LAND USE CHANGE DYNAMICS IN TWO CONTRASTING ANDALUSIAN MEDITERRANEAN WATERSHEDS (1977-2022) AND THEIR EFFECT ON SOC STOCKS

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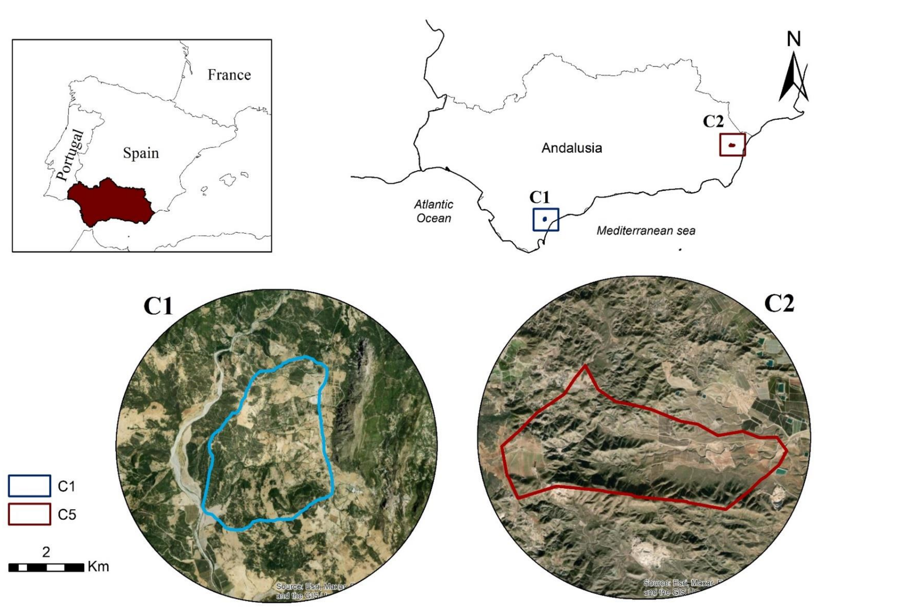
Research Motivation & Study Objectives

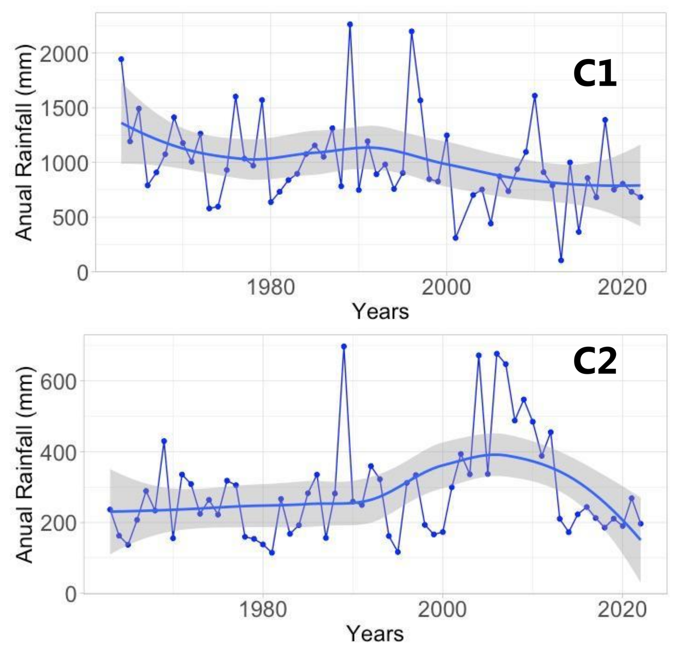
In the Mediterranean region, a significant increase in soil erosion and degradation processes has been identified as a consequence of climate change impacts. These processes are being accelerated due to intense human activity and frequent changes in land use, especially during the last decades. Under this paradigm, it is essential to conduct research aimed at determining the capacity to retain organic carbon (SOC Stocks) and its spatial distribution as an indicator of soil health and quality. From a methodological approach, the development of new technologies based on machine learning such as Random Forest is presented as a fundamental tool to address these challenges and generate more detailed knowledge. In this regard, this work aims to:

- Analyze changes in land uses over the last decades (1977-2022) and estimate which have the highest SOC Stocks.
- Assess the connection between current SOC Stocks and land use dynamics in recent years.
- Evaluate the importance of environmental variables (%), especially climatic characteristics, in SOC Stocks and generate detailed SOC Stocks mapping using Random Forest method.
- Analyze the relationship between soil erodibility and SOC Stocks.

Study area

Southern Spain is characterized by a pluviometric gradient ranging from 1,400 mm of annual rainfall in the western extreme (humid Mediterranean climate) to 150 mm of annual rainfall in the east (arid Mediterranean climate). In this study, two watersheds (C1 and C2) have been selected, each at opposite ends of the gradient and separated by 250 km. Both are characteristic of the Mediterranean mid-mountain region.





C1: Arroyo de la Pindolita – Valle del Río Genal (Málaga), characterized by a subhumid mediterranean climate (11.07 Km²).
C2: Rambla del Serrón – Campo de Tabernas (Almería), with arid mediterranean condition (15.4 Km²).

Material and methods

LAND USE CHANGE (1977-2022)

Use of geomatics technique including the use of GIS and remote sensing (Sentinel 2 and SPOT 6/7).

Both watersheds were analyzed at plot scale and the land use changes were adapted and cropped according to MUCVA* methodology.

SOIL ANALYSIS

Collection and analysis of 145 soil samples (0-10 cm) (67 in C1 and 78 in C2).

Calculation of Soil Organic Carbon Stocks:

$$SOC\ Stocks = SOC \times BD \times D \times (1 - G)$$

SOC Stocks (Mg ha-1); SOC is soil organic C percentage (g 100-1 g-1); BD is bulk density; D is soil depth (cm); G is coarse fragments (%).

MAPPING PROCEDURE – RANDOM FOREST

DataBase → Feature selection through statistical analysis (Pearson correlation coefficient) → Random Forest: prediction and modeling based on RMSE and MAE → Mapping results (ArcGis Pro)

STATISTICAL ANALYSIS

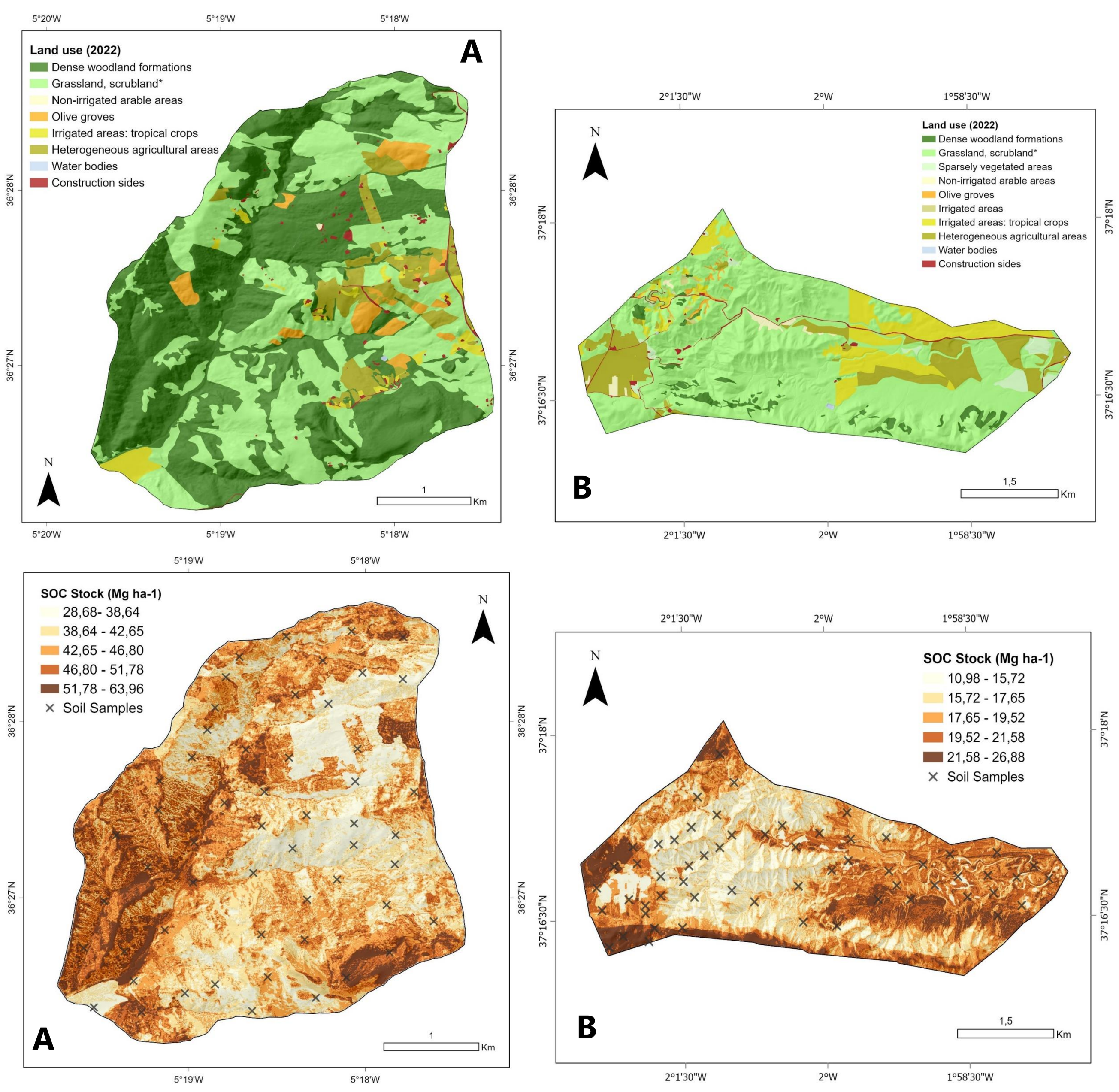
Summary and Conclusions

- The findings highlight contrasting dynamics between the C1 and C2 watersheds in terms of land use and the distribution of SOC Stocks. While C1 experiences an increase in WL formations and AG areas, C2 shows a more pronounced expansion in AG (tropical crops) and built-up areas.
- The difference in SOC Stocks values reflects the different climatic, environmental and land use conditions between the watersheds. Random Forest modelling reveals the influence of topographic and moisture variables on SOC distribution. Furthermore, a strong correlation between SOC Stocks and erosion processes is evident, especially in arid conditions.

Results

	C1						C2					
	1977	1984	1999	2003	2007	2022	1977	1984	1999	2003	2007	2022
Dense woodland formations	13.4	13.4	13.9	14.6	14.5	533.5	-	-	-	-	-	49.8
*Grassland, scrubland**	1,061.3	1,039.9	1,017.4	1,014.5	991.9	423.3	1,197.4	1,195.6	1,114.8	1,098.3	1,086.0	1,033.4
Open areas with sparse vegetation	-	29.9	48.7	48.7	68.3	-	34.0	34.0	44.0	39.4	41.1	31.2
Rainfed areas	32.6	24.0	12.9	14.1	14.1	0.5	74.1	72.8	85.4	67.3	75.2	14.1
Rainfed areas: olive groves	-	-	3.5	3.5	3.5	53.3	-	-	47.0	36.6	36.6	9.4
Irrigated areas	-	-	-	-	-	-	68.6	70.5	65.7	61.5	60.8	3.9
Irrigated areas: tropical crops	-	-	11.0	11.0	11.0	24.4	-	-	6.2	48.2	46.1	184.3
Irrigated areas: greenhouses	-	-	-	-	-	-	-	-	-	1.0	2.8	-
Heterogeneous agricultural areas	-	-	-	-	-	66.2	165.6	166.8	169.6	180.0	180.1	192.4
Wet areas and water bodies	-	-	-	-	-	0.2	-	-	1.0	1.0	1.0	1.2
Construction sides	-	-	-	0.9	4.0	10.4	0.4	0.4	6.4	6.9	10.3	22.9

Evolution of the area (ha) of land uses in C1 and C2 from 1977 to 2022
**Grassland formations, scrubs, shrubs and herbaceous plants with or without trees.*



Current land uses (2022) in C1 (A) and C2 (B)

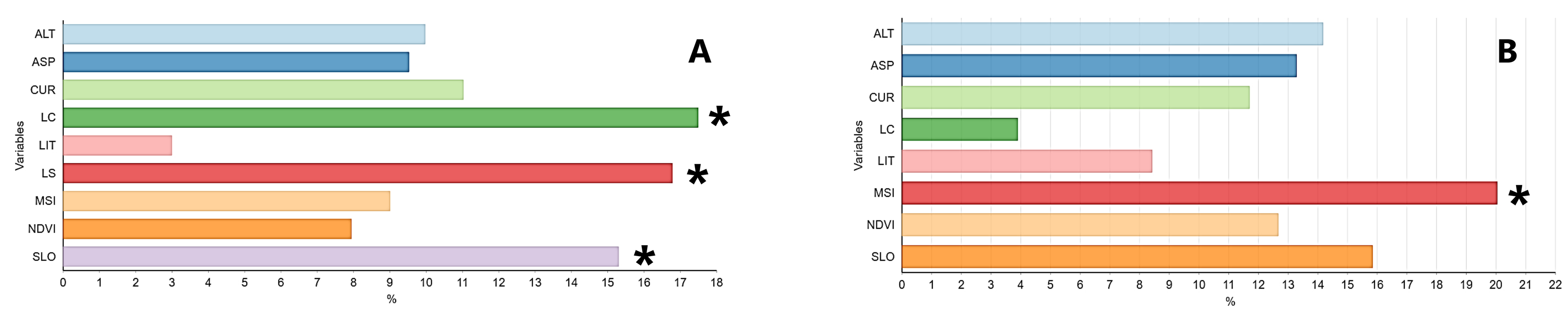
In C1, woodland formations have increased considerably at the expense of areas occupied by grassland. Similarly, agricultural areas have gained surface area, especially those under irrigation.

C2 has experienced a much more pronounced modification in agricultural lands, identifying a significant increase in tropical crops. Additionally, built-up areas have also seen strong expansion, especially in the last 20 years.

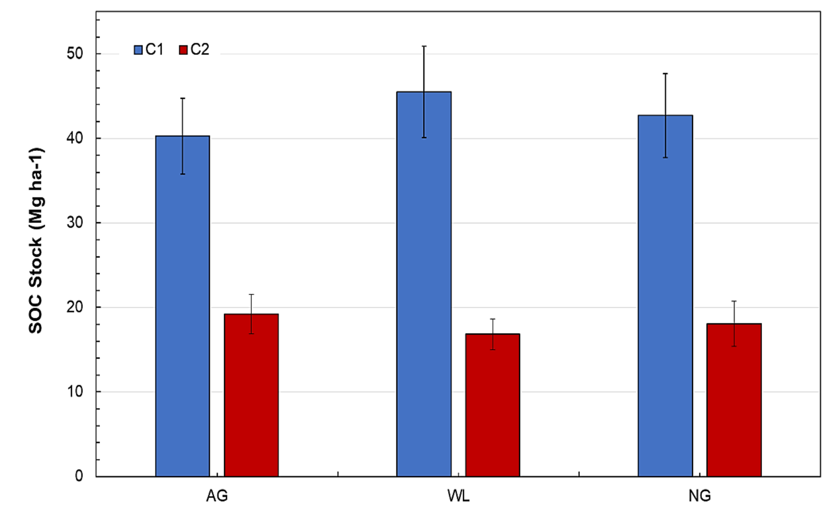
SOC Stocks (0-10 cm) (Mg ha-1) in C1 (A) and C2 (B)

The SOC Stocks values observed in C1 are more than double those in C2, where environmental conditions linked to aridity are a limiting factor for soil development.

From the RF prediction, SOC Stock distribution in C1 is influenced by variables associated with the physiography (LC, LS, SLO, CUR). Meanwhile, C2 places the most significance on variables related to the level of soil moisture (MSI).



Summary of variable importance (%) in C1 (A) and C2 (B) for SOC Stocks (Mg ha-1) modeling using Random Forest
ALT: Altitude; ASP: Aspect; CUR: Curvature Profile; LC: Land Cover; LIT: Lithology; LS: Factor LS-RUSLE; MSI: Moisture Stress Index; NDVI: Normalized Difference Vegetation Index; SLO: Slope



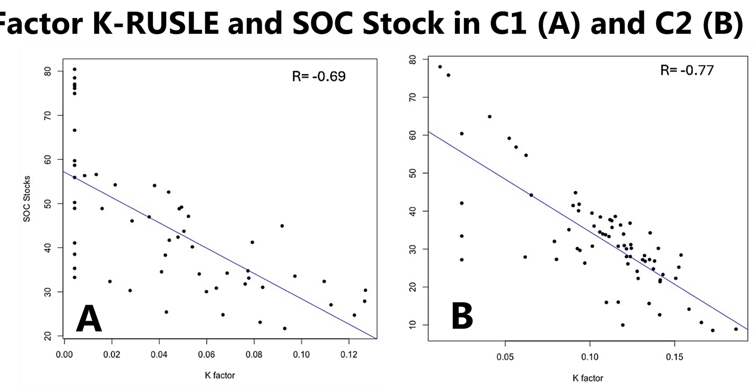
	C1		C2	
	X	*SD*	*X*	*SD*
AG	40.26	4.46	**19.21**	2.31
WL	**45.49**	5.43	16.85	1.83
NG	42.72	4.97	18.08	2.65

Graph and comparative table of SOC Stocks between C1 and C2 based on differents land uses
AG: Agricultural areas; WL: Woodlands; NG: Natural grassland.

WL are the formations with the highest SOC Stocks in C1, also being the most representative land use of the waterhed. On the other hand, AG is identified as the land use with the lowest SOC Stocks, mainly linked to rainfed agriculture with farming practices where bare soil surface predominates.
C2 exhibits a different dynamic. Agricultural areas, especially those under irrigation and where different tillage systems are applied, show higher SOC stocks in the top 10 cm of the profile, something that would likely change with depth. NG identifies very similar values.

Two-way correlation between Factor K-RUSLE and SOC Stock in C1 (A) and C2 (B)

The distribution of SOC Stocks is directly related to erosion processes in both watersheds. A very high negative correlation is observed between the K-Factor (RUSLE) and SOC Stocks, especially in arid conditions (C2, R = -0.77), where the most erodible soils are identified.



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