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Mapping tree mortality in Luxembourg using Convolutional Neural Networks

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A case study for the summer droughts 2018/19

Ecophysiology Group

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Motivation

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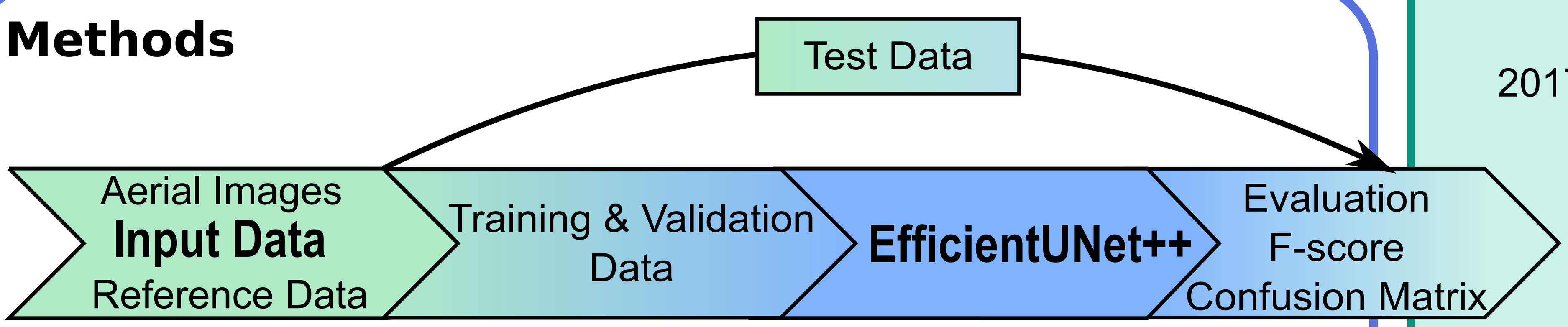
- Climate change is leading to an increase in **forest disturbance** from extreme weather events. Efficient techniques are needed to **monitor forest health** closely.
- The **summer droughts of 2018/19** have lead to widespread tree mortality in Central Europe.
- The country of Luxembourg provides free **high resolution aerial images (20 cm)** for the whole country, acquired on an annual basis. Aerial images represent a middle ground between high resolution UAV images and satellite data with extensive coverage.

Research Questions

1) Can freely-available aerial images in combination with Convolutional Neural Networks (CNNs) be used to identify annual canopy mortality countrywide?
2) Can our trained model be used to map subsequent years with no additional reference data?
3) Can we detect annual changes, particularly the impact of an extreme drought event?

Methods



- We visually assessed reference data for 2017 and 2019 at randomly selected forest sites in Luxembourg.
- Using the **EfficientUNet++** we tested four input combinations: single class of dead trees (**Single**), dead trees divided into coniferous and deciduous trees (**Multi**), **RGB** only and RGB+Near Infrared (**RGBN**).
- Per run we predicted tree mortality for 2017, 2018, 2019 and 2020 and calculated the area of dead canopy for each year, including a margin of error for the area estimate.

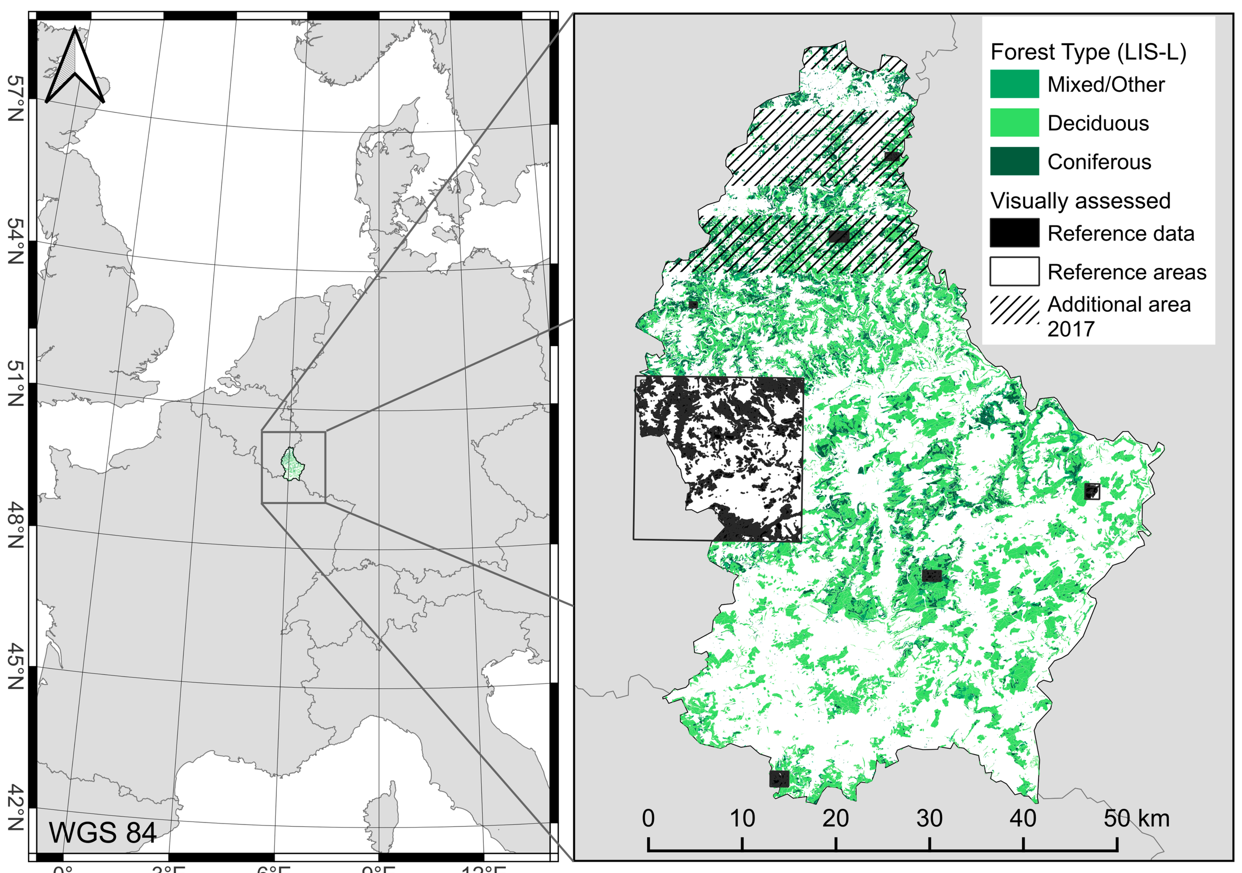
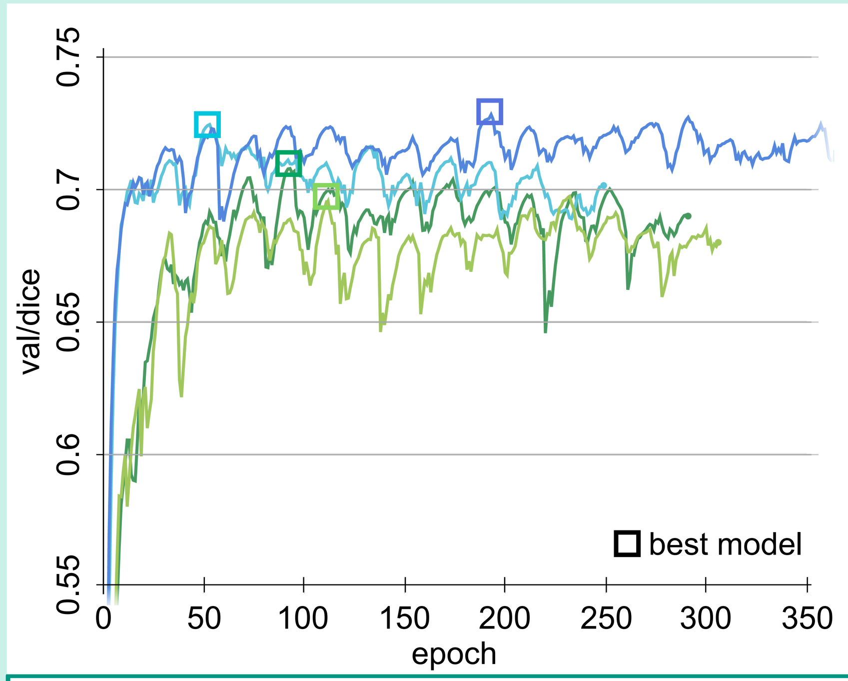


Figure 1: Map of the study site Luxembourg with forests (LIS-L) and reference areas that were visually examined.

Results

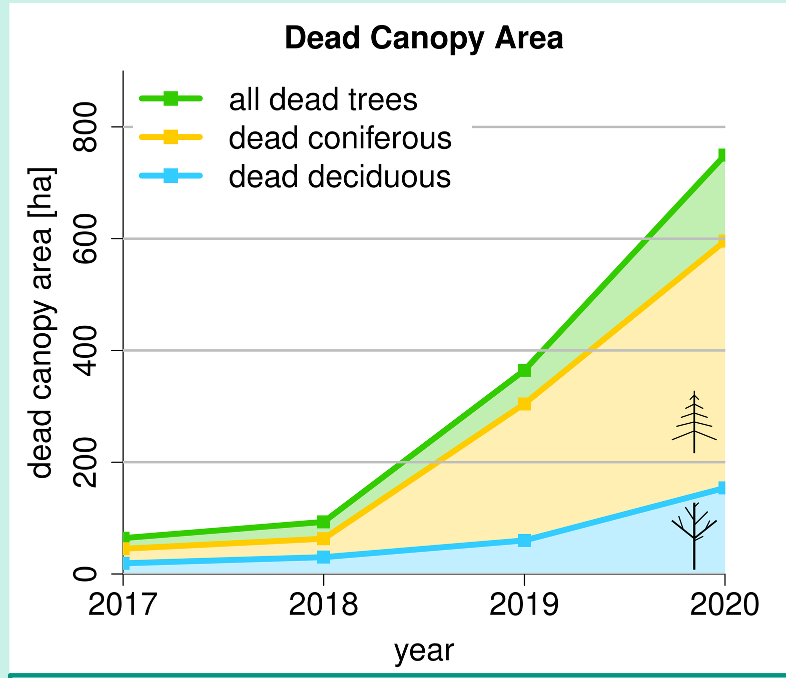
- All CNN model setups successfully mapped canopy mortality over all years.
- The area of dead canopy increased from 165 ha in 2017 to 881 ha in 2020.
- Conifers were disproportionately more affected by the disturbance event.



Multi/RGB	Single/RGBN	Single/RGB	Multi/RGBN
0.68	0.71	0.70	0.66

F-score

Figure 2: Training progression of the four models with learning rate annealing. The best model was chosen for the predictions. F-score = test/dice.



2017	2018	2019	2020
64 ha	93 ha	365 ha	750 ha

Figure 3: Mean development of dead canopy area from 2017 to 2019 for Luxembourg (Multi/RGB)

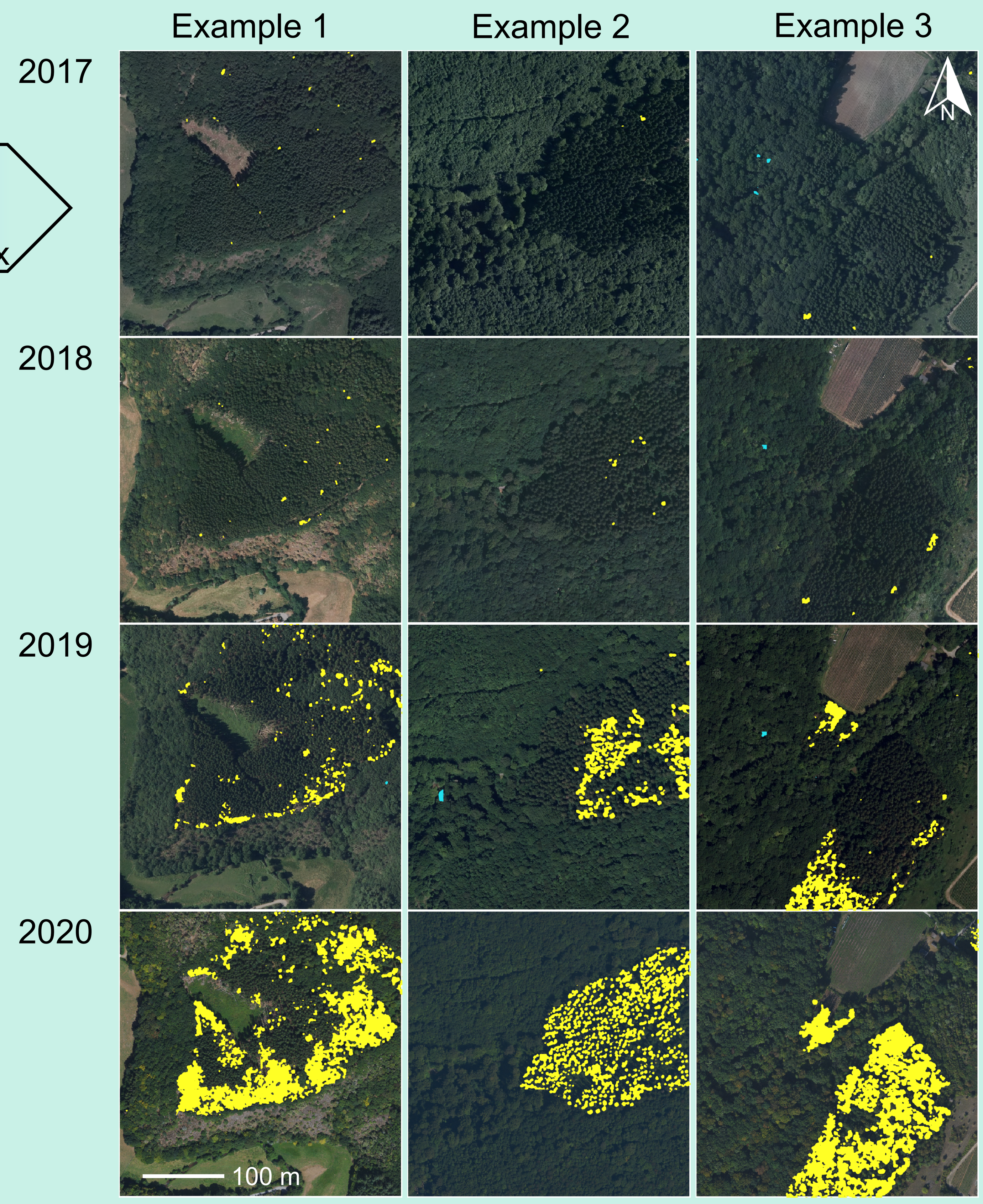


Figure 4: development of dead canopy 2017-2020 at three example sites

Conclusions

- There is a clear development in tree mortality between 2017 and 2020.
- Aerial images provide enough visual information for CNNs to detect dead trees.
- F-scores can be partially explained by the better performance of the model (more accurate delineation, finding missed dead trees (fig. 5).

➔ The model was able to predict dead tree coverage for all years throughout Luxembourg with good accuracy, even in years with no reference data (2018/20).

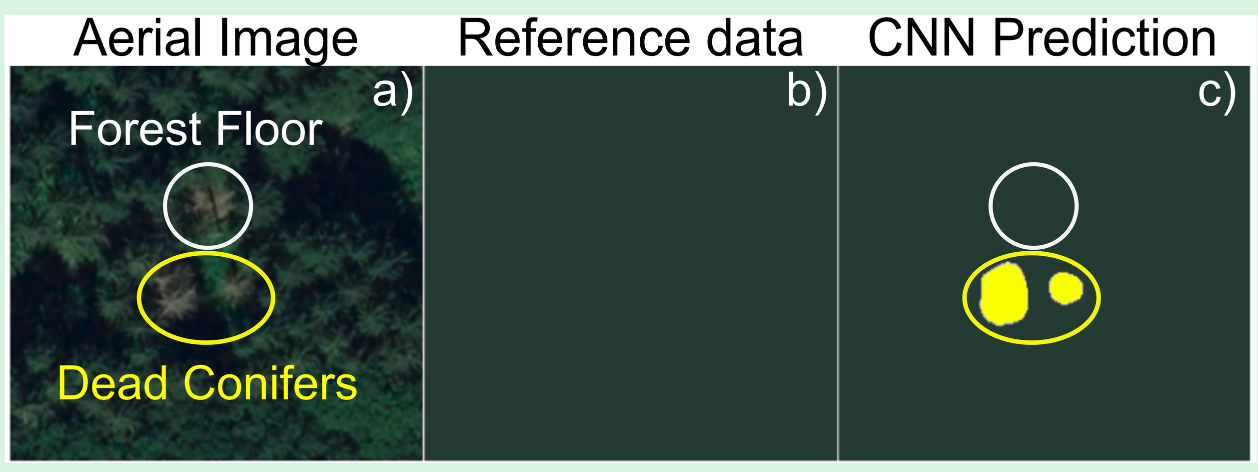


Figure 5: Example from model training: CNN algorithm correctly predicts dead trees (c) missed by the human eye (b). It avoids bare soil (see a).

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