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Screening groups of parameters using the Morris method to select parameters for variance based sensitivity analysis

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Abstract

A variance based sensitivity analysis (SA) requires a large number of model evaluations. In order to perform a variance based SA on a process-based whole-year grassland model for timothy, we arranged the 62 model parameters in 15 groups and used the less computationally expensive Morris method to identify which groups contained the most important parameters. We used observations and climate data from a northern and a southern location. The Morris method identified seven important groups for the southern location, and five groups at the northern which was selected for the variance based SA. At the northern location the most important parameters were related to frost tolerance, and at the southern location assimilate allocation and foliage parameters were most important.

Keywords: Sensitivity analysis; Morris' method; parameter groups; Sobol' method;

1. Main text

A process-based model for timothy (*Phleum pratense* L.) that considers both the growing season and the winter period was developed within the WINSUR project (Van Oijen *et al.* 2009; Thorsen and Höglind 2009). The model simulates the development of snow and ice in the field, the development of frost and ice encasement tolerance, and the dynamics of biomass, tillers and water soluble carbohydrates as influenced by winter stress factors like frost, ice encasement, and low light conditions. This is a complex model (62 parameters). In order to perform a variance based sensitivity analysis (SA), which is computationally expensive since this SA requires a large number of model evaluations, we arranged the parameters in 15 groups and used the less computationally expensive Morris method to identify which groups contained the most important parameters (Campolongo *et al.* 2006).

This study focused on the processes related to the winter period. The data available for was observations taken on plants during the winter at two different locations in Norway; one southerly (Særheim, 58°45′ N, 05°38′ E) and one northern (Holt, 69°39′ N, 18°54′ E). The variables measured were total number of tillers, dry matter, total non-strucural carbohydrate content in aboveground biomass, leaf area index and frost tolerance. The SA requires a scalar response. First we calculated the normalized root mean squared error for each of the five output variables

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($RMSE_{norm}(i)$). Secondly we calculated a weighted mean of these $RMSE_{norm}(i)$, termed $\overline{RMSE}_{norm}$ with weights according to their importance. We used $\overline{RMSE}_{norm}$ as scalar response for the SA.

The Morris method is suitable for identifying important parameters, or groups containing important parameters. We performed five SA experiments with group-configurations of parameters using the Morris method at each location (ten experiments in total). The index μ* was calculated for each group; the highest μ*-values identified the most important groups. At both locations, a visual inspection of the μ*-ranking of the groups after each SA experiment showed slightly different results with respect to the order of importance of the groups. For each location, based on the results from the corresponding five experiments, we selected a number of groups which on average was ranked. This was seven groups for the southern location, and six groups for northern location. These seven and six groups, respectively, contained the parameters for the more computationally expensive variance based SA using the Sobol' method. Since the selection of groups was slightly different for the southern and the northern location, we also made a third selection of groups. The groups in this third selection were the identical for both locations. The Sobol' SA was carried out using SimLab v.3.2 library and the Morris SA was based on MATLAB code, both available at http://simlab.jrc.ec.europa.eu/. The model was executed at each of these sampling points, and the $\overline{RMSE}_{norm}$ was used to calculate the sensitivity indices.

At the southern location, the Morris experiments suggested seven important groups (out of 15), with 30 parameters in total. The Sobol' First (S_i) order and Sobol' Total (S_{Ti}) order sensitivity indices identified seven important parameters. Three parameters were related to allocation of carbohydrates, two parameters were related to foliage processes, and one parameter were related to each of the processes frost tolerance and phenology, respectively.

At the northern location, six parameter groups were identified by the μ*-values as containing important parameters (five of the groups coincided with the southern location). In total 25 parameters were selected for the SA using the method of Sobol'. The indices S_i and S_{Ti} identified 11 parameters as important. Eight parameters were related to frost tolerance, and one parameter were related to each the processes of foliage and rooting depth.

The third group selection was a subset of five groups (out of the original 15) which obtained high μ*-values at both the southern and northern location; in total 21 parameters. The index S_i identified the same 4 parameters as important at both locations; three related to light use efficiency and one related to foliage. At the southern locations two parameters was notably involved in interactions (foliage and phenology), whereas at the northern location the same two parameters (foliage and phenology) in addition to seven of the frost tolerance parameters were notably involved in interactions.

In summary, we performed a SA in two steps on a complex process-based grassland model, focusing on the winter period. First by doing a screening exercise using groups of parameters. This screening identified the important groups containing the influential parameters. The parameters in the important groups were selected for a variance based SA using the method of Sobol'. The grassland model was run at two different climatic regions in Norway; Særheim (south) and Holt (north). Therefore the two step SA was performed at both locations. The group screening resulted in the selection of both coinciding and different groups of parameters. The main findings were that parameters related to frost tolerance was most important at the northern location, whereas parameters related to assimilate allocation and foliage was most important at the southern location.

In future work this SA should be conducted for both the winter period and the growing season.

2. References

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