FOREST ADAPTATION STRATEGIES TO CLIMATE CHANGE UNDER SOCIO-, ECOLOGICAL, & ECONOMIC UNCERTAINTIES - A CASE STUDY FROM SERBIA

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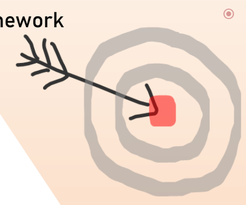
OBJECTIVES

Background & Research Problem

- Serbia is **Climate Change Hotspot**
- **Identified Science gap:** lack of data, models, yield tables, suitability maps
- **High uncertainty** for decision-makers
- Need for Forest Management directives & Governance Framework

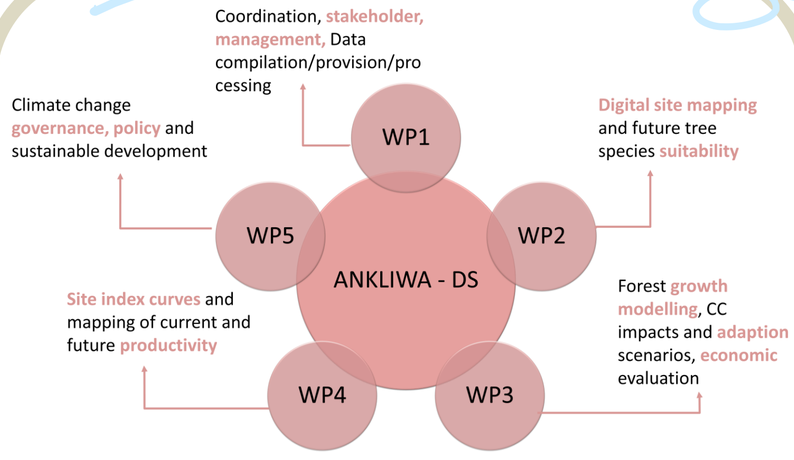


Research questions

- What are major CC risks & impacts for forestry & forest conservation?
- Species migration: What grows were & when under CC?
- Future productivity expectations?
- What are the costs of CC impacts & of adaptation measures?
- What are Stakeholder needs?

- **Science base** with Digital Site Mapping, forest growth- & economic models
- **Robust adaptation strategies** under future risks
- **Governance Framework** with "Climate Smart Forestry" approach
- **Bio-economic bridge** between ecology and efficient forest management

PROJECT OVERVIEW



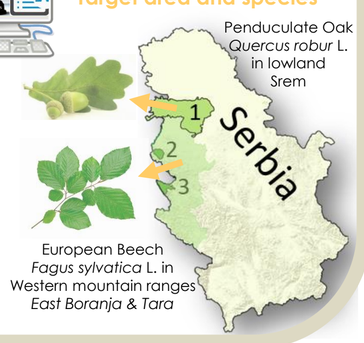
Interdisciplinary research combining natural sciences, modelling, economic and socio-economic approaches

METHODOLOGY

- Digital site mapping based on field work & digitalization /analysing existing maps & datasets
  Tree sampling for tree ring analyses combined with inventory analyses datasets, soil analyses
- Parameterize a process-based forest growth simulator (GOTILWA+) with field work (leaf area index, leaf morphology, results from WP2/4), inventory-, meteo data
- Develop & couple an economic model assessing CC impacts, develop robust management strategies under risk

- Stakeholder analyses with survey, questionnaires and expert interviews
- New governance framework for climate-smart forestry based on simulations, mapping and stakeholder feedback

Target area and species



SITE INDEX CURVES, PRODUCTIVITY MAPS

Sample results for Oak growth region in Srem

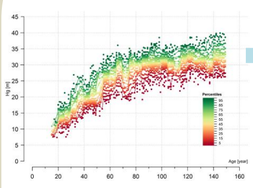


Fig. 3 | Top heights calculated for sample points and 19 artificial heights growth trajectories (points+lines). Different percentile ranges are coloured according the given scale.

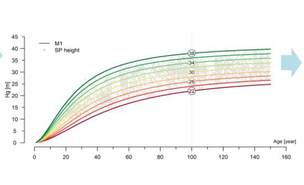


Fig. 4 | Site index and corresponding CAI curves based on dynamic GADA model M1 within the scope of empirical data. The numbers in circles show the corresponding values of the site index at age of 100 years

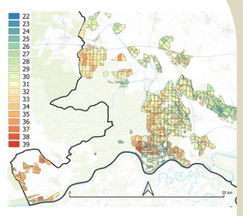


Fig. 5 | Prediction of SI100 for stands with pedunculate oak in eastern (lower) and western (upper) part of Ravni Srem regimes (b).

- Dynamic models of height growth based on generalized algebraic difference approach (GADA)
- **Ravni Srem is one of Europe's most productive sites for pedunculate oak**
- Mapping of current site index classes facilitates forest management planning and provides a bases for projecting future productivity evaluate climate change impacts (WP3).

SPECIES SUITABILITY MAPS

Sample for beech growth region

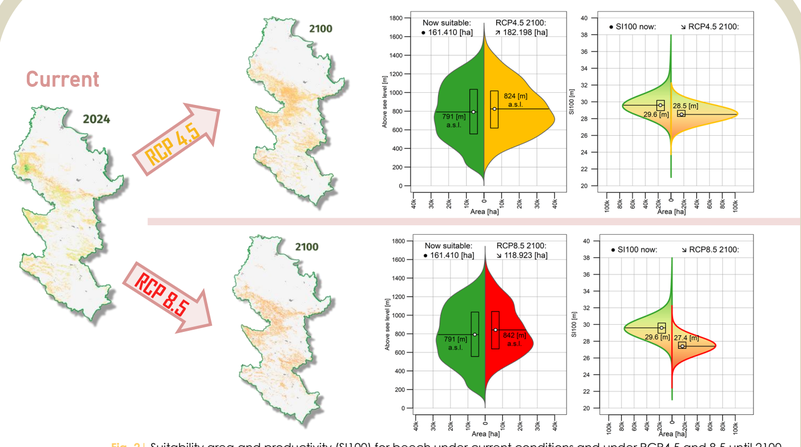
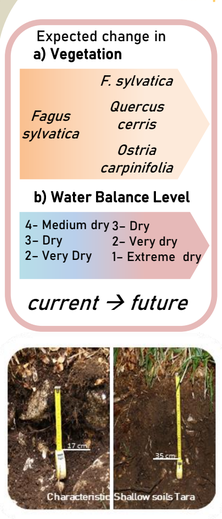


Fig. 2 | Suitability area and productivity (SI100) for beech under current conditions and under RCP4.5 and 8.5 until 2100.

- Gains in suitable area in RCP 4.5 (13%) & losses in RCP8.5 (26 %)
- **Decreasing suitable area in lower- & increases in higher altitudes**
- RCP 8.5 decrease productivity (SI100) more than RCP 4.5

DIGITAL SITE MAPPING

Sample for TARA mountains on bedrock Limestone



- Slopes dominate terrain with rich nutrient regime
- WBL from from 2 to 4
- **Drier sites with shifts to thermophilic species expected in the future**

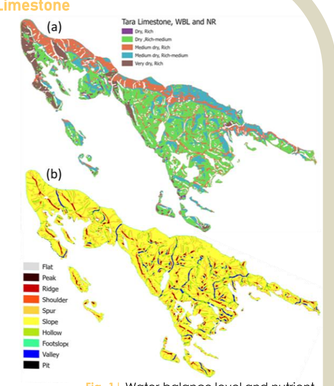
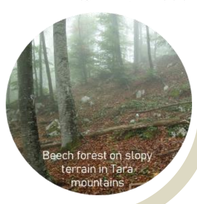


Fig. 1 | Water balance level and nutrient regimes (a) & terrain forms (geomorphons) (b).

Water Balance (WBL)	Periods of Water deficit	Nutrient regime (NR)
3- Dry	Long	Rich
2- Very dry	Very long	Rich
4- Medium dry	Occasionally long	Rich-medium
4- Medium dry	Occasionally long	Rich
3- Dry	Long	Rich-medium



PROCESS-BASED FOREST GROWTH MODELLING

Projection period 2020-2100 for Oak growth in Srem with GOTILWA+

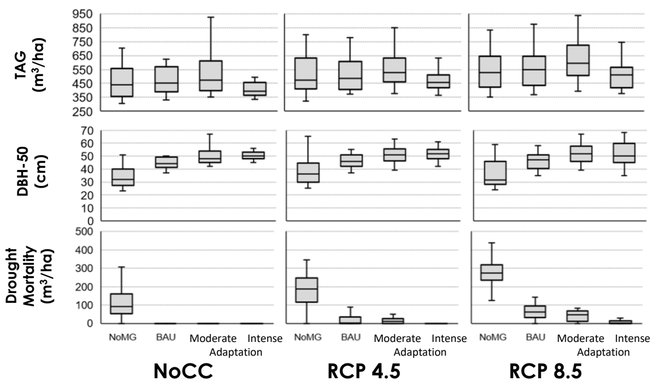


Fig. 6 | GOTILWA+ results at stand age 110 in year 2100 for three scenarios: no climate change (noCC), RCP4.5 & RCP8.5. Simulation start with stand age 30. TAG is Total Accumulated Growth & DBH-50 is mean diameter of 50 strongest trees. 4 Management – Strategies: No management (NoMG, business-as-usual (BAU), moderate and intense adaptation.

- 4 Management Scenarios: NoCC, BAU, Moderate & intense adaptation
- No Climate Change (NoCC), RCP 4.5 & RCP 8.5 x 6 climate models with & without CO_2 fertilization = 36 climate scenarios
- declining groundwater = 4 drought scenarios

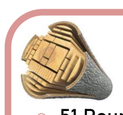
= 576 GOTILWA+ Sims

- CC increased productivity, but also drought induced mortality

→ **Productivity is not a good indicator for vulnerability!**

- Adaptation scenarios (earlier and heaver thinnings) reduced drought mortality and achieved target diameter faster (DBH-50)
- Moderate adaptation achieved highest productivity yield (TAG)

Economic Model



- Sorting & monetizing simulation output
- 51 Roundwood prices, 11 harvesting costs, 6 capital costs = 3366 combinations x 576 GOTILWA+ simulations = 1,454,122 combinations **or** ***States-of-the-world*** **of what could happen in the future**

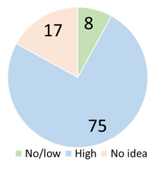
MAIN FINDINGS

- **Expected decline in site index quality**
- **Highly productive oak & beech in Serbia at risk**
- **Beech upwards migration to higher altitudes**
- **Declining groundwater levels increased strongly drought induced mortality in oak**
- **Highest economic risks under business-as-usual**
- **Adaptation through earlier, more intense thinning reduced notably downside risk**
- **A new governance framework for forest management under climate change is essential for successful implementation of adaptation measures**

STAKEHOLDER NEEDS

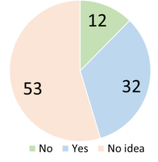
Main Survey 2021-2022

- 99 respondents from public, private & civil sector
- 21-24 questions for a) forest owners/users and b) other stakeholders



75 % Forest owners/users believe that climate change (CC) already negatively influenced their business activities

→ *Ecological impacts*: changes to ecosystems, species & natural processes due to disturbances. *Economic impacts*: sanitary plans → higher administrative costs, lower revenues due to oversupply after disturbances. *Social impacts*: land destruction (landslides, flooding) & restriction of activities (e.g. heat impacts, less tourism, guided tours), poverty of rural areas (drought impact on yields),



Only 32% of forest owners/users plan to adapt management activities in near future, while the majority is uncertain or even does not plan to adapt

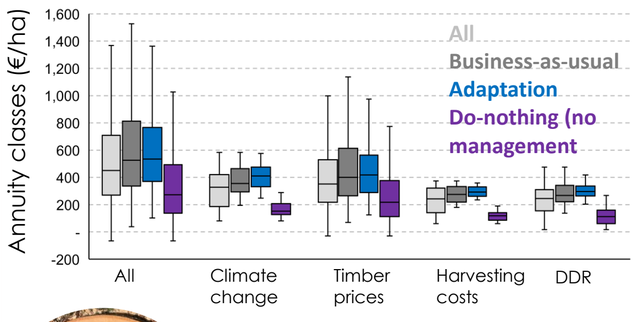
→ Climate change is not fully accepted at all levels of forest management. Intensified dialog with further information expected but also open to collaborate with relevant information and data to develop future forest management, and also a new forest governance system.

Gap/needs for improvement identified:

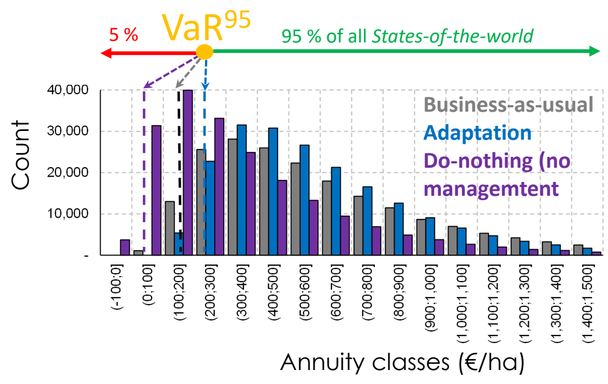
- Improving the strategical framework: resources for risk identification & assessment, planning guidance, documentation, consequences
- Improving the legislative framework: funding scheme for research & for adaptation measures and activities, accompany/ facility the change
- Improving institutional framework: connecting better multiple management levels, education and research with forest owners, functional connection of institutions and organizations

ECONOMIC RISKS & ROBUST ADAPTATION

Variability of annuities with uncertainty



Distribution of annuities



- Very high variability of projected annuities → **huge uncertainty for future forest management!**
- **Timber prices** contributed the highest uncertainty, more than climate change (=similar to DDR)
- **Value at risk** (VaR95) → how much an investments might lose with the given probability of 95 %
- **5 %** of the annuities of all projected States-of-the-World are lower than indicated threshold → **downside risk!**
- **Adaptation scenario decreased projected losses (*downside risk*) and thus enhanced economic robustness by ca. 30-60% despite projected losses in productivity under climate change (on average ca. 15%)**

FOR MORE INFORMATION PLEASE VISIT:

https://ankliwa.sfb.bg.ac.rs

Publications:

Kazimirović M, Stajić B, Petrović N, et al (2024) Dynamic height growth models for highly productive pedunculate oak (Quercus robur L.) stands: explicit mapping of site index classification in Serbia. Ann For Sci 2024 811 81:1–17. https://doi.org/10.1186/S13595-024-01231-0

Sperlich D, Hanewinkel M, Yousefpour R (2024) Aiming at a moving target: economic evaluation of adaptation strategies under the uncertainty of climate change and CO2 fertilization of European beech (Fagus sylvatica L.) and Silver fir (Abies alba Mill.). Ann For Sci 81:. https://doi.org/10.1186/s13595-023-01215-6

Manuscripts under review:

Kazimirović M, Stajić B, Petrović N, Baković Z, Marc Hanewinkel M and Sperlich D: Site index models for highly productive beech stands in western Serbia. Under review in European Journal of Forest Research.

Manuscripts under preparation:

Ljubicic, J., Kosanin, O., Sperlich, D., Kazimirovic, M., Stajic, B., Petrovic, N., Vasic, I., Nedeljkovic, J., Nonic, D., Hanewinkel, M., Weinreich, A., Bakovic, D.: Development of digital site mapping and e-stimating future tree species suitability in Serbia.

Sperlich D, Altunay D, Becker G, Ljubicic J, Kazimirović M, Petrović N, Hanewinkel, M.: Robustness of alternative silvicultural strategies for a sample stand of pedunculate oak (Quercus robur L.) in Serbia under climatic and economic uncertainty using process-based forest growth simulations.

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S4.4 Socio-ecological conflicts in forest management: risks of (not) adapting?
23–29 June 2024

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ptble Projektträger Bundesanstalt für Landwirtschaft und Ernährung

Development and implementation of adaptation strategies to climate change in forest management
Razvoj i primena strategija prilagođavanja klimatskim promenama u gazdovanju šumama
ANKLIWA-DS
German-Serbian bilateral research cooperation 2019-2024

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