Estimating Fusarium Head Blight Severity in Winter Wheat Using Deep Learning and a Spectral Index

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Background

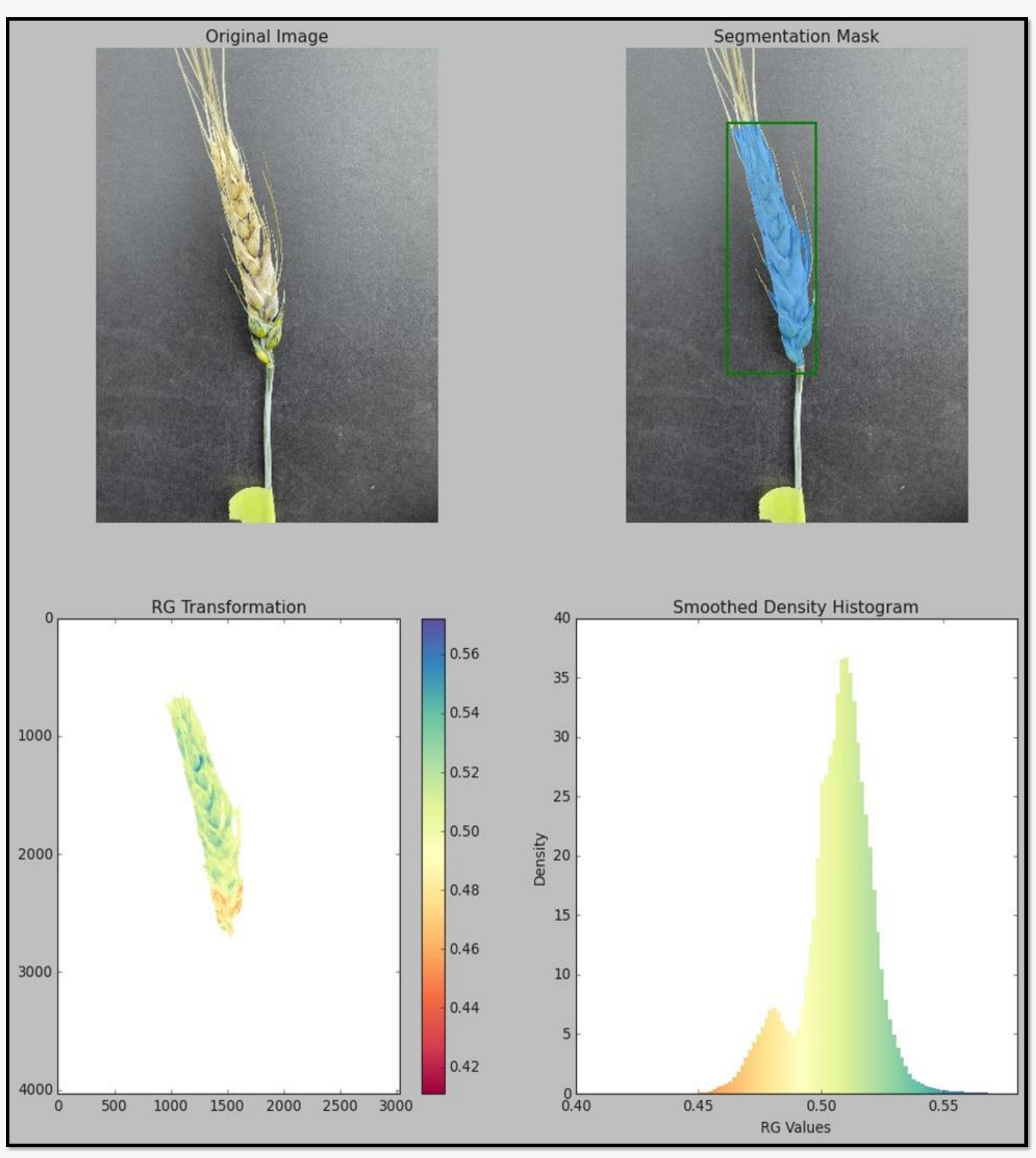
- Fusarium Head Blight (FHB) is a fungal disease caused by the pathogen *Fusarium gaminearum* (Fg) that can significantly decrease wheat yield
- Phenotyping for visual FHB resistance is a time consuming and subjective process
- Deep learning techniques, such as image classification, object detection and instance segmentation, have shown potential for disease detection
- Spectral indices have also been used to accurately detect FHB
- Past studies have only classified disease severity and have not been transferable to other data sets

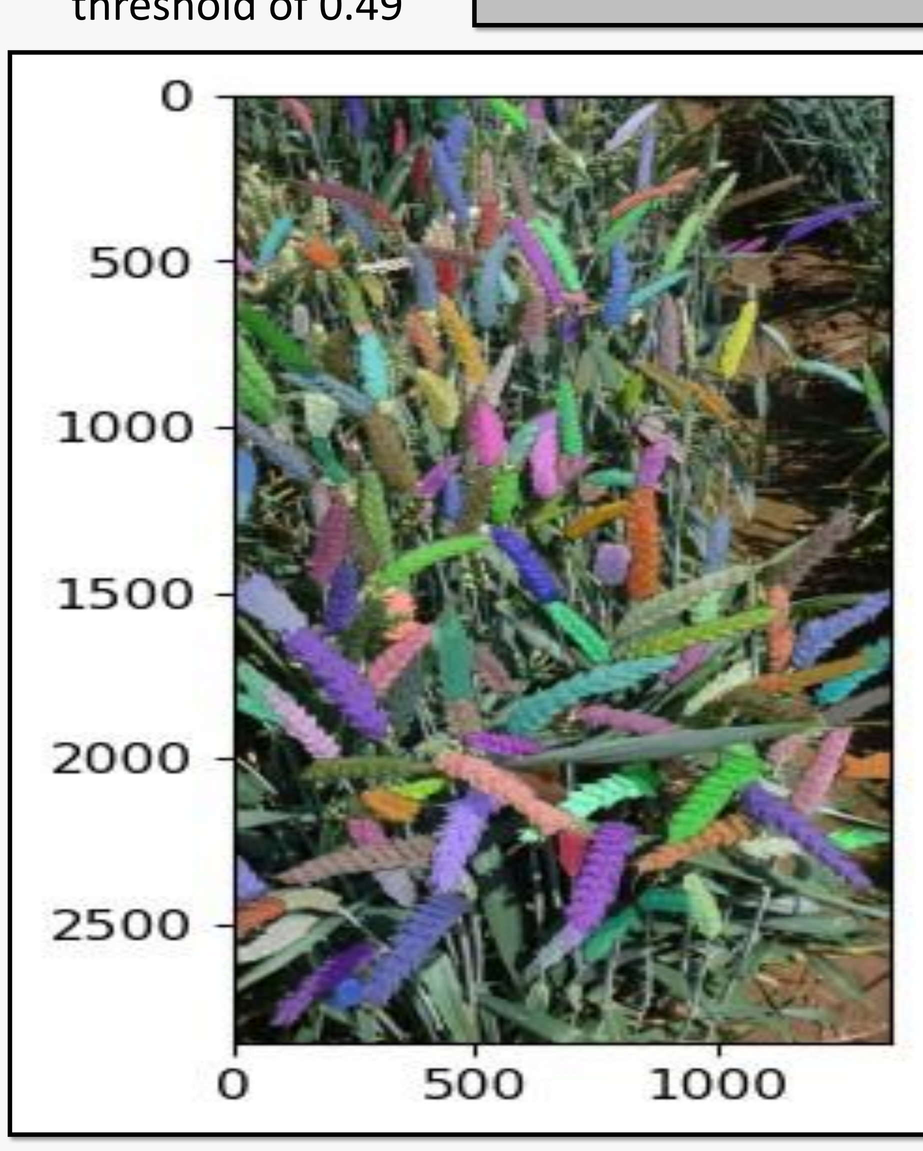
Objectives

1. Train a deep learning model to localize and segment single wheat heads
2. Develop a spectral index to estimate FHB severity for the segmented image regions
3. Compare the index estimations with visual severity estimates
4. Test the transferability of this workflow with outdoor plot level images

Materials and Methods

- 6 winter wheat varieties with varying degrees of FHB resistance were point inoculated with Fg at anthesis
- Plants were kept in a controlled environment optimal for fungal growth
- Visual severity measurements and RGB photos were taken 7, 10, and 14-days post inoculation
- A YOLOv8 object detection model was developed and combined with Meta's Segment Anything (SAM) to localize and segment the single wheat heads
- A normalized red/green ratio was used to separate healthy from infected tissue
- FHB severity was estimated by counting the number of pixels above the threshold of 0.49

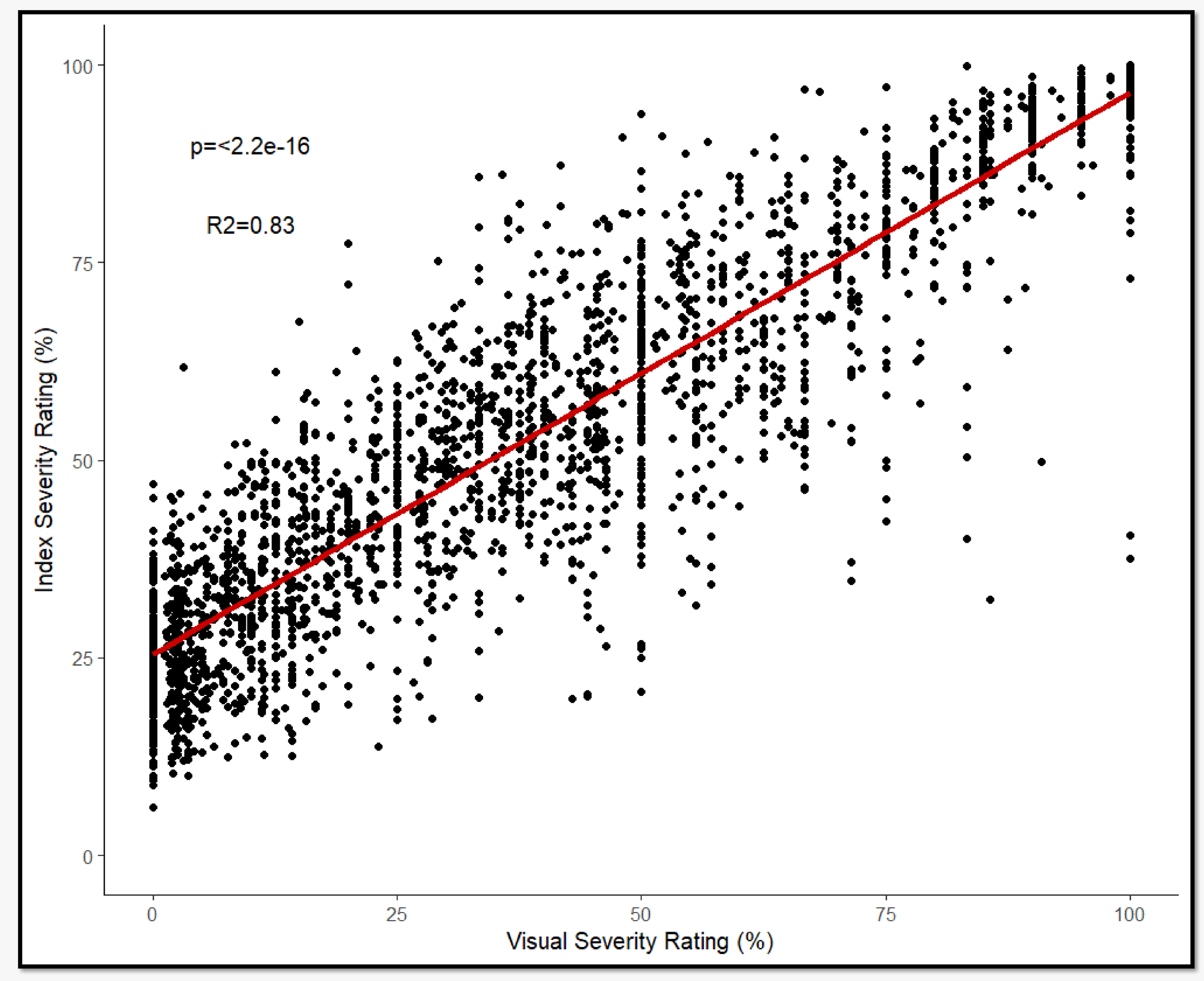




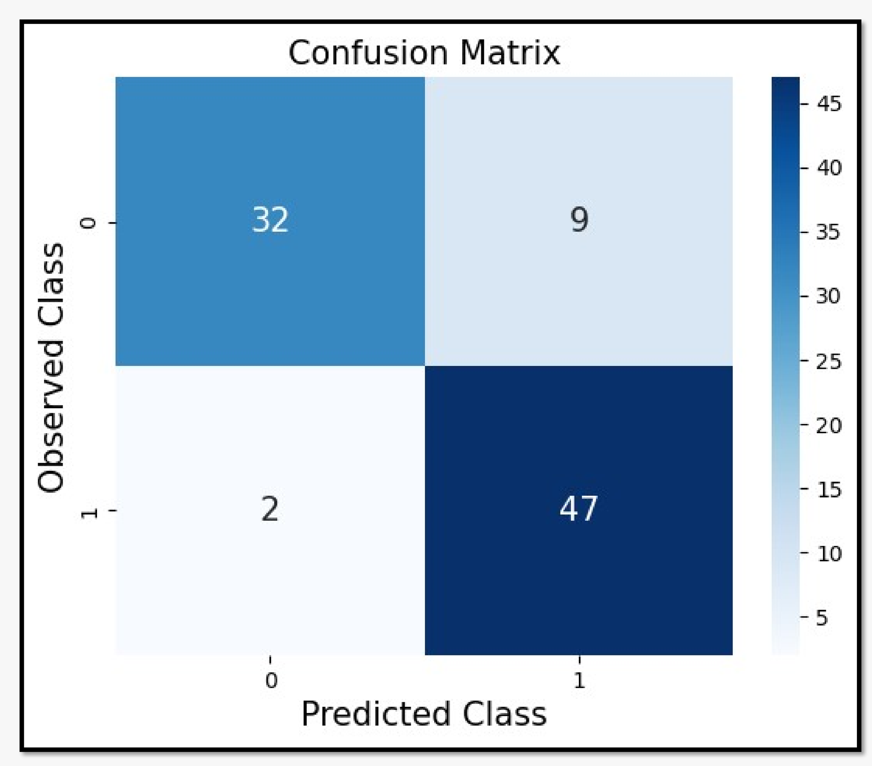
Original image taken by Rößle et al., (2023)

- A plot level wheat head detection model, combined with SAM, was used to segment wheat heads from RGB images of wheat plots
- The index was applied to the segmentation masks and a threshold of 0.49 was also found for these images
- This threshold was then used to separate healthy from infected tissue within the heads
- Stratified random sampling was performed on the mask pixels to determine accuracy of the index for both single head and plot level images, as seen in the confusion matrices

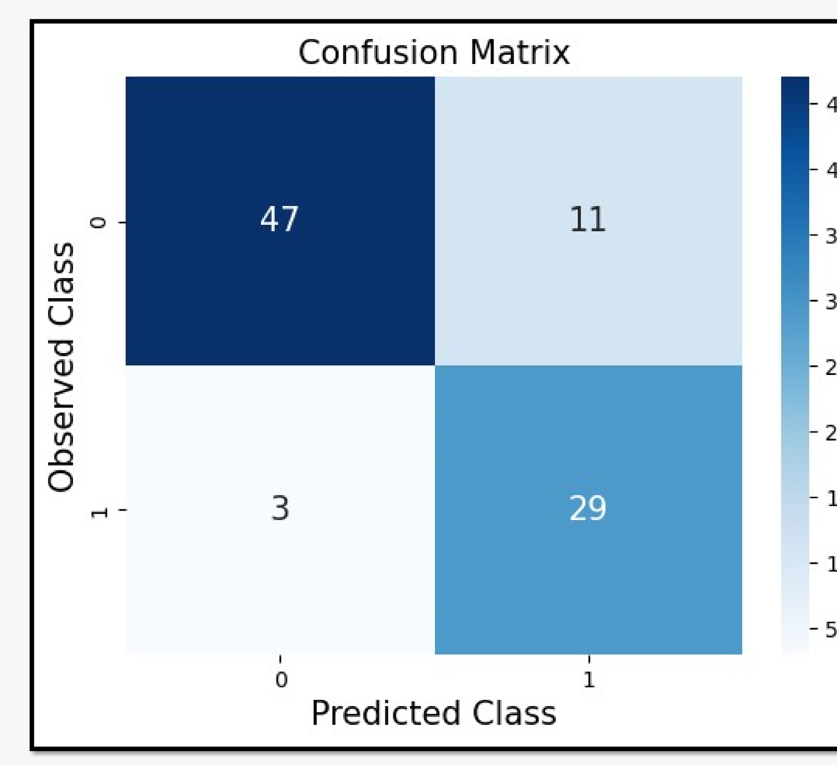
Results



Comparison to Visual Severity Estimates: The spectral index accurately predicted FHB severity, within the single head images, when compared to the visual estimates, with R^2=0.83, p=<2.2e-16, and RMSE=19.72. The spectral index is able to provide more precise estimates of FHB symptoms.



Single Head Index Accuracy: The spectral index accurately separated healthy from infected tissue within the single head images, with an accuracy of 87.8%, precision=0.89, and recall=0.88. Incorrectly segmented background pixels tended to be classified as infected.



Testing Transferability: The spectral index accurately separated healthy from infected tissue within the plot level images, with an accuracy of 84.4%, precision=0.86, and recall=0.84. The model tended to incorrectly classify pixels with strong glare as infected.

Conclusion

- The normalized red/green ratio, combined with deep learning, was able to accurately estimate FHB severity
- This workflow may be deployed in the field on whole wheat plots to increase the accuracy of severity estimations and significantly decrease the time required for phenotyping
- Therefore, improving selection efficiency for FHB resistance within wheat breeding programs

Future Work

- This workflow will be applied to the FHB nursery at Elora, ON and compared to visual severity estimates
- Producers may be able to scout fields for to estimate disease pressure using this technology in a mobile app