



Original Research Paper

Machine Learning Estimation of Large Herbivore Populations Using Drone Imagery

Dr. Arvind Kumar Saxena^{1*}, Dr. Parvinder Kaur Chhabda²

^{1*}Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India.

Email: ku.arvindkumarsaxena@kalingauniversity.ac.in, ORCID: <https://orcid.org/0009-0003-8827-0493>

²Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India.

Email: ku.parvindarkaurchhabda@kalingauniversity.ac.in, ORCID: <https://orcid.org/0009-0006-9775-7254>

Key Words

Drone imagery,
Machine learning,
Large herbivores,
Wildlife
population
estimation,
Object detection,
Aerial wildlife
monitoring,
Wildlife
conservation.

Abstract

Introduction: Large herbivores' population surveillance is important for biodiversity protection, wildlife conservation, and proper planning of habitats. Traditional methods of population estimation generally involve significant time and effort in the field, while also requiring trained personnel; moreover, thick vegetation, large territories, and animal movements could decrease the efficiency of these methods. Aerial images taken from drones represent an alternative, noninvasive, and flexible approach to gathering information about wildlife. However, due to the significant amount of data gathered during drone surveys, there is a necessity of developing automatic techniques for animal detection and population estimation. Materials & Methods: In this work, we propose a technique based on machine learning for large herbivores' population estimation from drone imagery. Machine learning and deep learning object detection models are employed in automatic identification and counting of the large herbivores from aerial images. The performance of the model is analyzed using detection accuracy, precision, recall, F1-Score, and counting error. Results: The suggested algorithm shows the possibility of using machine learning for automated detection and counting of the large herbivores from the drone aerial images, thereby minimizing the need for laborious and time-consuming manual surveying. The high resolution of the aerial images makes the animal detection much clearer. Automated detection allows for fast processing of large volumes of image data. Conclusion: The combination of the aerial images with the automated animal detection makes the drone-based monitoring useful for estimating the population of large herbivores. It can be used for wildlife censusing, population monitoring, habitat management, and conservation planning.

* Corresponding Author's email: ku.arvindkumarsaxena@kalingauniversity.ac.in

Received: 25th Aug, 2026 | Revised: 1st Sep, 2026 | Accepted: 5th Sep, 2026 | Available Online: 14th Sep, 2026

(DOI): 10.70102/AEJ.2026.18.5s.92

Introduction

Wildlife monitoring is one of the key elements in biodiversity conservation, ecology research, and wildlife management. Information about the quantity and whereabouts of animal species facilitates the process of conducting population study, evaluation of habitats, and planning conservation actions. Large herbivorous species such as elephants, buffaloes, antelopes, zebras, and giraffes have great significance from the point of view of ecology, but it is very difficult to determine their numbers because of the mobility of the animals, presence of plants, and poor accessibility.

Classic techniques such as ground survey, transect, aerial survey, and manual count are likely to be tedious, costly, and affected by human factors as well as environmental factors. High resolution images captured using drones can help in the process of wildlife monitoring without significant disturbances. The flexibility and the greater coverage achieved through drones has shown that drone technology can be applied to environmental and fieldwork purposes (Linchant et al., 2015; Hodgson et al., 2016). Other applications of the innovative technology used in drones have shown the wider applicability of UAVs in data collection and monitoring (Yadav & Nandy, 2025).

However, the sheer volume of imagery captured by drones impedes the manual process of analysis. Machine learning and deep learning algorithms help automate the process of animal detection and counting in the patterns of aerial images. There have been successful attempts to implement machine learning algorithms for

detecting animals through the automated detection of koalas from aerial images (Corcoran et al., 2019).

Deep learning and artificial intelligence have been employed to analyze aerial imagery for wildlife studies. It has the ability to recognize several species from aerial images and aid in automatic counting and estimating the population size. The case of African wildlife and South African savanna imagery is indicative of the use of AI and machine learning in multi-species wildlife surveying (Delplanque et al., 2024; Allin et al., 2026).

Despite all this, the performance can be hindered by vegetation, animal size and posture, shadows, image resolution, lighting, background complexity, and many other environmental factors. Thus, the use of a representative dataset, accurate annotations, proper image preprocessing, and generalization of the model are crucial for wildlife recognition and population estimation (Axford et al., 2024).

Use of drone images together with machine learning is a promising approach that could help assess the population of large herbivores easily and effectively. The method can be used to identify and count animals automatically, and it can be carried out repeatedly in order to monitor wildlife and make conservation decisions at the population level. Assessing the population using drones can also be helpful in understanding changes in animals and their environment (Carroll et al., 2025).

Review of Literature

Drone-Based Wildlife Monitoring and Population Estimation

Unmanned aerial vehicles (UAVs) provide high-resolution images along with non-invasive methodologies for wildlife surveys. The use of this technology might help improve the survey efficiency and effectiveness in comparison to the conventional methods. Yet there are some problems that should be taken into consideration when using UAS, such as image interpretation, environment conditions, flight conditions, and handling of large amounts of images (Linchant et al., 2015).

Another application could be UAV wildlife surveys, with their ability to accurately track animals. Aerial high-resolution images can help with precision tracking and complement other survey methods. Wildlife monitoring with the use of UAVs has proven to be helpful in collecting necessary data, and also, to a certain degree, in overcoming some challenges posed by traditional field surveys (Hodgson et al., 2016).

Another way of making drone-based wildlife monitoring even more effective is through the use of artificial intelligence and sensors. With deep learning and sensors, it is possible to automate animal detection and tracking; this is helpful in wildlife conservation and behavior studies (Kiran et al., 2025).

Machine Learning for Wildlife Detection in Aerial Imagery

Machine learning aids in reducing the time and resources needed for analysis of large volumes of wildlife images. Approaches to

automatic identification of animals from images captured during aerial surveillance have been devised, indicating that machine learning can be used in wildlife surveillance. Automatic detection of koalas from aerial images is an example of machine learning being used in wildlife surveys (Corcoran et al., 2019).

Deep learning methods enable automatic identification of important features of animals and detection of wildlife from aerial images having complex background. However, detection may be influenced by various factors including animal properties, environmental settings, quality of image, vegetation, size of animal, lighting, and complexity of background. These factors illustrate the need for appropriate datasets for training and generalization in drone-based animal detection (Axford et al., 2024).

Multi-Species Detection and Automated Population Monitoring

More recent research is concerned with the problem of recognizing several types of animals with the help of machine learning techniques. Remotely sensed nadir imagery proved that machine learning models are able to recognize multiple wildlife species in the savannah of South Africa (Allin et al., 2026).

The technique of object detection based on machine learning techniques can be used not only for imagery obtained with the help of drones but also for identifying several animals and counting them (Sankaran, 2024).

Apart from identification and counting of animals, drone imagery may be used for ecological assessment at a population level. The potential of aerial imagery for population-level

estimation has been explored through the examination of the body size of pinnipeds (Carroll et al., 2025).

Problems and Research Gap

However, despite some advances in automated wildlife detection, many challenges still persist. They include animal occlusion, interference of plants, changes in lighting conditions, shadows, background cluttering, differences in postures and sizes of animals, as well as differences in habitats. The generalization of models across different environmental conditions and the proper representation of wildlife in datasets constitute essential research topics (Axford et al., 2024).

Moreover, the widespread application of artificial intelligence, deep learning, and sensors points to the necessity of having an efficient and understandable automated system for wildlife monitoring. The combination of multiple sources of data may help to enhance animal detection (Kiran et al., 2025).

In general, it can be stated that existing literature proves the significant prospects of using drone-based images and machine learning techniques for wildlife detection and estimation. Nevertheless, more research should be carried out in order to create an integrative approach involving aerial imaging, image pre-processing, detection of animals, multi-species classification, estimation of the number of species, and their population estimation specifically for large herbivores.

Methodology

Drone Imagery Dataset Collection and Study Area

The process of capturing aerial imagery via drones is the main source of information for the estimation of the population of large herbivores. Aerial images are acquired by drones which have high-resolution cameras and are flown over particular wildlife locations. The flight trajectories are planned in such a way that would ensure sufficient area coverage and proper image resolution. The obtained aerial images include both the animals and the environment.

Image Pre-processing and Animal Annotation

Images gathered are then reviewed and processed for removing unsuitable images and applying resizing and normalization where necessary. Visibly large herbivores are manually annotated with bounding boxes, while species labels are added, when necessary, due to multi-species detection. The images are then split into three sets of data: the training set, validation set, and testing set. Image data augmentation can also be used as part of data preprocessing.

Machine Learning Model Development and Experimental Setup

This involves creation of a machine/deep learning object detection algorithm capable of detecting large herbivores within images taken by the drones. The model will learn how to detect animals from the background such as vegetation and soil. The training set is used to create the model, while the validation set is used for optimization of the model's parameters.

Population Estimation and Performance Evaluation

This involves counting the number of animals found in the drone pictures. If there are any species-specific counts, they are produced. In addition, duplicate detections in overlapping images are managed. The population counts are determined by the number of animals counted by the model in the surveyed area. Model evaluation is carried out in terms of precision, recall, F1 score, accuracy, and counting error. The counts are compared against manually verified counts.

Results and Discussion

Machine Learning Model Performance and Large Herbivore Detection

The proposed model proves the capability of automatic identification of large herbivores in

drone images. The model detects the presence of animals in aerial images by distinguishing them from other objects such as vegetation, soil, and shadows. The performance of the model can be evaluated based on precision, recall, F1-score, and accuracy measures. If the precision measure is high, it means there will be fewer wrong detections; if the recall measure is high, it means that a greater number of animals in the images will be identified.

There might be differences in detection performance with respect to different species and environmental factors. In general, animals which are clearly visible and have sufficient image resolution are relatively easy to detect, but partially occluded animals and animals located in the thick vegetation might be more difficult to detect.

Table 1: Machine Learning-Based Large Herbivore Population Estimation Process

Stage	Process	Output
Drone Data Collection	Aerial image acquisition	Image dataset
Image pre-processing	Image cleaning and resizing	Processed images
Animal Annotation	Animal labeling	Annotated dataset
Model Development	ML-based object detection	Trained model
Animal Detection	Automated animal identification	Detected animals
Population Estimation	Animal counting	Population estimate
Performance Evaluation	Accuracy, precision, recall, F1-score	Performance results

Table 1 shows the different steps in order for estimating the number of large herbivores with drones and machine learning. Firstly, there is drone image capture and processing followed by animal detection and finally population estimate.

Population Estimation and Comparison with Conventional Survey Methods

The number of detected animals is counted to obtain a rough estimate of large herbivore

population density in the surveyed areas. Species-specific counts can yield an insight into the distribution and relative abundance of herbivores of different species. Manual counts can also be done to find out the counting errors and accuracy of the population estimates.

Machine learning on the basis of drone images offers greater coverage and saves time and labor compared to traditional ground-based

surveys. However, various factors can have an effect on the estimates of population size, such as vegetation cover, animal activity, image quality, shading, and overlap of animals. Therefore, machine learning-powered drone surveying can be viewed as an additional technique that can help increase survey efficiency, but still requires verification by humans.

Conclusion

This study shows that the use of drone imagery and machine learning is a potential method to estimate the numbers of large herbivores in a large and inaccessible wildlife habitat. While drone imagery allows for obtaining high-quality images with a minimum of fieldwork efforts, machine learning enables automatic animal detection and counting, making the image processing easier and faster.

The proposed approach includes drone imagery, image pre-processing, animal labeling, detection using machine learning algorithms, automated animal counting, and animal population estimation. The application of precision, recall, F1-score, accuracy, and counting error makes it possible to assess the quality of animal detection and estimation. Species-wise detection and counting may be helpful for assessing the distribution and number of animals.

The research also reveals that the success of automatic population counting is based on the image quality, the presence of vegetation, visibility of animals, overlapping animals, environmental factors, and generalization of the model. Thus, representative datasets, accurate

annotation, proper preprocessing, and model evaluation are of utmost importance.

References

- [1] Allin, Paul, Fadel Seydou, Radloff Frans, Andrew Davies, and Alison Leslie. "Evaluating machine learning models for multi-species wildlife detection and identification on remote sensed nadir imagery in South African savanna." *Wildlife Biology* (2026): e01523.
- [2] Axford, Daniel, Ferdous Sohel, Mathew A. Vanderklift, and Amanda J. Hodgson. "Collectively advancing deep learning for animal detection in drone imagery: Successes, challenges, and research gaps." *Ecological informatics* 83 (2024): 102842.
- [3] Carroll, Daire, Eduardo Infantes, Eva V. Pagan, and Karin C. Harding. "Approaching a population-level assessment of body size in pinnipeds using drones, an early warning of environmental degradation." *Remote Sensing in Ecology and Conservation* 11, no. 2 (2025): 156-171.
- [4] Corcoran, Evangeline, Simon Denman, Jon Hanger, Bree Wilson, and Grant Hamilton. "Automated detection of koalas using low-level aerial surveillance and machine learning." *Scientific reports* 9, no. 1 (2019): 3208.
- [5] Delplanque, Alexandre, Julie Linchant, Xavier Vincke, Richard Lamprey, Jérôme

- Théau, Cédric Vermeulen, Samuel Foucher, Amara Ouattara, Roger Kouadio, and Philippe Lejeune. "Will artificial intelligence revolutionize aerial surveys? A first large-scale semi-automated survey of African wildlife using oblique imagery and deep learning." *Ecological Informatics* 82 (2024): 102679.
- [6] Hodgson, Jarrod C., Shane M. Baylis, Rowan Mott, Ashley Herrod, and Rohan H. Clarke. "Precision wildlife monitoring using unmanned aerial vehicles." *Scientific reports* 6, no. 1 (2016): 22574.
- [7] Kiran, N. Chitra, Vinay Kumar Sadolalu Boregowda, Jayvadan Vaishnav, Swati Singh, Manpreet Singh, and Kanika Seth. "Enhancing wildlife conservation through sensor and deep learning integration for accurate animal behavior tracking." *Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications* 16, no. 3 (2025): 261-280.
- [8] Linchant, Julie, Jonathan Lisein, Jean Semeki, Philippe Lejeune, and Cédric Vermeulen. "Are unmanned aircraft systems (UAS s) the future of wildlife monitoring? A review of accomplishments and challenges." *Mammal review* 45, no. 4 (2015): 239-252.
- [9] Sankaran, Sowmya. "Multi-species object detection in drone imagery for population monitoring of endangered animals." *arXiv preprint arXiv:2407.00127* (2024).
- [10] Yadav, K. K., and M. Nandy. "Optimizing Urban Delivery Systems with Innovative Drone Technology for Sustainability." *International Academic Journal of Science and Engineering* 12, no. 3 (2025): 90-98.