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Artan Hysa
EPOKA University, Faculty of Architecture and Engineering Tirana, Albania, ahysa@epoka.edu.al

Introducing NDVI, Tree Cover Density and Land Cover type as Fuel Indicators in the Wildfire Spread Capacity Index (WSCI), Case of Montenegro

Abstract

This poster presents an updated version of our previous GIS-based method developed for indexing the forest surfaces by their wildfire ignition probability (WIPI) and wildfire spreading capacity (WSCI). The previous study relied on a multi-criteria approach including a variety of factors of social, hydro-meteorological, and geo-physical character of the context. However, this study is challenging the drawbacks of the previous work, by introducing three new criteria regarding the vegetation properties in the area. Normalized Difference Vegetation Index (NDVI), Tree Cover Density (TCD), and land cover type are launched as indicators of fuel properties of the forest being indexed. The materials and software utilized here belongs to different open sources. CORINE Land Cover (CLC), Open Street Map (OSM), TCD via Copernicus high resolution data, and multispectral satellite images via Landsat 8 (Semi-Automatic Classification Plugin- SCP) are utilized as raw materials in a workflow in QGIS software. At this stage, the study area is the territory of Montenegro. Following the inventory stage, the indexing method relies on a normalizing procedure in QGIS and the assignment of weighted impact factor to each criterion via analytical hierarchy process (AHP). The WSCI value is derived as the sum of the products between the normalized class and the respective weighted impact factor of each criterion. Besides the methodological improvements the results of this work deliver tangible outputs in support of forest fire risk reduction in disaster risk management and fire safety agendas.

Keywords: *Disaster risk management; QGIS; Semi-automatic classification; Analytic Hierarchy Process; Montenegro.*

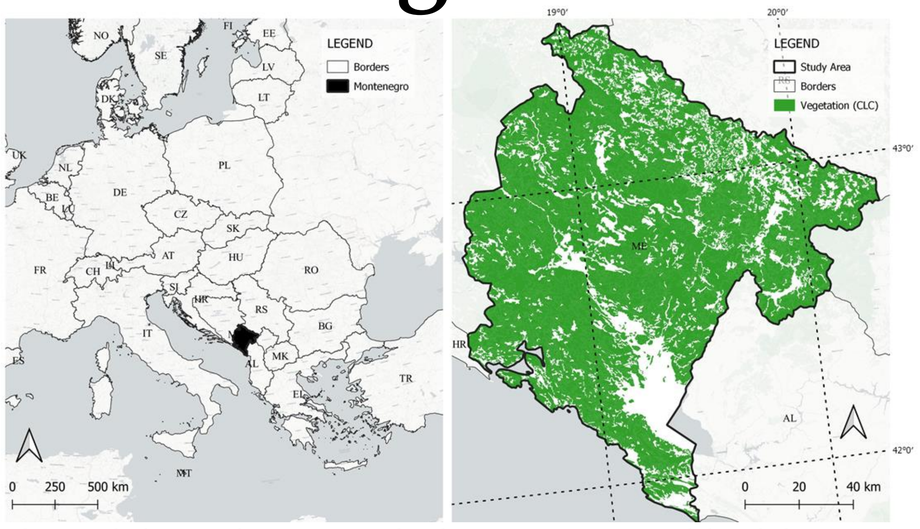


Figure 1. The location of Montenegro within the European continent and three fuel criteria; (a) vegetation type (CLC data of 2018), (b) tree cover density (TCD), and (c) NDVI.

Materials & Methods

WORKFLOW STAGES

I STAGE

Preparatory

First, the vegetated surface within the national borders are extracted from CORINE Land Cover data (CLC) as the core areas of analysis. A set of regular points grid (500 m) which overlaps with the vegetated surfaces is targeted as the main layer of reference points. This set will serve as pivot points to be loaded the inventory measurements for each criterion.

II STAGE

Inventory

An important step of the study is the inventory phase. It follows the inventory method developed by Hysa et al. (2017) which includes a procedure of recording the properties of the burned surfaces based on a variety of criteria. At this stage, the points layer is calculated new field of attributes per each criterion via QGIS field calculator.

III STAGE

Analysis

The loaded values of criteria are further normalized into a common range of values between 0 and 1 due to the diversity among individual raw ranges. Furthermore, the refinement stage includes the assignment of a weighted impact factor for each criterion. The method used here is the analytical hierarchy process (AHP) pairwise comparison

$$x' = x - \min(X) \;/\; \max(X) - \min(X) \qquad (1)$$

IV STAGE

Indexing

The main stage of the workflow is the indexing one. The WSCI values are calculated as a summation of the products between the normalized values of each criterion and the weighted impact factor. Thus, the WSCI value remains within a range between 0 and 1.

$$WSCI = \sum_{j=1}^{m} \beta_j C_j \qquad (3)$$

V STAGE

Validation

The final stage consists of a tentative for validation of the method. The results of the study are compared about the surfaces which according to CLC data of 2018 are already burned during recent years.

Table 2. Multi-criteria used in WSCI index calculation, including their respective relevancy and their impact factor within and among categories (β_j).

	SOCIAL			*CLIMATIC*				*PHYSICAL*				*FUEL*			
Criteria	*S1 Dist. to Urban Cent*	*S3 Dist. to any road*	*S4 Dist. to main road*	*E1 Solar radiation*	*E2 Precipitation*	*E3 Maximum temp.*	*E4 Wind speed*	*P1 Slope*	*P2 Aspect*	*P3 Altitude*	*P4 Dist to water*	*F1 Fuel type (CLC)*	*F2 Tree Cover Density*	*F3 NDVI*	
relevancy	+	+	+	+	-	+	+	+	+	-	+	+	+	+	
IF (within category)	0.24	0.09	0.67	0.05	0.20	0.09	0.66	0.27	0.11	0.05	0.57	0.14	0.54	0.32	
IF (category)	0.07	0.07	0.07	0.24	0.24	0.24	0.24	0.12	0.12	0.12	0.12	0.57	0.57	0.57	1.00
IF (β_j)	0.02	0.01	0.05	0.01	0.05	0.02	0.16	0.03	0.01	0.01	0.07	0.07	0.30	0.18	1.00

Table 1. The inventory results including the upper bound, lower bound and median values of WSCI indexing results for Montenegro.

	Criterion	unit	Max	norm	Median	norm	Min	norm	StdDev
E1	Solar radiation	MJ m^{-2}	22857	1	20890	0.459	19246	0	701
E2	Precipitation	mm	90	1	71	0.548	48	0	7
E3	Maximum temp.	∘C	31	1	20.1	0.429	12	0	3
E4	Wind speed	m s^{-1}	4	1	2.09	0.4	1	0	0
F1	Fuel type (CLC)	NA	9	1	6	0.667	0	0	3
F2	Tree Cover Density	%	99	1	55	0.566	0	0	34
F3	NDVI	ratio	1	1	0.70	0.824	0	0	0
P1	Slope	%	80	1	14.1	0.179	0	0	10
P2	Aspect	NA	10	1	5	0.5	0	0	3
P3	Altitude	m	2412	1	1148	0.479	-2	0	451
P4	Dist to water	m	43740	1	11452	0.264	8	0	7849
S1	Dist. to Urban Cent	m	39008	1	10336	0.267	52	0	6839
S3	Dist. to any road	m	12839	1	1305	0.103	1	0	1555
S4	Dist. to main road	m	20288	1	4588	0.228	17	0	3599
Result	**WSCI**			**0.705**		**0.469**		**0.068**	
	WSCI normalized			**1**		**0.629**		**0**	

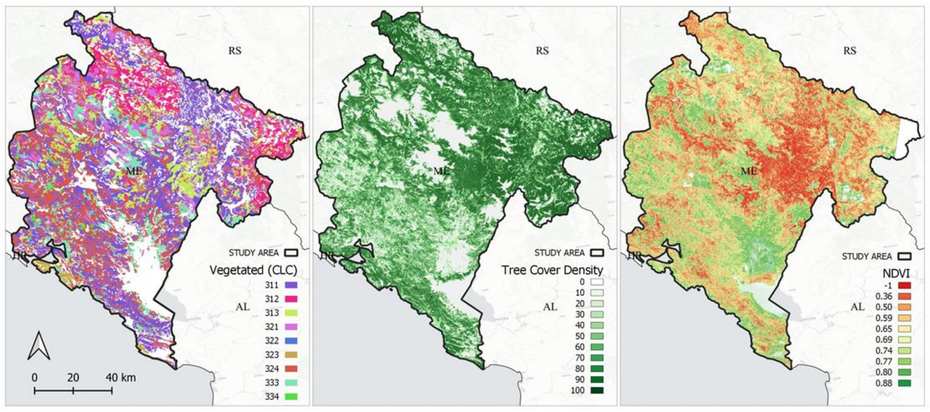
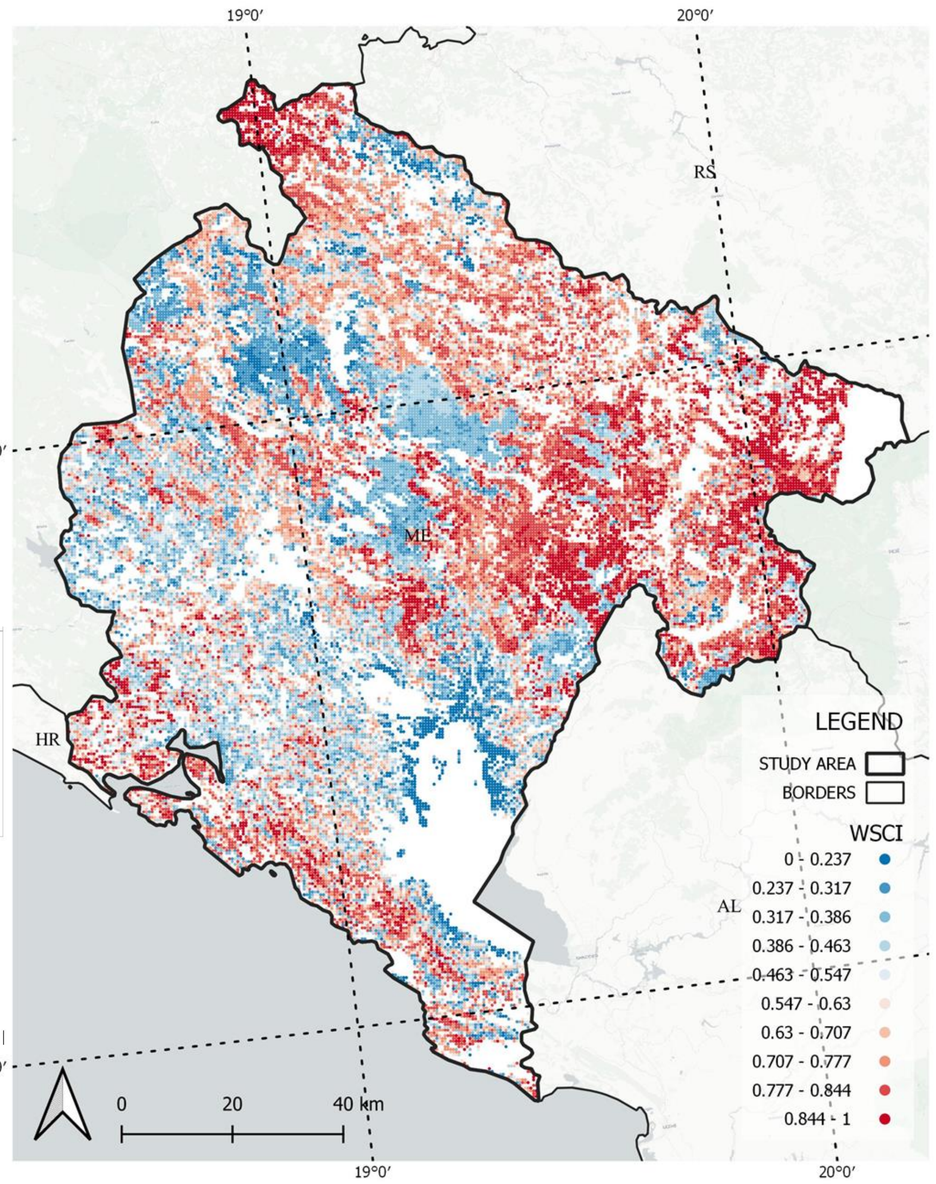


Figure 5. The normalized WSCI indexing results for Albanian territory.



Results

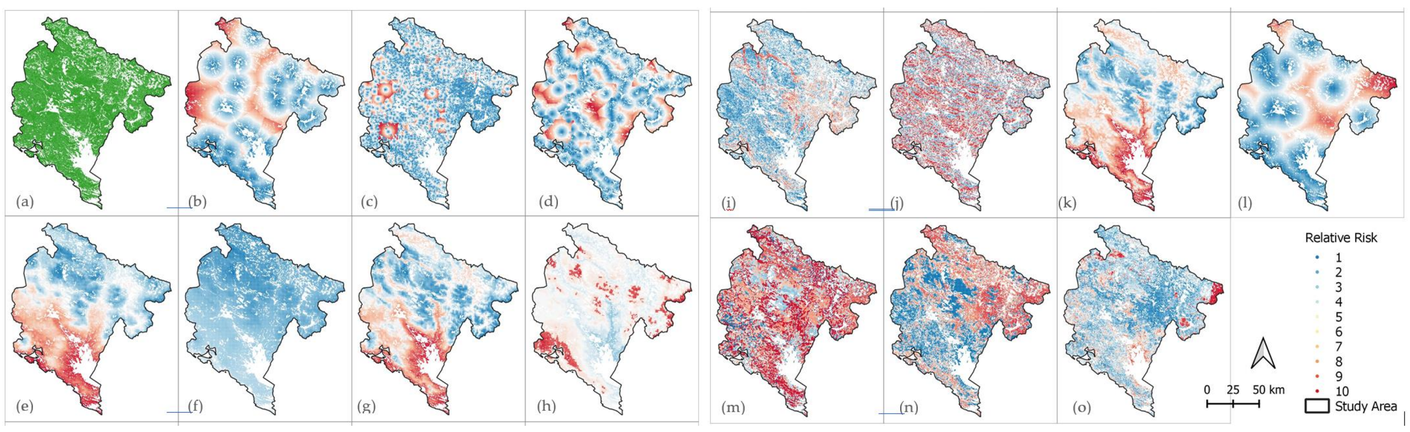


Figure 5. The territory of Montenegro including natural vegetation (a), and the relative risk map for each criterion; dist. to urban centers (b), dist. to main road (c), dist. to any road (d), solar radiation (e), precipitation (f), maximum temperature (g) wind speed (h), slope (i), aspect (j), elevation (k), distance to water (l), vegetation type-CLC (m), tree cover density (n), NDVI (o).

Conclusion

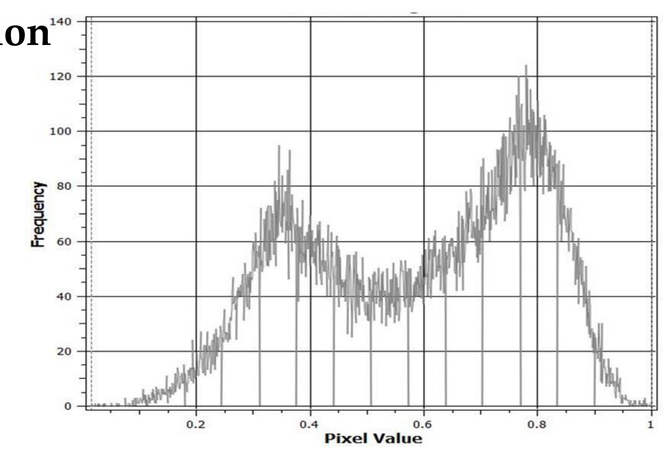


Figure 7. Histogram chart of the frequency of normalized WSCI values (0-1) for the territory of Montenegro.

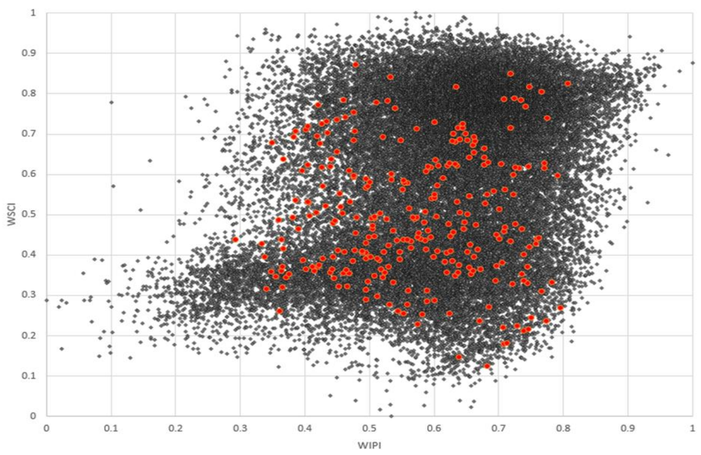


Figure 8. Scatter plot of WSCI to WIPI values for the territory of Montenegro (the values of points within burned areas are highlighted in red circles).

This poster presented an improved version of the GIS based method developed by Hysa & Baskaya (2019) for indexing the forest surfaces by their wildfire spreading capacity (WSCI). Relying on the original set of criteria, this study pushes forward three new factors regarding the fuel properties of the vegetated surfaces. Vegetation type in reference with flammability, the tree cover density, and the NDVI values are introduced as evidence about the composition of the fuel. The new criteria are informed by geospatial raw data being accessible as open source. Finally, the results of the study can be useful in support of disaster risk management and preventive measurements especially during the pre-occurrence phase. The WSCI map is helpful in highlighting hotspots within the Montenegro territory that must be carefully managed by the respective institutions at both local and national levels.