WATER RUNOFF AND ERODED SOIL FROM INTENSIVE PRECIPITATIONS ON DIFFERENT LAND USE TYPES IN SOUTH-WESTERN BULGARIA

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Abstract

The paper presents results of investigation on water runoff and soil erosion at different land use types in Maleshevska Mountain, South-Western Bulgaria. The study is based on long-term (1995-2007) stationary data collection which included measurements of the water runoff and the eroded soil from experimental plots of different land use. The quantity of daily precipitations $Q$ (mm) was recorded, the rainfall energy $E$ (MJ/ha), the maximum of 30-minute rainfall intensity $I_{30}$ (mm/min) and the precipitation indices $R_w = EI_{30}$ and $R_s = QI_{30}$ were estimated based on it, and the influence of these principal characteristics of the precipitations on the water runoff and eroded soil was investigated.

The largest amounts of water runoff and eroded soil were recorded for the fallow lands and the tobacco field. The lowest values were established for the grass-covered plots and the oak stand. The precipitation indices $R_w$ and $R_s$ were appropriate for distinguishing of different categories of runoffs: significantly higher amounts of water runoff and eroded soil were found for precipitations of high $R_w$ and $R_s$ indices - about three times as much as those of the medium ones.

Positive and significant correlations between the water runoff and the eroded soil with general downward tendency with the increase of the plant cover were established.

Key words: erosion, eroded soil, precipitation indices, land use type

INTRODUCTION

The soil loss estimation precision is of major importance in designing anti-erosion activities in any region, field or watershed. Thus, evaluation of the main man-manageable (land management activities, grazing) and natural factors (climate, vegetation, relief, soils, main rock) is required.

The quantitative evaluation of the soil losses has been initially based on dependences of the solid runoff on the main erosion-driving factors. Later on, methodological approaches of more complex nature have been proposed, as it was the case with the Universal Soil Loss Equation (USLE) by Wischmeier, Smith (1978) and its revised version RUSLE (Renard et al., 1997). Numerous models for estimation of the erosion have been recently developed worldwide. Sufficient long-term data are required for model examination and adaptation as well as for investigation of the relationships between the precipitation and the water and the solid runoffs.
Precipitations, especially the intensive ones, are the main factor for soil erosion. Their influence on the soil erosion is usually characterized by indices formulated from the quantity \( (Q) \), maximum intensity \((I)\), energy \((E)\) and duration \((t)\) of the rainfall (Wischmeier, Smith, 1978; Stanescu et al., 1969; Lal, 1976; Braunovic, 1996; Palecki et al., 2001). In the derivation of the Universal Soil Loss Equation Wischmeier, Smith (1978) defined the erosion index of a particular precipitation \( (R_w = EI_{30}) \) on the basis of established relationship between the soil loss and the product of the maximum 30-minute precipitation intensity \( (I_{30}) \) and its kinetic energy \((E)\). Dependencies of the quantities of the water and the solid runoffs on other index characteristics of the intensive rainfalls \( (R_1 = QI_{15}, R_2 = QI_{30}, R_6 = QI_{10}, R_o = Q/\sqrt{t}) \) have also been found (Stanescu et al., 1969; Mandev, 1976; Onchev, 1983; Rousseva, 2002) and subsequently applied for predicting the soil loss due to erosion. A number of studies, on the other hand, have shown the influence of the vegetation and the different ways of using land on the water runoff (Kostadinov, 1995; Olijnyk, 1999; Kulchytskyi-Zhyhailo, 2003; Dunjo et al., 2004, Oshurkevich, 2006; Konz et al., 2010).

The erosion processes in the mountainous regions of Bulgaria have been explored by numerous investigations (Kerenski et al., 1968; Kerenski, 1972; Biolchev et al., 1979; Angelov, 1986; Marinov, 1984; Kitin, 1988; Mandev, 1995, 1996, 1998; Marinov, 2007, 2009). Stationary observations of the hydrological and erosion processes on permanent plots and small watersheds have been carried out for more than 30 years (Raev, 1994, 2005; Marinov, 2009). The data recorded are applicable to study the relationships between the precipitation, the water runoff and the eroded soil, for model testing and for improvement of the research methodology.

The main objective of the present investigation is to evaluate and compare water runoff and soil erosion from runoff-inducing intensive precipitations at different land use types (oak forest, glade, pasture, fallow and tobacco lands) and to determine the influence of some characteristics of the precipitations on them on the basis of long-term stationary studies of permanent sample plots in Maleshevska Mountain, South-Western Bulgaria.

**MATERIALS AND METHODS**

**Site description**

The study was carried out on the territory of ‘Igralishte’ ecological and erosion investigation station situated in Sedelska river watershed basin in Maleshevska Mountain, South-Western Bulgaria. Four small watersheds of different land cover are set apart in the station area (Mandev, 1984; Marinov, 2009).

The watershed basin of Sedelska river is a part of Strumsko-Mestenska xerothermic zone of the South-Western Bulgaria. Previous studies identify the soils on the territory of the station as Luvisols (Mandev, 1984), which upper horizon has 1.31 to 1.34% humus content (Velizarova et al., 2010). The soils on the northern slope are characterized as relatively deep, of sandy to sandy-clay composition. The soils on the southern slope have clay-sandy to sandy composition and are shallow to very shallow and severely eroded.
The soil erodibility ($K$ factor) vary from 0.028 to 0.044 (Mg/ha)[(MJ/ha)(mm/h)]$^{-1}$, of average values 0.036 and 0.029 (Mg/ha)[(MJ/ha)(mm/h)]$^{-1}$ for sunny and shady slopes, respectively. The annual precipitations for the period 1973-2007 in the region of station are 605 mm, as about 46% of them are of quantity more than 20 mm (Marinov, 2009). The amount of precipitations peaks in November-December, with second smaller peak in May-June, while the rainfall is the lowest in January and September. The annual precipitations during the period 1984-1994, i.e. 11 consecutive years, were less than the average annual quantity characteristic for the region, which led to formation of pronounced drought period in July, August and September. The mean annual number of intensive rainfalls (of at least 5-minute intensity exceeding 0.180 mm min$^{-1}$) for the period 1976-2006 is 8.3, only 3 of which exceeding 20 mm of precipitation quantity. The mean annual temperature is 10.6 °C.

Data collection

Soil erosion monitoring can be carried out on-site (at plot level) and off site (at sub-catchment and catchment level) (Hartanto et al., 2003). In this paper are presented the results from surface and solid runoff investigations at plot level. Data collection took place from 1995 to 2007 and included measurements of the water runoff (m$^3$/ha) and the eroded soil (suspended material and sediments) (t/ha) from experimental plots of different land use established on southern (3 plots) and northern (5 plots) slopes (Table 1). The main types of land cover are oak forest, glade, pastures, tobacco field and fallow lands. The studies on the plots of fallow land and pasture have been performed in two trials in order to eliminate differences of the micro-environmental variation. Water and solid runoff were collected in the tanks after each precipitation.

Data of the water runoff and eroded soil caused by runoff-inducing intensive precipitations were analyzed. More than 100 runoff-inducing precipitations with quantity $\geq$ 9.5 mm were registered between 1995 and 2007. The quantity of daily precipitations $Q$ (mm) of intensity $I \geq 10.8$ mm h$^{-1}$ (0.180 mm min$^{-1}$) for 5, 10, 15 or 30 min were recorded. The rainfall energy $E$ (MJ/ha) and the maximum of 30-min rainfall intensity $I_{30}$ (mm min$^{-1}$) were calculated and further used for estimation of the precipitation indices $R_W = EI_{30}$ and $R_2 = QI_{30}$.

Statistical analyses

The influence of the factors rainfall quantity ($Q$) and land use type (Plot type), precipitation index $R_2$ and Plot type, and precipitation index $R_W$ and Plot type on the water and solid runoffs were studied by Repeated Measures Analyses of Variance (RMANOVA) for data sets of 98, 68 and 66 measurements, respectively. Preliminary investigation on the influence of the plot replication on the amounts of runoffs was performed in order to define the factor Plot type. Prior to the RMANOVA, the data sets for $Q$, $R_2$ and $R_W$ were classified into groups by two-step cluster analysis using the Log-Likelihood Distance as a distance measure and Schwarz’s Bayesian Information Criterion as a clustering criterion.
Bonferroni Multiple Range Test at p<0.05 for comparison of the means by factors followed the RMANOVA when significant influence of the studied factor was proven. Correlation between water and solid runoff was explored and analysed by experimental plots.

RESULTS AND DISCUSSION

Preliminary analyses

Statistically significant influence of the plot replication was observed for both the water and the solid runoff amounts (Table 2). Consecutively, each replication was considered as a different plot type and 7 plot types were designated and tested (Table 1).

The daily rainfall quantities for the period 1995-2001 varied between 8 and 77 mm and were clustered into 2 groups of moderate and high quantity precipitations. On the other hand, the precipitation index $R_2$ had values from 0.16 to 48.84 mm (mm h$^{-1}$) and was classified into 3 categories of low, medium and high values. The rates of index $R_w$ varied between 35.19 and 1148.98 MJ mm ha$^{-1}$h$^{-1}$, which were clustered into 2 groups of moderate and high values (Table 3).

Influence of the land use type and the precipitation on the water runoff

The RMANOVA showed that all analysed precipitation characteristics affect significantly the quantity of the water runoff (Tables 4, 5 and 6). Rainfall quantity of more than 40 mm caused 2 to 8 times higher amount of water runoff. The precipitations in the group of moderate quantity resulted in 1.83 to 51.63 m$^3$/ha water runoff while the high quantity rainfall produced water runoff of 14.44 to 117.16 m$^3$/ha (Fig. 1A).

Significantly higher (p=0.028) quantity of water runoff was caused by the precipitations of high value for the index $R_2$: mean water runoff of 58.15 m$^3$/ha vs. 21.45 m$^3$/ha and 23.33 m$^3$/ha for the medium and low values of $R_2$, respectively (Fig. 1C). Water runoff of 1.29 to 56.16 m$^3$/ha was recorded for the precipitations of moderate $R_w$ index, while significantly higher water runoff of 18.93 to 166.91 m$^3$/ha was measured for the rainfalls of high $R_w$ index (Fig. 1E).

The highest value of the water runoff was recorded for the fallow lands (plots 1 and 2) and the tobacco field (plot 6). The lowest values of the dependent variable were achieved for the pasture, glade and oak stand plots (Fig. 1A, 1C, 1E). Low quantities of water runoff have been recorded for lands covered with herbaceous vegetation as well as oak forests, which is in agreement with the results of other investigations where insignificant amounts of water runoff and eroded soil from natural forest stands and grasslands were found (Litovchenko, 1986; Midriak, 1990; Rafailova, 2004; Dunjo et al., 2004). The results for the oak stands are comparable to those for the grasslands (Fig. 1A, 1C, 1E), because of the characteristics of the larger part of this forest type, which at this advanced age (around 100 years) and management system is characterized by low canopy closure (up to 0.4). Consequently, the rainfall water interception is weakly influenced by the tree crowns and the runoff decrease is mainly due to the impeding
influence of the herbaceous floor cover. Statistically significant Plot×$R_2$ interaction was found (Table 5) due to change in the hierarchy of the plot means for the medium and the high $R_2$ values. The fallow land of northern aspect and the tobacco field (Plots 2 and 6) showed highest water runoff values (Fig. 1C), which can be ascribed to the lack of permanent vegetation cover, the soil erodibility status and the direct impact of the rainfall on the ground surface. For the low and medium index $R_2$ the tobacco field had highest value of water runoff, while for the precipitation with high $R_2$ index an abrupt increase of the runoff for the fallow land, up to the maximum measured values, was recorded (Fig. 1C). The pasture on the slopes with southern aspect was affected by the increase in the rainfall quantity from moderate to high more severely than the glade and the oak stand, which caused statistically significant Plot×$Q$ interaction (Fig. 1A). The steeper increase in the water runoff from the pasture on southern aspect with the increase in the $R_w$ precipitation index reflected in significant Plot×$R_w$ interaction (Fig. 1E).

Influence of the land use type and precipitation on the eroded soil

The quantity of the eroded soil as a dependent variable proved strong influence of the precipitation, characterized by $Q$, $R_2$, and $R_w$, and of the different land use types (Tables 4, 5 and 6).

The increased rainfall quantity caused doubling the mean amount of the eroded soil from the fallow lands and the tobacco field (Plots 1, 2 and 6) (Fig. 1B). The moderate quantity of precipitations resulted in 0.002 to 15. 274 t/ha solid runoff, while the large quantity of precipitations produced 0.006 to 33. 769 t/ha eroded soil.

A relationship between the rainfall quantity and the solid runoff is clearly distinguished which is in agreement with findings by other investigators (Roose, 1977; Arnoldus, 1978; Rousseva, 2002). Sirvent et al. (1997) established that eroded soil starts to increase after a certain threshold; above 15 mm of precipitation the sediments from uncovered soil clearly increased. Our investigation confirms that the largest quantity of precipitations do not necessarily produce the maximum soil erosion (Gonzalez-Hidalgo, 1994) because the recorded amounts of solid runoff vary within a broad range – up to 35.650 t/ha.

The precipitations of high index $R_2$ resulted in three times increase in the eroded soil than those of low and medium precipitation index $R_2$ (15.031 t/ha vs. 5. 888 and 5.085 t/ha, respectively). The average values of the water runoff and the eroded soil for the low index $R_2$ were slightly higher than those for the medium index $R_2$ (Fig. 1C, 1D), particularly for the plots of higher amounts of runoff. This might be due to the unequal number of cases in each of the sub-sets (Table 3), but also suggests that the precipitation index $R_2$ is a rainfall characteristic less appropriate for the runoff investigation and classification, at least for these particular region as its values from 0.1 to 25 (more than 95% of the registered values) cause comparable runoff amounts.

Significantly higher amounts of eroded soil (0.005-54.432 t/ha) were recorded for the rainfalls of high $R_w$ index than those of moderate precipitation index $R_w$ (0.002-18.328 t/ha) (Fig. 1F). More intensive erosion was observed for the precipitations of higher energy (Onchev, 1983; Rousseva, 2002), which seems decisive for the strong
Table 1. Characteristics of the sample plots

<table>
<thead>
<tr>
<th>Plot N/ Aspect</th>
<th>Land use type</th>
<th>Size, m × m</th>
<th>Plot area, m²</th>
<th>Slope, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Southern</td>
<td>Fallow land – Replicate 1</td>
<td>4 × 40</td>
<td>160</td>
<td>25</td>
</tr>
<tr>
<td>2) Northern</td>
<td>Fallow land – Replicate 2</td>
<td>4 × 25</td>
<td>100</td>
<td>30</td>
</tr>
<tr>
<td>3) Southern</td>
<td>Pasture – Replicate 1</td>
<td>4 × 40</td>
<td>160</td>
<td>25</td>
</tr>
<tr>
<td>4) Northern</td>
<td>Pasture – Replicate 2</td>
<td>4 × 25</td>
<td>100</td>
<td>30</td>
</tr>
<tr>
<td>5) Northern</td>
<td>Glade (grass cover &gt;60%, without grazing)</td>
<td>4 × 60</td>
<td>240</td>
<td>24</td>
</tr>
<tr>
<td>6) Southern</td>
<td>Tobacco field (tillage, planting and cultivation parallel to the contour lines)</td>
<td>4 × 25</td>
<td>100</td>
<td>25</td>
</tr>
<tr>
<td>7) Northern</td>
<td>Oak forests, managed through branch-cutting (grass cover 80-90%)</td>
<td>5 × 30</td>
<td>150</td>
<td>32</td>
</tr>
</tbody>
</table>

Note: The size of all plots was unified to 100 m² since 01.04.2001.

Table 2. Influence of the plot replication on the runoff amounts

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Water runoff</th>
<th>Solid runoff</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F-value</td>
<td>Level of Significance</td>
</tr>
<tr>
<td>Land use type</td>
<td>66.059</td>
<td>P &lt; 0.001</td>
</tr>
<tr>
<td>Land use type × Replication</td>
<td>9.117</td>
<td>P &lt; 0.002</td>
</tr>
<tr>
<td>Replication</td>
<td>8.202</td>
<td>P &lt; 0.005</td>
</tr>
</tbody>
</table>

Table 3. Classification of the main studied precipitation characteristics

<table>
<thead>
<tr>
<th>Factor group</th>
<th>Number of cases</th>
<th>Mean value</th>
<th>Standard deviation</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q (mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>79</td>
<td>23</td>
<td>8</td>
<td>8 – 39</td>
</tr>
<tr>
<td>High</td>
<td>12</td>
<td>56</td>
<td>10</td>
<td>43 – 77</td>
</tr>
<tr>
<td>$R_{wi}=EL_{30}$ (MJ mm ha⁻¹ h⁻¹)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>59</td>
<td>140.02</td>
<td>82.54</td>
<td>35.19 – 350.69</td>
</tr>
<tr>
<td>High</td>
<td>7</td>
<td>635.93</td>
<td>246.64</td>
<td>399.76 – 1148.98</td>
</tr>
<tr>
<td>$R_{ji}=QI_{30}$ (mm h⁻¹)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>41</td>
<td>5.21</td>
<td>2.75</td>
<td>0.16 – 9.51</td>
</tr>
<tr>
<td>Medium</td>
<td>24</td>
<td>15.29</td>
<td>4.48</td>
<td>9.86 – 25.21</td>
</tr>
<tr>
<td>High</td>
<td>3</td>
<td>40.30</td>
<td>9.59</td>
<td>29.93 – 48.84</td>
</tr>
</tbody>
</table>
Fig. 1. Mean values of the water runoff (A, C, E) and the eroded soil (B, D, F) by plots as influenced by the total daily precipitation $Q$ (A, B), the precipitation index $R_2$ (C, D) and $R_w$ (E, F). Means with the same letter are not significantly different at $p<0.05$ (Bonferroni multiple comparison test).
influence of the rainfalls of high $R_w$ on the formation of larger quantities of solid runoff. The fallow land of northern exposure appeared to be most susceptible to erosion (plot 2). The amount of solid runoff was more than 50,000 t/ha for the most intense and high quantity rainfalls (Fig. 1B, 1D, 1F). The small and similar quantities of eroded soil, regardless of the rainfall quantity for plots 4, 5 and 7 as compared to plots 1, 2 and 6, lead to manifestation of statistically significant Plot$\times$Q interaction. The fallow land of southern exposure (plot 1) showed steeper increase in the quantity of the solid runoff with the increase of the precipitation index $R_w$ than the tobacco field (Fig. 1F) and the amount of the eroded soil was quite invariable for the oak stand regardless of the $R_w$ index. These events have probably resulted in the manifestation of statistically significant Plot$\times$ $R_w$ interaction.

The highest amount of solid runoff (eroded soil) was recorded for the open lands (the fallow land and the tobacco field), which is largely due to the soil operations involving the use of heavy machinery and ploughing techniques, which have a direct effect on soil losses, essentially increasing them (Nunes et al., 2011). The pronounced dry periods in July, August and September recorded during the last 11 years, followed by the season of the most intensive rainfalls, specific to the region, additionally increased the soil vulnerability and reinforced the soil loss processes. Almost the entire annual amount of the eroded soil (10-70 t/ha) is caused by 3 to 5 rainfalls. These are precipitations of quantity higher than 10 mm and of maximum 30-min intensity ($I_{30}$) exceeding sometimes 50-70 mm/h. They belong to the second and the third group, in regard with the precipitation factor $R_w$ since its value in these cases exceeds 9.86. Amount of eroded soil from the fallow land of more than 100 t/ha was recorded in two cases only. Similar results about the number of the precipitations, which cause most of the annual solid runoff, were reported also by González-Hidalgo et al. (2007). They found that soil erosion in Western Mediterranean areas depends on a few daily events – over 50% of soil eroded annually belongs to just three daily erosion events. The most severe soil erosion is triggered by intense rainfall and the percentage of precipitations that produce the greatest erosion is very low (López-Vicente et al., 2008).

The difference in the eroded soil between the fallow land (plot 1) (averages 11.583, 10.326 and 11.359 t/ha, respectively) and the tobacco field (plot 6) (averages 11.913, 12.047 and 12.717 t/ha, respectively) is minor (Fig. 1B, 1D, 1F), which is due to the same soil erodibility characteristics (Velizarova et al., 2010), but the eroded soil at the fallow land on northern slope (plot 2) is significantly greater which most probably reflects the influence of the slope gradient.

The oak stands, although exposed to branch-cutting and being much less dense, prevent the formation of large quantities of runoff and eroded soil, because of the dense grass cover formed under the oak canopy, which increases organic matter and reduces soil erodibility to 'moderate' (Velizarova et al., 2010). The insignificant amount of eroded soil from them showed that the processes taking place there are closer to the natural ones, rather than to those influenced by the human interference. Few studies of the erosion on steep slopes under forest have been conducted and the soil losses measured annually
Table 4. Influence of the rainfall quantity $Q$ and the Plot type on the water runoff and eroded soil.

<table>
<thead>
<tr>
<th>Dependent variable Factor$^1$</th>
<th>Water runoff</th>
<th>Eroded soil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sum of squares</td>
<td>Degrees of freedom$^2$</td>
</tr>
<tr>
<td>Plot type</td>
<td>391443.36</td>
<td>2.72</td>
</tr>
<tr>
<td>Plot type $\times$ Q</td>
<td>62447.12</td>
<td>2.72</td>
</tr>
<tr>
<td>Error</td>
<td>525587.31</td>
<td>261.35</td>
</tr>
</tbody>
</table>

Tests of within-subject effects

Tests of between-subject effects

| $Q$                           | 124759.33     | 1            | 124759.33   | 34.14***                  | 439730.85     | 1             | 439730.85    | 9.82**          |
| Error                         | 350864.19     | 96           | 3654.84     |                           | 4254320.59    | 95            | 44782.21     |                        |

$^1$ Annotations of the factors are as defined in the text
$^2$ The degrees of freedom are recalculated according to the Greenhouse-Geisser correction for violation of the sphericity assumption.
$^3$ Significance level: *** – $P<0.001$; ** – $P<0.01$
Table 5. Influence of the precipitation index $R_2$ and the Plot type on the water runoff and eroded soil.

<table>
<thead>
<tr>
<th>Dependent variable Factor$^1$</th>
<th>Water runoff</th>
<th>Eroded soil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sum of squires</td>
<td>Degrees of freedom$^2$</td>
</tr>
<tr>
<td>Plot type</td>
<td>170115.25</td>
<td>1.877</td>
</tr>
<tr>
<td>Plot type $\times R_2$</td>
<td>29378.14</td>
<td>3.753</td>
</tr>
<tr>
<td>Error</td>
<td>232103.20</td>
<td>121.978</td>
</tr>
</tbody>
</table>

Tests of within-subject effects

| $R_2$                         | 25688.17     | 2           | 12844.08    | 3.77*         | 185677.17    | 2             | 92838.58    | 4.00*   |
| Error                         | 221353.19    | 65          | 3405.43     |              | 1486861.08   | 64            | 23232.20    |         |

Tests of between-subject effects

$^1$Annotations of the factors are as defined in the text

$^2$The degrees of freedom are recalculated according to the Greenhouse-Geisser correction for violation of the sphericity assumption.

$^3$Significance level: *** – $P<0.001$; ** – $P<0.01$; * – $P<0.05$; ns – $P>0.05$
Table 6. Influence of the precipitation index $R_w$ and the Plot type on the water runoff and eroded soil.

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Water runoff</th>
<th>Eroded soil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sum of squares</td>
<td>Degrees of freedom</td>
</tr>
<tr>
<td>Plot type</td>
<td>270954.29</td>
<td>2.44</td>
</tr>
<tr>
<td>Plot type $\times$ $R_w$</td>
<td>59642.37</td>
<td>2.44</td>
</tr>
<tr>
<td>Error</td>
<td>187532.71</td>
<td>156.30</td>
</tr>
</tbody>
</table>

Tests of within-subject effects

Tests of between-subject effects

$R_w$ | 101068.49 | 1 | 101068.49 | 43.74*** | 539928.80 | 1 | 539928.80 | 25.06*** |

Error | 147886.54 | 64 | 2310.73 | 1357382.57 | 63 | 21545.76 |

1. Annotations of the factors are as defined in the text
2. The degrees of freedom are recalculated according to the Greenhouse-Geisser correction for violation of the sphericity assumption.
3. Significance level: *** – P<0.001.
usually do not exceed 1 t/ha (Morgan, Rickson, 1995). Mandev (1995) found for the area of the present study that on northern slope the annual amount of the eroded soil is 76.0 t/ha for fallow land, up to 1.17 t/ha for glade, 0.195 t/ha for the oak forests, managed through branch-cutting. On southern slope the annual amount of the solid runoff attains values of up to 123.5 t/ha (average 75.0) for the fallow land and the tobacco field and up to 37.0 t/ha (average 6.0) for the pasture.

Statistically significant interactions between the investigated rainfall characteristics and the land use type were distinguished for both types of runoff in almost all cases. This specificity in the rainfall influence implies the presence of critical thresholds of the studied precipitation parameters, which differ according to the land cover of the exposed soil.

Our results showed that the rainfall quantity $Q$ and especially the precipitation index $R_W$, can be used with high reliability in evaluation of the precipitation influence on the runoff of the studied region and their advantages are better distinguished in the study of the solid runoff. These characteristics can be used to model the hydrological processes of the studied land use types, because of the specificity of their influence distinguished through the highly significant Plot type×$Q$ and Plot type×$R_W$ interactions.

Table 7. Correlations between the water runoff and the eroded soil

<table>
<thead>
<tr>
<th></th>
<th>Plot 1</th>
<th>Plot 2</th>
<th>Plot 3</th>
<th>Plot 4</th>
<th>Plot 5</th>
<th>Plot 6</th>
<th>Plot 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pearson correlation coefficient</td>
<td>0.854</td>
<td>0.346</td>
<td>0.378</td>
<td>0.607</td>
<td>0.810</td>
<td>0.464</td>
<td>0.248</td>
</tr>
<tr>
<td>Significance of the correlation</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.011</td>
</tr>
<tr>
<td>Number of cases</td>
<td>104</td>
<td>104</td>
<td>104</td>
<td>103</td>
<td>104</td>
<td>103</td>
<td>104</td>
</tr>
</tbody>
</table>
Correlations between the water runoff and the amount of the eroded soil

Positive and significant correlations were established between the water runoff and the eroded soil (Table 7). The correlations showed general tendency of decreasing with the increase of the plant cover and had lowest value (under 0.30) for the oak forests, managed through branch-cutting.

CONCLUSIONS

The largest amount of water runoff and eroded soil was determined from the fallow lands and the tobacco field and the lowest values – for the grass covered plots and in the oak stand. Significant influence of the precipitations on the amounts of the runoff and the eroded soil has been established. The highest amounts of eroded soil (up to 54.43 t/ha) were recorded for the rainfalls of high $R_w$ index and the highest precipitation quantities caused up to 33.77 t/ha of eroded soil.

The results showed that the rainfall quantity $Q$ and especially the precipitation index $R_w$ can be used with high reliability in evaluation of the precipitation influence on the runoff of the studied region and their advantages are better distinguished in the study of the solid runoff. These characteristics can be used to model the hydrological processes and to control the erosion, because of the specificity of their influence according to the land use type, suggesting the existence of critical threshold values of these characteristics according to the land cover. The precipitation index $R_2$, on the other hand, showed less appropriate for the runoff investigation and classification, because more than 95% of its registered values caused comparable runoffs amounts.

Positive and significant correlations between the water runoff and the eroded soil with general downward tendency with the increase of the plant cover were established.

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