Scaling up local population dynamics to regional scales - an integrated approach

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Introduction

In semi-arid savannas, unsustainable land use can lead to degradation of entire landscapes, e.g. in the form of shrub encroachment. This leads to habitat loss and is assumed to reduce species diversity. In BIOTA phase 1, we investigated the effects of land use on population dynamics on farm scale. In phase 2 we scale up to consider the whole regional landscape consisting of a diverse mosaic of farms with different historic and present land use intensities. This mosaic creates a heterogeneous, dynamic pattern of structural diversity at a large spatial scale. Understanding how the region-wide dynamic land use pattern affects the abundance of animal and plant species requires the integration of processes on large as well as on small spatial scales. In our multi-disciplinary approach, we integrate information from remote sensing, genetic and ecological field studies as well as small scale process models in a dynamic region-wide simulation tool.

Methods

We developed a regional state-and-transition model that simulates the dynamics of large scale vegetation patterns in the southern Kalahari (70x100km²). The model effectively integrates fine scale processes of vegetation dynamics in relation to land use, and is based on current vegetation structure and land use patterns (Fig.2). The study area is located around the BIOTA observatory "Alpha", including commercial (South Africa) and communal rangeland (Botswana) as well as parts of the Kalahari Transfrontier Park (Fig.1).

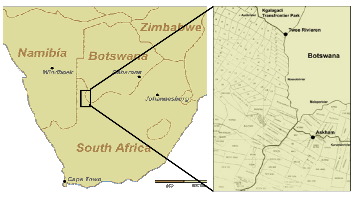

Fig.1: Location of study area.

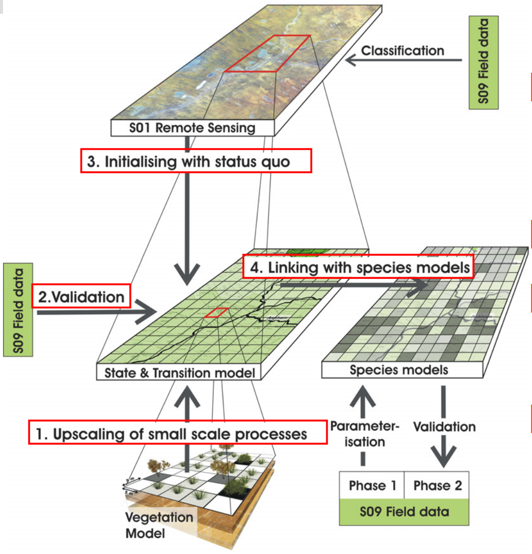

Fig.2: Overview of the landscape model, which combines remote sensing, modelling and field studies

Based on field data of habitat condition from BIOTA phase1, we identified nine vegetation states differing in the cover of shrubs and perennial grasses.

1 Transition probabilities between states for different grazing regimes and precipitation conditions were produced by a well-established spatially-explicit and high resolution model (5x5m²) of savanna vegetation (Jeltsch et al. 1996, 1997a, b, 1998, 1999).

2 The state-and-transition model output was successfully validated with empirical data (see Fig. 3).

3 The current vegetation status of the whole region was assessed by classifying Landsat satellite images with ground truthing data on 1km² scale and used as initialisation of the model.

4 The landscape model is currently linked to process-based and correlative population models of selected animals and plants based on ecological and genetical field studies.

This approach allows testing the influence of farm-based, region-wide land use scenarios on species abundance and diversity.

Model validation

The state-and-transition model simulates a realistic frequency distribution of vegetation states, which correspond to their distribution in 100 empirical vegetation surveys (F=13.45, P>0.10, n=100) (Fig. 3).

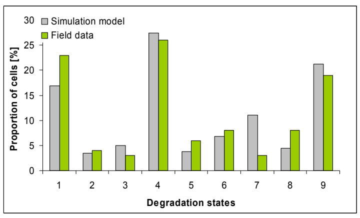

Fig.3: Distribution of the 9 vegetation states in the field (green) compared to simulation results (grey).

Sample simulation experiment

On the basis of a farm-scale grazing scenario we tested the impact of 20% increase in grazing intensity over 20 years on changes in vegetation status of the landscape. In a second step we linked the results with a correlation model that simulates the diversity of small mammalian carnivores (Fig.4).

Simulation results

A: We classified a LANDSAT satellite image to determine the current status of the vegetation and scaled cell size up to 1 km² for model initialisation.

B: The correlation model predicts regional differences in carnivore diversity (given as Shannon index, see Poster S09 Blaum et al.) based on vegetation status of the initial landscape.

C: For a 20% increase of the grazing impact over 20 years the landscape model predicts a clear shift in vegetation to a predominance of states with higher shrub cover (>state 3).

D: These habitat changes will lead to a strong decrease in carnivore diversity.

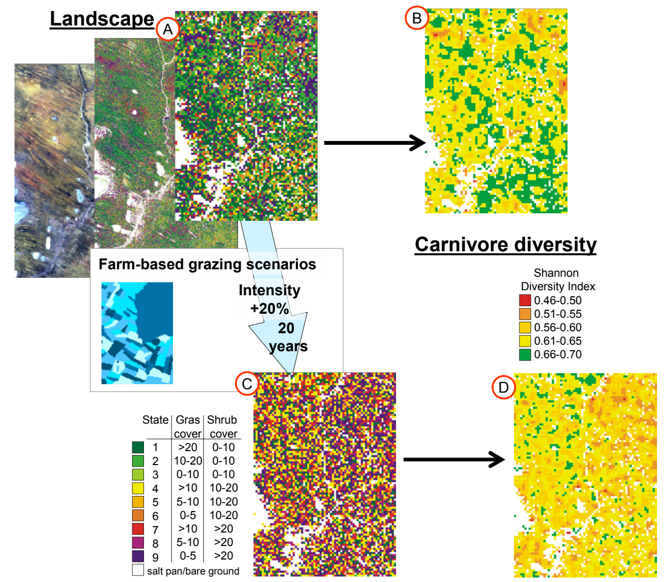

Fig.4: The simulation results show the negative effect of increased grazing intensity on carnivore diversity. Left: Landscape map, initialised with classified satellite image (A) and change of vegetation after 20 years of intensive grazing (C). Right: Diversity of carnivores for initial (B) and heavily grazed vegetation condition (D).

Conclusion

We presented here how system driving small scale processes can be successfully integrated in region-wide landscape models. This novel scaling up approach is an important step towards more reliable decision support tools for land use and conservation at relevant spatial scales. Our landscape model is currently linked to models of selected and indicative animal and plant species and empirical correlations. The sample linkage to carnivore diversity presented here indicates the predictive potential with regard to species diversity and abundance under future land use and climatic scenarios.

Outlook

In a possible next BIOTA phase this scale-crossing modelling approach could be applied to other BIOTA savanna regions. This would allow for the (i) integration of existing information, (ii) generalizing understanding of savanna systems, (iii) development of mechanistic and process-based decision support tools.

BIOLOG

Projektträger im DLR

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