

Assessment of UAV-Based Remote Sensing for Environmental Surveillance

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Abstract: Unmanned Aerial Vehicles (UAVs) have become indispensable tools for modern environmental surveillance due to their agility, cost-effectiveness, and ability to acquire high-resolution spatiotemporal data. This review evaluates the major technological, operational, and analytical components of UAV-based remote sensing and its applications across environmental monitoring domains. UAVs equipped with multispectral, hyperspectral, thermal, and LiDAR sensors enable detailed observations of vegetation health, water quality, soil conditions, wildlife distribution, and disaster-affected regions. The integration of geospatial analytics, machine learning algorithms, and cloud data platforms further enhances the interpretability and accuracy of UAV-derived information. Despite their advantages, UAV systems face challenges related to regulatory restrictions, limited battery endurance, weather sensitivity, data processing complexity, and the need for standardized methodologies. The review synthesizes current research findings to highlight the strengths and limitations of UAV-based environmental surveillance and identifies emerging trends such as swarm UAV systems, AI-driven image interpretation, and real-time mapping through edge computing. The study concludes that UAVs will continue to expand their role in environmental studies, making monitoring systems faster, more adaptive, and more data-rich.

Keywords: UAV Remote Sensing, Environmental Monitoring, Geospatial Analysis, Aerial Imaging, Ecological Surveillance

1. Introduction

UAVs have become a central component of modern remote sensing frameworks due to their high flexibility, rapid deployment ability, and superior ground sampling resolution. Unlike satellites, UAVs can capture imagery at low altitudes with minimal cloud interference, making them ideal for environmental monitoring applications [1]. Over the last decade, UAVs have significantly contributed to studies on vegetation dynamics, hydrology, wildlife surveillance, pollution assessment, and disaster management [2]. Their ability to generate high-density spatial data and integrate with analytical platforms has established them as indispensable tools for environmental sciences. This paper assesses UAV technologies, sensing modalities, environmental applications, challenges, and future development prospects

2. UAV Platforms and Sensor Technologies

UAVs used for environmental surveillance primarily include fixed-wing drones, rotary-wing drones, and hybrid VTOL systems. Fixed-wing UAVs provide long endurance and are suitable for large-area mapping, whereas rotary-wing platforms excel in maneuverability and low-altitude imaging [2]. The type of sensor mounted on the UAV determines the quality and relevance of environmental observations. Multispectral and hyperspectral sensors enable vegetation health analysis using indices such as NDVI and EVI, which have been widely used in ecological and agricultural monitoring [3]. Thermal sensors support wildfire detection, water temperature assessment, and heat leakage mapping in urban ecosystems [4]. LiDAR systems provide high-accuracy elevation models essential for soil erosion mapping, flood modelling, and forest canopy density estimation [5]. The fusion of these

sensors generates detailed environmental datasets surpassing traditional field-based methods in speed and spatial coverage.

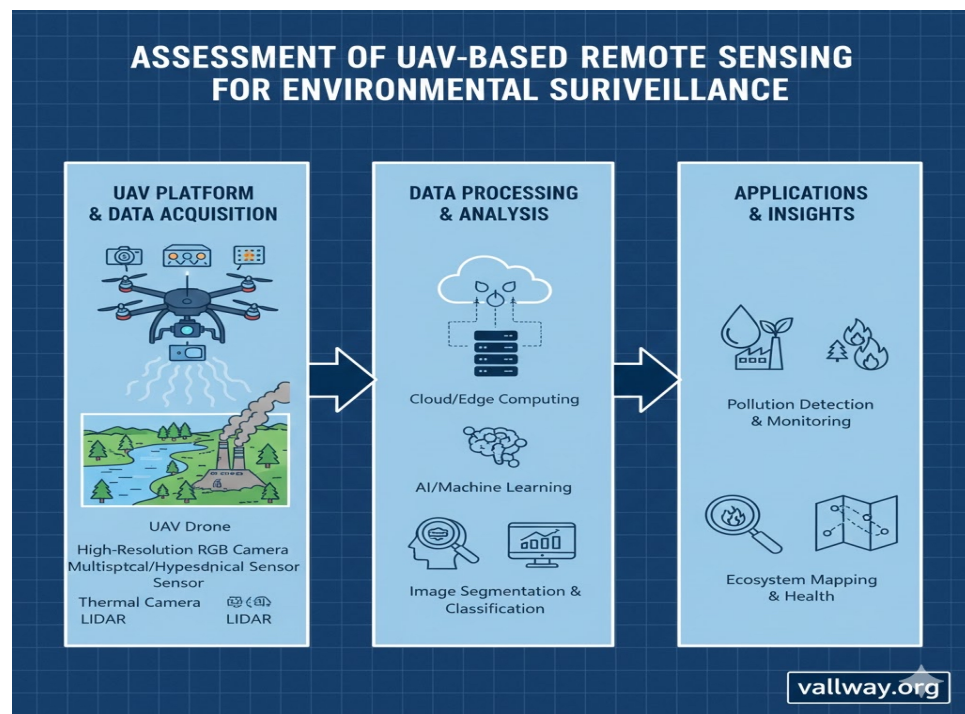


Fig. 1 UAV Based Remote Sensing

3. Applications in Environmental Surveillance

UAVs have demonstrated significant utility in vegetation assessment, offering precise mapping of crop stress, disease spread, and biomass variation. Nebiker et al. [3] showed that UAV hyperspectral imagery provides resolution unattainable by satellite platforms. In water resource monitoring, UAVs can track turbidity, algal blooms, and pollution dispersion in near real time [4]. Thermal and multispectral imagery have proven particularly effective in identifying contaminated water inflows. UAVs support wildlife monitoring through animal detection algorithms, heat signatures, and population mapping techniques. According to Christie et al. [1], UAV imagery reduces human-wildlife conflict risks by limiting direct interaction. In disaster management, UAVs deliver rapid situational awareness post-floods, landslides, and cyclones, providing high-resolution imagery for emergency response planning [5]. Additionally, UAV-based air quality sensing allows localized pollution assessment, which is often impossible with sparsely distributed ground sensors.

4. Data Processing, Interpretation, and Analytics

UAV imagery typically requires complex data preprocessing, involving radiometric correction, georeferencing, stitching, and orthomosaic generation. Machine learning models, including CNNs and SVMs, are increasingly used to classify land cover, detect anomalies, and automate ecological assessments [2]. Cloud and edge computing help address the heavy computational requirements by enabling real-time processing and reducing latency [4]. Recent advancements in AI-based image segmentation have accelerated the mapping of forest canopy gaps, burned areas, and shoreline changes [3].

5. Challenges and Operational Limitations

Despite their growing relevance, UAV systems face operational and technical challenges. Regulatory restrictions on altitude, flight zones, and beyond-visual-line operations often limit deployment [1]. Weather conditions such as rain and strong winds may disrupt data collection. Battery limitations reduce flight duration, especially for rotary-wing drones, affecting large-area surveys [2]. Processing high-resolution imagery creates a computational burden, requiring advanced workstations or cloud resources. Data privacy and security risks also arise during

environmental monitoring in populated regions [4]. Standardization of UAV methodologies remains an ongoing concern.

6. Conclusion

UAV-based remote sensing has transformed environmental surveillance by providing highly accurate, flexible, and cost-effective data acquisition mechanisms. The combination of advanced sensing technologies, AI-driven analytics, and geospatial modelling expands its applicability across ecological, agricultural, hydrological, and disaster-management sectors. Although challenges related to regulations, weather, and data processing persist, technological advancements continue to improve UAV efficiency and reliability. UAVs will increasingly serve as foundational tools for environmental research and sustainable ecosystem management.

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