sUAV GIS Integration: A Vegetation Health Study

Michelle A. Mannisto

South Dakota State University

Dr. Richard Stephans

GEOG 270: Introduction to Small UAS

12/13/2024

sUAV GIS Integration: A Vegetation Health Study

Small Unmanned Aerial Vehicles (sUAVs) and Geographic Information Systems (GIS) are transformative tools for environmental research. sUAVs collect high-resolution imagery, while GIS processes and visualizes large geospatial datasets. My earlier research on Prescott National Forest vegetation using satellite imagery was limited by low resolution, making it difficult to identify plant types. sUAVs overcome this challenge by providing detailed images that reveal plant types and health. This study explores the integration of sUAVs and GIS, workflows for plant health analysis, the benefits of combining these technologies, and some challenges in integrating the two technologies.

Overview of sUAV and GIS Technology

sUAV Technology

The sUAV has revolutionized various industries by offering cost-effective, versatile, and efficient data collection and monitoring solutions. These lightweight systems are equipped with advanced sensors such as RGB, multispectral, and LiDAR, enabling applications in agriculture, environmental monitoring, disaster response, and more (Colomina & Molina, 2014). Their ability to perform high-resolution aerial surveys at low altitudes has made them indispensable in fields requiring detailed spatial data (González-Jorge et al., 2017). As technology advances, sUAVs become increasingly accessible, fostering innovations in mapping, modeling, and automated operations (Aguera-Vega et al., 2017).

GIS Technology

GIS technology integrates spatial data with analytical tools to map, model, and manage geographic phenomena. GIS applications span fields like urban planning, environmental management, and disaster response, enabling users to visualize spatial patterns and relationships

(Goodchild, 2006). By combining geospatial data layers, GIS facilitates complex analyses, such as terrain modeling, resource allocation, and predictive mapping (Longley et al., 2015). Its integration with advanced technologies, including remote sensing and big data, has transformed decision-making processes. The accessibility of GIS has expanded with platforms like ArcGIS and QGIS, fostering innovation across disciplines, including sUAV piloting and data collection.

Data Collection Using sUAVs for Vegetation Health

According to Dronova et al. (2021), Pulakkatu-thodi et al. (2022), Eltner et al. (2022), and de Castro et. al. (2021), collecting data for sUAVs in vegetation health involves using drones equipped with advanced sensors, such as multispectral or hyperspectral cameras. These sensors capture high-resolution images and spectral data to assess plant health, stress levels, and growth patterns. By analyzing vegetation indices like NDVI, researchers can identify issues like pest infestations, nutrient deficiencies, or drought stress. UAVs enable rapid, cost-effective monitoring over large or inaccessible areas, providing actionable insights for precision agriculture, forestry, and ecological conservation.

Workflow for Vegetation Data Collection

Vegetation data collection with sUAVs follows a systematic workflow to ensure accuracy and efficiency (Dronova et al., 2021; Wich et al., 2022). See Figure 1 for a complete overview. The process begins with planning, including objective setting, site selection, and flight path design using software like Pix4D or DroneDeploy. Sensors like RGB, multispectral, or LiDAR are chosen, and necessary permissions are obtained. Before the flight, equipment is inspected and weather conditions are assessed. After the flight, data is processed to create orthomosaics or 3D models, and vegetation indices such as the Normalized Difference Vegetation Index (NDVI) are calculated. The results are visualized and integrated with other datasets to provide actionable insights for vegetation health monitoring and management.

Vegetation Health Indicators

Vegetation health indicators in sUAV imagery are derived from spectral, structural, and textural properties captured using RGB, multispectral, hyperspectral, or thermal sensors. Key indicators include vegetation indices like NDVI, Enhanced Vegetation Index (EVI), Normalized Difference Red Edge Index (NDRE), and Soil-Adjusted Vegetation Index (SAVI), which assess photosynthetic activity, stress, and soil reflectance. Canopy structure metrics, such as canopy cover and Leaf Area Index (LAI), provide insights into vegetation density and biomass. Thermal indicators, like canopy temperature, highlight water stress. Spectral reflectance patterns and visual cues like discoloration signal stress, disease, or nutrient deficiencies. These indicators enable precise vegetation health monitoring and management using sUAV technology (Dronova et al., 2021; Eltner et al., 2022; Solvi, 2023).

Application of GIS in Analyzing sUAV Data for Vegetation Health

GIS plays a key role in analyzing sUAV data for vegetation health by integrating spatial data from sensors, enabling detailed mapping and analysis across large areas (Dronova et al., 2021; Pulakkatu-thodi et al., 2022). It creates high-resolution vegetation health maps, correlates vegetation metrics with environmental factors like soil types and water availability, and helps diagnose stressors. GIS also supports temporal analysis to track changes over time and identify patterns, aiding site-specific management. UAV data integration with GIS enhances precision agriculture, conservation, and land management through data-driven decisions.

Importing and Processing sUAV Data in a GIS

According to Wich et al. (2022), importing and processing sUAV data into GIS starts with collecting high-resolution imagery or LiDAR data using sensors like RGB, multispectral, or hyperspectral cameras. The raw data is georeferenced with Ground Control Points (GCPs) for accuracy and processed using software like Pix4D or Agisoft Metashape to create products like orthomosaics or digital elevation models (DEMs). The data is then imported into GIS software (e.g., ArcGIS or QGIS) for further analysis. Vegetation health is assessed by calculating indices like NDVI, classifying vegetation, and overlaying other spatial data for comprehensive analysis.

Key Benefits of Integrating sUAV with a GIS for Vegetation Health Research

Integrating sUAVs with GIS provides key benefits for vegetation health research. UAVs capture high-resolution 3D data for precise mapping of vegetation structures, which helps identify stress or disease (Aguera-Vega et al., 2017). Combined with GIS, UAV-based remote sensing facilitates the creation of vegetation health indices like NDVI, allowing real-time monitoring and integration with other environmental data (Colomina & Molina, 2014). UAVs' high spatial and temporal resolution enables tracking of vegetation health over time, aiding early detection of stress, pests, or disease and supporting predictive models for vegetation management (Dronova et al., 2021).

Challenges and Limitations

However, this integration provides several challenges. A big challenge is data management, where large volumes of high-resolution imagery require significant storage and processing power. Georeferencing can also be difficult without accurate Ground Control Points (GCPs), impacting spatial accuracy. Weather conditions and flight restrictions can limit data collection, especially in harsh environments or regulated airspace. Additionally, sensor calibration is critical for reliable data, and errors can arise when integrating multiple sensor types. Technical expertise is needed to analyze complex datasets, which can be a barrier for some users (Colomina & Molina, 2014; Dronova et al., 2021).

Conclusion

Integrating sUAVs with GIS technology offers significant advancements in vegetation health research. By leveraging high-resolution imagery and powerful spatial analysis, researchers can monitor vegetation health, detect stress, and improve management strategies. Although challenges related to data management and regulatory constraints exist, the benefits—such as real-time monitoring, predictive modeling, and enhanced accuracy—are invaluable for agriculture, conservation, and environmental monitoring. This integration represents a transformative approach to vegetation health, providing a more comprehensive and data-driven understanding of plant conditions across landscapes.

References

Aguera-Vega, F., et al. (2017). Mapping and assessment of small-scale features in 3D using UAV photogrammetry. *Remote Sensing*, 9(7), 697. Retrieved December 4, 2024.

Colomina, I., & Molina, P. (2014). Unmanned aerial systems for photogrammetry and remote sensing: A review. *ISPRS Journal of Photogrammetry and Remote Sensing, 92*, 79–97. Retrieved December 4, 2024, from https://doi.org/10.1016/j.isprsjprs.2014.02.013

de Castro, A. I., Yeyin, S., Maja, J. M., & Peña, J. M. (2021). UAVs for Vegetation Monitoring: Overview and Recent Scientific Contributions. *Remote Sensing, 13*(11), 2139. Retrieved December 13, 2024, from https://doi.org/10.3390/rs13112139

Dronova, I., Kislik, C., Dinh, Z., & Kelly, M. (2021). A Review of Unoccupied Aerial Vehicle Use in Wetland Applications: Emerging Opportunities in Approach, Technology, and Data. *Drones, 5*(45). Retrieved October 28, 2024, from https://doi.org/10.3390/drones5020045

González-Jorge, H., et al. (2017). UAVs-based photogrammetry and remote sensing: A review. *Remote Sensing*, 9(12), 1170. Retrieved December 4, 2024.

Goodchild, M. F. (2006). GIS and public health. *The Professional Geographer*, *58*(3), 296-302. Retrieved December 4, 2024, from https://doi.org/10.1111/j.1467-9272.2006.00572.x

Longley, P. A., et al. (2015). *Geographic Information Science and Systems.* Wiley. Retrieved December 4, 2024.

Pulakkatu-thodi, I., Dzurisin, J., & Follett, P. (2022). Evaluation of macadamia felted coccid (Hemiptera: Eriococcidae) damage and cultivar susceptibility using imagery from a small unmanned aerial vehicle (sUAV), combined with ground truthing. *Pest Management*

Science, *78*(11), 4533-4543. Retrieved October 28, 2024, from https://doi.org/10.1002/ps.7073

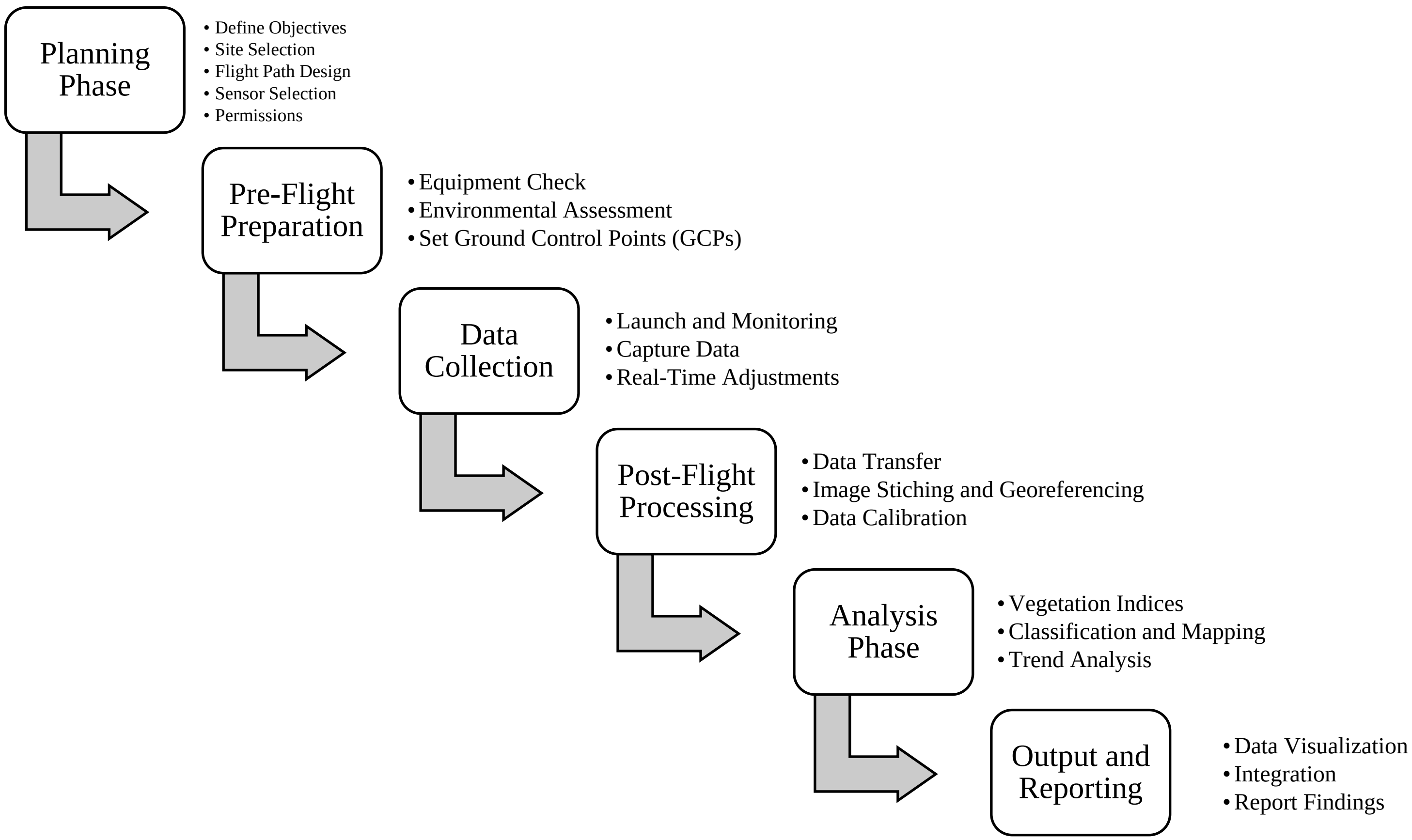
Solvi. (2023, March 10). *Which Vegetation Index Should I Use?* Solvi. Retrieved December 13, 2024, from https://solvi.ag/blog/which-vegetation-index-should-i-use/#:~:text=Commonly%20used%20multispectral%20vegetation%20indices,in%20health%20between%20individual%20plants

Wich, S. A., Spaan, D., Pintea, L., Delahunty, R., & Kerby, J. (2022). 4.8 UAVs in conservation research. *UAVs for the Environmental Sciences*, 403. Retrieved October 28, 2024, from https://core.ac.uk/download/pdf/572225244.pdf#page=404

Figures

Figure 1.

Flow chart showing the workflow for vegetation data collection using sUAVs. It begins with the planning phase, then the pre-flight preparation phase, the data collection phase, the post-flight processing phase, the analysis phase, and, lastly, the output and reporting phase.



Word Count: 1,459