The influence of the DEM resolution on the LS factor and SWAT estimates of soil erosion on the example of upland loess watershed in Poland.

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PRESENTATION PLAN

- Bystra catchment area
- Erosion
- RUSLE model
- LS factor
- Numeric Terrain Models (DEM) with a spatial resolution of 1 m, 5 m, 10 m, 30 m, 90 m.
- The difference in results between spatial resolution models.
- Conclusions

BYSTRA CATCHMENT

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Fig. 1. *Raster satellite image of Bystra catchment area (Google, 2017).*

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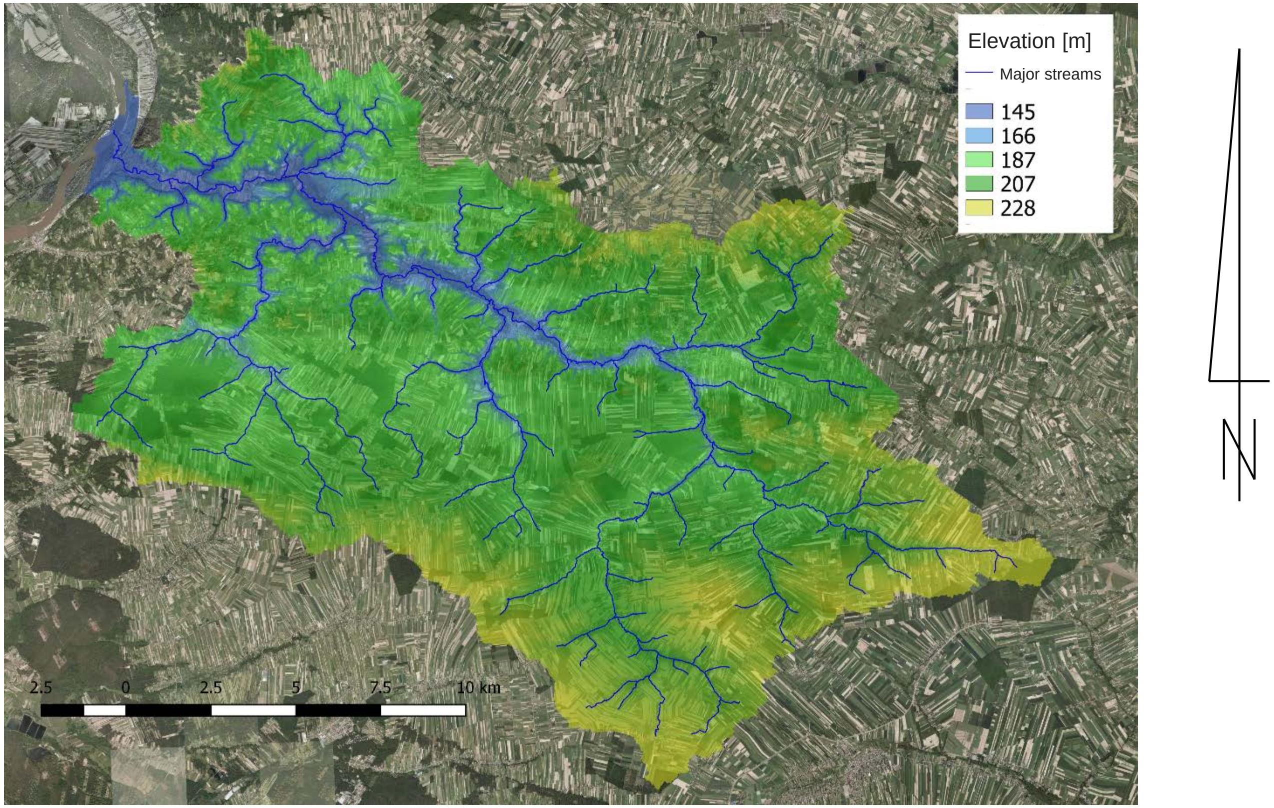

Fig. 2. *Bystra catchment.*

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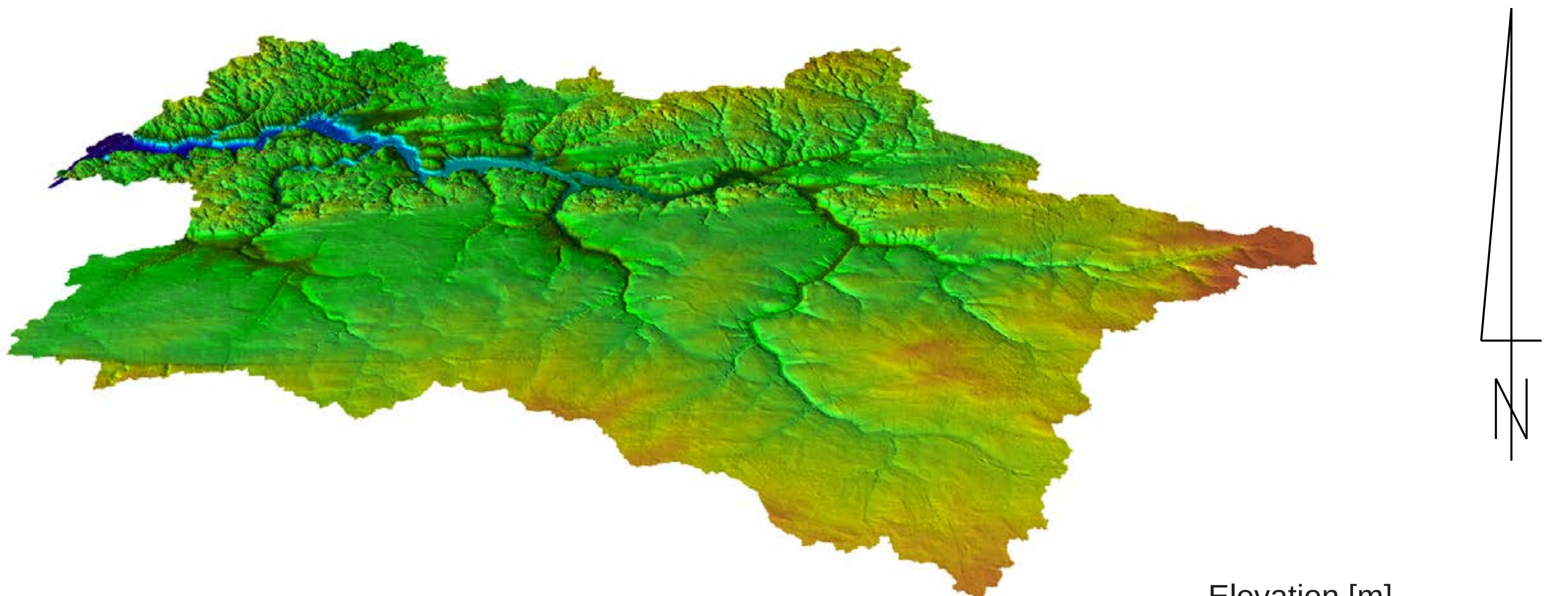
BYSTRA CATCHMENT



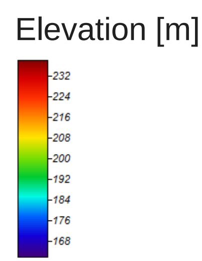


Fig. 3. *Bystra catchment– 3D image.*

SOIL EROSION

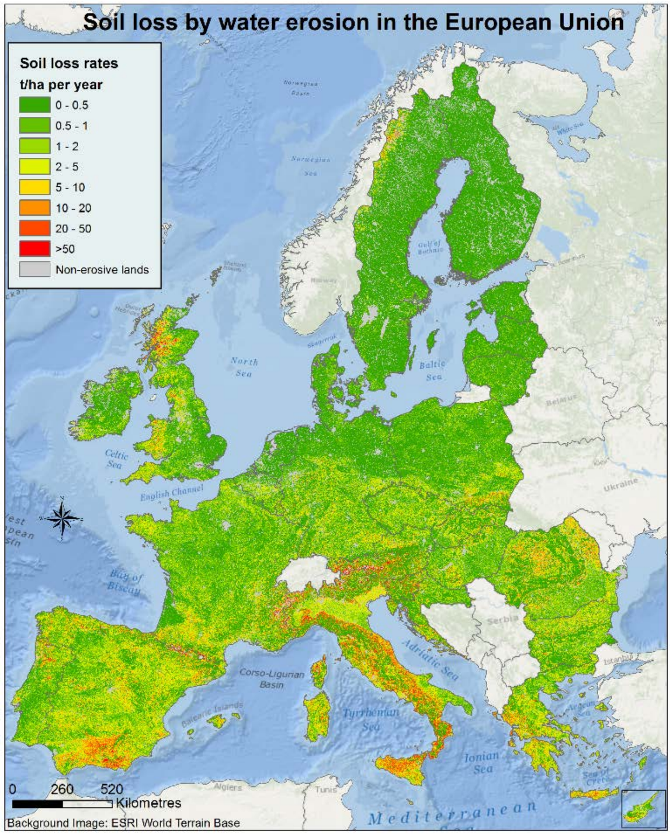


Fig. 4. *Map of soil loss rates in the European Union (Reference year: 2010) based on RUSLE2015 (Panagos, 2015).*

Table 1
Average soil loss rate (*E*-value) per country (all lands, arable lands), effect of Good Agricultural Environmental Condition (GAEC) practices, and share of EU soil loss.

Country		Overall Mean	Mean in arable lands	Mean in arable lands without GAEC	GAEC effect	% of the total soil loss in EU
		E ($t\ ha^{-1}\ yr^{-1}$) (%)				
AT	Austria	7.19	3.97	5.23	31.8	5.65%
BE	Belgium	1.22	2.06	2.71	31.8	0.30%
BG	Bulgaria	2.05	2.47	3.77	52.5	2.21%
CY	Cyprus	2.89	1.85	2.82	52.6	0.25%
CZ	Czech Republic	1.65	2.52	3.30	31.0	1.24%
DE	Germany	1.25	1.75	2.51	43.5	4.15%
DK	Denmark	0.50	0.61	0.68	11.4	0.20%
EE	Estonia	0.21	0.70	0.88	25.3	0.09%
ES	Spain	3.94	4.27	5.56	30.3	19.61%
FI	Finland	0.06	0.46	0.64	37.9	0.18%
FR	France	2.25	1.99	2.78	39.5	11.85%
GR	Greece	4.13	2.77	3.63	31.1	5.31%
HR	Croatia	3.16	1.67	1.80	7.5	1.74%
HU	Hungary	1.62	2.10	2.35	12.0	1.42%
IE	Ireland	0.96	1.32	1.52	15.7	0.55%
IT	Italy	8.46	8.38	9.80	16.9	24.13%
LT	Lithuania	0.52	0.95	1.02	7.5	0.32%
LU	Luxembourg	2.07	4.54	6.19	36.3	0.05%
LV	Latvia	0.32	1.01	1.11	10.1	0.20%
MT	Malta	6.02	15.93	18.72	17.5	0.01%
NL	Netherlands	0.27	0.54	0.68	24.7	0.08%
PL	Poland	0.96	1.61	1.79	11.2	2.92%
PT	Portugal	2.31	2.94	3.55	20.6	2.01%
RO	Romania	2.84	3.39	3.88	14.3	6.31%
SE	Sweden	0.41	1.12	1.31	16.6	1.57%
SI	Slovenia	7.43	4.63	5.33	15.0	1.49%
SK	Slovakia	2.18	3.54	4.09	15.6	1.03%
UK	United Kingdom	2.38	1.04	1.49	43.2	5.14%

Table 1. *Average soil loss rate (E-value) per country (all lands, arable lands), effect of Good Agricultural Environmental Condition (GAEC) practices, and share of EU soil loss.(Panagos, 2015).*

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Fig. 5. *Example of soil erosion in Bystra catchment.*

Fig. 6. *Example of soil erosion in Bystra catchment.*

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SOIL EROSION

Fig. 7. *Example of soil erosion in Bystra catchment area.*

Fig. 8. *Example of soil erosion in Bystra catchment area.*

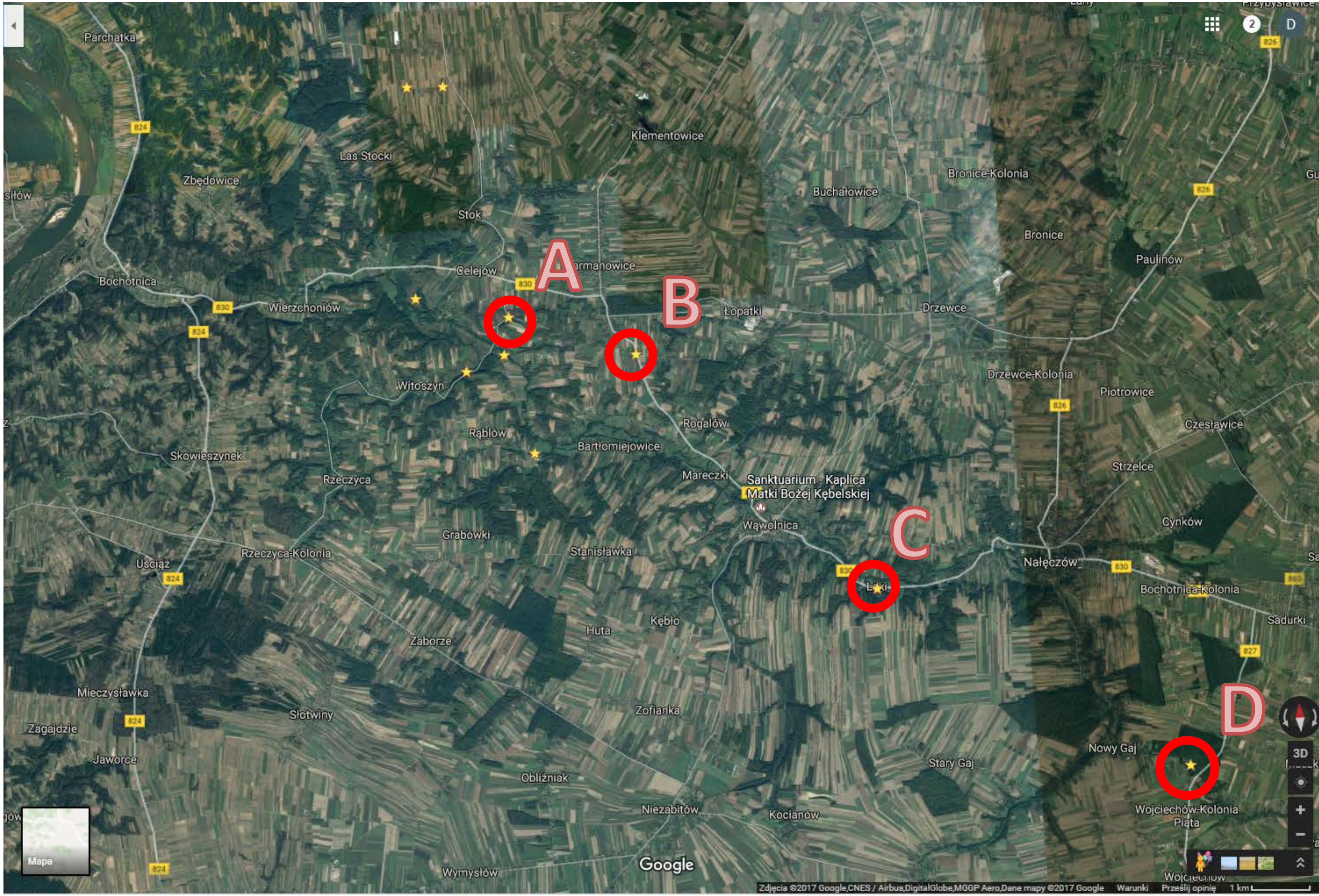

Fig. 9. *The place of photo location (Google, 2017).*

SOIL EROSION

Revised Universal Soil Loss Equation model computes average annual erosion from field slopes in tons/hectar per year (Renard, 1997)

$$A = R \cdot K \cdot LS \cdot C \cdot P$$

A = Computed Average Annual Soil Loss

R = Rainfall-Runoff Erosivity factor

K = Soil Erodibility Factor

L = Slope Length Factor

S = Slope Steepness Factor

C = Land Cover-Management Factor

P = Support Practice

LS FACTOR

$$L = \left(\frac{\lambda}{72.6\,ft.} \right)^m \text{ (Wischmeier \& Smith 1978)}$$

$$m = \frac{\beta}{(\beta + 1)} \quad where \quad \beta = \frac{\left(\frac{\sin\theta}{0.0896} \right)}{3.0 \times (\sin\theta)^{0.8} + 0.56}$$

$$S = \left(65.41 \times \sin^2\theta\right) + \left(4.56 \times \sin\theta\right) + 0.065$$

Formula 1. *Formula of LS factor (Wischmeier, 1978).*

LS FACTOR

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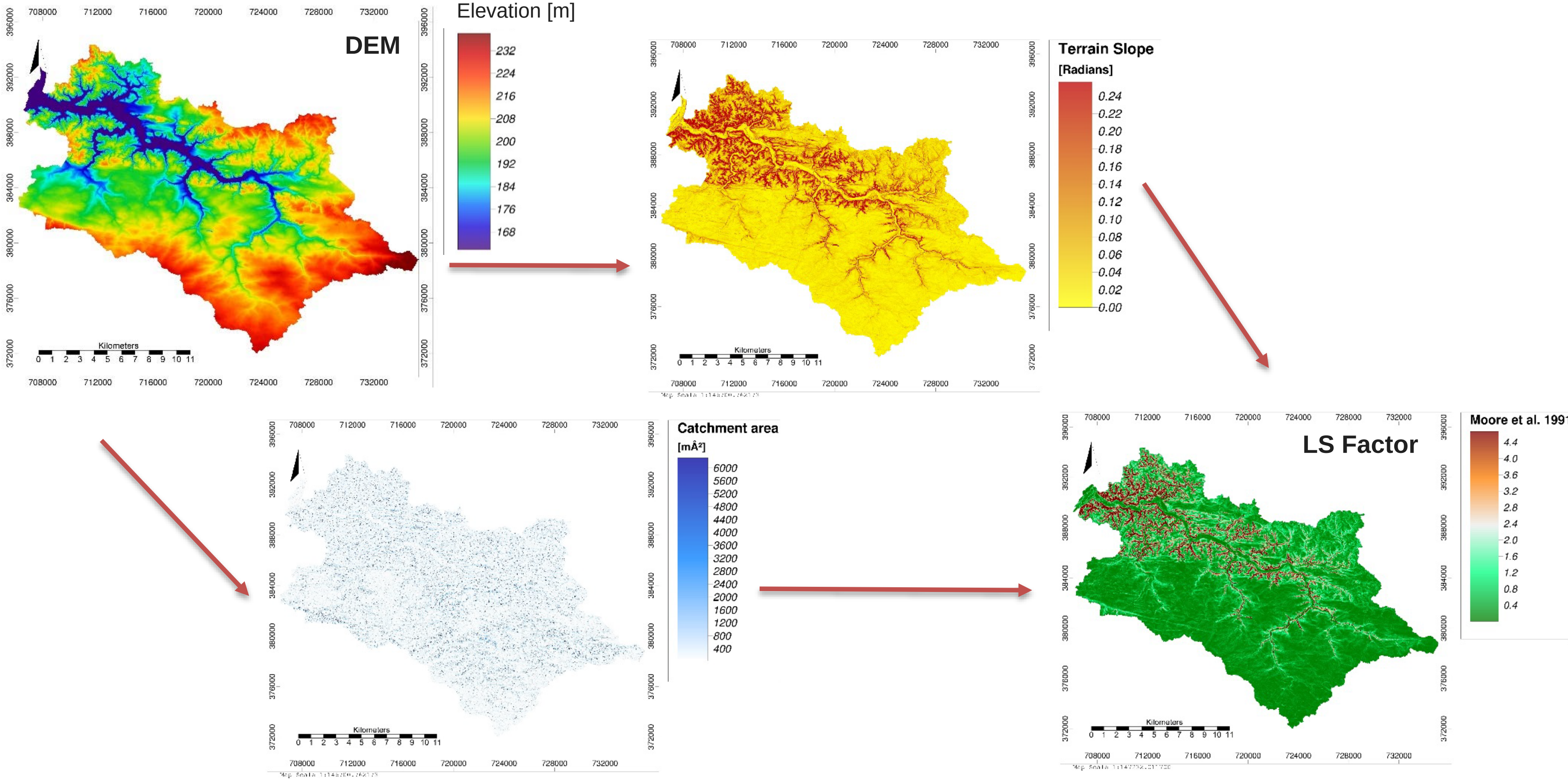

Fig. 11. *Creation LS factor step by step in SAGA GIS.*

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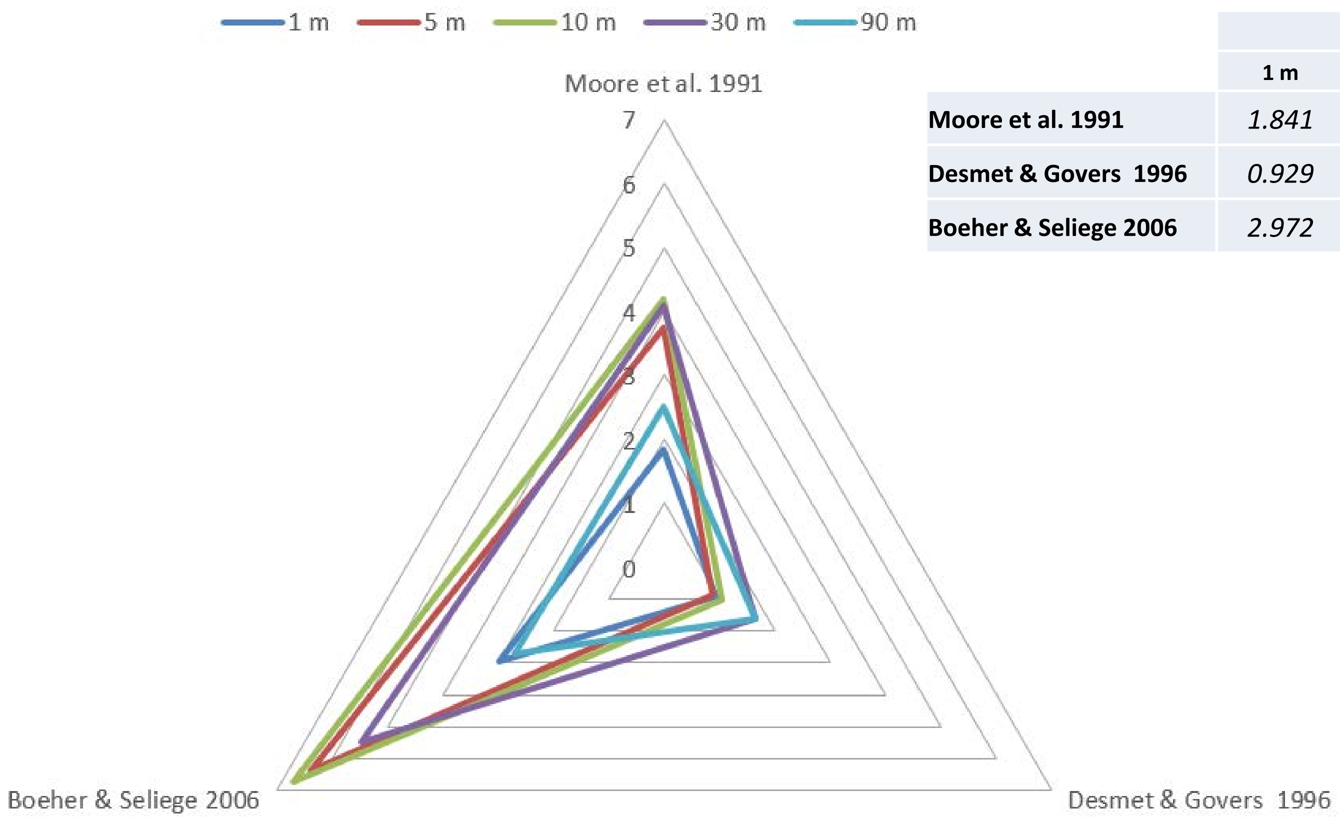
LS FACTOR

Method	Number of Data Cells	Cell size [m]	Aritmetic mean	Minimum	Maximum	Range	Variance	Standard Deviation
Moore et al. 1991	309816175	1	0.628	0.000	47.060	47.060	1.841	1.357
Desmet & Govers 1996	309816175	1	0.570	0.030	74.380	74.350	0.929	0.964
Boeher & Seliege 2006	309816175	1	0.583	0.060	111.025	110.966	2.972	1.724
Moore et al. 1991	12392647	5	0.926	0.000	38.601	38.601	3.749	1.936
Desmet & Govers 1996	12392647	5	0.609	0.030	27.154	27.124	0.883	0.940
Boeher & Seliege 2006	12392647	5	0.922	0.064	75.979	75.915	6.367	2.523
Moore et al. 1991	3101700	10	1.045	0.000	38.370	38.370	4.197	2.049
Desmet & Govers 1996	3101700	10	0.676	0.030	18.391	18.361	1.030	1.015
Boeher & Seliege 2006	3101700	10	1.029	0.065	73.906	73.841	6.700	2.588
More et al. 1991	326778	30	1.202	0.000	30.028	30.028	4.074	2.018
Desmet & Govers 1996	326778	30	0.857	0.030	12.726	12.696	1.634	1.278
Boeher & Seliege 2006	326778	30	1.135	0.065	52.845	52.780	5.453	2.335
Moore et al.1991	35770	90	1.102	0.001	19.242	19.241	2.502	1.582
Desmet & Govers 1996	35770	90	0.877	0.032	14.032	14.001	1.637	1.279
Boeher & Seliege 2006	35770	90	0.975	0.067	27.453	27.385	2.691	1.640

Table 3. *Statistics for LS Factor estimates for various spatial resolutions* - 9 parameter slope method (Zevenbergen i in, 1987).

LS FACTOR



	Variance				
	1 m	**5 m**	**10 m**	**30 m**	**90 m**
Moore et al. 1991	*1.841*	*3.749*	*4.197*	*4.074*	*2.502*
Desmet & Govers 1996	*0.929*	*0.883*	*1.030*	*1.634*	*1.637*
Boeher & Seliege 2006	*2.972*	*6.367*	*6.700*	*5.453*	*2.691*

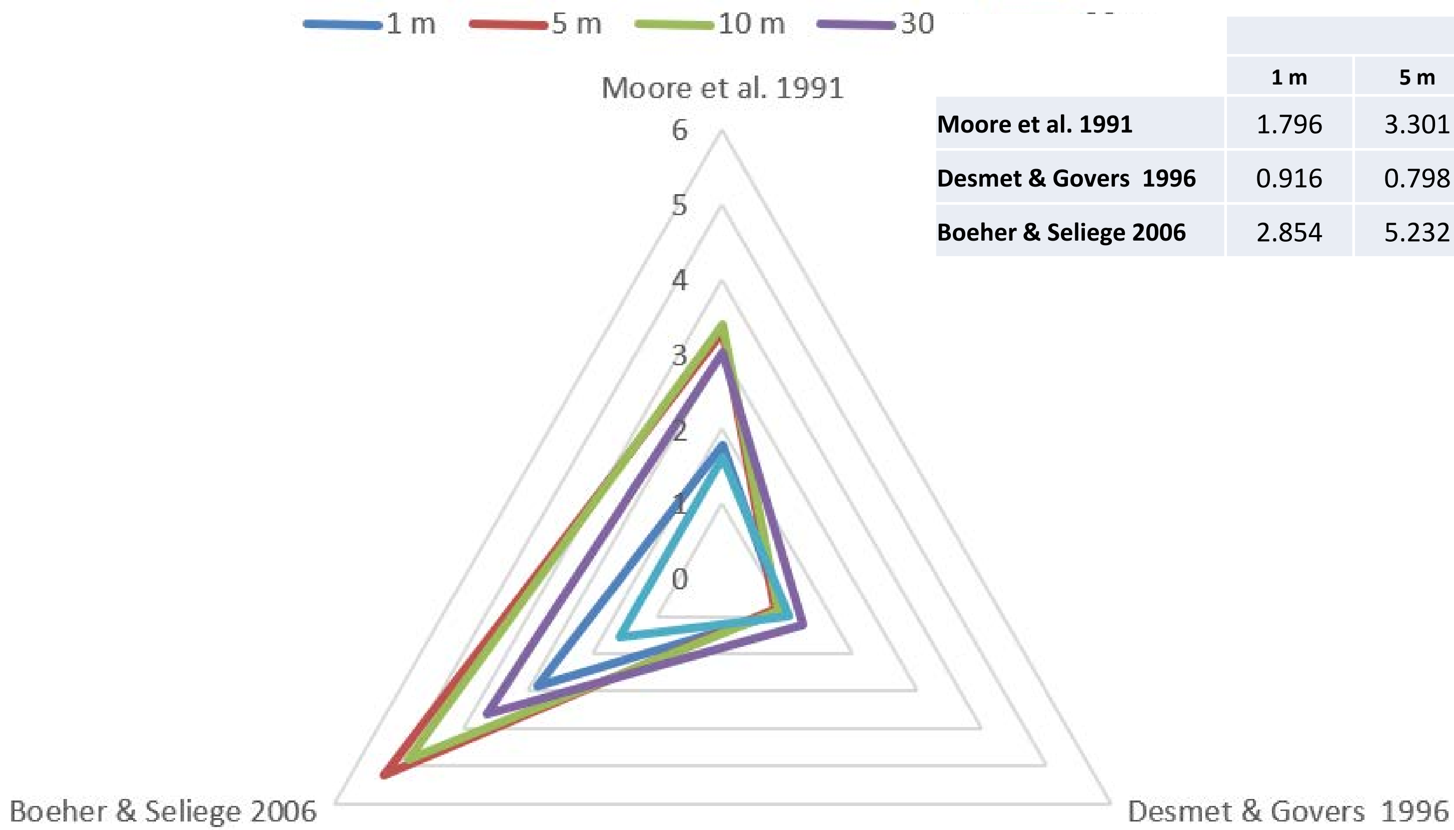
Graph 1. *Variance for all methods for spatial resolution 1, 5, 10, 30, 90 metres* - 9 parameter slope method (Zevenbergen i in, 1987)..

LS FACTOR

Methods name	Number of Data Cells	Cellsize	Aritmetic mean	Minimum	Maximum	Range	Variance	Standard Deviation
More et al. 1991	309816175	1	0.605	0.000	46.905	46.905	1.796	1.340
Desmet & Govers 1996	309816175	1	0.553	0.030	64.477	64.447	0.916	0.957
Boeher & Seliege 2006	309816175	1	0.566	0.059	110.484	110.424	2.854	1.689
More et al. 1991	12392647	5	0.886	0.000	34.876	34.876	3.301	1.817
Desmet & Govers 1996	12392647	5	0.591	0.030	24.651	24.621	0.798	0.893
Boeher & Seliege 2006	12392647	5	0.865	0.064	73.682	73.618	5.232	2.287
Moore et al. 1991	3101700	10	0.978	0.000	32.658	32.658	3.393	1.842
Desmet & Govers 1996	3101700	10	0.644	0.030	15.762	15.732	0.868	0.932
Boeher & Seliege 2006	3101700	10	0.933	0.065	61.530	61.465	4.845	2.201
More et al. 1991	326778	30	1.080	0.000	23.607	23.607	3.013	1.736
Desmet & Govers 1996	326778	30	0.781	0.030	11.773	11.743	1.236	1.112
Boeher & Seliege 2006	326778	30	0.984	0.065	39.487	39.422	3.621	1.903
Moore et al. 1991	35770	90	0.927	0.001	14.455	14.454	1.628	1.276
Desmet & Govers 1996	35770	90	0.735	0.032	12.529	12.498	1.019	1.009
Boeher & Seliege 2006	35770	90	0.797	0.067	19.153	19.086	1.576	1.255

Table 4. *Statistic for LS Factor results with a spatial resolution* - 6 parameter slope method (Bauer i in., 1985).

LS FACTOR



	Variance				
	1 m	5 m	10 m	30 m	90 m
Moore et al. 1991	1.796	3.301	3.393	3.013	1.628
Desmet & Govers 1996	0.916	0.798	0.868	1.236	1.019
Boeher & Seliege 2006	2.854	5.232	4.845	3.621	1.576

Graph 3. *Variance for all methods for spatial resolution 1, 5, 10, 30, 90 metres*- 6 parameter slope method (Bauer i in., 1985).

Fig. 12. *Compare LS factor results for spatial resolution 1, 10 and 90 meter. Compare three methods of create LS Factor.*

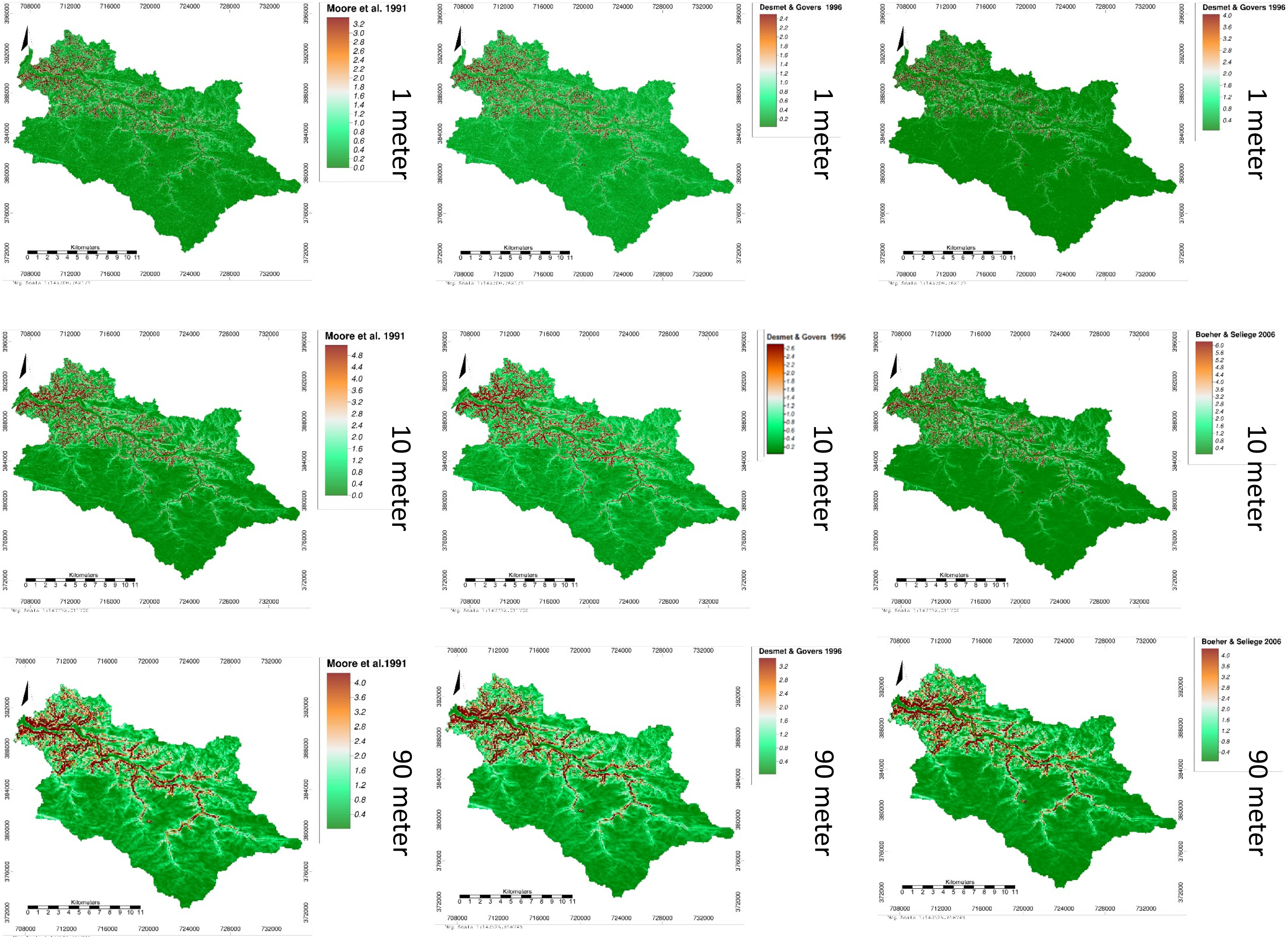
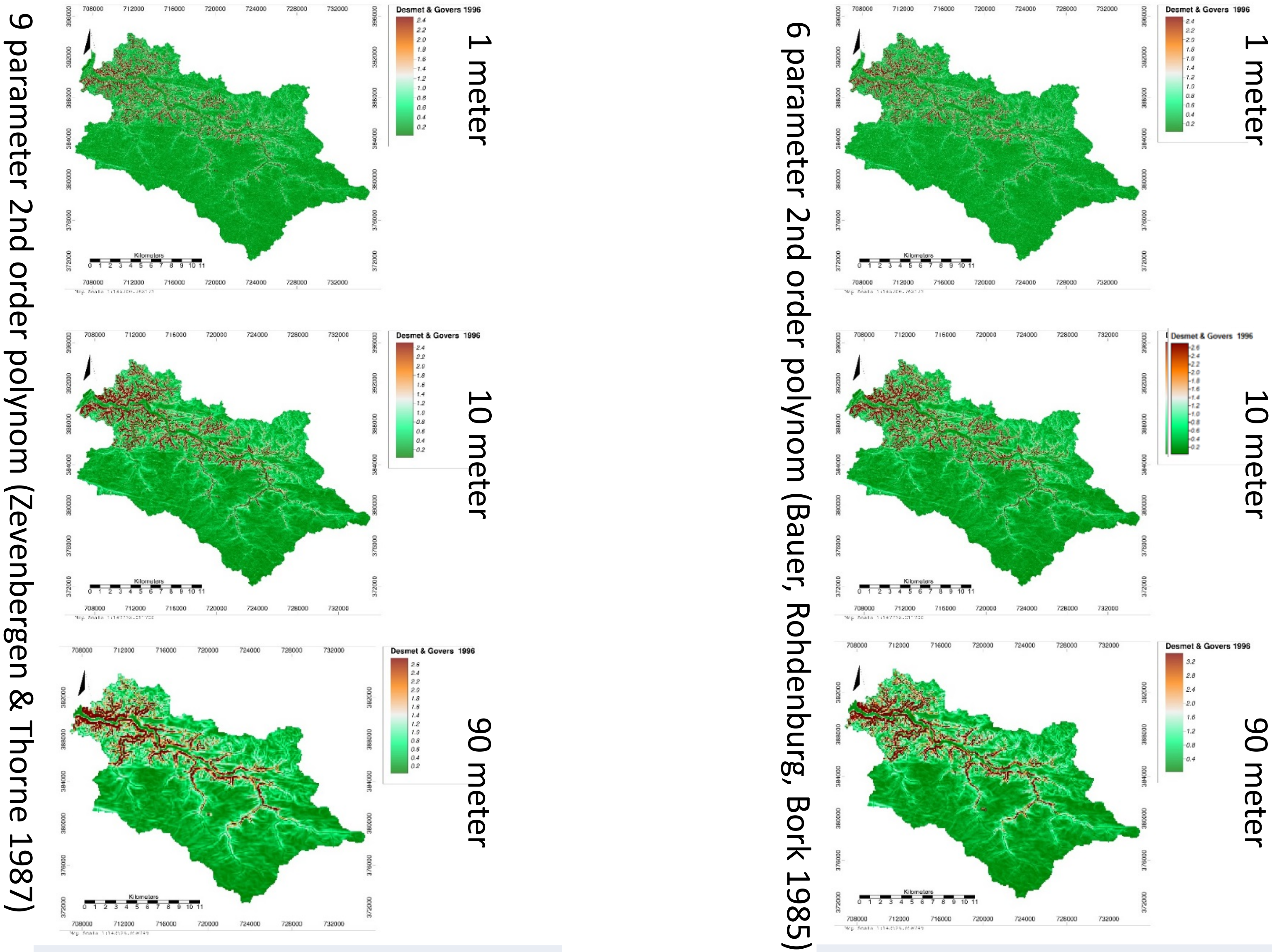


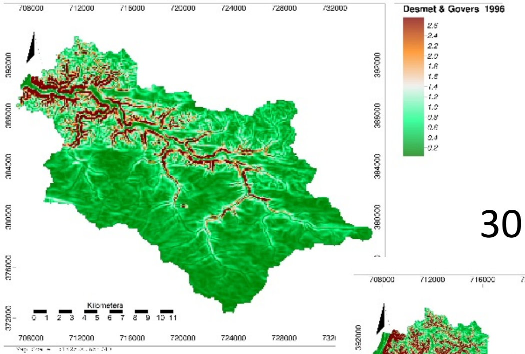
Fig. 13. *Compare LS factor results for spatial resolution 1, 10 and 90 meter. Compare two methods of create slope.*



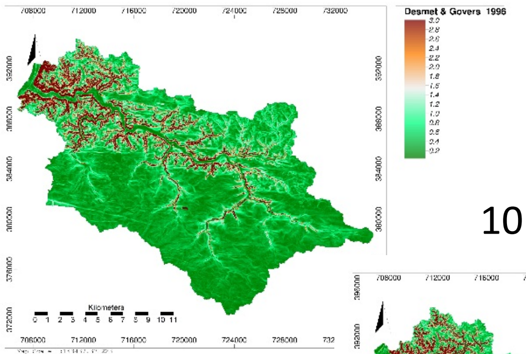
	Standard Deviation				
	1 m	**5 m**	**10 m**	**30 m**	**90 m**
Moore et al. 1991	*1.357*	*1.936*	*2.049*	*2.018*	*1.582*
Desmet & Govers 1996	*0.964*	*0.940*	*1.015*	*1.278*	*1.279*
Boeher & Seliege 2006	*1.724*	*2.523*	*2.588*	*2.335*	*1.640*

	Standard Deviation				
	1 m	**5 m**	**10 m**	**30 m**	**90 m**
Moore et al. 1991	*1.340*	*1.817*	*1.842*	*1.736*	*1.276*
Desmet & Govers 1996	*0.957*	*0.893*	*0.932*	*1.112*	*1.009*
Boeher & Seliege 2006	*1.689*	*2.287*	*2.201*	*1.903*	*1.255*

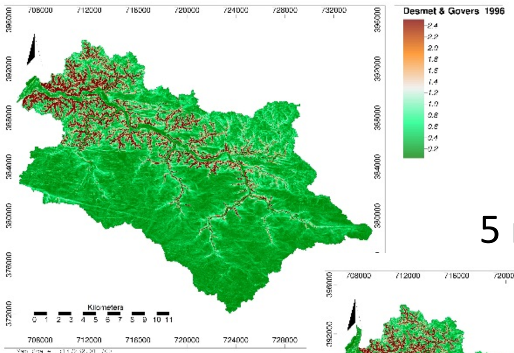
LS FACTOR



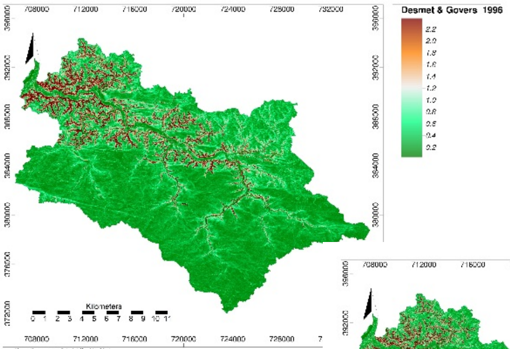
90 meters



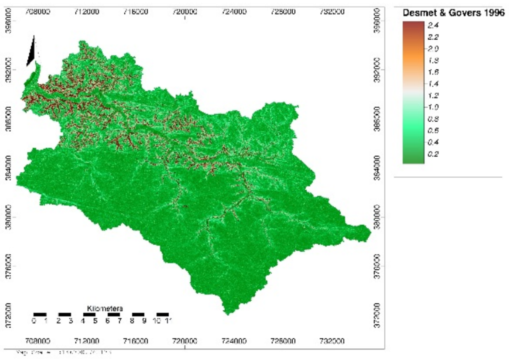
30 meters



10 meters



5 meters



1 meter

Fig. 14. *Comparison of LS factor estimates for spatial resolution 1, 5, 10, 30 and 90 meter for slope method* 6 parameter 2nd order polynom (Bauer, Rohdenburg, Bork 1985).

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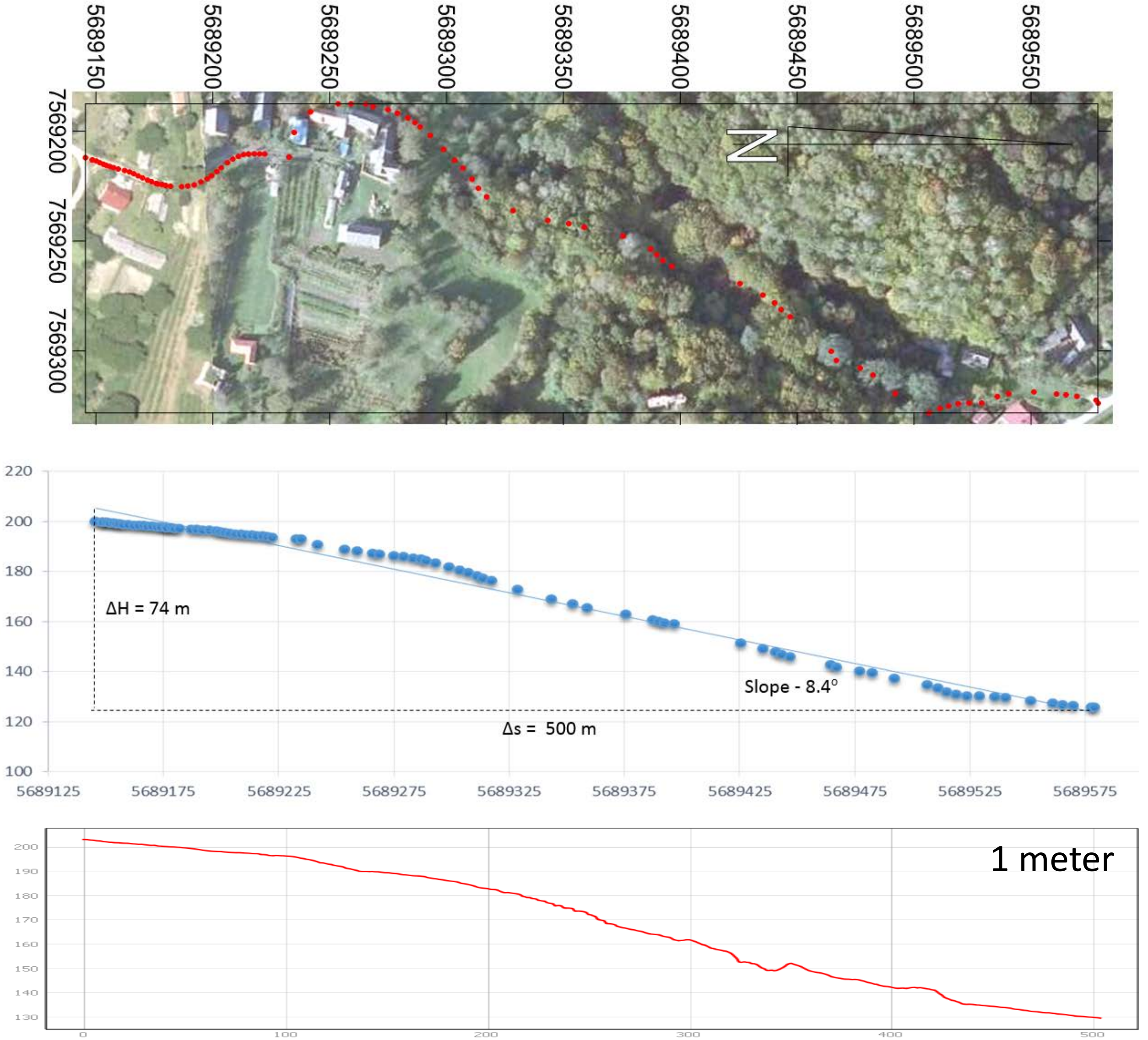
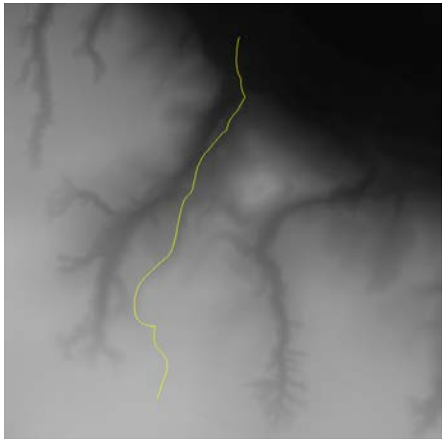
LS FACTOR





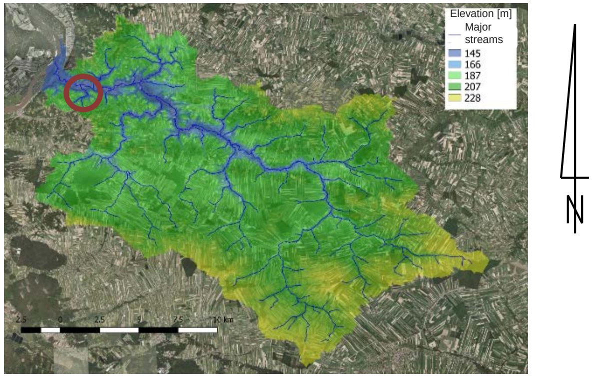
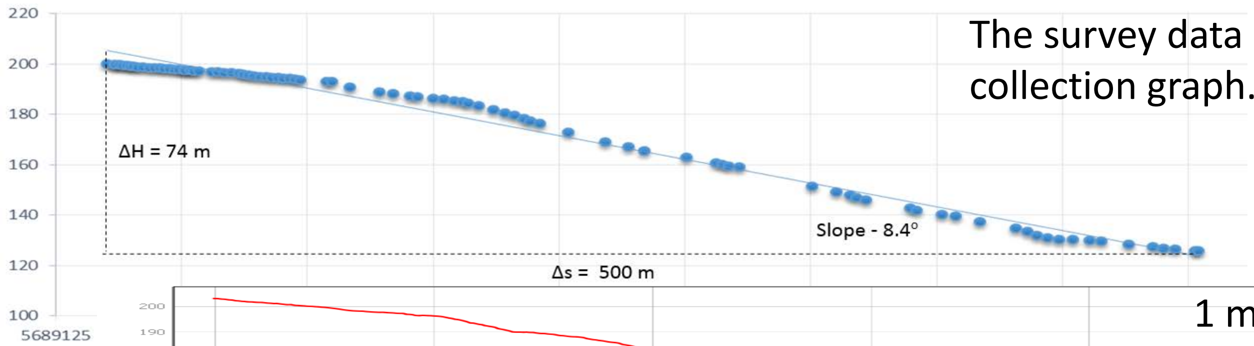
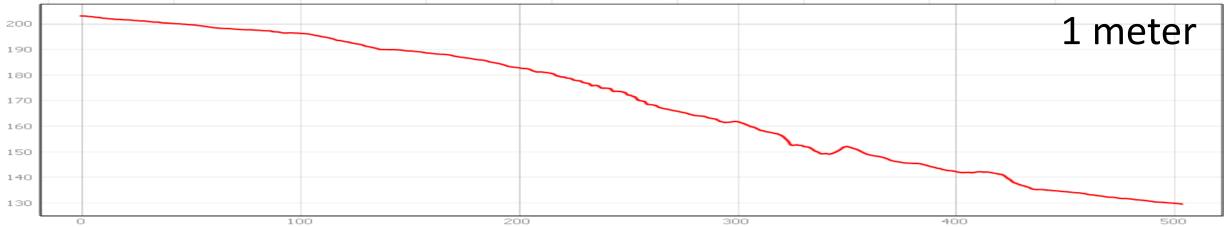
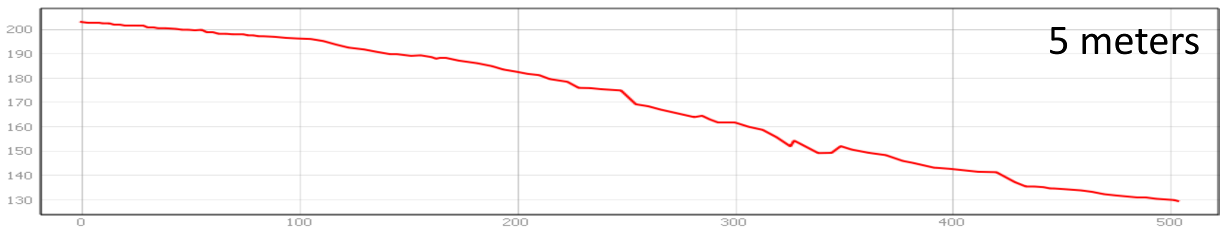


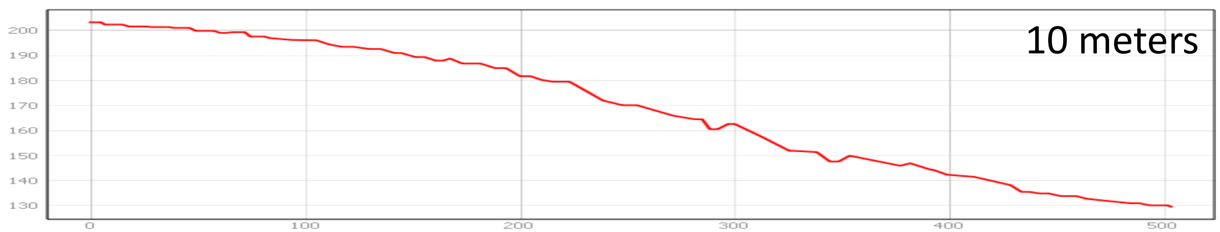
Fig. 15. *Comparison graphs of slopes for spatial resolution 1 meter with survey data collection which was made by a tachymeter.*

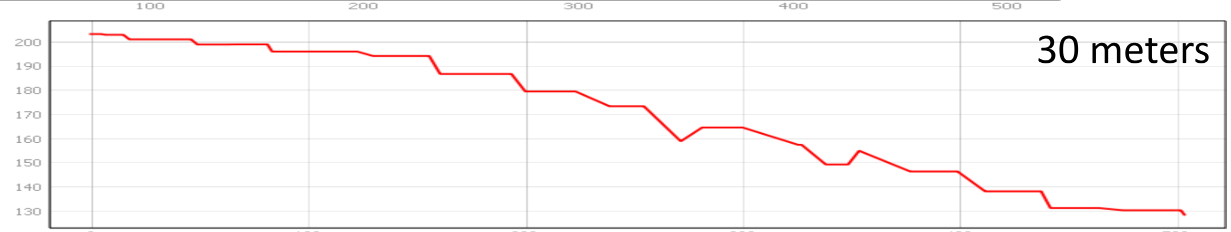
LS FACTOR











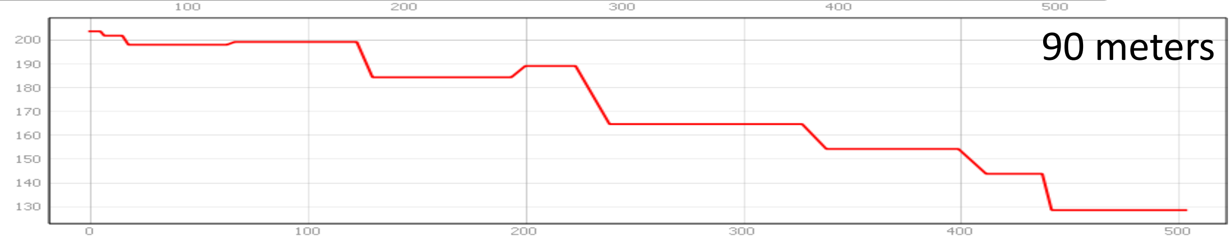


Fig. 16. *Comparison graphs of slopes for spatial resolution 1, 5, 10, 30 and 90 meter with survey data collection which was made by a tachymeter.*

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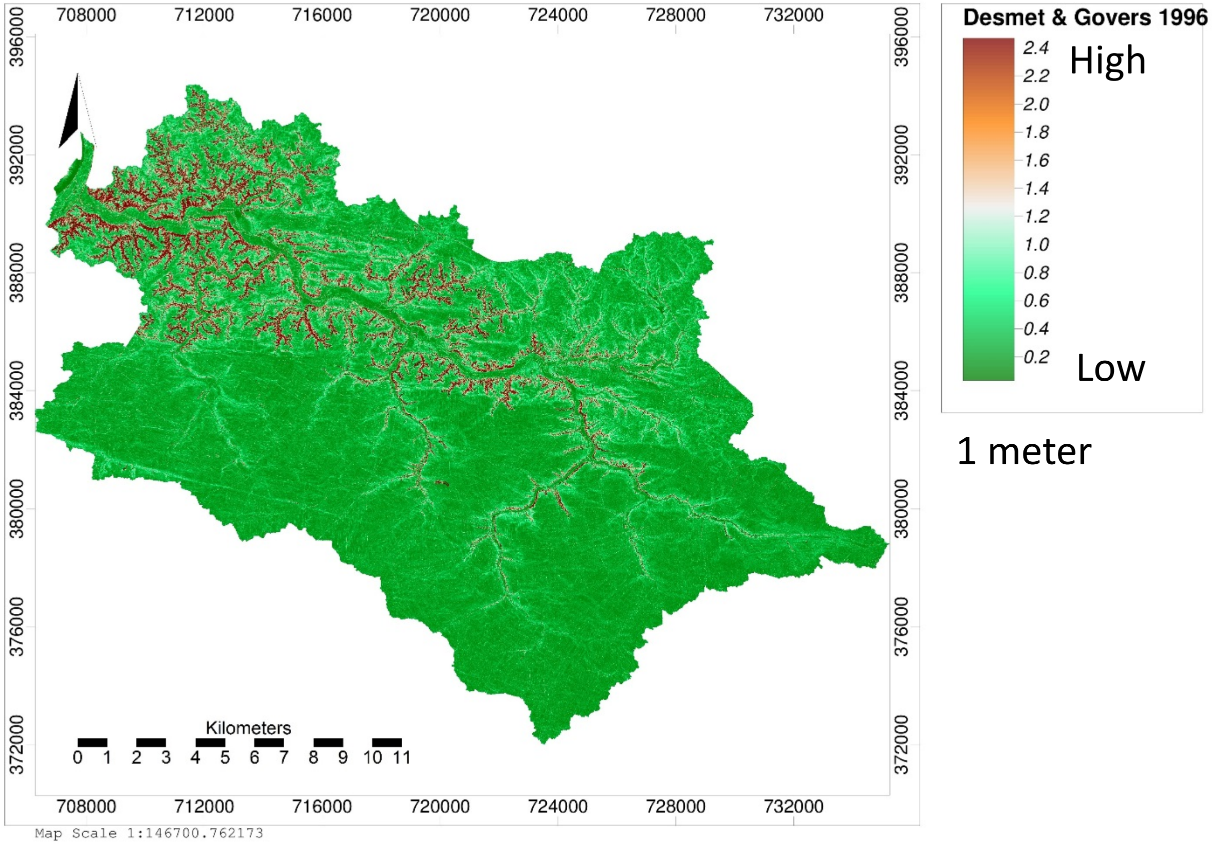
LS FACTOR



1 meter

Fig. 17. *The risk of erosion in the Bystra catchment areas.*

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Conclusion

- Desmet & Govers 1996 has the smallest variances for resolutions of 1, 5, 10, 30, 90 meters.
- The smaller variances are obtained using the 6 parameter 2nd order polynom model (Bauer, Rohdenburg, Bork 1985).
- LS factor for smaller resolution 10, 30, 90 meter shows risk of erosion in a larger area than LS factor for larger 1 and 5 meter NMT resolution.
- It is best to use 1, 5 and 10 meter resolution maps to create LS factor models.
- High risk of eroison is in the mouth of Bystra river to the Vistula in north-eastern part of map and also in Bystra riverbed.

Conclusion

- Europe-wide soil erosion risk base upon DEM of lower and middle resolutions, startng from GTOPO of 700m, through SRTM of 90m to EU-dem of 30m. The study shows that LS estimates depend strongly upon the DEM resolution hence older estimates of 700m should not be considered as valid, even for rough analyses. 90m assessments tend to overestimate the erosion intensity and they result in lowering LS factor at terrains with highly variable relief, like in Bystra catchment that in its Northern part has a dense network of gullies. As higher resolutions of DEM require a significant computer power to be used in wide-area analyses the trick is to find a best mmiddle resolution that can provide good estimates as compared to reference 1m DEM. From our investigations we learned that for upland catchment with variable relief the best compromise in terms of variance, mean ans std dev. Is the resolution 1, 5, 10 meters combined with slope estimates computed with 6 parameter method.

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Thank you