Section Organic and Low Input Agriculture, "Organic regulations opens door for breeding for diversity

LIVESEED

Boosting organic seed and plant breeding across Europe 2017 – 2021

EUCARPIA 21st GENERAL CONGRESS
22-27th AUGUST 2021
ROTTERDAM/THE NETHERLANDS

P. MENDES MOREIRA, Abco de Buck, Aina Kokare, André Pereira, Ambrogio Costanzo, Arncken-Karutz Christine, Charlotte , Floor van Malland, Jarosław Stalenga, Karl-Josef Müller, Ricardo Leitão, Edwin Nuijten, Linda Legzdina, Ágnes Bruszik, Monika Messmer

17:00 – 17:15 Breeding for Crop Mixtures and Agroforestry in Organic and Low-Input

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727230 and by the Swiss State Secretariat for Education, Research and Innovation (SERI) under contract number 17.00090. The information contained in this communication only reflects the author's view. Neither the Research Executive Agency nor SERI is responsible for any use that may be made of the information provided.

Escola Superior Agrária
Politécnico de Coimbra

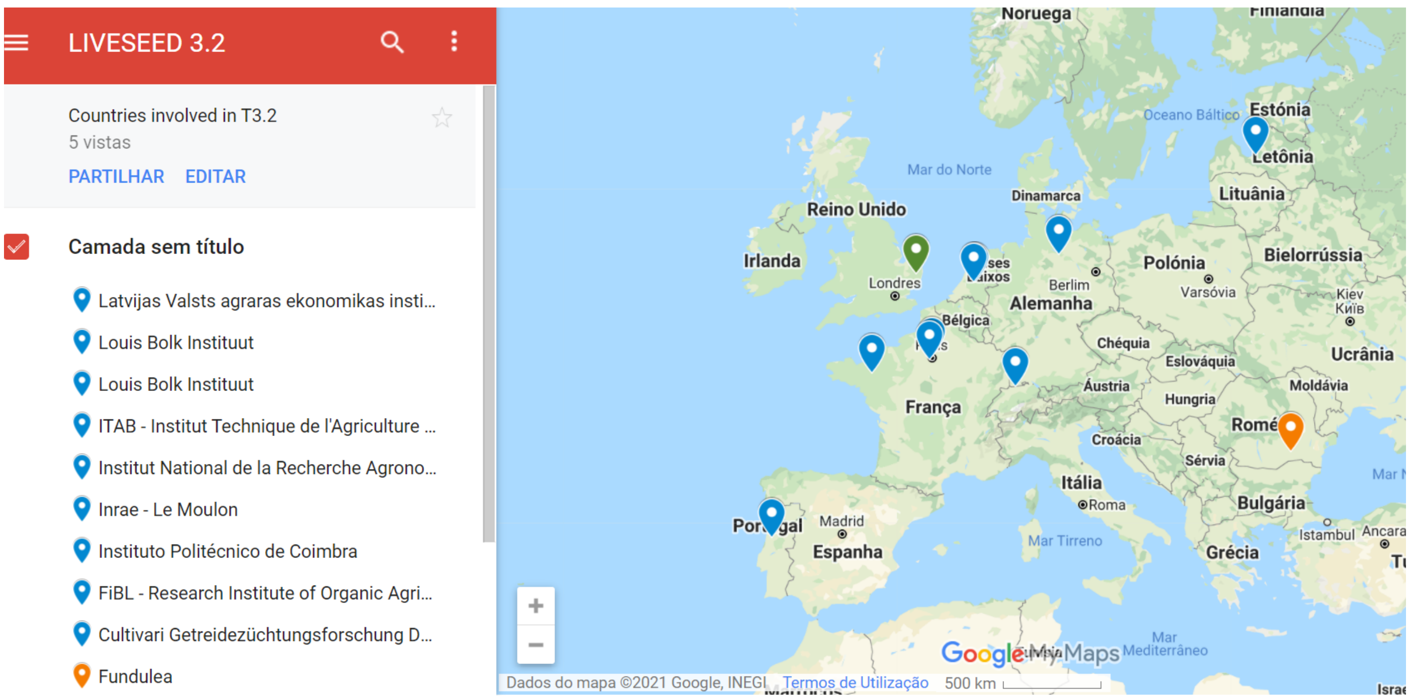
Breeding for Crop Mixtures and Agroforestry in Organic and Low-Input

1. Context
2. Methodologies
3. Main outcomes
4. Concluding remarks and next steps

1. CONTEXT

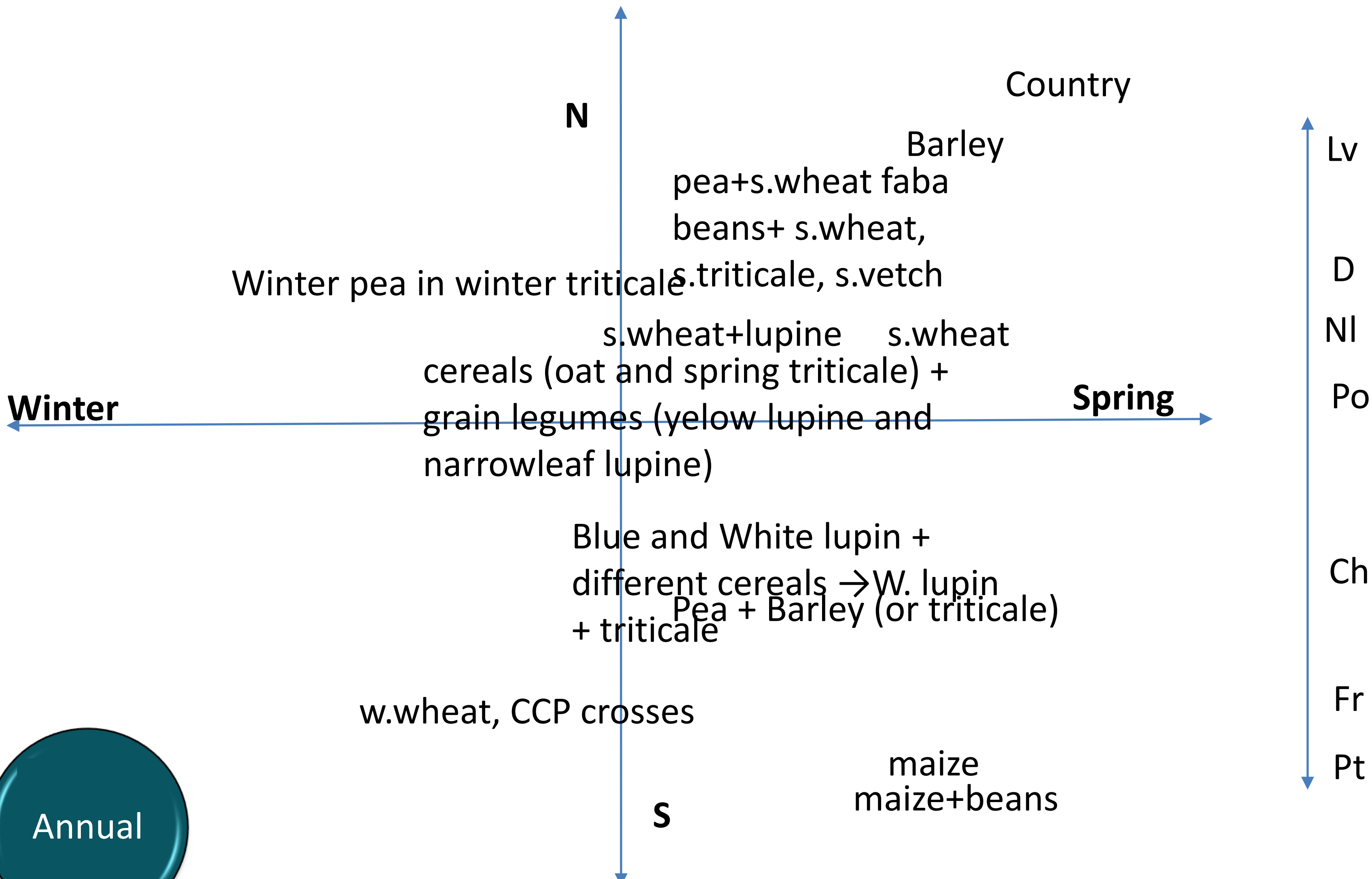
LIVESEED partners

- **26 field trials** carried out **by 12 institutions** in **10 different EU countries**
- **INRAE_F, UBIOS-F, ITAB_F, LBI_NL, AREI_LV, IPC-PT, FIBL-CH, GZPK-D, CULTIVARI-D, AGROSCOPE-CH, NARDI-RO, IUNG-PL**



LIVESEED partners

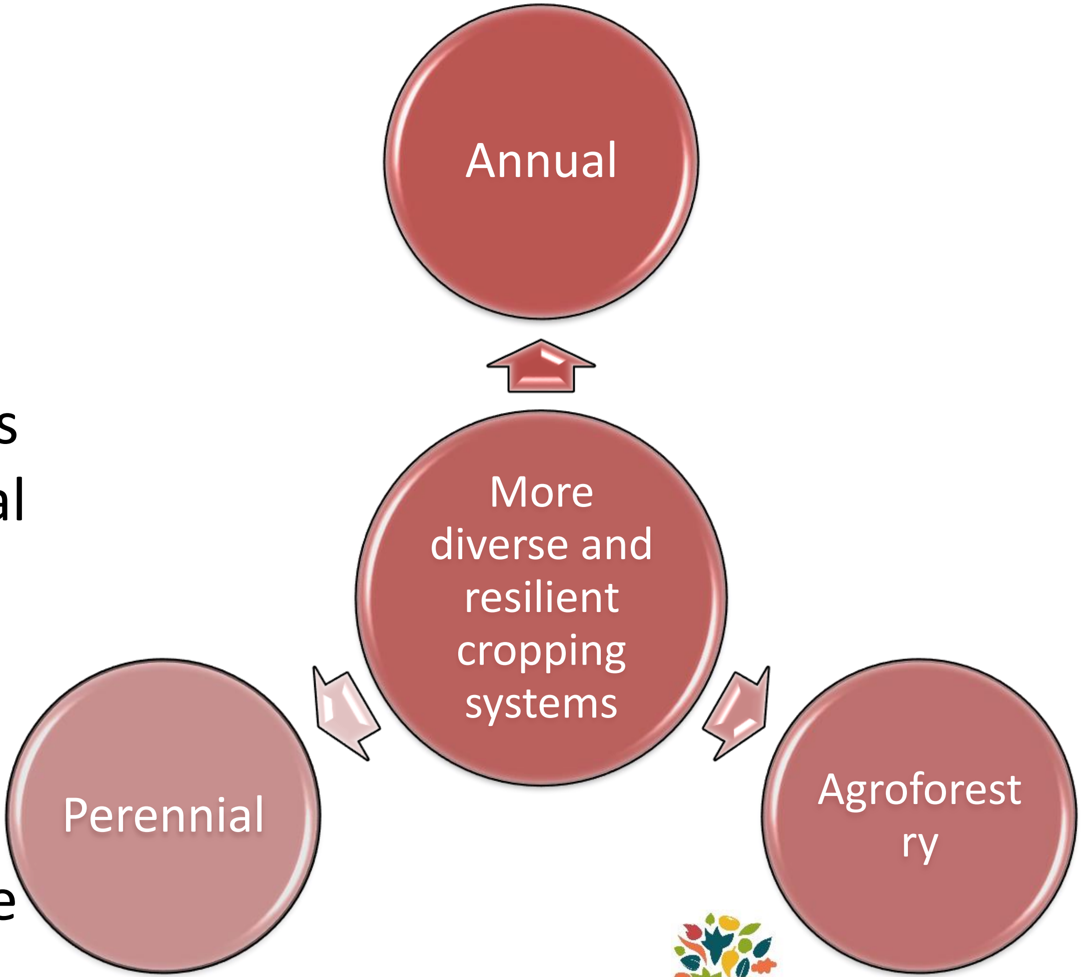
T3.2.1 Optimised annual crop mixtures, with a focus on cereals (Leader: AREI)



Annual

Improve crop resilience in organic agriculture by increasing diversity. The three levels of investigation

- **crop level** (through more diverse cultivars, cultivar mixtures and heterogeneous material)
- **field level** (through various types of mixtures of annual and perennial crops) and
- **systems level** (by increasing crop number and complexity of its relationships, such as done in agroforestry systems).



2. METHODOLOGIES

2. Methodologies

Project Meeting Valencia 2018: Planning of trials and discussions of breeding concepts: Describing the partners case studies and respective crops and crop systems

Annual reporting templates for trials disseminated and later yearly collected.

Partners were asked yearly to provide updates on their research plans and to provide their field trial data.

Project Meeting, Poland April 2019: Defining common objectives, hypotheses and analytic frameworks.

Interim evaluation of progress field trials to determine adaptation of trials in year 3-4 completed (Milestone 3.4)

Interim report on diversity management within plant breeding activities on cereals (Deliverable 3.1)

Task 3.2 Meeting October 2019: Progress in field trials and implications for hypotheses, statistical methodologies and the systems based approach as analytic framework

Project Meeting May 2020: discussion of lessons learned in multi-actor approaches, preliminary outcomes, and suitable breeding methods and tools for breeding for diversity

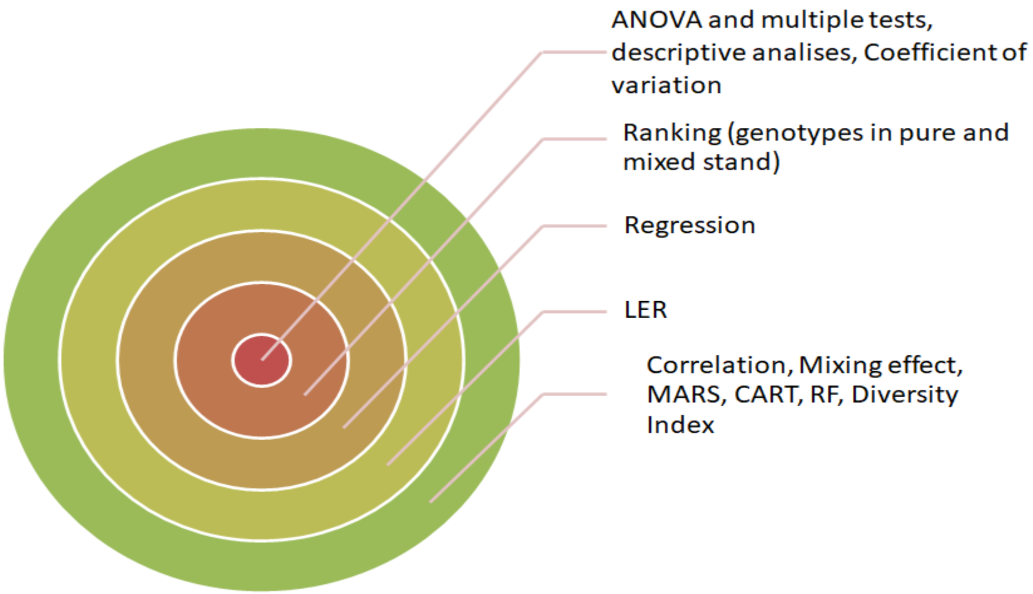
Workshop series to discuss: 18 Sept 2020: Statistical Methods 10 Nov 2020, 08 Dec 2020 and 21 Jan 2021: Statistical results & outcomes: Determining which statistical methods can be best be used by the partners for data analysis. Partners presented preliminary results to discuss commonalities and differences between the case studies, and the issues important for the toolbox for breeding for diversity.

Project Meeting March 2021: discussion on how the outcomes of the analyses will help to develop practical guidelines for breeding for more diversity

Report on enhancing resilience at systems level through breeding for diverse cropping systems (Deliverable 3.6)

Workflow of Task 3.2 in LIVESEED between 2017-2021

- **Meetings and steps of implementation**
- **Monitoring progress in the trials - Annual Reports**
- **Trial data collection (Connect with previous projects – ReMix)**
- **Data analysis**



Popularity of statistical methods from central to marginal among LIVESEED partners

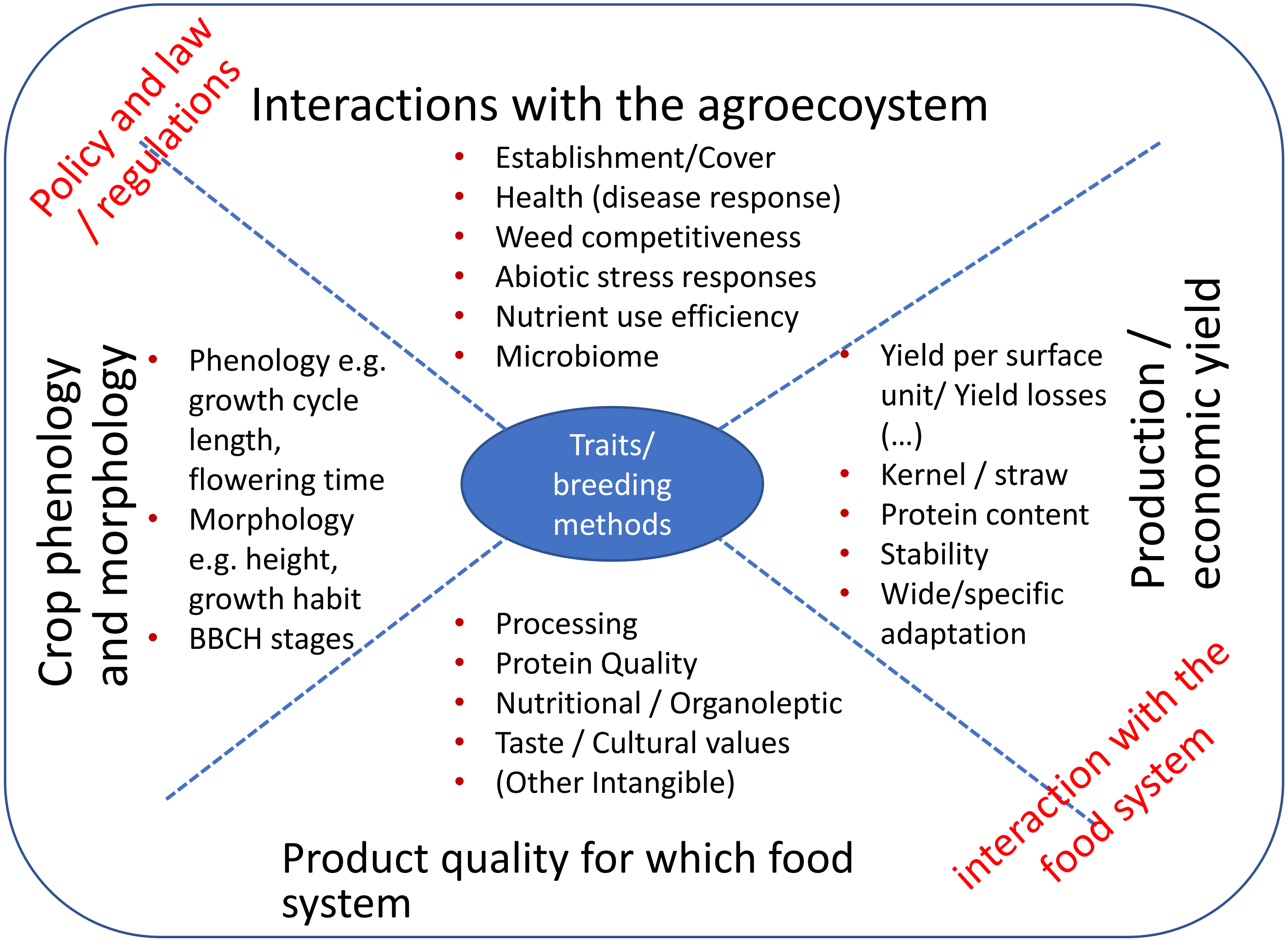
LIVESEED

Wolf traps. The **Peneda-Gerês National Park**, Portugal, [UNESCO biosphere reserve](). **What about the traits?**

LIVESEED

This project received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727230.

Systems-based Frame of Analysis



LIVESEED

This project received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727230.

Productive performance results of trials on inter-specific diversity, in terms of the importance of the characteristics contributing to breeding for resilience

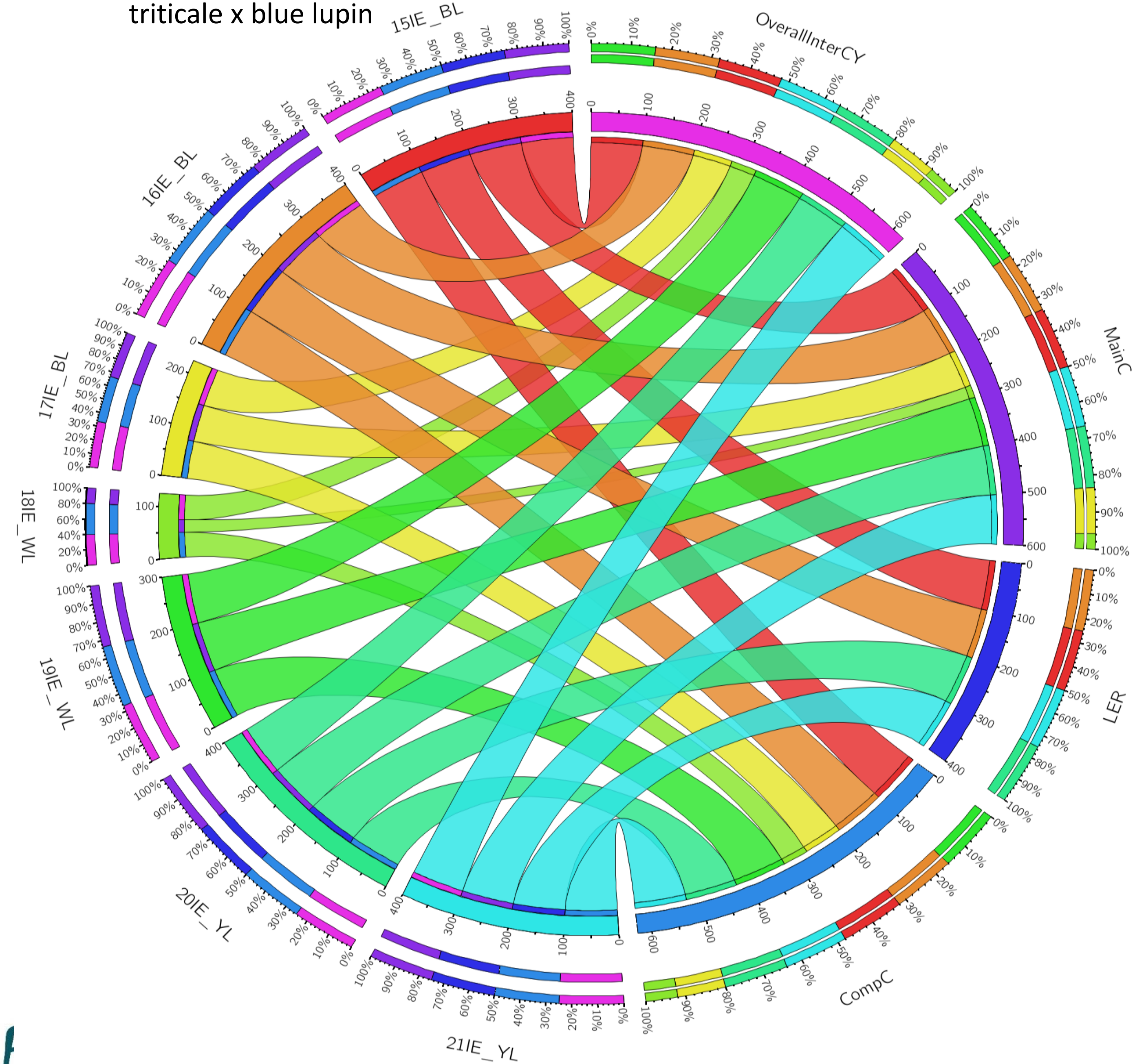
- The assessment was based on a scale of numbers associated with colours: -2 (Means a negative relationship between a certain trait and increased diversity in red colour), -1 (Means a negative trend between a certain trait and increased diversity in light red colour), 0 (Means no or no clear relationship between a certain trait and increased diversity in yellow), 1 (Means a positive trend between a certain trait and increased diversity in light green colour), 2 (Means a positive relationship between a certain trait and increased diversity in green colour).

					Productive performance							
					Yield					Yield comp		
					Main crop / Cereal	Companion crop / grain legume	Overall intercrop yield	Yield stability	Mixing efficiency (LER)	Seedhead density	Seedhead size	Seedhea fertility
Trial nr.	Trial short name	Partners	Trials	crop	MainC	CompC	OverallInterCY	YS	LER	SHDens	SHSize	SHFert
9	9IE_P	AREI	spring wheat x spring pea	pea	-1				na	1		
10	10IE_P	FiBL-CH-GZPK	spring triticale/barely - pea	pea	1	1	1		na			
11	11IE_P	Cultivari	winter triticale x winter pea (no wheat)	pea	2			2	na			
12	12IE_P	LBI	different cereals/pea	pea	2	2	2		na			
13	13IE_FB	LBI	spring wheat x faba bean	Faba bean	2	2	2					
14	14IE_FB	AREI	spring wheat/s. triticale x faba bean	Faba bean	-1				na			
15	15IE_BL	IUNG	mixed cropping spring triticale x blue lupin	blue lupin	2	2	2		2			
16	16IE_BL	IUNG	mixed cropping spring oat x blue lupin	blue lupin	2	2	2		2			
17	17IE_BL	FiBL-CH	mixed cropping blue lupin - different partners	blue lupin	1	1	1					
18	18IE_WL	FiBL-CH	mixed cropping white lupin - different partners	white lupin	-1	0	0					
19	19IE_WL	LBI	spring wheat x lupine	white lupin	2	2	2					
20	20IE_YL	IUNG	mixed cropping spring tirtricale x yellow lupin	yellow lupin	2	2	2		2			
21	21IE_YL	IUNG	mixed cropping spring oat x yellow lupin	yellow lupin	2	2	2		2			
22	22IE_V	AREI	spring wheat/triticale x spring vetch	vetch	-1				na			
23a	23aP_Gss	AGROS	grass-legume mixtures	grass					na			
23b	23bP_Gss	NARDI	grass-legume mixtures	grass					na			
24	24P_Ph	IPC	maize x beans	beans	2		2					
25	25SAF	INRA	tomato	tomato					na			
26	26SAF	IPC	of maize under coevolution, no results still	maize								

This project received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727230.

- *Traits from interspecific trials (Lupins) and the* ***production performance*** *associated, indicating also* ***what were the most relevant traits for the trials****. The width of each cord varies from 1 to 100 (1- negative relationship, 25- negative trend, 50- absent or no clear, 75-positive trend and 100-positive relationship) representing the relevance of certain traits for each of the trials.*

15 IUNG, mixed cropping spring triticale x blue lupin



LIVESEED

3. OUTCOMES

3.1 Concerning the traits and characteristics involved in general or specific mixing ability of cereal cultivar mixtures, CCPs or cereal-legumes mixtures, perennial grass-legume mixtures, and in crop adaptation in agroforestry systems

The LIVESEED interspecific trials cereals and leguminous crops (pea, lupin, alfalfa-grass mixtures) were tested based on the local agro-ecological conditions and farming contexts.

- Growing legume-cereal mixtures can improve competitiveness to weeds compared to a mono legume crop. *Such cropping system fits well within organic farm management.*

How to breed for improved mixing ability?

- Pea and lupin mixtures, **plant type** can determine whether breeding for mixing ability is necessary or not (e.g. plant height, leaf type, plant growth).
- The traits to look at, in a crop, for good mixing ability can be also very broad.

The importance of defining the objectives which performance and ecosystem functions should be improved, because in many cases it is not the total yield of the mixture, but:

- The yield of the two components that will be processed separately. For food purposes this is crucial to the quality of the grain separation to avoid the chances of allergenic (e.g. lupin that remain in the cereal grain)
- A mixed stand can improve the baking quality of wheat (e.g. combined with a legume crop).
- the companion crop must also have market potential next to good agronomic potential in mixtures.

LIVESEED

Perennial alfalfa-grass mixtures

- Using a nursery system with alfalfa and undersown lawn type grasses reduced weeding efforts in comparison to alfalfa pure stand. When working within a set of elite germplasm with reduced variation, it is recommended that the selection decision consider the cultivation system.

Questions on developing populations and mixtures in Agroforestry

(i) agroforestry systems are an environment or as a mosaic of microenvironments,

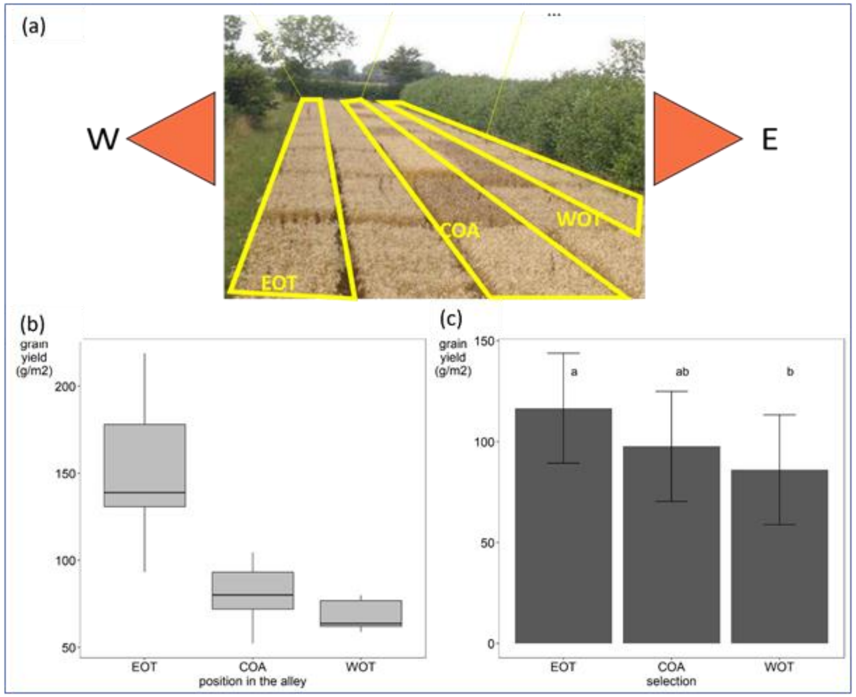
(ii) which breeding stage is suited best for which agroforestry, and

(iii) if agroforestry systems can offer new solutions for more effective breeding and variety testing for low-input systems could not be fully answered in the timeframe of the project.

LIVESEED

Questions on developing populations and mixtures in Agroforestry

A plot trial in an alley in Wakelyns agroforestry, with the East of trees (EOT), Centre of alley (COA) and West of trees (WOT) positions highlighted (a). Grain yield in the three positions (b) and of the EOT, WOT, and COA selected populations (c) in 2016. (c) shows the estimated marginal means generated from linear mixed model assuming, as random terms, the orthogonal effect of block and position in the alley. Bars with different letters are significantly different at a 0.95 confidence interval.



(i) the yield potential of a wheat population can be influenced by the position in an alley (constructed by two North-South oriented tree rows) where it has been multiplied, and (ii) presence of diseases (including seed-borne diseases) in a wheat population can be influenced accordingly due to differences in micro-climate (e.g., humidity and solar radiation).

R. LEITÃO – Successional agroforestry systems for Europe: the Portuguese example

SAFs was installed at ESAC-IPC (Portugal) under organic and low input environment in 2019 and can be divided in two steps: 1) Creation of the SAFs itself; 2) To start a maize CCP 'SinPre' and bean cultivars in co-breeding for SAFs and latter only with maize adapted to SAF. During the years of selection, it was possible to obtain seed for next seasons, determination of yield trial will be done this year

Installation: 400m2 (long term), Pedagogic purposes (2 courses 9 and 16-05-2019, 50 persons

- **Maize (1CCP) x Beans (2)** x herbaceous x trees. Started in 2019, i.e., 2 cycles of selection

Core Team
Walter Sandes
Rosa Guilherme
Daniela Santos
Isabel Dinis
Pedro Mendes-Moreira

The agroforestry systems

- Provide important opportunities for evolutionary and/or direct selection harnessing complex interactions that become even more complex when the level of genetic diversity (selection) of different perennial and annual crops is included.
- In these systems, plant-plant and soil-plant interactions provide to be more complex than previously assumed as spatial arrangement and microclimate play a major role.
- Further research is required to define the plant traits best adapted to intercropping both for alleys and interrow traits and the best performance in specific temporal and spatial positions.
- How to better understand and benefit from plant-soil interactions and holobiont as potential selection target?

LIVESEED

3.2 New breeding methods, experimental designs, and selection tools for various mixed cropping systems

The results in LIVESEED inter-specific diversity (crop mixtures) trials showed that the breeding needs:

- Clear goals adapted to a context-specific, both at the agro-climatic and value-chain level.
  - to have set for the plant type and the companion crop(s), which depend on the local context.
  - breeding for mixed cropping, needs evaluation both species in mixed stand and per se, because rank differences can be observed
  - When designing mixed stand cereal-legume evaluations, one or a few testers of the cereal crop (cultivars) can be sufficient when GMA effects are dominating, while there is no or little SMA.

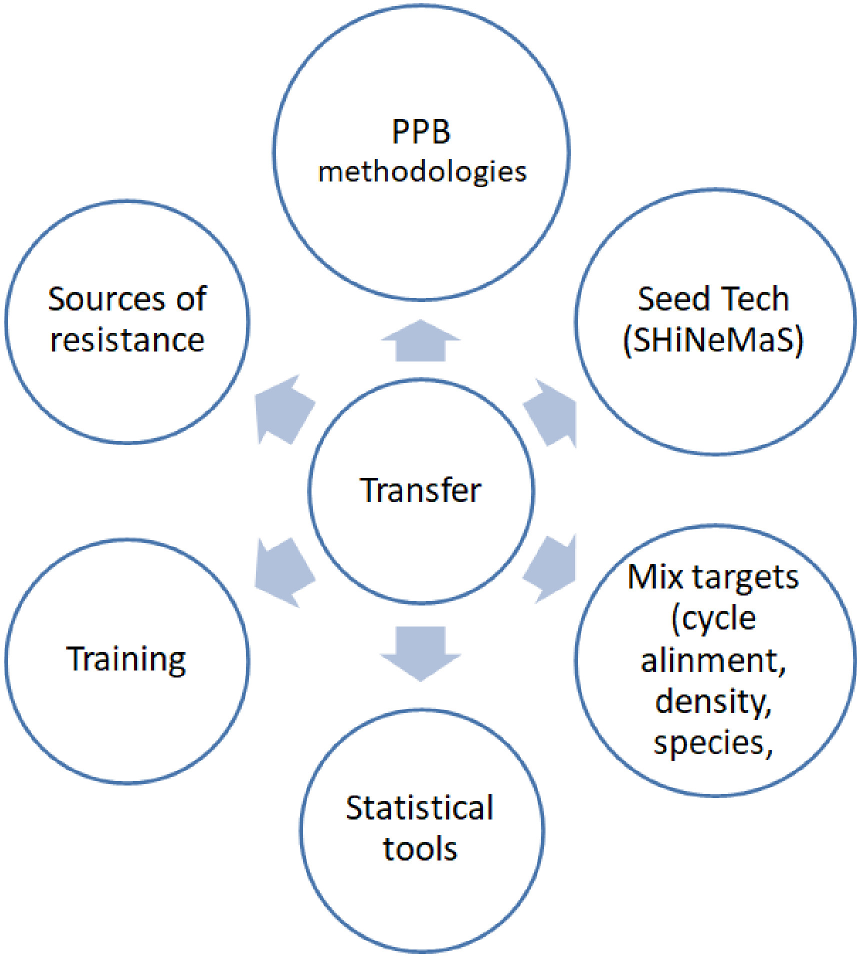
3.2 New breeding methods, experimental designs, and selection tools for various mixed cropping systems

- The type of companion crop also determines the crop phenotype to breed for.
  - Develop synchronization of the crop cycles to ease harvesting
  - To better cope with weed pressure, some companion crop proved useful in supporting the other, under unfavourable conditions.
- Agronomic aspects (such as plant density, seed ratio of the mixed crops, time of sowing, sowing depth, sowing method, soil type, and soil fertility) can be important factors that influence plant growth and hence the selection process and breeding progress.

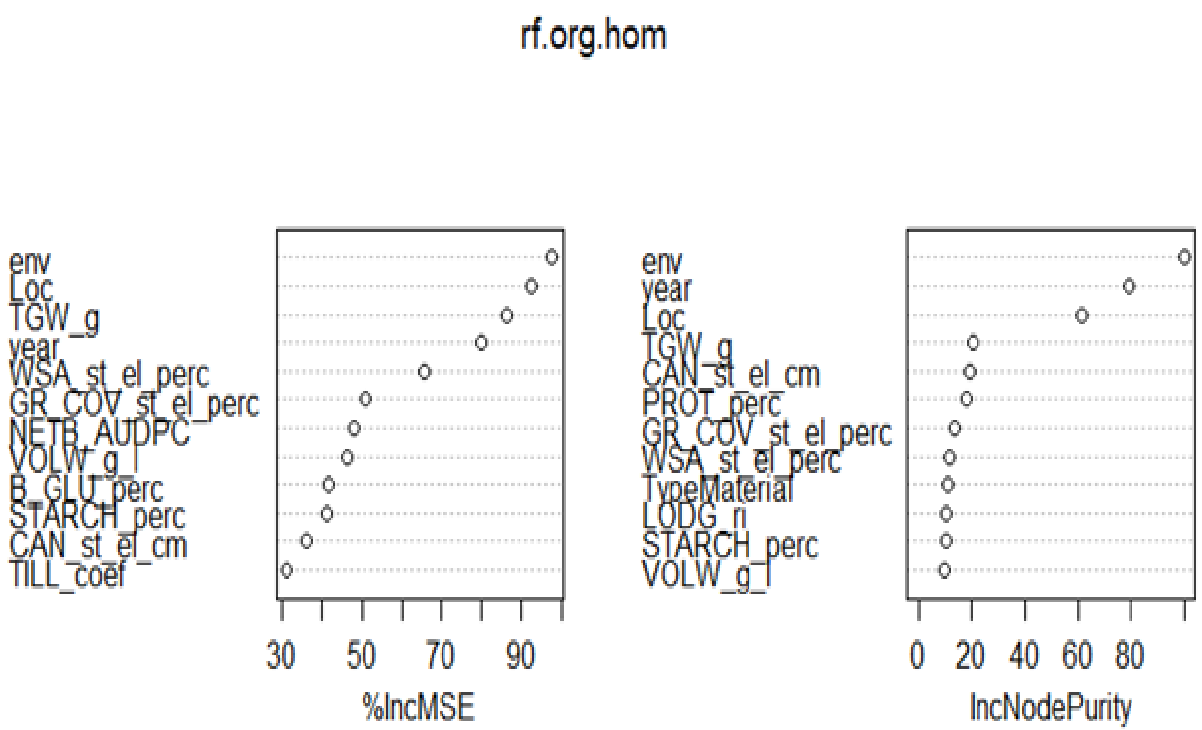
- Specific advantages of crop mixtures might vary considerably between agroecological zones, as local stress factors (e.g., competition for water, nutrients and light, different pest, and disease pressure) might have a greater influence.

LIVESEED

3.2 New breeding methods, experimental designs, and selection tools for various mixed cropping systems

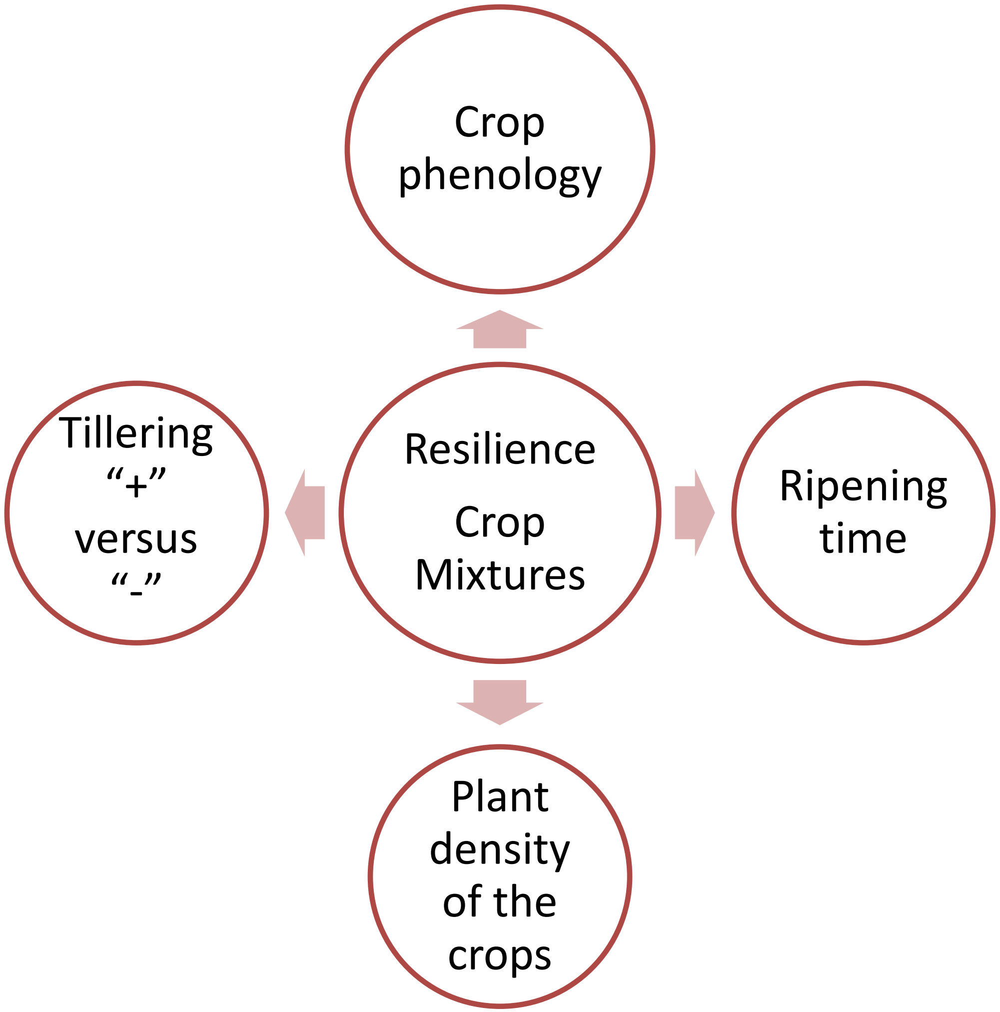


Statistical tools transfer from maize to barley



- Searching for tools to help on the selection

3.3 Improving resilience of crops with inter- and intra-species genetic diversity on field specifically fitted for organic farming



Tillering ability, directly related to plant density, is important for improved resilience at monocrop level, but can hamper or compete crop growth of the companion crop under specific conditions.

- trials mixing leguminous crops with cereals, contrasting results were observed with regards to better coping with weed pressure and lodging resistance.

LIVESEED

3.3 Improving resilience of crops with inter- and intra-species genetic diversity on field specifically fitted for organic farming

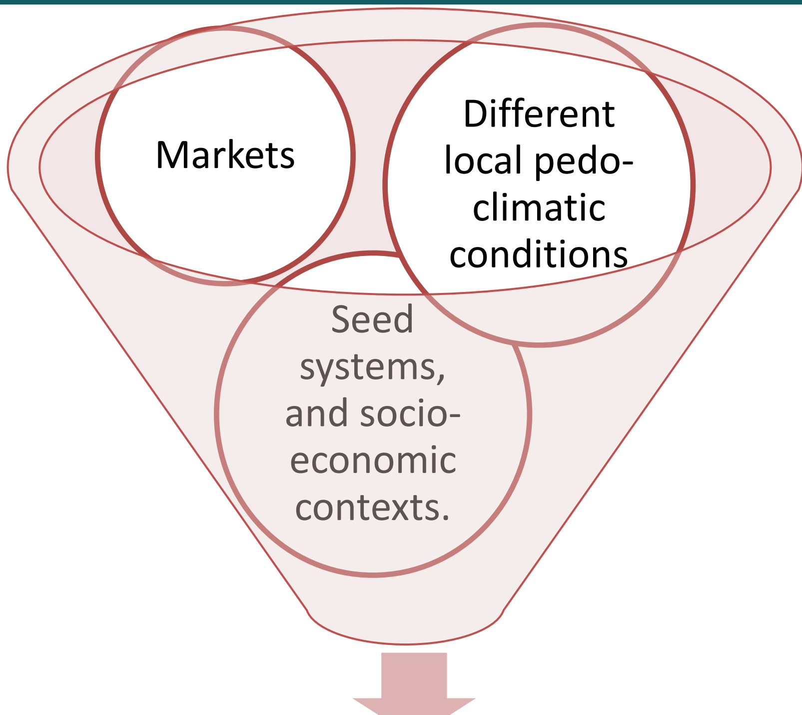
The overall conclusion

- intercropping seems to be a good solution to prevent lodging of legumes (e.g., pea)
  - for low-input conditions
  - disease resistance could not always be confirmed due to very low disease pressure

- In some specific cases crop mixtures may induce a conducive environment for specific diseases.
- or higher resilience in the lupin cereal mixtures in comparison to the crops sown in pure stands concerning yield stability over years.
- In the perennial alfalfa-grass mixture trials and maize-beans intercropping trials no clear improvement of resilience of the system were observed.

LIVESEED

3.4 Novel approach to co-design with farmers' blends of cultivars or species mixtures specifically according to their local conditions, market, and socio-economic context



Co-design approaches

(CCPs, DOPs, participatory ideotyping, involving farmers in the choice of the starting genetic material, culinary breeding, etc.)

acceptance of co-designed materials, and the co-creation process (e.g. CCPs country or farmer)

A multi-actor and transdisciplinary approach is needed

Maize-Pt – Farmers' evaluation and adaptation of the preferred germplasm

Culinary breeding – promote the use of maize germplasm search for new products to develop

LIVESEED

3.4 Novel approach to co-design with farmers' blends of cultivars or species mixtures specifically according to their local conditions, market, and socio-economic context

- From the experiences it can be concluded that researchers/facilitators will play a crucial role in the near future in providing capacity building for farmers, to enable them to work with such materials on their own.
- For the time being, farmers require the link with scientists for access to genetic materials, for selection methods, evaluation and statistical analyses and coordination.
- Farm advisory services could build in such programs for on-farm breeding across Europe to facilitate uptake.
- Farmers are willing to sacrifice land from production and their time to develop improved cultivars suited for their local conditions.

LIVESEED

3.5 Prove of concept for breeding for more diverse cropping systems

- For breeding for mixed cropping, different breeding tools can be helpful, depending on the set goal and the local context.
- Based on statistical analysis of the individual cases, most efficient strategies can be developed (e.g., if cultivars bred for monocropping can be used or if specific breeding for mixed cropping needs to be set up).
- For breeding for more diversity, considering the local context, good collaboration with farmers, processors and other value chain actors is crucial to integrate farmer and expert knowledge and to embed the new populations (OHM) and mixtures in the food system.
- Multi-actor approaches have a potential advantage of developing material better suited for the needs of the different actors with high adoption rate and a better distribution of the work reducing the financial costs.
- In the future, not only economic and ecological, but also social resilience of plant breeding will become more important as outlined in the systems-based breeding framework developed by LIVESEED (Lammerts van Bueren et al., 2018)

4. CONCLUDING REMARKS AND NEXT STEPS

4. Concluding remarks and next steps

- A general conclusion is that a breeding strategy with a focus on increasing diversity can contribute to yield stability and resilience (trial results from neutral to positive for the traits contributing to breeding for resilience).
- The results f(pedo-climatic conditions and socio-economic context).
- Several populations and mixtures were developed through the project, the uptake of which can be recommended or promoted for use and further development in low-input and organic farming.
- The results show that although some of the common hypotheses could be validated by several partners, it was not possible to have generic hypotheses that could be confirmed by all partners, and that it is important to have context-specific hypotheses.

4. Concluding remarks and next steps

- Multi-actor approaches were used to develop locally adapted populations with more stable performance. These participatory approaches proved to be very important for smaller crops, and for the engagement of farmers with the intention to develop their skills to do on-farm breeding in the future.
- However, horizontal upscaling across Europe requires more systematic exchange and training by advisors and knowledge institutions, and more systematic and long-term funding.
- The project also developed a range of breeding methods and statistical methods that are fit for use in different geographical regions and for different crops by breeders in the future, potentially in collaboration with farmers.

LIVESEED

4. Concluding remarks and next steps

- Agroforestry systems may not only provide opportunities to improving resilience but also allow a very different perspective on current farming, breeding, and research practices. Due to its complexity, and more research is needed to elucidate: the plant-plant interactions, the competition for resources, and the soil-plant interactions.
- Social resilience, if we are to implement the systems-based breeding framework developed by LIVESEED (Lammerts van Bueren et al., 2018). Aspects for future research could look at (i) Genotype x Environment x Social (GxEXS) interactions and how maintaining and enriching cultural diversity helps broaden the perspectives on breeding, (ii) how social resilience is formed in different breeding orientations, and (iii) how a more evolved social resilience influences the efficiency of the breeding process (e.g., definition of breeding goals or selection) in different seed systems.

LIVESEED

Thank you very much

- Acknowledgements to the W3.2, that actively participate and has been made possible to better contribute to **Enhancing resilience at systems level through breeding for diverse cropping systems**

LIVESEED

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 727230 and by the Swiss State Secretariat for Education, Research and Innovation (SERI) under contract number 17.00090. The information contained in this communication only reflects the author's view. Neither the Research Executive Agency nor SERI is responsible for any use that may be made of the information provided.