CC-WaterS- Climate Change and Impacts on Water Supply

Climate change induced effects on the predisposition of forests of the water protection zone “Wildalpen” to disturbances by bark beetles

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Introduction

Disturbances like forest fires, wind throws, insect pest outbreaks and subsequent clear cutting may lead to changes in hydrology and water quality:

- increased erosion
- decomposition of litter and humus
- leaching of nitrate.

Large-scale epidemics of forest pests may induce forest decline at landscape scale with subsequent long-lasting negative effects on water quality.

The European spruce bark beetle, *Ips typographus* (L.), is one of the most significant sources of mortality in mature spruce forest ecosystems.

Fig. 1: Stand-replacing disturbance of Norway spruce forests by outbreaks of *Ips typographus.*

The objective of this study was to apply a complex predisposition assessment system for hazard rating of bark beetle infestations and for the evaluation of climate change impacts for the water protection forests of the City of Vienna in Wildalpen (Fig. 2).

Material and Methods

Following steps have been done to adapt and apply the bark beetle phenology model and the hazard rating system:

-application of the bark beetle phenology model PHENIPS concerning start of dispersion, brood initiation, duration of temperature –dependent brood development, beginning of sister broods, voltinism and hibernation (Fig. 3)

- Spatial and temporal modelling of the phenology and voltinism of *Ips typographus* using past, present as well as projected climate data
- application of a stand- and site related long-term predisposition assessment system (PAS) using forest stand and site data, annual damage reports and outputs of phenology modelling as data input (Fig.4)
- mapping of endangered areas and assessment of future susceptibility to infestations by *I. typographus* based on regional climate models using GIS.

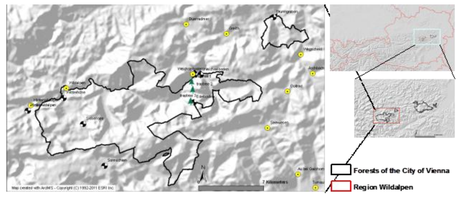

Fig. 2: Study region and location of trap trees and local weather recording stations at the water protection forest Wildalpen

Databases used for hazard rating:

- DEM
- Forest inventory data
- Site characteristics Climate date from local weather stations
- Annual forest damage reports

- Gridded climate data from ENSEMBLES:
  - Observed climate data 1951-2009 (EOBS)
  - Bias-corrected RCMs:
  - (resolution: 1x1km; emission scenario A1B)
    - Aladin
    - RegCM
    - PROMES

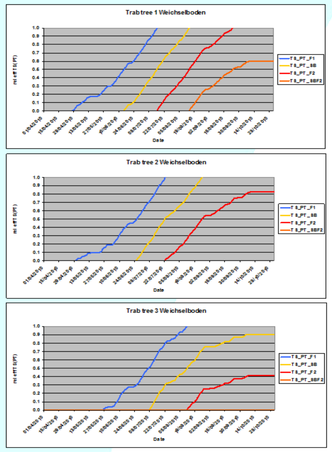

Fig. 3: Modelled effective thermal sums for three locations in Wildalpen separated by the different generations of *Ips typographus*. The model PHENIPS calculates the maximal potential development which is most relevant for hazard rating.

PAS – knowledge-based hazard rating system

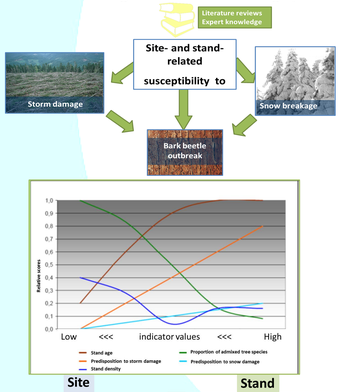

Fig. 4 :The susceptibility of stands and sites to disturbing agents (bark beetle infestations, storm and snow damage) was assessed using a complex predisposition assessment system . Empirical weighting numbers and predisposition points (i.e., penalty points) were attributed to the predisposition indicators.
The weighted predisposition values of the indicators were summed up and related to the maximum value of predisposition achievable within the system. The resulting relative sum was interpreted as the relative predisposition level of the assessment unit. Predisposition values at stand and site level were classified from the relative sums of predisposition scores (very low: ≤20% of the achievable sum; low: >20-40%; medium: >40-60%; high: >60-80%; very high: >80-100%). Finally, total predisposition was obtained by combination of stand- and site-level classes of predisposition.

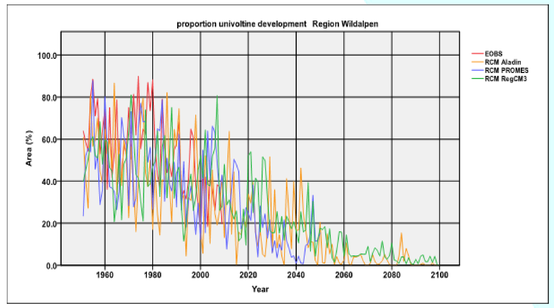

Fig. 5: Proportion (% of area) of univoltine development in the region Wildalpen, calculated with observed air temperature data (E-OBS) and with air temperature data from bias-corrected RCMs Aladin, PROMES, and RegCM3.

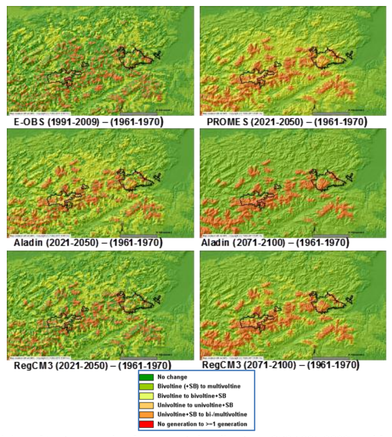

Fig. 6: Shift in voltinism of *Ips typographus* for present-day climate (E-OBS 1991-2009) and for projected climate conditions (RCMs Aladin, PROMES, and RegCM3; baseline climate period 1961-1990 and projections for the periods 2021-2050 and 2071-2100; SB: sister broods).

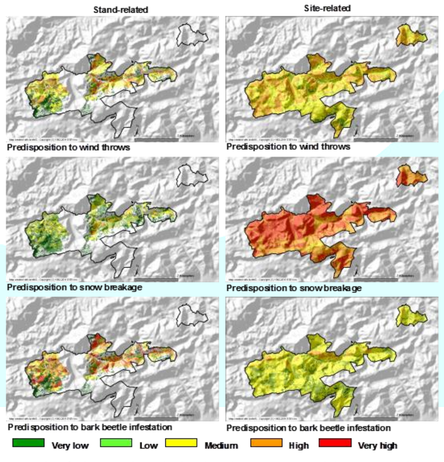

Fig. 7: Classified site- and stand-related predisposition to wind throws, snow damage, and bark beetle infestation of forest stands in Wildalpen.

Results

Modelling of bark beetle phenology with past and projected temperatures suggested drastic spatiotemporal changes in the voltinism of *Ips typographus* (Fig. 5).
A projected temperature increase of 2.98°C – 4°C until the end of the century will shift the development of *I. typographus* from predominantly univoltine to primarily bi- or multivoltine within the region of the water protection forest.
The comparison of modeled generation development based on observed present-day temperature conditions and climate conditions of the past revealed an already apparent shift in voltinism. The ongoing bark beetle calamity in Wildalpen (triggered by severe storm damages) coincides with an already expanded proportion of bivoltine generation development in the region. In the past, prevalent univoltine development and rapidly changing thermal conditions from year to year may have inhibited severe outbreaks of *I. typographus* in the region. However, projections of the generation development suggest that this inter-annual variability will be drastically reduced in future climate.

Changes affecting voltinism of *I. typographus* have a significant effect on population levels since annual population growth exponentially increases with the establishment of further filial generations. The projected shift from univoltine to bi- or multivoltine development affects primarily spruce-dominated montane and subalpine sites in the region Wildalpen (Fig. 6).

The assessment of site- and stand-related predisposition revealed a high susceptibility to bark beetle infestation of forest stands in Wildalpen. More than 65% of the total area was assigned to predisposition classes high or very high. Only 10% showed a low stand-related predisposition to bark beetle infestations (Fig.7). This high susceptibility is mainly related to the dominance of even-aged, spruce-dominated mature stands. A projected change in voltinism of *I. typographus* will additionally increase total predisposition of the stands to bark beetle infestations. Projections of predisposition of current forest stands for the end of the century indicate large continuous areas with high or very high susceptibility, a pre-requisite for extended epidemics of *I. typographus* (Fig. 8).

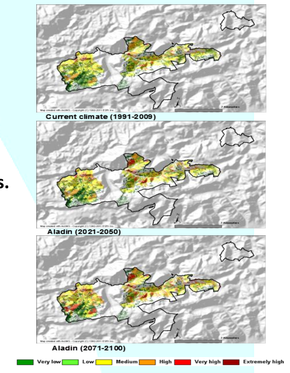

Fig. 8: Projected total (stand- and site-related) predisposition to bark beetle infestation of forest stands in Wildalpen using RCM Aladin.

Conclusions for forest management

The projected increased potential of bi- or multivoltine bark beetle populations and the spatial extension of highly susceptible stands have to be considered at planning silvicultural strategies and effective forest protection measures. Therefore a precise monitoring of beetles’ development is of prime importance. It is necessary for timely planning and execution of countermeasures especially in periods or regions with large populations and multiple generations of bark beetle. Using data from remote-accessible climate stations, PHENIPS can be applied as real time monitoring and early warning system for the beetles´ development phenology. This online monitoring tool for can be used for scheduling and timely realization of direct control and suppression measures like removal or debarking of infested trees or clearing of storm disturbed stands. Furthermore, it can useful for taking priority decisions and the timely setup of monitoring programs using pheromone traps and trap trees (http://ifff-riskanalyses.boku.ac.at).

Mapping of hazardous areas is essential for decision making in forest management in order to mitigate negative effects on hydrology, water yield and water quality. In future forest management will also have to implement the fact of disturbances as an important part of forest dynamics, where bark beetles can be considered as ecosystem engineers, driving regeneration, succession and biodiversity in spruce-dominated forest ecosystems.

References

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Acknowledgements

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