Thermal erosion of ice-rich permafrost in the Lena River Delta / Siberia – Determining the decisive factors using logistic regression

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Vast parts of Arctic Siberia are underlain by ice-rich permafrost, which is exposed to different processes of degradation due to global warming. Thermal erosion as a key process for landscape degradation in these regions causes the recent reactivation and formation of new landforms like thermo-erosional valleys and gullies. However, a statistical assessment about the decisive factors and the locations most susceptible to this phenomenon is still missing. We investigated the influence of different environmental parameters on the occurrence of recently observed thermal erosion using a GIS-based approach and statistical modeling by logistic regression. The study site is located on an island within the Arctic Lena River Delta and is mainly composed of ice- and organic-rich deposits of the Yedoma-type Ice Complex. Field surveys and mapping on the basis of high-resolution remotely sensed data revealed that thermal erosion occurs predominantly i) on very steep slopes along the margins of the island, ii) in the upper reaches of deeply incised valleys and iii) in gullies. In order to detect the regulation factors for those thermo-erosional landforms, we derived several environmental parameters using a high-resolution DEM and satellite imagery. We chose a stepwise logistic regression approach to reduce the full set of potential parameters. This approach allowed the selection of a parsimonious model, i.e. a best-fit model using as few parameters as possible. The parameters Contribution of warm open surface water, Relief ratio, Direct solar radiation and Snow accumulation turned out to be the decisive factors for thermal erosion. Uncertainties in the model due to sampling and model selection were evaluated both statistically and spatially through the generation of 100 models. Receiver Operating Characteristics (ROCs) were used to validate the spatial predictive capability of each model run. The consensus map as the median of all 100 susceptibility models represents the final susceptibility map. The agreement between mapped and predicted erosion turned out to be generally very high within the study site, confirmed by an Area under the ROC curve (AUC) of 0.957 for the consensus map. The variability of predicted erosion probabilities between the single models is about four percentage points per cell within the study site and thus, very low. We attributed the slight mismatches between observed and predicted erosion to the generation of the explanatory environmental parameters and the modeling approach. Model results seem promising for the spatial prediction of susceptible sites for thermal erosion and, thus, could be a tool to explain the geomorphic forming in this rapidly changing environment. As these results are based on a single case study, future investigation should focus on the transferability of the model by applying an external validation on other sites with comparable environmental conditions.