Cost Comparison of Drone and Foot Based Early Bark Beetle Detection

Paczkowski, S.; Jaeger, D.

1 Dept. of Work Science and Engineering, Faculty of Forest Science and Forest Ecology, Georg-August-University Göttingen
Structure of the presentation

Introduction
Methods: Analyzed Parameters
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Introduction

Serious damage by bark beetles:

**Canada**: net present value loss (average per year) of 1,274 million dollar between 2009 and 2054 \(^1\)

**USA**: annual loss of 1.5 million dollar between 1971 and 2000 \(^2\)

**Germany**: Increasing losses due to insect calamities from 2015 to 2019 (see inset: timber cutting due to damage in German forests) \(^3\)

-> Need for early assessment of bark beetle damage to prevent timber losses due to bark beetle gradation

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Introduction

Multispectral drone or satellite based methods have a low capability of early bark beetle infestation detection\(^1\)

BUT: Only early detection can prevent a beetle gradation with successive high losses of timber

Conventional early bark beetle assessment: Foot Based
- low time efficiency
- intermediate detection rate
- movement speed depends on the terrain

Alternative assessment: Electronic Nose Drone Based\(^2\)
- high time efficiency
- high detection rate
- movement speed independent on the terrain

\(^1\)Immitzer et al. 2019, AFZ-Der Wald 17, p. 20–23; \(^2\)Paczkowski et al. 2021, Forests 12(2), 228 [https://doi.org/10.3390/f12020228](https://doi.org/10.3390/f12020228)
Methods: Analyzed Parameters

Foot based assessment:

- Terrain slope (-50° to 50°) and relative share of this slope (0% - 100%) per ha
  - It was assumed that
    - The forester prefers the isohypsis in order to minimize walking efforts
    - Movement speed down the slope is higher than movement speed up the slope
    - The forester chooses either 10 m or 20 m distance between walking lanes

- Forest floor characteristics
  - A correction factor for decreasing movement speed was used (0.75; 0.5; 0.25) to simulate increasing ground obstacles, e.g. vegetation, gravel, soil erosion
  - Three literature sources on walking speeds (1.5 m × s⁻¹; 1.23 m × s⁻¹; 0.99 m × s⁻¹) were used to calculate the mean walking speed for ideal hiking road conditions

- The labor costs for a forester were calculated to be 47.6 € per hour

Knoblauch et al. 1996, Transportation Research Record; Langmuir et al. 1984, Scottish Sport Council; Renner 2019, RennerXXL
Methods: Analyzed Parameters

Drone based assessment:

- The flight path of the drone was modelled to be in 1 m distance to the tree crowns

- The length of the flight path per ha depended on
  - Distance between flight lanes
  - Slope of the stand
  - Conifer tree crown diameter (homogeneous age structure was assumed)

- The cost of the flight per ha depended on
  - Flight speed (1 m × s⁻¹ – 4.5 m × s⁻¹)
  - The labor costs for an engineer were calculated to be 70 € per hour
Methods: Calculation

All calculations were performed considering:

- Comparison between different area sizes (1 – 100 ha)
- The influence of the slope
- The cost per ha to compare both assessment methods
- The additional cost for accessing the forest location:
  - Forester:
    - Distance to forest location 10 km with 7 km road, 3 km forest road
  - Engineer:
    - Distance to forest location 100 km with 97 km road, 3 km forest road
    - Preparation (UAV activation and check) and postprocessing (UAV check, heat map calculation for early bark beetle infestation localization)
    - Battery exchange for large areas, depending on the flight speed
    - Accommodation and additional travel costs when assessing larger areas
Results:

Foot based assessment with 10 m walking lane distance:

Terrain Correction Factor 0.75

Terrain Correction Factor 0.25
Results:

Drone based assessment

Crowndiameter 4 m
Flight lane distance 4 m

Crowndiameter 4 m
Flight speed 2.5 m/s - 1
## Results:

Comparison between foot based and drone based assessment,
Optimum for foot based assessment:

<table>
<thead>
<tr>
<th>Slope [Grad]</th>
<th>Area [ha]</th>
<th>Costs [€]</th>
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<tbody>
<tr>
<td>-30</td>
<td>3 29 145 290 435 580 870 1.160 1.450 1.740 2.030 2.320 2.610 2.900</td>
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**Foot based assessment:**
- $1.05 \text{ m} \times \text{s}^{-1}$ walking speed, 10 m distance between walking lanes

**Drone based assessment:**
- 4 m distance between flight lanes, flight speed $2.5 \text{ m} \times \text{s}^{-1}$

**Green:** foot based assessment has lower costs

**Orange:** Drone based assessment has lower costs
### Results:

Comparison between foot based and drone based assessment,

Optimum for drone based assessment:

<table>
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<tr>
<th>Slope [Grad]</th>
<th>Area [ha]</th>
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**Foot based assessment:**

- **0.35 m × s⁻¹** walking speed, 10 m distance between walking lanes
- **Yellow:** foot based assessment has lower costs

**Drone based assessment:**

- **8 m distance between flight lanes**, flight speed **2.5 m × s⁻¹**
- **Blue:** Drone based assessment has lower costs
Conclusions

- Small areas are more likely to be assessed by the conventional foot based method
- The rougher the terrain and the steeper the slope, the more likely is the assessment by the drone based method
- Both methods are hard to compare, because the detection success rate of both methods has not been determined, yet
  - The detection success rate depends on:
    - Foot based:
      - Distance between walking lanes
      - Individual factors, e.g. personal fitness, eye-sight, experience
    - Drone based:
      - Flight speed
      - All factors influencing the emission of terpenes, e.g. temperature, wind, infestation intensity
Conclusions

- The decrease of the walking speed during the foot based assessment of large areas, depending on the personal fitness of the forester, was not included in the calculation model
  - With increasing area the decrease of the walking speed can increase the costs
- The investment costs of the drone equipment was not included in the cost calculation
Thank you very much for your attention!