ASSESSMENT OF FUTURE PRODUCTION AND CARBON SEQUESTRATION OF GRASSLANDS IN THE CARPATHIANS

Zoltán BARCZA[a,b]; Laura DOBOR[a]; Tomáš HLÁSNY [c,d]; Dobrolmil GALVÁNEK[e]; Dóra HIDY[f]

[a] Department of Meteorology, Eötvös Loránd University, Hungary
[b] Institute of Ecology and Botany, Centre for Ecological Research, Hungarian Academy of Sciences, Hungary
[c] National Forest Centre - Forest Research Institute, Slovakia
[d] Faculty of Forestry and Wood Sciences, Czech University of Life Sciences, Czech Republic
[e] Institute of Botany, Slovak Academy of Sciences, Slovakia
f Hungarian Academy of Science - Szent István University Plant Ecological Research Group, Institute of Botany and Ecophysiology, Hungary
e-mail: bzoli@elte.hu

ABSTRACT

The aim of this study is to estimate future changes in grassland productivity and carbon (C) balance in the Carpathians taking into account diverse environmental and anthropogenic drivers. In our approach calibrated and validated biogeochemical model (Biome-BGC MuSo v1.2) was coupled with a number of climate projections to estimate present day and future grassland productivity and C cycle. The simulations were driven by 10 climate change scenarios retrieved from the so-called FORESEE database (Open Database FOR ClimatE Change-Related Impact Sudies in CEntral Europe; http://nimbus.elte.hu/FORESEE/.

Because of limited information on distribution of grassland communities and management types, which substantially affect grasslands' carbon cycle, we used the so-called end-member logic; i.e. we defined representative grassland types (according to NATURA 2000 habitat type classification) combined with obvious management of each grassland type.

To exemplify, the end-members include semi-natural grasslands without management (habitat type 6520, Mountain hay meadows) and natural and semi-natural grasslands in poor soil and nutrient limited conditions without management (habitat types 6150, 6170 and 6210). The simulations were performed separately for each end-member for entire Carpathians. Finally, end-members have been combined to get spatially explicit simulation results. Net Primary Production (NPP) and different carbon cycle components (Gross Primary Production, Total Ecosystem Respiration, Net Biome Production) have been simulated for the entire Carpathians. Analysis of simulation results for the end-members revealed that future changes strongly depend on site conditions and management associated to grassland types. Combination of end-members showed that overall NPP trend in the Carpathians is close to zero, which means that NPP might remain unchanged under climate change. This is the results of the dominant role of grassland management (most of all mowing) in the Carpathians as has been represented by our simplified management map. Assessment of the overall carbon balance (expressed by Net Biome Production) indicated zero change, which means that the overall carbon balance might remain unchanged. Analysis of end-members indicated that under changing climate there is a potential for increasing grassland productivity in the future (positive effect of CO_2 fertilization) but management can ultimately negate this effect. The results indicated that coupled effect of climate change and management needs to be considered in the assessment of future grasslands productivity and carbon cycle in the Carpathians, though limited availability of spatially explicit information on grasslands management hampers such assessment. The proposed approach, based on the end-member logic, allows coping with this limit to certain extent.

Simulation desing

PROBLEM: Grassland habitats are highly heterogeneous:
-- diverse environmental factors: elevation, soil texture/hydrology, salinity, bedrock depth, nutrient availability
-- management practices: abandonment, mowing, (over)grazing, fertilization
No detailed information exist to reconstruct habitat types
→ opportunity: '**end- member logic**' (EML)

Simulate representative grassland types one by one for all pixels!
6 end-members have been constructed to represent habitat types:
without management:
EM1: optimal soil and nutrient availability
EM3: poor soil, nutrient limited conditions
grazed:
EM2: grazing from May to end of October, intermediate soil conditions
EM5: grazing from the middle of June to end of October, optimal soil
mowed once:
EM4: hay cut in the middle of June (harvested grass is transported away), optimal soil
grazed and mowed once:
EM6: hay cut in the middle of June than grazing lasts until end of October

→ Changing site parameters in Biome-BGC MuSo

NATURA 2000 code	description	management	representative end-member	soil conditions	depth to rock category in soil database	altitude
6150	Siliceous alpine and boreal grasslands	abandonment	EM3	poor soil	Shallow: 0-40 cm	1600-2200 m
6170	Alpine and subalpine calcareous grasslands					
6210	Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia)	abandonment	EM3	poor soil	Shallow: 0-40 cm	100-600 m
6230	Species-rich Nardus grasslands, on silicious substrates in mountain areas (and submountain areas in Continental)	grazing	EM2	poor soil	Shallow: 0-40 cm	600-1600 m
				intermediate soil	Moderate: 40-80 cm	600-1600 m
6510	Lowland hay meadows (Alopecurus pratensis, Sanguisorba officinalis)	mowing, combined mowing+grazing with equal weight	linear combination of EM4 and EM6 (1/2 EM4, 1/2 EM6)	intermediate soil	Moderate: 40-80 cm	100-600 m
				good soil	Deep: 80-120 cm or Very Deep: > 120 cm	100-900 m
6520	Mountain hay meadows	abandonment, mowing, grazing with equal weight	linear combination of EM1, EM4 and EM5 (1/3 EM1, 1/3 EM4, 1/3 EM5)	good soil	Deep: 80-120 cm or Very Deep: > 120 cm	900-1600 m

Carbon balance

$NBP = -NEE - L$

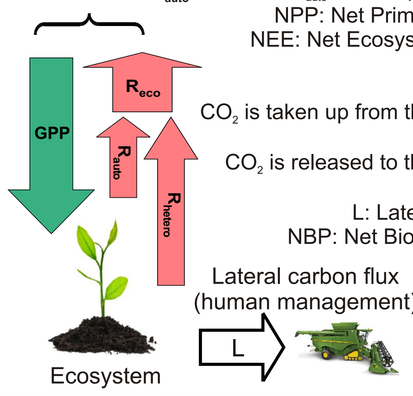
$NEE = R_{eco} - GPP$

$NPP = GPP - R_{auto}$

GPP: Gross Primary Production
R_{eco}:Total ecosystem respiration
R_{auto}: Autotrophic respiration
NPP: Net Primary Production
NEE: Net Ecosystem Exchange

negative NEE:
CO_2 is taken up from the atmosphere
positive NEE:
CO_2 is released to the atmosphere

L: Lateral carbon flux
NBP: Net Biome Production

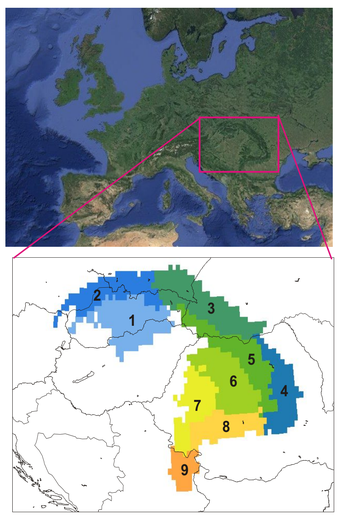


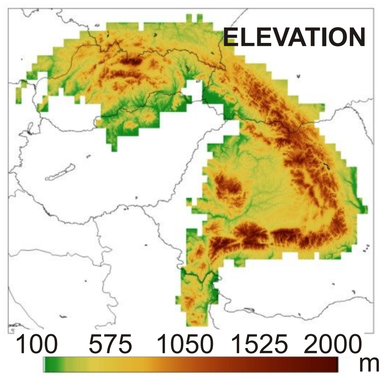
Lateral carbon flux (human management)

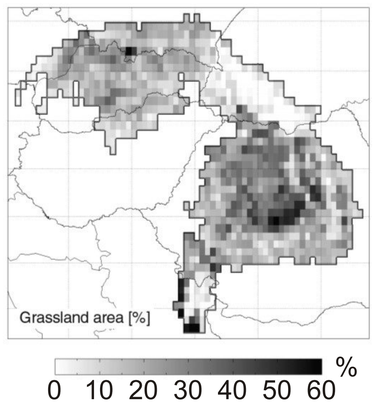
STEPS

1. Estimate the distribution of NATURA 2000 habitat types
2. Set up NATURA 2000 habitat types with the EMs (table above)
3. Run Biome-BGC for all EMs by pixels
4. Combine the habitat type distribution and EM specific results by pixels
5. Create a map with the combined results

STUDY AREA: Carpathians







REGIONS

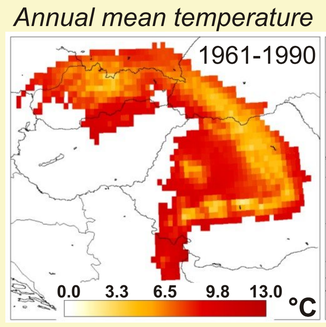
1. **Inner Western Carpathians**
2. **Outer Western Carpathians**
3. **Outer Eastern Carpathians North**
4. **Outer Eastern Carpathians South**
5. **Inner Eastern Carpathians**
6. **Transylvanian Plateau**
7. **Western Romanian Carpathians**
8. **Southern Carpathians**
9. **Serbian Carpathians**

TOOLS

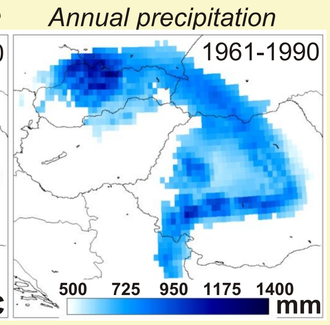
Climate projections

FORESEE database:
-- daily maximum/minimum temperature, precipitation
-- 1/6x1/6 degree horizontal resolution
-- observation based data for 1951-2009
-- ensemble of bias corrected climate data for 2010-2100
-- the target area is covered with 985 grid cells

Annual mean temperature



Annual precipitation

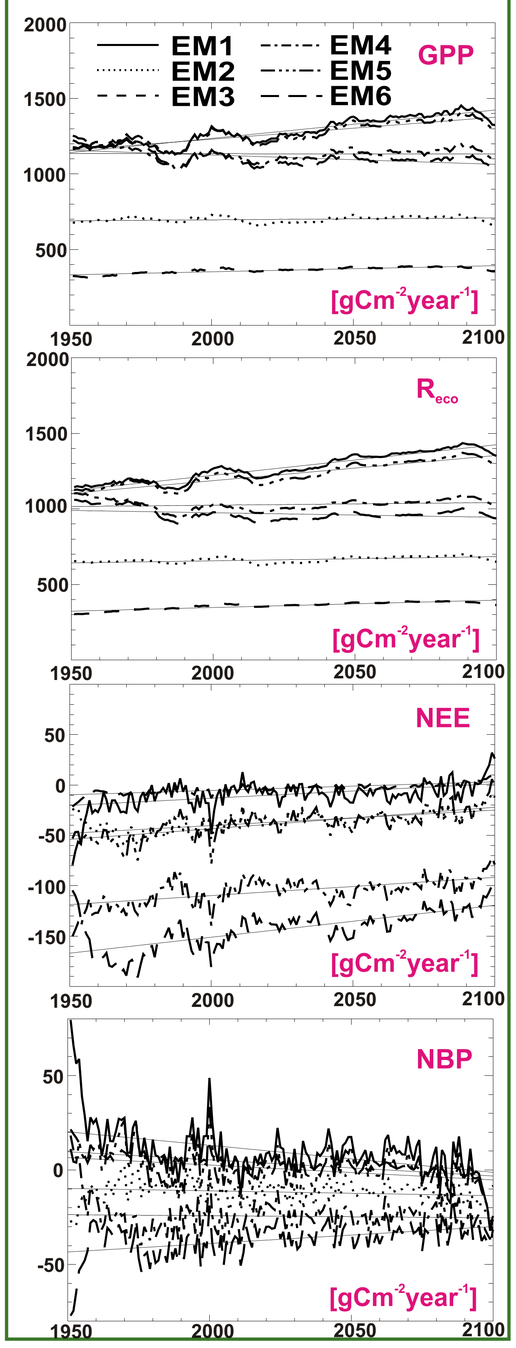


Biogeochemical model

Biome-BGC MuSo v1.2 (developed from Biome-BGC v4.1.1) simulates:
-- plant productivity,
-- carbon cycle components
-- full carbon balance of different terrestrial ecosystems
can handle:
-- typical management practices
-- drought effects on production and carbon balance

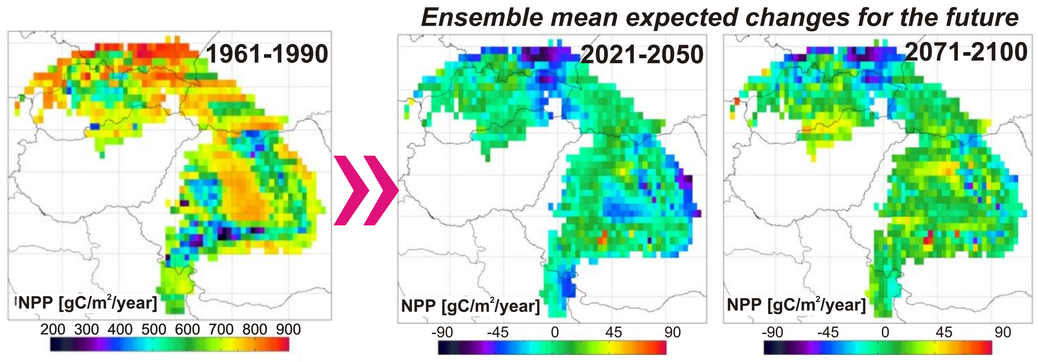
RESULTS

Mean time series for the entire Carpathians as estimated by the different end-members
-- 10 years moving averaging is used
-- straight lines: linear regression based on the smoothed time series

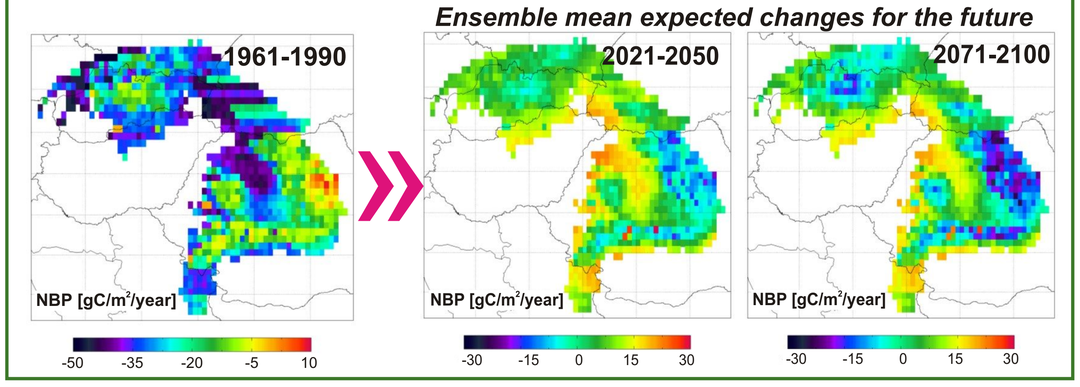


Mean NPP and NBP for the Carpathians for the past and for the future.
The maps were constructed with the combination of habitat type distribution

Ensemble mean expected changes for the future

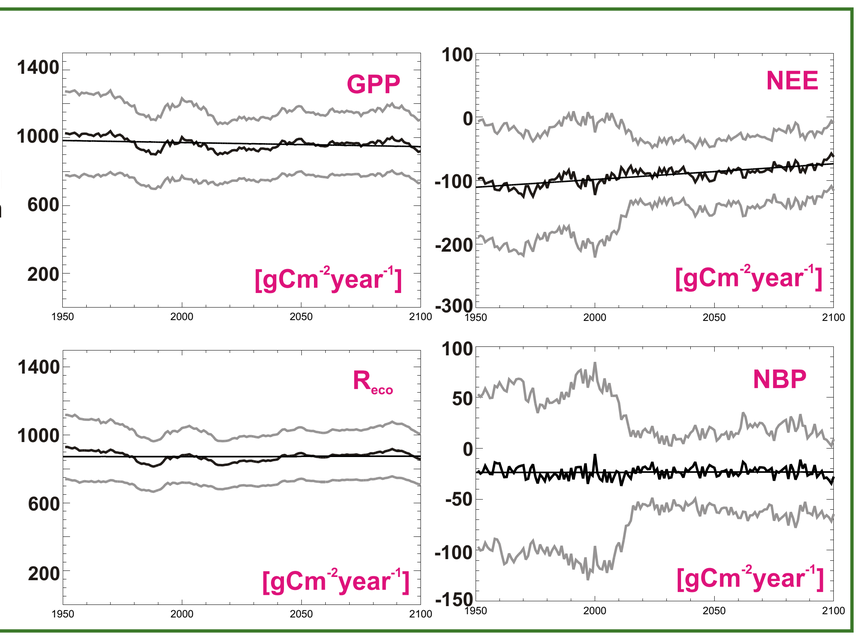


Ensemble mean expected changes for the future



Overall trend of different carbon balance components in the ENTIRE Carpathians based on the combination of end-members and habitat type distribution.
Time series are smoothed with 10 years moving average.

black lines: spatial mean
grey lines: spatial variability
straight line: linear trend



Conclusions

-- human interventions and site conditions are both important factors
-- In unmanaged case: NPP is increasing independent to the soil conditions
-- Grazing has a relatively small effect on the results
-- Mowing strongly modulates the future evaluation of grassland productivity
→ NPP decreases towards the end of the 21st century
-- Combined results suggested that the NPP might remain unchanged in the future up to 2100
-positive effect of CO_2 fertilization
-negative effect of meteorological conditions
-- Overall carbon balance (NBP) results indicated zero change (in spite of fertilization effect caused by increased level of CO_2)
Carpathian grasslands have considerable spatial and temporal variability in production and carbon balance

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