Biogeochemical characterization in the San Quintín mining area based on the NDV Index obtained through RPAS technology

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1. INTRODUCTION

The environmental issues caused by abandoned former mines, such as the San Quintín mining district, represent a major challenge due to soil and vegetation contamination by heavy metals such as lead, zinc, and cadmium. The San Quintín Mine is located in the southwest of the province of Ciudad Real, in the autonomous community of Castilla-La Mancha, Spain. For geolocation and navigation purposes, it is situated at 38°49’07’’ North latitude and 4°16’29’’ West longitude. *Quercus ilex* (holm oak) serves as a valuable bioindicator in these areas due to its capacity to accumulate metals. This study evaluates the interaction between soil and Quercus ilex using biogeochemical analyses and advanced technologies such as EDXRF and RPAS to map contamination distribution and propose ecological restoration strategies. Currently, the San Quintín area is undergoing an environmental restoration process led by the public company TRAGSA, and with the collaboration of IGeA-UCLM. This initiative focuses on ecological recovery, aiming to reintegrate the affected landscape and eliminate environmental risks associated to the abandonment of mine wastes.

2. METHODOLOGY AND ANALYSIS

The methodology for developing the biogeochemical characterization was carried out through multielemental analysis by X-ray fluorescence with energy dispersion (EDXRF), which allowed the determination of heavy metal concentrations in both soil and plant samples. Subsequently, a geostatistical treatment was applied to the obtained data, complemented with the creation of heat maps based on the NDVI index, calculated from images obtained using RPAS (Remotely Piloted Aircraft Systems) technology. All the methodology was applied to the elements of interest in each sample.

Figure 1.- Location of the study area

3. RESULTS

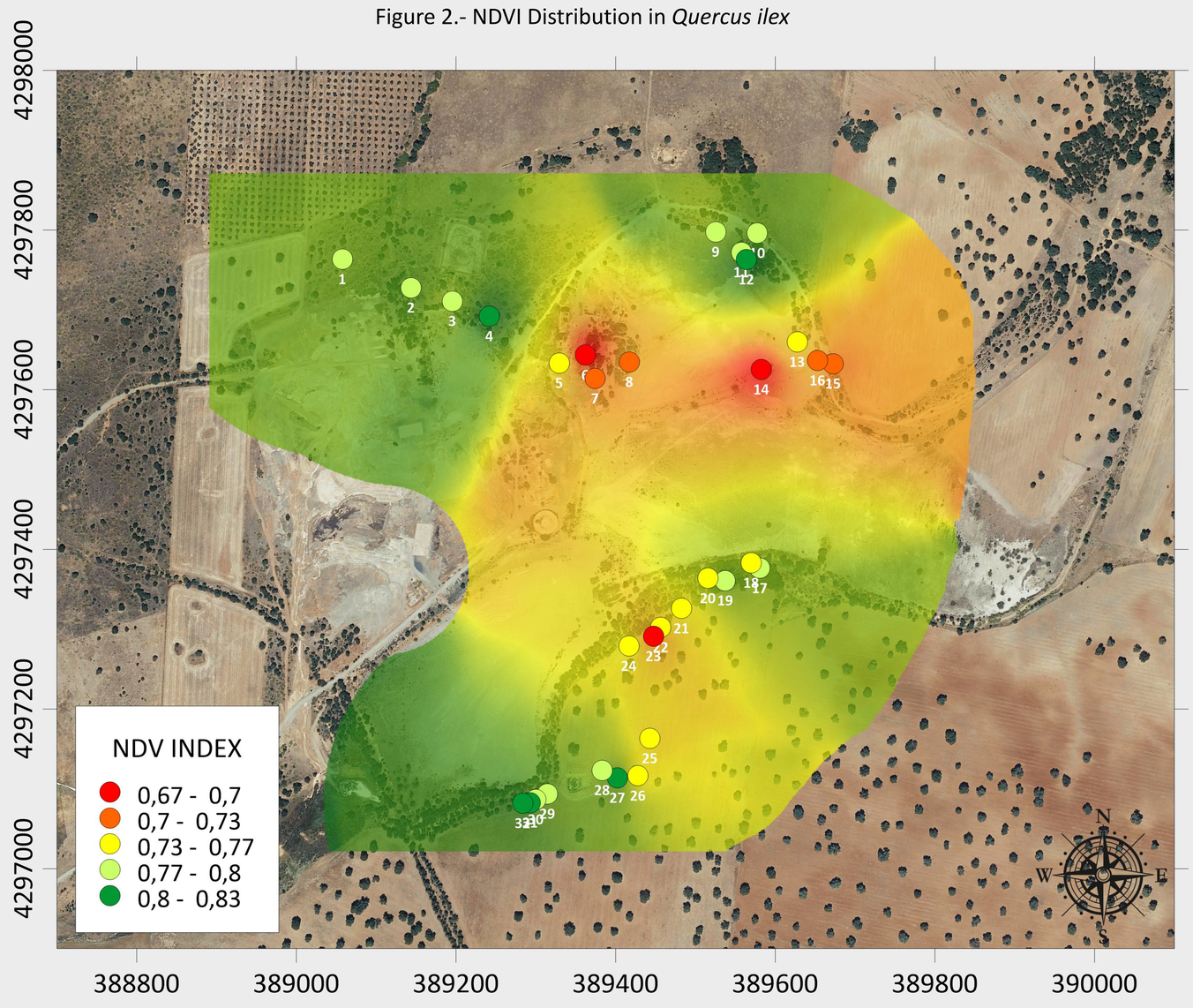
The Normalized Difference Vegetation Index (NDVI) values, obtained using RPAS technology for *Quercus ilex* in the mining area of San Quintín, ranged from 0.67 to 0.83. The lowest values were recorded near the mine waste dump (SQ-07: 0.72), indicating poorer plant health. In contrast, the highest values (SQ-12: 0.83) were found in more distant areas, towards the southwest of the study zone.

The spatial distribution of NDVI reveals a clear pattern: areas most affected by mining residues show lower NDVI values (red tones), while areas further away display higher NDVI values (green tones), indicating better physiological plant condition.

Among the nutrients analyzed, manganese (Mn) showed a positive correlation with NDVI. This micronutrient plays key roles in photosynthesis and oxidative stress defense. Its adequate presence is associated with better plant health in Quercus ilex, as reflected in higher NDVI values.

In contrast, NDVI tended to decrease with increasing levels of heavy metals such as lead (Pb), zinc (Zn), copper (Cu), and iron (Fe), suggesting a negative relationship between these elements and plant health.

Figure 2.- NDVI Distribution in *Quercus ilex*



4. CONCLUSIONS

Although mining activities ceased in 1998, soils in San Quintín mining area still exhibit elevated levels of heavy metals, particularly near waste dumps.

Quercus ilex shows physiological resilience, with no visible toxicity symptoms, but displays variable accumulation of nutrients and metals depending on location.

Manganese (Mn) is positively correlated with NDVI, highlighting its key role in plant health and photosynthesis.

NDVI decreases with higher concentrations of Pb, Zn, Cu, and Fe, indicating their negative impact on vegetation.

The ongoing ecological restoration will allow assessment of the intervention's effectiveness, using this study as a baseline reference.

4. REFERENCES

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