Detection of Pine Wilt Disease in Different Infected Stages Using Hyperspectral Drone Images

Niwen Li[1,2,3], Langning Huo[3], Xiaoli Zhang[1,2]

[1] Precision Forestry Key Laboratory of Beijing, Forestry College, Beijing Forestry University, Beijing, China
[2] The Key Laboratory for Silviculture and Conservation of Ministry of Education, Beijing Forestry University, Beijing, China
[3] Department of Forest Resource Management, Swedish University of Agriculture Sciences, Umeå, Sweden

Introduction

- Pine wilt nematode disease (*Bursaphelenchus xylophilus*, L.) is one of the major forest diseases in China.[1]
- The pine wilt nematode infects trees in the Pinus genus, and the infected trees usually die within three months. [2]
- The nematode cannot travel outside the wood independently but is spread by the main insect vector pine sawyer longhorn-beetles (*Monochamus spp.*,L.) during feeding and oviposition. [3]
- Removing the trees infected by the pine wilt nematode from the forest as early as possible is essential to control the spread. [2,4]

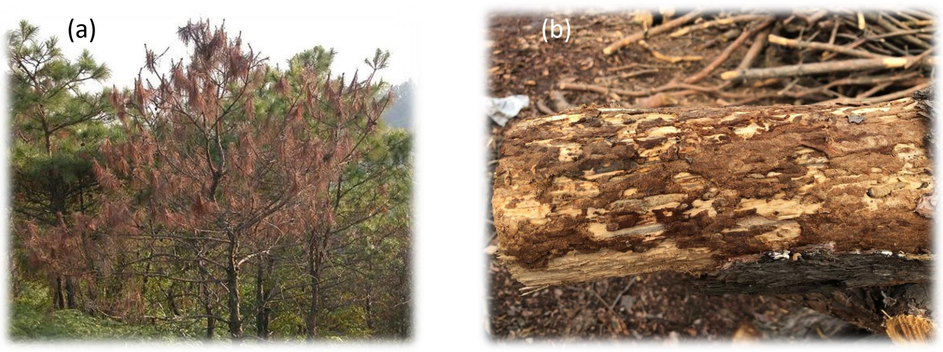


Figure 1. Pine wilt nematode infected trees. (a) the tree crown. (b) the larva of the media (longhorn-beetles) under the bark.

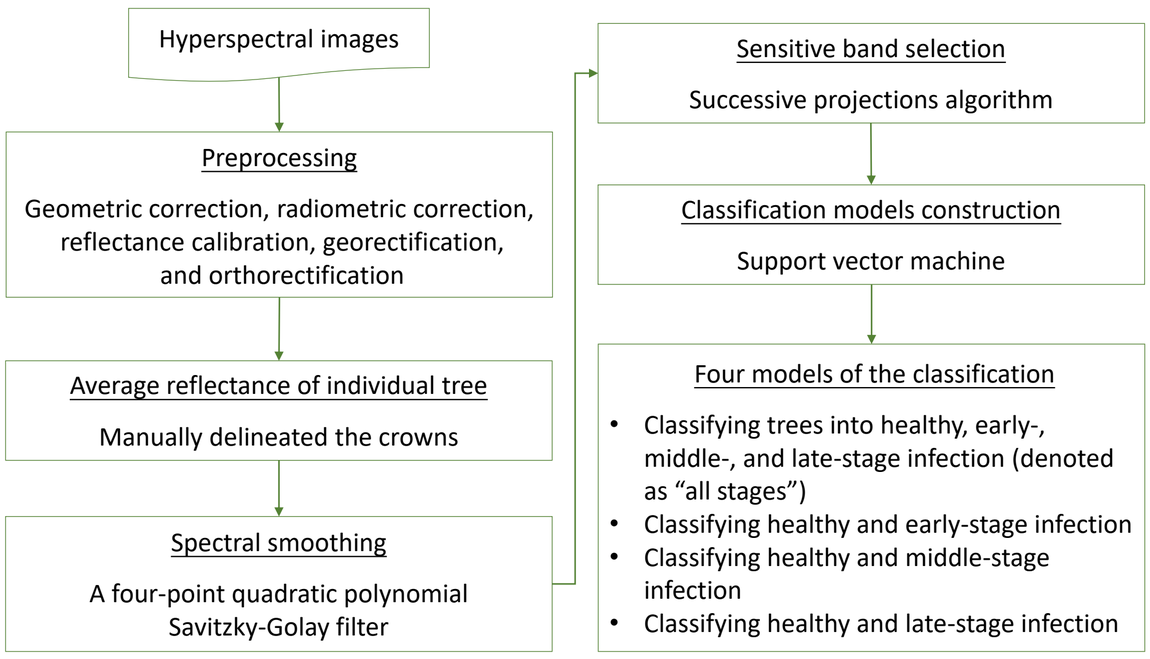
Material

- Study area:
  - Chaohu City, Anhui Province, China.
  - It was one of the earliest areas infected by pinewood nematode in China.
- Field data
  - The field data was collected in November 2019.
  - We set up six 25 m × 25 m plots and positioned them using a handheld differential global position system (DGPS).
  - The trees in the plots were positioned using a total station.
  - The health conditions were inventoried and categorized as healthy, early-, middle-, and late-stage infection, according to the color of tree crowns.
  - In total, 391 trees were inventoried and used as samples for this study.
- UAV hyperspectral images
  - We acquired the hyperspectral drone images on November 11, 2019, with a Nano-Hyperspec imaging spectrometer system mounted on a DJI Matrice 600 Pro drone.

Main parameters of the Nano-Hyperspec sensor

Parameters	Value
Wavelength range	400-1000 nm
Spatial bands	640
Spectral bands	270
Dispersion/Pixel (nm/pixel)	2.2
FWHM Slit Image	6 nm
Entrance Slit width	20 µm
Bit depth	12-bit
Weight without lens, GPS (lb / kg)	1.2 / 0.5

Methods



Results

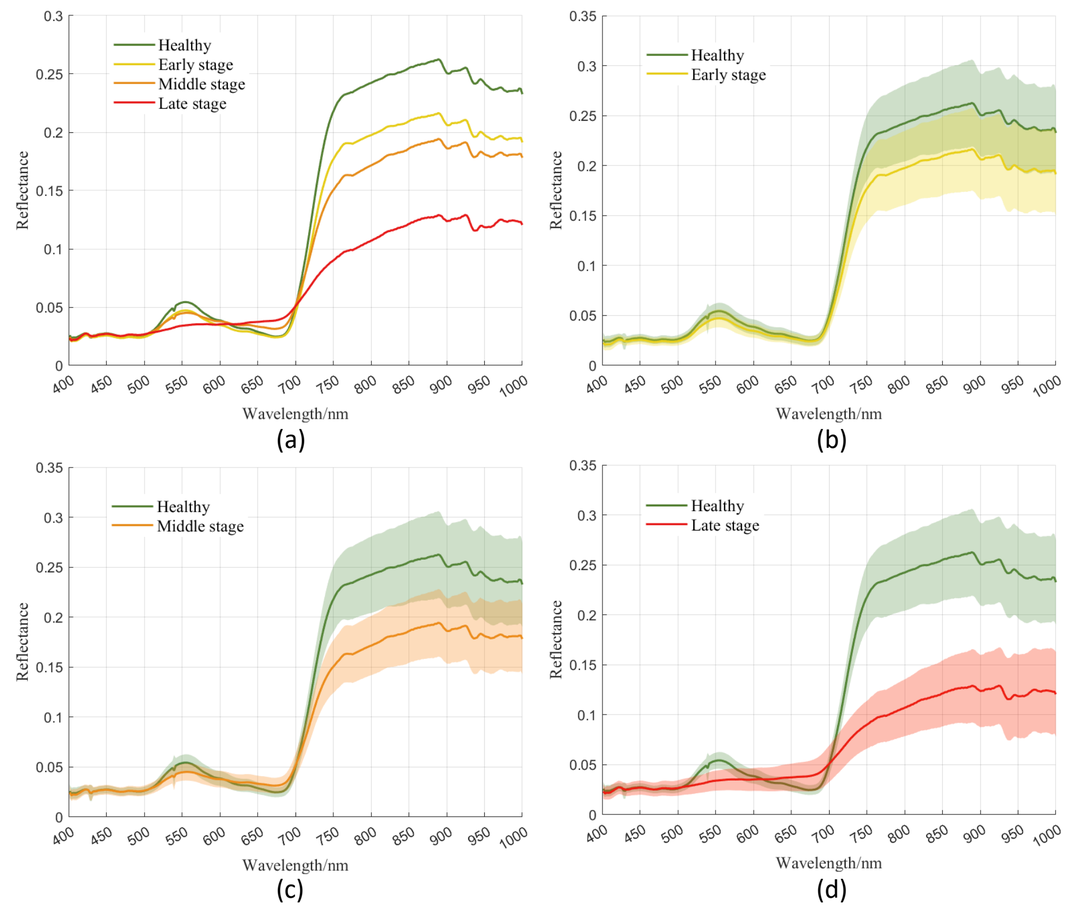


Figure 2. Mean spectral signature of tree crowns indifferent health status (a) and comparison between healthy and infected trees on the mean and standard deviation (std) of spectral signatures (b - d).

- The healthy, early-stage, and middle-stage infected trees exhibit similar spectral signatures as vegetations, while the late-stage infected trees already lose the typical spectral signatures of vegetations.
- The healthy and early-stage infected trees showed overlapping signatures.
- The ratio between red-edge and red bands decreased gradually from early to late stage.
- The SPA band selection also showed that the red and red-edge bands were the only sensitive bands for distinguishing healthy and early-stage infected trees, although the reflectance of those two bands overlapped more than other bands such as NIR.

Classification accuracy for different stages

Classified stages	Sensitive wavelength used for classification	Producer accuracy				Overall accuracy
		Healthy	Early stage	Middle stage	Late stage	
All stages	All 270 Bands	0.65	0.35	0.76	0.94	0.68
All stages	758 nm, 553 nm, 889 nm, 524 nm	0.71	0.76	0.35	0.71	0.63
Early stage / healthy	720 nm,680 nm	0.71	0.47	–	–	0.59
Middle stage / healthy	642 nm, 535 nm, 709 nm, 402 nm	1.00	–	0.59	–	0.79
Late stage / healthy	535 nm, 433 nm, 593 nm, 426 nm, 758 nm, 954 nm, 417 nm	0.94	–	–	1.00	0.97

Conclusions

- We explored the classification of individual trees with different infection statuses using hyperspectral drone images.
- When the infection developed into the middle and late stages, the tree crowns showed different signatures from the healthy ones, while during the early stage, the spectral signatures were similar to healthy ones, which decreased the detection accuracy.
- We used machine learning methods to determine the sensitive bands and classified trees with different infection statuses.
- The classification models distinguished middle- and late-stage infected trees well but yielded low accuracy in indicating healthy and early infections. The spectral signature showed a decreasing ratio between the red and red-edge bands during the infection.

Acknowledgement

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References:
[1] Wu, W.; Zhang, Z.; Zheng, L.; Han, C.; Wang, X.; Xu, J.; Wang, X. Research Progress on the Early Monitoring of Pine Wilt Disease Using Hyperspectral Techniques. Sensors (Basel) 2020, 20.
[2] Kim, S.-R.; Lee, W.-K.; Lim, C.-H.; Kim, M.; Kafatos, M.; Lee, S.-H.; Lee, S.-S. Hyperspectral Analysis of Pine Wilt Disease to Determine an Optimal Detection Index. Forests 2018, 9, 115.
[3] Kim, N.; Jeon, H.W.; Mannaa, M.; Jeong, S.-I.; Kim, J.; Lee, C.; Park, A.R.; Kim, J.-C.; Seo, Y.-S. Induction of resistance against pine wilt disease caused by Bursaphelenchus xylophilus using selected pine endophytic bacteria. Plant Pathol 2019, 68, 434–444.
[4] Syifa, M.; Park, S.-J.; Lee, C.-W. Detection of the Pine Wilt Disease Tree Candidates for Drone Remote Sensing Using Artificial Intelligence Techniques. Engineering 2020, 6, 919–926.