Exploring lead users as co-creators of innovation in forest sector

Insights from Social Practice Theory

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Examensarbete/Självständigt arbete • 30 hp
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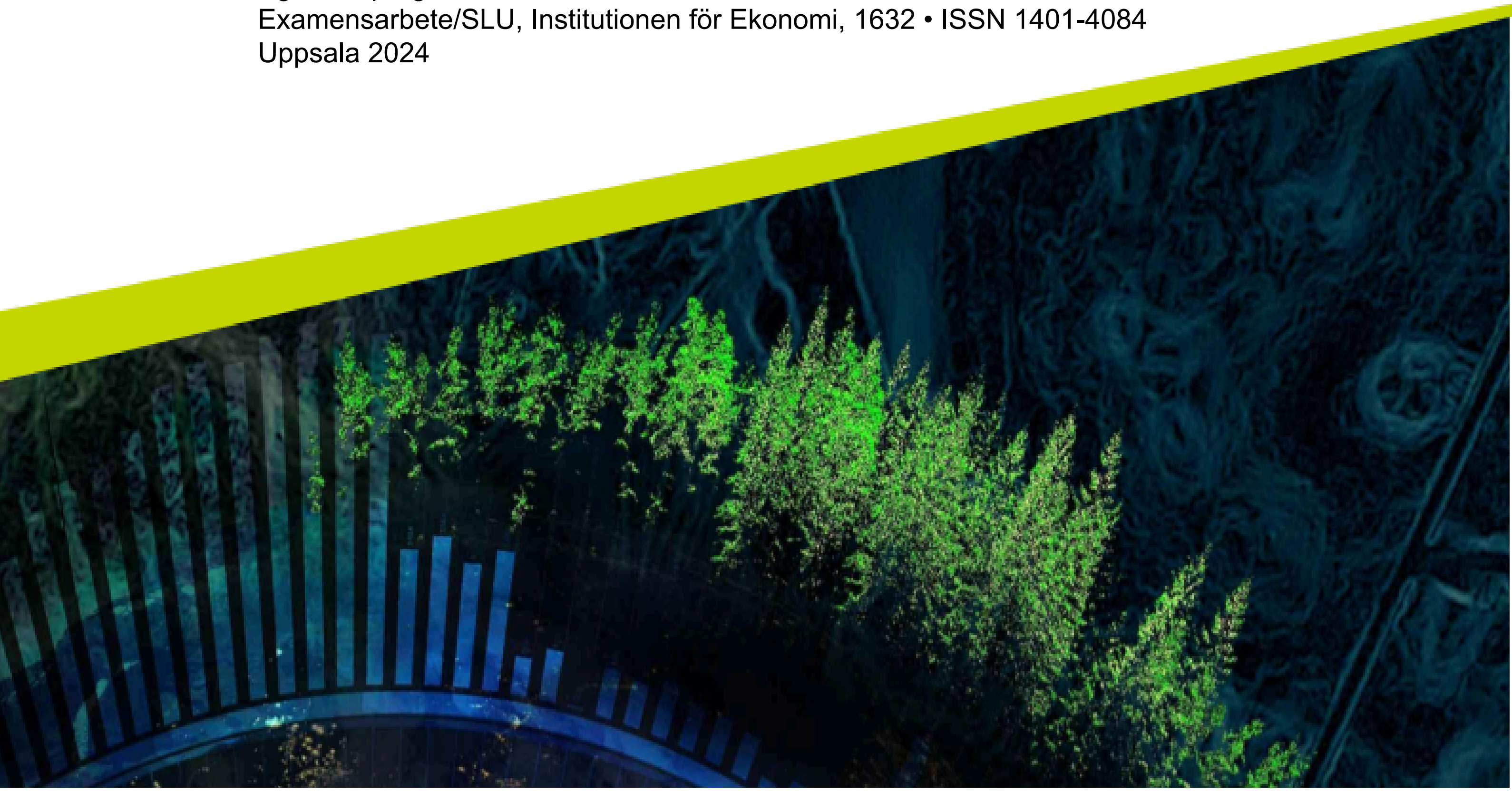
Fakultet för naturresurser och jordbruksvetenskap/Institution för ekonomi
Agronomprogrammet - ekonomi
Examensarbete/SLU, Institutionen för Ekonomi, 1632 • ISSN 1401-4084
Uppsala 2024



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Credits:	30 credits
Level:	Second cycle, A2E
Course title:	Master thesis in Business Administration
Course code:	EX0906
Programme/education:	Agriculture Programme – Economics and Management
Course coordinating dept:	Department of Economics
Place of publication:	Uppsala
Year of publication:	2024
Cover picture:	All featured images are used with permission from the copyright owner.
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Title of series:	Degree project/SLU, Department of Economics
Part number:	1632
ISSN:	1401-4084

Keywords: Drone technology, lead users, co-creation, social practice, innovation, adoption

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Abstract

Within the broader academic discipline of business administration, this thesis focuses on the intersection of production, innovation, and forest management practices. It aims to contribute to the understanding of why lead users adopt drone technology and how they co-create the process of innovation. Despite advancements in sustainable forest management practices, a gap remains in the effective utilization of new technologies like drones to enhance operational practices. Building upon broader concepts such as forest management and sustainability challenges, this study explores the motivations behind the adoption of drone technology by lead users and the collaborative efforts involved in the innovation process.

The research examines how lead users in the Swedish forestry sector integrate drones into their practices, addressing key questions such as the reasons for adopting the technology and the specific ways they contribute to co-creating innovation. By analyzing the experiences and practices of these pioneering users, the study aims to illuminate the practical benefits and challenges associated with drone technology in forestry. This includes understanding how drones enable more efficient forest monitoring, improve decision-making, and promote sustainable forest management practices. Through a case study approach, the thesis provides insights into the practical applications of drone technology, highlighting its potential to transform forest management by offering faster data collection, improved accuracy, and real-time information. It also addresses the barriers faced by users, such as regulatory challenges and the need for advanced skills, providing a comprehensive view of the current landscape and future prospects of drone technology in forestry.

Furthermore, the study builds on broader sectors such as agricultural practices, where drone technology is increasingly being adopted to enhance productivity and sustainability. Similar to forestry, agriculture benefits from drones through precise monitoring and resource management, which improves crop yields and reduces environmental impact. By drawing parallels between forestry and agriculture, this thesis underscores the transformative potential of drones across different sectors, highlighting their role in promoting sustainable and efficient operations. Ultimately, this study contributes knowledge to the fields of forest management and business administration, emphasizing the importance of technological innovation in advancing sustainable practices.

Keywords: Drone technology, lead users, technology providers, co-creation, social practice, innovation, adoption

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Introduction

In the first chapter, the author presents an introduction to the subject matter by providing a comprehensive background on the utilisation of drone technology in Swedish forestry. This establishes the context for an understanding of the broader implications of integrating such technology within the forestry sector, which constitutes a significant component of Swedish agriculture. The chapter then proceeds to articulate a problem formulation that the study intends to address, highlighting the challenges and opportunities associated with drone adoption in forestry. The research purpose and questions are then outlined.

1.1 Background

Innovation and technological development are of pivotal importance in the advancement of the Swedish agricultural sector, driving forward sustainability, efficiency and competitiveness. Sweden is a global leader in agricultural innovation, with initiatives that aim to transform traditional farming practices into high-tech, environmentally friendly operations. This commitment to advancement is evident across a range of agricultural domains, including the crucial forestry sector, which is undergoing a significant technological transformation (Swedish Cleantech, 2022). The agricultural technology revolution in Sweden is oriented towards two principal objectives: the enhancement of efficiency and the concomitant reduction of the environmental impact of food production (OECD, 2018). This dual approach is crucial for meeting Sweden's ambitious climate goals set for 2045 and ensuring long-term food security. Farmers and agribusinesses in Sweden are adopting cutting-edge technologies to address a range of challenges, including resource management, climate change adaptation, and economic viability.

One of the primary drivers of innovation in Swedish agriculture is the collaboration between various stakeholders. A collaborative approach is being adopted by research institutions, technology companies and farmers, with the objective of developing and implementing new solutions. To illustrate, the Agtech Sweden initiative, which is supported by approximately 100 different organisations, aims to establish an innovation environment for tomorrow's agriculture, with a particular focus on sensors, digital technology, and mechanics (Agtech Sweden, 2024). The scope of agricultural innovation in Sweden is broad, encompassing various aspects of farming. These include: *Precision agriculture* where Vultus Agtech for instance, employs satellite imagery to enhance the efficiency of fertilizer and water usage, with the potential to reduce consumption by up to 20% (Vultus, 2024). This is achieved through the use of digital technologies to monitor and optimize inputs, such as fertilizer and water, in real-time. Another area of focus is the development and testing of *autonomous electric machines* for tasks such as weed control in organic farming (RISE, 2019). This involves the use of advanced robotics and machine learning to automate tasks traditionally performed by humans, with the aim of enhancing precision, efficiency, and sustainability in agricultural operations (ibid). A principal objective is the *digitalisation* of agricultural processes. This entails the creation of innovative environments that facilitate the digitalisation, automation, and electrification of agricultural operations (RISE, 2024). The development of *sustainable practices* is also a priority. The objective is to develop technologies that will reduce agriculture's fossil footprint and enhance soil carbon storage (Swedish Cleantech, 2022). This emphasis on innovation and technology development in Swedish agriculture provides a robust foundation for understanding the sector's approach to various subsectors, including forestry (OECD, 2018). The principles of sustainability, efficiency, and technological advancement that drive innovation in broader agriculture are equally applicable to forest management and the timber industry. To fully comprehend the context of forestry innovation, it is essential to grasp the function of forestry and forest management within Swedish farm businesses. Sweden's agricultural landscape is distinctively intertwined with its forests, giving rise to a diverse and integrated approach to land management. This integration is anchored in historical practices and remains pertinent in modern Swedish agriculture and forestry (ibid).

The structure of Swedish agriculture is typified by a combination of crop production, animal husbandry, and forestry. Despite the relatively modest proportion of Sweden's total land area dedicated to agricultural production, with only 6.5% of the country's territory under cultivation, forests cover approximately 70% of the land area, thereby establishing forestry as an integral component of the broader agricultural landscape. Approximately 2.7 million hectares are utilized for agricultural purposes, while forests cover approximately 28 million hectares (OECD, 2018; Jordbruksverket, 2009). The forest industry constitutes a pivotal sector of the Swedish economy, directly employing nearly 70,000 individuals and indirectly supporting approximately 120,000 jobs including subcontractors (Swedish Forest Industries Federation, 2024). Sweden is a global leader in the production of forest products, ranking among the top exporters of sawn wood and being the fifth-largest producer of pulp for paper. This economic significance highlights the necessity for innovation in both the agricultural and forestry sectors. Forest ownership in Sweden is diverse, with 48% of forest land owned by family enterprises, 24% by large industrial forest enterprises, and the remaining by other private owners and the state. This ownership structure contributes to the varied approaches and innovations in forest management across the country (ibid).

The Swedish model of forest management is characterised by an emphasis on achieving a balance between ecological, economic, and social sustainability (Lindahl et.al., 2017). This approach is closely aligned with the overarching objectives of sustainable agriculture, fostering synergies between the two sectors. The implementation of sustainable forest management practices in Sweden has resulted in a notable contribution to carbon sequestration, with forests sequestering 94 million tons of carbon dioxide on an annual basis, which is nearly twice the amount of Sweden's total emissions (Girolami & Arts, 2018). The country's forest industry has reduced its emissions by over 60% since 2005 and utilises minimal fossil fuels in its processes, thereby exemplifying a profound dedication to sustainability (ibid).

The integration of innovative techniques in forestry, particularly those pertaining to precision forestry and drone technology, serves to enhance the advancements made in the field of agriculture. To illustrate, the utilisation of drones for forest inventory and management is analogous to the uptake of precision agriculture techniques in farming. This convergence of technology facilitates the implementation of more efficient and sustainable management practices for both agricultural and forested lands. In the field of forestry, drones are emerging as a significant innovation in the context of sustainable forest management (Michels et.al, 2023). Companies such as AirForestry AB have demonstrated the potential of drone harvesting systems, which can achieve a high degree of automation and compete with traditional ground-based harvesting methods (Airforestry, 2024).

As we examine the particular innovations in forestry, particularly the utilization of drone technology, it is essential to consider the wider context of integrated land management in Swedish agriculture and forestry. The innovations under discussion not only affect forest management but also have the potential to be applied and to have implications for the wider agricultural sector in Sweden. The adoption of drone technology in forestry addresses several challenges inherent to traditional forestry methods, which have been critiqued for prioritizing timber production over ecological conservation. Drones offer innovative methods for monitoring forest health, assessing tree stands, and planning forest management activities with greater precision and efficiency. This aligns with global trends towards more sustainable forest management practices, as evidenced by certification programs such as FSC and PEFC (Swedish Forest Industries Federation, 2024; RISE, 2024). The EU Forest Strategy for 2030, aligned with the EU Green Deal, further emphasizes the importance of efficient forest monitoring and data collection, in accordance with the aforementioned strategy. The potential of drone technology to provide real-time data and insights makes it an ideal tool for supporting these objectives (Michels et al., 2023). As those in the forestry sector who are at the forefront of adopting and innovating with drone technology contribute to the co-creation of solutions that address specific industry needs, they are acting as lead users. This user-driven innovation process is of great importance for the development of technologies that are not only technologically advanced but also practically applicable in the complex and varied conditions of forest management (Urban & von Hippel, 1988). The objective of this study is to evaluate the potential of drone technology as a tool for sustainable operations within the forestry sector and to gain insight into the role of lead users as co-creators of new technology. By examining the adoption and innovation processes of lead users in the Swedish forest sector, the study aims to provide valuable insights into the role of these early adopters in advancing drone technology.

1.2 Empirical issue

In Sweden, the media debate has intensified since 2005 due to environmental concerns regarding the necessity for diversifying forest management practices (Brukas and Weber, 2009). As the world grappled with growing concerns about ecological conservation, high-production forestry with intensive management practices came under examination. Sweden's forests have long symbolised the nation's economic backbone and societal prosperity (Swedish forest industries federation, 2024). In this context, forest managers are confronted with the challenge of reconciling traditional practices with the demands of modernity. They must balance economic considerations with environmental stewardship. The necessity of sustainable practices has become apparent in the context of forestry operations (Girolami & Arts, 2018).

This study focuses on the potential of drone technology in forestry, recognizing its capacity to support sustainable practices in forest management. Drones have the potential to revolutionise forest management by providing real-time data on forest health, facilitating precision forestry operations, and minimising environmental impact (Michels, et al., 2023). The traditional forest management approach includes habitat loss and soil destruction, which users of drones would prevent in practice by not entering the forest with machines to the same extent (Bettinger et al., 2017). The empirical problem lies in the discrepancy between the promising images of technological advances and their actual implementation in practical forestry operations. Despite the growing interest in drone technology, there is a noticeable lack of comprehensive research examining how these drones are actually used and experienced by forest practitioners, particularly when it comes to addressing the pressing environmental and operational challenges facing the forest sector. It is necessary to gain a deeper understanding of the real-world applications of drones in forestry, including factors such as user perceptions, operational challenges, and the integration of drone data in organisational activities.

1.3 Theoretical issue

The study is based on a business research perspective that acknowledges the fundamental unsustainability of traditional forestry practices (Bettinger et al., 2017). The development and integration of new technologies, particularly drones, are regarded as pivotal solutions to these sustainability challenges (Michels et al., 2023). Technology has the potential to address numerous issues in forestry, including more efficient use of resources, reduced environmental impacts, and improved productivity (ibid). To explore this potential, the study integrates multiple theoretical perspectives into one analytical framework, examining the implementation of drones into the forest sector. A key theoretical concept in this study is the role of users as co-creators of innovation (Urban & von Hippel, 1988). This perspective emphasises the importance of involving users in the development and adaptation of new technologies. In the context of drone technology, users are seen as integral to the innovation process. The involvement of lead users, those who have already adopted and are utilising drone technology in their forestry operations, provides valuable insights and feedback. These insights can be used to refine and improve the design and functionality of the technology, ensuring it meets the practical needs and challenges faced by forest managers (ibid). The present study aims to address a specific knowledge gap in the field of drone technology research, namely the co-creation of innovation. This gap includes understanding the operational challenges, user perceptions, and the needs that foresters have when improving their forest management practice. By targeting experienced lead users, the study seeks to uncover detailed insights into their needs and expectations, identifying the challenges and opportunities they face. This will contribute to a more nuanced understanding of the collaborative processes involved in the development of sustainable and efficient tools for forestry practices, with a particular focus on the diverse experiences and perspectives of lead users.

1.4 Aim and Research Question

The aim is to contribute with knowledge of lead users as co-creators of new technology. A case study was conducted on the leading forestry companies and drone experts in the Swedish forest sector. Based on this aim, the following research questions have been formulated:

- *Why do lead users adopt drone technology, and how do they co-create innovation?*

- *What challenges do users face when integrating drones into forestry practices?*

1.5 Delimitations

The limitations of this study are as follows: it begins with a geographical scope that is narrowed down to the Swedish forest sector, and it limits the findings to a national context. The investigation is focused exclusively on drone technology, with other forms of technological advancement in forestry being excluded. The case study targets lead users, that is to say, those who are early adopters and innovators in the field, rather than the broader population of forestry practitioners. The study is informed by a set of specific questions pertaining to the adoption and co-creation of drone technology, as well as the challenges faced by users. This approach may result in the overlooking of other aspects of drone integration. The study examines current practices and challenges without extensive consideration of historical trends or long-term future projections.

2. Theoretical framework

In Chapter 2, a theoretical framework is presented to provide a foundation for understanding the utilisation of new technology in forestry practices. The chapter comprises four main sections: sustainable forest management, linear innovation model, users of new technology, lead users as co-creators of innovation, and social practice theory. These sections offer a comprehensive exploration of the concepts and theories that underpin the adoption and integration of new technologies, particularly within the context of sustainable forest management.

2.1 Sustainable forest management

Traditional forest management typically involves the clear-cutting of entire forest stands, followed by replanting or seeding to regenerate the forest (Bettinger et al., 2017). Despite growing environmental concerns, the Scandinavian forestry tradition has largely maintained its methods, with only minor adaptations such as voluntary set-aside in less productive areas and increased retention of dead wood on clearcut sites. Fundamentally, the principles of silviculture have remained largely unchanged throughout this process (ibid).

Comparing German and Scandinavian forest management traditions, Brukas and Weber (2009) note significant differences. Forest management in Germany is deeply rooted in cultural and traditional values, with timber production driving the economic aspect. However, cultural values emphasise responsibility for the well-being of nature, which influences forest management practices. In contrast, Scandinavian forestry is closely linked to regional ecological and social conditions. The most important cultural factor is the public's right to access forests and connect with nature, leading to the goal of balancing timber production with ecological conservation and recreation. However, there are global regulations that will impact our Swedish forestry practices and strategies, namely Sustainable Forest Management (SFM). SFM is a critical component of global efforts to reconcile economic development with environmental conservation, as defined by the Food and Agriculture Organization of the United Nations (FAO, 2024). SFM is described as a dynamic and evolving concept that aims to maintain and enhance the economic, social and environmental values of all types of forests for the benefit of present and future generations. FAO promotes SFM through international cooperation and partnerships to address regional and global forest-related challenges, although its implementation varies widely, especially in tropical regions where enforcement is uneven (ibid). In Sweden, primary legislation such as the Forestry Act and the European Union Timber Regulation (EUTR) contribute to the country's precautionary approach to SFM (Skogsstyrelsen, 2023).

Brukas and Weber (2009) highlight the importance of SFM in adapting to a changing economic environment and emphasise the strong norms in Sweden that prioritise biodiversity, functioning ecosystems and the provision of ecosystem services. Different SFM methods are used worldwide, including silvicultural approaches such as regeneration, thinning and harvesting to maintain genetic diversity and ecosystem resilience. The choice between continuous cover and clear-cut regeneration methods depends on ecological considerations and management objectives, and practices vary across Europe. Non-timber forest products (NTFPs) provide economic opportunities while promoting conservation goals, and economic mechanisms such as REDD+ and certification schemes value goods and services such as carbon storage, hydrology, biodiversity and ecotourism. In conclusion SFM is a multifaceted approach to balancing economic, environmental, and social objectives. While significant progress has been made globally, there are still gaps in understanding the effectiveness of existing methods and mechanisms, particularly in Sweden (ibid).

Assessing the sustainability aspects of new technologies, particularly in the context of drone technology in forestry practices, presents several challenges. Currently, drones, or unmanned aerial vehicles (UAVs), are primarily used in forest management for tasks such as documenting storm damage, monitoring tree stands for pest attacks, and supporting inventory and action planning (Airforestry, 2024). However, the continuous development of this technology offers possibilities to improve the industry's environmental impact and soil degradation (Michels et al., 2023). The integration of drones into forestry practices, such as selective logging, where specialised drones identify and extract trees for felling, has the potential to minimise habitat disturbance and soil erosion risks. This process eliminates the need for machines to enter the ground, instead drones extract the trees through aerial flight (Airforestry, 2024). While drone technology enhances operational efficiency and aligns with sustainable forestry practices, there are still gaps in knowledge and inconsistencies regarding its full integration into sustainable forest management practices (Johnsson et al., 2022). To address this, it is essential to comprehend the implications of drone technology on forest management practices. Including the regulations that govern their usage and who is permitted to employ these methods. Foresters must obtain drone licenses, which involve passing theoretical exams and practical assessments to ensure safe and responsible drone operation (Transportstyrelsen, 2024). In the context of forest operations, adherence to regulations ensures safe and responsible drone usage. For instance, in the open category, drones are permitted to fly within the operator's line of sight and not exceed a height of 120 metres above ground level (ibid). Flights exceeding these limitations necessitate the acquisition of a specific category or certified category permit, which involves the completion of a predefined risk assessment tailored to the particular type of operation or flight in question, such as forest surveys or monitoring (ibid). Such permits enable the utilisation of drones for tasks such as aerial surveys, forest monitoring, or mapping in remote or restricted areas. This ensures the efficient collection of data while adhering to safety protocols and airspace regulations.

2.2 Linear innovation model

Gambardella et.al., (2016) presents a linear innovation model, which is also known as the traditional producer-centric innovation paradigm. In this model, producers assume the primary role in identifying market needs, conducting research and development, creating new designs, and ultimately bringing the innovations to market for sale. This paradigm is rather straightforward and follows a few key steps. The initial phase of the innovation process involves the study of user needs and preferences. This step is crucial for aligning the innovation process with customer requirements, as it allows producers to gain an understanding of the market demand for new products or services. In response to the identified user needs, producers invest in research and development activities with the objective of developing new designs and technologies that address those needs. This phase involves experimentation, prototyping, and testing to ensure the feasibility and effectiveness of the innovations. Once the new products or services have been developed, the producers move into the production phase, during which they manufacture the physical goods or deliver the services at scale. This stage involves the establishment of production processes, quality control, and logistics in order to bring the innovations to market. The final stage of the linear innovation process is the introduction of the new products or services to the market through sales and marketing efforts. The objective of producers is to capture market share, generate revenue, and achieve a return on their innovation investments, see *Figure 1* (von Hippel, 2016).

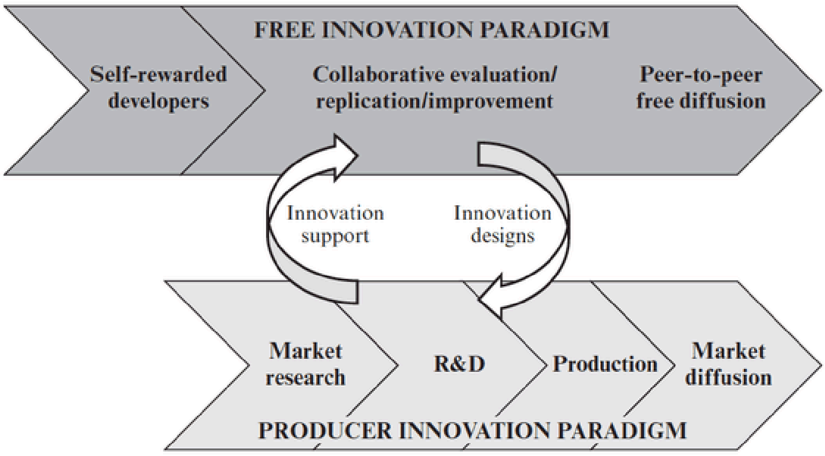

Figure 1: *The free innovation paradigm and the producer innovation paradigm (von Hippel, 2016).*

Critics argue that it does not account for the complex, iterative nature of innovation in dynamic sectors such as IT and digital media, where user involvement and feedback are crucial (von Hippel, 2016). Gambardella et.al. (2016) proposes a solution based on the concept of co-creation which represents a collaborative approach to innovation where producers and users work together to create value. Co-creation blurs the boundaries between producers and users, allowing for active participation and contribution from both parties throughout the innovation process. This collaborative model enables users to provide insights, ideas, and feedback that can influence the design and development of products or services (ibid).

The link between linear innovation and co-creation lies in the evolving nature of innovation paradigms. While linear innovation has been the traditional approach followed by producers, the rise of user innovation and co-creation has challenged this linear model. Co-creation emphasises the importance of engaging users as active participants in the innovation process, leveraging their creativity, knowledge, and experiences to co-create value. By integrating co-creation practices into their innovation strategies, producers can benefit from user insights, enhance product development, and foster closer relationships with their customers. This collaborative approach not only leads to more customer-centric innovations but also helps in creating a competitive advantage in dynamic markets where user preferences and technologies are constantly evolving (Gambardella et.al., 2016).

2.3 Users of new technology

In Shove et.al. (2005) article, they advocate for a reimagining of consumers from passive users to active and creative practitioners within their practices. The user's attitude towards sustainable practices varies depending on several different factors such as personal beliefs, values, knowledge and awareness of environmental issues. In Iveroth and Bengtsson (2014) they discuss the changing behaviour towards sustainable practices, and present actions of users and sustainable practice. Users with neutral attitudes can be a result of lack of information or incentives to change their behaviour. To change their behaviour there's a need of awareness and understanding to make them prioritise sustainability in their daily actions. In their article they focus on the relationship between education, social norms, access to resources and individual values (ibid). As competence increases, it creates material that assume a more sustainable character and the meaning of forestry takes a new form to sustain ecological improvement (Shove et.al, 2012). However, the users of more advanced technology are often tied to an organisation, with strategies and decision-making processes. The articles of Iveroth and Bengtsson (2014) bring forward several incentives for organisations to use sustainable methods in their operations, driven by economic, environmental, social and regulatory bodies. Deciding what sustainable strategies the organisation chooses to adapt, is a result for what the innovation would entail for the organisation in cost, efficiency, risk mitigation, stakeholder expectation and regulatory compliance (ibid).

The advantages of the move towards user-driven innovation are numerous and well-documented (von Hippel, 2011). Users are able to create innovations that meet their specific needs, which complements producer innovation and provides valuable data for further development. Additionally, user innovation has been shown to increase social welfare by being applicable in operational practice. Transferring product development activities from drone technology producers to users is challenging, but it can also lead to innovative solutions and increased user satisfaction. Companies and industries must adapt to this new reality, and government policy and legislation must keep pace with these changes (ibid).

Michels et al. (2023) assert that technical knowledge and equipment access are the primary barriers to drone adoption among forest managers. Tailored support and improved training initiatives would significantly enhance the uptake of drone technology. Clear and objective communication regarding the long-term economic benefits of integrating drones into forest management practices is crucial (ibid). As noted by Hippel (2011), the rapid innovation capabilities of users are due to the quality of computer software and hardware, improved access to user-friendly tools and components, and a richer innovation environment. These factors have significantly impacted the ability of users to innovate quickly (ibid).

2.4 Lead users as co-creators of innovation

According to Urban & von Hippel (1988), lead users of a new or improved product, process or service are those who exhibit two key characteristics. They encounter needs that will be widespread in a marketplace, but encounter them months or even years before the majority of that marketplace does. Additionally, they stand to gain significantly by obtaining solutions to those needs. It is important to note that these characteristics make lead users uniquely positioned to provide valuable insights and feedback for the development of new products, processes, or services. The two lead user characteristics specified provide valuable and independent contributions to the type of new product needed, as well as solution data that lead users are hypothesised to possess. It is important to acknowledge multiple perspectives and show respect for differing opinions in order to foster a cooperative atmosphere. In rapidly evolving product categories, such as many high technology products, manufacturers must analyse the real-world experience of users at the forefront of the trend to accurately understand the needs that the bulk of the market will have tomorrow (ibid).

Lead user analyses are a crucial tool for the development of new industrial products (Urban & von Hippel, 1988). It is important to acknowledge the value of lead user analysis in staying ahead of the competition and meeting the needs of the market. By identifying emerging trends early, they can unlock future market demands and preferences before they become mainstream. The unique perspectives, needs, and experiences of lead users can reveal innovative solutions and product features that traditional users may not have identified. By utilising insights from lead users, companies can confidently develop products that are ahead of the competition and better meet the evolving needs of the market. It is important to acknowledge the diverse perspectives of lead users and collaborate with them to ensure that their needs are met while also achieving business goals. Understanding the needs of lead users can help companies reduce the risk of costly product failures and focus their resources on developing products that have a higher likelihood of success in the market. A technology provider is defined as an entity engaged in the development and supply of new technologies to the market. They are designing products based on the input of lead users to create solutions that resonate with a broader customer base, leading to higher levels of satisfaction and loyalty. Lead user analyses offer a strategic approach to innovation by utilising the knowledge and experiences of users who are at the forefront of industry trends (ibid).

Co-creation is an essential concept in innovation theory and has significant applications when integrated with lead user analyses (Urban & von Hippel, 1988). It involves a collaborative effort between companies and lead users, focusing on jointly developing innovative solutions and industrial products. This method recognizes the exceptional insights, experiences, and expertise possessed by lead users and their potential to make substantial contributions to the product development process. The exchange of knowledge and expertise between companies and lead users can create innovative solutions that meet the needs of both parties. Companies provide technical capabilities and market knowledge, while lead users contribute their understanding of unmet needs and innovative ideas. This collaborative process adopts an iterative approach to ensure a balanced perspective and smooth flow of information. Co-creation is a highly effective and well-established iterative process where companies and lead users collaborate to refine ideas, prototypes, and solutions based on mutual feedback and insights. This collaboration facilitates continuous improvement and innovation, resulting in products that better align with market demands (ibid).

According to Urban & von Hippel (1988), the primary objective of co-creation is to generate significant value for both parties involved. Companies can greatly benefit from the distinctive viewpoints and insights offered by lead users. In turn, end users are empowered by actively participating in the decision-making process, which fosters a sense of ownership over the products being developed. This empowerment often results in increased user satisfaction and loyalty, while also accelerating the pace of innovation and harnessing the collective creativity and expertise, which can lead to significant breakthroughs and advancements. This statement highlights the importance of tailoring solutions and products to achieve success in the marketplace, which is a key factor in driving innovation (ibid).

2.5 Social practice theory

The integration of social practice theory with lead user and co-creation theories provides a comprehensive understanding of the adoption and integration of drone technology into forestry (Shove et.al., 2005). This approach elucidates the innovative contributions of lead users and examines how these innovations become routine practices within the forestry sector (ibid). While lead user theory and co-creation focus on user involvement in innovation, social practice theory provides insights into the incorporation of these innovations into existing social practices (Urban & von Hippel, 1988; Shove et.al., 2005).

In the article by Shove et.al. (2012), three elements are presented: material, meaning and competence, which should act as a schema between physical and mental activities in the form of background knowledge and motivation. The first element in Social Practice Theory (SPT) is 'material', including physical objects and resources associated with the particular practice. Material components exist to facilitate operations and are essential to their performance. The second, 'competence', refers to technical proficiency; knowledge, skills and abilities required to engage effectively in a practice. Competence is also seen as the norms, rules and conventions that govern the practice and this is developed through learning, experience and socialisation within a particular community of practice. These elements are essential for participants to engage meaningfully in the practice and to derive satisfaction from their involvement. Finally, 'meaning' is about social practice and includes the symbolic, cultural and social significance attached to a practice. It includes the values, beliefs, norms and narratives that give meaning to the actions and objects involved in the practice. In the social practice model, these elements are interrelated and mutually constitutive. Changes in one element can influence the others, leading to adaptations, innovations or transformations in the practice over time, see *Figure 2* below.

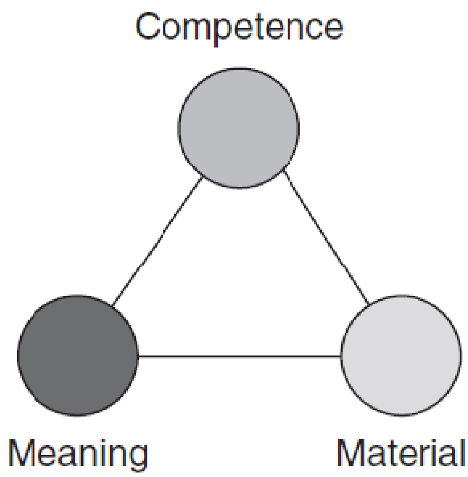

Figure 2: *Elements of social practice (Shove et.al., 2012).*

To study the use of drone technology in on-the-ground forest management practices, we can use practice theory as an analytical framework. SPT focuses on understanding what people do and the meanings, competences and material elements that make up these practices (Shove et.al., 2005). In this context, forest management ideas and sustainability concepts can be seen as meanings, while drone technology serves as a material element. Competence is the knowledge of how to integrate ideas about forest management and sustainability with drone technology to create more sustainable forest management practices. For example, using SPT as an analytical perspective can help explain how new technologies such as drones are adopted by users, often early adopters, to improve outcomes such as more sustainable forest management practices. SPT is valuable for studying how new practices emerge, stabilise and replace established ones. In SPT research, practices serve as the unit of analysis. Therefore, it's important to consider whether forest management involves established practices and whether drones are material elements integrated into these existing practices. By applying practice theory, we can explore how drone technology becomes embedded in forest management practices and contributes to sustainability goals, shedding light on the dynamics of innovation and adoption on the ground (ibid).

In the article by Shove et.al (2005) they suggest taking ideas forward by conceptualising consumers not as users but as active and creative practitioners, and appropriation as a dimension of the reproduction of practice. It's clear that practice involves the active integration of the three elements. Users play a crucial role in shaping and developing practices through their interactions with material objects, associated meanings and forms of competence. Practices are not static entities but are constantly evolving through the active engagement and contributions of users, producers and other stakeholders (ibid).

2.6 Theoretical synthesis

The social practice theory posits that users play an active role in shaping and developing practices through their interactions with technology (Shove et al., 2005). It is therefore crucial to understand this role if we are to comprehend the adoption of drone technology and the co-creation of innovation. In the forestry sector, this perspective provides insights into the factors influencing the adoption of technology and the collaborative processes that facilitate innovation. Users contribute their expertise, insights, and requirements, thereby influencing the development and application of drone technology in forestry practices (von Hippel, 2011). Lead users, who are early adopters of innovative technologies, actively participate in the shaping of their development and application (Urban & von Hippel, 1988) By studying lead users in the forestry sector who have adopted drone technology, researchers can identify the factors that influenced their decision to adopt the technology. Furthermore, the perceived benefits and contributions of these users to the co-creation of innovative practices can be examined. An understanding of the characteristics and motivations of lead users can inform the analysis of the adoption and diffusion of drone technology in forestry practices (Shove et.al., 2012).

The linear innovation model, which views innovation as a linear process, may not fully capture the complexities of innovation processes, particularly in the context of drone technology in forestry (Gambardella et al., 2016). An interactive perspective that considers feedback loops, user involvement, and co-creation is more suitable for this context, as it allows for a more nuanced understanding of the complexities involved. Social practice theory presents a framework for comprehending the interrelationships between individuals, technologies and contexts within the context of existing practices (Shove et al., 2005). In essence, it conceptualises practices as the routinised ways of doing things that are shared by members of a given community or social group. The concept of lead users represents early adopters of new technologies. These individuals or organisations provide valuable insights and feedback on technological development and refinement, thereby facilitating the transition from theoretical potential to real-world application (Urban & von Hippel, 1988). The process of co-creation ensures that the developed technology is tailored to the users' needs and challenges, thereby increasing the likelihood of successful implementation and adoption (ibid). An understanding of the operational context, as derived from SPT, and the integration of insights from lead users can facilitate the effective addressing of practical challenges through co-creation initiatives. For example, this could involve the development of user-friendly data processing tools or the implementation of measures to ensure regulatory compliance. *Figure 3* illustrates the convergence of the different theories and how they interact with each other to provide a framework for answering the aims and objectives of the study.

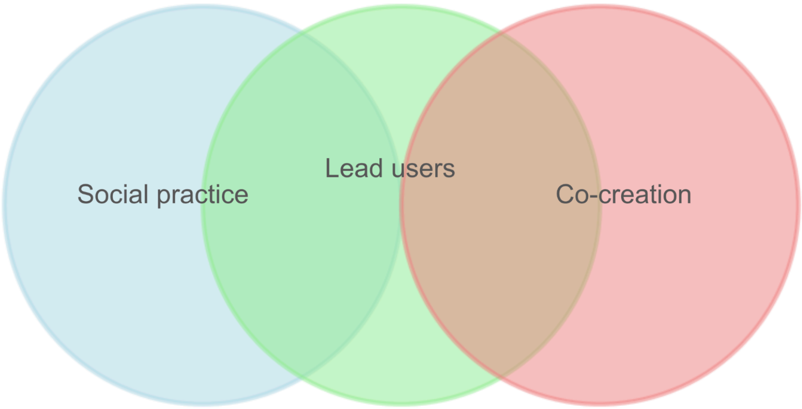

Figure 3: *Venn diagram illustrating the convergence of the various theories, own illustration.*

3. Research Method

In Chapter 3, the chosen methodology is presented as the foundation for the study, aiming to achieve its objectives and address the research question. This chapter also outlines the sampling strategy adopted, the conducted case study, and the procedures involved in data collection. Finally, potential criticisms regarding the chosen methodology are discussed, including considerations of validity and reliability.

3.1 Method

The study employs a qualitative method with an inductive approach, specifically in the form of a case study (Bryman & Bell, 2017). This approach was selected to provide an in-depth understanding of user perspectives on the use of drones in forestry operations. The qualitative method allows for the generation of rich, detailed insights into the experiences, perceptions, and behaviours of users, which are essential for exploring complex social phenomena such as the adoption of new technology. The inductive approach enables the generation of new theories or concepts based on the data collected, rather than starting with preconceived hypotheses. This is particularly valuable in exploring emerging topics where existing theories may be limited or insufficient. Other methods that could have been chosen include quantitative surveys or experiments. However, these methods may not have provided the depth of understanding needed to explore the nuanced user perspectives and contextual factors influencing the adoption of drone technology in forestry. Furthermore, quantitative methods may not effectively capture the subjective experiences and motivations of users as well as qualitative approaches (ibid).

The decision to discard quantitative methods was also influenced by practical considerations such as the limited availability of data and the exploratory nature of the research questions. By focusing on qualitative methods, the study can delve into the complexity of user interactions with drone technology and provide valuable insights for practitioners and policymakers in the forestry sector (ibid).

3.2 Research design

The case study design was selected because it provides a holistic view of the phenomenon within its real-life context (Bryman & Bell, 2017). By focusing on a specific forestry company or organisation, the case study can provide detailed insights into how drones are utilised in practice, the processes involved, and the impacts on various aspects of forestry operations. This includes understanding how drones are integrated into existing workflows, the challenges encountered during implementation, and the outcomes achieved. Furthermore, the case study approach facilitates the examination of both internal and external factors influencing drone adoption, such as organisational culture, stakeholder dynamics, regulatory constraints, and technological capabilities. This depth of analysis is crucial for gaining a holistic view of the phenomenon. Other design options, such as surveys or experiments, were considered but ultimately discarded for several reasons. Surveys, while useful for collecting quantitative data from a large sample, may not capture the intricacies and context-specific details of drone usage in forestry. They also may not allow for the exploration of underlying motivations, perceptions, and experiences of individuals involved in drone operations. In contrast, experiments involve controlled conditions and manipulation of variables, which may not accurately reflect the complexity of real-world forestry settings. Additionally, conducting experiments in forestry operations could be challenging due to logistical constraints and ethical considerations (ibid). The case study design emerged as the most suitable choice for this research due to its compatibility with the qualitative nature of the study, its ability to provide rich contextual insights, and its capacity to explore the multifaceted nature of drone implementation in forestry operations (ibid).

3.3 Sampling Strategy

The qualitative case study, employing an inductive approach, prioritises depth, relevance and richness of information in order to provide a nuanced and comprehensive understanding of the use of drones in forestry (Bryman and Bell, 2017). The aim is to explore the practical applications of drones within the context of forestry operations. The unit of analysis in this study is practice, focusing on how drones are used in real-life forestry settings. People and organisations serve as the context in which drones are utilised. This implies that the unit of observation is the information collected from individuals and their organisations regarding their experiences with drone technology in forestry. In accordance with the chosen method, purposeful sampling will be employed to select cases and participants that can provide comprehensive and insightful data related to the phenomenon of interest, namely lead users in forestry and technology providers. This sampling approach ensures that participants are directly relevant to the research question and can offer valuable insights into the practical applications and challenges of drone usage in forestry. In order to ensure diversity and variation among participants, the sampling criteria will include forest researchers, technology providers, and member groups associated with forestry. This approach allows for the exploration of different perspectives and experiences within the forestry industry, thereby enriching the depth of understanding gained from the case study analysis (ibid).

In this study, the participating firms have been classified into two distinct groups, derived from Urban & von Hippel (1988) article: lead users and technology providers. This categorisation is based on the roles that the firms in question play in the forestry sector, as well as their engagement with drone technology. The term "lead users" is used to describe a specific category of firms within the forestry sector that are engaged with drone technology (ibid). Holmen and Södra are classified as lead users in this study. As significant proprietors of forestland and prominent forestry enterprises in Sweden, they are positioned to spearhead the exploration and resolution of challenges inherent to forest management. These companies have a vested interest in the adoption and shaping of new technologies, with the objective of meeting their specific needs in forestry operations. Their considerable experience in the sector and their proactive approach to innovation render them ideal candidates for the lead user category. The following section will delineate the role of technology providers. Dianthus, Drone Center Sweden and the SLU are classified as technology providers. Dianthus is a company that specialises in the field of drone technology and the provision of related services. Drone Center Sweden is an organisation whose activities are centred on the development and application of drone technology across a range of sectors. SLU provides academic expertise and research capabilities in the fields of forestry and drone technology. This classification allows us to examine the interaction between those who are primarily users of the technology (Holmen and Södra) and those who are developing and refining the technology (Dianthus, Drone Center Sweden, and SLU). By distinguishing between these roles, we can better analyse the co-creation process and the specific contributions of each group to the innovation and adoption of drone technology in forestry (ibid).

3.4 Data collection

The analytical decision is to investigate the utilisation of drone technology in forest management practices. The case study research design enables the collection of data from multiple sources using a variety of methods. The data collection will be conducted through semi-structured interviews and secondary sources, including written journals and research reports, for the selected subject (Bryman and Bell, 2017). Prior to the commencement of the study, respondents will be provided with a preparatory mailing which will explain the purpose of the study and the themes that will be addressed. This will afford them the opportunity to prepare and inform themselves on the subject within their organisation, thereby increasing the likelihood of obtaining valid responses. A further advantage of the semi-structured interview method is that it allows for the spontaneous emergence of follow-up questions when the subject matter is discussed, thus enabling the respondent to expand on their responses if necessary. The interviews will be conducted in Swedish and subsequently translated into English for transcription. The participants will then validate the information gathered prior to publication. The objective of the review of secondary data was to obtain knowledge of the digital developments that are taking place or have taken place in the near future within the industry. This was achieved through the analysis of industry literature and earlier studies that have addressed the subject matter. The written material allowed the creation of an outsider's perspective image of the market, including the potential uses of the available products for Swedish forest management (Bryman and Bell, 2017).

In order to address the research question posed for this essay, namely how users of drones utilise the technology in practice and the challenges they face. In order to develop arguments in addition to those presented in the literature review, semi-structured interviews will be employed, see *Table 1*. The interviews are structured around five themes for discussion. These include questions pertaining to the practical use of drones in their company. The full list of questions can be found in Appendix 1. The interviews are recorded with the consent of the respondent, which ensures that important information is not inadvertently omitted and facilitates the transcription process, which streamlines the analysis of collected data. The transcription will be sent back to the respondent for validation, thus ensuring that the information is accurately conveyed in accordance with the original intention (Bryman and Bell, 2017).

Table 1: *Summary of respondents.*

Respondent	Title	Role in Social practice	Date	Duration	Format
Christian Syk	Holmen	Lead user	2024-02-28	15 minutes	Telephone interview
Urban Wahlberg	Drone Center Sweden	Technology provider	2024-03-26	25 minutes	Video interview
Jonas Bohlin	SLU	Technology provider	2024-03-28	20 minutes	Video interview
Fredrik Walter	Dianthus	Technology provider	2024-04-08	30 minutes	Video interview
Rasmus Pettersson	Södra	Lead user	2024-04-15	25 minutes	Video interview

3.5 Analysis of the empirical data

Thematic analysis was selected for this study. Primarily because it allows a systematic and rigorous examination of qualitative data (Bryman & Bell, 2017). Particularly when exploring complex phenomena such as the integration of drone technology into forest management practices. Thematic analysis enables the researcher to identify patterns, themes, and relationships within the data, providing a structured framework for interpretation. Additionally, it is well-suited for uncovering both explicit and implicit meanings embedded within the data. It also allows for flexibility in interpreting the data, accommodating diverse perspectives and experiences from participants. This aligns with the aim of the study to understand the practical implications, challenges, and benefits of adopting drone technology in forest management from the perspective of lead users. Furthermore, thematic analysis provides a clear and transparent process for organising and synthesising the data, making it easier to draw meaningful conclusions and insights. By grouping the data into themes related to adoption, co-creation and challenges, the researcher can systematically explore different aspects of the phenomenon under investigation. Other methods, such as content analysis or grounded theory, could have been considered but were ultimately discarded for several reasons. Content analysis focuses primarily on the content of the data without necessarily uncovering underlying themes or patterns. While grounded theory is a valuable method for generating theories from data, it may have been overly complex for this study's focus on identifying and understanding key themes related to drone technology adoption in forest management (ibid). Thematic analysis was chosen as the most appropriate method for this study due to its flexibility, systematic approach, and ability to provide rich insights into the research question. The themes applied in the analysis are: reasons for adopting drone technology, co-creation of innovation and challenges integrating drone technology into forestry practice. These themes were conducted to support the aim of this study which is to contribute to knowledge of lead users as co-creators of new technology (ibid).

3.5 Literature search

The literature consulted for this essay comprises written sources, including those from the Web of Science and Google Scholar. The keywords used were "Swedish forest industry," "forest management," "sustainability," "technology," "drones," and "digital means." In addition, sources from magazines and trade magazines were consulted via Google. The journals' own databases, in Airforestry and the Swedish Forest Industries Federation, were also searched using the keywords "drones" and "sector." The essay employs the theoretical frameworks of lead user, co-creation, linear innovation model, and social practice theory.

3.6 Validity and Reliability

In this study, the author has embarked on a journey of exploration, utilising triangulated data from interviews and research articles to gain an understanding of the phenomenon under investigation from multiple perspectives (Bryman & Bell, 2017). The triangulation includes websites such as Airforestry, Drone Centre Sweden and Swedish Forest Industries Federation. By gathering data from these disparate websites, the author has gained a more comprehensive and multifaceted understanding of the utilisation of drone technology in forestry. This has enhanced the validity and reliability of my research (ibid).

Along the way, the author has sought validation through peer debriefing with classmates during seminars and supervisor meetings to ensure the integrity and credibility of the research. This process has also helped to remain consistent and dependable in documenting methodological decisions, changes, and challenges, enhancing the reliability and transparency of my study (Bryman & Bell, 2017).

By conducting a comprehensive theoretical background, the author provides readers with a detailed description of the research topic, offering a comprehensive overview that strengthens the study's credibility and transferability. This invites readers to evaluate the rigour and robustness of the research endeavour. Throughout this journey, the author remains cognizant of thier own biases, assumptions, and preconceptions about the research topic, ensuring reflexivity at every step. This reflexivity is of critical importance in acknowledging the subjectivity inherent in qualitative research and illuminating the complexity of interpretation, thereby increasing the credibility of the results (Bryman & Bell, 2017).

3.7 Ethical considerations

The implementation of the study prioritised privacy and data protection throughout the research process (Bryman & Bell, 2017). Any personal or sensitive information collected from participants was stored securely and only the researcher had access to it. Steps were taken to ensure that data transfer and storage complied with relevant data protection regulations. In addition, participants were given the opportunity to review the transcripts of their interviews for accuracy and to provide additional feedback or corrections before their data were included in the study. This process further ensured transparency and trust between the researcher and the participants (ibid). Another ethical consideration was to maintain objectivity and avoid bias in data collection and analysis. Steps were taken to recognise and address the researcher's own biases and preconceptions, which promoted transparency and accuracy in reporting the results (ibid).

Finally, the study adhered to the ethical guidelines and standards set by relevant institutions and professional organisations, ensuring that the research was conducted in an ethical and responsible manner. Overall, these ethical considerations aimed to uphold the dignity, rights and well-being of all individuals involved in the research process while maintaining the integrity and credibility of the study (Bryman & Bell, 2017).

3.8 Delimitations

The study is specifically concerned with the use of drones in forest management within a particular geographical area, Sweden. It is delimited to the forestry sector, excluding other industries or sectors where drones may be used differently or have different implications. In particular, it examines the use of drones in forest management, excluding other types of technology or innovations that may also be relevant to the industry. The study concentrates on certain categories of organisations within the forestry sector, such as lead users which are major commercial forestry companies, excluding smaller enterprises or non-profit organisations. Furthermore, the study is delimited to a specific research method, which is qualitative rather than quantitative, excluding other methods which may provide different insights (Bryman & Bell, 2017).

4. Empirical data

In Chapter 4, an overview of the summaries derived from the conducted interviews will be presented. This chapter provides insights into the perspectives of key stakeholders in the field of drone technology and forestry management. Through interviews with lead users, including specialists in long-term planning, drone operators, founders of innovative companies, and planning managers, valuable insights were gained regarding the current challenges, opportunities, and future trends in utilising drones for forestry practices.

4.1 Empirical background

This chapter describes what a lead user in the field of drone technology and forestry management entails. The selected lead users in the study were chosen based on the characteristics outlined in the definition of lead users provided by Urban & von Hippel (1988). These individuals were identified as encountering needs that are likely to become widespread in the marketplace, but they encounter them months or even years before the majority of the market does. Additionally, they stand to gain significantly by obtaining solutions to those needs. The Specialist in long-term planning at Holmen, Operating chief of Drone Center Sweden, Acting operator for SLU's drone operations, Founder CEO and data analyst of Dianthus, and Planning manager at Södra were all selected as lead users because they are actively involved in the field of drone technology and forestry management. They are at the forefront of utilising drones in forest management practices, encountering emerging needs and challenges before they become mainstream in the industry (ibid).

These lead users possess valuable insights and experiences that can contribute to the development of new products, processes, or services in the field of forestry and drone technology (Urban & von Hippel, 1988). Their expertise allows them to provide feedback on the effectiveness of drone technology in addressing specific needs and challenges in forest management, ultimately driving innovation in the industry. By collaborating with these lead users, companies can gain valuable insights into emerging trends and preferences in the marketplace, allowing them to stay ahead of the competition and meet the evolving needs of the market. The integration of co-creation with lead user analysis enables companies to leverage the collective creativity and expertise of these individuals, thereby accelerating innovation and ensuring that the products developed resonate with end users.

Holmen is a company and Södra are a member organisations involved in forestry operations. The statement suggests that these entities could be compared to product users rather than developers of new technology. This means that they utilise technology developed by others (in this case, drones) rather than creating it themselves. However, despite not being the creators of the technology, they are still considered "co-creators" through the user perspective and "learning by doing" (von Hippel, 2003). This implies that they are actively engaged in the process of utilising and adapting the technology to their specific needs and requirements. Through their practical experience and feedback, they contribute to the ongoing development and improvement of the technology.

In the context of drones in forestry, Holmen and Södra play a pivotal role in identifying the needs that the drones must fulfil. Their hands-on experience in the field allows them to provide valuable insights into how drones can be effectively utilised to address various challenges and tasks within forestry operations. By engaging with the technology in this way, they contribute to the shaping of its development and ensure that it meets the specific demands of the industry. *Table 2* below provides a list of respondents to the interviews that will be presented in the subsequent section.

Table 2: *List of interviews.*

List of interviews	Title
Christian Syk	Specialist in long-term planning at Holmen
Urban Wahlberg	Operating chief of Drone Center Sweden
Jonas Bohlin	Acting operator for SLU’s drone operations
Fredrik Walter	Founder of Dianthus, CEO and data analyst
Rasmus Pettersson	Planning manager at Södra

4.2 Specialist in long-term planning at Holmen

Christian Syk, who works at Holmen, explains the current use of drones and its future development. He is a trained forester and works in the command centre of forestry at Holmen under the position of specialist with long-term planning. He explains that the organization underwent reorganization and now focuses more on the issue of drones as a practical sustainable method. In tract planning, drones are used more operationally in such a way as to have a camera up in the air to get an overview of the area. They are supported by computer programs in the iPad and can use the drone's GPS position to log various phenomena. Through the approach, they detect forest damage, but also other information that can be used as material for the planning of the forest area. They get an overview and can plan extractions of, for example, top breakage, which is characterised by whether the top of the tree is dry or resin-soaked or windfall, which constitutes the trees' resource absorption capacity of light, water and nutrients. What is being discussed to develop this technology is to use more high-resolution information that provides quick access about the health of the forest. As standard, Holmen has the right to a number of data sources, a national laser scan and also aerial images from the Lantmäteriet and other things, but in many situations Holmen wants even more high-resolution information faster.

Drones would be an effective method to collect large areas and gather a better detailed image of the forest in an early state, but this is not something that Holmen has done so far. There is technology for this type of method, but what prevents Holmen from using it today is the legislation, which means here that drone pilots cannot practise flying beyond visual range as this requires a certified licence. According to Christian Syk, a certified licence involves an extensive application process and together with the regulations, this is considered to be the biggest obstacle to developing the practice of drones in forestry. He also says that this is still a possible development, but that at the moment there have been other development projects that have been prioritised instead. There are limitations to what high-resolution data collection with drones can achieve in forestry to be sufficient when looking at following regulations linked to the environment, some things still need to be done on the ground such as tracking species occurrences and other things.

Christian Syk considers future areas of use for drones to be that they could carry higher payloads and sees development potential in the area of forest fertilization. Holmen has looked at being able to use larger drones to be able to carry out forest fertilization, which could save a lot of money and also be better from an environmental point of view, in that they have a better opportunity to control in detail than when they use helicopters that you use today. In this way, fertilization only takes place in the areas that are in greater need than others. The technology for thinning units for drones is a possible development on the right type of object, but it is a lot of work against gravity. It is energy-intensive and perhaps not such an efficient process either, but we do not close any doors to the technology.

4.3 Operating chief of Drone Center Sweden

Urban Wahlberg serves as the chief operating officer of Drone Center Sweden, an organisation dedicated to testing unmanned systems. Their facility specialises in testing a variety of flying systems, spanning water, underwater, ground, and aerial operations. Primarily, they focus on testing drones, currently evaluating a large drone capable of lifting around 600 kg, with plans to increase its capacity to approximately 1.5 tons. This drone is intended for tasks such as forest fertilisation and firefighting, covering an area of 25 square metres. They also engage in lobbying activities aimed at influencing policies and regulations regarding drone usage, particularly in the forestry sector. They discovered a 1800-square-kilometre test site, which they divided into four sections, and provided an ideal location for testing. However, navigating aviation regulations, including altitude restrictions of up to 2000 feet, poses challenges and often results in delays in obtaining permissions for each specific mission. Their testing primarily focuses on assessing the functionality of different systems in real-world scenarios. They also work on developing navigation and communication systems to enable precise control of drones, sometimes utilising GSM networks for enhanced accuracy. Additionally, they discuss potential applications and the need to adapt regulations to accommodate advancements in drone technology, particularly within the forestry industry. Their clientele, such as forestry companies, utilises the technology facilitated by Drone Center Sweden. They do not directly provide services to forestry companies but develop products that companies can utilise, such as LIDAR[1] cameras for forest management purposes. The potential applications of drones in forestry, such as forest fertilisation and surveying, are vast and limited only by imagination.

Challenges in drone technology include obtaining permissions for beyond visual line of sight flights and flights at higher altitudes. However, advancements in technology offer promising solutions. For instance, drones can be used for tasks like monitoring forest areas for post-storm damage or assessing water quality in lakes and rivers, which traditionally required significant manpower and time. The potential applications for drones are limitless. Small drones and large drones serve different purposes, with larger ones capable of flying in swarms. For example, during a forest fire, a group of 5 to 6 large drones can provide crucial information such as wind direction, smoke detection, and darkness levels. This significantly improves working conditions compared to traditional methods, allowing access to remote areas without risking crew. They can be used to locate hotspots and monitor areas prone to reignition using thermal cameras, preventing further spread

[1] "Lidar — Light Detection and Ranging — is a remote sensing method used to examine the surface of the Earth" (NOAA, 2023).

of the fire. Drone technology not only enhances efficiency but also improves safety by reducing the need for manual labour in hazardous environments.

Moreover, it provides valuable data for environmental monitoring and compliance with regulations. Despite their challenges with regulatory bodies like the Transportstyrelsen, efforts to influence policy and regulations continue to ensure the advancement and widespread adoption of drone technology in various industries. The forest is poised to become a key focus for product development, potentially emerging as one of the largest sectors. This is particularly significant on an international scale, with foreign companies seeking to test their innovations in Sweden. This trend is expected to intensify, given the limited airspace available for testing in continental Europe, prompting a surge in testing activities within Sweden. Urban Wahlberg expresses concern that current regulations are hindering the drone industry's potential growth, especially in forestry. They highlight the financial impact on forestry companies and other large corporations due to these restrictions. According to calculations, significant savings could be achieved if drone technology were fully utilised, potentially amounting to substantial annual savings for forestry companies across Sweden.

4.4 Acting operator for SLU's drone operations

Jonas Bohlin serves as acting operator for SLU's drone operations. He commenced by underscoring the functionality of drone systems and emphasised their effectiveness in aerial surveys. Once drones complete their mission and touch down, they can automatically upload collected data to the cloud, facilitating the generation of common products like accurate maps and 3D models. However, the challenge lies in translating rich, high-resolution data into forestry variables, a task addressed by several startups. He stressed the importance of implementing comprehensive process chains within forestry organisations to fully utilise drone technology's potential. Jonas identifies that often the issue is that you see that it's too much to incorporate all of this at once. Instead, the idea is that you buy drones, then you fly them, and then the person who has flown manually has to sit and build all this, and then it feels like it takes far too much time, it becomes too cumbersome. Jonas means that they need powerful computers, and then still have the problem of extracting forestry variables like getting tree heights, which makes it too difficult to apply in practice. He also acknowledges that there are companies that provide this entire chain. Which means that big companies can still incorporate those systems.

Jonas continues by explaining the next problem which is that with drones, users only are allowed to fly within line of sight. Svenska Cellulosa AB (SCA) tried it maybe 5 to 10 years ago; which a Norwegian data collection company called it the world's only manned drone. What they actually did was take the smallest helicopter, the cheapest one you can think of, and basically put the same camera system on it as you would find on a simple drone. So, it was a very cheap concept, and they flew with it. Often, the company wants to take a clearing here and then fly to something else further away, collect some data there, and then a person who goes up with a drone may manage 10 objects in a day because they have to drive a lot between locations. But for the helicopter, it takes a minute to move to the next spot and scan it. So, a person in a car with a drone may handle 10 objects per day, while the helicopter did 300. So, the economy has been much better with that technology use, and it applies to almost everything here. For large areas, like those of big forestry companies, it's cheaper to buy a manned aircraft and apply the same technology to fly over an entire municipality at once than to have a person do it. Being actively engaged in understanding the economic aspects and factors driving profitability is crucial. Jonas firmly believes that this inquiry lies at the heart of why drones are not being utilised to their full potential. It's not just about the drones themselves; rather, it's about cost-effectiveness and the opportunity to integrate additional services beyond mere surveillance. The limitations of drones, given their localized scope, are evident. However, their utility becomes apparent when one considers scenarios where on-site multitasking and data collection are feasible. Whether it's the need for real-time data or conducting aerial assessments before ground operations, drones offer practical solutions. This perspective is particularly evident in the practices of the Forestry Board, where drone deployment streamlines inspection processes, facilitating rapid and comprehensive assessments of logging sites. By leveraging drones, tasks that once demanded hours of manual labor can now be accomplished in minutes, resulting in significant time savings and improved operational efficiency.

Jonas has been somewhat involved in research projects of drone technology in the forest sector. Particularly those focused on considerations for leaving residues to document them in clearings. Employing drones for this purpose would be incredibly beneficial. Jonas participated as a mentor in a thesis project at the forestry school where they examined forgotten timber left behind on clearings, assessing the extent of wood lost between harvesters and skidders, contributing to the reasons for such documentation. As Jonas rightly pointed out, it's merely about recording what happened, signalling the completion of tasks. So, there are practical applications, but it's crucial to manage the financial aspect. The challenge lies not with the drones themselves but rather in the willingness to invest. Furthermore, as Jonas mentioned, there's a growing emphasis on sustainability, potentially shifting towards continuous forestry practices and precision forestry. In these contexts, the competition arises from various methods of gathering tree-level information across vast areas simultaneously, making it more cost-effective per stand than flying one drone per stand.

4.5 Founder of Dianthus, CEO and data analyst.

Dianthus comprises four individuals: Fredrik Walter, Daniel Nilede, Johan Bergström in Uppsala, and Jonas Kulin in Grums, outside Karlstad. Their focus lies in geographic information technology for the Swedish forestry sector, utilising remote sensing data to gather forest information. One of their key services is "skogskartor," widely utilised by major forestry companies such as Södra Skogsägarna and Mellanskog. They compile data from various sources, including laser scanning, aerial photos, satellite images, and existing mapping data, to create comprehensive forest management plans. Unlike drone-based methods, they primarily rely on more extensive techniques such as manned aerial surveys for this purpose. Their main focus is on forest mapping, but they also provide solutions for optimising logging road placement to minimise environmental impact. Additionally, they offer services to facilitate consultations between forestry companies and reindeer herders, although this doesn't directly involve drones or remote sensing.

They've also been involved in projects outside Sweden, including one in Tanzania where drones were used to map individual trees across large areas to aid in reforestation efforts. The areas covered in Tanzania were substantial, ranging from approximately 400 to 500 square kilometres. While they don't operate their own drones, they do have them available for research and development purposes, although they haven't been actively used for some time. Typically, they either hire drone services or receive data from partners for analysis. They're currently engaged in a project where they'll receive drone-collected laser data with high accuracy for further analysis.

Their clients primarily consist of private forest owners interested in gaining detailed insights into their forest assets, ranging from small parcels to large estates spanning thousands of hectares. Depending on the project scope, they either rely on manned aerial surveys or utilise available data sources from agencies like the Lantmäteriet to perform their analyses. While they have tested drones in the past, they've encountered limitations in their scalability for larger projects, leading Dianthus to focus primarily on manned aerial surveys for their current operations.

They primarily focus on developing methods, but they also collaborate with others when needed. For example, they receive data from customers to analyze using the laser drone. Dianthus works with Skyforest, which has a streamlined organization that makes it easy for customers to place orders, even for smaller properties. Despite having many orders, they are able to coordinate them with others and demonstrate their competence and expertise in the field. Fredrik claims drones are often left unused due to the complexity of handling data and the need for significant technical interest. However, companies like Skyforest eliminate the need for such interest. It can be quite expensive to do it yourself, especially if you are not really up to persuing doing it. But if you have someone to contact when you want the area flown, it can be a hassle-free experience. Skyforest has a good organization and IT infrastructure that can handle your flights efficiently and cost-effectively.

In their analysis, they question the effectiveness of current methods, suggesting that without the ability to assess individual trees, there's a risk of missing important details in the forest landscape. They argue that data at the individual tree level would provide more accurate insights and could lead to more sustainable practices, such as selective harvesting rather than clear-cutting. While some companies, such as Plockhugget in southern Sweden, are interested in selective harvesting, they haven't fully explored the potential of drones for this purpose. Instead, they rely mainly on data from manned flights by agencies such as Lantmäteriet, which provides hectare averages and lacks the resolution needed for detailed analysis. However, they believe that increasing the resolution of drone data could significantly improve forest modelling and decision-making, allowing industry to source specific types of wood more effectively. They point out that the lack of detailed information at the level of individual trees limits the accuracy of current methods, although they can provide reasonable predictions of forest types suitable for particular industries. They suggest that the use of drones with 3D capabilities could improve forest management plans, citing the example of Skyforest, which conducts thinning detection by analysing tree density per hectare. However, they emphasise that the current resolution of drone data is insufficient to accurately assess the need for thinning, as it only provides average values per hectare. They want to include more detailed data in Dianthus system in the future; it's in their development pipeline. At the moment, their focus is mainly on existing data sources, which are crucial for organisations like Skogsforum to invest in. The challenge with drone data is its limited availability at the moment, but initiatives such as Skyforest's infrastructure investments are boosting confidence in adopting such data sources. However, the continuous availability of data is essential for operational continuity. This reliance on a consistent flow of data presents a challenge for drone data, which lacks the stability of other lower resolution data sources.

Some companies are reluctant to invest in drone technology due to concerns about licensing requirements and operational complexity, although becoming a licensed drone pilot is relatively straightforward. However, misconceptions persist, leading some to believe that drone piloting requires extensive training or in-person courses, when in fact online certification is readily available. Clarifying these misconceptions could help overcome any reluctance to adopt drone technology.

The biggest difference between traditional plans and modern technology plans lies in cost, with traditional plans costing around SEK 200 per hectare, while Dianthus method costs only 10 SEK per hectare. Although traditional plans may offer more detail at a higher cost, they are often sufficient for the price. However, the aim is to streamline forest management planning to reduce costs, with or without drones. If done manually, they rely mainly on freely available data, such as tree height and volume grids from agencies such as Skogsstyrelsen, although it is easier to adjust compartment boundaries in the field. However, the identification of conservation objects in the forest, which is essential, remains a challenge in their plans. Drones with high-resolution capabilities could simplify manual work in the forest and help identify conservation objects automatically.

4.6 Planning manager at Södra

Rasmus Petterson serves as a planning manager, leading a team of 10 colleagues spread across an area, their main focus is on forest management planning. They also have personnel responsibilities and have been involved in several green projects, mainly related to planning and forest inventory. One project involved collaboration with Arbo air in Linköping, who developed an AI tool that analyses images at a pixel level to determine tree height and species based on pixel width. The collaboration lasted about six months. Another project was with Global Forester, also based in Linköping, who developed their field app and GIS tools for fresh aerial photography. They occasionally use these tools, especially in emergencies such as windstorms or timber damage, to take up-to-date pictures with drones for quick assessments. These projects, together with the use of drones for several years, have been a significant effort, especially for customer satisfaction by providing aerial images to help landowners with older forests.

When flying over larger areas, they will usually encounter airspace restrictions, as regulations often limit flights to within visual line of sight. This constraint requires careful route planning, often requiring repositioning to maintain visual contact, especially in areas of young forest where drones are easily spotted. There are also challenges in automatically outlining areas during drone flights for orthophotos, as operators need to know their position relative to the drone as they are not directly controlling it. In terms of qualifications, they have a standard drone licence (AB or similar), which is a requirement for all operators, and register each drone with an operator ID. They are exploring ways to extend flight distances, particularly for forest inventory, where flights are not over built-up areas, crowds, protected sites or infrastructure. While progress is being made in this area, it's uncertain how far they have progressed, although they are working with GIS experts to address these challenges. Despite reasonable regulations that take into account safety and privacy concerns, there are still challenges, such as the prohibition of photographing certain areas from a certain distance, that affect their work process.

When it comes to aerial photography, Södra has researched more advanced drones equipped with multi-lens cameras, although they haven't used them themselves yet. The drones they typically use are standard aerial cameras, such as a 32-megapixel camera without zoom functionality, which still takes good pictures. Compared to Lantmäteriet's satellite images, Rasmus Pettersson believes that drone images offer better quality due to their higher resolution, which allows zooming to the point where people can be distinguished in the images. As for their systems, they rely mainly on their field application, which integrates various tasks such as drawing areas for forest management plans, handling contracts, calculating volumes and tracking timber deliveries. This system also includes a drone mode that connects to drones through various apps, allowing users to view the forest layout from the management plan while tracking the drone's position on the map, facilitating route planning and marking areas directly on the map. Although this software was not developed by Södra, it is considered their system as it integrates seamlessly with their operations.

They see it as a forward-looking approach to make greater use of unmanned aerial vehicles. This could help avoid damage to sensitive areas during timber harvesting, particularly in very wet peatland areas where conventional logging methods could damage the water environment. However, they believe this is more of a long-term vision. In the short term, they believe the use of tools such as the company Arbo Air can provide could be promising. They've been impressed by some of the results, although they're not yet ready to adopt it as a product. In the long term, they think it could be fascinating. They have noticed that forests in different geographical regions have similarities, so the algorithms are sometimes quite consistent. They are excited about this aspect because drones can take volume measurements, which, if properly calibrated, could save a lot of time. However, their main challenge as planners is to preserve biodiversity and accurately describe habitats. This means identifying species and addressing issues

such as knee rot without disturbing ecosystems, especially for many threatened and red-listed species. There's a strong focus on this, in line with EU directives and conservation regulations. They acknowledge the dilemma of relying solely on aerial data and recognise the ongoing need for ground assessments. While some forest stands lend themselves well to generalisations based on drone imagery, older forests require continued ground-level monitoring to avoid detrimental actions that could endanger species.
Rasmus Pettersson expressed scepticism about relying solely on drone imagery and emphasised the indispensability of ground surveys, especially for identifying rare and threatened species. They emphasised the need for tools such as magnifying glasses and microscopes, stressing that even with advances, such tools remain essential for spotting tiny organisms that are critical to ecosystem conservation. While acknowledging the benefits of technology, they stressed the importance of human oversight to prevent inadvertent damage to the environment.

Södra has a project called "Bra Satt", which involves unmanned vehicles for planting trees. While drones aren't explicitly requested by customers, it's mainly organisations like Södra that are driving the proactive development of forestry practices. Despite some enthusiasm among forest owners, there's still a preference for traditional methods, such as physical forest management plans kept in folders, alongside digital tools. This preference may be due to a lack of familiarity or expertise with new technologies, rather than outright resistance. The difference in attitudes towards technology use doesn't seem to be strongly correlated with the size of forest holdings. While these are generally small forest owners with varying levels of interest and readiness for technological advances, larger forest owners may see greater benefits from drone-assisted assessments due to their larger land holdings.

They rely heavily on contracted services for most tasks, including logging and timber transport. While they have some in-house logging crews and a few trucks, the majority of their operations are outsourced. Regarding the use of drones to assess cleared areas after logging, there's no existing protocol for this within their organisation. However, they recognise the potential value of using drones to gain a comprehensive overview of areas after logging, particularly to assess the distribution of different tree species without physically entering the forest. There's an ongoing exploration of incorporating drones into their operations, particularly for conducting forest assessments. While they haven't fully implemented these ideas yet, they recognise the potential benefits, such as increased customer satisfaction and improved efficiency. They have experimented with drones that can fly inside forests to collect data on tree dimensions and species distribution. Although these efforts are still at an experimental stage, they see promising applications for future forest management strategies. The aim is to combine drone-collected data with traditional ground-based assessments to create comprehensive forest management plans. They also anticipate advances in AI technology for species identification, which will further enhance their ability to manage forests effectively.

5. Analysis and discussion

Chapter 5 presents a thematic analysis of the study, focusing on lead users, co-creation, and social practice. The chapter employs theoretical frameworks and empirical data to examine the reasons why lead users adopt drone technology, how they contribute to innovation, and the broader context of drone integration in forestry practices. Later in this chapter a discussion is presented, which provides further insight into the analysis. The discussion is structured according to the research questions.

5.1 Bridging forestry and agriculture

In the context of the contemporary agricultural and forestry sectors, the incorporation of advanced technologies such as drones is transforming conventional practices and providing innovative avenues for advancing sustainability and efficiency. This analysis examines the potential implications of adopting drone technology within the forestry sector, and considers how these innovations might influence broader agricultural practices.

The use of drones in forestry for tasks such as monitoring forest health and managing resources with precision can be directly applied to agriculture. Drones equipped with advanced sensors can provide real-time data on crop health, soil moisture, and pest infestations, allowing farmers to make informed decisions quickly. This capability aligns with the principles of precision agriculture, where technology is used to optimize resource use and improve crop yields (Croptracker, 2024). By adopting similar drone technologies, agricultural practices can become more efficient, reducing waste and enhancing productivity (Innovations News Network, 2023). The utilisation of drones for the acquisition of aerial imagery of agricultural fields enables the identification of areas requiring the application of fertilisers or pesticides. This practice serves to minimise the occurrence of chemical runoff and to reduce the environmental impact (Rani et.al., 2019). The incorporation of drone technology offers agricultural enterprises a competitive advantage, facilitating cost reductions and enhancing operational efficacy. The utilisation of drones eliminates the necessity for manual labour and the deployment of heavy machinery, thereby reducing fuel consumption and labour costs. Furthermore, the capacity to oversee extensive regions in a prompt and precise manner enables more effective risk management and a more expedient response to potential concerns, such as disease outbreaks or pest infestations. Such a proactive approach may result in increased yields and improved produce quality, thereby enhancing market competitiveness (Croptracker, 2024; Innovation News Network, 2023).

5.2 Roles and contributions in the co-creation process

In order to gain an understanding of the contributions made by each interviewed firm to the co-creation process of drone technology in forestry, it is essential to identify the specific roles they play. By differentiating between lead users and technology providers, it is possible to gain insights into the respective roles of each entity in the innovation and adoption of new technologies.

Holmen and Södra are classified as lead users in this analysis. As significant actors in the Swedish forestry sector, both companies play a pivotal role in managing extensive forest estates, facing challenges that necessitate innovative solutions. Holmen, for instance, has been engaged in the active testing of new technologies designed to combat forest pests, including the spruce bark beetle, thereby exemplifying a proactive approach to innovation (Arboair, 2022). Similarly, Södra, as Sweden's largest forest owner association, places great emphasis on long-term sustainability and innovation in its operations, thereby establishing itself as a pioneer in the adoption of new forestry practices (Södra, 2015). As lead users, Holmen and Södra provide invaluable insights into the practical applications of drone technology, thereby assisting in the shaping of its development to meet the demands of the real world. This study identifies Drone Center Sweden, Dianthus, and the SLU as technology providers. These organizations play a pivotal role in the development and provision of the technological solutions that Holmen and Södra implement. Drone Center Sweden and Dianthus are at the forefront of drone technology development and application, offering the technical expertise and innovations that are essential for advanced forest management. SLU provides academic research and technological innovations that facilitate the practical utilisation of drones in forestry. In their roles as technology providers, these entities engage in collaborative efforts with lead users to refine and enhance drone technologies. This process ensures that the resulting technologies are effective and aligned with industry needs. The differentiation between lead users and technology providers enables a detailed examination of the co-creation process. The input from companies such as Holmen and Södra is particularly invaluable in this regard, as it is based on first-hand experience and a comprehensive understanding of the difficulties faced in forestry. This provides crucial feedback that guides the development of new technologies. In contrast, technology providers apply their expertise to develop solutions that address these challenges. This collaborative approach ensures that innovations are not only technologically advanced but also practically applicable, thereby facilitating the development of more effective and sustainable solutions in forestry management. By delineating the roles of each entity, this analysis underscores the significance of collaboration between lead users and technology providers in driving innovation.

5.3 Lead users adoption of drone technology

Forestry management is confronted with a multitude of challenges, including the monitoring of remote areas and the efficient management of resources (Wahlberg, 2024). Traditional methods often fall short in addressing these complexities, thereby necessitating the development of new solutions that can enhance the efficiency of forest management practices (Raparelli & Bajocco, 2019). This chapter examines the first analytical theme, which is the necessity for innovative tools and technologies that can motivate the adoption of drone technology.

5.3.1 Tool for competitive advantage and improved management

From the perspective of lead users, drone technology is a transformative tool that significantly enhances their working practices and offers a competitive edge in the forestry industry (Michels et.al, 2023). These pioneering users employ drones to collect data more rapidly, manage forests with greater precision, and make more informed decisions, thereby maintaining a leading position in the competitive forestry landscape (Syk, 2024).

One of the most significant advantages of drones is their ability to rapidly survey extensive forest areas. According to the interview with Jonas Bohlin, the traditional ground-based methods of data collection are time-consuming and labour-intensive, often requiring days or weeks to cover the same ground that drones can survey in mere hours (Bohlin, 2024). Drones are equipped with high-resolution cameras and advanced sensors, which enable them to capture detailed images and data that provide a comprehensive view of the forest's canopy and undergrowth. This speed allows for more timely interventions, such as responding to pest infestations or environmental changes, and thus contributes to more effective overall resource management (Airforestry, 2024). The utilisation of advanced imaging technologies enables drones to provide detailed and accurate data regarding the condition of forests (Michels et.al, 2023). This level of detail is of critical importance for the successful completion of several crucial tasks. For instance, drones can map the distribution of tree species across a forest, monitor the health of individual trees, and detect the early signs of disease outbreaks

(Wahlberg, 2024). Such precision ensures that interventions are targeted and effective, thereby preventing minor issues from becoming significant problems. The acquisition of real-time data further enhances the decision-making capabilities of forestry professionals (Bohlin, 2024). The prompt availability of data permits rapid analysis and prompt responses to emerging issues. Lead users are able to make informed decisions regarding various forest management practices. For example, they can determine the optimal timing and location for thinning operations, ensuring that trees are not overcrowded and have sufficient resources to grow healthily. The adoption of drone technology has the potential to enhance the efficacy and productivity of forest monitoring. In addition, leading users are adopting drone technology to optimise forestry practices, including thinning operations, targeted replanting initiatives and accurate timber inventory (ibid). The utilisation of drones enables the identification of areas that require thinning, which serves to reduce competition between trees and promote healthier growth, thereby improving the overall vitality of the forest (Bohlin, 2024; Forest Europe, 2024). Furthermore, they assess the effectiveness of replanting projects by monitoring plant growth and survival rates, thereby ensuring that replanting efforts are effective and resources are used optimally (Pettersson, 2024). Furthermore, drones provide accurate data on tree height, diameter and volume, which is essential for the accurate timber inventory required for the planning of harvests and the sustainable management of forest resources (ibid).

5.3.2 Increased productivity and cost reduction

The integration of drone technology in forestry has the potential to significantly enhance productivity and reduce costs (Syk, 2024). This is achieved through the expedited assessment of forest conditions, the streamlined allocation of resources, and the reduction of labour expenses (Bohlin, 2024; Walter, 2024)). For example, drones can rapidly survey extensive forest areas, providing comprehensive data in a fraction of the time required by ground surveys (ibid). This expeditious assessment enables forest managers to distribute resources in a more efficacious manner, directing attention to specific areas that require intervention, such as zones infested with pests or sections requiring thinning (Airforestry, 2024). Furthermore, the high-resolution imagery and precise data collected by drones reduce the necessity for extensive manual labour, thereby minimising the necessity for costly ground surveys (Bohlin, 2024). Consequently, the expenditure incurred by forestry operations is significantly reduced, thereby enabling them to become more cost-effective. The substitution of traditional, labour-intensive techniques with advanced drone technology enables forestry companies to enhance their productivity while simultaneously reducing their operational costs (ibid).

5.4 Co- creation between lead users of innovation

This chapter examines various collaborative efforts in the advancement of drone technology for forestry applications. It explores the second analytical theme, how diverse stakeholders co-create the innovation by collaborating to develop tools and technologies tailored to the specific needs of forest management.

5.4.1 Collaborative efforts and development of tools

One of the principal aspects of co-creation in the field of drone technology is the collaborative efforts of diverse stakeholders. For example, Dianthus and Skyforest work together to analyse laser drone data for forest monitoring (Walter, 2024). By pooling their resources and expertise, these organisations can leverage the capabilities of drone technology to enhance forest management practices. This type of collaboration enables the development of more effective and efficient solutions that address the specific needs of the forestry industry (ibid). Co-creation furthermore encompasses the development of instruments and technologies that are tailored to the necessities of forest management (Urban & von Hippel, 1988). Entities such as Södra, Arbo Air, and Global Forester collaborate in the construction of AI and GIS tools for forest inventory and aerial photography (Pettersson, 2024). Through cooperative research and development initiatives, these organisations aspire to create instruments that streamline forest management procedures, enhance data accuracy, and enhance decision-making capabilities (ibid).

In the field of research and development, collaborative efforts are directed towards the advancement of drone technology for applications in forest management. For instance, Drone Center Sweden has formed a partnership with Södra to develop LIDAR cameras for the purpose of mapping and monitoring forest areas (Drone Center Sweden, 2024). By combining expertise in drone technology and forestry, these initiatives provide tools that address the challenges facing forest managers (Urban & von Hippel, 1988). The co-creation process extends beyond the development of hardware to encompass the design and implementation of navigation and communication systems tailored to the specific requirements of forestry applications (ibid). Drone Center Sweden develops advanced systems on behalf of the forest sector with the objective of ensuring safe and efficient drone operation in forest environments (Wahlberg, 2024). These systems enhance the usability and efficiency of drones in forestry. Furthermore, collaborative efforts extend to advocating for regulatory changes that facilitate the integration of drone technology into forestry. Organisations such as Drone Center Sweden advocate for policies that facilitate the development of drone technology in forestry. Through engagement with policymakers and regulatory agencies, these efforts aim to create an enabling environment for the adoption and deployment of drone technology in forestry practices (ibid).x

5.5 Challenges integrating drone technology into forestry practice

This chapter examines the challenges of integrating drone technology into forestry practice. It draws on Social Practice Theory to understand the adoption, competence development, and motivations behind the use of drones within the forest sector (Shove et al., 2005). By analysing the experiences of lead users, this chapter elucidates how drones are transforming forest management practices. It also highlights the potential displacement of traditional methods and the significant obstacles to achieving widespread and effective use.

5.5.1 User competence and skill development

The effective utilisation of drone technology necessitates the acquisition of significant competence and skill development among users (Shove et.al., 2005). Foresters and technologists must collaborate to enhance the capabilities of drones and adapt them for specific forestry applications. This process involves ongoing learning, experience sharing, and practical application (ibid). Foresters have to constantly develop the skills necessary to operate drones and analyse the collected data. Through intensive training programmes and hands-on field experience (Transportstyrelsen, 2024; Shove et.al., 2012). Collaboration with technologists further enhances these capabilities, allowing for continuous improvement and adaptation of drone technology to meet the unique needs of forestry operations (Urban & von Hippel, 1988).

5.5.2 Technological and operational challenges

The practical applications of drone technology in forestry are numerous and varied. Drones facilitate more efficient forest monitoring, improved management of forest resources, and enhanced reforestation efforts. The motivation for technological means over traditional methods underlies these benefits, which contribute to increased productivity and cost savings as well as better environmental outcomes (Bohlin, 2024). The use of drones for forest monitoring allows for the early detection of pest infestations and storm damage, enabling timely intervention and management (Airforestry, 2024). This not only helps in maintaining the health of the forest but also reduces economic losses by preventing widespread damage (Michels et.al, 2023). Despite the evident advantages, the integration of drones in forestry is not without significant challenges. Regulatory constraints, the complexity of data processing, and the necessity for human supervision remain significant obstacles (Wahlberg, 2024). Furthermore, the reliance on drone imagery alone is inadequate for certain tasks, particularly in older forests where ground-level monitoring is essential to avoid endangering species (Pettersson, 2024). Rasmus Pettersson at Södra, expressed scepticism about relying solely on drone imagery. He emphasised the necessity of ground surveys for identifying rare and threatened species, highlighting that tools such as magnifying glasses and microscopes remain indispensable (Pettersson, 2024). This underscores the importance of combining drone technology with traditional methods to prevent inadvertent environmental damage. Which also states motivation for preservation of traditional forest practices (Shove et.al., 2005).

5.6 Summary of analysis

In this chapter a summary of the analysis will be presented in the tabular form. The analysis is divided into three distinct empirical themes that frequently emerged during the case study, and are presented as follows: reasons for adopting drone technology, lead users co-creation of innovation, and challenges integrating drone technology into forestry practice.

The following section presents an overview of the primary motivations driving the adoption of drone technology by lead users. This overview in tabular form offers insights into the main reasons for changing forestry practices, see *Table 3*.

Table 3: *Reasons for adopting drone technology.*

Reasons for adopting drone technology	**Examples from case study**
The need for new solutions	The application of drone technology enables the monitoring of areas that are difficult to reach, the observation of the health of forests, and the early detection of pest infestation.
Tool for competitive advantage	The a priori goal is to achieve faster data collection, greater precision in forest management, and enhanced decision-making capabilities.
Efficient monitoring	Drones are capable of providing regular aerial surveys, high-resolution imagery, and real-time data acquisition.
Improving management	The utilisation of drones has the potential to facilitate optimised thinning operations, targeted reforestation efforts and the implementation of accurate timber inventories.
Increased productivity	The use of drones enhances productivity by enabling a more rapid assessment of forest conditions, a more efficient allocation of resources, and a reduction in labour costs.
Cost reduction	The use of drones allows for the reduction of manual labour, the avoidance of the necessity for costly ground surveys, and the reduction of operational expenses.

The lead users in the case study perceive drones as transformational, as they facilitate competitive advantages by enabling faster data collection, accurate forest management and informed decision-making. The use of drones to map extensive forest areas enables the capture of detailed images with high-resolution cameras and advanced sensors (Airforestry, 2024). This enables rapid response and effective resource management. The precision of drones facilitates the mapping of tree species, monitoring of tree health and early detection of diseases, ensuring targeted and effective interventions. Real-time data improves decision-making and optimises practices such as thinning and replanting (Michels et.al, 2023). Furthermore, drones provide accurate timber inventory data, which is essential for planning sustainable harvests (Brukas & Weber, 2009). The integration of drones increases productivity and reduces costs by speeding up forest assessments, streamlining resource allocation and reducing labour costs (Syk, 2024;Bohlin, 2024;Walter, 2024). The efficiency of drones minimises the need for extensive manual work and costly ground surveys, making forestry more cost-effective and profitable (Wahlberg, 2024; Walter, 2024).

Below, *Table 4* presents a summary of the next theme, namely the co-creation process between leading users for the development of drone technologies. It provides insight into which processes facilitate the adaptation of the innovation to market requirements.

Table 4: *Lead users co-creation of innovation.*

Type of co-creations	Examples from case study
Collaborative efforts	Dianthus and Skyforest are analysing laser drone data in order to monitor the forest.
Development of tools	Södra, Arbo air, and Global Forester are developing AI and GIS tools for forest inventory and aerial photography.
Research and development	Drone Centre Sweden is developing LIDAR cameras for use in mapping and monitoring forest areas.
Navigation and communication systems	Drone Centre Sweden is engaged in the development of advanced navigation and communication systems for drones.
Lobbying for regulatory changes	Drone Centre Sweden is advocating for policies that support the integration and advancement of drone technology in forestry.

An essential aspect of co-creation is that lead users collaborate to exploit the potential of drone technology. For instance, Dianthus and Skyforest are working together to analyse laser drone data and improve forest management through shared expertise and resources, leading to the development of tailored solutions.

This collaborative approach also includes the development of tools and technologies adapted to the needs of forestry. Companies such as Södra, Arbo Air and Global Forester are engaged in collaborative research and development projects focused on the development of AI and GIS tools for forest inventory and aerial photography. The objective of these projects is to streamline procedures, improve data accuracy and enhance decision-making. In the field of research and development, the partnerships are primarily focused on the development of drone technology for forest management. For instance, Drone Centre Sweden is collaborating with Södra to develop LIDAR cameras for mapping and monitoring forests. This initiative combines expertise in drone technology with forestry knowledge, aiming to address management challenges. Furthermore, collaborations are engaged in the design of navigation and communication systems tailored to forestry applications, with the objective of improving usability and efficiency. In addition, these partnerships advocate for regulatory changes to facilitate the integration of drone technology into forestry practices. To this end, organisations such as Drone Center Sweden engage with policy makers and regulators to create a supportive environment for the introduction of drones into forestry practices.

Lastly, *Table 5* provides an overview of the changes in practices that affect the integration of drone technologies and the development of innovation processes. The table illustrates how drones are changing forest management and the challenges that remain.

Table 5: *Challenges integrating drone technology into forestry practice.*

Challenges integration drone technology	**Examples from case study**
User competence	The necessity for training of forestry workers encompasses the acquisition of skills in operating drones and analysing data.
Skill development	The ongoing advancement of drone technology is enabling the adaptation of these devices for the purpose of forestry practices.
Technological and operational barriers	Regulatory constraints, data processing complexities, and the need for human supervision represent some of the key obstacles to be overcome.

Forestry faces major challenges in monitoring remote areas and managing resources effectively, which traditional methods are often unable to address. This chapter explores the need for innovative tools such as drone technology to improve forestry practices. For drone technology to be effectively utilised in forestry, it is important that users acquire significant competence and develop their skills (Shove et al., 2005). Collaboration between foresters and technicians is essential to improve the capabilities of drones for specific forestry applications, which involves continuous learning, exchange of experience and practical application (ibid.). Forest managers continuously develop their skills in drone use and data analysis through training programmes and practical field experience in order to meet the technological and operational challenges of forestry operations (Swedish Transport Agency, 2024; Shove et al., 2012). Collaboration with technologists further enhances these skills, facilitating continuous improvement and adaptation of drone technology to meet the unique needs of forestry (Urban & von Hippel, 1988). This emphasis on skill development is indicative of the dynamic nature of integrating drones into forestry, where collaboration and continuous learning are key components to success.

The integration of drone technology into forestry practices presents several complications, including regulatory constraints, data processing complexities, and the need for human oversight (Wahlberg, 2024). Moreover, the exclusive reliance on drone imagery is insufficient for certain tasks, particularly in older forests where ground-level monitoring is essential to avoid endangering species (Pettersson, 2024). These challenges highlight the necessity for comprehensive approaches that integrate drone technology with traditional methods to ensure effective and environmentally responsible forest management.

5.7 Discussion

This discussion chapter examines the impact of drone technology on forestry management, highlighting its benefits and the challenges encountered by lead users and technology providers. The analysis reveals that drones significantly enhance efficiency, improve safety, and provide valuable data for forest management. Additionally, the discussion emphasises the critical role of lead users and technology providers in driving innovation and adapting drone technology to meet specific needs. However, it also identifies several challenges, including regulatory hurdles, data processing difficulties, and varying levels of acceptance among users. The chapter emphasises the necessity for continued collaboration between drone manufacturers, technology developers, and forestry practitioners to address the identified issues and to optimise the use of drones in sustainable forest management. Furthermore, the discussion suggests that while drones are highly effective at the operational level, their full integration into forestry practices requires the overcoming of technical and regulatory barriers.

5.7.1 Why do lead users adopt drone technology?

Lead users are the first to identify and address needs that are not yet widely recognised in the marketplace. In this context, they are in a position to provide insights for developers of innovative technologies such as drones. In the interview with Jonas Bohlin, acting operator at SLU, the rationale behind the adoption of drone technology was discussed. The foresters adopt drones mainly for cost-effectiveness and efficiency reasons. A task that would typically take a day in a traditional acquisition process can be completed in approximately an hour with the use of airborne vehicles. In an interview with Holmen's employee Christian Syk, he highlighted that leading users leverage drone technology to gather high-resolution data in a timely and cost-effective manner, which can streamline decision-making processes. This is one of the reasons why lead users often turn to innovative solutions to enhance and optimise their operations. By adopting drone technology, lead users demonstrate their commitment to innovation and willingness to stay ahead of the curve. The potential cost savings associated with utilising drone technology was also raised in the interview with Urban Wahlberg, CEO of Drone Centre Sweden. The utilisation of drones for tasks such as forest fertilisation and firefighting can result in significant annual savings, rendering drone use an attractive proposition for leading users. He also raises the safety aspect when discussing the transition from manpower to drones in hazardous environments. The use of drones in such areas eliminates the risk to human life, making them an ideal tool for monitoring forest areas for storm damage.

The utilisation of drones in the monitoring of forest areas provides invaluable data, which can be used to ensure the implementation of sustainable practices and to verify compliance with legal requirements. These include forest inventory, land use planning, and timber tracking, which are mandated by the Forestry Act and the EUTR. By employing drones for tasks such as forest monitoring and inspection, lead users can identify and address potential issues before they become compliance issues, thereby reducing the risk of penalties or legal consequences. Urban Wahlberg, one of the founders of Drone Centre Sweden, is testing a number of potential solutions that drones can bring to the forestry industry. They engage in lobbying to influence policies and regulations on the use of drones. By actively participating and trying to influence the design of rules, they can ensure that drone technology is integrated into operations in a smooth and efficient way.

The integration of drone technology in forestry is also influenced by users' preferences and familiarity with new technologies. According to Rasmus Pettersson at Södra, there were differences among users, with some preferring traditional methods and lacking knowledge of drone operations and its systems. Others were more open to the changing technical environment. This resulted in a divergence of technology readiness levels, with the users' maturity still not being sufficiently developed to adopt drones into their practices. The technology itself is already in existence, but there is a lack of connection between the drone and the users' competence or capacity to utilise the technology. To explain the differences between users and how to achieve a more extensive integration of drones the social practice theory can be used. The competence aspect of social practice theory encompasses the knowledge, skills, and abilities required to engage effectively in a practice. In the context of the adoption of drone technology in forestry, competence encompasses not only the technical skills required to operate drones but also an understanding of how drones can be integrated into existing forestry practices. As users gain competence and the technology becomes more widely available, the integration of drones into forestry practices will become more extensive and routine. For user groups that value traditional practices and aim to minimise technological solutions, drones may not symbolise efficiency, innovation, and sustainability in the same way as they do for others. Instead, they may view drones as disruptive to traditional forestry practices and may resist their adoption. Their values and beliefs may prioritise the preservation of traditional methods, such as manual forest monitoring and inventory, over the use of technological solutions like drones. The narratives surrounding the use of drones may focus on concerns about job displacement, loss of skills associated with traditional practices, and the potential negative impacts on the environment or local communities. These users may perceive drones as threatening the cultural heritage and identity of forestry practices. It is therefore crucial to understand the meaning attached to drone technology adoption for these users in order to address their concerns and facilitate their acceptance of drones in forestry practices. It may be necessary to implement communication and educational initiatives to demonstrate the ways in which drones can be used in conjunction with traditional methods, rather than as a replacement for them. Additionally, involving these users in the co-creation process and integrating their perspectives into the development and implementation of drone technology solutions can help to bridge the gap between traditional values and technological innovation in forestry.

5.7.2 How do lead users and technology providers co-create innovation?

In the interviews, information is provided regarding the involvement of lead users and technology providers in the co-creation of drone technology innovation. Lead users often collaborate with drone manufacturers, technology developers, research institutions, and other stakeholders to share their expertise, insights, and requirements. The adherence to regulations and legislation is discussed in relation to testing teams, such as Drone Centre Sweden. Despite the advances in drone technology and the involvement of lead users in the co-creation of innovative solutions, there remain knowledge gaps and inconsistencies regarding the full integration of drone technology into sustainable forest management practices. Lead users collaborate with technology providers to ensure that solutions are tailored to their specific needs. However, it is of the utmost importance to comprehend the implications of drone technology on forest management practices. Including the identification of those who are permitted to employ these methods and the regulations that govern their usage. The adherence to regulations and legislation, such as those discussed in relation to testing teams like Drone Centre Sweden, is of the utmost importance. The clarification of these issues is important in order to ensure the effective and responsible utilisation of drones in forestry operations, while addressing environmental concerns and meeting economic objectives. This understanding will facilitate informed decision-making and contribute to the advancement of sustainable forestry practices.

The subsequent phase typically entails test teams engaging in discourse with system builders, such as Dianthus, or collaborating on projects with organisations such as Södra. It is likely that these organisations will subsequently assume responsibility for the construction of the solutions, with a view to further developing the innovation. During the testing phase, lead users such as Drone Centre Sweden and Dianthus play a crucial role in the refinement and improvement of drone technology prototypes and technologies. By actively engaging in testing processes and providing feedback on usability, functionality, and performance, lead users contribute valuable insights that help enhance the effectiveness of drones before their market release. To facilitate this process, lead users often participate in various collaborative platforms such as co-innovation workshops, and industry events specifically focused on drone technology. These platforms provide opportunities for lead users to exchange ideas, share best practices, and co-create innovative solutions with other stakeholders in the industry. Furthermore, lead users engage in open innovation platforms where they collaborate with a broader community, including startups, researchers, and technology enthusiasts. By sharing their knowledge and insights on drone technology, lead users contribute to the collective innovation ecosystem, fostering the development of cutting-edge solutions. Additionally, lead users form partnerships with startups and technology companies specializing in drone technology. This collaboration enables lead users to access solutions, leverage emerging technologies, and co-create innovative applications for drones across various industries. Furthermore, lead users actively participate in industry groups and standards development organisations dedicated to drone technology. Through their involvement in the development of industry standards, lead users influence the future trajectory of drone technology, ensuring interoperability and compatibility across different platforms.

5.7.3 What challenges do users face when integrating drones into forestry practices?

In the context of forest management, drones serve primarily for documenting storm damage and monitoring tree stands for pest attacks or infestations. Drones are used to support inventory, action planning and transport and can be used to support fire service in fire protection. The information obtained through digital maps, satellite scenes and sensor data from drones, can increase yields and reduce damage when the technology is fully introduced and developed. However, challenges persist, particularly regarding safe navigation beyond visual range and autonomous flight. The technology is continuously developing and one of the possibilities is to improve the industry's environmental impact and soil degradation. Usage of drones in the forest industry is supposed to be an answer for environmental policies and enable the economic aspect of the industry to continue. Users encounter regulatory challenges related to drone operations, such as restrictions on beyond visual line of sight flights and altitude limitations. According to Christian Syk, obtaining certifications and licences for certain drone operations can be time-consuming and complex. Which contributes to hindering the integration of drones into forestry practices.

It is possible that users may encounter difficulties in processing and analysing the vast amounts of data collected by drones. The assurance of the accuracy, reliability, and relevance of drone data for forest management decisions requires advanced data processing capabilities and expertise. In the context of social practice theory, the difficulties in processing and analysing vast amounts of drone-collected data can be seen as a barrier to the effective integration of drones into forestry practices. The initial investment and ongoing operational costs associated with drone technology can be a challenge for users, particularly for smaller forestry companies with limited budgets. The cost-benefit analysis of acquiring and maintaining drones is a significant consideration for users, particularly in light of the potential returns on investment. The co-creation theory posits that by working together, the parties in question can explore innovative business models that address the cost concerns of users. Such models could include leasing or subscription-based services, with the aim of making drone technology more financially viable for smaller forestry companies.

Despite the advances in drone technology, there are still significant gaps in knowledge and inconsistencies regarding the full integration of drones into sustainable forest management practices. Rasmus Pettersson's scepticism about the reliability of drone imagery as the sole source of data highlights one of these gaps, emphasising the necessity of ground surveys for identifying rare and threatened species. Furthermore, instruments such as magnifying glasses and microscopes remain indispensable for identifying minute organisms that are crucial to the conservation of ecosystems, despite technological advancements. While acknowledging the benefits of technology, it is necessary to address the challenges of relying solely on drones and ensure human oversight to prevent inadvertent environmental damage.

5.7.4 What are the potential benefits when utilising drones in forest management?

The potential benefits of drone technology in forestry operations, such as increased customer satisfaction and improved efficiency, are significant drivers for its adoption. Those engaged in the management of small forest holdings, who may exhibit varying degrees of interest and preparedness with regard to technological advances, stand to benefit from the utilisation of drone-assisted assessments. Drones offer the capacity to provide comprehensive and up-to-date information about forest conditions, thereby enabling forest owners to make well-informed decisions regarding their land management. For those with extensive land holdings, the benefits of drone technology are even more pronounced. The monitoring of larger areas is made more efficient and comprehensive by drones, which would otherwise be time-consuming and labour-intensive to undertake using traditional methods. This enhanced efficiency not only saves time and resources but also enhances customer satisfaction by providing timely and accurate information about forest conditions.

The integration of drone technology into forest management practices offers several benefits for sustainable forestry. The Airforestry website outlines several services provided by drones, including selective logging, where specialised drones identify and extract trees for felling. By efficiently locating trees ready for felling and extracting them from the ground, drones reduce the need for physical access to the forest, thereby minimising habitat disturbance and erosion risks. The use of drones also supports silvicultural approaches such as regeneration, thinning and harvesting, which are essential for maintaining genetic diversity and ecosystem resilience. In addition, the practice of reforestation, whether through natural regeneration or planting, enhances biodiversity, ecological balance and carbon sequestration. Economic mechanisms, such as the valuation of carbon storage through REDD+ and the promotion of non-timber forest products (NTFPs) through certification schemes and fair trade programmes, further incentivise sustainable forestry practices while providing economic benefits to local communities. Overall, the integration of drone technology into forest management not only improves operational efficiency, but also contributes to the conservation and sustainable use of forest resources, reflecting the industry's commitment to ecological stewardship.

Drones have the potential to address some of the challenges faced by forest managers in navigating the dimensions of sustainability. By providing efficient and accurate data collection capabilities, drones can support informed decision-making in forest management. For example, drones can help monitor forest health, identify areas for selective logging and assess biodiversity, thereby facilitating more sustainable land management practices. In the context of balancing economic production with environmental conservation, drones can help optimise timber production while minimising environmental impact. Through aerial surveys and mapping, drones can accurately assess forest conditions, allowing managers to identify areas suitable for harvesting while preserving biodiversity hotspots and sensitive ecosystems. This targeted approach to forest management can help mitigate the negative environmental impacts often associated with traditional clear-cutting practices. In addition, drones can enhance the implementation of sustainable forestry initiatives mandated by legislation such as the Swedish Forestry Act of 1993 and the EU's 2030 Forest Strategy. By providing real-time data on forest conditions, drones can support compliance with legal requirements and facilitate adaptive management strategies. Thereby, meeting evolving sustainability challenges. Overall, while drones are not a panacea for all the complexities of sustainable forest management, they can certainly be a valuable tool in the forest manager's toolkit. By harnessing the capabilities of drone technology, stakeholders can improve their ability to balance the economic, environmental and social dimensions of forest sustainability, ultimately contributing to more effective and harmonised forest management practices.

Overall, the insights gained from the adoption of drone technology in forestry can be leveraged to transform agricultural practices, promoting sustainability and providing economic benefits. As the agricultural sector continues to face challenges such as climate change and resource scarcity, the lessons learned from forestry can guide the development of more resilient and efficient agricultural systems. The cross-sectoral application of drone technology underscores its potential to drive innovation and sustainability in agriculture, paving the way for a more sustainable future.

6. Conclusion

Chapter six presents the conclusions of this study, which address the aim and research questions in relation to the main findings.

Despite the growing interest in drone technology, there is a noticeable lack of comprehensive research on how drones are actually used and experienced by forest practitioners, particularly in addressing pressing environmental and operational challenges. To ensure the technology meets the practical needs of forest managers, it is crucial to gain a deeper understanding of real-world applications, including user perceptions, operational challenges, and the integration of drone data into organisational activities. The study is a case study of different lead users in the forest sector. The aim is to address the knowledge gap by focusing on lead users' co-creation of innovation, and understanding the needs and challenges foresters face in improving their forest management practices. The addressed research questions will be answered below.

- *Why do lead users adopt drone technology, and how do they co-create innovation?*

- *What challenges do users face when integrating drones into forestry practices?*

The adoption of drone technology in forestry is driven by a number of factors, including the needs and requirements of lead users, co-creation efforts, and the embedded social practices within the industry. Lead users leverage drone technology to enhance operational efficiency, improve forest management practices, and gain a competitive edge in the market. Through co-creation efforts, stakeholders collaborate to develop innovative solutions tailored to specific industry needs, driving the advancement of drone technology in forestry. The insights provided by social practice theory are invaluable in understanding the challenges and opportunities associated with the adoption of drones in forestry. This theory emphasises the importance of addressing user preferences, competencies, and the meaning attached to technological innovations. For instance, some users adhere to traditional practice methods and are deficient in their knowledge of drone operations, whereas others are more receptive to technological advancements. Social practice theory helps to explain these differences by considering the values and beliefs. Users who prioritise traditional methods may perceive drones as disruptive, leading to the prioritisation of manual forest monitoring over technological solutions. Using the perspective of social practice theory, we focus on the routines, competencies and meaning that shape everyday practices. And by linking this to co-creation, emphasising the importance of involving users in the innovation process to address their concerns and facilitate the uptake of new technologies. The discussion highlights that involving users who value traditional practices in the co-creation process can assist in bridging the gap between traditional values and technological innovation. For example, communication and educational initiatives can demonstrate how drones can complement, rather than replace, traditional methods, thereby addressing concerns about job displacement and environmental impact.

The integration of drones into forestry practices is not without its challenges. Regulatory barriers, the complexity of data processing, and the need for human supervision are just a few of the considerations that users must take into account. On the other hand, drones offer tangible benefits for sustainable forest management. These include enhanced reforestation efforts, improved environmental monitoring and optimised forest management practices. The innovative ways in which drones are offering practices, the ability to monitor forest health, assess tree stands, and plan forest management activities with greater precision and efficiency are highlighted to illustrate some of these. They represent a promising tool to address the complex challenges facing the forestry industry and move towards more sustainable and efficient forest management practices. In conclusion, some forest stands may be suitable for generalisation from drone images. However, it is important to remember that older forests require continued monitoring on the ground to prevent harmful actions that may threaten species. Therefore, while recognising the benefits of drone technology, it is important to maintain human oversight to prevent unintended damage to the environment.

References

Airforestry. (2024). Re-inventing Forestry. https://www.airforestry.com/ [2024-02-09]

Agtech Sweden. (2024). An innovative environment for the agriculture of the future. https://agtechsweden.com/en/ [2024-08-04]

Arboair. (2022). Holmen testar Arboairs teknik i kampen mot granbarkborren. https://arboair.com/en/blog/2022/09/06/holmen-testar-arboairs-teknik-i-kampen-mot-granbarkborren/ [2024-08-08]

Bettinger, Pete., Boston, Kevin., Siry, Jacek. P., & Grebner, Donald. L. (2016). Forest management and planning. Academic press.

Brukas, Vilis., & Weber, Norbert. (2009). Forest management after the economic transition—at the crossroads between German and Scandinavian traditions,Forest Policy and Economics, Volume 11, Issue 8, 2009, Pages 586-592, ISSN 1389-9341, https://doi.org/10.1016/j.forpol.2009.08.009. [2024-02-13]

Bryman, Alan & Bell, Emma (2017). Business research methods. Edition 3 Stockholm: Liber

Croptracker. (2024) Drone Technology In Agriculture.https://www.croptracker.com/blog/drone-technology-in-agriculture.html [2024-08-08]

Food and Agriculture Organization in the United Nations (FAO). (2024) Sustainable Forest management. https://www.fao.org/forestry/sfm/en/ [2024-03-12]

Forest Europe growing life. (2024). Sustainable forest management. https://foresteurope.org/workstreams/sustainable-forest-management/ [2024-04-23]

Gambardella, A., Raasch, C., & von Hippel, E. (2017). The user innovation paradigm: impacts on markets and welfare. Management Science, 63(5), 1450-1468. https://doi.org/10.1287/mnsc.2015.2393 [2024-04-23]

Innovation News Network. (2023). How agriculture drones can enhance production. https://www.innovationnewsnetwork.com/how-agriculture-drones-can-enhance-production/40484/ [2024-08-08]

Iveroth, E., & Bengtsson, F. (2014). Changing behavior towards sustainable practices using Information Technology. Journal of Environmental Management, 139, 59-68. https://doi.org/10.1016/j.jenvman.2013.11.054 [2024-02-16]

Lindahl, Karin .B., Sténs, Anna., Sandström, Camilla., Johansson, Johanna., Lidskog, Rolf ., Ranius, Thomas., Roberge, Jean-Michel. (2017). The Swedish forestry model: More of everything? 1389-9341/© 2015 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND licence. http://dx.doi.org/10.1016/j.forpol.2015.10.012 [2024-03-05]

Michels, Marius., Wever, Hendrik., & Musshoff, Oliver. (2023). Drones take flight in forests: Uncovering the 'tree'-mendous potential and 'timber'-rific challenges for German forest managers by applying the technology acceptance model. Department of Agricultural Economics and Rural Development, Georg-August-University Göttingen, Platz der Göttinger Sieben 5, D-37073 Göttingen, Germany.Volume 157, December 2023, 103077. https://doi.org/10.1016/j.forpol.2023.103077 [2024- 02-08]

OECD (2018), "The Swedish agricultural innovation system", in Innovation, Agricultural Productivity and Sustainability in Sweden, OECD Publishing, Paris, https://doi.org/10.1787/9789264085268-9-en [2024-08-04]

Rani, A. L. K. A., Chaudhary, A. M. R. E. S. H., Sinha, N., Mohanty, M., & Chaudhary, R. (2019). Drone: The green technology for future agriculture. Harit Dhara, 2(1), 3-6. https://www.researchgate.net/profile/Alka-Rani-3/publication/335015248_HARIT_DHARA_21_DRONE_THE_GREEN_TECHNOLOGY_FOR_FUTURE_AGRICULTURE/links/5d4a9c5192851cd046a6ce02/HARIT-DHARA-21-DRONE-THE-GREEN-TECHNOLOGY-FOR-FUTURE-AGRICULTURE.pdf [2024-08-08]

Raparelli, Elisabetta., & Bajocco, Sofia. (2019). A bibliometric analysis on the use of unmanned aerial vehicles in agricultural and forestry studies, International Journal of Remote Sensing, 40:24, 9070-9083. https://www.tandfonline.com/doi/full/10.1080/01431161.2019.1569793 [2024-02-08]

RISE. (2024). Testbeds for industrialisation and verification. https://www.ri.se/en/our-offer/industrialisation-and-quality-assurance/test-beds [2024-08-04]

RISE. (2024). Digitalisation as a tool for sustainable and profitable agriculture https://www.ri.se/en/what-we-do/expertises/digitalised-agriculture [2024-08-04]

Shove, Elizabeth., & Pantzar, Mike. (2005). Consumers, Producers and Practices: Understanding the invention and reinvention of Nordic walking. Volume 5, Issue 1. https://doi.org/10.1177/1469540505049846 [2024-02-22]

Shove, Elizabeth., Pantzar, Mike., & Watson Matt. (2012). The dynamics of social practice - everyday life and how it changes. SAGE Publications. ISBN 978-0-85702-042-0.

Skogsstyrelsen. (2023) The Forestry Act. https://www.skogsstyrelsen.se/en/laws-and-regulations/skogsvardslagen/ [2024-03-12]

Swedish Cleantech. (2022). Resources and environment. Agricultural technology revolution innovation for sustainable farming. https://swedishcleantech.com/news/resources-and-environment/agricultural-technology-revolution-innovation-for-sustainable-farming/ [2024-08-04]

Swedish Forest Industries Federation. (2024). https://www.forestindustries.se/about-us/ [2024-02-14]

Södra. (2015). Annual report with sustainability report. https://www.sodra.com/_download/sp/annual-report-with-sustainability-report-2015.pdf [2024-08-08]

United Nation. (2024). Global objectives on forest. Department of Economic and Social Affairs Forests. https://www.un.org/esa/forests/documents/global-objectives/index.html [2024-03-12]

United Nation. (2024). Sustainability. Academic Impact. https://www.un.org/en/academic-impact/sustainability [2024-03-12]

Von Hippel, E. (2016). Free innovation (p. 240). The MIT Press.

von Hippel, E. (2011). Innovation by users. Innov. Perspect. 21st century, 181-197. https://www.bbvaopenmind.com/wp-content/uploads/2013/02/BBVA-OPenMind-Innovation-by-Users-Eric-von-Hippel.pdf.pdf [2024-04-11] von Hippel, E. (2001), User toolkits for innovation. Journal of Product Innovation Management, 18: 247-257. https://doi.org/10.1111/1540-5885.1840247 [2024-04-22]

Vultus. (2024). Analysis Platform. https://www.vultus.se/platform [2024-02-04]

Urban, G.L. & von Hippel, E. (1988). Lead User Analyses for the Development of New Industrial Products. https://doi.org/10.1287/mnsc.34.5.569 [2024-04-11]

Appendix 1

User perspectives on drones
a. Perceptions of drones:
What advantages do you see in using drones for forestry?
What disadvantages or challenges, if any, do you see in integrating drones into forestry practice?

b. Use of drones:
Can you tell us about your experiences of using drones in your work?
In what ways have you used drones in forestry? What specific tasks have they helped you with?
Have you noticed any changes in your work routine or productivity since you started using drones?

c. Integrating drone data into decision-making processes
How is drone data integrated into decision-making processes related to forestry?
How do you think the use of drone data affects the ability to make informed decisions regarding forest management?
Are there challenges or barriers to effectively integrating drone data into decision-making processes? If so, what are they? Regulations or licences?

d. Fulfilling environmental objectives
How does the use of drones contribute to achieving the environmental objectives set by decision-makers for the Swedish forest industry?
Can you give examples of how drones have helped to improve environmental performance or reduce environmental impacts in forestry?

e. Future developments and potential
How do you think the use of drones in forestry will develop in the future?
Do you see any potential new applications or innovations for drones in the forestry sector?

Appendix 2

Användarperspektiv på drönare
a. Uppfattningar om drönare:
Vilka fördelar ser du med att använda drönare för skogsbruket?
Vilka eventuella nackdelar eller utmaningar ser du med att integrera drönare i skogsbruks praktiken?

b. Användning av drönare:
Kan du berätta om dina erfarenheter av att använda drönare i ditt arbete?
På vilka sätt har du använt drönare i skogsbruket? Vilka specifika uppgifter har de hjälpt dig med?
Har du märkt några förändringar i din arbetsrutin eller produktivitet sedan du började använda drönare?

c. Integrering av drönare data i beslutsprocesser
Hur integreras data från drönare i de beslutsprocesser som rör skogsbruket?
På vilket sätt tror du användningen av drönare data påverkar förmågan att fatta informerade beslut angående skogsbruket?
Finns det utmaningar eller hinder för att effektivt integrera drönare data i beslutsprocesserna? I så fall, vilka är de? Regleringar eller licenser?

d. Uppfyllelse av miljömål
Hur bidrar användningen av drönare till att uppnå de miljömål som sätts av beslutsfattare för den svenska skogsindustrin?
Kan du ge exempel på hur drönare har hjälpt till att förbättra miljöprestandan eller minska miljöpåverkan inom skogsbruket?

e. Framtida utveckling och potential
Hur tror du att användningen av drönare inom skogsbruket kommer att utvecklas i framtiden?
Ser du några potentiella nya tillämpningar eller innovationer för drönare inom skogsbranschen?

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