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THESIS OF DOCTORAL (PHD) DISSERTATION

METEOROLOGICAL EFFECTS OF LAND COVER CHANGES IN HUNGARY DURING THE 20TH CENTURY

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BACKGROUND AND OBJECTIVES

Geological, paleontological and geomorphologic studies show that the Earth's climate has always been changing since it came into existence. The climate change itself is self-evident. Therefore the far more serious question is how much does mankind strengthen or weaken these changes beyond the natural fluctuation and changes of climate.

The global rise of sea levels, the decrease of snow cover in the northern hemisphere and the meteorological measurements clearly show that the mean temperature of the Earth increased significantly in the last 150 years. Further measurements clearly prove that the greenhouse gas concentrations in the atmosphere have also been increasing since the beginning of the industrial revolution. Many studies show that this process contributed to the global temperature rise. Moreover it is unquestioned that all climate changes in the past can not be explained by the greenhouse effect in itself, because it is only one among many other climate forcing processes.

For example the effect of changes in solar activity on the net radiation balance of the Earth is well known and the climatic impact of the periodically changing orbital parameters of our planet is also proved. Volcanic activity is another natural climate forcing process. Moreover the upper-air ozone depletion and the concentration of aerosols in the troposphere act in the opposite direction to the greenhouse effect. The large heat capacity of the oceans allows only the 50-70% of the potential warming that could happen in relation to the increases of greenhouse gases. Since not only the chemical composition of the atmosphere is affected through different anthropogenic influences, the climatic effect of land cover changes has also become an important factor in the current climate studies.

Thus, the investigation of greenhouse gas and aerosol concentration in itself is not enough to interpret the measured temperature and precipitation changes in the Carpathian Basin. Besides the modification of the hemispheric circulation system, the effect of land cover changes also plays an important role among the other climate forcing processes.

The aim of the present study was to restore the historical land cover changes and to simulate the meteorological consequences of these changes. This work tried to answer the following questions:

- What did the land cover look like in Hungary at the beginning (1900) and at the end (2000) of the 20th century? What kind of changes has occurred during these 100 years?
- How did the process of Hungarian land cover changes take place? How reliable are the available datasets?
- What kind of impact could the land cover changes have on the air temperature and humidity regime in Hungary during the vegetation period?
- What regional characteristics of meteorological impacts of Hungarian land cover changes can be detected?
- Could the land cover changes in Hungary affect the convective processes and through them the precipitation distribution during the vegetation period?

METHODS

The aim of the present study was to simulate the meteorological consequences of the land cover changes in Hungary. Two different land cover maps for Hungary were created in vector data format using GIS technology. The land cover map for 1900 was reconstructed based on statistical data and two different historical maps: the derived map of the 3rd Military Mapping Survey of the Austro-Hungarian Empire and the Synoptic Forestry Map of the Kingdom of Hungary. The land cover map for 2000 was derived from the CORINE land cover database.

Significant land cover changes were found in Hungary during the 20th century according to the examinations of these maps and statistical databases.

The MM5 non-hydrostatic dynamic model was used to further evaluate the meteorological effects of these changes. The lower boundary conditions for this mesoscale model were generated for two selected time periods (for 1900 and 2000) based on the reconstructed maps. The dynamic model has been run with the same detailed meteorological conditions of selected days from 2006 and 2007, but with modified lower boundary conditions. The set of the 26 selected initial conditions represents the whole set of the macrosynoptic situations for Hungary.

In this way, 2×26 "forecasts" were made with 48 hours of integration. The effects of land cover changes under different weather situations were further weighted by the long-term (1961-1990) mean frequency of the corresponding macrosynoptic types, to assume the climatic effects from these stratified averages. The detailed evaluation of the model results were made for three different meteorological variables (temperature, dew point and precipitation).

THESES OF THE DISSERTATION

I. The author quantified the Hungarian land cover changes for the 20th century based on the two different, reconstructed and derived land cover maps. Derived data from these maps were also compared to the land use statistical data of the Hungarian Central Statistical Office. It was found that:

1. The area of cropland decreased from 61.0% to 56.8% during the 20th century.
2. The urban areas increased from 2.4% to 5.7% during these 100 years.
3. The forest covered area in Hungary increased from 12.5% to 21.1%.
4. The area of grassland and pasture decreased from 16.0% to 9.5%.
5. The wetlands lost nearly two-thirds of their original territory; they decreased from 3.2% to 1.1 %.
6. The area of water bodies decreased from 2.3% to 1.9%.
7. Since at the beginning of the 20th century, the area of vineyards alone was as high 2.5%; at the end of the century the area of vineyards with the orchards together were only 2.2%. A maximum two-thirds of this was really vineyards.
8. Despite the differences between the statistical data and the derived data from the land cover maps, it can be shown that the different sources strengthen each other in both the direction and order of magnitude of land cover changes in Hungary.
9. The differences between the data sources are caused by the different categorizations and surveying techniques. The maps give more certain land cover data (because they do not use juridical categorization) and they have additional information about the spatial distribution of land cover categories.

II. The author used a grid of a 30 arcsecond resolution cells to further examine the two different land cover maps (for 1900 and 2000) and deduced the following statements about nation-wide land cover changes:

1. The expansion of urban areas took place generally to the detriment of cropland. Approximately 45% of the present urban areas were cropland at the beginning of the 20th century, about 20% was grassland and pasture and 3-4% vineyard.
2. The smallest changes occurred in the regional distribution of cropland during that century: 90% of the present croplands were also cropland in 1900.
3. The significant reforestation took place on areas of previous cropland, grassland and pastures. (About third of the present forests were previously cropland, 10% grassland and pasture).
4. Approximately 70% of the present vineyards and orchards replaced previous croplands; only 3% of them were planted on deforested areas. Since the area of vineyards significantly decreased in the 20th century, these numbers demonstrate the large regional distribution change in the production area of vineyards to flatter areas due to the mechanization of production.
5. Nearly one third of the present water bodies were cropland at the beginning of the 20th century; about 6% of them succeed previous wetlands.
6. Less than 30% of present wetlands were also wetland 100 years ago. Approximately half of them replaced cropland; 16% emerged in place of previous water bodies.

III. According to the simulations of the MM5 meteorological model the effects of Hungarian land cover changes during the 20th century can be summarized as follows:

1. The results show a +0.15°C warming of daily mean temperature nation-wide, while the rate of local warming (especially in the environs of cities) exceeded 1°C.
2. The effects of land cover changes produced the maximum temperature increase in the night hours. The ground heat flux plays the most important role in the development of these temperature differences.
3. The direct impact of land cover changes on the 2m temperature in East Hungary is twice as large as in West Hungary.
4. If the green vegetation fraction was handled as a land cover-dependent parameter during the model runs (which is a more real approach), the results show a more intensive temperature increase due to the land cover changes. In this case the daily mean temperature increase was +0.21°C nation-wide.
5. According to the simulations, primarily the daily values of dew point changes were apparent due to the evapotranspiration decrease. The greatest difference was -0.12°C nation-wide. The dew point increased gently in the night hours nation-wide in consequence of the simulated decrease of dew formation. The maximum difference was +0.06°C in the morning.
6. In spite of the fact that land cover changes do not have a significant impact on total precipitation nation-wide, the effect on precipitation distribution and intensity is considerable in all weather situations where precipitation occurred. In some cases there were local changes greater than 40mm.

APPLICATION OF THE RESULTS, FUTURE IMPROVEMENT POSSIBILITIES

Beyond further meteorological and climate simulations and sensitivity tests, the land cover maps which were created for the present dissertation could be the basic data for a following investigation from numerous areas of science. They could be used for modelling further environmental processes (such as carbon sequestration and hydrological processes). Research could also be done to find a connection between the Hungarian land cover changes and economic and social processes during the 20th century. In addition, these maps could help the large-scale ecological research in connection with species migration and biodiversity changes.

According to the simulations, the land cover plays an important role in the meteorological processes and therefore it is necessary to take the direct climatic effect of land cover change into account in the interpretation of climate change.

Further improvements of the adapted land-surface model are needed to improve the quality of hazardous weather events forecasts by the Hungarian nowcasting system and to reduce the uncertainties in investigations on the effects of land cover changes:

- Among the different land-surface parameters the model is very sensitive to the values of the green vegetation fraction. In the scientific literature there are some values of this parameter that do not correspond to reality (e.g. cropland and forest). The currently applied values of this parameter should be verified by measurements.
- The mean annual cycle of the most important land-surface parameters (such as green vegetation fraction, albedo and emissivity) for Hungary should be defined via measurements for all land cover categories because the vegetation varies significantly during the year. In his way,

this effect could also be taken into account during the simulations. In addition, the annual deviations from the average should be also quantified for these parameters to get information about the uncertainty and variety of the applied annual cycle.

- It should be worthy of consideration to add groundwater dependent and independent forest categories to the model. The rate of the evapotranspiration could be significantly influenced, when the forests reach the groundwater over large areas. This could be important in the Carpathian Basin because the dry periods can not limit the transpiration of forests significantly in such regions. Thus it could be valuable to calculate this effect within the model processes.

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