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The Use of Drones in Environmental Monitoring and Conservation

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ABSTRACT

Unmanned Aerial Vehicles (UAVs), often referred to as drones, have significantly transformed the methods of environmental monitoring and conservation. This work examines the technical progress in drone technology, its usage in environmental monitoring, and the barriers related to its implementation. Drones provide exceptional possibilities for comprehensive, real-time data gathering in difficult-to-reach locations, ranging from animal monitoring to evaluations of forest and water quality. Notwithstanding these advantages, obstacles like as data ownership, privacy constraints, and the exorbitant expenses of equipment and data processing continue to be substantial. Furthermore, the study explores forthcoming developments, such as the incorporation of drones with the Internet of Things (IoT) for immediate habitat monitoring, which have the potential to augment the functionalities of drones in conservation endeavours.

Keywords: Drones, UAVs, Environmental Monitoring, Conservation, Wildlife Tracking, Forest Monitoring.

INTRODUCTION

Drones, also called UAVs or UAS, are increasingly used for versatile applications. They offer an efficient and cost-effective method for environmental monitoring and conservation. Low-cost, high-quality drones are enabling widespread adoption in environmental science. They have the potential to serve as integrated systems for data collection and investigation. As drones become more accessible, there are opportunities for development in other fields. However, challenges like data ownership and surveillance need to be addressed [1]. Drones monitor environment: air, water, soil, waste. Sensors used for forests & biodiversity. Drones explore inaccessible areas. Future: IoT drones for real-time examination of habitats. Smartphone app controls drone system for site evaluation & solutions [2]. Drones enhance agency efforts to manage resources, benefitting civil society and small landholders. More education and training opportunities are needed, as well as outreach initiatives for conservation efforts. Ethical issues surrounding data ownership and privacy violations arise. The future of drone reign is a high-stake gamble with potential environmental benefits or unforeseen consequences [3].

TECHNOLOGICAL ADVANCEMENTS IN DRONE TECHNOLOGY

Over the last two decades, environmental monitoring and protection has become an important issue. Pollution, climate change, and biodiversity loss are just some of the many concerns that need to be addressed to ensure the survival of both Planet Earth and humanity as a whole. Whole scientific disciplines have emerged in response to these worries, resulting in more and more research and new fields of academic inquiry. In this context, the technological advancements that have taken place in the commercial drone market in the last ten years are looked upon with hopes of aiding conservationists in their efforts [4]. Discussions on the social, ethical, and ecological impacts of commercial drone technology in environmental monitoring are lacking in the literature. Limitations and caveats of drone use are mentioned, but the majority of the literature is optimistic. Questions arise regarding practical applications and the inaccessibility of some literature. This inaccessibility could widen the gap of injustice in environmental monitoring [5]. The systematic review of the available scientific literature on remotely piloted aerial vehicles (RPASs) or drones in environmental monitoring and protection should serve as a

source for answering these questions and concerns. Outdoor drone use is examined, but research on compact drones not meant for outdoor use is also included, as it provides important insights into some of the challenges faced in monitoring environments where traditional drones cannot operate [6].
Commercial drone technology has advanced rapidly, which has resulted in cheaper, efficient, and lightweight drones equipped with high-quality sensors, such as digital, infrared, and multispectral cameras capable of acquiring high-resolution aerial images in RGB and thermal wavelengths, active sensors that use lasers to produce topographical models, or high-frequency RGB cameras capable of producing aerial videos. As a result, the available literature on the use of drones in environmental monitoring and protection has surged together with these advancements [7]. Overall, with the increase in sensor payloads, the area covered, and flight lengths (with high-capacity batteries, flying time has long been increased beyond an hour), the increased automaticity of flight planning (now drones are capable of fully autonomously planning their flights and routes according to overlapping), and data acquisition (in many cases, continuous data acquisition is guaranteed throughout the flights thanks to the meticulously crafted software packages that are included with a drone purchase), have made it easier for conservationists to try using drones in their research. The majority of recent studies successfully tested drones for environmental monitoring or protection, and applied drone-generated data and data products to inform decisions and policy-making processes [8].

APPLICATIONS OF DRONES IN ENVIRONMENTAL MONITORING

Drones, or UAVs, are powerful tools for environmental monitoring and conservation. They have applications in wildlife tracking, forest monitoring, and vegetation characterization. They are used with tracking technologies to locate animals and record their locations. Drones equipped with thermal cameras can find tortoises. They are also used for tracking oceanic animals like turtles and whales. In vegetation monitoring, drones are more mobile than terrestrial devices and can cover extensive areas. They capture color images to extract data on patch characteristics and vegetation types. This data is compared to terrestrial measurements and shows good performance [9].

WILDLIFE TRACKING AND CONSERVATION

Conservationists use drones for wildlife tracking to improve efficiency and accuracy. Drones offer an alternative to costly helicopters and aircraft, generating topographic surveys and aiding wildlife tracking. Rapid advancements in drone technology have allowed for high-resolution image collection. However, progress is needed in loaded capacity, endurance, autonomy, funds, and sensor systems. Ground-based telemetry techniques are limited for highly mobile species, making wildlife tracking challenging. Manned small aircraft with radio telemetry stations are an option but are costly and require trained personnel. The use of drones for wildlife monitoring is a low-cost alternative that has gained interest. Drones have been used to count bird colonies, estimate marine mammal abundance, and monitor wildlife populations. They can be used with VHF telemetry systems for large-scale population monitoring. Simulations demonstrate accurate population assessment using this approach [10].

FOREST AND VEGETATION MONITORING

The degradation of forests and vegetation due to climate change and urbanization poses environmental challenges. Monitoring their health based on optical characteristics using remote sensing is of interest. Passive sensors measure radiation to assess the surface's properties. Multi and hyperspectral imaging on drones allows for low-cost monitoring at a higher resolution. They can retrieve key health descriptors and have been used in case studies on mangroves, forests, and reforested areas. Challenges and future perspectives of drone-based monitoring are discussed. Drones are popular for their accessibility and ability to collect detailed data, including disease detection. Forest health assessments using drones validate their use for monitoring [11].

WATER QUALITY ASSESSMENT

Drones can assess water quality using visible and near-infrared spectral bands, as demonstrated in a study conducted at Patoca Lake in Brazil. The study utilized a UAV with a Multi-Spectral Camera, controlled by a software package for mapping applications. The collected data were used to create georeferenced map products, which revealed distinct vegetation states in the areas [12]. The water background reflectance was estimated using the Dark Pixel method, georeferenced into the water mask, and calibrated to black pixels and clear-sky imagery. The calibrated image was subjected to atmospheric correction to compute remote sensing reflectance, rescue high-frequency variations, and apply topographic correction. A previous study highlighted formulas to estimate several water quality parameters in inland water bodies and conduct comparisons between reflectance and in situ data. The water quality in Patoca Lake was divided into four parameters: total suspended solids (TSS), chlorophyll-a concentration (CC), Secchi disk depth (SDD), and floating macrophytes deposition (FMD) [13]. The Swirgo's formula was chosen to estimate SDD, while Sweeney's formula was chosen to estimate TSS and CC. The match-ups between the parameter estimates and in situ provided r^2, slope, intercept, and root mean square error (RMSE) values of 0.88, 0.82, 0.98, and 27.95 for TSS; 0.88, 0.91, 1.80, and 5.39 for CC; 0.84, 0.82, -0.13, and 0.37 for SDD; and 0.67, 0.77, 5.54, and 18.11 for FMD. The models accurately estimated two parameters (TSS and CC), while SDD estimates should be used with caution. It was highlighted that Sweeney's model required further calibration for similar lakes, while Swirgo's model could be tested for similar flat environments [14].

CHALLENGES AND LIMITATIONS

Despite the advantages of using drones for environmental monitoring, there are drawbacks and limitations. This includes the high cost of drones and the complexity of collecting and analyzing data. Many drone suppliers do not provide assistance with data processing, requiring users to have trained staff or hire consultants. Additionally, processing high-resolution data requires expensive hardware. Cameras and remote sensors are cheaper than before, but still more costly than traditional monitoring gear. Some areas of research lack solutions for drone use. Standard operations and performance specifications for drones in environmental applications are undefined. Future developments should prioritize meeting user requirements and avoiding errors. There are still limitations compared to conventional approaches, and further development is needed for on-board sensors and data processing [6].

FUTURE TRENDS AND OPPORTUNITIES

Drones are a valuable solution for environmental sustainability. UAVs with CMOS cameras collect land-use data for machine learning techniques. Low-cost UAVs and optimized camera sensors improve data acquisition [15]. Research on drones for environmental monitoring and oil spill detection is complex and focused. Studies show that drone detection is feasible and promising, with emphasis on small multi-rotor drones and machine vision systems. Bayesian methods provide exact results for modeling oil spill size and environmental parameters, allowing for probabilistic sensitivity zone maps and minimizing environmental impact [6]. Drone modeling is essential for visual monitoring of an oil spill. Simulations conducted using COMSOL software can help track the spill and determine the sensor's sensing zone. The project also includes modeling a mobile platform with a fixed payload imitating a drone using a Kalman filter for accurate position prediction. Currently, the project is in the discussion stage, focusing on modeling priorities and developing a future course of action [16].

CONCLUSION

The use of drones in environmental monitoring and conservation represents a significant technological leap forward, providing conservationists with powerful tools for data collection and analysis. While drones offer numerous advantages, such as cost-effectiveness, accessibility, and the ability to monitor hard-to-reach areas, challenges related to data privacy, ownership, and the costs associated with sophisticated equipment and data processing need to be addressed. As drone technology continues to evolve, integrating it with IoT systems and improving sensor capabilities will be crucial for enhancing environmental conservation efforts. However, ethical considerations and regulatory frameworks must keep pace with these advancements to ensure that the deployment of drones in environmental monitoring is both effective and responsible.

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