Article

JIM
ISSN: 2183-0606
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Vol. 12, 3 (2024)
p. 276-319
AM: Jun/2024
SM: Oct/2023

Conceptualizing and Reflecting Co-design Processes for the Transformation Towards Insect-friendly Agricultural Landscapes - Experiences from Transdisciplinary Processes in three German Landscape Labs

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Abstract

Promoting insects in agricultural landscapes is a key challenge, due to their crucial role in food webs, ecosystem functioning and the provision of ecosystem services. To balance between ecological needs for action in order to stop biodiversity loss and practitioner needs, we combine a landscape lab approach with co-design processes in three different agricultural landscapes across Germany. The FInAL project aims at a long-term agroecological transformation of agricultural landscapes under real-world settings. Because the conceptual-methodological bases of co-design processes and the reflection of their outcomes are often lacking in empirical publications, we seek to address this research gap by exploring the following questions: 1) How should co-design processes be conceptualized and conducted to support the agroecological transformation in landscape labs? 2) What are the practical outcomes (tools, artefacts, measures, etc.) and the social outcomes as result of the individual and participatory reflection of the co-design processes and the cooperation within the project? Our framework for co-design processes combines and extends key elements from the theoretical and conceptual literature in this field. The empirical data for the process reflection consists of survey data, workshop minutes, field notes, and interpretations of results by the co-design core team. The innovative concept for the co-design processes applies the following key characteristics: process orientation, practitioners as co-designer, joint problem-framing and solution-orientation, design-orientation, and contribution to social empowerment. Furthermore, we developed integrative and transdisciplinary co-design processes with iterative feedback-loops, which encompass an analysis of actors' perceptions of biodiversity issues as well as a sequence of co-design workshops, field trips, and planning dialogues. The sequence of the participatory formats consisted of different elements: 1) jointly discussing goals and transformation pathways, the suitability and practicability of common insect-friendly measures; 2) promoting

DOI: https://doi.org/10.24840/2183-0606_012.003_00012

farmers' ideas and co-designing measures; 3) participatory mapping of planned measures at the landscape scale; and 4) reflecting the implemented measures and the transdisciplinary process itself. The first results of the participatory reflection include: participating farmers state that they are generally satisfied with the adaptable co-design process but they perceive that collaboration at landscape level has barely increased. For strengthening collaboration and empowering actors it is crucial to 1) build upon established science-practice networks; 2) involve landscape coordinators as regional intermediaries and permanent contact persons for all activities in the landscapes; 3) promote active and continuous involvement and co-experimentation at the landscape level that leads to mutual trust and co-learning; and 4) provide financial compensation as an incentive.

Keywords: living labs, agriculture, biodiversity, collaborative design reflexivity, social learning, empowerment.

Cite paper as: Busse, M. , Bartels, A., Beutnagel, M., Fick-Haas, V., Glemnitz, M., Holzhauer, S.I.J., Plaas, E., Scharschmidt, P., Dauber, J., (2024). Conceptualizing and Reflecting Co-design Processes for the Transformation Towards Insect-friendly Agricultural Landscapes - Experiences from Transdisciplinary Processes in three German Landscape Labs , *Journal of Innovation Management*, 12(3), 276-319.; DOI: https://doi.org/10.24840/2183-0606_012.003_00012

1 Introduction

Agricultural landscapes are diverse and characterized by dynamic patterns of ecosystems, land-use types and agricultural production and social systems. The climatic, geophysical, biogeochemical, economic, and socio-cultural conditions differ between agricultural landscapes. Agricultural landscapes face manifold and complex sustainability challenges, such as climate and land-use change (land-use intensification or abandonment) that may lead to loss of habitats, resulting in biodiversity decline, which have to be reconciled with food and feed production. To cope with these challenges, there is a need for profound transformational change in agricultural landscapes to encounter these complex sustainability problems (Vermeulen et al. 2018; Mupepele et al. 2019; Chaplin-Kramer et al. 2023). Regarding the biodiversity loss, it is essential to promote insects and other invertebrates because those are in particular affected by modern agricultural land use, resulting in a decline of species richness, biomass, and the ecosystem services performed by insects such as pollination or natural biocontrol (Cardoso et al. 2020; Mancini et al. 2023). Thus, urgent action is needed to maintain or promote the diversity and numbers of insects in agricultural landscapes (Cardoso et al. 2020; Samways et al. 2020). Habitat quality, especially structural diversity and resource availability for beneficial insects and other insects, must be improved through feasible and effective measures (Samways et al. 2020). One of the unsolved problems of current support programs is the contradiction between a low ecological efficiency but high acceptance by farmers of many annual biodiversity enhancing measures and the low acceptance but high efficiency of so-called "dark green" often permanent or multi-year measures (Tarjuelo et al. 2020; Pe'er et al. 2022). According to an international expert panel higher efficiency to stop the loss of farmland biodiversity needs a better design, closer monitoring, greater transparency, and closer engagement with farmers (Pe'er et al. 2022). The complexity of these problems is also characterized by the fact that counteractions will be only successful if addressing larger temporal and spatial scales because natural processes primarily run and manifest in landscapes, and could reinforce or compensate for local impacts (Landis 2017; Kremen and Merenlender 2018; Mupepele et al. 2019). Such landscape-wide approaches affect also many different local and regional actors (e.g. authorities, farmers, local residents, entrepreneurs), who additionally have evolved their own perspectives on these sustainability problems and visions about suitable landscape developments and transformation processes (Nassauer and Opdam 2008; Mupepele et al. 2019). Due to the multitude of sometimes diverging interests, sustainability problems cannot be solved by individual actors or on the basis of a single perspective (Lang et al. 2012; Zscheischler et al. 2017). Therefore, transdisciplinary knowledge integration and active collaboration between academics from different disciplines and non-academics is necessary for initiating a transformation process that is linked to ecological, economic, and socio-cultural sustainability of these landscapes and the whole agri-food system. Bringing different perspectives together, balancing diverging demands, jointly developing the problem framing, future visions, and social robust transformative orientations are seen as promising for the promotion of transformational processes (Mauser et al. 2013; GLP 2016; Moser 2016; Zscheischler et al. 2017). Transformational processes include fundamental changes in norms and values as well as technological, social and process-oriented or organisational innovations (Scoones et al. 2020). They require experimentation in initially small spaces and niches, but preferably under real-world conditions (Martin et al. 2018; Rogga et al. 2018). The living lab (or also called real-world lab) approach offers precisely such conditions (Schäpke et al. 2018; Hossain et al. 2019; McPhee et al. 2021) by contributing to transformation through 1) transdisciplinary research (TDR) and 2) long-term orientation as well as 3) creating experimental spaces for networking and 4) mutual learning and reflexivity. The importance of living lab approaches has increased significantly in recent years, and various context-dependent living lab types have developed over time from the initially technology-orientated MIT labs (Schäpke et al. 2018; McPhee et al. 2021). Often, they are differentiated according to their objectives and / or spatial reference. Nowadays, we can find among others (energy) transition labs, innovation labs or action labs (Nevens et al. 2013; Schäpke et al. 2018; Mahmoud and Morello 2021). Regarding their spatial orientation, most common and with the longest history are urban living labs or urban transition labs (Nevens et al. 2013; Steen and Bueren 2017; Frantzeskaki et al. 2018). Recently also rural labs (Schaffers et al. 2007; Zavratnik et al. 2019; Soini et al. 2023; Cascone et al. 2024) agricultural living labs (Toffolini et al. 2023; Lévesque et al. 2024), and landscape (living) labs (Gomez and Derr 2021; Busse et al. 2022) have emerged to address particular social-ecological problems in rural spaces or landscapes and encourage the call for collaborative actions (Lacombe et al. 2018; Haan et al. 2021; Hölting et al. 2022). Generally, living labs in rural spaces and agricultural landscapes share some common principles with urban labs, namely the sustainability focus, the complexity of problems which calls for active involvement, co-decision-making, multi-actor-approach, and context-based locality (McPhee et al. 2021; Toffolini et al. 2023; Cascone et al. 2024).

However, for promoting biodiversity in agricultural landscapes the choice of a spatially explicit approach at landscape level is necessary to tackle adequately the above-described sustainability problem and required conditions (see also chapter 2.1). However, to our knowledge, until so far there is hardly any scientific literature available that explicitly deals with the conceptualisation of living labs at landscape level and addresses the needs from a landscape ecology perspective. Reviewing existing living labs in agricultural contexts, Toffolini et al. (2023) identified three types: experimentation as a 1) game of creativity in a predefined space, 2) progressive contextual adaptation of innovations adoption, and 3) catalyst for long-term collaborative action. The third type is the one which most closely corresponds with the above mentioned key characteristics of real-world labs (Schäpke et al. 2018). The "Agroecosystem Living Labs" (MACS G20 2019; McPhee et al. 2021; Lévesque et al. 2024) also incorporate similar key elements that additionally make reference to the agricultural context: 1) TDR in real contexts, 2) co-design and co-development with the participants and 3) research that includes monitoring and evaluation 4) in working landscapes. This type of living labs requires not only accelerating the adoption of broadly accepted measures or asking for local needs by consultation. Moreover, it requires also a change in the way problems can be captured and solved, which can only be achieved through pro-active participation in decision making, increasing ownership, and empowerment (Manzini and Rizzo 2011; Glucker et al. 2013; Hölting et al. 2022). TDR, which is a key feature of these living labs, is generally based on a process of co-production of knowledge, whereby in TDR co-design is usually described as the first phase in order to jointly formulate research agendas and questions (Lang et al. 2012; Zscheischler et al. 2017; Hakkarainen et al. 2022; Fleming et al. 2024). Nonetheless, the vast majority of studies from applied research fields like agronomy (Martin et al. 2018), design studies (Sanders and Stappers 2008; Zamenopoulos et al. 2021), policy studies (Blomkamp 2018) or nature-based solutions (NBS) for green and blue infrastructures (Karrasch et al. 2017; Pérez Rubi and Hack 2021; Chapa et al. 2023) mean by co-design the joint development of strategies or solutions such as decision support tools (incl. scenarios), biodiversity-friendly farming measures, and new governance or business models (cf. Busse et al. 2023). Some authors use co-design in a similar way to co-creation (Sanders and Stappers 2008; Nevens et al. 2013; Steen and Bueren 2017; Sendra 2023), whereas others prefer the term co-creation as broader umbrella term (Steen and Bueren 2017; Zavratnik et al. 2019; Mahmoud and Morello 2021). However, the debate about the adequate choice of "co" terms and their definitions and distinctions, and the "right way" to apply these processes, is still continuing (Pérez Rubi and Hack 2021; Hakkarainen et al. 2022; Fleming et al. 2024). We use the term co-design in this publication. Although co-design is a very popular approach, only a few empirical studies explicitly define the term or provide a theoretical-methodological foundation of it (Busse et al. 2023). There are also only very few concepts and process models available on how co-design can be operationalised and their process outcomes assessed or reflected in a comprehensive manner. Busse et al. (2023) provide key elements of how to conduct co-design processes in land-use contexts (based on basic conception mainly from design studies, e.g. Sanders and Stappers 2008). A second useful concept is the one by Hölting et al. (2022) who define main process stages for the co-design with farmers to halt biodiversity loss. Both conceptions could serve as orientation for setting up co-design processes with similar purposes (see section 2.1). Regarding the reflection of the process quality and outcomes, Sendra (2023) provides a comprehensive list of ethical principles of co-design, and Fleming et al. (2024) describe principles for assessing co-design in Climate Smart Agriculture. We see both elaborations as partly helpful for conceptualizing reflection tasks. Beyond this, frameworks from TDR mainly provide orientation on social outcomes and broader impacts on the long run beyond the project scope (Lux et al. 2019; Guimarães et al. 2024). However, from our point of view, although many publications mention the importance of reflecting the “co“-processes, none of these frameworks provides a comprehensive guideline for it.

In parallel to a scarcity of conceptions for reflection, in empirical studies in land-use contexts, co-design processes are also rarely analysed nor report on how the process was conducted, whether set objectives were achieved or whether participants perceived it as beneficial (Busse et al. 2023). However, a continuous reflection of a co-design process is important because it supports the identification of strengths, opportunities, and limitations of the researcher-actors interaction (Neef and Neubert 2011; Lux et al. 2019; Pienkowski et al. 2023; Guimarães et al. 2024). Such reflection activities enable to adapt the transdisciplinary processes to participants' needs and to address uncertainties (adaptive reflexivity) (Schäpke et al. 2018; Lux et al. 2019). Additionally to these instrumental objectives, reflection also may serve to examine normative objectives, especially whether the co-design process promotes social learning (Glucker et al. 2013; Pienkowski et al. 2023) and building up social capital (Neef and Neubert 2011). Reed et al. (2010) understand social learning as a process that produces changes in the comprehension among participants through social interactions that impacts individuals and the wider group or community of practice. In the context of sustainability transformations, transformative learning is a type of social learning that leads to revising established thinking and acting (Rossi 2020). Joint experimentation (additional to co-design) as well as social and transformative learning through transdisciplinary processes are seen as important precondition for a wider adoption of sustainability innovations or biodiversity-friendly measures (Landis 2017; Toffolini et al. 2023).

Using the FInAL project (Facilitating Insects in Agricultural Landscapes in three landscape labs) with their embedded and structured co-design processes as case studies (Yin 2019), we address the above-mentioned shortcomings by exploring the following research questions:

1) How should co-design processes be conceptualized and conducted to support the agroecological transformation in landscape labs?
2) What are the practical outcomes (tools, artefacts, measures, etc.) and the social outcomes as result of the individual and participatory reflection of the co-design processes and the cooperation within the project?

2 Material and Methods

2.1 Case study description – the landscape labs in the FInAL project

The aim of the FInAL project is to promote a long-term agroecological transformation of agricultural landscapes. The focus is on creating more insect-friendly landscapes by implementing measures both inside and outside the productive sites (arable fields and grassland). Hence, we explore a holistic change at landscape level, 1) in-field through measures such as crop diversification, substituting annual through perennial crops and reduced chemical plant protection measures through integrated pest management, and 2) off-field through increasing landscape structural heterogeneity, the amount of semi-natural habitat, and the habitat connectivity. To do so, three landscape labs have been established in three German regions (figure 1). In line with the conception of living labs with a reference to the landscape level and Agroecosystem Living Labs, we define landscape labs as spatially-explicit and social spaces for experimenting agroecological transformation by conducting transdisciplinary research with a co-design of biodiversity-promoting measures, joint experimentation in real-world settings (integrating spatial choice and compensation), participatory reflection of the measures, monitoring at landscape level, and the process that leads to transformational co-learning (Schäpke et al. 2018; MACS G20 2019; Rossi 2020; Toffolini et al. 2023). The therefore needed transdisciplinary approach relies in the FInAL project on an active collaboration between different practitioners (people who operate in the landscape labs, see also description of the three landscape labs), researchers of scientific disciplines, and different coordinators in the co-design processes. Among the scientists are entomologist for specific insect groups, agro- and landscape ecologists, agronomists, economists, and researchers with expertise in transdisciplinary research, landscape sociology and ethnography. Coordinating project members are the three landscape coordinators of the labs as well as the scientific project leader, and the project coordinator. Since the co-design processes are a crucial component of the FInAL project it has strong links to other project components such as 1) the coordination of the three landscape labs, 2) the biodiversity monitoring, 3) and the development of land-use information via geographical information systems (GIS), economic, and evaluation tools as well as the acceptability studies.

The three landscape labs reflect typical agricultural landscapes in Germany where mainly conventional agriculture is practiced. Each landscape lab covers a landscape section of 3 by 3 km (900 ha). The Havelländisches Luch is located in the Federal State of Brandenburg and

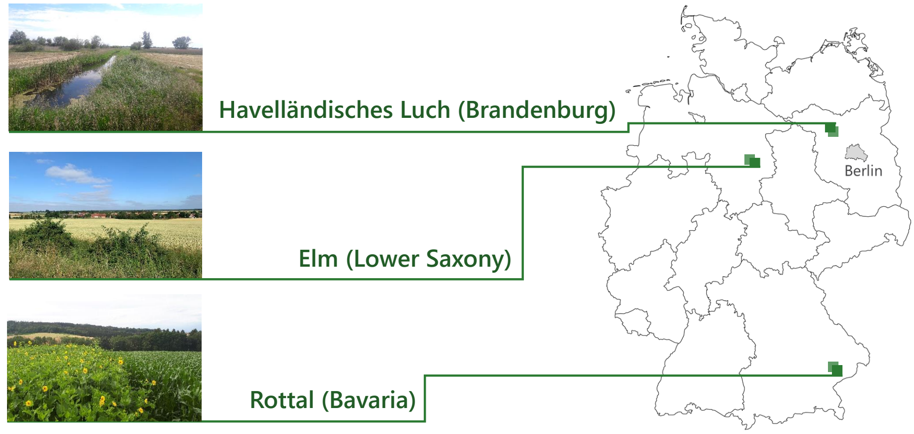

Figure 1. The three German landscape labs of the FInAL project

characterized by a slightly marshy land close to groundwater with a larger proportion of grassland (445 ha of 778 ha cultivated land). The grassland is used by farmers for livestock farming and for biogas production. However, crops are also produced on 333 ha, mainly maize, wheat, barley, and rapeseed. The farms vary in size between 31 and 1460 ha. The farm plots comprise about 15–20 ha. In the Havelländisches Luch, eight farmers, the local authority office and the water and soil association are actively involved in the FInAL project. The Elm region in Lower Saxony has a hilly relief and heterogeneous soil conditions. It is a typical arable farming location with predominant cultivation of cash crops (winter cereals and rapeseed). 488 ha of the 613 ha cultivated land are used as arable farmland and 122 ha as grasslands. In the Elm, the average farm size is 180 ha, whereas the single plots are between one and 10 ha. In the context of the German farm structure, these farms and plots can be considered as medium-sized. Among the practitioners who agreed to participate in the project are19 farmers and two local associations (an association of managing waysides and a nature conservation organization). Twelve farmers are already implementing insect-friendly FInAL measures. Ten participate actively in the regional co-design process. The Bavarian Rottal is a favourable location for agriculture due to fertile soils and sufficient precipitation (ca. 800 mm annually). Pig fattening is pursued in addition to arable farming, where mainly corn and wheat are grown. Due to the hilly conditions and extreme weather events in the last years, water erosion is a serious issue. The Rottal has a small structured landscape and the farm size is quite smaller than in the other landscape labs. Thirty farmers, four local authority departments and the local Landscape Conservation Association participate in the FInAL project. About 20 farmers are regularly active in the Bavarian co-design process.

In a nutshell, we used the co-design processes in the FInAL project to set up our multiple and embedded case study design (Yin 2019). “Multiple case study design” means that we include various case studies, namely the three co-design processes in the landscape labs. Additionally, we apply an “embedded case study design” by integrating more the one sub-unit per case study. In our cased, we included researchers and practitioners as analytical units to respond our research questions (see also 2.4). Generally, case studies are seen as adequate for in-depth investigations of current phenomena or problems within a real-word context (Yin 2019).

2.2 Design principles for setting-up the co-design processes (RQ1)

The collaborative approach in the FInAL project was designed according to the recommendations of Nassauer and Opdam (2008) who point out that sustainable landscape development requires scientific knowledge on landscape ecology and practical knowledge by integrating local people into a transdisciplinary research process. Nassauer and Opdam (2008) define design "as any intentional change of landscape pattern for the purpose of sustainably providing ecosystem services while recognizably meeting societal needs and respecting societal values." Additionally, we followed further recommendations by Nassauer and Opdam (2008) to develop placed-based, iterative, and flexible processes for landscape co-design to ensure continuous evaluation and reflection.

As described in the introduction, we use the term co-design for the process to jointly develop tangible outcomes and biodiversity-friendly measures. As co-design is differently defined in publication and there is no "one right" definition, we use as proxy the six key components of a co-design provided by Busse et al. (2023) for setting up our co-design processes in FInAL: 1) process orientation, 2) practitioners as co-designers, 3) design-orientation, 4) joint problem-framing and solution orientation, and 5) contribution to empowerment or deliberative democracy. For the key component "process orientation" the process model by Hölting et al. (2022) provides guidance for important stages and their main tasks. Figure 2 shows how the co-design key components by Busse et al. (2023) can be conceptually integrated into the process phases by Hölting et al. (2022).

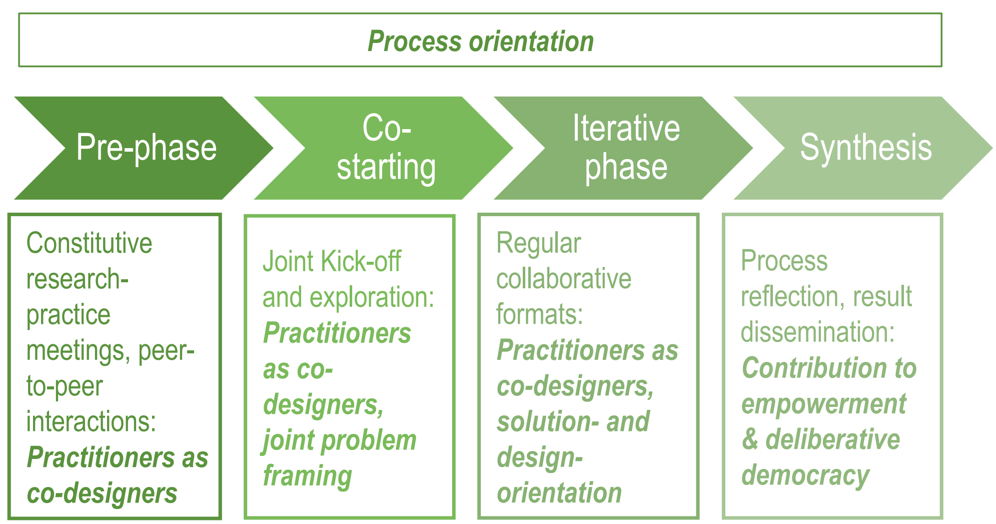

Figure 2. Central phases in a co-design process according to Hölting et al. (2022) and the integrated co-design key components by Busse et al. (2023) displayed in bold-italic, own compilation

2.3 Framework for reflecting the co-design processes and the project cooperation (RQ2)

Reflection of co-design is important to make the process adaptable to current needs of participants, unexpected conditions or unforeseen outcomes. We use a wide definition of the term reflexivity that stands for the individual or group's ability to examine their feelings, identities, reactions, behaviours, motives, and other attributes and how these influence what they do or think in a situation (Cambridge University Press, 2021). In the case of (ethnographic) research, reflexivity also serves to explore how human relations in field work and data interpretation are shaped by pre-existing knowledge and assumptions, identity and research designs and processes (Pienkowski et al., 2023). Thus, reflexivity is not only a common practice in every-day life but also in research settings. It can also be an object of research, when it is conceptually and methodologically embedded into research processes (Lux et al. 2019; Patton 2019; Fleming et al. 2024). Pienkowski et al. (2023) recommend consciously integrating reflective activities into research processes so that they can lead to concrete and purposeful actions. In our case, such actions are the adaptation of the co-design process to participants' needs and interests to ensure a process that is perceived as satisfactory by all. Reflexivity can also be transformative when not only adjustments are made in process design, but when goals are rethought, one's own thinking and actions are fundamentally questioned, and thus, a transformative learning takes place (ibid). Thus, studying reflexivity is rooted in a constructivist perspective, which assumes that people build their own reality based on individual value-based perceptions and social interactions with others (cf. Moon and Blackman, 2014)

To pursue such an adaptive (and transformative) reflexivity, our participants of the co-design processes (practitioners and researcher) reflect continuously on their experiences. The co-design core team, which is composed of experts from different disciplines (and are the authors of this paper), facilitates all reflective activities by providing a concept for reflection that includes diverse techniques and creates a save space for open discussions. The results of this reflective activities were then analysed and interpreted by the co-design core team. It is important to mention that the co-design core team is also part of the reflection. Therefore, a critical self-reflection of own expectations, goals, and positions is crucial (Neef and Neubert 2011; Lux et al. 2019; Moon et al. 2019; Patton 2019; Pienkowski et al. 2023).

As displayed in table 1, we base our framework for reflecting the co-design processes on the ten ethical principles of co-design by Sendra (2023) and align these principles to the above mentioned rationales of participation (Glucker et al., 2013). Both approaches are useful not only for conceptualizing the co-design processes, but also for reflecting on whether the goals and ethical principles have been achieved. The principles by Fleming et al. (2024) of early reflection, considering social structures and benefits (beyond individual shifts in mind sets), and evaluating co-learning effects can be also found in our framework.

2.4 Methods for collecting and analysing data to reflect the co-design processes (RQ2)

To capture and analyse the complex dynamics of transdisciplinary research processes from different perspectives, it is favourable to integrate different methods for an in-depth reflection (Burzan, 2016; Neef & Neubert, 2011; Patton, 2019). Thus, we applied a methodological plural approach by combining several methods from social ethnographical-social science in an explanatory subsequent design (Burzan, 2016; Creswell & Plano Cark, 2008): a quantitative survey (data collection and descriptive statistics) with a subsequent qualitative in-depth study for relating and interpreting results (Patton 2019). Furthermore, by involving co-design participants from practice and research in the reflection of the co-design processes in the three landscape labs, we apply also an multiple and embedded case study design (Yin 2019) (see also 2.1.).

With the survey, we aimed at an anonymous, individual, and standardized reflection by people who participated at least in one of the co-design workshops. The survey for practitioners was handed out in printed form to all workshop participants from practice directly after the 4th workshop round in spring 2022. Further participants of previous workshops who could not attend

Table 1. Our reflection framework for the co-design processes in the FInAL project: The main categories are based on the ethical principles by Sendra (2023) and aligned to the rationales of participation by Glucker et al. (2013). These categories were operationalized in survey questions (column 3) and thematic analysis categories (column 4 to 6)

Glucker et al. 2013	Sendra (2023)	Methods of data collection and topics			
		Survey	Workshop minutes	Field notes	Reflections on
Normative rationale	Design how partnerships are created from the early beginning	Being co-designer of goals	Feedback on influence on process design	Actively participating in process design & adaptation	Process design (active and early involvement), lessons-learnt
	Address power imbalances (social justice)	Being taken seriously, possibility to bring in own knowledge, satisfaction how decisions are made, wish for more say	Discussions about who should be involved and how	Learning about who should be involved and how	Who should be involved and how should involvement be created, lessons-learnt
	Provide skills to involve communities in decision-making	Understanding of ecological interactions, understanding actors' needs, more importance of ecological needs	Mutual exchange of ecological and practical knowledge	Notes on needed skills & knowledge	Needed skills of practitioners & researchers (experiences, attitudes, perceptions)
	Inclusive events and language	Having constructive discussions, satisfaction with workshops (facilitation, methods, topics)	Notes insofar methods and language are inclusive	Notes insofar methods and language are inclusive	Process design (facilitation and methods)
	Collective benefits	Better cooperation, higher awareness of insect biodiversity and suitable measures	Feedback on different types of benefits	Notes on perceived benefits	Cooperation at landscape scale, image improvement, payments
Substantive rationale	Co-design needs to involve collective thinking	Collaboration between practice and research team, possibility to bring in own knowledge, being co-designer of innovation	Joint design of innovations, feedback to developed results	Joint experimen-tation, feedback to developed results	How to methodologically promote collective thinking and choice of methods; interpretation of survey results
	Investigate and learn from existing social infrastructures	Better cooperation	Including and learning from farmers initiatives and other associations	Including and learning from farmers initiatives and other associations	Process design and the influence of existing networks

Table 1. Our reflection framework for the co-design processes in the FInAL project: The main categories are based on the ethical principles by Sendra (2023) and aligned to the rationales of participation by Glucker et al. (2013). These categories were operationalized in survey questions (column 3) and thematic analysis categories (column 4 to 6) (continued)

Glucker et al. 2013	Sendra (2023)	Methods of data collection and topics			
		Survey	Workshop minutes	Field notes	Reflections on
Instrumental rationale	Transparency and clarity	Trust in cooperation	Documentation & dissemination of results	Documentation & dissemination of results	Process design, documentation & dissemination
	Timing and resource	Frequency and time of events, preference of face-to-face events	Feedback on frequency and time of events	Notes on participation rates	Process design: formats, frequencies date, etc.; experimentation
	Process that starts before any decisions is made and goes beyond generating proposals	Being co-designer of measures, decision-making power by whom	Feedback on process design and roles	Notes on process design and roles	Process design: decision-making procedures and its consequences

received the survey via e-mail. It contained three main parts (co-design process, transdisciplinary cooperation, and role perceptions) that are based on the categories in table 1 (Glucker et al. 2013; Sendra 2023). The survey included items and statements to be assessed and some open questions (see appendix 1). A similar survey with adapted questions for researchers was send as online survey to the whole research team in autumn 2022. This survey contained filter questions for the research participants in the co-design workshops and broader questions on the transdisciplinary cooperation for all project researchers. Sixteen questionnaires from practitioners (eight from Rottal, five from Elm, and two from Havelländisches Luch) and 21 from the researcher team were returned and analysed. This corresponds to a response rate of participating practitioners of approx. 67 % considering the average participation rate of all workshop rounds and a response rate of project participating researchers of approx. 50 % considering all project employees (table 2).

For interpreting the survey results, we used qualitative data from minutes of the co-design workshops that are displayed in table 2 and include documentation of participatory reflection as well as from field notes from participatory observation and informal talks with participants, which were generated during the whole transdisciplinary research process (cf. Patton, 2019). For the analysis of the qualitative data we applied the content-related structured type of qualitative text analysis (Kuckartz, 2014) relying on deductive categories derived from the dimension and attributes displayed in table 1. Thus, the workshop minutes and field notes were used for analysing those dimensions and attributes, which were not included in the survey. Subsequently, in a reflection exercise the co-design core team discussed jointly the results from the survey, minutes, and field notes.

Table 2. Number of participants in the different workshops rounds.

Workshop round (date, live or online)	Participants from practice* + research** per landscape lab		
	Havelländisches Luch	Elm	Rottal
1 (Spring 2020, in person)	7 (3 + 4)	13 (9 + 4)	—
2 (Autumn 2020, online)***	8 (2 + 6)	12 (5 + 7)	18 (12 + 6)
3 (Spring 2021, online)***	12 (4 + 8)	18 (10 + 8)	23 (15 + 8)
4 (Autumn 2021, in person)	9 (3 + 6)	12 (5 + 8)	26 (18 + 8)
5 (Spring 2022, in person)	10 (3 + 7)	12 (6 + 6)	24 (18 + 6)
6 (Autumn 2022, in person)	15 (6 + 9)	18 (10 + 8)	19 (12 + 7)

* Even though there was some continuity in participation, not always the same people took part.

** Researcher were involved in the co-design workshops according their expertise on the specific workshop topics for co-producing target relevant knowledge. Thus, some researchers participated in several workshops, whereas others participated only once in none of the workshops.

*** Due to the COVID-19 pandemic we conducted these workshops online.

3 Results

3.1 Concept of the co-design process in the FInAL project (RQ1)

To answer RQ1 we structure this section in two parts: Firstly, we describe the main process phases of the co-design processes in the three landscape labs and how the researchers and practitioners work together. The second part gives an overview how we applied the co-design key elements described in the method section and figure 2.

Our co-design processes separated in different phases from a pre-phase with qualitative interviews on actors' motivations and a kick-off meeting until a synthesis phase (see figure 3). The co-design processes and synthesis are dynamic, iterative and continuously actions. Thus, until now, we can only draw first conclusions. The co-design processes in the first project phase of FInAL (2019-2022) consisted in 15 co-design workshops and six co-design field-trips in total. The workshop topics and workshop formats were not defined in advance, but iteratively built up from the previous workshop results in each lab. In this way, we were able to ensure that the topics and methods were always as close as possible to the needs of the local practitioners and place-based as well as that the process itself was very adaptable to real-world uncertainties and changing conditions. Another important principle for us is that the process design is grounded on active, early and continuous involvement of practitioners in the three landscapes, respecting their resources, capacities, interests, and values. The flexibility in the process design and acknowledging local conditions (incl. those of actors) was the key to keep the process alive and to avoid the common phenomenon of actor fatigue. We invited all land users who operate in the area of the landscape labs to actively participate in the co-design process and to collaborate for designing jointly their landscapes. The workshop and field trip participants from the practice are mainly farmers but also other practitioners such as local authorities and actors who are responsible for the maintenance for field margins and riparian stripes. The on-going and time-consuming process might not be suitable for all people (e.g. due to their personality and socialization, personal interests, or limited resources). However, in each landscape lab, we were able to build up a core group of actors who are really interested in the promoting insects, exchange, and co-learning participated actively and frequently in the workshops.

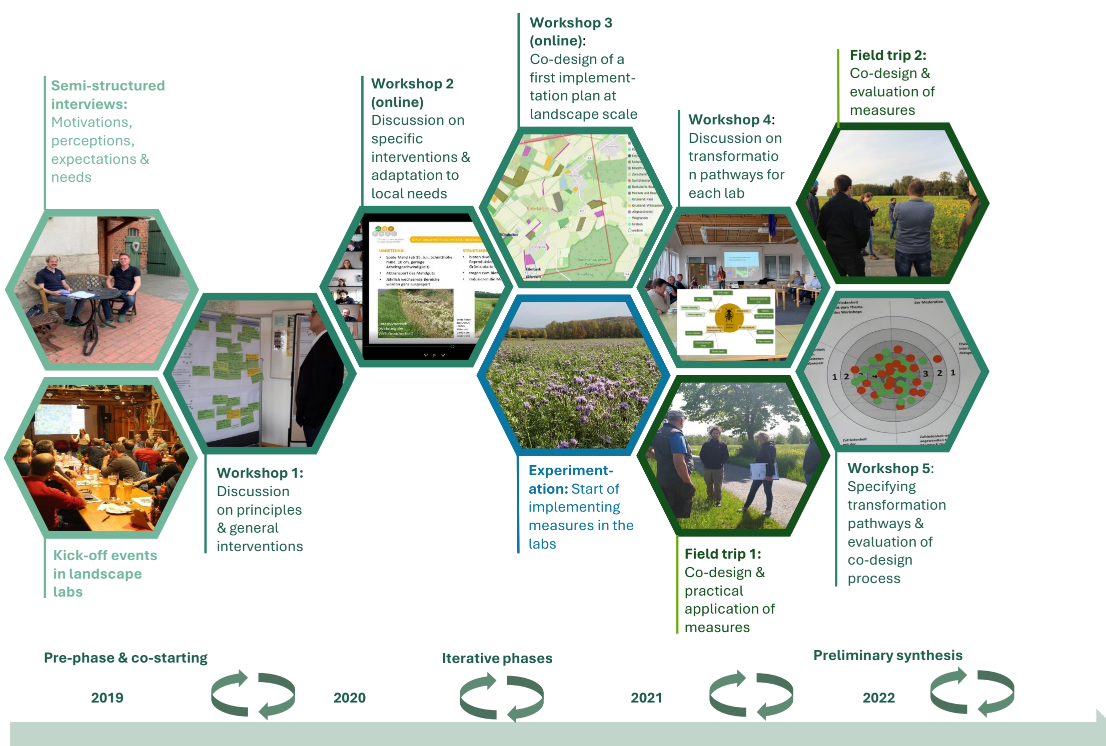

Figure 3. The different process phases of the co-design processes in FInAL landscape labs (2019-2022) according to Hölting et al. (2022) with their diverse event formats, such as interviews, kick-offs, co-design workshops, and field trips. Feedback loops served for continuous adaptation.

To maintain lively and smooth processes with continuous participation is often challenging: To overcome this challenge, we also planned from the beginning to have an intermediary person in each landscape: These landscape coordinators are responsible to steer all activities in the landscape labs including every-day communication with the local actors and built up trust. Having multimodal skills they support the co-design process, the implementation of measures, the biodiversity monitoring, and the dissemination of practical results (including presentations in the media). Thus, landscape coordinators have an important key role in the project.

We developed an integrative co-design process with iterative feedback-loops between scientists and local actors on joint enquiry and problem-solving, which encompasses several steps: revealing actors' values, perceptions, and motivations as well as a sequence of five co-design workshops and various field trips per landscape lab. These co-design events based on agro-ecological expert inputs and aimed at i) jointly discussing guiding principles and transformation pathways, ii) synergies/trade-offs, political-institutional framing conditions, and the practicability of possible solutions; iii) co-designing of preferred insect-friendly measures integrating actors' own ideas; iv) participatory mapping to locate measures at the landscape scale for further implementation; and v) reflecting the process. For a transparent and understandable procedure and further analysis all process steps and results were documented. Enabling the integration of different knowledge types is key to for tackling with complex sustainability problems, such as facilitating insect in agricultural landscapes

In the overall concept of the co-design processes, we considered the five co-design key components (figure 2): "Process orientation" was applied by acknowledging that co-design is more than a one-time event and, thus, by setting up a multi-step and adaptable process. We strive to treat everyone as equal partner that means as co-designer, co-implementer, and co-evaluator of measures and the co-design-process itself. Providing an inspiring and collaborative space for being innovative, critical, and reflective the FInAL project encourages and enables the actors to actively participate in decision-making and to take the shaping of future agricultural systems into their own hands instead of being passive recipients of scientific ideas or knowledge provider for scientific studies. Therefore, our cooperation activities generally aim to build on trust, empathy, and social learning and to sustain these social values over time. It was also important to us to create iterative processes that incorporate the framing of local sustainability problems, the development of suitable approaches and solutions, and joint experimentation. This means that the problems were described jointly, as often and as best as possible, to develop afterwards specific measures as solutions. The "design orientation" was supported through sound methods and adequate process facilitation. It was brought to life by incorporating creative methods for the co-design of measures as often as possible. This included collaborative mapping of measures at landscape level or promoting visionary thinking. However, it must also be mentioned that only a few creative methods were tried out because the involved actors showed little openness to them. Nevertheless, the scientific and practical input in workshops and field-trips, inspired the locale actors to get creative after the workshops.

3.2 Practical outcomes and reflection of the co-design process and project cooperation (RQ2)

Practical outcomes of the joint knowledge generation

In addition to setting up a process design that enables co-production of knowledge and co-learning, we also achieved practical outcomes in terms of maps and insect-friendly measures for implementation (see appendix 3 with list of implemented measures). In the first two workshops, the co-design core team (see also 2.3) discussed with the participants the current state-of-the art in insect-friendly measures as well as their practical and context-dependent suitability at local level to set up regionally adapted intervention catalogues. The measures were beforehand collected, reviewed and evaluated by an expert working group inside FInAL. In the third workshop, we co-designed implementation plans in terms of GIS maps for each landscape lab on basis of farmers' preferences and their own ideas (see figure 4). To co-design these maps we used our own GIS web platform developed specifically for this purpose. This means that beyond choosing measures from the catalogue every actor could come-up with own ideas, which were jointly discussed on their insect friendliness and further developed in detail. An additional outcome are the transformation pathways that indicate the aim and direction in which each landscape should be transformed (see appendix 2). The first sketches of these transformation pathways were mainly developed by scientists, but farmers' interests and needs, revealed in previous co-design steps, were also considered. These transformation pathways are landscape-specific and emphasize on insect groups, which are typical dwellers of open farmland habitats within the respective regions and provide the desired ecosystem services such as pollination and natural biocontrol. For each insect group ecologically effective measures were selected as well as synergies and trade-offs identified.

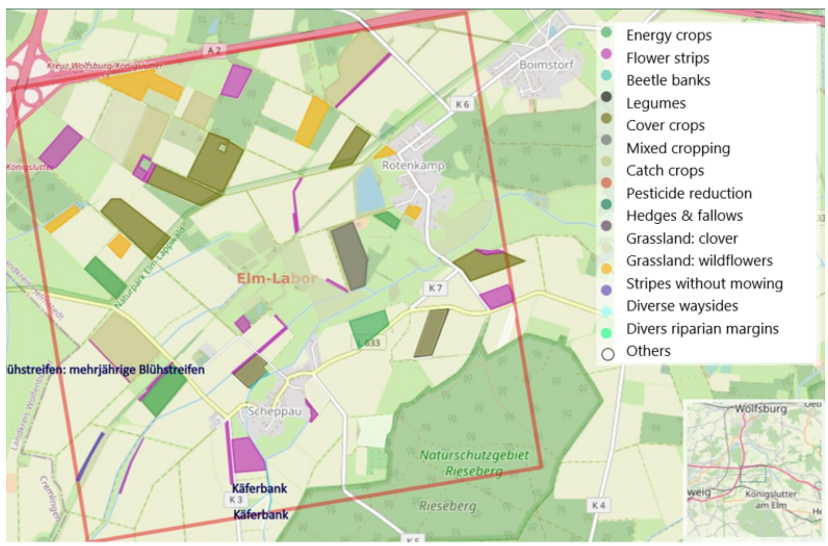

Figure 4. First implementation plan of the landscape lab ELM as practical outcome of the co-design process

Reflection of the co-design process and the project cooperation

The presentation of the reflection results is orientated to the survey structure and content. The attributes of the reflection framework (table 2) are integrated in the items and predefined statements.

Figure 5 shows that the farmers were more satisfied with the co-design workshops than participants from the research team. Nonetheless, both groups are generally satisfied with the co-design process, especially with the topics and the facilitation. The following quote from a farmer, which was expressed after the survey, illustrates this result:

> *"I particularly like the workshops in the project. Here you can exchange ideas with scientists and other farmers and always get new ideas on what you could try out on your own farm."*

Divergences exist regarding applied methods and achieved results in the co-design process. Methods were seen somehow critically because workshops could only be conducted online during

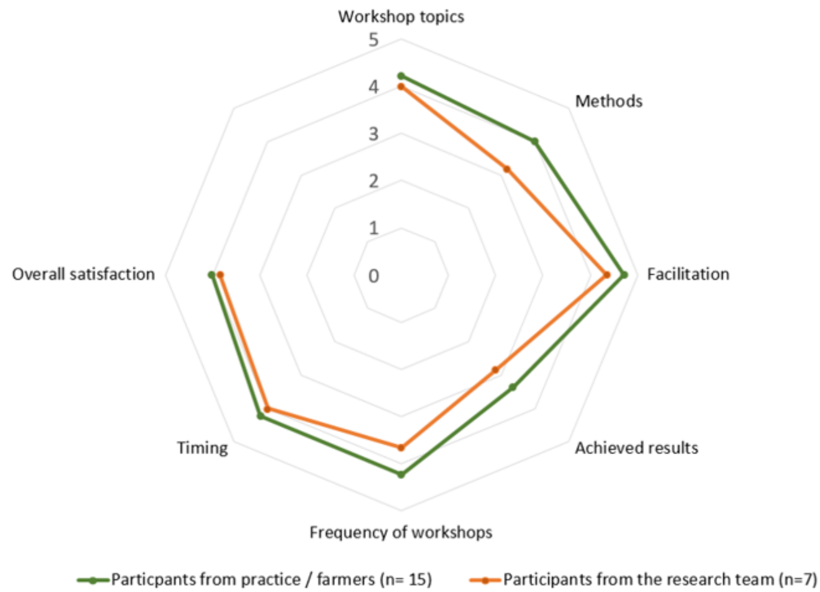

Figure 5. Evaluation of the co-design-workshops by participants from the practice and research team. (0 = no response, 1 = very dissatisfied, 2 = unsatisfied, 3 = partly satisfied, 4 = satisfied, 5 = very satisfied).

COVID-19 pandemic. Especially the participatory GIS exercise of mapping insect-friendly measures at the landscape level with the whole group of participants were perceived as long-winded and tiring. Achieved results were seen partly dissatisfactory because in some workshops the practitioners were reluctant to commit immediately to measures they may want to implement. It has shown that farmers need time for personal reflection before making a commitment. Additionally, in feedback discussions on the workshops, some participants of two labs complained that only a small number of landscape actors want to participate actively in the process. The reasons for this could be social and cultural impacts of current practices and former experiences as well as economic and political-institutional constraints. The latter refers primarily to the need to keep an eye on the profitability of one's own business.

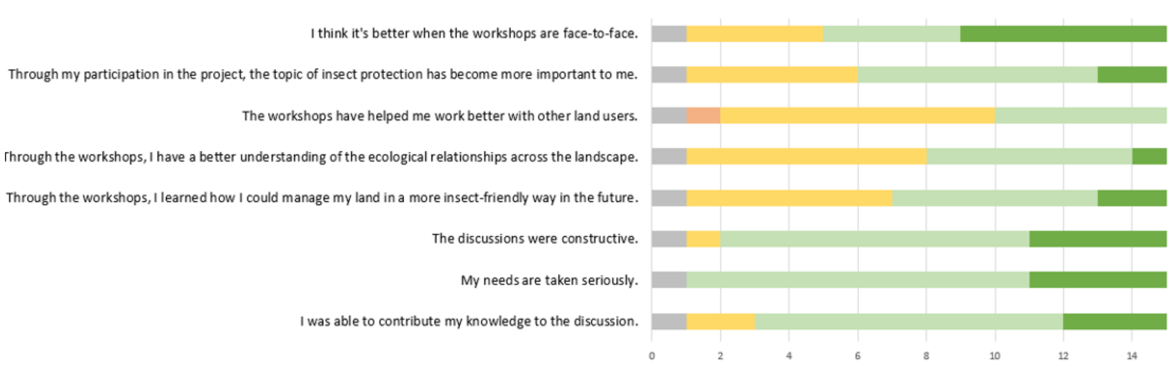

Figure 6. Statement evaluation of the co-design process by participants from practice (farmers) (n=15)

Evaluating predefined statements (figure 6), farmers pointed out that they are able to contribute with their knowledge, found that their needs are taken seriously and discussions are constructive. This means that workshops and field trips were perceived as fair formats for deliberation. In this sense, a farmer commented the following in a conversation:

"At the beginning of the project, I didn't know what to expect and was rather sceptical. But now I have to say: the project is moving us farmers forward. It takes our concerns seriously and together we are developing strategies for the future."

However, the practitioners have still the feeling that after four years of project work the collaboration between themselves has not considerably increased.

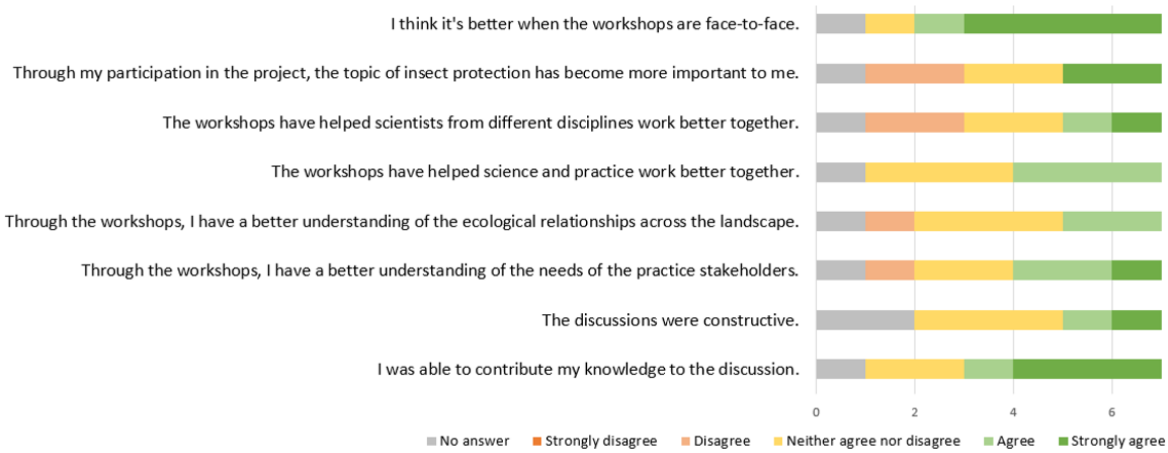

Figure 7. Statement evaluation of the co-design processes by the participating members of the research team (n=7)

The predefined statements on the co-design processes were evaluated more critically by the researchers than by the practitioners (figure 7). Apart from the preference for face-to-face workshops, researcher stated more critical and "neither agree nor disagree" answers. Many researchers do not perceive that the co-design process supported the interdisciplinary collaboration. It may not be surprising that the importance of insect biodiversity and ecological interactions at landscape level has not increased for the researchers, as both topics were already present at the beginning of the project. In contrast, the fact that the researchers' understanding of the needs of the farmers has not increased is more surprising because practical issues (needs, wishes, concerns, etc.) have been widely discussed in the workshops and this is just the main goal of such a transdisciplinary process.

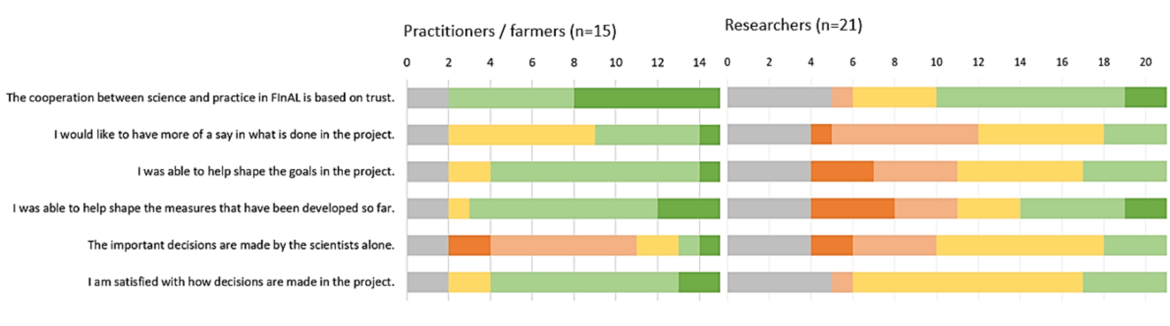

Figure 8. Evaluation of the science-practice cooperation in the project by farmers and researchers (n = 36)

Furthermore, practitioners evaluated the statements regarding the science-practice cooperation much more positively than the researchers (figure 8). Farmers perceive the relationship as trustful and are satisfied how decisions are made in the project. In the feedback rounds and from participatory observation we known that the landscape coordinators are well acknowledged by the practitioners due to building up a trustful collaboration based on strong ties to the lab regions and professional expertise, as the following farmer's quote underlines:

> *"The cooperation in the project works very well. It is important for the success of the project that the dialogue takes place via short communication channels. Without a landscape coordinator as a contact person and confidant, this would not be possible. I was initially concerned that this would not be guaranteed. Having a good contact person on site is worth its weight in gold."*

Farmers feel well involved in the co-design of measures and in the decision-making on the transformational goals. As the following quote shows, it is entirely up to them, which measures they want to implement and test:

> *"The big advantage of FInAL is that farmers can participate in designing measures. You don't get that anywhere else. As a rule, government programmes don't give you much freedom. The FInAL project is different. I really appreciate that."*

Less than half of the practitioners would like to have a stronger say on project contents. Comparing this to the researchers' opinion, only 14% (3/21) respondents would like to have more influence on the project content in the future. At the same time, only 19% (4/21) researchers state that they have influence on the project goals and co-designed measures. These findings were interpreted in the joint team reflection: Some researchers feel quite uncomfortable with the transdisciplinary research approach, mainly those who have less experiences in transdisciplinary collaborations. Even though, some researchers had complete opposite opinions by emphasizing that they indeed appreciate the transdisciplinary research mode and enjoy that new experience. In general, the critical results by researchers' on the co-design process and the cooperation reflects also there might be a general slight discontent with the project itself and some temporary tensions within the research team.

To complement this analysis with details that could not be covered by the survey, we add a self-reflection and positioning of the co-design team (composed of the co-design coordinator and facilitator, the three landscape coordinators, and the economic researcher): At the beginning of the project, only a few project team members had experience in transdisciplinary collaborations. The co-design process coordinator had long-term experience in research-practice collaborations and has additionally a formal ethnological-sociological background. Although this expertise is essential, the vast majority of project's members has a background in ecology or agricultural science. This also determines the relationship between the different scientific disciplines. It is also important to mention that each member of the co-design team had their own expectations and aspirations regarding the conceptualization of co-design process. This also has a strong influence on the process design and results. The strong commitment of the co-design core team to produce practical results and to build a trustful collaboration has supported the process flow and outcome. This team felt committed to the ethical principles of participation and especially of co-design (see 2.3 and table 1). However, this strong commitment did not necessarily apply to all participating researchers. As researchers are part of the knowledge co-production process, they influence the choice of topics, results, and the way of reflection. For instance, the co-design methods were initially set by academia, but gradually changed so that practitioners also expressed their expectation, which were taken into account. Thus, most of the researchers seek to acknowledge and consider the practitioners' ideas and concerns.

4 Discussion: Significance of the work for policy and practice

4.1 Preconditions for the conceptualization of co-design processes in landscape labs – Lessons learnt from FInAL

The establishment of living labs at landscape level (landscape labs) is a quite novel and innovative approach: Most agricultural living labs and biodiversity-oriented projects operate almost exclusively at farm level (cf. McPhee et al. 2021). Considering landscape ecological requirements (e.g. creating a biotope network for landscapes, combining production-oriented measures on fields with measures on semi-natural habitats, etc.) has been demanded for years (Landis 2017; Kremen and Merenlender 2018; Mupepele et al. 2019), but has so far only been implemented in very few transdisciplinary projects (e.g., Steingröver et al. 2010). Consequentially, it is also relatively new bringing different farmers and other actors who operate in the same landscape together to jointly design their landscape in order to make it more biodiversity-friendly. Furthermore, embedding thoughtfully conceptualized co-design processes in landscape labs or also in other forms rural real-world labs is innovative and has not yet been widely practised or documented in publications. The fact that this is a young field of research is also reflected in the fact that there is still relatively little theoretical-conceptual literature on co-design processes in the context of land use. Thus, certain principles or approaches have not yet been able to establish as scientific standards. At the same time, the scientific community and research practice are paying increasing interest and attention to co-design approaches (Blomkamp 2018; Busse et al. 2023; Sendra 2023). This has led to publications on empirical cases often having a weak theoretical-conceptual foundation, in that co-design is not defined or existing theories are rarely taken into account, and the processes are poorly or fragmentarily reflected (Busse et al. 2023). Evans and Terrey (2016) point out that such weak research practice can not only be problematic for scientific reasons, but can also lead to unsatisfactory results and unintended social effects: "Done badly [co-design], it can destroy trust systems; done well it can help to solve policy and delivery problems, stabilize turbulent lives, and life changes" (Evans and Terrey 2016).

Our experience has shown that co-design processes are complex and require high standards of conceptualisation, implementation and reflection. Not only theoretical-conceptual basics, but also methodological knowledge and practical experience in transdisciplinary research are necessary, which should be coordinated by experts in this field if available. In conclusion, natural and social science expertise must be brought together to develop and implement co-design processes for the transformation of agricultural landscapes. Such collaboration between "social and natural sciences will ensure that these processes are indeed guided by the best available information" (Bennett et al., 2017, 104). Furthermore, experts in knowledge integration must be involved who are able to combine different knowledge bases to develop practice-relevant solutions and scientific output that incorporates practical and local knowledge (Lux et al. 2019). Other important partners in co-design processes in landscape or rural labs are the landscape coordinators. Their involvement needs to be planned from the beginning by considering their functions, roles, and capacities. Landscape coordinators fulfil manifold roles in the day-by-day communication with local actors and contribute considerably to a continuous, adaptable and results-oriented process. Following Lange et al. (2016), the regional project coordinators in transdisciplinary projects enable access to local people, promote knowledge exchange and the consideration of regional or local demands.

4.2 Outcomes of the co-design process through reflection and their significance for policy

In many empirical articles on re-design of farming systems, NBS, and Climate Smart Agriculture, co-design processes are seldom or only very fragmentally reflected (Busse et al. 2023). In particular, the aspects of self-reflection and positioning of researchers remain usually unconsidered and are not included in the evaluation (Husson et al. 2016; Moraine et al. 2016; Lescourret 2017; Ferretti and Gandino 2018; Novoa et al. 2018; Asah and Blahna 2019; Pelzer et al. 2020; Périnelle et al. 2021; Busse et al. 2023; Selbonne et al. 2023). In contrast, we seek to provide a comprehensive reflection on how researchers and practitioners perceive our co-design processes and what are co-learning outcomes. Thus, we rely on evaluation plurality that includes participants as source for evaluation as advocated by Toffolini et al. (2023) or Fleming et al. (2024). Furthermore, we follow the recommendation of reflecting transdisciplinary endeavours in a structural manner (including inputs, processes, roles, and outcomes) to reveal strengths and weaknesses of the own research, to be adaptive during the process, and to assess whether set goals have been achieved (Moellenkamp et al. 2010; Neef and Neubert 2011; Glucker et al. 2013; Luederitz et al. 2017; Moon et al. 2019).

Regarding the evaluation of the co-design events, our study showed that the vast majority of participating practitioners and researchers are generally (very) satisfied with it, and emphasized the importance of trust to project intermediates such as landscape coordinators and workshop facilitators. Studies on co-designing NBS, Climate Services, and agri-environmental schemes find that when intermediaries interact closely and continuously with practitioners this leads to positively evaluated co-design processes and promotes trust (Karrasch et al. 2017; Falloon et al. 2018; Hurley et al. 2022). However, it is important that the intermediaries and facilitators possess a wide range of competencies: verbal communication and other interpersonal skills (such as sensitivity to group dynamics, flexibility, and neutrality), managing skills regarding time and organisation of events, and personal characteristics (such as adaptability to context, trustworthiness, and self-awareness) (Stewart 2006). Furthermore, and similar to our results, studies that aim at sustainable transformations in cities and empowering local communities show that close interaction at equal footing can promote the ownership of project results and shared responsibilities (Kenton and Singha 2018; Komatsu Cipriani et al. 2019). Thompson et al. (2017) found that through their transdisciplinary approach in projects on natural hazard management created social and personal benefits for the involved people, promoted two-way dialogue, enabled overcoming intrinsic challenges like lack of trust or diverging worldviews.

Regarding the co-learning of farmers as central actor group in our co-design processes, we draw a similar conclusion as other studies (Pahl-Wostl 2009; Rossi 2020) that transformative learning is hard to achieve, requires deep changes in farmers' thinking and governance structures. Farmers' values are often rooted in beliefs of the modernisation of agriculture (Rossi, 2020) and production orientation, which is often at odds with the value of farmers as landscape caretaker and biodiversity conservationist (Busse et al. 2021; Maas et al. 2021). For farmers who stick to production-oriented identities and narratives, productivity has priority over nature conservation, and they feel committed to produce as much and best as possible (Mills et al. 2017; Klebl et al. 2024). The change in self-perception from the exclusive producer of food, feed or raw materials to the provision of biodiversity and ecosystem services is only taking place very slowly (if at all), because the underlying value concepts are deeply rooted in people and society. Other studies come to similar conclusions (Burton and Wilson 2006; Warren et al. 2016). Hence the abroad acceptance of biodiversity-friendly measures and the commitment to transformation processes are impeded by the economic constraints they are facing, for instance the pressure to produce at and compete with world market prices (Busse et al. 2021; Klebl et al. 2024). Thus, without policy tools that make agroecological farming systems financially attractive to farmers it is difficult to overcome the lock-ins through co-design approaches (Kleijn et al. 2023). During the co-design in the FInAL project, we found out that policy instruments should provide a suitable compensation for biodiversity measures and appropriate framework conditions, which are not characterized by rigid guidelines, but by practical and simple features. This conclusion is supported by over 300 experts on the Common Agricultural Policy (CAP) (Pe'er et al. 2022).

Although transformative learning is difficult to achieve, the first successes have been observed after several years of intensive transdisciplinary project work and co- learning. For example, for some farmers, the choice of a particular crop or production method is not only dependent on its productivity, but now also takes into account biodiversity aspects. Klebl et al. (2024) confirm this by finding that intrinsic values of nature also play a role for many farmers in the way they manage their land, especially when holistic management strategies are pursued. Such positive results are the first step to an agroecological narrative, which should not only be supported by practitioners but also co-created with them to transform agricultural landscapes for more biodiversity and social responsibility (Bohan et al. 2022). In such co-design processes, production-oriented, intrinsic and relational values towards nature should be included in collaborative processes to create a comprehensive problem-awareness, mutually acknowledge worldviews, and eventually obtain broad-based endorsement of biodiversity measures (Klebl et al. 2024).

Further social outcomes of co-learning processes are cognitive or experimental knowledge generation (Rossi, 2020; Wood et al., 2014). In our case study, farmers had an interest in both: cognitive knowledge in the form of theoretical knowledge about insect biodiversity at the landscape level or monitoring data, and in experimental knowledge in the form of testing the practicability of new measures and improving existing ones. In this way, our farmers' appreciated to become co-designers by actively contributing their ideas and experiences to design new and locally suitable insect-friendly measures. This is a completely new research practice, especially for biodiversity research and research in the agricultural landscape context, as up to now farmers have mainly been consulted and asked to choose from a catalogue of scientifically predefined measures (Hölting et al. 2022; Busse et al. 2023). Also the CAP would benefit from "better engagement with farmers" (Pe'er et al. 2022). Since farmers' knowledge in the field of functional biodiversity at landscape level and the composition of landscapes is often limited and plays still a rather minor role for them or in agricultural advisory services (Kelemen et al. 2013; Maas et al. 2021), ecological knowledge integration and mutual exchange between science and practice on biodiversity is important for a sustainable transformation of agricultural landscapes. Therefore, knowledge integration about the ecological effectiveness and practicability of measures through experimentation coordinated by regional intermediates (ideally experts in biodiversity and agronomy) can be key for developing and testing cooperative agri-environmental programs for landscapes. This could not only ensure that larger sections of the landscape are covered with effective biodiversity-friendly measures but also soften the diverging perceptions on biodiversity and stimulate a mutual understanding of others' needs and constraints. This is in line with studies that found social impact in form of an increased problem-awareness and understanding of others' worldviews (Grove et al. 2016; Karrasch et al. 2017; Ferretti and Gandino 2018).

The co-learning effects for the scientific partners include the following aspects: Some academics perceived the transdisciplinary project work as new and saw positive learning effects for themselves here. This contribution to transformative learning resulted in a more positive attitude towards practitioners and that practitioner involvement was now considered more important. However, even though our co-design processes aimed at gaining cognitive knowledge about local conditions and interactions, the project researchers rated this learning effect as rather low. In contrast to our results, another agricultural study confirmed that researchers' understanding of farmers has increased considerably due to transdisciplinary research (Falconnier et al. 2017).

The FInAL core co-design team learned (among other things) that workshop participants need a lot of time to reflect on the points discussed (sometimes several months) before they commit to implementing measures or starting joint actions. This is contrary to what we initially assumed: to receive an immediate commitment to the issues discussed in or directly after each workshop. These different time lines in decision-making should necessarily be taken into account when designing future co-design processes - whether in more scientific or primarily policy-related contexts. Also different expectations of practitioners and researchers and among disciplines e.g., regarding the culture of collaboration and investigation should acknowledged as challenges that need attention when designing research policies and transdisciplinary projects (Thompson et al. 2017).

4.3 Critical discussion on applied methods and implication for further research

Although we tried to provide a comprehensive reflection of the process and its social outcome, we were also confronted with methodological constrains. For example, albeit it is an ongoing process where social learning will continuously take place, the survey could only be conducted in one specific moment. To identify changes over time, it is important to conduct surveys several times. Thus, it is planned to repeat the survey at a later stage in the course of the project. Even though our response rate among researchers and practitioners was quite good in the survey (see 2.4), hardly any statistic analyses are possible due to the small absolute number of respondents because it might lead to misinterpretations by producing statistical failures, random results, or "inflated" effects (Haas 2012). In this context, it is important to mention that we aimed at analytic generalization that is in line with the constructivist and interpretivist paradigm (Patton 2019) instead of predicting or extrapolating probabilities as external statistical generalization strives to do (Yin 2019). For the analytical generalization we used additionally the triangulation with qualitative data. This enabled a validation of our results, at least from our case studies. However, through including three case studies (the three co-design processes within the landscape labs) and discussing our results with findings from other studies allowed us to derive general conclusions in form of within-case comparison and case-to-case analysis. (cf. Yin 2019). These aspects of generalization are summarized in the conclusion section.

Regarding the critical examination of the participatory methods used in the co-design process, we would like to highlight two aspects: 1) online vs. face-to-face events and 2) the joint spatial mapping. 1) Events that we had to conduct online due to the COVID 19 restrictions, resulted in less intensive discussions between the participants. In our experience, face-to-face and especially field trips are better suited to stimulate an intensive discussion about measures and thus to support experimental co-learning. The fact that there is less personal exchange and weaker interaction in online formats than in live events was also confirmed by other projects dealing with the impact of the pandemic on transdisciplinary work (Sattler et al. 2022). 2) In the joint spatial mapping exercises, we used the WebGIS tool, which allowed us to better show the current land use at landscape level. However, the tool and the corresponding workshops were sometimes considered only partly useful, as the handling is not yet very user-friendly and not everyone wanted to disclose their intentions as to which measure they wanted to implement to the other participants. Therefore, on the one hand, the functioning and handling of the tool would have to be made more practice-friendly, and on the other hand the collaboration at landscape level between the practitioners should be strengthened. Encouraging such collaboration can be achieved by creating inspiring examples, showing ecological effects at landscape level, and fostering actors' ecological literacy.

5 Conclusion

With this study we showed how co-design processes in a transdisciplinary living lab project can be conceptualized and how the participants perceived the practical and social outcomes of this process. Such a detailed illustration and comprehensive reflection of long-term processes that build on a broad theoretical- methodological foundation are rare in literature. Through filling this research gap, this article contributes to new knowledge in the growing field of (agricultural) living labs and collaborative approaches. Further innovative aspects are the embedding of co-design processes in landscapes to cover biodiversity demands at the spatial scale they are needed as well as the involvement of farmers as active and reflective co-designers of their landscapes (together with researchers and other land users). Thus, our project is an example of how biodiversity measures can be developed jointly while taking into account ecological, economic, and social criteria. A wider impact of the experiences from our long-term processes is that they reveal success factors and constrains how to conduct co-design and continuous collaboration processes (beyond projects) in "working" agricultural landscapes. We identified that for strengthening collaboration and empowering actors it is crucial to 1) build upon established science-practice networks; 2) work with landscape coordinators as regional intermediaries and contact persons for all activities in the labs; 3) promote pro-active and continuous involvement and experimentation at the landscape level that lead to mutual trust, co-learning, and joint reflections; and 4) provide financial compensation as an incentive. These steps are also valid for other land-use-related living labs and might inspire the development of policy instruments such as collaborative agri-environmental schemes. Additionally, these recommendations could help to establish a new actors-based agroecological narrative for stimulating a long-term transformation.

Acknowledgement

We thank to all participants in this study. This work was funded by the German Federal Ministry of Food and Agriculture (BMEL) via the Agency for Renewable Resources (FNR; project number 22012018) based on a decision of the Parliament of the Federal Republic of Germany.

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7 Appendix

7.1 Appendix 1

Appendix 1.1.: Survey questions for scientists

Question	Description	Value description	Scale level
F1	Which workshops have you participated in?	0-6 visited workshops	
F2.1	How satisfied were you with the WS topics so far?	0=no answer, 1=not satisfied at all, 2=not satisfied, 3=partly satisfied, 4=satisfied, 5=very satisfied	ordinal
F2.2	How satisfied were you with the methods used in the WS so far?	0=no answer, 1=not satisfied at all, 2=not satisfied, 3=partly satisfied, 4=satisfied, 5=very satisfied	ordinal
F2.3	How satisfied were you with the moderation so far?	0=no answer, 1=not satisfied at all, 2=not satisfied, 3=partly satisfied, 4=satisfied, 5=very satisfied	ordinal
F2.4	How satisfied are you with the results achieved so far?	0=no answer, 1=not satisfied at all, 2=not satisfied, 3=partly satisfied, 4=satisfied, 5=very satisfied	ordinal
F2.5	How satisfied are you with the frequency of the WS so far?	0=no answer, 1=not satisfied at all, 2=not satisfied, 3=partly satisfied, 4=satisfied, 5=very satisfied	ordinal
F2.6	How satisfied are you with the timing of the WS in the year?	0=no answer, 1=not satisfied at all, 2=not satisfied, 3=partly satisfied, 4=satisfied, 5=very satisfied	ordinal
F2.7	How satisfied are you overall with the WS?	0=no answer, 1=not satisfied at all, 2=not satisfied, 3=partly satisfied, 4=satisfied, 5=very satisfied	ordinal
F3.1	Please rate the following statements: I was able to contribute my knowledge to the discussion.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal
F3.2	My needs were taken seriously.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal

Question	Description	Value description	Scale level
F3.3	The discussions were constructive.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal
F3.4	Through the WS I have a better understanding of the need of the practice stakeholders.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal
F3.5	The WS have helped scientists from different disciplines to work better together.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal
F3.6	The WS have helped science and practice to work better together.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal
F3.7	Through my participation in the project, the topic of insect conservation has become more important to me.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal
F3.8	I think it is better if the WS take place in presence.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal
F3.8.1	Comments on F3.8	open	
F4.1	What did you like about the workshops?	open	
F4.2	What did you like about the site visits?	open	
F5.1	What did you not like about the workshops?	open	
F5.2	What did you not like about the site visits?	open	
F6.1	What should be improved about the WS in the future?	open	
F6.2	What should be improved about the site visits in the future?	open	
F7	What other forms of cooperation would you like to see in the future?	open	
F8.1	In your opinion, what is your role in the FInAL project? What role would you like to take?	0=no answer, 1=your recent role, 2=desired role	nominal
F8.2	Role: Practice expert	0=no answer, 1=your recent role, 2=desired role	nominal
F8.3	Role: Specialist / expert	0=no answer, 1=your recent role, 2=desired role	nominal
F8.4	Role: Knowledge producer	0=no answer, 1=your recent role, 2=desired role	nominal
F8.5	Role: Provider of data and space	0=no answer, 1=your recent role, 2=desired role	nominal
F8.6	Role: Co-producer of knowledge	0=no answer, 1=your recent role, 2=desired role	nominal

Question	Description	Value description	Scale level
F8.7	Role: Data analyst	0=no answer, 1=your recent role, 2=desired role	nominal
F8.8	Role: Dissiminator of knowledge	0=no answer, 1=your recent role, 2=desired role	nominal
F8.9	Role: Innovator	0=no answer, 1=your recent role, 2=desired role	nominal
F9.10	Role: Promoter	0=no answer, 1=your recent role, 2=desired role	nominal
F9.11	Role: Coordinator	0=no answer, 1=your recent role, 2=desired role	nominal
F9.12	Role: Intermediate	0=no answer, 1=your recent role, 2=desired role	nominal
F9.13	Role: Project-critical participant	0=no answer, 1=your recent role, 2=desired role	nominal
F9.14	Role: Self-reflective participant	0=no answer, 1=your recent role, 2=desired role	nominal
F9.2	Do your current roles meet your expectations?	open	
F10.1	Please give a brief explanation.	0=no answer, 1=yes, 2=no	nominal
F10.1.1	In your view, has your role changed during the course of the project?	open	
F11.1	Please rate the following statement: The cooperation between science and practice in FInAL is based on trust.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal
F11.2	I would like to have a greater say in what is done in the project.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal
F11.3	I was able to help shape the goals in the project.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal
F11.4	I was able to help shape the measures that have been developed so far.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal
F11.5	The important decisions are made by the scientists alone.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal
F11.6	I am satisfied with the way decisions are made in the project.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal
F11.7	I was able to answer the practtioners' questions about ecological interrelations sufficiently.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal
F12	What added value do you see for yourself through participation in the project?	open	
F13	Further comments on the cooperation and the project in general:	open	

Appendix 1.2.: Survey questions for practicioners

Question	Description	Value description	Scale level
F1	Which workshops have you participated in?	0-6 visited workshops	
F2.1	How satisfied were you with the WS topics so far?	0=no answer, 1=not satisfied at all, 2=not satisfied, 3=partly satisfied, 4=satisfied, 5=very satisfied	ordinal
F2.2	How satisfied were you with the methods used in the WS so far?	0=no answer, 1=not satisfied at all, 2=not satisfied, 3=partly satisfied, 4=satisfied, 5=very satisfied	ordinal
F2.3	How satisfied were you with the moderation so far?	0=no answer, 1=not satisfied at all, 2=not satisfied, 3=partly satisfied, 4=satisfied, 5=very satisfied	ordinal
F2.4	How satisfied are you with the results achieved so far?	0=no answer, 1=not satisfied at all, 2=not satisfied, 3=partly satisfied, 4=satisfied, 5=very satisfied	ordinal
F2.5	How satisfied are you with the frequency of the WS so far?	0=no answer, 1=not satisfied at all, 2=not satisfied, 3=partly satisfied, 4=satisfied, 5=very satisfied	ordinal
F2.6	How satisfied are you with the timing of the WS in the year?	0=no answer, 1=not satisfied at all, 2=not satisfied, 3=partly satisfied, 4=satisfied, 5=very satisfied	ordinal
F2.7	How satisfied are you overall with the WS?	0=no answer, 1=not satisfied at all, 2=not satisfied, 3=partly satisfied, 4=satisfied, 5=very satisfied	ordinal
F3.1	Please rate the following statements: I was able to contribute my knowledge to the discussion.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal
F3.2	My needs were taken seriously.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal
F3.3	The discussions were constructive.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal
F3.4	Through the workshops I learned how I could manage my land in a more insect-friendly way in the future.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal
F3.5	Through the WS I have a better understanding of the ecological interrelationships in the whole landscape.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal
F3.6	The WS have helped me to cooperate better with other land users.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal

Question	Description	Value description	Scale level
F3.7	Through my participation in the project, the topic of insect conservation has become more important to me.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal
F3.8	I think it is better if the WS take place in presence.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal
F3.8.1	Comments on F3.8	open	
F4.1	What did you like about the workshops?	open	
F4.2	What did you like about the site visits?	open	
F5.1	What did you not like about the workshops?	open	
F5.2	What did you not like about the site visits?	open	
F6.1	What should be improved about the WS in the future?	open	
F6.2	What should be improved about the site visits in the future?	open	
F7	What other forms of cooperation would you like to see in the future?	open	
F8.1	In your opinion, what is your role in the FInAL project? What role would you like to take?	0=no answer, 1=your recent role, 2=desired role	nominal
F8.2	Role: Practice expert	0=no answer, 1=your recent role, 2=desired role	nominal
F8.3	Role: Implementation expert	0=no answer, 1=your recent role, 2=desired role	nominal
F8.4	Role: Specialist	0=no answer, 1=your recent role, 2=desired role	nominal
F8.5	Role: Provider of data and space	0=no answer, 1=your recent role, 2=desired role	nominal
F8.6	Role: Knowledge producer	0=no answer, 1=your recent role, 2=desired role	nominal
F8.7	Role: Innovator	0=no answer, 1=your recent role, 2=desired role	nominal
F8.8	Role: Promoter	0=no answer, 1=your recent role, 2=desired role	nominal
F8.9	Role: Project-critical participant	0=no answer, 1=your recent role, 2=desired role	nominal
F9.10	Role: Self-reflective participant	0=no answer, 1=your recent role, 2=desired role	nominal
F9.2	Do your current roles meet your expectations?	open	
F10.1	Please give a brief explanation.	0=no answer, 1=yes, 2=no	nominal

Question	Description	Value description	Scale level
F10.1.1	In your view, has your role changed during the course of the project?	open	
F11.1	Please rate the following statement: The cooperation between science and practice in FInAL is based on trust.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal
F11.2	I would like to have a greater say in what is done in the project.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal
F11.3	I was able to help shape the goals in the project.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal
F11.4	I was able to help shape the measures that have been developed so far.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal
F11.5	The important decisions are made by the scientists alone.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal
F11.6	I am satisfied with the way decisions are made in the project.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal
F11.7	The scientists were able to answer my questions about ecological interrelations sufficiently.	0= no answer, 1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, 5=sstrongly agree	ordinal
F12	What added value do you see for yourself through participation in the project?	open	
F13	Further comments on the cooperation and the project in general:	open	
F14	To which landscape laboratory do you belong?	1=HVL, 2=ELM, 3=ROT	nominal

7.2 Appendix 2

Preliminary transformation pathways

Promotion of flower visitors / pollinators in landscape lab Havelländisches Luch (HVL)

0. Storyline

Insects are an integral part of biodiversity and play an important role in our ecosystems. The aim of insect promotion programmes is not only to conserve and promote insects for their own sake, but above all to ensure the ecosystem functions carried out by insects. Many insect species provide elementary ecosystem services, for example for the pollination of plants, as a food source for other insects and other animal groups. Insect pollination is essential for the conservation of wild plants and for securing the yields and quality of many crops, and is therefore a focus of social interest. Although grassland crops and dominant cash crops have little or no direct economic dependence on insect pollination, measures to encourage flower visitors can make a significant contribution to society's appreciation of agriculture and represent an alternative objective to be taken into account in its use. The importance of this goal for agriculture in HVL has been repeatedly articulated by farmers involved in the FInAL project. It is certainly not the only objective for insect promotion in HVL, but it is a very central one and can contribute to the preservation of grassland use.

The promotion of flower visitors is aimed at very specific insect groups, the pollen gatherers and nectar consumers. The associated groups are explicitly mentioned in this transformation pathway (1.). So that these groups can be specifically promoted, in a second step their needs and requirements (incl. action requirements) for the necessary habitats in the agricultural landscape, including those for farmland, are summarised (2.) and measures are identified (3.) that contribute to improving the necessary habitat characteristics (here: above all the flower supply) for the target species groups. The list of measures helpful for this objective is not exhaustive and requires constant further development. For the selection of suitable measures, it is also important to consider possible synergies and trade-offs of individual measures (4.).

1. Target organism groups:

General (all groups of organisms relevant to pest self-regulation):

- Wild bees
- Hoverflies

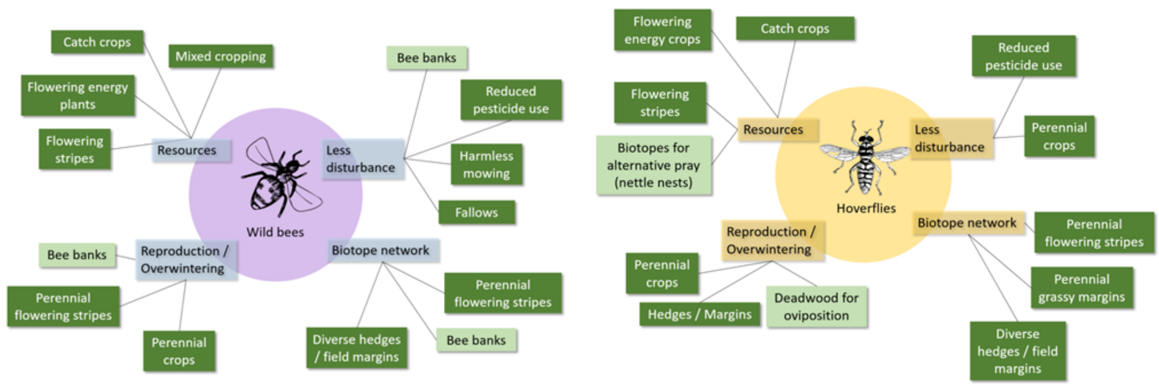
Synergies with beneficial insects are promoted by specifying the measures under 5.

- The best possible synergies with beneficial insects/fields (aphid antagonists lacewings, etc.) are achieved, for example, through the specific composition of the seeding mixtures and alternative regionally relevant crops

2. Requirements of target organism groups

Criteria	Organism group	Requirements
Availability of resources	Wild bees	All-year flowering availability / diversity of flowers
	Hoverflies	Continuous pollen and nectar supply for adult hoverflies (April to end of September) through suitable flowering plants
Reproduction / overwintering	Wild bees	Undisturbed soils or standing vegetation all year long (also over winter)
	Hoverflies	For predatory hoverfly larvae: alternative prey (e.g. aphids on hedge plants in spring)
Reduced disturbance	Wild bees	Reduced insecticide applications, insect-friendly mowing
	Hoverflies	
Biotope network	Wild bees	Perennial areas with no soil disturbance /standing vegetation, flowering supply and areas with reduced pesticide applications within a radius of 200m
	Hoverflies	Connected perennial structures and semi-natural habitats

3. Preferred measures for selected insect groups according to their requirements (light green measures are beneficial for one insect group and dark green measures are beneficial for various one insect groups)



Promotion of beneficial insects in landscape lab Elm

0. Storyline

Insects are an integral part of biodiversity and play an important role in our ecosystems. The aim of insect promotion programmes is not only to conserve and promote insects for their own sake, but also, and above all, to ensure the ecosystem functions supported by insects. One of these functions, which shows a close relationship, indeed a feedback loop, to agricultural use, is the biological control of pests, also called self-regulation. This function helps to reduce the use of chemical pesticides and costs and to strengthen biological regulation mechanisms. The importance of this objective for agriculture in ELM has been repeatedly articulated by farmers involved in the FInAL project. It is certainly not the only objective for insect promotion in the Elm, but it is a very central one.

The control of pests is primarily carried out by very specific insect groups. These are explicitly mentioned in this transformation pathways (1.). So that these groups can be specifically promoted, in a second step their needs and requirements (incl. action requirements) for the necessary habitats in the agricultural landscape, including those for farmland, are summarised (2.) and measures are identified (3.) that contribute to improving the necessary habitat characteristics for the target species groups. The list of measures helpful for this objective is not exhaustive and requires constant further development. For the selection of suitable measures, it is also important to consider possible synergies and trade-offs of individual measures (4.).

1. Target organism groups:

General (all groups of organisms relevant to pest self-regulation):

- Hoverflies
- Parasitoid wasps
- Ground beetles

Counterparts of regionally important pests:

- Cereal crops: aphids (autumn and spring), grain chafers.
  Counterparts: ladybirds, hoverflies, lacewings, aphid parasitic wasps, predatory gall midge
- Rape cultivation: weevils, glossy beetles, etc.
  Counterparts: ladybirds, ground beetles, short-winged beetles, larvae of net-winged beetles and ichneumon wasps.

- Parasitoids in general: maize cultivation: borers, root borers.
  Counterparts: ichneumon flies

Other regionally relevant crops

2. Requirements of target organism groups

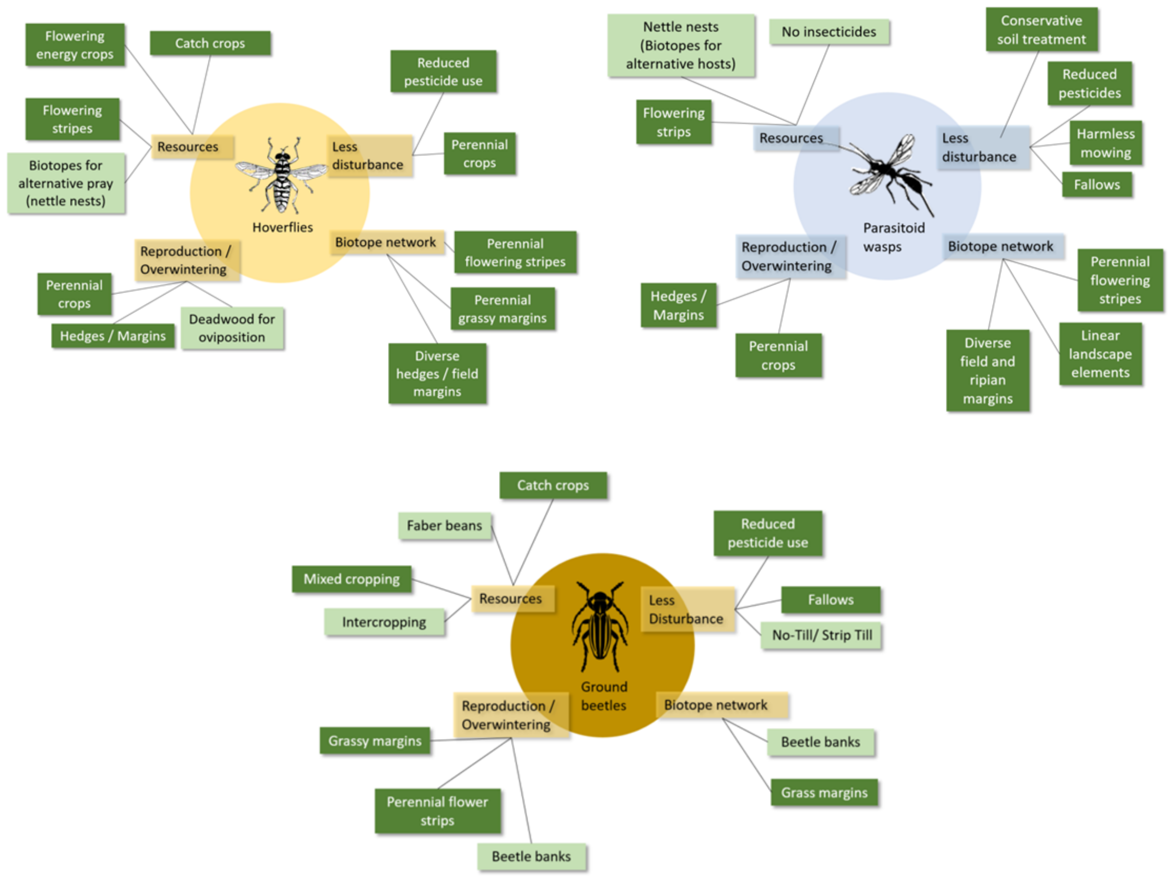
Criteria	Organism group	Requirements
Availability of resources	Hoverflies	Continuous pollen and nectar supply for adult hoverflies (April to end of September) through suitable flowering plants
	Parasitoid wasps	Continuous pollen and nectar supply for adult hoverflies (April to end of September, especially in autumn) Flowers with exposed nectaries, dense semi-natural habitats, nettle nests (clover and alfalfa fields) for intermediate hosts of aphid wasps
	Ground beetles	Not relevant, if any: residual weeds
Reproduction / overwintering	Hoverflies	For predatory hoverfly larvae: alternative prey (e.g. aphids on hedge plants in spring)
	Parasitoid wasps	Undisturbed soils for developmental stages hibernating in the soil (October to April), perennial habitats
	Ground beetles	
Reduced disturbance	Hoverflies	Reduced insecticide applications, insect-friendly mowing
	Parasitoid wasps	Low tillage (favourable: no-till, reduced tillage, conservation tillage), perennial crops, few insecticide applications, late mowing
	Ground beetles	Reduced tillage, direct sawing, reduced insecticide applications, insect-friendly mowing
Biotope network	Hoverflies	Connected perennial structures and semi-natural habitats
	Parasitoid wasps	Net of resources over time and space (landscape level)
	Ground beetles	Perennial strips with open soils, dense vegetation, fallows, and grassland within a radius of 500 m

3. Preferred measures for selected insect groups according to their requirements (light green measures are beneficial for one insect group and dark green measures are beneficial for various one insect groups)

Insect-friendly diversification of crops in combination of erosion control in the landscape lab Rottal

0. Storyline

Insects are an integral part of biodiversity and play an important role in our ecosystems. The aim of insect promotion programmes is not only to conserve and promote insects for their own sake, but also, and above all, to ensure the ecosystem functions supported by insects. The type of agricultural production and the structure of the agricultural landscape can push back harmful insects and promote beneficial insects. Pest populations worthy of control often benefit from large-scale monocultures and from narrow, low-diversity, crop rotations on the field or in the neighbourhood. Diversification with many crop species, long crop rotations and small fields



helps to maintain insect diversity and thus ensure a more favourable balance between pests and beneficial insects for agriculture. The importance of this goal for agriculture in the Rottal has been repeatedly articulated by farmers involved in the FInAL project. It is certainly not the only objective for insect promotion in the Rottal, but it is a very central one and can contribute to the preservation of grassland use.

Diversification in cultivation targets almost all insect groups. It aims to increase insect biodiversity and indirectly avoid pest accumulation while promoting the diversity of beneficial insects and flower visitors. These are explicitly mentioned in this transformation pathways (1.). So that these groups can be specifically promoted, in a second step their needs and requirements (incl. action requirements) for the necessary habitats in the agricultural landscape, including those for farmland, are summarised (2.) and measures are identified (3.) that contribute to improving the necessary habitat characteristics for the target species groups. The list of measures helpful for this objective is not exhaustive and requires constant further development. For the selection of suitable measures, it is also important to consider possible synergies and trade-offs of individual measures (4.).

1. Target organism groups:

Target species groups (and problems of maize cultivation):

- Wild bee (tillage in April)
- Hoverflies (lack of resources and lack to reproduce in season, April to end of September)
- Parasitoid wasps (tillage in April, lack of food in April/May)
- Ground beetles (tillage in April, lack of structure in May/June)

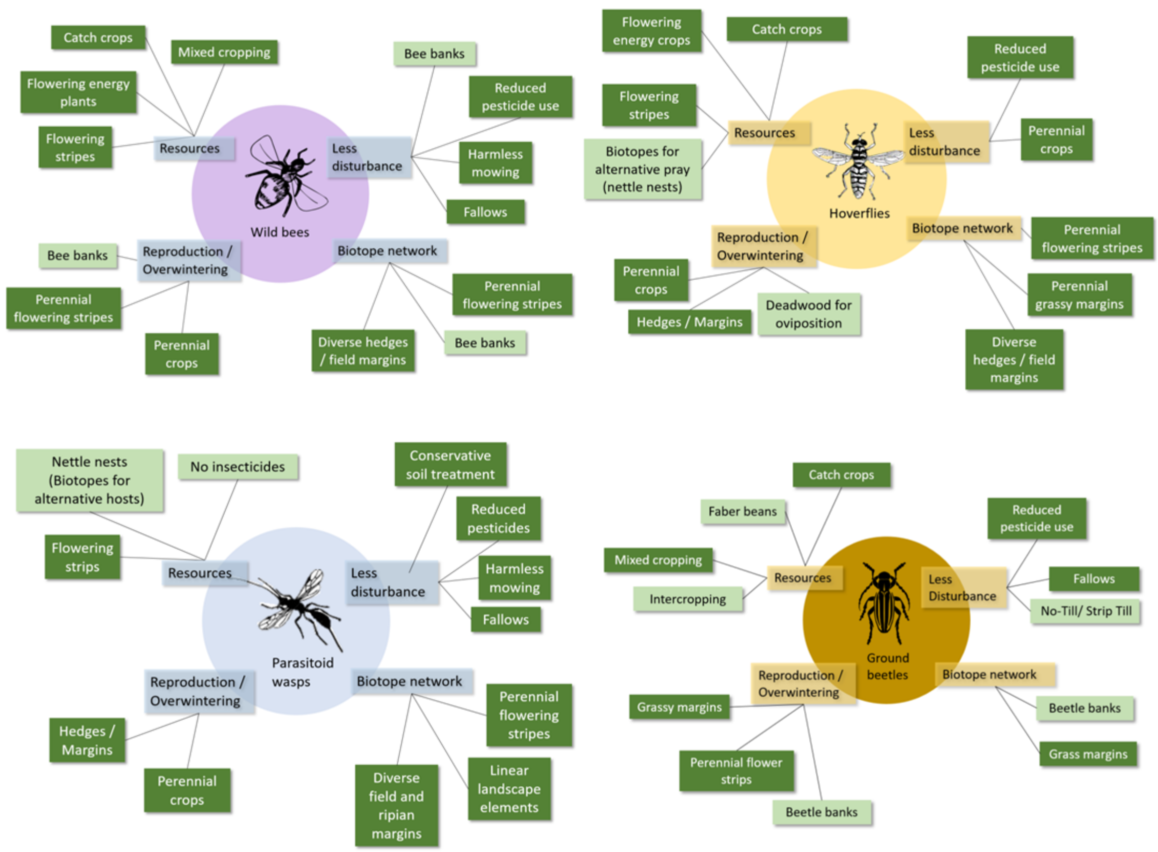
- Aquatic insects – divers groups

Negatively affected groups: Ground beetles, wild bees

2. Requirements of target organism groups

Criteria	Organism group	Requirements
Availability of resources	Wild bees	All-year flowering availability / diversity of flowers
	Hoverflies	Continuous pollen and nectar supply for adult hoverflies (April to end of September) through suitable flowering plants
	Parasitoid wasps	Continuous pollen and nectar supply for adult hoverflies (April to end of September, especially in autumn) Flowers with exposed nectaries, dense semi-natural habitats, nettle nests (clover and alfalfa fields) for intermediate hosts of aphid wasps
	Ground beetles	Not relevant, if any: residual weeds
	Aquatic insects	Structurally rich waters and water environments
Reproduction / overwintering	Wild bees	Undisturbed soils or standing vegetation all year long (also over winter)
	Hoverflies	For predatory hoverfly larvae: alternative prey (e.g. aphids on hedge plants in spring)
	Parasitoid wasps	Undisturbed soils for developmental stages hibernating in the soil (October to April), perennial habitats
	Ground beetles	
	Aquatic insects	Water bodies that are as little influenced as possible by pesticides and nutrient inputs, depending on the group, structurally rich banks or plant-rich riparian zones
Reduced disturbance	Wild bees	Reduced insecticide applications, insect-friendly mowing
	Hoverflies	
	Parasitoid wasps	Low tillage (favourable: no-till, reduced tillage, conservation tillage), perennial crops, few insecticide applications, late mowing
	Ground beetles	Reduced tillage, direct sawing, reduced insecticide applications, insect-friendly mowing
	Aquatic insects	Reduced pesticide use and fertilisers, erosion control, protection of riparian zones
Biotope network	Wild bees	Perennial areas with no soil disturbance /standing vegetation, flowering supply and areas with reduced pesticide applications within a radius of 200m
	Hoverflies	Connected perennial structures and semi-natural habitats
	Parasitoid wasps	Net of resources over time and space (landscape level)
	Ground beetles	Perennial strips with open soils, dense vegetation, fallows, and grassland within a radius of 500 m
	Aquatic insects	Riparian strips, hedges, perennial flowering and fringing strips, trees near water bodies (for some groups), (depending on the group, a certain distance from the water body must not be exceeded)

3. Preferred measures for selected insect groups according to their requirements (light green measures are beneficial for one insect group and dark green measures are beneficial for various one insect groups)



7.3 Appendix 3

Appendix 3: Implemented measures in the landscape labs

Insect-friendly measures	ELM			HVL			ROT		
	2021/22	2022/23	2023/24	2021/22	2022/23	2023/24	2021/22	2022/23	2023/24
Annual flower strips / areas	X	X	X	X	X	X	X	X	X
Perennial flower strips / areas	X	X	X	x	X	X	X	X	X
Fallow	X	X	X						
Riparian strips							X	X	X
Mowed / threshing material transfer in grassland								X	X
Grain legumes			X				X	X	X
Sunflower	X	X	X				X	X	
Grain legume mix cropping								X	X
Maize-Beans mix cropping	X	X			X	X	X	X	X
Silphium perfoliatum			X				X	X	X
Extensive grain		X							
Grain with undersowing							X		X
Oilseed rape with undersowing	X	X	X						X
Maize with undersowing							X		X
Diverse catch crop	X	X	X	X	X		X	X	X
Stubble fallow							X		
Strip cropping with cash crops		X	X					X	
Direct sowing							X	X	X
Perennial grass strips				X	X	X			
Clover sowing in grassland	X	X		X			X	X	X
Wild plans in grass land	X	X	X					X	
Temporal grassland				X					
Digital yellow trap			X						
Way side management			X	X	X	X			
Hedgerows									X

Biographies

Maria Busse. Maria Busse, PhD is landscape sociologist and leader of the working group "Co-Design of Change and Innovation" at ZALF (Research area 2: Land Use and Governance). Her research focusses on conceptualizing and conducting co-design processes in landscape labs as well as on understanding actors' thinking and acting in innovation or transformation processes in the fields of multiple land use systems and biodiversity conservation. She is also an expert in acceptability studies toward sustainability innovations and strategies for a collaborative landscape management.

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CRediT Statement: Conceptualization and methodology; Formal analysis, Investigation, Writing – original draft

Annette Bartels. Annette Bartels, PhD in agricultural sciences, is in charge for the landscape coordination in the FInAL project at the Lower Saxony Chamber of Agriculture. She coordinates all activities in the landscape lab and reference landscape in Lower Saxony. This covers the communication with the regional farmers and all other interest groups about the implementation of measures. She supports the co-design process and the scientific monitoring, and organizes events.

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CRediT Statement: Writing – review and editing

Karsten Beutnagel. Karsten Beutnagel, MSc, is an agricultural economist at the Thünen Institute (Research Department: Farm Economics). His research focuses on the collection and processing of farm data to calculate the costs and revenues of agri-environmental measures and alternative crops. Additionally, he works on agricultural policy frameworks and concepts for the design of agroecological payment systems.

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CRediT Statement: Writing – review and editing

Veronika Fick-Haas. Veronika Fick-Haas works as a landscape coordinator in the FInAL project at the State Institute of Agriculture (Institute of Agroecology IAB 4e - Insect Diversity and Natural Regulation). She is responsible for communication with farmers and all other interest groups in the landscape lab and reference landscape on topics relating to the implementation of measures, scientific monitoring, events and confidence building. Additionally she supports the co-design process in the Bavarian landscape lab.

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CRediT Statement: Writing – review and editing

Michael Glemnitz. Michael Glemnitz, PhD leads a working group on biodiversity in agrarian systems at ZALF (Research area 2: Land Use and Governance). He works in the interface between Agricultural Sciences, Landscape ecology, Biodiversity/ Nature protection and Impact assessment. Research activities include the spatial interactions between arable fields and their surrounding, monitoring of biodiversity on the landscape scale, and relations between species and landscape structural parameters. His expertise also covers On-Farm- and Living-Lab – research, as well as ecological accompanying research related to agro-environmental and agro-ecological measures

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CRediT Statement: Conceptualization and methodology; Writing – review and editing

Stephanie I.J. Holzhauer. Stephanie I. J. Holzhauer, Dr. rer. nat., currently works as scientific project coordinator of the transdisciplinary collaborative project FInAL at Johann Heinrich von Thünen-Institut (Thünen Institute of Biodiversity). Her research focusses on landscape-scale effects of the transformation of agroecosystems on insects, biodiversity, and other monitoring data, as well as on the integrative evaluation of the transformation process in landscape labs in comparison to living-lab and other approaches, regarding e. g. transferability and upscaling. Her expertise encompasses landscape ecology and landscape genetics of insects and plants in landscapes with spatio-temporal changes.

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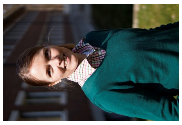
CRediT Statement: Writing – review and editing; Project administration



Elke Plaas. Elke Plaas has a Ph.D. in agricultural economics from the Georg August University Goettingen. She is senior research fellow at the Thuenen Institute of Farm Economics. Dr. Plaas' main areas of work are: socio-economic assessment of (soil) biodiversity, agricultural policy and environmental economic issues in Europe, CEEC and China, individual farm analysis of farms, water economics and rural development.
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