FLOODPLAIN FORESTS AND CLIMATE CHANGE – CURRENT STATE AND FUTURE PATTERNS

Mosner, E. [1] *– Schneider, S.* [2] *– Conradt, T.* [3] *– Lehmann, B.* [2] *– Hatterman, F.F.* [3] *– Leyer, I.* [1]

[1] Conservation Biology, University of Marburg, Karl-von-Frisch-Str. 8, 35032 Marburg, Germany, e-mail: eva.mosner@staff.uni-marburg.de
[2] Institute for Water and River Basin Management, University of Karlsruhe (TH), Germany
[3] Potsdam Institute for Climate Impact Research PIK, Potsdam, Germany

Abstract: Riparian softwood forests are highly endangered habitat types. At the River Elbe, river regulation by dyking and deforestation of riparian forests has caused severe reduction with only remnant stands left. However, because of their important role in terms of ecosystem function and services the need for the restoration of riparian floodplain forests is emphasized e.g. in Natura 2000.

Characteristic softwood forest species (willows and poplars) are bound to typical hydrological conditions. While adult vegetation might be less vulnerable to variations young life stages may only persist where suitable conditions are met.

Climate change might change hydrological conditions. This in turn might increase the loss of suitable habitats for softwood forest species not only for regeneration stages but also for established vegetation. Therefore, knowledge on the relation of hydrological parameters and presence of softwood forest species is needed.

Aim of this study was to identify ecologically suitable sites for the restoration of riparian floodplain forests based on hydrological parameters using a modelling approach. Results suggest that not only species but also life stages differ in abiotic requirements and interactions of abiotic factors can lead to shifts in the ecological niches of species. In a second part, possible effects of climate change scenarios on the current vegetation state in terms of alterations in vegetation composition were analysed. Results indicate partly fundamental changes of floodplain forest distribution. Findings of current and future patterns are essential for prospective management measures to assure restoration and conservation of floodplain forests.

Keywords: change of natural dynamics, climate change, reafforestation, identifying appropriate conservation and restoration objectives, biodiversity policy, ecohydrology

Introduction

Floodplains and their softwood forests are one of the most endangered habitat types in Europe due to human alterations like damming, dyking as well as land use changes. While at the Elbe River nearly all forest has vanished, its very high value in terms of biodiversity as well as improving water quality is recognised. Therefore, its restoration is one of the desirable objectives of ongoing conservation issues (e.g. Natura 2000). Riparian softwood forests show special adaptation to specific hydrological conditions. Besides, the interest to restore forests under natural conditions, weak competitiveness and the need for sufficient water supply at least for younger life stages limits riparian forest habitat. Moreover, today's conditions prevent spread of softwood forest species like willows since suitable establishing sites for sexual regeneration by seeds are missing. Also, effects of fragmentation might play a role in seed production of these dioecious and mainly insect pollinated species. Vegetative regeneration might not be equally successful for all species (e.g. because of different degrees of brittleness and success of vegetative regeneration itself) and besides, the risk of genetic depletion by solely dispersing vegetatively rises. Apart from being endangered anyway, riparian floodplain forests might be further threatened by climate change. Future predictions suggest a rise of temperature. Hattermann et al. (2007) modelled the effect of climate change on the hydrology of the Elbe River basin. The study demonstrates that while precipitation might vary strongly on a local scale with even positive tendencies, evapotranspiration will increase, which leads to smaller discharges for the rivers. If floodplain conditions like average water level, flood duration, water level fluctuations etc. which mainly structure riparian floodplain vegetation alter the highly adapted vegetation will be affected and presumably will decrease. But to what extend? Are species and/or life stages equally affected? The presented habitat modelling approach demonstrates the importance of specific hydrologic conditions for the occurrence of softwood forest species and the effect of changing conditions on species distribution.

Materials and methods

The study area is located in Brandenburg and Saxony-Anhalt, Eastern Germany (Latitude: 52.994794, Longitude: 11.753042) along the Elbe River from river kilometre 410-475 and comprises the area between dyke lines. Studied species are typical softwood forest willows of Central Europe with *Salix alba* and *S. x rubens* as arboriform vegetation and *S. triandra* and *S. viminalis* as shrubby vegetation.

The underlying data for this study were twofold: the biological and the hydrological information. First was built on a grid-based, stratified-randomized sampling design, where information about species (presence, species, age class) was gathered. The hydrological information (average groundwater level (AWL), flood duration (FD)) on the one hand was provided by analyses, based on annual river discharge for the period from 1964-1995 (Helms et al. 2002) and a high resolution DEM processed in ArcGIS 9.2 (ESRI). Groundwater level fluctuations (WLF) were calculated by cross correlation of ground water gauges of the active and the morphological inundation area with the river gauge of Wittenberge and regression of WLF with distance to the river to allow for extrapolation. Presence/absence data of species were analysed by means of logistic regression with stepwise backward selection and AWL, FD, WLF, and land use as explanatory variables. Best fit models were obtained by applying the Likelihood-Ratio-Test (Hosmer & Lemeshow 2000). Afterwards, models were validated by a 1000-fold bootstrapping procedure and model performance was checked considering AUC-values (Reiniking & Schröder 2003). With AUC-values above 0.7 models were accepted to be reliable and further used for species distribution predictions under current conditions as well as for predictions of a climate change scenario. The scenario was based on simulated river discharges (Hattermann et al. 2007) and focal explanatory variables were estimated analogous to above mentioned procedures. As a resulting measure, probability of occurrence for the species was calculated and used to compare the scenario with the Status Quo. All analyses were conducted in R (R Development Core Team, 2007) and ArcGIS 9.2 (ESRI).

Results and discussion

In general, all vegetation types and age classes showed significant relations with hydrological parameters and all models achieved reasonable AUC-values to allow for further usage (Tab.1). Differences between shrubs and trees in their response to hydrological conditions could be detected. Trees, no matter if old or young life stages showed only dependencies on AWL in a unimodal fashion whereas shrubs reacted also to WLF linearly as a single explanatory variable or in interaction with AWL.

Moreover, influence of hydrological variables and predictions were more reliable for younger life stages compared to older and so for shrubs compared to trees, which is demonstrated in R^2- as well as in AUC-values (Tab.1).

Different optima in terms of AWL or flood duration could be observed for shrubs and trees, as well as for life stages (Fig. 1). Old and young trees are found at sites with lower AWL compared to shrubs, i.e. occurring at higher elevations. In addition, old trees have a much wider niche compared to shrubs. This on the one hand demonstrates tree's ability to cover a wide range of different environmental conditions concerning water availability which is attended by longer roots of species. On the other hand, low competitive capability of shrubs limits its dispersion into higher elevations sites occupied by softwood trees whereas the water body of the river (oxbows, flooding channels, etc.) constrains the habitat to lower sites. Therefore, trees seem to be less vulnerable to changing conditions, because of their higher flexibility in terms of hydrological conditions. It can be stated that species show fairly low regeneration. While it is not clear, if fragmentation might play a particular role in sexual output, it is justified to assume, that lack of suitable regenerations sites is a major factor in diminishing regeneration of softwood forest species. This situation is further intensified by probable climate change. In general, habitat availability for all species declines with the predicted scenario, while strength of changes depends on age classes, as well as on species (Fig. 2). Least sensitive is old shrubby vegetation with only minor changes in probability of occurrence in all classes and even increasing high probabilities that can be explained by availability of sites formerly being too moist to bear woody vegetation.

Table 1. Best fit models, bootstrapped $R^2_{Nagelkerke}$ and bootstrapped AUC- values for the different vegetation groups

Species group	**Final model variables (hydrol.)**	$\mathbf{R^2_{Nagelkerke-korr}}$	$\mathbf{AUC_{korr}}$
Trees old	$AWL + AWL^2$	0.1688	0.7258
Shrubs old	$AWL + AWL^2 + WLF + AWL{:}WLF + AWL^2{:}WLF$	0.3911	0.8569
Trees young	$AWL + AWL^2$	0.3333	0.8946
Shrubs young	$AWL + AWL^2 + WLF$	0.4545	0.9102

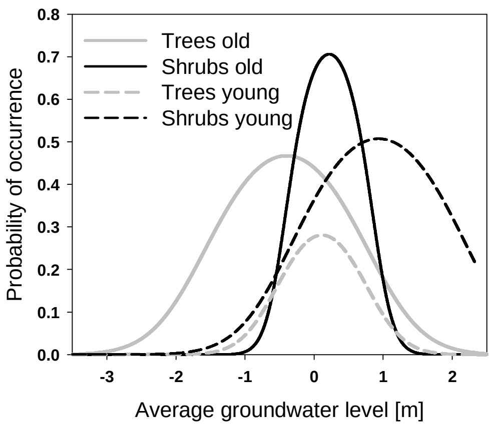

Figure 1. Probability of occurrence for the different species groups along a gradient of increasing AWL

Similar is found for young shrubby vegetation. Trees in both age classes on the contrary experience substantial loss of potential habitat. While low probability of occurrence classes rise, higher categories decrease with severest loss in the topmost classes (Fig. 2).

Predicting presence of species on the basis of probabilities of occurrence needs to specify a cut-off value that divides classes into presences and absences. Choosing a cut-off that matches predicted with observed occurrences, leads to dramatic results. The climate change scenario reveals that shrubs lose “only” about one to five percent of their habitat for young and old life stages, respectively, whereas tree habitat is decreased by 15% for young stages and a quarter for old. This is accountable by the loss of comparably dry sites, i.e. sites of high elevation that are then suited as hardwood forest sites. However, though softwood forest trees might be less vulnerable to changing conditions because of their wider niche considering hydrological conditions, loss will be most profound.

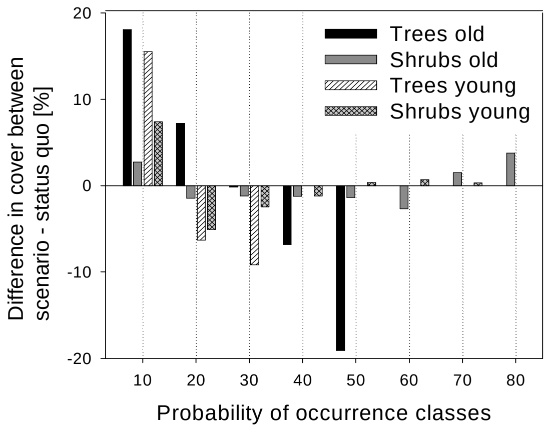

Figure 2. Differences in cover of probability of occurrence classes between climate change scenario and calculated status quo

Conclusions

Riparian softwood forest vegetation is highly adapted to specific hydrological conditions with clear differences between trees and shrubs. A precondition for a successful riparian softwood forest restoration is the availability of suitable conditions in terms of hydrology. This is in particular important for young life stages regardless of being sapling or scion. Moreover, under the assumption of climate change, altering hydrological conditions need to be considered, which further restrict the availability of adequate sites.

Acknowledgements

This project was funded by the Deutsche Bundesstiftung Umwelt (DBU).

References

Hatterman, F.F., Conradt, T. & Bronstert, A. (2007). Berechnung großskaliger Verdunstung unter den Bedingungen des globalen Wandels. Forum für Hydrologie und Wasserbewirtschaftung 21(07), 231-247.

Helms, M., Ihringer, J., Nestmann, F. (2002). Analyse und Simulation des Abflussprozesses der Elbe. In: Morphodynamik der Elbe. Schlussbericht des BMBF-Verbundprojektes (Ed.: F. Nestmann & B. Büchele), Eigenverlag Institut für Wasserwirtschaft und Kulturtechnik, Universität Karlsruhe, 91-202.

Hosmer, D.W. & Lemeshow, S. (2000). Applied logistic regression. Wiley, New York

Reineking, B. & Schröder, B, (2003). Computer-intensive methods in the anlysis of species-habitat-relationships. In: GfÖ Arbeitskreis Theorie in der Ökologie 2003: Gene, Bits und Ökosysteme (Ed.: H. Reuter, B. Breckling, & A. Mittwollen), P. Lang Verlag Frankfurt/Main, 100-117.