, time constraints)	hr
00-Insecticides exposure	hr
00-Insecticides exposure 1	hr
00-Insecticides exposure 2-4	hr
00-Insecticides exposure 5+	hr
00-Living with an agricultural worker	hr
00-Long working hours >8 to 9 hours/day	hr
00-Low maternal Folic Acid intake and carbamates exposure 3 months before or after conception	hr
00-Low maternal Folic Acid intake and chlorpyrifos exposure 3 months before or after conception	hr
00-Low maternal Folic Acid intake and organophosphates exposure 3 months before or after conception	hr
00-Low maternal Folic Acid intake and pyrethroids exposure 3 months before or after conception	hr
00-Maternal exposure to animal manure during the 5 years preceding the index child's birth	hr

Step 1 - Inventory of working and living conditions

PRF impact pathway Method: PRF *beta*

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National Research Center for Technology in Agriculture

Step 2 - Creation of a new LCIA method

General | Characterisation | Damage assessment

Name: PRF Beta

Version: 0 09

Structure

☑ Damage assessment ☐ Normalisation ☐ Weighting ☐ Addition

Comment

WA - Weak Association
MA - Moderate Association
SA - Strong Association
VSA - Very Strong Association

PRF impact pathway Method: PRF *beta*

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General | **Characterisation** | Damage assessment

Impact category	Unit
WA - Musculoskeletal	Exposure
MA - Musculoskeletal	Exposure
SA - Musculoskeletal	Exposure
VSA - Musculoskeleta	Exposure
WA - Cardiological	Exposure
MA - Cardiological	Exposure
SA - Cardiological	Exposure
VSA - Cardiological	Exposure
WA - Metabolic	Exposure
MA - Metabolic	Exposure
SA - Metabolic	Exposure
VSA - Metabolic	Exposure
WA - Cancers	Exposure
MA - Cancers	Exposure
SA - Cancers	Exposure
VSA - Cancers	Exposure
WA - Neurological ar	Exposure
MA - Neurological ar	Exposure
SA - Neurological an	Exposure
VSA - Neurological a	Exposure
WA - Respiratory	Exposure
MA - Respiratory	Exposure
SA - Respiratory	Exposure
VSA - Respiratory	Exposure
WA - Psychological	Exposure
MA - Psychological	Exposure
SA - Psychological	Exposure
VSA - Psychological	Exposure
WA - Generic	Exposure
MA - Generic	Exposure
SA - Generic	Exposure
VSA - Generic	Exposure

Compartment	Subcompartn	Substance	CAS numbe	Factor	Unit
Social		00-High psychological demand (quantity of work, intellectu		1	Exposure / hr
Social		00-Physical workload		1	Exposure / hr
Social		00-Repetitive tasks		1	Exposure / hr
Social		00-Sedentary posture		1	Exposure / hr
Social		00-Sitting		1	Exposure / hr
Social		00-Total Boby Vibrations (tractor driving)		1	Exposure / hr
Social		00-Vibration manual tools (hands and arms)		1	Exposure / hr

Step 3 - Listing all possible risk factors and their association with living and working conditions

PRF impact pathway Method: PRF *beta*

General		Characterisation		Damage assessment
Damage category	Unit	Impact category	Factor	Unit
Workers - Weak Assc	1	WA - Hearing damag	1	1 / Exposure
Workers - Moderate /	1	WA - Gastric cancer	1	1 / Exposure
Workers - Strong Ass	1	WA - Cardiovascular	1	1 / Exposure
Workers - Very Strong	1	WA - Metabolic syndi	1	1 / Exposure
Residential Pop - We	1	WA - Sciatic Pain	1	1 / Exposure
Residential Pop - Mo	1	WA - Back Pain	1	1 / Exposure
Residential Pop - Strc	1	WA - Neck and Shoul	1	1 / Exposure
Residential Pop - Very	1	WA - Upper Limbs	1	1 / Exposure
Consumers - Weak As	1	WA - Lower self estee	1	1 / Exposure
Consumers - Moderat	1	WA - Psychological d	1	1 / Exposure
Consumers - Strong /	1	WA - High level of str	1	1 / Exposure
Consumers - Very Strc	1	WA - Disability	1	1 / Exposure
		WA - Osteoarthritis	1	1 / Exposure
		WA - Cutaneous mela	1	1 / Exposure
		WA - Non-Hodgkin's	1	1 / Exposure
		WA - Renal cell carcir	1	1 / Exposure
		WA - Parkinson Disea	1	1 / Exposure
		WA - Numbness	1	1 / Exposure
		WA - Muscle weakne:	1	1 / Exposure
		WA - REM sleep beha	1	1 / Exposure
		WA - Colorectal carci	1	1 / Exposure
		WA - Myelodysplastic	1	1 / Exposure
		WA - Childhood brair	1	1 / Exposure
		WA - Amyotrophic La	1	1 / Exposure
		WA - Asthma	1	1 / Exposure

Step 4 - Creation of damage categories for each stakeholder group classified according to the degree of intensity, and their impact categories

PRF impact pathway Method: PRF *beta*

Outputs to technosphere: Products and co-products	Amount	Unit	Quantity	Allocation	Waste type	Category	Comment
Pest Control Calabria	1	hr	Time	100 %		Agri...\Social Themes	
Add line							

Outputs to technosphere. Avoided products	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Add line							

Inputs

Inputs from nature	Subcompartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Add line								

Inputs from technosphere: materials/fuels	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Add line							

Inputs from technosphere: electricity/heat	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Add line							

Outputs

Emissions to air	Subcompartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Add line								

Emissions to water	Subcompartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Add line								

Emissions to soil	Subcompartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Add line								

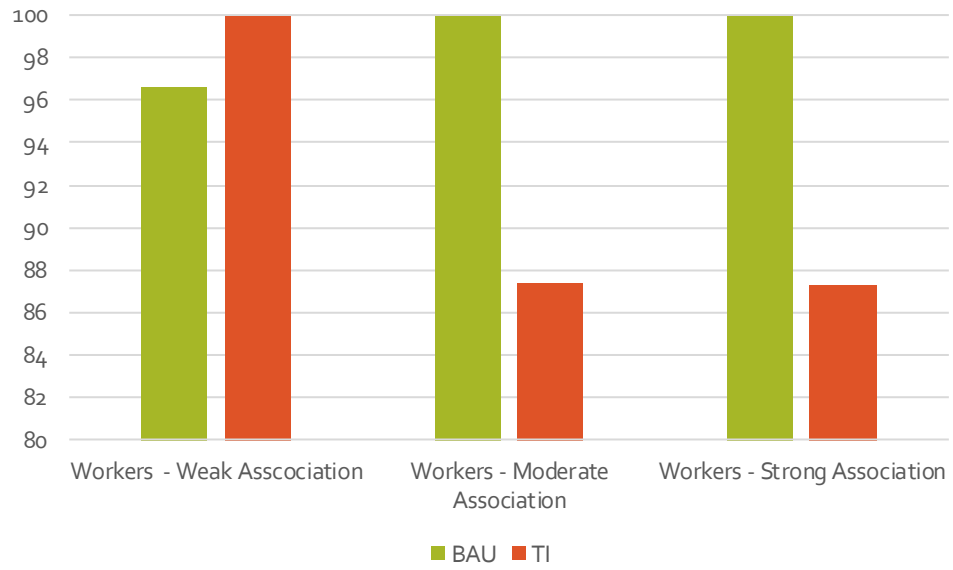
Final waste flows	Subcompartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Add line								

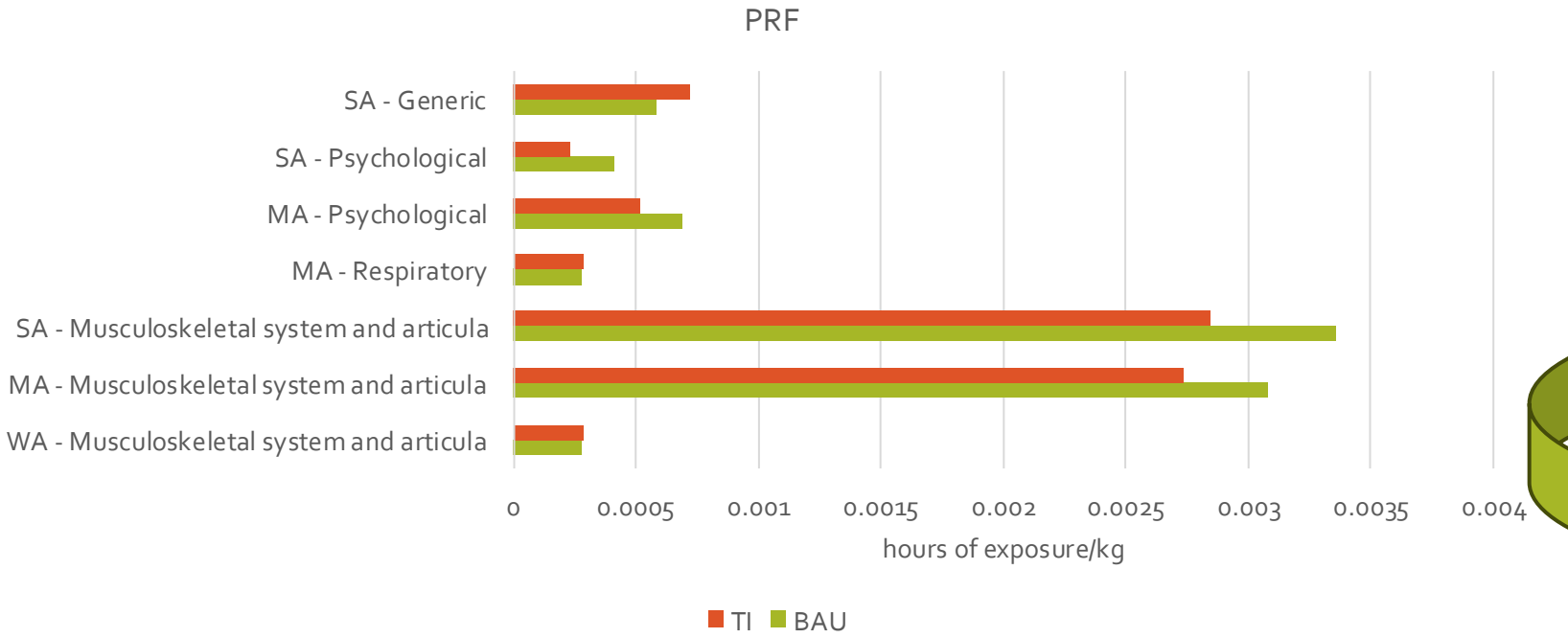
Non material emissions	Subcompartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Add line								

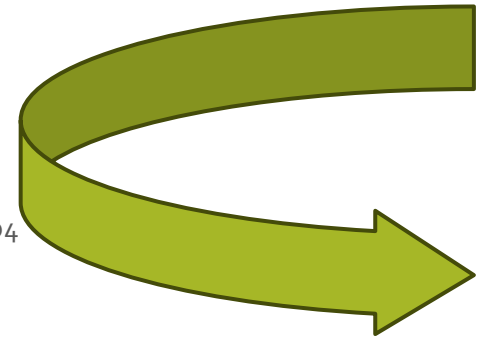
Social issues	Subcompartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
00-Total Boby Vibrations (tractor driving)		1	hr	Undefined				
00-Pesticides, insecticides, exposure		1	hr	Undefined				
00-Noise and vibrations		1	hr	Undefined				
00-Temporary employment		1	hr	Undefined				
00-Pesticide exposure		1	hr	Undefined				
00-Copper Oxicloride exposure		0,33	hr	Undefined				
00-Organophosphates insecticides exposure		0,33	hr	Undefined				
00-Insecticides exposure		0,66	hr	Undefined				

Step 5 - creation of life cycle processes

Results







Multicriteria analysis in progress

Conclusions

- **The Temporary Intercropping (TI)** strategy improves the economic sustainability of the rotation, ensuring wheat production also in the second year and reducing the economic losses observed in the BAU scenario.
- **High agronomic value**: the N and P supplied by the legume are comparable to the typical nutrient removal of Mediterranean cereal systems, allowing for a **potential reduction in fertilizer use**.
- **Improved environmental performance**: almost all impact categories show better results in the TI scenario (up to ~10% on average), thanks to production being maintained across all rotation years.
- **Greater agroecosystem resilience**: intercropping contributes to diversification, increased biodiversity, and improved soil conditions.
- **Relevance for the CAP 2023–2027**: TI offers a viable strategy for complying with Eco-scheme 4 while maintaining annual wheat production, limiting the economic penalties associated with BAU.
- **Social impact**: the TI scenario shows lower impacts associated with psychosocial risk factors, particularly in the moderate and strong association categories.

Thank you

giacomo.falcone@unirc.it