Summary
Climate change has been forecast and has been observed worldwide. This change could have substantial effects on natural ecosystems. As a consequence, it is questionable whether current nature targets, partly obligatory through law, may still be obtained in a future climate.

To assess the impact of environmental changes on terrestrial vegetation, scientists apply habitat distribution models, i.e. models that are capable of predicting the future spatial distribution of habitats. These habitat suitability predictions can be converted into maps of potential vegetation. Current models, however, generally use indirect and simple site factors to characterize habitats, resulting in a highly correlative relationship with the vegetation. Consequently, these models are likely to be inapplicable under changing climatic conditions.

In order to improve vegetation predictions for the future climate, process-based and climate-proof relationships between site factors and vegetation are needed. This thesis addresses the development of climate-proof relationships between soil moisture conditions and vegetation. Soil moisture is one of the main site factors that determine terrestrial vegetation composition.

Groundwater levels, and the related soil moisture conditions, vary in time due to temporal variations in meteorological conditions, both within and between years. Due to these temporal variations, systematic differences in the relationships between soil moisture conditions and vegetation are found when the relationships are based on too short measurement periods. Chapter 2 shows that data harmonization removes such differences and increases the general applicability of empirically derived relationships.

In order to capture the climate effects on oxygen stress to plant roots, caused by a surplus of soil moisture, a process-based model was developed. This model involves the relevant interacting soil physical, soil microbial and plant physiological processes in the soil-plant-atmosphere system. Chapter 3 demonstrates that constant soil moisture thresholds for the occurrence of oxygen stress are insufficient in the face of climate change, as these thresholds depend strongly on soil temperature, among other things. The new model takes relevant processes in the soil-plant-atmosphere system into account, and allows for the calculation of oxygen stress thresholds, also under changing climatic conditions.

The oxygen stress model was applied to derive a site factor for oxygen stress, i.e. a measure for the wetness of the soil to which the actual vegetation may be adapted, defined as root respiration stress (Chapter 4). Respiration stress enables to account for the effects of extreme rainfall events and high temperatures; it is especially the combination of these conditions that affects vegetation. Moreover, this combination is expected to increase in the near future. Indirect measures of oxygen stress that are currently used – i.e. the mean spring groundwater level and the sum exceedence values of groundwater level thresholds – underestimate the future occurrence of oxygen stress to plant roots because
they do not include essential climate variables like temperature and extreme rainfall events. Consequently, these indirect measures result in predicted future vegetations that are systematically too dry.

Besides oxygen stress, water stress (in terms of transpiration stress) also increases under changing climatic conditions. Increased rainfall variability in interaction with predicted changes in temperature and CO₂, appeared to affect soil moisture conditions and plant oxygen and water demands such, that both oxygen stress and water stress will intensify due to climate change (Chapter 5). Moreover, these stresses will increasingly coincide, causing variable stress conditions. These variable stress conditions were found to decrease future habitat suitability, especially for plant species that are presently endangered. The future existence of such species is thus at risk by climate change.

This thesis shows that the use of correlative, indirect relationships between site factors and vegetation in habitat distribution models should be discouraged. Predictions made with currently used correlative models should therefore be interpreted cautiously. The effect of climate change on moisture-related plant stresses is complex; both wet and dry extremes may be affected, and conditions that are not present under the current climatic conditions could occur in the future. In order to capture such effects, climate-dependent processes that directly affect vegetation should be analysed. By providing such analysis, this research contributes to one of the required improvements of habitat distribution models.