Semi-Markov switching linear mixed model for analyzing forest tree development

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Observed growth, as given for instance by the length of successive annual shoots along tree trunks, is mainly the result of three components: an endogenous component, an environmental component and an individual component. The endogenous growth component is assumed to be structured as a succession of roughly stationary phases separated by marked change points, asynchronous between individuals ([2]). The time-varying environmental component is assumed to take the form of local fluctuations, synchronous between individuals and was simply characterized globally in [2]. In order to separate and to identify these three components, we propose to use semi-Markov switching linear mixed models, i.e. models that combine linear mixed models in a semi-markovian manner; see [1] for an overview of Markov switching models. The underlying semi-Markov chain represents the succession of growth phases while the linear mixed models attached to each state of the underlying semi-Markov chain represent both the influence of environmental covariates as fixed effects and inter-individual heterogeneity as individual-wise random effect. A MCEM-like algorithm whose iterations decompose into three steps (sampling of states sequences given random effects, prediction of random effects given a state sequence and maximization) is applied for estimating semi-Markov switching linear mixed models. This statistical modeling approach is illustrated by the analysis of successive annual shoots along Corsican pine trunks influenced by climatic covariates. A “left-right” three-state semi-Markov switching linear mixed model, composed of two successive transient states followed by a final absorbing state, was estimated; each phase change corresponding to a growth increase. The estimated model showed that the influence of the climate is weak in the first growth phase (corresponding to the beginning of the plant life), then increases markedly with the phase while the part of inter-individual heterogeneity decreases more slightly.

References

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