Operationalizing Machine Learning Based Early Leaf Discoloration Monitoring in Switzerland's European Beech Forests

Colin Bloom[1], Andri Baltensweiler[1]

[1] *Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf, Switzerland*

Leaf discoloration in Central Europe's European beech (*Fagus sylvatica* L.) forests is usually triggered by seasonal declines in temperature and photoperiod. However, severe drought and unusually high temperature can also cause leaves to discolor and shed much earlier than normal. Trees that exhibit early leaf discoloration are known to be more vulnerable to crown dieback and mortality following drought. As a result, early discoloration is both a reliable indicator of drought stress and an effective early-warning signal for potential drought damage. Previous efforts used field observations of early leaf discoloration across Switzerland and annually normalized Sentinel-2 vegetation-index time series to successfully model and isolate early leaf discoloration signals from legacy effects of drought during both drought and post-drought periods between 2017 and 2023 (Bloom et al., in review). Here, we present efforts to operationalize this machine-learning approach and provide rapid, near real-time detection of evolving discoloration conditions across Switzerland's European beech forests. Our workflow builds on swisstopo's SwissEO Sentinel-2 surface-reflectance dataset, which rapidly processes and publishes new Sentinel-2 assets for Switzerland as they become available. For each new asset, we align all spectral bands to a 10-meter spatial resolution and mask the data for clouds, terrain effects, and a current estimate of Switzerland's European beech-forest area. Five vegetation indices (CCI, CIRE, EVI, NDVI, and NDWI) are computed, and running annual minimum and maximum values are updated for each index. These annual extrema are used to normalize the indices, an essential step for separating seasonal discoloration from lingering signals of disturbance and forest management measures. A trained Support Vector Machine Classifier (Bloom et al., in review) is applied to the normalized vegetation indices at each new time step to estimate emerging discoloration. This operational machine learning approach, currently being configured as an addition to Switzerland's ongoing national drought monitoring platform, provides foresters and forestry agencies with a timely, interpreted, and actionable signal of European beech forest stress. These efforts demonstrate how a traditional machine-learning research tool can be transformed into a digital resource that delivers continuously updated, decision-ready information to support proactive forest management, strengthen risk assessment, and guide timely interventions under climate-driven stress.

Bloom, C.K., Koch, T.L., Bose, A., Paganini, R., Meusburger, K., Walthert, L., Scherrer, D, Baltensweiler, A., in Review, Spatial and Temporal Patterns of European Beech Discoloration and Disturbance in Switzerland from 2017 to 2023. https://dx.doi.org/10.2139/ssrn.5343751