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Food systems and biodiversity

Progress and output 2019

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1 Introduction

The KB theme "Food and Water Security" aims to contribute to the SDG goal 2, 'Zero Hunger' as hunger and malnutrition remain major barriers to the development of many countries. Global change processes including climate change, increasing urbanization, depletion of freshwater resources, loss of biodiversity, and land and soil degradation exacerbate the challenge of achieving SDG2. This project particular focusses on the relations between biodiversity and (sustainable) food production systems to be able to guide food systems transitions in vulnerable regions. An integrated assessment framework will be developed in order to identify and to quantify trade-offs between biodiversity and different food system development pathways and a set of key indicators will be identified and selected. Such assessment framework should be applicable under different contexts and at different spatial and temporal scales. The assessment framework and indicator set will be tested in different case studies, where possible aligned with the other KB motifs and knowledge gaps will be identified.

In this document we report on the progress and output of 2019. In chapter 2 we present the draft assessment framework and in chapter 3 our research agenda for the next years is given. Chapters 2 and 3 in this report are deliverables 1 and 3 according our workplan for 2019. Both the assessment framework and research agenda are work in progress that will be further updated and refined during the course of the project.

1.1 Background and rationale

Many facets of biodiversity (genetic, species, functional) are considered to be important components in the transition to more sustainable and resilient food systems. Biodiversity is the basis (natural capital) for food production systems. Food systems are supported by a variety of ecosystem services and at the same time also provide ecosystem services. These systems regulate local and global climate conditions, provide (wild) food, and other goods like (bio)fuel, building materials, etc. Biodiversity can play an important role in improving the resilience of food production systems in multiple ways.

A more biodiverse farming system and landscape provides a stronger protection against environmental shocks as it is more resilient to absorb changes and will for instance reduce the impact of pests and diseases or the effects of climate change. At the same time wild variants of agricultural crops and livestock may harbour (genetic) features that may be useful for (future) breeding in order to be better adapted to changing environmental and climatic conditions. Loosing genetic diversity in wild relatives of crops and livestock will reduce options for more resilient future varieties of crops and livestock breeds.

In this context it is alarming that biodiversity is globally declining at an unprecedented rate in human history (IPBES 2019). Current food systems are among the dominant causes of deforestation and declining biodiversity.

The notion of environmentally sustainable food systems is one of the three themes of Dutch policy on food security, while biodiversity is also one of the key themes of the nexus thinking of the Ministry of Foreign Affairs. Moreover, biodiversity is also an integral component of the circular agriculture vision of the Dutch Ministry of Agriculture, Nature and Food Quality. And more recently, the European Commission launched a new European Green Deal on Climate and Biodiversity.

Within the food systems approach, biodiversity is included as one of the environmental drivers (van Berkum et al. 2018) that contributes to food systems performance. At the same time activities within food systems have impact on biodiversity. The many mutual relationships between biodiversity and food production are not well understood, and need to be operationalized in food systems transitions for achieving both: improved food security and maintaining biodiversity.

Scientific relevance
The interactions between biodiversity and food production activities are not simple linear relations, but involve more complex trade-offs and feedbacks that largely depend on the local context, and the spatial and temporal scales considered. Current research often still focusses on unidirectional relations neglecting relevant trade-offs and feedbacks that may occur, which potentially have large consequences for the medium and long term outcomes of transition pathways. Also interactions between different scales or production areas are often not taken into consideration. For example, measures that improve the status of biodiversity in one area may also have an effect on the productivity in this area. As a result, if total demand for the commodity remains the same, or even increases as a result of increasing human population and/or changes in consumption, this may result in the conversion of ecosystems elsewhere. Therefore, a systems approach is needed that effectively includes the effects of trade-offs and feedbacks in the interaction between biodiversity and food systems.

Aim
The aim of this project is to develop an assessment framework to support policy makers, industry, NGOs, farmers and other relevant stakeholders to:

- assess transition pathways for more sustainable and resilient food systems that make use of and value the contribution of biodiversity for resilient food systems and food and nutrition security;
- allow them to address and minimize the impact of food systems on biodiversity, or improve the positive effects of the food systems on biodiversity;
- understand feedbacks and trade-offs between food systems and biodiversity.

The assessment framework should be applicable under different contexts and at different spatial and temporal scales. The framework will allow us to explore and select the most relevant future research topics relating biodiversity with food security and eventually should allow us to address questions like:

- How to quantify the impact of food production methods and changes in these methods on biodiversity?
- How to optimize food production and at the same time protect biodiversity, at different scales and contexts (incl. the land sharing vs land sparing discussion)
- How could management practices and production methods on farming system level be adapted to support greater biodiversity?
- What are trade-offs and synergies between biodiversity, food production and wider sustainability aspects (climate change, water use, nutrients)?
- How to use genetic diversity to improve resilience of food production systems (varieties, breeds, mixed production systems and diversity at landscape level)?
- Which role can wild foods play to improve food security in resilient food systems in Africa and Asia and what is its future perspective?

Above questions will guide the development of the assessment framework and exploration of the most relevant future research topics. In all cases context and scale will be important elements to consider. The results and outcomes may differ for different contexts or different spatial and temporal scales.

1.2 Progress and output 2019

The project started 1 September 2019 and managed to realise significant progress in a few months. The project team represents a large variety of relevant expertise within WR. We have organised a number of internal workshops and brainstorm sessions to align expectations and to create mutual understanding of the challenges and opportunities related to the interface between food systems and biodiversity using the different team members knowledge base, including experts from WU. This time investment pays back in an effective collaboration among the team members, a common understanding of the challenges at hand, and has resulted in a draft assessment framework and a list of topics that need further research in the next phases of the project.

Early in the project we have identified a long list with a wide variety of relevant stakeholders and possible future clients. We have conducted interviews with a selection of 9 key stakeholders (SNV Netherlands, Oxfam/Novib, Agrifirm, Unilever, Danone, Rabobank, Syngenta, Ahold/Delhaize). An interview with WWF is planned for January 2020.

The stakeholders responded very positively to the rationale of the project and consider an assessment framework for biodiversity and food systems very relevant and highly needed to make deliberate decisions in their operations. Biodiversity is becoming increasingly important on the sustainability agenda of the private sector. There is an urgent need for transparent and evidence based assessment frameworks for biodiversity in relation to food system development pathways to support future policy-making and decision-making. All interviewees indicated that they would like to stay informed about the project's developments and that they are willing to collaborate in different ways. The interviews have provided a lot of insight in the relevant current and future challenges and questions these stakeholders have in relation to biodiversity and food systems. Moreover the interviews and positive responses are very motivating for further development of the project. In the next steps we will therefore continue to engage with these and possibly also other stakeholders.

On 12 December 2019 we have organised a workshop with WUR experts to get feedback and further input on our draft assessment framework. This has provided new insights on applicability of the framework (how it can be put to use for different stakeholders) and highlighted the challenges with data availability for quantification. Above all, it also has introduced the project to the wider WUR community and identified possible topics and experts for collaboration. Results of the workshop will be included in the draft research agenda in the first weeks of January.

An additional workshop with external experts will be organised in the first half of 2020, when the project is in a more mature stage.

In addition to the described outputs in this report also the following outputs are available in other formats:

- Summary of a literature review in excel (contributed to deliverables 1 and 3, this report).
- Overview of relevant WUR wide projects in which the relation between biodiversity and food plays a role (deliverable 2). The overview has been used to invite relevant WUR colleagues to a workshop to discuss the draft assessment framework.
- Pictures of whiteboard and flip-over notes generated during 2 brainstorm sessions on 1 and 12 November.
- A PowerPoint document with information on available frameworks and approaches used to feed the discussions during the brainstorm sessions.
- Powerpoint presentation of the framework presented during a workshop with invited relevant WUR colleagues (WU and WR) from outside the project.
- Synthesis of the stakeholder interviews. Also minutes (some in draft) of the interviews with the stakeholders (SNV Netherlands, Oxfam/Novib, Agrifirm, Unilever, Danone, Rabobank, Syngenta, Ahold/Delhaize) have been elaborated. However, to stimulate open discussions with these organisations, we have agreed that only the synthesis will be open to be shared within WUR, but the minutes and notes of interviews will only be used within the project team and will not be shared beyond.

Additionally the KB project has led to significant inputs into other initiatives and products:

1) We have contributed to a WUR white paper on the challenge of lifting smallholder farmers out of poverty while protecting forests and biodiversity (Waarts et al. 2019, edepot.wur.nl/507120). In the paper we propose various approaches, aiming to create significant impacts on the income earned by commodity farmers and their household members and to protect both forests and biodiversity and illustrate how private and public sectors can contribute.
2) We have contributed to a book chapter on the future perspectives of biodiversity in agriculture land. This chapter will be finalised in 2020: Schaminée, J.H.J. and van Rooijen N.M. *The Future*

of Agricultural Land: a perspective. In Carsten Hobohm (ed.) (exp. 2020) Perspectives for Biodiversity and Ecosystems, to be published in the Environmental Challenges and Solutions series of Springer Nature (https://www.springer.com/series/11763)

2 Draft assessment framework

2.1 Process

We have interactively built the draft assessment framework using a number of brainstorm sessions. As a basis during the kick-off meeting experiences with various existing frameworks and indicators were exchanged within the project group. After that we have had a number of brainstorm sessions to further generate ideas with the whole team (1 November 2019) or in subgroups. Notes on flip-overs that reflect the ideas and discussions are available in separate documents. In the meantime also the views of stakeholders were collected and literature was reviewed for further input. On 12 November 2019 the framework was further elaborated during a half day workshop. The subsequent draft framework was presented to and discussed with WUR colleagues during a half day workshop on 10 December 2019.

The development of the assessment framework is still in progress and will be updated with new insights and ongoing discussions with stakeholders and experts. After a further round of improvements the resulting draft framework will be discussed in a workshop with WUR and external experts during the first half of 2020.

2.2 Spatial scale is important

Differences between spatial scales are an important aspect to consider in the assessment framework. This is because at different spatial scales different processes or issues are important, but also the outcomes of management practices may strongly differ depending on the spatial scale used. As a simple example: an extensively managed farm field that replaces a species rich meadow may reduce the species richness of that particular field, but in contrast: in the larger landscape it may actually increase species richness as it increases variation in available habitats. In fact, contradictory findings on trends in biodiversity effects often are the result of that insufficient distinction is made between the different scales and the many biodiversity indicators that act at different scales (see Figure 1 and Figure 2, that are taken from McGill et al. 2015).

In addition, the possibilities for solutions of and subsequent conclusions on sharing vs sparing may strongly differ depending on the spatial scale considered (see for instance Figure 3). There will also be relations and interactions in effects at different scales that need to be considered (Figure 4) to be able to make comprehensive assessments of the relation between a food system and biodiversity. If inputs from other regions are being used (e.g. soy from Latin America in feed for dairy cows in the Netherlands), this dependence and its effects on biodiversity also need to be covered in the framework. Particularly in products with complex value chains and different inputs, the relations between the different spatial scales are relevant.

Related to the spatial scale is the choice of the functional unit considered in assessments. Examples are a unit of land (e.g. hectare) used for the production of a food product or a unit of food product (e.g. litre, or kg). Measures taken to reduce the impact on biodiversity often also have an effect on productivity, both now and in the future (resilience!) and thus on the amount of product produced. If for instance the unit of land (ha of grazing land) is used as functional unit, the measures may indeed reduce the negative impact on biodiversity on that particular unit of land. However, if the unit of product (kg milk, or kg of fat and protein corrected milk) is used, also the effect of lower productivity and/or quality is considered and the fact that additional land is needed for production is included (e.g. van Rooij and Arets 2016). Outcomes of the assessment then may be positive at the farm level, but less positive or negative at the unit of product level (e.g. van Rooij and Arets 2016). These trade-offs need to be covered in the assessment framework.

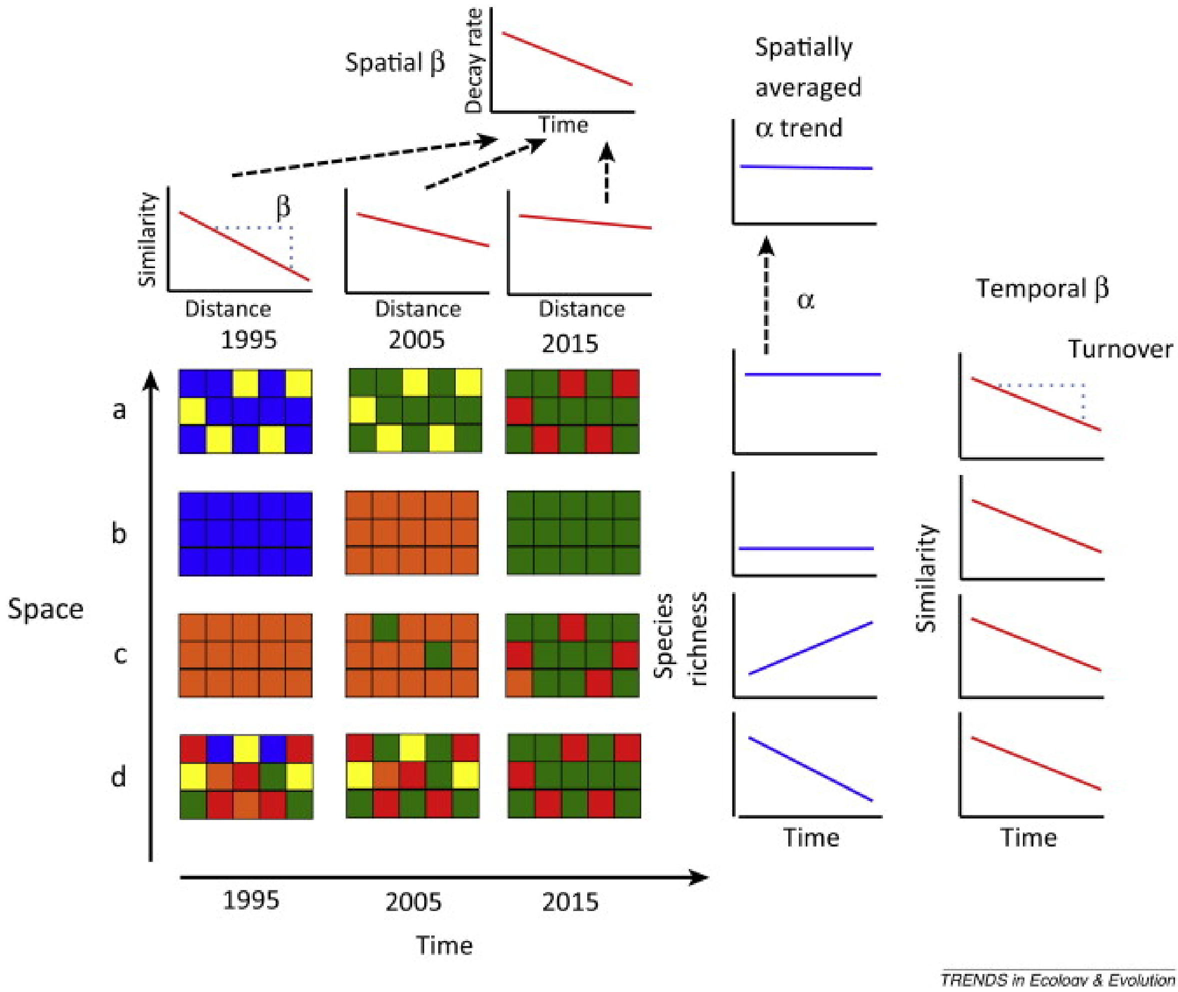

Figure 1. *Illustration of key types of biodiversity that can be measured. This figure follows four hypothetical communities (a–d) through three time periods (1995, 2005, 2015) (community abundance is constant, colours represent distinct species) demonstrating all of the major types of trends of* α *and β diversity. Alpha (*α*)-diversity is a measure for the number of species in a community. Beta (β)-diversity indicates the change in community composition across space (e.g., comparing similarity between communities a–d for one time period).*

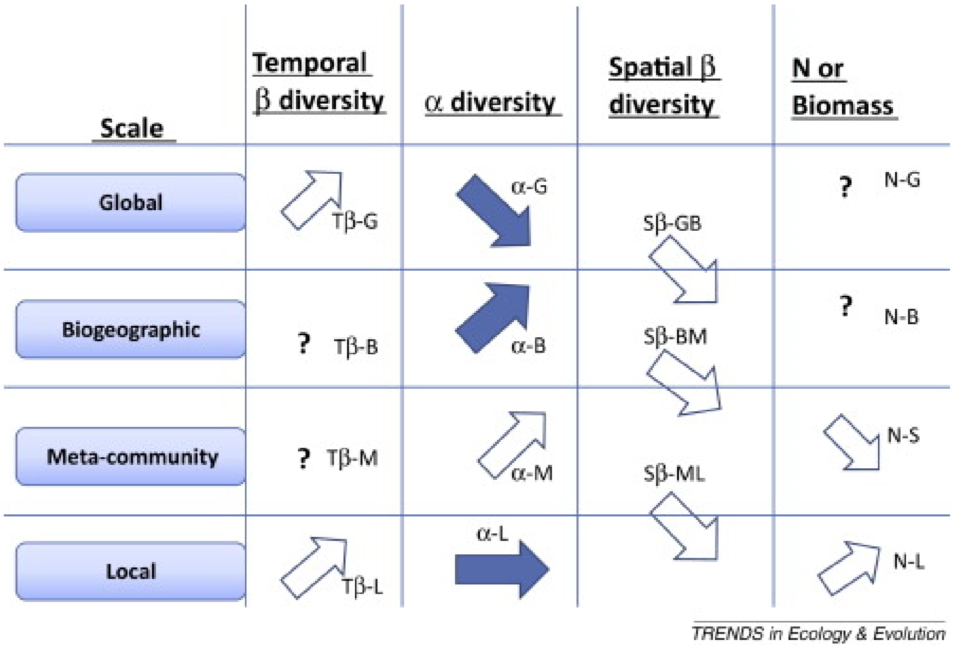

Figure 2. *Schema identifying 15 distinct trends in biodiversity. By breaking out spatial scales (here treated as four discrete scales) and different aspects of biodiversity, we identify 15 different types of trend. For example, α-B is a trend in species richness [i.e., alpha (α) diversity] at the biogeographical scale and N-L is a trend in abundance (or biomass) at the local scale. There are only three spatial beta (β)-diversity trends because spatial β diversity is a comparison across two scales. Unbroken arrows indicate knowledge of trends with substantial empirical data. Hollow arrows represent commonly hypothesized trends, often based on particular anthropogenic influences but not measured empirically often enough for us to feel confident about them. Question marks indicate four biodiversity trends identified in this schema about which there is little empirical evidence and little speculation. Figure and Caption taken from McGill et al. (2015).*

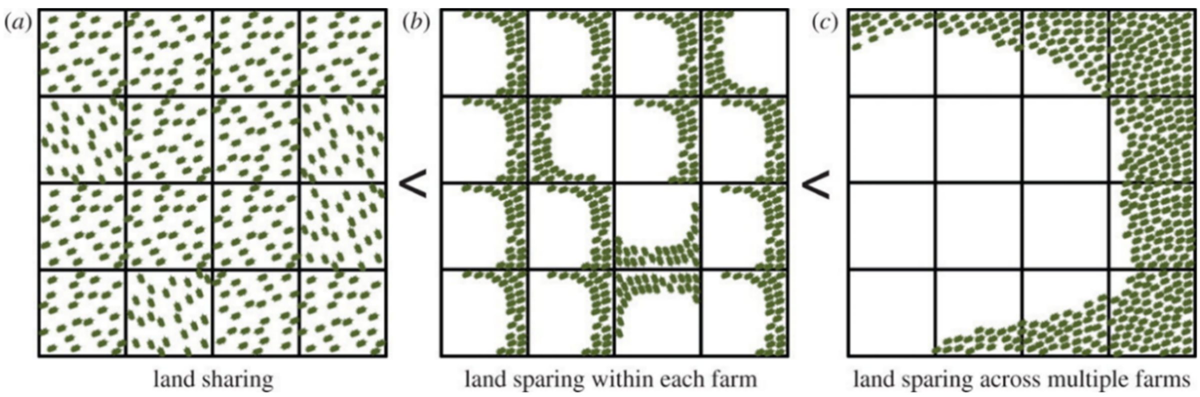

Figure 3. *Schematic summarizing what some 'biodiversity-friendly' certification schemes currently endorse (a) compared with landscapes that involve land sparing within large farms (b) or across a group of farms (c). In each landscape, the same total area (denoted by the green shapes) is given over to wild nature, but recent evidence suggests that its value for other species and for ecosystem services might increase from left to right, raising the question of whether certification could be realigned towards incentivizing high-yield farmers to collectively set aside adjacent areas of land for conservation. Figure and caption from Balmford et al. (2012).*

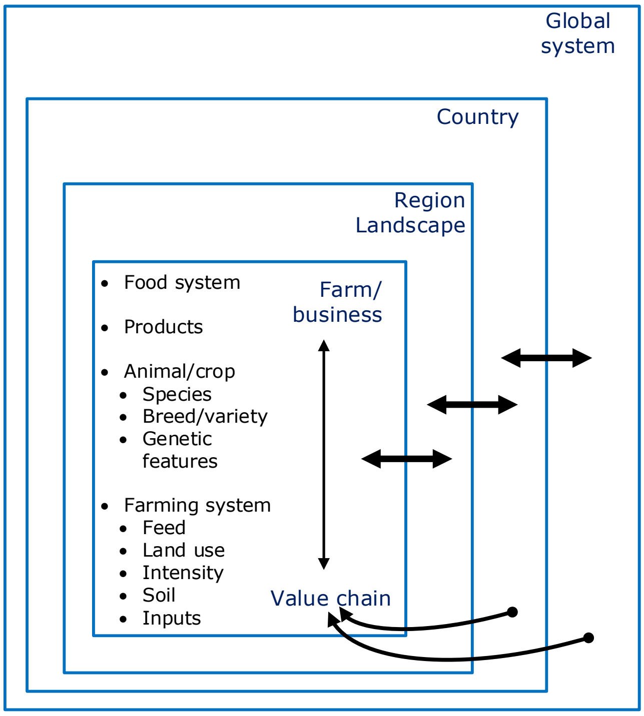

Figure 4. *At different scales, different dilemma's with different solutions and action perspectives are relevant.*

2.3 Draft assessment framework

Our current draft assessment framework relating biodiversity and food systems is illustrated in Figure 5 (the numbers in the next text refer to the numbers in this figure). For illustration, examples of activities and pressures are provided, but in the next steps of the project these still need to be selected and prioritised.

In a certain situation food is produced and supplied (Food Supply) through a combination of food system activities (1). Productivity and resource use efficiency of these food system activities are important aspects of this food system. The food system activities do not necessarily only include farm activities, but could also include other activities that result in pressures, like transport (greenhouse gas emissions, emissions of eutrophicating substances, etc), or storage (land use, emissions associated with storage).

Different food system activities that contribute to the food supply will result in a number of pressures (2) that in turn affect biodiversity (3) (positively and negatively). This effect may be different for different spatial scales (4) and also interactions between these spatial scales exist (5). Through ecosystem services and direct contributions (e.g. wild food) biodiversity supports the food supply (6). Also biodiversity may function as a filter protecting food supply for extreme events, resulting in more resilient food systems (7).

The aim of the project is to be able to assess the effect of different choices and provide action perspectives for more sustainable production. These actions can be targeted to the food system activities, including for instance alternative production systems that first need to be translated into its implications for the food system activities at different spatial scales. Actions also can be targeted at mitigating pressures, or supporting biodiversity, or a combination of these types of actions.

Even without all relationships being quantified, the framework can be used to support decision-makers and stakeholders by providing insight into all the aspects that need to be considered and the dependencies and trade-offs that may occur at different scales and support them in making transparent (policy) choices.

To be able to make transparent quantitative assessments (something mentioned by the stakeholders as urgently needed), the relationships in the framework (i.e. the arrows) need to be quantified. The ambition is to build a comprehensive assessment framework, but budget is limited. Therefore, as a starting point the assessment framework should be a general (but as specific as possible) model that is freely available, but that can be refined for specific questions from customers if desired. The model therefore needs to be flexible, and where possible quantitative, with the possibility for further development with future customers to determine specific relationships for specific issues. For example by using global key indicators that can be refined for specific cases.

To further (technically) build the assessment framework, we are exploring different suitable approaches that are able to include complex webs of relationships, are flexible and allow to combine quantitative and qualitative information, both from data sources and expert knowledge. Candidate approaches include Bayesian Belief Networks (see for example Smith et al. 2018) and the Decision EXpert (DEX) approach which was introduced by Rachel Creamer during the WUR workshop on 10 December 2019, (see for example Van de Broek et al. 2019).

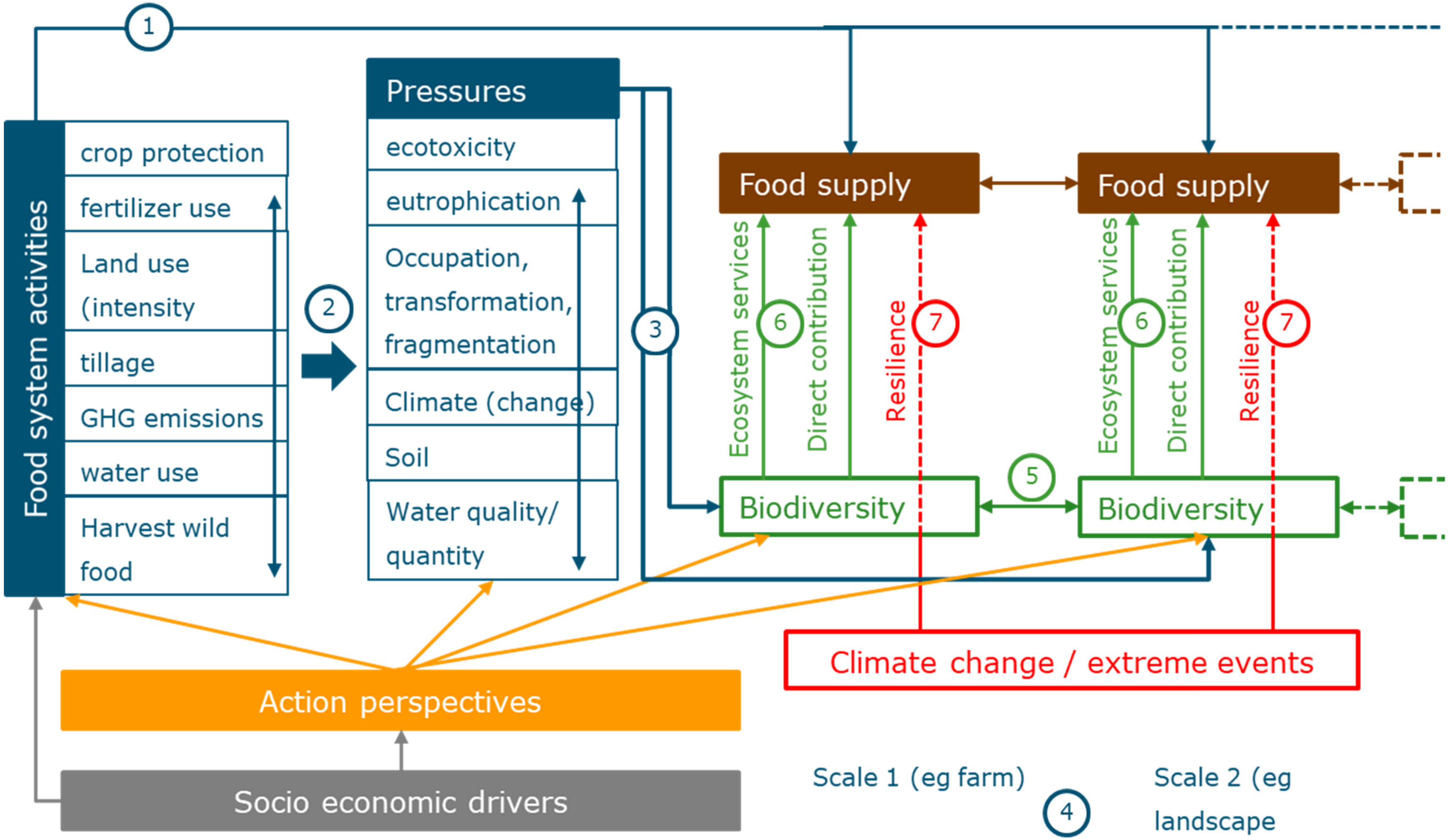

Figure 5. *Schematical representation of the draft assessment framework relating biodiversity and food systems. In a certain situation food is produced and supplied (Food Supply) through a combination of food system activities. Through potential pressures that are the result of these food system activities (here a few examples are given) biodiversity is affected (positively and negatively). This effect may be different for different spatial scales and also interactions between these spatial scales exist. Through ecosystem services and direct contributions (eg wild food) biodiversity supports the food supply. Also biodiversity may function as a filter protecting food supply for extreme events, resulting in more resilient food systems. The arrows represent relationships that need to be further qualified and quantified.*

3 Research agenda

A number of priority topics have been identified by the project group and need to be further researched over the next year(s). These are:

1. Dilemma's and action perspectives
2. Biodiversity indicators
3. Food system indicators
4. Pressure factors
5. Resilience

In subgroups these topics have been further elaborated as input to this (draft) research agenda. This will be further refined and elaborated in the first weeks of 2020.

Differences at different spatial and temporal scales are an important aspect that will be considered across the different priority topics. On this scaling topic we aim to closely collaborate with the motif on 'Multiple Scales and Extreme Events'

3.1 Dilemma's and action perspectives

Problem description
Different dilemmas are in discussion to optimize the balance between food production and biodiversity. Examples are the sharing/sparing debate, debate about intensifying or extensifying agricultural systems and types of production systems that are promising from a biodiversity and sustainability point of view. Other dilemmas would relate to trade-offs with the socio-economic system (e.g. poverty of rural populations). Different action perspectives to enhance biodiversity and food production/food security can be identified for farmers and other stakeholders like regional and national governments and companies. The effects of these perspectives are however unclear. They depend on context and scale and can be different for biodiversity and food production. Insights in trade-offs on other aspects like farm income and environmental quality of proposed actions is needed. Even when actions seem to be beneficial for both food production and biodiversity, they may not be implemented by stakeholders due to lock inns, like absence of logistics, markets for crops or business models, lack of funding to invest in desired changes, or mindsets of actors that prevent action.

Objectives

The objectives are to:

- indicate action perspectives for stakeholders operating at different scales that have a positive influence on either biodiversity or food production or both,
- quantify the impact of actions on both, in terms of [indicator biodiversity] and monetary benefits of food production at different scales,
- indicate/quantify the trade-offs with other sustainability aspects, looking for win-wins at different scales.

Results

- Indication of potential effects on biodiversity and food production, trade-offs, win-wins of action perspectives
- Scaling/list of most promising action perspectives and desired actions for different types of stakeholders
- Toolbox to guide promising action perspectives.
- Mechanism / action plans to realize the action perspective

Steps and activities

- Identifying and connecting the assessment framework with promising case studies to get further insight in dilemmas and action perspectives at different scales. Cases can be proposed by companies and NGOs and can come from other KB projects, Horizon 2020 project(s)
- Identifying dilemmas and action perspectives for selected cases
- Participatory process with stakeholders to identify dilemmas and action perspectives, obstacles that prevent actions to take place and possible actions to stimulate desired changes.

3.2 Biodiversity indicators

Problem description

Until now we have used biodiversity without a precise definition. However biodiversity can indicate many different things. Therefore, many biodiversity indicators exist, but which biodiversity indicators are most relevant for the biodiversity and food systems nexus, at different scales and for different contexts? What should those indicators be able to express and what are the relationships between different indicators?

Biodiversity indicators can indicate trends in number of species (i.e. scale dependent see section 2.2), or be aggregated indicators, for instance relating the status to a certain reference like the MSA indicator (Mean Species Abundance, see Alkemade et al. 2009). Other indicators include attributes of biodiversity quality (see eg McGill et al. 2015 and Table 1).

Table 1. *Different attributes of quality of diversity*

Aspect of quality	Comment
Functional diversity	Evidence suggests that ecosystem function may be higher or more stable with greater functional diversity
Trait diversity	Closely related to functional diversity but this is increasingly being used as a measure of phenotypic diversity in a community
Phylogenetic diversity	More evolutionary history is conserved when phylogenetic diversity is higher
Genetic diversity	More alleles preserved in a community give greater phenotypic variation and a higher possibility of adaptive evolution
Anthrophiles versus anthrophobes (incl agrodiversity?)	Some species are commonly associated with humans (e.g., crows, rats) and some avoid humans (e.g., wolves); the Anthropocene may be strongly filtering on this one trait
Rare versus common	Conservation biology is defined by some as the science of rarity (i.e., rare species)
Specialist versus generalist	Species that are highly specialized (i.e., narrow niche) are often deemed more in need of protection than generalists
Conservation value	Some species may need additional attention for conservation because they are for instance endemic (only occur in a certain location, or specific habitats) or are threatened (e.g. IUCN red list species).

Objective and result

Select biodiversity indicators that can be used within the assessment framework that provide information on different aspects of quality.

The indicators need to meet a number of criteria:

- Be able to provide relevant information to assess the foreseen dilemma's and action perspectives

- It should be possible to elaborate relationships between pressures and the biodiversity indicator
- It should be possible to elaborate relationships between biodiversity indicator and its contribution to food supply (through ecosystem services)
- There should be (sufficient) data available to quantify it

Activities

Based on the earlier literature search (eg. Hill et al. 2016; Isbell et al. 2017; Proença et al. 2017; Reid et al. 1993; Schmeller et al. 2018; Teixeira et al. 2016) a short list of indicators will be selected that meet the first three of the above criteria. We will do this by reasoning possible outcomes of a number of cases through our framework (without yet quantifying it, using what if type of questions; if this happens, what would then be the potential effect on the indicator and what kind of information would give this about the food system). In a next step a further literature review is done to assess if sufficient information is available to quantify the relationships with this biodiversity indicator.

3.3 Food system indicators

Problem description

Purpose of any human food system is to produce food for humans. Globally, a healthy diet for everybody is not yet achieved, and will remain a challenge for the future. Countries have committed themselves to SDG 2 "Zero Hunger" as one of the Sustainable Development Goals (next to e.g. SDG 15 to halt biodiversity loss). Therefore, any activity to improve biodiversity, where it is linked to human food systems, needs to be checked against its effects on food security. However, food security is not a simple outcome of producing enough food, but also depends on food prices and distribution. Especially for poor people, affordable food is a main concern. So, we need to define a number of indicators for different scales to monitor the development of food security as affected by biodiversity-related measures (and vice versa).

In principle, there are many scales from the field to the global level where food production and biodiversity are linked. For our framework, the most appropriate scales for food security indicators are

1. Farm level
2. National level
3. Global level

Ad 1. Farms throughout the world can be very different in their role of feeding people. They range from producing only for their own household (subsistence farming) up till producing mainly for the (inter)national market (commercial farming). This role with respect to markets affects the suitability of indicators, listed below.

Ad 2. For a country food imports and exports are important flows. Dependency on food imports makes a country vulnerable to what is produced elsewhere, including the costs for that, and the level of food exports may be important for the national financial balance.

Ad 3.The global level is needed to track any trade-offs between regions. If the food availability in one region is changed and the food demand remains the same, it may have consequences for food production and biodiversity in other regions.

For each of these scales indicators are needed that can be used to describe (changes in) food security. The following indicators can be used to check the effects of any biodiversity-related activity on food security: food production, crop/food price, net food imports/exports, % undernourished, and land requirement. Possibly, an indicator for food quality can be used as well, where it affects food security. For their use in the framework "practical" indicators are needed, which are precisely defined for each level (tailor made) and can easily be determined. These indicators may also differ among regions depending on data availability to assess their values. This requires additional research in 2020.

Purpose
Select a number of indicators, specifically for each scale and region, for monitoring and estimating changes in food security where these changes are linked to measures for stimulating biodiversity. These indicators need to be included in the framework to assess the relation between food security and biodiversity. Final result will be that a number of indicators will be defined and included in the framework to assess the relation between food security (SDG 2) and biodiversity (SDG 15).

Activities
For 2020 the following activities are envisaged:

- Check whether above indicators are sufficiently covering the theme of food security (SDG2) in relation to biodiversity, via literature and interviews of experts and stakeholders. If not, other indicators need to be defined.
- Find for each level (and region) the most suitable way to define and determine the indicators, e.g. food price for the national level and crop price for the farm level, and food production may be expressed in kcal and/or in kg protein, and may be compared with human requirements.
- Test the indicators in pilot (case) studies where the framework will be used to check their validity and usefulness. If they are not easily applicable, search for alternative indicators for food security.
- Determine relationships and trade-offs with biodiversity indicators.

3.4 Pressure factors

Problem
Different pressure factors will have an effect on biodiversity levels/indicators. Not all pressure factors operate at the same impact level. For instance, the intensity of land use has a strong direct impact on local biodiversity (e.g. Arets et al. 2017; Schipper et al. 2016), while climate change usually has a more gradual, but global impact on biodiversity (e.g. Nunez et al. 2019). Other factors, like nitrogen deposition has effects after surpassing a certain threshold or critical load.

Therefore, identification, qualification, prioritization and quantification of pressure factors in relation to biodiversity is important because it provides insight in the measures that can be taken to influence biodiversity. Also different action perspectives may have an effect on various pressures, not seldomly with trade-offs to other pressure factors. If actions result in reducing one pressure but increases another pressure, it is necessary to include both effects for assessing the outcome of actions.

Given the limited extent of the project, it may not be possible to include all possible pressure factors and their relations with biodiversity in the assessment framework. Therefore, a transparent selection and prioritization of the pressure factors to be considered for further quantification is needed. This should include the most important pressures in terms of potential extent of the impact, but the set of factors should also allow to capture the most important trade-offs between different factors.

Result
Overview of relevant pressure factors in relation to biodiversity. Factors are identified, qualified, prioritized and quantified. The aim is to quantify the relationships between pressure factors and biodiversity as much as possible. In cases where this is not possible, the relationships will be qualitative. Also insight is provided on the relationships among the identified stress factors themselves.

Actions
Literature review to investigate which pressure factors are relevant for biodiversity. Published relationships will be examined and possibly adopted.

3.5 Resilience

Problem description
In an extensive review DuVal et al. (2019)[1] identified a number of ways in which "biodiversity for food and agriculture" (BFA) contributes to enhanced resilience. Three broad categories characterize the role of BFA in resilience at different scales:

- conservation and use of genetic diversity and species diversity to support adaptation and continued evolution, including the characterization and evaluation of traits linked with resilience
- diversification of production system components to manage risk and mitigate the impact of climate change and variability of production
- habitat restoration for landscape/seascape complexity to support the supply of ecosystem services and the capacity of production systems to absorb and recover for disturbance or adapt to future conditions.

Resilience can be defined as the capacity of a system to absorb stresses and shocks, maintain function in the face of stresses and variability related to environmental change, and evolve into a system capable of withstanding a wide range of future conditions.
Important ways in which BFA contributes to resilience of production systems include i) providing resistance to, or tolerance of, shocks and stresses, ii) supporting adaptation and continued evolution, iii) maintaining stability, iv) supporting recovery from disturbances.
Biodiversity is an important factor in sustaining production over time. Resilience is also linked to spatial and temporal heterogeneity at different scales.

Indicators
Different components of BFA have been recognized as important indicators of resilience.
Indicators – farming system level:

- Resilience
  - Production stability and performance
  - Response diversity
  - Phenotypic plasticity
  - Adaptive capacity
  - Socio-economic risks
- Biodiversity
  - Varietal mixtures / crop and animal species diversity at farm level (over time)
  - Soil biodiversity
  - Diversity of above ground vegetation/natural habitats
  - Pollinators biodiversity

Indicators – landscape/seascape level[2]:

- Resilience
  - Spreading risks/buffering overall production against loss
  - Use of landscape features
  - Utilization of limited resources
  - Pests and disease pressure
- Biodiversity
  - Spatial diversification

Research needs and priorities
Resilience theory provides a valuable framework for understanding dynamics in production systems, assessing and measuring resilience are challenging, not least because of the multiple interacting factors that need to be taken into consideration.

Further research is needed to study i) the contribution of BFA to the resilience of production systems, ii) resilience promoting strategies that integrate diverse components of BFA at different scales.

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[1] Ashley DuVal, Dunja Mijatovic and Toby Hodgkin. The contribution of biodiversity for food and agriculture to the resilience of production systems. Thematic Study for The State of the World's Biodiversity for Food and Agriculture

[2] www.commonland.com

Long-term studies are needed to assess the contribution of BFA to resilience over a sufficient period of time, that include analysis of responses and interactions between the different factors contributing to resilience, and transformation towards diversity-rich production systems.
For this purpose, (a limited set of) relevant biodiversity and resilience indicators are needed.

Activity plan

2020

- further selecting and where possible quantifying the key relationships and indicators at farming system and landscape level
- incorporate biodiversity and resilience into the assessment framework
- identification of potential case studies and research locations
- collecting baseline data

2021

- apply and refine the framework in case studies

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