Optimising agricultural food production and biodiversity in European landscapes

Report of an online-Workshop

Anne Alix, Dany Bylemans, Jens Dauber, Peter Dohmen, Katja Knauer, Lorraine Maltby, Christoph J. Mayer, Zelie Pepiette, Balthasar Smith (eds)

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Thünen Report 98

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Optimising agricultural food production & biodiversity in European landscapes

All workshop participants contributed as authors to the development of this report. Participants are listed in Appendix 1.

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Abstract

An intrinsic feature of agriculture is the alteration of biodiversity within the cultivated area in favour of the production of the crop species. Ploughing, mechanical weeding or the use of herbicides, for example, reduce plant diversity and abundance, and influence other species that rely on these plants for food or habitat. However, both food security and biodiversity are important for human health and wellbeing. The overarching question is how can negative influences of agriculture on biodiversity be reduced and positive interactions be enhanced toward an efficient and sustainable food production. That is, how can we optimise (European) landscapes for food production and biodiversity.

Identifying a consensual and targeted solution to this optimisation problem requires the involvement of all relevant stakeholders in an open discussion informed by data and science. To this end a participatory workshop with a professional independent facilitator was organised under the auspices of the Society of Environmental Toxicology and Chemistry (SETAC) with participants from a range of affiliations from academia, authorities, farming, industry and Non-Governmental Organisations (NGOs). Participants were invited for their general or specific expertise and scientific knowledge and not simply to represent their institutions. To generate a truly collaborative and creative environment for discussion, significant time was allocated to trust building, articulating different perspectives, problem formulation and defining harmonised principles and criteria. The workshop was organised into four virtual workshops of half-day sessions spread between December 2020 and June 2021.

Through a process of visualisation, polarity mapping and reconciliation, differing perspectives on the advantages and limitations of managing agricultural landscapes for either biodiversity or food production were collated and ways to reduce potential conflicts discussed; the emerging themes being communication, education, collaboration, integration, application and incentivisation. Codeveloped agricultural scenarios were used to successfully identify approaches that would enable maintaining efficient and sufficient food production in Europe whilst significantly improving biodiversity in agricultural landscapes. Whilst many of the approaches identified were already in place, new (combinations of) approaches and ways to improve their implementation were identified. These included tailoring solutions to local needs and conditions, incentivising farmers to adopt specific approaches and using living laboratories to demonstrate the effectiveness of combining multiple approaches at scale. The workshop proposals and recommendations, which were agreed across all stakeholders, will contribute to reducing barriers to implementation of solutions and accelerating progress towards reaching the shared goal of optimising food production and biodiversity in European agricultural landscapes.

Keywords: agriculture, biodiversity, food production, farming, land management, scenarios, co-development, tailored solutions, incentives, sustainability

Content

Index of tables

Index of figures

Abbreviations

AES	Agri-Environmental Scheme (of the CAP)
BCO	Biological Control Organism
BVL	Biologische Bundesanstalt für Land- und Forstwirtschaft
CAP	Common Agricultural Policy
CSA farms	Community Supported Agriculture Farms
CIRCABC	Communication and Information Resource Centre for Administrations, Businesses and Citizens
DEFRA	Department for Environment, Food and Rural Affairs
EC	European Commission or European Council
EFSA	European Food Safety Authority
ES / ESS	Ecosystem Service(s)
EU	European Union
FAO	Food and Agriculture Organization
GAP	Good Agricultural Practices
GDP	Gross Domestic Product
GMO	Genetically Modified Organism
HNV farming	High Nature Value Farming
ICM	Integrated Crop Management (à IPM)
ICPPR	International Commission for Plant-Pollinator Relationships
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPM	Integrated Pest Management
IWM	Integrated Weed Management (à IPM)
MS	Member State
NAP	National Action Plan
NGO	Non-Governmental Organisation
OECD	Organisation for Economic Cooperation and Development
OF	Organic Farming
PPP	Plant Protection Product
PPP Regulation	Regulation REG 1107/2009/EC
SDG's	The UN Sustainable Development Goals
SDRN	Spray Drift Reducing Nozzles
SDRT	Spray Drift Reducing Technologies
SETAC	Society of Environmental Toxicology and Chemistry
SUD	Sustainable Use Directive (DIR (EC) 2009/128)
TEEB	The Economics of Ecosystems and Biodiversity; An organization to standardize classification and valuation of Ecosystem Services

TOPPS	To Prevent Pesticide Losses to Water; An ECPA initiated Project
UAA	Utilized Agricultural Area
UN	United Nations
VDF	Vegetation Distribution Factor
WFD	Water Framework Directive
WHO	World Health Organization, an UN Agency
WWF	World Wildlife Fund for Nature

Glossary

Agricultural intensification / intensive agriculture: Complex of agricultural practices that are used in various combinations to increase of agronomic output (harvested good) per area. Typical elements of intensification are high levels of soil management, plant protection and fertilizer application, high seeding densities, highly productive crop varieties and reduced crop diversity, irrigation, use of plastic mulches / tunnels to extend growing season or enable cultivation under otherwise unfavourable climatic conditions. Large field sizes are also generally viewed as an element of intensification; however, field size alone is not an indication of productivity and cultivation intensity. Intensification can occur in conventional, integrated and organic farming.

Agroecology: Agroecology is a holistic and integrated approach that simultaneously applies ecological and social concepts and principles to the design and management of sustainable agriculture and food systems, https://www.fao.org/agroecology/overview/en/. Wikipedia describes "Agroecology as an applied science that studies ecological processes applied to agricultural production systems not associated with any one particular method of farming, whether it be organic, regenerative, integrated, or conventional, intensive or extensive, although some use the name specifically for alternative agriculture". It further states "the term is often used imprecisely, as the term can be used as a science, a movement, or an agricultural practice" (https://en.wikipedia.org/wiki/Agroecology; June 2022). In the context of this workshop it has been used as applied science developing sustainable agricultural practices.

Agro-forestry: Concept of combining woody plants, trees with annual crops or pastures, such that the two components interact. Examples are fruit or timber tree lines in arable fields, lines of short coppice for biomass, fodder hedges, etc.

Beneficials: Beneficial arthropods such as predators or parasitoids of invertebrate pests that support biological control of pest arthropods.

Biodiversity: The variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part. This includes variation in genetic, phenotypic, phylogenetic, and functional attributes, as well as changes in abundance and distribution over time and space within and among species, biological communities and ecosystems (https://ipbes.net/glossary/biodiversity).

Biopesticide: Crop Protection Product based on a) micro-organisms (spores of bacteria, fungi) or entomopathogenic viruses, b) an extract or isolated substance of natural origin, or c) a semio-chemical (e.g., pheromone).

Conservation tillage: Form of soil cultivation that leaves at least 30% of crop residues on the soil surface to reduce soil erosion and maintain soil moisture. Beneficial for soil arthropods and farmers budget due to lower fuel and workload savings. However, increased soil coverage may decrease soil warming in spring and thus germination time.

Crop diversification: Increasing the number of crops grown on a farm to decrease e.g., pressure on soil, increase heterogeneity of vegetation and habitat cover in landscapes and seasonal stretch of resource availability. Crop diversification can be applied in a temporal (crop rotation) and/or spatial scale.

Ecosystem Services: The direct and indirect contributions of ecosystems to human well-being (TEEB 2018).

Fallow: Fallow land should not be viewed as surplus land which is permanently available, but as part of a production cycle. Fallow is a part of a crop rotation and describes the temporary suspension of cultivation for at least one vegetation period to achieve a recovery of soil fertility.

Flower strip: Sown strip of flowering plants along / within fields, primarily intended to provide food for pollinators and habitat for invertebrates.

Food security: Food security is the measure of the availability of food and individuals' ability to access it. Definition from the World Food Summit, 1996: *"Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life".*

Integrated Crop Management (ICM): According to the 'Natural Resources Institute' (University of Greenwich) ICM "is a system of crop production, which conserves and enhances natural resources while producing food on an economically viable and sustainable foundation" (http://projects.nri.org/nret/SPCDR/Chapter4/agriculture-4-4-1.htm), in line with the overall targets of this workshop, optimising biodiversity and food production targets. The UK 'Defra' (Department for Environment Food and Rural Affairs) defines ICM as a holistic "method of farming that balances the requirements of running a profitable business with responsibility and sensitivity to the environment". "ICM is a whole farm, long term strategy", which "combines the best of modern technology with some basic principles of good farming practice".

Integrated Pest Management (IPM): FAO definition: IPM is the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations. It combines biological, chemical, physical and crop specific (cultural) management strategies and practices to grow healthy crops and minimise the use of pesticides, reducing or minimising risks posed by pesticides to human health and the environment for sustainable pest management (https://www.fao.org/pest-and-pesticide-management/ipm/integrated-pest-management/en/).

Intercropping, catch crop, cover crop: Intercropping is an agricultural practice of planting an intermediate crop between two main crops. The catch / cover crop is sown directly after harvest of the first crop and often not harvested but used as green manure or forage for livestock. Before sowing the next main crop, non-harvested catch crops are mulched or ploughed into soil. Intercropping reduces soil erosion, suppresses spontaneous flora, fixes N during unproductive times, etc.

Land sharing: Is the principle of integrating nature conservation approaches into agricultural production across a region. Its characteristics are that of low-yielding farmland with higher biodiversity, but with less land available for the sole purpose of nature conservation (Fraanje 2018).

Land sparing: is the principle of segregating land for nature conservation from land for food (or agricultural) production within a region (Fraanje 2018). IPBES definition: "Land sparing, also called "land separation" involves restoring or creating non-farmland habitat in agricultural landscapes at the expense of field-level agricultural production - for example, woodland, natural grassland, wetland, and meadow on arable land (https://ipbes.net/glossary/land-sparing)."

Land sharing/sparing debate: Literature does not provide a homogenous definition for land sharing/sparing (e.g., Fischer et al. 2008, Franje 2018; IPBES https://ipbes.net/glossary/land-sparing, Table https://www.tabledebates.org/glossary/land-sparing-vs-land-sharing). Instead, there is a variety of definitions dealing with different spatial dimensions from field scale to landscape to even a global scale. Subsequently in the workshop the terms "land sparing" and "land sharing" were not always used unequivocally, as it remained open on where to locate terms in relation to the spatial scale and what level of nature conservation is needed to be considered land sharing. In practice, both extremes in isolation will not contribute to the overall workshop target; instead, there is need to find optimal solutions, which may differ spatially, temporarily, and depending on the species to be protected (Grass et al. 2019).

Lark window: A small patch within crop fields without crop or at lower crop density to provide an area suitable for larks to land and breed.

Monoculture: Monoculture agriculture is the practice of cultivating a single crop species – a monospecific, monodominant stand – on a specific area of land. In recent years, this definition has been significantly broadened and synonymized with modern, industrial and intensive agriculture and continuous monocropping. It is used more often by critics of modern agriculture than by farmers. The original definition of monoculture does not include any reference to time or definitive space and to how the monospecific stand is managed. How long it is grown; how much space it covers; and how it is managed are not inherent to what a monoculture is. (Lenné and Wood, 2022).

No-till practices: Practice of growing crops without tilling or respective major soil disturbance methods. It reduces soil erosion, increases water and organic matter retention and nutrient cycling. No till relies on herbicides or mulching to kill existing vegetation thereby freeing space for the intended crop that is directly seeded into the undisturbed soil layer (direct seeding).

Participatory workshop: At its most basic a participatory workshop is an organised event which brings a group of people together to seek their opinions, extract their knowledge and to solve problems in a collaborative and creative environment. (https://www.jisc.ac.uk/full-guide/planning-a-participatory-workshop, May 2022).

Precision agriculture/application technologies: Precision agriculture: farm management strategy, which allows for managing variations in the agricultural production system (e.g. in soil, weather, pest pressure) using innovative technologies to optimise agricultural production in terms of productivity, resource efficiency and therefore sustainability.

Precision application: applications of pesticides, including biopesticides, or fertilisers that are accurately focused on the target (pest, weed, plant affected by disease, and nutrition needs) at optimum rate and timing. It ranges from targeted and optimised application of any agricultural input (e.g. banded application) to sensor assisted application technology.

Protection goals: The specific goals of an environmental risk assessment in terms of what to protect, where to protect it, over what time period and with what degree of certainty (EFSA glossary) https://www.efsa.europa.eu/en/glossary/specific-protection-goals-era-pesticides.

Spontaneous flora: Plants developing spontaneously, not being actively seeded or planted, such as weeds developing from the soil seedbank, but also volunteer crops (plants developing from previous crops).

Sustainable / sustainability: Compare: https://en.wikipedia.org/wiki/Sustainability and https://en.wikipedia.org/wiki/Sustainable_food_system.

Executive Summary

Participants at this multistakeholder workshop shared a common aspiration to improve biodiversity in European agricultural landscapes and recognised the importance of safe food production in Europe. Working with co-designed scenarios, the workshop used an agreed set of common principles and criteria to identify approaches to enhance biodiversity in agricultural landscapes and reduce barriers to their implementation. Enhancing the development and uptake of available agroecological practices requires a transdisciplinary research approach in which the diversity of farmer experiences is considered and the effectiveness of specific approaches are demonstrated. The need to develop solutions tailored to local needs was highlighted, as was a lack of data required to facilitate such an advisory tool for farmers widely across the EU.

An intrinsic feature of agriculture is an alteration of the cultivated area in favour of the production of the crop species, thus altering biodiversity. However, both food security and biodiversity are important for a sustainable future and human wellbeing. How can negative influences of agriculture on biodiversity be reduced and positive interactions be enhanced toward an efficient and sustainable food production, that is, how can we optimise landscapes for food production and biodiversity? To this end a workshop based on participatory methods was organised under the auspices of the Society of Environmental Toxicology and Chemistry (SETAC) with participants from a range of affiliations from academia, authorities, farming, industry and Non-Governmental Organisations (NGOs) invited for their general or specific expertise and scientific knowledge. The target was to identify consensual and targeted solutions to this optimisation of sustainable and efficient food production and maintaining / improving biodiversity.

The workshop was organised into four workshops of half-day sessions spread between December 2020 and June 2021 and was supported by a professional facilitator. The main stakeholder groups were successfully brought together. The trans disciplinary discussions between different stakeholders enabled to build trust and the willingness to adapt individual positions and increase the knowledge related to the different disciplines presented. Keynotes were offered to present a problem formulation, provide state of the art information on relevant topics and propose terms and verbiage for discussion. After the workshop, the discussions allowed to formulate a set of recommendations in alignment with the pre-agreed criteria and principles, using the specific agricultural scenarios defined during the workshop as a guide.

To start with an open mind, participants were requested to envisage a future with thriving biodiversity and sustainable food production and imagine what farms and agricultural landscapes could look like in the future. Many envisaged a diverse agricultural landscape with many crops farmed in a sustainable but also efficient way, using diverse farming practices and including non-productive areas (e.g., flower strips, hedgerows). Future farming would use lower energy and chemical input and employ modern technology and knowledge to maintain efficient food production. Many also considered reduced animal production, valuation of food (and farmer's work), acceptance of increased costs for such more sustainable and more local production, reduced food waste and meat consumption.

Four keynote lectures were provided: J. Dauber presented scientific background and some views to stimulate the discussion about the relationship between biodiversity and agriculture. T. Gäbert provided a keynote presenting a farmer's view on optimising agriculture and biodiversity, illustrating how this works in practice. The author is managing a large farm in Brandenburg, Germany, where they have implemented measures to enhance biodiversity adapted to local conditions while maintaining farm profitability. M. Obersteiner presented the results of a multi-model ensemble approach used to assess whether and how future biodiversity trends from habitat loss and degradation in cultivated land can be reversed ("bending the curve of biodiversity decline"), while producing sufficient food for the growing human population, in accordance with the Sustainable Development Goals. F. Herzog presented agro-ecological innovations for sustainable production in Switzerland and focused on agroforestry and flower strips and ways to improve acceptance of these measures.

A polarity mapping exercise was used to identify the positive and negative aspects of focusing just on biodiversity or just on food production when managing agricultural landscapes. Workshop participants were tasked with considering how to reconcile the opposed views identified in the polarity mapping from the perspective of different stakeholders. Reconciliation requires: open and honest communication between different stakeholder groups; better understanding of the pros and cons of different approaches to managing agricultural landscapes; collaboration between all stakeholders to drive change and sustainable solutions; a

whole system approach that combines a suite of in field, on farm and off farm approaches and which takes the socio-economic context into consideration; application of new technologies and the tailoring of existing knowledge to develop effective solutions; incentivisation of farmers and fair food prices. An inventory of approaches and tools, which may be promising with respect to achieving the overall target of safeguarding the necessary level of efficient food production while improving the biodiversity in agricultural landscapes was developed.

Four different farm scenarios were designed, and participants were asked to recommend which of the approaches and tools to use under the specific conditions of the selected scenario. Participants identified and agreed upon a set of principles and criteria to be considered when evaluating the various approaches (e.g., open, indiscriminate evaluation based on science, data or experiences and transparent reporting and decision-making) and using standard criteria such as effectiveness, efficiency, relevance, coherence and sustainability. The exercise was executed at farm scale whilst envisaging the surrounding landscape. The suggested approaches were challenged for downsides, contradictory situations, ease of introduction and barriers to implementation. Such barriers like knowledge gaps, non-profitable investments or regulatory constraints were identified and described. Specific farm/farmer or landscape characteristics hampering or favouring the implementation of the approach were discussed. The measurability of effects is complex and can be demanding and very much depends on clear targets and adequate data collection. These aspects should not result in delaying actions which benefit both biodiversity and agricultural production.

Four case studies (arable farm with degraded soil, a low productivity mixed farm, a medium-size intensive orchard and a large intensive arable farm) were conducted in order to illustrate how the approaches identified in the inventory (and any approach not previously mentioned during the inventory) could support an improvement of biodiversity in different agricultural scenarios with no unacceptable loss of food production. The case studies reinforced the conclusion that a diversity of approaches exist, that include agronomic techniques, diversification at the crop and/or landscape level, habitat provision approaches, innovative and precision agriculture/application technologies and plant breeding as well as approaches such as agroforestry, active landscape management or transition to mixed farming systems. The scenarios also highlighted possible low hanging fruits or approaches that could be easily/further implemented, though the level of implementation remains for some limited and deserves actions towards incentives, advisory service and training to facilitate their availability to farmers. Overall, the analysis of the proposals for all four scenarios illustrated that there is no "one approach fits all", however the following was deduced from the analysis:

- The selection of the approaches to implement in a specific situation require to consider local agronomical, economic and environmental conditions as well as a clear vision on the biodiversity targets.
- In all situations, habitats are key for biodiversity, and small changes may provide good improvements.
- The farmer is key for the implementation of most approaches.
- Some approaches would need the support of financial or other types of incentives.
- The creation and/or reinforcement of extension services (assisted by up-to-date- IT tools) that support farmers with practical advice on agronomical and ecological aspects of the implementation of approaches is a critical element for the success of the approaches adopted.

To make a change and improve the situation regarding the workshop targets, actions of the various stakeholders are required. Therefore, participants were asked to identify approaches and activities already going in the right direction, to identify obstacles for their wider implementation, and to list possible next steps that would contribute to making the desired change. The purpose was to jointly identify specific steps for each stakeholder group that would, in combination with steps identified from each other stakeholder group, contribute to the overarching goal to optimise the situation for improving biodiversity and ensuring safe food production.

Developing solutions tailored to local needs and bringing them into action requires data collected at a regional scale about biodiversity and ecosystem services (both demand and supply) as well as of land use and management practices. Such data at the necessary spatial and temporal resolution are currently limited for European countries, either because of the lack of monitoring programmes or because existing data are not readily accessible. There is therefore a need for enhanced monitoring programmes and the generation of open access databases that collate information on biodiversity, ecosystem functioning and services, land use and management practices for European agricultural landscapes. Integrated pest/crop management are key concepts in optimising food production and biodiversity. Enhancing the development and uptake of available agroecological practices requires a transdisciplinary research approach in which the diversity of farmer experiences is considered and farmers take up a central role in testing and developing innovative and more sustainable farming practices. Increasing the awareness of farmers and farm advisors and demonstrating the effectiveness of specific approaches could be achieved by using living laboratories to generate a robust evidence base on the 'real-life' implementation of agroecological approaches and the consequences of moving towards sustainable farming in a European context. Optimising food production and biodiversity will also require the creation of an economic environment that enables farmers to ensure a viable income from their activities in food production and the delivery of other public goods and services.

The workshop has been successful in identifying consensual approaches which will lead to an improvement of biodiversity while maintaining efficient and safe food production in Europe. This was and can be achieved by an open minded and targeted collaboration between the relevant stakeholders based on impartial science, including farmer knowledge, and a transparent data-based evaluation of the various options.

1 Introduction

The relationships between habitats, their biodiversity and human well-being are varied and complex (Sandifer et al. 2015). Ecologists have been commenting on the consequences of biodiversity loss for human populations for over 40 years (Ehrlich and Ehrlich 1981, Ehrlich and Mooney 1983) and research activity was galvanised by the publication of the Millennium Ecosystem Assessment in 2005 (Mulder et al. 2015). Since then, there has been a significant increase in our understanding of biodiversity, ecosystems and ecosystem services as well as their contribution to human well-being.

The recent decade has seen an increasing societal awareness of the value of biodiversity, as reflected in extensive media coverage. Whereas there is general agreement about the relevance and importance of biodiversity, the definition of biodiversity varies (i.e., ranging from the number of species to the 'diversity within species, between species and of ecosystems' (UN, 1992) to including the variation in genetic, phenotypic, phylogenetic, and functional attributes, as well as changes in abundance and distribution over time and space within and among species, biological communities and ecosystems (IPBES online glossary; https://ipbes.net/glossary/biodiversity). Despite variation in how biodiversity is quantified (Heydari et al. 2020), protection of biodiversity together with limiting global warming are perceived as mutually supporting goals, and their achievement is deemed essential for sustainably and equitably providing benefits to people (Pörtner et al. 2021). Although there is now a "greater understanding about which policies, practices, technologies and behaviours can best lead to the conservation and sustainable use of biodiversity", "biodiversity is still being lost, ecosystems are still being degraded and many of nature's contributions to people are being compromised" (IPBES 2019). The actual magnitude and spatial and temporal scales of specific declines may still be a matter of debate (Purvis et al. 2019). Land use change has been identified as a major cause of biodiversity loss and agriculture as a primary driver of land use change and habitat degradation (IPBES 2019). Already quite a lot of measures have been implemented in Europe to stop or reverse the biodiversity losses, which are, however, apparently not sufficient yet (Batáry et al. 2015, Pe'er et al. 2017).

Agriculture is a cornerstone of human civilization. It was the origin of agricultural food production that enabled increasing numbers of people to settle and survive within an area and precipitated the development of complex infrastructures and societies. Human population growth and development is still correlated with improving agricultural techniques and increasing cultivation of land (Fedoroff 2015). An intrinsic feature of agriculture is the alteration of biodiversity within the cultivated area: the diversity of (plant) species is actively reduced in favour of growing the desired crop species. Throughout the history of rural Europe, a variety of land uses have interfered and interacted, have refined or replaced each other, resulting in a great diversity of agricultural landscapes (Plieninger et al. 2006). The traditional agricultural systems developing throughout Europe in historical times may have been characterised by both high- and low-intensity practices, but those were shaping heterogeneous landscapes with gradients of nutrient and labour inputs at local and regional scales (Plieninger et al. 2006). At the end of the 13th century, following a climatic optimum and a major increase of the human population to over 11 million[1], the area under agricultural land use[2] reached its maximum in central Europe (Bork et al. 1998). The agricultural land use at that time, however, instead of damaging biodiversity, even fostered habitat and species richness by slow rate of change over time, resulting in long periods of relative stability, management techniques that enhance the structural diversity of vegetation, the maintenance of a high proportion of semi-natural vegetation, low use of agrochemicals and generally much smaller individual fields providing much higher structural diversity (Baldock et al. 1995, Hampicke, 2006). At that time, about half the population was part- or full-time involved in producing food. Today in central Europe less than 1% of the people are farming, but the human population has multiplied without a respective increase in agricultural land. With approximately 45% of the total land area used for agricultural production (FAO-STAT 2019), the means of agricultural production have developed in ways much less biodiversity friendly. This is all the more important given that biodiversity in cultural landscapes is considered just as valuable as wild biodiversity (Phillips 1998), and remnants where traditional biodiversity friendly farming systems still prevail (i.e. HNV-farming systems)

[1] Estimate for central Europe according to Poschlod (2015, p.68).

[2] Estimate for the land area of Germany in 1300 is 36% arable land and 48% grassland and heath according to Poschlod (2015, p. 68).

are considered priority targets of biodiversity conservation in Europe (Strohbach et al. 2015). Agrobiodiversity or "biodiversity for food and agriculture", is defined as "the subset of biodiversity that contributes in one way or another to agriculture and food production" (FAO 2019). "It includes the domesticated plants and animals raised in crop, livestock, forest and aquaculture systems, harvested forest and aquatic species, the wild relatives of domesticated species, other wild species harvested for food and other products, and what is known as "associated biodiversity", the vast range of organisms that live in and around food and agricultural production systems, sustaining them and contributing to their output[3]" (FAO 2019).

Nowadays, a number of management practices used in agricultural food production still cumulate a negative influence on biodiversity. Ploughing, mechanical weeding or the use of herbicides, for example, reduce plant diversity and abundance, subsequently influencing other species that rely on such plants for food or habitat. Most factors leading to biodiversity decline in agricultural landscapes are linked to decreasing habitat quality and quantity driven by the reduced number of crop species and varieties grown, the area-wide and intensive use of pesticides and fertilisers, and the loss of structural and functional heterogeneity of the landscapes (Mupepele et al. 2021). In this situation and facing the challenges of future food production (Calicioglu et al. 2019), it becomes increasingly apparent that agrobiodiversity which helps sustain agricultural production systems and is contributing to their output is a natural asset which should not be neglected (TEEB 2018). From this perspective, wildlife-friendly farming methods, also referred to as land-sharing, are suggested to best be adapted for a biodiversity friendly food production but may be less productive hence requiring more agricultural land per unit of crop. Agricultural intensification, on the other hand, can free land for biodiversity conservation by increasing productivity per unit of agricultural area (also known as "land sparing" (Balmford et al. 2005)), but may increase detrimental effects on the environment, wildlife and human wellbeing in those agricultural areas. This dichotomy in the land-sparing/land-sharing framework however limits the realms of possibilities because both concepts are too simplistic for European landscapes which are dominated by cultural landscapes of wide gradients of productivity (Herzog and Schüepp 2013, Kremen 2015). Large, inter-connected protected areas are required to protect non-farmland species of nature conservation concern, high nature value farming is required to protect farmland species of nature conservation concern and semi-natural habitats combined with biodiversity measures are required to yield ecosystem services relevant for agriculture, and to allow migration of non-farmland and farmland species through the agricultural landscapes (Herzog and Schüepp 2013, Kremen 2015, Tscharntke et al. 2021).

However, both food security and biodiversity are important for human health and wellbeing. The overarching question, which is still not fully answered, is how can negative influences of agriculture on biodiversity be reduced and positive interactions be enhanced while maintaining efficient food production. That is, how can we optimise (EU) landscapes for food production and biodiversity considering the different footprints of the various agricultural practices in space and time. As defined by the World Food Summit (1996), food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. In order to achieve food security, policies and economic structures have aimed to produce ever more food at ever lower cost through investment in agricultural productivity, coupled with increased economic competition through the liberalisation of trade (Benton et al. 2021). Hence, the food system has been shaped over past decades by the 'cheaper food' paradigm (Benton et al. 2021). This paradigm has taken primacy over the goals of delivering human and planetary health and well-being, with increasingly problematic side-effects (Benton et al. 2021). The World Summit on Food Security (2009) had developed the concept of food security further, stating that "the nutritional dimension is integral to the concept of food security". Beyond that, the International Bank for Reconstruction and Development and the World Bank (2006) considered that: "Nutrition security exists when food security is combined with a sanitary environment, adequate health services, and proper care and feeding practices to ensure a healthy life for all household members". Since then the expression "food security and nutrition" (FSN) is commonly used (HLPE 2019). Achieving FSN for all, now and in the future is meanwhile recognized as a human right (HLPE 2019). The UN General Assembly (UNGA 2014), for example, defines the human right to adequate food as the right of every individual "alone or in community with others, to have physical and economic access at all times to sufficient, adequate and culturally acceptable food, that is

[3] Agriculture is taken here to include crop and livestock production, forestry, fisheries and aquaculture.

produced and consumed sustainably, preserving access to food for future generations”. This development of the concept of food security ultimately links to the goals and practices of food production. The paradigm of “ever more and ever cheaper food’ is obviously not helpful to sustain the future viability of agriculture. Therefore, a paradigm shift towards an agriculture that integrates the interdependent goals of producing enough and adequate food sustainably to meet rising human needs while contributing to resilience and sustainability of biodiversity and the environment is urgently needed (Rockström et al. 2017).

Such a paradigm shift is certainly an important prerequisite for achieving a repositioning of agriculture from its current role as a driver of global environmental change, to a contributor of transformation towards a sustainable world (Rockström et al. 2017). Still, this topic is highly complex and simple (or populistic) solutions will not be able to achieve the optimal combination of producing the required food and at the same time the intended biodiversity targets (Tscharntke et al. 2021). Despite some progress in science and practice towards sustainable agricultural systems, considering agroecological principles and practices and building both natural and social capital, national and EU policies for transitions toward sustainability remain insufficiently developed or counter-productive (Maes and Jacobs 2017, Pretty 2020). Although farm subsidies in the EU have increasingly been shifting towards targeted environmental outcomes rather than payments for production, synergistic benefits across whole agricultural landscapes have so far not been achieved (Maréchal et al. 2018). So what needs to happen next? There is some evidence that a redesign or transformation of agricultural production around agroecological approaches to sustainability can increase productivity, raise system diversity, reduce farmer costs, reduce negative externalities, and improve ecosystem services (Dainese et al. 2019, Oberč and Schnell 2020, Pretty 2020). Despite the evidence, there is still concern that such transformation will come at a cost and may affect markets and food prices as well as nature conservation (e.g. Meemken and Quaim 2018). Still, there should be a range of potential motivations for farmers to adopt sustainable practices for food production, but this motivation would have to be fostered by policy support for education, training and advice to build human capital (Pretty 2020).

To discuss potential options and pathways for optimising European landscapes for food production and biodiversity, we initiated workshop, organised in a series of workshops, to bring together experts from various areas (environmental scientists, farmers, authorities, industry and NGOs). The aim of the workshop was to, irrespective of participants' individual backgrounds, jointly develop a suite of potential solutions and targeted recommendations aiming to address this goal.

2 Workshop process

The objective of this workshop was to contribute to the ongoing debate aiming at informed decisions on multiple levels for future management of agricultural landscape, and more particularly how to achieve the double objective of biodiversity protection and food production. This double objective is often perceived as antagonistic, and as an equation that cannot be resolved. The workshop gathered participants from a range of affiliations (see also Figure 1), invited for their general or specific expertise and scientific knowledge on either or both aspects of the problem formulation (Heras-Saizarbitoria 2017, Reed 2008, Sauvé et al. 2016). In this workshop series it was accomplished to bring together members of three different farmer organisations, six agricultural chemical producers (industry), academia from ten different institutions and also regulators (both risk assessors and risk managers working in national or European authorities mostly related to crop protection product (CPP) regulation) from seven EU Members States and the UK as well as from EFSA and the European Commission.

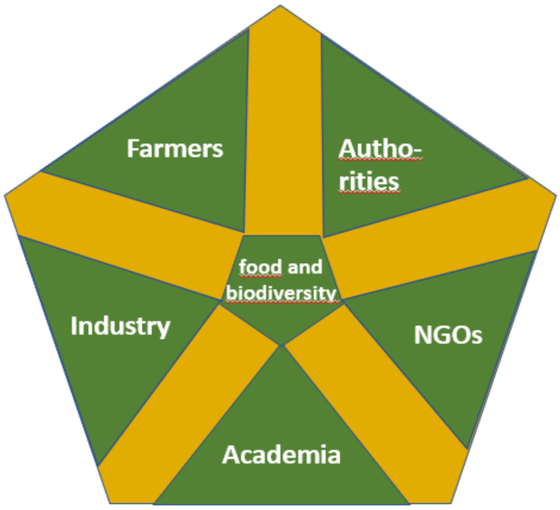

Figure 1: Overview affiliations of the participants

Source: Own data

From experience, in every workshop audience, each participant brings a unique perspective that results from the academic background, professional experience, and previous exchanges and readings, and that is also further crafted by language(s) and countries where the participant worked, or lived (Reed 2008, Sauvé et al. 2016). Thus, even with a common scientific knowledge, each input and perspective are unique and for it to be properly captured into a scientific dialog, it is critical to build the workshop around several key rules regarding time allocation and preliminary steps (Reed 2008):

- Ensure that the workshop will use common verbiage / language and ensure words mean the same by clarifying key definitions where needed (Sauvé et al. 2016).
- Plan to bring participants to the same level of understanding of the problem formulation through keynotes where basic scientific knowledge / state of the art is shared, while "cliches" or unverified statements are debunked.
- Ensure facilitation of the exchanges by a professional external facilitator (Reed 2008).
- Involve participants in the collection of published data and other relevant data to be used as a basis of discussions, and further on in the recommendations (Sterling et al. 2017).
- Involve participants in the definition of criteria and principle to judge on the relevance of the data collected to back up findings / recommendations (Sterling et al. 2017).
- Share the airtime: make sure everyone is offered a timeslot to express their opinion, share their own experience, vision on the situation and expectations for the future, ideas towards solution building, through

appropriate breakout group time, ensuring that conflicting points of views are expressed and addressed within the groups and thereafter in the process (Young et al. 2014).

- Ensure each idea proposed by a participant can get feedback, is used in the exchange and makes its way to the overall solution building.
- Involve all participants in the building of the proceedings, take home messages, case studies, and next steps prioritisation (Reed 2008).

To ensure that these key rules were followed the workshop was presented by a professional host who is trained to guide participants and moderate online sessions. It is important in such a trans disciplinary discussion between different stakeholders that trust is built and the willingness to adapt positions and increase the knowledge related to other disciplines (Reed 2008, Sterling et al. 2017).

The workshop was organised into four workshops of half-day sessions spread between December 2020 and June 2021, so that to ensure that the information shared could be processed by the organising committee and used to build the following workshop sessions.

The workshops were built with the following objectives:

Workshop 1 (December 2020)

The first workshop (two sessions of 4 hours each) aimed at getting participants to introduce themselves and their experience in the topic of the workshop and share their vision on cultivated landscapes ensuring both biodiversity and food production.

One keynote was offered so that to present the problem formulation and propose terms and verbiage, that participants could comment on and agree for use in the next sessions.

This was followed by further exchanges where participants could start offering potential tools and approaches that could be helpful to improve biodiversity in cultivated landscapes, tools which would then be collected in preparation of the second workshop.

Workshop 2 (January 2021)

The second workshop was built on the basis of the ideas and suggestions brought up during the first workshop and as follow-up homework. The call for input covered reference work on potential approaches / tools that may be promising with respect to achieving the overall target of safeguarding the necessary level of efficient food production while improving the biodiversity in agricultural landscapes.

The second objective of this workshop session was to define scenarios (cropping systems in landscapes), for which suitable approaches, respectively combinations of approaches should be developed. These scenarios, once agreed in plenary, would be further elaborated by groups of volunteers before the next workshop, so that they become useful to prepare specific and/or more holistic recommendations relevant for the respective scenarios, considering agricultural (food provisioning), environmental / biodiversity and socio-economic aspects. To support this process two keynotes were given.

The first keynote contained useful background for participants to start building the scenarios: a keynote was offered by a farmer to provide participants with the perspective of growers regarding realistic measures they are able to implement towards biodiversity conservation.

The second keynote offered economic figures on biodiversity decline across the world, trade-offs between efficient food production and biodiversity and potential global strategies so that to understand and discuss European landscapes with trade and exchanges in perspective.

After that the participants agreed to define criteria and principles to be used to select the approaches and tools to be further considered, so to ensure a common reference to their inclusion into further work.

Workshop 3 (April 2021)

The third workshop dedicated some time to finalise the exchanges on the criteria and principles to be used for a specific scenario exercise based on the results of the previous workshop.

A main task of this workshop was to start developing recommendations for a set of agricultural scenarios. Groups composed of participants from different backgrounds were set up to work in a trans-disciplinary way on approaches/recommendations. Each group was assigned one specific scenario and worked intensively on a set of recommendations for the case at hand following the agreed criteria and principles. This group continued the work after the workshop, to further refine the different agricultural scenarios, as homework in preparation of the last workshop. A final keynote was offered to present tools implemented in agroforestry and flower strips and provided examples of successful approaches.

Workshop 4 (May 2021)

During the fourth workshop, time was dedicated to pause and reflect on the objectives and expected remits of the workshop and more particularly reflect on:

- The trends that are already moving in the right direction?
- What obstacles are holding us back?
- How can we use the trends to overcome the obstacles?

A final presentation of the scenarios took place to collect final comments and reflect on how they can help in the preparation of the proceedings towards "example" recommendations to achieve the overall workshop target for optimised solutions of successful sustainable food production and equally improving biodiversity in respective deprived agricultural landscapes.

The structure and content of the proceedings was discussed, and input on participants' views on the next steps in terms of exchanges, forums for further discussion and expertise groups were collected.

Overall, the workshop was designed to dedicate as much time as possible for discussions and breakout groups, with 50% of the time for breakout groups to collect all voices and progress on scenarios and practical work (see figure 2 for the methodological pillars of the workshop). This approach created a very constructive baseline for plenary exchanges and homework. Dedicating a significant space for free exchanges allowed antagonist views to be expressed and discussed so that to explore ways to reconcile them into proposals to building strategies based on win/win approaches, but also on compromises to be used as a strong base for further improvement.

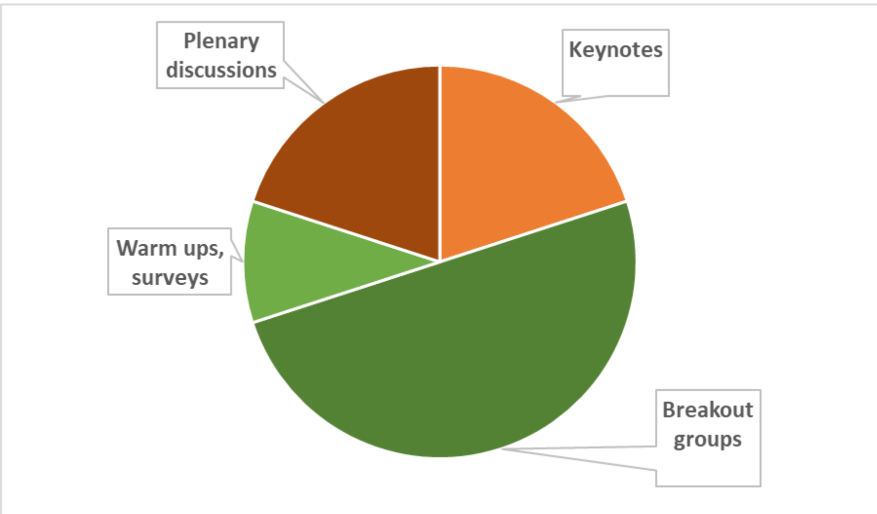

Figure 2: Methodological pillars of the workshop

Source: Own data

3 Workshop Outcomes

3.1 Envisioning the future European agricultural landscape

Workshop participants were asked to envisage a future with thriving agricultural food production and biodiversity, i.e., that maintained the capacity of European agricultural systems to feed the people in Europe but reduced the environmental impact of agricultural food production and enhanced biodiversity. Participants were asked to imagine what farms and agricultural landscapes could look like in the future and how production could be made more sustainable, while taking account of all aspects along the food chain. They were free to express their personal visions without restrictions regarding their realizability; they were not further discussed at this stage nor agreed upon between participants.

Workshop participants worked in three mixed-stakeholder groups to collect first ideas /a list of elements of their visions and collate and cluster them on flipcharts (see Appendix 3.1). The characteristics of the future agricultural systems envisioned by participants are summarised in Table 1 and grouped into five topics: food production and food chain; landscape management; society: farmers, consumers / people; technology; policy and regulation.

This table is a summary of the main elements brought forward by participants (see Appendix 3.1 for all contributions) without being further discussed regarding realizability. The intention was to collate visions of an ideal future agricultural landscape as a basis for the following more elaborate discussions on optimising food production and biodiversity.

Under the topic food production and food chain, farming practices such as crop rotation, the use of modern technology and diverse farming practices, the reduction of animal production and the promotion of mixed farming systems were envisioned as characteristics of more sustainable farming systems. Participants visualised a future offering a diversity of food that was affordable, accessible, and healthy for people; where local production and local markets play a more prominent role in the food supply; and where the import of food (while exporting environmental impacts), especially from outside Europe, is limited. Finally, they envisioned food supply chains that follow sustainability principles (e.g., reduced food waste, packaging and single use plastic).

The future management of the landscape envisioned by workshop participants supported diverse and connected habitats with a variety of landscape features (e.g. fallow land, trees, hedges, heaps of sand and stones) to support biodiversity and buffer zones along rivers to provide transition zones between the aquatic and the terrestrial environment. Agricultural landscapes would be managed to enhance soil biodiversity and functioning. The future management of landscapes would also enhance the resilience of food production and biodiversity to the impacts of climate change by enhancing soil health and connecting diverse habitats.

Under the topic Society: farmers, consumers and people, participants envisioned a future in which farmers were valued for both their contribution to food production and to landscape and biodiversity management. Farmers would have a mixed age range (attract more young people to farming), be rewarded for managing landscapes for biodiversity and receive training in sustainable approaches in production. Consumers would be better informed about food production and the costs of producing food and enhancing biodiversity. Meat consumption would be reduced. Consumers would value food much more and accept certain deficiencies (in the appearance) of their food and strictly reduce food waste. Better knowledge about farming, e.g., by respective education of pupils, will furthermore better connect farmers and society and improve mutual understanding.

Table 1: Elements of future agricultural systems envisioned by the participants (no ranking)

Food production **Food chain**	**Landscape management**	**Society: farmers, consumers and people**	**Technology**	**Policy and regulation**
Sustainable production approaches	Diverse and connected landscape with different habitats; landscape mosaic and variety to support / enable biodiversity	Value farmers for production and management of the landscape	Useful innovation such as e.g., drones, robots, solar energy	No effects on off crop areas; unavoidable effects restricted to the farmland
Diversity in farming practises Crop rotation Diversity in products	Variety of landscape features, (e.g., hedgerows, more trees, perennial and companion plants, refugees / biodiv. hot spots)	People enjoying the agricultural landscape; "healthy families going to and working on farms to produce healthy food"	Precision application to reduce environmental exposure	Rewarding farmers for safety of food
Agriculture equipped with modern technology	Rivers with huge buffer zones	Improving advice services to farmers and education	Reduced input of PPP and nutrients	Rewarding of farmers for diverse landscape management
Mixed farming production (animals/diverse crops, agro-forestry); cows back outside on their meadows	Managed to enhance resilience	Rewarding farmers for land management	Suitable technology for smaller fields, patchy agriculture	Diverse rules in Europe and outside, implications for products
Less animal production	Healthy soil to support soil functions	Contact between consumers and farmers, informed consumer	Technology to better integrate biodiversity in agricultural production	Policies have changed and farmers may get paid for other services than food provisioning.
Local / regional production, markets, and traceability to production site	Nature in off-crop areas and separated areas for nature conservation; wilderness areas	Reduce meat consumption; consumers value food and accept imperfections	Plant breeding for more adaptable varieties	
Production not subsidised	Ability to adapt to climate changes	No underpaid work in agriculture		
"Zero" food waste; reduced packaging	Don't disconnect nature and cities	More young farmers farming		
Food security: Affordable, accessible, and healthy food		Sensitising production, talking to farmers, eating fruits from trees		
Wide range of foods available. Avoid food imports		Sensitising nature, birds, and bees etc.		

Under the topic Technology, participants envisioned a future where technology was an important component of farming. They envisioned a greater use of non-fossil fuels (solar energy) and sophisticated technologies such as robots, sensors, aerial images, GPS technology. They visualised farms where precision agriculture and robotic systems were widely used, reducing the input and impact of chemicals (fertilisers, crop protection products, energy) and where plant breeding resulted in more resistant/resilient crops for production.

Under the topic Policy and regulation, participants envisaged a farming system where farmers were rewarded for the safety of production and diverse landscape management. They also envisaged a future in which regulations were simple and harmonised across Europe.

In summary, workshop participants envisioned a more diverse and sustainable food system that utilised advanced technology to reduce inputs, minimise environmental impacts and reduce food waste. They were looking for a more diverse and connected agricultural landscape that supported biodiversity, enhanced soil health and maintained food production. People would value food much more than today (e.g., accept higher food prices and reduce its waste), and there would be a greater awareness and appreciation of the contribution of farmers to both food production and biodiversity enhancement. Farmers would receive financial rewards for managing landscapes sustainably and would be well supported by advisors and trained in new methods. They would market their products largely locally/regionally, and food imports from outside Europe would be reduced.

3.2 Biodiversity and Agriculture

Keynote presentation by Prof. Dr. Jens Dauber
Thünen Institute of Biodiversity, Braunschweig, Germany

The aim of this introductory paper is to stimulate the thinking and discussion about the relationship between biodiversity and agriculture in the light of the workshops' topic "Optimising agricultural food production and biodiversity in European landscapes". The "and" in the title was deliberately chosen as a neutral connection between the two terms standing in the spotlight of this workshop to suggest an open-minded approach to achieving the goals of this workshop. As a matter of fact, the relationship between biodiversity and agriculture is all but neutral, but very different perceptions exist on whether this relationship is supporting, destructive or mutual.

Depending on the respective perception of the relationship, one could argue that an optimization of food production in an area may only be achieved if biodiversity would be conserved somewhere else, or vice versa, that biodiversity could only effectively be preserved outside of agricultural landscapes by conserving and creating natural habitats. Others may argue that biodiversity is a prerequisite of agricultural food production. Following this perspective, mainstreaming of biodiversity across agriculture and food production would have to be accomplished, because biodiversity includes components that are essential for feeding human populations and improving health and the quality of life (FAO 2021, WHO 2020). The variety and variability of ecosystems, animals, plants and micro-organisms, at the genetic, species and ecosystem levels, are perceived necessary to sustain human life as well as the key functions of (agro-)ecosystems (FAO 2019). If this is true, one may wonder how many agricultural production systems can still afford creating conditions on agricultural fields and in agricultural landscapes that are responsible for alarming losses of biodiversity in those landscapes (IPBES 2019).

These apparent discrepancies in the perception of biodiversity and agriculture are rooted in a broad spectrum of conceptions of what biodiversity actually is and of the functioning and efficiency of agricultural food production. Too narrow views, both on the complex concept of biodiversity and the complex system of agriculture often result in drawing lines of demarcation and hamper constructive exchange of ideas on an optimization of both. Over the last decades, the perception of nature and the goals of nature conservation as well as the ideas about the connection of nature and people was in flux (Mace 2014): before the 1960s nature conservation prioritised wilderness and intact natural habitats, generally perceived without people but thinking "nature for itself". The focus of conservation action was on species conservation and protected area management, which is still a dominant type of action and thinking today. The increasing awareness of the consequences of environmental pollution, habitat destruction and overharvesting in the 1970s and 1980s, led to the development of a "nature despite people" thinking in conservation with a focus on threats to species and habitats from human activities, and hence on strategies to reverse or reduce their impacts. That most of those strategies and endeavours had largely failed, because species extinction rates were escalating, pressures on habitats and biodiversity were ubiquitous and increasing, became evident by the late 1990s. During that time, and stimulated by the Millennium Ecosystem Assessment (2005), it was recognized that nature provides crucial goods and services for people and human wellbeing. Accordingly, the focus of conservation actions shifted from species and habitats to whole ecosystems. Conservation thinking moved toward "nature for people", and providing ecosystem goods and services through integrated ecosystem management to sustainably benefit people became its focus. In the most recent years, the perception has again moved from "nature for people" toward "people and nature" with the latter perspective putting less emphasis on managing nature to maximise the overall value of the human condition but more on the dynamic relationships between people and nature within socio-ecological systems. These developments have not resulted in a replacement of the respective views and motives over this time period but in a pluralism of perceptions that now underpin various framings of conservation that sometimes result in mutually supportive implementations, but sometimes cause tensions and frictions (Mace 2014). Hence, it may be helpful to keep this pluralism in mind when taking a closer look at the concept of biodiversity and from there develop some ideas on how different components of biodiversity may connect to agricultural food production.

The natural science-based definition of biodiversity as applied for the Rio convention on biodiversity (United Nations 1992) is already complex, covering several components and organisational levels of biodiversity:

“Biological diversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems”. The three main objectives of the Convention on Biological Diversity are i) the conservation of biological diversity, ii) the sustainable use of the components of biological diversity and iii) the fair and equitable sharing of the benefits arising out of the utilisation of genetic resources. These show that the thinking of “nature for people” had already entered the convention and had resulted in a politicised and economised concept of biodiversity, going beyond the conservation of its respective components toward the utilisation of biodiversity as a resource for human needs. This socio-economically expanded understanding of biodiversity was paving the way for paradigms such as natural capital (TEEB 2018), bioeconomy (European Commission 2012) and ecological intensification (Bommarco et al. 2013).

In order to handle this complex concept of biodiversity for our respective purposes of either nature conservation or accounting of natural capital, it may be useful to create a model kit of the natural science and socio-economic components of biodiversity (Figure 3). The components or building blocks of the model kit do of course overlap, interlock and interact with one another but isolating them mentally makes it possible to select those single or multiple components (or building blocks) from the kit that fit for our particular purpose most. The isolation is partly artificial, but may allow us to meet a particular challenge without being overstrained by the overall complexity of the concept. At the same time, the model kit reminds us that the building blocks we are dealing with are part of a larger construction which may lose its integrity if individual blocks were oversized or forgotten.

The model kit approach of course does not solve the problem that trade-offs exist between conservation and utilising biodiversity. In particular in the context of agriculture, win-win situations are difficult to achieve and different targets may have to be set for achieving the distinct goals of conserving biodiversity for its own sake and conserving it to safeguard ecosystem services (Purvis 2020). Ideally, the setting of targets would also consider the features of the respective agricultural system and landscape which could be highly distinct, inter alia depending on soil and climatic conditions, topography, remoteness to markets, regional farm sizes, production targets and specialisation of farming. Regional targeting and adaptive management of conservation tools are suggested for optimising biodiversity conservation in European agriculture (Conception et al. 2020). A targeted spatial allocation of biodiversity conservation schemes and ecosystem service schemes, based on where they are needed most in order to either meet the goals of protecting biodiversity per se or promoting environmentally sustainable agriculture may achieve much more effective schemes in the future (Ekroos et al. 2014). Where exactly which type of scheme would best be allocated of course remains a matter of debate and depends on whether regionalised goals for biodiversity and agricultural production can be agreed on by the relevant actors. Here, a simplistic, conceptual model is presented which may facilitate the debate and understanding of the usefulness of regionally targeted approaches to the optimisation of food production and conservation and utilisation of biodiversity (Figure 4).

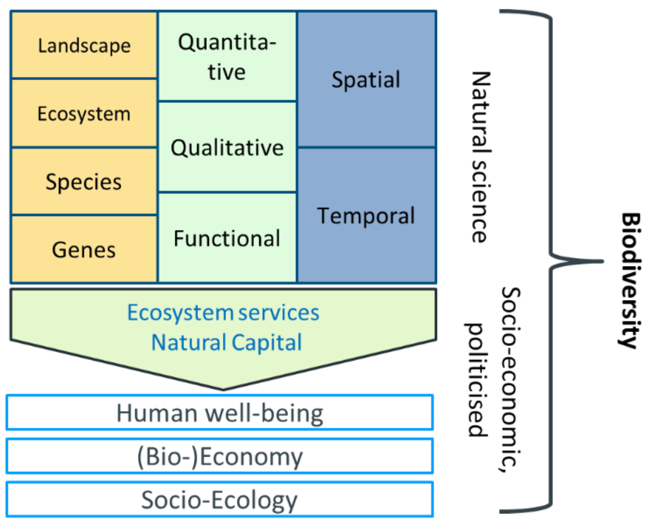

Figure 3: Model kit of the concept of biodiversity.

The natural science block of the concept contains the organisation levels of biodiversity from genes to the landscape which can be described from quantitative, qualitative and functional perspectives both in space and time. The socio-economic 'extension set' of the concept contains the components of biodiversity which are linked to the safeguarding and harnessing of ecosystem services by society and economy.

Source: Jens Dauber

This conceptual model shows an operating space for optimization strategies for biodiversity and food production in agricultural landscapes which is large enough to accommodate targeted schemes with a focus either on biodiversity conservation (upper left area within the operational space, Figure 4) or schemes for ecological intensification based on supporting ecosystem services (lower right area within the operational space, Figure 4).

Moving away from a place located on the white curve (Figure 4) towards an optimised situation within the operating space requires following a "socially-desirable pathway" (Brussaard et al. 2010). However, there is probably not one universal pathway, or optimization strategy, that would effectively lead to every target area within the operating space. Laying an effective pathway would require a thorough analysis of the conditions at the starting location and a clear understanding and description of the objectives of optimization or transformation. How this may apply for some of the existing strategies of nature conservation in agricultural landscapes and approaches to sustainable agriculture (Oberč and Arroyo Schnell 2020) is visualised in Figure 5. Here, the building blocks of the biodiversity model kit (Figure 3) are used to show which of the components of biodiversity are in the main focus of which of the approaches (Figure 5). Those strategies listed on the left-hand side of the diagram are originating from more nature conservation-based foci, following mainly objectives of segregating land from conservation purposes from land used for agricultural production. Those strategies listed on the right-hand side of the diagram are originating from foci of harnessing biodiversity and in particular ecosystem services for agricultural production. Looking at the whole picture, however, we see that the whole model kit and hence the concept of biodiversity as a whole is required to lay potential pathways and to make use of the full potential for optimization within the operational space (Figure 5). So, taking the variety and variability of agricultural landscapes and agricultural production systems at a national or pan-national scale into account, landscape-targeted approaches could support effective optimization of biodiversity and food production and achieve the distinct goals of conserving biodiversity for its own sake and conserving it to safeguard ecosystem services for and beyond food production. It only would have to be accepted that not each goal may be achievable in each landscape or production system.

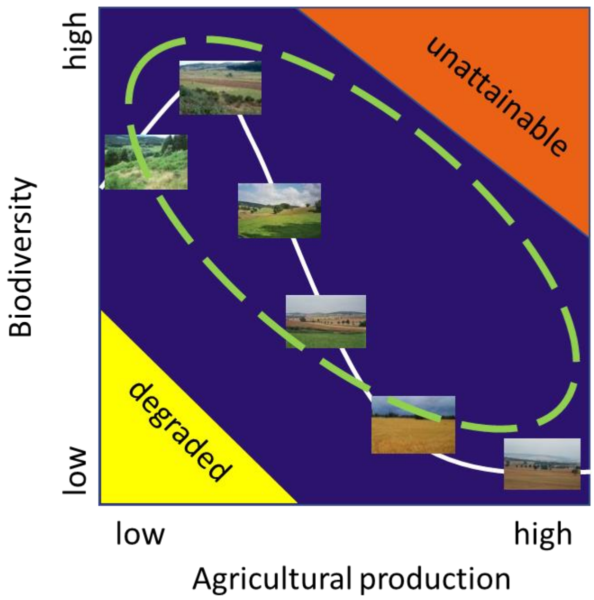

Figure 4: Schematic model of the relationship between biodiversity and agricultural production.

The area in orange at the top right is considered unattainable, since combinations of very intensive use with a high biodiversity value can hardly be realised in practice (compare Brussaard et al. 2010, WBGU 2021). The yellow area symbolises degraded landscapes of low productivity and low levels of biodiversity. The white curve schematically depicts the relationship between biodiversity and agricultural production in European agricultural landscapes under current land use and land management. Along this curve, pictures of typical agricultural landscapes are placed. The area inside the green broken line symbolises the area in which goals for biodiversity and food production may best be set. It is the operational space for optimization strategies for biodiversity and food production.

Source: Jens Dauber

Originating from the white curve, depicting the biodiversity-production relationship, and hence different agricultural landscapes, are green arrows which are symbolising potential desirable pathways leading to target areas within the operating space for optimization (Figure 5). The target areas are linked to different existing approaches or strategies. It is not the intention of this conceptual model (Figure 5) to suggest that the respective pathways would inevitably lead towards the target areas and the transformed biodiversity-production relationships within those areas. The different green arrows and areas rather point up the variety of pathways that may be developed for the transformation of the current situation. Starting from the same point of origin, the pathways could lead to different target areas with different biodiversity-production relationships, depending on which of the respective components of biodiversity are forming the objectives of biodiversity conservation and/or utilisation (Figure 5). It should also show that it may be much more difficult to reach a target area of high nature conservation value from a location of high productivity without considerably compromising the level of yield. By taking biodiversity into account as a resource for agricultural production, sustaining or even increasing yields may become achievable without compromising the level of biodiversity (e.g. in ecological intensification or crop diversification).

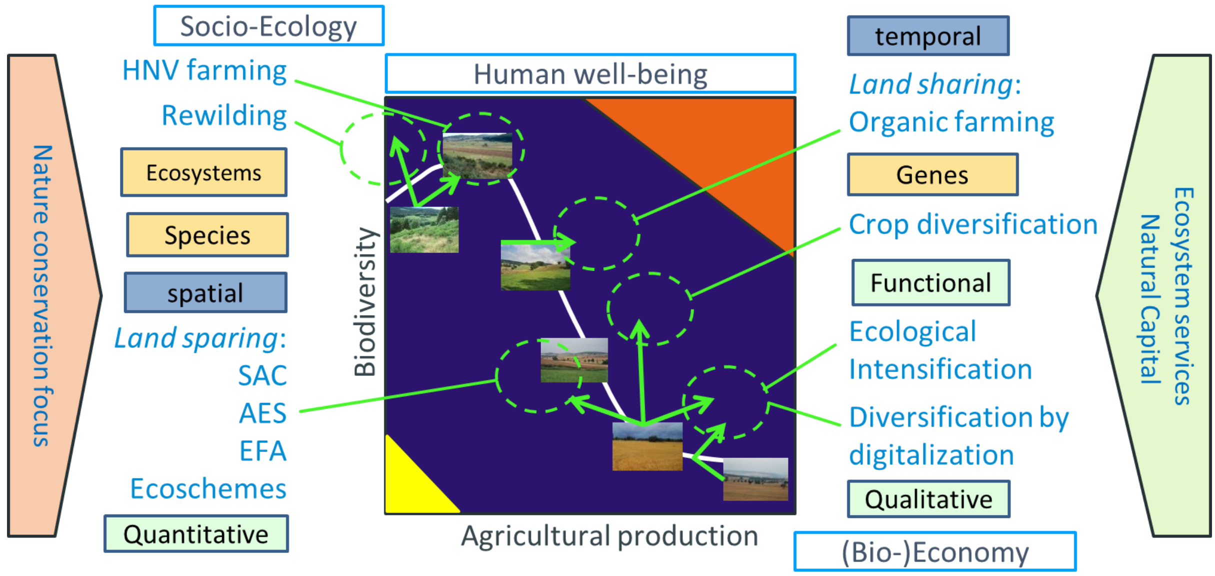

Figure 5: Target areas and pathways for the development of biodiversity and agricultural production.

The model depicts a variety of target areas (within the green broken lines) and the respective pathways (green arrows) of transformative approaches and actions connecting the current biodiversity-production relationship in agricultural landscapes (white curve) with the target areas. The target areas are connected to existing strategies and approaches. Those strategies listed on the left-hand side of the diagram are originating from more nature conservation-based foci, following mainly objectives of segregating land from conservation purposes from land used for agricultural production. Those strategies listed on the right-hand side of the diagram are originating from foci of harnessing biodiversity and in particular ecosystem services for agricultural production. The "building blocks" of the biodiversity model kit (Figure 3) are located closely to the respective strategies they are most tightly fitting to. SAC: special areas of conservation; AES: agri-environment schemes; EFA: ecological focus areas.

Source: Jens Dauber

At the lower right end of the white curve (Figure 5), concepts from bioeconomy may be applicable to foster crop diversification (Lichtenberg et al. 2017), ecological intensification (Bommarco et al. 2013) and digitalization of agricultural production (Basso and Antle 2020). At the upper left end of the curve, around the optimum of farmland biodiversity (EEA 2004), rural development for stabilising the social part of the socio-ecological farming systems may be required for preventing either abandonment or intensification of the production system, both resulting in loss of biodiversity (Fischer et al. 2012, Lomba et al. 2020).

In conclusion, it has been shown that the concept of biodiversity is much larger than "species richness" and that nature conservation can only provide partial solutions for solving the problem of biodiversity decline in agricultural landscapes. Those partial solutions are nevertheless essential for particular agroecosystems and landscapes of high nature value. Applying the perspective of "people and nature" (Mace 2014), sustaining nature's contributions to people will require targets around both the management of agricultural landscapes for resilient multifunctionality, in which biodiversity may play an essential role as resource for optimised agricultural production, and the conservation and restoration of natural ecosystems for the own sake of biodiversity (Purvis 2020). Targeted strategies and approaches are required which consider the characteristics of agricultural landscapes and the productivity of agricultural food production together with the potentials of transformation of those production systems towards sustainability (Sietz et al. 2022). But also, priority levels of biodiversity conservation issues have to be clearly stated and agreed on for designing pathways towards optimised biodiversity and food production. The diversity of agricultural landscapes and production systems makes it possible to discuss target areas and pathways for future optimised systems by using the best fitting "building blocks" of biodiversity for the respective concept, without risking the loss of some of the other "building blocks", at least when applying a national or pan-national view on biodiversity conservation and sustainable use in agricultural landscapes.

3.3 Identifying and reconciling different perspectives on food production and biodiversity

3.3.1 Polarity mapping

Addressing the challenge of complex environmental problems such as how to optimise food production and biodiversity in agricultural landscapes requires all stakeholders to work together towards a common goal. Whereas there was considerable agreement amongst workshop participants (i.e. a diverse range of stakeholders) on the characteristics of a future European landscape that optimises biodiversity and food production (compare chapter 3.1), there were different perspectives on exactly what an optimal solution should look like and how it may be achieved. To move the discussion forward, these different perspectives need to be explored in more detail so that we can begin to try and reconcile them. Agricultural production and biodiversity can be perceived as a polarity pair, as they are alternative possibilities that exist in tension with each other. Polarity mapping is a participatory approach that uses a visual framework to identify the upsides (positives, benefits) and downsides (negatives, costs) of focussing on each pole to the neglect of the other. The output is used to facilitate discussion aimed at reconciling different perspectives (Johnson 2014).

The visual framework used in the workshop is illustrated in Figure 6. The infinity symbol visalises the interdependencies between the two poles of agricultural food production and biodiversity. Managing agricultural landscapes just for food production may have several benefits (quadrant 1) but overemphasis on food production without considering effects on biodiversity may result in several downsides (quadrant 2). Managing agricultural landscapes for biodiversity may bring several benefits (quadrant 3), which may offset some of the downsides identified in quadrant 2. However, overemphasis on biodiversity without considering the effect on agricultural food productions may have downsides (quadrant 4), which may be offset by some of the upsides identified in quadrant 1.

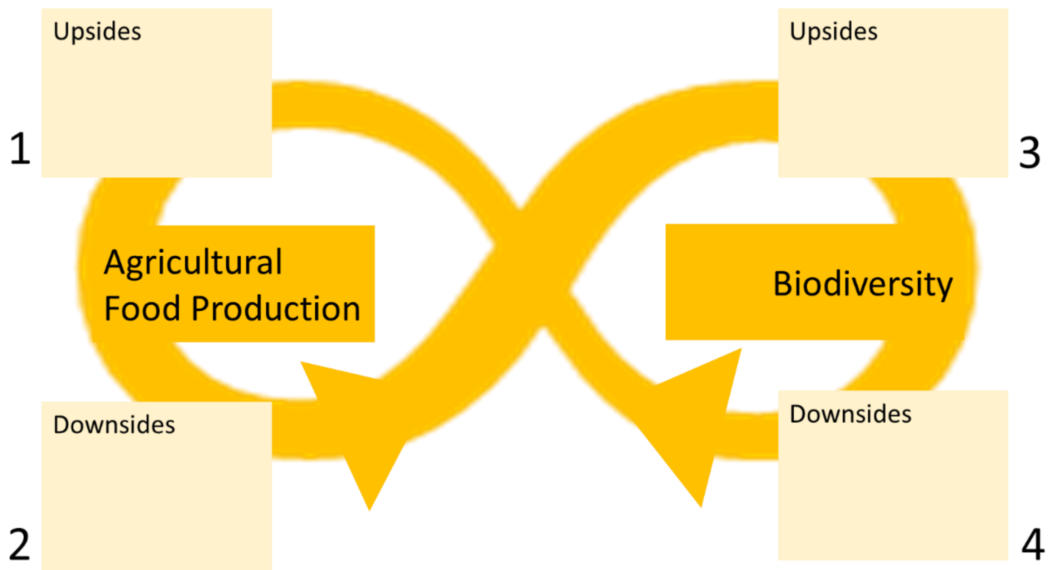

Figure 6: Polarity mapping framework.

The framework was used to collect stakeholder perspectives of managing European agricultural landscapes for agricultural food production or for biodiversity. Agricultural food production and biodiversity are identified as two poles, each of which have upsides (quadrants 1 and 3) and downsides (quadrants 2 and 4).

Source: Own presentation

Working in small mixed-stakeholder groups, workshop participants worked through the framework one quadrant at a time. They were asked for their perspectives on the upsides and then for their perspectives on the downsides of managing agricultural landscapes just for agricultural production or just for biodiversity. All perspectives were recorded (Appendix 3.2) and are summarized in Table A. It should be noted that participants were not asked to provide evidence to support their perspectives, which should therefore be treated as opinions that reflect their perception of the question, and not as factual statements. The main purpose of this exercise was to enable all stakeholders to record their perspectives, irrespective of whether other people agreed with them or not. All perspectives were respected and recorded, and no attempt was made to reach consensus at this mapping stage. Many of the possible upsides and downsides identified are context dependent and will not occur in all situations.

Table 2: Examples from polarity mapping exercise.

		Focus on agricultural production	**Focus on biodiversity**
Upsides	Food	Affordable, healthy accessible food; fewer food imports; more standardization.	Increased wild foods; increased crop diversity; potentially increased yield/quality for some crops.
	Environment	More productive land resulting in less land for agriculture and more land for nature.	More diverse landscapes; more resilient ecosystems; increased ecosystem services, enhanced environmental quality.
	Socio-economic	Increased efficiency, profitability & investment; increased attractiveness of agricultural jobs.	Increased visitors, employment & connectivity; reduced inputs and associated costs; higher social valuation of farming and farmers.
Downsides	Food	Overproduction and increased food waste; less resilient food systems; increase reliance on inputs (chemicals, energy, water).	Reduced food diversity; reductions in food quality/aesthetics; increased food prices/imports.
	Environment	Loss of habitat and habitat diversity; reduced resilience; unbalanced ecosystem services.	Land abandonment; less desirable biodiversity (e.g., increased pests, invasive species); off-shoring of environmental impacts.
	Socio-economic	Loss of small/local farming; reduced job opportunities; disconnecting farming from the general public.	Reduced farmer income and loss of competitiveness of the EU Agricultural sector; increased subsidies or payment for public services; risk of food poverty.

Full details are provided in Appendix 3.2. Example upsides/downsides are grouped into one of three categories: food, environment or socio-economic issues.

The polarity mapping identified issues related to food production, issues related to the environment and issues related to socio-economics (Table 2). The upsides of a focus on agricultural production may include affordable, healthy and accessible food and fewer food imports as a greater diversity and abundance of food can be produced within Europe. Because land is managed for higher yields, the total amount of land needed for food production may decrease, resulting in more land being available for other uses including nature conservation. Increased focus on food production may make farming more efficient and profitable thereby resulting in more investment and employment (direct and indirect).

However, an overemphasis on managing agricultural landscapes for food production may be associated with several downsides. These included overproduction and consequently greater food waste, and food systems that are less resilient to additional pressures, including the impacts of climate change. Reduction in the size or the diversity of off-crop habitats may result in reduced ecological resilience, reduced biodiversity and unbalanced ecosystem services. An overemphasis on food production may result in the loss of small/local farms as they are outcompeted by larger more intensive farms. Intensification may also result in increased inputs of water, chemical and energy, which may increase costs and exacerbate environmental impacts (e.g., pollution, climate change). Finally, an increase in the use of technology may result in lower manpower needs and therefore reduced employment on the farm with subsequent impacts on the local economy.

A focus on biodiversity may address some of the downsides associated with an overemphasis on food production. The upsides of a focus on biodiversity may include increased crop diversity, increased yield and quality for some crops, and increased wild foods. More diverse landscapes may result in more resilient ecosystems, increased ecosystem services and enhanced environmental quality. Because the environment is more attractive, more people may want to visit it, which may increase employment and increase connectivity between people and the agricultural landscape. The increased ecosystem services may reduce the need for additional inputs of energy and chemicals.

However, an overemphasis on managing agricultural landscapes for biodiversity may be associated with several downsides, which may include a reduction in food diversity, either because of the inability to support the current diversity of crops grown in Europe or if we do produce them, they may be more expensive pushing up food process or increasing food imports. Increased biodiversity may be associated with increased pest/disease pressures and farms may become less profitable. If farms are less profitable and reduced farmer income is not offset by increased subsidies or other incentives, farms may be abandoned, with consequent impacts on the local economy and the sustainability of rural communities.

3.3.2 Reconciling different perspectives

Optimising food production and biodiversity in agricultural landscapes requires reconciling the upsides and minimising the downsides identified in the polarity mapping. Workshop participants were tasked with considering how to reconcile the tensions identified in the polarity mapping from the perspective of different stakeholders: farmers, industry, governments, NGOs, scientists (Figure 7).

Six themes emerged from the reconciliation discussion: communication, education, collaboration, integration, application and incentivisation.

There is a need for open and honest communication that seeks to reconcile different views rather than polarise them. For example, rather adopting either a land sharing or a land sparing standpoint, consider whether a combination of land sharing and land sparing approaches could help optimise agricultural food production and biodiversity (e.g. Feniuk et al. 2019, Grass et al. 2020). The discussions during this workshop are part of that communication process, but they need to continue and workshop recommendations tailored to each stakeholder group, may facilitate this process. There is also a need for increased communication with consumers so that they understand the ‘value of food’ and the costs and benefits of enhancing biodiversity in agricultural landscapes.

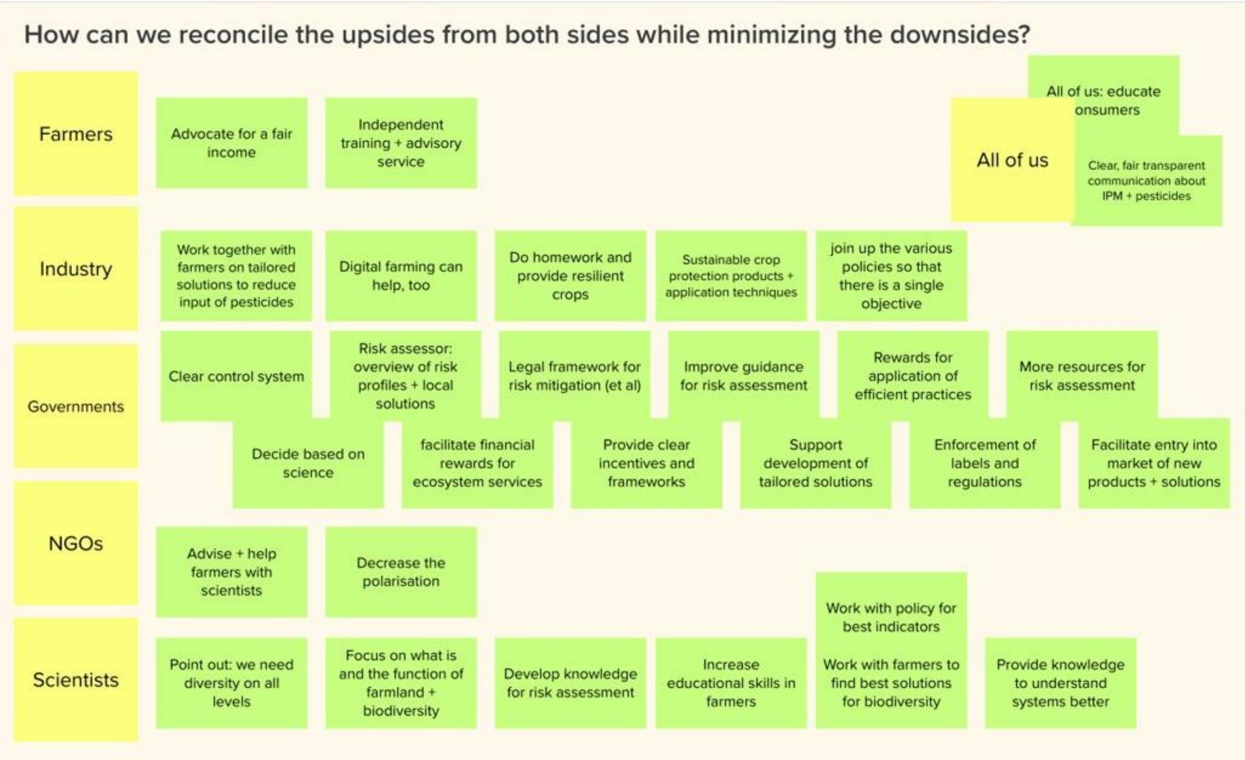

Figure 7: **What could different stakeholder groups do to help reconcile the upsides of agricultural food production and biodiversity whilst minimising their downsides?**

Source: Own data

To make informed decisions, farmers and consumers need to have a better understanding of the pros and cons of different approaches to managing agricultural landscapes and how to apply best practice. Optimising biodiversity and agricultural production is a complex problem and it is important to avoid oversimplification. What is required are targeted solutions that are fit-for-purpose. Many individual approaches for reconciling food production and biodiversity are already available and some examples of good practice exist (see 3.8.3. and Keynotes 3.2, 3.5, 3.6, 3.7). However, training and advisory services are required to ensure that farmers and consumers can benefit from the approaches available and that solutions are tailored to local conditions and specific needs.

Collaboration is essential if we are to move forward as all stakeholders need to work together to deliver change and sustainable solutions. For example, by collaborating with farmers and using ‘living labs’ to implement a variety of approaches and monitor their effectiveness in real farm situations, we will gain an understanding of their feasibility at larger scales, the importance of local context and the barriers to sustained change.

Sustainable solutions will require a whole system approach that combines a suite of in field, on farm and off farm approaches and which takes the socio-economic context into consideration. This will require managing landscapes and therefore we need to have integration across different regulations/policies. This not only includes regulations that deal with pesticides, habitats (e.g. Water Framework Directive) and species (e.g. Birds Directives), but it includes all policies and regulations that have an influence on how landscapes are managed and are impacted by anthropogenic activities. To move forward we therefore need to have an integrated approach across relevant policies so they are working towards a common objective, and they are not in potential conflict.

Future solutions will require the application of new technologies and the tailoring of existing knowledge to develop effective solutions. There is not one solution that is applicable everywhere. Rather we need to understand what works best where. This will require regulations flexible enough to enable tailored solutions and to facilitate the entry into market of new products and solutions (e.g.: more resilient crops, digital farming technologies, sustainable crop protection products and applications).

Changing the way we manage agricultural landscapes in Europe will cost money, whether that is to invest in new technologies, to change crops and livestock or to alter farm and land management practices. If farmers are going to change what they are doing they need to be incentivised. That may mean having public money for public goods (e.g., payment for ecosystem services) and fair food prices.

Workshop participants were clear that, under certain circumstances, agriculture can benefit from biodiversity and under certain circumstances biodiversity can benefit from agriculture. Therefore, when considering how to optimise food production and biodiversity in agricultural landscapes, it is not 'either food production or biodiversity' but 'food production and biodiversity'. However, achieving sustainable food production and enhanced biodiversity requires a collective effort. Different stakeholders need to work together, and farmers have a key role to play.

3.3.3 Inventory of approaches

Workshop participants were invited to share their references to "*approaches and tools, which may be promising with respect to achieving the overall target of safeguarding the necessary level of efficient food production while improving the biodiversity in agricultural landscapes*". These approaches and tools are defined as methods, practices and technologies used in agricultural production. They encompass both holistic whole-farm philosophies, such as agroecology or Integrated pest Management (IPM) and Integrated Crop Management (ICM), as well as specific practices such as uncultivated field margins, no-till cropping, and crop rotation (Figure 8).

The approaches listed in Figure 8 enter into broader categories, such as **landscape diversification**, meaning diversification of land use beyond the cultivated area, **crop diversification**, where there is an evolution from monoculture toward diversification in space, in the rotations and within the crops themselves, and **agricultural practices**, which regroup the management of field margins, of pesticide inputs, cultural practices, the introduction of integrated crop/pest management tools or agroecology principles.

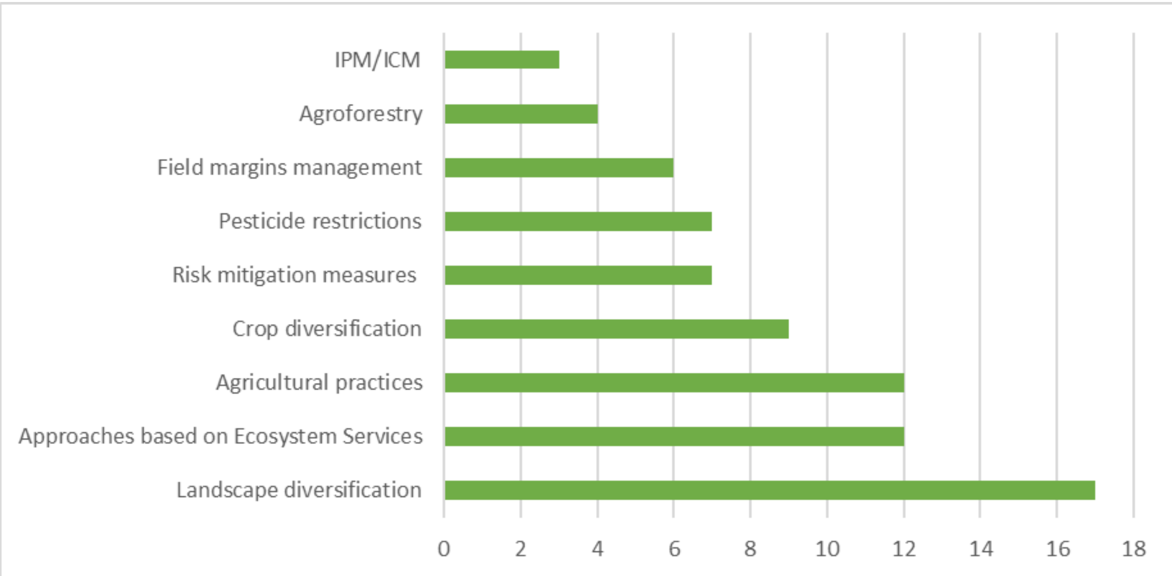

Figure 8: Number of contributions received per type of approaches and tool.

Some contributions covered multiple approaches, each count reflects one entry addressing the use of a particular approach.

Source: Own data

The category of approaches receiving the most contributions was landscape diversity. Previous reviews and inventories have highlighted the importance of implementing approaches that benefit biodiversity at the landscape scale to observe greater results and more sustainable results (Alix et al. 2017, Garnett 2020). It is therefore not surprising that **landscape diversification** has become a well described field of research. Besides the inventories referred to above, reviews have described the positive effects of Agro-Environmental Schemes (AES) when implemented at the landscape scale (Dicks et al. 2014, Emery and Franks 2012, Grass et al. 2016). AES are a policy tool that support farmers implementing wildlife and environmental beneficial measures, such as connecting habitats, field margins, set asides, wetlands and meadows, implemented alone or in combination but most importantly, at landscape scale (Science for Environment Policy 2017). Benefits are reported at all trophic levels (Alix et al. 2017) and examples were provided for carabids and pollinators (Aguilera et al. 2020, Scheper et al. 2013), but also on a range of Ecosystem Services (Tamburini et al. 2020, Tscharntke et al. 2005) crop production systems (Abdelmagied and Mpheshea 2020, Dauber and Miyake 2016, Lomba et al. 2020, Schulte et al. 2017). Connectivity is a key aspect of landscape-scale implemented measures (Grass et al. 2019) and adds to the benefits of balanced land sparing and land sharing approaches for optimized results (Grass et al. 2020a and 2020b).

Crop diversification, that involves diversifying production systems in space and time (rotations) is also part of landscape diversification and contributes towards input (i.e. fertilizer and nutriments management), soil structure management, habitat and ecosystem services diversification, land management distribution over time and a diversification of economic income (Abdelmagied and Mpheshea 2020, Aguilera et al. 2020, Dauber and Miyake 2016, Grass et al. 2020a, Lomba et al. 2020, Tamburini et al. 2020, Tscharntke et al. 2005, Bohan and Vanbergen 2020). **Agroforestry**, in (re)introducing trees on the cultivated land, also belongs to crop diversification).

Agricultural practices gather a range of approaches that can improve biodiversity and services at farm scale (Dicks et al. 2014), some of which already benefit from policy support (Abdelmagied and Mpheshea 2020, EC 2020, Oberč and Arroyo Schnell 2020). These practices encompass soil and water management practices, **pesticide restrictions** (Bock et al. 2020, ELO 2020, EP 2019, Lee et al. 2019) with the use of available crop protection alternatives in Integrated Pest / Crop Management programs (Ducrot et al. 2020, EP 2019, Oberč and Arroyo Schnell 2020), farmland management with an emphasis on field margins that provide habitat, ecosystem services, soil and water management, and pesticide transfer mitigation and risk mitigation, such as **field margins management** (Alix et al. 2017, CropLife Europe 2020, Dicks et al. 2014, Grass et al. 2016, Hackett and Lawrence 2014, Hötker et al. 2018, Jahn et al. 2014). **Agroecology** relies on the application of ecological concepts to support agriculture and involves technologies/practices that contribute to protecting biodiversity (e.g. agronomic practices, precision agriculture, plant breeding, exploration of new crop plants / rediscovery of forgotten plants/varieties, risk mitigation). Finally, holistic approaches that include the provision of **ecosystem services** have also proved to be successful at identifying beneficial actions towards biodiversity and services in productive systems (Abdelmagied and Mpheshea 2020, Ducrot et al. 2020, Ekroos et al. 2014, Grass et al. 2020a, Lomba et al. 2020, Tamburini et al. 2020, Tscharntke et al. 2005, Bohan and Vanbergen 2020).

Besides agronomic practices and policy related actions implemented in individual farms or in farm networks projects, the input received also reflected the importance of education and knowledge tools to achieve measurable results on biodiversity metrics. In particular, the following actions and approaches were provided:

- Increasing knowledge/skills to enhance awareness of tools, technology and management (e.g. training courses, extension services, farm-2-farm exchanges, demonstration trials and farms, farm visits).
- Projects involving farms/farmers aiming at introducing biodiversity/environment friendly methods / practices (e.g. research or pilot projects, description, monitoring and results, good practices).
- Educational tools to raise the public's awareness of agriculture and biodiversity issues (e.g. public and private initiatives, school and university programs).
- Farming models illustrating holistic approaches to assess the input and outcome of different growing models for crop production and biodiversity (e.g. ecosystem services studies, IPM implementation studies).

3.4 Possible next steps from a stakeholder viewpoint

This workshop series brought together members of different farmer organisations, crop protection and seed industry, academia, regulators and managers from seven European Member States and the UK, the EFSA and the European Commission and Non-Governmental Organisations. Each participant brought a unique perspective resulting from their individual professional background and the aim of the workshop was to draw on this diversity of perspectives to jointly identify solutions to optimise biodiversity and agricultural production. Focused discussions were organised to capture the range of stakeholder perspectives and to consider the specific contributions that different stakeholders could provide to identifying solutions.

In the polarisation exercise, discussions focused on how to reconcile the upsides of biodiversity and agricultural production while minimising the downsides (see also chapter 3.3 and specifically the Figure 7). In this exercise, participants were asked to identify signs that the situation was evolving in the right direction, to identify obstacles to desired change, and to list the possible next steps that would contribute to making the desired change possible. All participants were then asked to jointly consider the obstacles to desired change from the perspective of each stakeholder group in turn. The purpose was to jointly identify specific steps for each stakeholder group that would, in combination with steps identified from each other stakeholder group, contribute to the overarching optimisation goal to improve biodiversity while ensuring safe and efficient food production.

Below a selection of possible next steps is presented:

Farmers:

- Establish peer to peer communication and learning between farmers

Industry:

- Produce data that support the use of new technology (e.g. new application techniques, support to precision applications), new risk mitigation measures, in collaboration with regulators
- Improve availability to new technology also for small farms
- Produce toolboxes to communicate biodiversity and IPM aspects to farmers by the salesforces (e.g., applications on smartphones)
- Support conservation initiatives

Policy/regulators:

- Improve management of communal land also by better training of the staff
- Provide resources and a framework for good independent advisory extension services also on biodiversity issues
- Improve consistency between the different policy frameworks
- Create platforms for exchange between farm networks and scientists

Academia:

- Promote citizen science and the collection of meaningful data
- Engage farmers on ideation and execution phase of research
- Involve farmers in research for sustainable transformations and concentrate research on feasible solutions rather than pure scientific purposes.
- Improve transparency of funding and other support for research

Consumers:

- Reduce food waste
- Readiness to pay extra for biodiversity enhancements
- Improved awareness of agricultural production
- Better early education on agriculture
- Use the power of democratic processes

The complete slide set is presented in the appendices (Appendix 3.3).

3.5 Optimising agriculture and biodiversity: how this works in practice - a farmer's view

Keynote presentation by Dr. Thomas Gäbert
agt Trebbin eG, D-14959 Trebbin, Germany

The Agrargenossenschaft Trebbin eG (farmers' cooperative) is an agricultural company located south of Berlin cultivating almost 4000 hectares of land. Due to its cooperative structure, the focus is on the permanent preservation of jobs in agricultural production and rural areas. Additionally, the preservation and enhancement of our cultural landscape are operational goals as a basis for production as well as a natural habitat. Beside social and ecological sustainability, economic sustainability in the form of profit realisation and development of new business segments is the basis for the long-term existence of the company.

On this basis and over 30 years a company has been evolved that successfully farms its own land, offers a wide range of agricultural services to third parties and keeps almost 950 dairy cows and the corresponding offspring (Figure 9). Additionally, it offers an extensive range of workshop offers for agricultural machinery, commercial vehicles and construction machinery, rental and sale of construction machinery, sandblasting and varnishing for vehicles and facilities, gas station with garage, janitor service as well as a hotel with a public canteen and catering service. All these departments represent an effective diversification of the company to partly smoothen the large volatility in agriculture.

However, the central activity of the company is agriculture where agricultural land of about 2800 ha of arable land and 1150 ha of grassland are the basis. The average soil quality rating is "23" (corresponding to the lowest 5th part of the German soil assessment rating scale), and about 80% of all land are sandy to slightly loamy sands with no connection to groundwater. For this reason, the distribution of the precipitation (long-term average of 534 mm) is of major importance. The long-term average air temperature is 9,7 °C. The neighbouring teaching and research station of the Humboldt University, Berlin, determined a continuous increase in temperature of around 0,4 °C/ 10a since 1960.

Figure 9: Insight into the dairy cattle and calf stable

Source: Thomas Gäbert

While 2017 the distribution of the precipitation fitted the plants needs it was severely below their needs in 2018, 2019 and 2020, three years of drought. The sowing conditions were extremely unfavourable in those years and yield formation was severely restricted Figure 10).

Figure 10: Dust illustrating dry soil during sowing and extremely low pollination in maize caused by the severe drought

Source: Thomas Gäbert

In addition to the challenging natural conditions, it is particularly the legal framework that significantly limits our options to react. Growing demands from society that go beyond laws and regulations are increasingly influencing our management. Only in 2021 the adjustments to the Fertiliser Ordinance from 2017 were fully taking effect providing an insight into their long-term impact. The resulting effects are a reduction in the amount of fertiliser used, which may have been intended, however, regardless of the initial level. As we had been using low, targeted rates of fertilisers already before, in the end this consequently means lower yields and lower quality parameters. To compensate for the loss of necessary plant nutrients at least partly, large investments are being made to increase the storage capacity for liquid organic fertilisers, and further investments in precise application technology as well as smart agricultural technology are necessary.

In 2021 a total number of 12 different crops are being cultivated on 312 fields. This comes along with green fallow land and flower strips. Twenty-three colleagues are currently farming our fields and another 26 are taking care of the cattle. The good ratio between the number of colleagues and the cultivated land or the number of animals cared for, brings optimal conditions for a very close relationship to the land and an animal-friendly husbandry.

The combination of a low natural soil fertility with an optimised extensive level of production result in good preconditions for additional and targeted implementation of environmental measures. This causes relatively low opportunity costs. With skilled employees and a personnel specialisation, we are able to implement a very wide range of these measures.

Nevertheless, we are aiming at both an economical plant and animal production and large-scale promotion of biodiversity. This was the premise since we additionally focused on that topic. The level of approach was our single farm because of its size it has an already large regional impact. In small-scale agriculture it may be necessary to include several farms to gain a sufficiently large area. Since 2015, we have been planning measures to enhance biodiversity without strong interference into established production processes. Acquired experience and especially the consecutive (5 years in a row) and independent monitoring of biodiversity have continuously shown possibilities to adapt and improve the efforts. As an overall conclusion all single findings have shown that both targets are compatible with each other and stand in a dynamic relationship. This has led to an adapted objective which aims on a linkage of several biodiversity hotspots around the productive fields, which furthermore create insect migration paths. On the other hand, those species that are depending on crops also find their retreats. Only the targeted but separate preservation of both spaces leads to the desired success.

Controlled development of biodiversity
and not biodiversity by loss of control

We implemented several measures including some area-based and on-the-spot measures but above all strip-shaped measures. These measures contribute best to the linkage of different habitats and represent a habitat themselves. Furthermore, we have a lot of riparian strips for protection against drift of crop protection products and loss of soil into surface water. This also simplifies ditch grooming. Due to their floristic diversity flower strips - in our case primarily perennial strips - offer a rich feed supply all year round for many insects. Having partially bare ground in the flower strips or neighbouring areas, we also offer breeding habitats for many ground-nesting insects. Around 75 % of wild bee species in Germany are soil breeding species.

Flower strips are of major importance for insects but additionally are a crucial retreat for small game and birds, which benefit from the grazing and seed supply. Once the surrounding fields have been harvested, these strips offer all animals safe retreats, partly throughout the entire winter. For this reason, most of the flower strips are not mowed or mulched in autumn. This provides not only attractive cover and retreat for small game, but also plenty of opportunities for insects to hibernate in the plant stems (Figure 11). Region-specific adapted flower seed mixtures result in graduate flowering phases within a year that appeal to a wide range of insects. Also, on a yearly basis the flowering aspects appear very differently depending on the weather. Our flower strips show a wide range of different characteristics mainly depending on soil conditions (Figure 12).

Figure 11: Plant stems to hibernate

Source: Thomas Gäbert

Figure 12: Diverse flowering area in spring

Source: Thomas Gäbert

Skylark windows that are created in the grain crop rank among area measures or measures within the productive area. Within these areas skylarks as farmland species find a place to sunbathe between the dense grain stocks and for easy take-off and landing. In a similar way, extensive field strips support some insect and bird species as well as some wild herbs. These 10 to 50 m wide strips are based on strict regulations by the local government and are sown with twice the row spacing while no fertilisation or crop protection is allowed. Even though they are within the production area, both measures can easily be integrated into the operational process and only cause relatively small yield losses in large fields. Furthermore, the local government supports extensive field strips with adequate support for the expenses and yield loss.

To support the beneficial predator-prey relationships, we have set up bird of prey perches in many places, mainly on the grassland (Figure 13). Especially in places where there are no suitable structural elements, these simple poles with crossbars on top support birds of prey in their hunt for small rodents. Songbirds also use these seating options regularly. These small birds are further supported with many nesting boxes distributed along the edges of the fields, because natural tree cavities etc. are relatively scarce.

In addition to some seed gaps in the flower strips bare ground areas were created on some fallow land to give ground-nesting insect species a breeding habitat. However, some species of insects prefer to lay their burrows on a vertical surface. For this reason, we have also created break-off edges in two places (Figure 14). In addition to a very rapid colonisation by numerous insects, a large colony of sand martins also established itself on the break-off edge next to the stable. Bare grounds are easy to establish and can be integrated into both the operational processes and the operational areas.

Figure 13: Perches for birds of prey on the grassland

Source: Thomas Gäbert

Figure 14: Creation of break-off edges

Source: Thomas Gäbert

In order to get new perceptions about the needs of several insects, we established an 'insect hotel' with a lot of different inlay materials that we use as an indicator. This acts like a small-scale experimental station and should indicate the direction for planning measures on a larger scale. Aiming at an exchange of information and the coordination of the various beekeepers within the farm area we maintain good relationships with some beekeepers. Linked to this, new or reintroduced crops such as sunflowers or buckwheat are excellent honey plants and somewhat compensate for the termination of rapeseed cultivation in our area. Rapeseed has been a very important honey plant, but due to several restrictions in plant protection and the resulting low yields it was not profitable anymore.

Nevertheless, bees are negatively affected by the so-called summer slump which occurs between June and October. We try to fill this gap with a large variety of cover crops, among other things. In addition to this aspect, it is the long soil cover lasting over the winter and thus reducing nutrient leaching losses that make cover crops so worthy. Above all, the bio- and root mass of the cover crops is an important feed source for all soil-living organisms which itself is the basis and mandatory requirement for a biologically active soil. All aspects finally lead to the development of stable soil organic carbon, urgently needed in our sandy soils. Its main impacts are the storage of carbon, the enhanced water and nutrient storage capacity, an active soil life, better resistance towards soil compaction and erosion and the overall increased productivity of the soil.

A key aspect of our efforts on all aspects of biodiversity are closely linked to an extensive public relations work. The benefits of many measures are not obvious to a major part of the people. With numerous explanatory boards and regular information events, we try to explain what and why we are doing all these things. On the one hand it is important to raise awareness for the need to enhance biodiversity, but on the other hand also to make clear that there is the urgent need for compatibility with agricultural production (Figure 15).

This sharing of our own findings and experiences is supported by a comprehensive data collection by three experts from the field of nature and environmental protection (Figure 16). Focus of the investigations, which have been ongoing since 2016, are wild bees and wasps, ground beetles and spiders as well as birds. Thus, we have a long data series that is used to evaluate the effectiveness of the measures. On this basis we are planning future tasks and derive necessary corrections. In the end it's all about achieving the maximum possible effects under the current framework of a German farm rather than about the endless development of the theoretical optimum. We were not willing to wait that long. As an example, we already have found over 200 wild bee species, including several Red List species, in our area (Figure 17). Besides this, more unusual insects such as the praying mantis are also increasingly settling here, which may also be linked to the increasing temperatures.

Figure 15: Explanatory boards

Source: Thomas Gäbert

Figure 16: Pitfall trap in flower strip

Source: Thomas Gäbert

Figure 17: Male pantaloon bee on common chicory

Source: Thomas Gäbert

All these activities require resource (e.g., time, money, cultivation). While some measures can be implemented easily and quickly and fit into the operational process, other measures are sometimes associated with considerable costs. Overall, most of the measures are in the public interest. For this reason, the measures should be supported especially at the beginning by appropriate public funding. In the long-term, however, these services should be part of the product price and thus paid together with the agricultural product.

In summary, it can be stated that the experiences and findings of the first few years clearly show that an economical way of producing high-quality food is connectable with numerous measures to support biodiversity. If the measures are adapted to the local conditions and the production framework, a notable increase in biodiversity can be observed in a very short period. At the same time, however, agricultural productivity can be preserved, and biodiversity thus represents a kind of business branch extension. This is the safest way to long-term integration into the farm. It is important to note that both recognition and support from politics that should lay the basis. Finally, it should be mentioned that according to my own experiences as well as to recent evaluations (Leclère et al. 2020, Tscharntke et al. 2021) adapted conventional farming systems can dissolve conflict of objectives between insurance of food security and support of biodiversity better than organic certified farms can do.

3.6 Bending the curve of nature decline

Keynote presented by Prof. Dr. Michael Obersteiner[4]
Environmental Change Institute, Oxford University; Oxford, UK

The presentation is based on a research project in cooperation with and partly funded by the WWF (NL and UK), which was recently published (Leclère, D., Obersteiner, M., Barrett, M. et al. Bending the curve of terrestrial biodiversity needs an integrated strategy. Nature 585, 551–556 (2020). https://doi.org/10.1038/s41586-020-2705-y). About 60 researchers from 46 scientific institutions were involved in this project. A multi-model ensemble approach was used to assess whether and how future biodiversity trends from habitat loss and degradation in cultivated land can be reversed, while producing sufficient food for the growing human population, in accordance with the Sustainable Development Goals.

The study considered various scenarios: a) a baseline scenario (business as usual) b) single action scenarios, that considered actions on either supply-, demand-, conservation-efforts) c) combined actions (conservation + supply efforts, conservation + demand efforts, integrated action portfolio) plus additional efforts to reduce the decline trend such as increased yield, reduced waste, change in diet. The ensemble used four different 'land use models' combined with 7 different biodiversity models. The resulting model conclusions targeted mainly the global scale rather than the specific situation in the EU

The global relevance of the 'nature' sector is huge in terms of economy, ecology and social conditions: The World Economic Forum calculated that 50 % of the Gross Domestic Product (GDP) is nature based (even in a European country, France, it contributes to 36% of the GDP). Worldwide agriculture is the largest employer but also the largest source of child labour. 65 % of the working poor are depending on agriculture. Agriculture is also a major contributor to greenhouse gas emissions (between 21 and 37 % by wider definition), on the other hand, natural ecosystems are a major contributor in $C0_2$ gas emissions capture. Finally, agriculture and the associated usage of habitats is one of the largest drivers of biodiversity decline.

However, the significance of the agricultural sector in national GDPs and particularly in employment rates varies widely; while it is still very high in some developing countries, for example in Southeast Asia, the number of people working in agriculture is of marginal importance in high income OECD countries. There is a global trend towards the 'Lewis path', i.e., in terms of a labour transition between the 'capitalist sector' and the 'subsistence sector' (such as subsistence farming in less developed countries).

Global priority areas for biodiversity and biodiversity restoration are mainly in the global southern and tropical regions. It would thus not be wise to reduce food production in temperate regions allowing very efficient agricultural production in order to increase regional biodiversity to some extent while increasing food production in biodiversity hotspots such as tropical regions at the cost of overall much higher biodiversity losses.

The outcome of the multi model assessments indicates that it is possible to hold and reverse the biodiversity decline while still producing the required amount of food to feed the global human population, as observed in 34 out of 38 combinations.

[4] The following summary was produced by members of the workshop organising committee based on the presentation by M, Obersteiner and subsequently approved by the presenter.

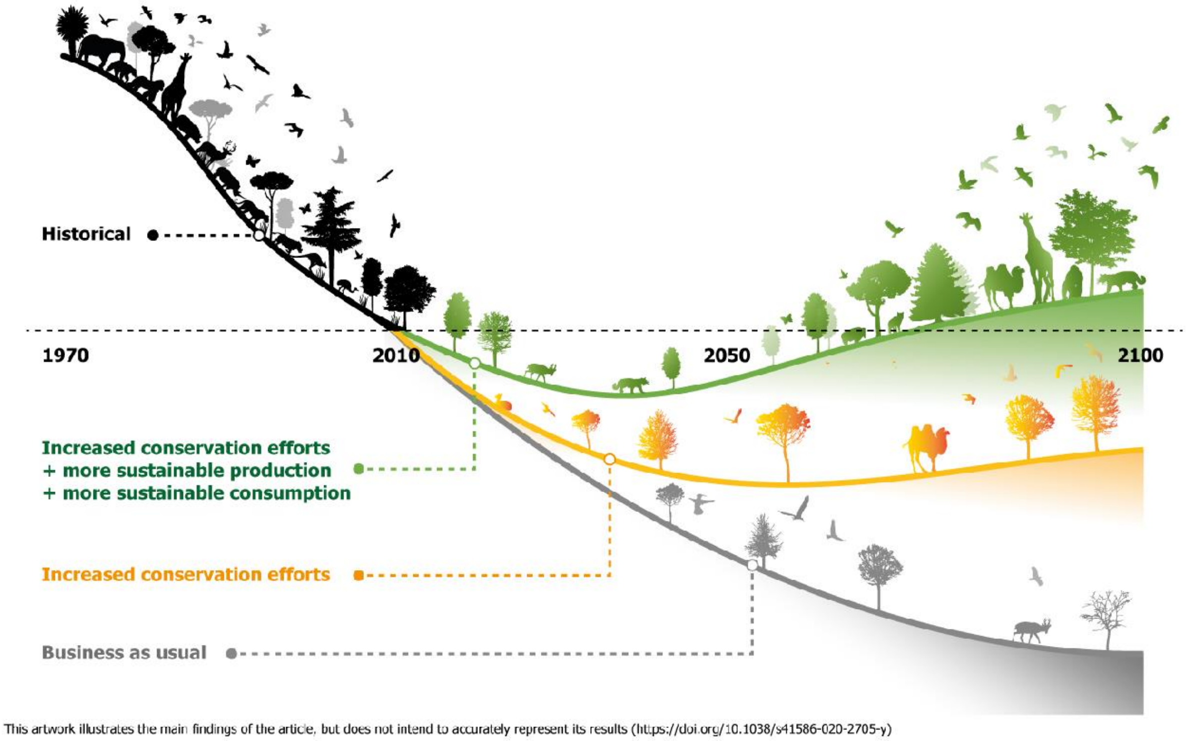

Figure 18: Bending the curve of biodiversity decline

Source: Living Planet Report 2020 (WWF); https://icriforum.org/wp-content/uploads/2020/09/LPR20_Full_report.pdf

Figure 18 illustrates the model outcomes depending on the actions taken. Bending the curve by 2050 is possible if societies implement the following actions:

- Adoption of an ambitious conservation & restoration plan
- Transform food systems from farm to fork
- Address other threats to biodiversity such as climate change, biological invasion.

This includes measures such as additional protection areas, increasing yield, reducing food waste and a shift in diets. However, it also shows we will face further severe decline in biodiversity if we ignore the problem and do business as usual.

The model results indicate that 'land sparing', i.e. producing crops with the best available technology, while leaving particularly less productive land as protected areas for nature conservation purposes, is an essential element of achieving the overall target.

The figures below indicate that only about half of the global cropland would be needed for crop production with the best available technology on this land, as well as indicating other environmental impacts resulting from these approaches.

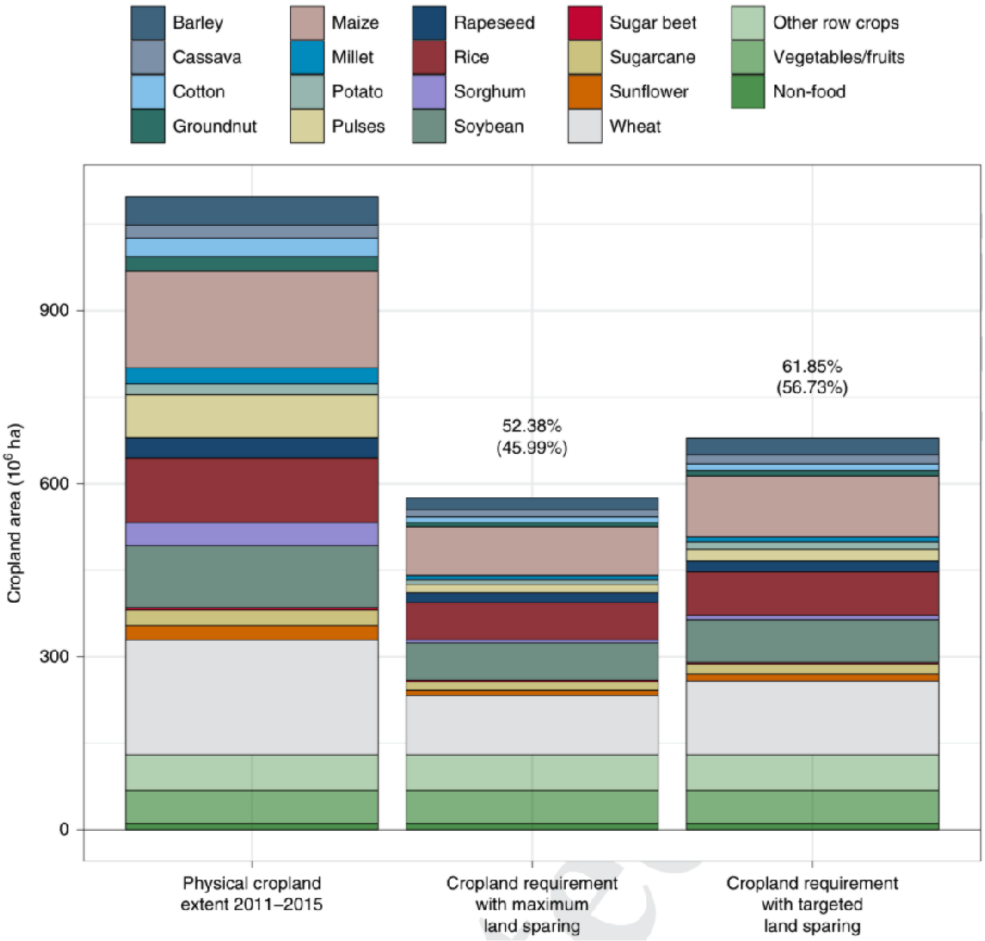

Figure 19: **Cropland area needed to feed the world considering the options cropland extension or maximum, respectively targeted land sparing approaches**

Source: Folberth, C. et al. The global cropland-sparing potential of high-yield farming. Nat Sustain 3, 281–289 (2020). https://doi.org/10.1038/s41893-020-0505-x

However, beyond the findings of the multi model outcomes, there are also many other discourses such as e.g. the IDDRI study, which claims that “an agro-ecological project based on abandoning pesticides and synthetic fertilisers and redeploying extensive grasslands and landscape infrastructures” would make it possible to tackle these challenges - ensuring sustainable food for Europeans, protecting biodiversity and natural resources, and mitigating climate change - in a coherent manner. This also implies eating less meat, but red meat (in contrast to other research which sees a higher environmental impact from the consumption of ‘red’ meat in comparison to other protein sources).

Maximum land sparing Targeted land sparing

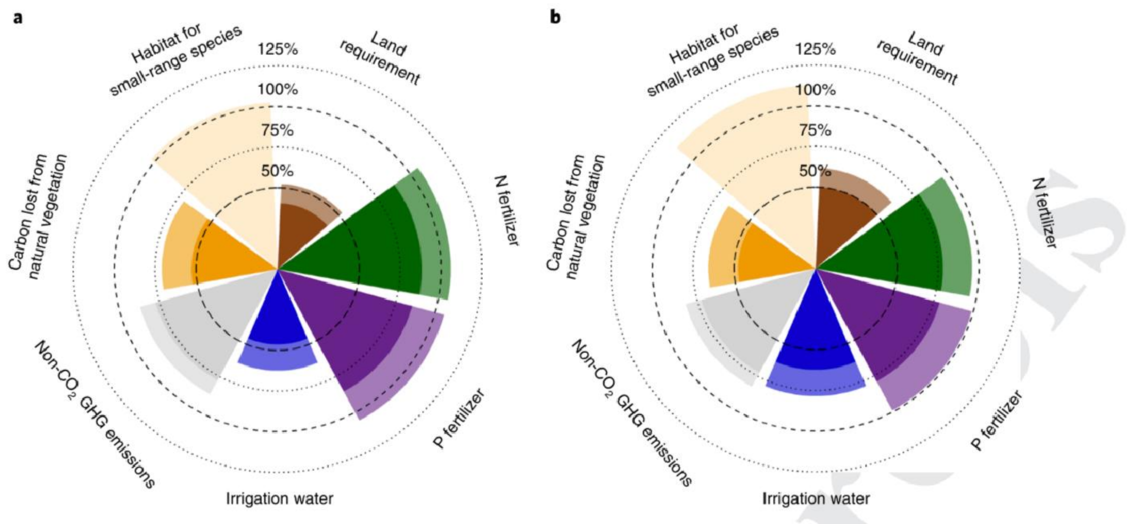

Figure 20: The impact of land sparing approaches with regards to other environmental impacts

Source: Folberth, C. et al. The global cropland-sparing potential of high-yield farming. Nat Sustain 3, 281–289 (2020). https://doi.org/10.1038/s41893-020-0505-x

The conclusions of the presentation were:

- There are many compromises to be struck, and the larger controversies are more likely to occur in the social domain (both in OECD and developing countries).
- The narrative associated to each model is eminently contextual and scale dependent, particularly considering:
  - The natural diversity of landscapes, regions, biotopes, climate
  - The social-political context in the related landscape, region
  - Technology dynamics, which can be
    - Incremental or
    - Break-through, disruptive
- We need a stronger science-based approach of more integrated assessments, which implies:
  - The natural diversity of landscapes, regions, biotopes, climate
  - More public investment
  - Innovative technologies incl. crop protection products
  - Degree of risk aversion towards technology and transition dynamics is a societal, political issue
    - e.g. when and how to apply the precautionary principle (use criteria as defined in the Rio Declaration, or apply in any case of uncertainty, or politically motivated either this or that way).

The subsequent discussion following this presentation indicated the benefits of the diversity of approaches; next to 'land sparing' also 'land sharing' should be considered. Furthermore, the either/or controversy between these two approaches should be avoided, instead both can go hand in hand, and depending on location and situation the emphasis on either of the approaches could prevail, respectively a targeted combination should be used.

3.7 Agro-ecological innovations for sustainable production: Mainstreaming agroforestry and flower strips in Switzerland

Keynote by Dr. Felix Herzog
Agroscope, CH-8046 Zürich, Switzerland

Introduction: Agroecology and ecological intensification

Agroecological innovation is high on the agenda in Europe and in Switzerland. Agroecology can be defined as the common ground between agronomy / agricultural science and ecology with the objective to mimic ecological processes in agriculture (De Schutter and Vanloqueren 2011, Herzog and Pfiffner 2016). In addition, there is the social dimension, which has its roots in the agroecological movement in Latin America, in relation to land rights and farmers' rights as opposed to large scale commercial farming (e.g. Altieri 2000).

While at the end of the 20th century, the European agricultural sector suffered from overproduction and policy measures were introduced to promote afforestation of farmland and set aside, the objectives have now changed. Agriculture should maintain current yield levels or even increase them. Yet, the intensification should be sustainable and should not further damage the environment (Helfenstein et al. 2020). This is why there is this interest in agroecological innovation and in ecological intensification. Ecological intensification techniques aim at increasing yield and yield stability, not by external inputs, but by fostering biological regulation mechanisms for managing agroecosystems (Doré et al. 2011). Kleijn et al. (2019) interviewed European farmers about the acceptance of 17 ecological intensification techniques. Among the top five, that 50% or more of the farmers indicated to "like", were agroforestry systems such as infield trees and hedges. Flower strips and beetle banks, on the other hand, were amongst the five most "disliked" ecological intensification techniques.

Both techniques – agroforestry and flower strips (Figure 21) – receive increasing attention by policy makers and farmers in Switzerland. This article summarises the current situation and speculates on future developments.

Figure 21: Silvo-arable agroforestry system and targeted flower strip.

Both elements are supported by the Swiss agricultural policy.

Source: Agroscope

Agroforestry systems

Agroforestry combines trees and crops and / or livestock on the same field, so that those components interact (Somarriba 1992). Agroforestry has a long tradition and is still widespread in tropical countries (e.g., home gardens, shaded cocoa plantations; Nair et al. 2021). Temperate agroforestry systems have been proposed in the 1990ies (Gold and Hanover 1987) and since then have been investigated and further developed by national and European research projects (e.g., Burgess and Rosati 2018). Results show that, if the components are well chosen, they create synergies and overall, the productivity on a field is higher than with sole cropping because natural resources (light, water, nutrients) are more efficiently used. This "overyielding" effect, which has also been observed in grasslands where combinations of different species with various characteristics lead to higher yields (e.g. Schaub et al. 2020), can amount to up to about 30% in temperate agroforestry systems (Sereke et al. 2015). At the same time, agroforestry systems reduce negative environmental impacts of intensive agriculture and increase ecosystem services and biodiversity (Palma et al. 2007, Kay et al. 2018, Rolo et al. 2021). Agroforestry is a good example, therefore, of an agroecological system in which ecological principles are applied to benefit both yield and the environment.

Researchers and pioneer farmers started to experiment with temperate agroforestry systems in the early 2000nds. Uptake by policy and by the majority of farmers, however, remained very limited in Europe. Also in Switzerland, the new term "agroforestry" first led to confusion amongst foresters ("this is not a forest") and opposition from the agricultural sector ("we finally got rid of the trees in fields to allow efficient, mechanised management – why plant trees again"?). Actually, in Switzerland, about 12% of the farmland consists of traditional agroforestry systems such as wooded pastures, hedgerows and traditional fruit orchards. Those systems are supported by agri-environmental policy measures mainly because of the biodiversity and landscape values that they provide (Herzog et al. 2018). The regulations, however, are flexible enough to allow experimentation with new types of agroforestry. Fruit tree orchards, for example, must be planted with fruit tree species (including wild fruit, nut trees, chestnut), but can also be intercropped without losing their qualification as "Ecological Focus Area". This is why pioneer farmers often choose fruit trees when establishing silvo-arable plantations (Kuster et al. 2012; Figure 22). Yet, some farmers also find the regulations too restrictive and prefer to design their own agroforestry system with e.g. forest trees, foregoing the subsidies ("This is my own project, I don't want to be restricted by subsidy regulations", as one farmer put it).

More recently, policy makers are showing increasing interest in agroforestry as a measure to mitigate climate change – and ecosystem dis-services in general. Kay et al. (2019a, 2019b) have identified target regions for agroforestry in Switzerland and for Europe. Several cantons have launched a co-creation approach with farmers who strive for implementing silvo-arable and silvo-pastoral agroforestry systems (https://www.agroforst.ch/projekte/projet-ressource-agro4esterie-de/) and a new agroforestry measure is foreseen at the national level. It would then allow to also support the planting of forest tree species in open farmland.

Figure 22: Silvo-arable agroforestry system with apples and a rotation of cereals, root crops and strawberries in central Switzerland.

Photos taken in 2011, 2017 and 2020.

Source: Agroscope

Flower strips

Sown flower strips have been developed in Switzerland from the 1990ies onwards for the promotion of farmland species that traditionally depend on open, arable landscapes. They consist of seed mixtures of about 20 (mostly wild) plant species (Vonlanthen et al. 2005). The main objective of those flower strips was, and still is, the promotion of target farmland species. Aviron et al. (2009) have shown that they are highly effective in promoting various arthropod groups, and they are also beneficial for farmland birds and other vertebrates such as the hare (Birrer et al. 2007).

More recently, in addition to the goal of biodiversity conservation, flower strips are also expected to promote ecosystem services such as pollination and pest control. Sowing flower strips as "bee pastures" was actually an initiative of farmers organisations with the objective to provide floral resources for bees throughout the year and to close the gap in flowering plant availability in early summer, when most mass flowering crops are ripening and no longer provide pollen and nectar (Ramseier et al. 2016). While the primary goal was the strengthening of honey bee colonies, wild bees and bumblebees were soon added as target species groups. Seed mixtures were modified accordingly and contained significant amounts of cultivated flowering plants (legume species, for example). The second ecosystem service that was targeted was the promotion of crop pest predators in order to suppress pests and even to reduce the application of insecticides. Based on field observations, on laboratory experiments and on the experience gained from the development of the original flower strip seed mixtures, plant combinations were created that attracted parasitoids, syrphids, lady beetles, etc. by providing food resources early in the season. Tschumi et al. (2015, 2016) found that crop pests were effectively suppressed in wheat and potato fields that were adjacent to such “targeted flower strips”. A specific seed mixture was also developed for the biological control of cabbage lepidopterans (Pfiffner et al. 2009). Flower strip mixtures are also under development for fruit orchards and for vineyards.

Broadening the focus from the promotion of farmland biodiversity to also promoting pollinators and pest control agents increased the interest of policy makers and of farmers (Herzog et al. 2017), but still the uptake amongst farmers is modest. Several seed mixtures are commercially available, and it is obviously difficult for farmers to make the right choice of the correct seed mixture for the purpose they pursue (Bättig et al. 2022.). The choice, in many cases, seems to be driven by the price of the seed mixture rather than by the biodiversity or ecosystem service goals. The original flower strip seed mixtures undergo a plant succession over several years and, if well managed, stay in place up to eight years. The more recent flower strips that target pollinators and pest control agents stay in place for only one or two years and are somehow part of the crop rotation.

Albrecht et al. (2020) have shown, however, that perennial flower strips are more effective than annual strips. This is probably also because when flower strips are sown in early spring, together with a spring crop, their establishment takes so much time that the first flowering resources are somewhat late for the promotion of pest control agents. Current research, therefore, aims at the development of perennial, early flowering seed mixtures. The research is strongly motivated by the need to reduce pesticide applications and to develop alternative solutions for managing pests and diseases.

Figure 23: Different types of flower strips.

(a) Biodiversity conservation, (b) promotion of pollinators, (c) promotion of pest control agents.

Source: Katja Jacot, (Agroscope)

Outlook

An agro-ecological transition has to adopt a landscape approach. The reason is that the organisms, which we want to promote for the delivery of ecosystem services, require a combination of different habitat types to cater to their main needs – shelter and food. Flower strips will attract pollinators and natural pest enemies that stem from the species pool in the surrounding landscape and, ideally, will support them to boost their populations. Yet, the surrounding landscape has to provide enough resources to sustain those populations with permanent habitats at sufficient quality and density. Bertrand et al. (2019), for example, have shown that the pollen collected early in the season by ladybeetles, lacewings and wild bees mainly stems from shrubs and trees, which are amongst the first plants to flower. *Salix*, *Prunus* and *Juglans* species were amongst the most frequently collected pollen types. Trees of those families are often used also in alley cropping agroforestry.

Adopting a landscape approach also requires the engagement of the different actors that make decisions and create the framework conditions in agricultural landscapes: farmers, policy makers, administrators (Jeanneret et al. 2021). Engaging them in a co-creation process will increase their commitment and may also speed up the agroecological transition because the empirical knowledge of local land managers and the scientific expertise of researchers can be combined.

3.8 Scenarios and Approaches

3.8.1 Description of the scenario/approach exercise[5]

Agriculture has changed the characteristics and structures of natural landscapes but at the same time, landscape and environmental characteristics have directed the way agricultural food production could perform and develop within the particular landscapes. Out of this interaction, a high diversity of landscapes and agricultural production systems has emerged. The context of farming largely defines its impact on biodiversity in such landscapes. On top the structure of the landscape is of utmost importance for the resilience of biodiversity in an agricultural landscape.

Examples of factors that influence the impact of agriculture on biodiversity are the intensity of land use and crop management, the size of farm fields, the type and variation of crops and cropping systems, the level of specialisation, the farm scale and focus (local production or export oriented, ecosystem services offered, …). Examples of factors of the landscape which will influence the (re)establishment of biodiversity on farmland are the richness and diversity of the landscape, the existence of elements which can connect spots of biodiversity in the landscape and the possibilities for shelter and dispersion of various groups of living organisms.

Those factors and their interactions are of varying importance, depending on the respective agricultural landscape and the trade-offs between agricultural productivity, often connected to the intensity of food production, and the level of biodiversity (still) present in the landscape. Therefore, it was considered helpful for the workshop process to discuss possible measures and strategies for optimising biodiversity and food production to be as concrete as possible. To facilitate this, a graph was developed, depicting the trade-off between agricultural productivity and biodiversity with the X-axis presenting a scale from low to high for agricultural productivity. This agricultural productivity should be interpreted in the broadest sense and could hence as well be read as farmers income or economic viability of the farm. On the Y-axis the level of 'on farm' biodiversity was plotted (Figure 24). For further simplification, the graph was partitioned into four quadrants: A) landscapes with low productive agriculture and low levels of biodiversity, B) landscapes with low productive agriculture and high levels of biodiversity, C) landscapes with high productive agriculture and low levels of biodiversity, and finally D) landscapes with high productive agriculture and high levels of biodiversity, latter as a potentially desired area of optimised biodiversity and food production (Figure 24).

In the second workshop an exercise in small groups of 5-6 participants, each representing all stakeholder groups but furthermore randomly selected, was set up to describe an imaginary farm and its landscape context (further called the 'Scenario'). In a first step, this Scenario had to be described in sufficient detail (crops and/or animals, size, intensity, soil type, dependence of external inputs, route to market, …) in such a way that people outside the group were able to recognize and comment on the situation. In a second step the group also had to agree on a level of biodiversity present on this imaginary farm and/or landscape context and had to position that Scenario by placing a yellow star symbol into the quadrant of the graph (Figure 24) in which the respective scenario would fit best. As a consequence, the yellow star symbol indicates the 'as is' situation of the Scenario in relation to agricultural productivity versus biodiversity. As multiple groups were having such discussions in parallel, this exercise resulted in 4 Scenarios which were positioned in either of the four quadrants of the graph, respectively after a revision in the quadrants A, B, and C (an 'as is' situation in quadrant D would be the targeted output and not need recommendations to achieve it).

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5 The workshop slides of the scenario exercise are presented in Appendix 3.6.

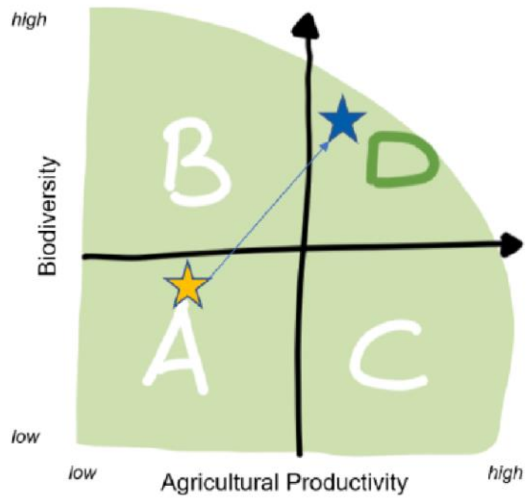

Figure 24: Graph of the scenario/approach exercise.

Here, for a selected case an estimate of agricultural productivity in its broadest sense was plotted on the X-axis and an estimate of on-farm biodiversity was plotted on the Y-axis. The current situation 'as is' of the scenario was indicated as a yellow star. The 'to be' situation, indicated by a blue star, was the realistic shift judged by the participants of the workshop in either productivity and/or biodiversity when selected approaches were used to improve the interaction of agriculture and biodiversity. The arrow indicates the final change resulting from the sum of various individual approaches to improve biodiversity at the farm.

Source: Own presentation

In later workshops (and also as 'homework' in between workshops) the exercise was continued in differently composed groups of again about 6 participants representing the various stakeholders that needed to discuss the challenging but realistic shift towards an improved 'to be' situation for a particular Scenario. The improvement could be along the X-axis (agricultural productivity) or the Y-axis ('on farm' biodiversity), but preferably along both axes. This potential shift was symbolised with a blue star symbol meaning that the yellow star symbolising the 'as is' situation was accommodated by a blue star symbolising the 'to be' situation. Generally, the blue star was oriented at the upper right side of the yellow star as the 'to be' situation was thought to improve as well on agricultural productivity (hardly relevant for scenario C) as on biodiversity compared to the 'as is' situation.

Yellow and blue stars of the same Scenario were connected by an arrow pointing in the direction of the blue star. This straight arrow symbolises the envisaged and probably simplified route to realise the intended shift from the yellow to the blue star, or in other words, the socially and technically desirable pathway of transformation. The length of the arrow, which correlates to the impact of the shift in either agricultural production or the 'on farm' biodiversity was different for the different scenarios and was determined by the expert judgement of the participants. The direction of the arrow was intended to be toward the upper right corner of the graph, although an arrow indicating a status quo or even a limited decrease of economic viability was possible as well and the choice of the arrow direction was again left to the expert judgement of the participants.

In particular situations examples were brought up in which the biodiversity could not be increased without potential losses in productivity and vice versa. This was usually the case for scenarios in which the level of biodiversity or the level of productivity was already very high. In nearly all cases, each shift, symbolised by the arrow, consisted of various elements, further called the 'Approaches' which need to be combined to the final shift (Figure 25).

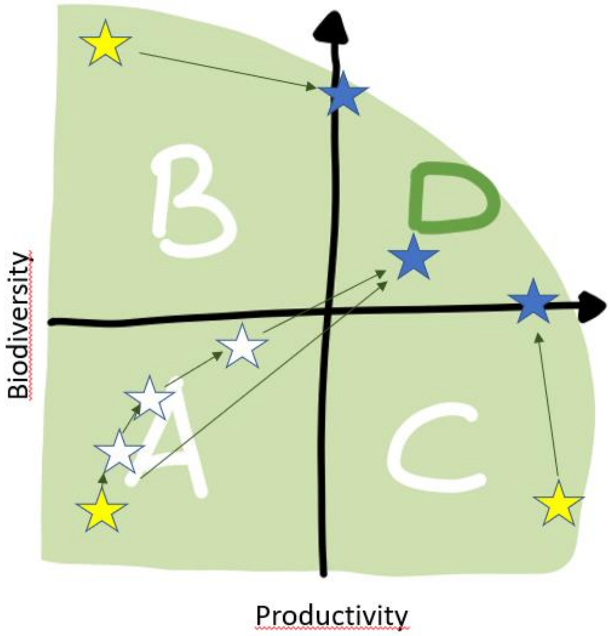

Figure 25: Extended graph of the scenario/approach exercise.

The shift from an 'as is' (yellow star) to a 'to be' situation (blue star) could not always imply an improved productivity and an improved biodiversity. In particular Scenarios, the increase of biodiversity will not lead to an increase of productivity (yellow star in Quadrant C). Similarly, a scenario for a farm with a poor productivity but high biodiversity might lead to an increased productivity with a minor loss of biodiversity (yellow star in Quadrant B). In most cases the path to the 'to be' situation will be constituted of different, smaller steps symbolising the necessary combination of multiple approaches (shown for the yellow star in Quadrant A).

Source: Own presentation

The approaches were listed and evaluated according to the defined criteria as effectiveness, efficiency, relevance, coherence and complementarity. In a homework, exercise group members were collecting evidence from scientific (peer reviewed) literature as well as from professional publications and recommendations. Several approaches brought to the table by the participants during the focused discussion for a particular Scenario shift were as well mentioned in other Scenarios. Therefore, it was considered whether approaches for a particular Scenario could be of significant importance for other Scenarios as well and for which Scenario they were certainly not an option. In the latter case it was discussed and described why this was not the case, which could be farm or landscape related.

Finally, the conceptual shifts of Scenarios by selected approaches were reconsidered. Pros and cons of approaches to perform the Scenario shift were discussed. Some of the approaches were likely to affect not only the farm but even a whole farming area. An assessment was made to list changes that need to occur at the level of various stakeholders: the farmer, the value chain, the society and the policy makers. A differentiation was made to list quick changes as well as changes that need to be developed, hence will occur only over a long term.

3.8.2 Principles and criteria to be considered when assessing the various approaches

Participants have identified a range of approaches, different methods, technologies, physical features, and management practices up to proposed changes in farm types and including holistic approaches such as Integrated Crop Management (ICM) or Whole Farm Systems[6], that all could contribute to improve biodiversity within agricultural production systems.

Before considering what might be appropriate in any particular scenario, an exploration of the principles and criteria to consider for this purpose was undertaken, in order to develop a common understanding of how to assess the suitability of an approach.

To this end a set of general principles was identified and agreed upon which should be considered when evaluating the various approaches and measures aimed to foster biodiversity in agricultural landscapes while securing agricultural food production. These general principles are:

- Assess all approaches according to the same principles and criteria.
- Be open to all approaches, avoid constraints or personal preferences.
- Assess the approaches based on scientific criteria.
- Take the complexity of biodiversity into account
- Take the complexity of agricultural food production into account.
- Take the diversity of farmer experiences into account.
- Take the global implications (trade, markets, international rules and standardisation, harmonisation etc) into account without letting these become an excuse/obstacle to take no action with regard to improving the sustainability of farming.
- List and, where possible, quantify the pros and cons of the respective approaches for both biodiversity and food production, considering sustainability aspects.
- Be explicit about the assessment unit; the smallest unit likely would be the farm scale, respectively the farm (or a group of farms) within the surrounding landscape.
- Prepare a transparent summary/report about the assessment including the pros and cons, the criteria applied, and potential key personal judgments made.

The standard criteria normally included in formal evaluation exercises are *effectiveness*, *efficiency*, *relevance*, *coherence* and *sustainability*, which when considered together with external factors, allow an assessment of the *impact* of the intervention under examination.

- *Effectiveness* relates to the degree of success in achieving the desired objective.
- *Efficiency* considers the relationship between the resources required and the benefits generated.
- The evaluation of *relevance* examines whether the intervention matches what is needed to fulfil the specific objective.
- The assessment of *coherence* explores synergies with other interventions, interactions and trade-offs.
- Appraisal of *sustainability* takes a holistic view of the overall system, and its durability beyond the timeframe of the intervention itself.

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[6] Whole Farm Systems: https://www.nal.usda.gov/afsic/whole-farm-systems

To use these high-level principles and criteria, appropriate evaluation questions, related to the particular context and objectives of the assessment exercise, need to be developed. The group discussed the practical application of these evaluation criteria to examine the suggested approaches, in order to develop a consistent means of identifying whether and in what circumstances a particular approach might contribute to a better balance between biodiversity and agricultural production. Specific points were made in relation to two of the criteria:

- In this context, *coherence* encompasses compatibility with the regulatory systems and national and international agricultural policies providing incentives and penalties applicable to agriculture, and
- S*ustainability* is understood to encompass environmental, economic and social considerations, and the interactions between them, over the full lifecycle of the intervention and its subsequent impacts on sustainability goals and societal benefit (see box on linkages between SDGs).

If coherence to regulatory systems and policies is counter-productive towards optimising the biodiversity and food production targets, this should be highlighted.

The group identified *the feasibility* of implementation of an approach as an additional criterion to be included, as it reflects how practical an approach would be for a farmer.

It was agreed that both qualitative and quantitative aspects should be considered, and that as the overall aspiration is to influence agricultural practices on the ground, the views and concerns of farmers are crucial. This implies that the development and application of criteria should not be dependent only on scientific sources but should also take account of other elements such as existing practices, behavioural characteristics and motivation.

The first essential is to identify the *objective*(s) of an approach, including general (e.g., improving biodiversity, and/or securing agricultural production and sustaining farm income) to more specific (e.g., provide habitat for invertebrates, or improve soil structure) objectives. Once the objectives are established, consideration can progress to how well, and to what extent, the approach fulfils the objectives, together with identification of other effects resulting from its implementation, positive and negative, and the interaction with other approaches, system elements and the wider environment, in both the short and long term.

The factors and associated questions that the participants identified as most relevant for this exercise are reported below (It was recognised that not all of these will be relevant for all approaches, and that in some cases there may be other potential impacts, for example on water or the marketability of a product):

Soil: what is the impact on soil microflora and fauna, levels of organic carbon, soil erosion, fertility and pH?

Fauna: how are species of insects, birds, amphibians, reptiles, mammals affected by the intervention, what are the groups that benefit from the approach and are there any potential downsides?

Flora (non-cultivated): what is the impact on non-crop plants within the cultivated area and off-field (considering food-web implications)?

Farm inputs: what are the increases or decreases in the short and long term in variable costs (labour (time and expertise), fertiliser, plant protection products, fuel, seeds, veterinary medicines), and fixed cost/infrastructure requirements such as specialised machinery?

Crop/livestock quality/yield: what changes would result in the yield and/or quality (and hence value) of the crop being grown, or the livestock being kept?

Farm income/resilience: what would be the impact on farm income/profitability, in the short and long term and what would it depend upon (markets, subsidies, diversification)? What would be the cost of additional investments needed? How would changes to the farming system/management affect long-term resilience (risk management, diversifying production/income sources etc)?

Complementary approaches/situations: what synergies can be identified, where combining different approaches would bring added-value, or trade-offs/compensations.

Contradictory approaches/situations: are there situations/scenarios where this approach would not be suitable (e.g., farm or enterprise types where it would not be beneficial, locations which would be inappropriate, or existing features/habitats which are more valuable)? Are there downsides from implementing the approach?

Ease of implementation: how simple or difficult would it be to successfully introduce the approach? Can it be integrated into the existing farming system, or is fundamental change needed? What level of skill/knowledge is required? Does it have high initial costs?

Barriers to implementation: Factors such as lack of awareness, level of knowledge and skill needed, cost, novelty/innovation, community acceptance, lack of market/processing capacity or restrictive regulations/potential penalties may all limit uptake of approaches that are recognised as useful. Policy makers (and relevant authorities) may be reluctant to provide financial support for measures for which it is complicated to control respect of the contract conditions.

Incentives/support needed for implementation: what is needed to overcome the barriers identified? For example, where approaches require high management capacity/skill, a prerequisite for uptake may be appropriate education/training and advice; where there are high start-up costs, or a considerable period before becoming profitable, funding may be needed (either for investments e.g. agro-forestry/woodland, or to cover a start-up period e.g. organic conversion); where non-market (public goods) benefits accrue to society, financial incentives may be required to encourage uptake; if there are regulatory constraints which limit uptake, changes to the regulatory framework may be appropriate (taking into account WTO rules).

Farm/farmer specific factors: are there specific characteristics of farms or farmers that may affect the attractiveness or likely uptake of an intervention, such as age, family situation, labour availability, farm size, current enterprises, land tenure, or financial situation?

Scale: Both temporal and spatial scales should be taken into account. Benefits for biodiversity and/or agricultural production/farm income may take time to appear, and/or incur costs prior to improvement (e.g., improving degraded soils and landscapes or the current rules for conversion to organic farming may lead to an initial significant drop in yields before an improved “ecological balance” (increased potential for natural control and nutrient (re)-cycling) is established and yields/quality rise). Some initiatives may require action at landscape scale in order to be effective (e.g., establishment of interconnected habitats, corridors, steppingstones for some species). The peer-to-peer effect, through example, encouragement, and exchange of experience can be important in generating uptake on a wider scale. Also, some approaches may work well on small scales however, implementation on a large scale may not fit to farm processes or capacities, e.g., due to the required labour intensity.

Broader consequences/external factors: what would be the impact on trade or the availability of products? Are there market outlets (direct consumers or intermediaries - processors, retailers) for the products? Are there impacts on other activities such as tourism?

Measurability/assessment: how will the effects of implementation be monitored? Have appropriate indicators been developed and is data available or being collected? Defining clear targets for the various approaches helps to define the measurables (and hence to assess whether and how objectives are achieved). However, the complexity of biological systems needs to be taken into account, meaning that it will often not be obvious or simple to assess the effectiveness and efficiency of an activity in clear-cut terms.

It was noted however, that whilst robust monitoring and data collection is necessary to fully assess the impacts of implementation, efforts to protect and preserve biodiversity are needed now, and neither incomplete knowledge nor imperfect conditions should stop action being taken to improve our common future.

Assessing proposed approaches against the list of principles and criteria will facilitate recognition of combinations of approaches which may be suitable in specific scenarios, to achieve particular objectives. It will help identify those which generate mutual benefits for both biodiversity and agricultural production, those that can achieve the highest impacts, and those that are the easiest to introduce and could have large-scale uptake.

How food connects all the Sustainable Development Goals (SDGs)

A model, developed by Johan Rockström and Pavan Sukhdev from the Stockholm Resilience Centre, moves away from the current sectorial approach where social, economic, and ecological development are seen as separate parts. It presents economies and societies as embedded parts of the biosphere and demonstrates that all the Sustainable Development Goals (SDGs) are directly or indirectly connected to sustainable and healthy food (Figure 26).

Figure 26: SDG Model developed by Johan Rockström and Pavan Sukhdev.

Source: Azote Images for Stockholm Resilience Centre, Stockholm University; https://stockholmresilience.org/images/18.36c25848153d54bdba33ec9b/1465905797608/sdgs-food-azote.jpg

The lowest tier of the model includes the SDGs linked to environmental sustainability: 6: Clean Water and Sanitation; 13: Climate Change; 14: Life Below Water and 15: Life on Land.

The middle tier includes the SDGs linked to society, the third tier those linked to the economy, and the whole is surmounted by SDG 17: Partnerships for the Goals | Strengthen the implementation and revitalise the global partnership for sustainable development.

This representation (Figure 26) of the model shows how a healthy biosphere is fundamental to maintaining society and economic activity. This is only possible when the Earth's natural resources are used sustainably, and the planet's safe operating space is respected.

3.8.3 Scenarios

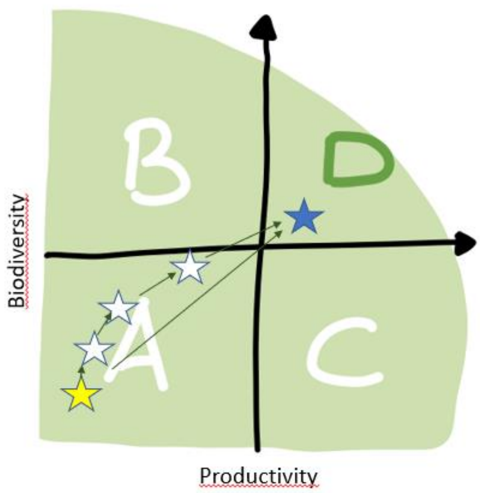
3.8.3.1 Scenario A1: Arable Crop Farm- Degraded Soil

Prepared by: *Christine Toelle-Nolting, Evrim Karacetin, Felix Herzog, Gerlinde de-Deyn, Inés Santín, Katja Knauer, Noa Simon Delso, Nora Temme, Peter Dohmen*

<table>
<tr>
<td>Scenario A1: Arable Crop Farm – degraded soil

Description of the current situation:

– Medium to large farm, medium to large field size (1- >5 ha)
– Low value commodities (e.g., wheat, barley, …)
– Limited rotation & crop diversity
– Former global market focus
– Low labour, medium technology
– Resistant / problematic weeds limit cereal cropping
– Degraded soils with increasing erosion, low organic matter, natural capital eroding
– High investments in external inputs (e.g., chemicals and energy), increasing to counter decreasing profitability
– High risk of farm abandonment
– Limited off-field structures (< 10%)</td>
<td>Scenario A1 (Graph Quadrant)


</td>
</tr>
<tr>
<td colspan="2">Taking into consideration the conditions of this scenario - an arable crop farm with degraded soil - many recommendations concern this specific item, i.e., the recovery and improvement of the degraded soil (ameliorate soil structure, increase organic content, improve soil health and biodiversity, etc.).

In parallel, it is recommended to integrate elements and practices in the surrounding of the fields that help reduce soil erosion and lead to biodiversity improvements, as well as general practices which reduce chemical and energy input to allow for more sustainable food production.

The process of restoring the degraded soil will take some time and - while biodiversity improvements may be achieved more rapidly – the intended sustainable increase in agricultural productivity is likely initially limited, requiring some growing seasons to establish.</td>
</tr>
<tr>
<td>General Approach 1</td>
<td>Consideration of sustainable general farming practices
Integrated Crop Management / Agroecology</td>
</tr>
<tr>
<td colspan="2">Application of the principles of Integrated Crop Management (ICM, including Integrated Pest Management IPM) considering agro-ecological knowledge</td>
</tr>
<tr>
<td colspan="2">Pros

Integrated crop management (ICM) as a system of crop production, which conserves and enhances natural resources while producing food on an economically viable and sustainable foundation, is in line with the overall targets of optimizing biodiversity and food production targets.</td>
</tr>
</table>

Cons

While there may be short-term reductions in food production, there are no major long-term drawbacks of ICM with respect to the overall targets of optimizing biodiversity and food production.

However, the general principles of ICM need to be translated into specific measures relevant for specific situations to become practically applicable.

The principles of integrated crop management are considered to be generally applicable and are recommended to be generally followed.

Limitations/prerequisites

The UK Defra states: “ICM will often necessitate changes to existing practices but most of all requires careful attention to detail, planning, monitoring and a commitment to the overall objectives” http://adlib.everysite.co.uk/adlib/defra/content.aspx?id=000IL3890W.17YM1ATT5LQDB0

ICM being a holistic approach covering a variety of concepts needs translation into specific measures and approaches working in specific scenarios/ situations to become practically applicable. A well working publicly funded technical advisory service (with agroecological knowledge) could be an essential element to help developing more specific and targeted recommendations (see also several examples in the following) for specific situations).

General considerations

‘**Integrated Crop Management’** (ICM) - according to the ‘Natural Resources Institute’ (University of Greenwich) – “is a system of crop production, which conserves and enhances natural resources while producing food on an economically viable and sustainable foundation” (http://projects.nri.org/nret/SPCDR/Chapter4/agriculture-4-4-1.htm). It is thus in line with the overall targets of this workshop, optimising biodiversity and food production targets. CABI’s (an international, inter-governmental, not-for-profit organisation) approach to make agriculture more sustainable and resilient uses Integrated Crop Management (ICM) by “developing and promoting innovative long-term solutions that increase agricultural productivity, while protecting and enhancing natural assets” (https://www.cabi.org/what-we-do/cabi-centres/integrated-crop-management/). The UK ‘Defra’ (Department for Environment Food and Rural Affairs) defines ICM as a holistic “method of farming that balances the requirements of running a profitable business with responsibility and sensitivity to the environment”. “ICM is a whole farm, long term strategy”, which “combines the best of modern technology with some basic principles of good farming practice”. The Defra provides a leaflet containing the main principles involved in ICM (http://adlib.everysite.co.uk/adlib/defra/content.aspx?id=000IL3890W.17YM1HHWVEODBB), which include practices that avoid waste, enhance energy efficiency, minimise pollution and embrace concepts of soil conservation and Integrated Pest Management’ (IPM).

Agroecology is defined by OECD as "the study of the relation of agricultural crops and environment (https://stats.oecd.org/glossary/detail.asp?ID=81). Wikipedia describes **“**Agroecology as an applied science that studies ecological processes applied to agricultural production systems.“ It further states “the term is often used imprecisely, as the term can be used as a science, a movement, or an agricultural practice“ (https://en.wikipedia.org/wiki/Agroecology). Here we use it as applied science developing sustainable agricultural practices. “The field of agroecology is not associated with any one particular method of farming, whether it be organic, regenerative, integrated, or conventional, intensive or extensive, although some use the name specifically for alternative agriculture" (Wikipedia).

Integrated crop management as a holistic agricultural production system, and agroecology as a multidisciplinary applied science considering ecological principles and applying them to agricultural production, seem to have similar targets. The principles and applied recommendations of ICM will often be based on agro-ecological sciences.

Examples of case studies or applications in real live situations

Integrated Crop Management in Albania successfully (significantly reduced chemical input and improved apple harvest quality) introduced by CAB International (CABI: DOI http://dx.doi.org/10.1079/CABICOMM-64-53).

A leaflet for farmers (in German) provides information on location and soil cultivation, crop rotation and intercropping, and fertilization and crop protection (https://llh.hessen.de/umwelt/ boden-und-gewaesserschutz/wasserrahmenrichtlinie/wrrl-newsletter-grundsaetze-des-integrierten-pflanzenbaus/).

Furlan et al. (2020) provide an example, how the ploughing timing of meadows in rotation may be a viable alternative to chemical insecticides, when the rotation includes meadows.

General Approach 2	**Landscape management, structural options**

There are various possibilities to add, maintain, or improve landscape structures as the main lever to improve biodiversity. Many of these are generally applicable (and not a specific solution for this scenario only).

Pros

Riparian buffer strips, such as grass margins – and even more so if they contain shrubs and/or trees - along rivers or other water bodies are important for semi-terrestrial insects (Petersen et al. 2004; Delettre and Morvan 2000) and are also beneficial for water insects due to the retention of nutrients or pesticides (Gericke et al. 2020; Hill 2019). Most semi-terrestrial insects are using the first 10 metres along the riverbank (Petersen et al. 2004; Delettre and Morvan 2000) as a habitat. In addition, several other insects like ground beetles and other predators use the riparian strips (Hering and Plachter 1997, Paetzold et al. 2005).

Such riparian buffer strips also reduce soil erosion and furthermore the emissions of CPPs and nutrients to the water. The buffer strips are most effective with a width of 5-30 m (Venohr and Fischer 2017).

An additional element to enhance biodiversity are flowering strips composed of annual and perennial plants, capable of maintaining insect-attracting flowers for a good part of the year. These can be considered positive elements in the landscape desirable for both people (aesthetic value) and nature. In this scenario it should be recommended to observe whether the spontaneous flora is more or less diverse. Most probably in the first years many species adapted to agricultural management will germinate and in a relatively short time will give way to other annual, biennial and perennial species; it may, however, be necessary to manage the flower strips (additional sowing or timely mowing) to achieve the required biodiversity.

Sown field margins increase biodiversity of pollinators (especially butterflies) as floral abundance and richness increase. Strips should be 6-9 m wide to avoid over-spraying with pesticides and fertilisers (Fluhr-Meyer and Adelmann 2020) and make it harder for predators to find nesting birds.

The introduction of hedgerows will have multiple benefits in this scenario, reducing soil erosion, improving soil fertility, providing additional structures which may also improve the esthetical value of the landscape but above all will increase overall biodiversity relevant for a whole range of species including plants, insects, birds etc. (Montgomery et al. 2020). To achieve the most benefit from hedgerows, they may need some management, however, without frequent disturbance (preferably less than every two years) and the timing and the intensity of trimming should be planned according to the breeding populations (Staley et al. 2016).

Smaller fields with long border lines in comparison to larger fields increase biodiversity (Tscharntke et al. 2005). Reducing field size and thus creating higher structural diversity is similarly effective in the protection of biodiversity as organic farming (Batary et al. 2017). This is due to the fact that smaller fields have comparatively larger margins, which may serve as habitat, and since more small fields usually also go hand in hand with larger crop biodiversity and with different timing for agricultural interferences. A recommendation can thus include that single fields should preferably not be wider than 100-200 m or they should contain non-crop strips at respective distances. It is possible to add respective landscape structures into the field such as flower strips within large fields or ’lark windows’ to provide habitat for soil breeding birds. Using perennial or wooded plants as separating stripes within agricultural crops is the field of agroforestry (see below).

Cons

All these measures will reduce the area of food production. Depending on the level of such measures this can be marginal or a significant reduction. They will concurrently reduce the income for the farmer which again can be marginal or significant. On top of that, most of these measures require active, time and money consuming management of the land.

Limitations/prerequisites

Many of these activities have a direct impact on the farmer who needs to be compensated for these efforts.

General considerations

Many of these measures are already in place and various financial support schemes exist to compensate the farmer. In addition, obligatory requirements are in place when using crop protection products such as the need for vegetated buffer strips to water bodies.

General Approach 3	**Reversion of soil degradation** – development of a healthy and sustainable agricultural soil

3.1 Integrated plant nutrient management to improve soil health

Pros

In degraded soils with low organic matter, additional fertilisation and potentially also irrigation is mandatory to guarantee good yield of cash crops. However, this is costly and in case of extensive inorganic fertilisation and water scarcity not sustainable and might lead to soil further degradation

(Amundson et al. 2015; Steffen et al. 2015). The approaches should thus contribute to reverse soil degradation and improve soil health.

An integrated perspective recognizes that soils are the storehouse of most of the plant nutrients essential for plant growth and that the way in which nutrients are managed will have a major impact on plant growth, soil fertility, and agricultural sustainability (Vanlauwe and Giller 2006). Mineral fertilisers, organic fertilisers such as manure, plant residues, and cover crops, nitrogen generated by leguminous plants, and atmospheric (nitrogen) deposition can all be important sources of 'inputs' to plant growth.

The soil fertiliser application methods are designed to optimise nutrient uptake and minimise possible off-site movement of nutrients by optimising crop nutrient uptake. However, soil nutrient availability changes over time. An integrated plant nutrient management (mineral or organic) should allow to address environmental considerations by tailoring nutrient applications to crop needs and soil conditions in order to eliminate both excessive applications that increase potential losses to water or air and insufficient applications that result in soil fertility degradation.

Given the scenario of very low soil organic matter content and hence low performance of soil functions associated with this, it may be necessary to consider a phase of grass, clover, and other forbs as perennial crop for a few years to increase soil organic matter, soil stability, hydrology and biology. This will help rebuild soil fertility and other soil functions.

Following the initial phase of soil rebuilding, one solution can be the implementation of an agronomic system that allows for continuous balance of nutrient removal (through crop harvest) and nutrient supply by means of enhancing soil nutrient conservation, increasing nutrient inputs through biological nitrogen fixation and through mixed cropping and crop rotations including catch crops. More organically managed soils, for example, often have more organic matter, more abundant and more active soil life and higher enzyme activities (Lori et al. 2017).

An additional option is the establishment of a soil microbiome that allows for nutrient fixation and provision to (symbiotic) plants. Here it has to be noted that extra nutrient input into the soil only occurs through biological nitrogen fixations, whereas the other nutrients are not 'created' but either are already sufficiently present in the soil or need being applied via fertilising. In addition, successful application of microbes helps maintaining soil health, improving water holding capacity, carbon storage, root growth, availability and cycling of essential nutrients, filtering pollutants and also in conservation of biodiversity (Kibblewhite et al. 2008, Keesstra et al. 2012, Nannipieri et al. 2017), while achieving beneficial effects for crop productivity and quality. Microorganisms can be added as part of complex organic fertilisers, as pure additives or can be recruited by addition of specific compounds such as acidifiers that support the establishment and maintenance of beneficial microbes (Pompa et al. 2011.)

Biochar can be added to agricultural soil, which influences the cycling of nutrients – particularly nitrogen – in the soil, as well as increase water-storage capacity. Biochar can be produced from organic waste and serves as a sponge for nutrients and a habitat for microorganisms. Biochar can sequester carbon and have beneficial effects on nitrogen (N) cycling, thereby enhancing crop yields and reducing nitrous oxide (N_2O) emissions (Hüppi et al. 2016). However, care needs to be taken about the quality and the origin of the biochar as some may have undesired chemical substances resulting from their specific feedstock and processing method or may be not produced in a sustainable manner (Hüppi et al. 2015, 2016).

Cons

The adaptation of the current agricultural practices to a more sustainable agricultural system that aims to profit from increased soil health by means of integrated plant nutrient management requires a certain transition phase. This means significantly limited harvest particularly in the first phase (hay); however, also limited costs provided the grassland establishment works out. Alternative income is needed for the (temporarily) set-aside land. In this transition phase application of inorganic fertilisers will be reduced or stopped and nutrient supply will be established by the tools integrated plant nutrient management can offer. Thus, the amount of inorganic fertiliser in the soil decreases while the content of nutrients being built-up in the soil as a consequence of integrated plant nutrient management increases. In this period yields may initially decline because the nutrient supply is not yet optimal.

Limitations/prerequisites

Beside the intermediate financial drawback due to limited yields, farmers will face the challenges to take the right decisions of optimal nutrient provisions with the more complex crop management system. Knowledge on best organic fertilisers such as manure, plant residues and cover crops, suitable crop rotations and potential addition of beneficial microbes to complement the soil microbiome for best soil health must be gained and applied. Extended and continuous monitoring of nutrient availability in the soil and nutrient uptake in the crop will need additional tools of analysis.

This approach will therefore entail setbacks in terms of temporarily reduced yields, which may have to be compensated for through promotion. The challenge will be to support farmers in further training so that they can optimally implement integrated plant nutrient management. A public technical advisory service and respective analytical laboratories should be available in support of farmers. In the long term, intensive further training can be compensated for by the relevant experience.

Financial support should also be provided to support farmers for improving regulating and supporting ecosystem services of soil (e.g., soil C sequestration although after conversion from perennial grassland to arable cropping with annual crops a lot of the C will get lost again).

General considerations

Healthy soil that acts as a dynamic and balanced living system was shown to suppress pathogens, sustain biological activities, decompose organic matter and thereby mineralise nutrients and support plant growth, inactivate toxic materials and recycle nutrient, energy, and water' (Sahu et al. 2019, Meena et al. 2016).

3.2. More diverse and targeted crop rotation '

including legumes, deep rooting pulses and less ‘low-value’ commodity crops

Pros

Generally, integrated crop management under semi-arid conditions is based on crop rotation and no-till practices. Farmers appreciate these practices because they save fuel, machinery, and time-consuming operations (Qamar et al. 2013). Crop rotation and no-till can be complemented by catch groups crops in between the main crop growing seasons to enhance the nutrient retention of the soil, reduce erosion and certain pests. This also promotes nutrient availability for the next crop and provides a habitat for a range of organisms (Gentsch et al. 2020) broadly benefitting biodiversity.

Crop rotation in such a scenario often involves two cool-season crops (intercropping of a cereal combined with legume crop) or a winter cereal combined with fallow period, with medium impact on the vegetation control because all crops have similar life cycles.

The inclusion of (flowering) legumes, through their N2-fixing abilities, will both benefit soil fertility and biodiversity, not only on soil microflora and soil fauna, but will likely have large benefits for insects, pollinators (if not cut to early) and consequently on insect feeders such as breeding birds.

Leaving fallow land is common in semi-arid conditions in attempts to restore the soil organic content and water balance. Considering the low crop output and the comparatively high level of input needed under these conditions, it is also economically often the most viable solution, while at the same time having positive effects on biodiversity in these systems. The spontaneous flora on the fallow land can increase biodiversity and foster farmland birds (Traba and Morales 2019, Sanz-Pérez 2019). In some cases, it can be beneficial for biodiversity to manage the fallow land extensively (Tarjuelo et al. 2020). Similarly, conservation systems (no-till or minimum-tillage) are preferred in order to avoid soil erosion. Out of control weeds will negatively affect the soil water and nitrogen content counteracting the effects of leaving the soil to fallow (Riar et al. 2010). If weeds are not controlled at the fallow stage, farmers need to rely on herbicides, which - if done regularly -may increase the probability of herbicide-resistant and hard-to-kill weeds (Chauhan et al. 2012).

Traditionally, in semi-arid areas, fallow is included in a cropping planning at short-term, and cereals swapped with fallow is seen commonly. The introduction of catch/cover crops instead of the fallow period within a rotation sequence could help to maintain the weed pressure at acceptable levels, prevent soil erosion, and increase the soil organic matter and provide habitat and food for many species. But this advantage on soil can be diminished if the catch crop reduces soil water retention excessively. Therefore, catch/cover crops need to be selected carefully using varieties adapted to semi-arid conditions, able to grow with low water demands.

A viable option can be sowing a legume (see above concerning selection of appropriate species/variety) crop on cereal stubble left on the field, which may also be utilised as animal feed. This will also be very important as habitat and food source for overwintering or migrating species.

The benefits of avoiding fallow periods, respectively periods of bare soil with no or very limited plant cover, and growing a diversity of plant species and varieties are mainly maintaining the soil organic matter and avoid soil loss as well as to manage spontaneous flora emerged within the field (Zangh et al. 2021, Lampurlanés et al. 2016, Loke et al. 2013, Bonciarelli et al. 2016).

A medium (about 3 years) /long-term (5 years or longer) management of crop rotation would include more crops in the rotation that help to control the flora within the field and improve the agroecosystem biodiversity at landscape level. Adaptations to the rotation planning need to be possible so that the farmer can better fit to the annual conditions.

It would be important that the choice of these crops in the rotation provide some resources for the surrounding fauna (e.g., melliferous or polliniferous crops). In addition, various additional elements to enhance biodiversity can be managed nearby the crop to enhance pest control by natural enemies and thus reduce the input of pesticides. However, it can also be a source of pests and diseases. Whatever effect is more important will likely depend on the specific situation and more information on the most suitable combination is needed (Anderson et al. 2009; Pisani Gareau et al. 2013, Dicks et al. 2016). Natural enemy (predator) / prey interactions are complex (Barbosa and Castellanos 2005). While the natural enemies are not likely to be able to control their prey (pest and pest outbreaks), they often contribute to have lower pest species abundances, thus a healthy and biodiverse structure helps reducing the frequency / potential for pest outbreaks (Mediene 2011, Staton et al. 2019).

Cons

Considering a larger diversity of crops, the farmer has to be able to market these crops which may be more difficult or less profitable for some crops, which may on the other hand be beneficial from the rotation and biodiversity perspective.

We need to consider more options such as life cycles, planting dates, row spacing, varying cultivar or planting date, fertilisation requirements (Karkanis et al. 2018, Huang et al. 2020).

Not using tillage can lead to specific weed problems (Gómez et al. 2013).

The extensive use of fallow land obviously will not support food production in the respective area. The same is true for land set aside for flowering strips, hedges etc. In addition, the off-crop areas may need some level of management (e.g., seeding, mowing, cutting) which will cost time and money for the farmer.

Limitations/prerequisites

Farmers would need specific training in integrated production, including other crops management and a guideline to choose a sequence of crops in rotation that help to reduce the flora impact, especially the plants that might become problematic within the field. For this guideline/technical assistance would be necessary at regional/local level.

It would be an additional incentive for the farmer if supported for adopting a change from low level activity fallow to actively cultivated cover crops within a crop rotation plan, in a flexible way, which would compensate for the practices necessary to implement this type of crop.

In general, the incentive system should be more flexible to allow the farmer to react to current needs while still being in line with overall crop rotation targets.

The emphasis on (deep rooting) legumes will be very relevant for the degraded soil as in scenario A1, but may be less relevant in highly fertile soils, although, from the perspective of enhancing soil carbon in soils deep-rooting enables better exploration of the soil profile enabling larger carbon inputs into the soil and higher nutrient and water use efficiency.

A prerequisite for adopting a wider range of crops would be a market for the crops intended in crop rotation.

In dryland farms, soil water content is the most limiting factor. So, not all crops, varieties or cultivars are productive in semi-arid conditions.

The farmer needs financial compensation and technical support for the implementation and eventually necessary management of flower strips, hedgerows, corpses etc.

General considerations

Weed control methods are of particular importance during the fallow period because more than 95% of seeds entering the seed bank in arable land come from annual weeds growing on the same land (Albrecht 2016.).

Long-term experiments can provide data regarding the agricultural, environmental and economic sustainability of different practices in semi-arid conditions, including helpful tool to design weed and crop management strategies (Santín-Montanyá et al. 2018, Fernández-Getino et al. 2015, Martin-Lammerding et al. 2015).

Examples of case studies or applications in real live situations

In this scenario, annual summer weeds, whose seeds are dispersed by the wind along the soil surface of dry fallow fields, are of special interest in conservation systems (Santín-Montanyá et al. 2020).

3.3. **Intercropping** – improve soil and help deal with resistant weeds

Pros

Crop diversification by intercropping has the potential to reduce global requirements for synthetic fertiliser N and consequently support the development of more sustainable cropping systems (Jensen et al. 2020). 'Catch crops', also referred as cover crops, can be integrated between two main crops instead of having a fallow period and can be incorporated into the soil as green manure to fertilise the succeeding crop. The major goal of this practice is the improvement of soil quality and the prevention of soil erosion or leaching losses of postharvest nutrients (Thorup-Kristensen et al. 2003). Therefore, catch crops are valuable tools for nutrient management in crop rotations as they tighten nutrient cycles and improve nutrient use efficiency in agricultural landscapes (Gentsch et al. 2020). Perennial cropping phase of mixed species grassland including biological N2-fixers, can also be perennial woody elements links to agroforestry for soil stabilisation and microclimate creation as well as providing habitat for insects and nectar for pollinators (Rabot et al. 2018).

Cons, draw backs

Catch crops may negatively impact the water balance unless suitable plant species/varieties are available which do overexploit the usually rare water resources.

Limitations/prerequisites

Availability of suitable species/ varieties for this region, which support both soil regeneration, but are equally beneficial for biodiversity (e.g., for overwintering birds).

3.4 **Reduce machinery use on soil** (low till / no till)

Pros

The use of heavy machinery and frequent mechanical disturbance of the soil often lead to soil compaction, soil erosion and have a strong impact on soil macrofauna, flora and other soil dwelling species (invertebrates and vertebrates).

These negative impacts can be avoided by conservation soil cultivation such as not till or reduced tillage practices.

The reduction of heavy machinery use also means a reduction in resources and inputs (e.g., petrol), reduces CO2 emissions (both from machinery and soil) and saves costs.

Cons

Conservation tillage might increase root-feeding nematodes and wireworms compared to conventional soil cultivation (Tahat et al. 2020) and may impede getting rid of resistant weeds.

No-till practices usually require the use of an herbicide. However, the impact of the targeted and balanced use of an herbicide on soil structure, soil fertility and soil organisms will generally be lower as compared to measures such as deep ploughing and the use of heavy machinery (a relevant science blog on the topic related to soil restoration can be found at: https://csanr.wsu. edu/hamstrung-by-ideology/; https://csanr.wsu.edu/comparing-effects-on-soil/).

Limitations/prerequisites

Acceptability of the measures is needed both by farmers (need to learn new practices as compared to well acquainted practices) and by the regulatory system with respect to herbicide use in no-till situations.

There may be situations, where soil cultivation such as deep ploughing etc. will be needed, for example due to problem weeds or nematode pressure. However, this should only be done when unavoidable while most of the years conservation soil cultivation should be the choice. Furthermore, the need to deal with problematic weeds and diseases can be reduced by appropriate crop rotation.

Some crops (some vegetables for example) may require a well-prepared seedbed to produce the best output. Proper compromises in such cases need to be considered.

General considerations

The focus of this approach is on soil biodiversity and functioning and on soil structure (Tahat et al. 2020). The use of heavy machinery will often lead to soil compaction and to ‘Unsuitable agricultural practices such as those causing soil salinization, acidification, compaction, crusting, nutrient deficiency, reduction in soil biota biodiversity and biomass, water imbalance, and disruption of elemental cycling reduce soil quality' (Lal 2015).

Examples of case studies or applications in real live situations

Under semi-arid conditions, the cumulative effects of conservation tillage techniques were found to have increased the seed density and species diversity in soil seed bank, and also improved water stable aggregates and organic matter content (Navas et al. 2021, Santín-Montanyá et al. 2016)

3.5 **Avoid / limit irrigation** or only apply targeted using appropriate technology

Pros

The excessive use of irrigation often causes soil salinization, acidification, crusting, and nutrient deficiency, disturbing soil health and soil function, destroying on the long run the basis for agricultural food production next to often non-sustainable use of rare water resources (Lal 2015). This must be avoided-to allow sustainable farming in the long run.

Cons

The limitation of irrigation will often lead to an initial decrease in crop production. However, in comparison to the long-term problems, this only a short-term disadvantage and needs to be accepted.

Limitations/prerequisites

The reduction in irrigation will not allow the production of some crops. It will also reduce crop production as compared to systems with unlimited irrigation.

The need for a targeted and sustainable irrigation requires knowledge, respective technology and eventually some investments. The use of water has to be sustainable, which means it will be rather limited in many areas.

General considerations -

Examples of case studies or applications in real live situations -	
General Approach 4	**Change in farming type**
4.1 Agroforestry	

Modern agroforestry systems integrate trees in farm types (livestock, crop production, vegetables, etc.) in a way that they can be managed using modern agricultural machinery and are economically attractive. Agroforestry may mitigate agricultural greenhouse gas emissions and can lead to substantial humus enrichment, not only in the topsoil, but down to a depth of 60cm (Seitz et al. 2017). Also, traditional agroforestry systems may still play a role in future land use, such as high-stem fruit trees in the temperate and Atlantic zone of Europe, Dehesas / Montados on the Iberian Peninsula and hedgerow landscapes in Brittany, in northern Germany and in central and Eastern Europe. They are adapted to the local landscapes and farm types, and they offer plenty of ecological benefits.

Pros

Agroforestry can lead to an overall higher biomass productivity due to more efficient resource use. Sereke et al. (2015) found an overall increase in productivity in silvo-arable alley cropping systems of up to 30%. Agroforestry systems are expected to be generally more resilient towards extreme weather events, which are expected to increase as a consequence of climate change (e.g. Nasielski et al. 2015).

Various environmental benefits have been demonstrated for agroforestry systems, either by means of experiments or through modelling studies. The roots of the trees can absorb extra nutrients and prevent them from leakages and protect the groundwater (Nair and Graetz 2004, Michel et al. 2007). The biomass from leaves and dying roots can increase the amount of carbon in the soil (Kay et al. 2019b) and thereby increase the fertility of the soil (Perez-Flores et al. 2017). The trees and shrubs can also provide habitats for insects or other animals, which can be beneficial due to pollination or natural pest control (Harterreiten-Souza et al. 2014, Montagnini et al. 2011). Due to this, the amount of fertiliser and pesticides can be reduced, also reducing the costs for the farmer.

Agroforestry can also prevent wind erosion due to the decreasing of wind speed and water erosion if tree lines are planted along contour lines of the terrain.

Trees are generally appreciated by the wider public as a landscape element, which improve the visual quality of agricultural landscapes (https://www.sciencedirect.com/science/article/pii/S0264837715000691).

Cons

A higher overall biomass production of trees in combination with crops is expected, due to more efficient resource use (nutrients, water, light). Yet, the food production may be reduced due to the conversion of part of the crop land to tree lines (about 10% of the area for a tree density of 50 trees/ha) and, once the trees develop, due to competition for light and water. (Sereke et al. 2015)

The initial investment for the planting of the trees is considerable and labour intensive. The establishment of an agroforestry system requires careful planning, and the system must be designed in a way that it matches the needs and expectations of the farmer. At the beginning, the financial return might not compensate for the investments due to the delayed harvest of the trees or tree products.

Farmers need to be aware that, when establishing an agroforestry system, they commit themselves for many years and the flexibility of land use and management is reduced to some extent.

In areas with limited ground water, the trees may compete with the arable plants for water. Besides being a source of beneficial organisms, the trees or hedges can also be a source for pests (Harterreiten-Souza et al. 2014). Trees also need to be protected from pests and diseases, in particular when fruit trees are planted. There, the application of pesticides can become particularly difficult because both fruits and crops must be protected from undesired pesticide residues (e.g., the time lags before harvest need to be respected). This applies to both, organic and integrated farming systems. Voles may pose a particular challenge for fruit trees because their root system needs to be protected from damage caused by voles. This requires careful controls of the vole population and may even incur the use of rodenticides in the first years after tree planting.

Currently agroforestry systems are not supported by the CAP and the area of the trees is subtracted from the area that is eligible for area related subsidies. As a solution the EU is currently discussing to promote agroforestry systems as an eco-scheme in the next CAP-period.

The management of agroforestry systems is more complex and requires additional skills (tree management). Agroforestry farming tends to be more labour intensive than monocropping.

Limitations/prerequisites

Requirements from a nature conservation perspective:

- Native trees species to increase the amount of associated species
- Should not be planted in areas protected for open land species
- A support of buffer strips next to the trees would be useful to further increase biodiversity.
- The trees should not be all harvested at the same time.
- Different tree species to increase habitat diversity
- More complex pest and disease control because restrictions for applications of both, trees and crops, need to be respected
- The area of the trees should be included in the area for direct payments of the CAP

General considerations -

Examples of case studies or applications in real live situations -

4.2 Agroforestry combined with cattle (beef rather than dairy) or sheep/goats/poultry

This will constitute a major to radical change in farming operations depending on whether just part of the land would be converted in such a way or the whole farm.

Pros

- See also general points for agroforestry above
- Income diversification
- From livestock
- The improved options for agritourism.
- Good for restoration of the degraded soil

– The restoration of soils via pastures, planting grasses and/or legumes can be used as fodder for the livestock – Trees provide protection from heat / cold -> good for animal welfare – Sheep and goats are more robust and require less input than cattle/beef – Dairy cattle will produce manure for soil quality / fertilisation	
Cons As mentioned above, this constitutes a big system change, which will need large capital investments (new buildings, stables, different machinery) and a lot of new knowledge and skills. Obviously, this requires the willingness and the ability of the farmer for such a major change (and will likely be less acceptable for older farmers). Depending on the combination of type of livestock and trees, trees may need protection from livestock.	
Prerequisites, limitations Due to the high capital investments required (and the likely low ability of the farm described here to provide such investment, a significant amount of external money is needed and/or major subsidies to support the conversion of the farm. On top of that, during conversion there will be very limited income. It further needs the willingness of the farmer to start learning (from scratch) and the availability of external knowledge, technical support.	
General considerations Likely only feasible for younger farmers and the availability of respective funds, financial and technical support.	
Examples, Case studies -	
General Approach 5	**Change in farming type**
5.1 Transform to mixed arable / animal farm	
Pros Transform to mixed arable / animal farm with cattle and use, for example, the legumes as feed or consider the cooperation with a cattle farm. More legumes, better soil and pastures will broadly benefit biodiversity, increased productivity by organic N inputs. It will also generate a more diverse income.	
Cons, draw backs This will require significant initial investments with respect to, money, labour, knowledge and time. May be considered as a bet on the future with uncertain results.	
Prerequisites, limitations – Financial support needed – Advice, training needed – Eventually, cooperation across farms required	

- Likely less suitable, acceptable for elder farmers

General considerations

Examples, Case studies

5.2 Transform to permanent crops e.g., almond or energy crops

Pros

Can be beneficial to biodiversity depending on the type of permanent crop.

Almond dry-farming requires few inputs and may provide a suitable habitat for example for pollinators (seasonal, particularly during flowering) and birds. With increasing global demand and the popularity of almond products, its value is increasing.

Cons, draw backs

High initial investment with years of low income to cover for.

In contrast to almond dry-farming, intensive almond farming as partly practised in the US (California) can be very profitable but is not a good example of high biodiversity or sustainability. It needs a lot of water and semi-arid regions hardly provide sustainable solutions for the water use (large investments for irrigated plantations).

Some permanent crops might need more pesticide input. In almond crops, there may be weed control problems between planting rows if a cover is not implemented, however, this may be managed by mulching, which also helps reducing soil erosion.

Prerequisites, limitations

- Well-drained soil.
- Significant financial investments needed (including respective machinery etc.) with several years of no return.
- The plantation-frame needs to be established according to the harvesting method.
- Almond plantations can require the work of bees for pollination.

General considerations

Almond in dry-farming, in semi-arid regions, is practised extensively on sandy or well-drained soils and on sloping land where no other annual crops are grown.

Almond dry- farming gives a return on investment from the fifth year onwards. The labour and inputs in this crop are low, so that despite low production it is possible to maintain a positive economic balance.

Examples, Case studies

5.3 Change some of the low commodity agricultural area to permanent pastures

Pros

Low inputs of money, energy, time, fertiliser, CPPs (i.e., costs in general), long-term improvement of soil

Broad benefit to biodiversity Increases landscape diversity and complexity providing many additional ecosystem services (Cruickshanks 2018) Depending on the type of pasture additional income can be available. If pastures include natural plants and some herbs, some additional products can be present (natural plants like nettle, thyme, mint...), however, with likely only marginal contributions.
Cons, draw backs Low income (however, partly offset by the lower costs) May in some cases be a source of problematic weed pressure in neighbouring crops (small drawback.
Prerequisites, limitations Subsidies will help and are often available already for pastures.
General considerations The ideas presented here are potentially useful options, however, to be implemented will need further input and background which is not the main expertise of this working group

3.8.3.2 Scenario A2: Low productive mixed farm

Prepared by *Alf Aagaard, Arnd Weyers, Christine Meisinger, Christoph Mayer, Jens Dauber, Mark Miles, Zelie Pepiette*

<table>
<tr>
<td>
Description of the current situation:

Medium size farm, large fields (1- >5 ha)
Standard family farm, partly traditional, some new technologies
Mixed arable, dairy cattle
Cereals, maize, hay, grass and maize silage
Subsidies needed to make a livelihood, limited commercial success
Low to medium productive soils, low rainfall
Limited off-field structures (< 20%)
ICM using chemicals as low as possible and as much as needed
Mainly manure from cattle, limited additional mineral fertilisers
Medium risk of farm abandonment

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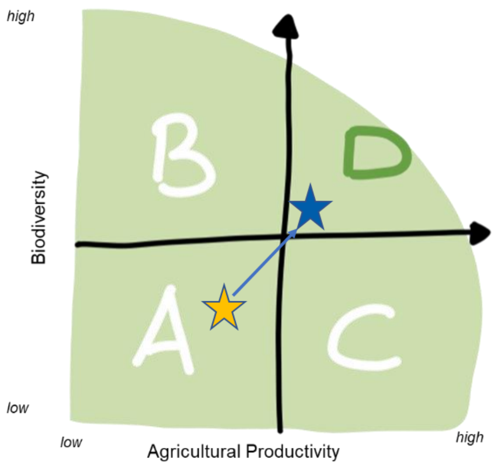
<td>
Scenario A2 (Graph Quadrant)



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The farm in its current situation is facing economic difficulties mostly due to limitations in production and productivity due to low soil quality, slightly adverse climate and perhaps some remoteness to markets. To become more profitable the farm has so far invested in intensification of production but has not become more successful economically. An increase of field size, removal of off-field structures and intensification of grassland management has however led to a decrease in biodiversity. Many recommendations concerning the farm in this scenario suggest approaches for diversifying the farm income while at the same time improving the situation and conditions for biodiversity. Many of the general approaches suggested may only be achieved when not only this single farm but the whole region decides to move towards a shared aim. The intended sustainable increase in agricultural productivity is based on opening new niches for a diversified spectrum of objects being produced and is likely to require a few growing seasons and co-developing value-chains before consistent improvements are seen.

Some of the general approaches discussed below may be easily combined while others are somewhat in competition to each other. Those that are most attractive to farmers (for whatever reason) are most likely to be implemented or maintained (Delecourt et al. 2019, Was et al. 2021, Hannus and Sauer 2021). Care should be taken on potential unintended effects of any approach promoted. Some desirable approaches may be impacted by other approaches with different targets and efficiency whereas some decisions would only have impact if done by several farmers in a region.

The intensity at which an approach is applied may also influence the agronomic and the ecological benefits it provides. There is always a risk that approaches that work are intensified or stepwise modified to optimise the output of agricultural production again. An approach previously beneficial for biodiversity may lose this feature (e.g., sophisticated machinery for mechanical / physical weed control may have similar effects on in-field biodiversity as the use of herbicides or mulching with plastic or growing soil-less in green-houses (e.g. Tscharntke et al. 2021).

General Approach 1	Refurbishing the landscape with more landscape structures, beneficial for animal welfare during production but also for tourism and hunting

Reestablishment and conservation of smaller fields, establishment of hedges, shadow trees, shelter belts combined with extensive livestock production. Reforestation of woodlots on lower productive land for forestry. Establish holiday lets on-farm and supporting infrastructure in the landscape such as hiking and biking trails. Off-set of low productive land (fallows, conservation contracts).

Pros

A landscape with smaller fields and rich in structures such as hedges and woodlots provides more habitat and green corridors with broad benefits for many organisms such as insects, birds, mammals and plants (e.g. Haddaway et al. 2018, Vasseur et al. 2013). Well managed hedges, e.g. cut every second year in alternating places, for example will have higher berry yield for songbird conservation or gamebirds (e.g. partridges). Habitat, especially at edge, improves biodiversity generally but also provides habitat for natural biocontrol agents, supporting IPM in crops.

From the perspective of climate and climate change adaptation, those landscape structures also provide windbreak / shelter for crops and livestock, reduce risk of soil erosion and facilitate water management by improving water retention and reducing run-off (Holland et al. 2017). Carbon sequestration is enhanced.

A diversification of income may result from ‘rough shooting’, thinning for biomass, specialty woodland products (chestnuts, elderflowers/berries, birch sap, mushrooms…) and eventually timber and firewood.

Local hunters may be interested in establishing hedges etc., effort and costs may be shared.

The higher recreation potential of the landscape may diversify income through tourism. Farmers can make use of redundant/obsolete buildings by turning them to holiday homes. Farm stays can increase visitors’ awareness of farming reality. They provide scope for sale of farm produce, networking and collaboration and add value to farm produce (cheese production, direct sales) with potential for HNV or other labelling to capture value from ecosystem services (ESS).

Agri-Environmental Schemes (AES) / fallows may provide temporary habitats serving as refuges for a large range of species. Those may be especially beneficial during times when managed areas provide little forage and shelter (e.g. planting season, after harvest, during some intercropping). Conservation contracts may support maintenance of economically marginal practices providing important habitats: grassland-fruit tree mixtures, low intensity arable fields (ancient crops, rare weed species) or recreate lost habitats for birds, insects or amphibians by recreating special habitats such as small ponds.

Cons

The existing farm equipment may not be suited for the type of management required. There is a need to manage hedges (time, labour, skill) according to local protection goals to maximise their biodiversity impact (Garratt et al. 2017). Hence there are high costs of establishment and protection in early years. The intensity of biomass use from thinning may also contrast biodiversity targets.

Farmers may be reluctant in accepting the reduction of arable land because reduced arable area (e.g. 5%) may be perceived by some farmers as hidden expropriation (i.e. fear of losing arable land permanently).

Potentially reduced yield through edge effects of woody structures (Raatz et al. 2019).

Biocontrol can be offset by higher pressure of other pests (e.g. voles), or the time lag between onset of economic pest damage and efficient biocontrol.

Public foraging activities for wild food may limit the own use of wild fruit, mushroom, etc. by the farmers.

There is a risk of losing biodiversity if open habitats of high nature value (often located on least productive lots) are used for planting of woodlots or are otherwise taken out of production (abandonment). A further risk for biodiversity comes from commercial monoculture planting of forest patches (e.g. with sitka spruce). Also, in light of climate change and for future use perspectives, non-native woody species are often more attractive (distinguish between established and integrated non-native plants and problematic ones).

In case of on-farm cheese production: Compliance with additional food hygiene requirements and/or certification may become too costly and too labour intensive for small family farms (additional/ separate facilities, bureaucracy, controls, vet costs…).

Refurbishment of old farm buildings often results in loss of nesting opportunities of swallows, owls and other farm birds. Even if the buildings are still used for livestock, existing hygiene and construction regulation may result in buildings no longer suitable for the traditional cohabitation of farm wildlife and livestock in farm buildings.

The wish to disperse awareness of farming reality among tourists may be off-set by “romantic story-telling” marketing necessary to compete with holiday lets in the region.

Agri-Environmental schemes (AES), if action oriented might not fulfil objectives if not applied in the right context or intensity. Additional advice, training, and support might be needed.

AES, if target oriented might lack implementation when difficult to integrate into farm routines. Additional bureaucracy to control meeting of targets or fear of failing meeting targets (loss of subsidy) may further decrease acceptance (Chaplin et al. 2021, Massfeller et al. 2022).

Fallows: problematic weeds may dominate during the first years of fallow. The seedbank may fill-up, increasing weed pressure and need for weed control in years following.

Conservation contracts: Budgets are often limited, and the focus is often species / habitat specific. Hence, those are options only for some farms and specific areas of their land.

Limitations/*prerequisites*

If landscapes are already highly wooded, additional tree planting may not be the best option, except for perhaps shelter belts/tree lines to create green corridors.

Tree planting is not suitable on all land types, e.g. drained peatland/carbon rich soil where rewetting is the better option

Take account of the local situation. Avoid compromising existing HNV open habitats, and only adopt measures which enhance rather than damage.

Use a mix of native species when planting hedges/woodland.

Green corridors need a landscape approach.

Farmers fear of losing land and flexibility (“hidden expropriation” based on higher protection levels of the newly established landscape elements or other legal frameworks that could prevent return to more agronomic productive use types).

Consider the impact of Legal land-use status rules (e.g. Germany). Inflexible rules may make farmers reluctant to accept the establishment of permanent structures. More flexible interpretation is needed.

Consider potential limitations on future use of plant protection products if species/function of concern may be promoted by hedges. This applies also for PPP's used in organic farming.

Mutual understanding between farmers, hunters and the local (agri)environmental agencies and their willingness to co-operate and compromise.

Needs for additional investments – e.g. machinery, seedlings, training

Farmers concerns on income - No significant immediate positive impact on farmer income unless subsidised by EU CAP or national/regional programmes and payment for public goods

Viability of holiday lets are dependent on the environment (immediate and in local area). Some farming activities incompatible (e.g. large-scale pigs or poultry)

Infrastructure for suitable hedge management is needed to streamline knowledge gaps, workload and investments on machinery (e.g. advisory services, machine co-operations, contract works).

Grant funding is often needed to help cover establishment costs of new landscape features (hedges, woodland, ponds).

Establishment of diversified activities such as holiday lets requires funding: loans/grants may be needed.

Trade-offs between land-use types: Fallows, AES, hedges etc. can be unattractive on productive soils that have higher return if planted with arable or energy crops. However, as soils in this scenario are characterised by rather low productivity, hence farmers' willingness to accept such measures is expected to range at the higher end.

The level of compensation/incentivisation for land-uses that do not directly contribute to farm income have to be adequate for "normal" return in an area. If not, they might not be competitive with other less preferred land-uses (as experienced since end of 90'ies when oilseed rape and maize became attractive for bioenergy production, or changing land-use for rural development: housing, infrastructure, business production sites….).

The value of AES is case specific. It may not always be obvious to a farmer which AES are most appropriate and at the same time well to implement in their management scheme. There is a risk that the most easy or trendy solutions are preferred to more effective ones. The resulting effects on biodiversity may be negligible.

Fallows may not be appropriate if problematic weeds are present (depends on crops grown).

Take account of the local situation. Each AES approach and AES schemes need integrated evaluation within farm(type)/regional context and offers for supervision.

Conservation contracts sometimes cannot compete with other land-use types. They are often inadequately paid, i.e. on an hourly contingent fit for bigger machinery but not for manual work that may be required to reach the conservation goal (e.g. use of mulcher for grassland / bushland management results in high arthropod mortalities during mulching followed by vegetal changes through soil nutrient enrichment because cuttings are not removed.

Appropriate compensation for the workload required to reach the conservation targets. Consider the need for manual work, proper machinery and reduced velocity of machinery. Cost for removal of biomass must not be neglected.

Check if livestock would do a better job and pay a trained person (e.g. a farmer, shepherd) for this. Facilitate access to appropriate grazers, non-permanent fencing material, infrastructure for herd movement or animal transports, training of sheepdogs and veterinarian support.

General considerations

Diversifying income generating activities, can support more overall robust systems (not as vulnerable to single stressor). Appropriate options will be dependent on the surrounding society and situation, and the facilities available.

Diversifying the landscape and introducing new features will support a more robust ecological system.

There is a chance to increase public awareness, by new interfaces between farming and the public.

However, constraints to adopting these approaches may include lack of time, the cost to acquire new skills, lack of interest/motivation, and/or lack of financing.

Farmers need to make decisions between skills and where to allocate their activities – likely to choose those that fit their interest and/or are most promising to provide financial returns/ incentives. It has to be accepted that farms are economic units that can provide direct and indirect landscape management services only as long as there is sustainable financial return on the farm activities.

Examples of case studies or applications in real live situations

Non-wood forest products in Europe – A quantitative overview | European Forest Institute (efi.int)

StarTree (star-tree.eu) (FP7 project on multi-purpose trees and non-wood forest products in Europe.

Making woodland work on the farm (soilassociation.org) (case study on introducing woodland into farm system – this one is from Scotland)

farm_woodlands_carbon.pdf (farmingforabetterclimate.org)

woodwise-spring-2020.pdf (woodlandtrust.org.uk) (collection of articles about benefits of woodland planting. In particular evidence is provided against introducing non-native trees as a response to climate change. The papers are each supported by more specialist references).

Native woodland establishment improves soil hydrological functioning in UK upland pastoral catchments - Murphy et al. (2021)

https://www.conservationevidence.com/actions/116

https://www.conservationevidence.com/actions/177

Eco swiss keeps the option that hedges can be returned back to arable, it usually doesn't happen. But increases acceptance of hedges.

General Approach 2	**Go Organic and/or diversify the cropping system**

To increase viability and stability of farm income by adapting principles e.g. of organic farming (with certification) and/ or by diversifying the cropping system. Increase resilience and stability of crop production and likewise improve biodiversity and ecosystem services (ESS) provision. Diversify crops – legumes, fruits, vegetables (e.g. alfalfa, blueberry)

The fundamental difference between organic and conventional farming is, that the former does not allow the use of synthetic fertilisers and pesticides, however, fertilisers and pesticides of natural origin (copper, sulphur, pyrethrins, azadirachtin, microbial pesticides, manure) are allowed and do also have side effects when applied at dosages and frequencies covering their efficacy range. The general public perception of organic farming is mainly that of a traditional farming style with certificates from the pioneering organic growers' associations and a philosophy of "working with nature". However, in the 1990'es the EU defined base level requirements and rules for certified organic production which is mainly based on the no-synthetic input paradigm. The system is well established, and many grower associations provide additional certificates, some with secondary standard requirements and extending nature-based philosophies. The range of organic production systems is meanwhile as diverse as that of conventional systems ranging from very extensive, low input systems to highly specialised and intensified farms. At its emergence organic farming was equivalent with diversification and extensification processes – due to the underlying philosophy and the need to mitigate the lack of synthetic fertilisers and pest control – this is not necessarily the case for a modern, highly specialised and intensively managed organic farm. Both conventional and organic production systems can reduce the environmental impact of agriculture by introducing ecologically-sound and production-oriented innovations and practices (Haller et al. 2020). By i) replacing the focus on prohibitions towards making organic agriculture more open to the use of scientific and technical progress, and by ii) making minimum requirements binding in the organic regulations, e.g. those relevant for nature and soil conservation, organic farming would develop into result- and impact-oriented agriculture (Haller et al. 2020).

Crop diversification is an approach principally open to all types of farming systems and may have highly variable objectives (Hufnagel et al. 2020). The diversification of crops through rotation, multiple cropping and species mixtures can help farming systems to become more resource-efficient, depend less on synthetic fertiliser and pesticide inputs, and meet the needs of end users for food, feed and industrial products and simultaneously deliver other ecosystem services and public goods (www.cropdiversification.eu, Lurette et al. 2020). Indeed, traditional organic farms were applying crop diversification and crop rotation schemes to maintain soil fertility and support natural pest control and suppress arable weeds when external inputs were barely allowed. Crop rotations have also been an effective traditional method for the mitigation of pest pressures. In this sense traditional organic farming has pioneered in bringing back extensive crop rotations and diversifications to modern agriculture. However, for improving also conventional farming practices, crop rotations and diversifications have been integral elements of the National Action Plans for implementation of the SUD.

Pros

Organic farming

Traditional organic farms often employ nature-based solutions in their farming practices, including comparatively higher biodiversity in their farming and on farmland. Hence those practices are also known as wildlife-friendly farming.

Many practices are favourable for soil biota development and carbon enrichment. Also, N- and P- inputs are usually low, decreasing risk of fertiliser spill-over to target areas. These practices are mainly a consequence of the lack of external fertilisers that require e.g., higher frequencies of green manure and/or fallows. Cover crops that suppress spontaneous weed populations are also often used as green manure and help reduce soil erosion.

Higher profit can be achieved especially when also certified by an organic growers association and/or if direct marketing is possible.

Transition to organic production is supported by various policies and most organic associations.

Some MS have established advisory services for transition.

Organic farms may have a marketing advantage for synergies when engaging with other rural activities, e.g. tourism, local markets.

Organic farms may secure purchasing of their produce and receive top up payments from retailers when complying to biodiversity and environmental goals (e.g. www.landwirtschaft-artenvielfalt.de).

Crop diversification

Erosion control: Intercropping/ catch crops/ cover crops help avoiding longer periods of bare soil.

Weed control: cover and catch crops can also be effective for control of many weeds as they efficiently prevent a refill of the weed seed bank during cropped and uncropped periods. Support of soil biota and fertility: Catch crops can function as green manure, longer crop rotations of crops with varying nutrient requirements prevent soil fatigue.

Reduction of N-wash-off by fixation of N in biomass by catch crops during otherwise non-cropped periods and by use of N-fixing legumes that allow reduction of external N-fertilisation.

Forage, shelter for wild fauna that can be provided by catch crops and alternating development of main crops on neighbouring fields.

Intermediate pasture forage for livestock (e.g. clover/grass following cereals, catch crops) may replace / reduce bought in feed.

Weed control (high density of inter crop suppresses high weed densities and refill of weed seed bank, short period of bare soil reduces periods optimal for weed seed germination, including germination of volunteer crops after harvest).

Strip farming spreads the same area as covered in a large field over smaller strips on several fields of the farm. This approach may increase in-field heterogeneity with positive effects on pest control and movement / shelter opportunities for soil meso- and macro-fauna.

Pest, pathogen, weed suppression and pesticide resistance management if well fitted into crop rotation.

Opportunity for exploring new markets (including direct marketing) providing new (habitat) structures, e.g. blueberries as an option to enter into agro-forestry (under cropping of pine stands).

Cons

Organic farming

Transition period of 2-3 years before product can be sold as organic and achieve an “organic premium”.

Depending on the crop system and soil and climatic properties, the yield in organic agriculture can be significantly lower.

Lower yield per ha may demand for greater area under cultivation. Effect on biodiversity has to be related also to the yield (e.g. Balmford et al. 2012, Tscharntke et al. 2021) (yield as function of quality and quantity).

Physical, thermal and mechanical weed control and intercropping suppress rare species of arable weeds flora and can also impact in-field fauna.

Risk of imbalanced nutrient flows (Zikeli et al. 2017)

Frequent physical/mechanical weed control favours soil erosion.

Organic pesticides are not free of unwanted environmental side-effects (e.g. the heavy metal fungicide copper and the bioinsecticides based on pyrethroid extracts and azadirachtin)

Crop diversification Intercropping may provide different resources to wild fauna than spontaneous vegetation following the (short) fallow after harvest shift in benefiting species.

Unwanted shifts in weed species spectra in adaptation to cropping systems and specific weed control schemes.

If intercrops are allowed seed setting to provide wildlife food, they may become weeds as volunteer crops (Volunteers crops are an agronomically important type of weed. The term is generally used for crop plants deriving from seed contamination or propagules / seeds shed from crops of previous cultivation cycles. Volunteer crops may be a critical refuge for crop pests and diseases reducing the advantages for crop rotation schemes. Sometimes volunteer crops are more difficult to control than "normal" weeds, e.g. volunteer rye in wheat, volunteer potatoes).

Catch crops may be difficult to fit into rotation scheme, in extreme situation catch crops may be utilised by pest/pathogen as host, thus maintaining/ enhancing pathogens/pest

Crops suitable, desirable for diversification and long rotation schemes often lack markets rendering their cultivation unattractive to many farmers.

Requirements of new crops may create new environmental issues, e.g. blueberries require acidic soils. This can lead to increased peat use, or the establishment of plantations underneath pines, may prevent conversion to mix forests.

Limitations/prerequisites

Organic farming

Farmer risk tolerance: If advisory service / demonstration farms not available, conversion to OF difficult and could be perceived as too risky; if farmer reluctant to learn new things / more labour intensive (mechanical weeding, direct marketing).

Transition to organic often used to require a full system change of cropping systems, management techniques. High risk and need to learn things from scratch.

Consultation and advisory services before choice of transition, supervision and funding production gaps during transition. Training in new cultivation techniques.

Support by the MS for transition to organic system and for ongoing maintenance may be a prerequisite as well as an offer of support for diversification, establishment of new enterprises (may be covered by CAP payments).

Farmer openness / readiness for change (interest, curiosity, finance, knowledge, training)

Availability of suitable infrastructure / resources (e.g. for direct marketing).

Consider market dynamics and possible on-farm developments that can off-set previous environmental advantages during upscaling of OF and crop diversification:

- Increased competition among organic producers can further reduce the price premium compared to conventional products.
- Increased market opportunities of organic products attract more competing players creating pressure on further professionalisation and economic optimization (tendency for intensification). For instance, the development of machinery and technology for soil and weed management has much improved recently. Mechanical weed management systems reach higher efficacy every year (not for all crops yet) reducing on-the-field the ecological advantages mechanical weed control used to have compared to herbicide use.

- Moving from field to (semi) closed systems to avoid pest pressure (e.g. walk-in tunnels, greenhouses, soilless cultures). This approach is excluding most of the natural field species, i.e. removing habitats.

Crop diversification

- Changing to exotic or regionally uncommon crops that do not (yet) have high pest pressure in the region. Some of these crops may provide less shelter and forage opportunities and/or require increased level of protection with plastic mulch or coverage to manipulate micro-climate (e.g. ginger and ginseng growing in Northern Germany, increased sweet potato growing with mulching foils in Germany).
- Lack of farming machinery suitable for mixed and intercropping systems.
- Targets of plant breeding so far do not consider suitability of crop varieties in mixed cropping. Plant breeding has to adapt the breeding goals towards requirements of diversified farming.

Requires existing market, promising market potentials or clear benefits on farm (additional forage for livestock). Financial/technical support to realise new ideas. Products of diversified farming require market support to become compatible with conventional, non- or less-sustainable products.

General considerations

Meanwhile in many specialty crops (fruit orchards, vine growing) IPM management is often close to organic, transitions would no more be a revolution.

Hybrid systems between organic and conventional farming become increasingly attractive for farmers (e.g. https://finka-projekt.de/).

Examples of case studies or applications in real live situations

https://ec.europa.eu/info/food-farming-fisheries/farming/organic-farming_en

Income support (CAP): https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/income-support/income-support-explained_en

OF is mentioned in directive 2009/128 as one method to achieve the sustainable use of pesticides; another option is staying with conventional farming practices and implementing and improving existing IPM methods and technologies.

Agriculture for species diversity https://www.landwirtschaft-artenvielfalt.de/

Multi-actor groups active within the projects of the EU crop diversification cluster (www.cropdiversification.eu)

Links to other agroecological practices such as permaculture (https://en.wikipedia.org/wiki/Permaculture), regenerative agriculture (https://en.wikipedia.org/wiki/Regenerative_agriculture)

https://www.frontiersin.org/articles/10.3389/fenvs.2021.643847/full (impact of pesticides on non-target soil invertebrates)

PLAID: Demonstration farm network, Set of virtual Demonstrations on farms:

https://plaid-h2020.hutton.ac.uk/sites/www.plaid-h2020.eu/files/Deliverable_4_2_PLAID_22Dec2018_final_LEAF.pdf

Mechanical slug control robot: https://www.youtube.com/watch?v=9RkrTvzKPK8

Network of organic demonstration farms (Germany):

https://www.youtube.com/watch?v=CttvHetKzFo

Demonstrationsnetzwerk Erbse / Bohne www.demoneterbo.agrarpraxisforschung.de

Organic Demonstration Farm Walks (Ireland): https://www.teagasc.ie/news--events/news/2016/organic-demo-farm-walks.php

Heideingwer" https://www.facebook.com/CellescheZeitung/videos/351564819350559/ video in German but pictures provide an impression of the cultivation system.

General Approach 3	**Diversify grassland management and specialise on local labelled produce (meat/milk/eggs)**

Maintenance of moderate grassland management, mowing schemes, fertilisation, vegetation communities, grazing regime.

Pros

More Soil Organic Carbon.

Premium product. Potential to produce high quality hay (pets), meat and meat products, dairy products based on high environmental animal welfare and/or regional branding. Sward diversity may increase feed quality in terms of trace elements and nutrients.

Adapted mowing regimes: increased plant diversity if ripening of seeds allowed; benefits fauna using meadows as habitat for breeding / foraging; mowing in temporal steps allows migration of fauna

Mowing type: "long grass" cutting with slow machinery allows survival of insects and other fauna compared to mulching equipment. Reduced velocity and mowing directions (inside out) also benefit fauna.

Advantages for animal health (less prevalence of pneumonia and other respiratory diseases) and well-being (free movement, social behaviour).

Low fertilisation benefits plant diversity.

Natural meadows provide higher diversity than sown grassland.

Low to medium grazing pressure benefits plant diversity.

Meat/milk/eggs marketed locally will generate roughly double revenues (per unit produce) compared to selling to retailers.

Positive impact in landscape (smaller units compared to large scale farming), more landscape diversity.

Supports grassland conservation (cattle on pasture rather feeding in stable)

Mixed poultry-livestock can have positive effects on controlling livestock parasites.

Cons

Less amount of hay/ha or grass for silage, nutritious value of total forage may be less than under higher mowing intensity; This can be an issue if the farm needs high energy feed for the live stocks

Limited market access to customers demanding natural hay in sufficient volumes (main profit may occur beyond farm at the retailers). Issue if critical volume of direct marketing cannot be reached due to lack/seasonality of customers and/or high local competition.

Plant diversity may include toxic plants contaminating harvested forage (e.g. *Colchicum, Senecio*) and perhaps less nutritious value per ha than sown and/or fertilised grassland. Problematic plants require management and may limit use, e.g. mainly grazing rather than hay production.

Negative impact on workload/ farm logistics due to mowing in temporal steps or slower machinery.

No mulching/cut processing: longer drying of cuttings (weather constraints, forage quality).

Dairy produce, even when marketed locally, is a very difficult market. Demand is hard to predict, needs good marketing skills and may incur surplus production (more waste food) if not managed well.

Local direct marketing of meat needs cooperation with a local butcher. This can be an issue if such infrastructure is already lacking.

Selling in local stores ("local product shelves") often requires expensive certification and (bi?) yearly renewals. Requires high sales volumes for being profitable.

Keeping livestock on pastures may come along with specific veterinary issues (blue tongue disease, liver fluke) and fears regarding expansion of large carnivore populations (In some regions of Germany farmers are currently highly concerned about expanding wolf populations. In the future they will learn to deal with that, but currently it may be an argument to keep live-stocks rather in stables than outside. Anyway, adaptation comes with additional investments required as a prerequisite for compensation in case of livestock losses to carnivores).

Limitations/prerequisites

Different sensitivity to plant toxins needs to be considered when feeding different livestock species, selling hay. Areas with high density of toxic plants may need to be excluded or require targeted management for control of these plants (e.g. ragwort).

Not enough labour force / economic return for the additional workload.

When pressure is high and other land-use / management options provide better return.

Mainly others profit from the aesthetics of the landscape (e.g. farm not participating in touristic revenues from letting rooms or local compensation payment for attractive scenery).

Is more an improvement in animal husbandry: smaller scale raising of cattle/pigs/sheep etc. moving away from "meat factories". Positive impact on biodiversity will likely come as a secondary effect (pasture vs. high intensity grassland) but is difficult to quantify.

Probably works better for farms close to customers who are prepared to pay higher prices for local produce.

General considerations

Extensification generally results in lower yield, particularly output of dairy and meat can be much lower than under intensive practices. While this may be considered by some not a drawback, this only works if less meat and dairy is consumed, which is more a societal than a farming issue.

Examples of case studies or applications in real live situations

https://www.thuenen.de/de/bd/projekte/berggruenlandprojekt-thueringer-wald/

PRO WEIDELAND label, awarded to dairy products whose raw ingredients have been sourced in a way that respects animal welfare and environmental protection https://proweideland.eu/en/

https://www.sciencedirect.com/science/article/abs/pii/S0308521X19308856?via%3Dihub

Frontiers | Incorporating Diversity Into Animal Production Systems Can Increase Their Performance and Strengthen Their Resilience | Sustainable Food Systems (frontiersin.org)

Do Chickens Help Solve the Cattle Parasite Problem? | Fact Checking Project on the Film Fresh (georgetown.edu) this one is from the US

https://fb.watch/6qwoVJksv5/

General Approach 4	**Advisory service & training systems and decision tools in relation to plant protection**

Support the farmers with quality and appropriate advisory services, and decision tools, for example to facilitate when to use pesticides, training in correct use of pesticides, mandatory regular equipment check (e.g., every 4 years).

Pros

Knowledge dissemination, quicker spread of approaches that work for farmers, supporting innovations.

Provides insight to support the successful up-take of approaches already tried in the region and other regions with comparable conditions.

Flexible, can be adjusted to individual farmers need, bi-directional learning (farmer – advisor), May incentivize farmers motivation for engagement.

Decision support tools can Increase biodiversity, for example through applying pesticides only when it is really needed, which also save money on pesticides, giving i.e., better balance between income and cost, Well-functioning equipment, that does the job with minimum harm and better knowledge on when/what/where/how to apply pesticides

Cons, draw backs

Costs for local/regional governments to employ highly skilled, motivated, independent, local advisory staff.

Lack of public visibility and acknowledgement of the work existing publicly funded advisory systems already conduct. This stipulates popular narratives that farmers would just do what they want and provides potential space for parallel political activities competing with the existing institutions.

Decision tools do not take account of all factors that need to be considered (agronomy, environmental enhancements, PPP applications, fertiliser…).

Complexity is enormous of targeted and multifunctional advice aiming to increase food production and biodiversity at the same time. For instance, the definition of “time when a plant protection product is really needed’ is often not quite clear and may be defined very differently. It is important to consider that crop varieties differ in pest tolerances, market values and ecological value. Also, for some pests only preventive sprayings are possible (damaged plants not accepted by market, effort for curative applications disproportionally high or no curative product available). Preventive sprayings may lead to overall less volumes applied and ensure that the limited time window for treatments are met because after certain crop growth stages treatments are not possible anymore (technical limitations, environmental label restrictions, time to harvest not sufficient for compliance with waiting period).

A farmer's most accepted teacher is another farmer. External advisors and trainers may only have answers to questions on their topic, but often may not be able to answer questions if farmers are concerned about indirect impact on other farm relevant topics.

Cost for farmer to pay for checks, to invest time for additional processes and bureaucratic hurdles

Cost to buy / maintain equipment.

Cost to society to establish a control system.

Cost (also in time) to get training.

Limitations/*prerequisites*

Advisory services/training important in any scenario.

Advisory systems already exist in many areas/regions however as being often a decentralised service they run under the radar of public and decision makers. *The role and value extension services and advisory bodies provide needs to be increased. As well as their visibility.*

Acceptance / Implementation is rather a matter of (narrow) economic, political and public finance cost/benefit considerations. *Don't act in simple top-down manner making farmers feel all others know better how to run their farms than they do. Find farmers that pick-up ideas and develop solutions. They can act as role models.*

Interpretation of "application when is really needed" as "only curative treatments allowed": Abstinence on preventive tools is contrary to IPM- Prevention is one of the fundamental principles in IPM – although it is mainly based on cultivation methods it does not exclude preventive use of PPP if this reduces effort + side effects of curative measures that would otherwise be needed. Would not work, where Weed/ pest/ pathogen pressure is very high.

Decision tools normally consider pest pressure and weather. *However, it is important to factor in local considerations (e.g. access to equipment, etc.)*

Pesticides must be applied with proper equipment, meeting technical standards.

Training must also include loading of pesticides and cleaning of equipment. Thereby avoiding point sources.

General considerations

Dissemination of ideas and innovations work quite well in the farmer community if farmers are convinced that the innovation is a chance that provides a real surplus. The issue for the environmental perspective is however, that farmers might not pick up the "right" innovations or are modifying the innovations according to their needs. As an example, when biogas plants were promoted in the 1990s, farmers did not use dung, manure, and organic waste instead maize became the most favourite resource for fermentation. This initiated the current boom of maize production in the EU, including decrease of other crops and crop rotation schemes.

Similarly, effective tillage machines for weed production are becoming increasingly attractive due to reduced availability of herbicides and are employed in the intensification of organic farming. The more effective this machinery becomes, the less non-crop vegetation will remain on fields as forage for animals. Moreover, frequent soil management is usually devastating for soil dwelling species (from soil breeding birds to earthworms, large carabids or small mammals or amphibians/reptiles). While herbicides have been used mainly at very early growth stages of the crop or at the end of the cycle as desiccants, sophisticated weed control machinery may be applied throughout the season in future.

Examples of case studies or applications in real life situations

<u>Plant protection advisory services:</u>

Rhineland-Palatinate (a German Federal State): The Dienstleistungszentrum Ländlicher Raum (DLR), a federal state-owned organization

(a) collects relevant Plant Protection information for conventional, integrated and organic agriculture from official websites. Pflanzenschutz Informationssystem (pflanzenschutz-information.de)

(b) employs Extensionists and advisors that provide additional information via the internet and farmers can call them (e.g. Pflanzenbau\Service\Ansprechpersonen\nach Schwerpunkt (domaene-oppenheim.de) to get info on very specific issues.

(c) They also have a farm network for conservation measures integrated in farming practices Partnerbetrieb-Naturschutz\Naturschutzmaßnahmen\Ackerbau (rlp.de)

<u>Information and research on pests, integrated management and production systems</u>

ISIP: (Integrated plant protection) Tips on what to do when, where and how

ISIP - das Informationssystem für die integrierte Pflanzenproduktion

IOBC (International Organization for Biological Control) deals with Integrated and organic production systems (basic and applied research, networks): Integrated Production, IP & IPM - IOBC-WPRS: International Organisation for Biological and Integrated Control, West Palaeartic Regional Section

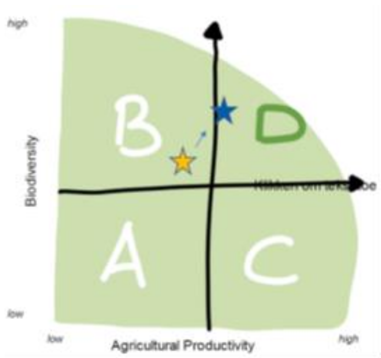
3.8.3.3 Scenario B: Medium-intensive IPM orchard

Prepared by: *Dany Bylemans, Claire Brittain, Virginie Ducrot, Sina Egerer, Emilio Gil, Oliver Koerner and Lorraine Maltby.*

The scenario is a perennial pome fruit orchard with many seasonal workers. No other crops are grown at the farm. The orchards are irrigated and fertilised with chemical fertilisers and foliar nutrients.

The production needs to be of excellent quality since fruit is sold via the cooperative to supermarkets in the country as well as to exporters. This type of fruit production is still very labour intensive with pruning, manual thinning (to complete chemical thinning) and picking being done with seasonal workers. Furthermore, crop protection treatments, mowing of the alleyways, IPM monitoring and mitigation measures against weather events like frost, hail and sunburn, are very intensive.

Scenario B (Graph Quadrants)



Description of the current situation

Honeybees (introduced just before flowering and removed afterwards) and solitary bees (permanent, nesting aids) are used for pollination.

The orchards are managed by adapting IPM practices, but it is still a very intensive cropping with a high plant protection product use, as much as possible selective for key beneficial insects. Since pome fruit is a tall growing crop, there is a high risk for pesticide spray drift. To limit this risk low drift nozzles are used.

The orchards contribute to the perception of the landscape and are appreciated by the local society, especially during flowering.

General Approach 1: Creation of suitable habitats
Option 1: Intercropping (grass strip with flowers)
Approaches suggested: The cropping area consists of trees planted in a row and a grass strip in between the rows. This grass strip is needed to allow regular passage with the tractor and avoid the formation of furrows. Whereas the grass is usually regularly mowed, it could be transformed into a flower strip, at least in the middle zone of the grass strip. This way, the zone between the tree rows keeps its function for easy tractor passage but offers a diversification of plants as well, which will attract beneficial and flower visiting insects.
Pros More pollinator species will cause better fruit set and more high-quality fruit (Cahenzli et al. 2017; Pfiffner et al. 2019). More predators and parasitoids by offering alternative food sources and preys/hosts (Cahenzli et al. 2019, Dib 2012, Gontijo et al. 2013, Zhiping et al. 2021). Potential to repel pests (Beizhou et al. 2012, Song et al. 2010). Relatively easy to apply: Compatible with current mower use if only the inner part of the grass stripe is not mowed (equipment is existing) (Herz et al. 2019, Pfiffner et al. 2018). Reduction of run-off and erosion.
Cons Increase pesticide exposure of pollinators and natural enemies? => Adjust spraying regime/technique. Increase of unwanted effects (pest populations, russeting of fruit) (Bone et al. 2009, Pcfruit (n.d.)) Attracts/stimulates population development and spread of (water) voles (Briner et al. 2005, Roos et al. 2019, Jaworska 1996, Wiman et al. 2009).
Limitations The role of these plots decreases over the years as they perform less due to competition with grasses. Especially non-perennial plant species are difficult to maintain. There is maintenance needed to keep performance (De Cauwer et al. 2005] which is also shown in other crop types than orchards (Ducrot et al. 2020). Inconsistent results (Campbell et al. 2017, Cole et al. 2020, Zamorano et al. 2020) Often only the increased biodiversity is described, not the beneficial impact on pests or fruit set or quality (Markó and Keresztes 2014, Markó et al. 2013).
Additional considerations This approach requires precision application of pesticides (to avoid exposure of beneficial insects on grass / flower strips) and a choice for pesticides that quickly degrade and/or are less harmful for these arthropods. The proposed approach of intercropping omits the small distance effect of flower strips for the presence of beneficial insects on the crop. As such the approach makes use of a special feature of the orchard, the grass strip, which turns into an advantage. The impact of flower strips on crop damage has to be followed up over multiple years. The effect is cumulative and can especially in orchards have carry over effects to the next season, like the effect of web spiders in autumn months may affect pest pressure in early spring (f.i. aphids).

The species composition of the flower strip should be carefully selected in view of their targeted visitors (pollinators, beneficial insects, …) and the competitiveness of selected flowers in local conditions, which is determined by soil properties and microclimate.
Examples of case studies or applications in real live situations Cahenzli et al. 2019. Project Eco-orchard (Core Organic Plus Project) (https://projects.au.dk/coreorganicplus/research-projects/ecoorchard)
Option 2: Mixed hedgerows
Approach suggested Perennial hedgerows offer a habitat for multiple species hence increasing biodiversity, in particular if the hedge rows consist of multiple shrub species (mixed hedgerow). The species composition should be selected as such that nectar and/or pollen supply is covering a wide range of time.
Pros – Secures the food supply (nectar, pollen) to flower visiting insects outside the flowering season of the pome fruit (Kruess 2003) – A mixed hedgerow provides shelter to a range of BCOs that help with natural pest control. A clear migration from the hedge to the orchard is observed (Ducrot et al. 2020, Bribosia et al. 2005a, Bribosia et al. 2005b, Maalouly et al. 2013) – Increase of insectivorous birds and reduced pest outbreaks (García et al. 2018) – Reduction of Spray drift (Lazzaro et al. 2008) – Reduction of wind damage causing fruit skin abrasion (Debras et al. 2008)
Cons – Reduced production area and/or competition for water/nutrients (Alix et al. 2017) – Overspray issues (i.e. continuous presence of pollinators)
Limitations – Inconsistent results, also in other crops than orchards (Albrecht et al. 2020) – Careful selection of hedgerow species is needed as they could be a host plant for orchard pathogens or pests (e.g., fire blight, …) (Pcfruit (n.d.)).
Additional considerations In some countries, legislation exists that planted hedgerows for biodiversity control cannot be removed anymore. This legislation is counterproductive as farmers don’t want to plant hedgerows at any place which could eventually become an obstruction. The number of beneficial insects is shown to increase faster as the number of phytophagous insect species when the number of shrub species in the hedgerow increases till a certain optimum. Beyond this optimal number, the number of phytophagous species is increasing continuously, but the number of beneficial species remains constant (Debras 2003). This indicates the importance of a careful and local selection of the hedgerow species.
Examples of case studies or applications in real live situations Debras et al. (2008)

Weninger et al. (2021) Belien et al. (2021)
Option 3: Phased or timed mowing
Approach suggested The grass strip in between tree rows can be mowed in alternation or less frequently. This allows a higher (and often diversified) vegetation
Pros – More extensive, better timed or phased (every other row) mowing supports beneficials (Herz et al. 2019, De Cauwer et al. 2005, Alhmedi and Beliën 2021) – Easy to apply, no extra cost, no special machinery – The higher vegetation offers protection against high temperatures due to evaporation.
Cons Attracts/stimulates population development and spread of (water) voles (Briner et al. 2005, Roos et al. 2019, Wiman et al. 2009).
Limitations None
Additional considerations
Examples of case studies or applications in real live situations
Option 4: Nesting boxes or shelters
Approach suggested The installation of specialised nesting boxes or shelters will render an increased presence of solitary bees, honey bees, (prey) birds, predatory mammals, reptiles and bats.
Pros – Presence of solitary bees or honeybees will increase fruit quality index and thus crop value (Ducrot et al. 2020) – Prey birds, predatory mammals and reptiles help to control vole populations (Murano et al. 2019) – Insect birds and bats help controlling certain insect populations (Dekeukeleire et al. 2020, García et al. 2021, Maslo et al. 2022) – Prey bird will reduce fruit damage by birds (Shave et al. 2018) – Nest boxes increase bird biodiversity (García et al. 2021)
Cons – Reduced performance if other very attractive crops (e.g. oil seed rape) present in the neighbouring landscape.
Limitations

- Difference in attractiveness due to location of the nesting box in the field and proximity of other attractive landscape elements (Ducrot et al. 2020).
- Makes spraying more difficult. Overspray issues with bird or prey exposure.

Additional considerations

Modern, young and productive orchards offer much less natural shelter as older orchards (Chmielewski 2019, Ahmad et al. 2018).

Additional work needed to install/maintain bees and nesting boxes ca. 16 hours/ha (Ducrot et al. 2020).

Examples of case studies or applications in real live situations

Krismann et al. (2020) Ecofruit project

Belien et al. (2021)

General approach 2: Land sharing & sparing options & Creation of suitable habitats

Option 5: Diversified landscapes

Approach suggested

Creation of suitable habitat is anticipated to be a key improvement because in diversified landscapes a wide range of host plants are present, which provide alternative food (pollen, nectar, preys or hosts) for pollinators, beneficial arthropods, predatory and insectivorous birds which are beneficial for the orchard. Moreover, reintroduction of those organisms is easily possible if prey or flowers are absent in the orchard or if management measures have decreased the populations in the orchard.

Pros

- Creates habitat and habitat connectivity in large landscapes.
- Provides refuges.
- Combination of margins (off crop area) and in-field areas, depending on the components of biodiversity and services that need protection, taking benefit of the use of multifunctional areas.
- Reduced pest pressure due to natural competition by beneficial species.
- Synergies with objectives of other frameworks – e.g., Water framework Directive.
- More beneficials, more pollinators, less pests, better pollination (Dainese et al. 2019).

Cons

- May reduce production surface (UAA; Utilized Agricultural Area) and related direct payments.
- May be a refuge to pests (although this may be compensated by being a refuge to beneficial species) so a balanced system is to be expected after several years.
- Needs a setting of specific protection goals, a dedicated risk assessment and guidance on how to implement and maintain multi-functional field margins to ensure minimising side-effects from PPP application.
- Applicability of beetle banks in narrow sized fields.

Limitations

- Subsidies to compensate for the loss of UAA.

- Need for definition of protection goal for these habitats based on the Ecosystem Services and functions they provide through an adapted risk assessment.
- Need to be taken into account in the new CAP in a more practical way regarding field margin use and compensation for the non-cultivated surface loss in relation to yield loss.

Additional considerations

The approach is a low hanging fruit: requires to prepare information together with extension services and farmer organisations for farmers – with easy access (Flyer) – on existing incentives in member states. Improve information on existing implications for PPP application – give recommendations for protection. Part of the CAP, but due to the administrative burden still currently implemented on a voluntary basis, we need to develop a scheme to promote and reward such initiatives.

The reduction of production surface might be more suitable or acceptable in less productive areas where the return of investment is already lower. However, since the income of the farmer is already under high pressure in those farms, a compensation is recommended.

A zero-risk policy of pesticide influx (f.i. by drift) into a multi-functional area, would hinder adoption by farmers. Eventual side effects of pesticides should be limited in time.

Examples of case studies or applications in real live situations

Alix et al. (2017) Mitigating the Risks of Plant Protection Products in the Environment. SETAC editions.

https://www.setac.org/store/ViewProduct.aspx?id=9006489)

https://www.rspb.org.uk/our-work/conservation/conservation-and-sustainability/farming/advice/managing-habitats/arable-field-margins/

https://farmwildlife.info/

Dicks et al. (2013), EC (2019), Hacket and Lawrence (2015), Hötker et al. (2018), Jahn et al. (2014), Lee et al. (2019), Topping et al. (2015)

https://ec.europa.eu/environment/nature/natura2000/platform/documents/functional_agrobiodiversity_eln-fab_publication_en.pdf

https://www.oiv.int/public/medias/6367/functional-biodiversity-in-the-vineyard-oiv-expertise-docume.pdf

Information on SUD in Germany

https://www.nap-pflanzenschutz.de/risikoreduzierung/schutz-von-umwelt-und-gesundheit/schutz-von-terrestrischen-organismen/

https://www.nap-pflanzenschutz.de/risikoreduzierung/schutz-von-umwelt-und-gesundheit/schutz-von-terrestrischen-organismen/

General Approach 3: Change of farming practices

Option 6: Intercropping by multiple crops

Approach suggested

Making advantage of the architecture of an orchard to use the inter-row space (replacing the grass strip) for an additional crop. Examples of such additional crops are asparagus, strawberry, aromatic plants or crops to feed cattle or enrich the orchard soil with nutrients like nitrogen.

Pros

- Additional cash crop generates additional income.

- Decrease of pest and disease abundance (Beizhou et al. 2012, Boudreau 2013, Dodiya et al. 2018, Pålsson et al. 2020).
- Could improve the nutritional status and/or the soil quality of the orchard (Ahmad et al. 2018, Gurin et al. 2021).

Cons

For use in additional cash crop, this approach requires a choice for crop protection products that quickly degrade or have low/no residues in food.

Limitations

- Need for precision application (e.g tunnel sprayer)
- Labour organisations should allow combination of crops to deal with work peaks (harvesting, …)

Additional considerations

Knowledge of and machinery investments for multiple crops is a prerequisite (also an option to team up). Fruit growers – because of the perennial crop - are very focused and should be encouraged to think about other crops. This would need extensive training and demo initiatives.

Non-edible cover crops should be considered as no issues with pesticide residues by drift can occur.

Examples of case studies or applications in real live situations:

None found

Option 7: Intercropping by multiple crop varieties and/or use of resistant varieties

Approach suggested

Orchards are often monovarietal fields with the exception that in many cases a pollinator variety is present at 7-10%. Adaptation of strains of pests and diseases to single host cultivars is described and is probably a continuous evolution often reflected by an initial low sensitivity of a new variety to pests or diseases, whereas its sensitivity increases when the acreage of this cultivar is increasing.

Pros

- The combination of multiple crop varieties reduces outbreaks of pests and diseases Alhmedi et al. 2021
- The combination of multiple crop varieties reduces the risk of poor pollination and fruit set

Cons

- Less efficient picking.
- Increase in labour input

Limitations

- Minor/resistant varieties might be less accepted by the market, which will lead to a loss of income
- Only for new orchards
- Less attractive for big farms without local selling
- Suitable varieties not available for all fruit types

Additional considerations Selected varieties should be suitable for the growing conditions like the soil and climate and ideally be tolerant for important pests and diseases as it will reduce the dependence of pesticides. Varieties used may need to change through time due to climate change.	
Examples of case studies or implementation and other references: Generally applied in small CSA farms (Community Supported Agriculture)	
Option 8: Diversification by the combination with animal production	
Approach suggested Chickens or livestock production in orchards	
Pro – Might reduce pest pressure by eating insects or fallen fruits. – Generates additional income. – Increases microhabitat diversity – Sheep can minimise the need for mowing (Corroyer 2014)	
Cons Predation of beneficial arthropods (in case of chickens)	
Limitations – The function of the grass strip for tractor passage should not be compromised. Population density of chickens should be low – Fencing needed – Larger livestock or flying/climbing chickens are not compatible with dwarf trees in intensive orchards	
Additional considerations – Most realistic and high stem or more extensive orchards (agro-ecology) – Branches lower as 1.2 m should be avoided (Corroyer 2014)	
Examples of case studies or implementation and other references Corroyer (2014)	
Option 9: Warning systems and Decision Support Systems - Knowledge updated risk assessment	
Approach suggested Improve uptake of state-of-the-art knowledge of pest and disease occurrence and risk assessment towards the impact on beneficial organisms and biodiversity.	
Pros – Increased feasibility by technological evolutions (smartphone use, Internet of Things, Artificial intelligence, Big Data Analysis)	

- Targeted and optimised timing of applications reduce pesticide use (Bangels et al. 2021, Rossi et al. 2012, Bylemans et al. 2021)

Cons

None identified

Limitations

- Farmers and workers need to be trained and familiarised with IT applications
- Very big, central managed fruit farms still use standard treatments all over the farm. Support at the executional level is needed due to variations of crop management practices between orchards or parts of the orchards
- Requires knowledgeable workers, clear and localised communications, which will result in extra expenses

Additional considerations

Support training, education and consultancy need to be permanent and at basic as well as more specialised level.

Examples of case studies or implementation and other references

None identified

Option 10: Use of trap plants

Approach suggested

Trap plants are plants which are much more attractive for particular pest species compared to the crop which enables early monitoring, local treatment, … Dead end trap plants can in very specific situations reduce pest populations by the interruption of the biological cycle (f.i. by incomplete development of larval stage, arrest of egg eclosion, …). Trap plants can be planted in the crop area or at the field edge and could be integrated in a push & pull strategy for pest control.

Pros

'Dead end traps' reduce pest development (Alhmedi et al. 2019)

Cons

None identified

Limitation

- Numbers/area of trap plants needed might be a limiting factor, depending on the attractivity of the trap plant compared to the crop.
- Good examples, applicable in practice are scarce
- Traps plants might attract pests (and later on their beneficials)

Additional considerations

Effective examples are very rare, especially in pome fruit orchards.

Examples of case studies or implementation and other references

None identified

General Approach 4: Alternative/more targeted uses of PPP
Option 11: Apply spray drift reducing methods
Approach suggested Spray drift in vertical crops as orchards is high compared to horizontal (arable) crops as the spraying direction is towards the side and the nozzle output is often at the height of 3 m or more as it is adapted to the tree height. Moreover, the droplets will easily pass through the trees which are at that moment without leaves. Drift reducing methods and technologies can reduce the contamination of the off-crop area (surface water or terrestrial area) by pesticides. Examples of drift reducing technologies are drift reducing nozzles, shielded sprayers or tunnel sprayers, anti-drift nets, …
Pros Shielded sprayers can reduce up to 99% of pesticide emission via drift and allows precision application => can reduce the overall treated area by 70% Alix et al. (2017).
Cons – Shielded sprayers cannot be used in orchards with large trees or orchards with hail nets – Anti-drift nets might cause visual pollution of the landscape – Anti-drift nets are sensitive for wind damage
Limitation – Drift reducing technology can be low cost (e.g., drift reducing nozzles) or expensive (tunnel sprayers). The latter are a considerable extra cost and considered as a non-productive investment – Shielded sprayers and tunnel sprayers are not practical for hilly areas or orchards with hail nets
Additional considerations Although in several countries, the use of drift reducing nozzles is mandatory, their daily used is not guaranteed. Perceived hurdles for application by farmers are: less good droplet distribution and crop penetration, easier clogging and if clogging happens it is harder to notice by the tractor driver. Adapted technology, training and demonstration can overcome these hurdles. Drift reduction classification schemes should be harmonised within the EU.
Examples of case studies or implementation and other references Lešnik et al. (2005) Fornasiero et al. (2017) Horizon 2020 project Innoseta (www.innoseta.eu)
Option 12: More targeted application of pesticides
Approach suggested Many air-assisted sprayers used in orchards lack adequate adjustment according to the crop characteristics. As a consequence, sometimes there is excessive coverage, sometimes there is failed coverage.
Pros

– Technology improvement offers the opportunity for a more consistent deposit on the trees and a strongly reduced deposit off-crop
Cons – Cost of technology
Limitation – Lack of knowledge and training
Examples of case studies or implementation and other references A study revealed that a 40% reduction of pesticide dose and volume could be obtained without reduced pest control levels (Xun et al. 2022).
Option 13: Use low risk substances, biocontrol agents, biopesticides and plant defence enhancers
Approach suggested Alternatives for pesticides are developed and brought to market by new and existing companies. These alternatives comprise the so called 'low risk' substances (US: GRAS compounds) which are compounds with a long historical use in food or plant defence enhancers, which don't have a direct killing effect on the pest or disease but evoke their effect by triggering the natural plant defence of the hose plant.
Pros – Potentially reduced risk to operator and environment – Increase plant tolerance to infection/infestation – Consistent and robust effects (i.e. pheromone disruption)
Cons – EU Active substance approval has fixed timelines and requirements (Reg. (EU) 1107/2009), with limited possibilities to increase speed. – Missing data might overlook risks (e.g., for physical mode of actions no data is needed) – Cost of alternatives for pesticides is often high and efficacy is often not guaranteed or even not clear, which leads to an increase in cost of crop protection at farm level Limitation – Requires more knowledge on the positioning and integration/compatibility with other practices. Farmers argue limited experience and limited available information. – Efficacy is often insufficient and will trigger repeated and corrective treatments – Adds considerably to the total cost – Additional information about the effect of spraying techniques is needed.
Additional considerations Speed up the assessment of 'low risk' substances and products and make the authorization less costly Ensure a minimal efficacy and information about the optimal use to avoid unnecessary spendings by farmers and occurrence of pest/disease resistance.
Examples of case studies or implementation and other references

State research and Development Programs e.g. In Germany coordinated by BLE (BLE is a central implementing authority within the scope of the Federal Ministry for Food and Agriculture (BMEL) https://www.ble.de/EN/Project-Funding/project-funding_node.html.

Farm to fork strategy: https://ec.europa.eu/food/horizontal-topics/farm-fork-strategy_en

Horizon2020 project Optima (www.optima-h2020.eu)

General approach 4: Socio-economic changes

Option 14: Differentiated tax on pesticides

Approach suggested

The impact of pesticides on the environment and biodiversity is very diversified. A differentiated tax for broad and narrow spectrum pesticides should be envisaged [18].

Pros

- Will lead to a gradual shift in pesticide use if the costs outweigh the benefits
- A self-enforcing system will be created

Cons

The consistent exclusive use of narrow spectrum pesticides will evoke the gain of importance of secondary pests and diseases. If they start to exceed economic thresholds, more pesticide treatments could be needed to tackle the variety of pests and diseases

Limitation

The result will depend largely on how the system is designed (front end incentive for the farmer)

Additional considerations

This requires a change in strategies for resistance management.

Examples of case studies or implementation and other references

Finger et al. (2017)

Falconer and Hodge (2001)

Skevas et al. (2012)

Aubert and Enjolras (2021)

Option 15: Ensure an adequate farmer income

Approach suggested

Several measures to improve biodiversity cost time and/or money. An adequate farmer income is a prerequisite to be able to invest in non-productive investments.

Pros

- Will also resolve the current issues with lack of succession and continuity of farming
- Will ensure sufficient food production in Europe as a strategic objective

Cons

- Might result in interference of the government with the liberal market
- Will lead to an increase of cost of food

Limitation

- Requires whole chain communication from farm to fork.
- Private-public partnerships needed for tailored solutions
- Efforts for ecosystem services by farmers are often not financially rewarded

Additional considerations

Farmer needs to be financially appreciated for delivering ecological services.

Efforts for ecosystem services contradict sometimes efforts for a maximal production. The latter is still the most rewarding for the farmer and is perceived as a short time benefit. Impacts on biodiversity are often long term and without direct personal reward. Train farmers for the benefit of the long-term rewards.

Examples of case studies or implementation and other references

Mouron et al. (2006)

Option 16: Direct marketing

Approach suggested

Farmers often have only a marginal part of the total value of their produce, which leads in many cases to a rather small income which leaves no room for non-productive investments related to biodiversity. Prices are in many cases only exceeding the cost of production when the fruit is perfect in size, in colour, in the absence of defects, …

Pros

- Fruit, which is not perfect, can be sold.
- Higher part of the value chain for the farmer leads to a better income
- Better understanding of the buying behaviour of the consumer will trigger actions that lead to higher quality, better taste, …
- Good resistant varieties which have less good properties as to storability, transportability, can be marketed
- Enables ‘story telling’ by which efforts for further steps in IPM or ecoservices can be indirectly valorised.

Cons

- Does not fit for every type and location of fruit farm
- Time consuming
- Might be negative for total carbon footprint (food miles per kg apple)

Limitation

- Platforms for food vending machines are preferable to avoid personal/time loss at selling point (unless shop is broad enough with regard to products offered) -> collaboration between farmers

– Works only well in specific places (a lot of traffic passing, touristic area, …)
Additional considerations Consumers and commercial channels should be taught to accept and pay a higher price for imperfect fruits. The percentage of interferences like pesticide applications, which is targeted to reach the ultimate percentages of perfect fruit is considered to be proportionally very high.
Examples of case studies or implementation and other references None identified
Option 17: Improved breeding
Approach suggested Current cultivars with a high commercial value are usually sensitive for many pests and diseases requiring regular pesticide use. This phenomenon is also a consequence of the success of such cultivar as commercial success will lead to higher proportion of this cultivar in the acreage, sometimes even a monoculture of that cultivar.
Pros New technologies (gene editing, marker assisted breeding) can speed up the availability of suitable disease resistant varieties without losing the good properties (taste, production, storability, …)
Cons Approval and public acceptance for gene editing is lacking in EU
Limitation Resistance against one pest or disease might evoke a higher sensitivity towards another pest or disease (the number of economically relevant pests and diseases species in pome fruit is high)
Additional considerations Resistant varieties must fulfil other requirements in the market like the acceptance in the market (taste, visual quality, storability, shelf life quality, …).
Examples of case studies or implementation and other references Röhrig and Hardeweg (2016)

General considerations

The approaches listed may as well be considered alone as in combination with each other, to maximise benefits for biodiversity and other ecosystem services. Many of the approaches are even considered to reinforce each other in respect to the final outcome for biodiversity and/or agricultural production, yet scientific proof of such an integrated approach on this outcome is lacking.

Approaches include opportunities of novel and high-tech methods as well as simple and straightforward practices which sometimes need only awareness, a mind shift or a different organisation of agricultural practices. However, some of the proposed approaches may lead to an increased risk for a lower (quality) production, an increased demand for labour, the appearance of management issues because of the increase of complexity and the need for special interferences at particular parts of the orchard, … can become obstacles for implementation. This is especially true for big farms and farms working with seasonal workers due to language and communication problems. We should therefore to a maximum take advantage of the hands-on ideas and practices of farmers for the further implementation of the proposed approaches and there should be room for interpretation and flexible adaptation of the approaches.

As the impact of the proposed approaches are often difficult to measure and results might vary between years, geographies, landscape and social contexts, living laboratories throughout Europe could be valuable tools to have cross-international learnings and exchange of experiences and to convince farmers and other stakeholders.

For orchards in particular, many effects will build up over time as it is a perennial crop. As an example, equilibria between pest and beneficial insect populations can be reached over time, of which most fruit farmers are very well aware. It remains, however, work in progress as farming practices like crop protection methods, are continuously in evolution (e.g., approval and disappearance of low risk or broad-spectrum pesticides). Established and broadly applied good practices might need rapid adaptation because of new invasive pest species, the effects of climate change, etc.

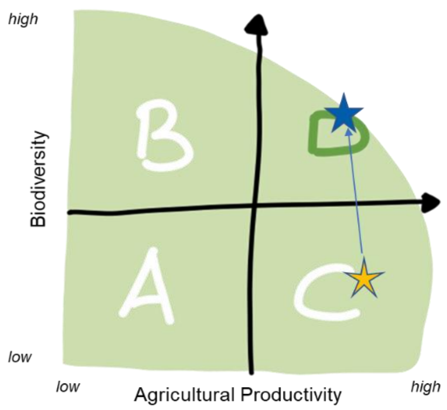
3.8.3.4 Scenario C: Large arable field farm

Prepared by*: Anne Alix, Ian Barber, Paolo Barberi, Peter Campbell, Mariana Ledesma, Balthasar Smith and Jacoba Wassenberg.*

<table>
<tr>
<td>Description of the scenario:

The scenario is a highly productive arable field displaying low biodiversity level, featuring large arable fields, located on highly productive soil in a flat geography.

Cultivated fields receive high fertilisation and crop protection levels.

The production is well connected to the global market, with limited connection to the local market.</td>
<td>Scenario C (Graph Quadrants)

</td>
</tr>
<tr>
<td colspan="2">General considerations

The approaches listed below are diverse and provide a range of tools that may be used in a wide range of landscape management situations, whether land sharing or land sparing predominate. The approaches may also be considered alone or in combination, to maximise benefits to biodiversity and other ecosystem services.

Some approaches constitute “low hanging fruits” in some definite context, depending on the production type or environmental conditions for example and in situations where the market adapts to crop diversification and the machinery is easily available. The CAP could play an important role to further support the implementation of approaches.

The list of references reflects a first insight on examples of situations where these approaches were implemented, and their efficacy was described. In general, we recommend reinforcing the implementation of monitoring efforts to further document the effectiveness of the approaches identified, particularly when used in combination, so as to enable the provision of recommendations based on the latest scientific data and updates in technology.

In addition, in line with the proposal for a reinforced Sustainable Farming Data Network (https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12951-Conversion-to-a-Farm-Sustainability-Data-Network-FSDN-_en), monitoring could be expanded to embrace both practices including the use of these approaches and ecological/environmental monitoring, so that live records of the progress is made at the farm level.

Finally, this list includes recommendations regarding the evaluation and availability of crop protection products compatible with the principles of the EU 2030 Biodiversity Strategy and of Integrated Pest Management (IPM), which apply across the scenarios (https://ec.europa.eu/environment/strategy/biodiversity-strategy-2030_en, https://www.iobc-wprs.org/ip_integrated_production/IP_tools_and_activities.html).</td>
</tr>
<tr>
<td>General approach 1</td>
<td>Crop diversification</td>
</tr>
<tr>
<td colspan="2">Crop diversification in this discussion included the introduction of additional crops in the cultivated area, instead of monoculture. The crops introduced can belong to the same group or to different groups, the objective being to diversify the landscape and habitat / resource elements involving the crop. Intercropping is included in this approach.</td>
</tr>
</table>

Approach 1.1	**Crop diversification in space**
This approach focuses on the diversification of the crops in the landscape, creating diversification of the habitat achieved at the same time.	

Pros

- Mutual benefit of growing different crops
- Habitat improvement at the landscape scale
- Spreads habitat disturbance related to cultivation intervention over time
- Reduced pressure on the soil
- Reduced pest pressure
- Revenue diversification
- Livestock: benefits many Ecosystem Services and provides economic diversification together with local livestock farms.

Cons

- Selection of crops conditioned by soil and climate
- Agronomical training may be needed
- New farming equipment may be needed
- For intercropping, crop protection requests confirmation of compatibility with all crops involved.

Limitations/prerequisites

- In conditions where the soil type and climate limit crop selection
- If the machinery or equipment is not affordable
- If the market for additional crops is not profitable
- Where soil quality triggers fertilisation during the first steps, until soil quality improves.
- Needs to be considered in the new CAP, so that subsidies are possible for new types of approaches e.g. agroforestry.

Examples of successful implementation of crop diversification

An example of a study where a positive relation between crop diversity and arthropod diversity was observed in arable crops (Aguilera et al., 2020), and the results of a meta-analysis reviewing the benefits of agrodiversification to above ground and underground biodiversity and related ecosystem services was published by Tamburini et al. 2020. Additional review of the benefit of crop diversification combined to other approaches can be found in Dicks et al. (2013) and Grass et al. (2016 and 2020 a and b). Dauber and Miyake, (2020), looked at the benefits of mixing food and energy crops at the landscape level. Schulte et al. (2017), showed the multiple benefits of integrating prairie strips into corn and soya cropland on insect taxa richness, pollinator abundance, native bird species richness as well as on total water runoff. Additional references on ongoing initiatives and projects can be found in Garnett (2020). The necessary trade-offs related to the cost of diversification on yields and compensations can be analysed and quantified as for example in Grass et al, 2020b).

Additional educational documentation is available (Bohan and Vanbergen 2020, Bock et al. 2020, EC 2020, ELN-FAB 2012) and recommendations proposed in the context of the CAP (Emery et al. 2012, Pe'er et al. 2019, ELO 2020, Zingg et al. 2019).

Approach 1.2	Crop rotation
This approach looks specifically into the introduction of crop diversity in the rotation and includes the introduction of cover crops and catch crops as a source of habitat and resource diversification.	
General considerations This approach is generally considered as a low-hanging fruit.	
Pros – Benefits soil quality and functions, water flow, nutrient cycle – Benefits biodiversity due to seasonality (e.g. winter stubble followed by winter cropping provide bird nesting sites) – Reduced pest pressure (and the need for crop protection) in the long term.	
Cons – Selection of crops conditioned by soil and climate – Agronomical training may be needed (e.g. grain legumes) – New farming equipment may be needed.	
Limitations/Prerequisites – In conditions where the soil type and climate limit crop selection – If machinery or equipment is not affordable – If the market for additional crops is not profitable – Where soil quality triggers fertilisation during the first steps, until soil quality improves – Need to be accounted for in the CAP so that to achieve biodiversity goals in the current CAP – There is a need for farmer training on important aspects of management.	
Examples of successful implementation of crop rotation The meta-analysis published by Tamburini et al. (2020) and additional reviews by Dicks et al. (2013) and Grass et. al (2016 and 2020a) provide a number of references. Additional educational documentation is available (ELN-FAB 2012) and recommendations proposed in the context of the CAP (Pe'er et al. 2019). Sweden has proposed recommendations as for example in Fångstgröda kan skydda morötter mot morotsbladloppa | Externwebben (slu.se).	
Approach 1.3	**Plant breeding**
This approach looks at the diversification of the offer in seeds and traits, so that to promote the use of crop varieties (new and revived) that present resilient / robust traits and diversify the crop itself at a larger scale. Research that reintroduces traits from ancient varieties is part of this approach.	
Pros – Reduced pest pressure – Possible solution to climate change.	
Cons	

- Current limited acceptance of engineered crops (GMO)
- May imply lower yields, which might in some cases be compensated in the long run if the variety is more compatible with climate changes
- Alignment with retailer/consumer requirements might need to be monitored.

Limitations/prerequisites

- If the market for additional crops is not profitable
- Availability of varieties
- Where the cultivation differs from current varieties that need training.

Examples of case studies

Unfortunately, examples of use of plant breeding remain limited in Europe. Döring et al. (2011) published their research on the reintroduction of genetic diversity in breeding.

General approach 2	Multifunctional field margins and non-cropped habitat, In-field beetle banks

Diverse approaches concern non-cultivated areas in the farmland that positively affect biodiversity. This includes field margins that provide habitat and resources to biodiversity and can constitute a buffer to spray drift and runoff/erosion at the same time.

Approach 2.1	Multifunctional field margins

General considerations

The approach is already implemented in European farms and is a low hanging fruit: requires to prepare information together with extension services and farmer organisations for farmers – with easy access (Flyer) – on existing incentives in member states.

The information on field margin implementation can be improved with additional information on any recommendations regarding pesticide application for the protection of the newly created habitat, particularly if ecosystem services are expected from the habitat.

The approach is part of the CAP, but due to the administrative burden still currently implemented on a voluntary basis, we need to develop a scheme to promote and reward such initiatives.

Pros

- Creates habitat and habitat connectivity in large landscapes
- Provides refuges
- Combination of margins and in-field areas, depending on the components of biodiversity and services that need protection, so that to optimise the use of multifunctional areas
- Reduced pest pressure due to natural competition by beneficial species
- Synergies with objectives of other frameworks – e.g. Water framework Directive.

Cons

- May reduce production surface (UAA) and related direct payments
- May be a refuge to pests (although this may be compensated by being a refuge to beneficial species) more prominent in short crop rotations
- Needs a dedicated risk assessment and guidance on how to implement and maintain field margins to ensure the absence of side-effects from PPP application

- Limited applicability of beetle banks in narrow fields.

Limitations and prerequisites

- Subsidies to compensate for the loss of UAA.
- Need for definition of protection goal for these habitats based on the Ecosystem Services and functions they provide through an adapted risk assessment.
- Need to be taken into account in the new CAP in a more practical way regarding field margin use and compensation for the non-cultivated surface loss in relation to yield loss.

Examples of successful implementation and other references

Several reviews are available that looks at the diverse categories of field margins and related benefits to biodiversity in different trophic groups as well as on the reduction of pesticide transfers (Alix et al. 2017, Dicks et al. 2013, Hacket and Lawrence, 2015, Meichtry et al. 2014, Oppermann et al. 2019, Scheper et al. 2013, Zingg et al. 2019).

Advice on the management of field margins dedicated to various services and biodiversity purposes is available in the UK. (https://www.rspb.org.uk/our-work/conservation/conservation-and-sustainability/farming/advice/managing-habitats/arable-field-margins/, https://farmwildlife.info/) or Sweden (Blommande Brunnar | Odling i Balans).

Member States have also published their list of measures towards field margins as for example Germany Information on SUD in Germany. (https://www.nap-pflanzenschutz.de/risikoreduzierung/schutz-von-umwelt-und-gesundheit/schutz-von-terrestrischen-organismen/, Kula et al. 2018). An integration in European policy has been performed (Science for Environmental Policy 2017).

Approach 2.2	**Permanent margins (trees and hedges)**

Pros

- Reduced transfers to surface water, adjacent ecotones like natural conservation areas
- Benefits soil quality and biodiversity
- Improves aesthetic services and value.

Cons

- Reduces production surface (UAA) and related direct payments
- May be a refuge to pests (although this may be compensated by being a refuge to beneficial species) more prominent in short crop rotations
- Needs a dedicated risk assessment and guidance on how to implement and maintain field margins to ensure the absence of side-effects from PPP application
- Long-term investment – only applicable for the landowner not tenants/land managers.

Limitations/prerequisites

- Subsidies to compensate loss of UAA
- Need for definition of protection goal for these habitats based on the Ecosystem Services and functions they provide through an adapted risk assessment
- Need to be taken into account in the new CAP in a more practical way regarding field margin use and compensation for the non-cultivated surface loss in relation to yield loss
- Part of the CAP, but due to the administrative burden still currently implemented on a voluntary basis, we need to develop a scheme to promote and reward such initiatives.

Examples of case studies or implementation and other references Examples and recommendations have been published in Oberč and Arroyo Schnell, 2020, and https://euraf.isa.utl.pt/projects/agforward.	
General approach 3	**Precision applications**
This approach includes targeted / directed pesticide applications, spot applications and application on the row only that are performed manually or through sprayers equipped with directed nozzles. Precision applications can also be performed based on data analysis such as soil / landscape vulnerability data.	
General considerations A number of projects are involving sensors able to detect e.g weeds and activate a spray on detection only. Sensors can equip any sprayer boom or be mounted on drones. This technology will be available in the near future. This approach can also include high-technology decision making tools for pesticides & fertilisers application in space and time (i.e. tools to detect and quantify pest pressure, privilege curative rather than preventive treatments). This approach is a low hanging fruit: in the framework of SUD - Introduction drift reducing technique on the whole application area. Limited investment is needed (only a set of new nozzles) with limited impact on treatment performance.	
Pros – Reduces chemical and fertiliser use to specific areas or weeds/pests being detected and reduces the total volume applied – Reduced prophylactic applications.	
Cons -	
Limitations/prerequisites – Requires adaptation of PPP guidance and/or enforcement (e.g. data required to define the adapted GAPs, and to address technical specifications of application technologies would that enter into ongoing Sustainable Use Directive revision or a dedicated guidance document on Precision Applications). – If access to technology and access to R&D not affordable.	
Examples of case studies or implementation and other references A simulation study focusing on weed impacts was published by Bürger et.al. (2008). Colbach et al. (2018) included high precision techniques in their analysis on crop production reconciled with biodiversity. A review of application techniques associated with risk reduction is available in Alix et al (2017). In Member States, policy decisions have been taken such as in the Netherlands for example, where 75% drift reduction is obligatory on all fields according to the Environmental Activity Degree: Driftreducerende spuittechnieken -Helpdesk water. Recommendation and advice is also published like this flyer on drift reducing techniques in Germany https://www.nap-pflanzenschutz.de/fileadmin/SITE_MASTER/content/Bilder/Risikoreduzierung/Pflanzenschutztechnik/Flyer_50_Prozent_Abdriftminderung_Web-2.pdf) and other tools (https://www.nap-pflanzenschutz.de/integrierter-pflanzenschutz/entscheidungshilfen/).	

General approach 4	Advisory tools and support services
This approach focuses on advisory tools and services aiming at improving agricultural practices for environmental purposes, biodiversity and IPM. E.g. comparison tool for environmental impact to select the products that best enter into their crop protection program.	
General considerations The approach is considered as a low hanging fruit: exchange information on country approaches, learn from each other and try to harmonise the best practices. Caution is needed, decision-making tools have to be specific enough to local conditions, to prevent errors in efficacy or resistance management, to avoid reduced income for the farmer.	
Pros Familiarisation with the approaches and helps farmers to see the benefits.	
Cons -	
Limitations and prerequisites – Requires time, staff, advisers, data collection and analysis. – Platform for an exchange of experiences and further promotion as well as trust building is needed. Such tools must be user friendly and require limited IT skills.	
Examples of case studies or implementation and other references Recommendations on IPM have been published (Belien et al. 2021, EP 2019, IUC 2020) and applications are available that provide access to IPM database and recommendations for product applications to limit pollinator exposure (https://www.corteva.com/products-and-services/europe/ipm.html). On waterbodies, diagnosis tools at the farm and watershed levels have been developed as for example in France, providing farmers with advice and tools to limit pesticide transfers to waterbodies and limit erosion, drainage and runoff (https://www.arvalis-infos.fr/view-258-arvoad.html) More generally a review of stewardship initiative developed in the public and provide sector was published (Alix et al. 2017) and training has been developed in a number of member States by TOPPS Prowadis http://www.topps-life.org/topps-prowadis-project.html). Online tools that support farmers in selecting crop protection options based on their needs as for example in the Netherlands (Environmental Yardstick for Pesticides - Pesticideyardstick) and Sweden (Bergkvist, 2004).	
General approach 5	**Monitoring data**
This approach expands the use of monitoring data in the risk assessment (in general not only PPP but most likely to be adapted in this area).	
General considerations The approach is considered as a low hanging fruit: exchange information on country approaches, learn from each other and try to harmonise the best practices.	
Pros – Generates knowledge on effectiveness of risk mitigation measures – Informs need for additional efforts of mitigation for certain critical substances that exceed quality standards (e.g. WFRD)	

- Provides data towards the validation of used models when revising guidance documents
- Improved holistic understanding of cause and effects.

Cons

- Complexity of field data/multiple cause-effects relationships
- Tailored design needed - fitting measurement protocols
- May imply long timelines to develop EU harmonised approaches such as GD
- Adaptation to different agricultural conditions in MSs.

Limitations and prerequisites

- Implication of farmers to share application data, farming network data.
- Inclusion of all scenarios
- Could be part of SUD action in MSs.

Examples of case studies or implementation and other references

Monitoring is recommended in the Biodiversity Strategy and F2F strategies (https://ec.europa.eu/environment/strategy/biodiversity-strategy-2030_en).

The main working groups dedicated on environmental and ecological monitoring are listed below:

- SETAC GW-Monitoring Document and interest group
- ICPPR Bee Protection Group working group on monitoring

General approach 6	Knowledge updated CPP risk assessment

The approach considers improving uptake of state-of-the-art knowledge into risk assessment including monitoring data, and to develop interim approaches to bridge time until GD revision or new GD are available.

General considerations

Some aspects may be low hanging fruits.

Pros

- Helps address known gaps in the risk assessment (e.g. Indirect / food web, vegetation distribution factor (VDF) in arthropod risk assessment) and improve the level of protection.
- Allows to account for technical progress in agricultural practice in the risk assessment.
- Would be beneficial in all scenarios.

Cons

- Harmonisation between MS could become more difficult if the status of guidance documents is not clear.
- The increase in the number of factors accounted for in the risk assessment may lead to increase the overall complexity
- Could reduce the number of registrations or uses.
- Lack of harmonised risk mitigation measures to implement to compensate for this.

Limitations and prerequisites

- Agreed procedure to make such agreements between MS needed, and legal framework.
- Availability of monitoring data.
- Reality check is needed to ensure the relevance for achieving the protection goals.

Examples of case studies or implementation and other references

EFSA publishes risk assessment guidance additional to existing guidance documents, at European level for PPP active substance assessment, e.g. https://www.efsa.europa.eu/en/publications

Zonal Committees publish zonal working documents with additional information on specific risk assessments, which are available on Circab (https://circabc.europa.eu)

General approach 7	**Low risk substances**

This approach proposes to speed up the assessment of 'low risk' substances and products and make the authorization less costly.

General considerations

Low hanging fruit: Exchange information on country approaches, regarding procedural question of PPP authorizations of low-risk products (e.g. reduced fees) and available subsidies for research for companies in this area.

Pros

- Improves availability of "low risk" products could reduce impact of PPP on biodiversity
- Would be beneficial in all scenarios.

Cons

- EU Active substance approval has fixed timelines and requirements (Reg. (EU) 1107/2009), with limited possibilities to increase speed
- Not to lower the degree of certainty in risk assessment due to missing data.

Limitations and prerequisites

- PPP authorization should be faster for low-risk products than normal products according to Reg. (EU) 1107/2009 Art.47 - 120 days
- Companies need generally more advice on authorization procedures – authorities are asked to take action
- Could be part of SUD action in MS.

Examples of case studies or implementation and other references

Recommendations are published in the State research and Development Programs e.g. In Germany coordinated by BLE (BLE is a central implementing authority within the scope of the Federal Ministry for Food and Agriculture (BMEL) https://www.ble.de/EN/Project-Funding/project-funding_node.html and the Farm to fork strategy: https://ec.europa.eu/food/horizontal-topics/farm-fork-strategy_en.

Webpages related to the Scenario C for further reading

Controlling the risks of pollution in the field by phytosanitary products in a catchment area - Arvalis site for field and watershed diagnosis tools (in French): https://www.arvalis-infos.fr/view-258-arvoad.html

Website for the exchange of information within the European Commission - publicly available information on national regulations and coordination between the Member States in the risk assessment of plant protection products – Circabc (registration required): https://circabc.europa.eu/webdav/CircaBC/SANTE/PPP%20Zonal/Library/Center/Public%20information

An Environmental calculation of Environmental Impact Points (EIP) for an unlimited number of pesticides - CLM Yardstick pesticide tool (fee – based): Environmental Yardstick for Pesticides - Pesticideyardstick.

Publications from the European assessment authority like Guidance Documents on risk assessment and conclusions individual active substances (Pesticides) - EFSA journal: https://www.efsa.europa.eu/en/publications

European Commission website on the farm to fork strategy: https://ec.europa.eu/food/horizontal-topics/farm-fork-strategy_en

Website with best-practice management advice for wildlife on farmland - farmlife: https://farmwildlife.info/

Integrated Pest Management (IPM) impact database for IPM Pro application: https://www.corteva.com/products-and-services/europe/ipm.html

Information on the national action plans concerning plant protection products in the remit of the Sustainable use directive - NAP Germany (in German): https://www.nap-pflanzenschutz.de/risikoreduzierung/schutz-von-umwelt-und-gesundheit/schutz-von-terrestrischen-organismen/

Royal Society for the Protection of Birds (RSPB) advice how to manage habitats for wildlife rspb: https://www.rspb.org.uk/our-work/conservation/conservation-and-sustainability/farming/advice/managing-habitats/arable-field-margins/

Possibility to join expert discussion groups on European level under the auspices of SETAC- SETAC interest groups: https://www.setac.org/general/custom.asp?page=JoinInterestGroup.

Information on Swedish flowering strip project (in Swedish): Blommande Brunnar | Odling i Balans

Swedish index for the protection of butterflies (in Swedish): Växtskyddsmedel i ytvatten - Sveriges miljömål (sverigesmiljomal.se)

Swedish recommendations on crop rotation (in Swedish): Fångstgröda kan skydda morötter mot morotsbladloppa | Externwebben (slu.se).

Project of the European crop protection industry's to reduce Plant Protection Product (PPP) entries into surface water from applications in the field - TOPPS Prowadis http://www.topps-life.org/topps-prowadis-project.html

4 Conclusions and Recommendations

4.1 General Agreements[7]

The overall aim of the workshop was to elaborate options and solutions on how to optimise the partly competing goals of generating sufficient food and halting / reversing biodiversity declines. To this end, a participatory workshop was organised with scientists from different professional backgrounds from the main stakeholder groups central to this debate, i.e., academia, regulatory authorities, farmers, industry and NGOs.

All participants shared the common goal of identifying suitable ways to optimise the targets of generating sufficient food efficiently while improving the biodiversity situation. It was generally recognized that this can be best achieved by cooperating and jointly developing efficient and effective solutions, which should then be broadly agreeable to society. The discussions revealed a high level of agreement on the main points relevant for the discussion.

- Firstly, participants agreed that both efficient food production within Europe as well as a high biodiversity status, relevant to European landscapes, are essential. Both production and biodiversity can support each other, however, participants agreed that there may be conflicts between both targets competing within a restricted land area.
- Diverse farming systems and diverse agricultural landscapes offering a variety of landscape features, ensuring connectivity of habitats, and requiring active landscape management are key elements for improving biodiversity and maintaining, restoring an attractive farming environment.
- Participants jointly called for a diversity of food preferably from local/regional production, that is affordable, accessible, and healthy for people.
- Participants agreed on the need to make food production more sustainable, limiting its environmental impacts, and reducing inputs (energy, chemicals), meat production. and food waste.
- The value and benefits of applying modern techniques such as precision farming, using digital solutions, satellite techniques etc. was recognised.
- Participants recognized that knowledge is key, this relates to further academic and applied research, training and information of farmers as well as information, education of consumers and the society.
- Participants concurred that solutions should be tailored to local needs and the respective situation; they generally involve combining multiple approaches (there is no 'one-size-fits-all' solution at all times).
- Integrated pest management / integrated crop management using agro-ecological knowledge are key concepts in optimising food production and biodiversity.
- It is necessary to put farmers into the focus, ensuring adequate remuneration, financial support for ecosystem service provision and to improve societal esteem of food and food production.
- While 'land sparing' was considered important to reach the food production and biodiversity targets (see keynotes by Gäbert [3.5 and Appendix 3.4] and Obersteiner [3.6]), it was agreed that both land sharing and land sparing aspects need to be considered (compare keynote by Dauber [3.2]). There should be no 'either or' discussion, instead both should go hand in hand and depending on the situation, location, and time either this or that aspect may prevail.
- Whilst new (combinations of) approaches were proposed, many of the approaches identified are already in place; however, they are not necessarily sufficiently implemented. Barriers for implementation were discussed and ways to overcome these barriers were recommended.

A high level of agreement was reached on many main points, although, of course, different stakeholders and likewise individuals expressed diverse perspectives on where to put the main emphasis (for example more on

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[7] See also workshop slides on conclusions and recommendations in Appendix 4.

the land sparing or land sharing aspect, more on technology or on ecology). Nevertheless, all agreed to consider all aspects open minded in the light of an impartial science and data-based evaluation of the various options (see also Principles and Criteria).

Finally, participants support the transfer of recommendations developed in this workshop into their respective organisations.

4.2 Principles and criteria to be considered when assessing the various approaches

A wide range of potential approaches (up to proposed changes in farm types and including holistic approaches) was identified appropriate for achieving the goal of optimising biodiversity and food production; even more are available and will be developed in the future. Which approaches, respectively combinations thereof, are to be recommended in specific situations should be based on an impartial science and data-based evaluation of the various options. To this end a set of general principles and criteria was identified and agreed upon to be considered during the evaluations. These general principles are:

- Assess all approaches according to the same principles and criteria.
- Be open to all approaches, avoid constraints or personal preferences.
- Assess the approaches based on scientific criteria.
- Take the complexity of biodiversity into account.
- Take the complexity of agricultural food production into account.
- Take the diversity of farmer experiences into account.
- Take global implications (trade, markets, international rules and standardisation, harmonisation etc) into account without letting these become an excuse/obstacle to take no action with regard to improving the sustainability of farming.
- List and, where possible, quantify the pros and cons of the respective approaches for both biodiversity and food production, considering sustainability aspects.
- Be explicit about the assessment unit; the smallest unit likely would be the farm scale, respectively the farm (or a group of farms) within the surrounding landscape.
- Prepare a transparent summary/report about the assessment including the pros and cons, the criteria applied, and potential key personal judgments made.

The standard criteria often included in formal evaluation exercises – and here, too - are effectiveness, efficiency, relevance, coherence, and sustainability, which when considered together with external factors, allow an assessment of the *impact* of the intervention under examination.

The group identified *the feasibility* of implementation of an approach as well as its measurability as additional criteria to be included.

It was agreed that both qualitative and quantitative aspects should be considered, and socio-economic aspects, too, must be taken into account.

4.3 Approach recommendations related to scenarios

Four case studies were conducted on different agricultural scenarios, being 1) arable farm with a degraded soil, 2) low productivity, mixed farm, 3) medium intensive orchard and 4) large intensive arable farm (Table 3). For each of the scenarios the participants were asked to choose approaches from the inventory (Appendix 3.5) for their value to benefit biodiversity and consider any additional approach if necessary.

Table 3: Short summary of approaches selected in the four case studies

Approach	Case study 1: arable farm, degraded soil	Case study 2: low productivity mixed farm	Case study 3: medium intensive IPM orchard	Case study 4: large arable farm
Habitat creation	Vegetated field margins, hedgerows (decrease soil erosion next to biodiversity benefits		Intercropping grass strip & flowers	Permanent / multifunctional margins
Landscape management	Landscape management	Refurbishing landscapes	Diversified landscapes	
Farming practice	IICM (consider agroecological science), soil health improvement, crop rotation / diversification, agroforestry	Diversify cropping Alternatives to PPPs	Intercropping multiple crops, warning systems	Crop diversification, precision farming, low risk substances
Support/incentives	Advisory service, training, decision tools, farmer incentives	Advisory service, training, decision tools	Income (payments, markets); PPP tax; Plant breeding	Advisory tools

Each of the approaches proposed was then discussed regarding the pros and cons it provides for biodiversity, agronomy and economy. In addition, the possible limitations to an implementation as well as the prerequisites to its implementation were identified. Finally, recommendations for each approach were proposed.

The inventory had already illustrated the diversity of the approaches available, both in specificity of action and purpose (see table below). Specific actions include precision applications, planting of flower strips, providing nesting boxes while more general approaches are crop diversification, technologies, cultivation methods and decision support systems while rather holistic approaches are agroforestry, active landscape management or transition to mixed farming systems. Differences in purpose refer to e.g. additional habitat provision, adopting cultivation practices with less environmental impact, stabilising the farm income, training and knowledge building or change in agronomic philosophy.

4.3.1 Approaches selected in the case studies

For case study 1, starting with highly degraded soils and very low productivity, the objective was to gradually increase soil health in a sustainable way, a more long-term process, accompanied by measures to improve biodiversity, which can show effects more instantly. Finally, this will increase overall productivity again. Large emphasis was given to integrated crop management and several approaches of integrated plant nutrient management. The latter includes less irrigation and tillage, fertilisation adapted to local crop requirements with an emphasis on increasing soil organic matter, targeted crop rotations/intercropping, and soil microbiome amendments. In addition, structural landscape elements like reduced field size coupled with vegetated margins or hedges were proposed in order to reduce erosion and provide habitat for pollinators and other beneficials.

As a more radical approach, several options for change in farming type were proposed for the recovery of the farms soil fertility, i.e. agroforestry, agroforestry coupled with life-stock or mixed arable farming with livestock.

In case study 2, the aim was to increase biodiversity in a low productive mixed farm by changing the focus of production from arable farming of a limited number of crops to a more diverse crop cultivation, and more emphasis on extensive livestock production. For the diversification of income. This is coupled with elements of landscape management (new hedges, woodlots, pastures) to increase habitats for wildlife and attractivity for letting tourist apartments. Crop diversification and extensive livestock management and hay production can extend rotation schemes, reduce the need for chemical inputs, unlock new market opportunities, and provide diversified habitats for wildlife on the farm property, increasing the farm's attractivity as a holiday location. Organic certification could also help to achieve higher prices for the produce, compensating for low productivity. Proper functioning advisory services and good decision support systems were considered as an approach that could generally facilitate the implementation and improvement of approaches by farmers.

In case study 3, a medium intensive orchard with a fair quality of biodiversity, the aim was to increase both productivity and biodiversity. The main limitation is that fruit quality must be maintained as the target markets are supermarkets and exports. The production is highly labour intensive and already follows IPM schemes. It was considered useful to improve habitats in the orchards by intercropping the grass strips with flowers, phasing the mowing to reduce disturbance and the provision of nesting boxes. Further emphasis was given on the reduction of the necessary plant protection inputs through more targeted applications and the use of more "low-risk" substances, biopesticides and biocontrol with beneficial arthropods. Efficacy of the management practices could be increased by the use of digital decision support systems. Direct marketing was seen as an option to reduce economic pressure on the production system, opening capacities for less intensive management. In addition, the case study offered options for a diversification of the production system itself e.g. by planting crops between the tree rows, integrating grazing animal production in the orchard or mixing varieties within the tree rows.

In case study 4, a large intensive arable farm the aim was, to keep a high level of productivity while improving biodiversity (moving from quadrant C to D). Crop diversification in space and time (rotations) was proposed to diversify landscape and habitats, spread habitat disturbance due to cultivation, diversify revenues, and reduce pest pressure and pressure on soils. Breeding was considered as a supplemental approach for crop diversification as it may help to develop new crops and varieties attractive for crop diversification. For habitat creation multifunctional field margins, non-cropped habitats, in-field beetle banks, and hedges were proposed. Precision applications, use of "low-risk" substances where applicable and advisory tools/support systems were seen as useful to reduce chemical inputs and to increase efficiency of cultivation practices while reducing risk to biodiversity. Further monitoring data and knowledge updates on risk assessment were considered useful to check efficiency on biodiversity of approaches mainly linked to crop protection.

It was acknowledged that most of the approaches brought up in the case studies were not new, and some were already suggested since a few years, and more efforts should be dedicated to support a broader implementation by farmers.

Among farming practices, several approaches were considered "low-hanging" fruits, such as phased mowing, use of precision application systems, drift reduction technologies or the use of low-risk substances. Precision application was also linked to general use reduction and risk reducing targets within the framework of the Sustainable Use Regulation and the other approaches were thought to be easily integrated into farmers routines as the existing machinery could be used.

Case study 3 identified habitat creation in orchards as a low-hanging fruit. Similarly, case study 1 and 4 concluded that the establishment of multifunctional field margins could be further implemented. The more complex approach of diversified landscapes, integrating aspects of land sharing and land sparing, was considered well achievable in case study 3, however, it requires that adequate information is prepared and communicated to farmers jointly by extension services and farmers organisations. Another low hanging fruit lies with advisory tools and support services. In case study 4, advisory tools and support services were considered ready to enable "exchange of information on country approaches, learn from each other and try to harmonise the best practices." It was emphasised that caution was necessary to ensure decision-making tools were sufficiently specific f*or* local conditions, to avoid negative impact on efficacy, resistance management and eventually the farmers income.

4.3.2 Approaches proposed across the case studies

A key theme for improving biodiversity in agricultural landscapes across all scenarios was habitat creation and the recommendation to manage landscape structures such as field margins, hedgerows, flower strips etc.. The call for crop diversification – an important component of biodiversity in agricultural landscapes - is also found in all scenarios. Furthermore, the importance of data and knowledge for gaining an optimal balance between food production and biodiversity was generally recognised by participants, accordingly, recommending appropriate advisory tools made available to the farmers. Farming practices should be sustainable and inputs of energy and chemicals, for example, should be reduced to the level necessary for safe and sustainable food production.

4.3.3 Limitations and pre-requisites of different approaches

There remain limitations to the implementation of approaches, which lie with the workload needed to implement an approach, the need for new skills or specific machinery, in situations where the approach may trade-off with general cultivation practice (weeds/pests acceptable in some growth stages but not in others) or when farmers see or fear negative impact to their long-term income. The latter also affects long-term approaches like transition to different production systems (e.g. organic, agroforestry) or higher investments on machinery and knowledge. The costlier and complex an approach is, the more a farmer needs to be convinced that it is beneficial for his farm and long-term income. Hence important prerequisites to overcome obstacles linked to approaches are a clear demonstration and communication on the benefits for the farmer through advisory / extension services, model-farms and demonstration trials, training and advice during implementation, provision of clear incentives and locally adapted financial compensation to cover income reduction and increased investments. Regarding the advisory system it was noted in case study 2 that the *"Acceptance / Implementation is rather a matter of (narrow) economic, political and public finance cost/benefit considerations. Don't act in a simple top-down manner making farmers feel all others know better how to run their farms than they do. Find farmers that pick-up ideas and develop solutions. They can act as role models."*

Other hurdles are observed if an approach requires the interaction of multiple actors. This concerns landscape management where multiple farms, private landowners and infrastructure define the landscape of a region. Apart from the need that multiple landowners create and shape the habitats in a landscape, land use changes from agriculture to settlements and infra-structure were identified as potential issues if the agricultural use becomes relatively less attractive. For direct marketing or marketing of a diversified crop production, farmers require sufficient access to potential clients otherwise the approach risks becoming economically obsolete.

Overall, the analysis of the proposals for all four scenarios illustrates that there is no "one approach fits all", however the following was deduced from the analysis:

- The selection of the approaches to implement to a specific situation requires consideration of the specific agronomical, economic and environmental conditions as well as a clear vision on the biodiversity target of the approaches selected.
- In all situations, habitats are key for biodiversity, and small changes may provide good improvements.
- The farmer is key for the implementation of most approaches.

- It is critical to integrate the agronomic constraints related to food production, and the economic environment that must enable farmers to ensure a viable income from their activities.
- The creation and/or reinforcement of extension services that support farmers with practical advice on agronomical and ecological aspects of the implementation of approaches is essential.

The following characteristics of an approach can increase its potential to qualify as a low hanging fruit:

- Clear benefit from the farmers perspective
- Low complexity and straight forward in action
- Easy integration into farmers routines
- No need for new equipment or new technology compatible with existing ones
- Utilisation of areas for biodiversity measures that are either not used for crop production or will have little impact on production
- Technology feasible to support different purposes
- Opportunity for farmer to stabilise income
- Simplicity of implementation: the more complex an approach the more it requires intensive support (extension & advisory services, training, communication, risk hedging)
- Training opportunities for the farmer.

4.4 Data gaps and areas of research

It was acknowledged by the participants of the workshop that agricultural production and biodiversity can support each other, but it was also seen that there may be conflicts between both targets competing within a restricted land area. Participants also concurred there is not a ‘one-size-fits-all’ solution at all times that would be suited for mitigating those conflicts, but solutions should be tailored to local needs and the respective situation, generally involving a combination of multiple approaches. To develop such tailored solutions and bring them into action would be facilitated by knowledge and hence data about the respective regional situation of biodiversity and ecosystem services (both demand and supply) as well as of land use and management practices with varying impacts on biodiversity. An obstacle is that such data in the necessary spatial and temporal resolution are often not available for broadly applicable science/data based 'expert systems for the European countries, partly because of the lack of monitoring programmes or because existing data are not accessible for science and decision-making approaches. Latter include data on land use at the field scale (e.g. from IACS data) and agronomic data at the farm scale. To overcome this obstacle, a wider monitoring of biodiversity and status and functioning of ecosystems and their services in agricultural landscapes is required. Information about pollination limitation in areas of production of insect pollinated crops such as many fruit crops for example could help in designing targeted solutions for the support of pollinating insects in that area. In addition, data on land use and management practices have to become more transparent to make science-based decision support for targeted actions possible.

All participants also agreed on the need to make food production more sustainable, limiting its environmental impacts, and reducing inputs including energy and chemicals. Integrated pest management / integrated crop management using agro-ecological knowledge were seen as key concepts in optimising food production and biodiversity. There may be two obstacles impeding the agro-ecological transformation of food production which are closely connected. First, many farmers in Europe do not perceive ecosystem services such as natural biocontrol as relevant for their production, most likely because this service can easily be substituted through pesticide applications at low cost. The same may be true for the connection between soil fertility and ecosystem services in soil versus mineral fertilisation. Second, agro-ecological practices in particular those connected to soil management and natural biocontrol are not well known by many farmers and farm advisors or they are uncertain about their reliability. Those approaches are also not well developed by applied research in Europe and for European farming systems. Approaches such as crop diversification, mixed cropping, use of trap and service crops, to name only a few alternative practices, are still underrepresented in agricultural research and rarely combined with research on digitalisation of farming. It may not be in the mindset of many agricultural scientists that such approaches could potentially help in an optimization of food production. The prospect that such practices may result in reduced yields becomes an obstacle for taking policy action and for researching and implementing on-farm practices. This is because it is believed that telecoupling or leakage and global markets would prevent achieving a higher sustainability because others in other areas would take over those high yielding but non-sustainable practices. Here a better evidence base on the true connections and consequences of moving towards sustainable farming in Europe may be helpful.

To efficiently tackle those problems of optimising food production and biodiversity, agricultural, economic, ecological and nature conservation research would have to undergo some transformation in the way complexity of biodiversity and of agricultural food production are considered. For example, by applying more transdisciplinary research in which the diversity of farmer experiences is considered and farmers take up a central role in testing and developing innovative and more sustainable farming practices. Based on the experiences made, agronomic constraints related to food production may be overcome by creating an economic environment that enables farmers to ensure a viable income from their activities in food production and the delivery of other public goods and services.

Data based expert systems and decision support tools available to farmers and farm advisors, combining for example frequently updated data on local weather, pest pressure and soil condition with regional targets on biodiversity conservation and harnessing of ecosystem services, together with best practice examples, may be helpful in the future for supporting farmers in making the right decisions at the right time in their respective location.

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Appendices

Appendix 1: List of Participants *[8]

Alberto Arroyo Schnell* / Barbara Oberc	IUCN (International Union for Conservation and Nature)
Alf Aagaard	Danish EPA
Alistair Leake	Game & Wildlife Conservation Trust's
Anna Rocha	ELO (European Landowners Organisation)
Anne Alix	Corteva Agriscience
Arnd Weyers	Bayer Crop Science
Balthasar Smith* / Christine Kula	BVL (German Bundesamt für Verbraucherschutz und Landwirtschaft)
Christine Meisinger	EU Commission, DG Sante
Christine Toelle-Nolting	NABU, Birdlife German branch
Christoph Mayer	BASF
Claire Brittain	Syngenta
Claudia Olazabal	EU Commission, DG ENV
Dany Bylemans	University of Leuven/ PCFruit
David Bohan	INRA (Institut National de la Recherche Agronomique)
Emilio Gil	Universitat Politècnica de Catalunya
Evrim Karacetin	Butterfly Conservation Europe
Felix Herzog	Agroscope, Zürich
Gerlinde de Deyn	WUR (Wageningen University & Research)
Ian Barber	Corteva Agriscience
Ines Santin Montanya	INIA (Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria)
Jacoba Wassenberg	Ctgb (College voor de toelating van gewasbeschermingsmiddelen en biociden)
Jens Dauber	Thünen Institute, Braunschweig
Jose Luis Prados	INIA (Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria)
Karin Nienstedt* / Zsuzsanna Koenig	European Commission, DG Sante
Katja Knauer	Swiss BLW (Bundesamt für Landwirtschaft)
Lorraine Maltby	The University of Sheffield
Mariana Ledesma	Kemi (Kemikalieinspektionen, Swedish chemicals agency)

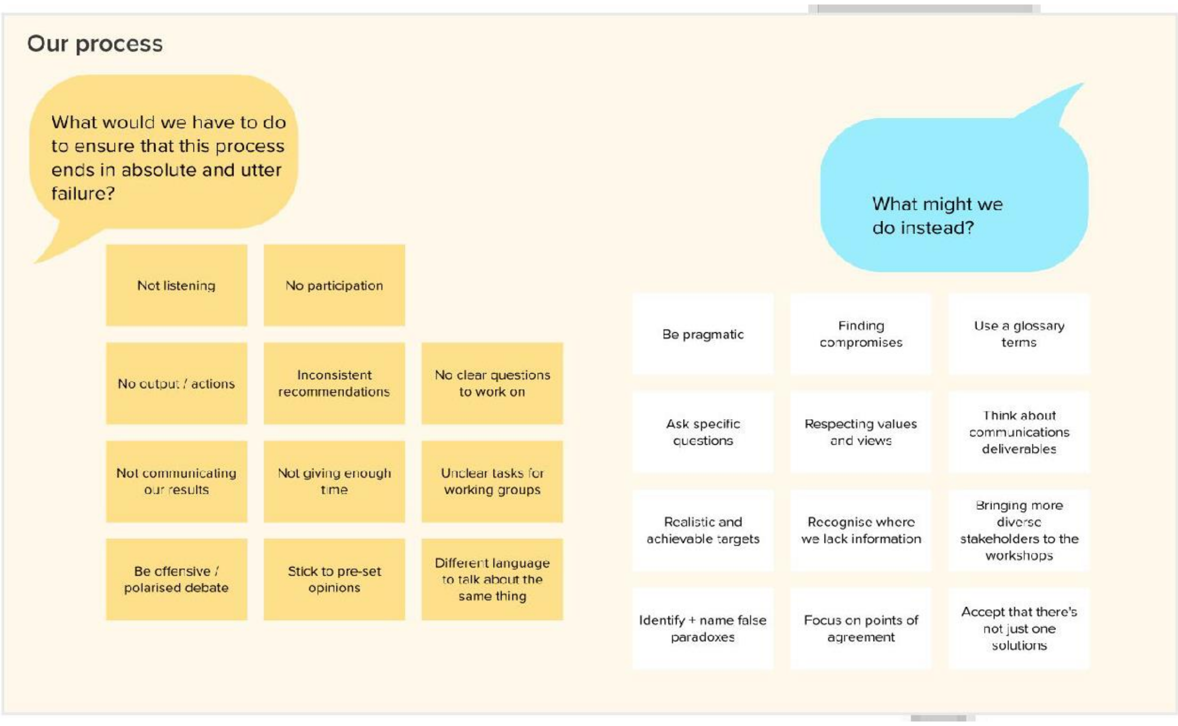
8 * Some participants were not able to attend all meetings and, where possible, were then substituted by another person from the same organisation

Mark Clook* / Mike Fryer	HSE, CRD (Health and Safety Executive, Chemicals Regulation Division), UK
Mark Miles	Bayer Crop Science
Michael Obersteiner	Environmental Change Institute; Oxford & IIASA,
Nenad Peric	COPA-COGECA (only part time)
Noa Simon-Delsoe	Beelife (European Beekeeping Coordination)
Nora Temme	KWS Saat SE & Co. KGaA
Olivier Körner	ADAMA
Paolo Barberi	Sant'Anna School of Advanced Studies, Pisa
Paula de Vera	COPA-COGECA
Peter Campbell	Syngenta
Peter Dohmen	Consultant
Rachel Sharp	EFSA
Richard Pywell	CEH (Centre for Ecology & Hydrology), Oxford
Rita Rapagnani	ENEA (Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile), Rome
Samuel Masse	CEJA (European council of young farmers), part-time
Sina Egerer	UBA (Umweltbundesamt, German Environment Agency)
Steven Kragten	Syngenta
Thomas Gäbert	Agrargenossenschaft Trebbin
Vanessa Mazerolles	Anses (Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail)
Virginie Ducrot	Bayer Crop Science
Wolfgang Krämer* / Benjamin Schreiber	AGES (Austrian Agency for Health and Food Safety)
Zelie Peppiette* / Andrea Furlan	EU Commission, DG Agri

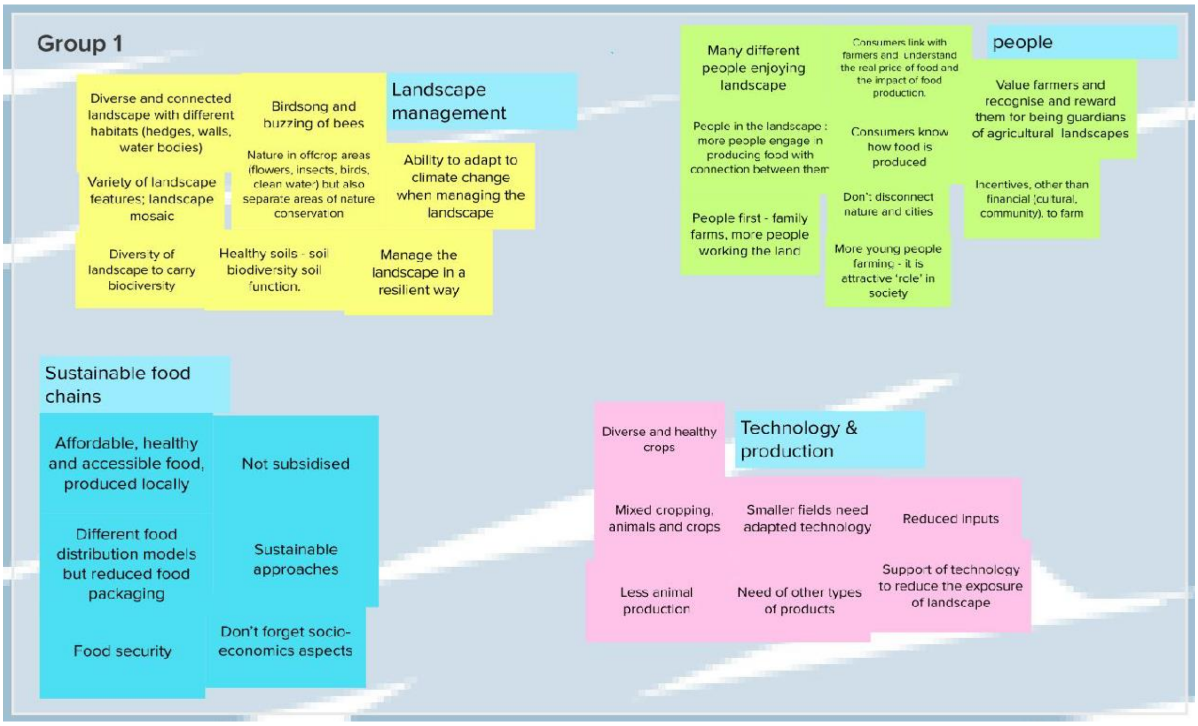
Facilitator: Wiebke Herding (ON:SUBJECT)

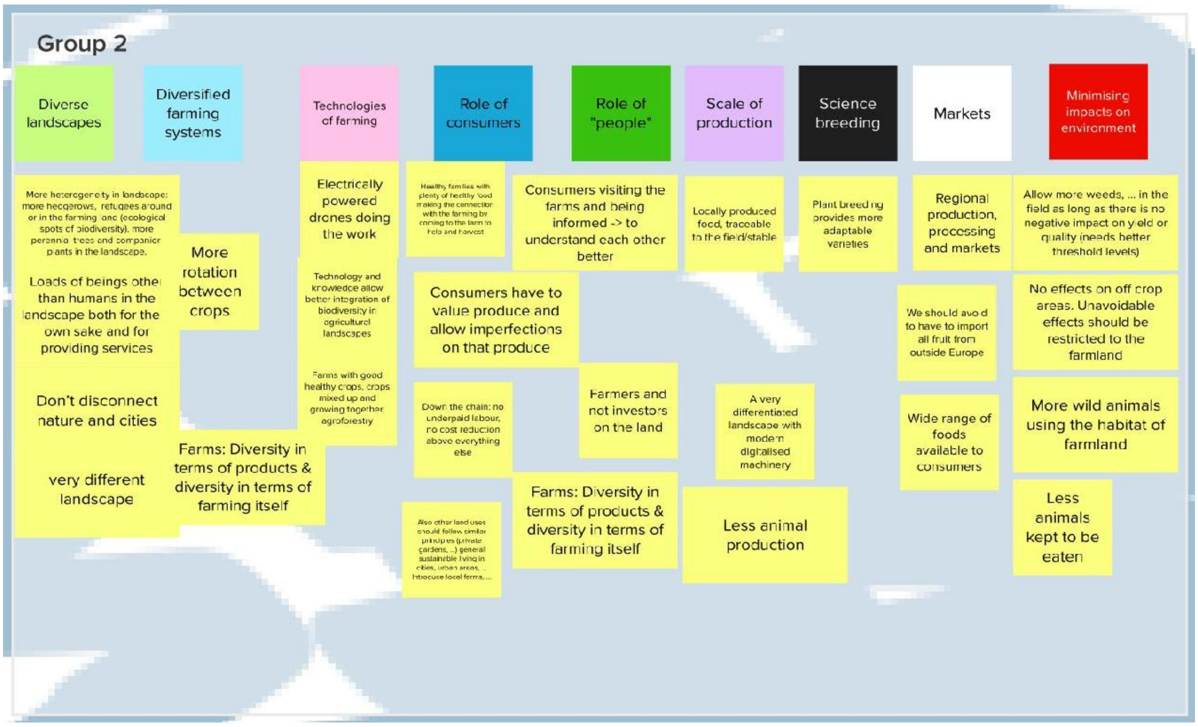
Organisational / technical support: Barbara Koelman (SETAC).

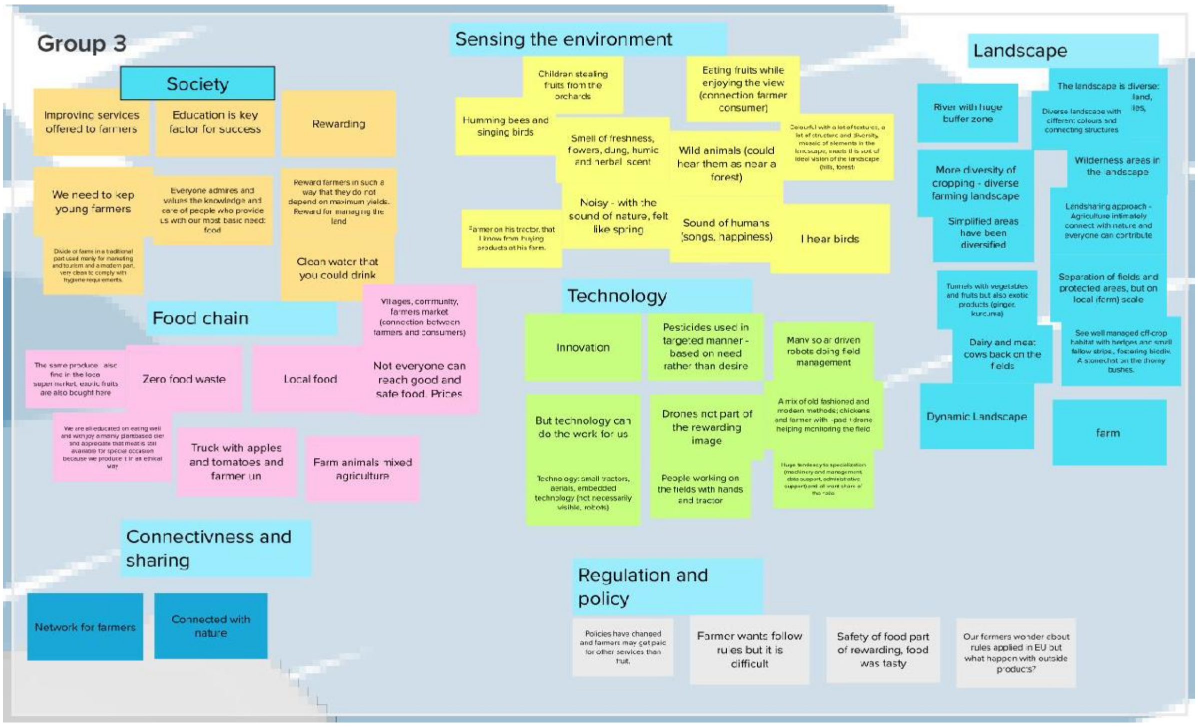
Appendix 2– Workshop process, meeting culture



Appendix 3.1: Workshop Envisioning a future







Summary slide from the January workshop

Envisioning a future agricultural landscape

Diverse, connected and resilient landscapes

- mixed farming; multiple crops/rotations, multiple landscape features, land sharing & land sparing

Sustainable food chains

- Affordable, healthy & accessible food; zero food waste; connection between farmers and consumers

Advanced technology

- Precision farming, drones, solar driven robots

Principles

- Biodiversity is important
- Food, and hence agriculture, is important
- Need to support both biodiversity and agriculture
  - Agriculture can benefit from biodiversity; biodiversity can benefit from agriculture
- Sustainable crop production requires a collective effort & farmers are key.

What we are hearing about biodiversity and agriculture

Can we be pragmatic and focus on obvious problems?

Towards a thriving future

- Understanding the importance of diversity in landscape and agricultural approaches
- Ensuring farmers can make a decent living producting healthy food
- Making space for people and wildlife
- Reducing inputs (energy, chemicals, water, transport distance...)
- Valuing food and connecting with people: consumers and farmers
- Adapting technology to context

Contributions

Science to provide & evaluate solutions

Education & communication

Society to accept higher costs

Farmers & industry

What we are hearing about biodiversity and agriculture

We should explore further

- Where do we have gaps in knowledge?
- What are potential solutions?
  - Technology & tools
  - Training and education
  - Biodiversity-friendly farming practices
  - Policies that reward ecosystem services
  - Innovation & research
  - Models and scenarios
- How do we evaluate them? In which contexts are they useful?
- What are bottlenecks to adoption of existing solutions?
- How much biodiversity and food production do we aim for (and where)? (political framework)
- How do we communicate our outcomes to be useful to society?
- How do we measure progress?
- How can we best collaborate in our different roles?

Emerging questions

- Compromise
  - How to achieve compromise between food production and biodiversity?
  - Are various stakeholders willing to find compromises?
- Solutions
  - What new tools and approaches do we have already that can help?
  - How to find realistic and scalable solutions?
- Economics
  - How to incorporate the economics within our debate and solutions?
  - Will society accept the costs for biodiversity?
- Education
  - How to educate consumers and society?
  - How do we get politicians to listen to science?

Appendix 3.2: Identifying and reconciling different perspectives on food production and biodiversity

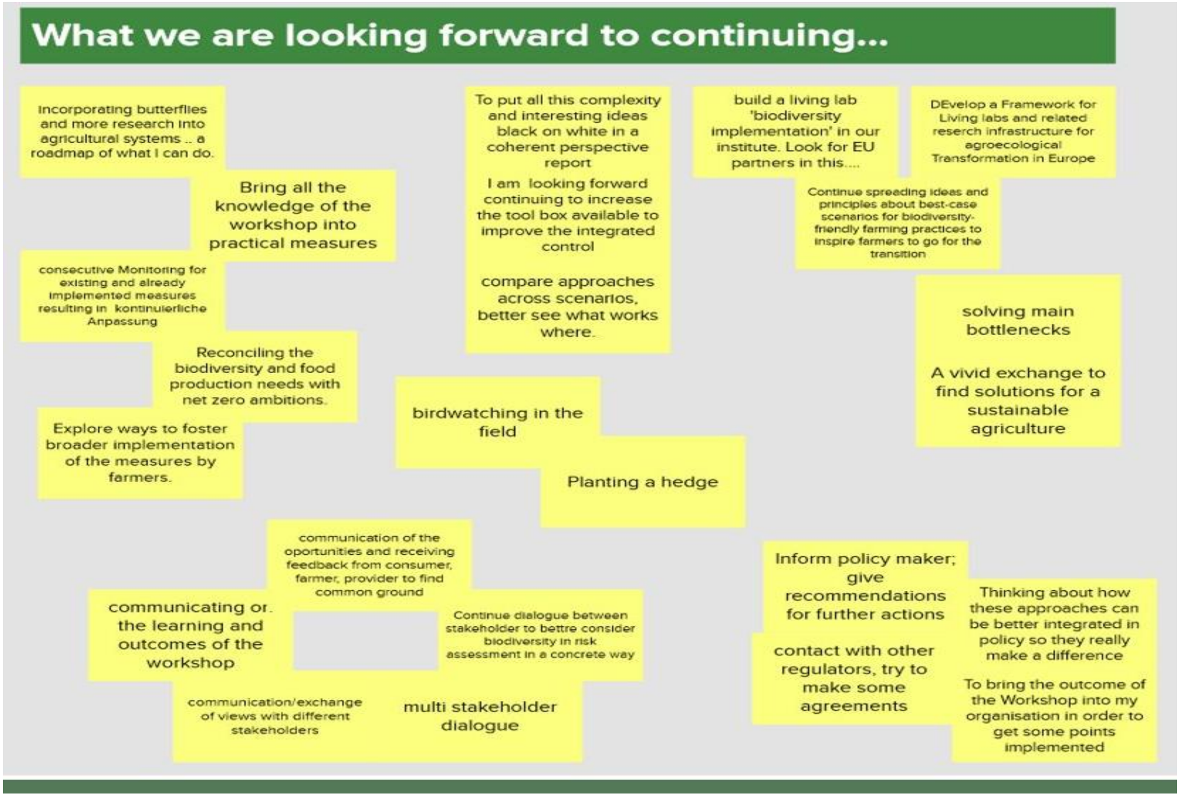
Table A3.2: Results of polarity mapping exercise in which workshop participants were asked to consider the upsides and downsides of focussing the management of agricultural landscapes for food production or on biodiversity. Perspectives were expressed by a diverse group of stakeholders and all perspectives were respected and reported, irrespective of whether other participants agreed or not. Participants were not asked to provide evidence to support perspectives, which should therefore be treated as options rather than statements of fact. Many of the upsides and downsides identified will be context dependent and the order of bullets points listed does not imply any ranking or relative importance.

1. Agricultural Food Production Upsides	2. Agricultural Food Production downsides	3. Biodiversity Upsides	4. Biodiversity downsides
● Agricultural services easier to make available ● Might increase quality of food ● Affordable healthy food ● Accessible food ● Easier to apply precision agriculture and mechanisation ● Appropriate/simple production system ● Food security ● Everywhere agriculture -> local production ● More standardisation ● Low variation per farm (easier) ● Low variation in food nutritional value ● Higher efficiency of farming/food production ● Quantity vs quality trade-offs ● Lower environmental emissions ● Less land needed for production so more land for nature	● Increased vulnerability of the food production system, loss of sustainability ● Potential for lowered resilience and adaptability of systems ● Risk of overproduction resulting in more food loss and food waste ● Reduction in food price due to dependency of on the market ● Intensive agricultural systems become dominant and low-input systems become less competitive and may vanish ● Potential loss of knowledge of alternative ways of producing ● Potential erosion of resource use efficiency ● Increased dependency on inputs (pesticides, fertilizers) ● More input, more energy needed	● Sustainable use of resources ● Reduced chemical inputs (pesticide & fertilizer) ● Increased diversity of food crops ● Higher yields and higher quality for some crops ● Resilient ecosystems (e.g., to climate change) ● Increase natural pest control (and reduced inputs) ● More pollinators and therefore natural pollination ● Increased soil health (structure and function) ● Increased wild foods ● Increased water quality ● More genetic diversity ● More diverse landscapes ● Potential health benefits from additional food crops ● Increased national reputation	● Less land for food production ● Might increase number and abundance of pest species ● Only high value, cash crop are produced, rest imported, i.e. reduced diversity of crops ● More labour intensive, requiring either higher work force (expensive) or more specialized machinery (technical intensification) ● Measures may be more extend costly (e.g. seed mixtures) ● More expensive food due to increased production cost / lower productivity ● Reduced food aesthetics ● Reduced shelf life leading to increased food waste ● Less quality commodities, less safety of food through contamination with natural toxins from weeds, fungi or

• Long term view needed to ensure sustainability. Biodiversity and soil quality are key for long term agriculture • Agriculture sector more attractive for investors • Agriculture supply chain profitability enhanced • Interesting for food chain stakeholders • Easier/cheaper/more efficient to provide agriculture-related services (advice, contracting, input supplies, market infrastructure, processing) • Focussing on agriculture everywhere would increase supply of locally produced food • Might increase attractiveness of farming sector jobs (status & income) • Might lead to good farmers' income • Less dependence on import • More efficient farming • Might lead to higher salaries for workers which could attract people and provide solution for lack of workers • Fewer workers needed in farming overall if production efficiency increases • Low production price	• Impact on biodiversity and environment is getting too big to cope with. • Unbalanced ecosystem services and loss of vital services • Educational aspects of nature - we become less aware of the environment • More simple and boring landscapes • Risk of loss of resilience at landscape level • Risk of soil quality degradation • Reduction of habitat • Risk of erosion of ecosystem services • Spill-over of environmental impacts from farming to other areas (urban) • Dependency on international trade is increasing • More pressure on farmers towards more productivity • Lock-in of farmers to operate within the narrow economic boundaries becomes even bigger • Reduced independence of farmers • Potential to drive small farmers out of business • Lose support of local farming • Potential for increased costs to maintain other services (e.g., clean water)	• Enhanced reputation and valuing of farmers and farming • Increased opportunities to observe and experience nature • Increased links between people and nature • increased recreational value and ecotourism • Increase wellbeing and public health • Increased value of products, other markets ("environmentally-friendly") • Increased diversity of income to farmers • More people employed in farming • Opportunities to support and revitalize local communities • More attractive places to live - property prices increase	bacteria (not marketable or at much lower prices) • Increased resistance to remaining PPP further reduces available options of integrated pest management. • Land abandonment • Rewilding might not bring as much biodiversity as if landscape was agriculturally managed (e.g., farmland specialists) • The resulting biodiversity not necessarily is what was initially expected (dominance of alien or otherwise unpreferred species) • There is a risk of outsourcing of some environmental problems to other regions • Impacts of climate change on biodiversity have to be considered (including crop, pest diversity and feasibility of agricultural systems) • The development of suitable seed mixtures with typical natural species is time consuming. • Farmers' income may go down • The implementation of measures enhancing biodiversity are time consuming and to some extent costly, impact on farmers income.

	• Disconnecting farming from general public and the rest of the world • Society has little say in decisions made in agriculture, choice of food consumption matter little, resulting in loss of food sovereignty • Agriculture at the risk of losing connection to ethical aspect (context related) • Mental and physical health issues may grow due to increased agrochemical inputs • Reduction in job opportunities in the farming sector		• Decrease of competitiveness of EU agriculture and increased need of imports • More subsidies needed to compensate for economic disadvantages (direct reduction of productivity, indirect reduction by spending time for other things) • Lower farmer satisfaction • Job attractiveness may decrease: lack generation renewal • Potential increase of disease vector species (e.g,. malaria) • Increasing food prices and eventually increased food poverty • Social unrest if food prices explode

Appendix 3.3: Possible next steps from a stakeholder viewpoint



Position: Industry

Round 1: What trends are already moving into the right direction?

- regulated sector with high regulatory standards
- sustainability as business opportunity (new market segments)
- increased sensitivity from consumer/public on need of BD-Ag balance--> new business opportunities
- development of new machinery to allow agroecology and sustainable practices
- voluntary certification as opportunity for differenciation
- sustainability is a marketing tool
- corporate responsability gaining more importance
- environmental aspects are highly regulated; ever increasing standards
- transparency initiatives
- IPM certifications

Round 2: What obstacles are holding us back?

- sustainability criteria somehow fluent (between retailer, between different sectors within food chain, public), different weighting on the 3 columns
- regulatory and burocratic hurdles (e.g. development of new biopesticides, microencapulations, insect hormone analoga)
- high initial investments for uncertain business volumes
- economic interest: need to do successful business while increasing sustainability --> but it is not charity
- too many concerns hampering development of innovations
- lacking IPM schemes for many crops/geographies yet (it takes time to develop)
- access to technologies in all countires to all farmers

Round 3: What are elegant steps that could make a difference here?

- foster the use of IPM more broadly
- produce data that support the use of technology, in collaboration with regulators
- consolidate database on risk mitigation measures to build confidence and promote their implementation
- initiate collaborative field work on technology and tools (include stakeholders)
- support of conservation innitiatives.
- reinforce salesforce awareness and communication toolbox on biodiversity aspects and IPM
- coordinate the access, recognition and support to new technologies (e.g. risk mitigation measures), and democratize access, facilitate access to smaller farms

Position: Policy/Regulators

Round 1: What trends are already moving into the right direction?

- EU Green Deal
Farm2Fork
CAP
- INitiatives to provide info to wider society and stakeholders to raise awareness
- More focus on ESS
- National level initiatives
- Taking more account of ESS in risk assessments of PPP
- zero pollutiohn ambition (food packaging etc)
- Awareness is growing of the issues that is driving policy maker
- Holistic approaches for example in SUD
- promotion of low risk pesticides
- Restrictions of chemicals for non-professional use
- F2F & Biodiv & forest strategy include concerns outside EU

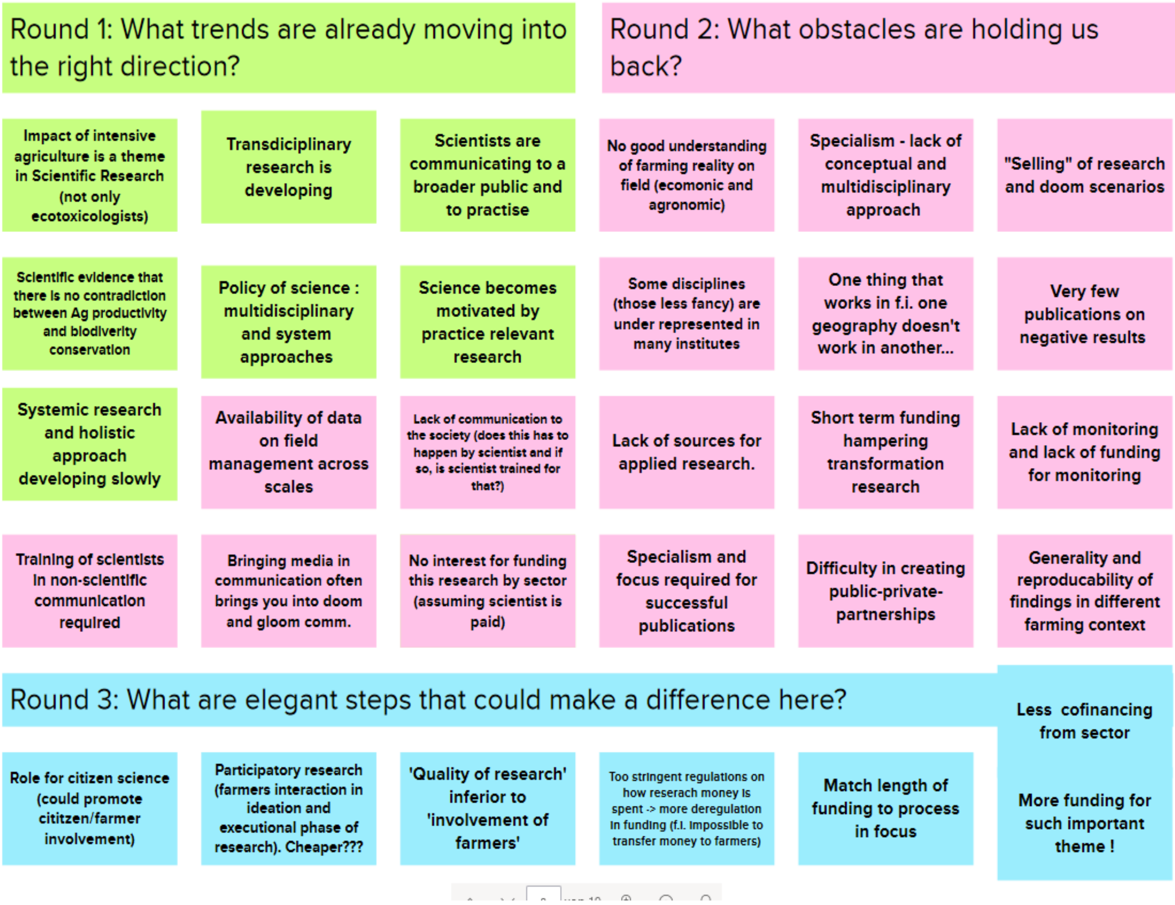
Round 2: What obstacles are holding us back?

- Not enough communication back to citizens to inform them
- Missing global ecological standards - World wide competition of farming systems
- Frameworks can lead to a minimum standard (first mover problem)
- Lack of evidence re techniques such as precision farming
- (non)acceptance of certain new technologies (eg crispr-cas for disease resistance)
- Missing balance on economical/ecological objectives in some member states and can be very different between MS
- Not taking enough account of systems such as agroforestry in policy/subsidies
- Focus too much on pesticides
- Missing harmonization/ alignment in European policy enforcement in MS (e.g. neonic use execptions)
- EU exports banned chemicals to other countriesaffects global biodiversity and ag production
- slow development to bring in low risk pesticides
- Funds of CAP should belong to society not subsidies for farmingsystems alone

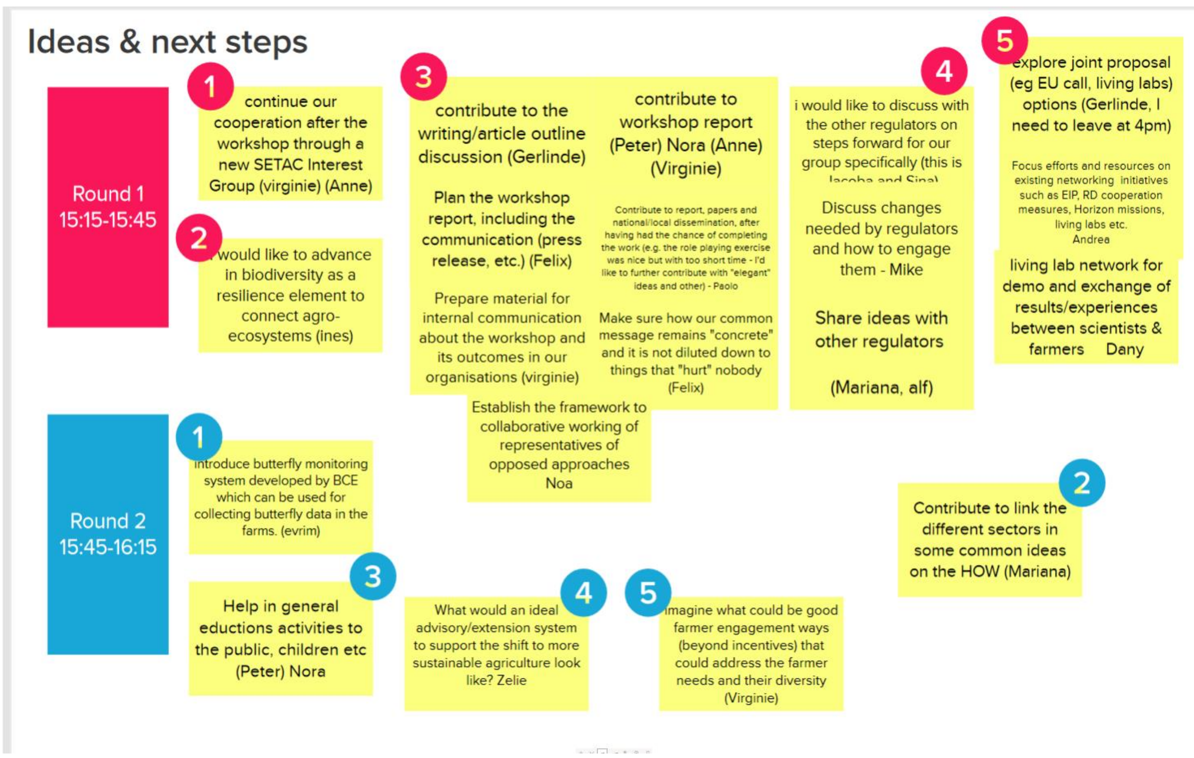
Round 3: What are elegant steps that could make a difference here?

- Training municipalities and authorities to manage their land for biodiversity
- Provide resources and a framework for good functional (free) advisory/ extensions services also on biodiversity issues
- Work on better consistency between policy frameworks in MS and between MS
- Create platforms for exchange between farm networks and

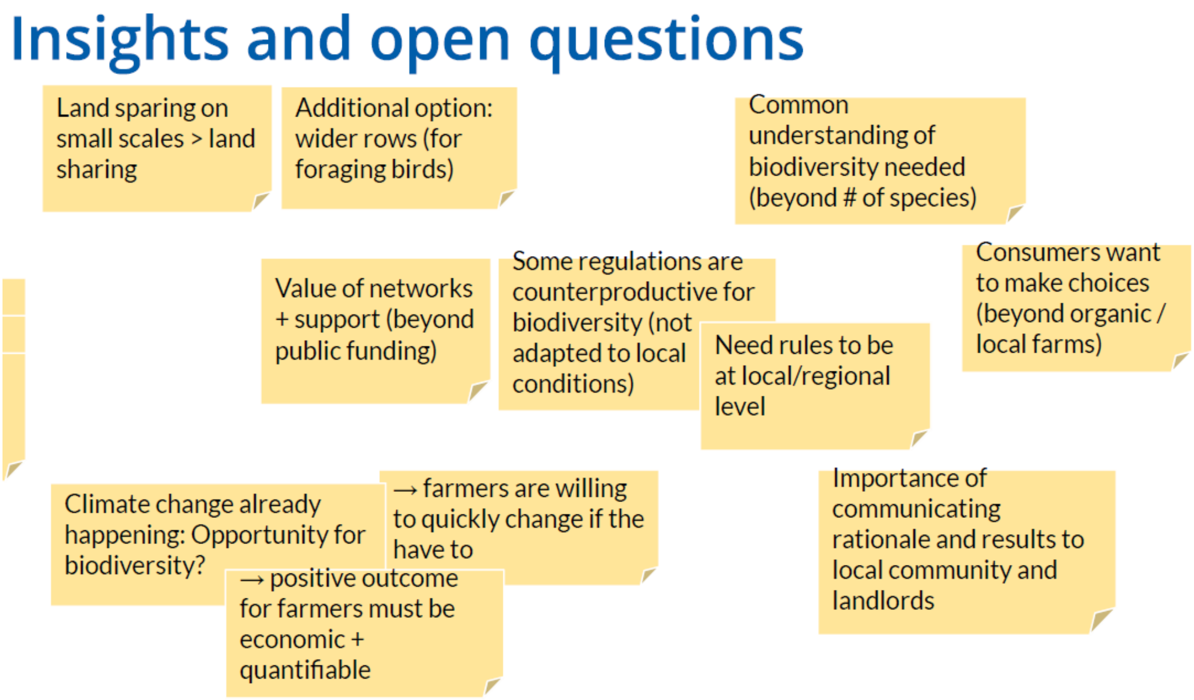
Position: Science




Round 1: What trends are already moving into the right direction?
Round 2: What obstacles are holding us back?
Increased awareness about food safety and environmenatal impacts of food production
increased awareness of nature - and its loss - in (agricultural) landscapes
increased availability and consumption of organic food and less meat consumption
Economics - consumer requirement for low cost food
consumer has broader choice of food, but different lables (e.g. local, fairtrade, organic) may be confusing
Increased awareness of the environmental impact of agriculture
more coordinated and integrated discussion of land management - joined up policy objectives?
Resistance to change - farmers know how to grow crop etc; consumers have particular food choices
Resistance to changing diet away from meat (from intensive livestock production)
increased awareness of some biodiversity (i.e. bees)
more systematic monitoring of nature - citizen science etc. Increased knowledge
Increased willingness to change personal behaviours to enhance biodiversity (private and public space). Also becoming more politically active (w.r.t. environment)
Lack of information to make more nuanced choices (i.e. not binary organic v non-organic)
Lack of labels indicating different types of "sustainability" limiting ability of consumers to make informed choices
Increased interest in where food is produced and in local production
Increased interest in reducing food waste and food miles
Increased engagement with conservation and biodiversity programmes
Limited availability of alternative produce ("ugly", mishaped food)
very high consumer requirements regarding appearance of food: "look over taste" (chemicals for appearance)
Round 3: What are elegant steps that could make a difference here?
Society acknowledges what famers do for biodiversity
Individuals actively support biodiversity enhancement in private and public spaces
Increase public understanding of how/where food is produced: consumers make informed choices and have realistic expectations of what is possible
Educate school children about food production/ waste and illustrate good practice via. school meals. Hands-on experience.
Reduce food waste (use of apps e.g 'too good to go') Accept non-perfect looking food and buy more seasonal food
Be more actively engaged in political debates (i.e. by voting)
Be willing/able to pay for biodiversity enhancements via increased food costs


Ideas & next steps
Round 1 15:15-15:45
1
continue our cooperation after the workshop through a new SETAC Interest Group (virginie) (Anne)
2
would like to advance in biodiversity as a resilience element to connect agro-ecosystems (ines)
3
contribute to the writing/article outline discussion (Gerlinde)
Plan the workshop report, including the communication (press release, etc.) (Felix)
Prepare material for internal communication about the workshop and its outcomes in our organisations (virginie)
contribute to workshop report (Peter) Nora (Anne) (Virginie)
Contribute to report, papers and national/local dissemination, after having had the chance of completing the work (e.g. the role playing exercise was nice but with too short time - I'd like to further contribute with "elegant" ideas and other) - Paolo
Make sure how our common message remains "concrete" and it is not diluted down to things that "hurt" nobody (Felix)
Establish the framework to collaborative working of representatives of opposed approaches Noa
4
i would like to discuss with the other regulators on steps forward for our group specifically (this is
Discuss changes needed by regulators and how to engage them - Mike
Share ideas with other regulators
(Mariana, alf)
5
explore joint proposal (eg EU call, living labs) options (Gerlinde, I need to leave at 4pm)
Focus efforts and resources on existing networking initiatives such as EIP, RD cooperation measures, Horizon missions, living labs etc. Andrea
living lab network for demo and exchange of results/experiences between scientists & farmers Dany
Round 2 15:45-16:15
1
introduce butterfly monitoring system developed by BCE which can be used for collecting butterfly data in the farms. (evrim)
2
Contribute to link the different sectors in some common ideas on the HOW (Mariana)
3
Help in general eductions activities to the public, children etc (Peter) Nora
4
What would an ideal advisory/extension system to support the shift to more sustainable agriculture look like? Zelie
5
imagine what could be good farmer engagement ways (beyond incentives) that could address the farmer needs and their diversity (Virginie)

Appendix 3.4: Keynote T. Gäbert: Insights and open questions following keynote presentation



Appendix 3.5: Inventory of approaches collected between workshop 1 and 2

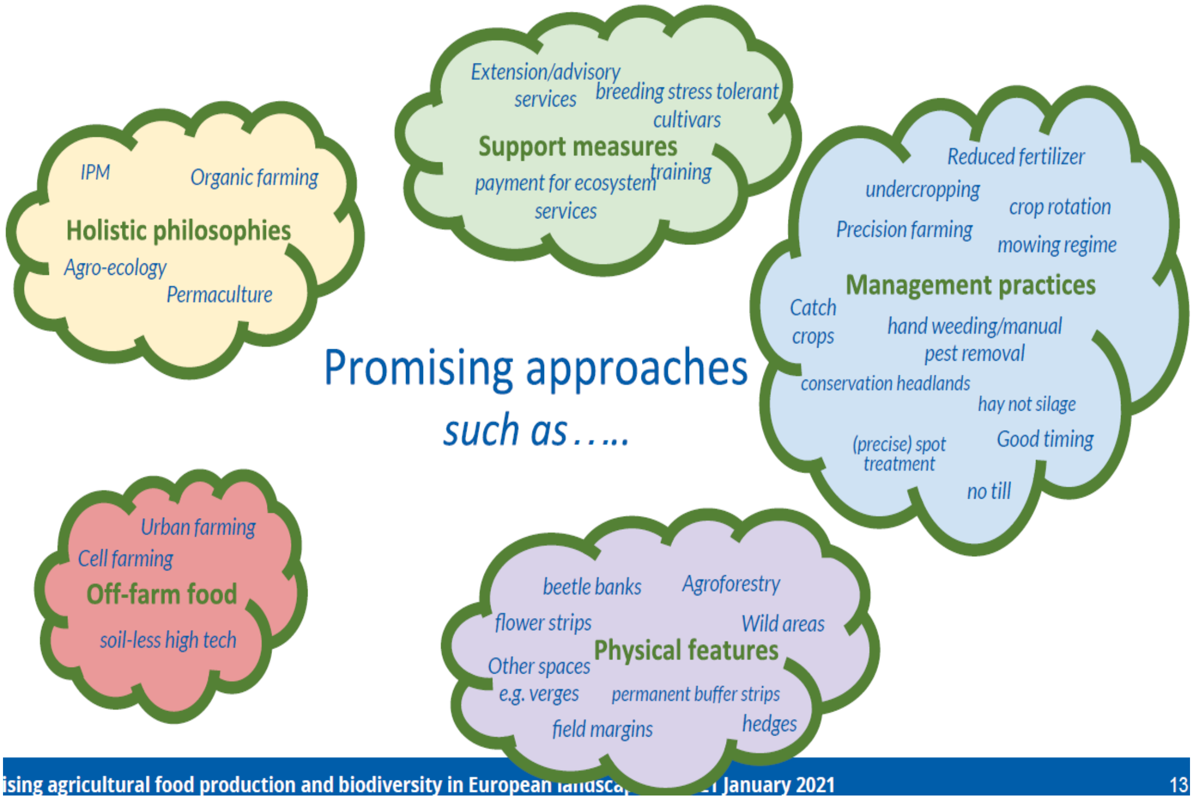
Approach	Benefit	Additional approach involved in the study	Author/organisation
Actions to enhance biodiversity in agriculture	Biodiversity		Garnett 2020
Advisory use of pesticides	Biodiversity		Lee et al. 2019
Agricultural practices	Biodiversity	Crop diversification, ecological focus areas, permanent grasslands	EC 2017
Agri-environmental measures	Biodiversity		EC 2019
Agroforestry	https://euraf.isa.utl.pt/projects/agforward	Agroecology	https://www.agforward.eu/
Agroforestry/agroecology	Biodiversity	IPM/ICP, ecosystem services approaches, agricultural practices	Oberč and Arroyo Schnell 2020
Biodiversity strategy	Biodiversity		ELO 2020
Crop diversification	Biodiversity	Landscape diversity, ecosystem services	Tamburini et al. 2020
Crop diversification	Carabid and pollinator communities in landscapes with semi-natural habitats		Aguilera et al. 2000
Crop diversification	Biodiversity	Ecosystem services	Tscharntke et al. 2005
Crop diversification	Biodiversity	Ecosystem services	Bohan and Vanbergen 2020
Crop diversification and semi natural habitats	Biodiversity	Permanent grasslands	Dauber and Miyake 2016
Ecosystem services	Biodiversity	Agricultural practices	FAO 2020
Ecosystem services	Biodiversity	Prairies strips	Schulte et al. 2017
Ecosystem services approaches	Biodiversity in pear production	Agricultural practices	Belien et al. 2021

Field margins and grassland	Range of species encountered within the crops / in the landscape	Crop diversification, multifunctional field margins	Garnett 2020
Field margins used as habitat and food resources	Range of species encountered within the crops / in the landscape	Multifunctional margins buffering exposure and transfers off crop	Alix et al. 2017
High Nature Value Farm	Biodiversity		Lomba et al. 2020
Inventory of actions to conserve biodiversity	Wildlife and biodiversity	Agricultural practices	https://www.conservationevidence.com/data/index?synopsis_id%5B%5D=9
Inventory of farmland conservation interventions through AES programs	Biodiversity	Multifunctional field margins, agricultural practices	Dicks et al. 2013
Inventory of farmland conservation interventions through AES programs	Biodiversity	Multifunctional field margins, agricultural practices	Dicks et al. 2018
Land sharing/land sparing	Biodiversity	Ecosystem services	Grass et al. 2019
Land sharing/land sparing	Tropical landscapes	Multifunctionality	Grass et al. 2020a
Land sharing/land sparing	Biodiversity		Grass et al. 2020b
Multifunctional field margins	Biodiversity	Risk mitigation measures	Hackett and Lawrence 2014
Organic farming	Biodiversity		EP 2019
Pesticide monitoring	Biodiversity		Vijver et al. 2017
Pesticide risk assessment	Biodiversity		Schäfer et al. 2019
Pesticide risk assessment	Biodiversity		Topping et al. 2020
Precision farming	Biodiversity		EC 2020
Risk assessment of pesticides	Non target arthropods		EFSA PPR Panel 2015
Risk assessment of pesticides	Non target plants		EFSA PPR Panel 2014
Risk assessment of pesticides	Soil organisms		EFSA PPR Panel 2017

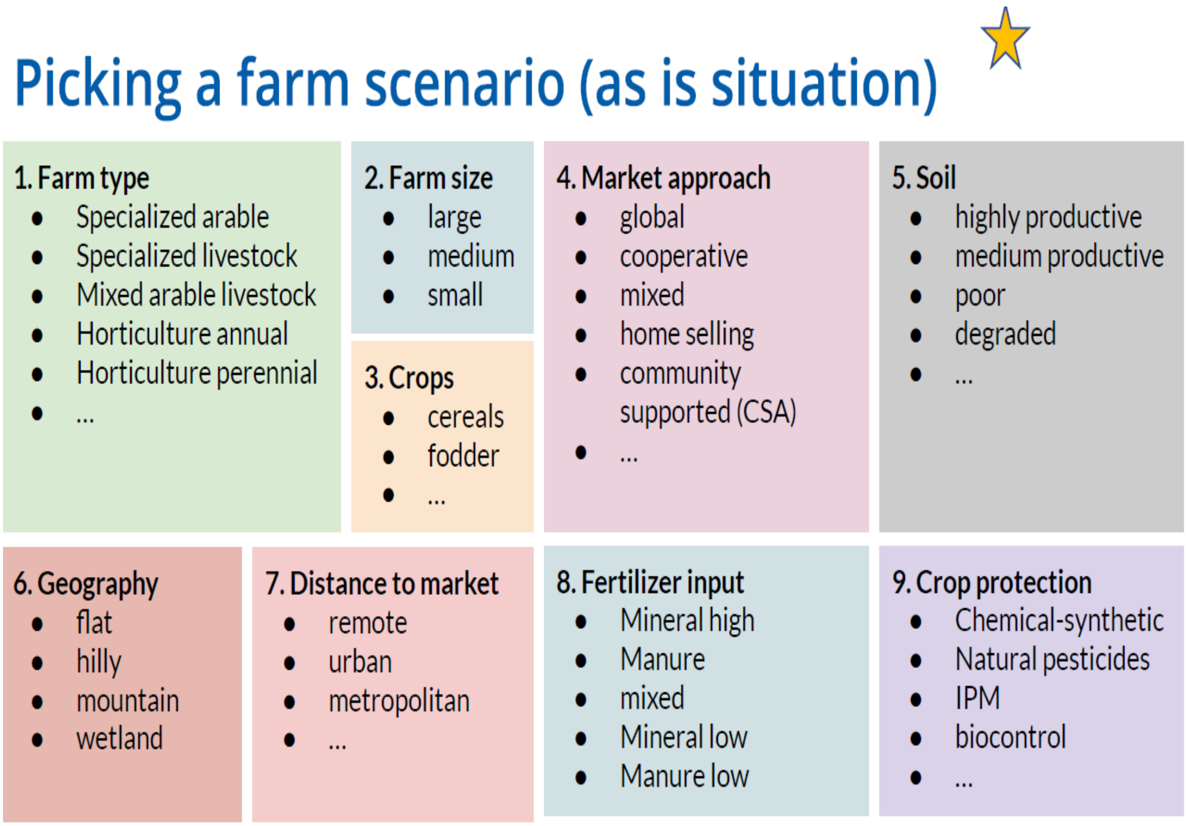
Risk management through the selection of pesticides with lowest risk to the environment	Range of species encountered within the crops / in the landscape		Altenburger et al. 2017
Risk mitigation measures	Biodiversity		Hötker et al. 2018
Risk mitigation measures	Biodiversity of free living birds and mammals in respect		Jahn et al. 2014
Risk mitigation measures	Biodiversity		Topping et al. 2015
Risk mitigation measures for pesticides	Range of species encountered within the crops / in the landscape	Multifunctional field margins	Alix et al. 2017
Sustainable intensification	Biodiversity		FAO 2019

Appendix 3.6: Scenarios and Approaches

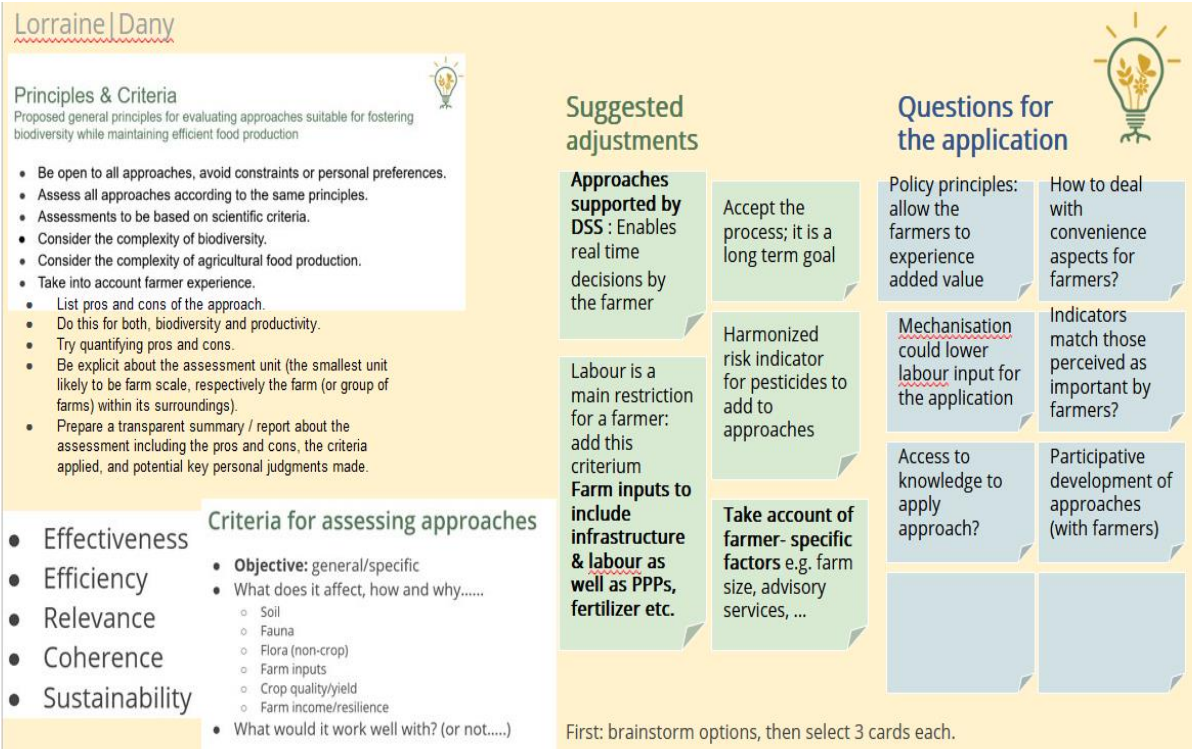
Approaches

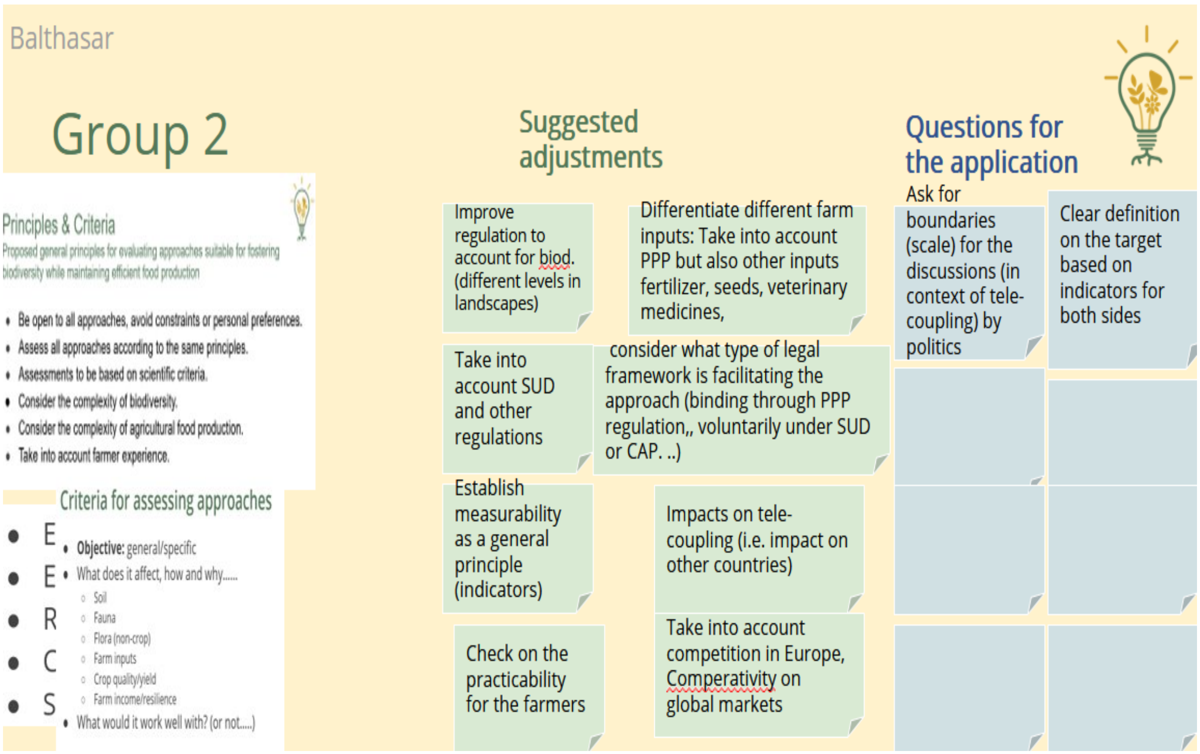


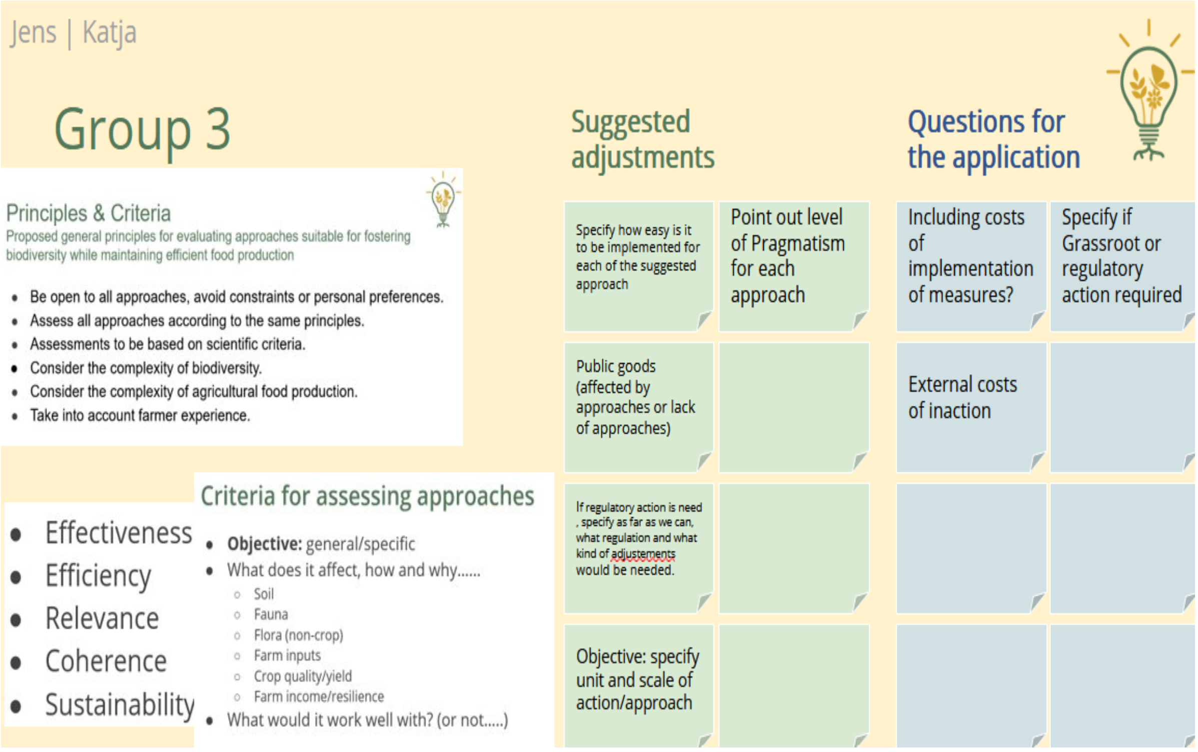
Appendix 3.6.1: Scenario set up

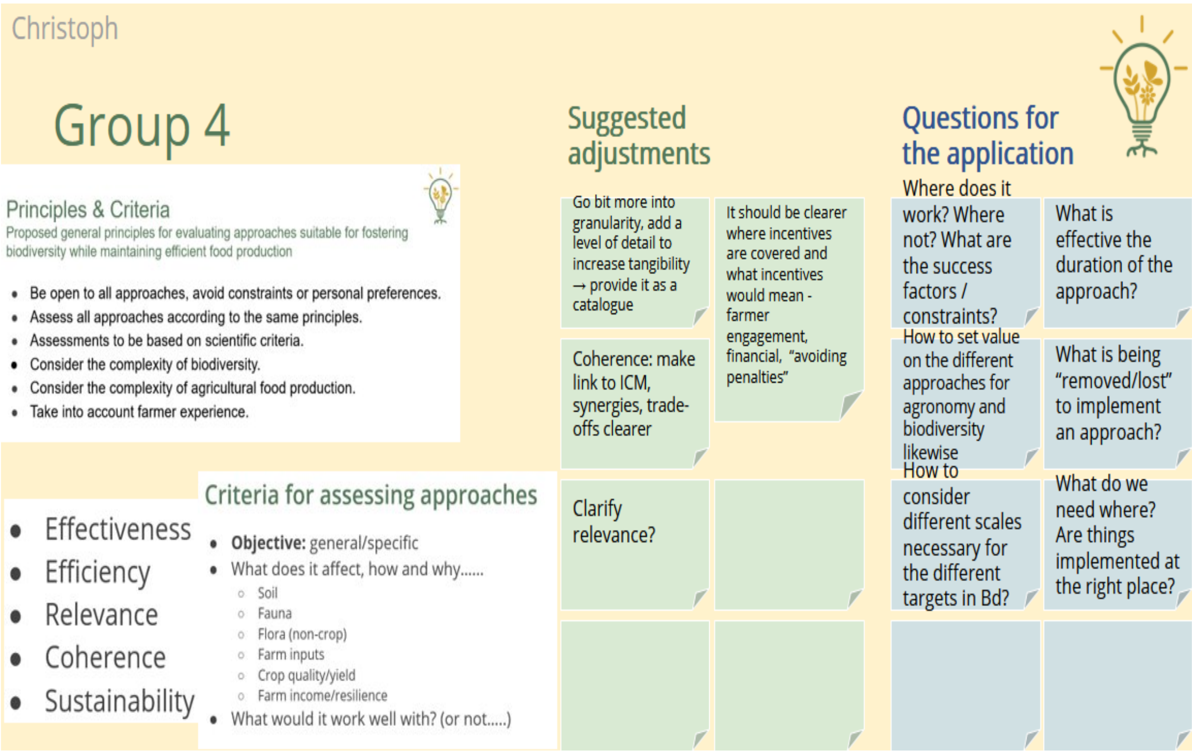


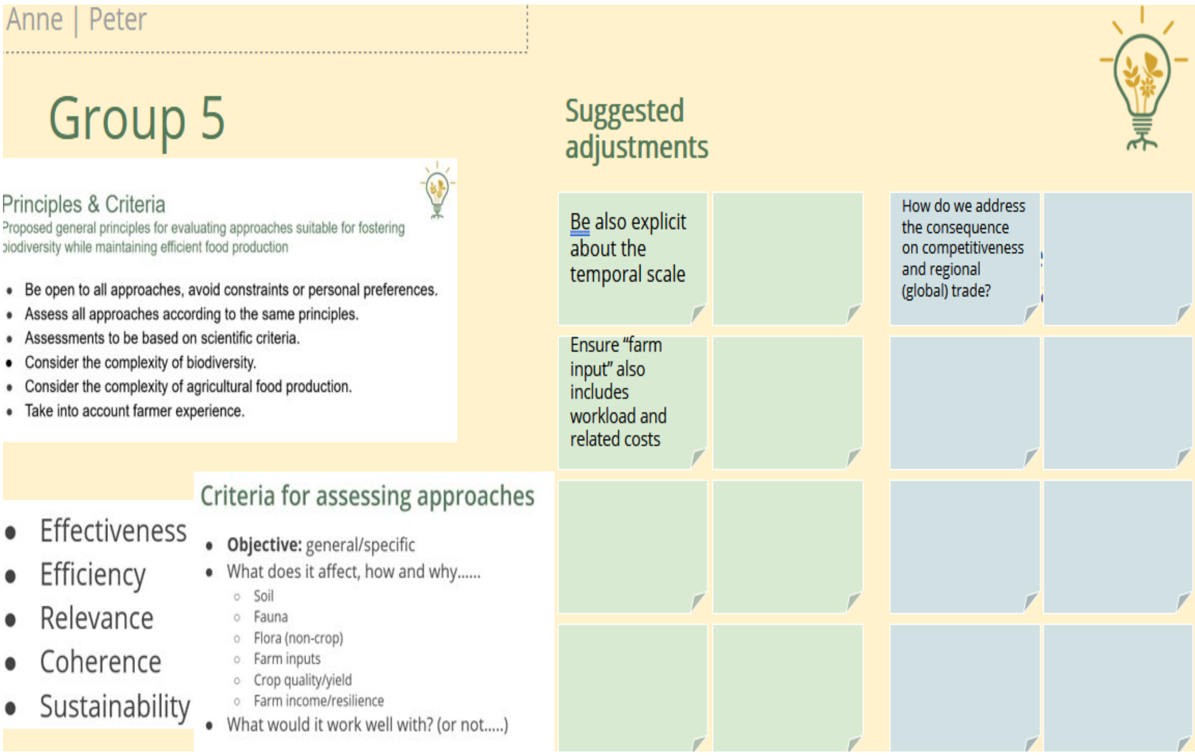
Appendix 3.6.2: Principles and Criteria

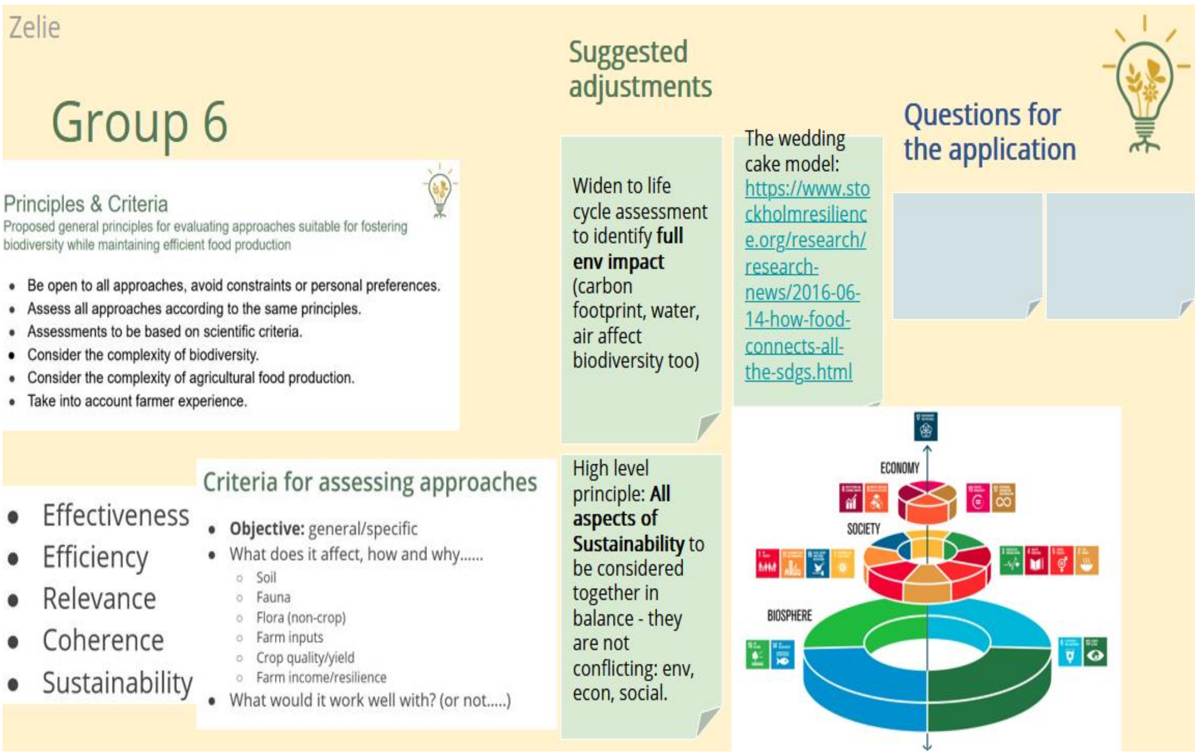


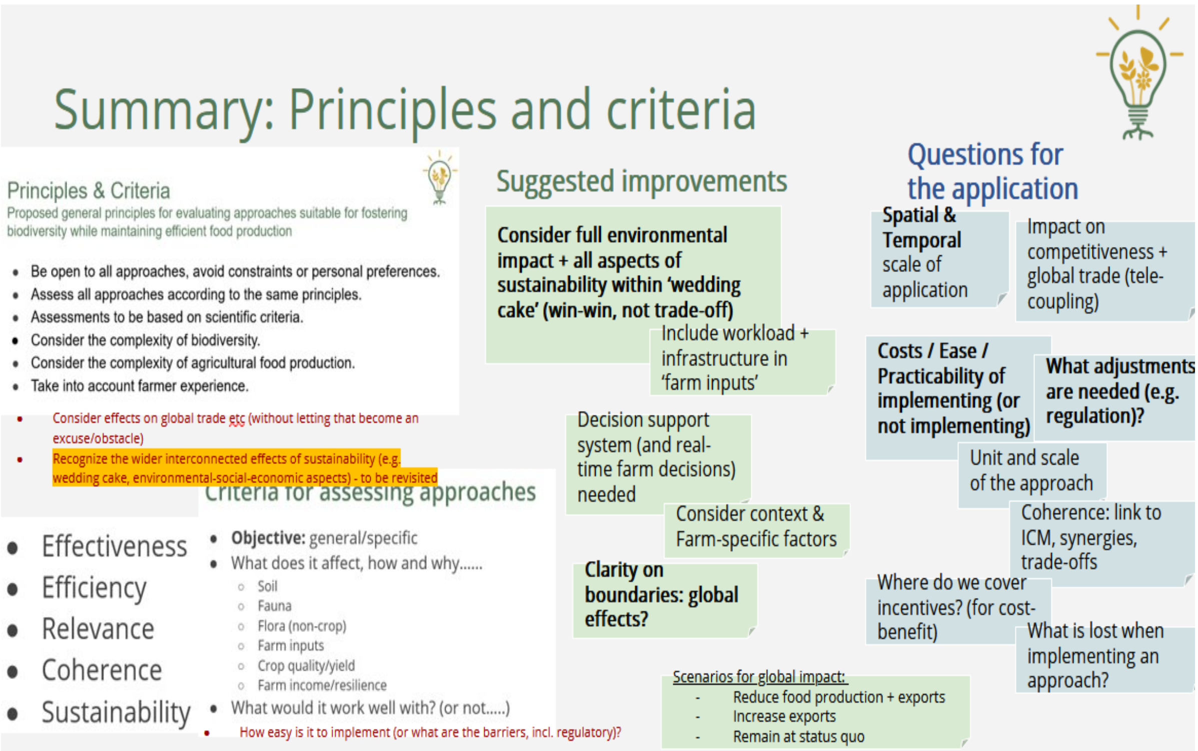



Jens | Katja
Group 3
Principles & Criteria
Proposed general principles for evaluating approaches suitable for fostering biodiversity while maintaining efficient food production
Be open to all approaches, avoid constraints or personal preferences.
Assess all approaches according to the same principles.
Assessments to be based on scientific criteria.
Consider the complexity of biodiversity.
Consider the complexity of agricultural food production.
Take into account farmer experience.
Criteria for assessing approaches
Effectiveness
Efficiency
Relevance
Coherence
Sustainability
Objective: general/specific
What does it affect, how and why......
Soil
Fauna
Flora (non-crop)
Farm inputs
Crop quality/yield
Farm income/resilience
What would it work well with? (or not.....)
Suggested adjustments
Specify how easy is it to be implemented for each of the suggested approach
Point out level of Pragmatism for each approach
Public goods (affected by approaches or lack of approaches)
If regulatory action is need , specify as far as we can, what regulation and what kind of adjustements would be needed.
Objective: specify unit and scale of action/approach
Questions for the application
Including costs of implementation of measures?
Specify if Grassroot or regulatory action required
External costs of inaction


Christoph
Group 4
Principles & Criteria
Proposed general principles for evaluating approaches suitable for fostering biodiversity while maintaining efficient food production
Be open to all approaches, avoid constraints or personal preferences.
Assess all approaches according to the same principles.
Assessments to be based on scientific criteria.
Consider the complexity of biodiversity.
Consider the complexity of agricultural food production.
Take into account farmer experience.
Criteria for assessing approaches
Effectiveness
Efficiency
Relevance
Coherence
Sustainability
Objective: general/specific
What does it affect, how and why......
Soil
Fauna
Flora (non-crop)
Farm inputs
Crop quality/yield
Farm income/resilience
What would it work well with? (or not.....)
Suggested adjustments
Go bit more into granularity, add a level of detail to increase tangibility → provide it as a catalogue
It should be clearer where incentives are covered and what incentives would mean - farmer engagement, financial, "avoiding penalties"
Coherence: make link to ICM, synergies, trade-offs clearer
Clarify relevance?
Questions for the application
Where does it work? Where not? What are the success factors / constraints?
What is effective the duration of the approach?
How to set value on the different approaches for agronomy and biodiversity likewise
What is being "removed/lost" to implement an approach?
How to consider different scales necessary for the different targets in Bd?
What do we need where? Are things implemented at the right place?


Anne | Peter
Group 5
Suggested adjustments
Principles & Criteria
Proposed general principles for evaluating approaches suitable for fostering biodiversity while maintaining efficient food production
Be open to all approaches, avoid constraints or personal preferences.
Assess all approaches according to the same principles.
Assessments to be based on scientific criteria.
Consider the complexity of biodiversity.
Consider the complexity of agricultural food production.
Take into account farmer experience.
Be also explicit about the temporal scale
Ensure "farm input" also includes workload and related costs
How do we address the consequence on competitiveness and regional (global) trade?
Effectiveness
Efficiency
Relevance
Coherence
Sustainability
Criteria for assessing approaches
Objective: general/specific
What does it affect, how and why......
Soil
Fauna
Flora (non-crop)
Farm inputs
Crop quality/yield
Farm income/resilience
What would it work well with? (or not.....)


Zelie
Group 6
Suggested adjustments
Questions for the application
Principles & Criteria
Proposed general principles for evaluating approaches suitable for fostering biodiversity while maintaining efficient food production
Be open to all approaches, avoid constraints or personal preferences.
Assess all approaches according to the same principles.
Assessments to be based on scientific criteria.
Consider the complexity of biodiversity.
Consider the complexity of agricultural food production.
Take into account farmer experience.
Widen to life cycle assessment to identify full env impact (carbon footprint, water, air affect biodiversity too)
The wedding cake model: https://www.stockholmresilience.org/research/research-news/2016-06-14-how-food-connects-all-the-sdgs.html
High level principle: All aspects of Sustainability to be considered together in balance - they are not conflicting: env, econ, social.
ECONOMY
SOCIETY
BIOSPHERE
Effectiveness
Efficiency
Relevance
Coherence
Sustainability
Criteria for assessing approaches
Objective: general/specific
What does it affect, how and why......
Soil
Fauna
Flora (non-crop)
Farm inputs
Crop quality/yield
Farm income/resilience
What would it work well with? (or not.....)


Summary: Principles and criteria
Principles & Criteria
Proposed general principles for evaluating approaches suitable for fostering biodiversity while maintaining efficient food production
• Be open to all approaches, avoid constraints or personal preferences.
• Assess all approaches according to the same principles.
• Assessments to be based on scientific criteria.
• Consider the complexity of biodiversity.
• Consider the complexity of agricultural food production.
• Take into account farmer experience.
• Consider effects on global trade etc (without letting that become an excuse/obstacle)
• Recognize the wider interconnected effects of sustainability (e.g. wedding cake, environmental-social-economic aspects) - to be revisited
Criteria for assessing approaches
• Effectiveness
• Efficiency
• Relevance
• Coherence
• Sustainability
• Objective: general/specific
• What does it affect, how and why……
○ Soil
○ Fauna
○ Flora (non-crop)
○ Farm inputs
○ Crop quality/yield
○ Farm income/resilience
• What would it work well with? (or not…..)
• How easy is it to implement (or what are the barriers, incl. regulatory)?
Suggested improvements
Consider full environmental impact + all aspects of sustainability within 'wedding cake' (win-win, not trade-off)
Include workload + infrastructure in 'farm inputs'
Decision support system (and real-time farm decisions) needed
Consider context & Farm-specific factors
Clarity on boundaries: global effects?
Scenarios for global impact:
- Reduce food production + exports
- Increase exports
- Remain at status quo
Questions for the application
Spatial & Temporal scale of application
Impact on competitiveness + global trade (tele-coupling)
Costs / Ease / Practicability of implementing (or not implementing)
What adjustments are needed (e.g. regulation)?
Unit and scale of the approach
Coherence: link to ICM, synergies, trade-offs
Where do we cover incentives? (for cost-benefit)
What is lost when implementing an approach?

Appendix 4: Conclusions, recommendations

April workshop reflection

What are we working towards

Workshop objective (from outline): facilitate progress in the optimization of landscapes for food production and biodiversity:

- recognize the complexity, and propose clear formulation of the problem and common definitions and understanding
- consider the various scenarios for crop production, the use of optimization functions for food and biodiversity per landscape unit, and the inclusion of alternative approaches utilized for food production and their assessment
- consider that the optimal solution may differ in space and time and therefore the need to identify specific risk management options, within the present legal frameworks of EU agriculture)

Summary/feed forward
Emerging Recommendations your feedback

- General importance of balancing production and biodiversity mentioned across comments
- Consumer in regards to improve consumption habits (2)
- Regulation (2): e.g. need for linkage of physical measures with support/educational measures and possibly with changes to regulation
- indicators of agroecosystems resilience (yield and biodiversity) (1)
- More space for „nature“ on farm scale (1)
- Addressed farmer directly / indirectly (> 50%)
  - Implement the easy and the proofed approaches (somebody felt there were to many „What-ifs“)
  - Include farmers in the identification of approaches
  - Create a tool-box / inventory including information on pros and cons
  - improve advisory services / education (facilitate integration to ICM)

Feed forward *keep in mind...*

- Recommendations can address various audiences – need to agree to focus on some specific
- We cannot solve all problems – acknowledge existing borders and workshop goals
- There is no one fits all – focus and be open for compromises
- Farmers are central for efficient and long-term implementation
    - Need for pragmatism
    - Sustainable approaches make sense to farmers → Understanding of agronomic benefits and constraints

What tangible outcomes can we agree on?

- December: summary is seen as consensus view (vision, principles, useful strategies)
- Clarity on who was in the room (and who wasn't - retail)
- List of literature
- List of approaches
- Quadrants for optimising both
- Principles + criteria
- Temporal and spatial scales for next steps

Future ideas

- Consultation with farmers
- Decision support tools
- Toolbox based on the approaches listed
- Inform CAP to support effective approaches
- Exchange with advisory services, trans-disciplinary approaches
- Write-up to be clear on definitions
- To identify: future actions for different actors

Thünen Report

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82	Marlen Haß, Martin Banse, Claus Deblitz, Florian Freund, Inna Geibel, Alexander Gocht, Peter Kreins, Verena Laquai, Frank Offermann, Bernhard Osterburg, Janine Pelikan, Jörg Rieger, Claus Rösemann, Petra Salamon, Maximilian Zinnbauer, Max-Emanuel Zirngibl **Thünen-Baseline 2020 – 2030: Agrarökonomische Projektionen für Deutschland**
83	Marc Simon Weltersbach, Carsten Riepe, Wolf-Christian Lewin, Harry V. Strehlow **Ökologische, soziale und ökonomische Dimensionen des Meeresangelns in Deutschland**
84	Claus Rösemann, Hans-Dieter Haenel, Cora Vos, Ulrich Dämmgen, Ulrike Döring, Sebastian Wulf, Brigitte Eurich-Menden, Annette Freibauer, Helmut Döhler, Carsten Schreiner, Bernhard Osterburg, Roland Fuß **Calculations of gaseous and particulate emissions from German agriculture 1990 – 2019** **Berechnung von gas- und partikelförmigen Emissionen aus der deutschen Landwirtschaft 1990 – 2019**
85	Andreas Tietz, Richard Neumann, Steffen Volkenand **Untersuchung der Eigentumsstrukturen von Landwirtschaftsfläche in Deutschland**
86	Katja Butter, Martin Ohlmeyer **Emissionen flüchtiger organischer Verbindungen von Holz und Holzwerkstoffen**
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91	Cora Vos, Claus Rösemann, Hans-Dieter Haenel, Ulrich Dämmgen, Ulrike Döring, Sebastian Wulf, Brigitte Eurich-Menden, Annette Freibauer, Helmut Döhler, Carsten Schreiner, Bernhard Osterburg, Roland Fuß **Calculations of gaseous and particulate emissions from German agriculture 1990 – 2020** **Berechnung von gas- und partikelförmigen Emissionen aus der deutschen Landwirtschaft 1990 – 2020**
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93	Heike Peter, Cornelia Tippel, Annett Steinführer **Wohnstandortentscheidungen in einer wohnbiographischen Perspektive : Eine explorative Studie in ländlichen und großstädtischen Kontexten**
94	Daniel Ziche, Erik Grüneberg, Winfried Riek, Nicole Wellbrock **Comparison of the LUCAS 2015 inventory with the second National Forest Soil Inventory : Comparability and representativeness of two soil inventories conducted in Germany**
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96	Jacob Jeff Bernhardt, Lennart Rolfes, Peter Kreins, Martin Henseler **Ermittlung des regionalen Bewässerungsbedarfs für die Landwirtschaft in Bayern**
97	Uwe Krumme, Steffi Meyer, Isabella M. F. Kratzer, Jérôme C. Chladek, Fanny Barz, Daniel Stepputtis, Harry V. Strehlow, Sarah B. M. Kraak, Christopher Zimmermann **STELLA - Stellnetzfischerei-Lösungsansätze : Projekt-Abschlussbericht**
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