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Patterns of late spring frost leaf damage and recovery in a European beech (Fagus sylvatica L.) stand in south-eastern Germany based on repeated digital photographs

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The seasonality of woody plants in cold and temperate climates is adapted to the annual course of temperature and photoperiod in order to maximise the length of the active growing season and, at the same time, avoid damages by frost events, especially by late spring frosts. Winter chilling, spring warming and finally photoperiod trigger the timely bud burst of European beech (Fagus sylvatica L.) which as a climax species is quite sensitive to winter frost and also as seedling to late spring frosts. However, due to relatively late and less varying dates of leaf unfolding, damages by late spring frosts should not occur each year. In case of a total loss due to a late frost event, F. sylvatica trees produce a new set of leaves which guarantees survival, but diminishes carbon reserves.
With a phenological camera we observed the phenological course of such an extreme event in the Nationalpark Bayerischer Wald in May 2011: Spring leaf unfolding, an almost complete loss of fresh green leaves after the frost event in the night 3rd to 4th May, a subsequent leafless period followed by re-sprouting. We modeled this special leaf development from day 80 to 210, observed as green% from the repeated digital camera pictures, using the Bayesian multiple change point approach recently introduced by Henneken et al. (2013).
The results for more than 30 trees predominantly suggested a model with five change points: firstly, start of the season, abrupt ending before the frost event, the loss by the frost event and after a longer period of recovery the second leaf unfolding (St. John's sprout) ending in full leaf maturity. Analyzing the results of these models the following questions were answered (1) how long is the period of recovery till the second green-up? (2) does the temporal course of the second leafing differ from the first one? (3) what are the individual factors influencing damage and recovery? (4) are individuals with early or late bud burst more prone to damage?
The five change points of the model almost perfectly matched the expected break points: i) start of the first greening between DOY (day of the year) 108 to 119 (mean 113), ii) end of greening and iii) visible frost damage after the frost on the night of May 3rd/4th (DOY 123/124), iv) re-sprouting 19 to 38 days after the frost, and v) full maturity around DOY 178 (166 to 184) when all beech crowns had fully recovered. Since frost damage was nearly 100%, individual susceptibility did not depend on the timing of first spring leaf unfolding. However, we could identify significant patterns in fitness linked to an earlier start of leaf unfolding.