Assessing Insect Biodiversity and Activity Patterns in Tropical Forests Using Entomological Lidar and Hierarchical Clustering Analysis

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Introduction

Virgin forests are vital for ecosystem health, and insects are crucial indicators of environmental well-being. Our research group has developed an entomological Lidar system, a remote sensing method to identify and profile insects in-flight, which provides valuable insights into their ecology and behavior[1]. This study investigates insect diversity and activity patterns across different canopy layers in the Taï virgin forest, Côte d'Ivoire, to aid in developing effective forest management strategies.

Methods

This study was conducted over three days in the Taï rainforest, where a near-infrared polarization Lidar system was deployed to scan the forest at various elevation angles.

This allowed us to map insect activity across different heights and provided a detailed view of the forest structure. For comparison, we also used conventional traps, including Malaise traps, zipline traps, and sweep netting. To analyze the Lidar data, we applied Hierarchical Clustering Analysis (HCA), an unsupervised machine learning technique[2]. HCA groups insect signals based on similarities in their modulation spectra[3,4], which correlates with observed insect diversity.

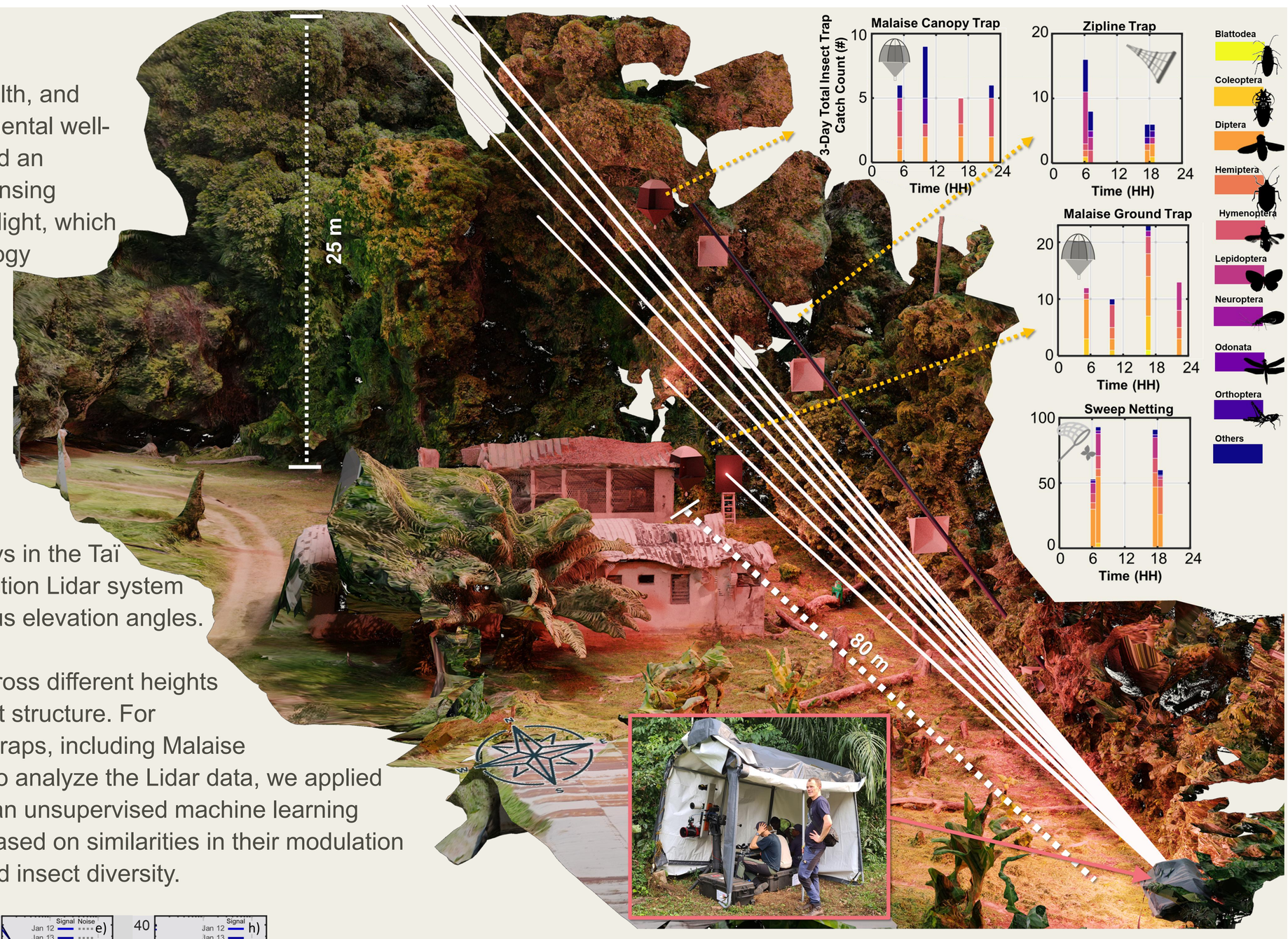


Fig. 1: A 3D-rendered representation of the experimental site showing the Lidar beams and trap locations.

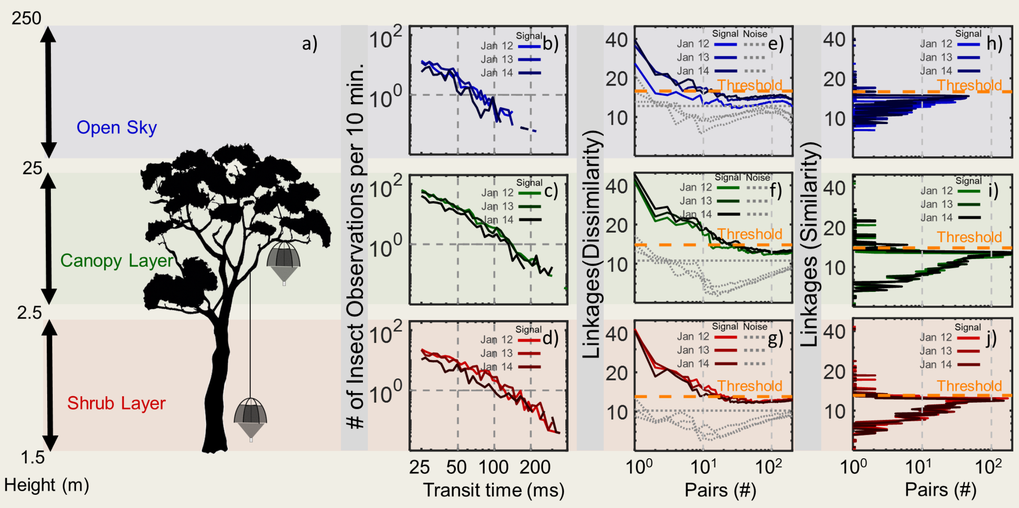


Fig. 2: Linkage values from the Hierarchical Clustering Analysis (HCA) are shown for each forest layer, with a threshold (dashed line) used to determine the number of insect clusters.

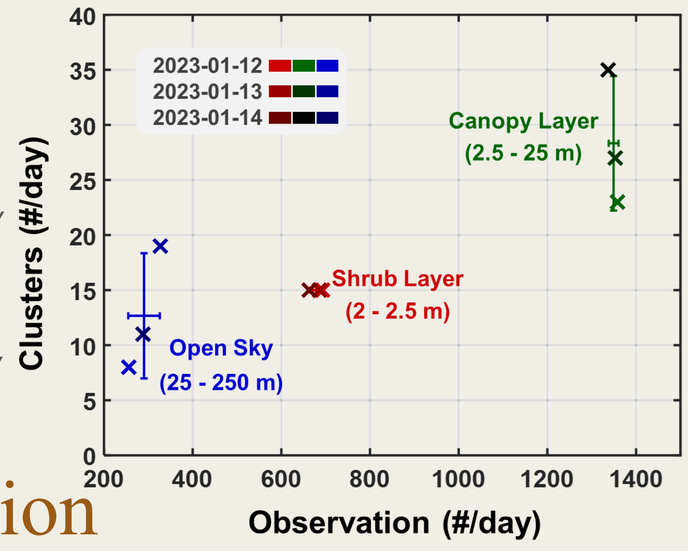


Fig. 3: Biodiversity estimates for the different forest layers are shown over the three-day study period.

Conclusion

Our study demonstrates that insect activity and biodiversity vary significantly across different forest layers and times of day. The application of HCA to Lidar data provides a robust method for assessing biodiversity and uncovering patterns that are valuable for ecological understanding and conservation.

Results

Over three days, the Lidar system recorded 19,369 insects, while the manual traps collected only 417, a difference of nearly two orders of magnitude. Our findings reveal stratified patterns of insect activity at distinct heights. The canopy layer (2.5 to 25 m) showed the most consistent insect activity throughout the day and night. HCA identified 129 distinct insect clusters, with the canopy layer consistently showing the highest number of observations and clusters. This highlights its importance for diversity. Based on signal characteristics, we made taxonomic inferences for some clusters; for instance, some likely represented mosquitoes and others could represent Odonata or Lepidoptera.

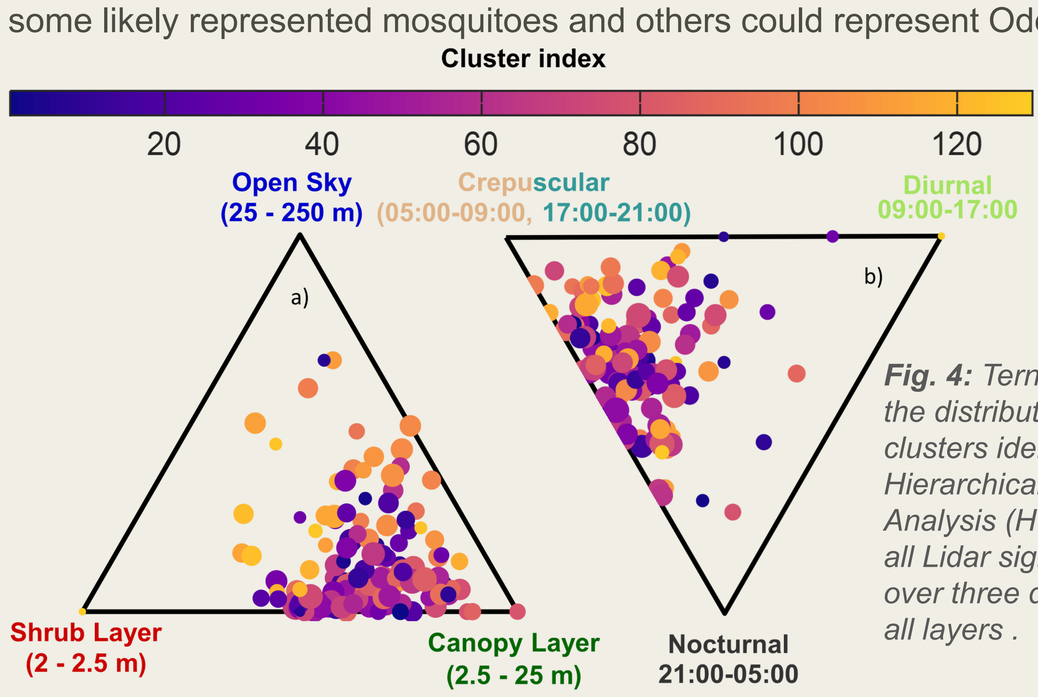
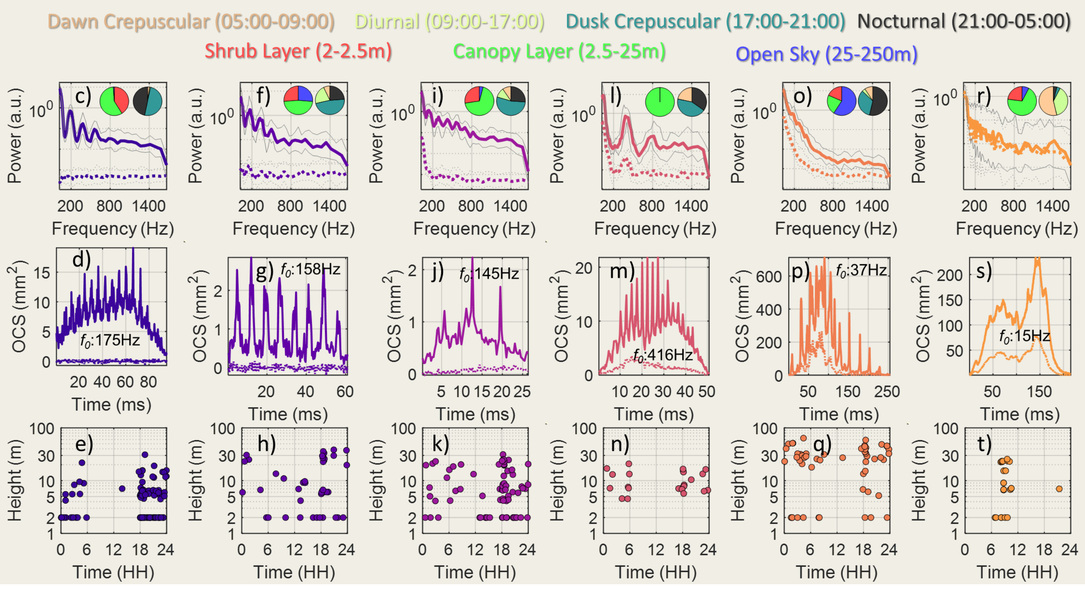


Fig. 4: *Ternary plots visualize the distribution of 129 insect clusters identified by Hierarchical Clustering Analysis (HCA) performed on all Lidar signals captured over three days and across all layers .*



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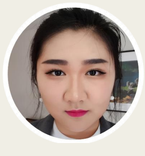

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References

1. Kouakou, Benoit & Jansson, Samuel & Brydegaard, Mikkel & Zoueu, Jeremie. (2020). Entomological Scheimpflug Lidar For Estimating Unique Insect Classes In Situ-Field Test From Ivory Coast. OSA Continuum. 3. 10.1364/OSAC.387727.
2. F. Murtagh and P. Contreras, "Algorithms for hierarchical clustering: an overview," Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery, vol. 2, no. 1, pp. 86-97, 2012.
3. D. Bernenko, M. Li, H. J. Månefjord, Samuel, A. Runemark, and C. B. Kirkeby, Mikkel, "Insect Diversity Estimation in Polarimetric Lidar," 2024
4. A. S.-D. Yamoa et al., "Lidar Reveals Distinct Insect Daily Activity and Diversity Between Habitats. ," (Submitted), 2025.

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