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RESEARCH ARTICLE

TRANSLATING THE MULTI-ACTOR APPROACH TO RESEARCH INTO PRACTICE USING A WORKSHOP APPROACH FOCUSING ON SPECIES MIXTURES

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KEYWORDS
agroecology, codesign, intercropping, knowledge sharing, participatory methods

HIGHLIGHTS

- Challenges in reconciling multi disciplinarity with clear expressions of single disciplinary concerns.
- Participant involvement was created bridging the gap between academia and practice.
- Collaboration potentials with actor networks to co-produce shared visions were recognized.
- A common language was developed concerning unfounded perceptions of barriers for change.
- The workshop was effective for producing a shared picture of research needs.

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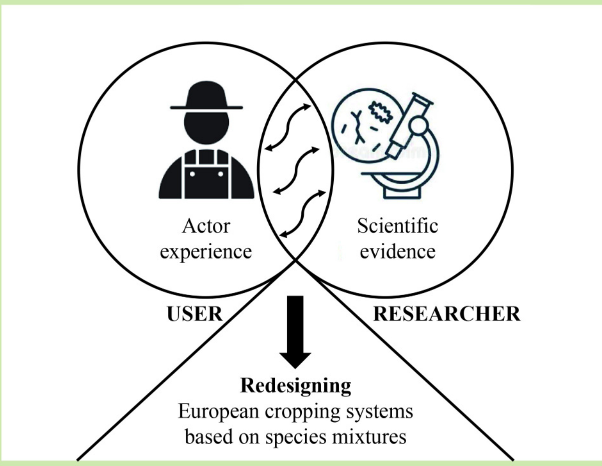
GRAPHICAL ABSTRACT



ABSTRACT

The EIP-Agri multiactor approach was exemplified during a 3-day workshop with 63 project participants from the EU H2020 funded project "Redesigning European cropping systems based on species MIXtures". The objective was to share firsthand experience of participatory research among researchers who were mostly not familiar with this approach. Workshop participants were divided into smaller multidisciplinary groups and given the opportunity to interact with representatives from eight actor positions in the value chain of the agrifood cooperative Terrena located in Western France. The four stages of the workshop were: (1) key actor interviews, (2) sharing proposed solutions for overcoming barriers, and (3) developing possible interdisciplinary concepts. Expressions of frustration were recorded serving both as a motivation for group members to become more aware of the scientific concerns and practices of their colleagues, as well as a recognition that some researchers have better skills integrating qualitative approaches than others. Nevertheless, the workshop format was an effective way to gain a common understanding of the pertinent issues that need to be addressed to meet overall multiactor-approach objectives. Working with the actor networks was identified and emphasized as a means to overcome existing barriers between academia and practice in order to coproduce a shared vision of the benefits of species mixture benefits.

1 INTRODUCTION

Benefiting from plant–plant interactions[1–3], species mixtures, the simultaneous cultivation of at least two species in the same field, have been grown since ancient times[4,5]. This agroecology strategy is shown to substantially improve land use efficiency[6] and contribute to productive but also resilient and environmentally-friendly cropping systems less dependent on external inputs[7–9] operating with competitive and facilitative interactions within the crop[10,11]. This contrasts with the current dominating cropping practices with large areas of monocultured species using modern cultivars narrowing the genetic base of crops[12]. Based on these generic interests, strategies to promote adoption of field-grown species mixtures must provide documented benefits over and above the established agriculture practices for farmers and other actors in the agrifood value chain[4,13,14].

In line with this, the European Commission has made the adoption of a multiactor approach, within the Agricultural European Innovation Partnership (EIP-Agri) a requirement for several research and innovation projects to receive funding. Novel project designs and structure are needed including the idea that innovative farming practices can be developed as elements of multilevel sociotechnical systems[15,16].

The application of a multiactor approach implies that potential users of research results must be integrated into the project team and that project partners with complementary types of knowledge must collaborate in the project activities from beginning to end. This is a laudable idea but, in practice, it implies a substantial change to the paradigm of knowledge production and dissemination, familiar to most researchers, which is often referred to as Mode 1 science, characterized by homogenous teams in terms of scientific background and well defined quality controls adopted by the scientific community[17–19]. When using a multiactor approach, the setting of specific research objectives is driven by knowledge needs expressed by the users or beneficiaries of scientific knowledge. Following such process of innovation, the subject of knowledge production is derived from the multiactor activity processes. It falls within a paradigm of knowledge production, referred to as Mode 2 science, which is conducted within the context of application, arising from problem solving and not governed by the paradigms of established scientific disciplines[19]. Involving actors more directly can help to design new ways of working and lead to realigning research trajectories with public preferences. In saying this, coherent adaptation of Mode 1 and Mode 2 practices is the authors' point of departure when addressing strategies to promote adoption of the production of species mixtures.

Crossing of disciplinary boundaries is regarded as necessary for solving societal problems. But what happens when two modes of science are designed to cohabit within the same project? Practicing the multiactor approach can threaten or even destabilize current Mode 1 forms for production of new knowledge, methods and tools[20–22]. The disciplinary organization in the established research system and successful interdisciplinarity require trust and mutual acknowledgment of each other's concerns and contributions[23–25]. It is a prerequisite for effective collaboration and knowledge sharing. Participatory creation of change[26] requires that good working relations among project partners be established and nourished[27,28].

The objectives of this study were (1) to highlight the richness of the main findings of converting to species mixtures that can be jointly produced during an intensive 3-day workshop with 63 participants from 24 partner institutions and (2) identify general recommendations for the adoption of similar approaches in other projects.

2 MATERIALS AND METHODS

Data for this study were collected during a workshop with 63 ReMIX participants (researchers, advisory services and private company representatives) from 24 project partners meeting each other face-to-face at the headquarters of the Terrena agrifood cooperative in Ancenis, Western France from May 15–17, 2018. Most of the workshop participants were trained Mode 1 scientists such as agronomists, plant breeders and mathematical modelers. The workshop had the following specific goals: (1) to practice good interdisciplinary working relations among the researchers and the social actors involved in a local agricultural value chain integrating the multiactor approach into the project consortium itself, (2) to initiate the creation of a joint situational analysis of the issues at hand and agree on commonly acknowledged research goals, (3) to initiate the development of a common language and appropriate forms of communication, and (4) to enhance mutual acknowledgment and awareness of the research contributions and working requirements of others.

2.1 Workshop organization

The workshop consisted of three sessions during which the workshop participants were divided into smaller multidisciplinary groups and given the opportunity to interact with representatives from eight distinct social actor positions in the value chain of the Terrena agrifood cooperative situated in Western France. The three sessions were organized as a 3-day iterative process with Day 1 for initial key actor interviews at Terrena, Day 2 for breakouts in smaller groups to discuss specific subjects or aspects of the broader theme, and Day 3 for plenary concluding sessions.

It was explicitly communicated to the workshop participants that the exercise was to give them firsthand experience in adopting the Mode 2 science approach with the intention to focus on scoping real life problems, and/or opportunities related to production and trade of species mixtures.

A questionnaire to evaluate the workshop (organization, structure, content, outcomes and suggestions) was distributed to all ReMIX participants after the workshop. Evaluation from the Terrena value chain actors was represented by the cooperative director during the plenary sessions on Day 3.

2.2 Workshop preparation

Terrena is a French agricultural cooperative located in Western France with its headquarters in Ancenis in the Loire Valley. The cooperative includes 22,000 farmer members and 14,000 employees with an annual turnover of 5.0 billion EUR. Beyond the agricultural cooperative, Terrena is an agrifood industry group, that collects and processes its member’s products.

Prior to the workshop, Terrena staff provided the organizers with eight actor positions available at the time: (1) an organic farmer, (2) a conventional farmer, (3) an agricultural advisor, (4) a logistic (storage) manager, (5) a miller, (6) a food ingredients producer, (7) a commercial director of agricultural machinery, and (8) the cooperative director (Fig. 1). Clearly, other relevant positions in the supply chain could have been included, such as commercial retail enterprises, consumers or local authorities representing policymakers but the point was to make distant stakeholders from other parts of the agricultural value chain appear as direct, living research partners for the researchers, not to give exhaustive coverage of all the issues of concern existing in the value chain.

The workshop participants were provided with short written narratives before the workshop introducing the position and situation of each of the eight Terrena actor representatives. These narratives were produced by Terrena staff based on a prior informal interview with the invited stakeholder representatives and their daily experiences. When distributing this material it was explained how the term ‘narrative’ implied a scientific status as a personalized, subjective account of the

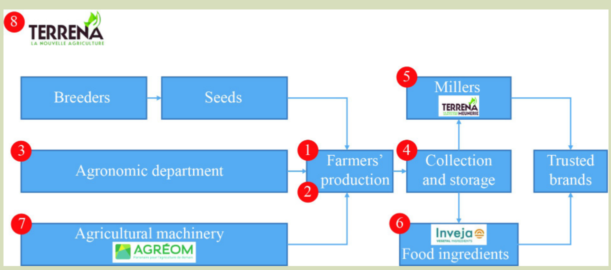


Fig. 1 The Terrena value chain based upon a defined strategy outlined in several companies (e.g., Agréom, Evelia and Inveja) and departments to support the production of food and feed to fulfill the economic interests of both consumers and farmer members. The numbers indicate the eight types of actors (positions) in the value chain: (1) an organic farmer, (2) a conventional farmer, (3) an agricultural advisor, (4) a logistic (storage) manager, (5) a miller, (6) a food ingredient producer, (7) a commercial director of agricultural machinery, and (8) the cooperative director.

situation from the point of view of each actor representative.

2.3 Workshop procedure

Activities during the workshop were organized in five steps each with a written assignment.

Step 1. On Day 1, the participants were divided into eight multidisciplinary workshop groups. The groups were predetermined based on background knowledge of the individuals. Each group had a facilitator responsible for ensuring required deliverables. The facilitator was briefed beforehand by the workshop organizers. The workshop groups were randomly matched with one of the selected Terrena actor representatives (Fig. 1) and sent on a short field trip to interview them in their respective workplaces. The workshop group was asked to consider the specific actor representative's situation and perspective on changing to species mixture practices that used agroecological principles.

Step 2. Using this qualitative empirical material, the groups were subsequently given instructions to identify and list possible opportunities and challenges of species mixture practices and then categorize them as environmental, technical, social or economic.

Step 3. Each group was given instructions to evaluate how the possibilities and challenges perceived by the actors were linked to other parts of the value chain and thus elaborate on the narratives provided. At the end of the day, each group jointly formulated an account of the context situated perceptions on benefits, risks and difficulties of species mixtures implementation seen from the positions of their respective actor in the local agrifood value chain (Assignment 1) and the views of this actor on the actions needed to promote species mixtures (Assignment 2).

Step 4. On Day 2, the groups were asked to suggest solutions for overcoming barriers along the value chain and for facilitating the adoption of species mixtures, including policy suggestions where appropriate. This was conducted without the influence of the respective Terrena actor. At the end of the day each group also jointly formulated suggestions for policy level measures or actions made by their actor with possible interlinkages to the local agrifood value chain actors (Assignment 3).

Step 5. In a plenary session on the final day, each group presented their perspectives and approaches to assessing and managing species mixtures based upon input from Days 1 and 2 (Assignment 4). The Terrena director, but not the other actor representatives, was present to set the scene for future Terrena species mixture activity discussions to inspire workshop participants and coming activities in each of the 11 local multiactor platforms. Day 3 was closed by a plenum evaluation by workshop participants of the experience in applying the multiactor approach principles during the workshop.

At the end of the workshop, the organizers collected minutes from each group (Assignment 5) and subsequently summarized these into short statements sent to the workshop participants and the Terrena actor representatives for feedback and validation. The authors of this article have turned these elements into a final narrative for further word-cloud analysis using the R packages SnowballC[29] and tm[30] with pre-processed text and stop words removed including stemming and lemmatization (Fig. 2).

3 RESULTS

3.1 Perceived benefits and risks of producing species mixtures

The workshop participants came to understand that species mixtures are primarily an advantage for the production part of the Terrena value chain (Table 1) rather than the processing part. Both farmers pointed out advantageous agroecological functions and services, such as increasing productivity through enhanced biodiversity, reducing the use of agrochemicals and thus preserving the environment, producing crops in a more natural way, among others. However, according to the crop advisor, species mixture practices are regarded as being more time consuming than monocultures. Reasons for this include more time needed for sowing (depending on machinery) and drying harvested materials during storage due to different maturity dates and sorting/cleaning before selling/challenging other priorities of the farm.

Further up the value chain, the logistic (storage) manager, the miller and food ingredients producer pointed out disadvantages with variability in species composition of the harvested products combined with difficulty of cleaning and sorting seed mixtures. A greater volume of species mixtures harvested would increase their operational period to ensure effective sorting including potential modification of present drying, handling and storage operations, with possible additional modifications required to current logistics and management. However, the miller saw opportunities including

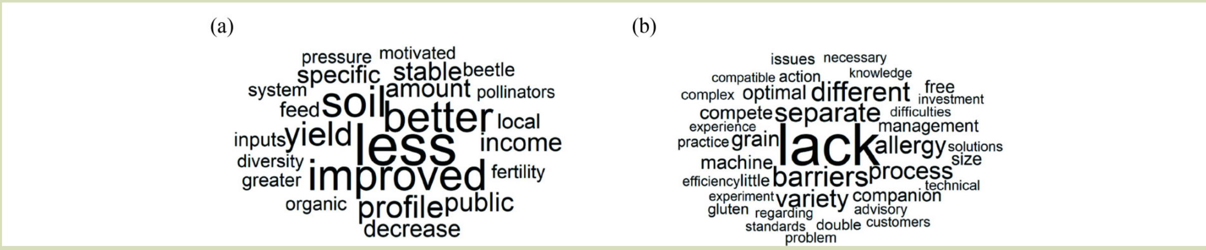


Fig. 2 Word clouds based upon a final narrative produced by the workshop organizers from collected minutes from each group verified by both the specific participants and the Terrena actor representatives and categorized for the benefits (a) and risks (b) across actor narratives using the R packages SnowballC[29] and tm[30] with pre-processed text and stop words removed including stemming and lemmatization to reduce inflectional forms and sometimes derivationally related forms of a word to a common base form. Words that only appeared once were removed.

improved flour quality with higher cereal protein content and the ability to access developing markets highlighting less inputs and a “greener” product in the marketing. This is in agreement with the benefits identified by the logistic manager around novel product development sold with a potential premium offsetting additional cost. From the perspective of the processor, the possibility of increased quality assurance through documented use of reduced external inputs in species mixture compared to monculture is of higher value than evidence of certain positive ecosystem impacts (Table 1).

Across the Terrena actors, it was agreed that linkages between consumer behavior and trust regarding their food products are crucial (Table 1). Both the farmers and the agricultural machinery commercial director highlighted the potential for reduced fertilizer and pesticide use when growing species mixtures as a major benefit. Savings associated with reduced chemical inputs, and possible overall yield increases might lower the cost of production and thereby increase the net income for farmers alleviating the concerns of the crop advisors that “time is money” (Table 1).

The word cloud analysis produced across actor narratives (Fig. 2) shows that less inputs, improved soil fertility, stable yields and greater diversity influencing pollinators and other beneficial organisms (such as beetles) and reduced soil degradation are all positive benefits which may motivate some farmers to change their practices (Fig. 2(a)). Benefits mentioned also include public awareness and future farming profiling, including a possible increase in organic farming options, reducing the pressure farmers face with potential new environmental regulations. Feed quality aspects are likewise highlighted together with specific and local management strategies and creating opportunities for expanded story telling linking farming products to issues of concern to consumers.

Regarding risks, lack of information/familiarity with species mixtures dominates the word cloud including advisory and other technical challenges (Fig. 2(b)). Another key risk is the possibility of reduced profitability because of the higher cost for the manufacturer of separating species compared with the standard monocultural strategies and logistics. Changing the situation to allow farmers to control a greater portion of the profit within the value chain requires investments in equipment and change of current management practices to offset the grain volume and quality standards of processors and retailers (Fig. 2(b)). Such investment costs and the fact that benefits sometimes accrue over the longer term (profit values) are regarded as critical risks for a wider diffusion of species mixture strategies in European farming systems. Another key challenge is the social and economic context in which farmers operate with lack of knowledge about the opportunities for species mixture production linked to new customers in alternative markets with, for example, specific gluten or other allergy requirements, or similar. In addition, support for the much needed local action initiatives and experiments to explore increased ecological intensification practices is another risk which reduces the efficiency of transition to species mixture production. Changing current management practices brings risks, and establishment of a free insurance system for farmers and other actors embarking on species mixture practices was highlighted together with suggested supportive actions in the formulation of contracts between the cooperative and farmers. The creation of economic incentives for farmers to switch to species mixture practices, or of attracting investments into the development of new storage and processing facilities was highlighted.

Technical and agronomic issues, such as experimentation with various species combinations, the design of species mixture systems considering specific constraints from the industry (e.g.

Table 1 Benefits and risks identified by the Terrena value chain actors interviewed

Actor	Actor	Biological/technical	Social	Economic
Organic farmer (1)	Benefits	Improved soil fertility since including lupin in cereal cropping, less diseases, improved soil biodiversity, more pollinators, soil structure improvement, improving climate adaptation.	Improved relationships with consumers and environmental organizations by showing willingness to change, open farming welcoming visitors, well-being, and better health.	Income stability, cost limitation, improved gross margins.
	Risks	Sowing techniques and weed management difficulties, lack of knowledge of suitable cultivars, combine harvester settings, grain separation, storage.	Critical neighbors with very little support for new strategies, conflict with other tasks on the farm in terms of timing.	Dependence on Terrena, spending more time and money on weed control and harvest/storage, no insurance for species mixtures.
Conventional farmer (2)	Benefits	Reduced soil erosion, improved water storage and soil health, modification of microclimate, increase in natural pollinators, reduced pesticide use.	Public approval for using less pesticides in order to help answer to health concerns, environmental protection, ground water protection, diversification and personal motivation.	Reduction in pesticide and fertilizer use, improved income, increasing on farm fodder production, (potential transition cost is not a relevant concern).
	Risks	Difficult sowing strategy, requires special equipment like sowing machinery, higher risk of weed infestation, companion crops require frost to disappear.	Low cost of pesticides is an obstacle for innovation, change in government policies in relation to subsidies, increasing public pressure for reduced pesticide use.	Extra cost for farm machinery, extra cost for seeds, reduction in government subsidies (pesticides are cheap).
Crop advisor (3)	Benefits	Lower risk of total crop losses, improved natural weed control, greater diversity across the crop sequence, disease reductions, reduction of pests despite less chemical control options, climate mitigation.	Fewer chemical inputs, consumer support, fulfill public legislative requirements, aesthetic landscape diversity and values, farmer knowledge sharing and inspiration.	Yield stability (of protein crops) and reliable income, minimal inputs and lower production costs, on-farm protein production, plant protein subsidy as a support for mixtures.
	Risks	Lack of competent advisors, knowledge gaps, lack of suitable cultivars, cultivars and breeding programs, lack of knowledge of rotation impacts on species mixtures.	Species mixture enthusiasts contradicted by traditionalists, lack of training at many levels, low government regulation understanding, viewed as knowledge and time intensive.	Government payments discriminate against species mixtures, current machinery not usually adapted, time consuming management (time is money).
Logistics (4)	Benefits	Farmer opportunity to benefit from natural processes, follows Terrena business strategy, new options with revision of storage system, support from processors and market.	NM	Increased yields and farmer income, novel product development, unique product label promoting environmental benefits, sold with a premium offsetting additional cost.
	Risks	Double labor requirement, problematic storage capacity, need for separate storage of allergen products, increased processing time, management of impurities, lack of quality standards.	NM	Restructuring of the storage facility, equipment updating, additional labor costs, allergen issues in final products, retailer misbeliefs, difficult to commercially benefit from.
Miller (5)	Benefits	A little improvement of flour quality, higher protein content, less inputs required than for monocultures, better overall quality profile of the flour.	Better nutritional profile, "greener" product (notably pesticide free), positive for the climate.	Reaching specific markets (production under specifications), more stable quality of mixtures, benefit from storytelling (agroecology principles)
	Risks	New techniques required, optimum fertilization is not possible, pesticide spraying challenging, processing can be more complex, technological risks including additional processing steps.	Allergy risks due to mixtures, demand for consistent taste of products harder to fulfill, mindset lock-ins in key value chain actors according to mixture potentials (taste and ecosystem).	Proportional uncertainty in harvested mixture, quality differences against standardized customer demand, limited market space, consumer reaction risks.
Ingredients (6)	Benefits	Less pesticide use, improved seed quality (protein content), ensure local feedstock production (enhance organic farming development).	Use for corporate social responsibility of companies – marketing, promotion of local produce, local feedstock of high quality, fulfill consumers expectations (low input).	High-end value chain possibilities, promising niche markets, attract consumers interested in paying extra.

(Continued)

Actor	Actor	Biological/technical	Social	Economic
	Risks	Increased impurities, problems with seed size homogeneity, mixtures and lack of gluten-free requirements.	Risk for farmers if consumers are not ready to pay (outside organic markets), mistrust of consumers with regards to environmental impacts, speculative health/quality benefits.	Cost of raw material with adequate purity (but ready to pay if it comes clean).
Machinery advisor (7)	Benefits	Balance with nature, improved self-regulation, reduced inputs.	Form farmer groups and cooperation to share few machines.	Lower inputs but higher productivity.
	Risks	No existing machines for optimum management, different regulations of pesticides in EU influence competition, safety and legislation reduce machine prototyping.	Consumers want cheap food products.	High investment cost in new machinery, mechanical solutions is more expensive than other inputs, no market drivers, demand side needs stimulation.
Director (8)	Benefits	Reduced pests due to intra species interactions, weed suppression, yield advantages with two components, earlier grain legume maturity, easier harvest.	New supply chain for mixed products opens the field for motivated and innovative farmers to try things out, network of forward-looking farmers.	Simultaneous sowing, no additional sowing necessary, no additional costs, only benefits.
	Risks	Difficult to separate grains, companion cropping not enough to suppress weeds, regrowth of companion crops, double costs: herbicides and new undersowing.	Slow adoption rates for companion cropping, intensity of change influence farmers interests and ability, simple species mixtures to start followed by more advanced systems.	Separating costs from 10 to 20 $EUR \cdot t^{-1}$, lupin is allergenic, so strict separation needed for human consumption, mixed products very specific and small markets.

Note: NM, not measured. The social part of benefits and risks was not included in the interview guide used for the logistics actor. For further information on the actors, see Fig. 1.

management of gluten content and allergens) or the development of appropriate machinery required for crop-production and in postharvest processes was highlighted as important for facilitating the use of species mixtures in Europe (Table 2). Lack of communication between different actors in the supply chain as well as between research and practice was highlighted pointing toward improved agricultural extension services including exchange of experiences and joint learning between producers, processors/retailers and consumers. Creation of economic incentives for farmers to switch to species mixture practices, or of attracting investments into the development of new storage and processing facilities was underlined. Involvement of downstream value chain actors buying grains at a competitive price but not currently willing to pay the farmers to produce the crops in the form of mixtures was seen as a critical issue to overcome.

3.2 Policy suggestions

Policy suggestions could be organized into five categories: regulation, subsidies, funding, information (promotion) and strategies (Table 3). The workshop participants agreed that several general regulatory measures would give mixed species cropping practices a relative advantage over monocropping practices like restriction, taxation or ban of the use of pesticides and fertilizers. The workshop participants also saw regulatory measures aiming at the internalization of external costs of agriculture (soil and environmental degradation, public health issues) would benefit mixed cropping practices. Loosening the current very stringent purity standards required of the crops throughout the processing chain was also mentioned.

Revised EU subsidy schemes, for example, rediversification using the already established eco-schemes are suggested. Such ecological intensification could also be supported by subsidies rooted in species mixture practices and agroecosystem functions and services delivered like increased resilient to climatic risks as another public good worthy of support. On a local scale, contributing to the establishment of public procurement of food originating from species mixtures was suggested highlighting, for example, impact for pollinators (biodiversity), nutrient use efficiency (environment) and plant protein substitution of animal protein (health).

Under the headline of “information/promotion”, the participants discussed specific actions needed to solve immediate technical and market related challenges. Specific actions involve initiatives to make products more easily recognizable for the consumers specific labels (e.g., La Nouvelle Agriculture®) for sustainable production making consumers aware of this aspect of the product, for example, reduced use of pesticides. Despite not being mentioned in Table 1 the plenum discussion on the final day of the workshop revealed the

Table 2 Categorized actions needed at each actor level to increase the use of species mixtures in Europe

Category/ Actor	Farmers (1, 2)	Crop advisor (3)	Logistics/ Ingredients (4, 6)	Miller/Machinery advisor (5, 7)	Director (8)
Technical and agronomy	Low input crops and suitable cultivars New machines Precision farming Separation equipment Innovative field technology Experiments/documentation	Design and advice Long-term effects Local assessments	Reward for low pesticide use	Develop new machines and technology for separation and drying	Harvesting technology Processing facilities Experimentation
Knowledge and competencies	Training Education Decision support	Training support Bottom-up and more facilitative advising Dissemination	Coordinated communication planning along the value chain	Educational paradigm shift Inform consumers on environmental benefits	Value chain engagement
Economy and finance	Insurance system Share machines Short value chain		Investments in new equipment Benefits shown in business planning		On-farm investment Premiums Long-term strategies
Policy	Organic farming Branding Influence collectors		Flexible farmer contracts Incentive creations	Change consumption patterns	Supportive policies Incentive creations Risk reductions Avoid internal company conflicts

Note: For further information on the actors, see Fig. 1.

possibility to develop and improve contracts with farmers even further by acknowledging the production of mixtures possibly including terms on sustainability indicators like soil conservation and soil fertility, stable yields, less need for pest and disease control allowing better pricing of products and thereby profits for the farmers.

Possible action strategies to get support from and influence the agroindustrial, sociotechnical landscape toward species mixtures highlighted the role of the European Union Common Agricultural Policy (CAP). A stronger second pillar (EU rural development policy) of the revised CAP (expected to be initiated January 1, 2023) was suggested, possibly supported by the EU wide plant protein plan. More direct funding was also suggested ranging from undertaking feasibility studies for adopting new practices or investing in new technology and equipment facilities for processing or running new marketing campaigns. The participants also mentioned the need for funding the appropriate training of agricultural advisory services, and of covering some of the subsequent advisory costs in this domain.

3.3 Workshop evaluation

A simple evaluation questionnaire was sent to all participants after the workshop, with a satisfactory response rate of 78% (Fig. 3). Reasons for not responding to the questionnaire are not available. The more open Mode 2 science questions in the evaluation revealed opportunities for improvement in this active participatory learning process strategy with both external (interview) and internal (group discussions and plenary) interactions primarily focused on discussion required to fulfill daily deliverables for the group. The evaluation showed that the participants found the workshop format suitable and the materials provided useful (Fig. 3) appreciating the explorative nature of the workshop discovering new aspects, as well as highlighting older ones. Nevertheless, participants suggested that the purpose of the workshop should have been more clearly explained and supported by more precise instructions. Also, it should be appreciated that research participants usually develop their careers within disciplinary setting and interdisciplinary involvements are often not formally recognized by their respective institutions.

4 DISCUSSION

In the present study, Terrena emphasized the context within which species mixtures are embedded and not necessarily representative of the wider production chain in the agricultural industry. In 2008, Terrena decided to put agroecology at the heart of its strategy focusing on how to produce more and better with less. In 2015, this strategy was completed with the creation of the trademark, La Nouvelle Agriculture®, to recognize the efforts of farmers who practice agroecology as compared to using established practices and thus allowing a

Table 3 Policy suggestions in subcategories for the promotion of species mixtures in Europe

Subcategories	Policy suggestions
Regulation	Restriction, tax or ban of the use of pesticides Restriction or tax on the use of fertilizers Internalization of external costs of agriculture Less stringent purity standards throughout the processing chain
Subsidies	Revised subsidy rules on: *legumes in rotations and in species mixtures* *ecosystem services* *mixtures as Ecological Focus Areas* New subsidies for: *species mixtures for food production* *species mixtures with legumes* *reduced use of pesticides* Support for alternative cropping system transitions
Funding	Feasibility studies (e.g., conversion of storage equipment) Possibilities for advisory cost reductions Advisor training Research in areas that develop the use of species mixtures Processing and marketing
Information (promotion)	Organization of knowledge exchange events New labels and trademarks for species mixture products (Quality Assurance Schemes) Farmer contracts acknowledging the production of mixtures, which includes terms on sustainable growth opportunities for mixtures Ecological intensification of farming based on species mixtures Transfer of scientific knowledge across the whole value chain
Strategies	Agroecology as a pillar of the Common Agricultural Policy (CAP) with species mixtures as an explicit example of an agroecological practice Local implementation of the EU member states protein crop strategies with species mixtures as an explicit component Public procurement of food containing legumes Educational programs and continuous training system Network of allies in favor of species mixtures Education of value chain actors (notably farmers, advisors, processors, consumers) Inform policymakers about the benefits and ecosystem services provided by species mixtures

higher price per unit produce to be returned. Species mixtures are included in the portfolio of agroecological solutions that a farmer can use to qualify for this trademark.

4.1 Interdisciplinary working relations

Increased emphasis on the need for science to address socially relevant problems focuses the perspectives of social and natural scientists, initially in defining these problems, but also in determining the appropriate approach to understanding them with a growing appreciation of the inherent complexity of nature and society[31]. The multiactor approach and participatory research imply the joint identification of challenging issues and agreement on what is already known about their nature and importance, causes, consequences and possible solutions. From there, participants decide what additional knowledge or knowhow needs to be produced and developed to determine relevant solutions and actions. Only then, it is possible to construct and agree on an appropriate analytical framework for the data and knowledge produced. The issue, however, is that such an approach is difficult to practice and manage. Individual researchers should be willing and able to translate their disciplinary perspective and methods into simpler concepts and be open to learning from others[32,33].

The challenge of establishing fruitful working relations among all the parties involved is significant. In some instances, this was evidence by a degree of professional frustration expressed by some of the participants exemplified by comments like, “Were these narratives of any scientific validity at all?” Some questionnaire responses suggested remedies for overcoming this with comments like, “too many participants” or “the interviews were too superficial and did not allow enough time to pursue particular aspects”, expressing the strong desire to collect more quantitative data. Also, some workshop participants felt obliged to refrain from pursuing their own interests because they had to let workshop group members from other disciplines ask the respondent about matters which

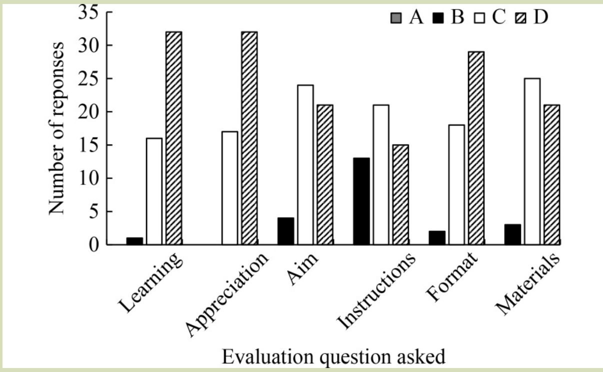


Fig. 3 Responses from 78% of the 63 participants to questions about the ReMIX workshop. LEARNING—You learnt something interesting, relevant and useful for your future work/collaboration. APPRECIATION—You appreciated the workshop format. AIM—The workshop aim was clear. INSTRUCTIONS—The instructions were clear. FORMAT—The format was suitable for this exercise. MATERIALS—The provided materials were useful. Scale: A, strongly disagree; B, disagree; C, agree; D, strongly agree.

were of concern to them.

The expression of concerns inside and outside the specific groups served as a motivation for other group members to become more aware of the scientific frameworks and practices of their frustrated colleagues. Positions of social and natural scientists on key issues may be so fundamentally different that they go unacknowledged until conflicts arise[21]. Experiencing this opened the minds of the workshop organizers to think about how to assure that such research elements are included when using similar approaches in other projects without excluding disciplines. Having said this, most participants acknowledged the value of knowledge sharing between specialists representing different scientific disciplines.

4.2 Joint situational analysis

Existing literature evokes challenging perceptions, routines, rules and regulations at the cropping system level[34,35], which together with the social and economic context in which value chain actors operate contest the system[36]. The interdisciplinary group discussions, actor face-to-face interactions and plenary discussions among the participants allowed the confirmation of an overall joint reading of the present situation. As highlighted in several scientific publications[37–39], workshop participants underlined the increasing awareness of the correlation between agricultural production and, for example, climate change and loss of biodiversity while still being able to produce food for a growing population in the future[40].

The workshop permitted the participants to develop a common understanding of a local agricultural value chain, which helped to realize a needed systemic understanding of the situation. The non-agronomist participants learned that successful production of species mixtures is about crop choices and complementarity, but also that it can be practiced through at least four basic spatial and temporal arrangements[5]. Other participants learned that species mixtures are a potential strategy to increase delivery of several agroecological services[[8,9,41]]. However, participants also realized that, depending on the cropping strategy, species mixtures might be disruptive to the current value chain (Table 2).

Moving from the local (niche) to the dominating regional/national practices, rules and norms (regime), to the European level (landscape)[15,42] the CAP seems, so far, to have been focused on stable food supply coupled with environmental protection. When farmers or other agrifood value chain actors are faced with species mixtures as an alternative, the benefits must overrule the perceived risks and difficulties. Furthermore, local negotiations and adjustments by relevant actors are a prerequisite for developing effective solutions fitted to the social and economic context in which farmers operate. Policy reforms at the CAP level could potentially be promoted by the agroecology paradigm[2,3,43] if opting for regulatory measures start to cover additional external benefits from agroecological practices like diversification[2,4,43]. The workshop suggested that enforcing restrictions on the use of pesticides[44–46] and fertilizers[47–49] will promote the adoption of species mixtures as they are less reliant on external inputs (than monocultures)[7,10]. Thus, constituting a conversion toward more environmentally friendly agricultural practices[9,48,50].

4.3 Sociotechnical innovation of the agricultural systems

Production of species mixtures entail a set of interconnected changes that reinforce each other; changes in technologies, processes, management, but also in institutions, routines, perceptions and attitudes. Difficulties (lock-ins) are to be expected. Agroecology has become a powerful tool for food system change when coupled with an understanding of how change occurs in society[3,51,52]. Several workshop groups underlined current consumer behavior toward more local and transparent value chains that might win back consumer trust that has been reduced in recent years by the general expansion of global value chains and large scale export oriented farms in Europe. In addition, during the plenum discussion on the final day issues of equity became apparent, as perceived benefits primarily are of relevance to farmers or, adversely, that farmers could be left alone with risks of failure unless contractual arrangements with cooperatives, subsidy schemes, or the market are changed.

The present dominant sociotechnical system with its shared routines, rules and norms, provides orientation and direction to the activities of the social groups operating within the dominant system. It takes time to change, for such disruptive cropping practices as species mixtures. Lack of exposure to diverse epistemological frameworks and team science skills, barriers to including actor perspectives, and variable levels of collegiate or management support to conduct integrative research limit such transitions[53]. The dominating one-way flow of information i.e. from research/advisory/industry to farmers telling them what to do rather than listening to problems or possibilities needs restructuring. This includes making use of local agricultural societies and democratic traditions of negotiating conflicting actor perspectives during research and innovation processes[4]. However, advice on novel practices also requires knowledge acquisition because the complexity of species mixtures functions and services, including required value chain actor transitions, may induce risk and uncertainty when developing new advisory practices[15]. There is a need to fund more participatory research in areas that develop the use of species mixtures with knowledge codesign and mutual learning in focus in order to overcome the implementation gap between research and practice (Table 3).

At Terrena, a normal procedure is to ask members to test potential solutions on their own farms, particularly the so-called “forward looking farmers”, with a prerequisite that they present their findings and experiences to other farmers. According to farmers interviewed they prefer to listen to other farmers than to advisors or researchers. One suggestion was the establishment of local farmer groups to share knowledge on how to evaluate species mixtures rather than as single products regarding agronomic, as well as social, economic and environmental performances. Another suggestion was to use social media (1) to increase peer-to-peer knowledge exchange to overcome potential geographical distances, as well as securing time efficient collaborations and (2) as a forum for acute daily problem solving among trusted colleagues using video and other real-time documentation.

The ability to create proactive engagement was identified as a key factor for successful transitions including the need for consumers-producers-policymakers collaboration. Terrena is closely connected with the demands of consumers through its food-industry subsidiaries. However, organization of dedicated value chains was highlighted as particularly challenging. Agricultural advisors and supplementary innovation brokers were recognized as important actors bridging science and practice, with the ability to support more local entrepreneurial initiatives. Nevertheless, agricultural advisors are often not sufficiently familiar with current knowledge about species mixture strategies and the brokers are locked in existing agriculture logistics and practices.

4.4 Recommendations to apply similar approaches in other projects

When participating in a workshop like this, all contributors get involved in the production of knowledge (science), the application of knowledge (technology) and the successful exploitation of knowledge (innovation)[19] challenging existing distinctions between basic and applied research[17,19]. Including the use situations[54] helps to bridge the gap between scientific concepts and the ways value chain actors operate. At the same time, this study exemplifies the need to provide more opportunity for scientific discussions on participatory approaches more broadly within researcher communities[55].

Increased awareness of the importance of integrating different perspectives to overcome the barriers for transition was echoed during the final plenum opening the way for actions for increased integration between partner competences to strengthen the collaborative environment in a project. Communication to the participants of the purpose and value of this kind of short, intensive interactive learning by doing exercise and adjusting facilitation tasks and practicalities could probably enhance positive interdisciplinary impacts. However, the authors are aware of the everyday life back at the home universities and other institutions, where rules for accrediting research, procedures for promotions and other criteria for academic life advancement possibly threaten to undermine any attempt to rethink research and practices, even when, according to major funding bodies, interdisciplinary approaches are a prerequisite for success. For that reason, it is a true challenge to engage university project partners, as universities continue to emphasize the ideals of the individual high-performing academic who publish in disciplinary journals.

A classical dilemma of project management when engaging in Mode 2 science approaches[17] is when active involvement of internal and external actors might lead to the emergence of additional research issues not necessarily foreseen in the approved research project proposal. Changing priorities may also require additional skills which are outside the current consortium. There is a need to consider how to make such management procedures more flexible to support the multiactor approach in future projects.

5 CONCLUSIONS

It is concluded that increasing the use of species mixtures requires a process where the purpose agreed, decisions made and activities planned become more concrete and, importantly, based on the understanding and reflections of those involved. However, using written narratives, and informal face-to-face discussions as facilitating forms of communication was not accepted by some participants as being scientifically valid although it constitutes an inevitable companion of the multiactor approach. Along the same lines it can be challenging to leave the reliance on robust quantitative data deeply embedded in natural science when understanding the agricultural field using a more interdisciplinary approach. Nevertheless, expressions of frustrations by some participants served as a motivation for group members to become more aware of the scientific concerns and practices of their colleagues creating an effective space to identify most pertinent issues to address. In saying this, evidence from the workshop highlight interest and willingness to work with the actor networks to overcome existing barriers between academia and applied practice in order to produce shared visions of species mixture benefits in European food systems using agroecology principles.

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Compliance with ethics guidelines

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