Post-fire soil erosion risk mapping using Landsat TM: results from the case of 2007 fire in Mt. Parnitha, Greece

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1. INTRODUCTION:

Wildfires have significant geomorphological and hydrological impacts, such as the increasing of soil erosion and instability phenomena to fire-affected environment. **Soil erosion** in undisturbed forested watersheds are typically very low, but increases of two or more orders of magnitude have been observed after forest fires (e.g. *Shakesby and Doerr, 2006*). The **objective** of the present study has been to assess the changes in soil erosion risk resulting from a as a result of a wildfire using Remote Sensing and Geographical Information Systems (GIS).

2. STUDY SITE AND DATASETS:

1. STUDY SITE: Our study region site comprises of the area of **Mt. Parnitha**, located approximately 30 km northwards the city of Athens, Greece (Fig. 1). Mt. Parnitha experienced severe wildfire from a wildfire on *June 28th, 2007*, suppressed 5 days later (*July 1st, 2007*).

2. SATELLITE DATASETS:
-Landsat TM images: 16 May 2007, 03 July 2007
-ASTER Global Digital Elevation Model v2

3. FIELD DATA:
-Meteorological data record
-Field soil investigation datasets

The collected datasets were converted into GIS map layers and projected into the Geodetic system EGSA'87.

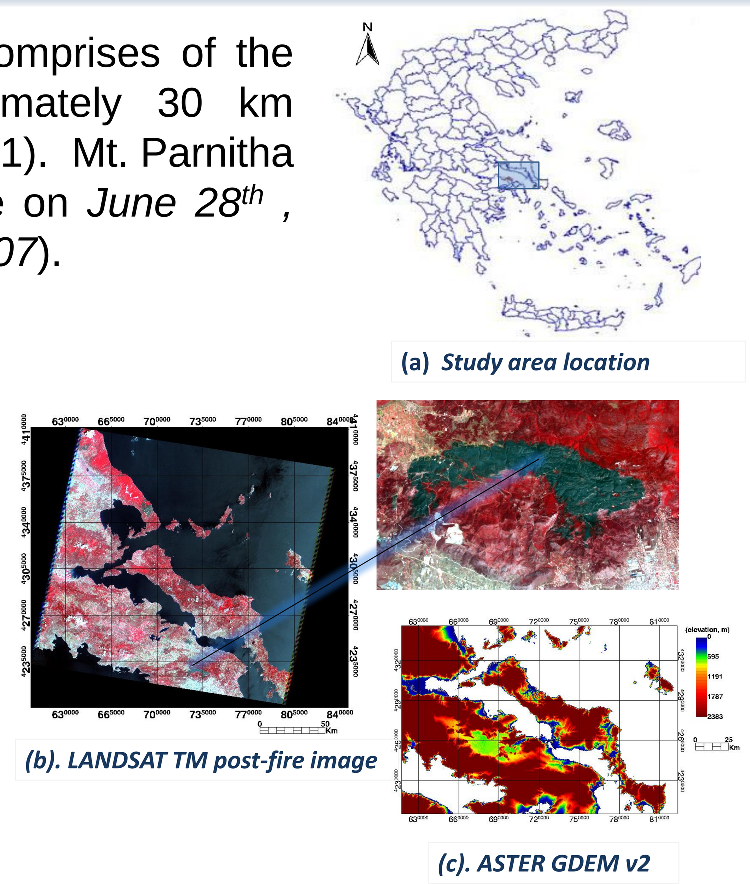

Fig. 1: (a):Study site location, examples of the acquired datasets for the study, (b): LANDSAT TM post-fire image showing the affected by the fire region, (c) ASTER GDEM v2

3. METHODS: *REVISED SOIL LOSS EQUATION - RUSLE*

The **Revised Universal Soil Loss Equation (RUSLE)** equation (Wischmeier and Smith, 1978) was implemented in the present study:

$$A = R * C * LS * K * P$$

where:

A=Annual soil loss (t ha^{-1} y^{-1}), ***R***=Rainfall erosivity factor (MJ mm ha^{-1} h^{-1}), ***C***=Conservation factor (unit less), ***LS***=Slope length and slope steepness factor (unit less), ***K***=Soil erodibility factor (MJ mm ha^{-1} hr^{-1} y^{-1}), ***P***=Conservation practice factor (unit less).

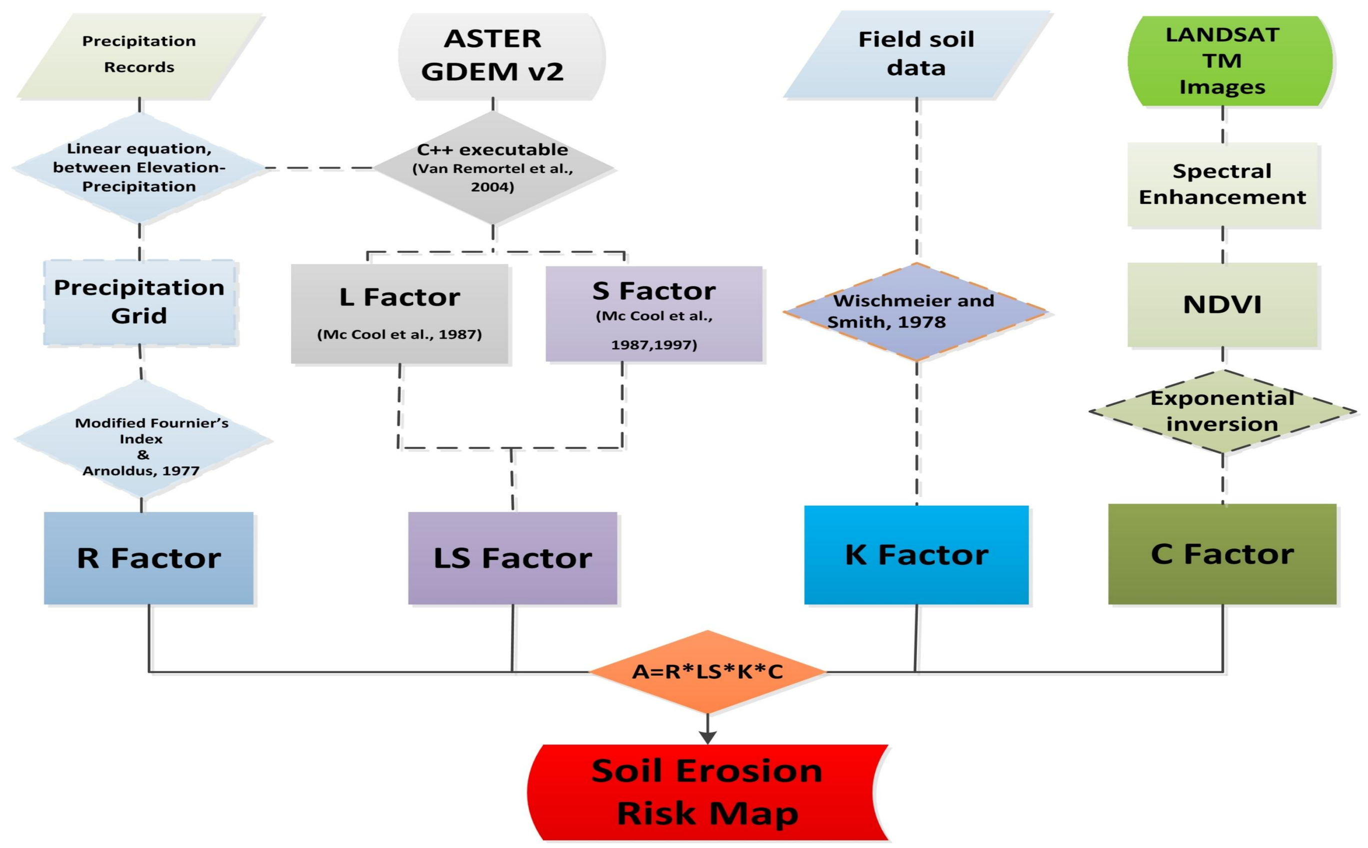

Fig. 2: *Overall methodology flowchart .*

Burnt area from the Risk-EOS Burnt Scar Mapping service (*Kontoes et al., 2009*) for this specific fire event was obtained and used in analysis. Two RUSLE-derived soil erosion risk maps before and after the wildfire event were exported, for further analysis.

4. RESULTS: *RUSLE FACTORS*

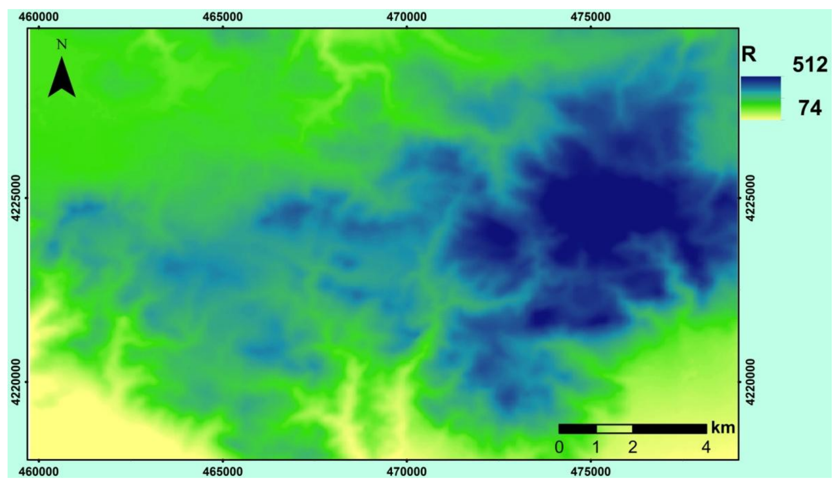

Fig. 3: *The **R (erosivity factor)** (MJ mm ha^{-1} h^{-1}/ yr), was computed from the Modified Fournier Index (MFI) (Arnoldus,1977, 1980), based on analysis of the region's meteorological stations records (1958-2010). R was assumed stable in both RUSLE calculations.*

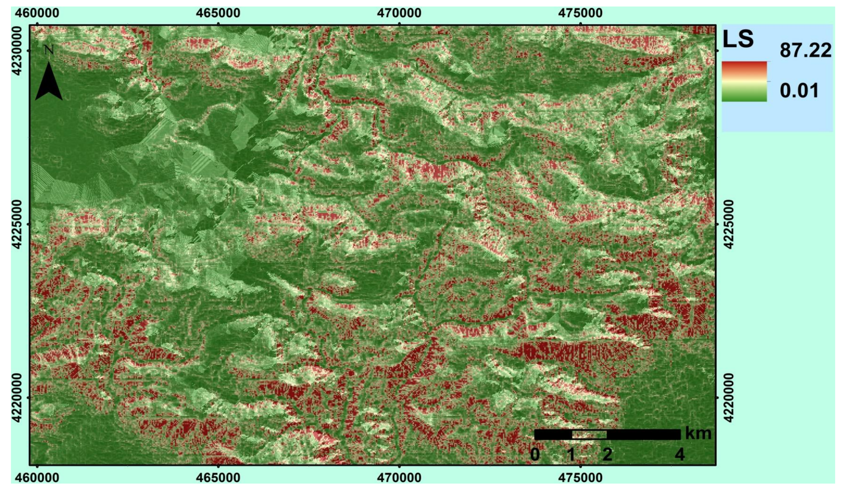

Fig. 4: *The **LS (topography factor)** was calculated using the DEM based on the algorithm formula of the overall flow path-based iterative slope-length accumulation introduced by van Remortel et al. (2004). LS was assumed stable in both RUSLE calculations.*

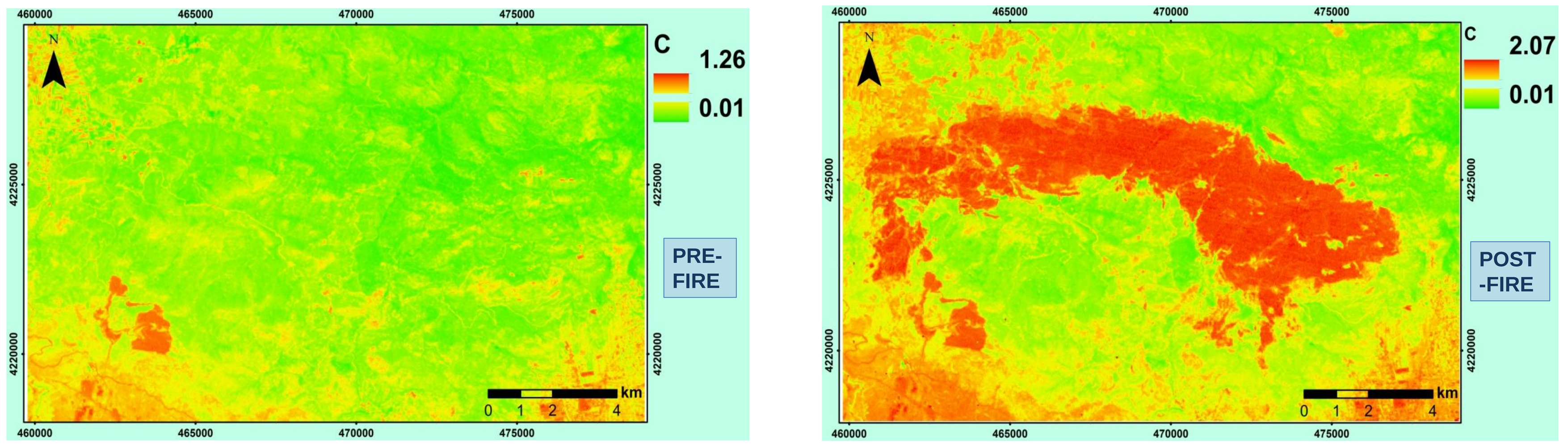

Fig. 5: *The **C (coverage factor)** was derived from the NDVI index of the pre-fire and the post-fire Landsat TM images.*

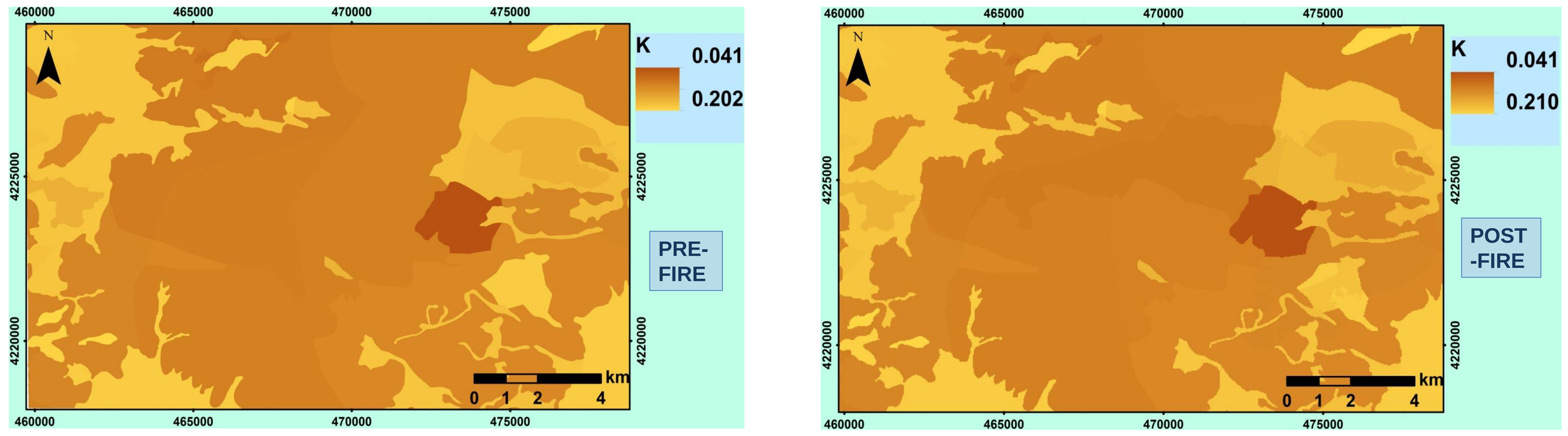

Fig. 6: *The **K (Erodibility factor)** (t ha MJ^{-1} mm^{-1}) for the soil conditions before and after the fire was calculated following Wischmeier and Smith (1978), in which percentages of the organic matter (derived from NAGREF) were inserted in the above equation based on the characteristics of the soil profile horizons.*

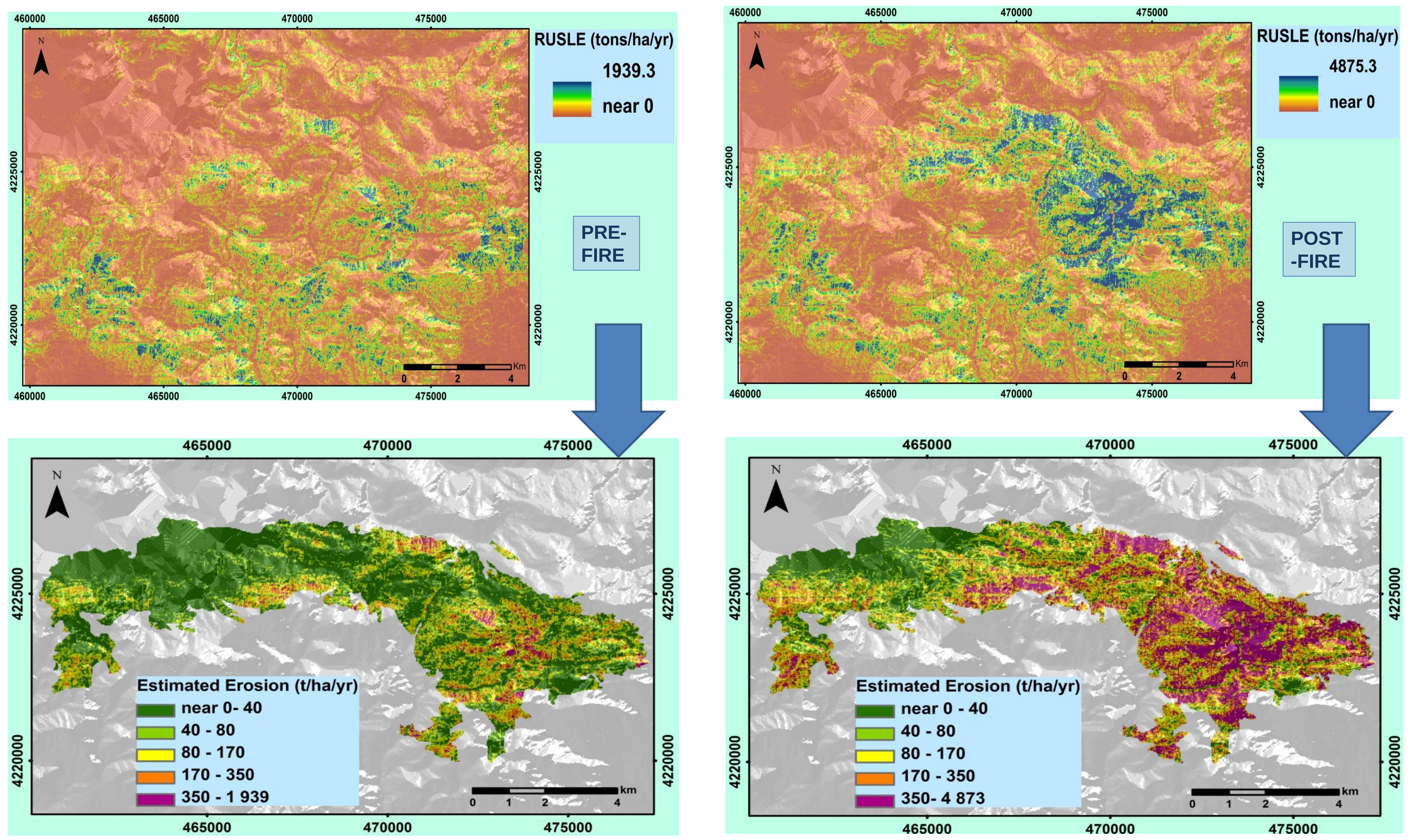

Fig. 7: *The final soil erosion risk maps (30 m) before and after the fire. The side images are illustrating the extracted burned area from the above maps.*

5. RESULTS: *SOIL EROSION RISK CHANGES*

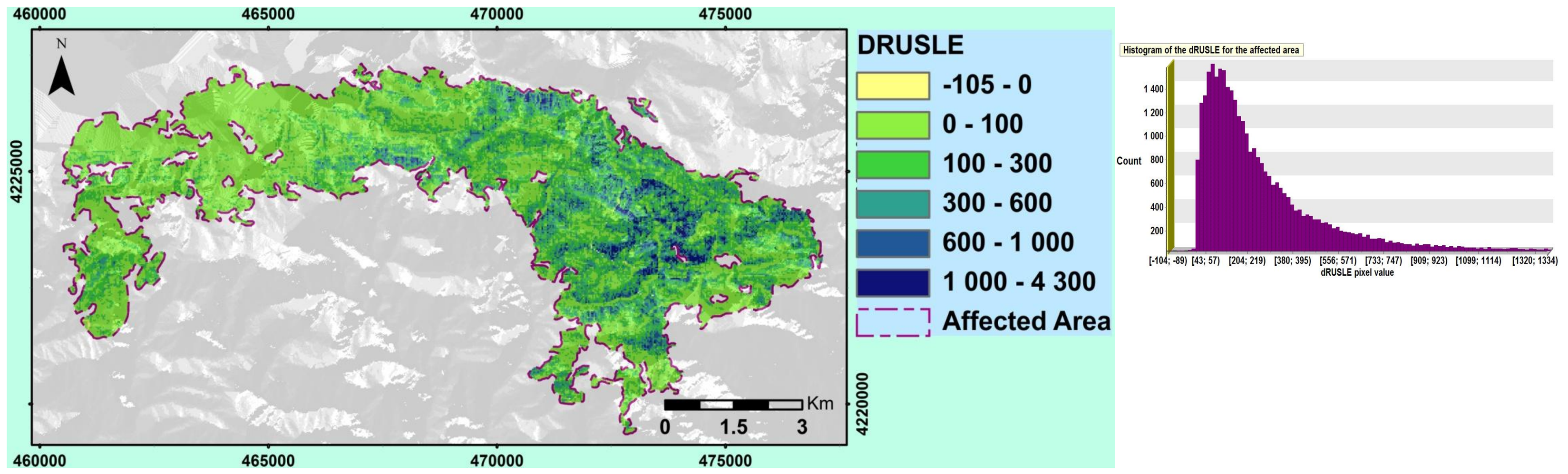

Fig. 9: *The RUSLE soil erosion risk difference map (left) and the corresponding map histogram (right).*

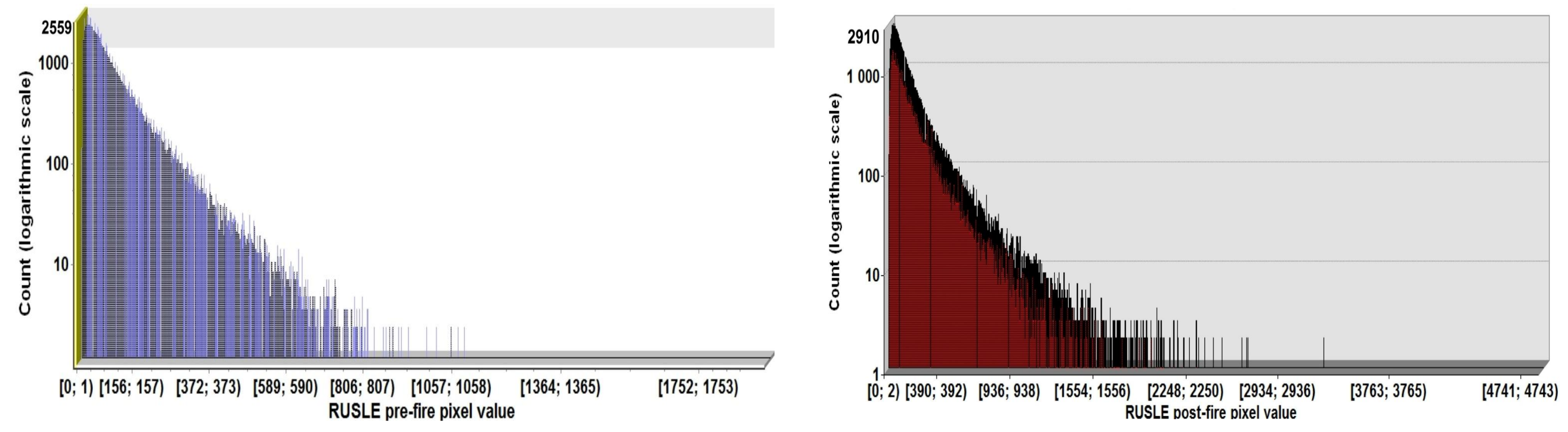

Fig. 9: *Histograms of the soil erosion risk maps produced from RUSLE before (left) and after (right) the wildfire.*

Table 1: *Statistics of the calculated RUSLE map layers.*

STATISTICAL DATA FOR THE RUSLE LAYERS (tn/ha/yr)						
Values	Area pre-fire	Burned area pre-fire	Area post-fire	Burned area post-fire	dRUSLE	dRUSLE on burned area
Min	near 0	near 0	near 0	near 0	-469	-105
Max	1939	1939	4875	4875	4298	4299
Mean	63	98	112	353	49	171
Std	87	108	179	339	129	230

Table 2: *Estimated soil losses per year for the studied area before and after the fire.*

	pre-fire	post-fire
Overall estimated soil losses (Ktn/year)	283,43 (Ktn/year)	1020,812 (Ktn/year)

Table 3: *Estimated percentage increase of the soil erosion rates calculated from the pixel values of the differenced RUSLE layer for the affected area.*

Percentage increase on the estimated by the RUSLE soil erosion rates						
% Increase (t/ha/yr)	No increase	0 - 50%	50 - 100%	100 -200%	200 - 300%	400 - 500%
% of the pixels of the masked area	0.07%	4.55%	7.45%	22.10%	18.82%	14.29%
% Increase (t/ha/yr)	500 - 600%	600 - 700%	700 - 800%	800 - 900%	900 - 1000%	more than 1000%
% of the pixels of the masked area	9.96%	6.52%	4.62%	3.06%	2.01%	6.23%

6. CONCLUSIONS:

❑. In overall, areas having a minimal soil erosion risk before the fire showed a considerable increase in erosion risk after the fire, as a result of natural environment destruction occurred from the fire outbreak.

❑. Increase in soil erosion rates was occurred after the wildfire in the affected area with a mean and st.dev ranging from 63 to 353 and from 87 to 339 tn h^{-1} yr^{-1} respectively.

❑. Obtained results are significant as they quantify the relative soil loss within the study area, highlighting vulnerable localities of soil erosion.

❑. Further work is underway in validating RUSLE outputs as well as in examining changes in soil erosion rates and spatial patterns after the wildfire as a function of topography, land cover and burning severity parameters.

References:

Arnoldus, H.M., 1977. Methodology used to determine the maximum potential average annual soil loss due to sheet and rill erosion in Morocco. FAO Soils Bull. 34, pp. 39–515. **Kontoes, C.C., Poilve, H., Florsch, G., Keramitsoglou, I., Paralikidis, S., 2009.** A comparative analysis of a fixed thresholding vs. a classification treeapproach for operational burn scar detection and mapping. International Journal of Applied Earth Observation and Geoinformation 11, 299–316.***Renard, K.G., Foster, G.R., Weesies, G.A., McCool, D.K., Yoder, D.C, 1997.*** Predicting soil erosion by water: a guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE). U.S. Department of Agriculture, Agriculture Handbook Number 703, 404 pp. ***Shakesby, R.A., Doerr, S.H., 2006.*** Wildfire as a hydrological and geomorphological agent . Earth-Science Reviews 74 , 269– *307.* ***Van Remortel, R.D., Maichle, R.W., Hickey, R.J., 2004.*** Computing the LS factor for the Revised Universal Soil Loss Equation through array-based slope processing of digital elevation data using C++ executable. Computers & Geosciences 30, 1043-1053. **Wischmeier, W.H. and D.D. Smith. 1978.** "Predicting Rainfall Erosion Losses: A Guide to Conservation Planning." Agriculture Handbook No. 537. USDA/Science and Education Administration, US. Govt. Printing Office, Washington, DC. 58pp.

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