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DEFORESTATION PROCESS CONSEQUENCES UPON SURFACE RUNOFF COEFFICIENTS. CATCHMENT LEVEL CASE STUDY FROM THE APUSENI MOUNTAINS, ROMANIA

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Abstract

This article describes the development and the application of a methodology that can be used in assessing the consequences of deforestation process and last but not least is showing that deforestation may have consequences upon runoff. The original spatial datasets used in the study were obtained in previous studies using Remote Sensing and digital cartography techniques. Thus, the method for assessing the consequences regarding the changes of the underlying surface characteristics involves the use of GIS. In this way we have obtained data that helped us to estimate the afforestation degree and the Frevert runoff coefficients used in the Rational Method for estimating runoff. The methodology was applied in three catchments from the Apuseni Mountains, Romania. By applying the assessing methodology for the considered catchments it could be noticed that when the afforestation degree drops down under the optimal level, the curve that is describing the weighted runoff coefficient variability is following close to the perfection the runoff variability. With the obtained results we were able to conclude which catchment had truly suffered from deforestation, and what catchment may have a high risk of floods caused by deforestation.

Key Words: *Deforestation, runoff, underlying surface characteristics, GIS, Apuseni Mountains.*

1. INTRODUCTION

Remote Sensing and digital cartography used for mapping lands covered by forest vegetation, and not only, is required as a condition through which we can extend the level of understanding the influence of deforestation process in shaping the runoff necessary conditions at the catchments level. Thus, the assessment of the deforestation process consequences wish to bring the contribution in this area regarding through the methodology used and as well through how we can correlate the results with the surface runoff coefficients. These coefficients may highlight the underlying surfaces characteristics changes because we assume the use of parameters that are directly involved in shaping runoff.

Considering this we intended to create a methodology to evaluate the consequences of the negative developments on the areas covered by forests, which occurred during the period 1974-2010 over three catchments in the Apuseni Mountains, Romania. The Apuseni Mountains area is a major part of Transylvania region. Geographically it is a subdivision of the South-Eastern part of the Carpathian Mountains, respectively in the Northwest side of Romania (**Fig. 1**). They are drained by a major hydrological network that has an important role in both organic and electricity production.

The area proposed for this study is an area represented by three catchments that are found within the Apuseni Mountains. These catchments are represented by: Răcătău (103 Km^2) (green), Beliș (84 Km^2) (red) and Someșul Cald (99 Km^2) (blue) (**Fig. 1**). The

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catchments altitude ranges between 675m at the lowest point inside Răcătău to 1759m the highest point from Someșul Cald catchment. The vegetation inside the area is characterized by coniferous forests represented by spruce and silver fir and small areas with mixed and deciduous forests mostly represented by beech and hornbeam.

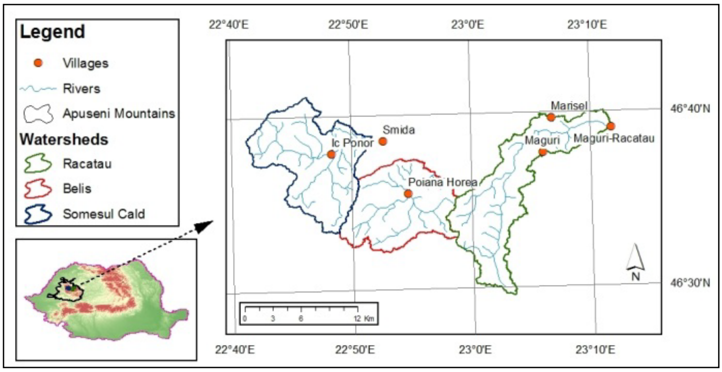


Fig. 1. Study area localization.

The database used in this study is composed from raster datasets for the land cover situation for the years 1974, 1988, 2000 and 2010, data obtained previously by *Costea et al. (2012)*; *Costea & Haidu (2010)*; ASTER GDEM v.2 (*http://www.jspacesystems.or.jp*) and soil maps 1:200000 (*ICPA, 1985*). In this way we were able to provide the runoff conditions for the moments 1974, 1988, 2000 and 2010.

2. METHODOLOGY

It is impossible to study or to assess from the field each catchment area in terms of forest cover and not only. That is why we use data and indicators that can be used to estimate the situation of a particular catchment in relation with the forest cover and in particularly with the role that the forest cover may have in shaping runoff conditions, especially through the underlying surface characteristics.

The methodology used in this study assumes the usage of some indicators (dimensionless parameters) like the afforestation degree and Frevert runoff coefficients which can provide a view over the catchments underlying surface characteristics. The methodology provided both parameters calculation and maps creation. This was possible because a GIS system was used. The system allowed us to build several tools which were used to integrate the previously obtained land cover data (*Costea et al., 2012*) and the rest of data necessary for the indicators calculation and mapping.

At the end, the obtained results were assessed by using the runoff variability obtained from the anomalies registered in the period 1974-2010. The runoff datasets are represented by the monthly average runoff values measured at the gauging stations from the catchments area.

2.1. Afforestation degree

Sustainable forest management is regarded as one of the most important contributions that the forestry sector can have in terms of sustainable development. The afforestation degree is an indicator that is considering this point of view. He also offers a wide variety of benefits. It is known that forest ecosystems provides protection for waters, by maintaining or increasing quality, aquifers restoration, soil protection, provides wildlife habitat etc. Catchment areas with low values of afforestation degree may be considered for afforestation stage, especially where these efforts are directed towards obtaining environmental benefits (*http://www.dnr.state.md.us*).

If forests are cleared on a larger surface or fragmented by other types of land cover, the consequences can be found in the catchment function degradation (transfer function). In general, the status of a catchment, especially in the mountainous area, is starting to degrade when the area covered by the forest drops below 65-75% from the total catchment area (*http://your.kingcounty.gov*). Different degrees of afforestation, in both space and time (about 40 years) may have major consequences over the water resources and runoff regime.

By using the data obtained by *Costea et al. (2012)*, which is representing with higher accuracy the land cover distribution in all the four moments of the analyzed period 1974, 1988, 2000 and 2010, we were able to highlight the afforestation degree evolution for each considered catchment.

The afforestation degree [C_p%] can be calculated by using the next formula:

$$C_p\% = \frac{Forest\ cover\ surface}{Catchment\ surface} * 100$$

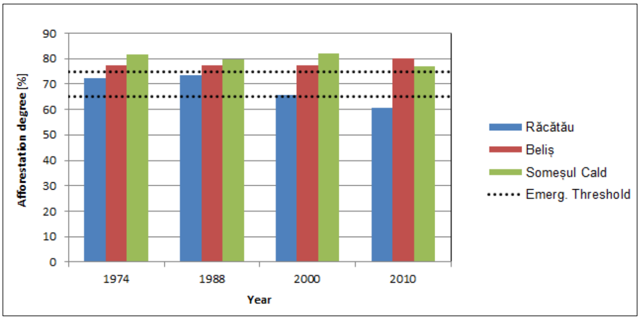


Fig. 2. Afforestation degree variability in the period 1974-2010.

Thus it can be seen in **Fig. 2** that the Răcătău catchment suffered the most because of forest clearance. Inside this catchment area the afforestation degree drops until 62.6% in 2010, under the emergency values considered to be the deforestation threshold for the catchments around the mountains area. The others two catchments retain the level of the afforestation degree over the considered threshold for the entire analyzed period. However it can be notice a higher negative forest surface variability inside the Someșul Cald catchment, especially at the end of the period when the afforestation degree is very close to the emergency threshold.

2.2. Frevert runoff coefficient

In general, the runoff coefficients are mathematical parameters which are calculated by using the hydrological water budget components. However, if we don't have any type of data for the water budget components, then the runoff coefficient can be determined on the basis of the land observations or by using studies conducted by some researchers. One of the most commonly method to identify the runoff coefficient value is the Frevert method adapted by Diaconu et al. (1995) and used by Bilaşco (2008). The method is using runoff coefficient tables in order to estimate the coefficient values.

By considering this we have developed a GIS model based on the Bilaşco (2008) model. The model is able to use raster datasets like land cover, soil texture, slope (in %) and it can provide results for the Frevert coefficient in both format, maps and tables, for the all four moments of time from the period 1974-2010. As a spatial result the Frevert coefficient variability for the period 1974-2010 is looking like in the **Fig. 3**.

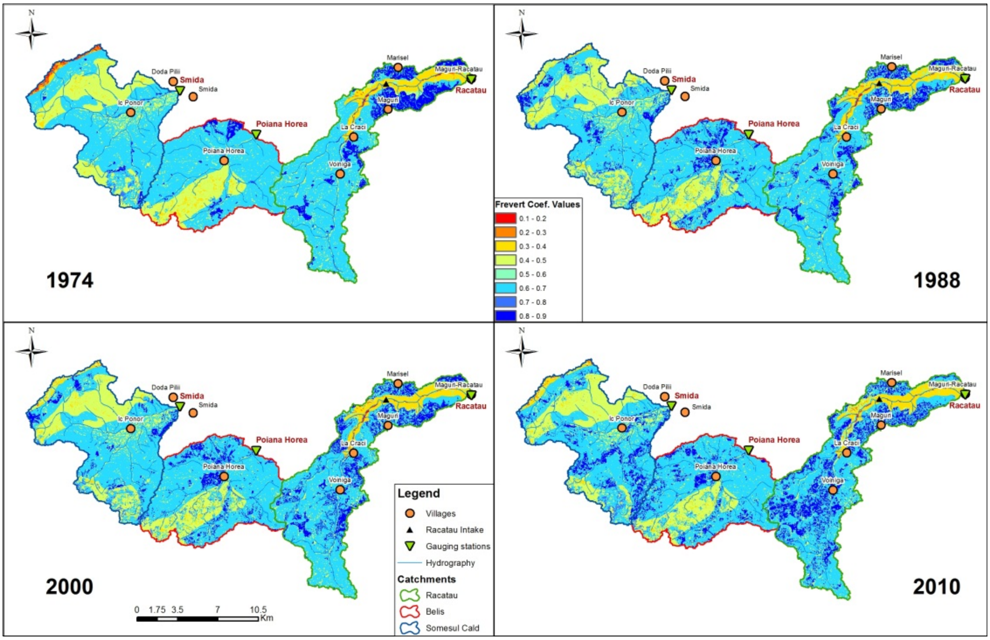
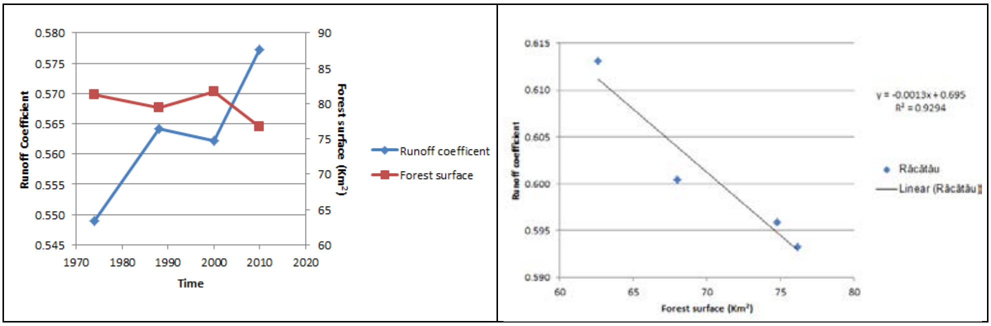


Fig. 3. Frevert coefficient spatial variability.

It can be notice in **Fig. 3** that there is significant-visual variability inside the Răcătău catchment area for the analyzed period; high values of the runoff coefficient appeared close to Voiniga village and around the peaks near the river mouth in the North-East. At the representation scale it can be notice as well that higher coefficient values variability can be found around the Poiana Horea village, inside the Beliş catchment, but they appeared at a constant rate compared to the others two. In the case of the Someşul Cald catchment the coefficient variability it is noticed more at the end of the analyzed period, in 2010, but here the variability is higher than the Beliş catchment situation. In the case of Someşul Cald catchment it can be notice as well that there is also a period when the runoff coefficient is registering a decrease around the year 2000.

In order to highlight in a better way the runoff coefficient variability we have calculated the weighted average value for each of the catchments. The obtained values were transposed in a graph which is representing the Frevert coefficient variability and the forest surface variability. In **Fig. 4a** there is a sample from Răcătău catchment area.

Later we found to be useful to measure the correlation between the catchment forest surface and the weighted average value of the Frevert coefficient. We found that the Răcătău catchment has the most pronounced correlation, around 0.96 (**Fig. 4b**); the second one was Someşul Cald with 0.85 and in the case of Beliş catchment we found “no correlation” between this two values. After that we decide to not consider Beliş catchment for further analyzes.



a) b)

Fig. 4. a) Răcătău catchment - forest surface vs. Frevert runoff coefficient; **b)** Răcătău catchment - forest surface correlated to Frevert runoff coefficient.

3. RESULTS

As a result, to indicate the deforestation possible consequences upon the changes at the level of the underlying surface characteristics, we chose to do a comparison between the runoff annual anomalies from the normal 1981-2010 and the runoff coefficient variability obtained from the values 1974, 1988, 2000 and 2010. We have done this only for Răcătău and Someşul Cald catchment because for the Beliş catchment we didn’t find any correlation between the Frevert coefficients and the forest surface variability. The resulted situations are looking like the ones in **Fig. 5** and **Fig. 6**.

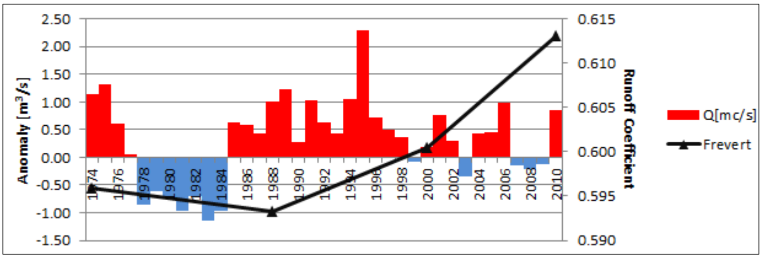


Fig. 5. Runoff coefficient variability compared to runoff anomalie - Răcătău cathcment situation.

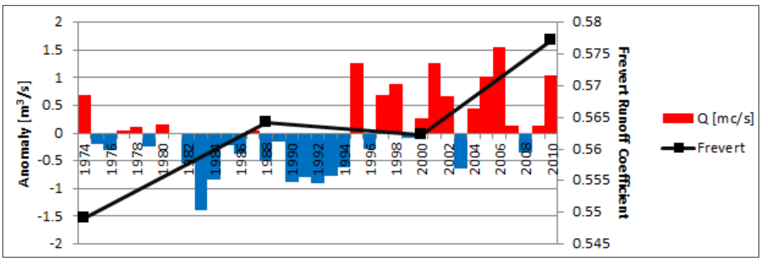


Fig. 6. Runoff coefficient variability compared to runoff anomalie - Someşul Cald situation.

In **Fig. 5** it can be seen that the recorded anomalies for Răcătău catchment decreased in the same period of time when the runoff coefficient decrease. We have to remember that the runoff coefficient is representing the weighted average value calculated by using the land cover data. This variability is found in an uptrend of forest surface (**Fig. 2**). After 1988, during a period of increasing both runoff and runoff coefficient, a period marked by intense deforestation is appearing. Unfortunately we do not have data to indicate the exact time of the cuttings. However, it can be seen that in the case of Răcătău catchment due to intense deforestation the runoff coefficient is following close to the perfection the runoff anomalies curve. We can connect this affirmation with the resulted afforestation degree (**Fig. 2**, **5**) where the corresponding value is under the emergency threshold. It is known that under these values the catchment function is affected. In the case of Someșul Cald catchment (**Fig. 6**) the runoff coefficient follows quite close the runoff anomalies. The weaker correlation (0.85) between the forest surface and runoff coefficients, the small number of land cover data trough the time and the resulted afforestation degree made a little bit difficult to relate the represented values. However, the resulted connection is representing very well the obtained results, especially at the end of the period.

4. CONCLUSIONS

The use of the indicators which can highlight the deforestation process consequences is essential. If the afforestation degree offers a simple view over the catchment forested area, the Frevert runoff coefficient offers a detailed point of view because it involves geographical features which are responsible for shaping the runoff.

In the case of Frevert runoff coefficient it can be notice that the curve follows close to the perfection the runoff anomalies during the period 1974-2010, especially for Răcătău catchment. We also noticed that in **Fig. 2** the forest surface is keeping its status under the considered emergency threshold for a long period of time. We can also see the positive situation regarding the deforestation inside the Beliș catchment. Here, other geographical features, different from forests, may have an influence over the runoff.

Finally we can say that forests, through deforestation (or not), from the catchments located around the mountainous area, are causing runoff negative (or positive) anomalies or if this is not 100% sure at least we can say that their influence can be found in the runoff variability curve.

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***http://www.jspacesystems.or.jp, ASTER GDEM v.2;

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