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Detecting spatial structures in throughfall data: the effect of extent, sample size, sampling design, and variogram estimation method

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In the last three decades, an increasing number of studies analyzed spatial patterns in throughfall to investigate the consequences of rainfall redistribution for biogeochemical and hydrological processes in forests. In the majority of cases, variograms were used to characterize the spatial properties of the throughfall data. The estimation of the variogram from sample data requires an appropriate sampling scheme: most importantly, a large sample and an appropriate layout of sampling locations that often has to serve both variogram estimation and geostatistical prediction. While some recommendations on these aspects exist, they focus on Gaussian data and high ratios of the variogram range to the extent of the study area. However, many hydrological data, and throughfall data in particular, do not follow a Gaussian distribution. In this study, we examined the effect of extent, sample size, sampling design, and calculation methods on variogram estimation of throughfall data. For our investigation, we first generated non-Gaussian random fields based on throughfall data with heavy outliers. Subsequently, we sampled the fields with three extents (plots with edge lengths of 25 m, 50 m, and 100 m), four common sampling designs (two grid-based layouts, transect and random sampling), and five sample sizes (50, 100, 150, 200, 400). We then estimated the variogram parameters by method-of-moments and residual maximum likelihood. Our key findings are threefold. First, the choice of the extent has a substantial influence on the estimation of the variogram. A comparatively small ratio of the extent to the correlation length is beneficial for variogram estimation. Second, a combination of a minimum sample size of 150, a design that ensures the sampling of small distances and variogram estimation by residual maximum likelihood offers a good compromise between accuracy and efficiency. Third, studies relying on method-of-moments based variogram estimation may have to employ at least 200 sampling points for reliable variogram estimates. These suggested sample sizes exceed the numbers recommended by studies dealing with Gaussian data by up to 100 %. Given that most previous throughfall studies relied on method-of-moments variogram estimation and sample sizes « 200, our current knowledge about throughfall spatial variability stands on shaky ground.