UNIVERSITY OF SOPRON

DOCTORAL (Ph.D.) THESIS

HYDROLOGICAL EXAMINATIONS ABOUT THE CONSERVATIONAL USEAGE OF THE FORESTS IN THE AREA OF THE KISKUNSAGI NATIONAL PARK DIRECTORATE

Bence Bolla

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University Of Sopron, Faculty of Forestry
Institute of Geomatics, Forest Opening-up and Water Management
Roth Gyula Doctoral School of Forestry and Wildlife Management Sciences
Nature Conservation (E6)
Rector: Prof. Dr. Faragó Sándor
Doctoral Programme Manager: Prof. Dr. Bartha Dénes
Supervisor: Dr. Kalicz Péter

1. Introduction

In Hungary, the extension of forests increased almost threefold due to several programmes (Alföldfásítási Program, Nyár Program, Fenyő Program) after the Treaty of Trianon. To recover the loss proved to be a challenging effort for many dedicated foresters. Due to the above mentioned afforestation programmes as well as committed professionalism, today the region between the Danube and the Tisza rivers has become the most afforested part of the Great Plain. Mainly alien species (Scotch fir, black pine, black locust tree stands) were planted to fix sand in the region. These afforested plantations in the Danube-Tisza Sandridge have been criticized by environmental NGOs from time to time. Governmental conservation managements regard this question considering more aspects, as several National Park Directorates manage forest stands in the area.

Groundwater levels have decreased significantly in the region between the Danube and the Tisza since the 1970s, and the tendency can be seen even today. Considering the importance of the issue, several researchers have dealt with it and have tried to find the reasons. The decrease of water level is a complex question. Several researchers mention not properly controlled water usage by resident population, horticulture and agriculture as a major cause, while others mention deep-boring used during looking for petroleum, natural gas and shale gas. Some other researchers suppose that sand-ridge forests can affect the levels of groundwater considerably leading to its decrease.

Concerning all the viewpoints and interests of conservation treatment, water management, agriculture and silviculture, it is a matter of great importance to start research into the water balance of the different forest stands. It is also important to research the process of water balance and to deal with its integration into conservation treatment. It can be useful for each sector to determine the role of different forest stands in water balance.

The main purpose of the research is to provide information about the water-balance features of sand-ridge forest stands in the area of the Kiskunsagi National Park Directorate and to monitor the changes in different types of forests.

While conducting the survey, I considered the following:

What is the impact of forest stands typical in the area of the Kiskunsagi National Park Directorate on changes in water level?

How does water balance develop in the examined deciduous and coniferous woods and in their neighbouring grasslands?

How can the results and the methods used in this research be integrated into conservation treatment and in the silviculture of Kiskunsagi National Park Directorate in the long term?

2. Material and methods

2.1. Research area

I did my research in sample areas in the area of the Kiskunsagi National Park Directorate. The two main sites comprised three forest stands in Bócsa and two other places in Pusztaszer. In Bócsa, I collected data in two stands (Scotch pine and grey poplar) and the grassland next to them. The forest stands are homogeneous, the trees are the same age and planted with the same technology. In Pusztaszer, in the other main area of my research, I collected data in an old black locust forest stand which rose from second growth and the grassland next to it.

I established and started to manage a rain gauge system in Kunadacs, in Bugac and in Bócsa. In each site, I surveyed soil parameters by doing field work and by doing laboratory tests. I examined ground-water samples from Bócsa and from Pusztaszer in the field and in laboratory as well. I also examined the typical parameters of the forest stands, that is, the health of the trees, and I detected the endangered species and other common species existing in these sites. I examined the habitats form the aspect of conservation treatment.

2.2. Applied methods

I measured the open-surface precipitation by using Hellmann rain-gauge units from 3 March 2012 to 31 March 2015. I measured precipitation daily in Bócsa, Bugac and Pusztaszer, on the other hand, in Balástya and Kunadacs two observers helped my work.

I estimated the interception and stem-flow of a forest stand (Bócsa 51 D), which is a monoculture of Scotch fir, and a forest stand (Bócsa 51 E), which is a monoculture of grey poplar over the period of 4 April 2012 and 24 October 2014. I conducted control measurements in the grassland next to the above-mentioned forest stands (Bócsa 51 TI 1).

The canopy interception was determined using three Hellmann rain gauge units (one of them was placed in a row of trees, another one was placed between two rows of trees, and the third one was put in a thin grove) and twenty funnels (each of of 280 cm^2) were applied in every meter in both forests at 1 meter height from the ground. Further ten gauge units (each of of 100 cm^2) were applied horizontally in a random way at ground surface. For calculation of stem-flow trunk collars (connected with collecting vessels) were settled for each tree. I built the trunk collar system with regard to the distribution of the diameters of the tree trunks.

Meteorological data (temperature, humidity, precipitation, radiation, speed and direction of wind) were collected with a BOREAS Meteo Global HI weather station applied in Bócsa 51 TI 1. This data collection was conducted hourly between 1 January 2012 and 31 March 2015.

I observed the ground-water level with Dataqua, LUB 222 sensors and HYGR data-loggers hourly in Bócsa and Pusztaszer between 25 November 2013 and 2 February 2015. In cases of the failure of the data-loggers, I had to use Dataqua, DA-OP LED water gauge weekly.

I collected data about soil moisture with a manual sensor and with automatic data-loggers in Bócsa 51 TI 1 (grassland), in Bócsa 51 D (Scotch fir stand) and in Bócsa 51 E (grey poplar stand). Automatic soil moisture measuring was surveyed with a HOBO MicroStation data-logger manufactured by Onsetcomp and with twelve 10 HS soil moisture sensors. The data collection took place in four soil layers (0-25cm, 25-50cm, 50-75cm, 75-100cm) in each site between 1 September 2013 and 1 May 2014. The soil moisture was observed with a TDR-system digital PT-1 soil moisture sensor. I measured it in 80-cm bulk layers weekly. I collected soil moisture data over the period of 31 December 2013 and 17 March 2015.

I compared the naturalness of the sites with β diversity method (Raup & Crick 1979), the index of diversity was given by the number of detected endangered species. I characterised the diversity of the sites by the number of endangered species. I verified the rate of the same species by using Jaccard index (Raup & Crick 1979).

2.3. Processing data

I processed the data collected during the survey with the following methods:

- manual measurements (open surface precipitation, canopy interception, stem-flow, ground-water, soil moisture) were processed with Microsoft Excel 2010. I also used Microsoft Excel 2010 to select and illustrate the data.
- automated soil moisture data could be selected and analysed by using authorised data-processing software. On the other hand, for the processing of meteorological and ground-water level data, Microsoft Excel 2010 and extension programmes were also necessary.

- for the estimating of water-balance I applied the water balance equation (Szász & Tőkei 1997) and the approach of White (White 1932, Loheide *et al.* 2005) to the processed data of the survey.

3. Results and theses

During the three years of the research 354,800 records were collected, out of which 6,137 records were collected manually and 348,663 were collected with data-loggers.

- The distribution of the precipitation varied in each sample area. In several cases, the quantity of precipitation was above the annual average, but the distribution of the rainfall proved to be uneven. On the other hand, there were long periods of drought during the course of sampling, e.g. in June in 2014. Out of the five sample areas, the largest quantity of daily rainfall could be recorded in Kunadacs on 31 March 2013.
- The average value of canopy interception was 23 per cent in the Scotch fir stand in Bócsa (in 2012: 22 per cent, in 2013: 24 per cent, in 2014: 23 per cent). It was 19,2 per cent in the grey poplar stand (in 2012: 18,5 per cent, in 2013: 20 per cent, in 2014: 19 per cent) between 30 March 2012 and 31 March 2015. As for canopy interception, in comparison with the published data in literature (Járó1980:16 per cent, Gácsi 2000: 19,5 per cent, Sitkey 2004: 25 per cent), in case of the Scotch fir stand my results proved to be more than the average published before.

  The canopy interception was lower in case of the grey poplar stand than the average published. This lower value can be explained by the lower closing of the canopy, the poor quality of trunks, the loose distribution of branches, missed treatments and many leaks caused by dead trees. It is difficult to compare the results with former references (Járó 1980: 24 per cent; Sitkey 2004: 23 per cent) since they refer to stands of different age, source and growth.
- The value of stem-flow was 4 per cent in the Scotch fir stand (in 2012: 1,5 per cent, in 2013: 4 per cent, in 2014: 2,5 per cent) and it was 10 per cent in the grey poplar stand (in 2012: 8 per cent, in 2013: 12 per cent, in 2014: 10 per cent) during the period of 30th March 2012 and 31st of March. 2015. Stem-flow value is lower in Scotch fir stands because the bark of trees is thick, rough and absorbent. On the other hand, this value is higher in grey poplar stands, as the bark of the tree is smooth, draining rainfall. In case of stem-flow, it is also difficult to compare references (Járó 1980, Gácsi 2000, Sitkey 2004) since they published only interception data and they regarded stem-flow as a negligible quantity.

- Meteorological data were similar to average in Bócsa between 1st January 2012 and 31st March 2015but extremes could be detected on several occasions (in April and July in 2013 as well as in June in 2014- long, dry periods). The total annual rainfall in 2012 was 420,6 mm, which is below the average, meanwhile it was above the average in 2013 (599 mm) and in 2014 (807,9 mm). Long, dry periods occurred in March, July and August in 2012, while August in 2013 and March in 2014 can be characterised as droughty.

  There were some dry periods typically in the spring and in the summer. The occurrence of the humid periods between 2012 and 2014 can be described as heterogeneous, which can be explained by the varied distribution of rainfall.
- The groundwater level was usually detected at 3,4 m in Bócsa over the period of 25th November 2013 and 2nd February 2015. This level is regarded as deep in Hungary, but in the region of Kiskunság Sandridge it is a typical value. It seems to be average according to former references (Gácsi 2000) and by Water Conservancy Directorate Directorate: 3,5m in Orgovány and 3,3 m in Bócsa in 2014. The average value of groundwater level was 2,1 m in Pusztaszer during the period of the research. This value of 2,1 m is above the average in Kiskunság Sandridge compared with the data of 2,8 m in Ópusztaszer in 2014 and 2,9 m in Balástya in 2014 by Alsó-Tisza-vidéki Water Conservancy Directorate in Szeged.

  Analysing groundwater level records, significant differences can be detected between the grassland and the forest stand. My results also establish that lower groundwater level records are typical under forest stands. Black locust and grey poplar stand are able to reach and absorb the groundwater with their roots from deeper layers. The detected coniferous stands are unable to reach and absorb the groundwater from deeper ground layers. Thus coniferous stands can only affect groundwater levels by interception throughout the year.
- In case of soil moisture, the differences between grasslands and forest stands were obvious. The soil moisture data detected in the grasslands followed the distribution of daily precipitation evidently. On the contrary, in the forest stands the value of soil moisture followed the daily rainfall slowly and unevenly.
- In my research the calculation (estimating) of water flow was based on field work as well as the basic values and edge specifications were always set with the help of field measurements. The analysis of water flow of the sample areas was conducted by the water balance equation. The differences were significant regarding the grassland, the

coniferous stand and deciduous stands in case of transpiration. The difference was noticeable between the grassland and the two forest stands. Transpiration in the coniferous stand was lower because the roots were unable to reach the groundwater level. The Scotch fir can only absorb water from rainfall infiltrating into the soil. The value of evapotranspiration was the highest in case of the grey poplar stand. Deciduous stands have extensive roots so they can have access to groundwater in the upper layers more easily.

- The grey poplar stand in Bócsa proved to be the most valuable habitat, according to the biodiversity analysis. Although the grey poplar forest stand transpires more water than the other two habitats, it is the most advantageous considering sustainable development. Thus we need to analyse habitats in their complexity.
- Conservation treatment requires the use of scientific results instead of some emotional approach. Scientific results contribute to appropriate nature protection and therefore local scientific results should be integrated into proper conservation treatments.

Thesis

1. The measuring system adapted by the author is suitable for doing long-term hydrological research in the area of Kiskunsagi National Park Directorate.

I measured the open-surface precipitation by using Hellmann rain-gauge units in five sample areas (in Balástya, Bócsa, Bugac, Kunadacs and Pusztaszer). Groundwater level measuring system was applied in five sites in Bócsa and in Pusztaszer. In Bócsa, I operated a weather station in one sample area, and I used an automatic moisture measuring system in three sample areas. By developing this measuring system further, it can be connected to other systems such as Forest Research Institute and can be used for long-term research in the future.

2. The fluctuation of groundwater level values measured in forest stands evidently correlate with increased transpiration in the growing season.

The difference in the fluctuation of soil moisture between the grasslands and the forest stands is obvious in Bócsa and in Pusztaszer. The data collected throughout my research prove that the examined forest stands absorb more water from deeper layers with the help of their root-system (layers which cannot be reached by herbaceous) This phenomenon affects deep seepage. The herbaceous vegetation influences soil moisture in the upper layers of the soil between 0-50cm. On the other hand, the values of soil moisture decrease in layers between 75-100cm as well in case of deciduous forest stands in the growing season.

In the forest stands and in the grassland, the volumes of soil moisture were similar to the results published by Hagyó in 2009. The fluctuation of the soil moisture values in the two upper layers (0-25cm, 25-50cm) in the coniferous stand was similar to the results by Gácsi in 1999. In the deeper layers of the ground (50-75cm, 75-100cm) the measured soil moisture values are more balanced and display typical trends.

3. Analysing groundwater level values, the significant differences between the grassland and the forest stand were evident.

Groundwater levels typically presented lower values under the examined forest stands throughout my research. The grey poplar stand in Bócsa and the black locust stand in Pusztaszer are able to reach and absorb groundwater from the deeper layers with the help of their root-system. The examined Scotch fir stand does not affect the groundwater levels as much as the deciduous forest stands. This statement corresponds to the results by Gácsi in 2010, on the other hand, it contradicts to the hypotheses by Major and Neppel (Major and Neppel 1988, Major 1994, 2002)

4. In the grey poplar stand and in the Scotch fir stand the fluctuation of both the interception and stock rainfall are influenced by the structure of the forest stand as well as by the physical features of rainfall.

Analysing the interception data I found that the values of interception are affected by rainfall, that is, by its quantity, intensity, distribution and physical features, as well as by the structure of the forest stands, that is, by the type of species, the distribution and the shape of the trunks, the density of the trees, the foliage and the health of the forest stand.

The values of the interception measured in the Scotch fir forest stand can be regarded as higher than the former results. In the grey poplar stand, the values of interception were lower than the average values, which can be explained by the lower foliage, by the poor quality of trunks, by the weak density of the branches as well as by the leaks due to the dead trees in the stand.

Analysing stem-flow values, I found that there is less stem-flow in pine forest stands, as pine has thick, absorbent bark. However, the value of stem-flow was higher in the grey poplar stand since grey poplar has smooth bark, which helps flow on trunks.

It is not always feasible to compare the results with the results found in literature because of the differences of the forest stands and the measuring methods.

5. The differences between the two forest stands and the grassland regarding transpiration and evaporation can be proved by calculating water-balance.

By using the water balance equation it is clear that the transpiration of both grassland was not much than of the neighbouring forest stands. In case of the Scotch pine stand, the value of evapotranspiration was lower since its root-system does not reach the groundwater level. Coniferous stands can only absorb water from layers infiltrated by rainfall. In the grey poplar and in the black locust forest stands, the value of evapotranspiration was the highest as it can absorb water from the upper and the deeper layers with the help of its expanded root-system.

6. The applied methods and the results of the research contribute to conservation planning and treatment.

The methods applied and the results are suitable for the professional establishment of further conservation treatment (Conservation plan, Natura 2000 plan). It can be evidently proved that habitats have an impact on water-balance and their impact should be considered together with other usually applied methods. These findings should be integrated into conservation planning and treatment.

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