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Probabilistic projections of climate change effects on sub-arctic palsa mires using the response surface approach

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Recent progress in estimating probabilities of future climate change allows to go beyond "what if"-type of scenarios to the quantified assessment of risks posed on a natural or human system. A challenge for a model-based impact assessment is the potentially high number of simulations that may prove impractical. Estimating probabilities of climate change impacts is demonstrated here in a case study about sub-arctic palsa mires.

Palsa mires, which contain peat with permanently frozen ice, are located at the outer margin of the permafrost zone and are expected to undergo rapid changes under global warming. These changes are expected to have a significant influence on the biodiversity of sub-arctic mires and could also potentially affect the regional carbon budget. We use a simple model describing the spatial distribution of palsa mires in Fennoscandia as a function of monthly temperature and annual precipitation to estimate the risk of palsa mires loss [1].

Impact response surfaces describing the change in area of palsa suitability were constructed from a sensitivity analysis of the impact model with respect to changes in mean annual temperature and precipitation. This required a simplification of the palsa mire model (that has more than two input variables) based on the analysis of the seasonal pattern of simulated monthly temperature changes. Joint distributions of projected changes in the two explanatory climatic variables, based on resampled AOGCM outputs [2], were superimposed onto the impact response surface so that the frequency of a given impact response could be evaluated. Results were compared to probabilistic projections obtained from the perturbed parameter simulations of the HadCM3 AOGCM of the Quantifying Uncertainty in Model Prediction project (QUMP) [3; G. Harris, pers. comm.]. Finally an attempt is presented to incorporate impact model uncertainty in the analysis.

It was estimated as very likely (>90% probability) that a loss of area suitable for palsa mires to less than half of the baseline distribution will occur by the 2030s and very likely or likely (>66%) that all suitable areas will disappear by the end of the 21st century under the A1B and A2 emissions scenarios. For the B1 scenario, it was more likely than not (>50%) that a small proportion of the current palsa mire distribution would remain until the end of the 21st century. The response surface method, though introducing additional uncertainty, gave reliable risk estimates of area loss with suitable climate condition for palsa mires compared to multiple simulations with the original palsa model. Potentially, it could prove to be a useful tool in other impact modelling studies, as it can substantially reduce the number of simulations needed to conduct a quantified risk assessment.

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[2] Räisänen, J. and Ruokolainen, L., 2006: Probabilistic forecasts of near-term climate change based on a resampling ensemble technique, Tellus 58A, 461-472.
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