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# Forest management effects on post-drought growth resilience: a new analytical framework applied to pine plantations

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Forest management can play an important role in addressing the issue of generalized canopy dieback and increase in tree mortality rates after severe droughts in both plantations and natural stands. In particular, there is interest in establishing the effects of thinning as a strategy to improve growth recovery after drought across tree species and climates. For that reason, we need a robust framework to determine general forest growth and drought resilience changes after thinning, and their temporal legacy. To that end, we designed a regression model to determine differences in radial growth, sensitivity to previous-year growth and drought, and long-term growth trends, as well as individual random variability. Once fitted based on basal area increment records, the model allows simulating post-drought and post-thinning growth trajectories based on the observed parameters. We computed drought resistance, resilience and recovery indices based on these trajectories, obtaining more reliable estimates than computing these indices based on the raw tree-ring records. Moreover, the simulations allowed us to calculate the time to recovery after a drought. We tested this analytical framework on five pine plantations of three species (*Pinus halepensis* Mill., *Pinus nigra* Arn. and *Pinus sylvestris* L.) under different thinning intensities, classified based on the average ranges of basal area removed as moderate (20-35%) and heavy (>35%) thinned. We found that thinning enhanced growth between +85 and +150%, and reduced previous-year growth dependence (between –13 and –26%) and climatic dependence (–23 to –49%). We interpret these effects as a result of competition reduction by thinning and a transitory alleviation of growth climatic constraints, particularly water shortage. Thinning consistently improved drought resistance (+4 to +20%) and resilience (+1 to +4%). Growth recovery, on the contrary, was reduced (–1 to –15%). Since the growth loss during the drought was reduced due to higher drought resistance, the recovery was proportionally lower. Thinning reduced the time to recovery by one to two years, and the thinning legacy effect persisted up to 15 to 20 years after thinning. Taken together, these findings enhance the benefits of adaptive silviculture in making pine plantations less vulnerable to unfavourable extreme climate events such as droughts. We present a novel and robust analytical framework to assess drought-thinning interactive effects on tree growth.