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Department of Forest Work Science and Engineering

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SUSTAINABLE FORESTS: ECOLOGY, MANAGEMENT, PRODUCTS AND TRADE

Cost Comparison of Drone and Foot Based Early Bark Beetle Detection

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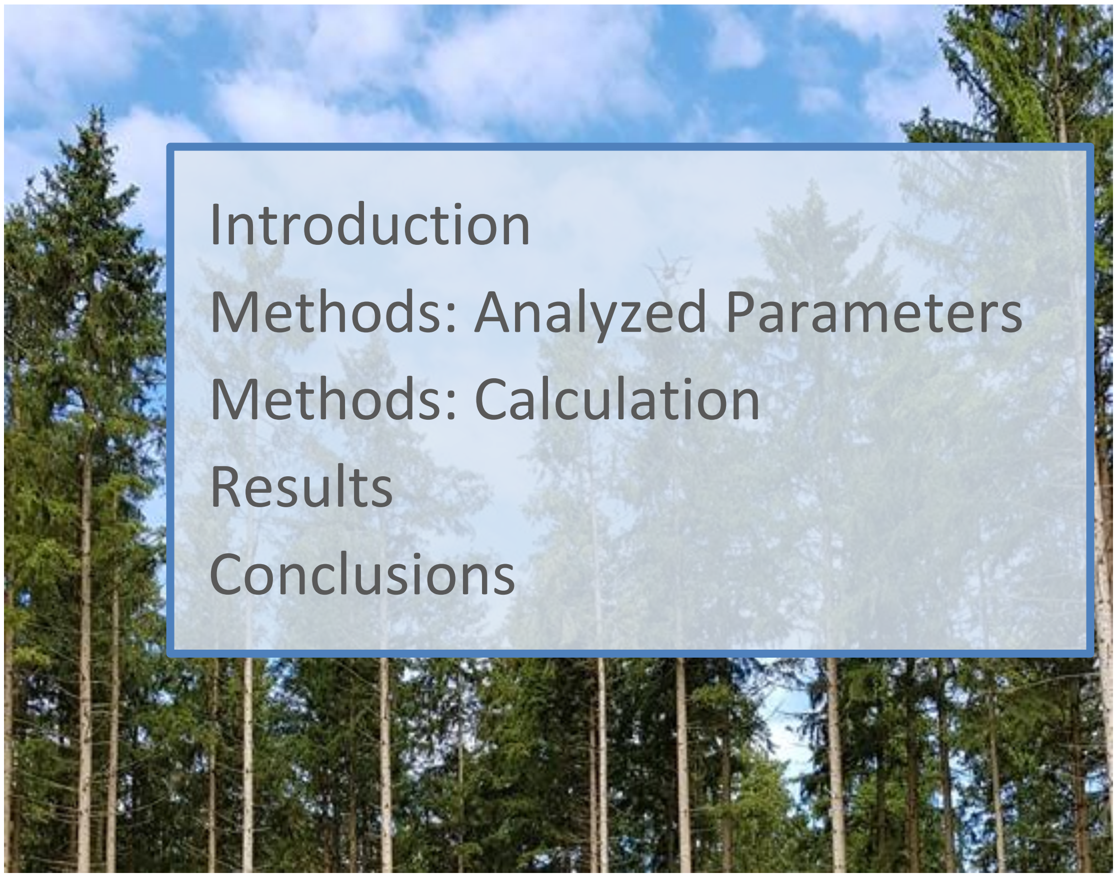
Structure of the presentation



- Introduction
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- Methods: Calculation
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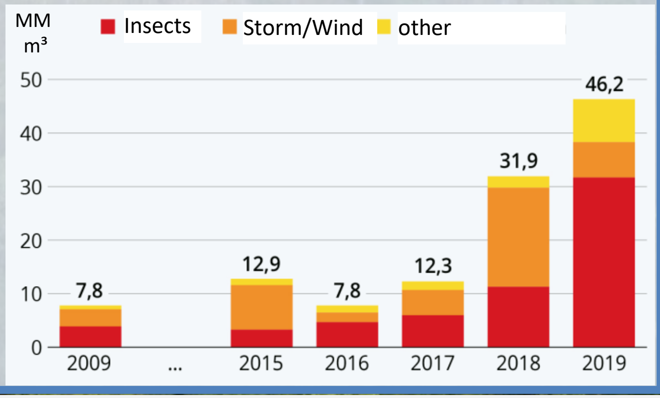
Introduction

Serious damage by bark beetles:

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

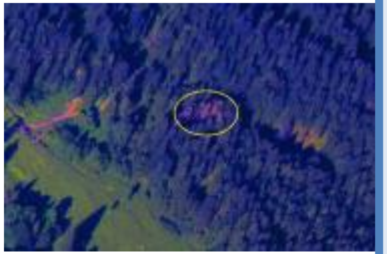
USA: annual loss of 1.5 million dollar between 1971 and 2000 [2]

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

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

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 choses 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 $\times$ s^{-1}; 1.23 m $\times$ s^{-1}; 0.99 m $\times$ 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

1Knoblauch et al. 1996, Transportation Research Record; 2Langmuir 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 ($1\ m \times s^{-1}$ – $4.5\ m \times s^{-1}$)
  - The labor costs for an engineer were calculated to be 70 € per hour

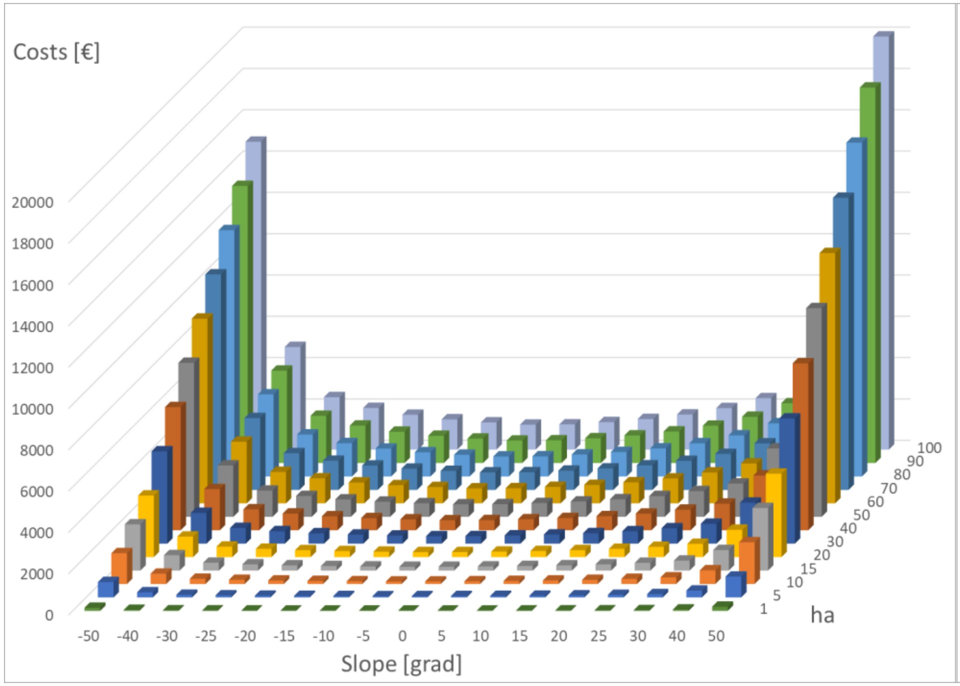
Methods: Calculation

All calculations were performed considering:

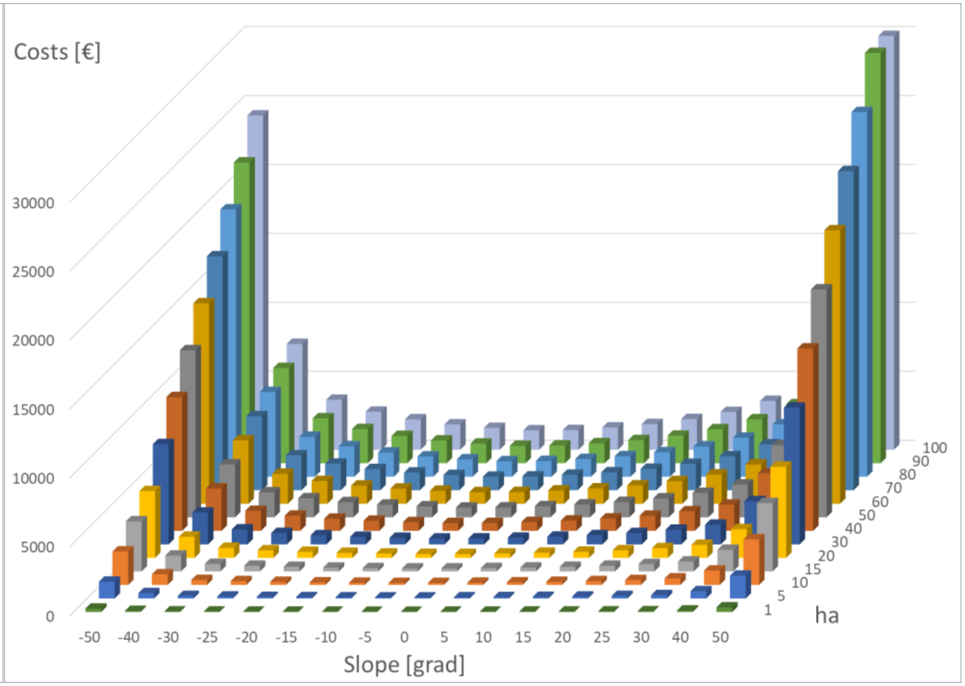
- Comparison between different area sizes (1 – 100 ha)
- The influence of the slope
- The cost per ha to compare both assessment methods
- The additional cost for accessing the forest location:
  - Forester:
    - Distance to forest location 10 km with 7 km road, 3 km forest road
  - Engineer:
    - 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:



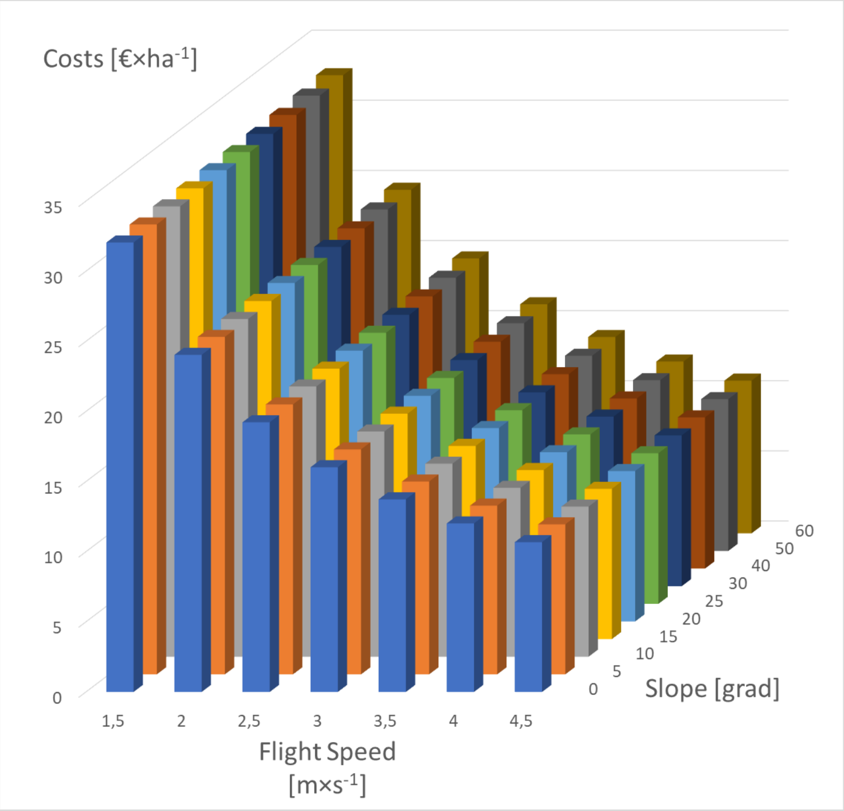
Terrain Correction Factor 0.75



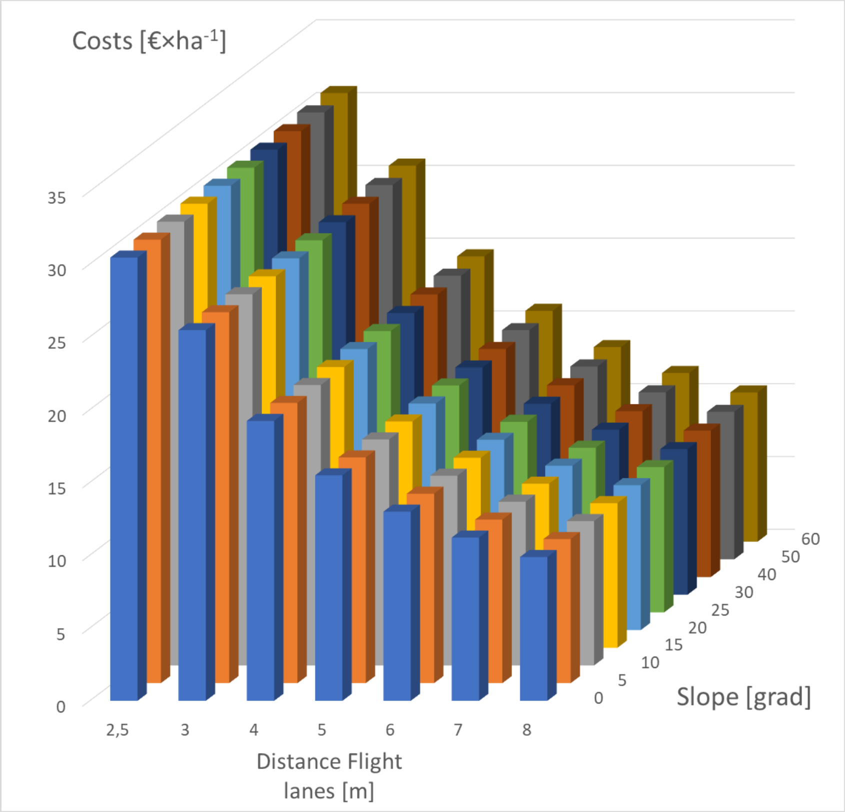
Terrain Correction Factor 0.25

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:

Costs [€]

Slope [Grad]	Area [ha] 1	5	10	15	20	30	40	50	60	70	80	90	100
-50	180	901	1.802	2.702	3.603	5.405	7.206	9.008	10.809	12.611	14.412	16.214	18.015
-40	59	294	587	881	1.174	1.762	2.349	2.936	3.523	4.110	4.697	5.285	5.872
-30	29	145	290	435	580	870	1.160	1.450	1.740	2.030	2.320	2.610	2.900
-25	23	113	226	339	453	679	905	1.131	1.358	1.584	1.810	2.036	2.263
-20	19	93	186	279	372	558	744	929	1.115	1.301	1.487	1.673	1.859
-15	16	80	159	238	318	477	636	795	954	1.113	1.272	1.431	1.590
-10	14	70	141	211	281	422	562	703	843	984	1.124	1.265	1.405
-5	13	64	128	191	255	383	510	638	765	893	1.020	1.148	1.275
0	13	65	129	194	258	387	516	646	775	904	1.033	1.162	1.291
5	14	71	143	214	285	427	570	712	855	997	1.140	1.282	1.425
10	16	80	161	241	322	483	644	805	966	1.127	1.288	1.449	1.610
15	19	94	187	281	375	562	749	937	1.124	1.311	1.499	1.686	1.873
20	23	113	225	338	451	676	901	1.127	1.352	1.577	1.802	2.028	2.253
25	28	142	284	426	568	852	1.136	1.420	1.704	1.988	2.272	2.555	2.839
30	37	186	373	559	746	1.119	1.491	1.864	2.237	2.610	2.983	3.356	3.729
40	79	395	789	1.184	1.579	2.368	3.157	3.947	4.736	5.525	6.315	7.104	7.893
50	245	1.224	2.448	3.673	4.897	7.345	9.794	12.242	14.691	17.139	19.588	22.036	24.485

Foot based assessment:
1.05 m × s^{-1} walking speed, 10 m distance between walking lanes

Drone based assessment:
4 m distance between flight lanes, flight speed 2.5 m × 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:

Costs [€]

Slope [Grad] \ Area [ha]	1	5	10	15	20	30	40	50	60	70	80	90	100
-50	429	2144	4288	6433	8577	12865	17154	21442	25731	30019	34308	38596	42885
-40	131	654	1308	1962	2616	3924	5231	6539	7847	9155	10463	11771	13078
-30	58	289	578	868	1157	1735	2313	2892	3470	4048	4627	5205	5784
-25	42	211	422	633	844	1266	1688	2110	2532	2954	3376	3798	4219
-20	32	161	323	484	646	969	1291	1614	1937	2260	2583	2906	3229
-15	26	128	257	385	514	771	1027	1284	1541	1798	2055	2312	2568
-10	21	106	212	317	423	635	846	1058	1269	1481	1692	1904	2115
-5	18	90	180	269	359	539	718	898	1078	1257	1437	1617	1796
0	18	92	183	275	367	550	734	917	1101	1284	1468	1651	1835
5	22	108	216	325	433	649	865	1082	1298	1514	1731	1947	2163
10	26	131	262	393	523	785	1047	1308	1570	1832	2094	2355	2617
15	33	163	326	490	653	979	1306	1632	1959	2285	2611	2938	3264
20	42	210	420	629	839	1259	1678	2098	2518	2937	3357	3776	4196
25	56	282	564	845	1127	1691	2254	2818	3381	3945	4508	5072	5635
30	78	391	782	1173	1564	2345	3127	3909	4691	5473	6254	7036	7818
40	180	902	1804	2706	3608	5412	7216	9020	10824	12628	14432	16236	18040
50	588	2938	5876	8815	11753	17629	23506	29382	35259	41135	47012	52888	58765

Foot based assessment:
0.35 m × s^{-1} walking speed, 10 m distance between walking lanes

Drone based assessment:
8 m distance between flight lanes, flight speed 2.5 m × s^{-1}

Yellow: foot based assessment has lower costs
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 !