Exploring Cropmarks: Leveraging Spectral Physically-based Reflectance Models for Enhanced Archaeological Detection

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Introduction

The detection of buried archaeological remains through optical remote sensing imagery has become a widely adopted technique. Researchers have examined the use of satellite, airborne, and low-altitude platforms, which capture the spectral responses of vegetation growing over shallowly buried archaeological sites [1-2]. Findings indicate that such approaches are effective for mapping and detecting archaeological proxies (cropmarks) across extensive areas. However, limitations persist, largely due to phenological variations in crop growth and specific environmental and soil conditions. To address these challenges, this study aims to develop regional physically based reflectance models that provide insights into soil and plant properties closely associated with crop mark formation.

Methods and Materials

The study employs a comprehensive phenological ground spectral signature dataset, spanning 400 to 900 nm (covering the visible and near-infrared spectrum), collected from a simulated archaeological environment in Alampra, Cyprus, during the period between 2011–2012. This dataset is utilized to estimate the physical properties (soil and plant) of both stressed (i.e., cropmarks) and healthy crops based on the PROSAIL physical model [3-4].

Results

Preliminary findings [5] offer valuable insights into crop mark formation. The PROSAIL model is utilized to construct large datasets of physically-based simulations of the ground-truth spectral data, analyzed by machine learning classifiers, enabled the development of simple binary threshold criteria at specific narrow bands, achieving over 80% accuracy in distinguishing cropmarks from healthy crop spectral signatures. The results indicate that this method is robust and adaptable to various environmental conditions and archaeological settings.

Discussion

The overall findings suggest that employing physically-based models to study cropmarks could enhance archaeological prospection surveys and offer useful spectral boundaries for decision-making and (spectral) discrimination between cropmarks and healthy crops

spectral signatures. Further experiments are planned, involving additional spectral datasets over the same area and testing these findings in other archaeological contexts across Europe.

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References

[1] Czajlik, Z.; Árvai, M.; Mészáros, J.; Nagy, B.; Rupnik, L.; Pásztor, L. Cropmarks in aerial archaeology: New Lessons from an Old Story. Remote Sens. 2021, 13, 1126
[2] Opitz, R.; Herrmann, J. Recent Trends and Long-standing Problems in Archaeological Remote Sensing. J. Comput. Appl. Archaeol. 2018, 1, 19–41.
[3] Féret, J.B.; Gitelson, A.A.; Noble, S.D.; Jacquemoud, S. PROSPECT-D: Towards modeling leaf optical properties through a complete lifecycle. Remote Sens. Environ. 2017, 193, 204–215.
[4] Berger, K.; Atzberger, C.; Danner, M.; D'Urso, G.; Mauser, W.; Vuolo, F.; Hank, T. Evaluation of the PROSAIL model capabilities for future hyperspectral model environments: A review study. Remote Sens. 2018, 10, 85.
[5] Agapiou, A.; Gravanis, E. A Machine-Learning-Assisted Classification Algorithm for the Detection of Archaeological Proxies (Cropmarks) Based on Reflectance Signatures. Remote Sens. 2024, 16, 1705. https://doi.org/10.3390/rs16101705