Master's Thesis | Sustainability Science (M.Sc.)

Biodiversity Monitoring in Food Forests

– State, Context and Implications.

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List of Abbreviations

AI	artificial intelligence
BfN	Bundesamt fuer Naturschutz (Federal Agency for Nature Conservation)
BUND	Bund für Umwelt- und Naturschutz e.V. (Association for Environmental and Nature Conservation)
CBD	Convention on Biological Diversity
CS	citizen science
ES	ecosystem services
NABU	Naturschutzbund Deutschland e.V. (German Nature Conservation Association)
NMVB	Nationaal Monitoringsprogramma Voedselbossen (National Monitoring Programme for Food Forests)
RQ	research question
SES	social-ecological system
SESF	Social-Ecological Systems Framework
UNCED	United Nations Conference on Environment and Development

1. Introduction

As humanity is currently facing multiple crises, we are in need of transformations towards sustainability in various sectors. One severe crisis constitutes the global decline of biodiversity, currently developing "faster than at any time in human history" (IPBES 2019: 11). For instance, the abundance of naturally present species has declined by 23 % on average in terrestrial communities (ibid.: 25). The drivers behind this drastic loss are predominantly human induced, whereby changes in anthropogenic land use are the most impacting ones, particularly agricultural expansion and urbanisation (IPBES 2019: 12; MEA 2005: 62). Biodiversity, simplified defined as the "diversity within species, between species and of ecosystems" (Secretariat of the Convention on Biological Diversity 2011: 4), is essential for human well-being. For instance, it provides so-called 'ecosystem services' (ES)[1] such as food (IPBES 2019: 12; MEA 2005: 19), space for recreation (MEA 2005: 19) and climate regulation (MEA 2005: 19; Wirth et al. 2024: 40). Accordingly, the biodiversity crisis and its conservation are recognised issues at different political scales (see BMUV 2024; European Commission 2021; Secretariat of the Convention on Biological Diversity 2011).

It is rather unlikely that the extremely high rate of biodiversity decline will be reversed within the next decades. Nonetheless, there are opportunities to reduce it (MEA 2005: 60). Correspondingly, regarding the current degenerating land use and agricultural practices, the concept of food forestry might be an alternative, local, extensive and biodiversity-friendly approach (see Albrecht and Wiek 2021a: 92; Härdtle 2024: 858; MEA 2005: 30; 71; Wirth et al. 2024: 49). Food forests refer to a type of multilayered agroforestry system in the temperate climate zone (Wiersum 2004: 124), which originated from indigenous agricultural practices in the tropics (Kumar and Nair 2004: 136; Wartman et al. 2018: 7). The core idea behind food forests is to mimic the structure of young, natural forest (edges) (Crawford 2021: 17; Moereels et al. 2024: 2; Riolo 2019: 2). Accordingly, the system is structured into three to seven vegetation layers of varying heights (Albrecht and Wiek 2021: 92; Jacke and Toensmeier 2005: 69), composed primarily of perennial plants that are either edible or otherwise beneficial for humans (Crawford 2021: 17; Jacke and Toensmeier 2005: 1; Schulz et al. 2022: 18). Food forests are characterised by a high degree of multifunctionality, as they can potentially offer ES well beyond agricultural production alone. Thus, they have the potential to address a broad spectrum of societal, economic and ecological challenges and needs (Albrecht and Wiek 2021: 102; Moereels et al. 2024: 3).

So far, research on temperate food forests is limited and only starting to increase throughout the last years (Moereels et al. 2024: 3; Roodhof 2024: 194; Wartman et al. 2018: 7). While many researchers and practitioners state assumptions about food forests having a positive impact on biodiversity (see e.g. Belcher et al. 2005: 245; Cariñanos et al. 2022: 136; Park et al. 2019: 8), only few published scientific

[1] The term 'ecosystem services' (ES) refers to properties or processes of ecosystems that humans directly or indirectly benefit from (e.g. food provision) (Costanza et al. 1997: 253).

studies actually provide first empirical insights into such (see Breidenbach et al. 2017; Kreitzman et al. 2022; Riolo 2019; Wendel et al. 2023; West 2006).

To extend these first insights, there is a need for extended, systematic and standardised long-term biodiversity monitoring, i.e. "the process of measuring the value (ideally quantitatively) of biodiversity components" (Hill et al. 2005: 65) in food forests (Moereels et al. 2024: 15; Wendel et al. 2023: 37; West 2006: 8; see NMZB n.d.a). Robust findings from such monitoring could promote the up-scaling of food forestry (Clark and Nicholas 2013: 1666; STATTwerke e.V. n.d.). So far, its legal and political recognition is limited (see e.g. Roodhof 2024: 204), and many food forests are organised as volunteer-based non- or low-profit projects (Albrecht and Wiek 2021a: 94; Roodhof 2024: 204; Wiek and Albrecht 2022: 2). In addition, biodiversity data could serve as a basis for decisions on biodiversity-friendly management actions in such projects (Moereels et al. 2024: 15; Wendel et al. 2023: 37; West 2006: 8).

First approaches to biodiversity monitoring in food forests already exist. Correspondingly, Park and Higgs (2018) proposed a monitoring framework for food forests, including the assessment of biodiversity. Different Dutch and German organisations made first attempts to establish monitoring schemes in food forests with different extents and methodological approaches (see Food from the Forest n.d.b; STATTwerke e.V. n.d.; University of Potsdam n.d.a; Wageningen University & Research n.d.b; Wendel et al. 2023). In addition, individual food forest projects sometimes perform self-organised biodiversity monitoring activities (see e.g. Janun Göttingen n.d.), but insights into these activities are scarce. Overall, this rather untransparent landscape of biodiversity monitoring appears insufficient to generate a robust data base on the impact of food forestry on biodiversity (see Wendel et al. 2023: 37; Wirth et al. 2024: 145).

In order to improve or establish concepts for biodiversity monitoring in food forests, it is necessary to gain an understanding of the current state and extent of existing approaches. In addition, as the social-ecological context of food forest projects shapes their biodiversity monitoring activities (see Park and Higgs 2018: 16), it appears beneficial to assess context factors. Correspondingly, this work is guided by the following research questions (RQs):

RQ1: What is the state and level of professionality of biodiversity monitoring activities in food forest projects?

RQ2: Which social-ecological context factors impact this state?

RQ3: Which implications can be derived from this for future biodiversity monitoring activities in food forests?

To approach these RQs, I applied an empirical and explorative research design with a focus on case studies. Following a mixed-method approach, I conducted an online survey first, considering a sample of 16 food forest projects performing biodiversity monitoring activities on their site. Second, I conducted semi-structured interviews with experts from two German and two Dutch food forest project cases from the former sample. Thereby, I approached food forest systems from a social-ecological systems (SES)-perspective, by using ideas and variables of the SES Framework (SESF) by E. Ostrom (see Ostrom 2007; Ostrom 2009).

The work is structured as follows: Initially, I will provide deeper insights into the theoretical background on food forests, biodiversity, monitoring and the underlying SES Framework. Second, I will present my research design and methodological approach in detail. Following short case descriptions, I will then present the survey results (RQ1) and the interview results (RQ2). Finally, I will discuss the key findings and derive practical implications for food forestry stakeholders regarding future biodiversity monitoring activities (RQ3). I will conclude with a summary and outlook.

2. Theoretical background

2.1. Food forests

Terminology

Overall, the concept of food forests refers to individual systems that are unique in their plant composition, size and (intended) functions but have in common a multilayered vegetation structure, complexity and multifunctionality. Various other terms are used to describe similar systems, such as 'forest gardens' (see Jacke and Toensmeier 2005: 1; Whitefield 1996: 15). However, in this work, I am referring to 'food forests', including sites of all sizes, in line with the recent scientific discourse (see Albrecht and Wiek 2021a; Roodhof 2024).

Vegetation structure

Food forests are a type of multilayered 'agroforestry system'[2] (Wiersum 2004: 124) that mimic the structure of young, natural forest (edges) (Crawford 2021: 17; Moereels et al. 2024: 2; Riolo 2019: 2). They are structured into three to seven vegetation layers of different heights (Albrecht and Wiek 2021a: 92; Jacke and Toensmeier 2005: 69), consisting of mainly perennial, edible or otherwise beneficial plants for humans (Crawford 2021: 17; Jacke and Toensmeier 2005: 1; Schulz et al. 2022: 18). Each food forest is a unique system with a distinct plant composition (Park et al. 2018: 285). Especially in young food forests, the vegetation is in an on-going state of succession (Breidenbach et al. 2017: 92-93; Wendel et al. 2023: 25).

Origin and dissemination of food forestry

While food forests only recently emerged in the temperate climate zone, similar systems were common in tropical and especially rural zones all along (Kumar and Nair 2004: 136; Wartman et al. 2018: 7). So-called tropical homegardens are one of the oldest forms of local subsistence economy in the tropics, dating back to at least 4000 years ago (Kumar and Nair 2004: 136). Inspired by those, food forest projects emerged as grassroot initiatives in the temperate climate zones since the 1970s (Crawford 2021: 373; Park et al. 2018: 285; Riolo 2019: 2; Whitefield 1996: 15). At about the same time,

[2] The term 'agroforestry' can be defined as "the deliberate integration of trees with agricultural crops and / or livestock either simultaneously or sequentially on the same unit of land" (Mosquera-Losada et al. 2008: 3).

the 'permaculture' movement[3] developed in Australia, which promoted food forests as well (Roodhof 2024: 194). Besides conventional businesses, many food forest projects currently operate on a volunteer- and non-profit-basis, for example due to a lack of legal and political recognition (Albrecht and Wiek 2021a: 94; Roodhof 2024: 204; Wiek and Albrecht 2022: 2). As I am examining Dutch and German food forest project cases in the present work, I am providing background information on the current state of food forestry in these countries in the following.

Food forestry in the Netherlands

The legal and political recognition of food forestry increased in the Netherlands both on the regional and national level throughout the last years (Albrecht and Wiek 2021b: 189; netwerk voedselbosbouw n.d.b; Roodhof 2024: 199).

Central to this was the 'Green Deal Voedselbossen'[4] (Green Deal) which was signed in 2017 by several Dutch around food forestry (netwerk voedselbosbouw 2017: 1). The coalition acknowledged the potential of food forestry and aimed to scale it up (netwerk voedselbosbouw n.d.a; Roodhof 2024: 194; 205). Thereby, it referred to food forests that fulfil their specific requirements of an area size of at least 0.5 hectares and at least four vegetation layers (netwerk voedselbosbouw 2017: 4). For example, the coalition achieved that the Dutch 'Ministry of Agriculture, Nature and Food Quality' and the joint provinces included the goal of establishing at least 1000 hectares with food forests on agricultural land in their 'Bossenstrategie'[5] (see Interprovinciaal Overleg, Ministerie van Landbouw and Natuur en Voedselkwaliteit 2020). In the course of this, food forests corresponding to the Green Deal definition were assigned to a certain agricultural land use type, which simplifies implementation and funding (netwerk voedselbosbouw n.d.a). Despite this progress, especially food forest projects that do not fulfil the requirements according to the Green Deal definition still face institutional obstacles (netwerk voedselbosbouw n.d.b; Roodhof 2024: 193, 205).

Because the Green Deal ended in 2021, the coalition continued its work as the independent 'Netwerk Voedselbossen'[6] (netwerk voedselbosbouw n.d.–d). The network is connected with the 'Stichting Voedselbosbouw'[7], which is supporting food forest projects and research (netwerk voedselbosbouw n.d.b; Stichting Voedselbosbouw Nederland n.d.a, n.d.b, n.d.d). In addition, the association 'Food from the Forest' brings together diverse food forestry stakeholders (Food from the Forest n.d.a; Roodhof 2024: 199).

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[3] The term 'permaculture', introduced by the Australians Bill Mollison and David Holmgren, stands for 'permanent agriculture'. Initially, it referred to the conscious design and maintenance of agriculturally productive ecosystems that exhibit the diversity, permanence and self-regulating capacity of natural ecosystems (see Mollison 2012: 11). By now, permaculture is a holistic approach to life that goes far beyond agriculture (see Permakultur Institut 2024).
[4] Green Deal Food Forests (free translation)
[5] Forest Strategy (free translation)
[6] Network Food Forests (free translation)
[7] Foundation Food Forest Agriculture (translation by DeepL)

Alongside these developments, the Dutch food forest community and its activities are increasingly growing (Roodhof 2024: 192–193). In 2024, A. Roodhof verified the existence of at least 207 food forest projects in the Netherlands in her research (ibid.: 196, 204).

Food forestry in Germany

In contrast to the Netherlands, food forestry seems to be an emerging phenomenon in Germany that has not yet received much political recognition or support (see e.g. BMEL 2023). Accordingly, I could not find much information on food forestry in Germany but gained some insights by being part of the (urban) food forest community myself.

Legally, there is no specific land use type for German food forests, but they can be assigned to several ones depending on their intended function (Schulz et al. 2022: 53). This complicates the implementation of food forest projects and leads to a lack of direct funding opportunities (see Roodhof 2024: 199, 204). The German community around food forestry appears to be larger than its political and legal recognition suggests. This is particularly reflected by the association 'Nahrungswald e.V.' and the project 'Urbane Waldgärten: Mehrjährig, mehrschichtig, multifunktional' (Urbane Waldgärten). They operate pilot food forest projects and offer a networking platform for (urban) food forest projects. Urbane Waldgärten is thereby supported by the federal government (Nahrungswald e.V. n.d.; University of Potsdam n.d.b).

In 2021, S. Albrecht identified 18 German food forest projects in her research (see Albrecht 2021). Since then, many more food forest projects have become part of the communities around Nahrungswald e.V. and Urbane Waldgärten.[8] Also, it can be assumed that there are several unregistered food forests as part of private initiatives (see Roodhof 2024: 196; 204).

Functions of food forests

Research on temperate food forestry is only starting to increase throughout the last years (Moereels et al. 2024: 3; Roodhof 2024: 194; Wartman et al. 2018: 7). Researchers assume that food forests fulfil a variety of functions and thus respond to a wide range of societal, economic and ecological challenges and needs (Albrecht and Wiek 2021a: 102; Moereels et al. 2024: 3), each food forest to a different extent (Albrecht and Wiek 2021a: 102).

First, food forests might provide socio-cultural services (Albrecht and Wiek 2021a: 100), such as opportunities for education (see Gobs 2025; Hammarsten et al. 2019) and research (Albrecht and Wiek 2021a: 97; Park et al. 2018: 287), positive impacts on human nutrition and health (see Nytofte and Henriksen 2019; Stoltz and Schaffer 2018) and possibilities for community building and participation (see Shi 2023; Stoltz and Schaffer 2018).

Second, food forests might have economic benefits (Albrecht and Wiek 2021a: 100). Income sources of food forest projects are diversified, as they often not only make an income with the yield of various food and other beneficial products but also from nursery and the offering of tours, workshops or

[8] see Appendix A for food forest inventory

home vacations (Park et al. 2018: 286). Hence, food forests might impact food access and security (see Clark and Nicholas 2013), "subsistence and cash incomes, as well as means for capital accumulation, risk spreading, labor saving, and possible demonstration of ownership" (Belcher et al. 2005: 245).

Third, food forests might offer environmental services (Albrecht and Wiek 2021a: 100). They might positively impact soil health, water regulation (Cariñanos et al. 2022: 136), carbon storage (see Lehmann et al. 2019; Schafer et al. 2019) and (agro-)biodiversity (see Riolo 2019; Rockwell et al. 2022). Also, food forests might mitigate urban heat (Albrecht and Wiek 2021a: 92; Cariñanos et al. 2022: 136).

2.2. Biodiversity and biodiversity monitoring

Biodiversity

The term and concept of biodiversity is rather uncertain and broad, which is reflected by many and vague definitions of it (Hamilton 2005: 90). In this work, I am considering the common definition provided by the 'Convention on Biological Diversity' (CBD)[9]: Biodiversity, or biological diversity (see Härdtle 2024: 11; Wirth et al. 2024: 1214), "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" (Secretariat of the Convention on Biological Diversity 2011: 4). This definition compromises the diversity of different biological organisational levels, from 'genetic diversity' over 'organismic diversity' up to 'ecological diversity'[10], whereby these levels are strongly connected (Härdtle 2024: 2–4; MEA 2005: 18). However, the CBD definition is criticised for not depicting all critical elements of biodiversity (Härdtle 2024: 5). Consequently, researchers frequently extend it with more attributes and features within the organisational levels (see Härdtle 2024: 5; IPBES: 1033; Wirth et al. 2024: 128).

As biodiversity is such a complex concept, I will focus on certain aspects in my work. Based on the classification of organisational levels and attributes of biodiversity by Härdtle (2024), referring to Noss (1990) and Schulze et al. (2019), I am considering the monitoring of biodiversity indicators representing the 'compositional diversity' and 'functional diversity'[11] of organisms, specifically the

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[9] The policy paper 'Convention on Biological Diversity' was signed by 168 member states at the 'United Nations Conference on Environment and Development' (UNCED) in 1992 to agree on a novel frame for biodiversity conservation (Härdtle 2024: 2).

[10] 'Genetic diversity' refers to the "the diversity of nucleotides, alleles, chromosomes, genotypes and other aspects of the genomic variability of organisms" (Härdtle 2024: 4), 'organismic diversity' to "the number and relative abundance of different taxa in a habitat, for example the number of existing species, genera, families, etc. […], which in turn are related to each other in a hierarchical, phylogenetic […] classification scheme" (Härdtle 2024: 4) and 'ecological diversity' to "the diversity of habitats, ecosystems, landscape types etc. within a reference area" (Härdtle 2024: 4; translation by DeepL).

[11] 'Compositional diversity' refers to the "description or labelling of the biological entities specific to an ecosystem or reference area" (Härdtle 2024: 5) (e.g. taxonomic group), 'structural diversity' to "the spatial arrangement of structuring elements that contribute to an overall appearance (physiognomy)" (Härdtle 2024: 6) (e.g. vegetation structure) and 'functional diversity' to "the functional contribution of different organisms to important ecosystem processes" (Härdtle 2024: 7; translation by DeepL) (e.g. nutrient cycling).

community (biocoenosis) and population[12] (see Härdtle 2024: 9–10). For example, I am referring to the indicators of the relative frequency of species (compositional diversity of community), abundance (compositional diversity of population) and mortality rate (functional diversity of population) (Härdtle 2024: 9–10; Noss 1990: 359). I am not referring to the agrobiodiversity of the planted edible plants in food forests but to the diversity of spontaneously occurring flora and fauna.

Biodiversity monitoring

The "process of measuring the value (ideally quantitatively) of biodiversity components" (Hill et al. 2005: 65) can be described as 'biodiversity monitoring'. Ideally this is done continuously, regularly or over a certain time period in a systematic and standardised methodological procedure to ensure comparability of biodiversity data (NMZB n.d.a). However, I am also including irregular or one-time count as well as unsystematic and unstandardised surveys into my research.

The emerging data on the state and development of biodiversity over space and time helps to address political, societal and scientific issues related to biodiversity and its decline (NMZB n.d.a), with various underlying purposes of different stakeholders (Basille et al. 2024: 8). Biodiversity monitoring often forms the basis for developing, implementing and evaluating conservation measures, as well as providing foundational research and fulfilling international reporting obligations (Hill et al. 2005: 65; NMZB n.d.a; Wirth et al. 2024: 142).

Given the various contexts and the complex concept of biodiversity, designing biodiversity monitoring schemes is challenging. For example, decisions on monitoring design, taxonomic groups, biodiversity indicators, frequency, time span and tools are required, which impact the quality of biodiversity data (see Hill et al. 2005). Consequently, various biodiversity monitoring programmes with different foci, extents, and approaches exist, operating at different spatial scales. Synthesising biodiversity data across such heterogeneous programmes is difficult yet necessary to estimate robust long-term trends (Wirth et al. 2024: 145). Further challenges in biodiversity monitoring programmes are related to a lack of frequent and long-term monitoring and data availability (ibid.: 145-146).

In light of these challenges, further advancement of biodiversity monitoring programmes is needed, in addition to already existing efforts (see e.g. biodiversa+ European Biodiversity Partnership). Researchers are calling out for the establishment of integrated, standardised and systematic biodiversity monitoring concepts (see Kühl et al. 2020: 464; Wirth et al. 2024: 57). Ideally, such a concept is characterised by 1) "a networked set of data types, sampling methods, designs" (Kühl et al. 2020: 464), 2) collaboration and complementation among stakeholders with joint institutional rules but also ownership, 3) adaptive capacity and 4) open data access (ibid.: 464, 471-472).

As biodiversity experts are rare and expensive (Danielsen et al. 2021: 495), the involvement of volunteers in biodiversity monitoring activities is already a common practice. It could be a relevant part of such integrated biodiversity monitoring concepts (Kühl et al. 2020: 463, 466), although a lack

[12] 'Population' refers to "the totality of individuals of a species present at a specific location and at a specific time" (Härdtle 2024: 889; translation by DeepL).

of data quality and taxonomic bias are well-known concerns (Wirth et al. 2024: 145–146). This "active participation of individuals who are not institutionally affiliated with the scientific community in scientific processes"[13] (Bonn et al. 2022: 12) can be described by the term 'citizen science' (CS). The level of participation can "range from short-term data collection to intensive use of free time to delve deeper into a research topic together with scientists and/or other volunteers"[14] (ibid.).

Although the establishment of both integrated and CS monitoring concepts is challenging due to diverse reasons (see Gönner et al. 2023: 26; Kühl et al. 2020: 472), they are promising approaches that potentially benefit scientific, societal, and political actors (see Bonn et al. 2022; Danielsen et al. 2021: 484–486).

2.3. Biodiversity and biodiversity monitoring in food forests

Biodiversity in food forests

Many researchers and practitioners state assumptions about food forest systems having a positive impact on biodiversity (see e.g.Belcher et al. 2005: 245; Cariñanos et al. 2022: 136; Park et al. 2019: 8), while others raise concerns about the plantation of non-native and invasive plant species as a potential threat to biodiversity conservation (see Moereels et al. 2024: 15).

Only a few empirical studies give actual insights into biodiversity so far. Both the results of studies assessing single (see Breidenbach et al. 2017; Riolo 2019; West 2006) and multiple (see Kreitzman et al. 2022; Wendel et al. 2023) food forest sites indicated positive effects on the diversity of wild flora, birds, insects in general, moths, ground beetles, spiders and fungi (Breidenbach et al. 2017: 92; Kreitzman et al. 2022: 21–25; Riolo 2019: 7; Wendel et al. 2023: 24; West 2006: 8).

Although the results from the two meta studies are already methodologically more robust than those from the case studies, this limited amount of data only provides a first snapshot of the impact of food forestry on biodiversity (Wendel et al. 2023: 37; West 2006: 8). For example, it does not address the above-mentioned concern of the consequences of planting non-native and invasive plant species in food forests (see Moereels et al. 2024: 15; Wendel et al. 2023). Hence, researchers emphasise the need for extended and systematic long-term biodiversity monitoring in food forests to prove those first impressions. This could foster the political and societal support for food forestry (Clark and Nicholas 2013: 1666; STATTwerke e.V. n.d.) and inform decisions on biodiversity-friendly management actions (Moereels et al. 2024: 15; Wendel et al. 2023: 37; West 2006: 8). The following monitoring programmes already develop in this direction.

Biodiversity monitoring in food forests

Apart from the monitoring framework proposed by Park and Higgs (2018) and self-organised biodiversity monitoring activities by individual food forest projects (see e.g. Janun Göttingen n.d.), five

[13] translation by DeepL
[14] translation by DeepL

official monitoring programmes focus specifically on food forests and include systematic surveys on biodiversity indicators in their research. Two of these programmes are located in Germany and three in the Netherlands.

The Dutch association Food from the Forest runs a CS project on biodiversity in food forests. They encourage and support volunteers in all types of food forests to collect data on herbaceous plants (The Plant et al.: 4).

Urbane Waldgärten and the 'Nationaal Monitoringsprogramma Voedselbossen'[15] (NMVB) involve both experts and food forest gardeners in the data collection on different floral and faunal taxonomic groups. While Urbane Waldgärten gathers data on three pilot urban food forest sites, 33 selected food forest projects across the Netherlands are involved in surveys as part of the NMVB (University of Potsdam n.d.a; Wendel et al. 2023: 10–11). First results from the NMVB are available in the report by Wendel et al. (2023), as presented above. Both Urbane Waldgärten and the NMVB intend to scale up their activities in future to establish a long-term, standardised monitoring programme for (urban) food forests in their respective countries (Stichting Voedselbosbouw Nederland n.d.c; Wendel et al. 2023: 10; U, 64).

The 'Insektenlebensräume und Strukturvielfalt in der Agrarlandschaft schaffen' (WASYS) project and the 'Wetenschappelijke Bodemvorming onder de Voedselbosbouw'[16] research project are exclusively expert-based food forest monitoring programmes. At WASYS, insect richness and abundance are assessed in five different pilot food forest systems (STATTwerke e.V. n.d.). In the latter project, two large food forests functioned as living labs from 2020 to 2024. Research on different floral and faunal taxonomic groups (Wageningen University & Research n.d.a) has been conducted on these since the beginning and is planned to continue (Stichting Voedselbosbouw Nederland n.d.d; Wageningen University & Research n.d.b).

2.4. Social-ecological systems and Social-Ecological Systems Framework

Social-ecological systems

Introduced by Berkes and Folke (1998), a SES is defined as a complex system with integrated social and ecological subsystems. These do not exist separately but are characterised by a strong mutual relationship with interactions and feedback (Biggs et al. 2022: 5–6; Harrington et al. 2010: 2778).

Like other researchers (see Aguilar-Støen et al. 2009: 56; Park et al. 2018: 290; Taylor and Lovell 2014: 299), I am regarding food forests as SES in the present work. Food forest systems consist of related social and ecological subsystems with interactions and feedback. For example, stakeholders in a food forest project were motivated to counteract degraded soils and biodiversity loss through conventional agriculture (social subsystem) and therefore decided to decrease the number of visitors to their food forest to reduce disturbance (ecological subsystem) (Albrecht and Wiek 2021: 97-98), which will likely

[15] National Monitoring Programme for Food Forests (translation by DeepL)
[16] Scientific Soil Formation under Food Forestry (translation by DeepL)

affect flora and fauna (interaction and feedback). Also, food forests comprise typical SES characteristics of resilience, adaptability and regeneration (Aguilar-Støen et al. 2009: 56; Taylor and Lovell 2014: 292; Wartman et al. 2018: 6; see Preiser et al. 2018: 2-3).

Social-Ecological Systems Framework

As proposed by E. Ostrom (see McGinnis and Ostrom 2014; Ostrom 2009, 2007), the 'Social-Ecological Systems Framework' (SESF) is a diagnostic multitier framework for the analysis of SESs (McGinnis and Ostrom 2014: 2; Ostrom 2009: 420, 2007: 25182) from an anthropocentric viewpoint (Binder et al. 2013: 14). Its application is broad and associated with a variety of theories, concepts, frameworks and methods (Partelow 2018: 3, 8).

Overall, the SESF consists of variables relevant to understanding SESs (McGinnis and Ostrom 2014: 2; Ostrom 2009: 420, 2007: 25182). In my work, inspired by the modifications as proposed by Hinkel et al. (2014) and implemented by Gain et al. (2019), the highest levels of such variables are the 'resource system' (RS) within the ecological subsystem, as well as the 'governance system' (GS) and the 'actors' (A) within the social subsystem (see Gain et al. 2019: 3; Hinkel et al. 2014: 6). These first-tier variables include multiple more specific variables on deeper levels (McGinnis and Ostrom 2014: 4; Ostrom 2009: 420, 2007: 15182). Furthermore, SESs are affected by exogenous influences from 'related ecosystems' (ECO) and 'social, economic, and political settings' (S) (McGinnis and Ostrom 2014: 3; Ostrom 2009: 420, 2007: 15182). Furthermore, the focal 'action situation' of biodiversity monitoring functions as the "entry point" (Ostrom 2007: 15186) to my application of the SESF (see Fig. 1). This sets the boundaries of my SESs (see Schlüter et al. 2012: 241), as I only included first- and second-tier variables into my research that are related to those activities in the assessed food forest projects. I am thereby focusing mainly on the impact of those variables on biodiversity monitoring activities but not on the relationships among them.[17]

[17] see Appendix G for codebook with included first- and second-tier variables and their definitions

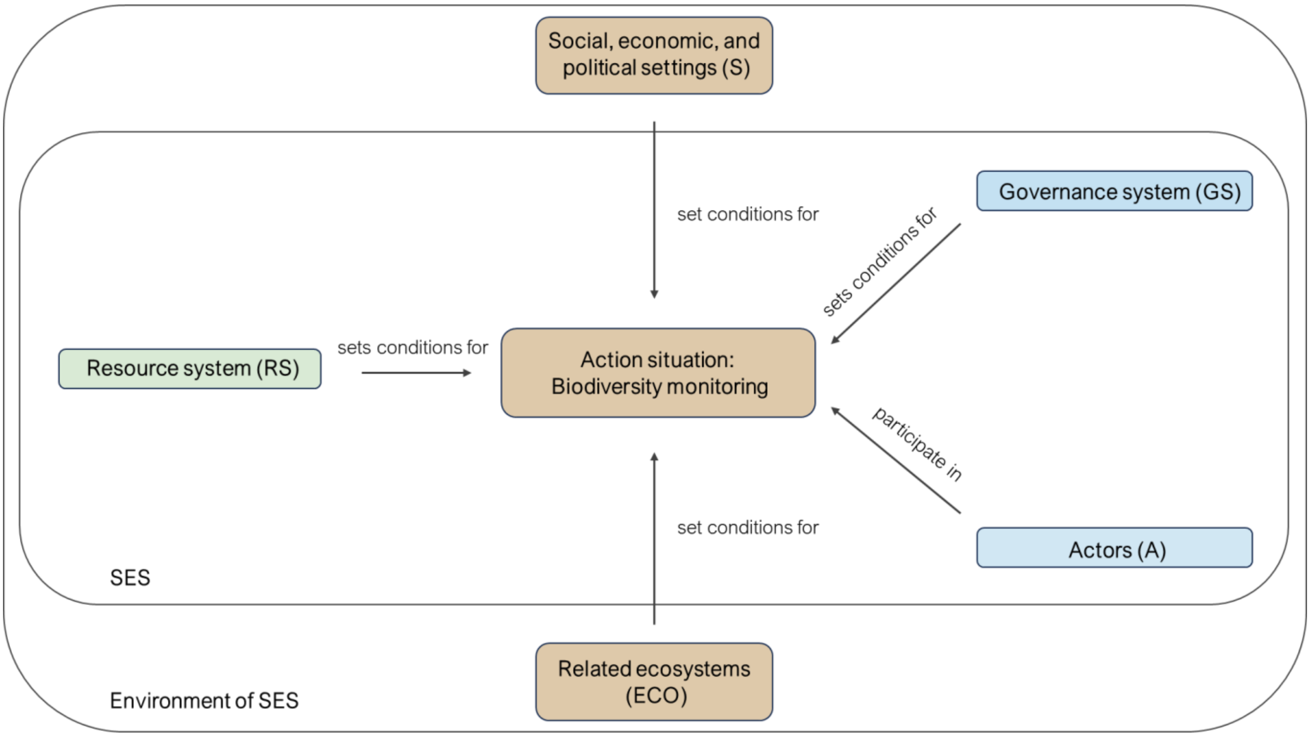


Fig. 1: Simplified adaptation of the Social-Ecological Systems Framework (SESF). Green: Ecological subsystem, blue: Social subsystem. Adapted from McGinnis and Ostrom (2014), Hinkel et al. (2014) and Gain et al. (2019). Own illustration.

3. Methodology

3.1. Research design

Overall, to approach my novel and practice-oriented research topic, I opted for an empirical and explorative research design, focusing on case studies. Inspired by Albrecht and Wiek (2021a), I thereby applied a mixed-method 'sequential quantitative-qualitative design', as described by Kelle (2022: 172). First, I conducted an **online survey** to gather representative data on the state and level of professionality of biodiversity monitoring activities in food forest projects (RQ1). Second, I conducted **semi-structured interviews** with experts to gain an in-depth understanding of the real-life situations of food forest gardeners leading to such (RQ2) (see Hug and Poscheschnik 2020: 109; 111; Kelle 2022: 165). Regarding the latter, I chose to include four **case studies** to ensure multiple and diverse insights (see Eisenhardt and Graebner 2007: 27) (see Fig. 2). Those insights served as a basis to derive general assumptions on biodiversity monitoring activities in food forests (see Berger-Grabner 2022: 163; Eisenhardt and Graebner 2007: 25; see Ridder 2020: 90). The entire empirical work was embedded into the ideas and variables of the SESF (see Cox 2014; Dartmouth College n.d.; Hinkel et al. 2015; McGinnis and Ostrom 2014). Finally, the interpretation of the survey and interview findings informed the development of implications for food forestry stakeholders regarding future biodiversity monitoring activities (RQ3).

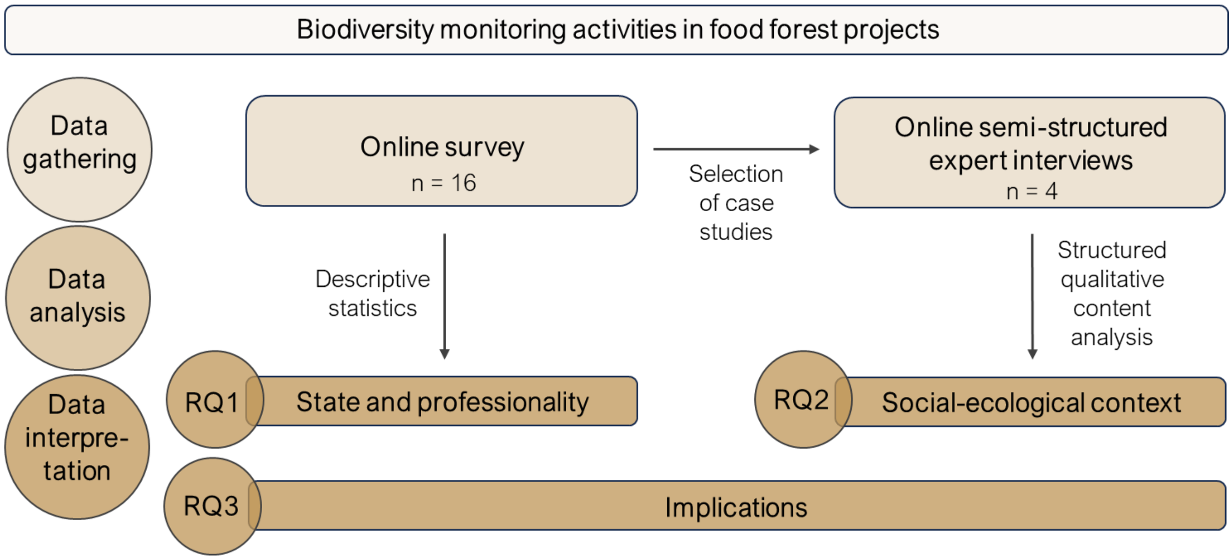


Fig. 2: Simplified methodological approach. Own illustration.

3.2. Online survey (RQ1)

Inspired by Miloslavich et al. (2018), I designed an anonymous **online survey** on the state of biodiversity monitoring activities in food forest projects in German and English, using the tool 'LamaPoll' (see LamaPoll n.d.), based on the guidelines on questionnaire construction provided by Gideon (2012: 106). The survey mainly contained multiple-choice and -answer questions, identified through literature research on biodiversity and monitoring (in food forests) (see Albrecht and Wiek 2021a; Binder and Middelanis 2024; Hill et al. 2005; Miloslavich et al. 2018 Table S3; Niemeijer and de Groot 2008; Norris et al. 2012; Park and Higgs 2018; Urry et al. 2019). In order to identify necessary adjustments, I pre-tested the survey with one expert on biodiversity monitoring and two laypersons (see Oldendick 2012: 30).[18]

Regarding the survey distribution, I decided to narrow my scope to European countries within the similar temperate climate zone according to the Köppen-Geiger classification (see Beck et al. 2018: 3) that are available in the global food forest inventory as created by Albrecht (2021), namely Germany, the Netherlands, Great Britain, France and Belgium. I sent my survey requests to 327 individual food forest projects listed in food forest inventories. Additionally, I asked repeatedly 26 other organisations dealing with food forestry, agroforestry or permaculture in those countries to spread it within their networks.[19] With this sampling approach, I tried to recruit as many suitable participants as possible (see Hibberts et al. 2012: 66), i.e. food forest gardeners who perform biodiversity monitoring activities on sites that are older than one month (see Albrecht and Wiek 2021a: 93).

A total of 16 food forest projects with different characteristics of their respective food forests, as presented in Tab. 1, provided useful survey responses. To reduce bias, I corrected misdeclarations within the raw data, which I identified through logic and later interview statements.[20] Subsequently, I

[18] see Appendix B for survey templates
[19] see Appendix A for food forest inventory
[20] see Appendix C for processed survey data

descriptively analysed the processed raw data using the spreadsheet programme 'Microsoft Excel'. As metrically scaled data was mainly distributed asymmetrically, I used the median value to depict the mean value (see Bourier 2008: 75; Hill et al. 2005: 51). Due to the small sample size, I included non-response items apart from frequency distributions.

Tab. 1: Characteristics of the food forests in the projects that responded to the survey.

Locations	• Germany: 8 (50 %) • The Netherlands: 5 (31 %) • France: 2 (13 %) • Great Britain: 1 (6 %)
Years of plantation	• After 2016: 12 (75 %)
Area sizes	• 0.05 - 5 hectares ($\bar{x}$ = 1.51 ha)
Surroundings	• Rural surroundings: 11 (69 %) • Urban surroundings: 5 (31 %)

Simultaneously with the survey design, I developed an indicator system for the level of professionality of biodiversity monitoring activities in food forests (see Tab. 2). I used it as a basis for the analysis to classify and contrast the level of professionality of the biodiversity monitoring activities in the food forest projects and cases.

Tab. 2: Indicator system for professionality of biodiversity monitoring activities in food forests.

Indicator category	Indicator topic	Operationalised indicator for professionality
General indicators	1. Responsibility	I1: Food forest project involved experts.
	2. Nature conservation instrument	I2: Food forest project used nature conservation instrument.
	3. Overarching monitoring programme	I3: Food forest project participated in overarching monitoring programme.
	4. Monitoring design	I4: Food forest project monitored more extensive than exclusively after plantation.
Specific indicators	5. Taxonomic groups	I5: Food forest project's number of monitored taxa is above the total median ($\tilde{x}$ = 2.5).
	6. Frequency	I6: Food forest project performed monitoring events, at least partly, more frequent than one-time or irregularly.
	7. Time span	I7: Food forest project's median number of years is above the total median ($\tilde{x}$ = 3)
	8. Up to dateness	I8: Food forest project has, at least partly, on-going monitoring activities.
	9. Extent	I9: Food forest project monitored more specific than exclusively on the total area.
	10. Tools	I10: Food forest project used more extensive tools than exclusively visual surveys.

Continuation Tab. 2

Context indicators	11. Indicators	**I11**: Food forest project gathered data among the indicator 'presence / absence'.
	13. Data storage	**I13**: Food forest project stored data not exclusively locally and analogously.
	14. Accessibility of data	**I14**: Food forest project made data accessible to others.

3.3. Case studies and semi-structured expert interviews (RQ2)

Of the 16 survey respondents, 13 voluntarily left their contact details to be available for further interviews. Seven food forest projects were located in Germany, five in the Netherlands and one in France. At first sight, considering the indicator system for professionality, their biodiversity monitoring activities ranged from unprofessional to professional. Out of these, I chose to consider two Dutch and two German food forest projects as **case studies** (cases), for each one project performing unprofessional biodiversity monitoring activities and one professional. Namely, the Dutch projects were 'Paradijsvogelbosje' (unprofessional) and 'Voedselbos D'Ekkers' (professional), and the German ones 'Permakulturgarten am Kaltbächle' (unprofessional) and Urbane Waldgärten (professional). With this sampling approach, I aimed to contrast "extreme" (Eisenhardt and Graebner 2007: 27) and diverse cases (see Eisenhardt and Graebner 2007: 27; Przyborski and Wohlrab-Sahr 2022: 133).

I conducted one **online semi-structured expert interview** per case. Within the context of my research, experts are defined as representatives of a food forest project and have extensive knowledge of, or responsibility for, biodiversity monitoring activities on the food forest site (see Berger-Grabner 2022: 152). Specific role descriptions of my experts in their food forest projects are provided in Tab. 3. Based on the theoretical background, the SESF, and survey results, I prepared a structured, yet open (Helfferich 2022: 876) interview guide according to Helfferich (2022: 881–885), Berger-Grabner (2022: 152), Kaiser (2021: 65–68) and Hug and Poscheschnik (2020: 136–139), which I pre-tested in German and in English with one layperson each (see Berger-Grabner 2022: 152).[21] The interviews took place on the videoconference application 'Zoom' (see Zoom Communications n.d.) between April 15 and May 5 2025, and lasted between 36 and 78 minutes. The records were transcribed with the help of the AI software 'noScribe' (see GitHub).[22]

[21] see Appendix E for interview guides
[22] See Appendix F for transcription rules and interview transcripts

Tab. 3: Role descriptions of interviewees of the food forest project cases.

Food forest project case	Interviewee	Interviewee's role description
Paradijsvogelbosje	P	• One of two owners • Personal interest in biodiversity and monitoring, professional background in science and methodology
Permakulturgarten am Kaltbächle	K	• Project owner • Personal interest and some professional background in biodiversity and monitoring
Urbane Waldgärten	U	• Project initiator, network manager and coordinator • Personal interest and professional background in biodiversity and monitoring
Voedselbos D'Ekkers	E	• Active volunteer within the larger volunteer group • Personal interest but no professional background in biodiversity and monitoring

I analysed the interview contents considering my research questions by applying a **structured qualitative content analysis** according to Kuckartz and Rädiker (2024), complemented by Mayring and Fenzl (2022), using the software 'MAXQDA 24' (see MAXQDA n.d.). Thereby, I used the survey, the interview guide, Kuckartz and Rädiker (2024) and in particular first-tier and second-tier variables of the SESF, as described by McGinnis and Ostrom (2014), Cox (2014), Hinkel et al. (2015) and the SESMAD project (Dartmouth College n.d.), as a foundation for the deductive codebook development. Within the process of two rounds of coding, this was complemented by the iterative development of inductive codes and fine-tuning of all codes. In a third round of coding, I applied the final codebook (see Kuckartz and Rädiker 2024; Mayring and Fenzl 2022).[23] With specific regard to frequently and extraordinarily applied codes, I approached the coded transcripts qualitatively from a case study perspective (see Kuckartz and Rädiker 2024: 81). Specifically, I contrasted the professional with the unprofessional cases and the German with the Dutch cases and set all cases in relation with each other.

4. Case descriptions

4.1. Paradijsvogelbosje (unprofessional)

The Paradijsvogelbosje, embedded into the 'Stichting Paradijsvogelbosje' (Paradijsvogelbosje Oosterwold 2025b), is a privately owned property which forms part of a "neighbourhood near the city of Almere where the municipality decided to let initiatives develop the landscape themselves" (P, 16; see Paradijsvogelbosje Oosterwold 2025a). Around 2,500 initiatives are responsible for their own garden plots and the surrounding landscape in Almere (P, 40). The two owners of Paradijsvogelbosje

[23] see Appendix G for codebook

started to develop a food forest on their property in 2016 (P, 14, 16). They maintain it themselves with the occasional help of friends, family, students and volunteers (P, 16, 108, 176).

The food forest and the property of Paradijsvogelbosje fulfil various functions. Beyond food production, processing and selling, the owners open their site to the public as a space for recreation, education, creativity, volunteering and community building (P, 16; Paradijsvogelbosje Oosterwold 2025b, 2025c). Furthermore, they intend to create a sustainable and natural landscape on their property (P, 16, 20) and in the neighbourhood to form a coherent ecosystem (P, 16, 20). To this end, they provide native trees to other garden initiatives (P, 34; Paradijsvogelbosje Oosterwold 2025b).

4.2. Permakulturgarten am Kaltbächle (unprofessional)

Permakulturgarten am Kaltbächle is a privately owned property near Lake Constance in Germany (K, 10). Since 2019, the sole owner, vegetable gardener and freelance artist establishes a permacultural garden, including a food forest, on the site (K, 10, 13). The project is not the owner's income-generating job but rather his heartfelt endeavour (K, 12). He thus describes the site as his experimental and utopian space (K, 10, 12, 16), "land art artwork" (K, 16) or "playground" (K, 10). Occasionally, friends, family members or volunteers help out with the project (K, 12).

The purpose of Permakulturgarten am Kaltbächle is bringing together biodiversity, soil protection and agricultural yield, which requires a co-existence of humans and nature, according to the principles of permaculture (K, 77; Permakultur am Kaltbächle n.d.). To provide space for education and community, the owner offers guided tours, workshops and events (K, 77; Permakultur am Kaltbächle n.d.). Although they generate some money through selling products, generating revenue is not part of the concept (K, 14, 72).

4.3. Urbane Waldgärten (professional)

Urbane Waldgärten, managed and coordinated by the University of Potsdam is a joint food forest project by multiple political and societal actors. Since 2021, it has been promoted for six years by the 'Federal Biological Diversity Programme' through the 'Federal Agency for Nature Conservation' (BfN) (U, 38; University of Potsdam n.d.b).

The novel concept of communal food forestry in urban environments in Berlin and Kassel is tested on three food forest sites at Urbane Waldgärten. The team promotes the joint development of operating structures for self-organisation with interested local citizens in the long term. Volunteers are already actively involved in developing and maintaining the food forests, as well as scientifically monitoring their ecological, climatic and social effects (University of Potsdam n.d.b; e.g. U, 38, U, 4, 10, 32).

In addition, the team organises yearly networking workshops for other German urban food forest projects and develops a knowledge sharing platform (University of Potsdam n.d.b). It is also plans to make the monitoring concept transferable to other projects (U, 64).

4.4. Voedselbos D'Ekkers (professional)

Voedselbos D'Ekkers is a volunteer-based neighbourhood food forest project in Berlicum, Netherlands (E, 12), which is embedded into the environmental non-profit organisation 'Stichting Landschapsbeheer' (E, 36; Stichting Landschapsbeheer Aa Dal n.d.). The municipality provided the volunteer group with two plots of agricultural land to promote a social neighbourhood project (E, 12, 14; Stichting Landschapsbeheer Aa Dal n.d.). In addition, they are receiving funding from various organisations to develop, maintain and monitor the food forest planted in 2020 (E, 20, 22, 26; Stichting Landschapsbeheer Aa Dal n.d.).

Beyond being a place for community building, education, and recreation in the neighbourhood (E, 96) (E, 96; Stichting Landschapsbeheer Aa Dal n.d.), the volunteers aim to provide "a food forest for the species" (E, 22). So far, revenue generation has not been the focus of the volunteers (E, 18). However, in the long term, they will need to generate an income from their sustainable food production to maintain Voedselbos D'Ekkers (Stichting Landschapsbeheer Aa Dal n.d.).

5. Results

5.1. State and level of professionality of biodiversity monitoring in food forest projects (RQ1)

In the following, I will present the survey results on the state and level of professionality of biodiversity monitoring activities (RQ1). First, I will focus on all 16 food forest projects that responded to the survey and second, on the four food forest project cases Paradijsvogelbosje, Permakulturgarten am Kaltbächle (unprofessional), Urbane Waldgärten and Voedselbos D'Ekkers (professional). Regarding the latter, I will contrast the unprofessional and professional cases. An overview of these results, embedded into the indicator system for professionality, is provided in Tab. 4.

5.1.1. All food forest projects

Overall, there was a strong variety in the responses from the 16 food forest projects regarding the state of their biodiversity monitoring activities. The food forest projects met the 14 indicators for professionality to varying extents. Three indicators were achieved by the majority of the projects, two by half, and seven by the minority.[24] The most frequent indicators were the usage of more extensive tools than exclusively visual surveys (I10) and the data gathering among the indicator 'presence / absence' (I11; 13, 81 %), followed by the involvement of experts (I1; 11, 69 %). In contrast, the usage of nature conservation instruments (I2) was only stated by five projects (31 %) and a monitoring design beyond exclusively monitoring after plantation of the food forest (I4), as well as the up-to-dateness of monitoring events (I8), by six (38 %).

[24] I did not evaluate the remaining two indicators for every single project.

General indicators

Eleven food forest projects (69 %) stated that they involve experts in their biodiversity monitoring activities (I1). This was followed by project-internal volunteers (8 projects, 50 %), project-internal employees and project-external students (4 projects, 25 %; see Fig. 3).

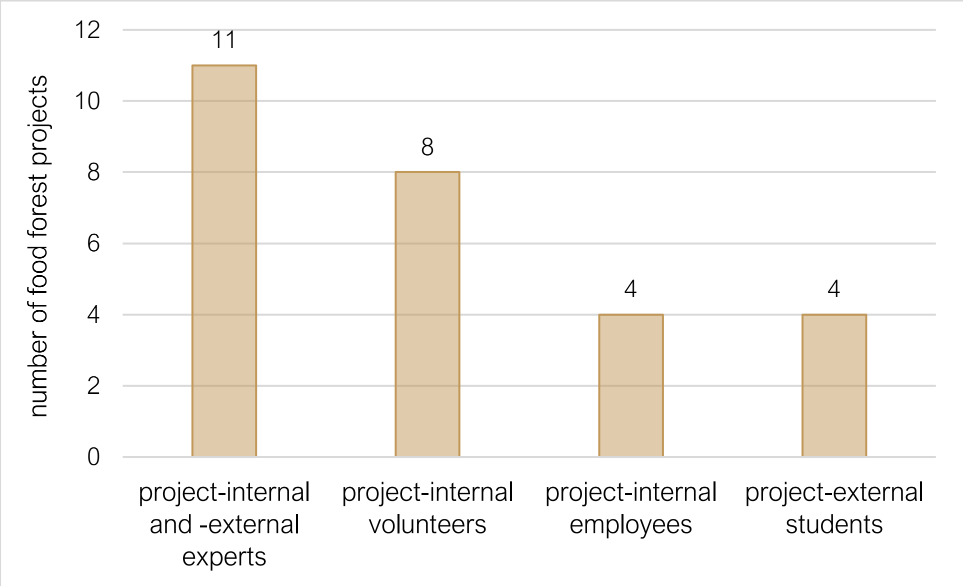


Fig. 3: Responsibilities for biodiversity monitoring activities. Absolute frequency of food forest projects (n = 16).

The majority of the food forest projects (11, 69 %) did not refer to a nature conservation instrument in the context of their biodiversity monitoring activities but five (31 %) mentioned to include, at least occasionally, Red Lists or the Habitat Directive (I2).[25]

Almost half of the food forest projects (7, 44 %) stated to take part, at least occasionally, in an overarching biodiversity monitoring programme (I3). Most frequently indicated were Bioblitz (5 projects, 31 %), the Dutch NMVB (3 projects, 19 %) and the Dutch Vlinderstichting (2 projects, 13 %; see Fig. 4).

[25] see Appendix C for processed survey data

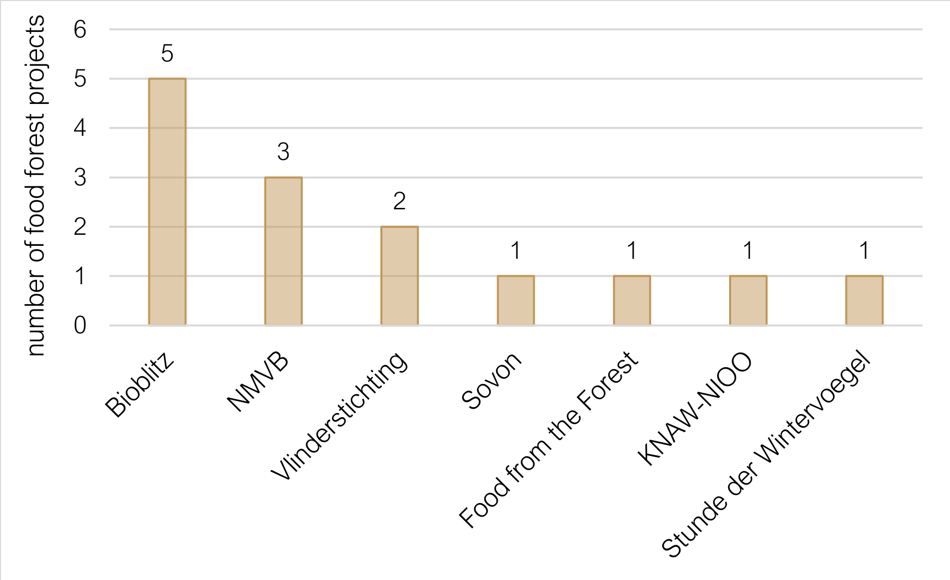


Fig. 4: Participation in overarching monitoring programmes. Absolute frequency of food forest projects (n = 16).

Well over half of the food forest projects (9, 56 %) stated to perform biodiversity monitoring exclusively after plantation of the food forest, while five (31 %) indicated to collect data both before and after plantation and one (6 %), Urbane Waldgärten (GER6) additionally mentioned a control area (I4).[26]

Specific indicators

The 16 food forest projects indicated 53 monitoring events of 17 taxonomic groups in their food forest areas. The most frequently mentioned were flora, including trees, wild herbs and flowering plants, grasses and other flora (12 projects, 75 %), followed by insects (11 projects, 69 %), including butterflies (6 projects, 38 %), wild bees (5 projects, 31 %) and ground beetles (2 projects, 13 %), birds (10 projects, 63 %), mammals (6 projects, 38 %), including bats (2 projects, 13 %), and fungi (3 projects, 19 %; see Fig. 5). The median number of taxa ($\tilde{x}$) monitored per food forest project was 2.5 (I5), ranging from one up to nine (NL5, Voedselbos D'Ekkers) taxa.[27]

[26] see Appendix C for processed survey data
[27] see Appendix C for processed survey data

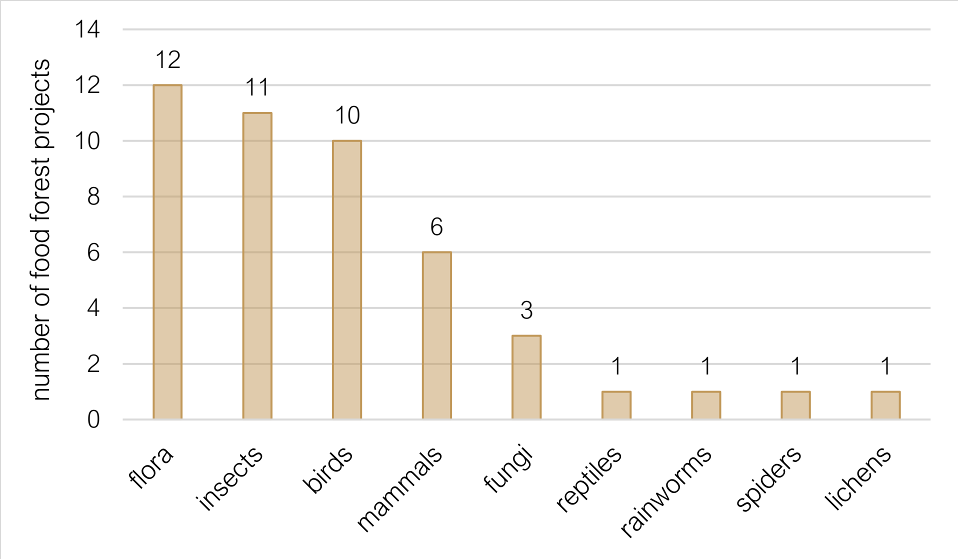
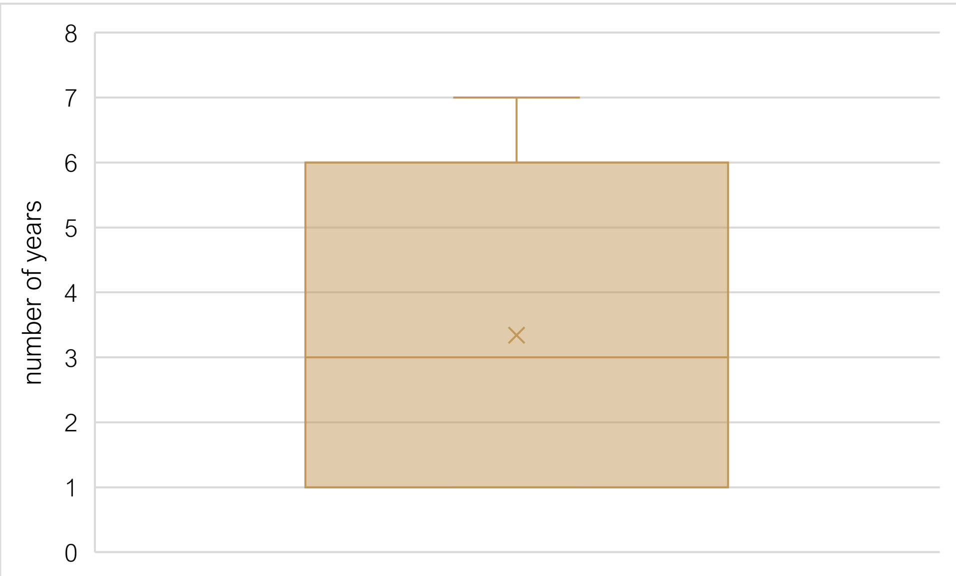


Fig. 5: Taxonomic groups monitored in biodiversity monitoring events. Absolute frequency of food forest projects (n = 16).

Most frequently, the food forest projects indicated that their monitoring events took place irregularly (11 projects, 69 %), yearly (6 projects, 38 %) and one-time or weekly (4 projects, 25 %).[28] Thus, in eight (50 %) food forest projects the monitoring events happened, at least partly, more frequently than one-time or irregularly (I6).

Excluding the one-time or not indicated events (n = 38), the median time span of monitoring event performance ($\tilde{x}$) amounted three years (I7), in a range between one and seven years (NL5, Paradijsvogelbosje; see Fig. 6a).[29] Overall, six projects (38 %) indicated on-going monitoring events (I8; see Fig. 6b).



[28] see Appendix C for processed survey data
[29] see Appendix C for processed survey data

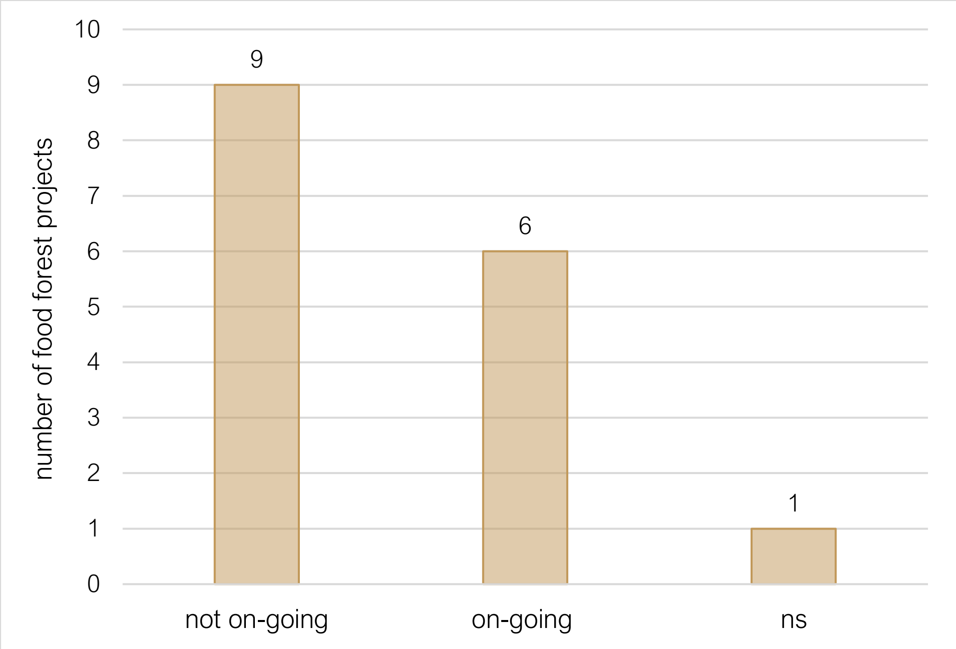


Fig. 6: a) Number of years of biodiversity monitoring event performance. Frequency distribution (n = 38). b) Continuation of biodiversity monitoring events. Absolute frequency of food forest projects (n = 16).

Most frequently, food forest projects stated that their monitoring events were performed on the total food forest area (14 projects, 88 %), in transects (6 projects, 38 %) and in quadrats (3 projects, 19 %; (GER6, Urbane Waldgärten; NL5, Voedselbos D'Ekkers; NL4, Paradijsvogelbosje).[30] Altogether, in seven food forest projects (44 %), at least in some monitoring events, specific parts of the food forest area were examined (I9).

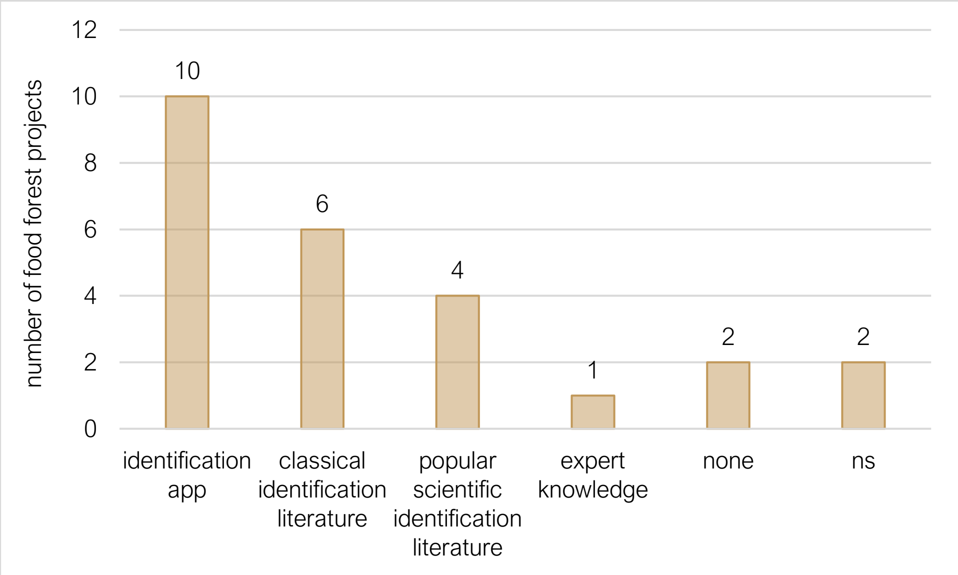
Visual surveys (15 projects, 94 %), photo and acoustic surveys (8 projects, 50 %) as well as traps (4 projects, 25 %) were the most predominantly named monitoring tools by the food forest projects. Thereby, acoustic surveys exclusively emerged in the context of bird and bat surveys.[31] Overall, in 13 (81 %) of the food forest projects, at least in some monitoring events, more than exclusively visual surveys were performed (I10).

In the 41 monitoring events specified by 14 food forest projects, 133 surveyed indicators out of 22 different indicator types were stated. The most prevalent ones were specie(s) richness (10 projects, 63 %), specie(s) presence or absence (9 projects, 56 %), dominant specie(s), density of individuals (5 projects, 31 %), population size, relative frequency of specie(s), Red List specie(s) and invasive specie(s) (4 projects, 25 %).[32] Overall, 13 (81 %) of the food forest projects gathered data among indicator specie(s) presence or absence (I11).

[30] see Appendix C for processed survey data
[31] see Appendix C for processed survey data
[32] see Appendix C for processed survey data

Context indicators

While two projects did not mention to use any tools for (re-)determination of species, ten projects (63 %) stated identification apps, followed by classical identification literature (6 projects, 38 %) and popular scientific literature (4 projects, 25 %; see Fig. 7a). Overall, eight projects (50 %) relied on more than exclusively identification apps in their (re-)determinations (I12). Regarding the identification apps, ObsIdentify / Observation.org (6, 35 %), iNaturalist and Merlin Bird ID (3, 18 %) were the most prevalent (see Fig. 7b).



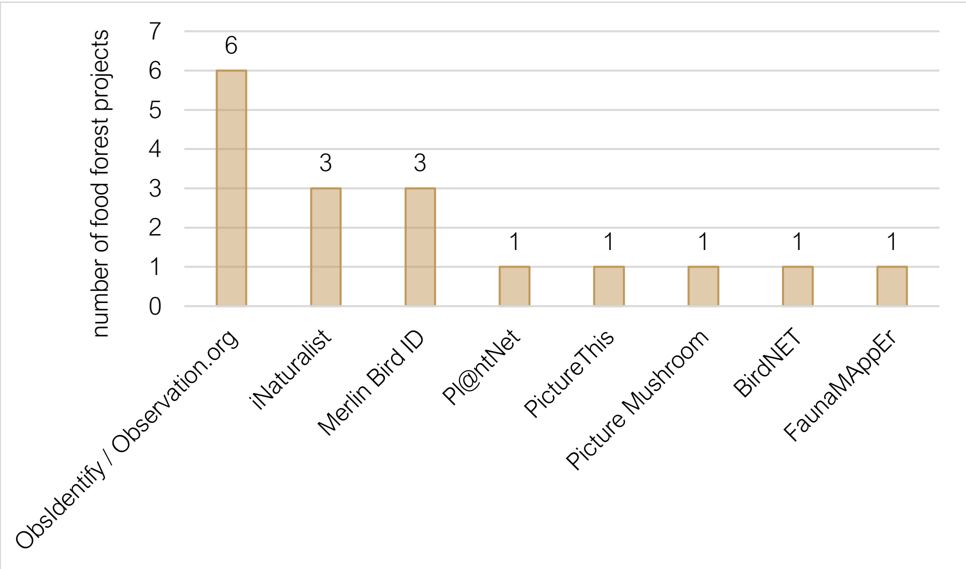
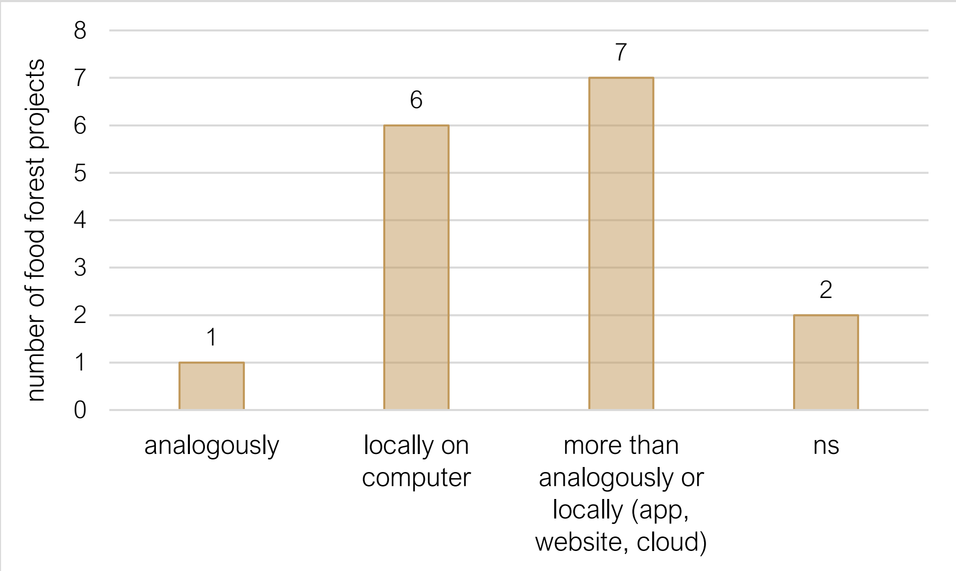


Fig. 7: a) Tools used for (re-)determination. b) Identification apps used for (re-)determination. Absolute frequency of food forest projects (n = 16).

Six food forest projects (38 %) indicated to store their biodiversity monitoring data exclusively locally on computers, and one project (GER3, 6 %) only analogously.[33] In contrast, seven projects (44 %) stated to save it in an app, website or cloud storage (I13; see Fig. 8a). Also, seven projects (44 %) mentioned to make their data accessible to others, while eight projects (50 %) did not (I14; see Fig. 8b).



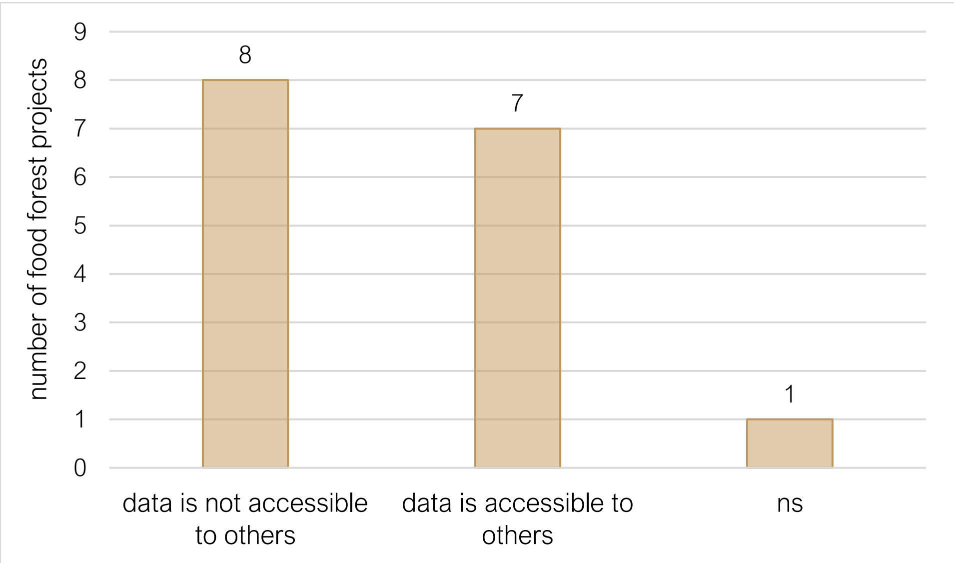


Fig. 8: a) Type of biodiversity data storage. b) Accessibility of biodiversity data to others. Absolute frequency of food forest projects (n = 16).

[33] see Appendix C for processed survey data

5.1.2. Food forest project cases

5.1.2.1. Comparison among all food forest project cases

A range of similarities are prevalent among the state and level of professionality of the four food forest project cases Paradijsvogelbosje, Permakulturgarten am Kaltbaechle (unprofessional), Urbane Waldgaerten and Voedselbos D'Ekkers (professional). This is reflected by their fulfilment of seven similar indicators for professionality, as presented in the following.

General indicators

Like most food forest projects (total: 11 projects, 69 %), all four food forest project cases involve experts in their biodiversity monitoring activities (I1). Furthermore, project-internal volunteers are involved in all cases and students in three, except Permakulturgarten am Kaltbächle. Urbane Waldgärten stated to have employees involved.[34]

Specific indicators

Overall, Urbane Waldgärten and Paradijsvogelbosje met all specific indicators for professionality and Voedselbos D'Ekkers and Permakulturgarten am Kaltbächle six out of seven.

All food forest project cases indicated a high number of monitored taxonomic groups relative to the median amount of monitored taxa per food forest project ($\tilde{x}$ = 2; I5). Thereby, mammals, birds, and flora were stated by all food forest project cases, and butterflies by all except Urbane Waldgärten.[35]

Apart from Voedselbos D'Ekkers, the cases' median number of years of biodiversity monitoring activities is above the total median ($\tilde{x}$ = 2; I7). Thereby, while the number of years is stable at Urbane Waldgärten and Permakulturgarten am Kaltbächle, it varies significantly between the individual monitoring events at Voedselbos D'Ekkers and Paradijsvogelbosje.[36]

All four cases belong to the minority of food forest projects with currently on-going monitoring events (total: 6 projects, 38%; I8), though, at Paradisjvogelbosje, this only applies to flora surveys. Like four further food forest projects, all cases perform some of their monitoring events irregularly but others more frequently (I6). Thereby, Urbane Waldgärten was the only case that did not indicate weekly events.[37]

As part of the majority of food forest projects (total: 13 projects, 81 %), all cases not only apply visual tools within those monitoring event, but photo surveys and acoustic tools were stated as well (I10).[38] Also, all cases gathered biodiversity data among the basic indicator 'presence / absence' (I11).

[34] see Appendix C for processed survey data
[35] see Appendix C for processed survey data
[36] see Appendix C for processed survey data
[37] see Appendix C for processed survey data
[38] see Appendix C for processed survey data

Context indicators

Like four other food forest projects, the cases (re-)determine their observations by both identification apps and books (I12). Thereby, similar to all food forest projects, ObsIdentify / Observation.org, iNaturalist and Merlin Bird ID were most prevalent.[39] As part of a minority of food forest projects (7, 44 %), Voedselbos D'Ekkers and Paradijsvogelbosje indicated to make their biodiversity data available to others (I14). However, the subsequent interviews revealed that all interviewees from the cases seemed to be at least open towards data sharing (e.g. E, 148; P; 14; U, 14).

5.1.2.2. Comparison among unprofessional and professional food forest project cases

The unprofessional food forest project cases met ten (71 %; Permakulturgarten am Kaltbächle) and eleven (79 %; Paradijsvogelbosje) out of the total 14 indicators for professionality, and the professional cases both 13 (93 %). Thereby, the unprofessional cases fulfilled about half of the otherwise, in relation to all participating food forest projects, rarely met indicators for professionality (Paradisjvogelbosje: 4, 57 %; Permakulturgarten am Kaltbächle: 3, 43 %). In contrast, the professional cases fulfilled (almost) all of them (Urbane Waldgärten: 6, 86 %; Voedselbos D'Ekkers: 7, 100 %; see Tab. 4). This picture is complemented by the interviewee's self-estimation of the level of professionality of their biodiversity monitoring activities in the food forest project cases, as interviewees P (Paradijsvogelbosje) and K (Permakulturgarten am Kaltbächle) stated to perform rather unsystematic surveys (e.g. P, 82; K, 32) and interviewees E (Voedselbos D'Ekkers) and U (Urbane Waldgärten) rather systematic ones (e.g. E, 38; U, 32).

General indicators

While the professional food forest project cases fulfilled all otherwise rarely met general indicators (I2 - I4), the unprofessionals only met one. In contrast to the unprofessional cases, Urbane Waldgärten and Voedselbos D'Ekkers used underlying nature conservation instruments (I2).

The professional cases and Paradijsvogelbosje indicated to be part of overarching monitoring programmes (I3). Thereby, Voedselbos D'Ekkers stands out due to its involvement in three extensive Dutch monitoring programmes, by the conservation societies De Vlinderstichting and Sovon as well as the NMVB.[40]

The professional cases and Permakulturgarten am Kaltbächle collected biodiversity data before and after the plantation of the food forest (I4). Urbane Waldgärten additionally involved control areas.[41]

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[39] see Appendix C for processed survey data
[40] see Appendix C for processed survey data
[41] see Appendix C for processed survey data

Specific indicators

Reminiscent to a minority of food forest projects (total: 7 projects, 44 %), the professional cases and Paradijsvogelbosje perform monitoring events not only on the total food forest area but also in transects and quadrats (Paradijsvogelbosje, Voedselbos D'Ekkers; I9).[42]

Context indicators

As part of a minority of food forest projects (total: 7 projects, 44 %), the professional cases and Permakulturgarten am Kaltbächle indicated to store their biodiversity data both locally and online (I13).[43]

[42] see Appendix C for processed survey data
[43] see Appendix C for processed survey data

Tab. 4: Indicator system for professionality of biodiversity monitoring activities in all food forest projects (n = 16) and food forest project cases (n = 4). Green: Indicator met by the majority of food forest projects (> 8, n = 16). Red: Indicator met by the minority of food forest projects (< 8, n = 16).

Indicator category	Indicator topic	Operationalised indicator for professionality	Absolute and relative frequency of all food forest projects (n = 16)	Paradijs-vogel-bosje (NL4)	Perma-kultur-garten am Kalt-bächle (GER8)	Urbane Wald-gärten (GER6)	Voedsel-bos D'Ekkers (NL5)
General indicators	1. Responsibility	I1: Food forest project involved experts.	11 (69 %)	Yes	Yes	Yes	Yes
	2. Nature conservation instrument	I2: Food forest project used nature conservation instrument.	5 (31 %)	No	No	Yes	Yes
	3. Overarching monitoring programme	I3: Food forest project participated in overarching monitoring programme.	7 (44 %)	Yes	No	Yes	Yes
	4. Monitoring design	I4: Food forest project monitored more extensive than exclusively after plantation.	6 (38 %)	No	Yes	Yes	Yes
Specific indicators	5. Taxonomic groups	I5: Food forest project's number of monitored taxa is above the total median ($\tilde{x}$ = 2.5).	ns	Yes (6)	Yes (5)	Yes (6)	Yes (9)
	6. Frequency	I6: Food forest project performed monitoring events, at least partly, more frequent than one time or irregularly.	8 (50 %)	Yes	Yes	Yes	Yes
	7. Time span	I7: Food forest project's median number of years is above the total median ($\tilde{x}$ = 3)	ns	Yes (6)	Yes (5)	Yes (6)	No (1)
	8. Up to dateness	I8: Food forest project has, at least partly, on-going monitoring activities.	6 (38 %)	Yes	Yes	Yes	Yes
	9. Extent	I9: Food forest project monitored more specific than exclusively on the total area.	7 (44 %)	Yes	No	Yes	Yes
	10. Tools	I10: Food forest project used more extensive tools than exclusively visual surveys.	13 (81 %)	Yes	Yes	Yes	Yes
	11. Indicators	I11: Food forest project gathered data among the indicator 'presence / absence'.	13 (81 %)	Yes	Yes	Yes	Yes

Continuation Tab. 4

	12. (Re-)determination	**I12**: Food forest project used more extensive (re-)determination tools than exclusively apps.	8 (50 %)	Yes	Yes	Yes	Yes
Context indicators	13. Data storage	**I13**: Food forest project stored data not exclusively locally and analogously.	7 (44 %)	No	Yes	Yes	Yes
	14. Accessibility of data	**I14**: Food forest project made data accessible to others.	7 (44 %)	Yes	No	No	Yes
Absolute frequency and percentage of fulfilled indicators (n = 14)				11 (79 %)	10 (71 %)	13 (93 %)	13 (93 %)
Absolute frequency and percentage of (fulfilment of) rarely met indicators (red) (n = 7)			7 (44 %)	4 (57 %)	3 (43 %)	6 (86 %)	7 (100 %)

5.2. Social-ecological context of biodiversity monitoring activities in food forest project cases (RQ2)

This chapter will cover the interview results on the social-ecological context of biodiversity monitoring activities in the four food forest project cases Paradijsvogelbosje, Permakulturgarten am Kaltbächle (unprofessional), Urbane Waldgärten and Voedselbos D'Ekkers (professional; RQ2). I will contrast the unprofessional and professional cases, as well as the Dutch and German ones. Simplified overviews of the social-ecological context factors of the biodiversity monitoring activities in each food forest project case are provided in Fig. 9-Fig. 12.

5.2.1. Comparison among all cases

Within the comparisons among all cases, social-ecological context factors of the state of their biodiversity monitoring activities emerged, specifically regarding the actors but also to the resource system.

Actors

Attitude towards monitoring concept

All interviewees seemed to have a positive attitude towards the use of identification apps within their biodiversity monitoring activities, whereby specifically iNaturalist (e.g. E, 154), ObsIdentify (e.g. U, 32), Merlin Bird ID (e.g. K, 30) and BirdNET (P, 126) were mentioned as helpful: "Und inzwischen gibt es ja auch so viele Tools [...]. Irgendwelche Apps [...] und Bestimmungshilfen. [...] Was echt toll ist" (K, 28).

Urbane Waldgärten chose to focus exclusively on ObsIdentify, which was thoroughly considered according to criteria such as the range of taxonomic groups, the user friendliness (U, 26) and the scientific quality of identification. Regarding the latter, interviewee U described ObsIdentify as outstanding, due to not only being AI- but also expert-based (U, 32). However, they did not degrade per se the quality of other identification apps but stated that "es ist einfach nicht handelbar, fünf verschiedene Apps zu haben und die dann auch auszuwerten" (ibid.).

Human resources

In all food forest project cases, project-internal volunteers (e.g. E, 12; K, 80; P, 168; U, 32) and project-external experts (e.g. E, 40; K, 32; P, 26; U, 4) are playing a role, to some extent, in the biodiversity monitoring activities. All interviewees ascribed volunteers an (intrinsic) interest in biodiversity and monitoring (e.g. E, 140; K, 44; P, 24; U, 32) as well as a limited level of expertise, as most of them do not have a corresponding professional background (e.g. E, 40; K, 66; P, 24; U, 33). While interviewees and volunteers E and P mentioned being "fond of scientific research" (P, 168; e.g. E, 38), interviewee and volunteer K, as well as the volunteers at Urbane Waldgärten, appeared to be less engaged in systematic approaches to biodiversity monitoring (e.g. K, 80; U, 22).

All interviewees associated project-internal and -external experts with a high level of expertise (e.g. E, 36; K, 72; P, 28; U, 4) and displayed a rather positive attitude towards them and their research (e.g. E, 160; K, 85-88; P, 26-28; U, 34): "And it adds value every time that these researchers revisit the food forest and you can see the development [...] of the plot" (P, 28).

All cases apart from Permakulturgarten am Kaltbächle already involve project-external students in their biodiversity monitoring activities to some extent (e.g. E, 70; P, 22; U, 52). At Paradijsvogelbosje, such involvement happens on a regular basis in the course of lower education student's practical training in applied biology (e.g. P, 22). At Urbane Waldgärten and Voedselbos D'Ekkers students appear irregularly but seem to conduct more professionalised surveys (e.g. E, 70-72; U, 34). Overall, all interviewees characterised at least the partly involvement of students as valuable (E, 72; K, 50; P, 88; U, 34). Thus, interviewee U advised that they "[...] würde eigentlich, wenn das möglich ist für Projekte, die wirklich ernsthaft Biodiversitätsmonitoring machen wollen, immer empfehlen, dass sie auch Expert:innen mit reinholen oder Abschlussarbeiten oder Leute, die sich halt [aus]kennen" (U, 34).

Motivation and purposes

To some extent, all interviewees stated education as one motivation and purpose behind the biodiversity monitoring activities in their food forest projects (e.g. E, 38; K, 32; U, 44), especially interviewee P regarding the involved students at Paradijsvogelbosje (e.g. P, 104). The scientific quality of the biodiversity monitoring activities was referred to by all interviewees (E, 38; K, 96), with particular interest by interviewees U and P (P, 28; U, 32), although interviewee P does not have the capacities to ensure it (P, 168). The use of biodiversity data for the evaluation of management measures (e.g. E, 54; K, 89-90; U, 4) and as a foundation for further management decisions (e.g. E, 126; K, 36; U, 44) was mentioned by all interviewees except P. Thereby, interviewee U discussed "[...] dass für so eine Evaluation [...] oft der Blick nicht so tief [ist] wie jetzt bei einem wissenschaftlichen Monitoring, wo man jetzt eine Artengruppe ganz genau erforscht, [...] und da wirklich der ganze Fokus darauf geht" (U, 52).

On a higher level, interviewee E advised other food forest projects that the design of their biodiversity monitoring concept "depends on what the goal is" (E, 120). For instance, they explained that food forest projects might be interested in sufficient yield and should monitor pollinators, as "more diverse pollinators means more the bigger harvest" (E, 136).

Resource system

Regarding the resource system of the food forest, all interviewees indicated that some taxonomic groups are either more convenient (e.g. E, 136; K, 42; P, 86) or more relevant (E, 122; U, 34, 38) to be assessed. The interviewees frequently stated that butterflies and birds are easily determined, while other insects are rather difficult (e.g. E, 136; K, 42). Thus, interviewee E advised other food forest projects "to start with the butterflies" (E, 122), as "it's a reasonably easy group to get into and attractive" (ibid.), as well as relevant (ibid.).

At Urbane Waldgärten, Voedselbos D'Ekkers and Paradijsvogelbosje, different food forest sections are considered within the biodiversity monitoring activities (E, 154; P, 138; U, 38) "[...] because you can expect different species in different microclimates" (P, 138). To enable the comparability of the data, "werden die gleichen Indikatoren erhoben über alle fünf Zonen, über alle Waldgärten" (U, 38) that belong to Urbane Waldgärten.

5.2.2. Comparison among unprofessional and professional cases

Social-ecological context factors of biodiversity monitoring activities related to actors, governance, and social, economic, and political settings were prevalent while contrasting the unprofessional and professional cases.

Actors

Attitude towards monitoring concept

The interviewees of the unprofessional cases both appeared to see value in conducting "a kind of survey to just write down everything you see" (P, 86, e.g. K, 80). Nonetheless, they were aware that this main approach within their biodiversity monitoring activities is rather unsystematic (e.g. K, 32; P, 88) and hence perceived room for improvement (e.g. K, 50; P, 168). Despite their, in comparison, systematic approaches, interviewees U and E seemed to perceive such as well (e.g. E, 38; U, 52). Thereby, learning from past challenges was mentioned as important (e.g. E, 160; P, 140-142).

Human resources

While the project-internal volunteers in the professional cases were initially instructed, and continuously supported by project-external experts (Voedselbos D'Ekkers; e.g. E, 40) or project-internal employees (Urbane Waldgärten; e.g. U, 32), those in the unprofessional cases seem to act mostly independently in their biodiversity monitoring activities (e.g. K, 32; P, 106-107). Contrastingly, interviewees K and P assigned themselves a certain level of expertise (e.g. K, 66; P, 86), which they estimated as limited in relation to experts (e.g. K, 66; P, 88). In terms of financial resources and time for biodiversity monitoring activities, interviewees and volunteers K and P stated to be restricted (e.g. K, 80; P, 88). This stands in contrast to the perception of interviewee E, who did not report on such constraints, although Voedselbos D'Ekkers is an entirely volunteer-based project as well (e.g. E, 20). Though, far more volunteers (e.g. E, 96) and further actor groups (e.g. E, 174) are involved in the project and their biodiversity monitoring activities. In addition, interviewee U generally observed that volunteers had increased time for biodiversity monitoring activities as soon as more fundamental questions in the development of the food forest were solved (U, 70).

In the professional cases, project-external experts play a central role within the biodiversity monitoring activities (e.g. E, 40; U, 4). Thereby, the Dutch experts appear to show intrinsic interest in food forests, whereas interviewee U reported that: "[...] die Gutachter, die involviert sind, die kommen schon so von ihrem Blickfeld eher so aus dem klassischen Naturschutz und waren am Anfang sehr skeptisch und sind aber eigentlich alle jetzt völlig am Ausflippen, was sich da alles einfindet [...] mit dem Gepflanzten" (U, 26). Nonetheless, both interviewees E and U clarified that the volunteers are markedly more on the food forest site than such experts (e.g. E, 36; U, 22). Thus, to create a bigger picture, the monitoring concept of Urbane Waldgärten aims to bring together the biodiversity data collected by the experts and the volunteers (U, 22). Based on their experience, interviewees E and U both gave the advice that volunteer-based food forest projects should collaborate with experts for their biodiversity monitoring activities (E, 160; U, 34).

As Urbane Waldgärten, in contrast to the other three cases, is not primarily volunteer-based, project-internal employees appear to fulfil considerably more work. Thus, interviewee U reported on tasks around their biodiversity monitoring activities related to coordination (e.g. U, 58), and instruction: "wir machen ganz schön Aufwand [...] in der Gruppe immer wieder Impulse zu geben, Vorträge zu geben, Ergebnisse vorzustellen, uns Formate zu überlegen und Leute mitzunehmen" (U, 72).

Motivation and purposes

The interviewees of the professional cases found evaluation, which was closely tied to funding, highly important as a motivation and purpose behind their biodiversity monitoring activities (e.g. E, 64; U, 4): "But it's really nice that we can show 'Okay, we see the level of species develop, and change, and become bigger over the years.' And as a result of that we get money" (E, 64). In addition, at Urbane Waldgärten only, the transfer of the monitoring concept to other urban food forest projects (U, 64), and especially the participation of citizens (e.g. U, 52) within the biodiversity monitoring activities occupies a central position. In terms of time investment (U, 20) and data quality (U, 52), interviewee U perceived challenges regarding the latter but also the potential of collecting a high amount of data (U, 32).

Governance and social, economic, and political settings

In addition to the already mentioned project-internal and -external actors around the biodiversity monitoring activities in the professional cases, external funders appeared to be particularly important. Interviewee E and U were "[...] talking a lot about money" (E, 64) as the financial situation (e.g. E, 58; U, 20) and partly the guidelines for biodiversity monitoring (e.g. E, 58; U, 52) of Urbane Waldgärten and Voedselbos D'Ekkers seemed to be closely tied to external support. Accordingly, interviewees U and E estimated the general availability of funding as fundamentally relevant (e.g. E, 64; U, 56). While interviewee E appeared to be pleased with the guidelines of their funders, interviewee U criticised the low level of those, because "[...] jedes Projekt hat halt seine eigenen Indikatoren und damit kommst du gar nicht in den Moment, wo du es vergleichen kannst" (U, 52). In contrast, interviewees P and K did not mention being dependent on external funding or institutional guidelines.

5.2.3. Comparison among Dutch and German cases

Within the comparison among the Dutch and German cases, few differences regarding social-ecological context factors of their biodiversity monitoring activities appeared. Most importantly, it became clear that "Deutschland ist einfach mehrere Jahre hinterher" (U, 64) concerning the political and societal establishment of the concept of food forestry.

Governance and social, economic, and political settings

This finding is indirectly reflected by support and funding opportunities for food forests and their biodiversity monitoring activities. Accordingly, the volunteer group around the Dutch case Voedselbos

D'Ekkers "had help from a lot of different directions, and [...] funds from a lot of different directions" (E, 174). These funds were not exclusively available to food forest projects but in their case dedicated to the development and monitoring of their site: "We have a lot of monitoring, and we have a lot of opportunities because of that funding" (E, 110). With respect to the biodiversity monitoring activities, experts from the conservation societies Vlinderstichting and Sovon voluntarily established a monitoring concept for butterflies, dragonflies and birds in the food forest (e.g. E, 40). Additionally, the NMVB approached them to participate (E, 64), which was financed by the local water board (E, 67), and the municipality pays them for biodiversity-friendly maintenance (E, 58). Based on their experience, interviewee E advised other food forest projects that "[...] a lot of those people, who are in the nature conservation thing, especially if they're also doing volunteering next to it, they are really invested in helping. [...] So, if I would do this again, I would just contact conservation groups and say 'Hey, do you want to take a look around, and see if there's anything interesting here?' [...] 'Do you want to help me set this up?' And a lot of them will do it for free" (E, 160).

Nonetheless, interviewee E revealed that such intensive support and funding opportunities as in Voedselbos D'Ekkers are not necessarily self-evident. Among others, they were related to the experience and commitment of volunteers in finding and applying for funding opportunities (E, 60, 62) and coincidence and luck (e.g. E, 173). This assumption is reflected by the other Dutch case Paradijsvogelbosje. Interviewee P did not mention receiving support or funding for food forestry or biodiversity monitoring activities and could not name an opportunity for the latter (P, 147). However, they also did not seem to make much effort for such (P, 147-154).

In addition, interviewee E underlined that funding opportunities are closely tied to the political institution's attitudes towards nature conservation (E, 106). Therefore, they assumed that they might become less in future in the course of the Dutch government's on-going political shift to the right (E, 106-107).

The German case Urbane Waldgärten receives dedicated funding from the Federal Biological Diversity Programme, which is not exclusively tied to food forestry but, among other things, enables them to conduct extended biodiversity monitoring activities (U, 34, 52). Both interviewees K and U reported to not having encountered support or funding opportunities specifically for biodiversity monitoring activities in German food forests so far (K, 46; U, 56). As interviewee U is making the experience that the involvement of external experts in monitoring activities is cost and time-intensive (e.g. U, 56), they stated that German volunteer-based projects often cannot afford such. The relation of a project to conservation societies such as the 'Naturschutzbund Deutschland e.V.'[44] (NABU) might counteract this issue (U, 68). Generally, they assumed that the German political and societal conditions for food forests and their biodiversity monitoring activities are changing as "[...] das schwappt auch aus den Niederlanden rüber" (U, 66). However, interviewee U did not draw inspiration from existing Dutch approaches to biodiversity monitoring in food forests when developing their concept (ibid.).

[44] German Nature Conservation Association (free translation)

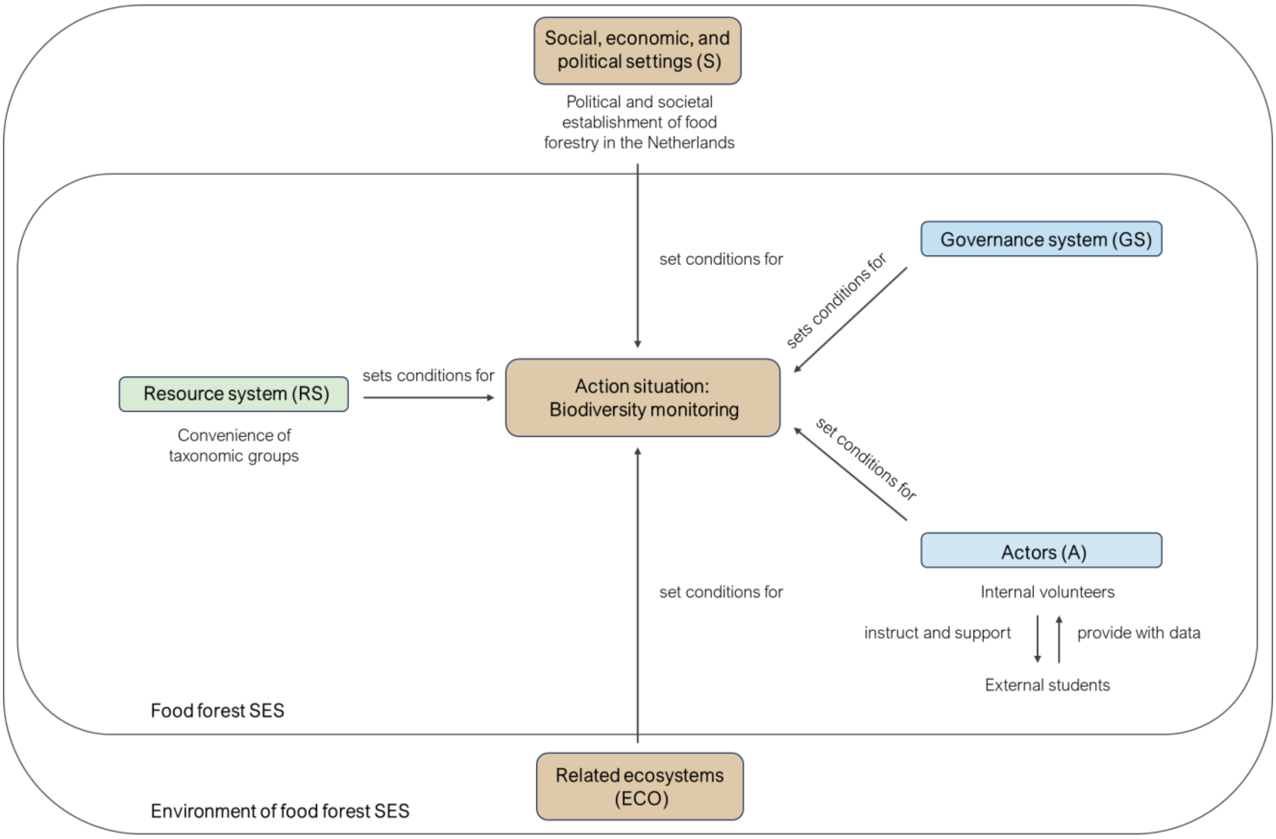

Fig. 9: Simplified illustration of the food forest SES at the project case Paradijsvogelbojse with regard to biodiversity monitoring. Own illustration.

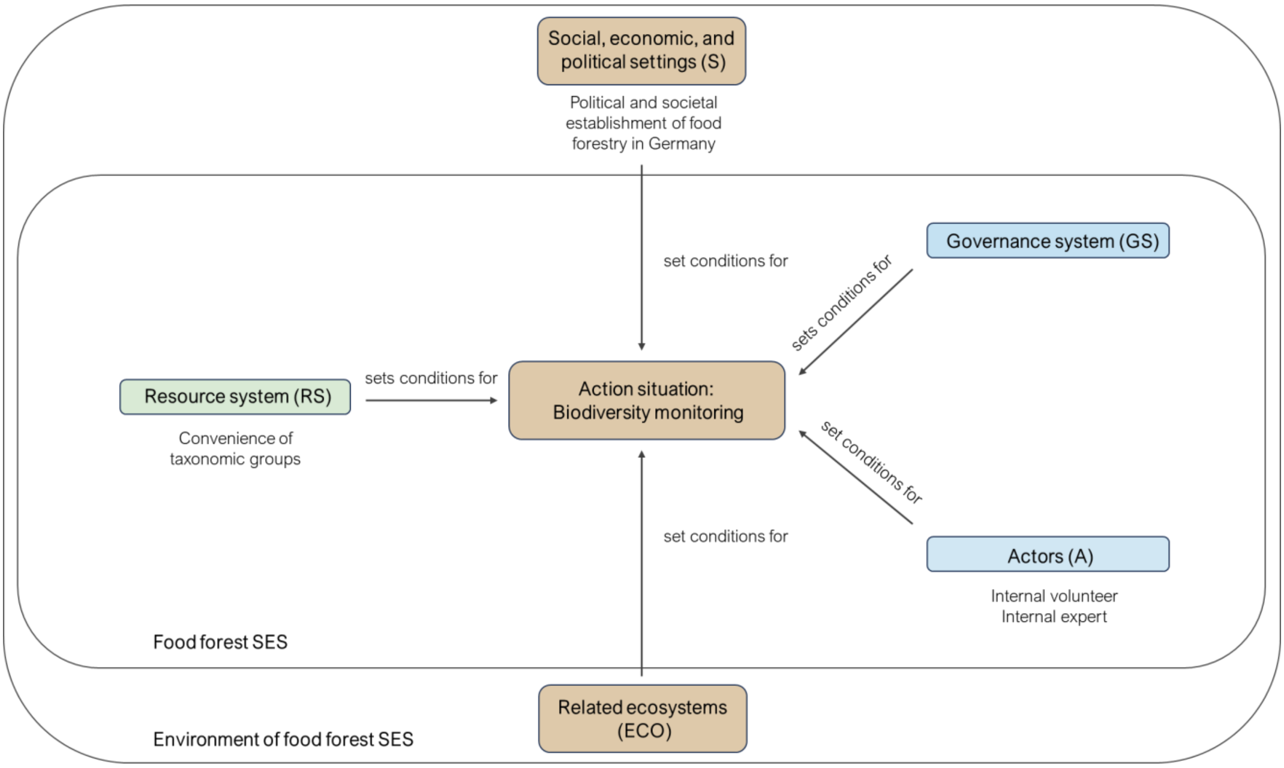

Fig. 10: Simplified illustration of the food forest SES at the project case Permakulturgarten am Kaltbaechle with regard to biodiversity monitoring. Own illustration.

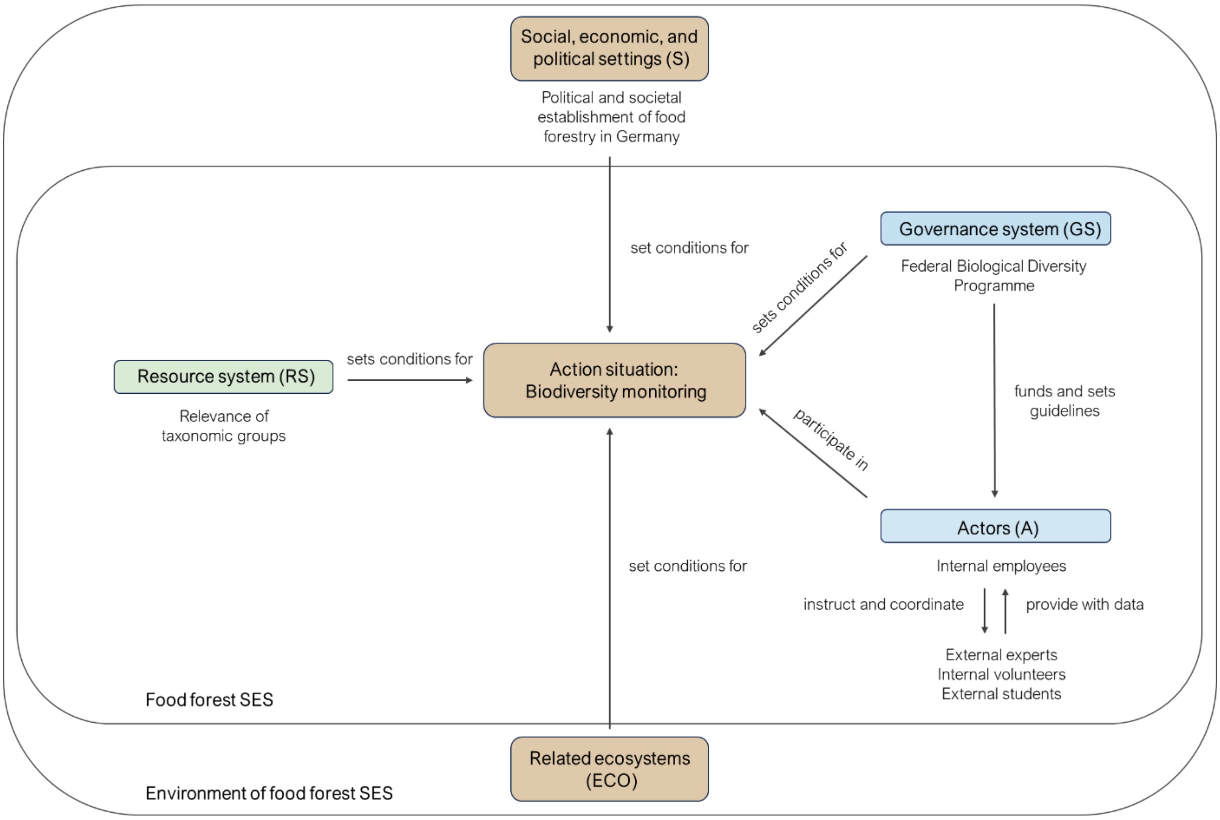

Fig. 11: Simplified illustration of the food forest SES at the project case Urbane Waldgärten with regard to biodiversity monitoring. Own illustration.

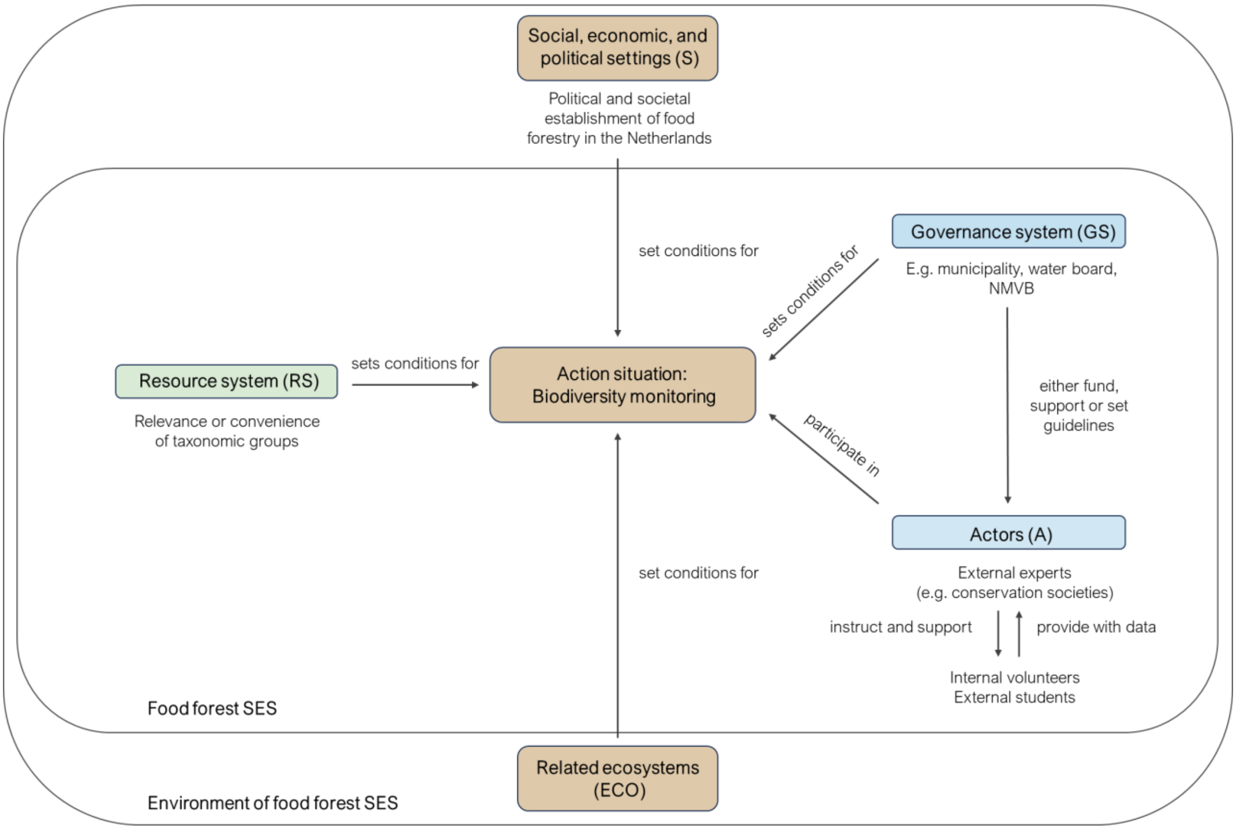

Fig. 12: Simplified illustration of the food forest SES at the project case Voedselbos D'Ekkers with regard to biodiversity monitoring. Own illustration.

6. Discussion

6.1. Key findings

Overall, this empirical study showed that the characteristics and the level of professionality of the biodiversity monitoring activities in the 16 food forest projects varied. Certain patterns emerged by comparing the unprofessional and professional, as well as Dutch and German projects and cases. These concerned the state, level of professionality and social-ecological context factors of biodiversity monitoring activities. More specifically, the following key findings arose:

RQ1: What is the state and level of professionality of biodiversity monitoring activities in food forest projects?

- The characteristics and indicators for professionality of biodiversity monitoring activities in the food forest projects were fulfilled by the 16 survey respondents to different extents. Half of the 14 indicators were only met by a minority of the food forest projects.
- The professional food forest project cases Urbane Waldgärten and Voedselbos D'Ekkers met a high number of and otherwise rarely fulfilled indicators for professionality of biodiversity monitoring activities, in contrast to the unprofessional cases Permakulturgarten am Kaltbächle and Paradisjvogelbosje.

RQ2: Which social-ecological context factors impact this state?

- The interviewees of the food forest project cases mostly emphasised social-ecological context factors of their biodiversity monitoring activities related to the social subsystem (actors, governance system) and social, economic, and political settings of their food forest SESs. Context factors related to the ecological subsystem (resource system) and related ecosystems were rarely or not mentioned.
- **Actors:** In all food forest project cases, volunteers played a central role in the biodiversity monitoring activities due to their high intrinsic motivation and their frequent presence on site. Thereby, the volunteers in the professional cases had more time and financial resources than those in the unprofessional ones. Likewise, experts assigned with a high level of expertise were more present in the professional cases. Students were involved to some extent in most cases, which was considered valuable.
- **Actors**: Frequently mentioned motivations and purposes of biodiversity monitoring activities within the cases were education, research, evaluation and foundation for further management decisions.
- **Actors:** Urbane Waldgärten stood out as the only case which is not entirely volunteer- but also employee-based. In addition, participation and transfer were important motivations and purposes behind its biodiversity monitoring activities.
- **Governance system and social, economic, and political settings**: The two professional cases received sufficient funding. Thereby, the conditions to obtain such and further support were

more favourable for the Dutch case Voedselbos D'Ekkers. Currently, more funding and support opportunities appear to be available in the Netherlands than in Germany.

- **Resource system:** The interviewees highlighted that certain taxonomic groups are more relevant or convenient for monitoring. They also considered it sensible to monitor different sections of the food forest.

6.2. Discussion of results and implications (RQ3)

In the following, I will discuss these key findings in relation to the broader discourse on 1) the improvement of biodiversity monitoring concepts and 2) the role of CS approaches thereby, as well as 3) the institutional establishment of food forestry in the Netherlands and Germany. Building on this, I will derive practical implications for food forestry stakeholders (RQ3).

6.2.1. Improvement of biodiversity monitoring concepts

Overall, I encountered rather heterogeneous patterns in the biodiversity monitoring activities of the food forest projects and cases, concerning their characteristics and level of professionality. Such heterogeneous characteristics of biodiversity monitoring activities in the food forest projects are partly reflected by the in-depth consideration of the four cases. In line with these findings, Miloslavich et al. (2018) obtained diverse answers on their survey on the characteristics of 104 biological observation programmes (ibid.: 2420-2421), though in marine ecosystems.

Regardless of these heterogeneous patterns, a broad categorisation of the food forest project cases into rather unprofessional and professional approaches to biodiversity monitoring was possible. Urbane Waldgärten and Voedselbos D'Ekkers fulfilled a similar number and almost similar categories of indicators, which might be assigned to their connection to official monitoring programmes. Though, it must be noted that the underlying indicators for professionality omitted details. In addition, as the two cases with rather unprofessional biodiversity monitoring activities still met over half of the indicators for professionality, they cannot be described as unprofessional per se, as they "[...] have fragments of this systematic research" (P, 24). Vice versa, the same accounts for the cases with rather professional biodiversity monitoring activities. For instance, at Urbane Waldgärten both systematic surveys by external experts and unsystematic surveys with ObsIdentify by volunteers were performed. Accordingly, the food forest projects and cases each comprise an individual combination of characteristics of biodiversity monitoring, pointing towards the classification into professional or unprofessional.

Generally, the heterogeneity of biodiversity monitoring concepts among programmes is an established issue addressed by various researchers (see Kühl et al. 2020: 463; Noss 1990: 361; Wirth et al. 2024: 145). The resulting difficulties in comparability of biodiversity data exacerbate the determination of robust long-term trends (Wirth et al. 2024: 145).

Reasons for heterogeneity

The complexity of biodiversity as a concept requires various methodological approaches to monitoring (Hill et al. 2005: 3). Though, in a complex SES like a food forest, the reasons for such heterogeneous biodiversity monitoring concepts are more diverse (see Firkowski et al. 2021: 1671; Rissman and Gillon 2017: 92; Wendel et al. 2023: 37). Accordingly, as my findings show, each food forest project case is embedded into individual social-ecological context factors, which influence the characteristics and level of professionality of the actor's biodiversity monitoring activities. Thus, the context factors related to the social subsystem were particularly prevalent. Considering the development of the monitoring framework for food forests and referring to the framework for the selection of environmental indicators by Niemeijer and de Groot (2008b), Park and Higgs (2018) put it in a nutshell:

> "Apart from goals, scales, and landscape contexts of a project, resources available and required for monitoring significantly influence the selection for monitoring parameters as monitoring involves a range of skills, knowledge, equipment and time, and each monitoring measure has distinct requirements" (ibid.: 16).

Indeed, I found that the underlying goals substantially influenced the extent of biodiversity monitoring activities in the cases. For instance, Urbane Waldgärten and Voedselbos D'Ekkers are both obliged to communicate their results to their funders and thus need to follow professional monitoring schemes. As interviewee E suggested, food forest gardeners should carefully consider the goal of their biodiversity monitoring plans in order to choose an appropriate approach (E, 136; see Hill et al. 2005: 3).

Further issues beyond heterogeneity

There are further considerable issues within the biodiversity monitoring activities of the food forest project cases. First, only seven (44 %) of the survey respondents made their data available to others. This aligns with the common challenge of monitoring data often being unavailable, making joint analyses difficult (see NMZB n.d.b, n.d.c; Wirth et al. 2024: 145). The willingness of the interviewees towards data sharing is not necessarily self-evident (see Kühl et al. 2020: 467) but might be assigned to the community culture and common interests within the food forest movement (see Albrecht and Wiek 2021: 101; Roodhof 2024: 204). This implies the need to establish a central, common and user-friendly data platform (see Kühl et al. 2020: 472).

Furthermore, the median time span of biodiversity monitoring events in the 16 food forest projects was quite short, and only six (38 %) projects indicated currently on-going events. This prominent problem of a short period of biodiversity data collection prevents the determination of long-term trends (see Wirth et al. 2024: 146), which is of particular importance in systems with a high rate of ecological succession like food forests (Wendel et al. 2023: 37). Most importantly, this lack of long-term monitoring can be assigned to the young age of the food forest projects and the temperate food forest movement in general (see Crawford 2021: 373; Park et al. 2018: 285; Riolo 2019: 2). Accordingly, interviewee U observed that volunteers had more capacities for biodiversity monitoring once the food forest became more established, as more fundamental questions were solved (see U, 70). Further reasons, especially regarding the lack of continuous monitoring, are probably diverse. For example, food forest projects are generally not exclusively focused on biodiversity and monitoring but have various underlying intended functions and resulting activities (see Albrecht and Wiek 2021: 101; Roodhof 2024: 204). Overall, it is desirable that well-established food forest projects with an interest in biodiversity and monitoring prioritise performing their biodiversity monitoring activities in the long-term. Moreover, my findings imply the need for the establishment of structures that facilitate such.

Towards an integrated biodiversity monitoring concept

An approach towards the establishment of such structures might be the development of an integrated, standardised and systematic biodiversity monitoring concept for food forests (see Kühl et al. 2020: 464; Wirth et al. 2024: 57). In light of my findings, such a development might be challenged by "a lack of awareness of joint opportunities, required expertise and possibly also lack of enough will" (Kühl et al. 2020: 467) by food forest projects and official monitoring programmes. For example, Urbane Waldgärten did not use the existing NMVB as a reference point for developing its monitoring programme.

Despite a lack of collaboration, the five official monitoring programmes on food forests already reveal some similarities, for instance regarding taxonomic groups. Further, on a smaller scale, Voedselbos D'Ekkers, Urbane Waldgärten and the monitoring programmes already compromise some characteristics of an integrated monitoring concept. For instance, collaboration among volunteers and experts is part of the monitoring schemes (see e.g. University of Potsdam n.d.a; Wendel et al. 2023: 24–27).

This, together with the generally modern, open, bottom-up and collaborative way of thinking within the food forestry community (see Albrecht and Wiek 2021a: 101; Roodhof 2024: 204), could be an adequate basis for the development of an integrated biodiversity monitoring concept (see Kühl et al. 2020: 467). The low number and early stage of monitoring concepts and programmes can be seen as a chance to foster such from the beginning. This could prevent the further establishment of several individual monitoring schemes, as it is already the case in biodiversity monitoring activities of other habitats (see Naeslund et al. 2023: 16; Wirth et al. 2024: 145).

In the so far rather uncoordinated landscape of biodiversity monitoring activities, it might require a central governing institution to develop an integrated monitoring concept, which could "foster and facilitate the functionality of the networked approach by enabling processes of integration of stakeholders, self-organization, and transfer of knowledge" (Kühl et al. 2020: 471; see Loos et al. 2015: 46; Roodhof 2024: 199). The German project Urbane Waldgärten and the Dutch organisations could provide starting points for establishing such. They already partly function as connecting institutions within the food forest community. However, there is room for improvement in terms of collaboration among them (see Roodhof 2024: 199). While desirable, it remains unclear if the establishing a transnational governing body would be feasible, given the differences in institutional recognition between Germany and the Netherlands.

Existing efforts of creating synergies between other monitoring programmes beyond food forestry can be used as a reasonable orientation for establishing an integrated monitoring concept for food forestry (see Kühl et al. 2020: 465; Wirth et al. 2024: 146). Thereby, stakeholders should consider the diverse social-ecological context factors that food forest projects are embedded into (see Kühl et al. 2020: 473). Accordingly, all kinds of interested food forest projects should ideally have the opportunity to participate in an integrated monitoring concept.

6.2.2. Role of citizen science approaches

Project-external experts and project-internal volunteers were crucial in the biodiversity monitoring activities of food forest projects and cases. Thereby, while experts were assigned a high level of expertise, volunteers demonstrated high intrinsic motivation and availability. These findings align with the general pattern of a large amount of biodiversity data collected by volunteers (see Chase and Levine 2016: 457; Kühl et al. 2020: 463; Loos et al. 2015: 45), as experts are often rarely available and expensive (see Danielsen et al. 2021: 495). Therefore, notably in SES, CS approaches to biodiversity monitoring are valuable (see Fischer et al. 2015: 147–148). Especially the case of Voedselbos D'Ekkers revealed that the collaboration between volunteers and experts can increase the extent and level of professionality of biodiversity monitoring activities.

My findings emphasise that both professionals and volunteers are already taking advantage of the existing CS approaches to biodiversity monitoring in food forest projects. Thus, at Urbane Waldgärten and Voedselbos D'Ekkers, employees / experts particularly rely on the volunteers to increase the amount of collected comparable biodiversity data (see Loos et al. 2015: 45), as they are frequently available and comprise local knowledge on the food forest system (see Chase and Levine 2016: 459–460). Meanwhile, volunteers have the chance to increase their scientific and ecological literacy (see Bonney et al. 2009; Danielsen et al. 2021: 484; Gönner et al. 2023: 12), deepen their knowledge on the food forest and adequate management practices, as well as their sense of ownership and community (see Chandler et al. 2017: 290; Danielsen et al. 2021: 485–486; Gönner et al. 2023: 21). Such advantages are also implied by the underlying motivations and purposes by the interviewed volunteers K, E and P, which ranged from research and education to evaluation and foundation for further management decisions. Thus, volunteer-based data collection in food forests already serves purposes beyond data generation.

In light of these advantages of CS approaches to biodiversity monitoring in food forests, interested volunteer-based food forest projects should use the available opportunities to participate in existing programmes. For instance, Paradijsvogelbosje could participate in the CS project offered by Food from the Forest (see Food from the Forest n.d.b). Other food forest projects currently without such opportunities could benefit from the following learnings for their individual volunteer-based monitoring schemes.

Learnings for volunteer-based monitoring

During my research I encountered an elevated interest by the food forest projects and monitoring programmes (see University of Potsdam n.d.a; Wageningen University & Research n.d.a; Wendel et al.

2023: 10, 24-27) towards the monitoring of the taxonomic groups of flora, insects, birds and mammals. Beyond reasons of relevance and convenience, i.e. level of expertise and available technology (e.g. identification apps) as indicated by the interviewees (see e.g. E, 122; K, 42; P, 86; U, 34), this finding might be assigned to general societal preferences towards charismatic taxonomic groups (see Chandler et al. 2017: 292; Danielsen et al. 2021: 484; Troudet et al. 2017: 3). Accordingly, my results mostly correspond with the large-scale taxonomic biases within the CS-based data base 'Global Biodiversity Information Facility' (GBIF) (see GBIF n.d.), in proportion to the number of known species within these groups, determined by Troudet et al. (2017: 3). However, the considerable interest in insects reflected in the food forest monitoring schemes contradicts their findings, as insects are largely underrepresented in GBIF. Even though this is based on the extremely high species richness in insects (Troudet et al. 2017: 10), it suggests that volunteers in food forest projects can contribute to the monitoring of challenging species groups to some extent if perceived as relevant (see Chandler et al. 2017: 292; Troudet et al. 2017: 10). For example, interviewee E advised to start with butterflies to approach the challenging insect monitoring (see E, 122). In light of these findings, food forest projects and CS monitoring programmes should choose taxonomic groups not only out of societal preference but also out of relevance, provided that the required expertise and technology are available. Therefore, biodiversity experts and scientists involved in the co-creation of monitoring schemes should promote the consideration of relevant but underrepresented species (see Troudet et al. 2017: 10). Though, as it is already the case at Urbane Waldgärten, challenging or disliked species groups should be surveyed by themselves to complement the volunteer-based data collection.

Furthermore, my findings reveal that identification apps were popular among food forest projects and cases as helpful tools that allow volunteers to counteract their lack of expertise partly, thus expanding their scope of monitoring possibilities (see Danielsen et al. 2021: 484). Consequently, Observation.org / ObsIdentify and iNaturalist were frequently indicated. These are not only identification apps but platforms, contributing reviewed data to GBIF (Kaufmann and Lindner 2021: 96). As a result, even food forest projects not participating in official monitoring programmes, such as Permakulturgarten am Kaltbächle or Paradijsvogelbosje, automatically make their data available to scientists. Although these scientists do not explicitly assess the impact of food forestry on biodiversity, the use of Observation.org / ObsIdentify and iNaturalist is a recommended opportunity to easily contribute to science, validate own data through experts or other volunteers and have an autonomous opportunity for central and joint data storage (see Kaufmann and Lindner 2021: 95–96; 100). Hence, based on criteria such as taxonomic range, user-friendliness and data validation by experts, both Urbane Waldgärten and Kaufmann and Lindner (2021: 97) conclude that the use of the platform Observation.org and its identification app ObsIdentify are most suitable for CS-based biodiversity monitoring (in food forests). This evaluation might inspire other food forest projects. Additionally, I found that further identification apps specialised on certain taxonomic groups, such as Merlin Bird ID or BirdNET, were also popular among food forest projects as they can continuously be used for species identification. Still, a central upload of all observations into iNaturalist or Observation.org is most desirable.

Up-scaling of citizen science approaches

In the long-term, CS approaches with different levels of participation (see Haklay 2013: 116) for different kinds of food forest projects should ideally be up-scaled, as part of an integrated monitoring programme of biodiversity monitoring in food forests as described above. The greater the likelihood that interested food forest projects can participate in joint approaches, the more comparable biodiversity data is available to prove the impact of food forestry on biodiversity. Based on my findings, stakeholders should consider the following aspects to improve or establish such approaches.

Interviewee U raised concerns about the data quality of volunteer-sourced biodiversity data (see U, 52), in line with concerns of researchers (see Loos et al. 2015: 47). However, this challenge can be addressed through the conscious design of monitoring schemes and data validation (see Gönner et al. 2023: 12; Loos et al. 2015: 47). Accordingly, the use of the expert-validated identification app ObsIdentify is a step in the right direction.

In addition, the case of Voedselbos D'Ekkers showed that the initial instruction of volunteers by experts, followed by their gradually higher level of responsibility, increased the extent of biodiversity monitoring activities and probably data quality. This process was perceived as successful in other, non-food forest-related CS-based monitoring programmes as well (see Eicken et al. 2021: 476; 479-480; Loos et al. 2015: 47). However, generally, it is questionable that the volunteers will ever entirely act without professional support, for instance with regard to data management (see Loos et al. 2015: 47).

Furthermore, I found that the motivations and purposes of volunteers in food forest projects regarding biodiversity monitoring activities go beyond data collection, which also aligns with findings from other CS programmes (see Eicken et al. 2021: 467). Accordingly, it is known that the iterative co-design among experts and volunteers is important to maintain the volunteers' interest. For instance, the emerging biodiversity data should not only serve scientists as a foundation to prove the impact of food forestry on biodiversity but also support the volunteers in taking practical management decisions (see Eicken et al. 2021: 467; Wendel et al. 2023: 37).

In light of these findings, CS approaches with a close collaboration of experts and volunteers seem to be a promising concept for biodiversity monitoring in food forests. In order to essentially scale up such approaches in biodiversity monitoring in food forests, ideally as part of an integrated monitoring concept, it requires more collaboration among already existent approaches (see Gönner et al. 2023: 26), sufficient funding opportunities (see Eicken et al. 2021: 479; Fischer et al. 2015: 148; Gönner et al. 2023: 26) and a central institution that ensures data management and evaluation (see Chase and Levine 2016: 461).

6.2.3. Favourable institutional conditions in the Netherlands

During my research, I encountered that differences among Germany and the Netherlands regarding project-external support and funding opportunities for food forest projects influenced the extent of biodiversity monitoring activities. This aligns with previous research on food forestry, implying that food forest projects are dependent on national policies (see Belcher et al. 2005: 250) and related subsidies (see Roodhof 2024: 197) or other ways of funding (see Albrecht and Wiek 2021b: 193).

The Netherlands

The Dutch food forest project case Voedselbos D'Ekkers stood out due to its diverse support and funding opportunities from various institutions, partly aimed at specifically promoting the volunteers' biodiversity monitoring activities. Notably, their requested involvement in the NMVB clearly reveals that the extent of their biodiversity monitoring activities benefits from the developments around the Dutch Green Deal Voedselbossen (see Stichting Voedselbosbouw Nederland n.d.d). This most probably applies also to other food forest projects that participate in the NMVB (see Albrecht and Wiek 2021b: 189).

Beyond that, it is remarkable that experts from the conservation societies Vlinderstichting and Sovon, which are not specialised on the habitat of food forests but on the taxonomic groups of butter- and dragonflies and birds (see De Vlinderstichting n.d.; Sovon n.d.) established an initial monitoring concept for those in Voedselbos D'Ekkers and other food forest projects (see Wendel et al. 2023: 37). This could be explained with Roodhof's finding that food forestry is not only politically and legally but also societally recognised in the Netherlands (Roodhof 2024: 192–193). Also, it aligns with the generally pivotal role of non-governmental institutions in biodiversity monitoring (see Kühl et al. 2020: 463; Wirth et al. 2024: 144).

However, interviewee E emphasised that such favourable conditions are not easily obtained but related to the volunteer's knowledge of funding opportunities, coincidence and luck (see E, 60, 62, 173). The former goes in line with the findings by Roodhof (2024: 193). During her research, she also found that Dutch food forest projects not covered by the Green Deal definition particularly face institutional obstacles, such as financial support opportunities (ibid.: 204-205). So far, the NMVB was only interested in the participation of food forest projects that fit this definition (Wendel et al. 2023: 10–11), and some food forest projects have to pay for their participation (see E, 67). Thus, beyond the lack of interest and capacity expressed by interviewee P (see P, 147-154), a potential "lack of knowledge about legal and financial aspects of food forests" (Roodhof 2024: 193), institutional acknowledgement but also a lack of coordination and transparency within the Dutch food forestry landscape (ibid.: 199, 203-205) might explain the little or missing institutional support and funding for biodiversity monitoring activities at the other Dutch food forest project case Paradijsvogelbosje, and potentially many other food forest projects.

Despite partly favourable conditions, these findings imply the need for more integration of food forestry and biodiversity monitoring activities into Dutch "laws, regulations, and available subsidies" (Roodhof 2024: 193) as well as transparency and accessibility of funding opportunities. The plans of the NMVB are progressing in this direction. The team is planning to include up to 50 food forest projects, also non-agricultural smaller ones, in its programme in order to establish a long-term, standardised monitoring programme with improved data availability and comparability among a diverse sample of food forests (Stichting Voedselbosbouw Nederland n.d.c; Wendel et al. 2023: 10).

Among other factors, this might be a step to enable scientifically interested food forest gardeners, such as interviewee P, to intensify the biodiversity monitoring activities on their site.

Not every food forest project with an interest in systematic biodiversity monitoring will have the chance and resources to participate in such an overarching monitoring programme. In addition, political developments and corresponding support for food forestry might be uncertain. For these projects it might be advisable to use low-threshold approaches such as the CS project by Food from the Forest (see Food from the Forest n.d.b) or to approach experts from Dutch conservation societies or universities, as interviewee E proposed (see E, 160).

Germany

In contrast to Voedselbos D'Ekkers, the German food forest project cases reported on rare institutional support or funding for biodiversity monitoring activities. This finding aligns with the general lack of political and legal acknowledgement of food forestry in Germany (see e.g. BMEL 2023) and interviewee U's estimation of the food forest movement being younger in Germany than in the Netherlands (see U, 64).

Urbane Waldgärten receives extensive funding from the BfN, enabling them to conduct intensive biodiversity monitoring. However, the funding is not specifically dedicated to food forests and tied to requirements that volunteer-based food forests projects, such as Permakulturgarten am Kaltbächle, cannot fulfil (see BfN n.d.). Nevertheless, this funding implies that a German governmental institution acknowledges food forestry as a potentially biodiverse land use type. This underlines the perception of interviewee U that food forestry is becoming more established in Germany (see U, 66).

According to interviewee U, the involvement of experts in biodiversity monitoring activities is favoured but highly time- and cost-intensive and can therefore not be afforded by volunteer-based food forest projects (see U, 56). Voedselbos D'Ekkers as a completely volunteer-based food forest project confounds this statement. Instead, interviewee E even encouraged other food forest projects to approach experts for free support in monitoring activities, due to their positive experience with conservation societies (see E, 160). These contrasting statements suggest an increased recognition of food forestry among Dutch non-governmental institutions (see Roodhof 2024: 192–193) but could also be assigned to Urbane Waldgärten having to stick to specific guidelines. As the two large German conservation associations NABU and 'Bund für Umwelt- und Naturschutz e.V.'[45] (BUND) both have relations to the concept of food forestry (see BUND Kreisgruppe Wolfenbüttel 2016; NABU Landesverband Bremen n.d.; U, 68), it might be advisable also for German food forest projects with limited resources to follow the advice of interviewee E.

Unlike the Dutch official monitoring programmes, volunteer-based food forest projects cannot participate in the German ones so far. However, Urbane Waldgärten intends to establish a systematic and comparable biodiversity monitoring concept that volunteer-based urban food forest projects can easily apply. This might be the entry point towards more extensive data collection on biodiversity in

[45] Association for Environmental and Nature Conservation (translation by DeepL)

food forests in Germany. As this approach potentially excludes rural food forest projects such as Permakulturgarten am Kaltbächle, those could also try to approach experts or students for voluntary support.

Overall, better institutionalisation of food forestry in Germany is desirable (see Albrecht and Wiek 2021b: 198). Most probably, Urbane Waldgärten is a good starting point leading to improvement. Their biodiversity monitoring results might increase the acknowledgement of food forestry, which in turn might increase support and funding opportunities for biodiversity monitoring activities in food forest projects.

6.3. Overview of implications (RQ3)

Based on my findings, the following table gives an overview of potentially beneficial implications for food forest projects and other food forestry stakeholders to improve or establish biodiversity monitoring concepts in future (RQ3).

Tab. 5: Overview of implications for improvement or establishment of biodiversity monitoring concepts for volunteer-based food forest projects and other food forestry stakeholders (e.g. scientists, experts, political actors).

	Volunteer-based food forest projects	Other food forestry stakeholders (e.g. scientists, experts, political actors)
Overarching monitoring concept	• Use the existing opportunities (e.g. Food from the Forest)	• Foster development of integrated monitoring concept for all kinds of interested food forest projects from the beginning • Foster collaboration between existing official monitoring programmes
Actors	• Collaborate with experts	• Foster CS approaches with different levels of participation
Time period	• Perform long-term monitoring	• Ensure long-term monitoring
Taxonomic groups	• Choose taxonomic groups not only out of societal preference but also out of relevance (e.g. insects) • Start with easier taxonomic groups (e.g. butterflies) • Rely on experts for monitoring of too difficult or disliked species	• Promote consideration of relevant but underrepresented species
Data management	• Use Observation.org / ObsIdentify or iNaturalist as central and joint data platform	• Establish a central, common and user-friendly data platform • Ensure data evaluation
Identification apps	• Use Observation.org / ObsIdentify or iNaturalist as identification app with validation • Use taxonomic group-specific apps (e.g. Merlin Bird ID, BirdNET) for specific identifications	• Support the use of identification apps, especially Observation.org / ObsIdentify

Continuation Tab. 5

Support and funding opportunities	• Use the existing opportunities, although not yet necessarily food forest- or monitoring-specific • Approach voluntarily working experts, e.g. from conservation societies or universities	• Increase (food forest- and monitoring-specific) support and funding opportunities • Increase transparency and accessibility of support and funding opportunities
Institutionalisation of food forestry		• Establish central governing institution Dutch stakeholders: • Increase integration of food forestry and biodiversity monitoring activities into laws, regulations and subsidies German stakeholders: • Bring forward institutionalisation of food forestry

6.4. Reflection

Positioning

First and foremost, I must declare that my choice of the research topic and my perspective on it is not neutral, particularly given my involvement in the German urban food forestry community (see Hug and Poscheschnik 2020: 118). This circumstance most probably facilitated my outreach to, and trust building with, food forest gardeners in projects (see Helfferich 2022: 881).

Research design

Fundamentally, my research design appeared adequate for approaching my research topic. However, although I already chose my four case studies to contrast "extreme" (Eisenhardt and Graebner 2007: 27) and diverse food forest project cases (see Eisenhardt and Graebner 2007: 27; Przyborski and Wohlrab-Sahr 2022: 133), more cases would have provided a broader perspective (see Albrecht and Wiek 2021a: 102; Eisenhardt and Graebner 2007: 27).

Integrating food forests into the concept of SES (see Aguilar-Støen et al. 2009: 56; Park et al. 2018: 290; Taylor and Lovell 2014: 299) seemed appropriate. In particular, the first-time application of the SES framework by E. Ostrom (see Ostrom 2009, 2007) to food forests indeed provided me with sufficient ideas and variables to guide my interview research (see Cox 2014; Dartmouth College n.d.; Hinkel et al. 2015; McGinnis and Ostrom 2014). Adopting such a SES perspective on food forests, alongside other related theories and frameworks (e.g. leverage points, see e.g. Abson et al. (2017)), could inform future research. This would further contribute to our limited understanding of these complex systems.

Online survey

During my research, certain methodological issues arose, in particular due to the survey research. Accordingly, my online survey was clearly subject to sampling and unit non-response bias (see Bautista 2012: 37-38, 43; Engel and Schmidt 2022: 453–454), resulting in the non-representative final sample size (n) 16. Although I sent my survey requests to 327 individual food forest projects and 26 networks, the survey link was opened 190 times.[46] While I cannot estimate in detail the number of food forest projects actually performing biodiversity monitoring activities on their site, I could not recruit all of them. For instance, only three out of the 33 Dutch food forest projects participating in the NMVB responded to my survey (see Wendel et al. 2023: 10). Also, the survey sample was biased towards Dutch and German food forest projects. This might be due to my limited ability to reach out to food forest projects in other countries, as well as to the general establishment of food forestry in my target countries.[47]

In addition, while 43 food forest projects initially indicated to perform biodiversity monitoring activities on their food forest site, only 16 respondents adequately completed the survey.[48] As most respondents cancelled the survey as soon as the actual content-related questions on their biodiversity monitoring activities started, it can be assumed that they were overwhelmed by those. Retrospectively, interviewee P mentioned having "thought your survey was, in principle, oriented to full-blown biological biodiversity research" (P, 82). This was not my intention but might have deterred other food forest projects from participating. These issues imply the need, for my part, for more careful survey design and advertisement in future works (see Engel and Schmidt 2022: 454–459; Gideon 2012: 91).

In retrospect, the interview statements revealed discrepancies in the survey responses of the food forest project cases. Although I corrected these, it can be assumed that the survey data is subject to further bias from self-reported responses, probably due to respondents feeling overwhelmed, unmotivated or distracted (see Engel and Schmidt 2022: 463). This is reflected in survey statements such as "I tried to fill in the survey as accurately as possible, but it wasn't easy and might be confusing" (NL2), "bin ich mir auch eher unsicher in den Angaben" (GER6) or "too much to tell here" (FR1), as well as occasional non-responses to items (see Engel and Schmidt 2022: 462–463).[49] Overall, while the survey data was neither representative nor fully valid, it appeared sufficient to provide an overview of the state of biodiversity monitoring activities in food forest projects.

Regarding the survey data analysis, it is important to note that the indicator system for professionality of biodiversity monitoring activities in food forests, though based on literature, was self-invented. Primarily, it served the integration of survey results in order to classify and contrast the food forest projects. While this approach was helpful for my work, it is not necessarily transferable and might be advanced by other researchers in future.

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[46] see Appendix C for survey statistics
[47] see Appendix A for food forest inventory
[48] see Appendix C for survey statistics
[49] see Appendix C for processed survey data

Case studies and semi-structured expert interviews

During the structured qualitative content analysis of the interview transcripts, it was impossible to achieve intercoder reliability within the scope of my sole-author thesis. Nevertheless, I attempted to achieve intracoder reliability by conducting multiple coding rounds (see Kuckartz and Rädiker 2024: 50; Mayring and Fenzl 2022: 695).

In terms of content, it is important to note that the interviewee U's perspective differs fundamentally from that of the other interviewees. Interviewee U is the initiator, network manager and coordinator of Urbane Waldgärten, the currently most relevant German pilot food forest project, which intends to develop a transferable (biodiversity) monitoring concept. Their experience in the development of a volunteer-based, yet professionalised, biodiversity monitoring concept in food forests provided me valuable insights that complemented the equally important volunteer's perspectives of the other interviewees (see Eisenhardt and Graebner 2007: 28). Although not viable in the scope of this thesis, including a volunteer's perspective on Urbane Waldgärten as well as expert's perspectives on the other three food forest project cases might have created a bigger picture. This could be interesting for future research.

7. Conclusion

Overall, despite certain methodological constraints, this empirical study showed that the characteristics and the extent of biodiversity monitoring activities among food forest projects were rather heterogeneous, although they could be classified as either unprofessional or professional. Actor- and governance-related factors (social subsystem) impacted this state particularly. Volunteers played a central role in biodiversity monitoring activities in all food forest project cases due to their frequent presence on site. These findings align with the well-known issue of heterogeneous approaches to biodiversity monitoring, given the complexity of biodiversity and SES, as well as with the common involvement of volunteers in such approaches to counteract the limited availability of experts.

The food forest project cases Urbane Waldgärten and Voedselbos D'Ekkers already perform professionalised biodiversity monitoring activities. As good practice examples, their concepts revealed that the collaboration between experts and volunteers is particularly convenient for such activities. Beneficial factors for these CS approaches were ensuring advantages for both experts and volunteers, providing sufficient instruction for volunteers and having support and funding opportunities. Regarding the latter, the circumstances for acquiring such support and funding currently appear more favourable in the Netherlands than in Germany, given the respective general political, legal and societal acknowledgement of food forestry in the countries.

Volunteer-based food forest projects that are interested but less well-resourced, such as the cases of Permakulturgarten am Kaltbächle and Paradijsvogelbosje, should take advantage of the current opportunities to facilitate and professionalise their monitoring approaches. For instance, it seems recommendable to integrate the expert-validated identification app ObsIdentify and the corresponding biodiversity data platform Observation.org.

Furthermore, my findings suggest that food forestry stakeholders need to foster the development of an integrated biodiversity monitoring concept for food forests from this early stage, including CS approaches. The existing concepts in food forest projects and overarching monitoring programmes could provide the basis for this. However, these need to collaborate, ideally under the coordination of a central governing institution.

In order to pave the way for such an integrated biodiversity monitoring concept, more practical research is required. Accordingly, the perspectives of other stakeholders involved in biodiversity monitoring activities and existing programmes should be considered, such as scientists or experts. As this work has mostly highlighted actor- and governance-related factors, more emphasis should be placed on environmental system-related ones. For example, conducting a study resulting in relevant yet viable biodiversity indicators could be valuable.

Overall, this work provided valuable initial insights and implications for biodiversity monitoring activities in food forest projects. These can be used to improve such activities in future. This is urgently needed in order to demonstrate the impact of food forestry on biodiversity. In turn, these insights could increase the political and societal support for the concept of food forestry, which seems to be a promising concept in light of our multiple crises.

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9. Appendices

Appendix A	Food forest inventory
Appendix B.1	English survey template
Appendix B.2	German survey template
Appendix C	Processed survey data and survey statistics
Appendix D.1	English information on data privacy for interviews
Appendix D.2	German information on data privacy for interviews
Appendix E.1	English interview guide
Appendix E.2	German interview guide
Appendix F	Transcription rules and interview transcripts
Appendix G	Codebook

The food forest inventory (appendix A), the survey templates (appendices B.1 – B.2), and the interview guides (appendices E.1 – E.2) can be accessed via the following publication. The interview and survey data cannot be published due to legal reasons.

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