Understanding German foresters' intention to use drones

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Abstract: As unmanned aerial vehicles or drones are a cost-effective tool for several forest management purposes, this is the first study investigating the use of drones for forestry purposes and identifies factors influencing foresters' intention to use drones. By using partial least square structural equation modelling (PLS-SEM), an extended Technology Acceptance Model (TAM) was estimated to investigate factors influencing German foresters' intention to use drones based on a sample with 215 foresters collected in 2022. The TAM explains 42% of the variation in the intention to use a drone of which perceived usefulness for forest management is the strongest predictor. The results are of interest to policy makers, extension services as well as practitioners.

Keywords: drone; digitalization; Technology Acceptance Model; Partial Least Squares Structural Equation Modelling; Unmanned Aerial Vehicle; forestry

1 Introduction

Sustainable forest management and planning requires foresters' understanding of the forest dynamics for which the collection of field data is necessary, which can be time consuming and expensive. Unmanned aerial vehicles or drones can improve the efficiency of traditional acquisition since data collected by satellites or airplanes do not meet the needed spatial and temporal resolutions for regional or local forestry objectives. Drones can overcome these shortcomings as they can be equipped with GIS as well as infrared/thermal and multispectral cameras, which are suitable for real-time applications as they combine high spatial resolution, quick turnaround times and low operational costs. As a result, drones can be used for (precision) forestry inventory, 3D mapping, disease detection and management, forest stockpiles measurement as well as forest fire management and documentation [Da21]. Despite the promised benefits of this instrument for (sustainable) forest management, no study has yet focused on the usage of drones in forestry from the users' point of view. In specific, foresters' perceived barriers and benefits of drone usage have so far not yet been captured in the literature. Furthermore, as drones are not yet widespread, it is worthwhile to focus on foresters' first perceptions and attitudes

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towards drones. Hence, this study aims to investigate the factors, which influence the foresters' intention of using drones. For this purpose, an online survey using a standardized questionnaire was conducted from December 2021 to February 2022 resulting in a sample of 215 German foresters. Perceived barriers and benefits in drone use are assessed. The Technology Acceptance Model (TAM) framework [Da89] is adapted in the context of drone usage in forestry and influencing latent factors for foresters' intention to use drones are estimated and evaluated by applying partial least squares structural equation modelling (PLS-SEM) [Ha16].

2 Material, methods and hypothesis generation

Before the survey started, foresters were informed that they could stop the survey at any point. The questionnaire was divided into four parts and was evaluated by practitioners before it was sent to forest managers via e-mails from forestry professional associations in Germany. In the first part, the foresters were asked to provide socio-demographic and forest business-related information. In the second part, foresters were asked if they use a satellite, smartphone and/or tablet for forestry purposes. Foresters who use a smartphone and/or tablet for forestry purposes were asked if they use apps for forestry purposes. The third part of the survey focused on the use of drones. Users of drones were asked what benefits they see in their use. Non-users were asked what potential benefits and what reasons they see against the use of drones. In the last and fourth part, foresters were asked to evaluate 13 statements to estimate a TAM (Fig. 1) on a 5-point Likert scale (1 = high disagreement; 5 = high agreement). The TAM was estimated using PLS-SEM in SmartPLS3 [RWB15] and is explained in the following.

The TAM is the most applied framework to study an individuals' intention to adopt a technology. In the TAM, perceived usefulness is defined as an individuals' belief it enhances their job performance. Perceived ease of use refers to an individuals' belief that using a technology is effortless. The TAM proposes a positive relationship between perceived usefulness and an individuals' intention to use a technology. Hence, the more useful a technology is perceived, the higher the intention is to use a technology (ITU). Likewise, the easier the use of the technology is perceived, the higher the intention is to use the technology. Furthermore, the model assumes that the easier it is perceived to use the technology, the higher the perceived usefulness of the technology [Da89] is. Figure 1 shows the adapted model for the context of drones in forestry and associated hypotheses. Since drones can be useful for the forest management in general (e.g. forest inventory), but also for forest health management in specific (e.g. detection of diseases), the original construct perceived usefulness in the TAM was adapted to the construct perceived usefulness for forest management (PUFM) and supplemented by the upstream construct perceived health management benefits (PHMB). The original construct perceived ease of use is divided in two sub-constructs for the perceived ease of use in controlling the drone for take-off, landing and flying (PEOU – Handling) as well as for the perceived ease of use in the use of data and knowledge of data formats (PEOU – Data).

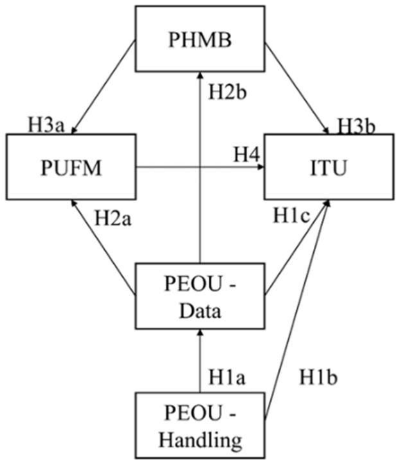

Fig. 1: Proposed TAM for the intention to use drones for forestry purposes. PEOU - Data = Perceived Ease of Use - Data, PEOU - Handling = Perceived Ease of Use - Handling, ITU = Intention to Use Drones, PHMB = Perceived Health Management Benefits, PUFM = Perceived Usefulness for Forest Management, H = Hypothesis

3 Results, discussion and concluding remarks

3.1 Descriptive results

215 usable records remained for the analysis after data cleaning. The average participant is 49 years old and 12% of the participants are female. Out of all participants, 20% completed an apprenticeship in forestry and 47% hold a technical college or university degree in forest science. Based on the self-reported risk attitude, the participants are on average risk-averse. Most participants were the owner (37%) or manager (34%) of the forest enterprise. The larger share of managers might also explain partly the high share of highly educated participants. More than half of the participants work in private forest enterprises (61%) followed by communal forest enterprises (14%) and state-owned forest enterprises (13%). The average size of the forest area managed amounts to 10,594 ha. With respect to digital instruments, 10% of the participants currently use a drone, while 6% have used a drone in the past, but are no longer using one. 27% of the participants use satellites. 69% of the foresters use a smartphone for forestry purposes, of which 62% also use apps related to forestry. A tablet is used by 43% of the foresters for forestry purposes, of which 72% use apps related to forestry. The most stated reasons against the use of drones are that the technical equipment as well as technical knowledge are not yet sufficiently developed to use the data provided by drones. Furthermore, costs are another reason stated against the use of drones (Fig. 2). Drone users and non-users perceive a

timelier response to calamities, a quick help in decision making as well as faster and more accurate data collection as the benefits when using a drone (Fig. 3).

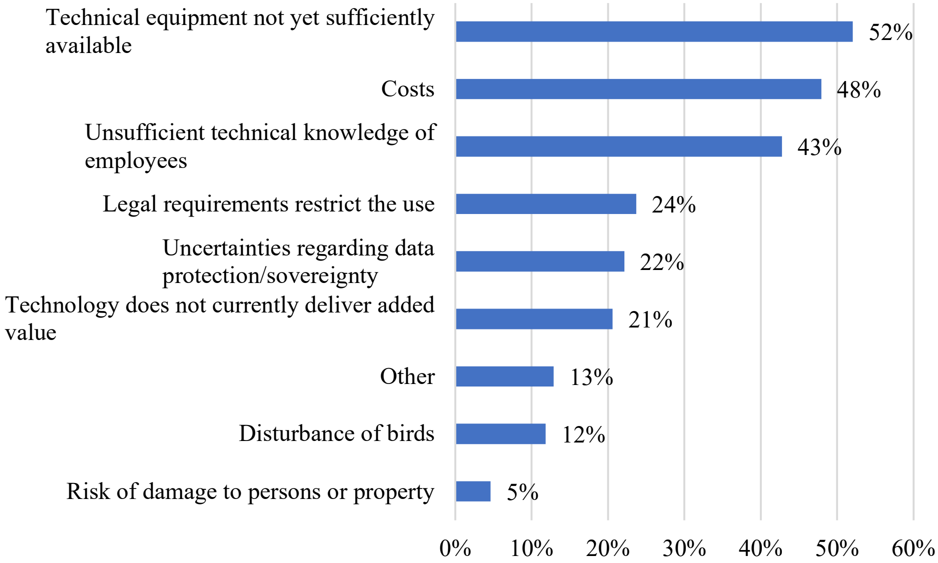

Fig. 2: Reasons against drone usage by non-users (N=194). Multiple answers possible

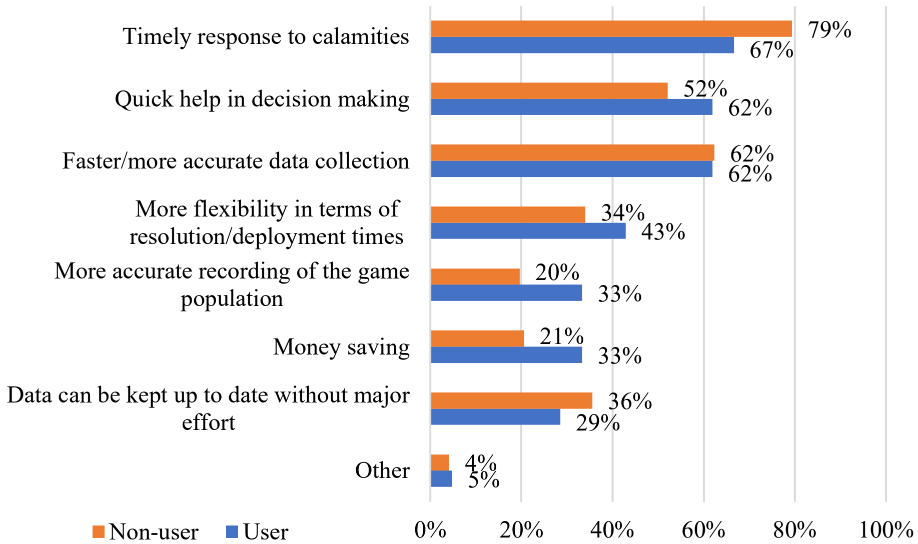

Fig. 3: Benefits of user's drone usage (N=21) and expected benefits for non-user's drone usage (N=194). Multiple answers possible

3.2 Model results, discussion and concluding remarks

All quality criteria given for models in PLS-SEM are met. Indicator reliability (lowest factor loading 0.795, cut-off level > 0.7), internal consistency (lowest composite reliability 0.848, cut-off level > 0.7), convergent validity (lowest average variance extracted 0.658, cut-off level > 0.5) and discriminant validity (highest Heterotrait-Monotrait ratio 0.866, cut-off level 0.9) are given [Ha16]. Explained variance (R^2) of the target construct *Intention to Use Drones* amounts to 42.8 %.

Table 1 shows the estimation results for the PLS-SEM model. All hypotheses are supported by the model except for H1b and H3b. Hence, just being able to control a drone does not statistically significantly positively influence a foresters' intention to use a drone. Likewise, perceived health management benefits do not trigger foresters' intention to use a drone. H1a (PEOU – Handling → PEOU – Data) is given support by the model since the path coefficient is statistically significant with the expected positive sign. If the control of a drone is perceived as easy, then also the use of the data is perceived more easily. Hence, a forester who is informed about the control of a drone, might also be more inclined to become familiar with the data formats and information provided by a drone to use them effectively. H2a (PEOU – Data → PUFM), H2b (PEOU – Data → PHMB) and H1c (PEOU – Data → ITU) are also given support by the model, as all path coefficients are statistically significant with the expected positive sign. The combined results imply that especially knowledge and familiarity about data formats are important to increase the perceived usefulness for forest management, perceived health management benefits and intention to use drones. H3a (PHMB → PUFM) can be given support by the model as the path coefficient is statistically significant with the expected positive sign. Hence, gaining information about the health of the stock via drones increases the perceived usefulness of drones for the forest management. Lastly, H4 (PUFM → ITU) is also supported by the model which implies that if the usage of drones is perceived useful for the forest management, it also increases a foresters' intention to use drones.

The results imply that foresters need more information on how a drone can be used in their forestry enterprise. In detail, it could be helpful for foresters to be educated in the areas in which drones can not only assist them but also the associated cost and time savings as well as potential decision support and improvement. For this purpose, future research should focus in depth on one or two areas of drone application, e.g. forest monitory, and investigate foresters' associated barriers, motives and expectations. This could be helpful to specifically help professionals to assist foresters in understanding the benefits of using a drone. In this context, policy makers should provide (financial) support for consultation and support. With respect to the construct PEOU - Data, the results are also underlined by the descriptive results of barriers stated by the non-user (Fig. 2) that technical knowledge and equipment is not sufficiently developed yet to use the information provided by a drone effectively. Hence, providers of drones should strive for clarification which equipment is needed and in which data formats the information is provided. Furthermore, recurring in-person visits by professionals to assist forest managers in performing certain analysis. Likewise, developers should focus in providing user-friendly software environments to handle data that is also robust to individual tasks. For further research, it could also be of interest to investigate the familiarity of foresters with several aspects of digitalization (e.g. data formats, data security). This could be fruitful for developers to make the software more user-friendly. Furthermore, it could help professionals to assist foresters as they can precisely tackle knowledge gaps. As a result, (perceived) costs for foresters could be reduced (Fig. 2). Costs might not only include the costs of purchasing the software but also time costs for designing and programming flight routes as well as performing technical analysis of the collected data.

H [a]		**β** [b]	**Support H?**
PEOU – Handling → PEOU – Data	H1a	0.613***	Yes
PEOU – Handling → ITU	H1b	0.086	No
PEOU – Data → ITU	H1c	0.186*	Yes
PEOU – Data → PUFM	H2a	0.463***	Yes
PEOU – Data → PHMB	H2b	0.149*	Yes
PHMB → PUFM	H3a	0.397***	Yes
PHMB → ITU	H3b	0.030	No
PUFM → ITU	H4	0.473***	Yes

[a] H = Hypothesis, PEOU - Data = Perceived Ease of Use - Data, PEOU - Handling = Perceived Ease of Use – Handling, ITU = Intention to Use Drones, PHMB = Perceived Health Management Benefits, PUFM = Perceived Usefulness for Forest Management, β = Path coefficient

[b] Bootstrapping results with 10,000 subsamples.

R^2(ITU) = 0.429; R^2(PHMB) = 0.022; R^2(PUFM) = 0.426; R^2(PEOU – Data) = 0.376

$p < 0.001$ ($p < 0.01$; $p < 0.05$) is indicated by *** (**; *)

Tab. 1: Estimation results (N=215)

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