Multigroup Latent Structural Equation Modelling as a statistical tool to assess the stability of soil nitrifying communities in agroforestry systems

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Résumé

Abstract ecological attributes are commonly approached with measurable variables. As an example, the stability of communities is estimated as the combination of their resistance and resilience. Identifying the causal relations that influence such attributes is a statistical challenge since correlation does not imply causation. Studying these relations in spatially complex ecosystems adds another level of complexity, since the relations may be spatially structured. Structural equation modeling (SEM) is an adapted statistical tool to address such issues. SEM allow to model abstract attributes through latent variables that are described using a set of observable variables. In Multigroup Latent SEM (ML-SEM), postulated causal relations that explain these attributes can then be tested and compared given spatial compartments.
This study aims at disentangling the causal relations that explain the stability of soil nitrifying communities (i.e., micro-organism that oxidize ammonium into nitrate) in two silvopastoral systems (i.e., pastures with hedges or with alley-cropping tree rows). To do so, we developed a 3-step ML-SEM approach. The first step consisted in the identification of possible causal relations and the development of a directed acyclic graph to test theses relations across the compartments (next to the trees, 1.5 m and 10 m from the trees). The second step consisted in the conception of the experimental design for data acquisition, and the third step consisted in the implementation of the ML-SEM to test differences in causal relations across the silvopastoral systems and their compartments.
Results revealed that the causal relations explaining the stability of nitrifying communities differed between the two silvopastoral systems. The tested ML-SEM model was unable to validate the causal relations in the hedgerow system, but validated those in the alley-cropping system. It showed that nitrification stability was positively related to higher soil organic carbon content and lower soil bulk density, which invites to consider practices that enhance these latter to improve de stability of the nitrogen cycle in silvopastoral systems. Finally, the ML-SEM methodology we used could inspire other studies on causal relations in spatially complex ecosystems but requires considerations about number of replicates to capture the spatial organization of such systems.

Mots-Clés: Structural Equation Modelling, Microbial stability, Nitrogen cycle, Soil, Grassland, Agroforestry

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