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HIDRODYNAMIC EXAMINATIONS IN POINT OF SURFACE LAND USE IN THE DANUBE-TISZA SAND RIDGE AREA

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Abstract
A number of theoretical and practical research increasingly confirms the hypothesis that human activity is becoming even stronger impact on our climate and changes its natural processes. The processes taking place during these changes are mainly affecting those sensitive areas where there is a high spatial and temporal variability of precipitation. If we examine the Danube-Tisza Sand Ridge precipitation levels, overall we conclude that it represents a very extreme part of Hungary where the 500 mm average rainfall can often create critical climate situations. The primary purpose of our work is to analyze the water supply conditions of six sample points with MODFLOW. The exploration of near-surface water conditions can get us closer to the understanding and solving of the area's drying-out problem.

1 Introduction

The primary purpose of our work is to analyze the water supply conditions of six sample points. In the processing and analysis of data the MODFLOW hydrodynamic process modeling program has provided assistance which is mainly suitable for permanent and non-permanent underground water flow modeling. By using this model, our main purpose was to forecast changes in the hydrological conditions of modified surface covered areas. The exploration of near-surface water conditions can get us closer to the understanding and solving of the area's drying-out problem.

2 Method

2.1 The sample points

The selection of our measurement points primarily occurred based on surface land use (*Figure 1*). The most important aspect of the appointment of the points was that we could examine the water supply of as many land use types – typical of the area – as possible. Another important aspect was that the points should be located in areas where different groundwater ratios were observed. Out of the six sample points four are located in the Ridge areas (1361, 1387, 1458, 4144), and two points are in the valley of the Danube (4141, 1375), thus the groundwater conditions can vary significantly between sample points. Water shortages affect mainly of our ridge points, whereas at the points in the Danube Valley a rise in groundwater levels can be observed. In the present work we will be presenting and analyzing one measurement points (1361) in more detail.

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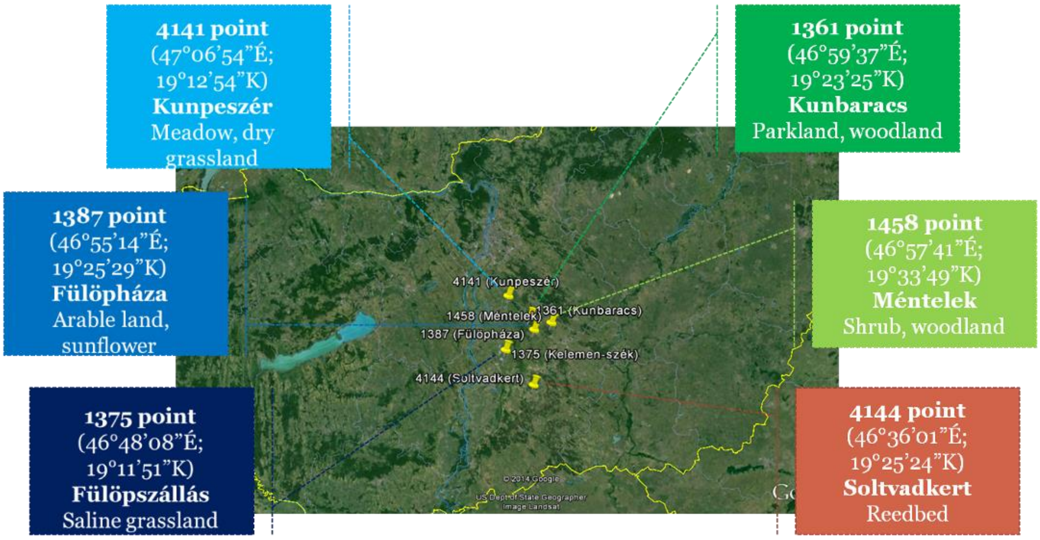

Figure 1. The locations of the sample points

The 1361 well and sample point can be found west of Kunbaracs in a grove-like, wooded area (46° 59' 36.61" N, 19° 23' 25.52" K). Soil samples were collected from three levels: an upper, darker colored humus level (0-40 cm); a lighter, less humus-like layer (40-80 cm); and under these with a sharp transition a layer of bright yellow color of sand. The type of soil was determined to be a humic sandy soil. The groundwater well was installed in January of 1960. Except for the beginning of the 1990s, the ground water level in the well is measured continuously. In the measurement data a significant decrease of the groundwater level is observed (*Figure 2*).

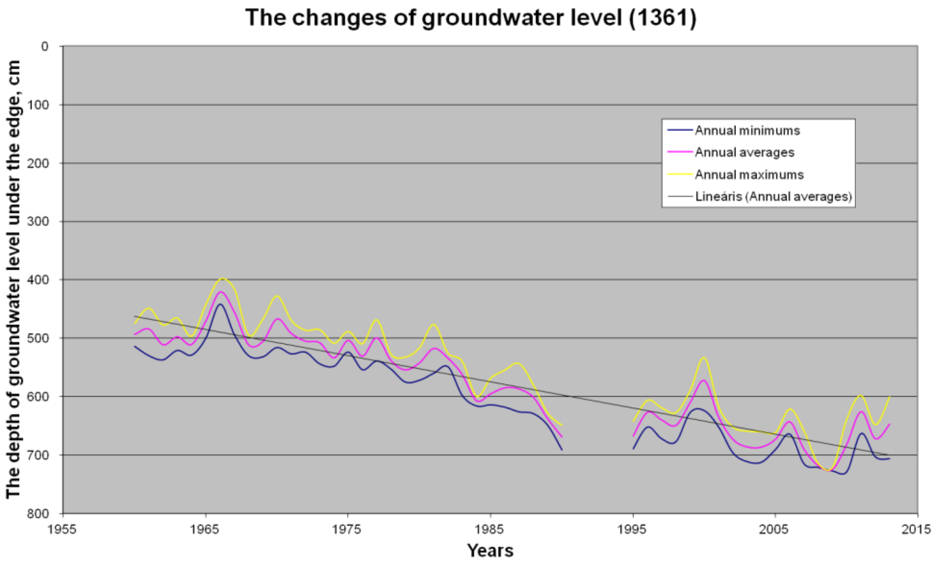

Figure 2. The changes of groundwater level of well 1361

2.2 The hydrodynamic modeling process

Based on our objectives and our geological knowledge of the area, for the modeling of the hydrodynamic processes in the subsurface we chose the Processing MODFLOW package. The primary reason for the choice of this model was that no strong computing background was needed, because the software is easy to use and with good geological-hydrogeological knowledge an appropriate model can be constructed that helps controlling the spatial-temporal changes of the parameters and their effects.

MODFLOW [1] is a complex three-dimensional system for modeling below surface permanent and non-permanent water flows and for solving transportation modeling problems.

MODFLOW provides the user with a hydrodynamic model operating on the principle of finite difference, professional graphics rendering, advanced calibration tools, particle tracking module, as well as transportation models [2].

During the hydrodynamic modeling we solve the basic equation of leakage in order to determine the pressure levels and concentrations. Hydrodynamic models are usually numerical models that are based on the use of finite difference. MODFLOW solves the execution of the groundwater flow equation's finite difference method by using the continuity equation. In the cells the sum of all in- and outflow of water equals to the change in the amount of water stored there. The density of the water table is permanent, the continuity equation can be written as the balance of flow for the cell [3].

$$\sum Q_i = SS\frac{\Delta h}{\Delta t}\Delta V$$

where: Q_i - the amount of water flowing into the cell with the correct sign (m^3/day)
SS - finite difference element (cell) of storage coefficient (l/m)
ΔV - the volume of the cell (m^3)
Δh - pressure changes during the time period Δt (m/day)

To carry out hydrodynamic modeling, large amount of data is required, such as hydro-geological and topographic data (groundwater level, geological structure, topography), leakage hydraulic data (hydraulic conductivity, void ratio), other hydrological data (evapotranspiration) and data on the impact of human activities (concentrated water abstractions or water provision values). In our current work, due to the maximum length requirements, we do not deal with a more detailed description of the model construction.

2.3 Description of the study area

A critical point of model preparation is the demarcation of modeled space as data collection focuses mainly on this map section. For the modeled area a 2 by 2 kilometer region surrounding the Kunbaracs (1361) sample point was chosen (1: Y675100, X184300; 2: Y677100, X184300; 3: Y677100, X182300; 4: Y675100, X182300) (*Figure 3*).

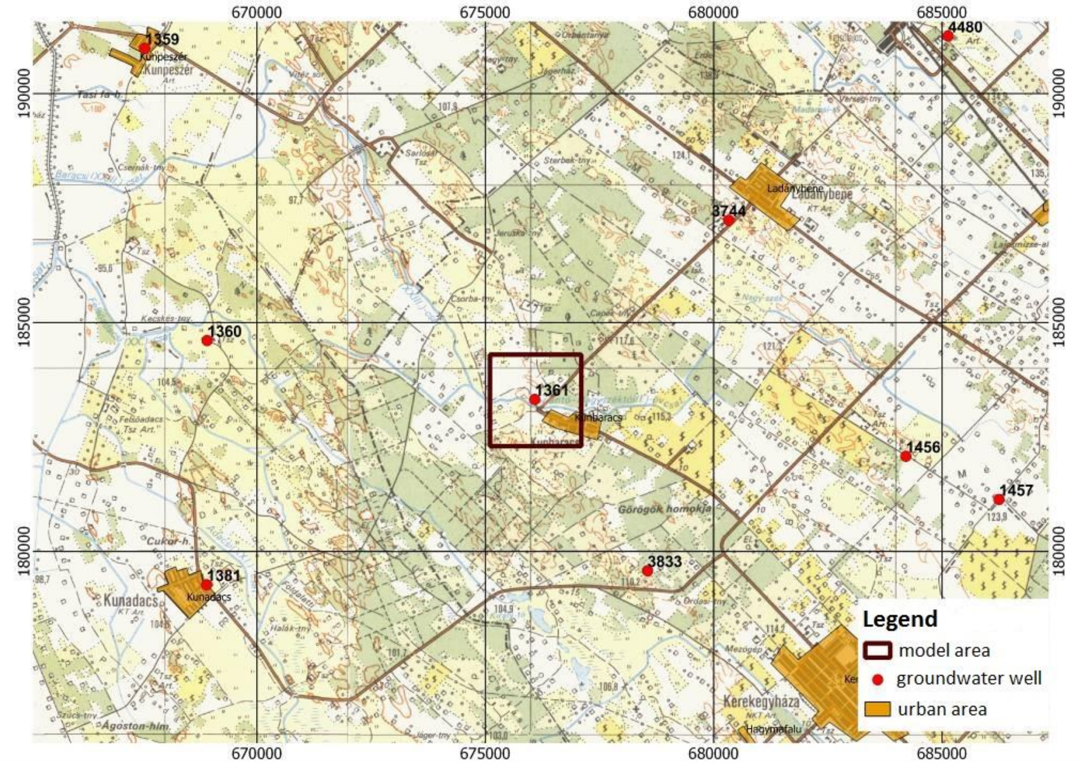

Figure 3. The study area (in the middle)

As previously described, the point is characterized by a scrubby, woody environment. The introduction of forests into agricultural lands has significant effects on ecosystem-level processes. Evapotranspiration of forests is generally greater than vegetation in similar circumstances due to the increased leaf surface, the greater roughness of forest and the larger relative rooting depth compared to herbaceous vegetation. In the sub-humid climate of the Great Plain, where rainfall is usually not sufficient to maintain woody vegetation, trees may only be able to survive long periods of drought when they are able reach an utilize the ground water supplies. Under these conditions, planted forests modify the water and saline balance of the original grassland or agricultural areas, reducing the original level of groundwater and increasing the salt concentration in both the soil and the ground water [4]. During modeling several scenarios were tested, in some of which we assumed that during the test months the forest cover was removed. The tested year was 2014.

With the selection of the Kunbaracs sample point our primary goal therefore was, that by modeling the hydrodynamic processes that played out in the sample plot, we could demonstrate the impact of forests on the groundwater.

3 Results and discussion

With the help of the calibrated model the examination of various scenarios was possible. The running parameters were unchanged for each scenario, only transpiration data have been changed in areas where the forests are located. In the study area we only assumed penetration, i.e. lateral flow is not calculated during model run.

3.1 Scenario "A": Examination in the months of June and July with forest cover

In this scenario we studied the changes induced by the precipitation fallen in June and July of 2014. Our results can be found in *Figure 4.* In the modeled area, in June of the year under review, the rainfall was 30 mm. However, in July slightly more rain fell in the area, as the monthly precipitation was 87 mm. The difference observed in the amount of precipitation, along with infiltration values is also clearly reflected in the differences in results between June and July.

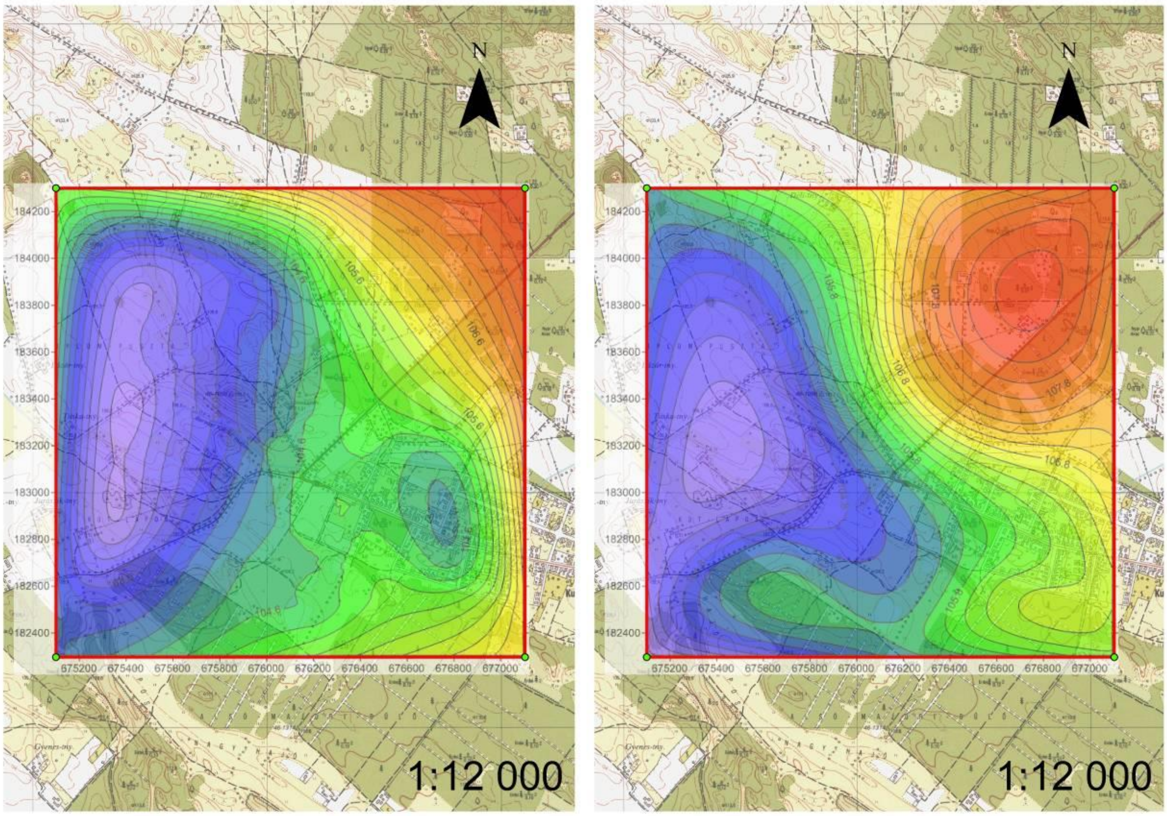

Figure 4. The groundwater level in June and July of 2014 with forest cover

If we examine *Figure 4*, it is clear that in June for a large part of the area water levels were falling, whereas in the month of July groundwater levels were rising in most parts of the study area. The primary reason being that in July, due to higher precipitation amounts, infiltration values were also higher. The north-eastern part of the area is situated around 2-3 meters higher than the south-western part.

3.2 Scenario "B": Examination in the month of July without forest cover

During this scenario we assumed the absence of forests in the plot, consequently transpiration values diminished greatly in most of the area. Due to the decrease in transpiration values in the study area an increase in the local water table has occured, which is clearly visible in *Figure 5.* We have tested the difference between the groundwater levels of the unforested areas and the region's monthly average groundwater levels for July, the results of which can be seen in *Figure 5*. The absence of forests resulted in an increase in groundwater levels in the area.

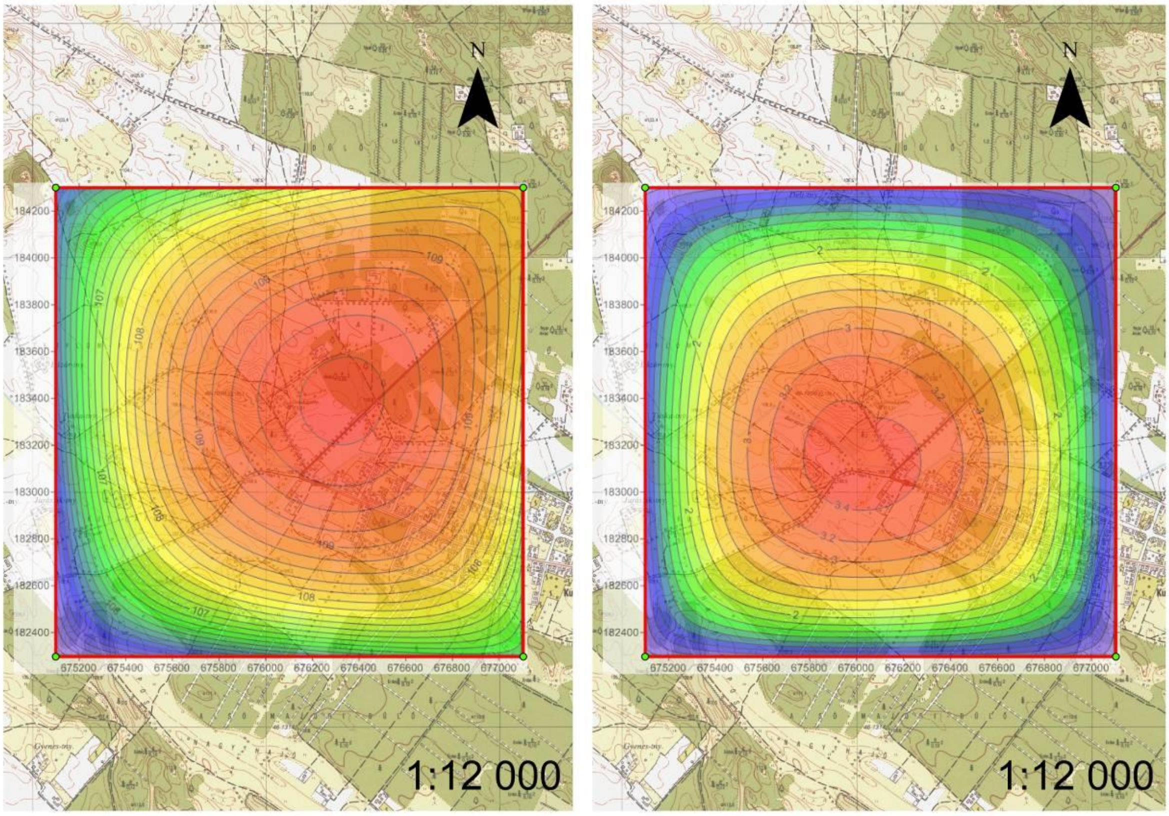

Figure 5. The groundwater level changes in July of 2014 without forest cover (left). The difference between the groundwater levels of the unforested areas and the region's monthly average groundwater levels in July (right).

If we look at the results, we can conclude that the model has probably miscalculated during the run. The results can be refined by the modification and the coordination of the model parameters which will not result in groundwater level increases on such a scale. We have defined for our model so called soft boundary conditions, which means that the constant water pressure areas were not found directly on the edge of the modeled area, but these values were pushed 300 meters away from the edge of the modeled area. To obtain more realistic results, we will probably have to increase this distance during the next run. It follows from the results that another major problem of the constructed model is that the modeled area's water supply system is out of balance. The infiltration values are probably too high compared to the evapotranspiration values. We have built up to a depth of 6 meters evapotranspiration model does. The evapotranspiration values of vertical optimal results are achieved by reducing the volume, because if we consider Figure 11, we can see that the impact of evapotranspiration decreases exponentially with depth.

4 Conclusions

All in all, as a result of our hydrodynamic modeling, we can conclude that the model was not accurate enough to detect small changes. With the expansion of the sample area, the modification of the boundary conditions and with the better coordination of infiltration and transpiration parameters the results probably would have been more reliable. By entering the values of anthropogenic impacts the model's accuracy and its results could be refined. Among our objectives is the creation of hydrodynamic models for the remaining five sample points during which the structure of the model would increase in complexity.

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