Remote sensing-based detection of BSNB: A comprehensive review and UAV-based, spatially explicit assessment

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Introduction

- Brown Spot Needle Blight (BSNB) poses a significant threat to loblolly pine (*Pinus taeda*) forests in the southeastern United States, with outbreaks reported in 36 of Alabama's 67 counties (Alabama Forest Commission, 2022).
- The disease continues to spread, necessitating quarantine measures and early detection strategies for effective management.
- Ground surveys are essential for pathogen detection and support phytosanitary and forest management efforts, but they are spatially limited and subject to assessor variability.
- Remote Sensing (RS) offers a complementary approach to field-based methods, enabling broader and more consistent monitoring than ground-based assessments.
- RS techniques have been applied to detect and map *Dothistroma* Needle Blight (DNB) and Pine Wilt Disease (PWD), but research on RS-based BSNB detection remains limited.
- This presentation integrates a systematic literature review with a UAV-based multispectral detection study to evaluate RS methods for BSNB and identify remaining research gaps.

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BSNB Symptomatology

How does it look?

BSNB symptoms initially manifest as chlorotic flecks on needles; these progress to resin-soaked necrotic bands and lesions. As infection advances, needles turn brown and are shed prematurely, leading to defoliation.

Symptoms of Brown Spot Needle Blight (*Lecanosticta acicola*) on loblolly pine (*Pinus taeda*).(a) Close-up of infected needles showing chlorotic flecks, banding, and necrotic lesions. (b) symptomatic shoot with needle discoloration, lesion formation, and early defoliation.

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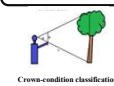
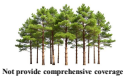
Problem Statement

Why Remote Sensing?

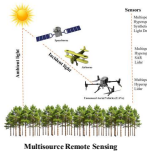
Traditional Methods (Ground-based assessments) → **Challenges** (Labor-intensive, time-consuming, small scale) → **Remote Sensing** (Multi-source data) → **Goal** (Enhanced monitoring, early intervention)



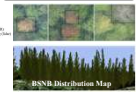
Crown-condition classification



Not provide comprehensive coverage



Multisource Remote Sensing



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Study Objective and Research Questions

This study integrates a systematic literature review with a UAV-based multispectral detection study to evaluate current remote-sensing (RS) methods for BSNB and to define the remaining research gaps.

Specific objectives

(i) Quantify the extent to which RS can detect and monitor BSNB across spatial scales.

(ii) Identify advantages and limitations of RS approaches from other pine-needle diseases (e.g., DNB, PWD) and their applicability to BSNB.

(iii) Apply UAV-borne multispectral imagery with machine-learning classifiers to detect and map healthy and BSNB-infected pine trees.

(iv) Evaluate point-cloud–derived metrics from UAV multispectral data for individual tree detection (ITD) to estimate infected-tree density.

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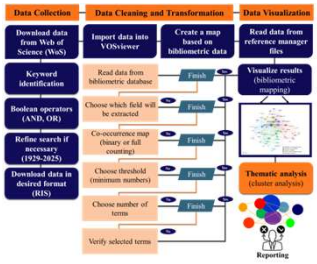
Methodology (Literature Review)



Methodology Flowchart.

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Methodology

Search criteria and publication results.

Seach Criteria	Purpose	Publications
"Pine Needle Diseases"	Recent publication trend for BSNB	653
"*Lecanosticta acicola*" OR "*Mycosphaerella dearnessii*" OR "*Scirrhia acicola*" OR "Brown Spot Needle Blight" AND "Detection Methods" AND "Remote Sensing"	Specific focus on BSNB detection using RS	84
"Pine Needle Disease" AND "Remote Sensing"	General remote sensing applications in pine disease detection	173

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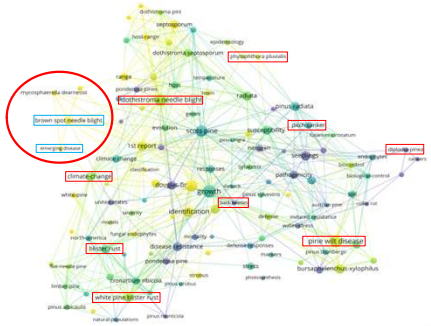
Results



VOSviewer

Bibliometric network visualization of needle disease research trends.

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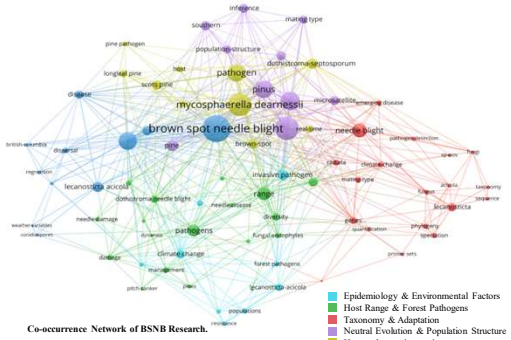
Results



VOSviewer

Co-occurrence Network of BSNB Research.

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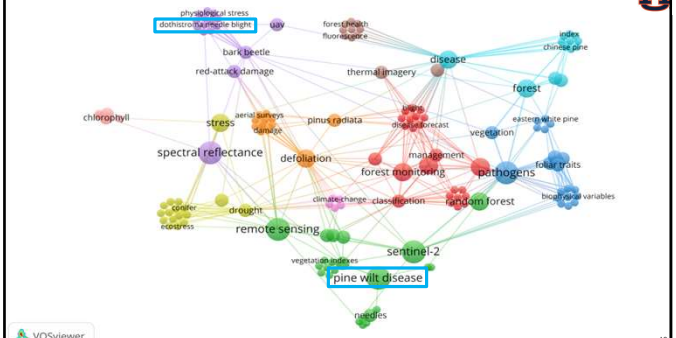
Results



Remote sensing applications in the study of pine needle diseases.

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Key Findings

- Bibliometric analysis shows limited research on RS applications for BSNB detection, despite its established use in *Dothistroma* Needle Blight and Pine Wilt Disease studies.
- RS-based approaches for DNB detection have demonstrated effective utilization of spectral data, while PWD monitoring has integrated machine learning techniques for improved classification accuracy.
- Although geospatial analysis has been applied to BSNB in climate studies, its integration with RS for direct disease detection and monitoring remains unexplored.
- Combining RS-based classification and machine learning methods could enhance early detection and tracking of BSNB, providing a more comprehensive approach to disease management.
- This study highlights the need for future research to optimize RS-based methodologies, refine predictive models, and integrate multi-source data to improve BSNB monitoring and risk assessment.

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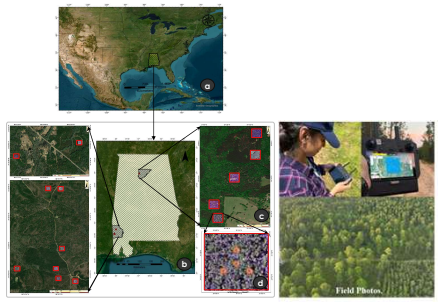
Study Area



(a) Spatial overview of Alabama study areas. (b) County locations (Cullman, Washington). (c) Plot extends over high-resolution basemaps. (d) Field-sampled tree positions used for ITD validation.

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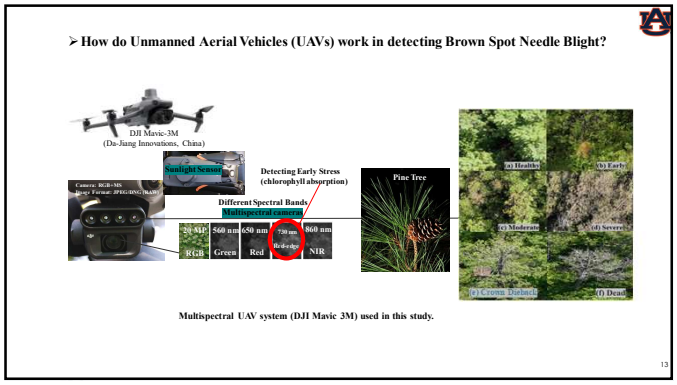
How do Unmanned Aerial Vehicles (UAVs) work in detecting Brown Spot Needle Blight?
DJI Mavic-3M
(Da-Jiang Innovations, China)
Sunlight Sensor
Camera: RGB+MS
Image Format: JPEG/DNG /RAW
Detecting Early Stress
(chlorophyll absorption)
Different Spectral Bands
Multispectral camera
20 MP
RGB
560 nm
Green
650 nm
Red
730 nm
Red-edge
860 nm
NIR
Pine Tree
(a) Healthy
(b) Early
(c) Moderate
(d) Severe
(e) Current Outbreak
(f) Dead
Multispectral UAV system (DJI Mavic 3M) used in this study.
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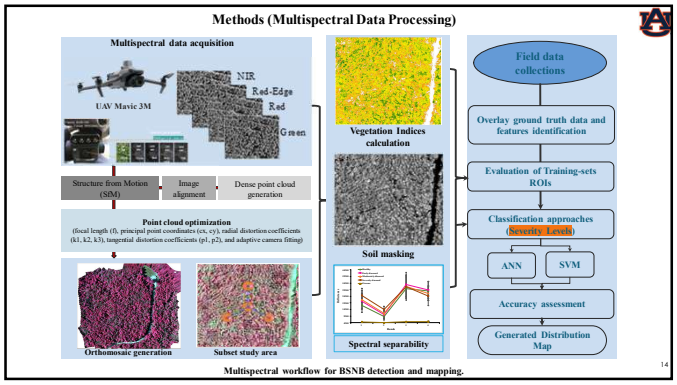
Methods (Multispectral Data Processing)
Multispectral data acquisition
UAV Mavic 3M
NIR
Red-Edge
Red
Green
Structure from Motion (SfM)
Image alignment
Dense point cloud generation
Point cloud optimization
(focal length (f), principal point coordinates (cx, cy), radial distortion coefficients (k1, k2, k3), tangential distortion coefficients (p1, p2), and adaptive camera fitting)
Orthomosaic generation
Subset study area
Vegetation Indices calculation
Soil masking
Spectral separability
Field data collections
Overlay ground truth data and features identification
Evaluation of Training-sets ROIs
Classification approaches (Severity Levels)
ANN
SVM
Accuracy assessment
Generated Distribution Map
Multispectral workflow for BSNB detection and mapping.
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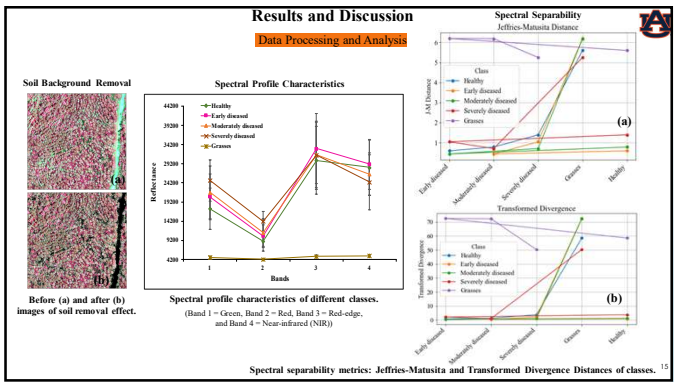
Results and Discussion
Data Processing and Analysis
Soil Background Removal
(a)
(b)
Before (a) and after (b) images of soil removal effect.
Spectral Profile Characteristics
Healthy
Early diseased
Moderately diseased
Severely diseased
Grasses
Reflectance
Bands
Spectral profile characteristics of different classes.
(Band 1 = Green, Band 2 = Red, Band 3 = Red-edge, and Band 4 = Near-infrared (NIR))
Spectral Separability
Jeffries-Matusita Distance
JM Distance
(a)
Transformed Divergence
Transformed Divergence
(b)
Spectral separability metrics: Jeffries-Matusita and Transformed Divergence Distances of classes.
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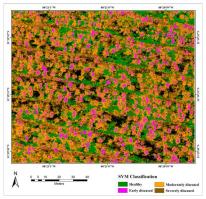
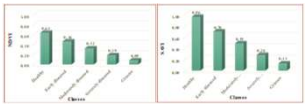
Classification Results



SVM Classification.

Showing accuracy assessment of ANN and SVM classification.

Accuracy Results (Average of 9 Plots)	
Artificial Neural Network (ANN)	**Support Vector Machine (SVM)**
Overall Accuracy: 91.64%	Overall Accuracy: 92.48%
Kappa Coefficient: 87.89%	Kappa Coefficient: 89.14%



Optimal Spectral Indices for Disease Classification and Severity Levels.

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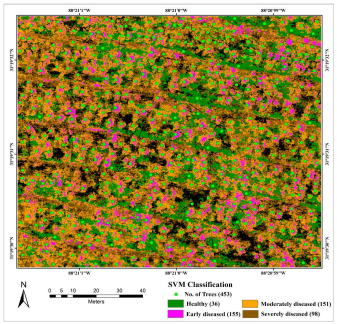
Individual Tree Detection (ITD)



BSNB severity distribution map with individual tree detection.

Multispectral-Metrics for Individual Tree Detection (ITD).

Accuracy Metrics	Results	Accuracy Metrics	Results
True Positive (TP)	463	False Positive (FP)	85
False Negative (FN)	304	True Negative (TN)	22
Precision	0.85	Recall	0.61
F-score	0.71	Omission Error	0.39
Commission Error		1.16	

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Conclusions

- UAV-based multispectral imagery enables effective detection of BSNB severity in loblolly pine.
- Support Vector Machine slightly outperformed Artificial Neural Network in classification accuracy.
- Spectral profiles confirmed clear differences between healthy and diseased crowns, especially in red and red-edge bands.
- Individual Tree Detection achieved strong precision but lower recall, highlighting room for improvement.
- Approach provides a scalable, non-invasive tool for forest health monitoring and management.
- Ongoing Work: Combine light detection and ranging (lidar) with our UAV multispectral data to better detect BSNB and its structural impacts at the tree level.
- Then scale up with satellite data (e.g., Sentinel-2) to monitor BSNB across larger areas over time.

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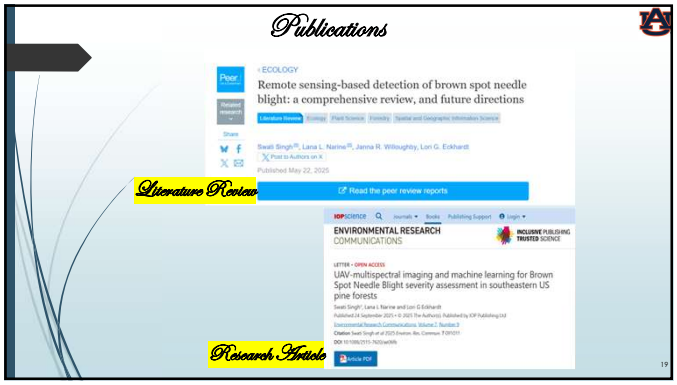
Publications



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Acknowledgements

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Thank you

Questions & Suggestions?

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