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NEGATIVE IMPACTS OF SNOW MELTING ON THE SOIL

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Abstract

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Intensity of snowmelt erosion was computed for cadastral areas of Pohořelice, Strážnice, Kuchařovice, Holešov, Dukovany, Vizovice, Velké Meziříčí and Bystřice nad Pernštejnem on the base of 1980–2006 data for the period November to March. Mean long-term soil loss was estimated according to ZACHAR (1981) equation on the base of average rate of snowmelting, amount of melting water, outflow and infiltration characteristics, topographical factor, soil factor and vegetation factor. For the studied localities the average rate of snowmelting varied from 2.29 $mm.day^{-1}$ to 7.90 $mm.day^{-1}$. Also amount of melting water reached the maximum in Bystřice nad Pernštejnem in dependence on climatic region (6.11 cm of water column). Outflow and infiltration characteristics varied from 0.94 to 1.14. High value of topographical factor (10.5) was assessed in Vizovice. Soil factor was estimated according to main soil unit from Estimated Pedologic-Ecological Unit EPEU. Its values varied from 0.31 in Velké Meziříčí to 0.47 in Holešov. Vegetation factor varied from 0.2938 in Vizovice to 0.4881 in Kuchařovice. Average soil loss as a consequence of snow melting varied in interval from 0.61 $t.ha^{-1}.year^{-1}$ in Pohořelice to 30.08 $t.ha^{-1}.year^{-1}$ in Vizovice.

erosion, snow melting, soil loss

The melting of snow cover can bring several negative impacts to the environment. When sudden thawing occurs it can trigger flood accompanied by soil erosion losses. Main feature of snowmelt erosion is freezing of surface soil layer in winter. The water is extracted from the soil aggregates and forming small ice crystals around them, which destroy soil aggregates. Simultaneously the water from lower horizons rises into freezing zone. So when the thaws comes a mass of fine soil particles is released. Freezing of soil causes also reduction of snow water infiltration to the deeper soil layers. Soil thawing starting from the surface, relatively intensive erosion begins even thought the first amount of thawing snow is small. In addition to this the protecting effect of vegetation in the spring is poor, arable soils are often completely bare or cover by small plants of winter crops.

The selective effect of flowing water depends mainly on mechanical texture of eroded soil. Data of melt-water erosion losses show that the losses increase with soil permeability.

The importance of snow water erosion may be judged by analyzing bed load floe at various times of year. As the illustration of conditions in central Europe, average monthly flows of bed load in rivers of Slovakia presents Tab. I. In all chosen rivers the maximum of discharge of bed loam is reached in spring period (March, April) probably as a consequence of snow melting. Average seasonal maximum of water content of snow (processed for period 1961–2000) is represented in Fig. 1.

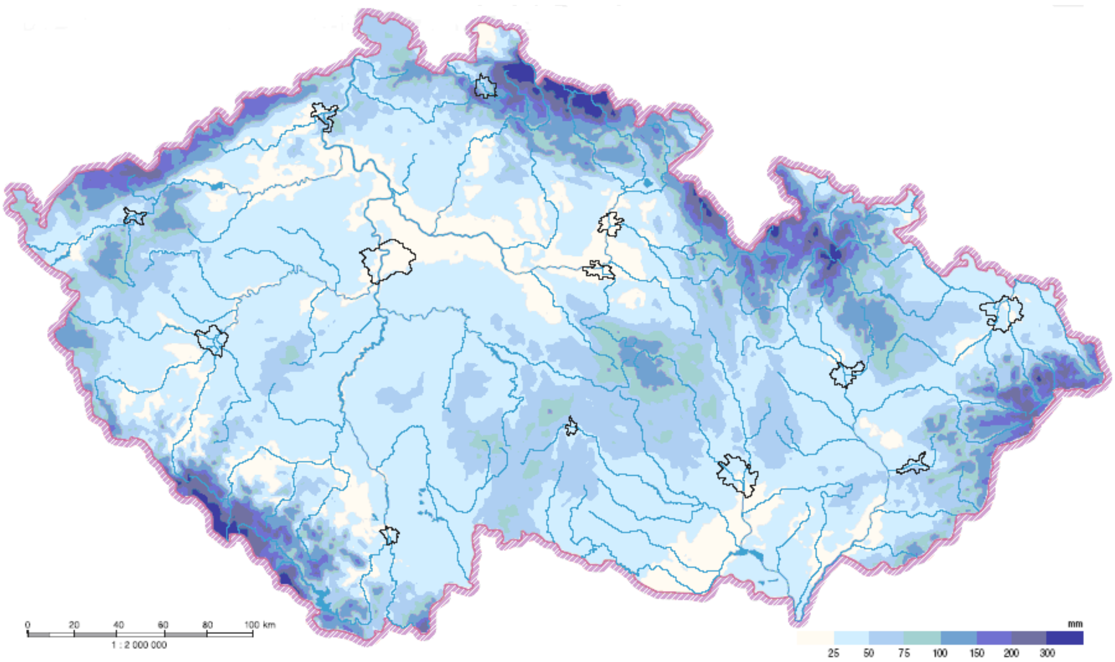
This meant the risk of extensive flood coming, because in March the probability of a sudden and quick warming increases. Such warming can be stronger than in winter and may also be accompanied by more plentiful rainfall with the subsequent quick melting of snow cover. Supported by rainfall, the snowmelt caused a considerable rise of water stream level (Annual Report of Czech Hydrometeorological Instuitut, 2006).

MATERIAL AND METHODS

Snowmelt erosion plays an important role in many areas of The Czech Republic (CZ). Mean long-term soil loss was estimated according to ZACHAR (1981)

I: *Mean monthly discharge of bed loam in various rivers (kg.s⁻¹) (ZACHAR, 1981)*

Month	River						
	Dunaj	Morava	Nitra	Váh	Hron	Laborec	Uh
January	46.14	2.19	2.10	4.54	2.22	3.47	7.74
February	189.57	3.92	4.68	17.80	20.18	22.25	15.35
March	395.67	5.51	7.16	51.60	42.85	13.63	13.90
April	212.02	5.86	7.46	68.45	20.92	14.75	24.68
May	272.14	3.36	1.60	18.45	8.55	7.45	12.95
June	398.78	1.71	0.57	18.55	4.20	3.33	8.42
July	734.92	7.15	2.65	60.80	7.59	1.37	5.54
August	288.38	2.14	1.16	12.95	8.48	1.24	2.33
September	86.00	0.80	0.29	3.17	1.48	1.29	3.12
October	82.75	1.41	0.44	5.32	2.55	2.95	3.99
November	29.43	0.65	0.29	4.15	0.67	2.08	2.87
December	79.77	1.88	1.83	28.80	6.97	11.75	24.21



1: *Average seasonal maximum of water content of the snow cover (Climate Atlas of Czechia, 2007)*

equation. On the base of CHMI (Czech hydrometeorological institute), CSO (Czech Statistical Office) and RIASC (Research Institute of Amelioration and Soil Conservation) data the input factors for computing were assessed. South Moravia localities with different climatic condition (characteristic by climatic region by EPEU – Estimated Pedologic-Ecological Unit) were chosen for quantification of erosion manifestation during pre-spring period.

Intensity of snowmelt erosion was computed for cadastral areas of Pohořelice, Strážnice, Kuchařovice, Holešov, Dukovany, Vizovice, Velké Meziříčí and Bystřice nad Pernštejnem on the base of 1980–2006 data for the period November to March. For this period the consistence database of inputs required for intensity of soil erosion assessment was available. Input data for assessing were following: mean snowmelt rate, mean amount of water arise from thawing, infiltration and outflow characteristics, factor of soil erosivity, topographical factor and factor of vegetation protection. All factors are related to non–vegetation period (November 1st to March 30th). Each area lies in different climatological region (according to EPEU) and in various production regions (see Tab. II and Fig. 2).

II: *Characteristics of chosen climatological stations*

Climatological station	Altitude m a.s.l.	Latitude	Longtitude	Climatic region	Production region
Pohořelice	183	48° 58´ 39´´	16° 31´ 00´´	0	Maize
Strážnice	176	48° 53´ 57´´	17° 20´ 17´´	0 and 3	Maize
Kuchařovice	334	48° 53´ 00´´	16° 05´ 00´´	2	Maize
Holešov	223	49° 19´ 07´´	17° 34´ 24´´	3	Sugar beet
Dukovany	400	49° 05´ 45´´	16° 08´ 04´´	4	Cereal
Vizovice	315	49° 13´ 23´´	17° 50´ 38´´	6 and 7	Forage
Velké Meziříčí	452	49° 21´ 14´´	16° 00´ 33´´	7	Potato
Bystřice n. Pern.	573	49° 30´ 54´´	16° 15´ 00´´	7 and 8	Potato

2: *Chosen climatological stations of CHMI network*

Snowmelt erosion intensity was computed from the empirical formula ZACHAR (1981).

$$Es = m . h . k . FZ . LS . C . K, \quad (1)$$

where:

Es – the intensity of soil erosion (t.ha^{-1}.year^{-1})
m – the rate of snow-thawing (mm.day^{-1}) in the 20–day period when the most intensive thawing take a place
h – amount of water derived from snow during thawing period (cm)
k – runoff coefficient for soil saturated by water
FZ – factor of frozen soil (number between 1.5 and 3)
LS – topographical factor (L – factor of slope length, S – slope factor)
C – vegetation factor
K – soil factor.

Amount of water derived from snow during thawing period (h) was assessed on the base of (SWC) snow-water content data of CHMI. Snow-water content of total snow cover represents amount of water contained in snow cover rising from its melting. SWC has been determined in mm of water column.

Rate of snow-thawing (m) has been assess as water amount in cm of water column derived from snow during thawing period (h) divided by number of melting days multiply by 10 (recount from cm of water column to mm per day).

Runoff coefficient (k) and Factor of frozen soil (FZ): for the period of snow melting (soil is saturated by water) the runoff coefficient is equal to 0.5. Factor of frozen soil depends on soil freezing stage regarding to limited infiltration and susceptibility to erosion during thawing period. For non-frozen soil FZ is 1.5, for total frozen soil is 2 and for stage when non-frozen layer is founded above frozen layer the FZ is 3. Determination of frozen soil factor is just approximate and in the case of missing data of soil freezing is possible to use average value 2.

Topographical factor (LS) expresses influence of slope and its length on erosion. Value of slope factor (S) and factor of slope length (L) were computed by formula:

$$LS = ld0,5\ (0,0138 + 0,0097s + 0,00138s2), \quad (2)$$

where:
ld– unimpeded slope length (m)
s – slope (%).

Average value of unimpeded slope length for area of CZ is 250 m. Slope (s %) was assessed on the base of EPEU (fourth position of number code represents combination of slope and exposition).

Soil factor (K) depends on soil grain content, content of organic matter, soil structure and its permeability. Those futures influence the soil infiltration capability, soil resistance against erosion, incidence of rain drops and surface runoff. For estimation of melting-water erosion intensity the K factor was established on the base on EPEUs – MPUs (Main Pedological Units – second and third position of number code) and their areas by weighted average method.

Vegetation factor (C) means vegetation influence on soil. For snowmelt erosion risk assessment the data of CSO were used. It means the information of agriculture soil fund average single crop area in single districts of Moravia and Silesia in which the chosen cadastral areas is included (Pohořelice – district Břeclav, Kuchařovice – district Znojmo, Strážnice – district Hodonín, Holešov – district Kroměříž, Dukovany – district Třebíč, Vizovice – district Zlín, Velké Meziříčí a Bystřice nad Pernštejnem – district Žďár nad Sázavou). For estimating of C factor in non-vegetation period the influence of rainstorm was not included. C factor of single crops was assessed according to five planting periods (based on phenological phases).

RESULTS

Average amount of melting-water varies from 14.2 mm (Kuchařovice) to 61.1 mm (Bystřice nad Pernštejnem). Average melting time varies from 6.12 days (Kuchařovice) to 10.12 days (Velké Meziříčí). Maximal rate of snow thawing (7.9 mm.day^{-1}) was determined in Bystřice nad Pernštejnem and minimal (2.29 mm.day^{-1}) in Pohořelice. Amount of melting-water consist in climatological conditions of area. Duration of melting is given by weather course (accession of plus temperatures eventually precipitation occurrence).

Runoff coefficient (k) multipled by Factor of frozen soil (FZ) varies from 0.94 (Kuchařovice) to 1.14 (Velké Meziříčí). Range of this parameter is not so significant and is influenced by temperature character of winters and by soil characteristics.

Estimation of Topographical factor LS is just approximate, because it does not involve different slope lengths. High value of LS factor 10.05 was found out for Vizovice. This area lies in Vizovice highlands and its mean slope is 16.2%. Minimal value was assessed for Pohořelice – plain area with mean slope 2.7%. LS factor is constant during a whole year.

Range of Soil factor (K) results is in comparison with other factor very narrow, varies from 0.31 (Velké Meziříčí) to 0.48 (Vizovice). K factor is not directly influenced by climatological factors. Its value is constant for a whole year and is function of pedological characteristics entirely.

Vegetation factor (C) reached high value in areas of maize production region (Pohořelice, Strážnice, Kuchařovice) with planted crops maize, sugar beet, vegetable, orchards, grapevine etc. and low value in areas of potato and forage production region (Vizovice, Velké Meziříčí and Bystřice nad Pernštejnem) with planted of crops with high soil protective effect. C factor depends on climatic conditions, which determined suitable crops for planting. The value of C factor decreases with climatic region, but in overall overview the erosion intensity raises with climatic region.

High value of soil loss during non-vegetation period (36.08 t.ha^{-1}.year^{-1}) was assessed in Vizovice. Mean water amount rising from snow via melting is 39.3 mm. Melting rate was 6.82 mm.day^{-1}. Vizovice district had among the others judged localities high value of LS factor. It was given by high slope of the area (10.2%). Soil factor had a mean value 0.48. C factor was the lowest from all localities as a consequence of large area green lawn.

III: *Mean soil losses (Es) and values of single factors*

	M	h	k . FZ	LS	K	C	Es (t.ha^{-1}.year^{-1})
Pohořelice	2.29	1.62	1.09	0,80	0.39	0.4837	0.61
Strážnice	3.68	1.44	1.01	1.32	0.35	0.4478	1.11
Kuchařovice	3.68	1.42	0.94	1.53	0.43	0.4881	1.58
Holešov	3.19	1.94	0.96	0.99	0.47	0.4483	1.25
Dukovany	3.77	2.18	0.97	1.71	0.44	0.4164	2.50
Vizovice	6.82	3.93	0.95	10.05	0.48	0.2938	36.08
Velké Meziříčí	5.21	4.21	1.14	6.59	0.31	0.3277	16.73
Bystřice nad Pernštejnem	7.90	6.11	1.13	3.82	0.33	0.3277	22.55

Mean soil loss less than 1 $t.ha^{-1}.year^{-1}$ was assessed for cadastral area Pohořelice. In Strážnice, Kuchařovice and Holešov the soil loss was also relatively low (about 1 $t.ha^{-1}.year^{-1}$) Average amount of melting water did not reach 20 mm in any of those localities. Mean melting rate for Pohořelice was lower than 3 $mm.day^{-1}$, for Holešov was equal to 3,19 $mm.day^{-1}$, for Kuchařovice and Strážnice 3,68 $mm.day^{-1}$. LS factor for those localities varied from 0.80 (Pohořelice) to 1.53 (Kuchařovice). Planted crop was mainly maize, so C factor reached to high value.

DISCUSSION

Soil erosion as the consequence of snow melting has been researching in many northern European countries (Finland, Norway, north part of Poland and Germany). This phenomenon has been often mentioning also in publications of American and Canadian authors. Possibility of application of those results to Czech condition is limited, because of different climatic and natural conditions. Water erosion as a destructive element means relevant problem in the Canada. Widespread method of soil loss estimation in the USA and Canada as well as in central Europe conditions is Wischmeier and Smith equation (USLE).

$$A = Rt \cdot K \cdot L \cdot S \cdot C \cdot P, \quad (3)$$

where:
Rt – Raindrop R and snowmelt Rs erosivity ($MJ.mm.ha^{-1}.year^{-1}$).

Assessment of input parameters differs from assessment used in this paper. For instance snowmelt erosivity is based on methodology by Mc COOL (1982) modified for Alberta condition by TÁJEK *et al.* (1985). This methodology is based on assessment of water equivalent of average snow amount at the end of March. The assessment of snow amount is based on Atmospheric Environment Service data (TREIDL, 1981). Rs is possible to count by the use of formula:

$$Rs = f \cdot S \cdot D, \quad (4)$$

where:
S – average snow depth on 31st March (mm)
D – snow density ($g.cm^{-3}$)
f – 1,0 in the case of using metrical units.

Using this methodology for our climatic condition is impossible because the snow cover has not been occurring at the end of March there. In contradistinction to methodology used here does not include melting rate and freezing and outflow characteristics.

SOUHRN

Negativní dopady tání sněhu na půdu

Pro sledované lokality byly určeny průměrné rychlosti tání za období 1981–2006 v rozmezí 2,29 $mm.den^{-1}$ až 7,90 $mm.den^{-1}$. Rychlost tání sněhu se zvyšuje s rostoucí nadmořskou výškou, resp. klimatickým regionem. Nejnižší hodnoty dosahuje v Pohořelicích, nejvyšší v Bystřici nad Pernštejnem. Množství vody, které se uvolňuje ze sněhové pokrývky a průměrná rychlost tání dosahují v souladu s členěním do klimatických regionů a nadmořskou výškou maximálních hodnot v Bystřici nad Pernštejnem (6,11 cm vodního sloupce a 7,9 $mm.den^{-1}$). Na této lokalitě byla stanovena druhá nejvyšší hodnota intenzity eroze v předjarním období, 22,55 $t.ha^{-1}.rok^{-1}$. Nejnižší hodnoty množství tavné vody se vztahují k nejníže položeným lokalitám z klimatických regionů 0 až 3 (Pohořelice 1,62, Kuchařovice 1,44 a Strážnice 1,42 cm vodního sloupce). Hodnoty týkající se odtokových poměrů a infiltrační schopnosti půdy se na sledovaných lokalitách výrazně neliší a pohybují se v intervalu od 0,94 až 1,14. Není zde patrná žádná přímá souvislost s nadmořskou výškou ani klimatickými podmínkami. Tyto charakteristiky velmi úzce souvisejí s půdním klimatem a fyzikálními a chemickými vlastnostmi půd. Topografický faktor charakterizuje sklonitostní poměry daného území. Nejvyšší hodnoty (10,05) dosahuje v katastrálním území Vizovice. Ve srovnání s ostatními zájmovými lokalitami je tato hodnota podstatně vyšší. Hodnota LS vyšší než 5 byla kromě Vizovic stanovena pouze ve Velkém Meziříčí (6,59). Průměrná dlouhodobá ztráta půdy v důsledku tání sněhu se zvyšuje s rostoucí hodnotou topografického faktoru. Faktor erodovatelnosti půdy byl určen podle hlavní půdní jednotky dle BPEJ. Hodnoty K faktoru kolísají v rozmezí od 0,31 ve Velkém Meziříčí do 0,47 v Holešově. Obdobně jako odtokové a infiltrační charakteristiky (k.SZP) vykazuje tento faktor velmi malou variabilitu. Není možno vysledovat závislost mezi hodnotou K faktoru pro jednotlivé lokality a rostoucí intenzitou eroze. Průměrná dlouhodobá ztráta půdy erozí vodou z tajícího sněhu v mimovegetačním období na vybraných lokalitách dosahuje hodnot od 0,61 $t.ha^{-1}.rok^{-1}$ v Pohořelicích do 30,08 $t.ha^{-1}.rok^{-1}$ ve Vizovicích i přes to, že v okrese Zlín, kam toto území spadá, byl stanoven nejnižší faktor ochranného vlivu vegetace C (0,2938). Procentická výměra orné půdy je zde pouze 56,1 %, což je nejméně ze všech sledovaných okresů a zastoupení trvalých travních porostů je 36,4 %. Nejnižší intenzita eroze byla zjištěna na lokalitě Pohořelice, která je součástí okresu Břeclav (výměra orné půdy 81,4 %). Z uvedeného vyplývá, že faktor C nehraje při erozi z tání sněhu klíčovou úlohu.

eroze půdy, tání sněhu, ztráta půdy

SUMMARY

For the studied localities the average rate of snowmelting during the period 1980–2006 varied from 2.29 mm.day^{-1} to 7.90 mm.day^{-1}. Melting rate increases with altitude and climatic region. The slowest melting was found out for Pohořelice, the fastest for Bystřice nad Pernštejnem. Also amount of melting water reached the maximum in Bystřice nad Pernštejnem in dependence of climatic region (6.11 cm of water column). At this locality the second high value of non-vegetation erosion intensity (22.55 t.ha^{-1}.year^{-1}) was find out. The lowest amount of melting water relates to localities of lowest altitude belong to climatic region 0 to 3 (Pohořelice 1.62, Kuchařovice 1.44 and Strážnice 1.42 cm of water column).

Outflow and infiltration characteristics did not vary significantly. The range of the results was 0.94 to 1.14. There was not any direct connection with altitude and climatic conditions. Those characteristics related to soil climate and physical and chemical soil features closely.

LS factor characterizes topography of localities. High value (10.05) was assessed in Vizovice. In comparison with another judged localities this value was significantly higher. LS factor higher than 5 except Vizovice were assessed just for Velké Meziříčí (6.59).

Soil factor was estimated according to main soil unit from EPEU. K factor value varied from 0.31 in Velké Meziříčí to 0.47 in Holešov. Analogously to outflow and infiltration characteristics (k . FZ) the K factor was not so variable.

Vegetation factor varied from 0.2938 in Vizovice to 0.4881 in Kuchařovice.

Average soil loss as a consequence of snow melting varied in interval from 0.61 t.ha^{-1}.year^{-1} in Pohořelice to 30.08 t.ha^{-1}.year^{-1} in Vizovice.

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