How to take Vegetation Inspection to the Next Digital Level

Digitalisierung im Vegetationsmanagement

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Summary
At Netze BW, one of the largest distribution grid operators in Germany and part of EnBW, a GIS-web-app has been developed that allows technicians to digitally record vegetation inspection activities. Rather than relying on paper-based methods, all 450 technicians are now equipped to digitally document vegetation encroaching on power lines. The focus for this year is on the automatic detection of critical vegetation from airborne LiDAR data, aiming to integrate this remote sensing analysis into the web-app to enhance the automation of the inspection process. This article outlines the iterative transition from traditional paper-based methods to a digital approach in vegetation management.

Keywords: LiDAR, GIS, digital transformation, vegetation management, power line maintenance

Zusammenfassung
Bei Netze BW, einem der größten Verteilnetzbetreiber in Deutschland, der zur EnBW AG gehört, wurde eine GIS-Web-App entwickelt, mit der Monteure und Monteurinnen Trassenpflege-Maßnahmen digital erfassen und bearbeiten können. Anstatt wie bisher Maßnahmen zu kritischer Vegetation in verschiedenen Tabellen und auf Papier zu erfassen, tragen nun alle 450 Monteure diese in ein zentrales digitales Web-App Tool ein. Dieses Jahr liegt der Fokus auf der automatischen Erkennung kritischer Vegetation aus LiDAR-Daten und der Integration solcher Fernerkundungsanalysen in die Web-App, um den Inspektionsprozess weiter zu automatisieren. In diesem Artikel wird der iterative Wechsel von einem papierlastigen zu einem digitalen Trassenpflegesystem beschrieben.

Schlüsselwörter: *LiDAR, GIS, Trassenpflege, Freileitungsinspektion*

Fig. 1: Technicians inspecting and repairing grid components

1 Introduction

It is crucial for energy grid operators to conduct regular inspections of their grid and surrounding vegetation to avoid potential electrical outages or fire hazards. These inspections are necessary to identify any equipment that may be failing or that needs to be repaired (Fig. 1). Additionally, it is important to inspect the vegetation by pruning it regularly to prevent it from encroaching on power lines. This pruning process must consider the rights of property owners, regulatory compliance, and environmental restrictions.

Emerging studies indicate that the use of remote sensing techniques, such as those provided by drones or satellites, can be effective in identifying dangerous vegetation and faulty components along the grid (Lodetti et al. 2022, Fang et al. 2020, Yang et al. 2020, Liu et al. 2019). These technologies are being adopted more frequently by grid operators. For instance, Westnetz and Axpo have implemented drone technology for inspecting their grids (Axpo 2022),

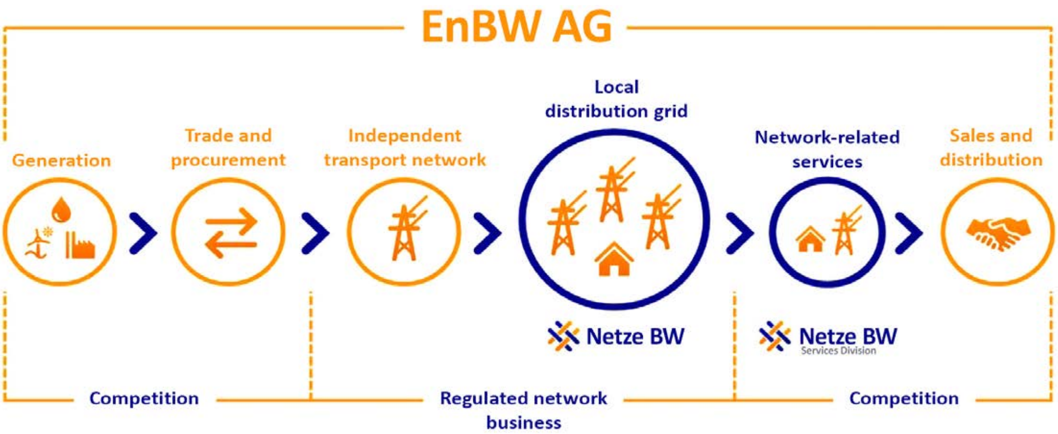


Fig. 2: Netze BW's role as a distribution grid operator belonging to the EnBW AG

and E.DIS, has employed satellite imagery to monitor vegetation (Naujoks et al. 2021).

At Netze BW, which is one of the largest distribution grid operators in Germany, belonging to the energy supplier EnBW AG (Fig. 2), the initiative was taken to explore how modern technologies can enhance the inspection routines. The innovation team at Netze BW has initiated a project known as NETZinspect (Netze BW 2024, Surmann et al. 2022), to improve inspection along it's 110kV grid. The project concentrates on developing three products namely digital vegetation inspection, airborne asset inspection aiming to automate inspection with drones and AI-based image analysis, as well as an asset media platform aiming to create a platform to store and find all asset related media data. The focus of this paper lies on the digital vegetation inspection that the author of this paper is responsible for.

Regarding vegetation inspection, the initiation of testing remote sensing technologies for vegetation analysis in NETZinspect began in 2021. Following initial experiments with satellite imagery, this technology was set aside due to insufficient accuracy (m instead of cm), prolonged data delivery times (months instead of weeks), and high analysis costs. Consequently, in 2023, a pilot project utilizing LiDAR (Light Detection and Ranging) technology was launched to identify critical vegetation with greater detail and speed. A similar approach has been realized by E.ON Sweden (Richter et al. 2023).

This paper describes the iterative approach in digitizing the vegetation inspection process and adding remote sensing (namely LiDAR) to detect critical vegetation along the high voltage power lines.

2 Vegetation Inspection

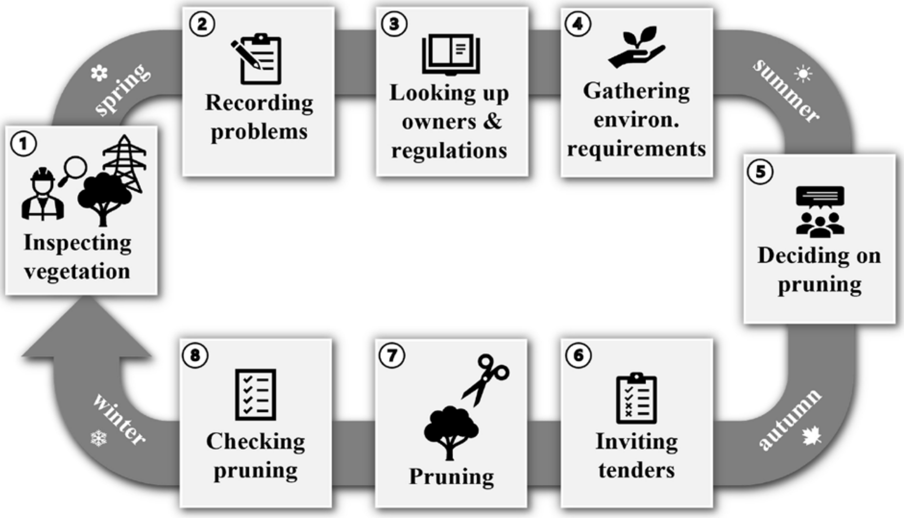
The annual inspection of vegetation along Netze BW's 7460 km of 110 kV high voltage power lines involves a multi-step process (Fig. 3):

1. Conducting on-site vegetation inspection
2. Documenting critical vegetation
3. Identifying landowners and specific regulations for environmentally protected areas
4. Obtaining permissions and environmental requirements from authorities
5. Discussing with landowners and authorities (on-site) to determine the scope of pruning
6. Inviting contractors for tenders and detailing the pruning work and any environmental considerations to potential contractors
7. Execution of the pruning by the selected contractor
8. On-site verification of the completed pruning work

This procedure integrates various data sources, including details about landowners, environmental rules, and planned pruning operations. It necessitates effective communication between several parties, such as the field technicians, property owners, regulatory agencies, and the pruning contractors. Documentation of the required pruning work was traditionally managed on paper or in Excel spreadsheets, with additional research conducted using paper maps (Fig. 4).

3 Digitizing Vegetation Inspection

Recognizing the need for a more streamlined process, a digital solution based on ArcGIS Enterprise was developed to centralize the necessary data for all communication related to the inspection workflow (Crommelinck et al. 2023).



↑ Fig. 3: Process of vegetation inspection for high voltage power lines at Netze BW

← Fig. 4: Technician looking up information about landowners and environmental restrictions in paper plans

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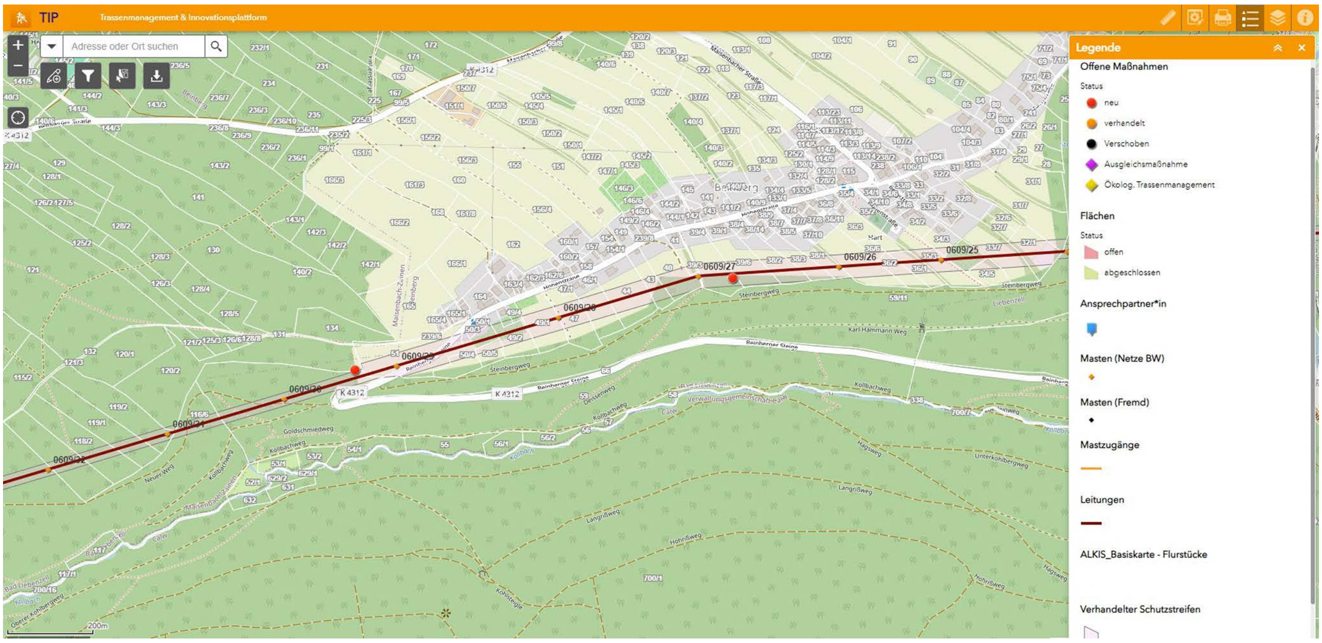

Fig. 5: Web-based GIS system (TIP) showing pruning tasks (dots) along the high voltage power lines (red line)

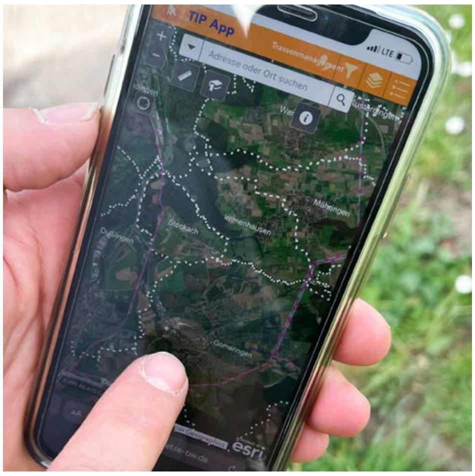

Fig. 6: Mobile version of TIP to be used in the field to record pruning tasks

A web-based Geographic Information System (GIS) named Trassenmanagement & Innovationsplattform (TIP) was created, which allows technicians to record pruning tasks and automatically adds all relevant information about landowners and regulations (Fig. 5).

At the beginning of 2022, a pilot program was initiated with 80 technicians who were instructed to use TIP for that year's vegetation inspection. TIP was launched with basic features and was continuously refined based on user feedback, which was collected in monthly review sessions. Through this agile development strategy, a mobile version of TIP was adopted for recording and verifying pruning work (Fig. 6), and a desktop version for managing related

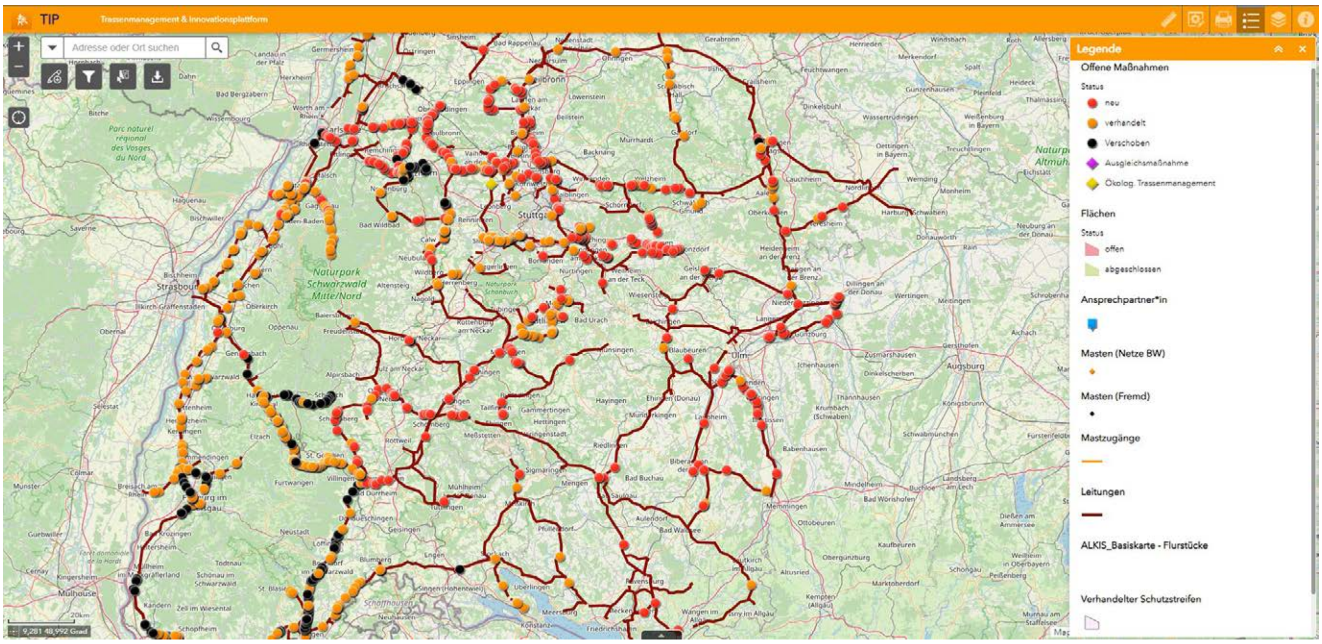

Fig. 7: Pruning tasks recorded in TIP (Trassenmanagement & Innovationsplattform)

administrative tasks (Fig. 5). Online trainings of one hour for small groups of technicians were organized, followed by optional support via mail or phone.

During the TIP pilot at Netze BW in 2022, it was discovered that digitizing the vegetation inspection process led to a faster and more reliable workflow. By consolidating all necessary information on a single web-based platform accessible to various stakeholders, steps that were previously prone to time consumption and errors have been eliminated. Information is now readily available both in the field and the office, and field navigation has been simplified, as technicians can locate information based on their current position. The success of the application is attributed to an agile development method, which involved creating new features in close cooperation with the technicians. Their ongoing feedback and suggestions have been fundamental in creating a tool that has received positive evaluations from most technicians. In 2023, a rollout of TIP to all 450 technicians working on vegetation management was organized, which, according to their estimations, now saves 1050 hours per year that were previously spent on vegetation management tasks.

Currently, TIP displays 1265 open pruning tasks along the power lines (Fig. 7).

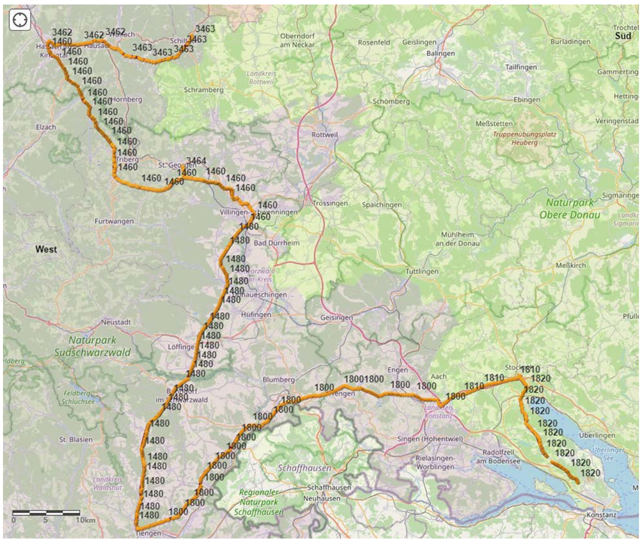

Fig. 8: 200 km of high voltage power lines for which LiDAR data and imagery were captured.

4 LiDAR for Vegetation Inspection

After the digitization of the vegetation management workflow, the integration of remote sensing technology was possible to optimize the recording of pruning tasks. In 2023, a partner company called Visimind was tasked with collecting and analyzing airborne LiDAR data and imagery for 200 km of high voltage power lines (Fig. 8). The capture was done by a helicopter that flew with 50 km/h in 110 m height to capture the power lines in 6 h. The helicopter carried the LiDAR sensor and different camera sensors.

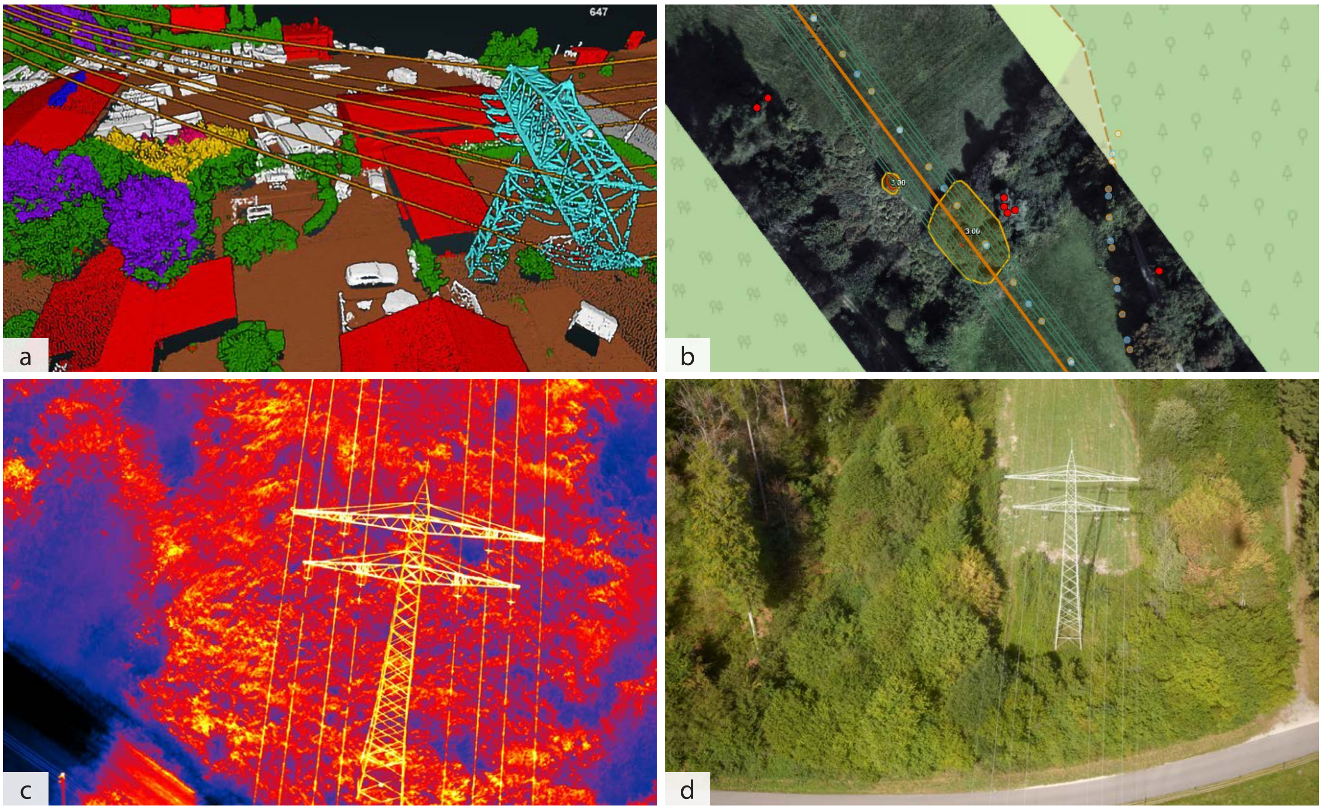

Fig. 9: Airborne LiDAR and imagery data obtained by helicopter: (a) classified 3D point clouds, (b) orthoimages, (c) thermal images, and (d) high resolution images

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Fig. 10: (a) grow-in trees and substructures displayed with polygons of different critically/distance and (b) displayed in TIP. The orange buffer helps locate the grow-in polygons from a zoomed-out view.

The LiDAR data were captured in a 100 m wide corridor with a density of 100 points/m², which resulted in a sub-decimeter accuracy. The LiDAR data was delivered classified into the following classes: vegetation, ground, building, water, wire structure, noise and unclassified. The cameras consisted of a Phase One camera with 100 mega pixels that captured high resolution images, a vertical-looking RGB camera to create orthoimages (10 cm/pixel resolution) and a thermal camera (FLIR A8581 f/2.5, 3.0–5.0 µm). The thermal images are not relevant for vegetation inspection – they were captured to validate their usefulness for further inspection tasks.

The data (Fig. 9) obtained eight weeks after data capture included classified 3D point clouds, orthoimages, thermal images, and high resolution images.

The results included grow-in trees that could grow into the power lines from underneath (Fig. 10a) and fall-in trees that could fall into the lines from alongside the power lines. The grow-in and fall-in trees were incorporated as vector layers (polygons and points) into the vegetation inspection tool TIP to make them easily and offline accessible for technicians (Fig. 10b). The classified point clouds were accessible through a 3D webviewer from the partner company Visimind.

5 LiDAR validation

To validate the results, several steps were taken:
1. The critical vegetation identified through LiDAR was compared with items recorded in TIP
2. Attributes obtained through LiDAR, such as tree type and distance to power lines, were verified in the field
3. Meetings with technicians in the field were conducted to understand how they utilized the data and to gather their feedback (Fig. 11).

The results proved to be very convincing:
1. There were 58 critical sites identified through LiDAR that had not yet been included in TIP
2. No errors were found in the LiDAR data during field validation
3. The feedback from technicians was overwhelmingly positive; they confirmed that the capture of critical vegetation through LiDAR was more complete and accurate compared to traditional surveys. They also appreciated that the new method was safer, as it eliminated the need for climbing poles to measure distances between trees and power lines – a task that is both dangerous and costly. Additionally, the inclusion of tree type in the

Fig. 11: (a-b) Validating LiDAR results in the field with technicians

LiDAR results was valued for its importance in estimating future growth. In the long term, technicians were convinced that the results would aid in negotiations and communications with landowners, authorities, and pruning companies.

6 Conclusions

Owing to the positive evaluation and feedback on the LiDAR and image capture, there will be a continued focus on this technology. The emphasis this year is on further integrating the LiDAR and image data into TIP and providing access to external parties to ease negotiation and communication processes. Another LiDAR and image data capture is scheduled for summer 2024 to evaluate growth models, which could potentially extend the vegetation inspection cycle. Following this, a decision will be made regarding a final rollout of airborne LiDAR and imagery for vegetation inspection. Concurrently, an investigation is underway to determine additional use cases (such as asset inspection, grid planning and construction, as well as weather-dependend grid operations) that could benefit from a joint capture and analysis of LiDAR data , due to time-consuming approvals, as well as limited payload and reach of the drones.

In the context of the NETZinspect project, which explores the application of drones for virtual asset inspection, the project team is contemplating the use of this technology as a potential alternative to helicopter surveys. To date, the team has not conducted any investigations to detect critical vegetation using 3D image matching techniques derived from drone-captured imagery. The experience with satellite image analysis for vegetation use cases was found to be unsatisfactory, as the image matching did not meet the necessary standards for accuracy and could not "see through" vegetation as LiDAR can. Additionally, capturing data with drones presented challenges, as it was neither easy nor feasible to do so on a wide scale.

Based on the experience with vegetation inspection, the recommendation is to first digitize the existing workflow before making iterative changes. The feedback and readiness of the users, namely the technicians, have been crucial in developing a solution that is both functional and valued. Building trust and readiness to adopt new technologies and data, such as LiDAR, is a time-consuming process, but is essential for the success of similar digitization projects.

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