# Evaluation of Monitoring on Modrava Catchments

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**Abstract**: In this paper is presented the comparison of the selected hydrometeorological data from two experimental micro-scale catchments Modrava 1 (0.1 km$^2$) and Modrava 2 (0.17 km$^2$) in upper parts of Bohemian Forest. These catchments differ mainly in the vegetation cover – a dead forest with very young trees (Modrava 1) and primary forest clearings with 10 to 15-year old young forest (Modrava 2). For comparison were used the data monitored close to the catchments outlets during the hydrological year 2007. Average hourly rainfall and runoff data were analysed. During the winter season, snow water equivalents were measured and the maximum value was added to the rainfall amount measured during the vegetation season for the estimation of total year precipitation on each catchment. The data of the air temperature and water conductivity measured in hourly time intervals were also compared. For the estimation of differences between the monitored data sets the cumulative values of the characteristics observed during whole year were computed. It follows from the comparison of the time series that the time rainfall distribution was similar during the year on both catchments with a higher total year precipitation and hour intensities on the catchment Modrava 2. The time distribution and total runoff depth were similar on both catchments. On Modrava 1 a faster recession of hydrographs could be seen which might relate to a lower retention capacity. The value of the water conductivity on the catchment Modrava 1 depended more on the changes of the runoff depth. The maximal values occurred during the peak discharges or in time of hydrographs rising. This fact can be the result of a lower stability of the soil profile in the catchment with dead forest cover.

**Keywords**: experimental watersheds; hydrological monitoring; hydrological balance

Since the bark beetle calamity in the Bohemian Forest National Park (Šumava NP) in the nineties of the last century have been studied the problems of the impact on the forest ecosystems by this sudden change (Podrázský *et al.* 1999) as well as different methods of regeneration management (Matějková & Jonášová 2004). One of the questions was the changes in the hydrological regime in the catchment areas, where the mountain spruce forest died off during a very short period (Zimmermann *et al.* 2000).

Three experimental catchments were established for the evaluation of the bark beetle calamity impact on the hydrological regime in 1998. These three localities differed in the forest cover and its management. Modrava 1 catchment – a locality under Roklan (V koutě) at the territory where the dead spruce forest was left, Modrava 2 catchment – a locality under Malá Mokrůvka (Doupě) at the site of the forest clearing in the place of primary spruce forest with man-made regeneration, and Modrava 3 catchment – a locality under Vysoký stolec (Vlasatá cesta) at the site of a healthy mixed forest. The rainfall, runoff, and air temperature were monitored on these catchments during the vegetation period from August 1998 (Kuna & Kuřík 1998), and in 1999 the water conductivity monitoring started (Křovák & Kuřík 2001).

The comparison of one rainfall-runoff event, monitored on all three experimental catchments at same time with similar rainfall characteristics, revealed that the highest specific peak discharge (15.4 l/s/ha) occurred on the catchment Modrava 1, a lower peak discharge (6.2 l/s/ha) on the catchment Modrava 2, and the lowest one (0.54 l/s/ha) on the catchment Modrava 3 (Kuřík *et al.* 1999). Pavlásek *et al.* (2006) carried out the data analysis from Modrava 1 and Modrava 2 catchments, where selected rainfall-runoff events were compared, in which their dependences on particular characteristics were established.

The problem with the comparison of the Modrava catchments was the short period of monitoring in the course of the year, which enabled only the comparison of selected rainfall-runoff events. For a general comparison, the evaluated hydrological balance was missing. For these reasons the monitoring has been carried out since April 2006 continuously. This approach has been enabled by two relatively moderate winters, when the watershed was accessible. A problem in the data record occurred with the Modrava 3 catchment where a datalogger failure occurred. The results of the present monitoring are the data series from Modrava 1 and Modrava 2 catchments for the hydrological year 2007.

## MATERIAL AND METHODS

For comparison were selected time series from Modrava 1 and Modrava 2 catchments for the hydrological year 2007. Brief characteristics of the experimental watersheds are introduced in Table 1.

Runoff was measured with the help of Thomson weir with a pressure sensor at time intervals of 2 minutes in the outlets of both watersheds. In the vicinity of the outlets were also measured the rainfall using a tipping bucket rain gauge with a catch area of 200 cm$^2$ in the height of 1 m above the terrain at time intervals of 2 minutes, the temperature in a height of 2 m above the terrain at the time intervals of 1 hour and water conductivity at the time intervals of 1 hour. For the estimation of winter precipitations, regular monitoring of the snow cover was carried out. The data of the snow cover height and snow density had been determined at intervals of 2–3 weeks. From these values was established average snow water equivalent for the catchment area.

The recorded data, except those for the snow water equivalent, were evaluated in one hour time steps for the whole hydrological year. The flow rate was processed as the average hour flow from the two-minute data on Thomson weir, the rainfall for a given hour was estimated as the rainfall amount from the previous hour, temperature and conductivity were taken directly from the measurements. From the time series only those parts were selected where both dataloggers operated simultaneously. The time series parts where one dalalogger was out of work were excluded. To the precipitation amount was added the maximum value of average snow water equivalent on the catchments at the end of the winter period (30. 3. 2007).

For the comparison purposes, the flow rate was transferred into the runoff depth. The average values of the hydrological characteristics evaluated and their cumulative values from the beginning of the hydrological year were computed. For the estimation of the total amount of the dissolved substances in the outflow from the catchment area, the values of conductivity were multiplied by the height of the runoff.

## RESULTS AND DISCUSSION

From the hydrological year 2007 were, after the exclusion of the non-measured periods on the experimental catchments Modrava 1 and Modrava 2, evaluated the time series of hourly flow rates from 8476 hours, i.e. total 353.2 of days of the hydrological year 2007. The summary of the evaluated data sets is introduced in Table 2.

The charts comparing hourly rainfall amounts are depicted in Figure 1. Figure 2 shows the precipitation amounts cumulatively summed in the course of the year.

The comparison of average hourly runoff depths on the catchments Modrava 1 and Modrava 2 is shown in Figure 3. In Figure 4 is depicted the comparison of the cumulative values of the runoff depths during the hydrological year 2007.

The comparison of the temperature fluctuations on both catchments is shown in Figure 5. Figure 6 shows the cumulative values of hourly temperatures in the hydrological year.

The data sets of the monitored conductivity are shown in Figure 7. In Figure 8 are shown the

Table 1. Brief characteristics of experimental catchments Modrava 1 and Modrava 2

| Characteristics | Modrava 1 catchment | Modrava 2 catchment |
|---|---|---|
| Locality | under Roklan (V koutě) | under M. Mokrůvka (Doupě) |
| Forest cover | dead forest stand | clearing with young forest |
| Catchment area ($km^2$) | 0.10 | 0.17 |
| Min. altitude a.s.l. (m) | 1216 | 1197 |
| Max. altitude a.s.l. (m) | 1270 | 1330 |
| Length of thalweg (km) | 0.485 | 0.745 |
| Slope gradient | 0.09 | 0.21 |
| Soil type | podsol | podsol |
| Geologic subsoil | paragneiss | granite, paragneiss |
| Soil profile depth (m) | 0.4–0.7 | 0.6–1 |

Table 2. Summary of evaluated characteristics from experimental catchments Modrava 1 and Modrava 2 for the hydrological year 2007

| Characteristics | Modrava 1 catchment | Modrava 2 catchment |
|---|---|---|
| Average flow rate (l/s) | 1.40 | 2.41 |
| Average specific discharge ($l/s/km^2$) | 14.0 | 14.2 |
| Minimum measured specific discharge ($l/s/km^2$) | 0.037 | 0.501 |
| Maximum measured specific discharge ($l/s/km^2$) | 678 | 789 |
| Annual runoff depth (mm) | 426 | 432 |
| Annual amount of measured rainfall (mm) | 1208 | 1410 |
| Maximum water storage in snow cover (mm) | 409 | 354 |
| Total annual measured rainfall (mm) | 1617 | 1764 |
| Maximum hour rainfall depth (mm) | 13.8 | 43.6 |
| Runoff coefficient (–) | 0.26 | 0.25 |
| Average temperature (°C) | 4.7 | 6.14 |
| Minimum measured temperature (°C) | –18.9 | –16.2 |
| Maximum measured temperature (°C) | 29.5 | 31.5 |
| Average value of conductivity (S/cm) | 0.040 | 0.049 |
| Minimum value of conductivity (S/cm) | 0.024 | 0.034 |
| Maximum value of conductivity (S/cm) | 0.083 | 0.069 |

cumulative values of conductivity multiplied by the height of runoff in the respective hour.

The Modrava experimental watersheds have been operated since 1998. The catchments were primarily established with the aim to compare the influence of three different forest covers on the hydrological regime in the selected localities. Until now, only the data have been available from the vegetation seasons of the monitored years, approximately from June to October. With such data it was possible to study the catchments behaviour using only single rainfall-runoff events.

However, the main supply of water in the spring and early summer months in the mountain locations in central Europe is the snow cover. The forest cover plays an important role in the melting period (Hríbik *et al.* 2009) and its degradation can change part of water balance in catchments.

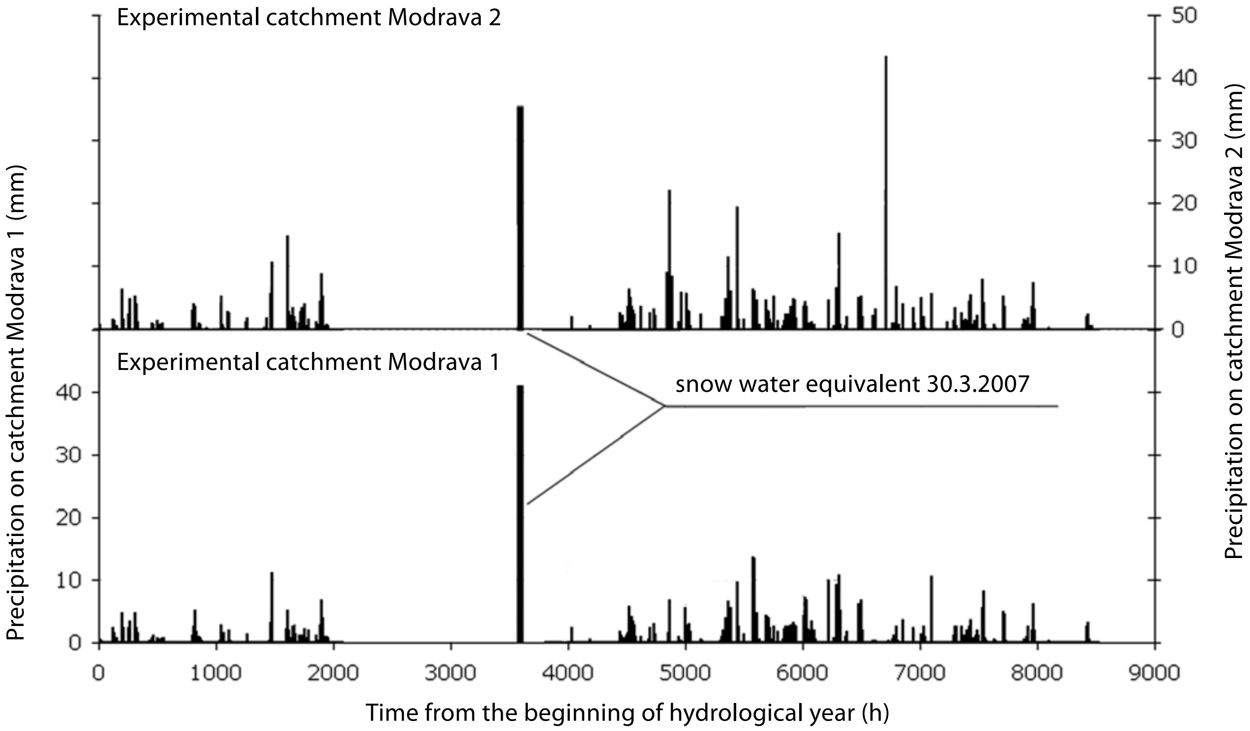


Figure 1. Comparison of hourly rainfall depths on Modrava 1 and Modrava 2 catchments in the hydrological year 2007

The changes of the forest cover can also affect the variability of the air deposits and their concentrations in the snow cover (Hríbik & Škvarenina 2008) which affects the outflow water quality.

After the data monitoring during the whole hydrological year 2007, the catchments characteristics could also be compared from the point of view of the hydrological balance. This hydrological year, however, was atypical in the mountainous area as well as in the entire Czech Republic because of a very moderate winter.

In comparing the precipitation occurrence on the experimental watersheds Modrava 1 and Modrava 2 in the course of the hydrological year 2007 (Figure 1), one can notice a similar time distribution of the rainfall events in the course of the year. The

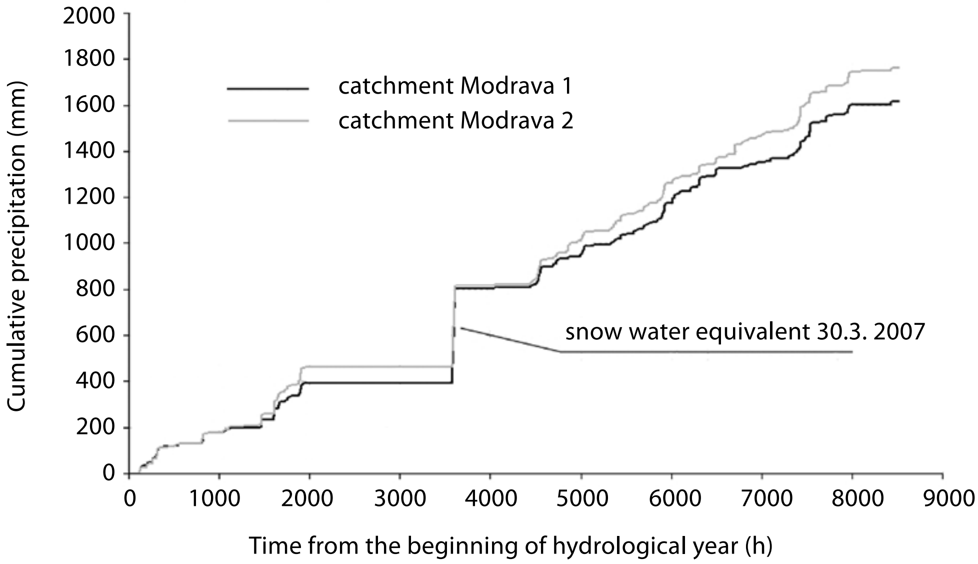


Figure 2. Comparison of the cumulative values of hourly rainfall depth on Modrava 1 and Modrava 2 catchments in the hydrological year 2007

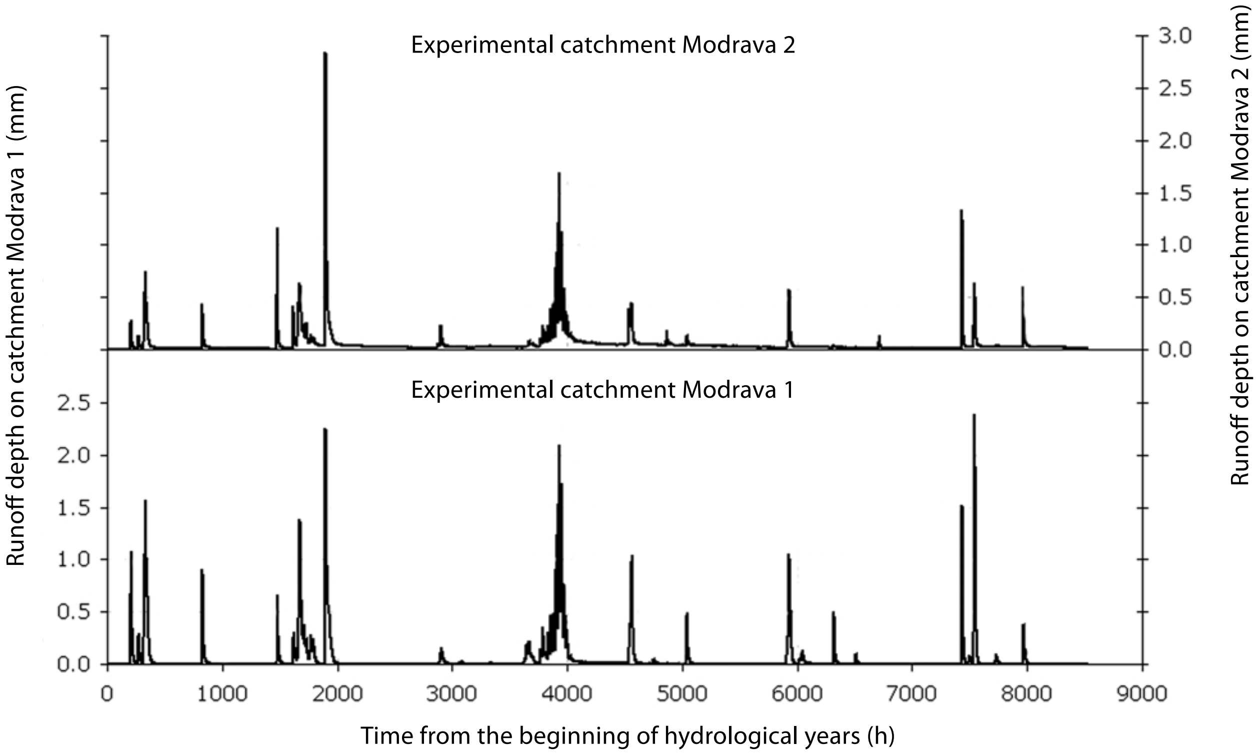


Figure 3. Comparison of average hourly runoff depths on Modrava 1 and Modrava 2 catchments in the hydrological year 2007

Modrava 2 catchment showed higher hourly rainfall intensities. The Modrava 1 catchment had a higher snow water equivalent at the end of the winter period. This fact is evident in Figure 2 showing the conformance in the course of the cumulative values of the precipitation amounts between both catchments. Total amount of the cumulative precipitation values was higher with the catchment Modrava 2. Total difference in precipitations was 147 mm. This fact does not support the previous results of the measuring in which generally higher precipitation amounts were monitored on the Modrava 1 catchment.

Comparing the average hourly flow rates from Modrava 1 and Modrava 2 catchments (Figure 3), it can be said that the majority of important events

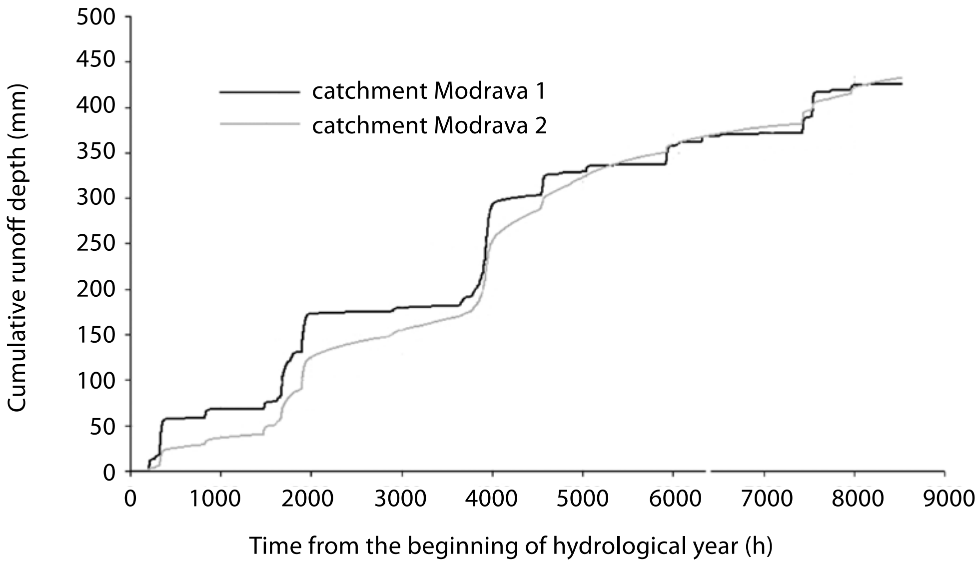


Figure 4. Comparison of the cumulative values of hourly runoff depth in the hydrological year 2007

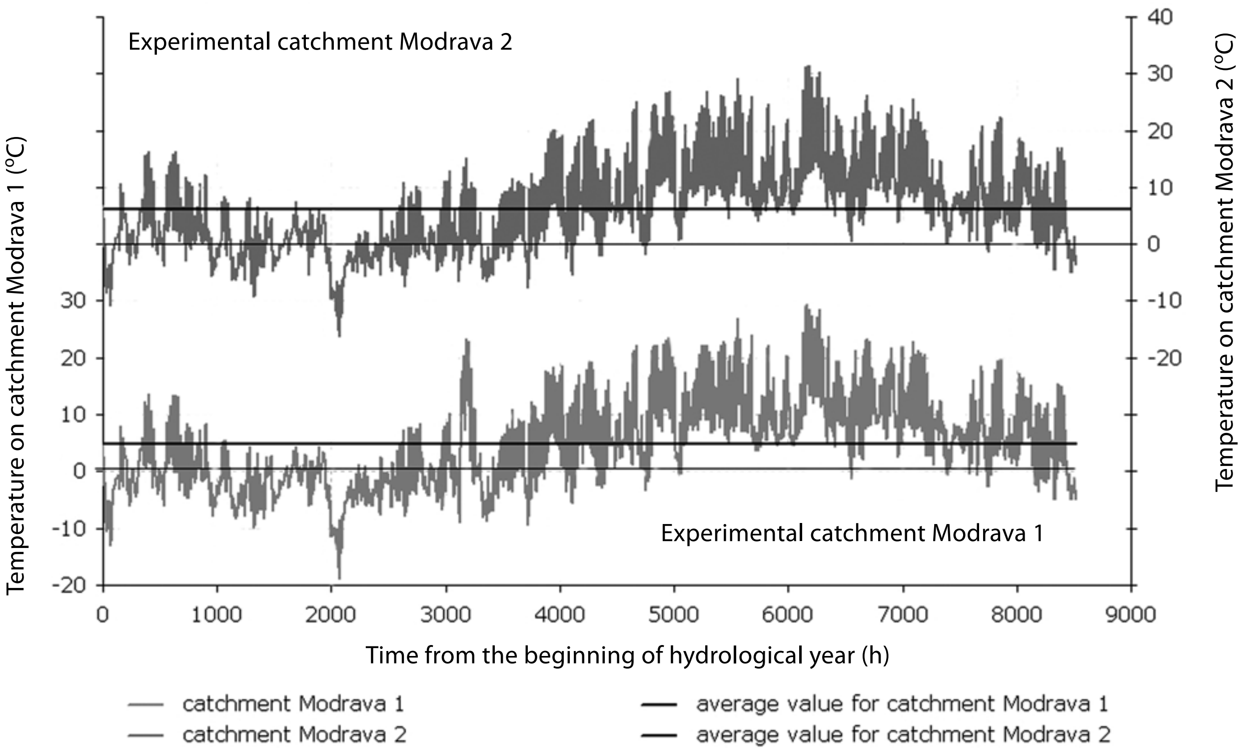


Figure 5. Comparison of average hourly temperatures on Modrava 1 and Modrava 2 catchments in the hydrological year 2007

occurred simultaneously. Their time distributions and times of peaks were approximately in accordance. Small differences in the time of hydrographs rising give evidence rather for the movement of particular rainfall events than for a response of the monitored catchments to those events. The culminations of the runoff depth are, with some exceptions, higher for the Modrava 1 catchment, which is in accordance with other results (Kuřík *et al.* 1999). The most important period in the course of the year was the runoff from the snow melt, which influenced the height of the basic runoff for next months. However, if we compared the cumulative heights of runoff in the course of the year (Figure 4), it was discovered that the higher peak discharges on the Modrava 1 catch-

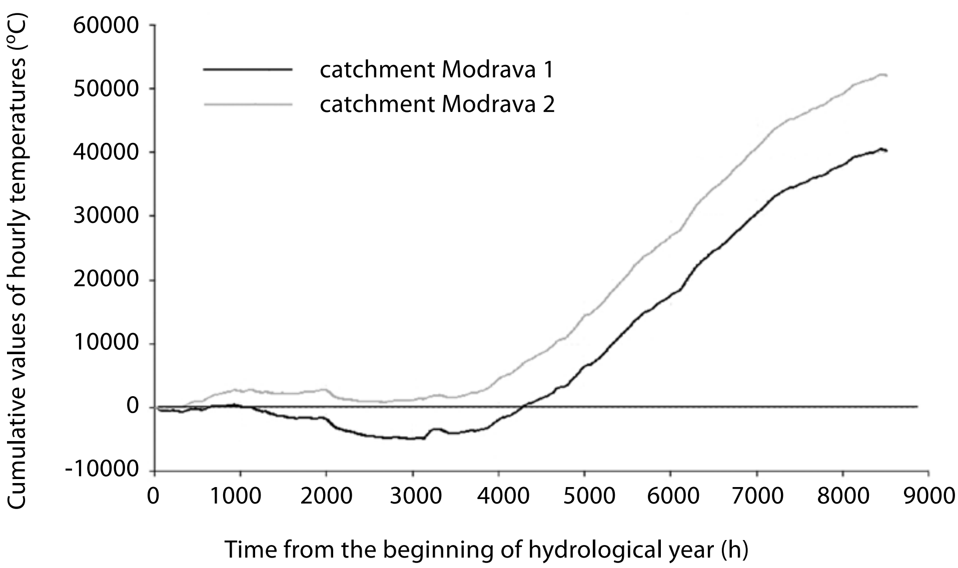


Figure 6. Comparison of cumulative values of hourly temperatures in the hydrological year 2007

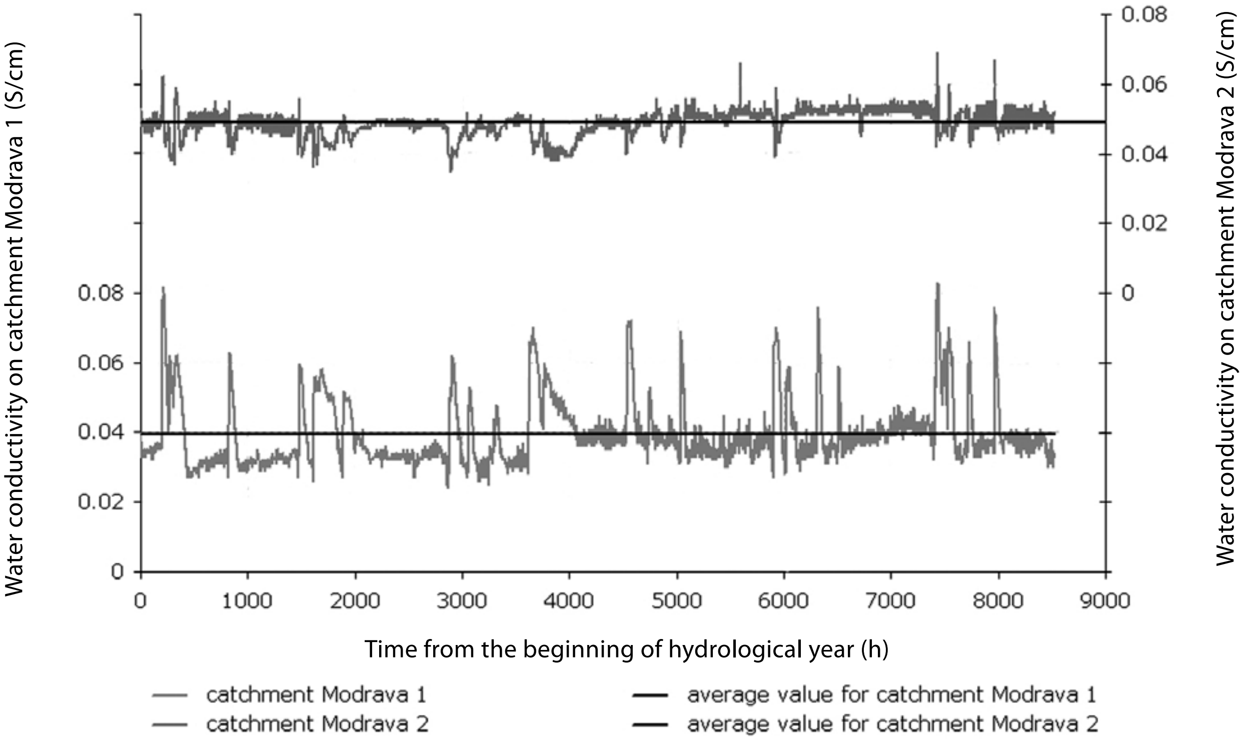


Figure 7. Comparison of hourly values of the conductivity of outflow water on catchments Modrava 1 and Modrava 2 catchments in the hydrological year 2007

ment were balanced by a more gradual water runoff from the Modrava 2 catchment, the total height of runoff in the hydrological year being comparable in both catchments. The Modrava 1 catchment is characterised by a faster growth of the cumulative values of the runoff height during and immediately after the rainfall-runoff event. The reaction of the Modrava 2 catchment starts at a similar period, but the response to the rainfall event is more prolonged (gradual recessions of the hydrographs). This fact can show a higher retention capacity of the Modrava 2 catchment. According to the investigations, this catchment has a deeper soil profile. Therefore the question arises; if this higher retention is caused by the cover which is currently a young forest.

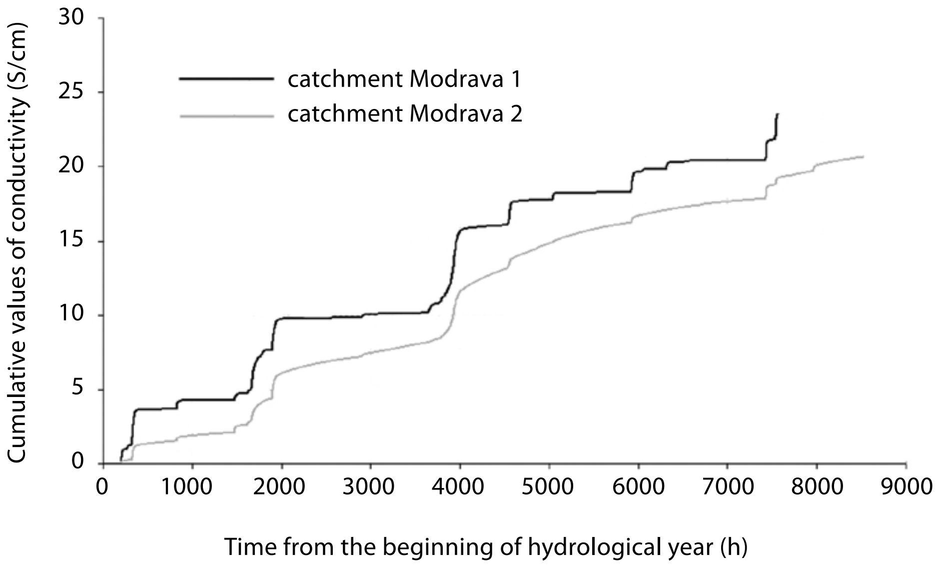


Figure 8. Comparison of cumulative values of the water conductivity multiplied by runoff depth in the hydrological year 2007

For the survey of the climatic characteristics on the watersheds were compared also the courses of hourly air temperatures (Figure 5) which represent a significant characteristic influencing evapotranspiration from the monitored territory. The temperature courses were consistent in the course of the year, except one event in the spring period. On the Modrava 1 catchment, the temperature is approximately 1.5°C lower then that on the Modrava 2 catchment. This difference did not concern the average temperatures only, but also the minima and maxima of daily temperatures. This fact is evident in Figure 6 showing the comparison of the cumulative values of hourly temperatures in the course of the year. This conclusion is in disagreement with the results of measurements from the year 2002, in which only minor variations were observed in the daily temperatures of the Modrava 2 catchment (Tesař *et al.* 2004).

Interesting is also the comparison of the values obtained in the measurements of water conductivity (Figure 7) which shows the presence of a number of dissolved substances in water. A higher stability in this parameter was shown with the Modrava 2 catchment. The Modrava 1 catchment showed a more unstable regime of the dissolved substances outflow from the catchment which was more dependent on the course of runoff. At the beginning of the runoff response of the watershed, the conductivity on the Modrava 1 catchment increased, thus indicating fast washing up of substances from the catchment, contrary to the Modrava 2 catchment, where the reduction in conductivity occurred in the majority of events due to the dilution of the dissolved substances by the drainage water. The average value of the drainage water conductivity was higher with the Modrava 2 catchment. The comparison of the values of conductivity multiplied by the height of runoff (Figure 8) which should indicate the total amount of the washed-up substances from the catchment, makes evident that on the Modrava 1 catchment a more significant substance loss occurs. This fact can account for the temporary instability of the ecosystem – dead forest.

## CONCLUSION

The data obtained in the course of the hydrological year 2007 on the experimental watersheds Modrava 1 and Modrava 2 revealed the existence of similar climatic conditions on both catchments. However, detailed analysis of the particular characteristics measured indicated that the Modrava 2 catchment possesses a higher retention capacity and a higher stability in point of view water quality. On this catchment were observed more gradual courses of the falling limbs of hydrographs as well as a lower amount of the dissolved substances in the outflow from this catchment. But from the data analysis, it is not possible to establish what portion of the catchment behaviour is dependent on the different vegetation covers and what portion is influenced by other hydrological characteristics.

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