DEVELOPING A MECHANISTIC APPROACH TO MODEL THE EFFECTS OF CLIMATE CHANGE ON FOREST DYNAMICS IN COMPLEX MOUNTAIN LANDSCAPES

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INTRODUCTION AND OBJECTIVES

Anthropogenic climate change has the potential to impact a variety of natural processes across scales in forest ecosystems, affecting their structure, composition and functioning. Recognizing forest ecosystems as **complex adaptive systems** (cf. Grimm et al. 2005), interactions and feedbacks between these dimensions of ecological complexity (Loehle 2004) need to be considered in addition to first order effects to fully assess the potential impacts of climate change. Modeling is a primary tool to address ecological complexity; however, the traditional schools of process-based forest ecosystem modeling generally reflect a **reductionist approach**, strongly focusing on individual dimensions of ecological complexity (i.e., functional complexity in physiological models; structural and compositional aspects in gap models; spatial complexity in landscape models). Here we address the question of how to bridge this gap and scale physiological and structural processes and their **interactions** to larger scales, in order to simulate landscape level ecosystem dynamics under climate change as emerging system property.

We present the newly developed simulation model **iLand** (**i**ndividual-based forest **Land**scape and **d**isturbance model), which uses a hybrid approach (cf. Seidl et al. 2005) balancing population dynamics, ecophysiology and landscape ecology. A hierarchical multi-scale approach ensures not only a robust scaling of detailed ecosystem processes but also enables a thorough model evaluation against a variety of independent data sources at different scales. Here we demonstrate iLands capabilities to simulate (i) **functional complexity**, i.e. ecosystem productivity over an extensive environmental gradient, (ii) **structural complexity**, i.e. multi-species, multi-layered old growth ecosystems, and (iii) **spatial complexity**, i.e. the ability to address these phenomena at the scale of forest landscapes.

CLIMATE CHANGE

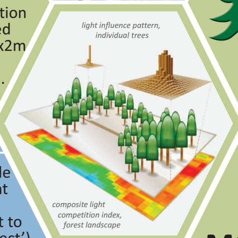
Competition

entity: individual trees

pattern-based approach (cf. ecological field theory)

continuous light competition field over the simulated landscape, resolution: 2x2m

determines a trees rel. competitive success for resources



iLand
individual-based forest landscape and disturbance model

http://iland.boku.ac.at

Ecophysiology

radiation interception & use efficiency (stand level)

environ. constraints: daily water availability, temperature response (first order dynamic delay), nitrogen

allocation: allomet. ratios

mortality: C-balance

Scaling

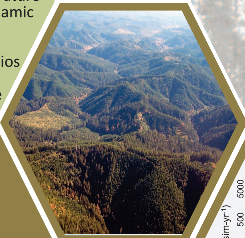
hierarchical multi-scale approach

modular structure, capturing processes at their inherent scales

dynamics at higher hierarchical levels constrains lower levels

pre-processing, highly optimized imple-mentation (C++)

MODEL DESIGN



Evaluation design

productivity over a wide environmental gradient

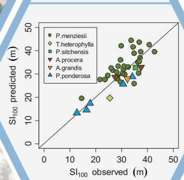
FIA Phase 3, Pacific coast to central OR (‘Oregon transect’)

single species, even-aged simulations (cf. yield tables)

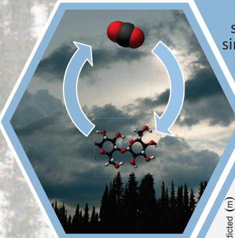
response variable: dom. height age 100 (SI_{100})

FUNCTION

Results

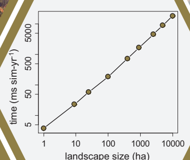


R^2=0.620 | RMSE=4.71



SCALE

Results



computation scales linearly with landscape size

Evaluation design

scalability of the individual-based process model to landscape scale

neutral landscape, random distribution, mean N/ha=500

standard office computer

response variable: computing time per landscape area

STRUCTURE

Evaluation design

complex stand structure in old growth forests

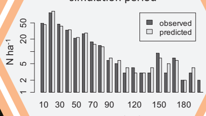
HJ Andrews experimental forest, western Cascades, OR

20+ years vegetation data, 1 ha reference stands

response variables: dbh-distribution basal area

Results

result shown for reference stand 31, end of 23 year simulation period



P_{KS}=0.980

MANAGEMENT

DISTURBANCE

DISCUSSION AND OUTLOOK

Recent advances in the understanding of ecosystem dynamics highlight the central role of **complexity** for the functioning of ecosystems (Sierra et al. 2009). Consequently, complexity is also receiving increased attention as important concept in the sustainable stewardship of ecosystems (Puettmann et al. 2009). Here we presented a simulation approach that is explicitly designed to quantitatively address and scale these aspects. iLands foundation in general physiological principles and its good performance over a wide environmental gradient support the models suitability to applications under changing climatic conditions. Due to its high resolution and spatially explicit design the model is particularly suitable to address **climate change impacts in heterogeneous mountain landscapes** with strongly varying local exposure levels (Daly et al. 2009). Furthermore, its ability to simulate structurally and compositionally heterogeneous forests highlights iLands potential in **supporting management questions** with regard to biodiversity conservation and restoration ecology. The traceability retained by aiming for an **intermediate level of complexity** (i.e. the Medowar zone, cf. Grimm et al. 2005) in implementing key ecosystem processes is a relevant aspect with respect to such potential future applications. Currently under development is a spatially explicit module of seed dispersal and regeneration, which will allow the study of landscape scale **tree species shifts** in response to climate change. Furthermore, modules of **disturbance agents** (i.e. wildfire, wind, bark beetles) are currently being adopted into the iLand framework in collaboration with the LANDIS-II modeling community (Scheller et al. 2007). More information and updates can be found under http://iland.boku.ac.at.

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