Mapping the dieback of several tree species in Centre of France using Sentinel-2 derived indices

Florian Mouret, Milena Planells, Louise Beaudonnat, David Morin, Hilaire Martin, Cécile Vincent-Barbaroux

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11/2024

Overview

Context

- RECONFORT project, part of the SYCOMORE programm of Centre-Val de Loire Region. Project leader : Cécile Vincent-Barbaroux (@ U. Orléans). Target: Develop approaches and tools to better assess forest dieback.

- SUFOSAT project, funded by ADEME. Project leader : Milena Planells (@ Cesbio). Target: Develop the use of satellite data to monitor forest parameters and evolution (height, volume, DBH, clear-cuts, health status).

Forest dieback context

- Forest dieback due to successive droughts and heat waves of the last few years.
- Acceleration of this phenomenon in the coming years.
- A generalized weakening of several species is already observed in the forests of the Centre-Val Loire Region (Département de Santé des Forêts, 2018)

Forest dieback

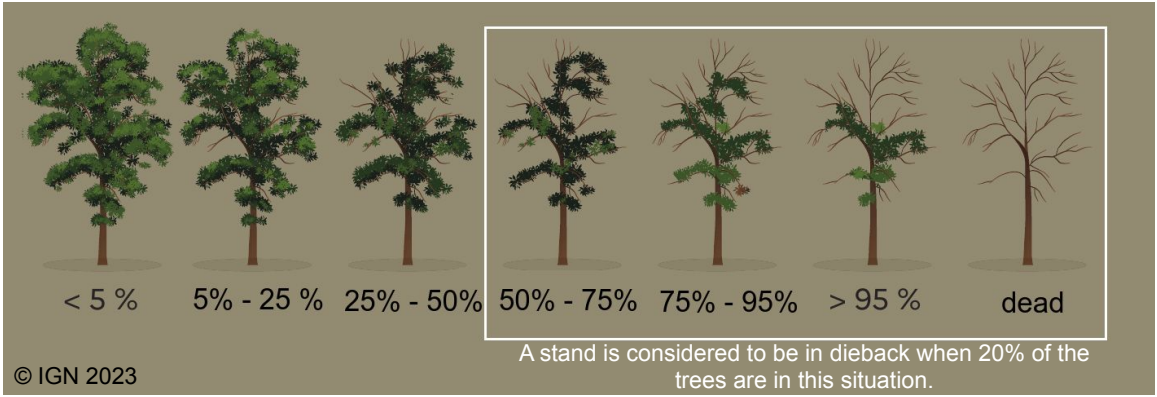


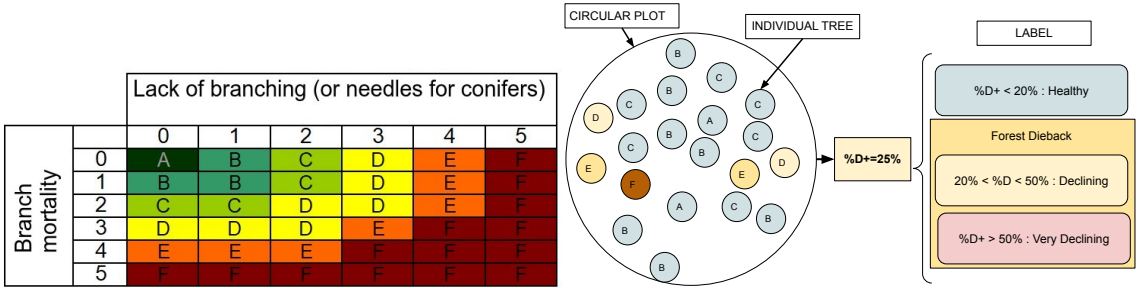
Figure: Percentages of canopy loss. Source: IGN (2023)

As defined by the French Forest Health Service, a plot (or stand) is declining if more than 20% of its trees are declining, i.e., have a canopy loss higher than 50%.

Labelling protocol : DEPERIS method

Figure: Dieback is assessed by looking at dead branches (blue) and lack of branching / ramification (red). Image: French Forest Health Service DSF / agriculture.gouv.fr

Labelling protocol : DEPERIS method



(a) Tree-level health status

(b) Plot-level health status

Figure: Protocol used in France to assess forest health.

Overview

Ground truth : oak plots

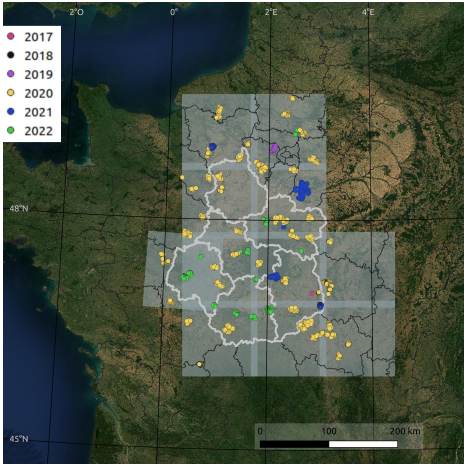
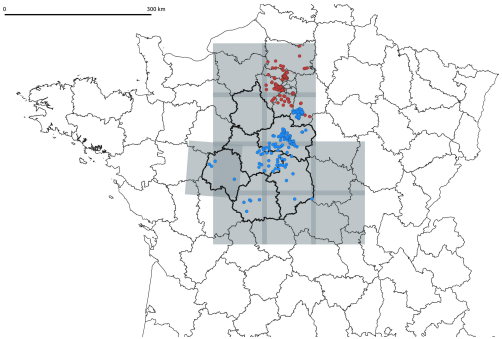


Table I
REFERENCE DATA PER YEAR AND DIEBACK CATEGORY.

Year	# Plots	Healthy	Declining	Very declining
2022	300	111	97	92
2021	433	81	131	221
2020	1685	1202	338	145
2019	135	46	40	49
2018	120	50	52	18
2017	65	37	25	3
TOTAL #	2738	1527	683	528
TOTAL %	100.00%	55.77%	24.95%	19.28%

Figure: The colored dots locate the reference data, with each color representing a labeling year

Ground truth : pine and chestnut plots



Blue : pine trees, Red : chestnut trees

Table: Chestnut

Year	# Plots	Healthy	Decl.	V. Decl.
2022	188	55	71	62
2020	197	43	55	99
TOTAL	385	98	126	161
TOTAL %	100%	25.45%	32.73%	41.82%

Table: Pine

Year	# Plots	Healthy	Decl.	V. Decl.
2023	147	103	40	4
2021	9	3	6	0
2020	91	76	14	1
TOTAL	247	182	60	5
TOTAL %	100%	73.68%	24.29%	2.02%

Overview

Proposed workflow for operational monitoring of forest dieback

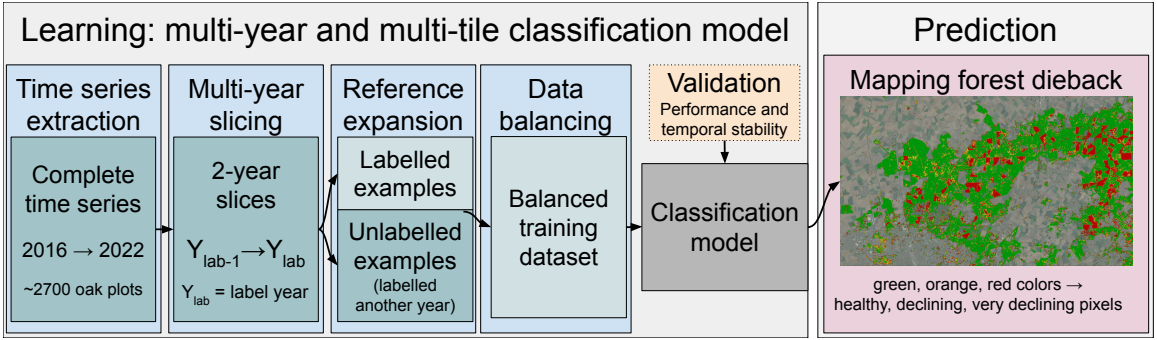


Figure: Mouret et al. (2024a)[1].

[1] F. Mouret et al. Toward an operational monitoring of oak dieback with multispectral satellite time series: A case study in Centre-Val de Loire region of France. IEEE JSTARS, pp 1–18, 2024.

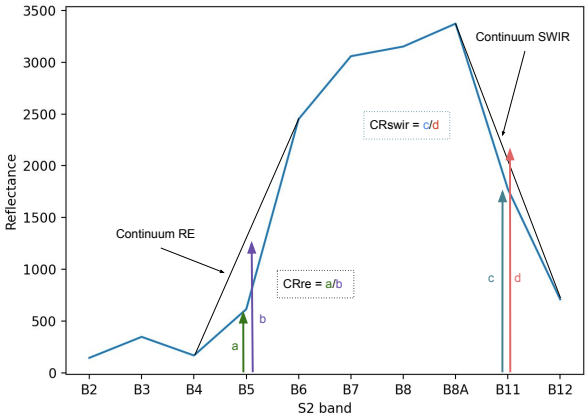
Simplified workflow

Figure: Mouret et al. (2024a)

→ **based on Iota2 processing chain (CESBIO)**

- Easier deployment
- Robust processing chain
- ...

Vegetation indices based on continuum removal



$$CR_{swir} = \frac{B11}{B8a + (\lambda_{B11} - \lambda_{8a}) \times (\frac{B12 - B8a}{\lambda_{B12} - \lambda_{8a}})} \quad (1)$$

$$CR_{re} = \frac{B5}{B4 + (\lambda_{B5} - \lambda_{B4}) \times (\frac{B6 - B4}{\lambda_{B6} - \lambda_{4}})} \quad (2)$$

Figure: Reflectance of a healthy plot (Orléans forest) in summer (29/06/2020) and its continuum RE and SWIR (inspired by the figure in Dutrieux et al. (2021))

Multi-year slicing

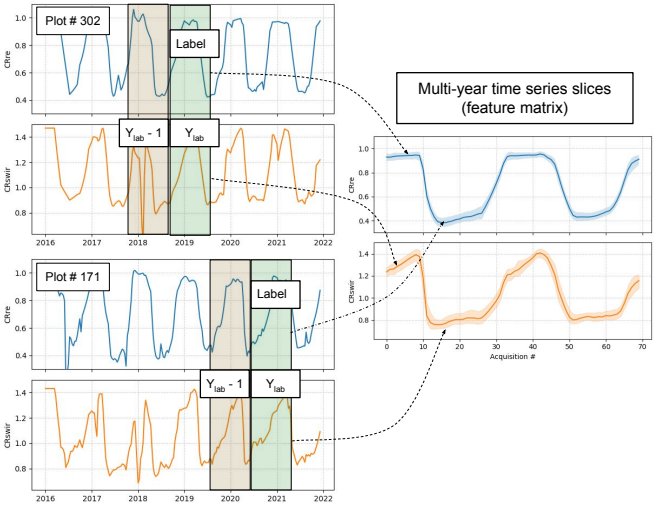
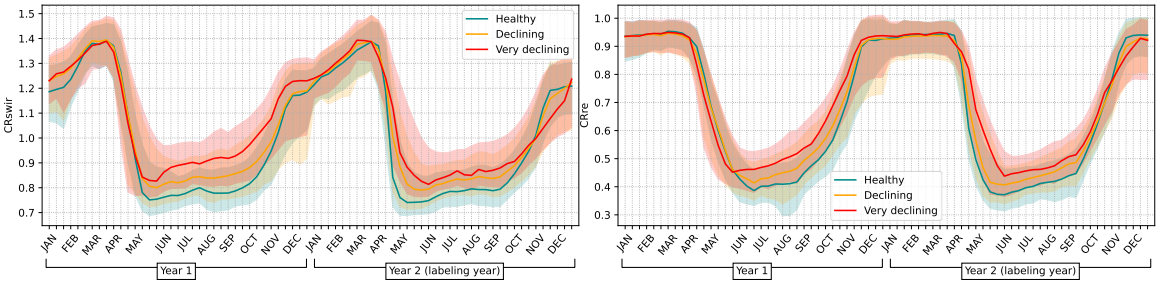


Figure: Illustration of the multi-year slicing used to create the feature matrix when using two indices.

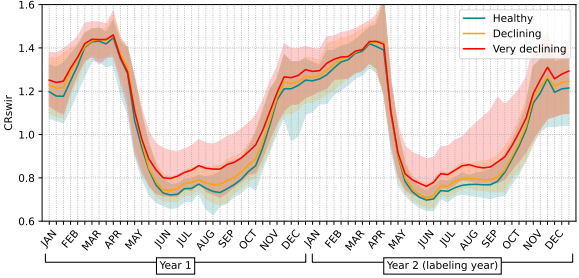
Input features (oak plots)



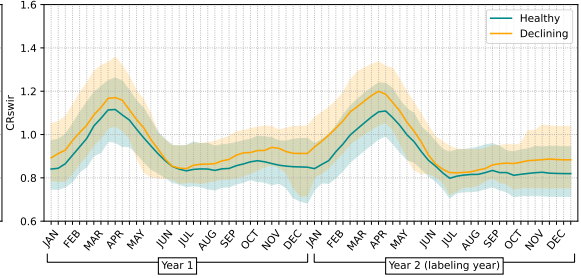
(a) CRswir (b) CRre

Figure: Time series of (a) CRswir and (b) CRre indices of the learning dataset acquired over 2 years prior to labeling (Year 1 is the year before labeling and Year 2 is the year of labeling). The colors cyan / orange / red correspond respectively to healthy, declining and very declining plots based on the percentage of trees with grades lower than D. The solid line corresponds to the median value of the class and the shaded area to its interquartile range.

CRswir for pine and chestnut



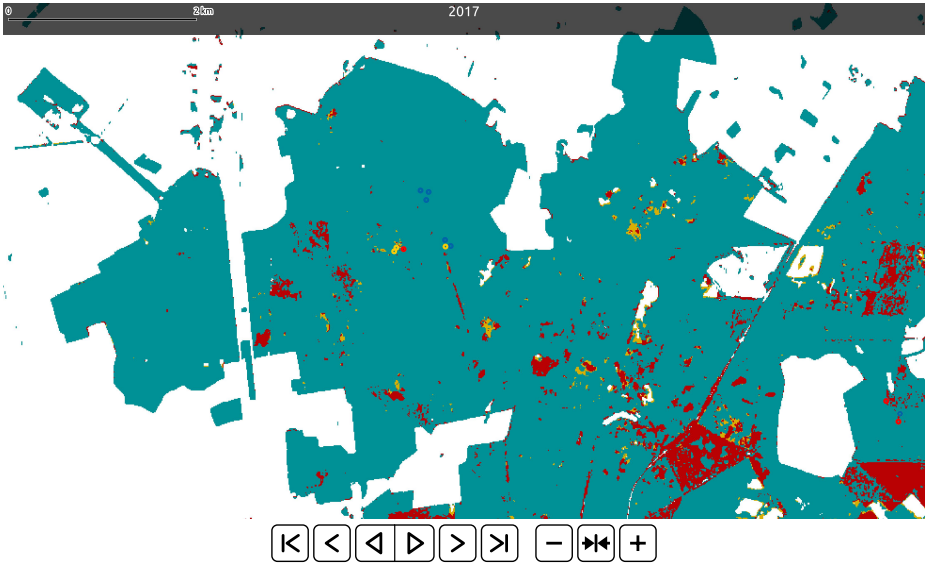
(a) Chestnut



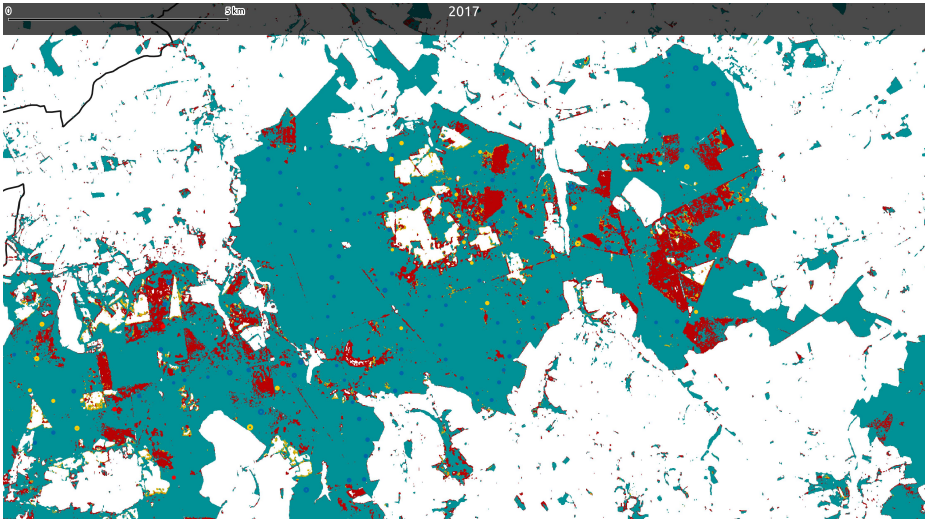
(b) Pine

Overview

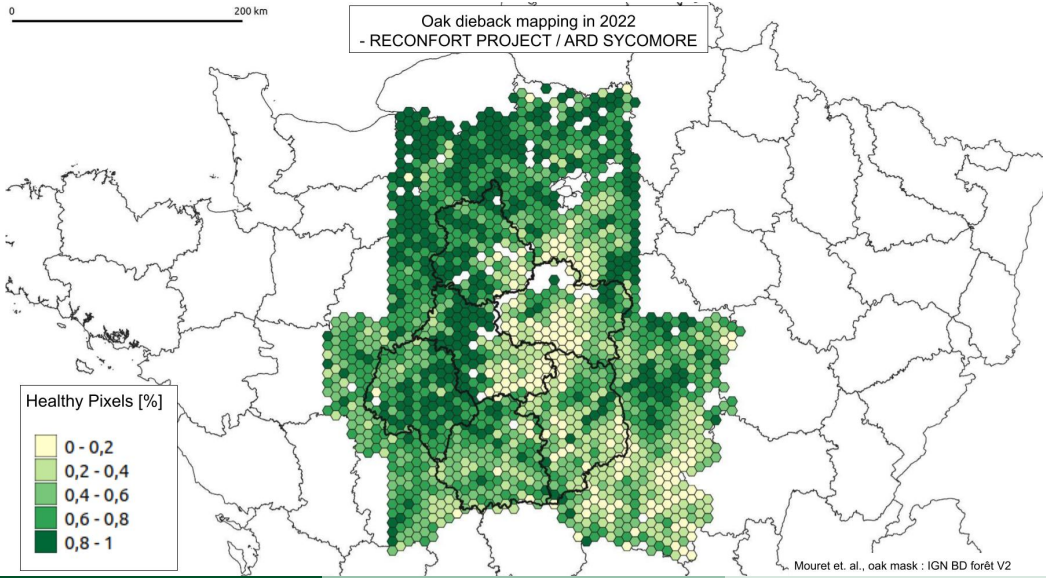
Map production (Orléans)



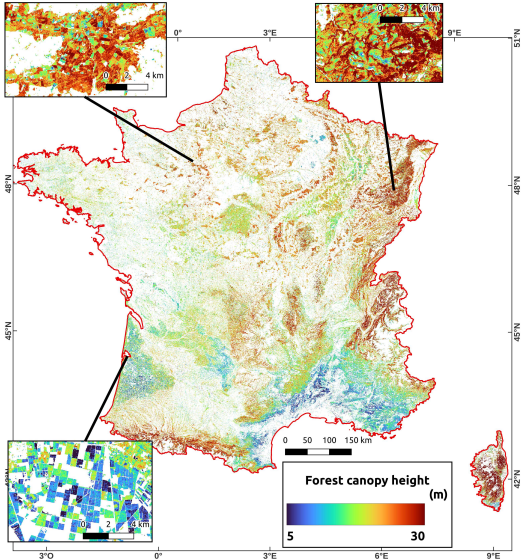
Map production (Tronçais)



Map production (2022) - oak



Height maps (SuFoSat project)



- Height map produced for whole France in 2020 using ML and handcrafted features from S1/S2/ALOS data.
- Available at `https://zenodo.org/doi/10.5281/zenodo.8071003`.
- Associated reference: Morin et al. (2023).

Dieback maps vs. height maps

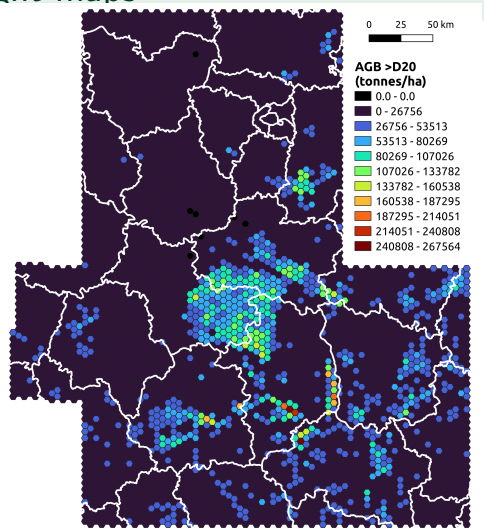
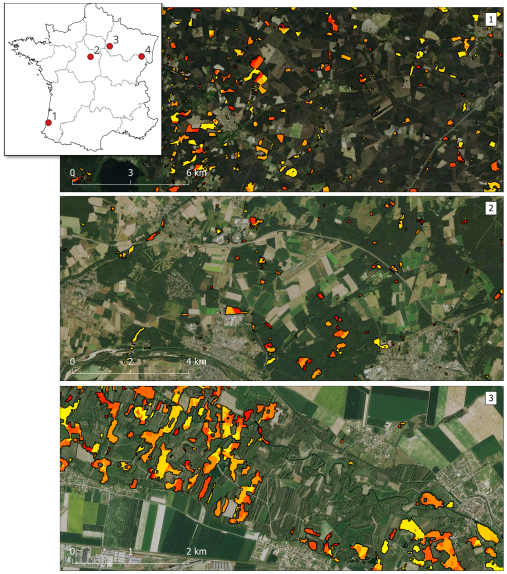


Figure: AGB of oak areas (BD Foret V2) with a majority of declining pixels

Clear-cuts detection by the GlobEO team (SuFoSat project)



- Clear-cuts detection maps produced from 2018 up to date for the SuFoSat project.
- Freely available at `https://ee-sufosatclearcuts.projects.earthengine.app/view/sufosat-clearcuts-fr`
- Associated paper: Mermoz et al. (2024)
- Clear-cut detections by S1 not impacted by dieback

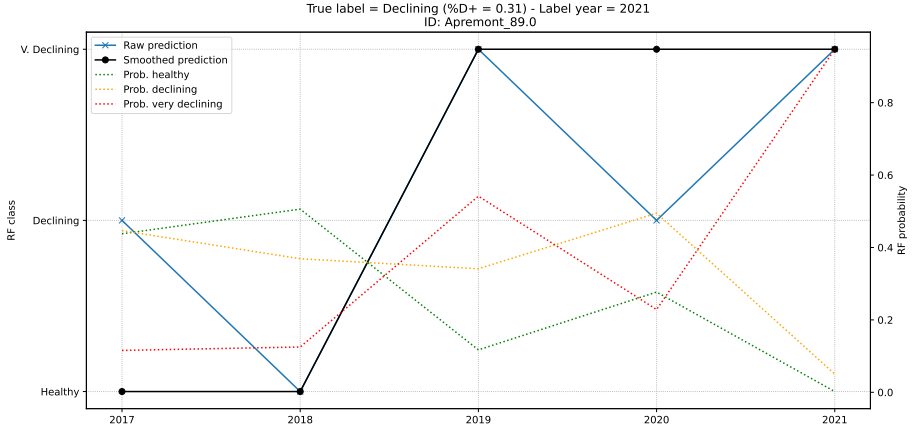
Overview

Conclusion

- **Dieback maps:**
  - Generic **dieback detection** method that can map forest dieback of various tree species **over time** without intensive tuning
  - Accurate mapping is possible, especially to separate healthy / declining areas (ground validations were successful)
  - Additional results: S1 does not appear to be sensitive to dieback Mouret et al. (2024b)
- **Clear-cuts maps:** freely available in France (2 months delay) and Guyane, Gabon, South-East Asia (tropisco.org)
- **Height maps**: simple ML methods can perform well

Some perspectives

- Oscillations (optimistic / pessimistic predictions) are possible (phenological changes)
  $\rightarrow$ using post-processing can be useful to stabilize the mapping



- Can we train a generic model using tree species information ?

Some perspectives (Dieback)

- **Supervised approach:** training plots needed + potential generalization problem → Weakly supervised methods, foundation models ?
- Model not adapted to young trees → reference data needed, include height and density ?
- **Label definition:** DEPERIS methods at the plot-level vs. ML + S1/S2 at the pixel-level → methodological improvement possible ?
- Extend to other tree species / regions in France → need for more ground data for training and validation (new campaigns will be conducted in 2025)
- Include height and other structural metrics in dieback detection → Discussions needed with LIDAR community

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