Field Determination of the Specific Input Characteristics to Calculate the Value of C Factor of Time-variable Crops for the Revised Universal Soil Loss Equation (RUSLE)

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Abstract: To determine specific characteristics necessary for the computation of the C factor in RUSLE for time-variable crops, measurements were carried out in fields with selected agricultural crops grown by conventional practices. Sloping plots on an experimental area in Třebsín locality and farm fields were used to measure surface runoff and soil loss by erosion in conditions of natural and simulated rainfall. Basic characteristics to compute the C factor were determined in the particular growth phases of selected crops – sunflower, flax, poppy and rape. Effective root mass, canopy cover and fall height of rain drops were measured.

Keywords: soil erosion by water; soil loss; RUSLE; time-variable characteristics of crops; effective root mass; canopy cover; fall height

The increasing damage caused by surface runoff and water erosion makes it necessary to use measures that would reduce such damage. The first step is to quantify the degree of the soil susceptibility to erosion and accordingly, to propose efficient conservation measures (Váška 1993). To determine the field soil loss, erosion equations that have been developed and intensively tested are used. In the USA, the universal soil loss Equation (USLE) was derived which employed the basic factors of soil erosion by water in the best way for the time being (Wischmeier & Smith 1965). In the course of practical applications of the equation, the particular factors were specified, mainly those that describe soil cultivation, climatic and topographic conditions. Some improvements were applied in the updated version USLE 2 (Wischmeier & Smith 1978). The basic structure of the universal equation was not changed, but the factor values were extended and the possibilities of C factor specification to describe the conservation effect of the canopy cover of soil were outlined. USLE was adapted to the conditions of the Czech Republic and the factor values were defined in greater detail (Janeček 1992, 2002). In 1985 it was decided in the USA to revise USLE on the basis of new research and applied soil conservation technologies. In 1997 the so called Revised Universal Soil Loss Equation – RUSLE was presented (Renard *et al.* 1991, 1997). Currently, we have tested the validity of this equation according to the results of field measurements including the complementation of the respective database by these results. These data are mainly the values of

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C factor that describes the effects of the canopy cover of soil on (decreasing) erosion.

C factor in RUSLE

C factor represents the conservation effect of vegetation. The RUSLE C factor is the ratio of soil loss by erosion in specific tillage conditions to soil loss from bare soil on the USLE unit plot. This factor indicates the effects of canopy covers on (decreasing) erosion and used field operation in relation to cover development (plant growth, height, and canopy cover), residues of preceding cover and tillage practices according to the frequency of rainstorms during the year.

The height and canopy cover of plants reduce the energy of raindrops impact on the soil surface. It influences the surface runoff and soil loss. In RUSLE the so called soil loss ratio (SLR) is computed: it is the ratio of the soil loss under actual conditions of conventional management to the soil loss under new soil-conservation management systems.

The SLR value is computed for each time period for which some parameters are constant (type of cover, type of field operation and effects of rainfall erosivity). The C factor can be computed for time invariant or time-varying conditions. The time-invariable option is used for pastures and meadows for which the conditions are nearly constant or the soil loss does not vary; average values of C factor are used in this case. The time-varying (inconstant) option is applied if the cover and soil properties affecting the soil losses by erosion vary either due to the change in soil tillage or due to the crop rotation. RUSLE considers 15-day periods and the C factor is computed for the whole rotation (Jakubíková 2004).

The soil loss ratio is computed from five multiplied subfactors (Renard *et al.* 1997):

$$SLR = PLU \times CC \times SC \times SR \times SM$$

where:
- SLR – soil loss ratio for the given conditions
- PLU – subfactor of prior land use
- CC – subfactor of canopy cover
- SC – subfactor of surface cover
- SR – subfactor of surface roughness
- SM – subfactor of soil moisture

Basic input data are effective root mass (RM), canopy cover (CC) and fall height (FH) of raindrops (for more detail, see Jakubíková & Váška 2005).

Effective root mass RM in the upper 10 cm of soil

This variable influences the value of PLU (prior land use subfactor). It varies over time in relation to the course of plant growth. Root mass values for common crops are given in the RUSLE program or the User's guide (SWCS 1995), for the other crops they can be computed from the Mg/Mc ratio, where Mg is the above-ground biomass of the given crop at maturity, and Mc is the mature above-ground biomass of the most similar core crop with characteristics given in the list of crop databases; to compute the root mass of another crop the value of the root mass of the main crop will be multiplied by this ratio. This procedure can be used only if the yield is in such a range that the ratio of residues to yield does not change.

Canopy cover of soil surface (coverage) CC

This subfactor represents the percentage of the soil surface covered by the canopy that intercepts raindrops but is not in direct contact with the soil surface. It varies over time in relation to the course of plant growth. CC values for common crops are given in databases of the respective crops or in the User's guide (SWCS 1995), for the other crops the values will be computed from the expression $(Mg/Mc)^{0.5}$ by which the CC value of the main crop will be multiplied to obtain the required value for another crop.

Fall height of raindrop FH

It is used to compute the canopy cover subfactor CC. It varies over time in relation to the plant growth. It is defined as the average path of the raindrop falling from the plant on which it was previously intercepted. A procedure of estimation of this variable is to determine it as the percentage of the total plant height (e.g. the fall height for maize was derived as ca 60% of the total height of the maize plant). Figure 1 shows the diagram for FH determination.

Computation of the fall height:

$$FH = 1/3\ (H_t - H_l) + H_l$$

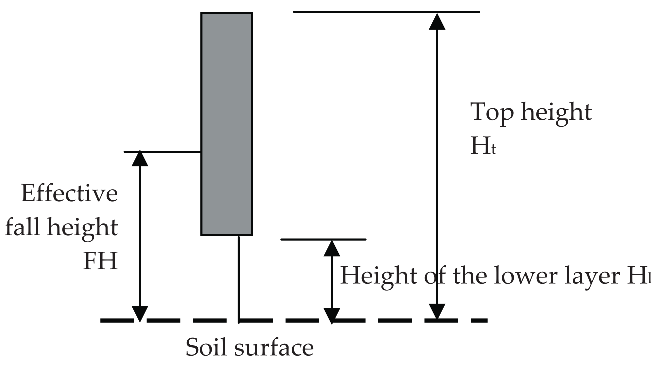

Figure 1. Determination of the fall height for the cylindrical shape of the plant body

MATERIAL AND METHODS

To measure the above characteristics of selected crops, sloping runoff plots located at Třebsín near Jílové (Prague-West district) were used. Flax, spring rape and sunflower were sown on these plots; additionally a plot with no cover was used for comparison. We measured and evaluated the effects of both – a natural rainfall of various depths and intensity that caused surface runoff, and a simulated rainfall produced with a portable field rainfall simulator.

We also measured the characteristics for poppy at Blaženice area (Benešov district), winter wheat and winter rape at Černičí area (Benešov district), by means of a rainfall simulator in field conditions. To locate the experimental areas see Figure 2.

Dates of measurements:

poppy: 9.4.–22.7.2004 (4× measurement of CC, 3× measurement of RM and FH),

flax: 14.4.–22.7.2004 (8× measurement of CC, 3× measurement of RM and FH),

spring rape: 14.4.–22.7.2004 (6× measurement of CC, 6× measurement of RM and FH),

sunflower: 14.4.–22.7.2004 (7× measurement of CC, 3× measurement of RM and FH),

winter wheat: 15.8.–20.10.2004 (3× measurement of CC, RM and FH),

winter rape: 15.8.–20.10.2004 (3× measurement of CC, RM and FH).

We measured the three most important input crop characteristics necessary to determine C factor, i.e. effective root mass, canopy cover and fall height of raindrop.

Effective root mass RM

Samples were taken following the RUSLE methodology, i.e. from the upper layer of soil to the depth of 10 cm and on a 10 × 10 cm area using a spade, in rows and in the inter-row space. The samples were dried in a laboratory at a temperature of 72°C for 24–48 hours, annealed, weighed, and the results were converted to kg/ha. Only the roots of diameter (d) less than 2 mm were considered.

Canopy cover CC of soil surface (coverage)

Evaluation was done using photographs that had been taken with a digital camera fixed on a steel stand at a constant height above the soil surface (1.5 m) while the 1 m^2 area was photographed. Measuring points were designated and measurements were carried out at the same points. A three-band color spectrum was used to evaluate the photos on the basis of the areas of the colors represented in the photo. The percentage of canopy cover was determined in this way.

Effective fall height FH of raindrop

This input variable was determined by measurements in the growth phases of plants, and their shapes given by the prevailing presence of leaves in the upper and lower parts of plants (Figure 1).

RESULTS AND DISCUSSION

The lowest values of root mass were determined for winter wheat – 20 g/m^2, and for flax – 66 g/m^2 (after 120 days of growth). It corresponds with the type of roots of this crop that are very fine, brittle and little branched. The root mass reached the highest values for sunflower – 267 g/m^2 (after 90 days of growth); its roots are very firm, strong and hardly decomposable, their structure is branched and their number is high (applies to $d \leq 2$ mm).

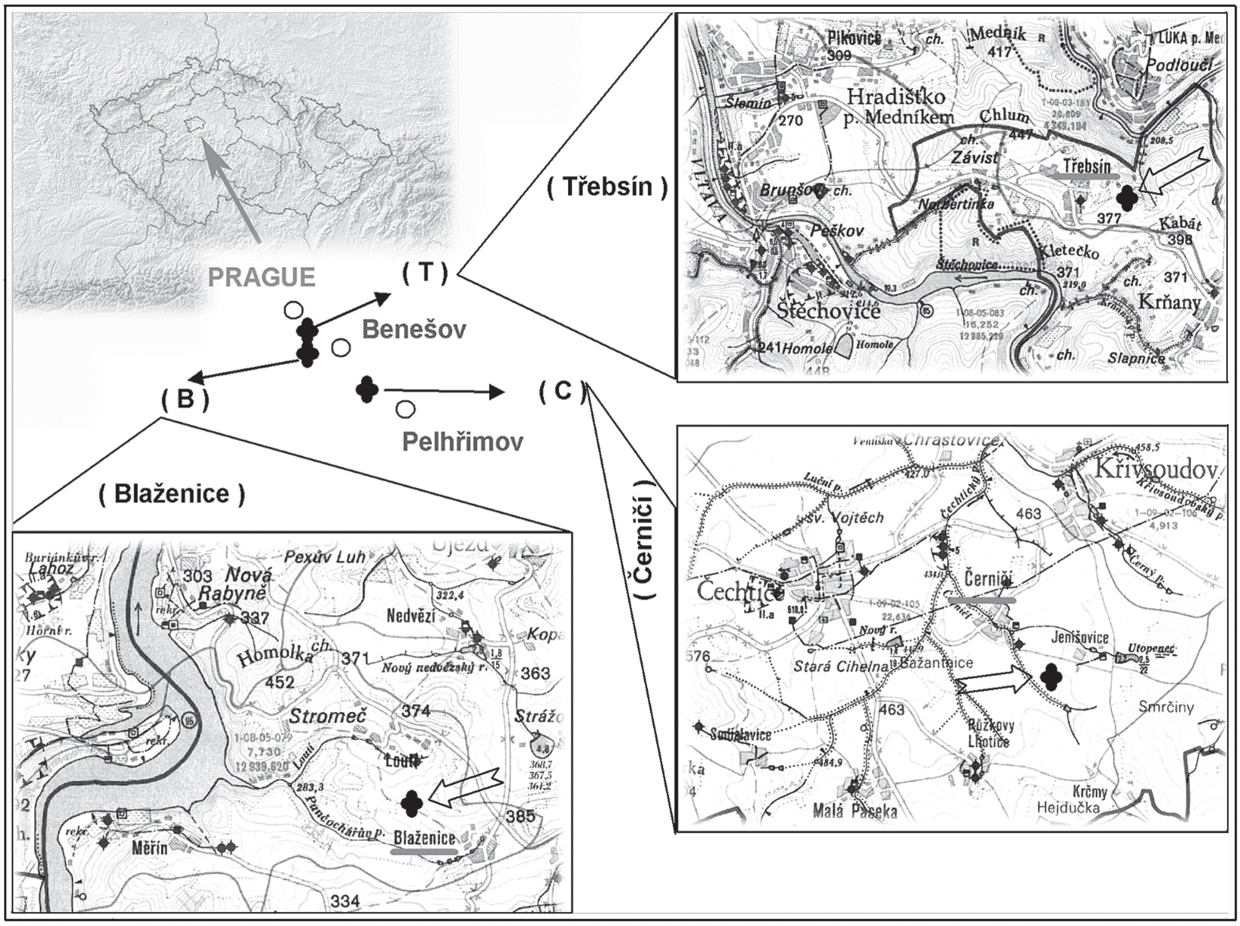

Figure 2. Experimental research areas at Třebsín (T), Blaženice (B), and Černičí (C)

The lowest values of an increase in canopy cover were found out for flax – 52% of cover (after 120 days of growth) while winter rape reached the highest CC values – 95% (after 75 days of growth before the winter season). It confirmed the high conservation effect of this crop on decreasing erosion. The high CC value – 85% was also found for poppy.

Table 1. Maximum values of RM, CC and FH[1]

	Crop/Time (day)					
	poppy/105	flax/120	spring rape/120	sunflower/90	winter wheat/75	winter rape/75
Variable	max.	max.	max.	max.	max.	max.
RM (g/m^2)	76	66	92	267	20	45
CC (%)	85.0	52.0	50.0	60.0	53.5	95.0
FH (m)	0.33	0.55	0.27	0.55	0.05	0.10

[1]Maximum values of the specific crop characteristics are related to the end of 2004 (e.g. the date for the end of the second part of the project QF 3089). The research will continue in 2005, when the higher values of CC, RM a FH are expected, first of all for winter wheat and rape (these crops reaching the final cover circa in April/May). The results of experimental measurement obtained during the 2005 will be presented in the final report concerning the third part of the project QF 3089 in February 2006

Table 2. The values of surface runoff and soil loss for flax and comparison with bare soil

Date	Day	CC (%)	RM (kg/ha)	FH (cm)	Rainfall depth (mm)	Average rainfall intensity (mm/h)	5-day total (IPS) (mm)	Surface runoff (mm)	Soil loss (kg/ha)
Rainfall simulator									
8.6.	55	33	635	21	17.0	51.6	11.9	0.03	1.0
29.6.	76	39	815	31	17.3	51.6	0.2	0.25	2.0
Natural rainfalls									
21.6.	68	37	695	28	13.0	12.3	14.1	0.00	0.0
23.6.	70	37	725	29	5.5	16.5	25.7	0.00	0.0
8.7.	85	43	944	36	21.0	11.6	5.8	0.43	0.1
Bare soil (natural rainfall)									
21.6.	–	–	–	–	13.0	12.3	14.1	0.73	644
23.6.	–	–	–	–	5.5	16.5	25.7	1.61	1 165
8.7.	–	–	–	–	21.0	11.6	5.8	7.60	46 860

The lowest values of the fall height of raindrops were recorded for poppy – 0.33 m (after 105 days of growth). It is in agreement with the leaf position for this crop because leaves are placed mainly in the lower part of the plant. As expected, sunflower showed the highest FH values – 0.57 m (after 75 days of growth). It corresponds with the height of the plant and with the balanced position of leaves along the vertical axis which is suitable for interception of the falling raindrops. Table 1 presents the maximum values of measured characteristics for selected crops.

The evaluation of natural rainfalls and rainfall simulator data confirmed the highest conservation effect for flax among the tested crops. Natural rainfall caused only a small surface runoff in the case of high rainfall depth (21 mm), and the soil loss was also negligible. Similar results were obtained for measurements with the rainfall simulator when the surface runoff and soil loss were insignificant at relatively high rainfall intensity (1.8 mm/min). The highest surface runoff was measured for sunflower plots; compared to flax it was up to ten times higher. Measurements with the rainfall simulator showed a larger difference in soil loss, almost 300 times higher. Spring rape is a suitable crop for soil protection, because the measured values of surface runoff and soil loss were only slightly higher than for flax. Bare soil, i.e. the soil surface totally unprotected with canopy cover, is presented for the purposes of comparison (see Part 2 of Tables 2–4).

Based on the measured values and their evaluation, the highest RM and FH values were obtained for sunflower. However, from the point of view of reducing erosion, the most important parameter of canopy cover is rather low for this crop (60%). It was also documented by the values of surface runoff and soil loss. Winter rape has the capacity of almost 100% cover of the surface and shows

Table 3. The values of surface runoff and soil loss for spring

Date	Day	CC (%)	RM (kg/ha)	FH (cm)	Rainfall depth (mm)	Average rainfall intensity (mm/h)	5-day total (IPS) (mm)	Surface runoff (mm)	Soil loss (kg/ha)
Rainfall simulator									
8.6.	20	33	635	21.0	17.0	51.6	11.9	0.03	1.0
29.6.	76	35	815	31.0	17.3	51.6	0.2	0.25	2.0
Natural rainfalls									
21.6.	68	33	1250	8.6	13.0	12.3	14.1	0.00	0.0
23.6.	70	33	1279	8.9	5.5	16.5	25.7	0.00	0.0
8.7.	85	39	1476	13.4	21.0	11.6	5.8	0.55	5.3

Table 4. The values of surface runoff and soil loss for sunflower, for comparison with the bare soil see Table 2

Date	Day	CC (%)	RM (kg/ha)	FH (cm)	Rainfall depth (mm)	Average rainfall intensity (mm/h)	5-day total (IPS) (mm)	Surface runoff (mm)	Soil loss (kg/ha)
Rainfall simulator									
8.6.	41	25	260	15	18.50	54.0	11.9	3.10	395
29.6.	62	43	1300	42	17.25	51.6	0.2	3.33	284
Natural rainfalls									
21.6.	54	35	875	32	13.00	12.3	14.1	0.28	12
23.6.	56	36	975	35	5.50	16.5	25.7	0.40	16
8.7.	71	51	1840	45	21.00	11.6	5.8	2.37	86

very good soil conservation effect in the growth phase. Poppy is also a crop with very positive conservation effects, because the values of all three parameters are quite high.

CONCLUSION

The field measurements provided partial results that are input values for the computation of C factor in the RUSLE model. The results were obtained in the initial phase of testing the procedure of computation of erosion risk using this equation for selected crops grown by conventional field operation. The data will be applicable for the creation of database files allowing the RUSLE extension for conditions of this country.

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