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# Digital Tools in Agroforestry: Exploring Stakeholder Perceptions in light of Regional Policy Frameworks across the Federal States of Germany

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# List of Abbreviations

| | |
|---|---|
| AbL | Arbeitsgemeinschaft bäuerliche Landwirtschaft |
| AF | Agroforestry |
| BMEL | Bundesministerium für Ernährung und Landwirtschaft |
| CAP | Common Agricultural Policy |
| DeFAF | Deutscher Fachverband für Agroforstwirtschaft |
| EU | European Union |
| FAO | Food and Agriculture Organisation |
| GPS | Global Positioning System |
| Ha | Hectare |
| IoT | Internet of Things |
| PA | Precision Agriculture |
| PLF | Precision Livestock Farming |
| SDG | Sustainable Development Goal |
| SF | Smart Farming |
| SLF | Smart Livestock Farming |
| SSNM | Site-Specific Nutrient Management |
| UAV | Unmanned Aerial Vehicles |

## Summary

This study explores the still emerging sector of modern agroforestry in Germany and the role of digital tools in supporting its development. Employing quantitative research methods from two different data sets, this study is able to compare demographics and perceptions of stakeholders in agroforestry in relation to this still limited research field. The first data set uses data from the DeFAF Agroforestry Map based on self-registered entries from stakeholders across Germany. This provides an overview of the current distribution of agroforestry in the different federal states. The second data set uses data collected from the online DigitAF survey on digital tools in agroforestry. This asked participants questions related to their current role in agroforestry, their farm infrastructure and available resources, as well as their perceptions towards various factors related to agroforestry and digital tools. Results showed that states with investment funding schemes for agroforestry had a higher number of registered agroforestry systems, as well as a higher perceived financial well-being amongst participants. The usage of digital tools in agroforestry on the other hand, did not coincide with the higher prevalence of agroforestry in these states. Factors which were potentially influences on the usage of digital tools were age and gender, with women seeing lower adoption rates, as well as younger stakeholders. Attitudes towards digital tools were significantly more positive from stakeholders who use digital tools, compared to stakeholders which do not. Key barriers to the adoption of digital tools were distrust in data protection, scepticism about the benefits of digital tools, as well as varying levels of confidence in the ability to implement digital tools. The latter was particularly low for women, as well as stakeholders with lower educational attainments.

# 1. Introduction

Transforming agricultural systems worldwide is one of the most critical challenges in the pursuit of sustainable development. More than any other sector, agriculture is comprehensively integrated amongst most of the 17 Sustainable Development Goals (SDGs), linking together issues of poverty, food security and nutrition, sustainable water management, ecosystems and biodiversity, human health, responsible consumption and production, and climate action (United Nations 2025). In light of this urgent need for more sustainable agricultural practices, agroforestry emerges as a promising approach to address several of these complex issues.

Leakey defines agroforestry as a dynamic, ecologically-based, natural resource management system that integrates trees in farmland and thus, diversifies and sustains smallholder production (Leakey 2017). This is generally practiced with the intention of developing a more sustainable form of land use by improving farm productivity and providing environmental and social benefits. Agroforestry has been proven to enhance various environmental characteristics compared to conventional practices, including soil health and soil structure, water quality and water retention, biodiversity, and carbon storage (Mayer et al. 2022; Zhu et al. 2020; P. Udawatta, Rankoth, and Jose 2019; Dollinger and Jose 2018; Waldron et al. 2017; Mbow et al. 2014). Furthermore, agroforestry systems have demonstrated socioeconomic benefits through improved agricultural productivity, stability of crop yields and income, and farm system resilience especially to climate change and weather fluctuations (Octavia et al. 2023; Waldron et al. 2017; Leakey 2014).

Despite the various benefits agroforestry presents, there is still a lack of adoption especially in temperate regions (Nair, Kumar, and Nair 2021). Germany is an interesting case study for this research field. As a central European country with a variation of climates and soil types, conditions offer a wide range of agroforestry practices. Furthermore, certain regions are particularly prone to wind erosion and drought, emphasising the opportunities agroforestry could provide (Litschel et al. 2023). Across Germany, agroforestry is gaining momentum with organisations such as the non-profit *Deutscher Fachverband für Agroforstwirtschaft* (DeFAF), the German Agroforestry Association, working together with various agricultural stakeholders to develop agroforestry in Germany. At the end of 2023, the DeFAF recorded 161 agroforestry systems with a total area of 1304 ha across Germany, based on self-registered entries from stakeholders (DeFAF 2024b). The true number is higher, but difficult to estimate as it is not comprehensively monitored.

There is some literature, as well as various master theses, on agroforestry in Germany addressing farmer-perceptions of agroforestry, as well as barriers to its adoption (Litschel et al. 2023; Böhm and Hübner 2020; Tsonkova et al. 2018; Luick 2008). The barriers which farmers and other stakeholders face when adopting agroforestry practices have been studied worldwide, with a global literature review finding five key encountered issues; i) availability or quality of knowledge on technical and agronomic matters; ii) perceived socio-economic struggles; iii) labour or time intensity; iv) high upfront economic investment; and v) availability of technical support (Tranchina, Reubens, et al. 2024). Similar struggles were reflected in a European study on stakeholder perspectives on agroforestry, where increased labour, complexity of work, management costs and administrative burden were seen as the key negative aspects (García de Jalón et al. 2018). An underlying solution to address a number of these issues could be the development and expansion of tailored digital tools in agroforestry.

Digital technologies in agriculture are designed to enhance agricultural efficiency and support informative decision-making and risk management. The increased agricultural efficiency can lead to enhanced field productivity, reduced operation costs, reduced labour, and support in management as well as technical knowledge (Papadopoulos et al. 2024; Balasundram et al. 2023; Bacco et al. 2019). Furthermore, in light of the growing need to address environmental and socioeconomic pressures caused by conventional agriculture, digitalisation has gained attention as a means to enhance sustainability across food systems by producing more food on less land and with fewer inputs (Balasundram et al. 2023; MacPherson et al. 2022; Rotz et al. 2019). Combining the role agroforestry can play in the transformation to sustainable agriculture, alongside the benefits digitalisation provides for farm management and resource efficiency is thus an important pathway to explore.

There is little literature on digital tools in agroforestry, either due to a lack of adoption rates, distribution, research interest or research access. Tranchina et al have conducted a study on agroforestry and stakeholder perspectives on digitalisation in agroforestry from six countries across Europe (2024). This was also conducted within the scope of the DigitAF project which will be further elaborated on in the methodology section. The study found that stakeholders in agroforestry do use digital tools, most frequently for decision support, followed by research, and training (Tranchina, Burgess, et al. 2024). Furthermore, respondents stated that the ideal tool needs to be clear, intuitive, and user-friendly. The agricultural working group *AbL* will also publish results from their survey on members' attitudes towards the management of agroforestry systems in due course (AbL 2024).

A variety of digital tools for agroforestry systems are available, with over 40 different tools presented in the DigitAF Agroforestry Tools Catalogue (DigitAF 2025). This online catalogue uses a "FAIRness" score to enable an assessment preview of each tool and therefore, allowing users to search for resources depending on their specific criteria and needs. Some examples of tools used by agroforestry stakeholders in Tranchina et al's study were *Yield Safe*, *Farm Carbon* Calculator, *LandIS*, and *FarmOS* (2024). These tools aim to address the additional aspects that need to be considered in the management of agroforestry systems. Decisions such as which trees to plant, where to plant them, the financial implications of integrating trees and shrubs on the farm, the synergies of inputs and many more, are examples of factors incorporated into these tools to meet the specific needs of the user. Exploring the role these tools play in the establishment and ongoing management of agroforestry systems is important for revealing possible opportunities to ease the path into long-term agroforestry adoption.

When looking at stakeholder perspectives of digital tools in agroforestry in Germany, the only literature available is Tranchina et al's study on agroforestry and digitalisation in Europe, which did include participants from Germany (2024). The survey also included some questions that will be used for this study, making comparison easier. Therefore, this study aims to build on this research with focus on Germany and address the gap in the literature by exploring the research question:

*What are stakeholders' perceptions of digital tools in agroforestry in Germany?*

This will be explored with the following sub questions:

1. *Do stakeholders in agroforestry use digital tools?*
2. *Are there differences in attitudes towards digital tools in agroforestry between different demographic groups?*
3. *Are there differences in attitudes towards digital tools in agroforestry depending on whether stakeholders have access to agroforestry investment funding?*
4. *What are stakeholders' attitudes towards data protection?*

In order to answer these research questions, a quantitative survey was undertaken together with the DeFAF, which asked stakeholders in agroforestry to answer various questions in relation to their perceptions of digital tools in agroforestry. Considering the aforementioned barriers to agroforestry adoption, this study seeks to find synergies between regional agroforestry subventions, knowledge of agroforestry, the role of digital tools in agroforestry management, and attitudes towards data protection. These insights aim to inform digital tool providers, policymakers, research institutions, and other stakeholders in agroforestry about the current state of digitalisation in agroforestry, as well as areas for improvement to address the needs of stakeholders in agroforestry and support the development of agroforestry in Germany. Due to the lack of literature in this field, this research is primarily exploratory, with the aim of gaining a preliminary understanding of this topic from which research questions, hypotheses and theories can be formulated and devised for future studies. However, a set of hypotheses will also be formulated prior to the results on the basis of literature on digitalisation in agriculture more generally.

The following chapter studies the background of this research field, focusing on agroforestry and its benefits, digital tools in agriculture, and the agricultural and political context of Germany. This is followed by the methodological chapter which describes the exploratory nature of this study, formulates the hypotheses which will be tested with this study, defines the study design with reasoning, and presents the conduction of the survey alongside data collection. The fourth chapter summarises the results using primarily descriptive data analysis alongside a correlation analysis. Subsequently, the discussion chapter will analyse these results in light of the formulated hypotheses, previous literature results, and within the broader study context. Further research questions and hypotheses to be explored in future research will also be outlined. The discussion also includes a critical assessment of the study limitations. Finally, the conclusion chapter will synthesis the findings and highlight the key implications for digital tool providers, policymakers, consulting companies, as well as research institutions.

# 2. Background

## 2.1 Agroforestry benefits

Intensive farming practices often employed in conventional agriculture, have contributed towards significant environmental challenges such as the deterioration of soil health, water scarcity and water pollution, and the rapid loss of biodiversity and ecosystem functions (UNEP 2023; P. Udawatta, Rankoth, and Jose 2019; Godfray and Garnett 2014; Pretty and Bharucha 2014). Additionally, the associated land-use changes and practices are contributing to climate change, making mitigation and adaptation strategies in agriculture essential. The significant threats posed by conventional agriculture have led to a broad consensus in science and politics to shift towards more multifunctional and sustainable farming practices. One viable alternative is agroforestry.

Agroforestry has various definitions, yet this study adopts Leakey's original definition that emphasises the diversification and dynamic aspect of integrating trees with crops and/or animals on the same land management unit (Leakey 2017). This approach can diversify and sustain production, yield and income as well as enhance ecosystem functions, and increase farm resilience to climate change (FAO 2024). Alongside these socioeconomic benefits, agroforestry systems can provide environmental benefits by enhancing soil quality and water retention, reducing soil erosion, conserving and enhancing biodiversity, and improving microclimates. Agroforestry has been practiced for millennia, yet in light of the challenges posed by modern agriculture, it is gaining renewed attention internationally as a sustainable alternative to conventional agricultural practices.

There are various ways in which the implementation of trees in agricultural systems can provide these benefits. Firstly, soil nutrient availability and soil fertility can be improved through the increased soil organic carbon provided by trees on the field (Dollinger and Jose 2018; Cardinael et al. 2017). This is mainly due to the accumulation of additional leaf litter and other organic matter in the soil. This process in turn supports root growth and nutrient uptake, further enhancing carbon storage in the soil (Ramaswamy et al. 2022; Suárez et al. 2021; Cardinael et al. 2017). Carbon storage in the soil as well as in trees on the field contribute to climate change mitigation. Additionally, deep root systems help break up compacted soil and improve soil structure, thus enhancing the necessary movement of water and air through the soil (Rathore et al. 2022; P. Udawatta, Rankoth, and Jose 2019).

In turn, these processes enhance soil microbial dynamics, a fundamental component of soil- and overall ecosystem health, which has positive effects on biodiversity as well as crop production (Beule, Vaupel, and Moran-Rodas 2022; P. Udawatta, Rankoth, and Jose 2019). Another key provision of certain agroforestry systems is the windbreak provided by tree rows. This can reduce soil erosion caused by wind, as well as reduce evapotranspiration and thus enhance water-use efficiency (Udawatta and Gantzer 2022; Thevs, Aliev, and Lleshi 2021).

When looking at biodiversity, agroforestry can enhance species richness with trees and shrubs providing habitats for certain disturbance-resistant species (P. Udawatta, Rankoth, and Jose 2019). For example, a study in Canada observed that between 1995 and 2014, avian species richness almost doubled in a tree- based intercropping system, with this system measuring higher avian species richness than the monocrop system throughout the entire study period (Gibbs et al. 2016). Furthermore, tree- and hedgerows in agroforestry systems can create natural corridors for wildlife, which enhances landscape connectivity (Bentrup et al. 2019). Some types of agroforestry systems, such as forest farming where crops are grown beneath a prior-existing forest canopy, can reduce the initial conversion of natural habitats, especially when compared to conventional agriculture where fast areas of land are typically cleared.

From the farmer’s perspective, crop yield and productivity increases have been observed in various agroforestry farm systems across the globe (Pretty and Bharucha 2014). This can largely be accredited to the various ecosystem services mentioned previously: soil fertility, prevention of soil erosion, and water supply management. Depending on the species of trees planted, the products gained from trees such as fruits, fodder for livestock, and wood, can further diversify and stabilise the farmer’s income and resource supply (Waldron et al. 2017). Additionally, the shade provided by a tree canopy is especially relevant for crop and livestock farming in sunny climates prone to drought, establishing shelter for livestock and reducing water consumption of crops (Zhu et al. 2020). With rising global mean temperatures increasing these pressures, agroforestry can support climate change adaptation in agriculture.

## 2.2 Agroforestry classification and prevalence

With its diverse range of land management practices, agroforestry can be classified based on various criteria, including farm system components, dominant land use, spatial organisation, or temporal sequence (Leakey 2017). Most frequently however, agroforestry systems are categorised into three types: agrisilviculture (the combination of crops and trees, including shrubs/vines), silvopastoral (the combination of pasture/animals and trees), and agrosilvopastoral (the combination of crops, pasture/animals, and trees) (FAO 2024). The dynamic nature of agroforestry allows the method to be tailored to the needs of each farming system, taking into account farmer and community needs, availability of resources, local environmental conditions, site-specific factors, and markets and value chains.

The suitability of an agroforestry systems is thus highly dependent on localised- and site-specific factors. For example, an area particularly prone to severe effects from droughts and wind erosion such as Brandenburg in Northeast Germany, would benefit from windbreaks or shelterbelts (Litschel et al. 2023). These are single or multiple rows of trees or shrubs in linear configurations, which can be effective in cutting wind speed and thus reducing soil erosion as well as evapotranspiration (Thevs, Aliev, and Lleshi 2021). Pioneers of agroforestry such as Thomas Domin in Brandenburg, whose farm is one of the first to introduce trees on the field in the region, has already proven the effectivity of reduced wind erosion compared to his conventional fields without trees (Schirmer 2021). This was particularly effective in reducing dust clouds in the summer period which plagued the local village. In light of the need for climate change adaptation strategies, this will become increasingly crucial with higher temperatures and longer periods of drought intensifying the risks of soil erosion.

The prevalence of agroforestry is difficult to measure, partly due to the diverse range of forms it comes in, as well as its integration into other types of agriculture. When considering the very broad definition of agroforestry as agricultural land with at least 10% tree cover, it accounts for 46% of all farmland globally with particular prevalence in Southeast Asia, Central America and South America (Zomer et al. 2016). Tropical regions represent 78% of all agroforestry worldwide, whilst 22% is seen in temperate regions (Nair, Kumar, and Nair 2021). However, this agroforestry classification assumes that all agricultural land with trees are agroforestry systems, which ignores the “intentional” component of the aforementioned definition. This can also be observed in den Herder et al.’s study which aimed to determine the distribution of agroforestry in Europe, basing data collection on the 2012 EU *in situ* land use and land cover survey (LUCAS) (den Herder et al. 2017). This utilises photointerpretation or direct surveyors in the field, again using an observational method to identify agroforestry rather than inquiring about the intentional management of the farm system. However, this alternative type of monitoring would require in-depth survey research of each farm, which is difficult especially for an entire continent such as Europe. There are variations in the threshold set for tree cover to classify a system as agroforestry, as will be seen in Germany's different funding scheme requirements outlined later on.

Den Herder et al.'s study observed 8.8% of European agricultural land to be agroforestry, with the accuracy of these results being debateable but still a valuable insight (den Herder et al. 2017). By far the most prevalent agroforestry was silvopastoral (livestock and trees) covering around 15.1 out of the total 15.4 million ha, followed by high value tree agroforestry at 1.1 million ha, and arable agroforestry at 0.3 million ha (den Herder et al. 2017). Agroforestry is mostly established in southern European regions with Spain in first place, then southern France, Greece, and Italy. This could potentially be due to the emphasis on shade provided by tree cover, which is especially relevant in sunnier regions. However, other climates such as temperate in central Europe can still benefit from the various other ecosystem services and socio-economic provisions that have been observed in agroforestry systems (Dmuchowski, Baczewska-Dąbrowska, and Gworek 2024; Bentrup et al. 2019; Cardinael et al. 2017; Gibbs et al. 2016).

## 2.3 Agroforestry in Germany

Wood pastures and semi-open pastures have a long history in Germany, alongside other central European regions (Luick 2008). These were traditionally used for the production of fodder, fruits, wood or timber, as well as grazing for livestock which were communally managed for the summer pasture. Wood pastures play a unique role particularly in the Alps, where the system is practiced as part of local culture and has become crucial to public and federal interest (Luick 2008). Today, the most prevalent traditional agroforestry systems are windbreaks, hedgerows, and orchard meadows with the latter still having high nature and cultural value (Tsonkova et al. 2018). Modern, production-oriented agroforestry also exists in Germany, especially in the form of short rotation alley cropping which involves trees with rapid juvenile growth being harvested in short rotation cycles every three to seven years (Litschel et al. 2023; Tsonkova et al. 2018). The woody biomass gained is usually used in the form of wood chips for bioenergy or timber, and can provide periodically high energy outputs (Litschel et al. 2023).

According to the measured LUCAS data, Germany might present a significant area of agroforestry in Europe in absolute terms (263,500 ha), however the proportion of agroforestry of utilised agricultural area was measured at only 1.6% in 2012 (den Herder et al. 2017). More recent data can be found on the DeFAF agroforestry map from 2023, however as this is based on self-registered entries, the recorded establishment of agroforestry systems is much lower at 1,304 ha (DeFAF 2024b). Additionally, this might present a certain gap between farm systems which classify themselves as agroforestry, and those which have tree cover on the field or practice agroforestry farming but are not aware or do not want to classify themselves as agroforestry. The DeFAF agroforestry map shows the majority of registered systems to be silvopastoral (45%), followed by silvoarable (39%), and agrosilvopastoral (16%) (DeFAF 2024b).

There are various characteristics which have been identified as barriers to adoption of agroforestry in Germany. Firstly, Tsonkova et al's study found a lack of knowledge about agroforestry amongst farmers and stakeholders, with the concept frequently being associated with traditional practices which are deemed incompatible with modern agricultural management (2018). However, as agroforestry has been gaining momentum in more recent years with the founding of the DeFAF over five years ago and the introduction of subventions for agroforestry, this trend may be on the path to change. Litschel et al.'s study focusing on key actors' perspectives in North Eastern Germany, found that complex bureaucratic funding structures, as well as high start-up costs were widely perceived barriers to agroforestry adoption (Litschel et al. 2023). This was coupled with unfitting requirements and categorisation of agroforestry in the subsidy system, and a low subsidy amount from both the federal state as well as the European Common Agricultural Policy (CAP) (Litschel et al. 2023). Additionally, the workload was deemed too high which can deter many farmers. These perceived barriers were echoed in a European-wide study, where increased labour, complexity of work, management costs and administrative burden were seen as the key negative aspects of agroforestry by stakeholders (García de Jalón et al. 2018). The following section will address the complex bureaucracy and funding structure available for agroforestry in Germany. Then the barriers associated with lack of knowledge, increased labour, complexity of work and management will be assessed, and how digital tools can be utilised.

## 2.4 Funding schemes for agroforestry in Germany

Agroforestry in Germany is subject to a range of regulations which are primarily rooted in the CAP, with subsidies for farmers shaped by two pillars. The first pillar includes direct payments to farmers. Since 2023, agricultural enterprises have been able to receive an annual subsidy for the management of agroforestry systems through the eco-regulation *Öko-Regelung (ÖR) 3* (BMEL 2023b). This annual subsidy was increased from the original 60 Euros per hectare of wooded area, to 200 Euros in 2024 (BMEL 2023a). Since this change, an increase in applications for subsidies for these wooded areas has been recorded from 51 ha in 2023, to 173 ha in 2024[1] (BMEL 2024b). However, this is still far from the goal of 7500 ha set by the Ministry of Agriculture's "CAP Strategy Plan" (BMEL 2024b). Furthermore, the DeFAF argues that although this development is a step in the right direction, the subsidy should be increased to at least 600 Euros per hectare of wooded area in order to cover the costs required to maintain agroforestry systems, as well as substantially promote the adoption of agroforestry practices (DeFAF 2024a).

The requirements to receive the subsidy are also complex and specific, limiting the proper layout of agroforestry systems which can be highly versatile and tailored to the field in question (DeFAF 2022). The new adjustments for to the eco-regulation for 2025 show significant improvements of this by eliminating the required minimum width of wooded strips and allowing greater flexibility in the minimum distance between wooded strips (BMEL 2024a). Additionally, the maximum allowed share of wooded area in an agroforestry system will be increased from 35% to 40%, whilst the previously mandatory submission of a "utilisation plan" for the agroforestry system will be dropped (BMEL 2024a). Whilst these show positive changes in the bureaucratic complexities that face agroforestry adoption, the subsidy still has significant limitations, including the ability to harvest different crops in one agroforestry field, as well as an extensive list of prohibited tree species in agroforestry systems (DeFAF 2024a). Furthermore, the subsidy excludes organic farmers who already receive subsidies related to organic farming, from additionally receiving agroforestry subsidies (DeFAF 2023). In light of the upcoming national election in February 2025, a likely change in government under the possible leadership of the Christian Democratic Party could see unravelling of these improvements over the next few years (Awater-Esper 2025).

[1] Data recorded from May in both 2023 and 2024

The second CAP pillar is based on voluntary schemes implemented at federal state level in Germany, which includes support for investments in agroforestry systems (BMEL 2023b). Whilst this allows funding schemes to be adapted to state-specific needs, it has led to only a few states introducing agroforestry support at all. The federal states which have established individual subsidy programs for agroforestry systems are Bavaria, Mecklenburg-Western-Pomerania, Lower Saxony, and Saxony. An overview of these programs can be seen in Table.1.

*Table 1: Investment Funding Schemes for AF in the Federal States of Germany*

| | Subsidy scheme | Max. possible funding per AF project | Time frame |
|---|---|---|---|
| Bavaria | Max. 1566 €/ha for woody vegetation<br>Max. 4138 €/ha for shrubs<br>Max. 5271 €/ha for tree produce | 50,000€, at maximum wooded area 9.5 - 31.93 ha | 01.01.2023 – 31.12.2027 |
| Mecklenburg-Western-Pomerania | Max. 1566 €/ha for woody vegetation<br>Max. 4138 €/ha for shrubs<br>Max. 5271 €/ha for tree produce | 300,000€, at maximum wooded area 56.9 - 191.57 ha | 14.07.2023 – 31.12.2027 |
| Lower Saxony | Initial grant up to 40% of expenditure for establishment of first silvoarable AF | 20,000€ | 26.04.2023 - 31.12.2024 |
| Saxony | Funding up to 40% of investment which is min. 50,000€, only silvoarable AF | 5,000,000€ for whole period 2023 - 2027, min. 8 ha field size | 01.01.2023 – 31.12.2027 |

(Bayerisches StMELF 2024; Sächsisches SMEKUL 2023; MKLLU MV 2023; Niedersächsisches MELV 2023)

Bavaria was the first state to introduce an investment funding scheme for agroforestry systems, including traditional meadow orchards and modern agroforestry (Bayerisches StMELF 2024). The amount of subsidy depends on the structure of the system, with farmers being able to receive a maximum of 1566 €/ha for woody vegetation, 4138 €/ha for shrubs, and 5271 €/ha for tree produce such as food and high-value timber. The maximum funding per agroforestry project is capped at 50,000€, at a maximum wooded area of 9.5 - 31.93 ha. However, only silvoarable and silvopastoral alley cropping systems are funded, with the requirement that the farming field is at least 3 ha large. Furthermore, agroforestry projects can ony be funded if the application is registered before the system has been established, placing further restrictions on farmers receiving funding.

Mecklenburg-Western-Pomerania’s subsidy scheme is similar to Bavaria’s, with the same amounts for the different woody vegetation structures. However, there is no minimum field size, and the maximum funding per project is capped at 300,000€. The maximum wooded area is also much larger at 56.9 - 191.57 ha.

Lower Saxony offers only an initial grant of up to 40% of the investment expenses to establish an agroforestry system, with a maximum funding amount of 20,000€. However, this funding is limited to a farmer’s first agroforestry system and only covers expenses in purchasing planting material and protection such as fencing, meaning other expenses including labour costs or maintenance of the system are not eligible. Only silvoarable systems are included in the scheme, however there is no minimum size of cultivated area or wooded area required.

Saxony’s funding scheme also only includes silvoarable agroforestry systems, with up to 40% of the investment being subsidised. The maximum funding for the entire scheme period of 2023 – 2027 is 5,000,000€ with no differentiation between system structures as long as it is silvoarable. However, there is a required minimum investment of 50,000€ to receive any funding in the first place, as well as a field size of at least 8 ha. Additionally, the farm manager must prove sufficient qualifications such as an agricultural training certificate for various levels of investment support. This could exclude farmers who do not have the required certificates from receiving funding, distorting the support system based on educational background.

Although there are differences in the four state funding schemes, they all share various limitations on which systems and farmers can receive funding. This does not encompass the high diversity of agroforestry systems, or the inherent benefit of tailoring agroforestry to the site-specific context and needs. With Lower Saxony and Saxony also exclusively funding silvoarable systems, this ignores silvopastoral systems which made up 45% of registered systems in the DeFAF AF map, and agrosilvopastoral which made up 16% (DeFAF 2024b). The bureaucratic hurdles of specific distancing regulations and required proof of a management concept are also not easing the path of agroforestry adoption (DeFAF 2023).

Furthermore, the provided subsidy amounts are nearly not enough to cover the costs of agroforestry establishment and management, which the DeFAF along with 100 stakeholders who signed a 2023 open letter addressed to agricultural ministers and senators, argued need to be increased drastically (DeFAF 2023). As only four states have established an agroforestry funding scheme, other states should be encouraged to follow suit. There are three more states which subsidise agroforestry consulting; Baden-Württemberg, Brandenburg, and Thuringia, but these are yet to establish investment support for the agroforestry systems (BZL BW 2024; Brandenburg MLEUV 2023; Landesverwaltungsamt Thüringen 2023). Alternatively, the introduction of a national funding scheme could cover this gap.

Addressing barriers to agroforestry adoption is thus largely interwoven with administrative burdens and the need to reform funding schemes. There is a variety of literature which addresses this issue (Tsonkova et al. 2018; Litschel et al. 2023; Klimke, Plieninger, and Zengerling 2024; Rois-Díaz et al. 2018). Whilst reforming funding structures is evidently a deciding step in expanding agroforestry in Germany, the potentiality of digital tools has still been sparsely researched. When considering the perceived issues of increased labour, management, and financial costs associated with agroforestry, as well as complexity of work and lack of required knowledge, digital tools could alleviate these challenges to various extents.

## 2.5 Overview of digital tools and technologies in agriculture

Digital tools and technologies are generally designed to enhance the efficiency of farming systems. Tools such as automation and control systems, data processing softwares, web-based applications and mobile tools can aid in increasing farm profitability by monitoring, evaluating and managing key farm components (Balasundram et al. 2023). This includes crop stress levels, livestock stress levels, soil conditions, water resources, and weather fluctuations, amongst other essential elements. As a result, farm productivity can be enhanced as well as product quality, with reduced operation costs, more informative decision-making and lower risk in the management system. From a sustainability perspective, this increased efficiency can alleviate agricultural pressures on the environment. Reduced water stress levels through the optimisation of irrigation practices, reduced chemical inputs, alongside a reduction in the area of land required has led digital technologies to be hailed as a sustainable solution (Papadopoulos et al. 2024; MacPherson et al. 2022; Balasundram et al. 2023).

There are various technologies in the agricultural sector which have emerged as forms of digitalisation to increase farm management efficiency. Precision Agriculture (PA) involves the application of farming inputs concerning irrigation, pesticides, fertilisation, seeding and planting, and tillage, in the right amount, at the right place and time. This can also be applied to livestock with Precision Livestock Farming (PLF). Raw data can be extracted from various sources including satellite images, in situ sensors and mobile sensing platforms (Balasundram et al. 2023). This can improve various agricultural perspectives; a) agronomic perspective by considering the real-time needs of crops and livestock; b) technical perspective by establishing better time management; c) environmental perspective by reducing agricultural inputs and effects and; d) economic perspective through increased productivity, yield efficiency and reduced amount of input needed (Dayioğlu and Turker 2021).

Smart Farming (SF) usually refers to technologies that utilise sensors, robots, and Internet of Things (IoT) that are interconnected across the field to collect and analyse data for the management system (Wolfert et al. 2017). There is also Smart Livestock Farming (SLF) where these technologies can be applied in livestock housing. Compared to PA which only takes into account in-field variability, SF bases management not only on location, but also data from context, situation and triggered by real-time events (Wolfert et al. 2017). Yet as these categories largely overlap, various technologies such as site-specific nutrient management (SSNM), satellite maps, Global Positioning System (GPS), Unmanned Aerial Vehicles (UAV) and robotics can be used for multiple types of digital farming management (Figure 1).

*Figure 4: The Fundamental Components of Digital Agriculture from Cell Phone to Blockchain Technology*


*The fundamental components that make up digital agriculture can be seen in the blue blocks. This includes tools such as UAV technology, smart sensors, mobile and web-based applications, and precision positioning technology. Strategies and methodologies are also included with data analysis approach and simulation and modelling.*

(Abiri et al. 2023)

Whilst digital tools and technologies can play a crucial role in enhancing farm management efficiency and mitigating environmental pressures from agriculture, these benefits can only be realised with efforts from- and collaboration of technology providers, policymakers, researchers, and farmers (Balasundram et al. 2023). These technologies can be expensive and difficult to access, whilst also presenting a learning curve for both farmers and other stakeholders which might require additional training. Tranchina et al's study found stakeholders in agroforestry to especially value the user-friendliness and simplicity of tools, as well as an intuitive graphical interface to minimise the learning curve for users (2024).

The realisation of benefits from digitalisation have been observed to depend on various factors such as the farm size, management capabilities, user-friendly applications, and homogeneity of the location (Gabriel and Gandorfer 2023; Reith, Frisch, and Kunisch 2023; Munz, Gindele, and Doluschitz 2019). Collaboration amongst farmers, research institutions, and agricultural professionals will be required to develop, monitor, and assess the effectiveness of digital technologies (Balasundram et al. 2023). Furthermore, due to the novelty and consistently evolving nature of digital agriculture, there is still uncertainty surrounding its impact on sustainability as well as the power dynamics at hand (MacPherson et al. 2022). With digital tools collecting and analysing large quantities of farm data, there are concerns about ownership, control, privacy, security, and sovereignty of data (MacPherson et al. 2022; Rotz et al. 2019). The question of who has access to and control over this data reveals challenges and power dynamics between the various actors involved, which should be considered when assessing the role of digital tools in agriculture.

## 2.6 Agricultural digitalisation in Germany

Germany does not have a comprehensive policy dedicated specifically to digitalisation in agriculture (MacPherson et al. 2022). However digitalisation is included in one of the 12 “action areas” in the 2035 Arable Farming Strategy (BMEL 2020). This strategy includes the following digitalisation measures; i) establish an independent quality control entity to assess digital applications; ii) improve soil health through digital tools; iii) promote digital technology for small and medium-sized farms, alongside multi-farm use; iv) establish statutory framework conditions for digitalisation; v) establish nationwide coverage of GPS and ensure access to data for farms; vi) establish test sites across Germany; and vii) review conditions to establish sovereignty of data for farmers (BMEL 2020).

Whilst data from the early 2000s shows Germany’s adoption of agricultural technologies to lag behind many other large-scale agricultural regions worldwide (Lowenberg-DeBoer and Erickson 2019), a more recent comprehensive database of digitalisation in German agriculture is missing. Research on the factors affecting the adoption of digital technologies has been conducted. When looking at the adoption of PA as a digital technology, various studies found that with increasing farm size, the adoption rates and perceived benefits of PA increased in Germany (Gabriel and Gandorfer 2023; Munz, Gindele, and Doluschitz 2019; Paustian and Theuvsen 2017). This confirms how economies of scale can enhance the benefits digital tools present. However, it may also reveal the potential problem that digital tools are tailored towards larger farm sizes, as smaller farms have different needs which need to be taken into account for effective digitalisation (Pfaff et al. 2022). Although 45% of farms in Germany are under 20 ha large, digital innovation tends to focus on larger farms with the needs of smaller farms potentially being overlooked (Kümmelberger, Hackfort, and Gugganig 2024).

Other factors affecting PA adoption were observed in Paustian and Theuvsen's study, with results showing that full-time farmers were more likely to adopt PA than part-time farmers (2017). Farmers with less than five years of experience in crop farming, as well as those who already had 16-20 years of experience were more likely to have adopted PA, indicating the experienced farmers on the one hand, and young technology-savvy farmers on the other (Paustian and Theuvsen 2017). The age group in-between may be missing out on the advantages of digitalisation. Furthermore, higher level of education correlated with economic and ecological benefits of digital technologies being valued higher, suggesting that skilled workers might increase the realisation of the advantages of digitalisation (Munz, Gindele, and Doluschitz 2019). This reveals that training programs for farmers and advisors need to be strongly geared towards new digital technologies.

Considering the available research on digital tools in agriculture, this study aims to address these potentials and challenges within the context of agroforestry. Leaning on the results found by these previous studies on digitalisation in agriculture, hypotheses have been formulated which will be outlined in the following section.

# 3. Methodology

## 3.1 Research objective

The objective of this study is to gain an understanding of the role digital tools play in the establishment and ongoing management of agroforestry systems in Germany. This includes assessing the prevalence of the adoption of digital tools in agroforestry, as well as potential demographic differences such as age, gender, and farm size. Furthermore, the perceptions of stakeholders who work in federal states which have investment funding schemes for agroforestry and those which do not will be compared, to reveal whether this is a determining factor. The aim is to shed light onto the potential advantages these tools present, as well as to identify the gaps in their usage and thus key leverage points. The following hypotheses have been formulated, partly leaning on the previously explored contextual research:

**H1**: States with agroforestry investment funding schemes have a higher prevalence of agroforestry

**H2**: Younger stakeholders are more likely to adopt digital tools in agroforestry

**H3**: Larger farms have a higher adoption rate of digital tools in agroforestry

**H4**: Farmers from states with agroforestry investment funding schemes are more likely to adopt digital tools in agroforestry

The study will analyse the collected results in light of whether or not they support each hypothesis respectively (Chapter 5 Discussion). Subsequently, further theories and hypotheses may be formulated as a result of the data analysis, to be investigated in future research.

## 3.2 Exploratory study

This study is primarily exploratory, aiming to gain insights into the emerging research field of digital tools in agroforestry in Germany. Döring differentiates between three types of study designs: exploratory, explanatory and descriptive (Döring 2023c). Exploratory research intends to gain a preliminary understanding of an unexplored research area, from which research questions, hypotheses and theories can be formulated and devised for future studies (Döring 2023c; Wolf et al. 2016). Explanatory research on the other hand, intends to identify, verify and assess specific hypotheses which have been derived from established theories (Döring 2023c). Although this study has formulated hypotheses based on previous literature on digitalisation in agriculture, these are preliminary. Explanatory research questions require comprehensive theoretical understanding of the field in question, usually investigating hypothesised causal mechanisms (Wolf et al. 2016). As there is little to no literature on digital tools in agroforestry in Germany, this study falls predominantly into the field of exploratory.

Descriptive studies on the other hand are used to determine relative or absolute frequencies, averages of variables or correlations amongst populations, focusing on ‘how’ rather than ‘why’ (Wolf et al. 2016). Although descriptive data analysis will be conducted for this study, it will be within the context of exploratory research and not to collect and analyse empirical data. Descriptive studies generally aim to determine characteristics, effects and distributions within large populations (Döring 2023c). Firstly, the scope of this study is not broad enough to describe a large population, as the abundance of stakeholders within agroforestry in Germany is still uncertain yet most likely still relatively low. Secondly, as mentioned previously concerning explanatory research, there is too little comprehensive understanding of the topic. Thus, an exploratory research design has been adopted for this paper.

Exploratory studies often use qualitative research methods such as qualitative survey questions or interviews, as these often allow for unrestricted answers which can give useful insights into unexplored fields of research (Döring 2023a). However, as this study is aiming to compare stakeholder perceptions across various groups, it is suitable to collect as many individual perspectives as possible in order to identify possible correlations and patterns. Interviewing a small number of individuals from across the federal states would likely give interesting insights into their perceptions of agroforestry and digital tools, however this could not then be extrapolated to compare different demographic groups or states. Conducting in-depth interviews with a larger sample of stakeholders would be ideal, however this falls outside of the feasible resources available for this study. Thus, a quantitative survey was conducted in order to gain an overview of perceptions across Germany.

Döring states that quantitative data methods can be used for exploratory studies (2023a). These typically involve non-probabilistic samples that are easily accessible, where a wide range of variables are collected. This is accurate for this study, as the survey sample has not been selected randomly but rather has been selected according to the criteria of being a stakeholder in agroforestry. Furthermore, the survey includes a substantial range of questions hence a wide range of variables, in order to increase the chances of identifying relevant or potentially unexpected effects. This is supported through the use of descriptive and visual data analysis. Cluster-analysis can also be used to identify certain differences or patterns between groups within the study sample (Döring 2023a). For this study, differentiating between responses from individuals in federal states with state subventions and those without subventions would be of interest, to understand the efficacy of funding schemes. Furthermore, factors such as age, education, type of farming system and type of stakeholder are relevant groupings, based on previous findings explored in the background chapter.

## 3.3 Study design

The study design is comprised primarily of a quantitative survey, alongside data from the DeFAF agroforestry map. Whilst the background chapter presented published data from the DeFAF map at the end of 2023, this study includes unpublished data from the end of 2024 which was provided by the DeFAF. This provides new insights into the development and distribution of agroforestry systems across Germany, as well as the prevalence of different agroforestry types. An overview of the share of stakeholders including agroforestry systems, scientific facilities, information or education offices, and interested parties can be observed. The data will then be compared with the survey data by looking at aspects such as digital tool usage in light of agroforestry distribution.

The main body of data used for this study is derived from the online quantitative survey on digital tools in agroforestry in Germany. The survey was conducted in collaboration with the DeFAF as part of the broader Horizon Europe project DigitAF, which aims to increase the implementation of agroforestry practices across Europe by overcoming socio-technical barriers (DigitAF 2024). The project embodies a consortium of 25 European and international partners, which established and are working with six Living Labs across the EU to develop and improve digital tools tailored to the needs of diverse agroforestry stakeholders. Within the context of this project, the survey was designed and established by the DeFAF in early 2024 with the objective of collecting multi-stakeholder perspectives on digital tools in agroforestry across the federal states of Germany. The target respondents are stakeholders working in agroforestry, meaning that the sample is not randomly selected but rather represents perspectives from relatively informed and interested parties in agroforestry, thus the results should be interpreted within this context.

The survey was conducted using Google Forms where participants could self-administer their participation. Approximately 15 minutes were needed to complete the survey, with a total of 37 questions split into 5 sections. The following section outlines the survey questions and how they were chosen.

## 3.4 Survey Questions

The development of the survey questions entailed a two-step process. The first step consisted of the establishment of an extensive survey which was used in Tranchina et al's study within the scope of the DigitAF project (2024). The content included detailed questions on digital tools in agroforestry, as well as policy-related questions, technical, economic, and administrative issues, and tree, crop, and animal interactions (Tranchina, Burgess, et al. 2024). These topics had been introduced to the participants prior the survey conduction during meetings of the Living Labs, with the survey being slightly adapted to local context for each respective Living Lab. The second step entailed the DeFAF selecting the most interesting and relevant questions from this extensive survey, to be compiled into a new survey focused on digital tools in agroforestry. I joined the project after this questionnaire had been established, hence I had no influence on the final questions.

The survey questions were categorised into five sections. However, as the sections and questions had been compiled from the original extensive survey, these were sometimes not aligned into the most cohesive order. Thus, for the sake of clarity, this study has slightly adapted the groupings into the following five categories:

i) Characteristics of respondents

    This includes age, gender, federal state in which the participant works in, educational background, occupation, farm size, and finally the type of farming system the participant works in.

ii) Farm infrastructure and available resources

    Participants are asked to score their knowledge in agroforestry, as well as the level of digitalisation their farm enterprise is currently at, the available internet connection and mobile service, their perceived financial situation, as well as level of workload.

iii) Behavioural characteristics of respondents

    This includes questions on how far participants perceive themselves as trusting of others, passive, lazy, or creative, amongst others.

iv) Digital tools usage

    Participants were asked whether or not they use digital tools in their farm enterprise, as well their intention to implement digital tools within the next five years.

v) Attitudes towards digital tools in agroforestry

Respondents were asked multiple sub questions in respect to their attitudes towards each of the following five factors: (a) interest and enjoyment in interacting with digital tools; (b) the ability to implement digital tools; (c) the necessity to implement digital tools for farm efficiency; (d) the influence of others to implement digital tools; and (e) trust in data protection.

This study chooses to leave out category three “behavioural characteristics of respondents” from the data analysis. Although these personality traits may be relevant factors affecting the adoption of digital tools in agroforestry, they address individual behavioural and cognitive variables which rather fall under sociological or psychological research and can be explored thoroughly in a separate study.

The majority of questions were posed using a Likert-type scale, excluding yes or no questions or questions on the general characteristics of respondents. Likert scaling is one of the most widely used approaches to measuring respondents’ attitudes in survey research, asking participants to indicate the intensities of their specified measured characteristics (Döring 2023b). Depending on the topic of the question, the scaling included to what extent respondents:

i) Agree or disagree with a statement
ii) Believe a topic to be positive or negative
iii) Believe s statement to be applicable or not applicable to their situation
iv) Find a topic important or unimportant
v) Have knowledge of a given topic
vi) Trust or do not trust

There were six response options, starting at e.g. Strongly disagree, Disagree, Somewhat agree, Agree, Strongly agree, and finally the option to not answer. Once the data was collected, answers were converted into a numerical five-point scale, where 1 = Strongly disagree and 5 = Strongly agree. Responses with no answer or “prefer not to answer” were marked as 0.

## 3.5 Survey conduction

My first responsibility, in collaboration with the DeFAF, involved distributing the survey. The first target group were stakeholders that had registered their agroforestry enterprise in the DeFAF's agroforestry map and had agreed to share their contact details. This consisted of 122 contacts distributed across 12 of the 16 federal states, of which three email addresses turned out to be invalid. These contacts were systematically listed according to federal state and assigned a personal code. In June 2024, I proceeded to send out survey invitation emails to each individual, explaining the objective of the survey within the context of the DigitAF Horizon Europe project as well as this study. Furthermore, in order to increase participation incentive, the survey included a prize draw of three books on the topic of agroforestry which was funded by the DeFAF. After two weeks, individuals which had not yet participated in the survey were sent a reminder email to kindly fill out the survey.

After a limited number of responses came back, further institutions linked to agroforestry and agriculture more generally were contacted with the request to distribute the survey amongst their members. This included the various federal state institutions of the agricultural working group *AbL*, as well as the German Farmer's Federation (DVB) and their respective state federation. Unfortunately, only the *AbL Mitteldeutschland* agreed to include information about the survey in their newsletter at the end of July 2024, with a link to participate in the survey. Some institutions rejected the request, but most never responded.

Additionally, flyers with information on the survey as well as a QR code linked to the survey were printed and distributed by the DeFAF at the *Bauerntag* (farmer's day) at the end of June 2024 in Cottbus. The flyer was also sent out alongside the yearly DeFAF report by post to the association's members. At the end of September 2024, the DeFAF included an invitation to participate in the survey in their newsletter. The survey was concluded at the end of October 2024, with three participants drawn at random as the winners of the prize draw.

## 3.6 Data processing

The online survey data was uploaded from the protected Google sheet to Excel. Four additional respondents who had participated in a previous trial-survey in Brandenburg containing the same survey questions, were added to the data set. The first step was to clean the data to remove any anomalies and reorganise the data in a unified structure. As most responses were recorded nominally on a Likert-type scale, these were converted into a numerical scale from 1- 5 to allow for statistical analyses. Some data inputs with multiple responses where the responses were contradicting each other were removed e.g. one participant indicating “I strongly agree” and “I do not agree” for the same question. Multiple responses where the responses were not necessarily contradicting were averaged e.g. one participant indicating 5 for “I strongly agree” and 4 for “I agree” for the same question was converted to a response of 4.5. Binary responses were converted into dummy variables, with yes = 1 and no = 0.

The fifth category of questions asks respondents about their attitudes towards digital tools. This included multiple sub questions which were asking respondents about the same underlying factor e.g. how far respondents enjoy and are interested in interacting with digital tools. This particular factor asked respondents to score their aggregability with statements such as “I like to test the functions of new digital tools” and “It is enough for me that a digital tool works; I don’t care how or why”. The responses of these sub questions were combined to create a composite score for each respondent concerning the respective factors (Lee 2011). These composite scores are equivalent to latent variables, of which the means as well as consistencies of the set of questions representing each factor were calculated using DataTAB.

As the sample size will be relatively small due to the still niche practice of agroforestry in Germany, primarily descriptive analyses will be conducted to reveal potential trends in the data. These trends can still be informative, as exploratory research gives us initial insights into potential theories and patterns which can be verified with further research. Daniel argues that for exploratory objectives small sample sizes can suffice, as the researcher is not attempting to make conclusive analyses (2012). As a rule of thumb for nonprobability sampling, around 20-150 participants can be sufficient depending on the research design for exploratory research (Daniel 2012).

Considering Johnson and Morgan’s analysis of survey scale data, descriptive analysis first evaluates frequencies to understand the frequency distribution of the results (2016). For measures of central tendency, the mean and median will be assessed. Concerning measures of variability, standard deviation will be calculated. These descriptive analyses will be compared across different demographic groups such as age, educational background, and gender using Pivot Tables on Excel. To compare results between states with investment funding schemes for agroforestry and those without different statistical tests were carried out. For the farm infrastructure and resources section a Mann-Whitney test was conducted using DataTAB. This was chosen due to the independent samples of these two groups, as well as the likert-type scaled questions (Döring 2023b; Albers 2017). The Mann-Whitney test can help determine whether one group tends to rank higher than the other group. For the section comparing the latent variables, the Mann-Whitney test is not appropriate as the data inputs are not on an ordinal scale anymore, but rather compiled averages of respondents' perceptions. A t-test would be applicable if the study sample was larger, however due to the smaller study sample, we only compare the means.

Finally, to evaluate whether there are correlations between separate variables, two correlation matrices was created using Excel and DataTAB. The first correlation matrix includes farm infrastructure and resource variables using the spearman correlation analysis. This was used due to the likert-type ordinal scale of the farm infrastructure questions (Humble 2020). The second correlation matrix includes the calculated latent variables for the five factors in relation to perceptions of digital tools. This correlation matrix uses the Pearson correlation analysis, as the compiled values are not on an ordinal scale anymore, but in the form of metric values (Humble 2020). As the sample size is relatively small, only a correlation value larger than 0.4 was categorised as significant to increase reliability of the results.

# 4. Results

## 4.1 DeFAF Agroforestry Map

Data from the DeFAF agroforestry map at the end of 2024 shows a total of 203 self-registered agroforestry systems in Germany, an increase by 42 registries since the end of 2023 (Table 2). The total agroforestry system area has also increased from 1304 ha to 1703 ha, marking an additional 399 ha in 2024.

*Table 2: DeFAF AF Map Data of Distribution across Germany's Federal States, 2024*

| State | Number of AF systems 2024 | Total AF area 2023 | Total AF area 2024 | % Increase in AF area |
|---|---|---|---|---|
| *Baden-Württemberg* | 28 | 165 | 181 | 9.6 |
| *Bavaria* | 41 | 274 | 274 | 0.1 |
| *Brandenburg* | 19 | 221 | 362 | 63.8 |
| *Hessen* | 30 | 86 | 136 | 58.2 |
| *Mecklenburg-Western-Pomerania* | 6 | 51 | 73 | 42.2 |
| *Lower Saxony* | 30 | 222 | 305 | 37.4 |
| *North Rhine-Westphalia* | 11 | 35 | 38 | 8.1 |
| *Rhineland-Palatinate* | 11 | 11 | 72 | 553.6 |
| *Saarland* | 1 | 15 | 15 | 0 |
| *Saxony* | 6 | 18 | 26 | 44 |
| *Saxony-Anhalt* | 8 | 118 | 121 | 3.1 |
| *Schleswig-Holstein* | 6 | 32 | 32 | -1.6 |
| *Thuringia* | 6 | 57 | 68 | 19.6 |
| ***Total*** | **203** | **1304** | **1703** | **30.6** |

*13 out of the 16 federal states were included in the AF Map. Total AF area includes the area of agroforestry systems registered in the DeFAF agroforestry map. The DigitAF survey responses will be explored in the following subchapter, however have been included in this table for later comparison of the response rates and agroforestry distribution.*

The largest number of agroforestry systems was recorded in Bavaria with 41, followed by 30 in Hessen and Lower Saxony respectively. The four states with investment funding schemes had an average number of 20.75 AF systems, whilst the other nine states without investment funding schemes had a somewhat lower average number of 13.3 systems. The largest area of agroforestry in ha is led by Brandenburg (362), Lower Saxony (305), and Bavaria (274). The total area of agroforestry in Germany increased by 30.6% from 2023 to 2024, with the most significant increase seen in Rhineland-Pfalz (553.6%) although the initial small area allowed for higher exponential increase. Brandenburg saw the second largest increase, which is especially significant in light of the relatively large area it already had. Saarland, Bavaria and Schleswig-Holstein hardly changed or did not change.

Additionally, the frequencies of the different types of agroforestry across Germany were distributed as follows: silvoarable (93), silvopastoral (79), and agrosilvopastoral (31). Looking at stakeholder types apart from agroforestry systems, there were 18 Interested parties in agroforestry, 18 consulting companies, 17 research institutions, and 6 related service providers.

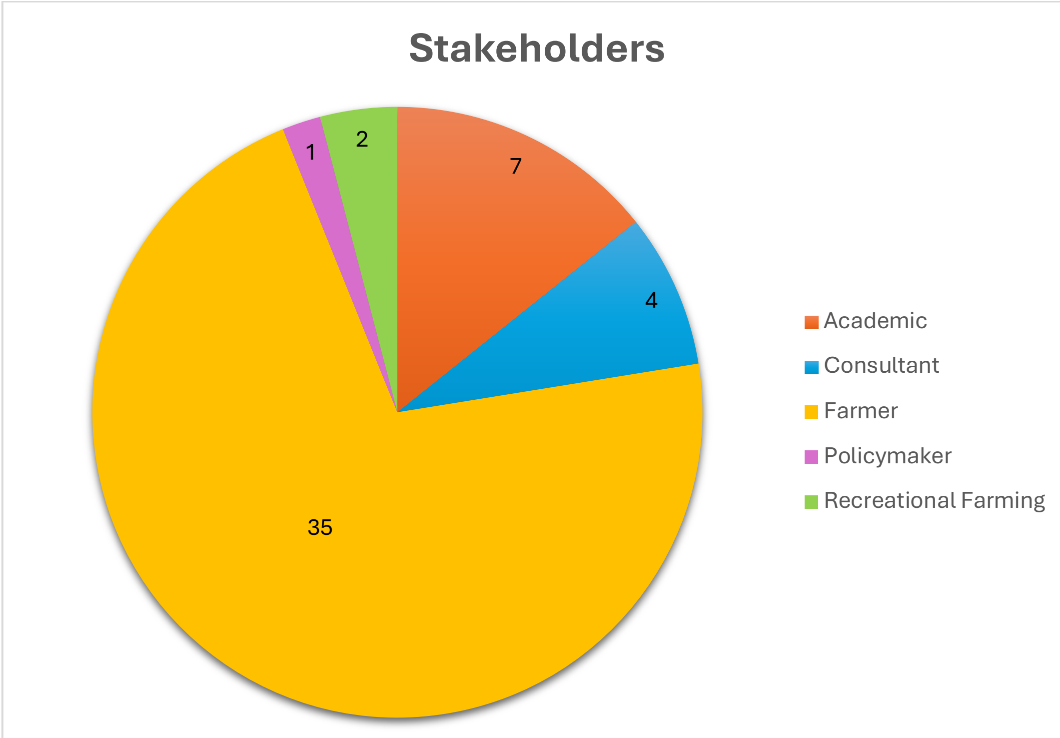
## 4.2 DigitAF Survey Descriptive Analysis

A total of 49 stakeholders from 9 federal states completed the questionnaire, including the 4 additional entries from the trial-survey in Brandenburg. That makes up 24% of the total 203 self-registered agroforestry systems from the DeFAF agroforestry map. Calculating an accurate response rate is difficult, as although the majority of responses were submitted after having contacted the initial target group from the DeFAF agroforestry map contact list, individuals independent from the agroforestry map were also contacted through the external newsletter and distribution of the survey flyer. We can assume it is somewhat lower than 24%.

### *4.2.1 Respondents Demographics*

The first section of the survey concerned general characteristics of the respondents. The distribution of respondents across Germany's federal states is as follows: Bavaria (10), Brandenburg (8), Baden-Württemberg (7), Hessen (7), Lower Saxony (5), Mecklenburg-Western-Pomerania (2), Saxony-Anhalt (2), Rhineland-Palatinate (2), Saxony (1). Looking at gender, 67.3% of participants identified as men and 28.6% as women. Age was relatively evenly distributed, with ages 18-35 years encompassing 26.53%, 36-50 years 28.57%, 51-65 years 34.69%, and 66+ years 10.2%. Concerning the occupational representation of different stakeholders in agroforestry, farmers and landowners made up the largest share with 35 participants, followed by 7 academic representatives from education and research, 4 farming consultants, 1 political representative from government or administration, and 2 other stakeholders who indicated their involvement in recreational farming (Figure 2).

*Figure 5. Pie Chart of the Occupations of Stakeholders Represented in the Survey*




*The pie chart illustrates the large share of farmers represented in this study with a total of 35 out of 49 respondents. This was followed by 7 academics and 4 consultants. Policymakers were only represented by 1 respondent, whilst 2 participants were involved in recreational farming.*

Respondents could not choose multiple answers concerning their occupation; however, a few "non-farmers" gave answers to questions concerning their individual farm characteristics such as size and infrastructure, suggesting that stakeholders were involved in more than one profession. Therefore, these answers have not been excluded from the data sample concerning farm characteristics.

The sample showed a high level of education, with 9 respondents obtaining a doctoral degree, 7 a master's degree, 11 a diploma, 9 a bachelor's degree, 7 a high school certificate, and 4 completing secondary school (up to 16 years old). One person did not disclose their educational background. Farmers had the largest range of educational attainment spanning from secondary school education to doctoral degrees, whilst the other stakeholder groups mostly obtained at least a bachelor's degree or higher (Table 3). Yet the majority of farmers still obtained higher education with many respondents indicating *Diplom Ingenieur*, a traditional engineering degree somewhat equivalent to a master's degree in engineering. The other groups almost exclusively obtained university education ranging from bachelor's degrees to doctoral degrees, with only one consultant obtaining a secondary school education.

*Table 3. Educational Level Obtained According to Stakeholder Group*

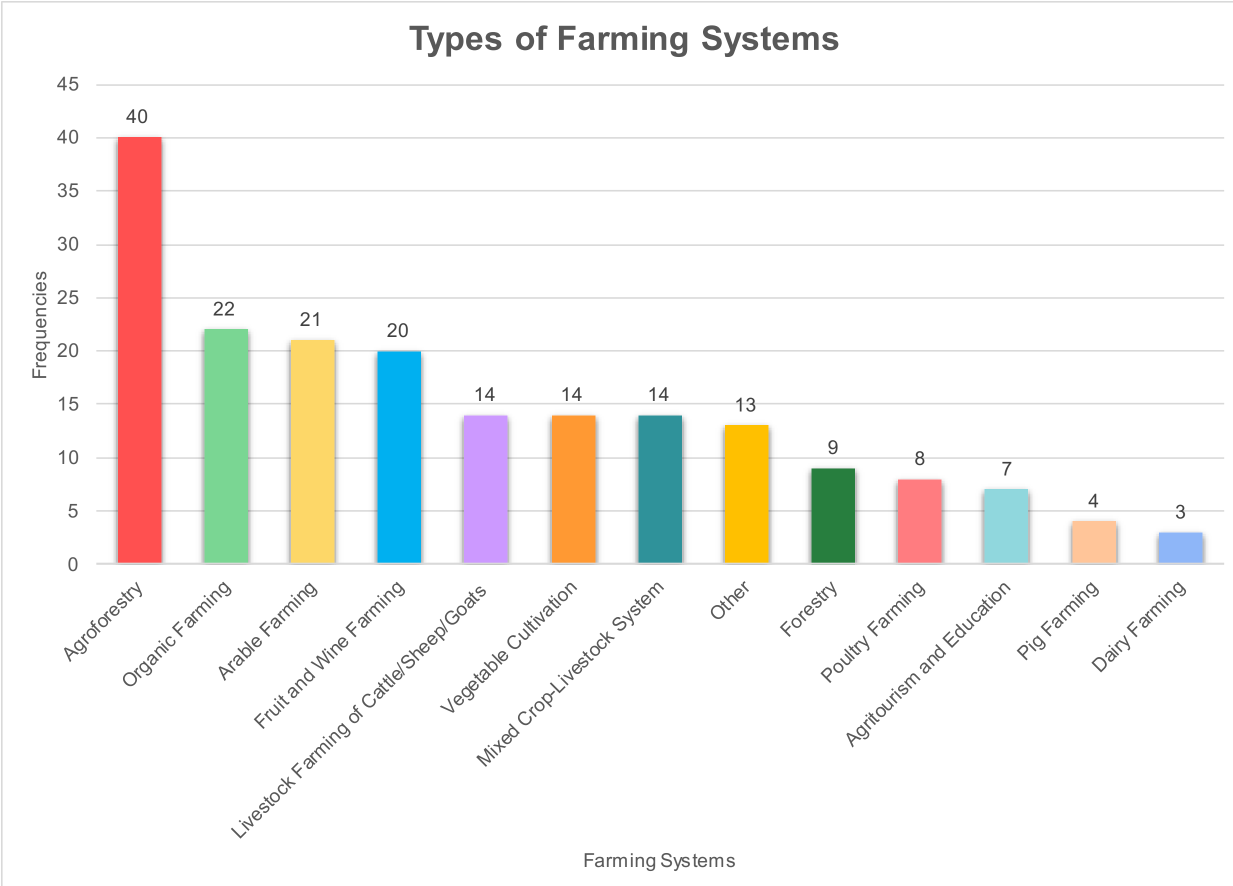
| | | Stakeholder | | | | | |
|---|---|---|---|---|---|---|---|
| | | Farmer | Policymaker | Academic | Consultant | Recreational Farming | **Total** |
| *Education level* | *Secondary School* | 3 | 0 | 0 | 1 | 0 | **4** |
| | *High School* | 7 | 0 | 0 | 0 | 0 | **7** |
| | *Undergraduate and Graduate degrees* | 18 | 1 | 4 | 3 | 2 | **28** |
| | *PhD* | 6 | 0 | 3 | 0 | 0 | **9** |
| | ***Total*** | **34** | **1** | **7** | **4** | **2** | **48** |

*The category "Undergraduate and Graduate degrees" includes bachelor's degrees, diplomas, and master's degrees. These three educational certificates were combined into one category to reduce confusion over the proper categorisation of the traditional diplomas in Germany. Secondary School is equivalent to the German "Realschule" and High School is equivalent to the German "Abitur". The total is 48 as one person did not disclose their educational background.*

The average farm size was 49.4 ha[2], somewhat lower than the 65 ha average across Germany. The largest average was seen in Saxony-Anhalt (200), followed by Brandenburg (88), Lower Saxony (48.8), Hessen (46.4), Bavaria (42.1), Saxony (15.6), Mecklenburg-Western-Pomerania (14.5), Baden-Württemberg (11.2) and Rhineland-Pfalz (0.8). Considering the types of farming systems, the majority of participants selected agroforestry (40). As multiple selections were possible, other types of farming systems were also relatively highly represented (Figure 3). Organic farming (22), arable farming (21), and fruit or wine farming (20) were the leading categories after agroforestry, with mixed crop-livestock systems (14), vegetable cultivation (14), and livestock farming of cattle, sheep or goats (14) receiving the same distribution.

[2] This calculation includes all stakeholders who indicated their farm size, including "non-farmers".

*Figure 6. Bar Chart of the Types of Farming Systems Represented in the Study*




*The bar chart shows the representation of each farming type in the study sample. As respondents could choose multiple farming types, there are many more data entries than there are respondents. Therefore, all the frequencies added together is greater than the total number of respondents in this study sample.*

### *4.2.2 Farm Infrastructure and Available Resources*

In order to understand the conditions under which respondents are working in agroforestry, questions were asked concerning individuals' farm infrastructures and the availability of resources. Looking at agroforestry in general, respondents were asked to indicate the level of agroforestry knowledge they would ascribe themselves on a scale of 1 to 5, with 1 being the lowest and 5 the highest. A mean score of 3.73 was recorded which is relatively high, with the majority of participants indicating level 4 or 5 (Table 4). Only three participants chose level 1 or 2.

*Table 4. Farm Infrastructure and Available Resources according to Respondents' Perceptions*

| | *AF Knowledge* | *Farm Digitalisation* | *Internet Connection* | *Mobile Service* | *Financial Situation* | *Workload* |
|---|---|---|---|---|---|---|
| *Mean* | 3.73 | 2.85 | 3.74 | 3.11 | 3.04 | 3.77 |
| *Median* | 4 | 3 | 4 | 3 | 3 | 4 |
| *Mode* | 4 | 3 | 4 | 4 | 3 | 4 |
| *Standard Deviation* | 0.88 | 1.22 | 1.17 | 1.18 | 0.8 | 0.55 |

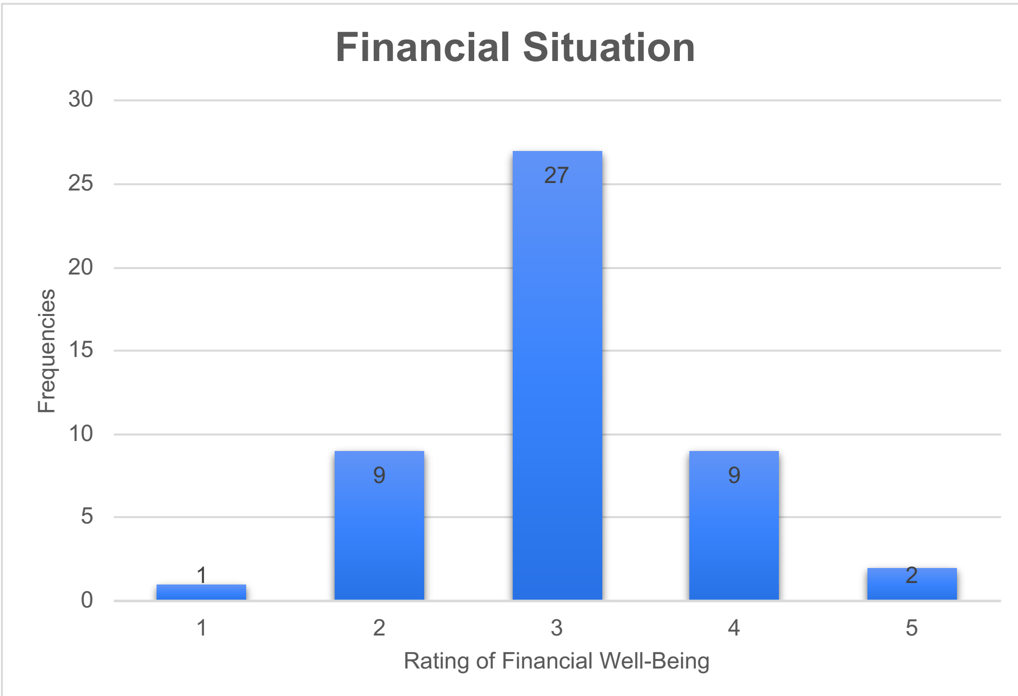
*Data includes all stakeholders. All variables are classified on a scale from 1 to 5, with 1 indicating a low level and 5 a high level. Farm Digitalisation refers to the level of digitalisation the respondent has been acquainted with and has implemented in their farming system. Internet Connection and Mobile Service refers to the availability of these connections on their farming system. Financial Situation indicates how good or bad the respondent finds their own financial situation. Workload represents the level of perceived workload, with 1 and 2 indicating too little, 3 neutral, and 4 and 5 too much.*

Considering the degree of digitalisation of respondents' farming systems, the mean level of farm digitalisation was slightly below the median at 2.85, although the standard deviation was higher than the other variables suggesting some variability between participants. The highest frequencies were still seen in level 3 "I know that there are digital tools in agroforestry and am seeking further information", or level 4 "I use digital tools in agroforestry to a small extent and am seeking further information", with both categories receiving 11 indications respectively. When looking at the different age groups, the highest mean was in fact seen in the oldest group of 66+, with an average digitalisation of 3.6. The younger age groups all averaged between 2.63 and 2.83. With regards to gender, women had a lower mean of system digitalisation with 2.5, compared to the mean of 3 for men.

Available internet connection was relatively high (3.74), slightly higher than available mobile service (3.11), with both values indicating high variability in the sample.  Looking at the different age groups, there were some discrepancies. The youngest age group scored the highest mean for available internet connection (4), whilst this was the lowest for 51–65-year-olds (3.6). The group of 51-65 also scored lowest for available mobile service (2.8), with the oldest group of 66+ somewhat surprisingly scoring the highest mean of 3.4. In relation to farm size, we see the largest farms which are 100-400 hectares large, scoring the highest mean for both internet connection and mobile service.

When asked about their own perceived financial situation, respondents averaged at 3.04 with 56% choosing level 3. This implies that the majority perceived their financial situation as not particularly good or bad. When looking at the overall distribution, a relatively equal number of participants were positioned at either end of the scale, with 11 indicating level 4 or 5, and 10 indicating level 1 or 2 (Figure 4).

*Figure 4. Bar Chart of Respondents' Perceived Financial Situation*




*The bar chart illustrates respondents' own perceived financial well-being, with the question in the survey expressed numerically on a scale from 1 to 5. This means that there is no qualitative description corresponding to the levels.*

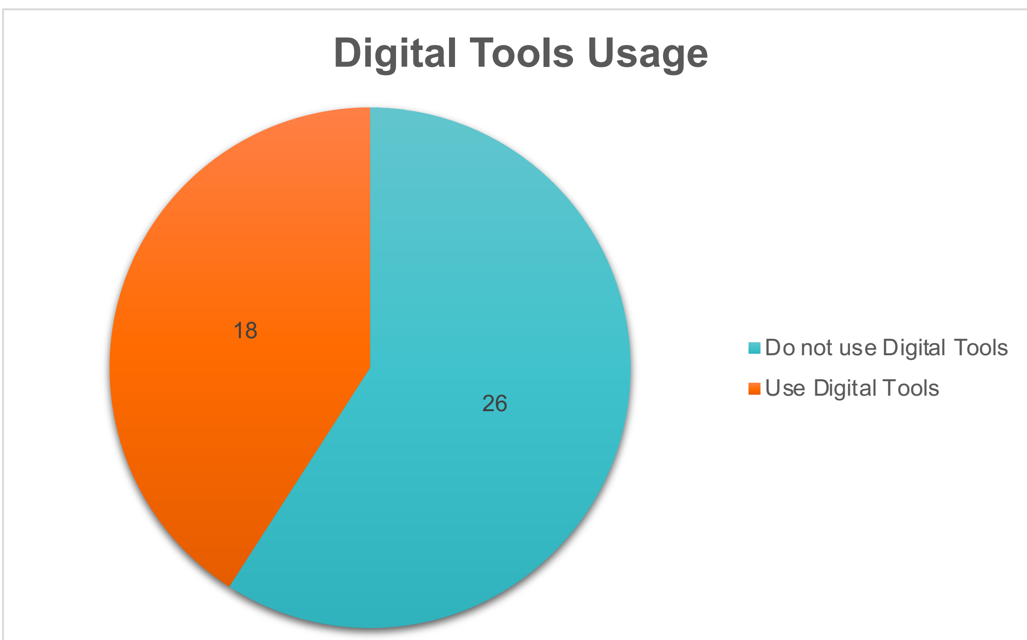
Looking at respondents' occupations, most types of stakeholders scored an average perceived financial situation that reflected the entire sample's mean of around 3. However, the group of consultants had a lower mean of 2.5. Comparing the different age groups, the perceived financial situation improved with age. The youngest group 18-35 had the lowest mean rating of financial well-being with 2.62, followed by 36-50 with 3.07, then 51-65 with 3.13, and finally 66+ with 3.8. The difference is especially significant when comparing the youngest age group and the oldest age group.

Respondents were asked to evaluate how high their workload is on a scale of 1 to 5, where 1 corresponds to much too low, 3 indicates that it is balanced, and 5 being much too high. The mean perceived workload was relatively high at 3.77 with a low standard deviation, whereby all 49 respondents indicated a level of 3 or above. Therefore, all respondents deemed their workload as balanced or too high. This was similar for all occupational stakeholder groups, with the policymaker indicated that their workload was much too high. The majority of respondents, 31 out of 49, chose level 4 “too high”. This was similar for all age groups which all averaged between 3.4 and 4 and thus, suggesting that the perceived workload within our sample did not change significantly with age. There were also no significant discrepancies found between the different farm sizes or educational levels.

### 4.2.3 Digit Tools Usage

Looking at the use of digital tools amongst agroforestry stakeholders in our sample, a larger share of stakeholders indicated that they do not collect farm data digitally or use apps or softwares to manage their farm. 26 respondents indicated “no”, whilst 18 indicated “yes” (Figure 5). If only farmers are considered for this question, the share is similar with 20 farmers indicating “no” and 13 “yes”. Out of the 4 consultants in the sample, only 3 participated in this question with 2 indicating that they do not use digital tools whilst 1 consultant indicated that they do use digital tools. This reveals that within the study sample, digital tools are not used by the majority with no significant difference between farmers and other stakeholders.

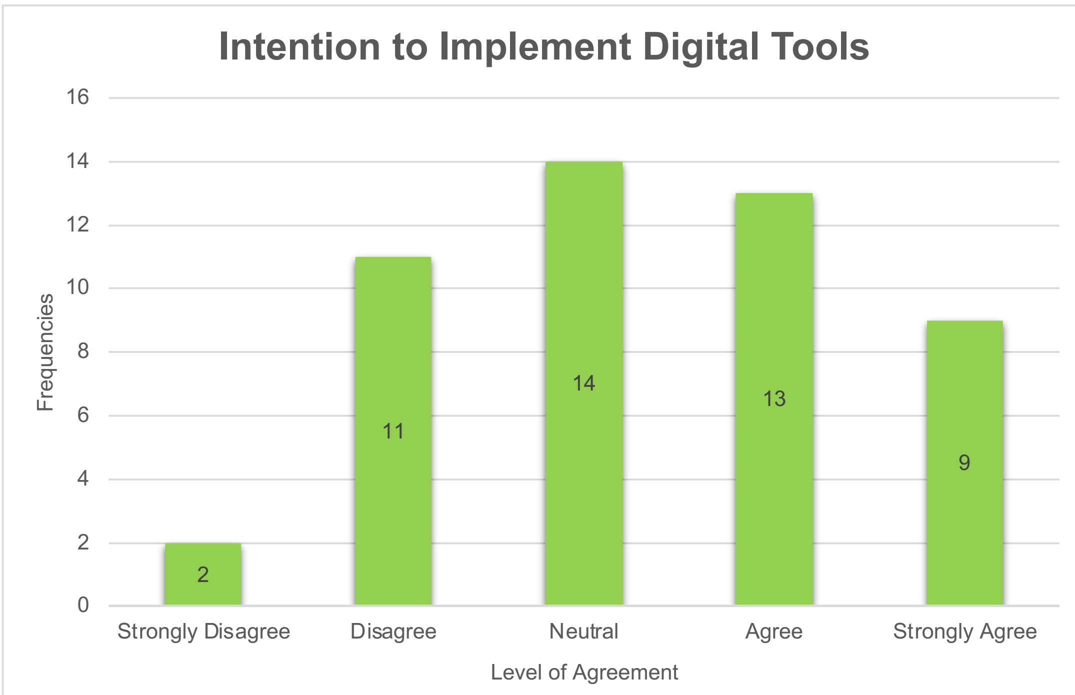
*Figure 5. Pie Chart Representing whether or not Respondents use Digital Tools*




*The pie chart shows the share of respondents who use digital tools and those which do not for all stakeholders. The total number of respondents for this question is 44, as 5 respondents chose not to answer*

Respondents were also asked about their intention to implement digital tools in agroforestry in the next five years. The majority responded “neutral” (14), closely followed by “agree” (13), “disagree” (11), “strongly agree” (9), and finally only two chose “strongly disagree” (Figure 6). The mean (3.33) was somewhat higher compared to the following statement in the survey concerning respondents’ *absolute* certainty to implement digital tools in agroforestry in the next five years (3.18). However, overall, these results show a high variability in respondents’ intentions to digitalise their farming systems in the coming years.

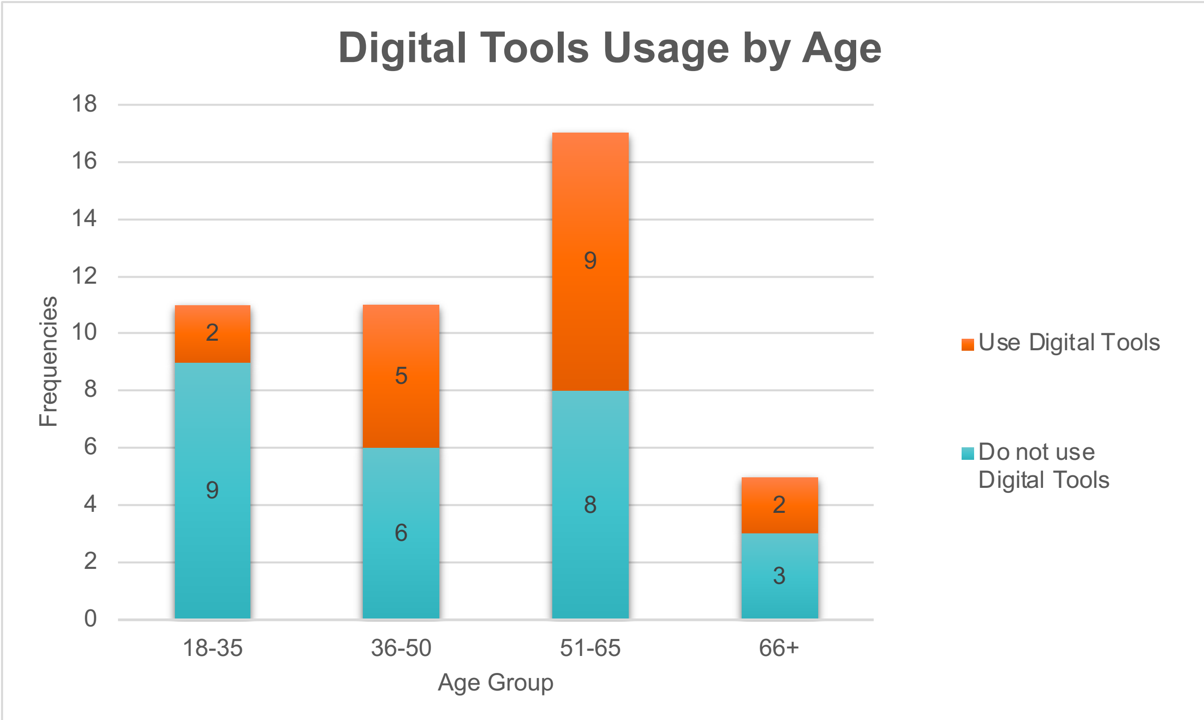
*Figure 6. Bar chart of Respondents' Intentions to Implement Digital Tools in AF in the Next 5 Years*




*The bar chart depicts the frequencies of each level of agreement corresponding to the statement “I intend to implement digital tools in agroforestry on my farm in the next 5 years”.*

Comparing different age groups, there was a noticeable variation considering the usage of digital tools, as well as the intention to implement them in the coming years. When looking at the current usage of digital tools, we can see that for the age groups 36-50, 51-65, and 66+, there was a relatively equal share of respondents who use digital tools and those which do not (Figure 7). Somewhat surprisingly however, the youngest group 18-35 predominantly does not use digital tools in their farming system, with only 2 out of 11 responses indicating that they do.

*Figure 7. Bar Chart of Respondents' Digital Tools Usage According to Different Age Groups*

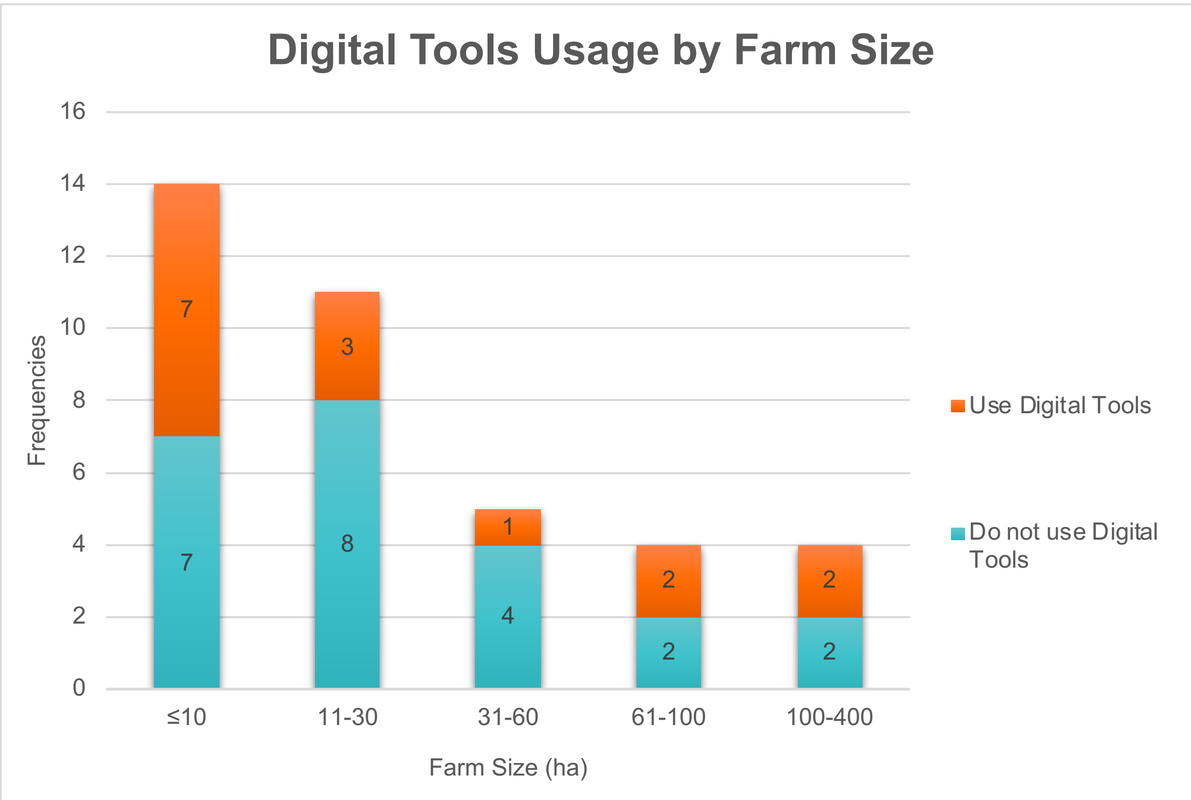



*The bar chart shows the share of digital tools usage for each of the different age groups. Age groups were already categorised in the survey, with respondents having the option of selecting one of these four groups. The red segment represents the share that uses digital tools, whilst the blue segment represents the share that does not.*

Yet this pattern changed when looking at the intention to implement digital tools in agroforestry in the next 5 years. The group of 18–35-year-olds measured a mean score of 3.31, close to the 3.33 average for all respondents. The majority of this youngest group chose either "neutral' or "agree", with only 2 out of the 11 respondents indicating "disagree". This suggests that although the youngest group is lagging behind on current use of digital tools, the majority is not opposed to adopting tools in the future. The group of 36–50-year-olds had a mean score of 3.5, with a larger range of responses. Significantly, the group over 66 had the highest mean of 4.2, with all respondents in this group choosing either "neutral" or a positive response of 4 or 5. The lowest score was achieved by 51–65-year-olds with 2.94, with a greater share of respondents indicating that they disagree with the statement to implement digital tools in the future, compared to a positive agreement. This was also the only group which included "strongly disagree" responses.

Farm size is another factor that could influence the adoption or willingness to adopt digital tools. However, the results did not reveal particular discrepancies according to farm size, with no significant relationship found between farm size and digital tools usage. The categories of smallest farms which are smaller or equal to 10 ha, farms between 61 and 100 ha large, and the largest farms ranging from 100 to 400 ha, all saw an equal share of participants using digital tools and not using digital tools (Figure 8). The farms which were 11-30 ha or 31-60 ha large saw a majority not using digital tools, indicating a lack of digitalisation for medium-sized farms in this sample.

*Figure 8. Bar Chart of Digital Tools Usage According to Farm Size*




*The bar chart shows the share of digital tools usage for different farm sizes. Farm sizes have been categorised into 5 different groups following data collection. The smallest recorded farm was 0.35 ha, with the largest being 400 ha. The red segment represents the share that uses digital tools, whilst the blue segment represents the share that does not*

Looking at digital tool usage in agroforestry in relation to gender, we find that a smaller share of woman use digital tools in comparison to men, with 46.7% of men indicating that they use digital tools, whilst only 25% of women did.

### *4.2.4 Attitudes towards digital tools*

The first question concerning stakeholders' perceptions of digital tools, asked respondents to rank their attitudes towards digitalisation in agriculture and towards digitalisation in agroforestry on a scale of 1-5. 1 was equivalent to "very negative", whilst 5 represented "very positive". Overall, these scores were positive. The mean score for agricultural digitalisation was 3.88, somewhat higher than the mean of 3.77 for agroforestry digitalisation. There was an evident positive correlation between these two variables with a correlation coefficient of 0.79. This suggests that there is no evident perceived disparity between the digitalisation of agriculture and the digitalisation of agroforestry in this study sample.

Survey questions which were addressing the same underlying factors were grouped together to create various latent variables. A factor analysis reveals the means for these latent variables, as well as the consistency of the set of questions representing each factor, and the variability of responses. For all latent variables, the Cronbach's alphas were relatively high and thus we can rely on the latent variables to be representing their respective underlying factors accurately (Table 5).

*Table 5. Factor Analysis of Attitudes towards Digital Tools in Agroforestry*

| *Factor* | *Latent variable mean* | *Median* | *Cronbach's alpha* | *Standard deviation* |
|---|---|---|---|---|
| *Interaction with digital tools* | 2.81 | 2.5 | 0.93 | 0.86 |
| *Ability to implement digital tools* | 3.32 | 3.33 | 0.77 | 0.85 |
| *Necessity of digital tools for efficiency* | 2.79 | 2.88 | 0.88 | 0.91 |
| *Influence of others to implement digital tools* | 2.21 | 2.25 | 0.8 | 0.83 |
| *Trust in data protection* | 2.3 | 2.27 | 0.88 | 0.67 |

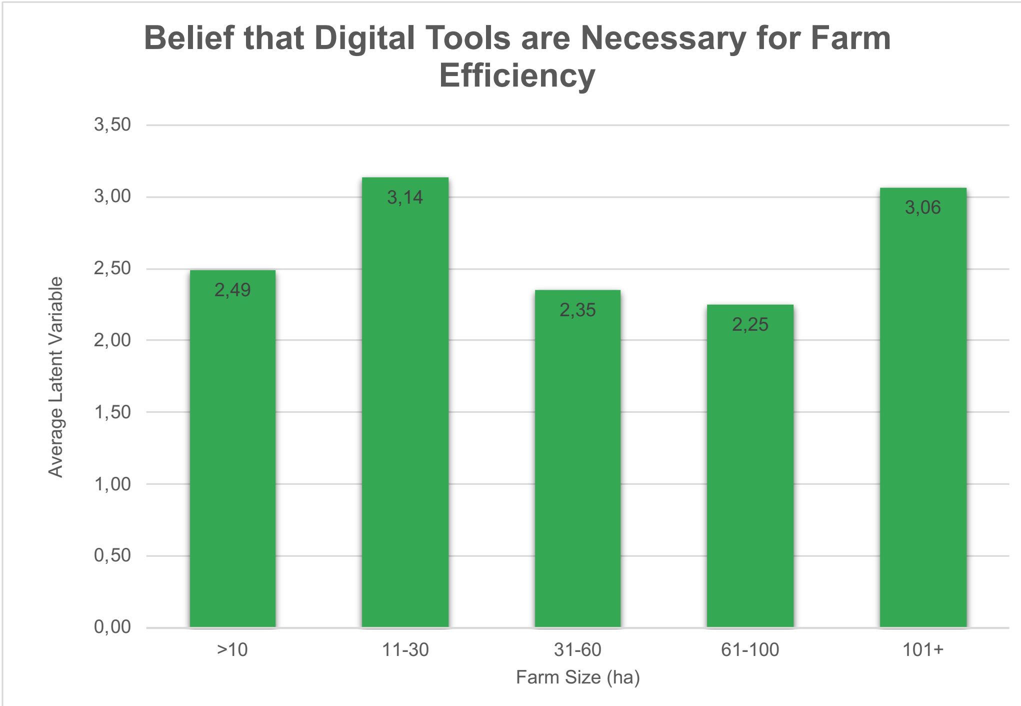
*The latent variable measures the mean of all participants' composite scores for the set of questions respective to each factor. Cronbach's alpha measures the internal consistency of a scale of questions, with values closer to 1 indicating a high consistency and thus reliability, and values closer to 0 lower consistency.*

The first factor "interaction with digital tools" concerns participants' interest and enjoyment in interacting with digital tools. Means closer to 1 indicate that participants do not enjoy interacting with digital tools, whilst means closer to 5 indicate that they do. The mean latent variable for all participants was 2.81 and the median 2.5, suggesting that on average participants are not especially excited to use and understand digital tools. When looking at the different stakeholders, consultants had the highest mean (3.42), whilst the other stakeholder groups all had mean latent variables closer to that of the entire group. Considering farm size, this factor was lowest for the group of 31-60 ha measuring a mean latent variable of 2.1, and the group of 61-100 ha with 2.29. The other farm sizes were closer to the 2.81 sample average.

The belief that participants are able to implement digital tools according to their knowledge and resources had a higher overall average, with a mean of 3.32 for the factor “ability to implement digital tools”. This suggests that the sample is relatively confident in their abilities to implement digital tools. Considering educational background, the group with the lowest score was the one which had attained a high school certificate (2.76), whilst the highest was measured for doctoral degree participants (3.81). Looking at farm sizes, the group which stood out was those between 31-60 ha with a mean of 2.6 which was much lower than the rest. Women scored significantly lower (2.9) compared to men (3.47).

The factor concerning participants’ perceived necessity to implement digital tools for farm efficiency was not particularly high with a latent variable mean of 2.79. Notably, the standard deviation was comparatively high suggesting that participants are less unified on this factor compared to the others. The age group above 66 had by far the highest mean of 3,4, whilst the other age groups remained closer to the overall mean. Regarding farm size, the lowest means were seen for the groups between 31-60 ha and 61-100 ha (Figure 9).

*Figure 9. Bar Chart of How far Respondents Believe Digital Tools to be Necessary for Farm Efficiency According to Farm Size*



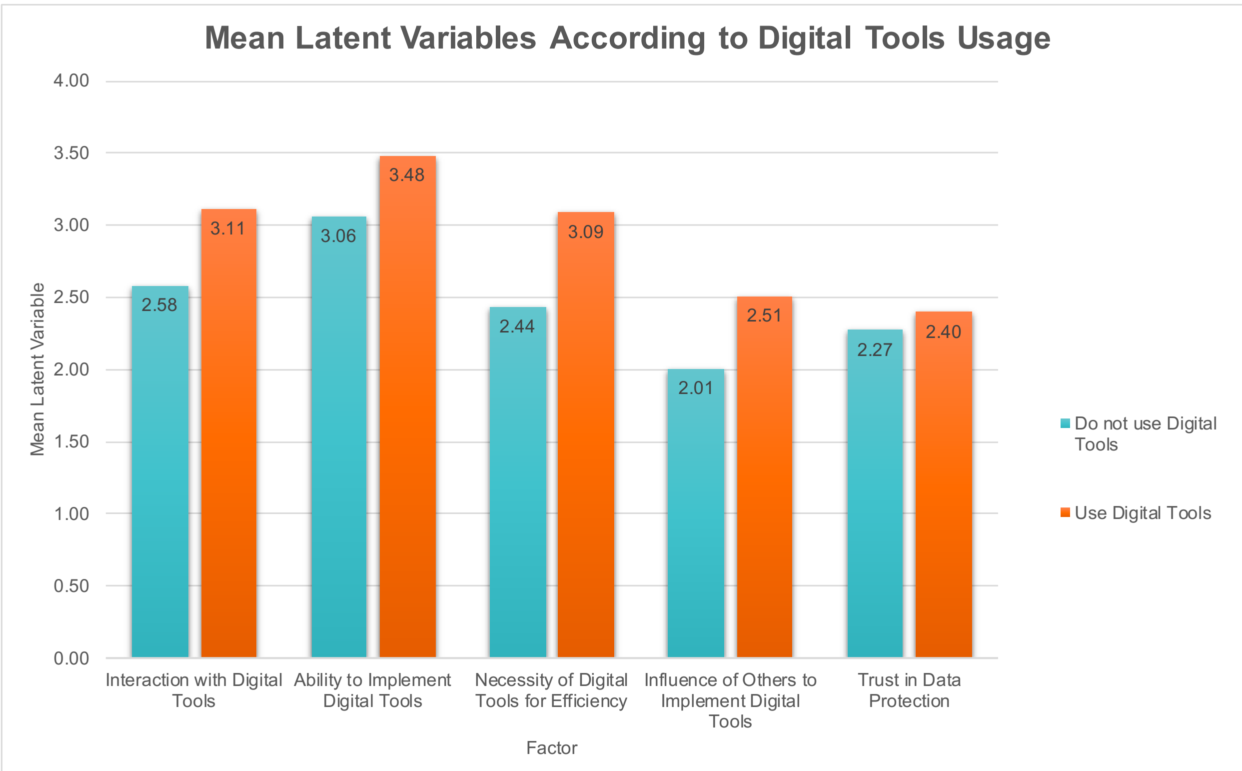

*The y-axis measures the mean latent variables for the factor concerning the belief that digital tools are necessary for farm efficiency. The mean latent variable can be seen for each farm size group defined along the x-axis.*

The factor concerning influence of others to implement digital tools had a relatively low mean of 2.21, suggesting that farmers, consultants, and friends of the participants are not widely recommending the use of digital tools. All age groups reflected this average except the 66+ group, with a mean of 2.98. Stakeholders did not show great discrepancies except for the policymaker, who indicated a level of 1 and therefore revealing that hardly anyone is promoting the use of digital tools in agroforestry to them. Farm sizes did not measure significantly differently.

The factor "trust in data protection" was also low, indicating that participants are generally not trustful of digital tool providers having access to- and protecting their data. Once again, the age group over 66 had a higher mean that stood out, with 3.09 compared to the average 2.3. Comparing the different farm sizes, we find that the group of 11-30 ha had the highest mean in data trust with 2.85, whilst the significantly lowest mean was measured for farm sizes between 61-100 ha with 1.66.

The factor which showed discrepancies for all mean latent variables was whether or not participants use digital tools. For all five latent variables, we see the group which does use digital tools scoring higher means than the group which does not (Figure 10).

*Figure 10. Bar Chart of all five Factors Examined in Relation to Digital Tools According to Digital Tools Usage*




*The x-axis shows the different factors included in this study's factor analysis, with the respective mean latent variables for the group which does use digital tools (orange) and the group which does not use digital tools (blue).*

For almost all five factors, we see the group which uses digital tools scoring a higher mean by around 0.5 more points than the group which does not use digital tools. Only the factor concerning trust in data protection showed a similar mean for both groups, suggesting that the experience of using digital tools regularly does not significantly increase participants' trust of digital tool providers having access to- and protecting their data. Otherwise, we see the group which uses digital tools indicating higher levels of interest and enjoyment in using digital tools, higher confidence in their ability to implement them, a greater belief that digital tools are necessary for farm efficiency, and greater influence of others around them promoting the implementation of digital tools.

## 4.3 Comparison of DeFAF Agroforestry Map data and DigitAF survey data

Before looking more specifically at the results according to the availability of investment funding schemes, we can compare our overall sample results to the data recorded from the DeFAF Agroforestry Map. We can see a general trend where states which recorded the highest number of agroforestry systems in 2024, were also the states that received the highest number of survey responses (Table 6). This is particularly the case for Bavaria, Hessen, and Baden-Württemberg, which are amongst the top five states with the most recorded agroforestry systems. Bavaria had the most agroforestry systems with 41, as well as the most survey responses with 10. Those states which had the lowest number of agroforestry systems below 10, such as Mecklenburg-Western-Pomerania, Saxony, and Thuringia, also had very low response rates or no responses at all. Yet there is no perfect correlation between these data sets, as Brandenburg had the second highest number of responses in the survey with 8, but the fifth highest number of agroforestry systems with 19. Lower Saxony also has a high number of agroforestry systems but falls somewhere in the middle with 5 responses from the survey.

*Table 6. Data from the DeFAF Agroforestry Map alongside data from the DigitAF survey*

| *State* | *Number of AF systems 2024* | *Total AF area 2024* | *Survey responses* | *Survey AF systems* | *Survey digital tools usage %* |
|---|---|---|---|---|---|
| *Baden-Württemberg* | 28 | 181 | 7 | 6 | 67 |
| *Bavaria* | 41 | 274 | 10 | 8 | 33 |
| *Brandenburg* | 19 | 362 | 8 | 4 | 57 |
| *Hessen* | 30 | 136 | 7 | 7 | 33 |
| *Mecklenburg-Western-Pomerania* | 6 | 73 | 2 | 1 | 50 |
| *Lower Saxony* | 30 | 305 | 5 | 5 | 20 |
| *North Rhine-Westphalia* | 11 | 38 | 0 | N/A | N/A |
| *Rhineland-Palatinate* | 11 | 72 | 2 | 2 | 0 |
| *Saarland* | 1 | 15 | 0 | N/A | N/A |
| *Saxony* | 6 | 26 | 1 | 1 | 0 |
| *Saxony-Anhalt* | 8 | 121 | 2 | 1 | 50 |
| *Schleswig-Holstein* | 6 | 32 | 0 | N/A | N/A |
| *Thuringia* | 6 | 68 | 0 | N/A | N/A |
| ***Total*** | **203** | **1703** | **49** | **40** | **41** |

*The data highlighted in the first two columns is from the DeFAF Agroforestry Map from the end of 2024 for each represented federal state. The last three columns show us data from the DigitAF survey. The survey responses show us how many respondents came from each respective state. The Survey AF systems show us how many respondents indicated that their farming system is agroforestry. The survey digital tools usage %, shows us the share of respondents from each state that indicated that* *they use digital tools in agroforestry. The total for this last variable is 41, as 5 respondents did not answer this question, 3 respondents work nationally and do not work in a specific state, and 3 respondents did not disclose their state.*

Looking at the distribution of survey respondents who indicated that their farming system incorporates agroforestry, we similarly see a higher number amongst those states which had a higher number of agroforestry systems recorded in the DeFAF Agroforestry Map. Bavaria had the highest number with 8 respondents indicating their management of agroforestry, followed by Hessen (7) and Baden-Württemberg (6). However, this result may not be so surprising as the survey sample consists of stakeholders in agroforestry. Thus, the higher response numbers will likely correlate with more agroforestry systems in the survey.

Regarding the share of respondents who indicated their use of digital tools, the highest percentages were recorded in Baden-Württemberg (67%) and Brandenburg (57%). Mecklenburg-Western-Pomerania and Saxony-Anhalt also saw 50% use digital tools, however as these samples consisted of only 2 participants, these statistics may not be so insightful. Bavaria on the other hand only saw a third of respondents use digital tools. The following section will look at these factors amongst others, by differentiating between states with investment funding schemes and states without.

## 4.4 DigitAF survey factor analysis of investment funding schemes

Refocusing on the survey data alone, this study examined whether the availability of investment funding schemes influenced respondents' attitudes toward digital tools in agroforestry. As the sample size is relatively small, the differentiation between each of the 10 represented federal states and their respective funding schemes in this survey will not be analysed in order to reduce the risk of insignificant results. Instead, the participants were grouped by states which have an established agroforestry investment funding scheme, and those which do not. States were allocated dummy variables where 1 indicated participants from states with funding schemes and 0 without. As this factor only concerns funding schemes for farmers, the comparative analysis only includes participants who categorised themselves as farmers, a total of 35 respondents. 16 farmers came from states with funding schemes, 15 from states without, and 4 did not indicate the state in which they practice, revealing a relatively evenly distributed sample.

### 4.4.1 Farm infrastructure and available resources

Looking at the differences in farm infrastructure and available resources between the group of farmers which comes from states which have agroforestry investment funding schemes, and the group which comes from states which do not, we find only one statistically significant difference. This difference was seen when comparing the own perceived financial situations of these two groups. Participants from states without investment funding schemes measured a mean of 2.7 whilst those from states with the investment funding schemes measuring at 3.5 (Table 7). The effect size r was 0.52 which is a large effect.

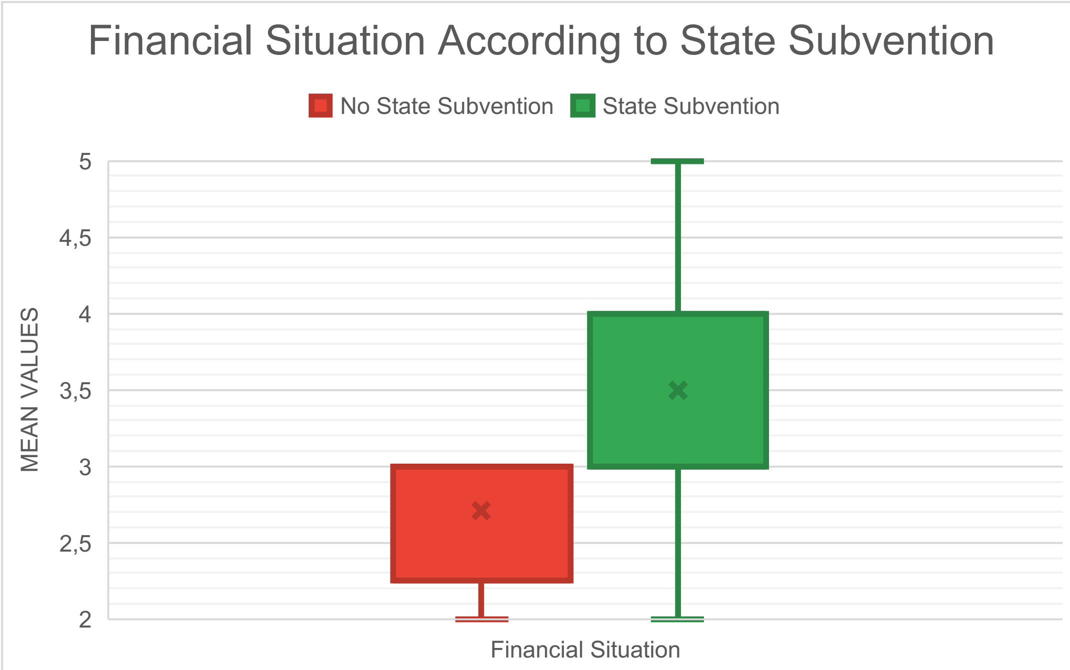
*Table 7. Mean Values of Farm Infrastructure and Available Resources for Farmers*

| *Question* | *State Subvention Mean* | *No State Subvention Mean* | *p* | *r* |
|---|---|---|---|---|
| *AF Knowledge* | 3.88 | 3.33 | 0.202 | 0.25 |
| *Farm Digitalisation* | 2.71 | 2.73 | 0.983 | 0.01 |
| *Available Internet Connection* | 3.56 | 3.69 | 0.948 | 0.01 |
| *Financial Situation* | 3.5 | 2.7 | 0.012 | 0.52 |
| *Workload* | 3.94 | 3.7 | 0.318 | 0.22 |

*The mean values between the group with state subvention for agroforestry and the group without are shown in the first two columns. A Mann-Whitney U-test was conducted to determine the statistical significance (p) of the difference between these two groups, and the effect size (r). The p-value determines whether or not the null hypothesis is rejected, with the null hypothesis being that there is no difference between the samples. The level of significance was set at 0.05, with p-values >0.05 being insignificant. The effect size r according to Cohen (1988) is 0.5 = large effect, 0.3 = medium effect, 0.1 = small effect, <0.1 is no/very small effect.*

Looking at the distribution of scores concerning financial situation, the highest and most frequently indicated ranking from farmers without investment schemes was 3, whilst farmers with the option of investment schemes went up to 5 (Figure 11). The state subvention group mostly chose 3 or 4. No one chose level 1 from either group.

*Figure 11. Box plot of Perceived Financial Situation for Farmers in States with and without Subvention*



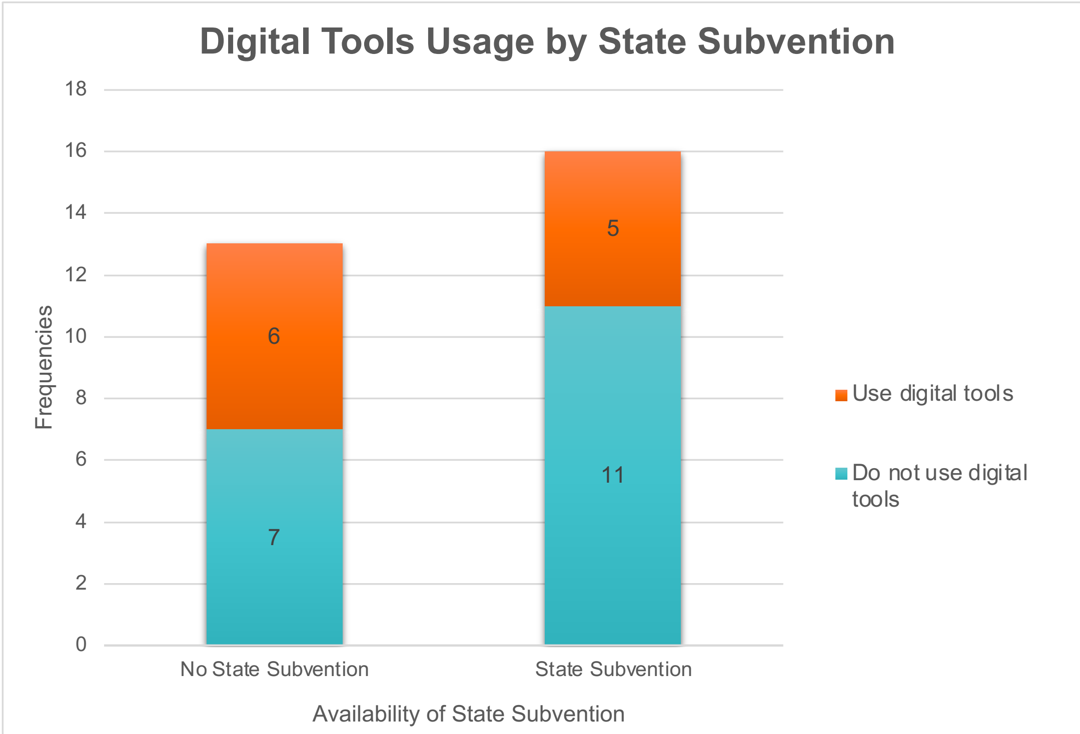

*The boxplot shows the two groups of respondents with no state subvention, and those with state subvention. On the y-axis the perceived financial situation is illustrated. The group with state subvention has a significantly higher mean and larger range than the group with no state subvention.*

Whilst the other variables did not show a statistically significant difference between the two groups, the mean score for Agroforestry Knowledge was higher for the group of farmers in the state subvention category (3.88), compared to the group without state subvention (3.33).

### *4.4.2 Digital Tools Usage*

Looking at farmers' digital tools usage according to the availability of agroforestry investment funding schemes, we see some variation. Interestingly, the group of farmers from states without state subvention saw a relatively equal share of participants use digital tools (Figure 12). However, the group of farmers from states with agroforestry subvention saw a larger share not using digital tools, with around 69% indicating that they do not use digital tools on their farm.

*Figure 12. Bar Chart of Digital Tools Usage between the Group with State Subvention and the Group without State Subvention*




*The bar chart shows the share of farmers who use digital tools within the two groups indicated on the x-axis; respondents from states with investment funding schemes for agroforestry and respondents from states without investment funding schemes. The group with no state subvention saw 15 respondents answer this question, whilst 16 from the group with state subvention answered.*

This suggests that within this study sample, stakeholders from states with investment funding schemes for agroforestry are less likely to be using digital tools in agroforestry. However, as two respondents from the group without state subvention chose not to answer this question, this is not fully representative.

### *4.4.3 Attitudes towards Digital Tools*

Looking at how farmers' perceptions towards digital tools in agroforestry differed between these two groups, we see some discrepancies. The group of farmers from states with subventions measured a higher mean for the factors of ability to implement tools, influence of others to implement tools, and trust in data protection (Table 8).

*Table 8: Comparing Factor Analysis between States with Subvention and States without*

| *Factor* | *Mean* | *Standard Deviation* |
|---|---|---|
| ***Interaction with digital tools*** | | |
| *State Subvention* | 2.71 | 0.84 |
| *No State Subvention* | 2.8 | 0.85 |
| ***Ability to implement digital tools*** | | |
| *State Subvention* | 3.28 | 0.62 |
| *No State Subvention* | 2.88 | 0.72 |
| ***Necessity of digital tools for efficiency*** | | |
| *State Subvention* | | |
| *No State Subvention* | 2.75 | 0.93 |
| | 2.86 | 0.84 |
| ***Influence of others to implement digital tools*** | | |
| *State Subvention* | 2.43 | 0.7 |
| *No State Subvention* | 2.01 | 0.9 |
| ***Trust in data protection*** | | |
| *State Subvention* | 2.59 | 0.89 |
| *No State Subvention* | 2.13 | 0.52 |

*The table shows each factorin question in the first column, differentiated between the group of farmers from states with subventions and the group of farmers from states without subvention. The two means for the two groups are presented with respect to each factor in the second column. The standard deviation for each mean can be seen in the third column.*

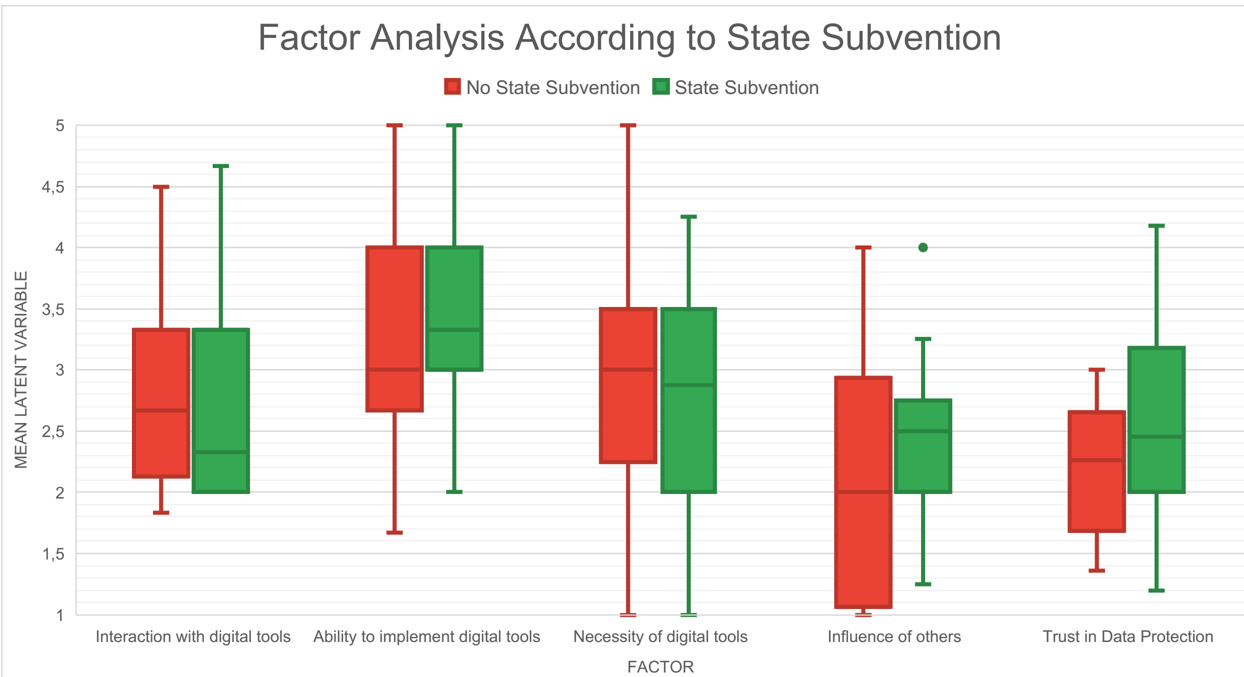
The factor of “ability to implement digital tools” summarised respondents’ answers to questions which asked how far they believe they can implement digital tools according to their knowledge and resources. The group of farmers who have access to state subventions scored a higher mean of 3.28 compared to the group without access with 2.88. This suggests that within our sample, the farmers who work in states that provide state subventions are more likely to believe that they can implement digital tools on their farms.

Regarding the influence of others to implement digital tools, we also see the group of farmers with access to state subventions scoring a higher mean, indicating that this group is more likely to have experienced farmers, consultants, and friends to recommend using digital tools in agroforestry. Yet the standard deviation for the group without access to state subventions had a relatively high standard deviation, suggesting there is more variability within this group’s answers. A similar trend is seen for the factor of trust in data protection, where the group of farmers with access to state subventions scored a mean of 2.69, compared to the

2.13 from the farmers without the state subventions. Compared to the other values, this mean from farmers without state subvention also measured the lowest standard deviation at 0.52, indicating that this group is relatively homogeneous on this topic of data protection.

The other two factors of interaction with digital tools and necessity to implement digital tools for farm efficiency did not show notable difference between these two groups, which is further reflected in their similar distributions (Figure 13).

*Figure 13: Boxplot of the Factor Analysis between States with Subvention and States without Subvention*




*The Boxplot indicates the differences in measured latent variables for the two groups of State Subvention and No State Subvention. The blue plots show us the results for the group without state subvention, whilst the red plots show the results for the group with state subvention.*

The most significant difference can be seen for the factor data protection, with the group of state subvention measuring a larger range as well as higher boxplot on the ranking scale. The somewhat higher scoring for the ability to implement digital tools, and influence of others also reflects the difference in means. Yet the factors concerning interaction with digital tools and the necessity of digital tools show relatively similar boxplots. This suggests that for the farmers in our study sample, state subventions in agroforestry are not necessarily affecting the farmers' level of interest or enjoyment in interacting with digital tools in agroforestry.

Likewise, this factor is not greatly affecting the belief that farmers need to implement digital tools in their farm in order to enhance their farm's efficiency.

## 4.5 Correlation analysis between variables

### *4.5.1 Correlation analysis between farm infrastructure and resource variables*

In order to reveal potential correlations between the different variables we have analysed from the entire study sample, a correlation matrix was created. This allows us to see whether certain variables are correlation with others. First, we consider the variables addressing participants' farm infrastructures and their available resources, alongside their overall perceptions of digitalisation in agriculture and agroforestry (Table 9).

*Table 9: Spearman's Correlation Matrix of Farm Infrastructure and Available Resource Variables*

| | | System Digitalisation | AF Knowledge | Financial Situation | Internet Connection | Mobile Service | Digitalisation in Agriculture | Digitalisation in AF | Workload |
|---|---|---|---|---|---|---|---|---|---|
| System Digitalisation | Correlation | 1 | 0,15 | -0,04 | 0,14 | 0,01 | 0,47 | 0,44 | -0,12 |
| | p | | ,369 | ,825 | ,407 | ,933 | ,003 | ,006 | ,473 |
| AF Knowledge | Correlation | 0,15 | 1 | 0,37 | -0,05 | -0,03 | -0,28 | -0,42 | -0,06 |
| | p | ,369 | | ,024 | ,781 | ,85 | ,09 | ,009 | ,745 |
| Financial Situation | Correlation | -0,04 | 0,37 | 1 | -0,27 | -0,02 | -0,13 | -0,14 | -0,15 |
| | p | ,825 | ,024 | | ,112 | ,925 | ,433 | ,411 | ,371 |
| Internet Connection | Correlation | 0,14 | -0,05 | -0,27 | 1 | 0,46 | 0,27 | 0,18 | 0,03 |
| | p | ,407 | ,781 | ,112 | | ,004 | ,112 | ,279 | ,855 |
| Mobile Service | Correlation | 0,01 | -0,03 | -0,02 | 0,46 | 1 | 0,26 | 0,1 | -0,03 |
| | p | ,933 | ,85 | ,925 | ,004 | | ,119 | ,547 | ,852 |
| Digitalisation in Agriculture | Correlation | 0,47 | -0,28 | -0,13 | 0,27 | 0,26 | 1 | 0,84 | 0,21 |
| | p | ,003 | ,09 | ,433 | ,112 | ,119 | | <.001 | ,211 |
| Digitalisation in AF | Correlation | 0,44 | -0,42 | -0,14 | 0,18 | 0,1 | 0,84 | 1 | 0,16 |
| | p | ,006 | ,009 | ,411 | ,279 | ,547 | <.001 | | ,337 |
| Workload | Correlation | -0,12 | -0,06 | -0,15 | 0,03 | -0,03 | 0,21 | 0,16 | 1 |
| | p | ,473 | ,745 | ,371 | ,855 | ,852 | ,211 | ,337 | |

*The correlation matrix shows each Spearman's correlation coefficient for the respective two variables. Values between -1 and 0 are negative correlations, whilst values between 0 and 1 are positive* *correlations. Only a correlation coefficient above 0.4 or below -0.4 will be counted as significant due to the small study sample. Below each correlation coefficient is the p-value, indicating the statistical significance of the correlation. The level of significance is set at p = 0.05.*

The strongest correlation can be seen for the two variables “Digitalisation in agroforestry” and “Digitalisation in agriculture”, with a coefficient of 0.84 and a reliable p-value of <.001. This indicates that participants who have a positive view digitalisation in agriculture, also view digitalisation in agroforestry positively. We also observe statistically significant correlations when looking at participants attitudes towards digitalisation, and how far they have implemented digital tools in their farming system. The variable “system digitalisation” and the variable “digitalisation in agriculture” have a positive correlation coefficient of 0.47, whilst a positive correlation coefficient of 0.44 is also observed between “system digitalisation” and “digitalisation in AF”. This indicates that participants who have a higher level of information and implementation of digital tools in agroforestry, also have a more positive perception of digitalisation in agriculture and digitalisation in agroforestry.

When we consider the variable “AF Knowledge”, we see a negative correlation with “digitalisation in AF” and a significant p-value of 0.009, suggesting that respondents who indicated a higher agroforestry knowledge have a more negative attitude towards digitalisation in agroforestry. Available internet connection and mobile service were positively correlated with a coefficient of 0.46, suggesting that if respondents have good availability of either internet connection of mobile service, they will also have a good connection of the other. The other correlation calculations revealed either a weak- or no correlation, or the p-value was insignificant.

### 4.5.2 Correlation analysis between latent variables

This section assesses potential correlations between the five factors associated with participants’ perceptions of digital tools in agroforestry. A correlation matrix with the respective latent variables was created to reveal any significant correlations (Table 10). Various significant positive correlations were found between these five factors. Looking at the first factor “Interaction with digital tools”, we see significant positive correlations with the factors “Ability to implement digital tools” and “Necessity of digital tools for efficiency”. This indicates that participants who enjoy and feel more comfortable using digital tools in agroforestry, also believe they have the ability to implement digital tools according to required knowledge and resources and have a greater belief that they need digital tools to enhance farm efficiency. There is an even stronger positive correlation between these two latter variables of "ability to implement digital tools" and necessity of digital tools for efficiency", with a coefficient of 0.58.

*Table 10. Pearson's Correlation Matrix of the Five Factors Associated with Participants' Perceptions of Digital Tools in AF*

| | | Interaction with Digital Tools | Ability to Implement Digital Tools | Necessity of Digital tools for Efficiency | Influence of Others to Implement Digital Tools | Trust in Data Protection |
|---|---|---|---|---|---|---|
| Interaction with Digital Tools | Correlation | 1 | 0,42 | 0,49 | 0,26 | 0,28 |
| | p | | ,004 | <.001 | ,072 | ,057 |
| Ability to Implement Digital Tools | Correlation | 0,42 | 1 | 0,58 | 0,36 | 0,23 |
| | p | ,004 | | <.001 | ,013 | ,121 |
| Necessity of Digital tools for Efficiency | Correlation | 0,49 | 0,58 | 1 | 0,56 | 0,4 |
| | p | <.001 | <.001 | | <.001 | ,005 |
| Influence of Others to Implement Digital Tools | Correlation | 0,26 | 0,36 | 0,56 | 1 | 0,18 |
| | p | ,072 | ,013 | <.001 | | ,228 |
| Trust in Data Protection | Correlation | 0,28 | 0,23 | 0,4 | 0,18 | 1 |
| | p | ,057 | ,121 | ,005 | ,228 | |

*The correlation matrix shows each Pearson's correlation coefficient for the respective two variables. Values between -1 and 0 are negative correlations, whilst values between 0 and 1 are positive correlations. Only a correlation coefficient above 0.4 or below -0.4 will be counted as significant due to the small study sample. Below each correlation coefficient is the p-value, indicating the statistical significance of the correlation. The level of significance is set at p = 0.05.*

Continuing with the variable "Necessity of digital tools for efficiency", a strong positive correlation was also found with the variable "Influence of others to implement digital tools", with a coefficient of 0.56. This suggests that participants who view digital tools in agroforestry as essential for farm efficiency, are also more likely to have received encouragement from their network to adopt these tools. Finally, there was also a positive correlation between "Necessity of digital tools for efficiency" and "Trust in data protection", implying that participants who indicated a high score for the necessity of digital tools, are also more trustful of service providers correctly handling and protecting their farm data.

# 5. Discussion

The results reveal how the characteristics and perspectives of a relatively small and diverse group of stakeholders in agroforestry can be highly variable. Nevertheless, some patterns and trends were observable and can shed light onto the perceptions towards- and factors influencing the establishment of digital tools in agroforestry.

## 5.1 Demographic representation

Looking at our two data sets from the DeFAF Agroforestry Map and the DigitAF survey, we find some consistency in the distribution of agroforestry and the survey response rates across the different federal states. Although this was not a perfectly linear relationship, it does provide a measure of reliability for the degree of representation of the study sample. The higher representation of agroforestry systems from the DeFAF Agroforestry map and survey respondents in Bavaria, Brandenburg, Baden-Württemberg, and Hessen could indicate higher prevalence of agroforestry in these federal states. The higher average number of agroforestry systems for the four federal states with investment funding schemes compared to the states without, supports our first hypothesis: states with agroforestry investment funding schemes have a higher prevalence of agroforestry. However, this hypothesis is not definitively proven. It could be that there are more farmers, or that there is more agricultural land in these states. Additionally, there may be more stakeholders willing to participate in initiatives such as the DeFAF or the DigitAF survey in these regions, whilst those who are less engaged may be overlooked. This can be similarly interpreted for the three states which did not yield any survey responses, suggesting the need for more targeted outreach especially in these underrepresented areas in future studies. Nevertheless, whilst the representation of agroforestry in each state is difficult to calculate, it is still insightful to record where engaged stakeholders in agroforestry are practicing and to continue building on this database. The increase in self-registered agroforestry systems in the DeFAF Agroforestry Map from 2023 to 2024 already demonstrates this positive development.

Looking at the individual characteristics of the survey participants, there was a higher representation of men with 67.3% men and 28.6% women, somewhat lower than the 36%

of women in agriculture Germany-wide (Bundesinformationszentrum Landwirtschaft 2023). Perhaps there are less women working in agroforestry compared to other agricultural practices, or less women are interested in digital tools in agroforestry. This second hypothesis would be supported by the survey results showing women to be less likely to be using digital tools in agroforestry than men. Women also scored lower levels concerning how far they have digitalised their farming system. Furthermore, women were significantly less likely to believe in their ability to implement digital tools in agroforestry, with regards to having access to the necessary resources and knowledge. On the other hand, Tranchina et al's study on digital tools in agroforestry found their study sample from Europe to have a higher proportion of female respondents (2024), suggesting that women do not necessarily have to be less interested or present in digital tools in agroforestry.

The relatively high educational attainment of respondents with 25 obtaining a bachelor's degree or higher, could indicate that stakeholders in agroforestry generally have a high educational background. This was particularly observable for non-farmer stakeholders, whilst farmers had a larger range of educational backgrounds. However, specified agricultural training was not included in the response options or added by respondents in the "other" category. There are European-wide statistics on the share of farmers who have obtained training in agriculture, which would have been interesting to compare with our sample's educational distribution. Other stakeholders including consultants, policymakers and academics almost exclusively obtained a bachelor's degree or higher, revealing a potentially skewed educational distribution in agroforestry. However, these stakeholder groups were also much smaller than the farmer group and thus, may have failed to capture accurate representation of educational attainment.

A great diversity of farming systems was represented in the study sample. A large majority identified as agroforestry practitioners, yet with substantial overlap with other farming systems such as organic farming and arable farming. As respondents largely chose agroforestry alongside other farming systems, we can see that agroforestry is perceived as a complementary rather than standalone strategy. This highlights the multifunctionality of agroforestry and the ability to integrate the practice into various farming systems. Furthermore, given the limitations of agroforestry subsidies, it highlights the need to permit the integration of agroforestry with other farming practices such as organic farming, without affecting eligibility for these subsidies.

## 5.2 Farm Infrastructure and resources

Looking at the conditions under which respondents are working in agroforestry, we see particular differences between the sample's age groups. The oldest group of participants aged 66 and above, demonstrated high mean scores for factors concerning digitalisation on their farm, such as how far their farm system is digitalised and their available internet connection and mobile service. This could reflect a certain level of experience that comes with age, as was found in Paustian and Theuvsen's study, where farmers who had the longest years of experience were more likely to have adopted precision agriculture technologies (2017). On the other hand, it does not fully explain the higher levels of available internet connection and mobile service.

Another factor which saw discrepancies between age groups was the participants' own perceived financial situation. The lowest mean rating was seen in the youngest group of 18–35-year-olds, which progressively improved with each ascending age group. This suggests that younger stakeholders in agroforestry could be facing more financial challenges compared to older individuals, potentially due to higher and more recent start-up costs, or less experience in the field. Access to agroforestry subsidies and related resources may need to be more specifically tailored towards the needs of stakeholders entering the sector. Future studies should delve deeper into the factors affecting the financial conditions of stakeholders, to identify key leverage points.

Two factors concerning farm resources and infrastructure yielded fairly homogeneous results. Firstly, there was an overall high level of self-perceived agroforestry knowledge, which reflects the strong representation of participants' management of- or involvement in agroforestry farming systems. This may not be surprising due to the niche target group of stakeholders in agroforestry for this survey. Secondly, there was an unmistakably high level of perceived workload, with the majority of respondents indicating that their workload is too high. However, no significant correlation was found between workload and farm digitalisation, revealing that respondents who had a higher level of farm digitalisation did not necessarily have a lower perceived workload. Although these digital technologies and tools are tailored to enhance farm efficiency and thus intended to reduce avoidable workload, this did not seem to be the case for this sample. In light of the literature review on digital tools in agriculture, this result could reveal potential limitations for reaping the full benefits of digital tools (Balasundram et al. 2023). Factors such as management capabilities, using the most applicable tools, and how user-friendly the tools are could be influencing management and thus workload. This could be addressed through effective consultation on appropriate digital tools. It could also be that digital tools in agroforestry are not yet optimised for the specific needs of agroforestry stakeholders. It is worth noting that high workload may also be difficult to substantially alleviate, especially in demanding professions such as farming even with effective digital tools.

## 5.3 Digital Tools Usage

The relatively low level of digital tools usage and farm digitalisation in this study sample indicates a potential gap of digitalisation in agroforestry. This was generally reflected amongst the different types of stakeholders represented, with no significant difference seen in digital tools usage between farmers and other stakeholders. Participants' intention to implement digital tools within the next five years was also rather modest, suggesting that a large portion of the sample is either not convinced by the advantages of implementing digital tools for their farm practices, or do not believe they have the means to. A comprehensive database of agricultural digitalisation in Germany would be insightful to understand whether this potential gap is specific to agroforestry, or whether it reveals a continued low level of adoption in German agriculture since the recorded data from 2000 (Lowenberg-DeBoer and Erickson 2019).

Looking at the different age groups, interestingly the youngest group of participants saw the lowest share of digital tool users. This contradicts our second hypothesis: younger stakeholders are more likely to adopt digital tools in agroforestry. The otherwise assumed notion that younger individuals are more engaged with modern technology and tools does not apply to this case. Limited financial resources may be preventing younger stakeholders from adopting digital tools they perceive as costly. Tranchina et al's study found that stakeholders frequently voiced that tools should be either free of charge or at an accessible fee (2024). This could be a viable hypothesis, especially in light of the results showing younger participants were not opposed to adopting digital tools in the future. Negative answers towards future implementation were rather seen amongst the group of 51–65-year-olds. Yet when considering the factor analysis concerning participants' interest and ability to interact with digital tools, the group of 51-65-year-olds did not reveal significantly different results from the rest of the sample. The accessibility and user-friendliness of digital tools may be perceived differently across the stakeholder age groups for different reasons. Tranchina et al's study did not differentiate between age groups, but found that the majority of stakeholders required simplicity, clarity, intuition, and user-friendliness in an ideal digital tool (2024). This needs to be considered and incorporated by digital tool providers as our study participants may be lacking some of these features in digital tools in agroforestry.

Considering the factor of farm size with respect to digital tool usage, our third hypothesis is also contradicted: larger farms have a higher adoption rate of digital tools in agroforestry. There was no significant relationship found between farm size and digital tool usage, whilst medium-sized farms revealed the lowest rates compared to the other size categories. Despite various other studies finding larger farms to be more likely to adopt precision agriculture technologies (Gabriel and Gandorfer 2023; Munz, Gindele, and Doluschitz 2019; Paustian and Theuvsen 2017), this study indicates that this is not reflected within agroforestry. Perhaps agroforestry requires types of management practices which do not rely on digital tools, regardless of farm size. Alternatively, digital tools in agroforestry may not be tailored towards certain farm sizes. It would be insightful for future research to look at the factor of farm size in agroforestry management, and how digital tools can play a role in this.

## 5.4 Attitudes towards digital tools

The results concerning stakeholders' attitudes towards digital tools in agroforestry sheds light onto potential underlying dimensions affecting adoption. Participants indicated an overall lack of enthusiasm and interest when engaging with digital tools. Yet the relatively high mean for the perceived ability to implement digital tools suggests that this is not necessarily due to a lack of self-confidence in knowledge or resources. Other factors such as limited time, familiarity, as well as mere interest could be contributing to some stakeholders viewing digital tools as difficult or unappealing. At the same time, the apparent correlation between educational background and the perceived ability to implement digital tools is important to take note of. Stakeholders who had lower educational attainments seemed to be less confident in their abilities to implement digital tools, whilst the highest confidence was seen in those who had acquired doctoral degrees. This disparity could be addressed through accessible training programs and initiatives. On the other hand, expertise in digital tools might initially be more useful for consultants in particular, as they need to be able to advise thoroughly on these tools.

Perceptions on the necessity to implement digital tools for farm efficiency were highly variable, illustrating a mixed picture for the realised benefits of digital tools. This contradicts Tranchina et al's study, which found 90% of all stakeholders stating that new digital tools or models could be either useful or very useful for all the farm management areas that were studied (2024). It is possible that the framing of the question had an effect on participants responses, as Tranchina et al's study emphasise the word "could". On the other hand, the diverse forms and applications of agroforestry practices may lead some stakeholders to find digital tools in agroforestry very useful, whilst for others they are not so suitable. The stakeholders with medium-sized farms seemed to be the least convinced of the necessity of digital tools. This group also scored lowest for their enjoyment in interacting with digital tools, as well as their belief in themselves to be able to implement digital tools. The preliminary findings of Kümmelberger, Hackfort, and Gugganig's study supports these results, as their sample revealed medium-sized farms to be using digital technologies the least (2024). This was argued to be partly attributed to digital technologies in agriculture being primarily tailored towards large-scale farming, and overlooking the needs of small- and medium-sized farms. However, as aforementioned our results did not show larger farms to be using digital tools more. Thus, there may be other factors relevant that are specific to agroforestry. Nonetheless, ensuring that digital tools in agroforestry are applicable to various farm sizes is important in avoiding the exclusion of interested stakeholders.

Trust in data protection was relatively low for all stakeholders, revealing a potentially significant barrier to the adoption of digital tools. This reflects the concerns about data privacy in agriculture more generally (MacPherson et al. 2022; Rotz et al. 2019). Addressing these concerns from both the providers' side as well as governmental side is essential. Firstly, providers of digital tools need to prioritise data protection measures and clearly communicate these to their users. Secondly, data protection and transparency policies are necessary to protect farm data and reduce uncertainty and conflict over ownership, control, security, and sovereignty of data (MacPherson et al. 2022).

Important to note is that for all five studied factors in relation to the perceptions of digital tools, we saw stakeholders who use digital tools having more positive attitudes than stakeholders who do not. Whether this is a correlation or a causation is difficult to determine, as it could be that stakeholders who are more interested in digital tools are more likely to use them in the first place. On the other hand, it could be that the experience of using digital tools could lead to users to gain more interest and confidence in interacting with digital tools.

## 5.5 Influence of state investment funding schemes

When comparing farmers' perspectives between those from states with agroforestry investment funding schemes and those from states with no investment funding scheme, an evident result is the difference in perceived financial situation. This indicates that these funding schemes are pivotal in alleviating financial pressures for farmers in agroforestry. Drawing upon the literature review, multiple studies show that high start-up costs and management costs are significant barriers to agroforestry adoption in Germany, Europe, and worldwide (Tranchina, Reubens, et al. 2024; Litschel et al. 2023; García de Jalón et al. 2018). Tranchina et al's study also found the overall greatest perceived obstacle for agroforestry stakeholders to be the necessity of large investments to set up agroforestry systems (2024). Thus, investment funding schemes should be expanded to other federal states in Germany. With the recently applied changes to the national agroforestry subsidies for 2025, including the increase in direct payments to agroforestry farmers (BMEL 2024a), this challenge will hopefully be somewhat alleviated for some farmers. Continuing to monitor this progress from the position of farmers across the different states is important to understand the sufficiency of this financial support.

Looking at the usage of digital tools, we see the group of farmers from states with investment funding schemes containing less digital tool users than the group of farmers from states without the schemes. This rejects our fourth hypothesis: farmers from states with agroforestry investment funding schemes are more likely to adopt digital tools in agroforestry. This suggests that investment funding schemes do not necessarily play a supportive role in facilitating digitalisation in agroforestry. Although our results suggest a higher prevalence of agroforestry in states with investment funding, this does not seem to extend to the use of digital tools. However, when comparing farmers' attitudes towards digital tools, these were more positive in the group from states with investment funding. This group showed more confidence in their ability to implement digital tools, more trust in service providers to correctly handle their data, as well as greater influence from their network to implement digital tools. Perhaps these regions have stronger social or professional networks advocating for digitalisation. This discrepancy between the lack of digital tool usage, and the comparatively positive attitudes towards digital tools should be explored more deeply. Future studies focusing on this issue should potentially employ qualitative methods such as interviews, in order to gain more insight into the driving forces behind this.

## 5.6 Correlation of variables

Stakeholders who had a higher level of digitalisation in their farm system also had a more positive view of digitalisation in agriculture and in agroforestry. This suggests that stakeholders who engage with- and have experience with digital tools, also have a more positive perception of digitalisation in a broader context. Whether this is the positive attitude spurring on digital adoption, or the experience with digital tools allowing a more positive attitude cannot be determined. Yet it follows a logical conclusion that established users of digital tools are also less opposed to them. The factor analysis of the latent variables also revealed this trend. Participants who felt more comfortable with- and enjoy using digital tools were also more confident in their ability to implement them. They were also more likely to view digital tools as necessary for farm efficiency. This is where training programs and workshops with stakeholders in agroforestry could be useful, whereby participants could try out relevant tools and become more accustomed to them.

Interestingly, stakeholders who scored themselves a higher level of agroforestry knowledge were more likely to have a more negative perception of digitalisation in agroforestry. This suggests that the most experienced and knowledgeable stakeholders in agroforestry may not be convinced of the applicability of digitalisation in agroforestry. Perhaps the fundamental practices of agroforestry are not perceived as particularly compatible with modern digital tools. However, a positive correlation was measured between digitalisation in agriculture and digitalisation in agroforestry, implying that attitudes towards digitalisation are not necessarily specific to the agroforestry sector. On the other hand, it could be that current digital tools in agroforestry are not adequately tailored towards the needs of agroforestry stakeholders. Tranchina et al's study found respondents expressing the need for practical guidance and technical advice on matters including the support for crop, plant, and tree selection based on soil and landscape aesthetics, as well as tools for optimal area design and harvesting efficiency (2024). However, this did not include data on how far respondents deem these resources to be currently lacking or missing. Further research on the specific gaps in digital tools in agroforestry would be needed to build on this preliminary insight. It might also be revealed that certain aspects of agroforestry are not compatible with digitalisation.

Stakeholders who are being encouraged by others to adopt digital tools were also more likely to view digital tools as necessary for farm efficiency. This reflects the social factor that can influence individuals from adopting certain beliefs or practices. Dessart et al find that the adoption of sustainable farming practices by neighbouring farmers to increase the likelihood that a farmer will follow suit (2019). With organisations such as the DeFAF enabling the development of a tight-knit community of agroforestry stakeholders, this factor could become ever-more decisive.

## 5.7 Study limitations

Results should always be viewed critically within the context of the study's limitations. As this study sample is relatively small with 49 respondents, it will not be fully representative of stakeholders in agroforestry in Germany. This is also reflected in the lack of respondents from some federal states, making it unsuitable to compare data within the agricultural, geographical, and political context of each state. Whilst this would have been insightful, clustering the states together into two groups made it possible to still yield valuable results. The limited extent of statistical analyses, such as the t-test, also prevented further hypothesis testing between the different variables. However, overall trends through the use of descriptive and correlation analyses still revealed patterns and trends that can be tested with further research. Considering the context of the still emerging sector of agroforestry in Germany, this will hopefully gain more momentum in the near future.

Certain limitations were also observable in the content and structure of the DigitAF survey. Whilst interesting questions focused on digital tools in agroforestry were compiled from the original extensive survey, some enlightening questions were excluded which would have been relevant. For example, which digital tools participants use would be insightful especially when comparing with factors such as farm size and the rate of digital tool usage. Additionally, asking participants which form of agroforestry they practice (agrisilviculture, silvopastoral, or agrosilvopastoral) could have shed light on the applicability of different digital tools. A further question on whether participants actually applied for- and benefit from state investment funding schemes for agroforestry would have provided further clarity on this aspect, as this study assumed farmers from states with the funding schemes automatically obtained them. Moreover, the structure of the questionnaire lacked cohesion in certain areas, with certain questions being ordered in sections that were not logically intuitive. For example, participants were asked if they are currently using digital tools in agroforestry after being asked multiple questions on their attitudes towards digital tools, as well as their intention to implement tools in the near future.

Using a quantitative methodology for this primarily exploratory study also has its drawbacks, as deeper explanations behind participants' answers were not given. Likert-scale answers are easy-to-use and provide comparable ordinal numeric data, however it is important to note that the survey participant indicates simplified answers on complex decisions under uncertainty (Dombi and Jónás 2021). Furthermore, participants could not make multiple selections for certain questions such as their occupation. This potentially underrepresents the multifaceted involvement of stakeholders in agroforestry, as well as muddies some of the data which was meant to be categorised according to stakeholder type. Some of these informational gaps can be filled with future studies, which potentially also employ qualitative research methods in order to contribute towards the developing image of agroforestry in Germany.

# 6. Conclusion

Agroforestry is steadily gaining momentum in Germany, with an observable increase in the number of stakeholders actively engaging in its development and implementation. This study noted a higher prevalence of agroforestry in states with investment funding schemes for agroforestry, indicating that these schemes may be pivotal in facilitating the adoption of agroforestry practices. This also supports our first hypothesis that states with agroforestry investment funding schemes have a higher prevalence of agroforestry. Financial support can help alleviate the substantial costs in implementing and maintaining agroforestry systems, as was further highlighted by the disparities in perceived financial wellbeing between these different federal states. The new increases in national subsidies will hopefully contribute towards addressing this issue and continue driving the development of agroforestry in Germany.

The role that digital tools on the other hand seems relatively modest in light of this study's results. State subventions did not appear to promote the adoption of digital tools in agroforestry, rejecting out fourth hypothesis. Certain barriers such as distrust in service providers to correctly handle users' data, as well as a lack of conviction of the benefits digital tools present may be limiting the adoption of digital tools in agroforestry. Digital tool providers need to ensure transparency and confidentiality in their handling of users' data, in order to reassure users that they can safely use their products. Furthermore, training programs and workshops based on digital tools can support stakeholders in interacting with digital tools and ease the learning curve. This should perhaps be particularly targeted towards women working in agroforestry, as well as stakeholders who are more likely to have obtained lower educational levels. These demographic groups were the least convinced by their abilities to implement digital tools. Future research can test these hypotheses; (a) women are less likely to implement digital tools in agroforestry; and (b) stakeholders will lower educational levels are less confident in their abilities to implement digital tools. Supported by the survey results, experience with digital tools in agroforestry leads users to develop a positive attitude towards their benefits and reliability.

Stakeholders managing medium-sized farms were also the least likely to realise the benefits of digital tools in agroforestry, reflecting a broader gap in addressing the needs of such farmers within digitalisation in agriculture. This yields a further hypothesis: medium-sized farms are the least likely to realise the benefits of digital tools in agroforestry. Digital tool providers should review the applicability of their products to these stakeholders, as they may be more tailored towards large-scale or smallholder systems. The diversity of agroforestry systems may present certain challenges in incorporating the needs of all stakeholders in these digital tools. However, continuous improvement in addressing the overarching needs of users is important to ensure equitable access to technological advancements. This can also be said for younger stakeholders, who may be facing greater financial struggles with the accessibility of digital tools.

In conclusion, this study has provided preliminary findings on the perceptions of stakeholders on digital tools in agroforestry, building on the growing but still limited research on the adoption and application of such tools in this field. However, it also underscores the complexity of finding conclusive results in a still emerging sector. Whilst the study provides valuable first insights into the perceptions of stakeholders in agroforestry, the results still need to be viewed within the limited scope of the study's representation. Future studies should aim to address these limitations by expanding outreach and employing mixed methods to capture a more developed image of these initial findings. As agroforestry expands, this data will likely become more accessible. Nevertheless, this study still provides an introductory overview of the role digital tools play in agroforestry in Germany. Addressing barriers such as scepticism about benefits, distrust in data protection, and varying levels of confidence among different demographic groups, could allow digital tools to play a more significant role in supporting agroforestry management systems.

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# Appendix

## Appendix I: Survey Questions

Umfrage zur Agroforstwirtschaft und die Nutzung digitaler Tools (Original German survey questions)

1. Ich bestätige, dass ich die Informationen in diesem Formular gelesen und verstanden habe und erkläre mich mit der Teilnahme an dieser Studie einverstanden.
2. Bitte geben Sie den Code an, falls Ihnen dieser per Einladung zugeschickt wurde (oder überspringen Sie diese Frage):

*Abschnitt 1: Charakterisierung der Umfrage-TeilnehmerInnen*

1.1 Bitte wählen Sie Ihre **Altersklasse:**

- o 18-35 Jahre
- o 36-50 Jahre
- o 51-65 Jahre
- o 66+
- o Kein Angabe

1.2 Welches **Geschlecht** haben Sie?

- o Männlich
- o Weiblich
- o Divers
- o Keine Angaben

1.3 **In welchem Bundesland** üben Sie Ihre Geschäfte oder Tätigkeiten aus? (z.B. in der Landwirtschaft, Betriebsberatung, Forschung etc.)

1.4 Welchen höchsten Bildungsabschluss haben Sie?

- o Kein formaler Bildungsabschluss
- o Realschule
- o Abitur-Allg. Hochschulreife
- o Bachelor Abschluss
- o Master Abschluss
- o Doktorat-PhD
- o Keine Angabe
- o Other

1.5 Welcher Art von TeilnehmerIn sind Sie?

- o LandwirtIn, LandnutzerIn o. FlächeneigentümerIn
- o BeraterIn

- VertreterIn aus Politik & Verwaltung
- MarktakteurIn
- VertreterIn der Bildung & Wissenschaft
- Other

*Abschnitt 2: Spezifische und allgemeine Fragen zum landwirtschaftlichen Betrieb*

1.6 F Bitte geben Sie die Größe Ihres Betriebs in ha an

1.7F Was ist Ihr **Betriebstyp**? (Sie können mehrere Optionen auswählen, bei Vorhandenen Agroforstsystemen bitte "Agroforstwirtschaft" mit auswählen)

- Ackerbau
- Gemüsebau
- Obst-oder Weinbau (z.B. Olive, Äpfel, Wein)
- Gemischt-Betrieb (Tierhaltung plus Ackerbau)
- Tierhaltung (Schweine)
- Tierhaltung (Geflügel)
- Tierhaltung (Rinder/Schafe/Ziegen)
- Tierhaltung (Milchvieh)
- Agroforstwirtschaft, Agroforstsystem
- Forstwirtschaft
- Agro-Tourismus und Bildung
- Ökobetrieb (Richtlinien der biologischen Landwirtschaft)

*Abschnitt 3: Wissen, Wahrnehmung und digitale Tools in der Agroforstwirtschaft*

3.1 Wie schätzen Sie Ihr Wissen über Agroforstsysteme ein?

- 1
- 2
- 3
- 4
- 5

*Abschnitt 4: Soziale Aspekte und Verhalten*

5.1 Mit der folgenden Frage möchten wir genauer verstehen, wo Ihr Betrieb bei der digitalen Entwicklung gerade steht. Bitte kreuzen Sie die Antwort an, die im Moment am besten auf Sie zutrifft.

- Mit dem Begriff Digitalisierung in der Agroforstwirtschaft kann ich nichts anfangen.
- Ich habe bereits erfahren, dass es digitale Technologien in der Agroforstwirtschaft gibt. Allerdings kenne ich die Details noch nicht und habe auch nicht das Bedürfnis nach detaillierteren Informationen
- Ich weiß, dass es digitale Technologien in der Agroforstwirtschaft gibt, und bin bereits auf der Suche nach Informationen

- Ich bin mit digitalen Tools in der Agroforstwirtschaft vertraut und habe ihre Vor- und Nachteile für mich bewertet und mich für oder gegen den Einsatz einer Technologie entschieden.
- Ich verwende in begrenztem Umfang digitale Tools in der Agroforstwirtschaft und suche nach weiteren Informationen dazu.
- Ich verwende regelmäßig digitale Tools in der Agroforstwirtschaft.
- Ich möchte nicht antworten
- Other

5.2 Wie beurteilen Sie Ihre finanzielle Gesamtsituation?

- 1
- 2
- 3
- 4
- 5

5.3 Fragen zur Internet- und Mobilfunkversorgung

- Meine Internetverbindung ist ausreichend für die Nutzung digitaler Technologien
  - Ich stimme überhaupt nicht zu
  - Ich stimme nicht zu
  - Ich stimme eher zu
  - Ich stimme zu
  - Ich stimme vollkommen zu
  - Ich möchte nicht antworten
- Mein Mobilfunkempfang auf den Flächen ist ausreichend für die Nutzung digitaler Technologien
  - Ich stimme überhaupt nicht zu
  - Ich stimme nicht zu
  - Ich stimme eher zu
  - Ich stimme zu
  - Ich stimme vollkommen zu
  - Ich möchte nicht antworten

*Abschnitt 5: Fragen zur Motivation*

5.4 Wie stehen Sie zur Digitalisierung in der Landwirtschaft generell?

- Sehr negativ
- Negativ
- Neutral
- Positiv
- Sehr positiv
- Ich möchte nicht antworten

5.5 Wie sehen Sie die Digitalisierung in der Agroforstwirtschaft?

- Sehr negativ
- Negativ
- Neutral
- Positiv
- Sehr positiv

- Ich möchte nicht antworten

5.6 Wie treffen die folgenden Aussagen auf Sie zu? (bitte eine Antwort pro Zeile auswählen)

Antworten:

- Trifft überhaupt nicht zu
- Trifft nicht zu
- Neutral
- Trifft zu
- Trifft vollständig zu
- Ich möchte nicht antworten

Aussagen:

- Ich bin eher zurückhaltend
- Ich vertraue anderen leicht, glaube an das Gute im Menschen
- Ich bin bequem, neige zur Faulheit.
- Ich bin entspannt, lasse mich nicht durch Stress aus der Ruhe bringen.
- Ich habe wenig künstlerisches Interesse.
- Ich gehe aus mir heraus, bin gesellig.
- Ich neige dazu, andere zu kritisieren.
- Ich erledige Aufgaben gründlich
- Ich werde leicht nervös und unsicher.
- Ich habe eine rege Phantasie, bin phantasievoll.

5.7 Wie wichtig sind Ihnen die folgenden Aussagen? (bitte eine Antwort pro Zeile auswählen)

- Mein eigener Chef zu sein ist für mich....
  - Sehr unwichtig
  - Eher unwichtig
  - Neutral
  - Eher wichtig
  - Ich möchte nicht antworten
- Meine Maschinen selbst reparieren und warten zu können, ist für mich …
  - Sehr unwichtig
  - Eher unwichtig
  - Neutral
  - Eher wichtig
  - Ich möchte nicht antworten
- Unabhängig von Experten zu sein ist für mich …
  - Sehr unwichtig
  - Eher unwichtig
  - Neutral
  - Eher wichtig
  - Ich möchte nicht antworten

5.8 Wie hoch ist Ihre Gesamtarbeitsbelastung? (Wie hoch ist Ihr Arbeitsaufwand insgesamt?)

- Viel zu wenig
- Zu wenig
- Harmonisch
- Zu viel
- Viel zu viel

**5.9** Im Folgenden geht es um Ihre Interaktion mit Technologie im Allgemeinen. Unter „digitalen Diensten“ verstehen wir Apps und andere Softwareanwendungen sowie Mobiltelefone, Computer, Navigationssysteme (*bitte pro Zeile eine Antwort auswählen*).

Antworten:

- o Stimme überhaupt nicht zu
- o Stimme nicht zu
- o Stimme eher zu
- o Stimme zu
- o Stimme vollständig zu
- o Ich möchte nicht antworten

Aussagen:

- Ich beschäftige mich gerne ausführlicher mit digitalen Dienstleistungen.
- Ich teste gerne die Funktionen neuer digitaler Dienste.
- Ich beschäftige mich hauptsächlich mit digitalen Dienstleistungen, weil ich es muss.
- Wenn ich einen neuen digitalen Dienst vor mir habe, probiere ich ihn intensiv aus.
- Ich verbringe gerne Zeit damit, mich mit einem neuen digitalen Dienst vertraut zu machen
- Es reicht mir, dass ein digitaler Dienst funktioniert; es ist mir egal, wie und warum.
- Ich versuche zu verstehen, wie ein digitaler Dienst genau funktioniert.
- Es reicht, wenn ich die Grundfunktionen eines digitalen Dienstes kenne.
- Ich versuche, die Möglichkeiten eines digitalen Dienstes voll auszuschöpfen.

5.10 Einige Fragen zu Ihrer Absicht, digitale Dienste in Agroforstsystemen einzusetzen:

Antworten:

- o Trifft überhaupt nicht zu
- o Trifft nicht zu
- o Neutral
- o Trifft zu
- o Trifft vollständig zu
- o Ich möchte nicht antworten

Aussagen:

- Ich beabsichtige, in den nächsten 5 Jahren digitale Modelle und Tools in der Agroforstwirtschaft auf meinem Betrieb einzusetzen.
- Ich habe die feste Absicht, in den nächsten 5 Jahren digitale Modelle und Tools in der Agroforstwirtschaft auf meinem Betrieb einzusetzen.
- Der Einsatz von digitalen Modellen und Tools in der Agroforstwirtschaft auf meinem Betrieb reduziert die Menge an Input (z.B. Dünger) für den Betrieb.
- Der Einsatz digitaler Modelle und Tools in der Agroforstwirtschaft in meinem Betrieb bringt mehr wirtschaftliche Vorteile als der Verzicht darauf.
- Ich muss digitale Modelle und Tools in der Agroforstwirtschaft in meinem Betrieb einsetzen, um die Produktion zu maximieren.
- Ich muss digitale Modelle und Tools in der Agroforstwirtschaft einsetzen, um Arbeitszeit zu sparen.
- Die meisten Menschen, die mir wichtig sind, sind der Meinung, dass ich digitale Modelle und Tools in der Agroforstwirtschaft in meinem Betrieb einsetzen sollte.

- ☐ Landwirtschaftsberater meinen, dass ich digitale Modelle und Tools in der Agroforstwirtschaft in meinem Betrieb einsetzen sollte.
- ☐ Andere Landwirte, mit denen ich regelmäßig zu tun habe, würden mir zustimmen, dass ich digitale Modelle und Tools in der Agroforstwirtschaft in meinem Betrieb einsetzen sollte.
- ☐ Ich fühle mich von anderen Landwirten unter sozialem Druck gesetzt, digitale Modelle und Tools in der Agroforstwirtschaft in meinem Betrieb einzusetzen.
- ☐ Ich habe das Gefühl, dass ich über ausreichende Kenntnisse verfüge, um digitale Modelle und Tools in der Agroforstwirtschaft in meinem Betrieb einzusetzen.
- ☐ Ich habe alle Voraussetzungen (z. B. Internet, Finanzen, Eignung der Technologie), die ich brauche, um digitale Modelle und Tools in der Agroforstwirtschaft in meinem Betrieb einzusetzen.
- ☐ Ich bin zuversichtlich, dass ich die Hindernisse überwinden kann, die mich daran hindern, in den nächsten 5 Jahren digitale Modelle und Tools in der Agroforstwirtschaft in meinem Betrieb einzusetzen.

5.11 Erfassen Sie **Betriebsdaten** auf Ihrem Betrieb digital oder nutzen Sie Apps oder Software zur Verwaltung Ihres Betriebs *(z. B. Weide-/ Vegetationskartierung, Ertragskartierung, Bodenkartierung und Daten zur Einzeltier- oder Herdenfütterung)*?

- o Ja
- o Nein
- o Ich möchte nicht antworten
- o Other

**5.12** Eine Frage zu Ihrem Wissen über die **Datennutzung**: Deckt Ihr Vertrag mit einem Dienstleister oder Lieferanten auch die Nutzung der Daten ab, z.B. im Rahmen einer automatisierten Datenerfassung durch Maschinen, Software und Apps ab im Betrieb?

- o Ich weiß überhaupt nichts darüber
- o Ich weiß nichts darüber
- o Neutral
- o Ich weiß etwas darüber
- o Ich weiß viel darüber
- o Ich möchte nicht antworten

**5.13** Inwieweit stimmen Sie den folgenden Aussagen zu? (*bitte eine Antwort pro Zeile auswählen*)

Antworten:

- o Ich stimme überhaupt nicht zu
- o Ich stimme nicht zu
- o Ich stemme eher zu
- o Ich stimme zu
- o Ich stimme vollständig zu
- o Ich möchte nicht antworten

Aussagen:

- Ich bin damit einverstanden, dass Dienstleistungs-/Technologieanbieter wie John Deere oder Anbieter von Wetterstationen direkten Zugang zu meinen Betriebsdaten über die von ihnen für mich erbrachten Dienstleistungen haben.
- Ich bin damit einverstanden, dass Dienstleister/Technologieanbieter direkten Zugang zu allen Kundendaten, einschließlich meiner Daten, haben und diese Daten zur Erzielung von Gewinn für sich selbst nutzen.
- Ich erkläre mich bereit, mehr für den Dienst oder die Technologie zu bezahlen, um im Gegenzug die Rechte an meinen betrieblichen Daten selbst zu behalten.
- Ich bin damit einverstanden, dass die Dienstleister/Technologieanbieter meine Betriebsdaten verwenden, wenn ich im Gegenzug weniger für die Dienstleistung oder Technologie bezahle.
- I agree to share farm data, such as fertilizer and pesticide use, with technology providers and service providers.
- Ich bin damit einverstanden, Betriebsdaten, wie z. B. den Einsatz von Düngemitteln und Pestiziden, an Behörden (Staat, EU, Regionalregierung) weiterzugeben.
- Ich bin damit einverstanden, dass Produktionsdaten an Technologieanbieter und Dienstleister weitergegeben werden.
- Ich bin mit der Weitergabe von Produktionsdaten an Behörden (Staat, EU, Regionalregierung) einverstanden.
- Ich bin damit einverstanden, dass meine Daten zentral auf einem Server gespeichert werden.

**5.14** Einige Fragen zu Ihrem Vertrauen in die Datensicherheit? (*bitte eine Antwort pro Zeile auswählen*)

- Der Dienstleister verspricht Ihre Daten vor unbefugten Zugriffsicher zu schützen (Datenschutz). Wie sehr vertrauen Sie ihm?
  - Überhaupt kein Vertrauen
  - Eher kein Vertrauen
  - Neutral
  - Eher Vertrauen
  - Vertraue darauf vollständig
  - Ich möchte nicht antworten
- Der Dienstleister verspricht Ihre Daten vertraulich zu behandeln und nicht an 3. weiterzugeben. Wie sehr vertrauen Sie ihm?
  - Überhaupt kein Vertrauen
  - Eher kein Vertrauen
  - Neutral
  - Eher Vertrauen
  - Vertraue darauf vollständig
  - Ich möchte nicht antworten

## Appendix II: Invitation Email to Participate in the DigitAF Survey

Sehr geehrte(r) Frau/Herr X,

mein Name ist Sophia Oakes, ich bin angehende Agrarwissenschaftlerin und am Ende meines Masterstudiums an der Humboldt Universität zu Berlin. Ich fertige derzeit unter Betreuung durch Herrn Dr. agr. Rico Hübner vom Deutschen Fachverband für Agroforstwirtschaft (DeFAF) e.V. und Herrn Dr. Robischon von der HU Berlin im Projekt DigitAF meine Abschlussarbeit für das Studium an. Dies umfasst eine Umfrage zum Thema digitalen Tools in der Agroforstwirtschaft.

**Ich möchte Sie herzlich einladen, an dieser wichtigen Umfrage teilzunehmen**.

Ihre Teilnahme ist von großem Wert, da Ihre Erfahrungen und Meinungen helfen werden, den Einsatz digitaler Tools in der Agroforstwirtschaft besser zu verstehen und weiterzuentwickeln. Darüber hinaus könnten die Fragen Ihnen eventuell neue Tools und Methoden vorstellen, die ihre Arbeit unterstützen.

Wir haben Sie ausgewählt, da Sie aufgrund Ihrer teils langjährigen Erfahrungen in der Agroforstwirtschaft schon in Erscheinung getreten sind und wir würden Sie bitten, im Projekt DigitAF mitzuwirken. Daher haben Sie auch einen individuellen Code erhalten.

**Hier geht's zur Umfrage:**

**Ihr persönlicher Code: XXXX**

Ziel des Projektes DigitAF ist es, gemeinsam mit PraktikerInnen, Interessens- und MarktvertreterInnen digitale Instrumente (z.B. Tools, Modelle, Apps) zu testen und Anregungen zu deren Verbesserung und möglichen Vereinfachung geben. Sie hätten daher die Möglichkeit, bei kommenden Veranstaltungen diese Tools auszuprobieren und an deren Verbesserung mitzuwirken und sich mit Gleichgesinnten auszutauschen.Mit Ihrer Teilnahme unterstützen Sie nicht nur meine Abschlussarbeit, sondern leisten auch einen wichtigen Beitrag, dass das Thema Agroforstwirtschaft in Deutschland ernster genommen wird und entsprechende politische Unterstützung erfährt.

Als kleines Dankeschön für Ihre Teilnahme nehmen Sie ***automatisch an einer Verlosung teil***, bei der Sie eine Auswahl von 3 schönen Büchernzur Agroforstwirtschaft gewinnen können.

**Achtung:** Das Ausfüllen der Umfrage dauert etwa **15 Minuten**. Ihre Aussagen in der Umfrage werden selbstverständlich nach EU-Standard anonymisiert (DGVO Konform).

Bei weiteren Fragen oder Unklarheiten zur Umfrage können Sie mich sehr gerne kontaktieren: **email**

Wir würden uns sehr über Ihre Teilnahme bis **XXXX 2024** freuen.

Mit freundlichen Grüßen aus Berlin,

Sophia Oakes

**Eigenständigkeitserklärung**

Ich versichere, dass ich die vorliegende schriftliche Arbeit selbständig verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel verwendet habe, alle Ausführungen, die anderen Schriften wörtlich oder sinngemäß entnommen wurden, kenntlich gemacht sind und die Arbeit in gleicher oder ähnlicher Form noch nicht für andere Prüfungen verwendet wurde sowie keiner anderen Prüfungsbehörde vorgelegen hat.

Ich habe alle Stellen, die dem Wortlaut oder dem Sinn nach (inkl. Übersetzungen) anderen Werken entnommen sind, unter genauer Angabe der Quelle (einschl. des World Wide Web sowie anderer elektronischer Datensammlungen) deutlich als Entlehnung kenntlich gemacht. Dies gilt auch für angefügte Zeichnungen, bildliche Darstellungen, Skizzen und dergleichen.

Zusätzlich versichere ich, dass ich beim Einsatz von IT-/KI-gestützten Werkzeugen diese Werkzeuge in der unten genannten „Übersicht verwendeter Hilfsmittel" mit ihrem Produktnamen und der Versionsnummer, meiner Bezugsquelle (z.B. URL) und Angaben zur Nutzung vollständig aufgeführt sowie die Checkliste wahrheitsgemäß ausgefüllt habe. Davon ausgenommen sind diejenigen IT-/KI-gestützten Schreibwerkzeuge, die von meinem zuständigen Prüfungsbüro bis zum Zeitpunkt der Abgabe meiner Arbeit als nicht anzeigepflichtig eingestuft wurden („Whitelist"). Bei der Erstellung dieser Arbeit habe ich durchgehend eigenständig und beim Einsatz IT-/KI-gestützter Schreibwerkzeuge steuernd gearbeitet.

Mir ist bekannt, dass bei Verstößen gegen diese Grundsätze ein Verfahren wegen Täuschungsversuchs bzw. Täuschung gemäß der fachspezifischen Prüfungsordnung und/oder der Fächerübergreifenden Satzung zur Regelung von Zulassung, Studium und Prüfung der Humboldt-Universität zu Berlin (ZSP-HU) eingeleitet wird.

Paris, 12.02.2025

…………………………………………………………………………………………..
Ort, Datum, Unterschrift

## Whitelist

Folgende Programme müssen nicht aufgelistet oder bewertet werden. Diese Programme können ohne weitere Angaben genutzt werden:

- ✓ Microsoft Office, LaTeX, OpenOffice, iWork, Google Docs
- ✓ Google Scholar, ResearchGate, Web of Science
- ✓ Datenbanken der Universitätsbibliothek
- ✓ Literaturverwaltungsprogramme (Zotero, Endnote, Mendeley, etc.)

## Übersicht verwendeter Hilfsmittel

**Ausfüllhinweise:**

Bitte geben Sie an, welche Programme Sie im Rahmen Ihrer Arbeit verwendet haben. Bitte tragen Sie dazu bei jeder Nutzungsart ein, welches Programm Sie genutzt haben. Pro Nutzungsart können mehrere Programme eingetragen werden. Sollten Sie ein Programm anders genutzt haben, als in der Tabelle gelistet, ergänzen Sie diese Nutzungsart bitte in den dafür vorgesehenen Feldern.

Sofern Sie sich unsicher sind, ob ein Programm unter "künstliche Intelligenz" fällt, tragen Sie es ein. Es erwachsen Ihnen keine Nachteile durch die Nennung des Programms.

**Checkliste: IT-/KI-gestützte Schreibwerkzeuge:**

| **Nutzungsart** | **Programm** | **falls relevant: betroffene Abschnitte** *(Bitte geben Sie Seitenzahlen an, sofern es nicht auf das gesamte Dokument zutrifft.)* |
|---|---|---|
| Generierung von Ideen/Brainstorming | | |
| Literaturrecherche | | |
| Übersetzung von Texten | DeepL Translator: Version 2024. URL https://www.deepl.com/en/tr | Annex 2: Umfrage Fragen |
| Zusammenfassen von Quellen | | |

| | | |
|---|---|---|
| Inhalte auf andere Art und Weise erklären lassen (z. B. Konstrukte, methodische Vorgehensweisen, Analysen) | ChatGPT. Version 2024. https://chatgpt.com | Chapter 4 Results (pg 32-60) |
| Erstellen von Textabschnitten, welche als Vorlage dienen | | |
| Überarbeitung von eigenen Textelementen (bitte Seitenzahl der Arbeit angeben) | | |
| Auswertung von Daten (z. B. Schreiben von Codes, Definieren der passenden Auswertungsmethoden, Erstellen von Abbildungen) | DATAtab: Version 2024. Online Statistics Calculator. DATAtab e.U. Graz, Austria. URL https://datatab.net | Table 5. Table 8. Table 9. Table 10. Figure 11. Figure 13. |
| Rechtschreibprüfung, Grammatik und Schreibstil | | |
| Visualisierungen zu illustrativen oder dekorativen Zwecken | | |
| | | |
| | | |
| | | |
| | | |

Ggf. weitere Erklärungen: