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DRONES AS INFORMATION SYSTEM ARTIFACTS SUPPORTING ENVIRONMENTAL SUSTAINABILITY IN FINNISH FOREST INDUSTRY

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Ympäristöllisen kestävyyden heikkeneminen on yksi merkittävimmistä uhista elämälle maapallolla. Biodiversiteetin kaventuminen, ilmastonmuutoksen kiihtyminen, ympäristösaasteiden lisääntyminen, napajäätiköiden sulaminen ja merenpinnan nousu vähentävät laaja-alaisesti elämisen mahdollisuuksia nyt ja tulevaisuudessa. Ympäristöllisen kestävyyden kannalta metsillä on erityisen tärkeä rooli hiilinieluina ja monipuolisina elinympäristöinä. Tästä johtuen metsäteollisuuden, metsänomistajien ja julkisten organisaatioiden toiminnalla on keskeinen vaikutus metsien ja ympäristön kestävyyden tukemisessa. Digitalisaatio ja tietojärjestelmät ovat vauhdittaneet ilmastonmuutosta ja luonnon resurssien ylikäyttöä. Tätä kehityskulkua vasten ympäristötietojärjestelmien tutkimus pyrkii edistämään organisaation prosesseja, käytäntöjä ja toimintaa sekä niiden kokonaisvaltaista hallintaa, jotta liiketoiminnasta syntyviä haitallisia vaikutuksia voitaisiin minimoida ja ympäristöllistä kestävyyttä tukea tietojärjestelmien avulla. Koko organisaation kattavien järjestelmien ohella tarvitaan ketteriä, tehokkaita ja joustavia käytännön sovelluksia ympäristötavoitteiden saavuttamiseksi. Yhdistämällä nämä ulottuvuudet ja tavoitteet, tässä tutkielmassa tarkastellaan droonien hyödyntämistä tietojärjestelmäartefakteina sekä niiden sosiaalisia, teknologisia ja informationaalisia ominaisuuksia ympäristöllisen kestävyyden tukemiseksi Suomen metsäteollisuudessa. Viitekehyksenä sovelletaan tietojärjestelmäartefaktin käsitettä, toiminnallisten käyttömahdollisuuksien lähestymistapaa, luonnollista resurssiperusteista näkökulmaa, kolmen pilarin malliin perustuvia ympäristötavoitteita sekä institutionaalista teoriaa. Empiirisenä perustana hyödynnetään laadullista monitapaustutkimusta, jota varten haastateltiin 13 asiantuntijaa metsäsektorilta, droonipalvelu- ja IT-konsultointiyrityksistä sekä ympäristöhallinnosta käyttämällä puolistrukturoitua haastattelumenetelmää. Löydökset osoittavat droonien soveltamisen tietojärjestelmäartefakteina tukevan ympäristöllistä kestävyyttä metsäsuunnittelun, metsätuotannon, metsänomistamisen ja ympäristöhallinnan prosesseissa ja tehtävissä. Drooneja voidaan käyttää täsmällisissä, kustannustehokkaissa ja reaaliaikaisissa tiedonkeruun ratkaisuissa. Toisaalta teknologiset, lainsäädännölliset sekä tiedonhallintaan, olosuhteisiin ja saatavuuteen liittyvät rajoitteet heikentävät droonien käytettävyyttä. Drooniratkaisut toimivat edistyksellisinä organisaation prosessien, menetelmien ja yhteistyön kehitysalustoina ympäristöllisen kestävyyden tukemisessa.

Asiasanat: ympäristölliset tietojärjestelmät, ympäristöllinen kestävyys, toiminnalliset käyttömahdollisuudet, luonnollinen resurssiperusteinen näkökulma, institutionaalinen teoria, tietojärjestelmäartefakti

ABSTRACT

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The degradation of environmental sustainability is one of the most significant threats to life on earth. Biodiversity loss, acceleration of climate change, increased environmental pollution, melting of polar ice caps and sea level rise are reducing living possibilities widely now and in the future. For environmental sustainability, forests have a particularly important role as diverse carbon sinks and habitats. Therefore, the activities of forest industry, forest owners and public organizations has a central impact in supporting the sustainability of forests and environment. Digitalization and information systems have contributed to acceleration of climate change and overexploitation of natural resources. Against this progression, green information systems research aims for improving organization's processes, practices and activities and their comprehensive management in order to minimize harmful effects caused by business operations and support environmental sustainability with information systems. Along with organization-wide systems, agile, effective and flexible applications in practice are needed to achieve environmental goals. By combining these dimensions and objectives, the utilization of drones as information system artifacts and their social, technological and informational characteristics are observed in this study to support environmental sustainability in Finnish forest industry. As a framework, the concept of information system artifact, approach of functional affordances, natural-resource-based view, eco-goals based on triple bottom line and institutional theory are applied. For the empirical foundation, qualitative multiple-case study is utilized for which 13 experts were interviewed from forest sector, drone services and IT consulting companies and from environmental governance by using semi-structured interview technique. The findings indicate that applying drones as IS artifacts supports environmental sustainability in the processes and activities of forest planning, forest production, forest ownership and environmental governance. Drones can be employed for accurate, cost-efficient and real-time data collection solutions. However, the restrictions concerning technological, legislative, data collection, conditions and availability weaken the applicability of drones. Drone solutions as progressive development platforms facilitate organizational processes, practices and collaboration in supporting environmental sustainability.

Keywords: green information systems, environmental sustainability, functional affordances, natural-resource-based view, institutional theory, information system artifact

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1 INTRODUCTION

Climate change and deterioration of the nature create substantial and irreversible negative impacts on the society, economy and environment. Greenhouse gases, harmful emissions, consumption of toxic materials, hazardous waste and, in general, the excessive use of fossil fuels and other natural resources are damaging the nature's resilience comprehensively. Since these effects are caused globally by industries, private and public companies, nations and individuals, versatile and collaborative efforts in different domains must be executed. The drastic changes in climate and environment have direct and indirect influences by decreasing biodiversity, melting polar ice caps, rising sea level, generating unlivable areas and, thus, narrowing possibilities for the future. As a whole, climate change is perceived as the greatest threat to earth's future for the social, economic and, particularly, *environmental sustainability* is challenged in unprecedented ways.

Although broad governmental and political efforts must be conducted to assist environmental sustainability, global market economy with its transformative and innovative abilities constitutes a major force that can change the current behaviors and enable environmental sustainability worldwide (Elliot, 2011). At present in the era of digitalization, business is increasingly shifting towards digital solutions being applied within organizational business processes, practices, products, services and development. While information technology (IT) and information systems (IS) enable effective and innovative digital solutions, they are part of the problem regarding climate change and environmental degradation, because it requires lots of electricity and natural resources to use, manufacture and dispose IT devices. However, IS and IT can be also applied reversible for minimizing environmentally harmful impacts and supporting transformations and activities towards environmental sustainability. Therefore, the *green IS* paradigm has been introduced in IS research to delineate action possibilities, opportunities, practices and frameworks for achieving these positive environmental sustainability outcomes with IS solutions.

Besides wide-ranging changes in organizational systems, practices, processes and behavior are needed to support environmentally sustainable endeavors, exploring opportunities of employing useful and flexible applications of smaller scale will similarly contribute necessary knowledge on utilizing a green IS for environmental sustainability. Thus, research studies aiming for ingenious and influential findings based on diverse research foundations and promoting collaboration among disciplines should be conducted to realize the transformative effect of green IS, in its entirety (Malhotra, Melville & Watson, 2013). In addition, studies for developing existing frameworks and establishing new practical models, examining pioneering applications by organization alliances, and involving private and public organizations of different sizes (Elliot & Webster, 2017) are required to acquire the potential benefits of green IS research completely.

Drones, as contemporary physical and digital innovations applied in several industries, are practical tools for aerial imaging, measuring and monitoring of different areas, terrains and constructions. Besides integrating versatile technological components, operational drone solutions require and provide platforms for social and informational capabilities.

In order to delimit climate change and support environmental sustainability, forests as diverse ecosystems, carbon sinks and lungs of the planet are indispensable. By absorbing greenhouse gases, releasing oxygen and offering fertile soil and habitat, forests are considered as the most essential solutions in resolving these long-lasting and expanding environmental crises. Since forests are logged and utilized as resources to create products and services in global economy, forest industry has a major responsibility in managing the sustainability of forests. Forests as resources can be scarce and very slowly or never renewing into their primary conditions, depending on the specific area, biodiversity and ecosystem. Hence, forest industry companies must engage in managing the biodiversity and wealth of forests with a long-term vision based on supporting environmental sustainability.

In this thesis, these distinct perspectives are incorporated to discover possibilities of utilizing drone solutions in Finnish forest industry for supporting environmental sustainability. Then, these drone-based forest industry solutions are evaluated to understand the specific dynamics, mechanisms and synergies facilitating environmental sustainability efforts and transformations.

The theoretical basis of this study is built upon the perception of *IS artifact* (Lee, Thomas & Baskerville, 2015) to examine the social, technological and informational components of drones as IS artifacts, and the *functional affordances* framework (Seidel, Recker & vom Brocke, 2013; Hanelt, Busse & Kolbe, 2017) is employed to evaluate the action possibilities and capabilities of the specified drone solutions in forest industry. Considering the environmental objectives and strategic capabilities within the business context and its aspects, the *natural-resource-based view* (Hart, 1995) and the outlook on *eco-goals* (Elkington, 1998; Dyllick & Hockerts, 2002; Watson, Boudreau & Chen, 2010) are combined for analysis. Whereas the institutional isomorphisms, or pressures, concerning the *institutional theory* (DiMaggio & Powell, 1983) are reviewed for regarding the possible restrictive factors and effects in developing and adopting drone solutions. As a navigating structure, the *belief-action-outcome framework* (Melville, 2010) is applied to construct understanding on the research context and facilitate valuable data analysis.

The empirical investigation of this thesis is constituted on qualitative research and semi-structured interviews, thus having drones as IS artifacts supporting environmental sustainability in forest industry as the phenomenon and individuals as the cases of this multiple-case study. The participated 13 interviewees are experts working in forest industry, drone operations and applications, IT solutions and environmental governance. The empirical research was based on positivist research philosophy (Orlikowski & Baroudi, 1991; Darke, Shanks & Broadbent, 1998) and the collected data were analyzed by the approaches of open, axial and theoretical coding (Corbin & Strauss, 2008).

The findings of this thesis unveil the distinctive dimensions of activities supporting environmental sustainability in forest industry and the functionalities of drones as IS artifacts in organizational processes, practices, products and services to reduce harmful impacts and advance environmental sustainability. By describing the relevant use contexts, attainable capabilities and possible limitations regarding drones, practical applications and beneficial opportunities for implementing and developing drones as IS artifacts in forest industry are elaborated and proposed. With the achieved empirical discoveries and generated model, organizational behavior, actions, objectives and business transformations towards environmental sustainability can be observed, planned and managed thoroughly.

1.1 Research questions

In this thesis, the emphasis is on the existent green IS literature to investigate with a qualitative multiple-case research approach the use contexts, capabilities, restrictions and developments of an IS artifact in enabling environmentally sustainable actions and impacts within forest industry. These perspectives are incorporated to examine and answer the specific research questions of:

1. How drones can be applied as IS artifacts in forest industry?

2. How environmental sustainability can be supported in forest industry by utilizing drone solutions?

First, the objective of this thesis is to discover and identify the actual and potential use possibilities of drones as IS artifacts in forest industry. This aspiration is gained by constructing a theoretical framework based on the current literature, evaluating the collected empirical data and paralleling the produced results collectively. Second, the outlined opportunities of utilizing drones in forest industry are considered to determine their utility in supporting activities for environmental sustainability.

Consequently, the intention is not to look into and describe the most appropriate, profitable or resource-efficient methods to improve sustainability on very detailed or all-encompassing level. Neither the focus is on specifying definitely successful, step by step, guidelines for utilizing and deploying drone solutions in forest industry. As a whole, the aim of this thesis is to provide a practical and flexible perception on employing drones as IS artifacts in developing organizational processes, practices and solutions to establish environmental sustainability as the strategic, foremost, business goal and capability to pursue.

1.2 Thesis outline

To answer the research questions, this thesis is divided into reviewing the theoretical foundations, describing the conducted empirical investigation, evaluating the generated findings, discussing the outcomes and, eventually, concluding the research study in its entirety.

In the chapter 2, for outlining the theoretical foundation, the literature review process, main theoretical findings, commonly used theories and relevant research subjects are discussed based on the existing green IS literature. Next, in the chapter 3, the theoretical framework founded upon the existing green IS studies and utilized within the empirical research of this thesis is presented and examined. In the chapter 4, the research methodologies and phases concerning the empirical study are considered in detail. The research techniques, forest industry and drones as specific contexts, overview on the interviewees and activities related to data collection and analysis are introduced.

In the chapter 5, the discovered findings based on the empirical data are gathered and presented with illustrative examples from the interviews. First, the general findings on environmental sustainability objectives, use contexts, capabilities, restrictions and improvements regarding drones in forest industry solutions are displayed. Second, by evaluating the applied theoretical framework, a new model for observing and planning the particular goals, capabilities, action possibilities and potential outcomes of employing drones as IS for environmental sustainability is constructed. Finally, by merging the elicited findings and constructed framework, the defined research questions are answered.

In the chapter 6, the outlined findings and developed framework are discussed. Implications for theoretical purposes and practical solutions by different stakeholders are specified. In the chapter 7, the study and the achieved results are summarized comprehensively. The limitations concerning the foundations, phases, decisions, interpretations and applications of this research are estimated. Finally, aspects for future research efforts are deliberated. In the end of this thesis, the references of the employed research literature and online sources and the interview guide as an appendix are presented.

2 LITERATURE REVIEW

Within the existing IS literature, green information systems (green IS) are considered as organization-wide systems aiming for minimizing environmentally harmful impacts and promoting environmental sustainability. In order to accomplish individual, organizational or societal objectives, green IS incorporate people, processes and IT solutions with cooperative and integrative applications and initiatives (Watson et al., 2010). In fact, these kinds of systems are viewed as comprehensive approaches to support environmental sustainability by IT-enabled solutions, whereas in the research domain of green IT, the goal is to minimize the negative effects caused by the manufacture, use and disposal of hardware and IT applications (Elliot, 2011).

In this thesis, the objective is to understand drones as IS artifacts and explore drone solutions advancing environmental sustainability in forest industry. Hence, the green IS research and perspective are emphasized in this study, whereas the aspects of green IT are applied only for examining energy efficiency, sustainable use and hardware and software performance. In this chapter, the conducted literature review on green IS research is outlined by reviewing the search procedure, gathered findings, key theories and key topics regarding this thesis and, finally, summarizing the obtained insights on green IS literature.

2.1 Search procedure

To establish a comprehensive foundation based on green IS literature, the selection process of research articles is discussed next. In order to generalize and perceive the decisions and features of this study, the overall characteristics on searching, collecting and selecting the literature are considered.

Focusing on green IS and their applications, several journal articles, conference papers, academic books and some theses have been published. Nevertheless, to gain as openly produced, critically assessed and accurately validated knowledge as possible on green IS research domain, only peerreviewed journal articles were searched and selected for this study. To confirm that an article was published in a high-quality journal having the best or second-best rating, the Publication Channel Search of Finnish Publication Forum (Julkaisufoorumi) was used for confirming and evaluating academic journals.

For searching and selecting the most significant articles of green IS research, search words and terms "green IS", "green IT", "information systems", "environmental", "sustainability", "sustainable", "performance", "strategy" and "initiative" were used and combined. Google Scholar, Scopus, JSTOR, AIS Electronic Library, IEEE Xplore Digital Library and ACM Digital Library were applied for searching research articles and conference papers. Due to the interdisciplinary characteristics of green IS, using various online databases and libraries was necessary in order to generate a comprehensive understanding on the topic, develop an appropriate framework for the empirical research and review the elicited findings, thus answering the research questions.

After collecting the total amount of 142 research articles, the studies were analyzed by writing down the most essential viewpoints and results of each study into an Excel worksheet. This worksheet functioned as an inclusive literature database that enabled highlighting certain aspects and evaluating the articles with a consistent procedure. The specific columns in this database were reference, journal, publication year, context, theoretical background, definitions, used theory, factors, approach, key findings, limitations and notes. Thus, besides providing a holistic foundation for learning and understanding green IS research, the worksheet enabled efficient categorization and assessment of different and similar outlooks on green IS literature. In addition, the evolution of this research field could be reviewed more thoroughly as well as findings and research gaps were discovered more explicitly by cross-examining the research articles.

Since 142 articles cannot be utilized very efficiently in a master's thesis and the articles included also non-empirical, conceptual, and opinion-based studies, the suitability of each study was reviewed after analysis. From the collected articles, the studies that were either published in a journal belonging to the Senior Scholars' Basket of eight top journals (Members of the College of Senior Scholars) in IS field or based on empirical evidence were selected for this study. Overall, after revising the contents and emphases of this thesis with the gathered articles, 31 research studies on green IS context were selected for the literature review.

All of these 31 studies were published in academic journals, of which 45% were empirical and 7% conceptual studies from top basket IS journals and 32% were empirical studies from other journals. Reviewing the selected studies, green IS and environmental sustainability are relatively new topics, phenomena and viewpoints in IS research. The selected studies were published during 10 years from 2008 to 2017 and most of them were published in 2011-2013 (52%) and 2017 (26%). To consider research methodologies, in 66% of the studies quantitative methods were used, whereas 31% were based on qualitative approaches. In one study, applied methods were used. However, a few studies utilized both quantitative and qualitative approaches. Within these studies, data were collected equally by conducting surveys (31%), interviews (31%) and analysis for historical data (31%). In addition, experiment and observation were both used in a single study. From interviews, the most were semi-structured (64%) while only

2 were founded on unstructured form. Structured interviews and focus groups were applied both in 1 research. From the theoretical perspectives, in 55% of the studies green IS was used as the main foundation, whereas in 21% green IT was the key paradigm. The theoretical backgrounds of supply chain management, human resource management and sustainability IS/IT/ICT were all employed in 6% of the studies. Also, both IT capability and corporate social responsibility were used as a guiding theory in a single study.

As a whole, research studies focusing on and applying green IS have been conducted for about ten years. So far, most of the studies have been quantitative, based on archival data or conceptual in their essence. However, creative, solution-based and impactful studies utilizing different research lenses and collaboration among disciplines must be conducted to realize the transformative effects of green IS (Malhotra et al., 2013). This thesis is founded on qualitative research convention; thus, the context, characteristics and constructs of the applied theoretical framework are investigated and employed flexibly, as guiding structures. This approach allows elaborating, criticizing, and expanding the existing theoretical foundations while also generating insights about drones as IS artifacts and developing new opportunities to support environmental sustainability by using drone solutions in forest industry.

2.2 Main findings

Based on the literature analysis, the most central findings of the selected studies are reviewed in this section. To form a suitable configuration on the selected literature for empirical investigation, frameworks, environmental management systems, strategies and practices regarding green IS are considered. For green IS discipline and practice, examining individuals and groups as well as evaluating revolutionary solutions and improvements are essential (Elliot & Webster, 2017). In this thesis, the focus is on the latter to study drones as combining IS artifacts in forest industry solutions which can be utilized to develop organizational capabilities and promote environmental sustainability.

2.2.1 Green IS framework for environmental sustainability

Since the context of green IS consists of multiple perspectives, functions and components, specific frameworks have been established for categorizing and observing them. In this chapter, the developed frameworks conceptualizing activities and relations on green IS are examined.

Categorizing the research of environmentally sustainable IT and IS, Jenkin, McShane and Webster (2011) establish a green IT/S research framework. Motivating forces, initiatives, orientation, and impacts related to environmental sustainability are identified as the key dimensions affecting each other (Jenkin et al., 2011). Ryoo and Koo (2013) applied this framework and enhanced it with environmental sustainability alignment defined as the cooperative force between environmental sustainability orientation and environmental impact. Although green IS practices can produce environmental and economic benefits through marketing and manufacturing functions (Ryoo & Koo, 2013), the potential effects, integration with environmental programs and communication to improve work practices may not be considered and perceived sufficiently in organizations (Jenkin et al., 2011). Accordingly, efficient communication, integration and overall management of sustainability aspects and IS are essential factors in facilitating successful and profitable implementation of green IS, as in drones as specific solutions supporting environmental sustainability.

To measure relevant factors of environmental sustainability, Molla, Cooper and Pittayachawan (2011) developed the instrument of environmentally sustainable IT performance (eSITP) drivers based on cross-sectional and cross-country survey of IT managers. In eSITP, the central constructs impacting environmental and economic value are eco-process, eco-learning, eco-brand and eco-value governance. From this viewpoint, organization should focus on its abilities of learning, innovating and developing valuable processes, products and services regarding sustainability. To improve environmentally sustainable IT performance, organization can reinforce its skills brand managing and improving skills, and its competencies for controlling different outcomes based on sustainability. (Molla et al., 2011.) In general, organization can emphasize variety of activities to facilitate environmentally sustainability, for which it is essential to evaluate and determine the most relevant solutions and trade-offs between economic and environmental performance. Consequently, these decisions have a major impact on applying and developing effective capabilities by utilizing IS for endeavors improving sustainability.

For framing potential research orientations, Melville (2010) proposes the belief-action-outcome (BAO) framework connecting organizational aspects with IS and environmental sustainability, which can be applied as a foundation for green IS theory development. The outline of BAO framework is presented in Figure 1. BAO can be categorized as a meta-level framework for designing and conducting research on environmental sustainability. Melville defines that in BAO sustainability issues are reviewed from three distinct perspectives: emerging beliefs and cognitive states on sustainability, organizational and individual actions on environmentally sustainable practices and processes, and outcomes on financial and environmental performance. When utilizing BAO, distinct relations and interactions are analyzed on micro or macro level to consider how belief formation, action formation and environmental outcomes affect each other (Melville, 2010). Hence, for belief formation, Melville outlines that the societal and organizational structures, and psychic state on environmental sustainability are the key constructs influencing the beliefs about environment. In action formation, the psychic states are transformed into individual actions which impact social and organizational systems and, therefore, result in changes of societal or organizational behavior as an outcome. (Melville, 2010.)

Because its orientations and propositions on green IS research approaches, BAO framework has been applied thoroughly in studies focusing on IS and environmental sustainability. It functions as a comprehensive model for analyzing and understanding the micro and macro effects when investigating relations, effects and dynamics of IS and environmental sustainability. BAO classifies and defines how different structures, states, actions, and behaviors are connected with each other, and how specific beliefs are converted into actions and affecting sustainable behavior within organization or other social system.

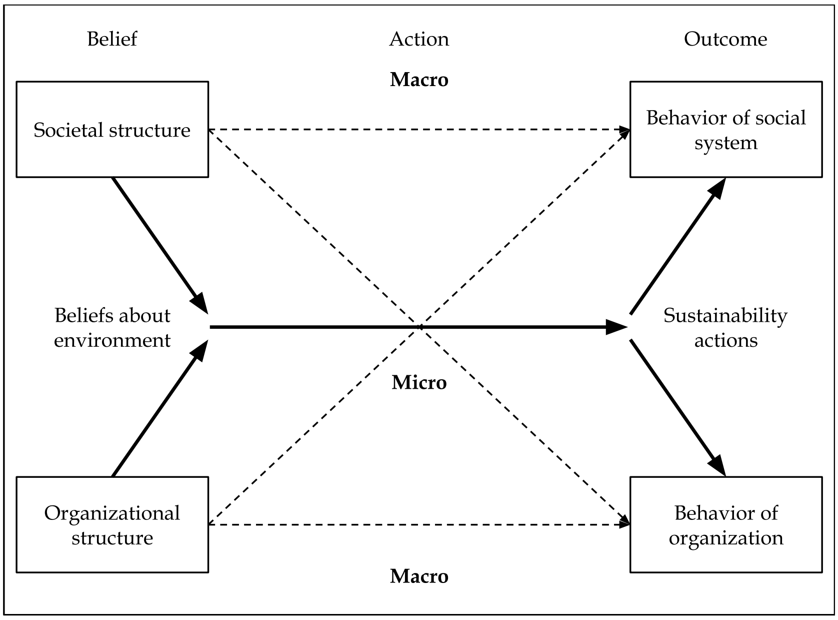

FIGURE 1 Belief-action-outcome (BAO) framework (Melville, 2010)

Due to its scope and flexibility as a guiding framework for green IS research, BAO is utilized in this study for perceiving the overall mechanisms behind organizational transformations towards environmental sustainability. It provides a broad perspective for considering the possibilities and restrictions on how drone solutions can be applied, developed and deployed for environmental sustainability.

2.2.2 Environmental management systems

Integrating business processes, practices, and technological applications, an environmental management system (EMS) incorporates these relevant activities enabling value creation based on environmental sustainability. Therefore, EMS includes organizational practices and processes for minimizing negative environmental impacts and enhancing operational productivity (EPA, 2019). For assessing these technical solutions defined in the research literature, EMS, their characteristics and relevance for drone solutions are reviewed next.

In addition to enhancing organization's competitive advantage, an effective system can minimize negative environmental impacts, reduce possible risks and facilitate responsibility (Zhang, Liu & Li, 2011). For a successful system implementation, the non-functional requirements, such as security, accuracy and performance are significant features. Besides these attributes, minimizing environmental impacts and thus creating solutions for tackling climate change should be also established as the principal non-functional requirements in software engineering. (Zhang et al., 2011.) In developing EMS based on green IS approach it is focal to examine the environmental perspectives, take the economic impacts into account, and evaluate organization’s present and future situations. Moreover, for managing resources and environmental impacts, the long-term changes, possibilities and challenges should be considered thoroughly.

Besides organization-wide settings, green IS can be designed to motivate individuals for more sustainable behavior. IS and applications can be utilized for monitoring resource consumption and offering feedback on a certain behavior (Loock, Staake & Thiesse, 2013). By developing applicable goal setting features, more energy-efficient behavior can be encouraged, since consumers are able to determine their individual goals while receiving practical information on consumption and advices for saving energy. Correspondingly, default goals affect also consumers' behavior for which they must be reviewed and set rigorously, or they should be left without any exact consideration, since incorrect defaults can have harmful effects. On the other hand, feedback on performance that can generate savings will motivate consumers to revise their personal goals. To support continuing more energy-efficient behavior, specific feedback on collected data and individual features of the measured domain will encourage consumers. (Loock et al., 2013.) Due to these possibilities, green IS applications and EMS can be designed and deployed more effectively by motivating users' behavior with detailed and personalized feedback and goal setting abilities.

Within operational research domain, EMS have been studied to explore how green IS solutions and their capabilities affect green supply chain management (GSCM). GSCM practices are defined as manufacturers’ collaborative activities among suppliers and customers to contribute environmental sustainability, which are based on minimizing toxic material consumption, emissions and waste and thus enhancing environmental performance (Green Jr, Zelbst, Meacham & Bhadauria, 2012). Consequently, Darnall et al. (2008) indicate that besides having positive effects internally, firms adopting EMS successfully will improve environmental performance and sustainability also within their supplier and customer networks. Because of these network effects, GSCM practices and processes are significant factors supporting sustainability among the organization's operating environment.

Successfully implemented and deployed EMS facilitate monitoring, measuring and optimization within the organization's processes and operations. By utilizing all the social, technological and informational abilities of EMS, effective stakeholder relations, environmentally sustainable decision-making and individual behavior can be supported. In fact, drones can be integrated as solutions of EMS for monitoring, measuring and imaging e.g. forest areas, water systems and production facilities. As a whole, implementing an inclusive EMS integrated with accurate sensor technologies, such as drone-based data collection, makes it possible to monitor and support environmental sustainability thoroughly and optimize industrial processes effectively.

2.2.3 Towards green IS strategy

Reducing detrimental impacts and supporting environmental sustainability requires a long-range perception and commitment of the organization. In addition to facilitating environmental values, green IS strategies must constitute wide impacts within the business processes internally and externally. Especially, Cooper and Molla (2017) outline that the organizations have to manage strategically how they can generate environmentally driven and IS-enabled transformations by balancing the complicated and long-lasting impacts related to environmental challenges with the fast-paced business activities and orientations on the market. Consequently, the strategic viewpoints in the green IS literature are examined next based on the capabilities and strategy types aiming towards specific eco-goals.

In general, Chan and Ma (2017) sort the environmental strategies concerning IT as green IT strategies and IT-enabled green strategies. These strategic perceptions focus typically either on the foundations of green IT or green IS. Based on green IT strategies, organization aspires to minimize the negative environmental impacts caused by manufacturing, utilization, and disposal regarding IT. On the other hand, IT-enabled strategies are founded on applying IT for environmentally friendly practices and innovative solutions. (Chan & Ma, 2017.) Hence, IT-enabled strategies can be considered as more comprehensive approaches towards solving environmental problems by having IS solutions as strategic capabilities.

Organization-wide IT capabilities integrated and built upon valuable resources, such as IT infrastructure, technical and managerial skills, knowledge assets and synergies, can enhance business performance successfully (Bharadwaj, 2000). These capabilities can also have an indirect and positive impact on company's performance through the development of proactive corporate environmental strategy. Such strategy can be a dynamic capability for the company, since it provides solutions for stakeholder requirements by continuously transforming business environment and facilitating effective development of competitiveness. (Benitez-Amado & Walczuch, 2012.) In strategic management literature, Teece, Pisano and Shuen (1997) determine dynamic capabilities as the organization's abilities for integrating, constructing and reconfiguring internal and external competences in order to prepare for quickly evolving business environment. Eisenhardt and Martin (2000) describe dynamic capabilities as the processes of an organization to apply resources systematically in order to respond and generate market change, which include integrating, reconfiguring, obtaining and, also, releasing resources. Hence, dynamic capabilities incorporate the routines and practices concerning organizational and strategic processes when markets change continuously and dynamically (Eisenhardt & Martin, 2000).

Applying organizational dynamic capabilities by taking the social, technological and informational elements into account, an applicable green IS strategy can be formed. Reviewing potential green IS-based strategies, Jenkin et al. (2011) define four adapted strategy types that include environmental sustainability initiatives of the organization. Each strategy type encompasses the features of preceding strategy types. Jenkin et al. argue that a type 0 strategy is merely an image-oriented approach for which organization makes announcements on conducting business based on environmental policies, but due to insufficient resources these environmental policies cannot be implemented and deployed successfully. In the type 1 strategy, the objective is to have resource-efficient operations and prevent negative environmental effects by using and controlling natural resources powerfully and reducing waste. The type 2 strategy concentrates on development of production processes which should be redesigned by managing the life cycles of products and services continuously and minimizing the environmentally harmful impacts. Therefore, the type 2 strategy can be perceived as a strategy aiming for product stewardship. The type 3 strategy is based on an organization-wide mindset supporting environmental sustainability for which the global negative impacts regarding environmental issues are reduced and compensated in the organization's economic activities and business growth. In type 3 strategy, organization is redesigning its structures and activities significantly by employing clean technologies and committing to the target of minimizing waste and emissions to zero. (Jenkin et al., 2011.)

Identifying and determining relevant environmental strategies must be founded on the unique business context of the company. Molla (2013) argues that the eco-learning, eco-process, eco-brand and eco-value governance functions, defined in environmentally sustainable IT performance (eSITP) instrument, enables recognizing significant perspectives and thus decision-making on environmental strategy. Learning skills, sustainability aspects within processes and brand management, and evaluating material and immaterial consequences for the environment are the key capabilities of an organization to apply green IS initiatives, innovations, organizational culture, behavior and processes (Molla, 2013). By applying these versatile capabilities and incorporating company's environmental orientation and practices, green IS strategy constitutes the foundation for improving reputation and cost efficiency, and developing green innovations (Loeser et al., 2017). Furthermore, as organizations have assembled distinct bundles of resources based on IS-enabled and environmentally driven capabilities, the valuable insights and knowledge on solving environmental problems and supporting sustainability should be shared collaboratively (Cooper & Molla, 2017).

Green IS strategy encompasses diverse components and objectives within organization and its business context. Since business and natural environment are evolving continuously and unpredictably, a well-functioning green IS strategy can become a dynamic and flexible capability for achieving economic, social and environmental goals. In that case, a company can create market change and long-term competitive advantage due to influential solutions and market positioning founded on environmental sustainability. Especially, to deploy drone solutions in forest industry, the business and environmental strategies must be aligned with the drone-based operations and activities for environmental sustainability.

2.2.4 Practices and initiatives

Green IS practices are the concrete activities assisting and reshaping organizational processes to enable environmental sustainability. In employing and developing green IS practices with specific initiatives, organization can deploy its green IS strategy to generate environmental and economic effectiveness. To realize these benefits, organization must integrate its supply chain and human resources management and IT resources by involving automation, transformation, IT infrastructure and information sharing thoroughly (Dao, Langella & Carbo, 2011). Next, the attributes linked with these practices and initiatives are outlined, which affect the success and outcomes of employing practices and initiatives regarding drone solutions.

Green initiatives can be perceived as the desired changes, abilities and activities which are made possible by successful green IS implementation in organization's business processes. Accordingly, Wang, Brooks and Sarker (2015a) argue that green initiatives require appropriate social structures and attitude within organization. For instance, structures increasing or reducing action possibilities for sustainability are improved recycling, information and environmental monitoring, complex technological solutions, and minimized energy consumption. On the other hand, the spirit in green IS initiatives can be considered as general understanding about particular technological solution based on values and objectives, which support deploying these efforts. (Wang et al., 2015a.) Consequently, to implement environmentally sustainable practices and initiatives by using drones in forest industry, the organizational structures and spirit towards environmental issues must be aligned with the use contexts of drone solutions.

Since employees and their abilities are one of the most essential and strategic factors improving environmental performance, the human resource management (HRM) of firm and the IS solutions concerning HRM can also promote sustainability. Drones are relatively new solutions and to use them successfully for environmental sustainability, both people's and organization's behavior, capabilities and opportunities in applying drones must be assisted with applicable HRM practices. Hence, Renwick, Redman and Maguire (2013) classify green HRM practices that can develop green abilities, encourage employees towards green behavior and deliver green possibilities. First, when facilitating and enhancing green skills, company can focus on sustainability by specifying environmental perspectives in its job descriptions, selecting green aware employees and educating individuals concerning sustainability issues and green behavior. Second, to motivate employees, company can utilize detailed objectives and indicators for environmental performance and implement a system to reward and compensate sustainable behavior. Finally, offering environmental opportunities, company can involve and engage employees to promote sustainability for which environmental culture and collaboration with other companies will support green HRM practices. (Renwick et al., 2013.) Thus, employees regarded and nominated as green IS champions can motivate organizational green behavior (Hedman & Henningsson, 2016) and establish networks for sharing knowledge and developing green abilities efficiently (Seidel et al., 2013). To utilize and manage these possibilities and advantages successfully, applicable HRM practices for drone solutions should be developed and deployed in a systematic way.

The drone products and services have to be applied with the organizational systems that function as platforms for collecting, sharing and analyzing drone-based data. Describing specific green IS practices, Loeser et al. (2017) outline process re-engineering, implementation and use of environmental management systems (EMS), and application of environmental technologies as the main practices facilitated by information systems. Process re-engineering enabled by IS combines business transformation and redesigning of business and production processes in order to promote resource efficiency. As wide-ranging solutions, EMS enable monitoring of resources, emissions, and waste by using IS, which supports more transparent tracking of processes and reporting on environmental issues to external stakeholders. In general, to minimize negative environmental effects in different use contexts, versatile digital solutions and smart systems can be employed flexibly in developing novel products and services. (Loeser et al., 2017.) To enhance green IS practices in using drones, organizational processes, organization-wide environmental monitoring systems and smart solutions must be reviewed thoroughly and applied with drone solutions.

In acquiring all the capabilities and benefits of using drone solutions for environmental sustainability, integration and alignment of organizational practices is essential in managing drones as green IS solutions. Ryoo and Koo (2013) determine that in aligning green IS practices successfully, the coordinating functions between green practices, marketing and manufacturing improve both environmental sustainability and economic performance. In fact, business intelligence systems incorporating different indicators and functions have a significant impact in order to manage and develop sustainable practices within organization (Petrini & Pozzebon, 2009). In general, managing green practices collaboratively within organization can improve both environmental and economic performance, which, as a result, can motivate more firms to implement environmentally sustainable practices. By integrating organizational capabilities, business functions and intelligent systems, drones as IS solutions can be facilitated and developed effectively with suitable business practices. In addition, new opportunities regarding business and environmental solutions by using drones can be stimulated due to motivation to utilize drones flexibly in versatile activities.

In deploying drones as a green IS solution, the usability and potential benefits of the solution and behavior of individuals must be evaluated. For promoting sustainability, IS can be utilized effectively if the primary tasks, interactions, credibility and social aspects are supported and deployed well within the system (Corbett & Mellouli, 2017). Especially, IS should provide competitive, accessibility and financial advantages for the end users, which will motivate them to continue using the system in their work (Marett et al., 2013). Hence, individuals are more encouraged to use IS when it supports additional applications and makes their work easier and less costly and, in general, decreases their cognitive effort. If a green IS solution is tailored well into its use context, organizational commitment towards sustainability initiatives can be communicated clearly and more relevant information can be utilized, which will promote employees' overall engagement for environmentally responsible behavior. (Corbett, 2013.)

Considering the comprehensive connections between practices, initiatives and strategies, it depends on the business and environmental objectives and context how well certain green IS practices can be adopted. Besides using drone solutions, other supportive and administrative business activities regarding drone use and applications can also contribute to environmental sustainability. For minimizing environmental degradation and enhancing resource efficiency, Jenkin et al. (2011) denote that appropriate waste disposal, reuse and refurbish of IT, and power management abilities can form the foundation in improving energy efficiency and sustainability. Besides monitoring and optimizing manufacturing processes thoroughly, digital solutions such as digital collaboration tools and platforms, e-commerce and entirely paperless interactions compared to numerous business trips and excessive paper use, can support sustainable development and knowledge sharing within and between organizations (Jenkin et al., 2011). Furthermore, as collaborative and social platforms, IS can be used to mediate diverse and complex functions for facilitating environmental sustainability initiatives (Hasan, Smith & Finnegan, 2017). Likewise, for incorporating various operators and activities, a green IS function as an integrated information ecosystem combining relevant data, processes, people and IT capabilities. Green IS solutions can thus be employed as holistic platforms for monitoring different conditions and situations in the business context and managing the overall progress of sustainability initiatives. (Corbett & Mellouli, 2017.) As a whole, to realize and integrate these sustainable improvements, environmental sustainability must not be managed merely as a supporting function but, especially, as a strategic capability of the organization (Petrini & Pozzebon, 2009).

Green IS practices and initiatives are established on technological, informational and social activities aiming to execute the strategic orientation and organizational decision-making. These activities require effective applications and integrations of IT solutions, management and business processes to minimize negative environmental impacts caused by production and business operations. Implementing green IS initiatives and practices are influenced dynamically by people's motivation, attitude and knowledge and organization's structures, values and capabilities related to business and environmental transformations. Therefore, justifying, encouraging and engaging people among the organization and its key stakeholders must be reviewed and promoted thoroughly to develop drone applications for environmental sustainability. The all-encompassing social, technological and informational characteristics on deploying drone solutions can be perceived from the perspectives of green IS practices and initiatives. This way, using the facilitating capabilities of IS within organizational processes, business and environmental sustainability transformations can be achieved by combining and promoting green IS initiatives and practices and deployment of drone solutions successfully.

2.3 Key theories

In the selected green IS research literature, a few key theories were applied commonly for diverse research objectives. Next, these theories and their characteristics are discussed to form an applicable foundation for the empirical investigation. Having the backgrounds on organizational research domain, the natural-resource-based view, institutional theory and eco-goals are reviewed first. Then, founded upon IS research, the theories on IS artifacts and functional affordances and their connections between environmental sustainability are described.

2.3.1 Natural-resource-based view (NRBV)

In green IS studies, the resource-based view (RBV) has been applied thoroughly. Based on strategic management, Wernerfelt (1984) defines that in RBV the concentration is shifted from company's products to its resources and resource position on the market to evaluate the strengths and weaknesses and generate profitability. Moreover, Barney (1991) argues that within organizations the heterogeneity and immobility of resources creates a foundation for dynamic resources which should be rare, valuable, difficult to substitute and imperfectly imitable to create sustained competitive advantage. Hence, Grant (1991) outlines resources being the inputs for different production processes for which resources are the major sources for developing organizational capabilities. In order to accomplish diverse activities and tasks effectively and profitably, these capabilities based on applications of resources are essential. Overall, capabilities can be viewed as the main sources for competitive advantage. (Grant, 1991.)

However, in the natural-resource-based view (NRBV) delineated by Hart (1995), it is argued that markets are reliant on versatile physical ecosystems, which have a restraining influence on competitive advantage and strategy. Due to this physical dependency, in generating sustained competitive advantage companies have to establish and focus on the strategic capabilities of *pollution prevention*, *product stewardship* and *sustainable development*.

For *pollution prevention* the key enabling resource is continuous improvement by reducing emissions and waste and advancing competitiveness by lowering costs. Supporting *product stewardship*, the resource of stakeholder integration is essential to decrease the life cycle costs of products and, therefore, create proactive advantages against competitors. Founded on the organizational resource of sharing a long-term vision, *sustainable development* decreases the environmental burden caused by company's development and growth, which can produce competitive advantage in the future and improve company's positioning on the future markets. (Hart, 1995.) As a whole, sustainable development was originally outlined by the Brundtland (1987) commission as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Resource-based view and its extension natural-resource-based view enable holistic evaluation of necessary constructs concerning organizational and IS-related issues. Utilizing NRBV, the attributes of organizational resources, capabilities, business performance and sustained competitive advantage can be investigated systematically. NRBV provides suitable foundation for evaluating the objectives, activities and integrated organizational resources related to drones as IS solutions contributing to environmental sustainability. In order to perceive the organizational context and its particular mechanisms affecting resources and capabilities, the pressures based on institutional theory are outlined next.

2.3.2 Institutional theory

Incorporating the factors and aspects affecting organizations in business environment, the institutional theory clarifies the dynamics and pressures on deploying and using information systems for certain objectives. Specifically, Orlikowski and Barley (2001) suggest that by utilizing these institutional approaches in IT studies and by correspondingly employing the material characteristics of IT research in organizational studies, both research fields will gain valuable insights due to these functioning interactions and transformations. In defining the theory of organization and thus creating the foundation for institutional theory, Selznick (1948) describes organizations as systems, economies and social structures which adapt over time. This economic viewpoint emphasizes the relationships of available resources, organizational effectiveness and structures, whereas the social structures encompass individuals contributing to cooperative systems and impacting the organization's effectiveness (Selznick, 1948).

Founded on these constructs and mechanisms, DiMaggio and Powell (1983) distinguish three institutional pressures which transform similar organizational shapes and structures, by the isomorphic changes of organizations, as in *coercive*, *mimetic* and *normative isomorphism*. *Coercive isomorphism* occurs due to the formal or informal pressures created by other organizations, government or society, which is actualized in the form of regulations, requirements, legislations or cultural expectations (DiMaggio & Powell, 1983). *Mimetic isomorphism* arises as a result of uncertainty of organizations, since they imitate successful activities, endeavors and strategies of other, possibly competing, organizations (Liang, Saraf, Hu & Xue, 2007). *Normative isomorphism* results from professionalization which is delineated as the professionals' continuous strive to develop work features, their urge to involve in the training of future professionals and their need to constitute a knowledge base and justification for their professional autonomy (DiMaggio & Powell, 1983). Furthermore, Liang et al. (2007) argue that because of professional networks and formal education, individuals with equivalent abilities and orientations would be recruited for similar positions, which will eventually lead to disregarding of distinguished organizational behavior and its potentially beneficial characteristics.

The institutional pressures cause broad and unexpected changes within organizations, their operations and business contexts. Nevertheless, considering and evaluating these pressures can provide detailed and useful perceptions for developing IS solutions in organizational domain and resolving the likely obstacles and restrictions in deployment and use. Hence, to define the objectives for applying IS solutions within organizational processes and contexts for environmental sustainability, the particular eco-goals are reviewed in the following section.

2.3.3 Eco-goals

Eco-goals describe the environmental objectives and outcomes that can be accomplished when employing IS solutions within business processes, practices and management for supporting environmentally sustainable outcomes. Therefore, in managing corporate sustainability, the environmental, economic and social dimensions must be considered comprehensively among organization (Dyllick & Hockerts, 2002).

Elkington (1998) delineated in the triple bottom line the goals aiming for environmental, economic and social sustainability. For achieving these specific goals, organizations, industries and government entities have to promote collaboration and thus establish extensive and efficient relationships for stakeholders and partnerships (Elkington, 1998). As a whole, based on these triple bottom line objectives, Dyllick and Hockerts (2002) outline six criteria for corporate sustainability as in eco-efficiency, eco-equity, eco-effectiveness, sufficiency, socio-efficiency and socio-effectiveness. Within the selected green IS literature, the classification for eco-goals including *eco-efficiency, eco-equity,* and *eco-effectiveness* are emphasized, which characterizes the organizational perceptions, approaches and activities towards minimizing harmful impacts and promoting environmental sustainability.

First, focusing on *eco-efficiency*, company is motivated by the economic pressures on the market, for which it pursues cost reductions and higher profits. Having this goal, the outlook is that markets and government regulations are the major factors in solving environmental problems (Watson et al., 2010), as company aims for reducing environmental impacts by enhancing its resource use and performance.

Second, the core notion of *eco-equity* is to consider the possibilities of future generations facing the consequences generated by overexploiting the natural resources and damaging the environment. To ensure eco-equity, a change on social and corporate norms is required, which may take place by internal transformations among organizations, by the influence of other companies acting as opinion leaders or by the sustainability regulations on different governmental levels. (Watson et al., 2010.)

Third, in *eco-effectiveness* the aim is to stop environmental degradation by reforming the economy fundamentally, which necessitates significant individual and organizational transformation for long-term sustainability and profitability. (Watson et al., 2010.) Eco-effectiveness is the ultimate and ideal environmental goal for companies to advance and reconstruct business strategies, practices, operations, management and their integrations. Thus, it encourages organizations to reconsider and justify their reason for existence comprehensively.

As clearly and applicably defined objectives for environmental sustainability, eco-goals offer a useful perception on restructuring organizational processes and capabilities in practice and for empirical intentions. Linking these resource-based, institutional and environmental dimensions and objectives into IS functions and capabilities, the theoretical view on IS artifacts is discussed next.

2.3.4 IS artifact for sustainability

Since an information system is a quite broad entity, the outlook of IS artifact by Lee, Thomas and Baskerville (2015), presented in Figure 2, is being utilized for observing green IS in a more detailed and structured way. In this thesis, the view on IS artifacts as encompassing entities incorporating technology, information and social artifacts (Lee et al., 2015) is adapted to examine the features and abilities of using drones in forest industry solutions for supporting environmental sustainability.

A *technology artifact* is considered as a tool that is human-created and used for solving a problem, achieving a goal or serving a purpose which is determined, understood and sensed by human. Whereas an *information artifact* represents the information created by humans, which is transferred directly by verbal statements or written reports or indirectly by using a program to retrieve information. A *social artifact* includes social relations and interactions among or between people, which supports problem-solving, goal achievement or serves the individual purposes of a person. Hence, a complete IS artifact is fundamentally an interactive system which distinct components and mechanisms generate synergies with each other. An ensemble of IS artifact can be completely different than its constituents are intrinsically, therefore an IS artifact is superior to the sum total of its components independently and separately. (Lee et al., 2015.)

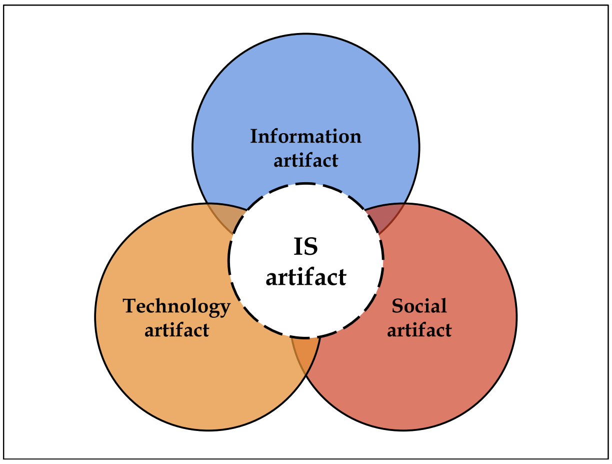

FIGURE 2 IS artifact (Lee et al., 2015)

To connect the IS artifact perception with the aspects of green IS, the IS and IT capabilities for supporting environmental sustainability must be aligned.

Consequently, several classifications have been formed for green IS in the IS and IT research.

From an IT perspective, the concept of green IT has been determined as a hardware- and software-based approach to tackle negative environmental impacts. However, the definitions on green IT differ and the emphasis has shifted from greening IT towards managing hardware and software. Wang, Chen and Benitez-Amado (2015b) underline the difference between greening IT and using IT for environmental management for which IT can both facilitate useful solutions and be a major part of the problems regarding environmentally harmful impacts. More broadly, green IT can be perceived as a general framework for the IT department of a company, which supports environmentally sustainable operations in the particular business context. Hence, based on the specific infrastructure, components and devices, organization should develop appropriate green IT practices by reviewing its sourcing, operations and disposal regarding hardware and software (Loeser et al., 2017).

In addition, the collaborative process of integrating IT and environmental management is a core capability incorporating the abilities to enhance environmental management by applying IT solutions. To achieve this, technical and business skills are essential in accomplishing successful combinations between IT and environmental management processes. (Wang et al., 2015b.) Thus, the commitment and participation of the entire organization and, especially, the top management is a key factor which must be encouraged. Besides environmental outcomes, announcements about improving sustainable decision-making can produce more positive shareholder responses than announcements on sustainable products, services or IT assets and infrastructure (Teo, Nishant & Goh, 2017). As a whole, green IT and decision-making regarding sustainability and IT can elicit positive environmental and economic results besides influencing organizational operations and practices internally. For developing and implementing an IS artifact, these green IT aspects affect, mostly, the technological components, their life cycle and operability in the business environment. However, the decisions regarding green IT matters have a fundamental impact on constructing and applying IS artifacts as IT-enabled solutions for environmental sustainability.

Green IS research explores the degradation of natural environment by developing IT-based solutions for not only minimizing the negative impacts of IT but also for promoting environmental sustainability in the organizational processes, business activities, products and services. This approach incorporates the foundations of green IT, but it is built upon more organizational and IT solution-based aspects. Since IS can function as platforms of social, technological and informational interactions for individuals and groups, and support internal or external collaboration, initiating and enabling sustainability behavior has a significant effect on the organizational environment and culture. Certain individuals, or green IS champions, can encourage organization for environmentally sustainable business operations for which green IS can be founded on the particular responses and processes to the changed requirements (Hedman & Henningsson, 2016). Furthermore, utilizing green IS solutions, these champions can gather a sustainability champion network for sharing useful information, learning and promoting sustainability transformations throughout the organization (Seidel et al., 2013). This way, combining social, technological and informational applications and practices related to IS artifacts, organizations can become more sustainable and environmentally aware.

Environmental sustainability can be supported with IS artifacts by applying pertinent approaches, practices, initiatives and frameworks to understand the dynamics between environmental sustainability and IS solutions. As an extensive paradigm, green IS research integrates green IT practices and the social, technological and informational IS artifacts to contribute environmental sustainability. Since the focus of this study is to understand and describe how drones can be utilized as IS artifacts in forest industry to support environmental sustainability, the IT-based applications to improve environmentally sustainable endeavors, as in green IS solutions, are emphasized in this study. Therefore, integrating the environmental and organizational viewpoints with IS artifacts and considering the potential action possibilities of IS solutions in tackling environmental degradation, the functional affordances defined in IS literature are reviewed next.

2.3.5 Functional affordances

The versatile abilities of IS artifact can facilitate environmental transformations within the organization's practices, processes and business environment. In this section, these functional affordances as in the action possibilities of a specific IS artifact are outlined. First, the definition of functional affordances within IS field is specified, and, second, the applications of functional affordances enabling organizational sustainability transformations are discussed.

To understand the connection of IS and its user, Markus and Silver (2008) define the concept of functional affordances by distinguishing the relationship between a particular user or group of users and a technical object. Based on this aspect, user's possibilities to utilize a technical object are influenced by one's personal capabilities and intentions. This way, the possibilities for target-oriented actions are delineated for specific user groups who are employing the examined technical objects. (Markus & Silver, 2008.) Furthermore, Leonardi (2011) evaluates the material properties and perceived materiality of technologies from the viewpoint of affordances. Leonardi proposes that users can have a different perception on the affordances that a technological artifact, or system, enables, although they still may have similar understanding on the materiality of the system. These material properties of a technological artifact offer diverse possibilities for target-oriented actions in different contexts and for users with different objectives and skills. (Leonardi, 2011.)

Hence, in operating towards specified goals, an IS artifact can support a user group's activities and define their action possibilities. Correspondingly, the IS artifact may not support the activities or provide anything worthwhile for a user group with distinct objectives and capabilities. Therefore, in the context of green IS, organizations can review the functional affordances to evaluate and manage the possibilities and actions to develop sustainable practices and processes to foster the organization's goals on environmental sustainability.

Applying the socio-technical systems (STS) theory by Bostrom and Heinen (1977, Seidel, Recker and vom Brocke (2013) recognize and describe four principal functional affordances of using IS for sustainability transformations. Hence, people, task, technology and structure are exercised as the main dimensions of STS in analyzing organizations, based on the socio-technical model by Leavitt (1965). Overall, the functional affordances can be assigned into the two major categories of *organizational sensemaking* affordances and *sustainable practicing* affordances. (Seidel et al., 2013.) As an extension to the study of Seidel et al., Hanelt, Busse and Kolbe (2017) contribute two additions, or subcategories, to the sustainable practicing affordances. These IS affordances can be developed by applying valuable resources, capabilities and business processes which facilitate operational, economic and environmental performance within organization and among its business partners. Next, the types and characteristics of functional affordances are outlined. To present these affordances accurately, the organizational dimensions of people, task, technology and structure are applied for the analysis. An overall summary of the functional affordances and their main features are structured into Table 1.

Sensemaking affordances of IS create a foundation for individual's activities in outlining, interpreting and understanding the complicated and extensive perspectives on environmental sustainability transformations (Seidel et al., 2013). In fact, sensemaking refers to people's orientation to form comprehensible meanings in order to decrease ambiguity and instability, and thus enable performance in changing situations (Weick, Sutcliffe & Obstfeld, 2005). Weick (1995, 17) recognizes organizational sensemaking as a distinct process that can be distinguished from other organizational processes related to defining, describing and understanding complex issues. Consequently, sensemaking is founded on different organizational characteristics and actions. It can be viewed from its identity construction, retrospective reflection, social interaction, simultaneity and continuity, interaction with sensible environments, foundation of signals or cues, and by its driving forces based more on plausibility than precision which affect sensemaking processes (Weick, 1995, 17). As a whole, sensemaking is influenced by versatile and complex features embedded within organizational environment, people and social interactions. By disseminating essential information to stakeholders, sensemaking affordances decrease ambiguity and enable analytical assessment on sustainability-related matters among organization (Hanelt et al., 2017). For sensemaking affordances, IS solutions function as platforms by supporting sustainability transformation indirectly. Thus, *reflective disclosure* and *information democratization* are relevant IS functional affordances providing different possibilities towards green transformation within organization's business context. (Seidel et al., 2013.)

Reflective disclosure enables evaluating the current environmental situation interactively within the organization and creating applicable and alternative work practices to promote environmental sustainability (Seidel et al., 2013). Founded on the belief-action-outcome (BAO) framework by Melville (2010), Seidel et al. classify the action possibilities for reflective disclosure as belief and action formation and outcome assessment. In reviewing reflective disclosure with organizational dimensions, technological capabilities of IS enable monitoring, analyzing and presenting environmental indicators. Consequently, reflective disclosure supports the development of structures for sharing knowledge throughout the organization and improves utilization of the key performance indicators (KPIs) in environmental management. For people, reflective disclosure fosters personal goal setting and awareness in sustainable work practices through communicating and reassessing the IS capabilities. Finally, the tasks can be reviewed and reimagined comprehensively, based on beliefs, actions and outcomes, for generating sustainable work practices. (Seidel et al., 2013.)

Information democratization induces dissemination of relevant information on the sustainability-related subjects and thus the accessibility and interaction features of IS provide useful structures for creating new KPIs and managing environmental initiatives. By motivating people to share ideas and contribute developing sustainable work practices, the task of participation effect in information democratization allows shaping new goals and practices and managing information for environmental sustainability. (Seidel et al., 2013.)

Sustainable practicing affordances describe the direct effects of IS on sustainable work practices within organization (Seidel et al., 2013). Consequently, Hanelt et al. (2017) denote that these affordances can improve sustainability of work practices by diminishing the negative impacts of business processes or making environmentally reasonable decisions on the location of business processes. Thus, *output management*, *delocalization* (Seidel et al., 2013), and additionally *technological flexibility* and *digital eco-innovation* (Hanelt et al., 2017) are outlined as the specific affordances for sustainable practicing.

Output management requires flexible configuration and control features of IS for monitoring, managing and visualizing environmental impacts of examined outputs. When output management affordance is deployed in the company, new sustainable policies and work practices are created through the development of personal goals, organizational norms, certifications and training activities related to output management. Behavior conditioning effect especially is a directive task for output management, as it promotes sustainability through educating and conditioning towards sustainable work practices. Eventually, the behavior conditioning effect can result in employees' strong commitment towards the individual goals and the organizational norms and policies. (Seidel et al., 2013.)

Delocalization is based on location independency in work practices. Collaboration and file sharing abilities provided by IS can be viewed as the core characteristics, which will minimize redundant work traveling. Thus, the work virtualization effect supports the formation of new structures, such as policies, indicators and incentives, encourages people to reassess current work practices and decreases the dependency of resource movement. In addition, organizational training for sustainability-aware employees can bring about practical solutions for remote work and therefore promote delocalization. (Seidel et al., 2013.)

Technological flexibility is founded on the abilities of supporting IS and Hanelt et al. (2017) argue that applying different solutions, in an economic and environmentally sustainable way, offers transformative outcomes and enhances performance in business processes. Accordingly, information and automation facilitate connectivity and integration among people, technological solutions and infrastructures. By utilizing supporting IS, less ambiguity will emerge, and more accurate information will be discovered because of the digital solutions within the business processes. Based on increased knowledge and certainty on business processes, more efficient and environmentally sustainable solutions and conceivably eco-innovations can be established. (Hanelt et al., 2017.)

Digital eco-innovation affordance, promoted by supporting IS, incorporates physical and digital elements in constructing new arrangements for environmentally sustainable innovations. These innovations can be e.g. novel digital services, products, business models or business processes. When implementing digital eco-innovations, the negative effects are reduced and more positive outcomes are realized in business processes, which will initiate new objectives and opportunities for environmentally sustainable management. (Hanelt et al., 2017.)

The functional affordances conceptualize the foremost possibilities that IS can enable for organizational sustainability transformations. Based on the studies of Seidel et al. (2013) and Hanelt et al. (2017), the model of functional affordances can be applied for analyzing, evaluating and developing IS capabilities for sustainability. In this thesis, the functional affordances are utilized for exploring the capabilities of drones as IS artifacts in forest industry solutions to support environmental sustainability.

TABLE 1 Functional affordances of green IS, structure adapted from Seidel et al. (2013).

Type	Functional affordance	Description	Reference
Organizational sensemaking affordances	Reflective disclosure	Revising the belief formation, action formation and outcome assessment related to work practices	Seidel et al. (2013)
	Information democratization	Sharing information from internal and external sources and improving interaction regarding sustainability	Seidel et al. (2013)
Sustainable practicing affordances	Output management	Managing output and consumption of environmentally harmful resources	Seidel et al. (2013)
	Delocalization	Reducing the importance of location in work practices	Seidel et al. (2013)
	Technological flexibility	Utilizing supporting IS to improve collaboration and integration	Hanelt et al. (2017)
	Digital eco-innovation	Developing novel, environmentally sustainable solutions by combining digital and physical components	Hanelt et al. (2017)

2.4 Key topics for the research questions

The most essential subjects in answering the research questions can be classified by outlining the theoretical perceptions, strategies and goals, and organizational practices to promote activities and endeavors for environmental sustainability.

First, to evaluate drones and their specific abilities from the viewpoint of applicable research approaches, the conceptualization of IS artifacts by Lee et al. (2015), with the social, technological and information components creating potential synergies, functions as a fundamental perception on the research subject. Viewing the possibilities, capabilities and restrictions of integrating these components is essential in order to understand the dynamics, behaviors and pressures concerning drone solutions in forest industry. To recognize the various research dimensions, the BAO framework by Melville (2010) outlines possible orientations and linkages between organizational levels, behaviors, structures and mechanisms in aiming for environmental sustainability transformations. From the viewpoint of employing drones as IS artifacts, BAO characterizes the organizational and social effects for incorporating appropriate competencies, configurations and motivation to enable actions improving environmental sustainability in forest industry solutions. In addition, it offers a model for perceiving the progressions and life cycles in organizational sustainable development.

For identifying different use possibilities and purposes of drones, the vision on functional affordances by Seidel et al. (2013) and with its extensions by Hanelt et al. (2017) is pertinent in answering the research questions. The defined sensemaking and sustainable practicing affordances allow recognizing and describing distinct action capabilities of using drones in forest industry solutions. In addition, these IS-based affordances provide solutions for assigning environmental goals and beliefs into specific work practices and operations.

To pinpoint and categorize certain limitations or restrictions regarding drone as IS artifacts and forest industry solutions, the coercive, mimetic and normative isomorphism of the institutional theory by DiMaggio and Powell (1983) can be employed for observing and describing these transforming and constraining impacts. Generating drone-based solutions in forest industry require flexible collaboration, proficient integration of knowledge and resources, and proactive decision-making in altering situations and requirements. Therefore, institutional pressures offer useful perceptions for managing the internal and external influences on applying IS artifacts.

Second, to define the certain goal and strategy for drone operations in supporting environmental sustainability, the natural-resource-based view by Hart (1995) characterizes the pollution prevention, product stewardship and sustainable development as the strategic capabilities. These purposes present the potential opportunities for developing and deploying drone solutions in forest industry context. Combining strategic management with environmental aspects, NRBV highlights the importance of applying valuable resources and exploring potential applications proactively to establish long-term capabilities for supporting environmental sustainability and competitive advantage.

The organization's eco-goals as in eco-efficiency, eco-equity and eco-effectiveness (Elkington, 1998; Dyllick & Hockerts, 2002; Watson, Boudreau & Chen, 2010) estimate the relevance of the strategic objectives and performed activities towards environmentally sustainable outcomes. Hence, eco-goals can be applied for determining the success, benefits and limitations of drone solutions and the arrangements of organizational processes, in general, for tackling environmental degradation and improving sustainability. Particularly, the green IS strategy types (Jenkin et al., 2011) incorporate the notions of NRBV and eco-goals into functional practices. For IS artifacts, these approaches allow more focused alignment and assessment of business activities with the environmental strategies.

Finally, besides green IS strategies emphasizing certain procedures, the holistic environmental management systems and specific green IS practices, described in the literature, provide necessary insights for deploying green IS solutions. Drones as IS artifacts can be integrated and developed with both organization-wide EMS, green supply chain management and solutions affecting behavior of individuals of groups. For optimizing production, drones can offer real-time, accurate and diverse data collection, which can be shared with suppliers, customers and other stakeholders in order to advance environmental decision-making. Since development of drone solutions demands appropriate knowledge, skills and resources, forming functional relations and collaborations is critical task to apply drones as IS artifacts for environmental sustainability.

Operative green practices as in re-engineering, implementing and utilizing particular EMS (Loeser et al., 2017) and coordinating and aligning versatile organizational functions (Ryoo & Koo, 2013) necessitate effective social structures and attitude towards green initiatives (Wang, Brooks & Sarker, 2015a). Within these efforts, IS solutions allow capabilities for mediating complex and changing functions extensively (Hasan et al., 2017), thus drones as IS artifacts incorporated with environmental management systems and as proactive forest industry solutions can be utilized for managing initiatives and practices thoroughly.

Applying these theoretical viewpoints outlined in green IS literature, drones as IS artifacts can be investigated comprehensively to discover the dynamics, relations and capabilities within the both organizational and environmental context of this study. As a whole, these key topics function as lenses to identify and evaluate the elicited results for accumulating the green IS knowledge base empirically and practically.

2.5 Summary of the literature review

Based on the conducted literature review, supporting environmental sustainability with drones as IS artifacts can be investigated and approached from several perspectives. Elliot (2011) denotes the major categories in research literature concerning environmental sustainability as environmental, societal, governmental, industrial and alliances, organizational, and individuals and groups in organizations. In this thesis, the emphasis is on organizational and environmental aspects, which define the objectives, choices and interpretations of the theoretical and empirical study. From an environmental angle, conceptual methods and contributions of IT solutions are evaluated, whereas from an organizational perspective, the focus is on organizational approaches, implementations and outcomes to support environmental sustainability (Elliot, 2011). With these standpoints, the existing literature and theories linking these organizational and environmental emphases are employed. Consequently, to extend the knowledge about sustainability domain and establish capabilities for managing these insights effectively, the transformative opportunities of green IS in business and society contexts should be developed (Malhotra et al., 2013).

The existing green IS literature proposes conceptual approaches and flexible practices for deploying IS artifacts to support environmental sustainability. Combining IS, organization and management research with an environmental emphasis, the green IS paradigm aims for connecting information management capabilities comprehensively in order to tackle nature's degradation and facilitate sustainability initiatives. For resolving the research problem, the proposed frameworks, theoretical constructs and relations, environmental objectives and practices, and action possibilities regarding business operations, organizational behavior and IS artifacts are applied. These viewpoints are utilized for planning, managing and evaluating the empirical research.

The concept of IS artifact, NRBV, institutional theory and eco-goals are employed as theoretical foundations. The contents of these models are integrated BAO framework and strategic approaches of green IS in order to generate a practical understanding on implementing drone solutions within organizational processes and actions. The integration of IS artifacts and functional affordances forms the basis for the empirical investigation and analysis. Hence, the use possibilities, limitations and opportunities of drones as IS artifacts in forest industry solutions are considered built upon their relevance for environmental sustainability improvements.

Investigating drones as IS artifacts within forest industry solutions for supporting environmental sustainability can be considered from several aspects and with diverse methods. Thus, the existing green IS literature assist in outlining and guiding the research approaches, data collection and analysis thoroughly. Although these versatile dimensions provide analytical and comprehensive examination on the phenomenon, more flexible and applicable framework for empirical investigation is needed. Hence, the applied theoretical framework focusing on the research context is outlined in the next chapter.

3 THEORETICAL FRAMEWORK

For investigating an IS artifact supporting environmental sustainability, considering all the different research orientations ranging from individual, organizational, societal and global settings and focusing on diverse solutions can be too exhausting for a single empirical study. Thus, besides offering precision, the applied research framework should facilitate efficient and flexible analysis. In this chapter, for examining drones as IS artifacts in forest industry and within its diverse solutions, a theoretical framework based on the existing literature is formed by delineating the applied foundations, constructs and associations.

An IS artifact can include versatile objectives, tasks and processes, which are achieved by its effective capabilities and functions. These goals could be related, for example, to improve economic success, societal well-being, individual capabilities or knowledge creation. In this study, the concept of IS artifact is used for IS solutions combining social, technological and informational elements. These distinct elements enable social interaction and planning abilities, different technological applications and integrations with other IS, and information collecting, refining and sharing among individuals and systems.

Employing IS artifact for improving environmental sustainability requires organizational commitment for developing, implementing and adopting environmentally sustainable practices, processes and behavior. As a whole, facilitating environmental sustainability transformations in business processes, practices and management necessitates continuous improvement and assessment by the organization.

In this thesis, the research focus is on drones as IS artifacts and how they can be used to support environmental sustainability in forest industry. For this objective, the aspects of pollution prevention, product stewardship and sustainable development defined in NRBV (Hart, 1995) are considered and attached into the theoretical framework. In general, these strategic capabilities offer practical standpoints and categories to evaluate organizational approaches and orientations in environmental efforts.

Because information systems which are used in organizations are combinations of social, technological and informational elements, there are multiple factors having diverse effects on how an information system is applied for achieving specific organizational or environmental goals. Since the issues regarding environmental sustainability are corresponding individual, organizational and societal contexts widely, thus for providing appropriate aspects for green IS field from management approaches, the institutional theory can be applied (Elliot & Webster, 2017). Consequently, reviewing these impacts in practice, the theoretical view of institutional pressures is considered as guiding constructs.

As a whole, tackling climate change by creating new solutions is a goal-oriented process in which individual and organizational beliefs lead to certain actions and outcomes. To perceive this comprehensive development and its characteristics, the BAO framework (Melville, 2010) is adapted as a directing concept behind organizational decision-making, behavior and structures. In order to merge all these different research approaches, the theoretical model by Gholami et al. (2013), presented in Figure 3, is utilized as a guiding foundation for the empirical investigation by facilitating data collection, analysis, findings and their assessment.

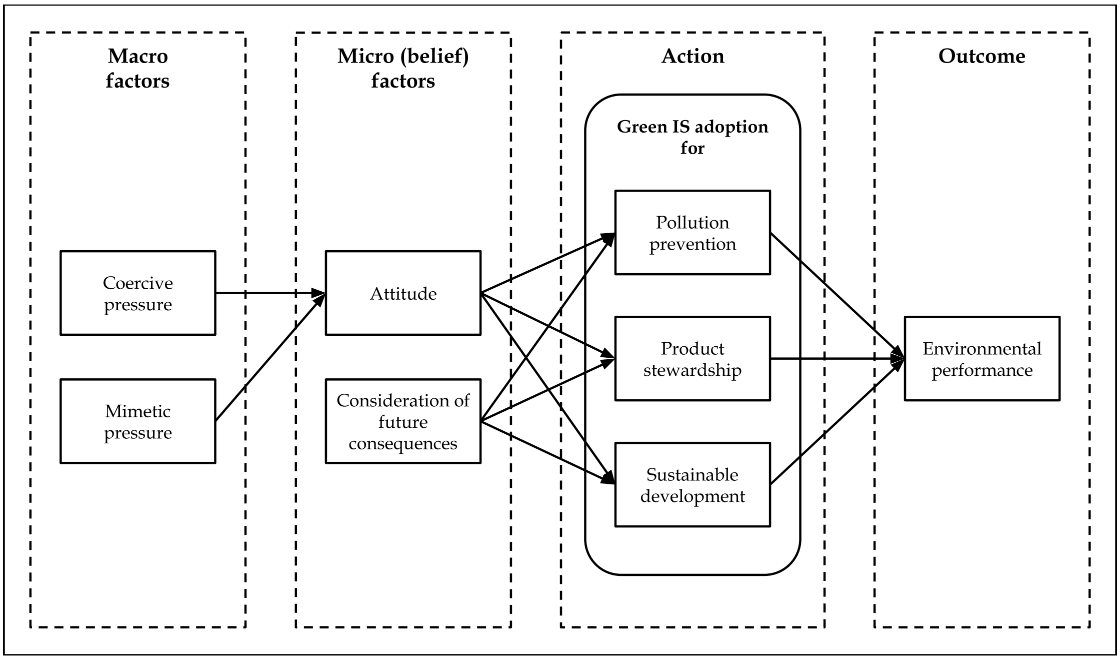

FIGURE 3 Green IS adoption affecting environmental performance, adapted from Gholami et al. (2013)

As a whole, green IS should be adopted within organization by defining the specific environmental benefits and outcomes clearly, thus assisting organizational sensemaking and sustainable practicing. To detect and evaluate these use possibilities and consequences in applying drone IS artifacts, the theoretical view on functional affordances (Seidel et al., 2013; Hanelt et al., 2017) is employed as a research lens for interpreting and integrating the collected data and generating new perceptions on IS capabilities supporting environmental sustainability in forest industry solutions.

In the existing green IS literature, diverse abilities, factors and outcomes on how environmental sustainability can be facilitated by using IS artifacts have been studied to some extent. Nevertheless, in the reviewed studies the impacts and capabilities of green IS solutions were not investigated by focusing on drones as IS artifacts in forest industry tackling environmental degradation and supporting endeavors for environmental sustainability. In this thesis, these research gaps are realized by investigating drones with the perception of IS artifacts including technology, information and social components and how drone-based solutions can support environmental sustainability in forest industry.

4 METHODOLOGY

The qualitative study on drones in forest industry and how drone use support environmental sustainability was carried out in spring 2019. To investigate this phenomenon, multiple-case study approach and semi-structured interviews built the foundation for data collection and analysis.

4.1 Research approach

To realize and evaluate the choices made in collecting and analyzing the data, the research process and its characteristics is specified in this section. The research approach and philosophy and different phases are defined to form a foundation for the empirical study.

Qualitative research approach is employed in this study, to gather and analyze data and generate findings based on expert interviews. In qualitative research the focus is on how people observe and understand different subjects and relations by their individual experiences and intuition (Stake, 2010, 11). More specifically, qualitative studies are typically interpretive and situational by their nature, for which researcher has to gather relevant understanding, evidence and theories on the certain context. Hence, the interpretations and findings can be specified and justified thoroughly. (Stake, 2010, 15-16.)

To investigate information systems, qualitative research offers answers to versatile "how" and "why" questions. For example, qualitative approach can offer understanding on how system's use is perceived among individuals and organizations, how causal relations are formed, why a system is functioning in a certain way and how should it be developed and improved (Kaplan & Maxwell, 2005). Stake (2010, 15-16) delineates that specific strategic choices and objectives should be made in qualitative research. Thus, besides providing useful knowledge, qualitative research can also support developing practices or policies, which can be achieved by representative cases or unique cases. In justifying the decision-making, a specific standpoint on the subject should be had in the research or as an outcome of the research by concentrating logically on the most reasonable explanation or producing several distinctive rationalizations. Overall, qualitative approach is aiming to offer either generalized or specified understanding on the subject. (Stake, 2010, 15-16.) Comparing to quantitative findings, qualitative methods enable also more concrete utilization of the outcomes by having a practical relation to the studied context (Kaplan & Maxwell, 2005).

Adopting qualitative research paradigm enables comprehensive assessment of drone IS artifacts which are used versatilely in forest industry. However, since the qualitative research in this study is based on relatively small sample, it can offer more specific and contextual understanding than provide generalizations beyond industries and use contexts. Therefore, collecting and evaluating experts' views, experiences and opinions on how drones can be used to support environmental sustainability is the focusing point in this study. With qualitative approach, practical and useful knowledge is gained for managing and developing drones and their utilization as IS artifacts. To achieve this, suitable qualitative research strategy must be applied.

To evaluate and choose a relevant qualitative approach, drones as IS artifacts in Finnish forest industry as the phenomenon to be studied and multiple-case research strategy constituted the methodological foundation in this study. In IS research, case study is the most common qualitative approach (Darke et al., 1998). Thus, applying a typical methodology provides a solid and operational foundation to approach new and complex solutions and contexts. In addition, to generalize, evaluate and, possibly, repeat the findings can be achieved successfully and thoroughly by utilizing widely used case study approach. In case study, a single unit or multiple units of analysis, or cases, are investigated in depth to facilitate concentrated and profound analysis, however defining clear boundaries in a case study can be challenging (Blatter, 2012). If compared to quantitative surveys, case studies lack deduction, control, and repeatable and generalizable findings. Nevertheless, with case study approach, extensive and detailed knowledge can be explored, and demonstrating and complex models can be generated. (Gable, 1994.) The multiple-case strategy, particularly, enables theory building, cross-case analysis and description of a certain phenomenon and, moreover, it supports discovering and generating hypothesis (Benbasat, Goldstein & Mead, 1987). By reviewing the participated individuals as cases and the unit of analysis of this study proved to be useful basis for conducting the interviews, analyzing the results and eliciting relevant findings.

Overall, most of the central features of case studies defined by Benbasat et al. (1987) were realized and followed in the empirical research. The different aspects concerning the unit of analysis were investigated thoroughly by having relatively few individuals from a specific industry to be interviewed. Independent or dependent variables, manipulation or other experimental controls were not used in advance or during the interviews, thus the phenomenon was observed in a fairly natural setting. Consequently, having emphasis on answering "how" and "why" questions and current developments concerning drone use in forest industry, the interviews were conducted with an open, integrative and explorative research outlook. It is also typical for case study to gather data from several sources and with different techniques. (Benbasat et al., 1987.) Although the expert interviews were used as the main source of data collection, multiple publicly available project reports, company websites, news articles and drone solution materials were reviewed for focusing the empirical investigation and analysis. Furthermore, a few events concerning forest industry, forest management and industrial IS solutions were visited in order to understand the research context and guide the study better.

Case study strategy can provide valuable results and discoveries in empirical research, but there are also weaknesses related to using case study as a research approach. In considering the specific strengths, Eisenhardt (1989) outlines that case studies can support novel and, likely, empirically valid theory development including testable hypotheses and constructs if theory-building process has been successful and based on relevant evidence. However, utilizing all the collected empirical evidence can result in too complicated, wide-ranging and impractical theory or excessively specific and constricted theory that cannot be generalized or applied well (Eisenhardt, 1989). As a whole, it is essential to balance between narrowness and wideness and between generalizability and particularity in qualitative theory development, especially, when the objective is to understand a nascent and versatile solution in a specific context. Thus, with multilevel theorizing different aspects, factors and functions in theory development can be assessed, such as perceiving how and why a focal phenomenon affects on an individual, team, department or organizational level and what kind of dynamics are interacting within these mechanisms and creating valuable outcomes (Zhang & Gable, 2017).

Considering the foundation for argumentation, a positivist research philosophy defines well the applied reasoning and outlook of this thesis. When applying positivist approach, the physical and social realities are generally perceived as objective and independent entities which are functioning without people being aware of them (Darke, Shanks & Broadbent, 1998). With this perspective, the emphasis is on deterministic explanations and causal relations regarding the studied phenomena. Thus, the whole process and relationship between subjects are measured by employing predefined aspects and procedures systematically. (Orlikowski & Baroudi, 1991.) Hence, theoretical constructs and aspects and an objective and systematic mindset towards socially and independently affecting factors of the research context are reviewed. Nevertheless, the data were collected and analyzed, and the findings were generated with an interpretive and explorative mindset throughout the empirical investigation.

4.2 Research context

Establishing the specific phenomenon of the empirical research, the Finnish forest industry was chosen for the research context and utilizing drones as IS artifacts within this industry was selected for the particular object to be investigated.

These decisions on the context were made, since resources, production and other activities in forest industry are dependent on the nature's sustainability. Without correct balancing and supporting actions, forests as ecosystems and forest industry would not endure. Versatile measuring and planning methods have been used in forest industry and, as one of the most recent, innovative and flexible techniques, drones and drone-based solutions are currently developed, deployed and used for supporting sustainable forest management. For observing different components and characteristics of the research context, the forest industry in Finland and drone IS artifacts are discussed next.

Forests are invaluable for the world and especially for Finland. The cultural history, societal development, globalization and dynamic progress in becoming one of the leading countries in smart technologies and digitalization have all been impacted by the livelihood acquired from forests. On the whole, Finnish employment, economy and ecology are greatly impacted by forest industry, thus it has also a major role in political decision-making. To this day, forests are considered as the most important resources in Finland and the forest industry produces directly and indirectly over one fifth of the overall export revenue in Finland. Companies in Finnish forest industry produce e.g. paper, paperboard, chemical pulp, sawn wood, plywood, bioenergy and wood-based fuels, paper and wood products, and diverse forest management services. Besides Finland, the biggest Finnish forest industry companies have a wide influence on the global market, since the three largest Finnish forest companies are among the 10 largest forest companies in Europe and two of them are also among the 10 largest forest companies globally. (Finnish Forest Industries, Statistics.)

For Finnish forest industry it is typical that the large and global forest companies purchase their wood resources mainly from private forest owners. In total, there are around 350,000 family holdings of over two hectares forests, which have altogether over 600,000 individual owners. For these holdings, 30 hectares is the average size of a forest and 60 years being the average age of a forest owner. Hence, families have the majority of forest land in Finland by owning 60 percent of the land which produces 70 percent of the yearly wood growth in Finland and supplies 80 percent of the total timber demands of Finnish forest industry. The remainder of forests is owned by the Finnish government (about 25 percent), forest companies (less than 10 percent), and municipalities, local parishes and other consolidations that own forests together. (Luke, Forest ownership.)

Due to the prevalence of private forest holdings, forest companies are working in collaboration with private forest owners and offering forest management services for their needs. In addition, since the younger generations, who are inheriting the forests, might not have as much knowledge and skills on forest holding and management, companies are delivering digital solutions for managing, monitoring and viewing forest lands remotely with mobile and online applications. In recent years, a trend in Finnish forest ownership has been both the fragmentation and increasing of forest lands, since the amount of less than 10-hectar and over 100-hectar forests is growing (Luke, Forest ownership).

To support environmental sustainability, forests absorb emissions and function as carbon sinks. Consequently, the level of logging affects the amount of annual absorbed emissions by forests, which must be considered in forest planning and management. Since forest industry has such a strong effect in Finnish society and economy, managing forests as carbon sinks and, on the other hand, controlling the forest economy as a whole involve also diverse political influences and strategies.

For managing forests efficiently and sustainably, techniques such as laser and satellite scanning from the air and manual measuring in terrain have been applied. Besides these conventional methods, newer monitoring solutions have been deployed in forest industry, such as drone-based emission and photogrammetric measurements. Although, these new applications can be used effectively, in general, compared to having a forest expert measuring the areas with handheld mobile devices, profitability and successful results are also depending on how accurately, quickly and easily all the necessary and applicable measurements can be obtained. Especially, if multiple revising measurements must be conducted on a specific area, achieving cost or process efficiency can be difficult or impossible. Thus, diverse measuring techniques and practices of different altitudes, accuracies and with different tools are utilized in forest industry. When reviewing the accuracy and intervals between different measuring technologies, a single pixel in drone images can be the equivalent to about 2-3 cm on ground (Wingtra, Image Quality; DroneDeploy, Resolution) while with very high resolution satellite images a single pixel can be the equivalent to about 30 cm (EOS, Satellite Data: What Spatial Resolution Is Enough for You?).

In developing cost-efficient and valuable services based on digital applications, companies and public organizations in forest industry are employing different methods and technologies for measuring and monitoring forests. These approaches create the basis for synthesizing and refining the gathered data within IS solutions, which would support both economic and environmental performance. Drones as one of the latest techniques can offer new and convenient opportunities for imaging, measuring and monitoring forests. Drones can include several technical applications and function as a platform for business operations and information sharing. Thus, drones can be viewed as IS artifacts and components of IS solutions.

Considering the characteristics and competences, there are many different terms and definitions related to drones and their use. Drone is a general term for all unmanned vehicles operating on land or water or flying in the air. Abbreviations such as RPAS (Remotely Piloted Aircraft System) and UAS (Unmanned Aircraft System) are also often used in contexts concerning unmanned aviation, whereas previously used UAV (Unmanned Aerial Vehicle) is replaced commonly with the term UA (Unmanned Aircraft). In addition, drone can be a model aircraft, utilized for sport and recreational purposes, or a remotely piloted aircraft applied for aerial work and operated remotely from a pilot station. (Droneinfo.fi, FAQ RPAS.) Both unmanned airplanes and copters are deployed for different use cases and contexts. In this study, the focus is on unmanned multirotor copters that are the most common UAs and widely used in forest industry. Multirotor copters consist two or more rotors and usually drones are four-rotor copters or, in other words, quadcopters. As the goal of this thesis is to study how drones as IS artifacts support environmental sustainability in forest industry, drones are perceived as unmanned multirotor copters and RPASs. Thus, the emphasis is on applying and developing drone IS artifacts and perceiving their social, information and technology related elements which are combined and utilized in forest industry. Since these applications are viewed on a more conceptual level than considering them from very detailed and technical viewpoints, the generalized and well-known term *drone* is used in this thesis.

Currently, several drones and drone applications for different contexts and for consumer and professional use are available on the market. In general, ready-to-use products for amateur and recreational purposes can be purchased quite affordably whereas professional drone solutions can be adapted and acquired based on distinctive contexts and requirements. As unmanned aircrafts, drones are made of lightweight and complex composite materials which makes it possible to have the minimum weight with optimized material strength and flight abilities and silent operation since the materials can absorb vibration. Applied with the central flight controller in drones, gyroscopes and inertial measurement units are employed to manage flight stability, acceleration and rotation. Modern drones can use both GPS and GLONASS as navigation systems that are critical for accurate mapping, surveying and e.g. rescue missions. To avoid collisions and obstacles, vision sensors and ultrasonic, infrared, LIDAR and time of flight sensors are applied separately and together in drones. (DroneZon, How Do Drones Work and What Is Drone Technology.)

Drones can be utilized diversely in agriculture, safety and rescue missions, indoor inspections, land surveys, filmmaking, construction, infrastructure, marketing, mining, energy sector and oil and gas production. (DroneDeploy, Drone Solutions; UAV Coach, The Top Professional Drones for Serious Commercial UAV Pilots). Drone solutions are employed for inspecting, videoing and mapping areas and objectives, monitoring emissions, detecting damages and measuring specific indicators. These functions are achieved with photogrammetric, hyperspectral, multispectral and thermal images and videos, laser scanning surveys and emission measurements. The drone-collected data can be processed and gathered for further analyses or shared in real time within an online platform, if the bandwidth and capacity for data transfer are sufficient.

To accomplish specific missions, drones are flown and operated by pilots using remote controllers. Although a single drone enables flexible data collection, utilizing drone groups working together to execute a mission supports more efficient and accurate data collection. However, the legislation in Finland does not yet permit extensive automation capabilities and the use of drone groups. Currently, a drone operates for about 20-60 minutes depending on which sensors it carries and how large payload it has. On the market, most drones are electrically operated and have rechargeable batteries, but due to their limited flight time and carrying capacity, there are also hybrid drones available and in development which contain both batteries and combustion engines.

Drone technologies and their use are developing quickly and therefore the current legislation must be modified and new guidelines for drones as UAs and comprehensive RPASs must be generated. In Finland, the Transport and

Communications Agency has determined the basic ABC rules for flying a drone, which are also implemented into their free mobile app:

A. Always fly in visual contact.
B. Flying above crowds is forbidden.
C. Always fly below altitude of 150 m.
D. Flying above inhabited areas is allowed when the drone weighs less than 3 kg, you have familiarized yourself to the area and made sure that flying in the area can be done safely.
E. Respect other people's privacy.
F. Flying close to airports has its own rules, which are easiest to understand by using Droneinfo mobile application.
G. Using common sense will get you far. (Droneinfo.fi, ABC for flying a drone)

EU wide rules by European Union Aviation Safety Agency were published in June 2019 and are taken into use in July 2020. As of July 2020, it is required for drone operators to register themselves in the particular EU Member State where they are conducting business most regularly or where they have their residence. (EASA, EU wide rules on drones published.) In addition, there will be a restricted 'Open' category for drone users, which defines horizontal distances from people and recreational, residential and industrial buildings and areas for drones of different weights (EASA, Civil drones (Unmanned aircraft)). In 2020, there will be a mandatory pilot test for drone users to ensure they have necessary knowledge and skills to fly drones safely close to people, buildings and other objects (Hohtari, 2017).

4.3 Overview of the interviewees

Potential companies and interviewees for the study were searched from manufacturing and job search fairs, where a few potential contacts were found. When planning the research study more specifically, the focus shifted from the wide and general manufacturing industry into forest industry, due to the great impacts forest industry has on both Finnish economy and natural environment. Also concentrating on one particular industry enabled more accurate data collection and analysis. Furthermore, the case to be studied changed from green information systems to drones, since drones as a single and relatively new solution and a development platform came across as noteworthy and beneficial topic to study. After refining the research focus, potential companies and persons for the interviews were searched online. The participated interviewees and their expertise, regarding drone use in forest industry, are observed in this subchapter.

To find interviewees for the study, relevant companies which had done drone-based solutions and projects in forest industry were gathered into an Excel document. Information on drone projects and solutions was collected from news articles and company websites. In reviewing and selecting potential organizations, the aim was to have interviewees from three distinct categories: forest companies, drone solution companies and public organizations. The purpose for this approach was to collect data on utilizing drones from different perspectives, find out various drone use cases and contexts and realize the capabilities and challenges concerning drone use in forests.

Contact information of the interviewees were searched from organizations' websites, news articles on drones and from professional networking site LinkedIn. Altogether 24 persons from different companies and institutes were contacted by phone and email. Generally, the contacted people were motivated to either participate or recommend another expert with more experience on drones in forest industry. Hence, couple experts were contacted and interviewed by applying snowball sampling, as in having another person's recommendations to recruit an expert from his/her acquaintances within a distinct context of expertise (Biernacki & Waldorf, 1981). All communication regarding interviews was in Finnish as all contacted people and organizations were Finnish.

Overall 13 experts were interviewed and a total of 12 interviews were conducted. 11 interviews were done for a single interviewee, while one interview was attended by two interviewees. Although the participated people represented and were employed in certain organizations, these organizations are not analyzed specifically in this thesis. In this thesis, the units of analysis are experts of forest industry and drone solutions companies. Therefore, the cases of this study are experts as in individuals.

Since there are quite few companies and experts in Finland regarding drone applications in forest industry, interviewees' names, company names or sizes are not expressed in this thesis to maintain anonymity and confidentiality, as agreed with the interviewees. A summary on the participated interviewees and the given interview IDs for analysis is found from the Table 6. All interviewees had experience of operating drones or utilizing drone collected data for products and services, development projects or research studies. Considering the job positions of experts, 4 interviewees worked at the executive level as a chief executive officer (CEO) or chief technology officer (CTO), while 2 interviewees worked as a director in their company. 5 participated interviewees were managers and 2 specialists of forest conservation and research in the study.

The experts were interviewed in Finnish and mostly by phone, since 8 of 12 interviews were done via phone and 3 interviews were done similarly by using a Skype call. 2 experts were interviewed face-to-face in Jyväskylä. One interview (ID11) was participated by 2 experts of whom one was interviewed face-to-face in Jyväskylä and another by a Skype call simultaneously. When contacting the experts, the agreed duration for the interview was 30 minutes. However, the average realized duration of all interviews was 34 minutes and 11 seconds, for which the interviews ID08 and ID11 as over 40-minute interviews had a major effect. All interviews were done during less than two weeks at the end of April and beginning of May 2019, because the interviews wanted to be done as a compact and consistent phase before collecting and analyzing the data.

TABLE 2 Summary of the interviewees

Interview ID	Expert ID	Position	Interview type	Company focus	Duration (minutes)	Date
ID01	E01	Environmental Manager	Phone	Forest industry	30:22	23.4.2019
ID02	E02	CEO	Phone	Forest consulting and software	26:25	23.4.2019
ID03	E03	Director of R&D	Phone	Monitoring solutions	27:32	24.4.2019
ID04	E04	CTO	Phone	Forest consulting and software	34:00	25.4.2019
ID05	E05	Service Manager	Skype call	Technical consulting	35:34	25.4.2019
ID06	E06	Conservation Specialist	Phone	Public administration	25:41	25.4.2019
ID07	E07	CTO	Phone	Forest consulting and software	25:50	25.4.2019
ID08	E08	Forest Management Manager	Face-to-face	Forest industry	42:14	26.4.2019
ID09	E09	Director of Sales and Business Development	Skype call	IT solutions	34:43	29.4.2019
ID10	E10	Research Scientist	Phone	Public research institute	34:53	2.5.2019
ID11	E11a	Forest Data Manager	Face-to-face	Public administration	58:33	3.5.2019
	E11b	Project Manager	Skype call			
ID12	E12	CEO	Phone	Aerial photography	34:27	3.5.2019

The interviewees represented diverse organizations that operate in forest industry. Although investigating the organizations as such is not of interest in this study, considering the business contexts defines also the knowledge and expertise domains of the interviewees. A simplified categorization based on the organizations' business focus and use of drones is outlined in Figure 4 by using the interview ID indicating the interviewee's organization. Public organizations and forest industry companies are separated from drone solution companies, because both public and forest industry organizations are operating generally as customers for an individual drone solution company or an assembly of drone solution companies. In addition, due to the small total number of interviewees from public and forest industry organizations, they are considered as two separate use contexts having both shared and some dissimilar attributes within them.

To review the drone solution companies, each interview is mapped based on the company's business focus. The horizontal axis defines the type of knowledge and services a company is delivering to their customers. Companies on the left side (TC) are producing IT and engineering services and products for forest industry customers, while companies on the right side (FC) are more specialized in applying forest data and delivering forest management solutions. The vertical axis determines if a company is typically either collecting data with drones (DO) or using and refining drone-based data (DM).

In the coordinate system, the numbers 1 and 2 represent how strongly a company is focused on a particular activity, compared to other companies, and how important this activity is for the company according to its offered solutions in forest industry. For example, if a company has a value 2 in a category, it indicates that the company's business and knowledge is focused especially on that category in forest industry and its expertise is not founded as much on the category positioned on the opposite side of that particular axis. In practice, these variations among companies are relatively subtle, for which the categorization is constructed only within these companies to highlight and describe the main differences for analyzing the data.

From the interviewees, 4 represented a company offering especially forest-based consulting (ID12, ID04, ID07 and ID02), whereas 3 interviewees' organizations (ID05, ID09 and ID03) deliver IT and engineering related consulting services and products for forest industry. Two companies (ID05 and ID03) are providing solutions which include flying drones or developing products by flying drones and managing data collected by drones. One company's (ID12) business is founded mostly on flying drones in diverse operations and transferring the collected data but having expertise in forest industry. ID09 and ID04 are both experts in managing, refining and integrating the data for products and services, with the difference of ID04 working more closely in forest industry. Companies ID02 and ID07 have comprehensive knowledge of delivering forest consulting services and applications, however ID07 has more to do with drone operations while ID02 is more concentrated on managing data from versatile sources.

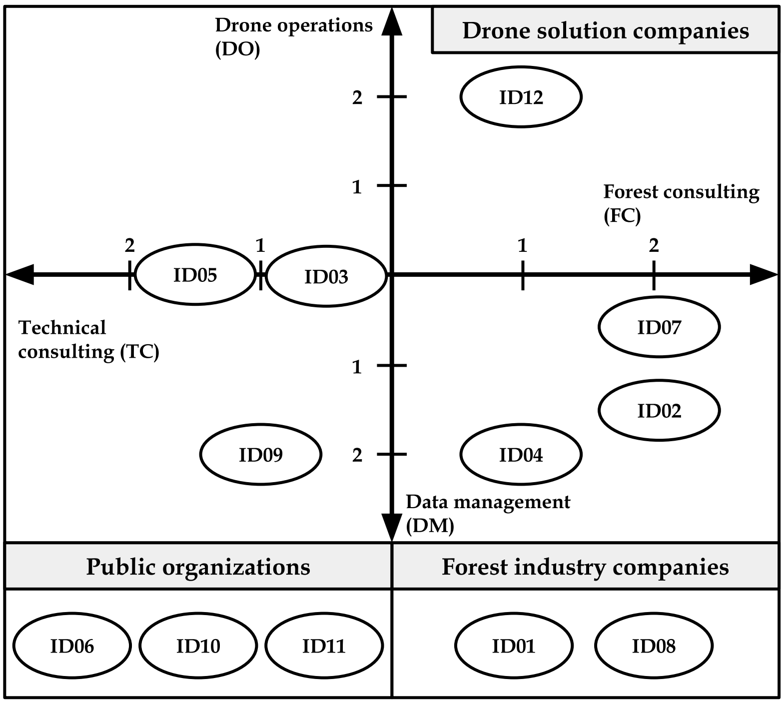

FIGURE 4 The fields of expertise of the interviewees

As it can be seen from the categorization, the participated interviewees represent quite different companies that utilize drones in the business. Since most of the drone solutions companies are relatively young and small or medium-sized enterprises with a specific focus area, they are collaborating extensively and generating solutions together. Although there are some companies delivering drone solutions by imaging, monitoring, managing data and offering forest applications, several companies with different expertise are cooperating within a nationwide network to offer valuable and cost-effective services.

4.4 Data collection

The empirical data for qualitative study were collected by semi-structured interviews. Having drones as IS artifacts and drone use in Finnish forest industry as the phenomenon of interest and participated individuals as cases, a positivist multiple-case research approach was employed. Besides interviews, relevant knowledge for data collection and analysis on drone applications and forest industry were gathered from company websites, project reports, marketing materials and forest industry events. Regardless, the conducted expert interviews were the primary source for data collection.

Being the most often used interview method in qualitative IS studies, semi-structured interviews are founded on a flexible structure, which supports improvisation and more direct interaction with participants since the researcher is typically also the interviewer (Myers & Newman, 2007). The research context in this thesis incorporated investigation of different organizations and solutions, a wide-ranging industry and environmental impacts that can be gained both directly and indirectly in business. Therefore, applying a flexible interview approach and technique enabled detailed knowledge collection from experts and categorization of diverse functions, dynamics and goals related to drones and their use in forest industry.

For each interview, the data collection included certain phases of recruiting participants, scheduling the interview, sending necessary information about the study and, finally, conducting the interview. First, the potential expert interviewees were contacted by explaining the research focus and approach and motivating why their company and knowledge is of interest. Second, if the contacted person wanted to participate, the interview was scheduled and general practices regarding the study and interview were discussed and agreed upon. Third, after the first contact, an email with more precise information on the study and an attached research permission file was sent to the person. Finally, the interview was conducted by accepting the research permission at the beginning and using the interview guide for asking questions. The interview guide, presented in Appendix 1, was applied as a common guideline during interviews for directing specific questions and establishing a structure for making notes, creating codes and analyzing the data. Due to the available online information about the contacts, both the contacting and scheduling at the beginning was done only by email for 1 interviewee, while with the rest of the interviewees the contacting and scheduling was conducted via phone.

Each interview was recorded with a portable recording device and, besides agreeing on the research permission, an approval to start the recording was asked from the interviewees. The recording device was placed close to the phone or laptop speakers enabling clear sound and interaction. However, there were some errors in audibility and voice clarity, probably, due to inefficient mobile network or phone service, which made it difficult to understand some words and phrases. These difficulties were resolved by repeating the question again during the interview or by analyzing the recording multiple times with slower playback speed during the data analysis phase.

Written notes were taken which made it possible to ask more accurate questions and gather answers more extensively. Taking notes promoted continuous learning and improving the interview protocol and structure, since it facilitated creation of ad hoc categorizations, explanations and definitions on the topic. The interviewees had wide-ranging expertise from different areas concerning drones and for successful data collection it was necessary to ask targeted questions with understandable and context-specific meanings.

In general, theoretical aspects related to the interview questions had to be modified into more understandable and practical aspects. Hence, it was essential to distinguish each interviewee's viewpoints on the research context to inquire about the subject and collect pertinent data as accurately as possible. To achieve this, taking notes was both decisive and practical routine. Especially, since the studied context was not very familiar and clear at the beginning of the data collection, reviewing notes and asking clarifications for certain answers also encouraged interviewees to participate thoroughly and thus support comprehensive data collection.

4.5 Data analysis

After conducting the interviews, the recorded audio files were collected into one folder and named by using the specific interview ID, date and time. All the written notes were examined after each interview and after the whole interview process, which assisted in focusing the data analysis and evaluating the interviews systematically from different perspectives. Next, the distinct actions and phases during data analysis are considered, for which a guiding overview is visualized into Figure 5.

When all the interviews were completed, the interview recordings, 6 hours 50 minutes and 14 seconds in total, were transcribed. The transcribing was done with VLC media player and Microsoft Word by listening single phrases, sentences and words, for which each recording was played and repeated in 2–5-second-long parts and, if necessary, playback speed was also decreased. All the questions and answers were transcribed, but every single verbal expression, partial or repetitive word was not gathered. Overall, the complete transcription document included 58 pages of text with the font size of 10.

After transcribing and reviewing the previously taken notes, all the interviews were examined systematically in Excel by creating codes for specific attributes of the answers. At first, each interview was analyzed within a separate sheet of an Excel file. Then, all the interview data with individual identifiers were combined into the final Excel database which included all the answers and coded attributes divided on different sheets by a specific category. These coded attributes were certain characteristics, viewpoints, opinions, activities, general details or relations concerning e.g. forest management, drone solutions and their objectives. A single code could be formed by a word, multiple words or a short sentence, which indicated a certain attribute of the interview answer.

The interview coding included three phases having different techniques and practices on exploring, managing and integrating the data. The focus of these phases was similar to the distinct approaches of open and axial coding and theoretical sampling described by Corbin and Strauss (2008). As a result of coding and interpretation process, concepts including specific ideas and their features and dimensions as in variations of concepts were extracted. Then, in achieving conceptual saturation, the relationships, dimensions and variations of concepts were outlined and refined to develop higher-level categories or themes. (Corbin & Strauss, 2008, 143, 159.)

Consequently, during the first and second phase, the data analysis was founded more on inductive reasoning than having a deductive approach for evaluating the collected data. Before theoretical coding, several alternative explanations and options were explored, thus extending and widening the understanding based on the data. Whereas in the theoretical phase, the identified and developed concepts were allocated to certain constructs and relations in the theoretical framework and foundation. Although the theoretical constructs from green IS research were employed to generate findings, the collected data were analyzed inductively and independently without concentrating on evaluation of the existing theories or models. These theoretical perspectives were integrated in the third phase of theoretical coding in order to align the results with the applied research literature. In general, these coding phases overlapped with each other to some extent and the actions of each phase were conducted, reviewed and improved continuously and repeatedly.

During the first phase of open coding, each interview transcription was analyzed and coded individually in a separate Excel sheet. All aspects, opinions and factors that could be potentially relevant for the study were coded and collected, thus having more open and all-encompassing approach than focusing on reducing and limiting the data. As a whole, the collected mass of data was broken into parts consisting specific concepts, which were evaluated by their characteristics and scopes related to the topic (Corbin & Strauss, 2008, 195).

Second, in the axial coding phase, the codes from different interviews were reviewed and assembled together systematically based on similar interview questions, characteristics or contexts regarding the coded answers. Therefore, the generated concepts were united and crosscut with each other based on their attributes (Corbin & Strauss, 2008, 195). In practice, the answers were divided and gathered into separate Excel sheets representing specific attributes, possibilities, objectives and limitations related to forest industry, drone use and environmental sustainability.

Third, in theoretical sampling, the coded answers were examined and linked with the existing theoretical models and constructs. During this phase, the analysis was founded on highlighting the most eminent codes for the storyline and classifying individual concepts that contain distinct attributes, connections, differences and dimensions related to the topic (Corbin & Strauss, 2008, 143, 195). Thus, the aspects of green IS research, NRBV, institutional theory and eco-goals were utilized as guiding lenses for discovering similarities, variations and potential improvements within the collected data.

After these coding phases, the codes were evaluated and consolidated in order to reduce the amount of codes and generate inclusive themes. The codes were investigated and developed thoroughly by assessing their relevance in answering the research questions. Therefore, the themes based on codes were produced to contribute empirical and practical considerations and aspects on the topic. Codes that were very detailed or focused e.g. on a technical component, about overly general issues, relevant for another topic or emphasized personal or organizational opinions and agendas too strongly were dismissed.

The primary data were collected from several individuals representing different organizations in drone and forest industry and the secondary data, as in project reports, news articles and materials on drone solutions, were considered for assessing and elaborating the developed concepts, dimensions, connections and themes. In general, combining several and versatile data sources and cross-checking the made interpretations and inferences, the findings can be extended and validated in qualitative research (Kaplan & Maxwell, 2005). Throughout the analysis, the collected data were triangulated by focusing on learning, integrating and improving the lower-level concepts and higher-level themes regarding the research context. This way, the theoretical foundations, research objectives and interview answers were able to be consolidated and investigated effectively.

As the themes were generated, revised and improved once again, they were finally translated from Finnish into English. For reporting on the findings, the most describing interview answers, or vignettes, were gathered for each category and aspect of the findings. During reporting, these examples and their applicability were also reconsidered and elaborated in order to choose the most expressive vignettes for the final report.

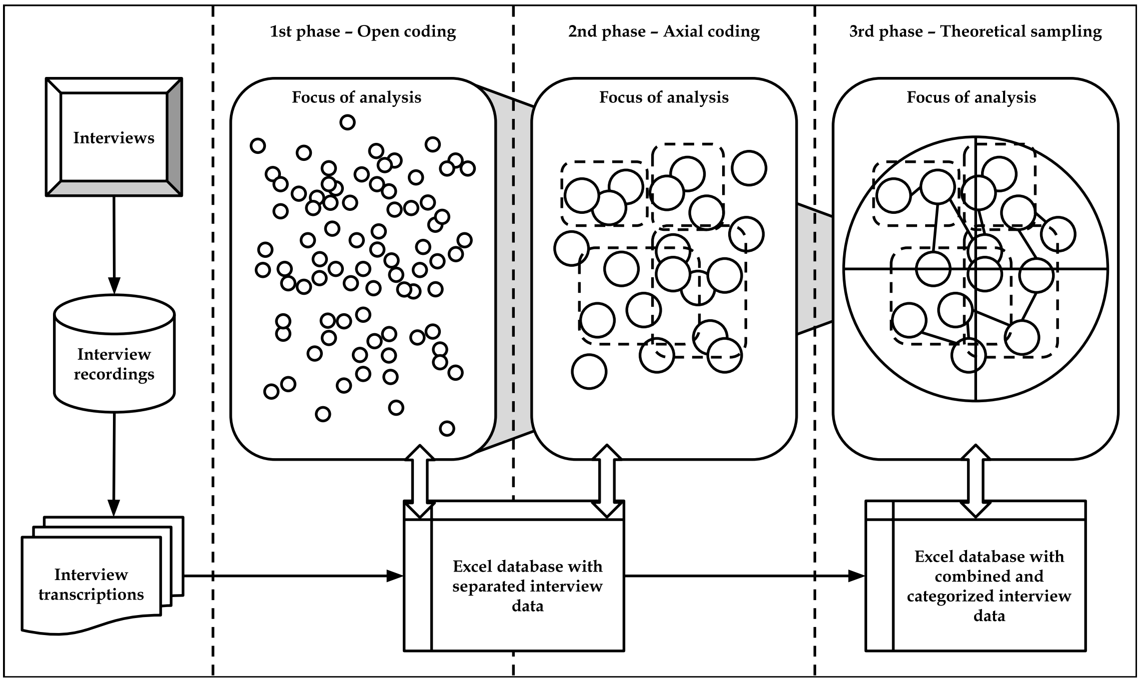

FIGURE 5 Overview on data analysis

5 FINDINGS

The expert interviews provided diverse perspectives, opinions and explanations for understanding, managing and developing drones as IS artifacts in various forest industry solutions. Identifying specific themes and attributes which affected the observed theoretical and practical constructs, both shared and opposite viewpoints were identified from the interview answers. First, the discovered findings on foundations and building blocks of the developed model are delineated in section 5.1. Second, to shape these foundations and their relations into a holistic model, the framework on drones as IS artifacts for environmental sustainability is created in section 5.2. Finally, the research questions are answered in section 5.3 based upon the generated findings and developed framework.

5.1 General findings

As a result of comprehensive data analysis, a few foundations as in principles, use contexts, objectives and restrictions concerning drones and environmental sustainability in forest industry were distinguished. In this section, the general findings based on these particular categories are outlined with describing vignettes from the interviews.

5.1.1 Environmental sustainability as fundamental principle

In all interviews, environmental sustainability was seen as a top priority for the organization's operation and existence. On a scale from 0 to 5, where 0 means it is of no importance and 5 that it is the most important factor, the interviewees gave the average value of 4.36 and the median of 4 for environmental sustainability. Although having this kind of single quantitative question in qualitative interview study does not provide notable and generalizable findings, it indicates that within this interviewee group managing, improving and decision-making based on environmental sustainability is meaningful. As a whole, all the experts underlined the importance of taking environment into account in today's business and operation, but all the interviewees from private companies understandably emphasized economic profitability as the most essential and fundamental factor in business.

The findings based on interviews uphold the assumption that environmental sustainability can indicate and include different perceptions, functions and processes, which are dependent on organization's business environment, customers, products and services. Thus, the interviewees from public organizations, forest companies and drone solution companies had similar concepts and outlooks with different emphases on importance and support of environmental sustainability. From an environmental governance perspective, environmental sustainability can be viewed as the basis for forest economy from 4 distinct perspectives.

> "Historically, perhaps the longest is this so-called sustainability of wood production so that forests are not logged more than they grow, the forest stock is accumulating continuously, and the forest resources remain usable for future generations. [...] The ecological sustainability meaning that the diversity of forests, the living organisms in forests and the types of habitat are remaining sufficiently. [...] The third is the so-called social sustainability denoting that the forests still offer work and living. [...] The fourth is the cultural sustainability so the forests are used for recreation, and also the cultural things in forests, relics and other things we have in our forests for a long time, barrows and memorial trees, [...] the aim is to preserve them so that the forests would be used more extensively, not just economically. We know today that exercise in the forest lowers blood pressure and (brings about) versatile effects, which can be seen as part of this cultural sustainability." - E11a

Therefore, in public organizations environmental sustainability is seen both as a guideline in everyday practices and an operational principle defined by various laws related to forests, water systems, soil and nature in general. Since the public entities are focused on environmental governance, environmental sustainability is also a legislative objective incorporating specific measuring and monitoring. In forest laws it is determined, that the forests must be managed sustainably.

> "Forest thinning cannot be too powerful, there are certain statutory limits below which the number of trees cannot go. [...] Especially valuable habitats of the forest law [...] which handling is very restricted or even prohibited." - E11a

For example, streams in natural state, having own microclimate and certain conditions, are very valuable for different species. In wood production, the public organizations are overseeing and controlling the industrial plants which is founded also on monitoring the laws. Overall, forest and environmental laws and their enforcement creates the basis for forest industry, since the public organizations are aiming to ensure by different measurements that the environmental sustainability is achieved. These laws cover forest economy and industry comprehensively, since e.g. managing forests, modifying the soil, reviewing the effects on water systems, measuring the impacts of forest industry, and evaluating forest financing are monitored and reviewed thoroughly.

When defining environmental sustainability from a forest organization's viewpoint, the aim is to control the balance of natural resources and biodiversity in forests and other habitats and thus carrying out the forest laws and certifications.

> "A care is taken to ensure that logging rates are at a maintainable level so that forest resources are not overexploited. In the operation, the waterways, endangered species and valuable habitats are protected. These things are handled through the requirements of forest certifications which provide the standards and indicators to the operation." - E01

Since forest industry companies both produce wood-based products and offer forestry services, managing forests, environmental sustainability, production and products' lifecycle can be linked with each other in the long-term.

> "In forest management adding broadleaved trees, increasing mixed forests. Single-species wood fields are no longer grown, so diversity is enhanced. [...] The goal is to get more forests under good forest management, keep the forests well-wooded and thereby increase the amount of carbon sequestered. When the wood is used or heavy-duty wood is grown for production, they can be made into products where carbon is sequestered for a long time." - E08

Forest companies are aiming to increase carbon sequestration and take long-term environmental impacts into account, which is facilitated by good forest management practices. These practices have been modified over the years by applying the gained experiences and knowledge on efficient and sustainable forestry.

In production environment and supply chain, it is important for a forest industry company to minimize emissions, the use of fossil fuels and make processes more resource efficient.

> "Environmental sustainability is that in the case of industrial processes or in the use of resources and other raw materials, this is done in an active way to minimize any environmental damages and emissions and the situation is actively monitored." - E03

> "Considering the climate, so the factories are aiming to abandon fossil fuels completely. [...] Recycling different resources to have as resource-efficient production as possible. [...] The supply chains are evaluated to minimize the use of fossil or other resources. Thus, the climate and the environment can be conserved." - E08

Furthermore, responsibility, safety and societal viewpoint are significant factors in sustainability matters in general, which have also direct and indirect effects on the environment.

> "To create well-being into society, a responsible company culture is very important and [...] an accident-free working environment is our goal that is closely monitored and from some near miss events (it is examined), what can be learned." - E08

> "If we talk about our own organizational culture and company, then of course we are encouraged to do something like that (environmental sustainability). For example, you

> don't have to travel to your workplace every day and we do a lot of remote work and so on [...] We are aiming to collaborate only with companies which take these environmental perspectives into account." - E04

However, since the drone solution companies offer versatile services for private forest owners and companies, the end users can define ultimately the emphasis on environmental sustainability and how the delivered applications are utilized.

> "Environmental sustainability comes from the end user, not directly from us or to us. The end user, for example a forest company or a forest owner, is able to manage his/her assets with better tools and practices with our service." - E07

These companies are offering applications for their customers' needs, which requires close collaboration and development together. Hence, leveraging their solutions for certain objectives, such as sustainability of the environment or wood production, is depending on the customer.

> "We have an interest in developing tools to understand better the effects of the operation. Using our tools, we have good examples of [...] how to consider other values than wood production values. It is always up to the customers to decide how to utilize these tools." - E04

Generally, environmental and economic factors are affecting each other simultaneously on the market, through customers and in the organization culture. It is contingent on how individuals and organizations apply these different viewpoints in their developed solutions, business strategy, work practices.

> "It is a very important value (environmental sustainability) for us because it is also a very important value for our customers. [...] Being a business enterprise, profitability and financial issues are obviously necessary for us. [...] In my opinion, these are not harmful to each other, sustainable development and economic profitability, but maybe even the other way around." - E09

To review these perspectives, objectives and actions concerning sustainability in forest industry, all discovered conceptions from the interviews are compiled into Table 3. The triple bottom line incorporating economic, social and environmental sustainability (Elkington, 1998) is applied as a basis for grouping the sustainability-related viewpoints.

When considering the eco-goals of eco-efficiency, eco-equity and eco-effectiveness (Dyllick & Hockerts, 2002), the supporting and adapting activities on sustainability can assist in achieving them. It is up to the forest organizations, how widely they use various activities in their operation. Thus, environmental management is ultimately depended on how successfully these activities have an impact either by minimizing the negative effects, enabling the durability of resources for future generations or contributing the environment with positive improvements.

TABLE 3 Forest industry actions supporting sustainability

Sustainability principle	Emphasis on sustainability	General actions
Economic	Logistics Reducing fossil fuels Resource efficiency Safety Wood production	Developing forest economy Effective forest management Monitoring quality, health and safety Optimizing supply chain Supervising industrial plants Supporting cooperation Recycling resources Working remotely
Social (Societal)	Contributing health Cultural destinations Promoting well-being Providing livelihood	Responsible organization culture Responsible stakeholder relations Sharing forest information Supporting recreational activities
Environmental	Biodiversity Carbon sequestration Climate Habitat Legislation Soil Timber Water system	Certification Conservation Controlling laws and regulations Creating long-lasting products Ensuring diversity in forests Managing quality of forest work Monitoring emissions Proactive forest management Protecting endangered species Reforestation

5.1.2 Drone use contexts and capabilities in forest industry

Drone products and services are used for different purposes in forests and forest industry. With these solutions forests can be managed and monitored to achieve economic, social or environmental objectives in various use contexts. From the expert interviews, the specific use contexts of forest planning, production, ownership and environmental governance were identified. To describe and review these domains, the activities supported by drones and the characteristics of drone use are outlined in this subchapter.

In **forest planning** drones can be applied generally for managing large areas from the air and to collect useful data for operational and business development. Especially, drones can be utilized as quick and practical tools besides other more traditional, methods and techniques.

> "Operational planning, large areas are very handy to piece together with a drone. When it comes to a few tens of hectares, it can practically capture the entire area in less than an hour's flight providing very detailed, tree-specific information." - E11b

The functional advantage of these new solutions is to deliver measurement material with reasonable costs, which has not been possible before.

> "To produce remote sensing material in practice that has not previously been able to produce, much more accurate image material than before. The other is the cost factors, [...] relatively inexpensive hardware and can easily image even smaller areas at a time." - E04

In commonly used airplane-based solutions the fixed costs are very high. Thus, in order to use airplanes, the imaged area must be quite large to achieve cost and operational efficiency. Although drones can provide accurate and valuable images from a forest area and its ecosystem, images collected by commercial satellites are perceived more cost-effective and practical when it comes larger sites and scalability.

> "Aspects related to forest biodiversity (can be surveyed by drone). But honestly, with commercial satellite imagery the monitoring can be much more cost-effective, if preferred." - E02

Nevertheless, compared to other techniques drones provide accurate and flexible measurement options for forest inventory of a smaller area. For areas less than 100-200 hectares, they enable versatile business functions and support work practices to plan more effectively.

> "For forest level planning, logging tracking, controlling the forest law, and in general collecting any material for relatively limited area of less than 100 to 200 hectares" - E07

> "We use the drones to support our own work. They are utilized for reality capture, we get an accurate point cloud, accurate information about those objects, and then get it to the design table." - E05

Before forest operation, companies and forest owners are able to choose the most suitable actions, practices and techniques by mapping and measuring a forest plot and its trees comprehensively. This enables more focused and successful forest planning in the long term.

> "For forest service entrepreneurs in pricing the work, it can provide a predetermined idea of labor demanding, even when it comes to managing the forest cleaning. The quality of the work done – quality control, self-control, how the work looks like and if it has been implemented according to the goals." - E11b

By gathering and integrating all the accurate data collected with drones, forests and forest operations could be planned at a single-tree level. Yet all the trees can be mapped with a specific location and distinguished by defining them with certain attributes.

> "Drone can be used to determine exactly tree type, so to a single wood accuracy. It is possible to determine the location, size, wood type and sturdiness of the wood, all these factors." - E08

To collect and utilize all the necessary data, versatile scanning technologies can be attached to a drone. Application of various measuring and monitoring methods, two- or three-dimensionally, is essential to gather relevant amount of practical and useful data. Eventually, the analyzed and synthesized data allows creation of a forest data model.

> "Creating a three-dimensional model with drone imaging, either using a laser beam scanner or photogrammetry. [...] to get the exact source information that can be used to build a data model" - E05

Being created, these models can be updated or improved with future measurements providing practical knowledge for planning the forest area and estimating possible scenarios and growth regarding e.g. trees, biodiversity and water system. Hence, merging various scanning techniques together enables in-depth collection and application of forest data. Ultimately, processing and refining the data makes it possible to construct a complete digital image on the forest.

> "If we have the most accurate digital image [...] we would get to the accuracy of a single tree, [...] so a model that knows where every tree in the forest is, what kind of tree it is, what age it is and so on. Thus, we can do many things digitally and efficiently." - E09

After forest operation, all remaining trees can be reviewed with drones and other scanning methods. This provides valuable information for planning future operations efficiently and ensuring that the forest operations have been implemented as planned and agreed. Since there are many variables concerning forests, having digital images, data models and knowledge on previous operations supports successful decision-making and choosing between different possibilities. Companies can identify similar forest areas to allocate applicable actions and techniques beforehand and assess how well has the forest operation been executed.

> "Once we know the situation, we will understand – what the thinning intensity has been, on what kind of trees it has focused, what kind of trees are left there. [...] It would provide helpful information on the growth forecast after treatment, and it would always be treatment per unit, [...] pattern-specific forest data." - E10

To support effective and sustainable growth, forests demand continuous attention. However, if a maintaining or restoring activities are done at the wrong time, the impacts will not be as desired. With drone-based accurate images, forest owners and companies can also time and balance specific actions correctly by reviewing available resources, costs, forest growth and biodiversity.

> "If it is possible to determine from the air when would it be necessary to go to the forest at the right time to do cleaning and others, the forest will be able to grow well as soon as possible." - E08

Drones can be utilized during the entire life cycle of a forest to plan and manage the forest area, its trees, soil, flora, water system and biodiversity. With drone-based images and digital models, versatile visualizations, estimations and simulations can be executed to improve goal-oriented planning in the long term.

In **forest production**, drones facilitate real-time data collection for monitoring and enhancing operations and maintaining infrastructures. At industrial plants, drones are applied for examining visually how processes are executed and managed, what kind of functions are placed at the sites and how different infrastructures are maintained and used. Generally, drones offer valuable information for managing and optimizing industrial plants with precise and practical measurements on central indicators.

> "On a general level, have certainly got good results from [...] wood terminal, so now you can see the cubic meter level, soil types, sorting the soil types." - E02

Since there are several buildings, districts and physical processes located at factory areas that are commonly smaller than 1,000 hectares, drones can be used efficiently for monitoring and measuring the areas. The drone-based images can then be used for managing and developing the production or supply chain.

> "At wood chip storages at factories [...] it has been found to be easy to shoot from the air at the factory area." - E08

Maintaining and monitoring infrastructures and logistics in forest production requires a lot of resources, costs and investments. Drones allow continuous and real-time data collection by images and videos, which can be shared quickly if data network is available and it has sufficient capacity.

> "For industrial sites, maintaining the buildings and infrastructures. To monitor them with a whole new level of efficiency along with all the other activities, since the cameras are constantly flying and filming." - E03

Similarly, as in forest planning, data and digital models on forests and production processes can be utilized to simulate and optimize harvesting, manufacturing and planting. By developing and using these digital twins, forest owners and companies are able to design more effective solutions, manage production with certain characteristics and emphases, and evaluate decision-making before actually realizing the decisions.

> "Digital information can be used for planning and simulating harvesting operations, forest planting and management. [...] Digital twins, a digital model being as complete representation as possible [...] can be used in the design phase, without having physical equipment, to do simulations." - E09

In addition, drones are quite dexterous tools in generating video and image material for marketing, selling and promoting specific areas from the air. Besides imaging the forest work before and after, drones can be applied during the operation by assessing if it is being done successfully. Consequently, the logger, operating company, forest owner or public organization can evaluate the forest work by taking e.g. the work efficiency and objectives, commission, contract and legislation into account.

> "In logging, the harvesting entrepreneurs are using drones [...] to find out, how does the operation look like from above." - E10

To support forest production, drones are used as flexible and practical tools at industrial sites for monitoring, maintaining and developing production processes. Because the factories are quite large areas and include different sized and formed constructions and surroundings, drones as remotely and nimbly controllable devices provide useful platform for versatile sensors and cameras. Furthermore, the imaging capabilities of drones can be employed to generate visual materials and products on e.g. forests, factories, operations and the environment.

In **forest ownership**, drone-based data and images offer valuable methods for motivating forest owners to manage their assets more regularly and effectively. Realistic and accurate images on a specific forest area enables forest owners to view their assets practically and remotely. At present, plenty of forests are or about to be inherited in Finland and a large part of the current and future forest owners do not probably have necessary skills, knowledge and enthusiasm for forest management. Therefore, explicit and useful visualization, digital services and products on the collected forest data are of the essence in ensuring successful forest management now and in the future.

> "Changes of generation, there are a significant number of forest owners who have never visited their forests, remote forest owners. When their plots are undergoing forestry operations or logging, the visual end product, drone air image for example, [...] will certainly help the forest owners." - E11b

If a forest owner wants to buy or sell a forest area, having the latest information and images on the area can both motivate the owner and make the trading more transparent. Updated images and more descriptive information on the forest area are particularly important if the aerial images and collected forest data are outdated.

> "In forest sales, there are more and more aerial imagery available which gives a realistic view. The spatial information, aerial imagery from open sources are 2-3-years-old information that can be updated fairly efficiently with drone images." - E10

In a wider perspective, using drone collected, accurate and realistic information within digital platforms, companies, private forest owners and public organizations can review the most suitable forest areas for their needs. Accordingly, they can use these platforms e.g. for finding the most suitable resources for their production and services, allocating inspections regarding quality and legislation on certain areas and encouraging for collaboration to offer and develop products and services.

> "Considering the wood trade, wood buyers and companies, can use digital information to find suitable raw material sources for their production plan. [...] To approach the forest owners and perhaps optimize harvesting operations effectively in a particular area." - E09

In the use context of forest ownership, drones support creation of updated and diversified forest inventory, more transparent wood trade and more efficient management of forest property. Due to the more comprehensive knowledge, forest owners and organizations can plan and optimize their activities, collaborate with each other and find useful resources to develop new solutions. Generally, more accurate, extensive and visual information that can be understood easily promotes more reliable business practices in buying, selling and managing forest areas. Using drone-based solutions can therefore encourage people to participate in wood trade and forest management based on certain economic, social or environmental goals.

In **environmental governance**, one of the key activities is to control forest, environmental and financial laws. For this effort, drones are used in versatile ways to review the quality and results of forest operations.

> "To assure the quality of the various forest operations [...] when the soil is being modified, whether there are sufficient number of modification traces, is the modification done consistently on the area, are the trees planted according to the objectives, what is the quality of work there." - E11b

Specific indicators and values are determined in laws and certifications regarding forests, nature and water systems, which can be assessed with drone-based data. Both economic and environmental indicators can be evaluated by applying drone images and measurements with other scanning methods and previously collected forest inventory data. Besides measuring the viability of trees, drones offer relevant options and solutions for inspecting biodiversity from several different viewpoints.

> "You can monitor certain biodiversity aspects, reserve trees, zones for game, and, of course, point load and algal blooms in waterways, solid substances. [...] And of course, floods are one of the issues related to sustainability, situational information is very quickly needed." - E02

> "Monitoring ditches to ensure they have been made as planned and the water protection issues have been considered. [...] In groundwater areas, monitoring of soil treatment." - E06

Especially, in supervising the water protection structures of forestry and providing data quickly for repairing weather, flood, insect or animal damages drones are found to be valuable and functional applications. By utilizing drone images and measurement data collectively within IS and previously gathered data on valuable habitat and endangered species, environmental governance can be supported effectively by several aspects. Employing drone-based data and assuring accountability to promote environmental sustainability requires functioning collaboration between and among private and public organizations and interaction with forest owners.

The identified contexts of utilizing drones to advance environmental sustainability in forest industry are gathered into Table 4. From the expert interviews, the contexts of forest planning, production, ownership and environmental governance were recognized as the major categories of using drone-based solutions. These solutions support and promote informational, technological and social activities in forest industry, while within each context certain characteristics are highlighted in applying drones for environmental sustainability.

TABLE 4 Identified use contexts for drones as IS artifacts

Context	Activities supported by drones	Characteristics in drone use
Forest planning	• Imaging forest area, operation and biodiversity • Creating digital models with single-tree accuracy • Reviewing work practices, pricing, costs, objectives and future aspects in planning	• Visualizations • Digital models and simulations • Estimations
Forest production	• Maintaining and developing infrastructures, logistics and processes • Monitoring production, storages and supply chain • Generating internal and external materials and applications for decision-making, learning and marketing	• Real-time data collection • Operations management • Visual products and simulations
Forest ownership	• Providing realistic and understandable visual information on forest assets • Finding appropriate resources • Optimizing forest management and harvesting operations	• Accurate forest inventory • Asset management • Transparency and openness
Environmental governance	• Improving control on forest, environmental and financial laws • Examining biodiversity and sustainability aspects of forests, soil, water systems and the air • Supporting valuable habitat and endangered species	• Legislation and certifications • Accountability • Collaboration between and among organizations

Drones are employed in forest industry to support planning, production, ownership and environmental governance. This is realized through direct and indirect drone-based solutions in which they function as the most essential capability or a major component of the IS.

Based on the expert interviews and the amount of mentioned activities, drones are especially useful for planning forest operations and developing forest production. This was quite anticipated, since the interviewees worked mostly in business companies than in public organizations and these use contexts provide the most explicit results for profitability. However, the identified contexts of forest ownership and environmental governance were highly emphasized in the interviews, since the difficulties regarding environmental sustainability and change of generation and their impact on planning and production must be resolved. To observe specifically how these functions within different use contexts are enabled by drones, the findings on drone capabilities in forest industry are deliberated next.

For evaluating different kinds of drone capabilities, the functional affordances framework by Seidel et al. (2013) with extensions by Hanelt et al. (2017) is employed. First, the capabilities of drones in forest industry are described and evaluated based on the sensemaking affordances of reflective disclosure and information democratization. Second, the capabilities are reviewed with the sustainable practicing affordances of output management, delocalization, technological flexibility and digital eco-innovation.

To define the features on **reflective disclosure** in drone use, the focus is on evaluating how forest work practices and the beliefs, actions and outcomes concerning these practices can be revised and improved by utilizing drones as IS artifacts. Generally, in practical forest work drones can be employed before a forest operation, e.g. forest thinning and tree planting, to review how the area would look like after the operation is completed.

> "Can simulate various operations, such as thinning operations, and see what the area will look like after the planned thinning and simulate tree planting." - E09

This way forest owners and companies can decide whether the operation would provide desired outcomes, should the area be left as such or could there be a better solution – environmentally, socially or economically. Thus, the data and images collected by drone can encourage the forest owner or company to evaluate environmental values and current work practices in their decision-making and operation. With drone-based digital information, versatile simulations can be performed remotely without travelling and going into the forest and thus possibly creating environmentally harmful effects on the soil, habitat or climate. Especially, by simulations focusing on different economic, social or environmental factors, companies or private forest owners can decide whether those operations would be necessary or successful if assessed from the relevant perspectives. As a whole, more detailed information on the current situation in the forest supports long-term decision-making, since after harvesting or other forest operation the trees cannot be restored immediately.

In choosing the correct work practices and techniques, drones will help forest operators to review the area, its characteristics and potential outcomes from the air if needed. When evaluating forest damages and selecting the best options to repair or prepare for them, drones can be utilized flexibly to map all the fallen or damaged trees and collect data for estimating the realized and potential impacts. In that case, the forest can be assessed based on its still viable and available resources, biodiversity, suitability of work practices and safety of the forest operation.

> "(To assess the snow damages) we want to know quickly what kind of damages there are and whether it is practical to repair them or to let the trees decay, and thus (support) diversity. [...] Instead of waiting and arranging some aerial photographs or going into the forests by foot, which is also a bit dangerous." - E11a

On the other hand, the trees cannot be identified very well from the air if the terrain is snow-white, the weather conditions make flying difficult or there is not enough lighting. Besides examining trees and forest areas from the air, measuring the forest machine tracks after the operation can be done efficiently.

> "Once the forest machine has gone, the area could be mapped quickly and processed with a 3D model which can calculate logging road dents accurately and show the impact it has had on the environment at this site." - E10

Depending on the tracks, the operator can respond to it in the current forest work area and also plan and prepare better for the next operations and areas. This would provide practical and current information for reflecting and developing work practices in forest operations.

> "It would give results and information on how, for example, at this time of logging with this equipment, has it been environmentally sustainable or acceptable harvesting?" - E10

Therefore, using drone collected images and data, forest companies could create more useful and accurate services for managing, harvesting, thinning and planting forests. For customers, drone images and visualizations would improve transparency and accountability in ordering general or modified forest services. Overall, drone-based images and data could become as a guarantee for the acquired forest products and services, since the quality and short- and long-term consequences have not been able to confirm beforehand than after the forest work is done.

In Finland, most of the forest owners are not companies but individuals who have diverse skills and knowledge on forest management and their forests in general. Many owners have inherited their forests, are from the younger generations and do not have as much expertise or interest to manage their forests. With visual, easily available, generalized and representative information, forest owners are able to understand their forests better. Specifically, forest owners can revise their belief, action and outcome assessment regarding their forest assets.

> "More and more forests are owned by younger generations who inherit the forest, live in cities, may not have any understanding of forest management, wood trade, and may not want to go there. Forest owners can take advantage of digital information about their forest holdings, have better control over forest assets, and can trade timber online." - E09

Although younger forest owners do not have as much in-depth expertise related to forest management, they often utilize digital services, marketplaces and platforms in their everyday life. By using more accurate images and realistic visualizations on forest areas and assets, they can understand their forests more thoroughly and get interested in managing forests efficiently and possibly with an environmental emphasis.

> "To create a relationship with their own forest in a different way than before, when the forest information was only in numbers and long-range aerial photographs." - E11b

In addition, forest owners can get motivated to learn more, manage their forests actively based on specific goals and emphasize certain values strategically in forest management and ownership. These advantages facilitate economic profitability, social interaction among stakeholders, and consideration of environmental values in forest asset management.

To evaluate viewpoints on **information democratization**, the solutions in forest industry are considered based on how information sharing from different sources and communication related to environmental sustainability are supported by drones. In general, drone IS artifacts enable detailed measuring of indicators being valuable for producing wood products or forest services cost-effectively.

> "(Drones are used) for measuring volumes, as for counting trees, general area mapping. To check how the boundaries are aligned, for example. At the moment, the most essential is to collect more accurate tree information, i.e. volumes, lengths and such information" - E12

Although measuring different volumes, boundaries and parameters would provide useful data primarily for economic needs and purposes, having more accurate knowledge on the available resources would also benefit environmental objectives. By producing less waste and minimizing loss, the resource efficiency can be enhanced with drone-based measurements in production. Particularly, mapping and imaging the factory area can be achieved quickly with drones.

> "You can have video or still image from the copter constantly and share it with others at the same time. More people can watch what is happening in real time. A large factory area, if you check it by foot or with a car, [...] drone can get it done much quicker." - E06

For planning, monitoring and collecting data accurately, drones can be employed with other applications and systems. Using drone images and data, companies can deliver to their customers, or utilize internally, practical visual materials and simulations to control the work quality and to inspect how the forest plot would look like before and after the operation. Forest owners and companies might have different expertise on forest management, thus explicit drone-based data and images would enable more balanced understanding and knowledge on the forest assets.

> "With the drone picture you can tell: "This is what your group of saplings looks like after forest work". [...] Defining it to someone who does not know the forest, so instead of just numbers this kind of visual material is pretty good." - E11a

Applying drones, both customers and forest companies could make better decisions regarding economic, social and environmental goals, which would democratize the available information on forests.

In traditional forest management, only the average size and average amount of the trees are known, but with drones the trees can be identified individually and observed more thoroughly.

> "Drone inventory or drone provides 100 percent sampling, meaning all trees are discovered." - E07

> "All trees are identified with drone - a few percent remain (unidentified) if they are under other trees or smaller trees. We can see the size distribution, [...] we know more about the amount of wood, and especially the amount of timber assortment, that is, how much log, fiber and how much spruce, pine, birch." - E08

With more extensive, realistic and not estimated information being gathered from different sources, the wood supply chain and production can be enhanced comprehensively.

> "We would know better what is in the woods and what would be the correct cutting instructions. [...] The mills' wood needs could be fulfilled by fewer groves from a smaller forest area in total." - E08

Combining previously collected and drone-based data altogether, the complete and correct tree size distribution information can be created. Therefore, forest companies could use this planning information to supply the right amount and certain type of wood from specific forest plots to a factory that refines those woods into the most suitable products. Forest companies could improve profitability and optimize their supply chains with diverse factors and features. This optimization can be based on costs, location, logistics, quality, production efficiency, social aspects and environmental impacts.

Environmentally harmful outputs can be minimized indirectly by improving the use of resources and choosing the most suitable techniques in forest work. The forest growth models have been developed by applying the forest inventory data, which are used for updating the forest planning information. With drones the growth of forests can be revised more regularly and accurately. Also, the information on trees and terrain could be upgraded more thoroughly.

> "Growth is increased annually in accordance with these national growth models. [...] If drone use is made really effective, then in principle, the growth could be verified more regularly and [...] that the forests would not be overcut all the time." - E08

Overall, from the viewpoint of information democratization drones facilitate more balanced information in wood trade and forest management. Forest owners, companies and public organizations can collect and use drone-based data and images more flexibly for their decision-making. However, when e.g. a forest company collects data with a drone on a forest area, the data will not be openly available by default and the company will not commonly share that data freely. But since companies and public organizations do not probably have expertise, devices, resources or interest to utilize drones on their own, making accurate measurements and visualizations with drones necessitates cooperation with other companies and operators. To realize all the benefits of drone imaging and measuring, diverse organizations and individuals should create functional company and stakeholder networks. Having well-organized operating structures and processes, drones can be applied for sharing valuable information from different sources and contexts and improving environmental sustainability aspects in forest industry.

Considering **output management** affordance, the emphasis is on evaluating how environmentally detrimental resources and outputs are managed in forest production**.** With drone-assisted data measuring, surveys and measurements on difficult objects are much faster than with conventional methods. At industrial sites, drones can be flown closer to the constructions and production facilities to gather information and create comprehensive visualizations on emissions.

> "It enables area mapping that has not even been possible before. Three-dimensional concentration surveys can be conducted at industrial sites and the spread of emissions can be studied." - E03

Conducting drone-assisted emission surveys, more precise and real-time data on certain objects can be collected. Therefore, companies can evaluate and develop their production processes from another perspective, which allows responding to detected changes or harmful effects in the processes. Furthermore, if an industrial process is producing excessive amounts of harmful discharges or not working properly, drone-based emission measurements can indicate how and when the machines, components or infrastructures applied in the process must be modified, maintained, repaired or replaced.

By creating effective applications on drone-assisted emission surveys, forest companies can develop proactive systems to optimize their production, use of resources and reduce environmentally harmful emissions and impacts. These improvements would enhance profitability and cost-effectiveness, since emission trading as a countermeasure would require more costs and since countries are aiming at becoming carbon neutral and thus supporting environmentally friendly companies.

For managing water systems in forest industry, drone images are used to observe and estimate water discharges and algae growth from the air. Using accurate aerial images on the current situation, the damages can be fixed and prevented by discovering how they were emerged.

> "Discharges of water systems and some algae deposits, or of this type or humus discharges, [...] when the surface of the lake has been imaged a discharge ditch can be seen leaking sludge" - E01

With up-to-date and versatile information on forests and water systems, appropriate forestry work can be done at the right time by taking the environmental aspects into account. Particularly, in terms of carbon sequestration, making timely, targeted and correct activities in the forest is essential. When the final felling has been done, the forest must be regenerated as soon as possible.

> "If the forest is empty for a few years before new trees are planted, it will take many years before that forest becomes a carbon sink." - E08

Forest transformation to carbon sinks is a long-term and systematic process in which land regeneration has a significant effect. To support the goals of climate and carbon neutrality, time is of the essence as forests should be brought to efficient and sustainable growth quickly.

> "When a lush soil is quickly regenerated, it will release more carbon, at first, than it absorbs, but in 15 years a single forest can become a carbon sink." - E08

Making the harvested forest area again into a carbon sink, quick response and activities for renewing the soil and forest is required. To achieve as fast and correct operations as possible in restoring the environment, utilizing drones is a relevant possibility. In reducing the emissions after harvesting and supporting the carbon sequestration, drones can be employed for collecting useful measurement. data for forestry operations, planning and production.

To facilitate **delocalization**, using drone-based images and data allows remote processes and practices in reviewing environmental impacts and different indicators related to forest management. By combining drone-assisted measuring and other scanning methods and tools thoroughly, forest owners and companies can minimize visits to the site by gathering required data at once.

> "There is no need to travel to the site so often to make focus measurements [...] by a single visit, accurate measurements and significant cost savings are achieved." - E05

To achieve delocalization of work practices, the collected data can be processed and interpreted differently and multiple times to find useful information. Additionally, drone-collected data can be utilized to develop a database for certain forest areas with individual characteristics and also evaluate all the collected data with each other.

> "If needed, the data can be viewed afterwards and reinterpreted in the office. Compared to going to the forest again." - E07

When imaging forest area with drone, applying versatile sensors simultaneously makes it possible to have data from different perspectives and create diverse understanding on the area. Establishing a comprehensive database and system to explore the forests requires efficient data processing tools and statistical methods. To take advantage of delocalization benefits of drones, collecting, refining and adapting data of different types is significant. Thus, collaboration among various operators is usually needed to have relevant skills and resources. Having efficient processing methods and inclusive data in use, drones promote delocalization by supporting remote management and minimizing visits to the site. This is realized with powerful data processing and analyzing tools.

To enhance **technological flexibility**, drones as supporting IS are employed for advancing collaboration and integration of different stakeholders and systems. When drones are used as practical everyday tools in processes and systems, the creation of products and services can be done more flexibly.

> "Just like everyone has cell phone cameras in their daily use, we have drones at our disposal for certain individuals and units. [...] It has become a wrench, one more tool and it can be utilized in many ways." - E04

Considering the current conditions, variables and factors affecting forest operations, drones assist integration of useful methods and tools, and development of new useful solutions. Therefore, in improving everyday work practices, drones can be applied as a platform for other sensors and measuring techniques.

> "The drone itself is just a new tool by which a sensor - be it a camera or laser beacon or whatever [...] can be flown more cost-effectively in certain cases." - E04

However, this necessitates modifications and reformation of work practices and business processes. By utilizing drones as flexible and practical tools, the next process steps can be done in a faster cycle. In forest planning, drones are used for producing visual and detailed information, which required earlier more preparations, costs and time beforehand. Valuable forest visualizations and process solutions will be generated, when drone-based data can be shared within diverse systems without excessive interaction, planning or technological integrations.

> "The designer can get to the design right away, and in that process can jump to the job 1-2 days faster. Before [...] it might have taken days or weeks." - E05

Having drones and drone imaging as an available option, aerial data can be collected for everyday and situational purposes if needed. Especially, to repair and forecast weather, insect or animal damages in forests or measuring harmful effluents in water systems, efficient aerial imaging assisted by drones promotes faster response and preventative actions.

> "For a momentary need a mapping can be made in a particular area [...] – for example, storm, snow, bark beetle or insect damage. [...] The scale and impact of damages can be predicted and estimated." - E10

At the moment, there are several challenges related to forest monitoring with aerial images, previously collected forest inventory data or field surveys. The available data can be outdated, inaccurate or incomplete and the data collection and maintaining can be time-consuming, costly, difficult or even dangerous for forest workers.

> "Examining the terrain - a man walks through large forest areas - is quite a difficult task. Drone enables fast, real-time, accurate, detailed production of information and images quickly and cost-effectively." - E11b

When using these conventional methods, the decision-making is often based on estimations and general models including average calculations. To resolve these challenges, drone images and solutions deliver practical alternatives.

> "Drones are [...] very cost effective, I do not know if compromise is the right word. But the traditional aerial images, [...] there are years between these different aerial images. They are, of course, shot higher and have a lower accuracy than drones." - E11b

Applying drone images and solutions efficiently, the data used for decision-making can be forest-specific, current and accurate. Particularly, these improvements allow more detailed and applicable forest management. Environmental sustainability can be perceived not only by employing general best practices but also by conducting focused activities providing the most suitable outcomes at an individual forest area.

> "(To protect valuable habitats in the forest law) a drone image can be used to outline the protection zone. [...] The field inspectors have always tracking devices and map applications with them, so it (drone picture) provides very good support for outlining the habitat, where the logging will stop." - E11b

As adaptable solutions, using drones makes it possible to discover new ways of collecting measurement and visual data in forest industry. To assess the technological flexibility aspects, drones encourage to improve processes, invent new capabilities and explore alternative applications in solving the emerged challenges.

Finally, the **digital eco-innovation** affordance of using drones assists incorporation of physical and digital applications to create new solutions for supporting environmental sustainability. Ultimately, when the data transfer capacity of mobile networks and operating time and autonomy of drones are upgraded, drones could fly and monitor almost around the clock at areas that are valuable or important for e.g. forest production or planning. Separate drones or flock of drones could execute multiple tasks independently.

> "Process interruptions can be detected immediately, firing points of biomass stacks can be detected more quickly, and all these require constant monitoring. This is currently difficult to accomplish by any other means than with a drone or a drone flock that would work tirelessly there." - E03

Drone flocks could notify if some boundary emission, output or supply values are exceeded to allocate appropriate correcting actions efficiently. Additionally, drones could solve, independently or by controlled remotely, dangerous or damaging situations e.g. by extinguishing small fires, bringing useful equipment to a remote site or carrying a light cargo from one place to another.

As a whole, merging the data from different sources in the long term and momentarily can facilitate development of more sophisticated and proactive systems in forest industry. In forestry operations, environmental sustainability can be improved by combining and analyzing ground and aerial data collected by forest machines and drones. At the beginning of logging or other forestry operations, the machine traces could be measured to assess potential environmental impacts at the site.

> "Combining the movement resistance data of the forest machine and this information would lead to proactive systems. [...] It would be possible to detect if the machine's movement resistance is at some level at the site, what the harvesting trace would be after the trees have been collected from there. " - E10

In addition, by gathering and converting information into a digital model on the forest or production processes, the economic, social and environmental viewpoints can be estimated systematically.

> "More than just the economic uses of the forest are collected into the digital models, such as protected areas, historic sites, and all that, including forest biodiversity and sustainable development." - E09

With the help of physical and digital information from diverse sources, novel solutions for environmental sustainability could be developed. Before forest inventory data could have been only numbers, but by integrating drone-based data and other scanning methods, information on forests can be visualized and refined effectively. Drone-assisted measurements make possible to gather high-quality, valid and accurate information on forests, which can be merged with other systems and machines in forest industry.

By utilizing physical and digital components, solutions for situational awareness and production optimization can be generated by employing drones. Besides profitability and economic factors, these solutions can be focused on monitoring and exploring factors that support biodiversity and sustainable development. For forest owners, these systems can motivate socially to learn more about environmental aspects and participate in promoting sustainability in forests. In addition, drone-based data could be integrated into a public digital service where people could find e.g. interesting historical locations, trails, new recreational activities and ways to improve environmental sustainability in forests.

As a summary, all the observed and assembled functional affordances from the qualitative interviews are displayed in Table 5. In the table, the relations between the functionalities achieved by utilizing drones as IS artifacts with the corresponding functional affordances are outlined based on the findings.

TABLE 5 Functional affordances of utilizing drones as IS artifacts

Functional affordance	**Functionalities facilitated by utilization of drones**
Organizational sensemaking	
Reflective disclosure	Assessing quality, equipment, methods, and costs in work practices visually and proactively
	Delivering updated and exact forest data in planning, simulating and executing focused forest operations
Information democratization	Improving and harmonizing knowledge in decision-making by more open and available forest data
	Motivating collaboration in applying capabilities and creating solutions for environmental sustainability
Sustainable practicing	
Output management	Measuring and visualizing emissions from the air and in difficult places in real time
	Promoting timely precautions and corrective actions for harmful emissions and damages
Delocalization	Minimizing visits to the site by collecting sufficient and necessary data at once
	Supporting remote planning, decision-making and reinterpretation by effective data processing applications
Technological flexibility	Integrating and enhancing process capabilities as flexible data collection tools
	Adding new options and possibilities for solving daily, situational and physical challenges
Digital eco-innovation	Enabling data fusion of machines and IS by visual data and from aerial perspective
	Optimizing supply chain and production with digitalized and real-time forest data

When the organizational processes, work practices and agility as well as people's knowledge, skills and learning abilities are employed efficiently, drones enable useful and valuable capabilities with organizational sensemaking and sustainable practicing affordances. Finally, if the opportunities of drone capabilities and affordances are applied and explored completely in the particular use context, drones facilitate versatile creation of economic, social and environmental innovations.

Nevertheless, there are significant obstacles and constraints that must be resolved to utilize both general and revolutionizing advantages of drones and their use in forest industry. In the next section, these restrictions are considered.

5.1.3 Restrictions for drone use in forest industry

Drones that are applied in forest industry and professional business contexts are relatively recent devices. As IS artifacts, the technological, informational and social components of drones are not yet functioning the most effective way or they lack competences and abilities, which are necessary to generate valuable products and services. Adopting drones can be a sluggish progress, because the available drone solutions are insufficient or not cost-effective and the attitude towards disruptive technologies can be negative. Likewise, legislation and possible risks must be taken into account properly. To realize all these aspects in forest industry, the specific restrictions of drone use are reviewed next.

Since drones are flying electrical devices, they can cause diverse risks for general safety. If a technical malfunction is occurred, drone can create dangerous situations by striking or effecting on other objects or areas on land, in water and in the air.

> "If it drops to a peat field, then there is a risk of fire, and everything like that must be considered." - E06

Drone hobbyists are a wide-ranging group of people and they have different kinds of skills, abilities and equipment in use. Moreover, drone hobbyists have diverse purposes and goals for their drone use, which are difficult to control by motivating for complying with general guidelines and best practices.

> "Anyone who buys a drone can then fly up to 500 meters and disturb aircraft or government helicopter operations or anything like that. [..] Depending on how serious incidents are actually happening, so this common airspace – will it be deployed." - E03

Based on the interviews, the general opinion is to allow drones for professional user even though they would be denied for hobby use as a safety risk. By having a relevant training and understanding and therefore a specific permission for flying drones, professionals would be able to utilize drones in their work.

On the market, there are not companies or company networks that are widespread enough. Therefore, all the necessary forest areas cannot be imaged or measured to enable thorough controlling, planning and managing of forestry operations and forest laws. Forest sites to be measured are small and shattered, which requires nationwide network of operators and companies.

> "It will be expensive if you do not have sufficient drone equipment in use. [...] We need to get some kind of platform-based drone company network that shoots these destinations." - E11b

These company structures should be able fly drones from few locations, use different sensors, and then integrate, process and visualize the collected data into valuable and customizable products powerfully and cost-effectively. Since drone imaging is a relatively new measuring technique and the studies and pilot tests have been executed for a smaller scope, drones have not been employed yet for a larger scale production. Consequently, the available and appropriate devices, applications and software can be too expensive or their licenses not fitting for the specific use context.

> "There should be flight planning or mission planning software, but at least for the time being the licensing policy and price restrict their use" - E06

Overall, the collected data must be processed and refined effectively in order to utilize it in developing valuable products and services and generating profitability. At the moment, the drone-based data processing demands more improvements to enable flexible creation of new applications and opportunities.

> "Data processing [...] is not very advanced yet. [...] In order to really get any benefit from these pictures, refining the information is more difficult. [...] Images into rational information, numbers and so on." - E04

In reviewing the institutional pressures on using drones, the legislation, change resistance and lack of knowledge and skills are the most impacting restrictions within drone and forest industry. First, as a coercive isomorphism, the current regulations are seen as too limiting, which reduces possibilities to create cost-efficiency in processes. Yet the regulations in Finland are relatively flexible compared to other countries in EU but considering and implementing all the current and future viewpoints of the legislation is complex.

> "Legislation is a bit complicated that the EU harmonizes at European level, but it is great to see where it goes. Apparently in Finland, since this drone legislation is very liberal here, it will be tightened up." - E03

Due to the visibility requirements legislation does not support autonomous drones, which affect widely both in applying drones and developing automatic solutions. Thus, solving situational problems and creating useful solutions with drones can be challenging, because cost-effectiveness and process efficiency are not perceived generally achievable.

> "You cannot do anything practical with them, for example in forest inventory, if such requirement is taken literally. If there must be 3 observers there to fly even 50 hectares of land." - E01

Even though the current drone legislation still makes it possible to conduct various activities in forest areas, its expected changes in the future can make drone operations more difficult and less effective. The lowering of flight altitude can reduce the extent of forests being able to measure and image during a single flight.

> "There has been talk of dropping the flight altitude to 120 meters, which is quite common practice in Europe. It is not a good thing for us, because even 30 meters does quite a lot in terms of how much can be photographed." - E12

Second, as a mimetic isomorphism, the change resistance in forest industry slows down development and improvement activities. Since organizations are reviewing and possibly imitating the capabilities and value creation of their competitors and other organizations, and due to the dynamic and competing situation on the market, the organizations are not eager to explore and deploy new solutions in their business. Within organizations, employees might have negative opinions and attitudes towards robotization by utilizing robots to optimize and improve operations and possibly replacing human labor.

> "What slows down is the natural resistance to change, if things have been done somehow for decades, there is no need to change them, especially if there is some kind of robot involved." - E03

As drones have not yet been applied widely in forest industry, organizations do not have as much experiences of them and are therefore not particularly interested in implementing drone solutions in their production.

> "When examples and experiences become available then the use of drones increases. More and more operators, so dare to adopt technology." - E07

Third, from the viewpoint of normative isomorphism, since forest organizations have similar knowledge e.g. on forest management and not substantially knowledge and skills on drones, the organizations are not encouraged to apply drones in their operations.

> "Dare to adopt new technology stronger and faster and dare to think differently, unfortunately it is often missing. It is only about daring to try new technology in own operation and work." - E05

In this case, normative and mimetic pressures overlap and affect similarly, as lack of experience and knowledge create change resistance and less motivation for utilizing drone applications. Additionally, people can have negative attitudes and bias towards drone solutions, which generates reluctance on deploying and using them. These reactions, however, can be solved possibly by sharing relevant information openly and training people to achieve important tasks more efficiently and usefully with drones.

> "Opinions and prejudices, there is still a lot of people having incorrect perception about what they can or cannot do. Of course, staff training (is important), whether there are enough or trained people who can use these drones." - E06

The technological capabilities are constantly improving in drones as the potential use contexts and general interest in utilizing them are increasing. At the moment, it can be difficult to review the most suitable drone solutions, which can be used for achieving certain tasks in specific weather and other environmental conditions. In general, the flight and operation capabilities are the most significant features to develop.

> "The technical field is quite wide and varied. The conditions limit operation and characteristics of technical equipment. Therefore, the development of flight abilities is an important component in the equipment." - E11a

Difficult weather, operating area and lighting conditions can have a comprehensive effect whether drone can be flown and utilized for certain tasks in particular period of the year. Besides strong wind, rain and too humid or cold conditions, the surrounding environment reduces the operability of drones, if the visibility and requirements for distance and safe flight operations cannot be ensured.

> "At the moment in the big factory halls [...] we cannot fly inside. It does not always work at the moment, and one of the limitations is the weather. The devices cannot be flown in intense wind or rain." - E06

Although drones enable accurate and effective imaging of relatively large forest areas, the current battery capacity of drones is still a major technical restriction not allowing data collection for areas of hundreds of hectares large at once. Operators must map and measure the areas separately in cycles of about 30 minutes to 1 hour after which the battery must be changed. Hence, companies have to carry multiple charged batteries with them and plan the operation based on battery capacity. In addition, since drone operators are using commonly photogrammetry imaging in Finland, the areas can be measured only when the trees can be identified from the terrain as there are leaves in trees and not too much snow.

> "It is a physical limitation that it is not suitable for large areas because it is not allowed or difficult to fly high and for long periods. [...] At present the activity is limited to the summer season, or to the season when there are leaves in trees." - E07

Due to these technical restrictions, the drone operations must be scheduled for short time periods to collect all the necessary data at once. If the batteries lasted longer and automatic drone flights could be done higher, potential time and cost savings could be gained in measuring and inspecting varied forest areas. By using hybrid drone, having battery and combustion engine, these automated robotic flights could be possibly implemented.

> "Currently, the flight time and battery capacity of drones [...] is so weak that robotics flights cannot be made. New hybrid drones and other combustion engine drones are emerging, which creates a potential foundation for it (robotic flights)." - E05

Due to enhanced process efficiency significant benefits on costs and effectiveness can be obtained with drone solutions, despite the poor weather, lighting or other environmental conditions that could delay the drone operations.

> "It is a new type of tool that is valuable and can be used even better. [...] Overall, it waits a few days, but it can be multiplied back by doing it with this new technology versus doing it with some old technology." - E05

In considering the factors related to information its collection, sharing and processing, there are many variables and viewpoints that should be taken into account. When delivering drone-assisted visual products to forest owners or companies, managing the forest as an object for measurements can be challenging.

Drone operators and forest companies must decide how issues on logistics, costs, varying conditions, accuracy, regulations and sufficiency of data collection are managed. Operators need effective work practices, technologies and capabilities for processing the collected data into an understandable and useful format. The drone-assisted images and measurements on forests can contain errors, and to correct them, appropriate precautions, tools and activities must be applied. If the measurements cannot be used due to mistakes and errors in data collection, mapping the area once again can create too much excessive and not expected costs.

> "The results may be unusable or require calibration and adjustment, and it will cost an unreasonable amount of time and expenses." - E02

These challenges and surprises can reduce the motivation and interest in utilizing drones for conducting various tasks and process phases and supporting other functions and activities within the business environment.

In forest industry, mapping and measuring the forest areas and trees individually can be done accurately with drones. However, the forest areas can be very different, since the type, size and age distribution of the trees and the characteristics of terrain and water system are distinctive. As a result, all the activities cannot be executed successfully with drones and thus conventional methods must be used. Specifically, in mapping young forests individual trees cannot be identified as accurately with drones as measuring them by a forest expert who examines the area and evaluates when the next most suitable forest operation should be executed.

> "Young forests, which are seedlings and have lots small of birchwood, so with the drone the exact time and need for the operation cannot be possibly defined as well as in the terrain." - E08

When utilizing entirely drone collected data, the next treatments and operations have to be decided based on calculations and assessments that have been conducted for the available data. Consequently, with drone images it is more difficult to determine the amount and condition of growing trees. For older forests where the trees have grown enough and can be identified, drone-based estimations on the most suitable forest operations provide more accurate results.

Similarly, the environmentally and historically valuable objects and places, e.g. creeks, springs and endangered species, cannot be measured effectively without visiting and examining the objects at the location. However, when the objects and locations are collected and mapped into a system, drones can be employed for reviewing how they are reserved and maintained and thus support environmental sustainability.

> "Forest law sites, nature sites require more detailed handling or visits, all of them are not necessarily visible from the air. [...] The objects that are already known [...] can be checked with drone without going there if they have been spared." - E08

Besides the operational challenges, using drone IS artifacts can be difficult without relevant resources, knowledge and skills. Developing processes by drones could be limited as a whole if practical technologies and abilities are not at the company's disposal. Therefore, it would require active creation of partnerships and collaborations with other companies and operators having the necessary capabilities.

> "With drone we could not determine the issue (snow damage), [...] when there are hundreds or even thousands of hectares of snow-white terrain, the image should be set to the coordinate system so that it would be useful." - E01

Hence, the available drone products cannot be used as out-of-the-box solutions since they often necessitate adaptations and internal development based on the use context. At the moment drones can be flown quite easily but collecting and especially integrating the gathered data into various systems can be a difficult task. In applicable measuring and imaging solutions, the application programming interfaces (APIs) might be very limited and not supporting modifications or integrations with other useful systems. Due to these limitations, deploying drone-based data collection and creation of automated procedures by combining diverse applications cannot be achieved simply.

> "Application programming interfaces can be limited, there may be device manufacturers' own systems in which interfaces may not be built. Automation and the development of automatic functions, is certainly one area that needs to be developed." - E05

Because these solutions can be used to gather a lot of accurate data, the data transfer capacity is a central challenge in implementation, especially when they are used in distant forest areas. Currently, transferring all the data via mobile networks is not practical and proficient for which operators need to go back to the office in order to transfer data to clients. This creates, obviously, delays and costs to the projects and business processes and, in the first place, decreases the potential profitability gained by using drones.

> "At the moment the data network does not work at the sites, so data cannot be transferred directly from the flight zone to anywhere. Data is collected so much that the capacity of the cellular networks is insufficient." - E07

Altogether, as drone-assisted forest data collection is not yet very common and widely used method, there are not clear standards and definitions what and how should be collected. From the viewpoint of customers, explicit standards should be created for drone products so that the collected data could be applied usefully.

> "The user of the information who is ordering the job so how can one ensure that relevant and useful information can be received. It requires standardization." - E11a

When the data has been gathered and assembled, the ownership, quality and domain could generate limitations for future applications. The company that has processed the data into specified information on a forest area has also used its resources and capabilities. These efforts create costs, which should be covered by selling access rights to that information.

> "The source and the accuracy of that information (is a great challenge). And then of course to whom it is available. [...] If it is owned by one party, it would not like to share the information freely. - E09

Although there is diverse forest information available openly and freely, more accurate, current and specific information having certain business value would not be shared generously. Thus, managing the information ownership can also generate restrictions in developing environmentally sustainable solutions founded on drone-assisted imaging and measuring.

All the recognized limitations and their detailed characteristics defined in this subchapter are categorized into Table 6.

TABLE 6 Restrictions of drone use in forest industry

Restriction on using drones	Specific challenge related to drones
Possible safety risks caused by drones	• Risk of collision and damaging the environment • Fire hazard • Interfering the air traffic
Lack of drone solutions available on the market	• Not widespread network of drone companies • Excessive prices and licenses • Processing the data into an understandable and applicable format
Institutional pressures	• Requirements on visibility and flight altitude limit performance (coercive) • Resisting attitudes and prejudices towards new technologies (mimetic) • Lack of knowledge (normative)
Immature technological components in drones	• Flight abilities • Battery capacity • Not support for automation, robot flights or APIs • Weather conditions impacting operability
Ineffective information management	• Ensuring the quality and feasibility of collected information • Weather, lighting and flora affecting perception and operation on different seasons • Insufficient data transfer capacity • Gathering sufficient amount of data • Applying the information in various systems • Managing ownership and sharing of information • Logistics and transportation in data collection

As emerging solutions in forest industry, utilizing drone as IS artifacts still include significant challenges and restrictions which must be resolved with developed social, technological and informational features related to drone use.

The legislation, available solutions and products, skills and understanding and applied components need to be reviewed and advanced continuously, practically and with a long-term vision. To develop better functionalities and new features for drones as IS artifacts, the development objectives specified in the interviews are examined in the following section.

5.1.4 Developments for drone solutions

Although there are several restrictions and challenges related to using drones in forest industry, drones are seen as potential solutions to collect high-quality forest data for different purposes. To solve the diverse problems, the development goals and needs provided by the interviews are reviewed next. In this section, these various objectives are reviewed from the viewpoints of forest industry, social and business possibilities on the market, technological improvements and informational capabilities. Thus, utilizing IS artifact features as a framework that support environmental sustainability.

First, considering forest industry as a whole, using drone-based images and data collection would offer beneficial options and possibilities to develop new services and products. In general, when generating novel solutions, the characteristics of forest industry must be applied. In other industries raw materials come from big supplier companies, whereas in forest industry natural resources come from several individuals who are mainly consumers.

> "In Finland, about half (of the trees) comes from private forest owners, and there are in fact over 600,000 of them in Finland, so an industry where a large number of raw material suppliers are in fact consumers who are very different." - E09

These versatile objectives and emphases of forest management that the forest owners have must be considered in developing valuable digital services. In order to utilize all the available resources to create environmentally sustainable applications, more accurate and extensive knowledge collected from various forest areas and forest owners has to be shared effectively. Furthermore, forest owners and customers could be encouraged to participate in improving production and developing new solutions by taking environmental sustainability into account, thus facilitating a kind of crowdsourcing abilities in forest industry.

Since the open laser scanning data can be outdated and inaccurate, other approaches that enable better decision-making should be reviewed and applied. Especially, for updating forest operations with real-time and focused measurements, drone images combined with other measuring methods offer valuable perspectives to find more beneficial options or practices.

> "Updating information about a forest can be much more effective with a mini-aircraft or drone than with traditional field measurement, and the accuracy can be much better." - E10

To obtain useful knowledge, drone-assisted products and services enable new ways to approach and create solutions for diverse customers in forest industry. Although novel measurement tools and methods can provide practical solutions, conventional techniques to manage forests are still needed. Based on the benefits and limitations concerning a specific method, it can either substitute previously used techniques or offer new alternatives to conduct a certain forest management task. Likewise, drone-assisted imaging and data collection can improve methods and processes, but field work and satellite imaging are still needed to enable context-specific, knowledge-based and large-scale data collection in forest management.

> "It (laser scanning data) is quite accurate, but it may not be enough and the evaluation of forests in the field is still an evaluation. [...] I do not see work in the field disappearing anywhere or laser scanning. [...] None of these things exclude one another." - E12

In developing drones and their use in forests, the integration with other scanning and measuring techniques is essential. This way more extensive amount of relevant data could be utilized to support economic, social and environmental sustainability and goals. Combined with previously collected data, drone imaging could offer more focused and effective monitoring of forest areas to prevent damages and improve sustainable forest growth. Besides traditional techniques, drones support renewing the current practices by offering faster response and preventive actions with accurate and agile aerial imaging.

> "Real-time, agile tracking flights could be one (solution) to map in snow and wind damages, where lots of wood have fallen, and which are favorable for bark beetles. Damaged areas are cumbersome and dangerous to map in the field, [...] very clumsy, slow and expensive." - E11b

Furthermore, by having accurate data gathered from the air or in the terrain, the individual retention trees can be mapped effectively with a drone image. With versatile knowledge on the forest area and the environment, the forest owner or company could choose the most optimal tree groups to be spared in a forest operation. Additionally, birds of prey are important for the ecosystem and supporting the environmental sustainability for which mapping and saving their nests can be beneficial aspect in forest management.

> "If the forest is photographed before harvesting, then it be can reviewed from the viewpoint of biodiversity. [...] Old and heavy aspens are excellent, so a location information can be given to individual trees and lock these trees so that they will not be logged. [...] The nests of birds of prey can be seen from above, so to save these, and [...] at least the landowner can be informed on these." - E11b

As a whole, forest services can be enhanced by providing valuable information on certain characteristics of the forest area and viewpoints regarding sustainable forest management. With more extensive knowledge, forest owners are able to make more focused decisions and manage their assets based on specific goals. Similarly, easily available and cost-effective mapping methods are can support forest industry and forest companies to assign actions while sustaining competitive position on the market. Since the environment budgets are not easily increased and they are possibly reduced due to the market situation, drone solutions allow sufficient and targeted activities for environmental monitoring.

> "The budgets available in the forest industry, at different mills, environmental budgets, in particular, seem to be more downward than upward. Drones allow relatively inexpensive measuring and mapping operations to produce sufficient data." - E03

Having drone-based images and measurements included to forest services as default component, forest owners and companies could review more thoroughly the applicability, necessity and success of forest operations.

Second, from social perspectives drones will be useful in creating new services to visit forests and solving problems in forest management and planning. From this perspective, the emphasis is on interaction and achieving specific goals by utilizing drone IS artifacts for which tools and platforms for collaboration are essential. Moreover, to motivate people and provide useful information flexibly, solutions for forest gamification are being reviewed and developed in forest industry. To facilitate activities and services to visit e.g. historical sites, improve well-being and offer new leisure possibilities in forests, drone-assisted images and measurements could be applied in versatile platforms for planning different purposes of forest use. With a comprehensive digital model, this kind of service planning can be optimized in order to find the most suitable locations and protect the most vulnerable areas. Thus, environmental sustainability can be improved by sharing relevant information about forest ecosystems for customers or making preserving actions to maintain or recover the current natural conditions in certain areas. Overall, having a working digital model on the forest, the operations can be planned and allocated precisely. Therefore, the damages forest machines produce on the terrain could be minimized and the operations could be focused only on specific trees and areas.

> "The authentic nature experience is not meant to be replaced, but maybe the machines do not need to rumble as much in forests if everything could be optimized well in the digital model." - E09

However, there are not several or easily available drone products or solutions on the market which would enable wide-ranging development of different forest services. Having clearly stated and promoted information about prices, functionalities, contexts and restrictions of a specific drone solution, both forest companies and private forest owners could acquire practical products and services for their requirements and needs. Since efficient use of drones requires expertise of various phases and activities, solutions including data collection, management and interpretation would be beneficial to ensure the quality of forest work and support environmental sustainability.

> "In classical, or when talking about remote sensing, the interpretation, it is the most challenging and what produces the usability and the product." - E01

A significant development goal in utilizing drones, is to establish an operational platform for transferring and employing the collected data successfully in production. Accordingly, business processes should be reviewed and modified to facilitate drone imaging and measuring in daily operation. Managing and employing this sort of digital and integrative chain would enable creation of profitable forest products for different customers and contexts.

> "We need to develop this chain to make it even faster [...] to get a drone pretty fast there, whether it is imaging or laser scanning material, so we would have this chain ready so the information would be gathered, processed and then a complete plan would be created." - E08

Developing drone solutions promotes social interaction among and between different companies and people within forest industry. Applying drones requires in-depth knowledge and skills, which motivates for collaboration and thus combination of versatile capabilities. This way, new and effective processes and applications can be generated to improve profitability, social well-being and environmental sustainability.

Third, considering technological development perspectives, automation, robotics, artificial intelligence and upgraded technical devices for drones will be necessary to establish environmentally sustainable solutions in forest industry. Longer flight and operation time will be achieved with hybrid drones using batteries and combustion engine, which can be viewed as a compromise if observing the overall environmental impacts. In general, realizing all the technological capabilities and using drone as a multipurpose platform necessitates that the organizational processes and technical components are integrated effectively, and sufficient data transfer competences are deployed.

> "If all these blocks and processes are in order and 5G networks are in use, then in principle, almost real-time data can be analyzed and created with a very short delay." - E02

This enables utilizing drones within versatile systems by modifying digital and physical solutions flexibly for specific purposes. To develop operating and profitable solutions, having powerful data management procedures is essential.

> "A pipe from drone-generated information to different information systems must be built. [...] The information produced by drones goes into some kind of processing pipe, and from there such information is produced, which can be directly used in various information systems." - E04

In refining the gathered data for different needs and use contexts, automated and secure processing is required. Without effective processing capabilities, all the potential benefits cannot be obtained. If already collected and applied data from a particular forest area is not sufficient for other purposes, the area must be mapped again, which would create excessive costs and delays. Above all, drones can produce large amounts of accurate data on forest, and in order to use the collected data, automated data processing and refining functions have to be in place.

> "Drone produces remarkably accurate data reaching the level of individual trees, then the amounts of data become quite large and a one threshold question is the automation of data processing." - E04

Compared to photogrammetric imaging, Light Detection and Ranging (LIDAR) will allow more thorough and accurate measuring also in difficult lighting conditions. LIDAR technologies are seen as potential options in mapping forest areas and creating forest inventories.

> "LIDAR has a higher penetration ability, [...] which makes it easier to find the ground. But the photogrammetry, it is very sensitive to the undergrowth or growth, and then it is harder to say where the real ground goes there." - E12

> "If and when it develops, it allows year-round filming so that forest inventories can be done also in winter. Or at least during the leafless period, if not with a terrible snow cover." - E07

However, the current LIDARs suitable for drones are low powered for which they have to be used and flown at lower altitudes of about 40 to 50 meters. Since the operation time in drones are limited, lower altitudes reduce even more the overall output being able to complete with drone-assisted mapping. Also, the few LIDARs that could be used successfully are costly at the moment. Due to these restrictions, productivity and cost-efficiency cannot be attained and thus current LIDARs are not generally used in production.

> "It is just so expensive right now, there are cheaper LIDARs on the market, but their accuracy is not sufficient." - E12

Drone operators are waiting for more powerful and cheaper LIDARs which can be flown at the normal drone altitude in order to enable practical and cost-efficient operations. Without these improvements, LIDAR technologies are not yet competitive or reasonable in drone use.

Along with automated capabilities in interpreting the collected data, applications based on artificial intelligence, robotics and machine vision can be included in drone imaging and measuring. To check and monitor certain indicators or areas in forests, machine can be more thorough and productive than human as sensor technologies become more accurate and effective.

> "Machine vision, automatic scanning and automatic functions and then artificial intelligence in the background, if compared to traditional methods, drones allow a lot of automatic functions which are currently checked by people." - E05

In general, similar technologies and devices are used in drones as in other aerial survey methods. Nevertheless, when the legislation facilitates utilizing the latest technological advancements, drones are worthwhile platforms for deploying automated activities and processes in forest industry

> "If the legislation develops, there will be some automation. [...] The technologies used in sensors and data processing are mainly the same as those used for the interpretation of airborne remote sensing data." - E04

Many different technological devices and sensors can be attached to a drone for collecting specific type of data. The flight altitude, payload, operation time, legislation and yet too expensive equipment affect the development of drone use technologically.

Finally, assessing development possibilities from the informational perspectives, drones contribute assembling valuable forest inventory and making more focused decisions based on actual and detailed information. One of the most suitable and beneficial drone-assisted applications would be situational awareness systems at industrial areas.

> "Situational awareness systems or the like will be evolved, and automatic information will be received." - E05

These systems could integrate automation, artificial intelligence and machine learning capabilities to measure more efficiently and provide critical information for decision-making. Especially, drone imaging combined with effective data processing, real-time visualizations could be generated.

> "Visualization is a bottleneck these days, no one has yet built information systems that can visualize changes right away." - E02

Thus, changes in productivity or emissions can be monitored more accurately and appropriate actions to maintain or improve production can be conducted. When all the collected data is managed within a data storage or a digital model, effective analytics and machine learning algorithms could be applied to explore novel opportunities or innovations in improving environmental sustainability.

> "With such powerful, intelligent algorithms, we could also quite well [...] discover, design, or find ways to do things intelligently and in a way, to optimize as well from a sustainable development perspective." - E09

With accurate, real-time and extensive digital models, the entire production and supply chain in forest industry could be understood comprehensively. Consequently, these sensemaking possibilities facilitate digitalization of versatile contexts in forest industry and for its customers.

> "The better the production plan information could be communicated to the beginning of harvesting, the more optimized we are able to use the forests. [...] The whole supply chain to the customer, there is a lot of digitalization and finally recycling back" - E09

Ultimately, pervasive, focused and proactive digital solutions for managing the entire production and supply chain can be established by applying and sharing drone-collected data throughout the forest industry systems. Therefore, environmental sustainability and sustainable development can be supported by logging only the necessary amount of specific raw material for production. Loss and waste would be minimized already in harvesting as well as in monitoring the production processes with real-time and drone-assisted situational awareness systems. In that case, resource efficiency would be enhanced extensively with more traceable and manageable production.

> "The dream is [...] to basically know the chain digitally through. When a certain tree is standing in the forest, we would then know to which end product any part of that log eventually ends up. It would be in complete control meaning we should have this kind of traceability through the chain." - E09

As a whole, drones as IS artifacts promote information sharing in forest industry and developing novel solutions to support environmental sustainability. This can be accomplished directly by improving decision-making in forest planning, conserving and regenerating forest areas and reacting to or preventing harmful changes in forests and production. Indirectly, environmental sustainability can be achieved by developing real-time, automated and proactive systems that are capable for effective analytics and self-learning, which enable optimizing resource efficiency and productivity in forest industry. Drones enable applicable solutions and practices in forest industry, but all the opportunities are not yet realized or perceived. As a whole, the potential developments delineated in this section are summarized and described by their focusing areas into Table 7.

TABLE 7 Potential drone developments in forest industry solutions

Development focus	Description	Examples
Forest industry	Generating valuable solutions by combining drone imaging, versatile monitoring techniques and diverse data sources into digital platforms	• Visually and clearly assessable forest products and services • Customer involvement in production and development • Agile field practices • Saving new types of information on forests
Forest management and social experience	Discovering beneficial options for forest management and use with digitalized and extended knowledge	• Forest operation optimization with realistic digital models • Efficient platforms for collecting, transferring and interpreting the data • New opportunities for recreational use • Collaboration and gamification platforms for learning and sharing knowledge
Technological capabilities	Utilizing the latest technological improvements to enhance performance and capabilities of drone solutions	• Real-time forest data analysis by 5G networks • Automation, robotics, AI and machine vision abilities in collecting, processing and distributing the data • More accurate and year-round operations with LIDAR
Information management	Accelerating and increasing the utilization of knowledge with focused, pervasive and proactive solutions	• Situational awareness systems • New insights by visualizations, intelligent algorithms, AI and machine learning • Digital management of the entire supply chain and production

In forest industry, drones can become multifunctional tools and IS artifacts in delivering forest-based services and products for diverse customers and use contexts. Drone use is yet in its early stages, but practical solutions are continuously emerging. Typically, the first forest industry applications are developed by having objectives on increasing profitability and resource efficiency. However, as the market evolves and available services and knowledge develop, more advanced applications can be generated to promote social well-being, biodiversity and thus environmental sustainability with forest-based solutions.

5.2 Drones as IS artifacts for environmental sustainability

As defined previously in this chapter, the social, technological and informational elements of using drones facilitate supporting environmental sustainability in the contexts of forest planning, production, ownership and environmental governance. By developing and deploying effective drone IS artifacts, organizational sensemaking and sustainable practicing affordances and valuable functionalities related to them can be achieved in order to minimize negative impacts and establish environmentally sustainable practices. Conversely, challenges regarding safety, market situation, institutional pressures, unsatisfactory devices or inadequate organizational processes decelerate cost-efficient and useful implementations. First, for creating the primary requirements for constructing a new model on drones as IS artifacts, the features within the applied theoretical framework, their relevance and associations based on the practical insights from the conducted interview study are discussed. Second, a novel framework modeling drones as IS artifacts supporting environmental sustainability is composed and itemized by its combined structures and affiliations.

5.2.1 Empirical insights on the theoretical framework

The employed theoretical framework consisted of four distinct stages with specific perspectives affecting green IS adoption and eventually environmental performance. In the framework, macro factors of coercive and mimetic pressures had a joint impact on the micro or belief-related factor of attitude. Then, the attitude with, another micro-level factor, consideration of future consequences affected the actions of pollution prevention, product stewardship or sustainable development, as in the strategic capabilities of NRBV. Finally, these capabilities contributed to green IS adoption that enabled environmental performance. (Gholami et al., 2013.)

As the theoretical framework was utilized as a guiding tool for the empirical investigation and interviews, it offered useful approaches to consider during the data collection, analysis and interpretation. However, the framework as a research lens turned out to be too concentrated on the perceptions of institutional pressures, attitude and strategic capabilities to adopt green IS. Providing quite general, widespread and straightforward viewpoints, the theoretical framework performed well in studying comprehensive ideas, effects and possible connections to examine drones in forest industry solutions. In addition, reviewing the attitude and consideration of future consequences on green IS adoption, the framework enabled general discussion when studying restrictions and experiences of drone use and deployment.

During the interviews, the focus of the study was refined continuously as it developed more practical and detailed based on versatile solutions and action possibilities. Therefore, the initial theoretical framework could not be adapted thoroughly with the collected data to support analysis and creation of findings.

Although the institutional pressures, attitudes and future considerations were important aspects affecting drone utilization, it would require more individuals or organizations to participate in order to conduct a comprehensive cross analysis and gain valuable results on how these factors advance or reduce green IS adoption and environmental performance. Quite similarly, the applied framework did not offer an outlook of constructs or relations on activities which would support outcomes regarding environmental sustainability. Moreover, the view on green IS solutions and their potential capabilities are not delineated distinctly in the framework as its objectives and advantages are founded on structuring and describing the relations and effects between macro and micro factors, top-level actions and combined environmental performance.

Since the aim for this study is to investigate drones as integrating IS artifacts including social, technological and informational components in forest industry solutions and to discover their use possibilities to support environmental sustainability, the applied theoretical framework has to be modified for this purpose and, in fact, an entirely new one must be developed. By utilizing its overall structure, objective and function of adopting green IS, the initial theoretical framework contributes beneficial concepts for the new model.

In formulating the new applicable model, the perception on drones as IS artifacts constitutes the main foundation and lens for framing the selected entities, interactions and options comprehensively. Providing a connection between strategic capabilities and green IS solutions, the NRBV offers practical constructs to review and combine organizational resources, processes, goals and behavior in order to facilitate environmentally sustainable outcomes. With the strategic capabilities, the eco-goals as a preliminary specification of organizational orientation categorizes clearly the resource-related decisions which impact the elaboration of particular strategic capabilities. To consolidate the relation between these capabilities and environmental sustainability based on the generated findings, the model on action possibilities as in functional affordances is attached to the developed framework. Because the institutional pressures were not observed as influential components as in the initial framework, they are linked as generally affecting limitations to utilizing drones, as outlined within the findings. In addition, the activities of exploring new business possibilities and improving drones as IS artifacts are merged into a drone-related development function as a contributing factor in the new model.

The theoretical framework directed the research process flexibly by offering an outlook towards the studied context, data collection and analysis. Being a quite universal and simple instrument, the framework provided helpful perspectives to consider in planning, conducting and improving the interview procedure. Furthermore, by incorporating multiple theoretical constructs as an application for empirical research, the applied framework supported efficiently the assessment and connection of the discovered findings with these concepts and relations, which enabled the development of a new model founded on the empirical observations.

5.2.2 Constructing novel framework

To accomplish environmental goals in supporting eco-efficiency, eco-equity or eco-effectiveness in forest industry, diverse factors and perspectives must be taken into account when exploring and deploying drone capabilities. Both internal and external variables affect utilization of drone-assisted measuring and monitoring methods, since the available skills, technologies, resources and current legislation have a major influence on employing and developing drone solutions. The comprehensive rationalization based on the expert interviews and theoretical foundations is composed into Figure 6. The arrows from left to right represent successful decision-making, behavior and actions towards more environmentally sustainable business operations and activities.

First, when considering drones as IS artifacts, they can be employed in forest industry to support environmental sustainability by effectuating a particular eco-goal into the business and operational objectives and processes. In the figure, the magnifier is used to depict the overall consideration of drones as IS artifacts. For visualizing the elaboration and integration of eco-goals with the organizational goals and processes, the triangle as a funnel filtering and harmonizing these activities is illustrated in the figure.

Second, by aiming for the eco-goals and integrating organizational resources, skills and knowledge or forming collaborative company relations and networks with the appropriate capabilities, drones can be adopted for enabling strategic capabilities of pollution prevention, product stewardship or sustainable development. In the figure, the adoption process of drones as IS artifacts is outlined as a rounded box. This process and justification within organization can be founded upon activities towards the strategic capabilities that are depicted with normal, sharp-edged, boxes.

Third, in gaining the functional affordances, the limitations regarding drones are restricting and reducing the potential benefits. However, by developing novel applications focusing on social, technological or informational artifacts, the restrictive effects can be mitigated, and new solutions and opportunities will be produced. Hence, the arrows from limitations and development affecting the arrow of decision-making and actions towards functional affordances. Also, the pentagons of drone development pointing right and drone limitations pointing left represent these supporting and restricting impacts, respectively.

Fourth, as the strategic capabilities of using drones are deployed effectively within the organizational and business processes, the organizational sensemaking and sustainable practicing affordances and the corresponding drone functionalities can be realized. In the figure, the rounded box illustrates the functional affordances as process regarding organizational behavior, activities and applications. These diverse aspects can be structured with the theoretical understanding on organizational sensemaking and sustainable practicing, as grey boxes in the figure, and the specific affordances, as white boxes inside the grey ones, which can be achieved by effective application of drones as IS artifacts. Although these theoretical viewpoints are quite thorough in perceiving the possible functional affordances, there can be also other action and use possibilities and their combinations that are not yet distinguished within IS research.

Finally, due to the dynamic and successful application of a single affordance or multiple affordances, environmental sustainability by preserving or improving biodiversity, nature's resilience, sustainable growth and the entire ecosystem in forests can be supported. Besides environmental characteristics, sustainability concerning economic performance and profitability, social and societal well-being and historically invaluable locations and objects in forests can be contributed.

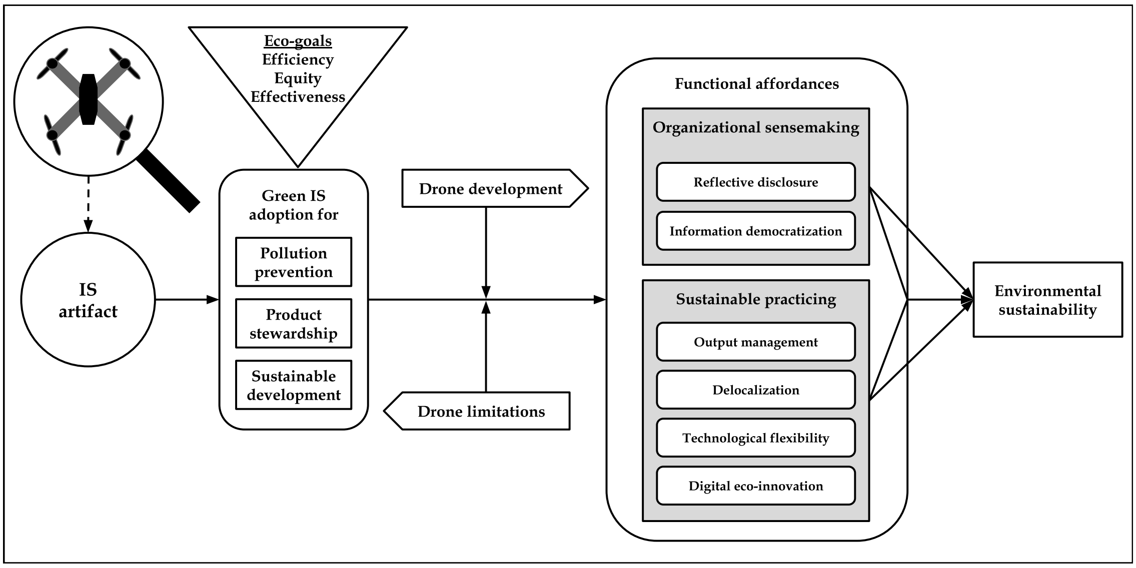

FIGURE 6 Drones as IS artifacts supporting environmental sustainability

With operative, flexible and collaborative company networks founded upon sharing knowledge and advancing competences throughout the drone-assisted data gathering, processing and applying, valuable resources can be integrated to enable pollution prevention, product stewardship and sustainable development in forest industry.

Utilizing the full potential of drones requires thorough planning and motivation within the organization. Although objectives and intentions based on environmental sustainability could encourage companies continuing to apply drone operations, the financial and competitive advantages of drone use are the first and foremost objectives to pursue. Nevertheless, the environmental factors and sustainable development are perceived as significant principles which must be managed thoroughly and systematically. The participated experts from forest and drone solution companies and public organizations underlined the long-term and comprehensive impacts that forest resources have on the entire economy, society and nature.

Drones can be practical tools in exploring better options and useful opportunities for improving processes and work practices. As IS artifacts, reviewing the social, technological and informational components offer beneficial perspectives to manage and develop capabilities, limitations and possibilities. These aspects combined with environment-based and forest-specific characteristics and the connections with functional affordances, applicable solutions for environmental sustainability can be evaluated, generated and deployed within forest industry context. With accurate, digitalized and shared knowledge on forests, individuals and organizations are able to make more exact and successful decisions, plan forest use based on their needs and discover preferable applications in order to achieve business objectives and advance environmental sustainability.

5.3 Answering the research questions

Since the research focus in this thesis was to study how drones can be used as IS artifacts and how drone solutions can support environmental sustainability in forest industry, answering these questions is based on describing the mechanisms which enable, advance and limit the causal relations within this specific context. Understanding the dynamics between different capabilities, restrictions and opportunities related to drones as IS artifacts and the research context, potential synergies and improvements can be identified and developed. By reviewing the existing green IS literature and potential research contexts, significant research gaps were identified. These different needs were specified into research questions of (1) how drones can be applied as IS artifacts in forest industry and (2) how environmental sustainability can be supported in forest industry by utilizing drone solutions.

First, specific use contexts, capabilities, restrictions and potential developments related to drones as IS artifacts were recognized and described based on the expert interviews. Drones are employed for activities related to forest planning, production, ownership and environmental governance. Within these contexts, using drones as IS artifacts facilitates capabilities based on organizational sensemaking and sustainable practicing. Nevertheless, limitations related to safety, availability, regulations, opinions, knowledge, technological components and information management must be resolved to reach the full potential of applying drone IS artifacts. Hence, several ongoing and upcoming improvements are expected, which will enable versatile social, technological and informational abilities within drones and drone-based applications.

Second, to understand the dynamics of utilizing drones in forest industry solutions, the constructed new framework outlines particular opportunities, phases and objectives, which must be implemented successfully to support environmental sustainability. Precise environmental goals must be deployed thoroughly to recognize valuable strategic capabilities when employing drone IS artifacts within a specific business context. These capabilities have to be refined systematically and individually to prevent the negative effects of possible limitations regarding drone solutions in forest industry. Facilitated by developing drone IS artifacts and capabilities in collaboration, functional affordances as in organizational sensemaking and sustainable practicing can be achieved. Eventually, as these affordances are managed, integrated and developed proactively within organizational processes, environmental sustainability is supported and contributed by drones as IS artifacts.

6 DISCUSSION

Establishing a green IS by merging effective capabilities strategically and utilizing drones as IS artifacts within flexible solutions provides operational foundation for realizing environmentally sustainability in forest industry. To review the significance of the obtained findings of this study, relations with the research questions, existing studies and practical applications are investigated in this chapter.

6.1 Theoretical implications

This thesis contributes to the existing research literature by responding to the need for more practically oriented green IS studies and providing empirical findings based on integrated disciplines and theoretical models. In addition, this study reveals how a relatively new application can be reviewed as IS artifact and how it can be employed within a traditional industry and its processes to achieve not only economic and social objectives but also environmental sustainability.

It was expressed in the IS research community that more solution-based, creative and effectual studies combining various theoretical lenses and research subjects are needed for realizing the potential benefits of green IS in enhancing business transformations (Malhotra et al., 2013). For this demand, this thesis provides useful knowledge on the domains of forest and drone industry and how utilizing drone solutions can result in positive environmental sustainability outcomes. Climate change and degradation of natural environment are one of the major issues in global economy at the moment and, for solving these challenges, different operations and disciplines must be developed and integrated. Combining the existing concepts and findings from green IS and organizational research with drone applications in forest industry, this study offers solutions to utilize green IS approaches, business and environmental objectives and drones as IS artifacts for transforming organizational processes, practices and behavior and to support environmental sustainability. Likewise, the restrictions and opportunities regarding social, technological and informational aspects of drone solutions in forest industry are reviewed, which constitutes a beneficial foundation for further studies on drones, IS artifacts, environmental solutions and green IS domain.

In reviewing research as a framework, the motivating forces, initiatives, emphasis, effects (Jenkin et al., 2011) and integration between activities related to environmental sustainability (Ryoo & Koo, 2013) are key entities affecting within research studies on green IS. These different aspects were evaluated during the theoretical and empirical investigation as they are useful starting point in both taking all relevant factors into account and outlining the specific green IS research. Correspondingly, the organizations' learning, developing and innovating capabilities to generate environmentally sustainable processes and solutions, as defined in eSITP instrument (Molla et al., 2011), were assessed when creating the interview procedure and analyzing the collected data.

From a qualitative research perspective, it is thus necessary to form, articulate and manage as clearly and practically as possible how and why the green IS-based study will be performed. Despite being a popular and trending topic, environmental sustainability and actions for supporting it can be overly conceptual and ambiguous. Hence, having a solid foundation for qualitative inquiry, e.g. structured or semi-structured interview form and effective practices for data analysis, is needed for delineating the research focus, applying versatile perspectives, gathering pertinent knowledge and discovering answers for the research problem.

Furthermore, when considering the generated findings and the research process entirely, the BAO framework by Melville (2010) provided useful standpoints on micro and macro levels to distinguish how different environmental beliefs and desired outcomes are related to certain individual and organizational actions. Such framework is applicable in exploring relevant research topics and potential gaps and, also, examining real world solutions, conditions and behaviors in the context of information systems and environmental sustainability. Applying BAO, this thesis offers insights from forest industry to consider beliefs, actions and outcomes in supporting environmental sustainability with drone solutions. As defined in findings, the various contexts regarding environmental sustainability and drone use were described, as in beliefs and organizational and societal structures on micro and macro levels. Then, drone capabilities, restrictions and developments delineate action possibilities for both specific and organization-wide drone IS artifacts, which can enable changes within organizational processes or social systems to support positive environmental outcomes.

In evaluating the relevance of the applied perceptions and models, theories based on organizational goals and institutional mechanisms as well as theories conceptualizing IS abilities and possibilities constructed a relatively flexible research lens for focusing the empirical investigation in practice. To understand specific functions and their benefits, the strategic capabilities defined in NRBV (Hart, 1995) can be employed as a simple classification for diverse drone-based operations in forest industry. Similarly, eco-goals and institutional theory are convenient in characterizing complex social, economic and environmental dynamics, but these types of simplifications can be also too limiting for planning, conducting and managing a green IS research project. Thus, empirical data criticizing and not fitting into any of these models should be considered as well for developing more suitable insights on the context of green IS, forest industry and drone solutions.

This study offers empirical understanding on the sensemaking and sustainable practicing affordances of IS (Seidel et al., 2013; Hanelt et al., 2017) to identify, evaluate and facilitate organizational processes and practices within environmental sustainability transformations. With the social, technological and informational components of the IS artifact (Lee et al., 2015), both IS-based and organizational capabilities, opportunities and limitations concerning drones as IS solutions can be recognized and described thoroughly. As many of them are hidden, overlapping or indirect in their essence, all the organizational and IS-related mechanisms cannot be understood to enable successful decision-making or qualitative study. Hence, having a coherent and systematic empirical approach fosters exploring complex relations, dimensions and attributes on the IS-based activities in organizational context.

Constituted on these theoretical foundations and empirical findings, the model of drones as IS artifacts supporting environmental sustainability (Figure 6) outlines the diverse options, goals, factors, actions and possibilities, which must be evaluated and controlled in order to gain environmentally sustainable outcomes by using IS artifacts. Besides drone solutions in forest industry, this conceptualization suggests noteworthy considerations and research interests also in other contexts. For instance, other industries, private or public organizations or company networks aiming towards more environmentally sustainable processes enabled by developing new IS-based solutions, integrations or competences can acquire beneficial viewpoints and action possibilities from the model. Moreover, developing and specifying this theoretical perception on the environmental sustainability progressions and transformations necessitates further qualitative, quantitative and applied investigations.

Because the applied theoretical framework and perception was both simple and practical enough, the excessive complexity of findings was avoided. Hence, operational insights for distinct use contexts, capabilities, restrictions and development of drone solutions were produced. Dividing the semi-structured interview procedure into a few categories created a firm and understandable structure for the interviewees to participate, review and share their experiences and opinions, and discover potential new ideas and improvements on the topic. Furthermore, a functioning interview protocol and structure facilitated effective data analysis. As a matter of fact, employing the techniques of open, axial and theoretical coding by Corbin and Strauss (2008), as instructional practices, endorsed thoroughly not only the data analysis but also planning and executing the entire empirical investigation.

6.2 Practical implications

As the research context was based on drones as IS artifacts in forest industry and their capabilities and opportunities to support environmental sustainability, the findings of this thesis contribute, particularly, to the development of forest industry planning, processes, methods and decision-making. Next, these implications and opportunities for practical applications are evaluated based upon the stakeholder categorization established in Table 8.

As a whole, customers in forest industry can become more aware and interested in managing their forest assets with emphasis on sustainability. However, it is not often clear which choices and actions are the most suitable to support sustainability when planning and purchasing forest products and services. Applying the proposed model, forest industry customers can review alternative economic, social and environmental objectives, and drone capabilities supporting them, to make more focused decisions based upon accurate data collection, integrations of organizational abilities and effective collaboration. Despite large forest corporations have a major effect on the nature by their production, customers and individuals who deliver the required resources or acquire and use, directly or indirectly, products related to forest industry can also evaluate and support environmental sustainability through their choices and actions. To reduce the ambiguity in planning and supporting environmental sustainability from the standpoint of forest industry customers, the generated findings and model can be applied to develop transparent and multisided digital platforms for sharing information on drone-based operations, solutions and opportunities in forests. By using the findings for a dynamic and collaborative platform, customers can get relevant information on forests more openly in order to purchase and manage services related to forest industry. In addition, individuals and companies can get interested in cooperation and business development opportunities with other companies as valuable information is being shared openly within an expert community.

With the findings specified in this thesis, forest owners can assess their needs, requirements and objectives when considering drone imaging as an applicable alternative for measuring and monitoring forests and supporting environmental sustainability. At the moment, drone solutions for forest management are not easily available and merely upcoming to the markets. Therefore, it will be useful for forest owners to try drones themselves or learn more about different use contexts, applications and potential capabilities of drone-based monitoring and mapping solutions. Especially, when obtaining forestry services or products, all the details, outcomes and scenarios cannot be viewed beforehand distinctly. In this case, information on available drone solutions, before and after images, simulations and accurate data on forest operations are beneficial for improving forest management and implementation of forest operations. Thus, the findings contribute valuable perspectives to consider when revising the planning, methods and control of forest work enabled by precision mapping of drone solutions. By developing and adopting generally approved and standardized practices on the market, forest owners, whether they are conducting the operations themselves or not, are able to create more precise and applicable requirements, manage their assets systematically and explore new options to utilize and conserve forests.

Among forest industry companies, these findings can be employed comprehensively when evaluating potential drone IS artifacts in supporting forest production, planning and resource management, particularly from the viewpoint of environmental sustainability. At the moment, forest companies are piloting and testing drone-based services before deploying and launching them for production and customers. Besides forests, some drone applications are used at factory sites for maintaining and monitoring resources, infrastructures and safety. Based on this thesis, opportunities, synergies and gaps within these different domains and actions can be observed to enhance capabilities of drone-assisted activities. Overall, by integrating and reconfiguring internal and external competences (Teece et al., 1997) and creating market change by novel assemblies of resources (Eisenhardt & Martin, 2000), drone solutions have potential to become adaptive platforms and dynamic capabilities for various business processes of forest companies, if they are implemented and operated proactively. As business operations are becoming more and more digitalized, drone-assisted processes in forest industry facilitate accurate, transparent and real-time management of supply chain and production. By enhancing resource efficiency throughout the industrial processes and establishing activities for environmental tracking, forest companies can eventually support sustainable development by the digitalized options of drone solutions. Therefore, the extensively collected data can be gathered to optimize different activities, learn valuable insights and generate new applications by using, for example, data analytics, machine learning or artificial intelligence.

Furthermore, in reviewing the environmental budgets and allocating resources for environmental operations, drones as flexible tools for accurate monitoring and measuring can be evaluated well with the findings of this study. Besides more conventional field measuring, airplane mapping or satellite imaging, drones as IS artifacts provide practical alternatives to examine, manage and analyze forests, land areas, waterways, flora and biodiversity. Based on the findings and proposed model, organizations can also consider the pressures regarding the competition and legislation, for which they can begin to acquire relevant experts, knowledge and resources and form functioning company networks with necessary partners. With the findings, forest companies are able to concentrate their development activities on specific resources, capabilities or dimensions within their operations, which will assist the improvement, deployment and adoption of drone solutions to support environmental sustainability in their organizational processes, practices and behavior.

For drone operators and drone and IS solution companies, this study offers a holistic framework for planning, implementing and deploying versatile drone solutions and supporting drone applications in forest industry. Drone consulting companies can employ the findings to explore the most essential capabilities, tackle probable restrictions and improve practical applications by combining and supporting necessary IS solutions, business processes and practices within development projects. For drone operators it is crucial to create cost-effective and functioning partnerships with other operators and companies having distinct capabilities in order to gain customers, provide services and achieve projects successfully. Therefore, the findings are beneficial for perceiving the forest industry domains in detail, creating new business possibilities and discovering associates to share applicable resources. Using the model, drone solution companies can evaluate the action possibilities and business potentials to manage forest industry projects for environmental sustainability. Consequently, drone solution companies can concentrate their research and development activities on the revealed challenges and capabilities of drones in order to build competitive platforms and functions for various operations and future opportunities.

Although some difficulties related to drones cannot not be resolved without extensive technical and legal improvements, well-functioning data processing, accessible and extensible drone solutions, resource-efficient and nationwide operations and flight and imaging abilities need to be advanced from an IS standpoint. Based on the presented findings and model, IS solution companies can discover new ways and alternatives to map, control and support certain phases and activities in forest industry solutions, thus improving sustainability indirectly. Especially, these insights can be applied to detect the most significant stages and relations to ensure and improve the data quality, integrations and performance of various systems. By utilizing the perception on data and applications, IS companies are able to explore new possibilities to collect, combine and analyze data from various sources within drone-based forest industry solutions. In addition, intelligent components can be developed and added into different phases of processes and operations to contribute all-inclusive data collection and visibility. Hence, valuable drone applications for prominent economic, social and environmental needs and objectives can be implemented.

From the standpoint of public governance, the findings reveal domains to emphasize various activities concerning environmental, forest and financial regulations and to improve nationwide controlling. Since public organizations are major entities in providing open data on forests, gathering and sharing accurate and current drone-based images on various open platforms can encourage forest owners, customers and companies to review and support environmental perspectives more thoroughly. By establishing extensive and detailed information on forests into open digital platforms which could be also filtered and exported to other systems, individuals and private and public organizations would be able to explore new ways and solutions to benefit from forests in a sustainable way and promote economic, social and environmental values. As this thesis offers multiple approaches, applications and possibilities on using drones both in forest industry and other domains, the findings can be evaluated to delineate drone-related regulations, guidelines and requirements more precisely. To assist business, health and safety and hobby aspects related to drone use, appropriate policies for funding, training and controlling drones and drone industry must be developed on national and global level by governments and public organizations. For this effort, the model on drones as IS artifacts as well as the presented findings offer wide-ranging and systematic perception regarding forest operations, business processes and environmental sustainability.

These factors must be taken into account in legislation by considering thoroughly how drone solutions enable useful and unprecedented possibilities, what are their downsides in different contexts, and how various operators and operations can be both facilitated and regulated successfully.

Establishing and utilizing drone solutions in forest industry to support environmental sustainability requires diverse expertise, dynamic capabilities and proactive business processes by integrating social, informational and technological competences effectively. Due to these requirements, it is extremely difficult and almost impossible for a single company or public organization, not to mention an individual, to obtain and combine them successfully. Moreover, since forests as ecosystems and business contexts are distinctive and influenced by different conditions, the gathered knowledge base and the most suitable methods are constantly evolving and yet partially insufficient. Therefore, cooperation projects, training programs, partner networks and commonly accepted standards are needed to achieve all the benefits of drones as IS artifacts. As a whole, the findings are valuable for creating and encouraging such applications in forest industry and other contexts by offering a holistic model and practical constructs as foundations and starting points for further development.

TABLE 8 Implications for appropriate stakeholders

Stakeholder	Problem	Solution based on findings	Explanation
Forest industry customer	Uncertainty in supporting environmental sustainability by direct or indirect market activities	Drone-assisted forest data platform for promoting collaboration among expert community	Sharing insights and experiences on drone operations to enable transparent forest service procurement and management
Forest owner	Ambiguous preparation, execution and control of sustainable forest operations	Proactive planning by drone-based monitoring and simulation solutions	Revising and standardizing forest work requirements, methods and management with precision mapping
Forest company	Insufficient budgets and market pressures reducing the importance of environmental sustainability	Digitalization throughout the business processes with real-time and detailed tracking by drone-assisted forest solutions	Optimizing the production and supply chain and promoting sustainable development with adaptable, extensible and cost-efficient drone applications
Drone operator	Inadequate resources to combine and process drone-collected data on sustainability indicators	Establishing operational drone company networks	Sharing valuable capabilities to tackle the restrictions of drone applications and to deliver competitive drone-based services
Drone solution company	Managing drone-based data collection and processing in forest industry projects	Building a customizable platforms and functions based on drone capabilities	Focusing on the capabilities of drones as IS artifacts and exploring options to resolve constraints
IS solution company	Gathering, integrating and refining drone-collected data across systems and processes	Improving integrations and data quality among different systems	Developing intelligent capabilities within forest industry solutions to gather, utilize and manage data efficiently
Public governance	Lacking resources for nationwide controlling of environmental legislations	Public platform including forest inventory, regulations, and available drone operators and services	Organizing drone-based forest data and assets, practical guidelines and local drone operators

7 CONCLUSION

To conclude the conducted research study and thesis as a whole, the developed findings on drones as IS artifacts and their abilities for supporting environmental sustainability in forest industry are recapitulated next. Likewise, the limitations regarding the implemented study and achieved findings are discussed, and, finally, prospective topics and areas for further research are evaluated.

7.1 Summary

Green IS research domain is constituted on the notion of minimizing environmentally harmful impacts and discharges and, possibly, supporting sustainability in business operations, processes and behavior with IS. In order to achieve environmentally sustainable outcomes, drones as IS artifacts, facilitating accurate, dexterous and flexible action possibilities, can be utilized in forest industry solutions to integrate valuable resources, develop new abilities and generate strategic capabilities. For employing the conceptual opportunities and benefits related to green IS paradigm, drones as both physical and digital platforms enable potential solutions to explore and combine pertinent social, technological and informational competences in endeavors regarding environmental sustainability.

7.2 Limitations

Although the various phases and activities were planned, executed and managed both systematically and carefully, the possible limitations concerning this study and its applications are investigated next. These potential obstacles are assessed from empirical and practical perspectives.

Empirically, it required several endeavors of demolishing, reorganizing and redeveloping the inclusive model on the findings. When proceeding from literature review towards interviews, the green IS adoption model by Gholami et al. (2013) was utilized as a directing instrument. Despite this model's applicability and convenience in observing adoption of IS solutions for environmental sustainability, an entirely new model had to be established from the very beginning to correspond with the context of this thesis. Combining different theoretical foundations, the novel and proactive model aims for delivering extensive insights and understanding on the topic, which could be considered also its weakness. Having only one, less complex, theoretical perspective might have offered more profound and representative knowledge on the studied phenomenon.

Since this research is based on qualitative and semi-structured interviews, the accuracy and relevancy of the generated model have to be estimated in future research. All the questions and open discussions during interviews cannot be measured or allocated to a particular construct and viewpoint. Thus, there could have been false interpretations or assumptions during the data collection and analysis, which could have led to inaccurate creation of themes, relations or dimensions in the model and findings.

Due to the positivist research philosophy having predetermined theoretical constructs and perceptions, some results on the examined real-life phenomenon may have been forced to fit into these demarcated conceptions. Nonetheless, generating and aligning the findings based on these existing concepts was quite flexible and progressive. Merely encompassing the institutional isomorphisms and pressures to the interviews and, eventually, into the established model was not realized as straightforward or adequate. A few opinions and experiences concerning these pressures were ascertained, but after the first couple interviews, direct questions on institutional pressures were bypassed as not relevant or suitable for the interview situation. Yet, some evident results and findings about restrictions and limitations of drones were addressed as influences of institutional pressures.

Practically, this study proposes lots of distinct possibilities, phases and activities which could result in supportive undertakings on environmental sustainability, if carried out successfully and effectively. The actual affirmative impacts achieved by these advised action cannot be either measured or distinguished rigorously, in general. Hence these findings should be regarded as encouraging and guiding prospects for developing and utilizing drone solutions and drones as IS artifacts and, especially, exploring profitable capabilities in order to support environmental sustainability. In addition, from the aspects of business environment, all the adversely affecting factors as in operation or project costs, insufficient or inappropriate resources, competition, industry-specific characteristics and legal perspectives were not evaluated in depth. These viewpoints were not examined thoroughly due to limited access to applicable sources having usable information and intention to reduce complexity regarding the research context and studied phenomenon.

To evaluate the collected data, conducting interviews in less than two weeks supported efficient data gathering and coherent interviewing. Conversely, learning the specific subjects and creating a wider understanding on the topic could have been more effective if the interview and analysis phases had overlapped with each other and executed partly simultaneously. During the research process, recognizing and conceptualizing the most significant contexts and their relationships was, however, possible later on. Since the technologies and applications used in drone solutions, forest industry and environmental governance include many detailed characteristics and relationships, both theoretically and practically, it required a diverse effort to comprehend and relate each perspective in order to conduct and manage an IS research study. In retrospect, having more substance knowledge on the topic beforehand could have contributed even more accurate and profound data collection and analysis.

7.3 Suggestions for further research

Green IS research has been conducted only for about 10 years, thus several different research approaches, phenomena, contexts and subjects should be applied to obtain valuable findings on using IS for environmental sustainability. When considering this thesis and its foundations, future studies about drones, IS artifacts, green IS capabilities and forest industry must be conducted by applying both qualitative and quantitative research strategies. Therefore, potential research goals and subjects are outlined next.

Since the overall possibilities of using drones as IS artifacts in forest industry were investigated within this study, it would be noteworthy to focus on a specific drone solution. Studying a single drone-assisted service for imaging, monitoring or measuring certain indicators in forest industry or other private or public context, the IS artifact approach would be also beneficial in describing, for instance, the impacts and relations of company networks, organizational practices, technological components, information management capabilities and business objectives. Moreover, IS research could be founded on integrating or assessing new innovations, technological capabilities or software development practices in generating novel drone-based solutions or processes.

For accumulating the understanding on the IS artifact approach in green IS domain, future studies could be concentrated on examining the social, technological or informational artifact of a certain IS solution functioning towards promoting environmental sustainability. Likewise, it would be beneficial to distinguish the economic or social sustainability aspects and how all these outcomes can be supported by IS. By perceiving the dynamics and mechanisms behind IS, organizational processes and practices more thoroughly, recognizing potential synergies, managing knowledge and capabilities, and creating valuable integrations would be more successful.

Correspondingly, to investigate the functional affordances and their influences in business transformations for environmental sustainability, further qualitative and quantitative studies on evaluating a single affordance or many affordances or comparing their effects would be significant. With a quantitative survey, the factors, causalities, relations and other possible variables could be estimated and explored concerning the functional affordances.

By exercising the proposed model of this thesis as a guiding framework, the critical factors within different phases for deploying an IS solution to support environmental sustainability can be inspected. The total impacts of costs, resources and business environment could be reviewed in order to tackle the restricting factors and improve organizational behavior, decision-making and control in green IS adoption. Furthermore, to measure the balancing effect of deploying and adopting a green IS solution, research on measuring the actual compensations and improvements by a green IS and appreciating alternative options or applications to support environmental sustainability would be essential. Since the climate change itself is unavoidable and has already took place, it will be necessary to investigate how IS capabilities and solutions can be employed for adapting to social, economic and environmental transformations caused by the changes in the climate and deterioration of the nature.

The value of green IS research is in compounding theoretical and pragmatic perspectives to generate inventive and advantageous insights to reduce negative and irreversible impacts and contribute positive and improving outcomes for environmental sustainability. Achieving empirical and practical perceptions on how environmental sustainability can be facilitated by IS calls for creative, solution-based and original research aspirations.

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APPENDIX 1 INTERVIEW GUIDE

A0) Taustatiedot *(Background information)*

1. Hyväksytkö tutkimuslupalomakkeen? *(Do you accept the research permission?)*
2. Mikä on nimesi? *(What is your name?)*
3. Missä organisaatiossa työskentelet? *(Where do you work?)*
4. Mikä on työtehtäväsi? *(What is your job position?)*

A1) Ympäristöllisen kestävyyden määrittely *(Definition for environmental sustainability)*

1. Miten määrittelisit ympäristöllisen kestävyyden?
(How would you define environmental sustainability?)

2. Kuinka tärkeä toimintaa ohjaava arvo ja tavoite ympäristöllinen kestävyys on organisaatiollenne? (0-5 -asteikolla: 0 = ei minkäänlaista merkitystä, 5 = organisaation toiminnan ja olemassaolon kannalta tärkein arvo)
(How important value is environmental sustainability for your organization? On a scale of 0 to 5: 0 = of no importance, 5 = the most important value for the organization's operation and existence)

3. Millaiset ympäristöllisen kestävyyden tavoitteet organisaatiossanne on?
(What kind of goals for environmental sustainability do you have in your organization?)
   a. Millaiset lyhyen ja pitkän aikavälin tavoitteet teillä on?
   (What kind of short- and long-term goals do you have?)
   b. Miten nämä tavoitteet saavutetaan?
   (How are these goals achieved?)

4. Mistä ympäristöllinen kestävyyden hallinta ja edistäminen muodostuu organisaatiossanne?
(How are environmental sustainability management and improvement created in your organization?)
   a. Mitä kokonaisuuksia tai osa-alueita siihen kuuluu?
   (What are their entities or components?)
   b. Miten strategianne tukee ympäristöllistä kestävyyttä?
   (How do your strategy support environmental sustainability?)

Q1) Droonien käytön tavoitteet *(Goals for using drones)*

1. Miksi drooneja käytetään metsäteollisuudessa? Mikä motivoi niiden käyttöön?
(Why are drones used in forest industry? What motivates for their use?)

2. Mihin drooneja käytetään metsäteollisuudessa?
(What are drones in forest industry used for?)
   a. Miten laajaa droonien käyttö on?
   (How extensive is the use of drones?)
   b. Miten helposti droonit on käytettävissä?

(How easily can drones be used?)

3. Millaisissa käyttökohteissa ja paikoissa olette hyödyntäneet drooneja?
(What kind of use contexts or places have you utilized drones for?)
4. Mitä droonit mahdollistavat metsäteollisuudessa ja ympäristöasioissa?
(What do drones enable in forest industry and environmental matters?)
    a. Mitä ne mahdollistavat verrattuna aiempiin menetelmiin?
    (What do they enable compared to previous methods?)

5. Mihin droonit eivät sovellu metsäteollisuudessa?
(What are drones in forest industry not suitable for?)

6. Mitkä ovat tärkeimmät kehityskohteet drooneissa?
(What are the most important development areas in drones?)

7. Mitä tavoitteita teillä on droonien hyödyntämiselle?
(What goals do you have for utilizing drones?)
    a. Mitä lyhyen aikavälin ja pitkän aikavälin tavoitteita teillä on droonien hyödyntämiselle?
    (What short- and long-term goals do you have for utilizing drones?)

8. Mitä tavoitteita teillä on droonien hyödyntämiselle ympäristöllisen kestävyyden edistämisessä?
(What goals do you have for utilizing drones to improve environmental sustainability?)

Q2) Droonien käyttöönotto ja käyttäminen *(Deployment and use of drones)*

1. Mitkä asiat vaikuttavat droonien käyttöönottoon metsäteollisuudessa ympäristöllisen kestävyyden edistämiseksi?
(What things affect the deployment of drones in forest industry to improve environmental sustainability?)
    a. Mitkä asiat edistävät tai rajoittavat droonien käyttöönottoa?
    (What things improve or limit the deployment drones?)
    b. Mitä haasteita liittyy droonien käyttöönottoon?
    (What challenges are related to the deployment of drones?)

2. Miten droonien käyttö soveltuu muiden tietojärjestelmien kanssa?
(How does the use of drones apply with other information systems?)
    a. Miten muut tietojärjestelmät tukevat tai rajoittavat droonien käyttöä?
    (How do other information systems support or restrict the use of drones?)
    b. Mitä uutta droonit luovat tietojärjestelmiin?
    (What new do drones create into information systems?)

3. Miten ihmisten asenteet vaikuttavat droonien käyttöönottoon?
(How do people's opinions affect the deployment of drones?)

4. Miten tulevaisuuden näkymät vaikuttavat droonien käyttöönottoon?
(How do future perspectives affect the deployment of drones?)

5. Miten määräykset ja lainsäädäntö vaikuttaa droonien käyttöön?
(How do regulations and legislation affect the use of drones?)

6. Millaiset edellytykset erilaisilla yrityksillä ja asiakkailla on käyttää drooneja?
(What kind of competencies do different companies and customers have for using drones?)

Q3) Droonien vaikutus ympäristölliseen kestävyyteen *(Impact of drones on environmental sustainability)*

1. Miten droonit vähentävät ympäristölle haitallisia vaikutuksia metsäteollisuudessa?
(How do drones decrease harmful effects for the environment in forest industry?)
   a. Missä prosesseissa? Millaisten tietojärjestelmien osina?
   (Which processes is this possible in? What kind of IS components do drones function then?)
   b. Miten droonien käyttäminen näissä prosesseissa tai tietojärjestelmissä vähentää ympäristölle haitallisia vaikutuksia?
   (How does the use of drones in these processes or information systems decrease harmful effects for the environment?)
   c. Miten haitallisten vaikutusten vähentäminen varmistetaan?
   (How is the decrease of harmful effects confirmed?)

2. Miten droonit edistävät ympäristöllistä kestävyyttä metsäteollisuudessa?
(How do drones improve environmental sustainability in forest industry?)
   a. Missä prosesseissa? Millaisten tietojärjestelmien osina?
   (Which processes is this possible in? What kind of IS components do drones function then?)
   b. Miten droonien käyttäminen näissä prosesseissa tai tietojärjestelmissä vähentää ympäristölle haitallisia vaikutuksia?
   (How does the use of drones in these processes or information systems decrease harmful effects for the environment?)
   c. Miten ympäristöllisen kestävyyden edistäminen varmistetaan?
   (How is the improvement on environmental sustainability confirmed?)
   d. Mitä muita menetelmiä ympäristöllisen kestävyyden tukemisessa käytetään?
   (What other methods are used to support environmental sustainability?)

3. Mitä uusia mahdollisuuksia droonit luovat?
(What new possibilities are created by drones?)

4. Mitä haasteita droonien käyttöön tai kehittämiseen liittyy?
(What challenges are related to the use or development of drones?)

5. Mitä uusia liiketoimintamahdollisuuksia droonit luovat?
(What new business opportunities are generated by drones?)
   a. Miten droonien hyödyntäminen ympäristöllisen kestävyyden edistämiseksi vaikuttaa liiketoimintaan?

(How does the utilization of drones for improving environmental sustainability affect business?)

6. Millaisia projekteja droonien kehittämiseen teillä on ollut tai on käynnissä?
(What kind of projects concerning the development of drones have you had or are currently ongoing?)
7. Mitkä toimijat tai sidosryhmät ovat tärkeitä droonien käytön kehittämisessä?
(Which operators or stakeholders are important for the development of using drones?)

8. Miten drooneja tulisi kehittää, jotta niiden käyttö olisi ketterämpää ja tehokkaampaa?
(How drones should be developed so that their use would be more agile and efficient?)

9. Millaisia asiakkaiden tarpeisiin soveltuvia droonituotteita ja -palveluita on markkinoilla saatavilla?
(What kind of drone products and services applying to the needs of customers are available on the market?)

X) Lopetus *(Ending)*

1. Tuleeko mieleen muita asioita liittyen droonien käyttöön ympäristöllisen kestävyyden tukemiseksi metsäteollisuudessa?
(Do you have any other viewpoints in mind regarding the use of drones for supporting environmental sustainability in forest industry?)

2. Tuleeko mieleen muita asioita liittyen tähän tutkimukseen?
(Do you have any other things in mind related to this study?)

3. Mitkä organisaatiot tai ketkä asiantuntijat voisivat tarjota hyödyllisiä näkökulmia tätä tutkimusta varten?
(Which organizations or experts could offer useful viewpoints for this study?)