

COMPARISON OF MULTISPECTRAL DATA FROM UAV AND SATELLITE IMAGERY FOR MONITORING THE VEGETATION STATUS OF GOLF COURSES

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<https://doi.org/10.11118/978-80-7701-087-0-0072>

Abstract

Recreational areas such as golf courses represent a specific type of landscape element whose maintenance requires intensive vegetation management, particularly in terms of irrigation, fertilization, and regular turf maintenance. Considering the environmental impacts of these activities, there is an increasing need for methods that enable more efficient and environmentally sustainable management of such areas.

This contribution focuses on the use of multispectral data for monitoring the vegetation condition of turfgrass areas on a golf course and compares different sources of remote sensing data. Specifically, data acquired from an unmanned aerial vehicle (UAV) DJI Mavic 3M and satellite systems Sentinel-2 and Planet are analyzed. The acquired imagery was processed into orthophotos and multispectral layers, from which selected vegetation indices (e.g., NDVI and GNDVI) were calculated.

The analysis focuses on comparing spatial resolution, level of detail, and the ability to identify spatial variability in vegetation condition among the different data sources. The results show that UAV imagery provides highly detailed information on local vegetation changes, while satellite data enable regular monitoring of vegetation development over a broader temporal scale. The combination of both approaches therefore represents a suitable tool for supporting the sustainable management of recreational areas, optimizing irrigation regimes, and reducing the excessive use of fertilizers and other environmental inputs.

Key words: UAV; multispectral imaging; vegetation indices; recreational landscape; golf courses; sustainable turf management; Sentinel-2; Planet; remote sensing

Introduction

The management of many golf courses is currently undergoing a fundamental transformation. Traditional uniform maintenance is gradually being replaced by a modern concept known as “precision turfgrass management” (Carlson, 2022). This approach utilizes advanced technologies to accurately map the condition of playing surfaces and subsequently apply water and fertilizers in a targeted manner. As a result, resources are not wasted on healthy turf but are directed exclusively to problem areas that genuinely require intervention (Straw, 2020).

Targeted application of inputs thus represents a response to increasing environmental sustainability demands while also generating significant economic savings due to its efficiency (Carlson, 2022; Caturegli, 2016).

A key prerequisite for implementing this concept in practice is the application of remote sensing methods. Zhang (2019) highlights the irreplaceable role of multispectral imaging in this context, as it enables the detection of vegetation stress before visible symptoms appear. The analysis of vegetation indices such as NDVI, GNDVI, and NDRE allows for precise quantification of vegetation vitality. The diagnostic potential of this approach has been confirmed by Caturegli (2016) and Zhang (2019), who demonstrated a strong correlation between vegetation indices, nitrogen content in plants, and overall turf health.

Based on these findings, considerable attention is currently devoted to selecting the optimal data acquisition platform. Golf course managers typically choose between unmanned aerial vehicles (UAVs) and satellite systems. The aim of this study is to compare the usability of UAV, PlanetScope, and Sentinel-2 data for efficient golf course management in accordance with the concept of precision turfgrass management.

Methods

The research was conducted at the Prague City Golf Zbraslav course, which represents a typical example of intensively managed sports turf with high demands for irrigation and fertilization. The total area of the eighteen-hole course is 1.81 km² (Figure 1A). The comparison of remote sensing data outputs (UAV, PlanetScope, Sentinel-2) was carried out at the level of hole no. 14 (Figure 1B), where two sub-areas were defined: green and fairway. It is assumed that the different management of these areas results in varying requirements for irrigation, fertilization, and maintenance intensity.

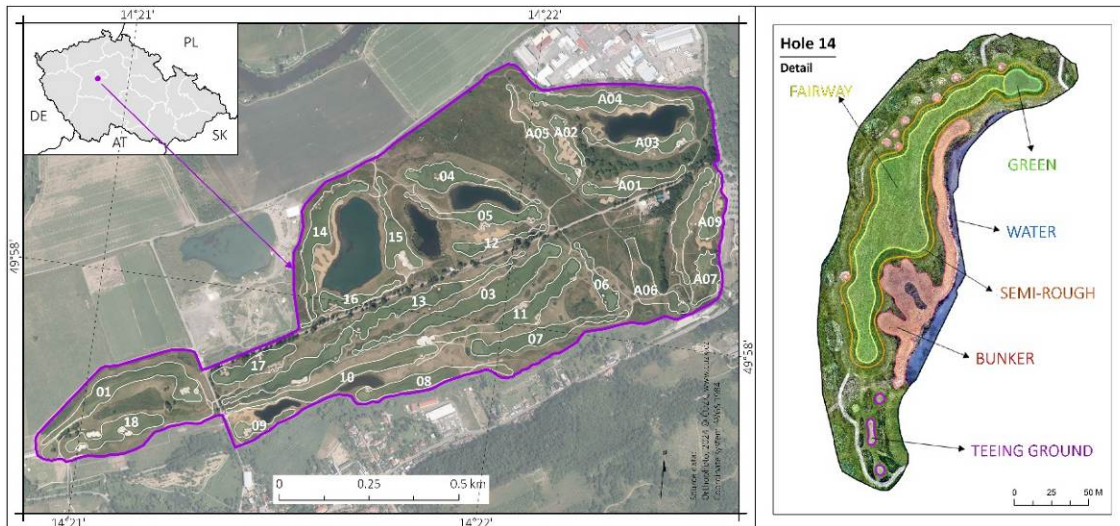


Fig. 1: Location of the study area

Overview and parameters of input data:

i) **Unmanned aerial vehicle (UAV):** Data were acquired on 23 October 2025 using a DJI Mavic 3M at an altitude of 120 m. The system is equipped with an RGB camera and four multispectral sensors. The resulting ground sampling distance (GSD) is 3.23 cm/pixel for the visible spectrum and 5.53 cm/pixel for multispectral bands (Green, Red, Red Edge, and NIR).

ii) **Sentinel-2 satellite (Copernicus):** As a representative of freely available data, an image acquired on 21 October 2025 was used. The system provides a spatial resolution of 10 m in key visible and near-infrared bands, while selected red-edge bands and derived indices have a resolution of 20 m.

iii) **PlanetScope constellation:** A representative of commercial satellite systems, PlanetScope imagery from 21 October 2025 was used, with a spatial resolution of 3 m/pixel. The unit price of archival data ranges approximately between 1.80–2.25 USD/km². However, the minimum purchase requirement is 250 km², resulting in a total acquisition cost exceeding CZK 13,000 for a single order. Satellite data were selected to temporally correspond with UAV flights. Due to orbital parameters and cloud cover conditions, the closest available cloud-free images were used to ensure a valid comparison.

Raw UAV data were processed into orthophotos using DJI Terra software. Subsequent analysis and comparison with satellite imagery were performed in ArcGIS Pro 3.6.2. The GNDVI (Green Normalized Difference Vegetation Index), utilizing near-infrared (NIR) and green bands, was selected to assess turf vitality due to its high sensitivity to chlorophyll content and its correlation with nitrogen concentration in biomass.

Results and Discussion

The analysis confirmed significant differences in spatial resolution (GSD) among the evaluated platforms. UAV imagery (3.23–5.53 cm/pixel) enabled precise detection of local turf defects and irregularities in input distribution. PlanetScope data (approximately 3 m/pixel) captured coarser variability across fairways. The spatial resolution of Sentinel-2 (10–20 m/pixel) proved to be limiting for precision turf management purposes (Figure 2).

The analysis also identified areas requiring more intensive intervention as well as zones in optimal condition. Locations with GNDVI values below the average of a given sub-area can be classified as priority zones for agronomic intervention. Conversely, areas with above-average index values indicate sufficient nutrient and water saturation, eliminating the need for uniform input application.

Conclusion

This study evaluated the applicability of remote sensing methods for precision turfgrass management. The results confirm that UAV technologies provide the most reliable identification of local areas requiring increased management attention. PlanetScope imagery with a spatial resolution of 3 m/pixel produces significantly more generalized values, and its application therefore requires a dedicated economic evaluation (cost versus information value compared to UAV data).

The use of Planet SkySat data should also be considered. Its spatial resolution of 50 cm/pixel represents a suitable compromise between highly detailed UAV imagery and coarser PlanetScope

data. Sentinel-2 imagery was found to be not suitable for high-resolution turfgrass management applications due to insufficient spatial detail.

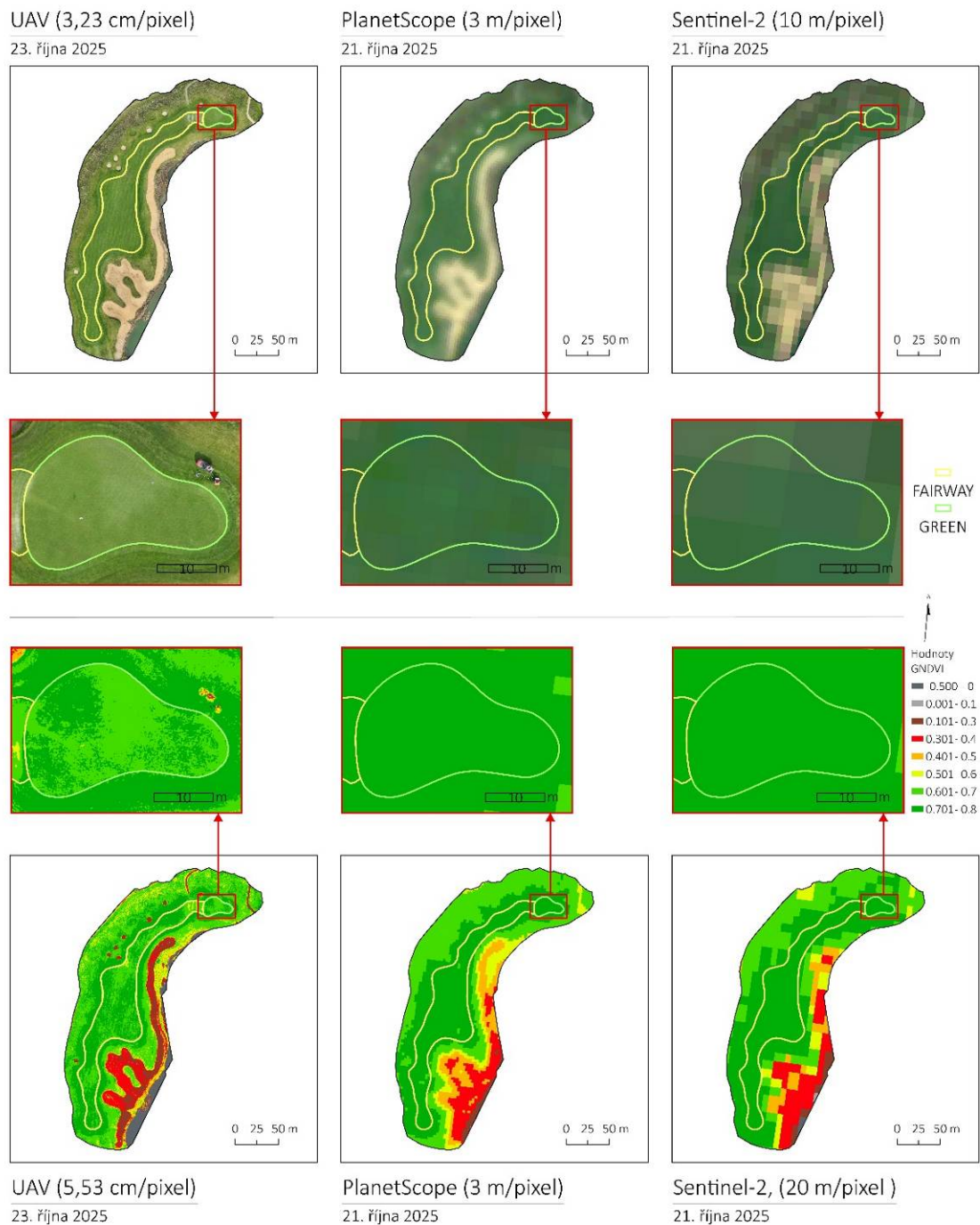


Fig. 2: Comparison of spatial resolution of data sources

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Acknowledgments

This study was supported by the project QL26020476 “Effective control of soil conservation technologies based on erosion monitoring” within the Programme for the Support of Applied Research of the Ministry of Agriculture of the Czech Republic for the period 2024–2032 (ZEMĚ II).

The study was also supported by the project CZ.01.01.01/0823_036/0005281 “CleverFarm, a.s. – Proof of Concept 2 – CleverIrrigation 2.0 – smart autonomous irrigation for urban parks and sports areas”, funded under the Operational Programme Technologies and Applications for Competitiveness by the Ministry of Industry and Trade of the Czech Republic.

Souhrn

Rekreační oblasti, jako jsou golfové hřiště, představují specifický typ krajinného prvku, jehož údržba vyžaduje intenzivní management vegetace, zejména pokud jde o zavlažování, hnojení a pravidelnou údržbu trávníku. S ohledem na environmentální dopady těchto aktivit roste potřeba metod, které umožňují efektivnější a environmentálně udržitelnější správu takovýchto ploch. Tento příspěvek se zaměřuje na využití multispektrálních dat pro monitorování stavu vegetace travnatých ploch na golfovém hřišti a porovnává různé zdroje dat dálkového průzkumu Země. Konkrétně jsou analyzována data získaná z bezpilotního letounu (UAV) DJI Mavic 3M a satelitních systémů Sentinel-2 a Planet. Pořízené snímky byly zpracovány do ortofotomap a multispektrálních vrstev, ze kterých byly vypočteny vybrané vegetační indexy (např. NDVI a GNDVI). Analýza se zaměřuje na porovnání prostorového rozlišení, úrovně detailu a schopnosti identifikovat prostorovou variabilitu stavu vegetace mezi různými zdroji dat. Výsledky ukazují, že snímky z UAV poskytují vysoce detailní informace o lokálních změnách vegetace, zatímco satelitní data umožňují pravidelné monitorování vývoje vegetace v širším časovém měřítku. Kombinace obou přístupů proto představuje vhodný nástroj pro podporu udržitelného managementu rekreačních oblastí, optimalizaci režimů zavlažování a snížení nadměrného používání hnojiv a dalších environmentálních vstupů.

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