University of West Hungary
Faculty of Forestry

Theses of doctoral (PhD) dissertation

Analysis of forest-climate interactions, applying the regional climate model REMO

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Background and objectives

Natural vegetation is a dynamic component of the climate system. Not only the distribution of vegetation is determined and limited by temperature and precipitation conditions, but also vegetation has an effect on the biogeophysical properties of the land surface, which plays an important role in determination of weather and climate.

Changes of the land cover due to climatic conditions and human influence feed back to the atmosphere, lead to the enhancement or reduction of the original climate change signal. Forests, due to their larger leaf area and roughness length, lower albedo and deeper roots compared to other vegetated surfaces, affect the exchange of water, energy and momentum with the atmosphere. These processes are very complex and their variability is large both in time and space.

Several papers have addressed the warming effect of boreal forests and the cooling and moistening effect of tropical forests. Most uncertain is the climatic effect of temperate forests. They can cool or warm the surface air temperature depending on the characteristic of the studied region.

Hungary has a special ecologic position on the border zone of closed forests and forest steppe (lower forest limit), which is especially vulnerable. The increase of drought frequency can lead to decrease of the forest cover across this region, which phenomenon is not typical in humid areas of the world. This emphasises the need of regional scale information about the future tendencies of probability, severity and duration of droughts.

In the last century, afforestation is started to increase and it is planned to continue also in the near future. Climatic effects of the possible reduction or the proposed increase of forest cover in Hungary for longer, consecutive, future time periods have so far not been investigated. Information about the forest-climate interaction and its spatial differences is essential not only for the assessment of the climate protecting effect of forests, but also for the development of the adaptation strategies in the next decades.

Therefore the dissertation investigates the biogeophysical feedbacks of forest cover change

- on the regional climate,
- in the temperate zone, in a relative small region (Hungary),
- for the future (21st century).

For the simulation of the climatic effects of forest cover change, forest-related processes of the investigated region have to be represented realistically in climate models. This study focused on interception. To understand the processes of interception in a forest ecosystem more in detail, local scale measurements and modelling are essential. The aim was to point out the basic meteorological and stand characteristics connected to interception, which should be included also in a regional climate model for more detailed and appropriate representation of the effect of forests on the water and energy balance on fine horizontal resolution.

To analyse future climatic conditions and forest-climate interactions during the summer months in Hungary, research questions of the dissertation are ordered into four groups:

- Climate change and drought trends
- Feedback of forest cover change on the regional climate
- Climate change altering effect of afforestation
- Measuring and modelling of interception on local scale

Data and methods

Forest-climate interactions have been investigated for Hungary in the 21st century, applying the regional climate model REMO.

The projected tendency of temperature and precipitation means and the probability and severity of droughts have been analysed for summer, based on the results of IPCC-SRES[1] emission scenario simulations (B1, A1B, A2; in 0.44° horizontal resolution). The most drought affected region has been determined.

For estimation of the biogeophysical feedbacks of forest cover change on the regional climate, three different land use change scenarios have been prepared (in 0.176° horizontal resolution), which have been used as land cover input for the climate simulations.

- *Maximal afforestation scenario* (2021-2050, 2071-2100): the whole vegetated surface of Hungary was assumed to be forest. Additional forested areas were all deciduous.
- *Deforestation scenario* (2071-2100): the whole forested area over Hungary was replaced by grassland.
- *Potential forest cover* (2021-2025): based on a survey of ecological potentials for afforestation in Hungary, marginal agricultural croplands were replaced by deciduous and coniferous forests.

Results of the land cover change simulations have been analysed relative to the reference simulations with present forest cover for the corresponding time periods. For precipitation, magnitude of the feedback of maximal afforestation (2071-2100) has been compared to the magnitude of the climate change signal (2071-2100 vs. 1961-1990). Spatial differences of the possible climate change altering effect have been investigated for three selected regions.

The process of interception and its influencing parameters has been studied on local scale through field measurements and through the adaptation of the hydrologic model BROOK90 for the Hidegvíz-Valley near Sopron.

[1] Intergovernmental Panel on Climate Change – Special Report on Emission Scenarios

Theses of the dissertation

1. Under enhanced climate change (2051-2100) for the B1, A1B and A2 emission scenarios, probability and severity of summer droughts are projected to be significantly higher, droughts may occur in every second summer. The consecutive dry periods will last longer than in the second half of the 20th century.
    - The tendency of warming and drying and the expected increase of the probability of extreme dry summers are largest in the southwest part of Hungary.

2. Based on the simulation results of the regional climate model REMO, changes of larger continuous and homogenous forest blocks influence the regional climate in Hungary.
    - In the period 2071-2100, maximal afforestation resulted in increase of the simulated evapotranspiration (10-15%) and precipitation (up to 10-15%) and decrease of surface temperature (up to 1°C) for summer, in the whole country.
    - During the whole summer the cooling and moistening effect of maximal afforestation dominates. After the available soil moisture limits transpiration, the evaporative cooling effect decreases and the role of the albedo effect starts to increase.
    - Climatic effects of deforestation are weaker and have the opposite sign than those of maximal afforestation.

3. Forest cover change according to the potential afforestation survey (7% increase of the forest cover in country mean) has a very slight feedback on the regional climate compared to the maximal afforestation scenario (microclimate in the forest stand is not represented in the model).

4. For the 21st century, maximal afforestation weakens the projected climate change signal in Hungary.
    - For summer, the simulated tendency of drying can be reduced in the whole country, due to the precipitation increasing effect of maximal afforestation.

- The projected climate change signal for precipitation is independent from the extent of the present forest cover.
- The effect of forests on precipitation has almost the same magnitude under moderate and enhanced climate change.

5. The climate change weakening effect of maximal afforestation differs among regions. It is simulated to be the largest in the northeastern area (here, 50% of the projected precipitation decrease can be relieved), whereas the smallest in the southwestern region.
    - In the investigated northeastern area, simulated number of extreme dry summers can be reduced (from 9 to 5) and severity can be decreased through maximal afforestation.

6. Applying the one-dimensional hydrologic model BROOK90 with hourly precipitation inputs, duration and intensity of the rainfall event can be determined more accurately than from the daily precipitation sums. Thus, the simulated interception is in better agreement with the measurements.

Application of the results

The obtained simulation results indicate that for Hungary, in the 21st century, projected warming and drying of summers is quite strong. The simulated increase in probability and severity of droughts may cause drastic changes of zonal beech forests in the forest/steppe limit.

From practical point of view, the regional scale simulation of the occurrence, duration, severity and spatial distribution of droughts under future climate conditions may provide clearer insights for the review of adaptation and mitigation strategies and the maintenance of forest-related socio-economic and ecosystem services.

Results of the dissertation underline the relevance of the investigation of forest-climate interactions:

- They provide useful information and experiences for the better understanding of the forest-related processes and vegetation-atmosphere interactions in the climate model simulations on regional scale. The results can contribute to the further development of models.
- They represent the first regional assessment of the possible climate change weakening effect of forest cover increase for long future time periods.

The climatic benefits of the investigated potential afforestations are surprisingly negligible. Although the effects of forests on the local climate are favourable (this microclimatic effects in the forest stand are not represented in the model), nevertheless, the survey shows that climatic conditions cannot be influenced by potential afforestation on regional scale.

Probability and severity of droughts projected for the 21st century can only be reduced by large, continuous forest areas. Analyses of the spatial differences in the weakening effects of afforestations can help to identify the areas, where forest cover increase is the most beneficial and should be supported to reduce the projected tendency of drying. Areas, where forest cover increase has less or no effect on the climate can also be delineated.

Based on the deforestation scenario, some regions can be identified, where decrease of forested area enhances the climate change signal. Here, the existing forests should be maintained to avoid the additional warming and drying of the region.

Though climate change cannot be relieved by the investigated potential afforestations, results of the dissertation concerning the climatic feedbacks of forest cover change and its spatial distribution for the 21st century could be an important basis of the future forest policy. They may improve also the public awareness of ecological services of forest cover and its role in adapting to climate change.

Publications

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