

Machine Learning for an Efficient and Targeted Downy Mildew Management in Hop

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Motivation

Pseudoperonospora humuli downy mildew poses a significant threat to hop production. The **Peronospora warning service** [1] is a unique advisory system integrating **weather data** and **airborne sporangia** monitoring to issue targeted spraying recommendations built on **40 years** of expertise [2].

Burkhard spore trap →

Benefits:

- Reduced fungicide applications
- Significant cost savings for hop growers

Challenges:

- Legacy technology limits scalability and integration
- Manual sporangia counting is labor-intensive and error-prone

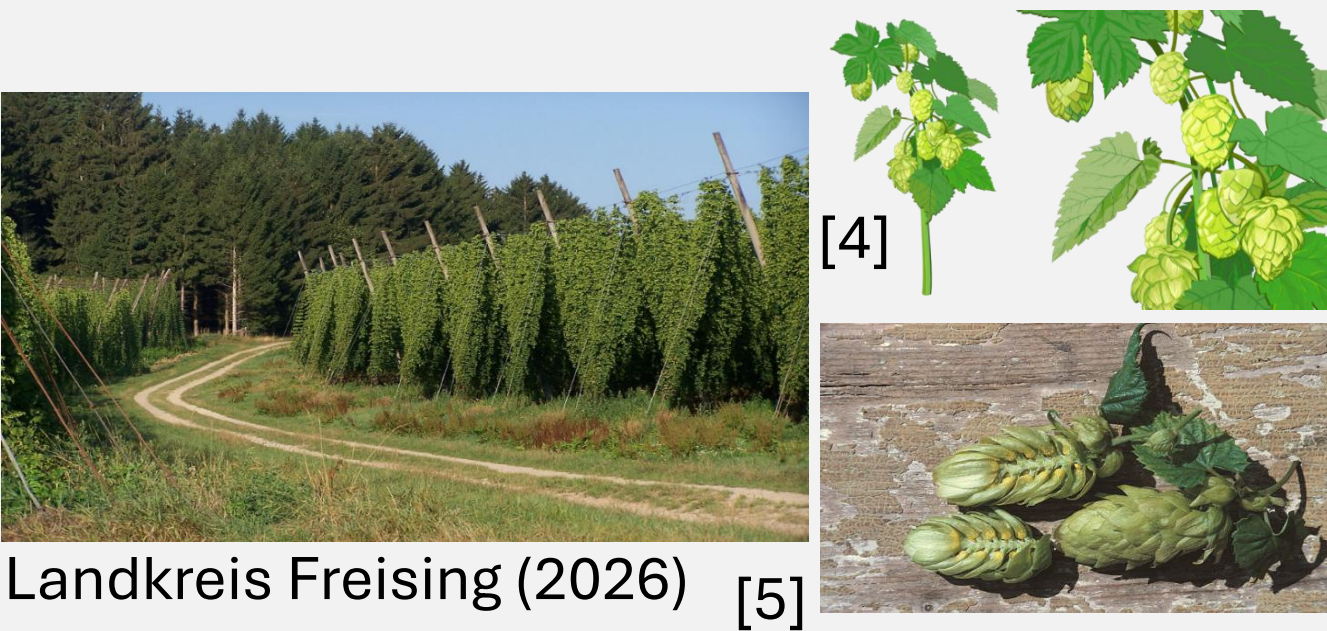


Sebold & LfL (2025)

Background

Hops (*humulus lupulus*)

- Perennial crop
- Grows 6-8 m high
- Plant protection** intensive
- Buds are mainly used for brewing beer
- Germany has the largest connected cultivated area worldwide (Hallertau)

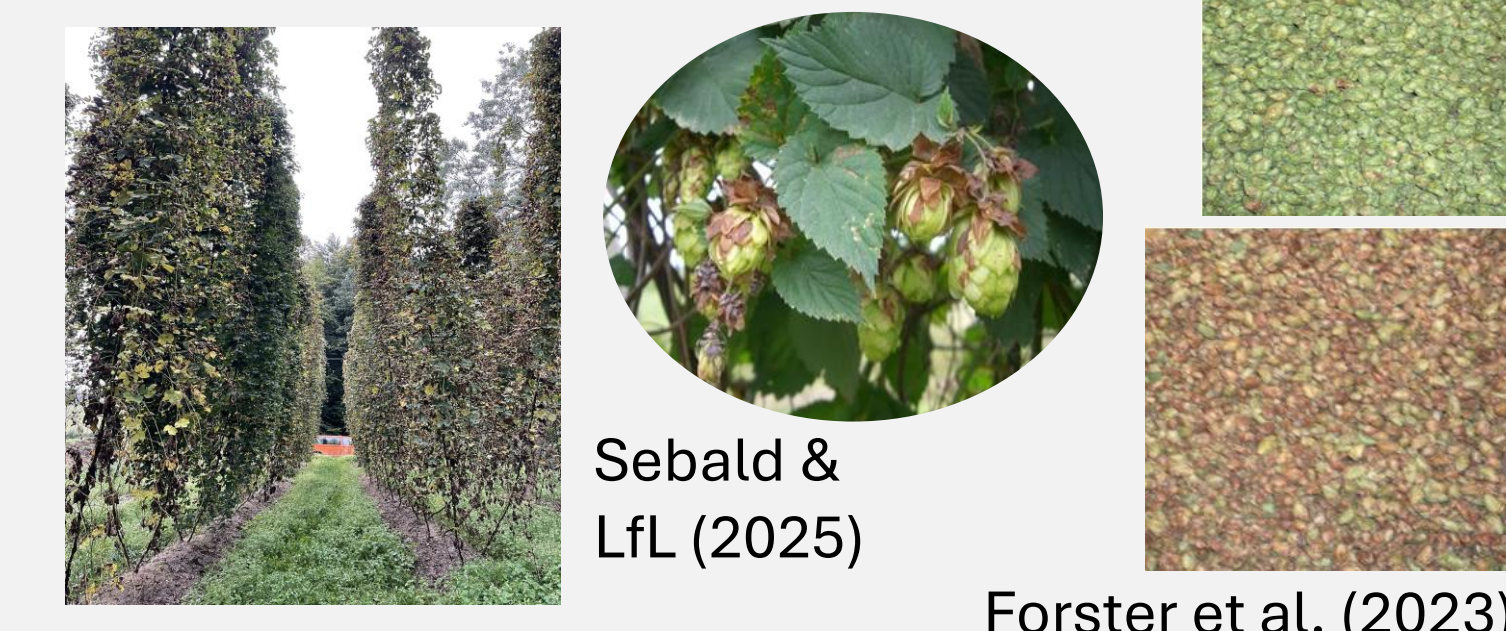


[4]

[5]

Downy Mildew in Hops

- Pathogen: oomycete *Pseudoperonospora humuli* [3]
- Infects new plants by releasing sporangia
- Airborne sporangia** travel to new plants and invoke a **secondary infection**
- Risk of complete crop loss



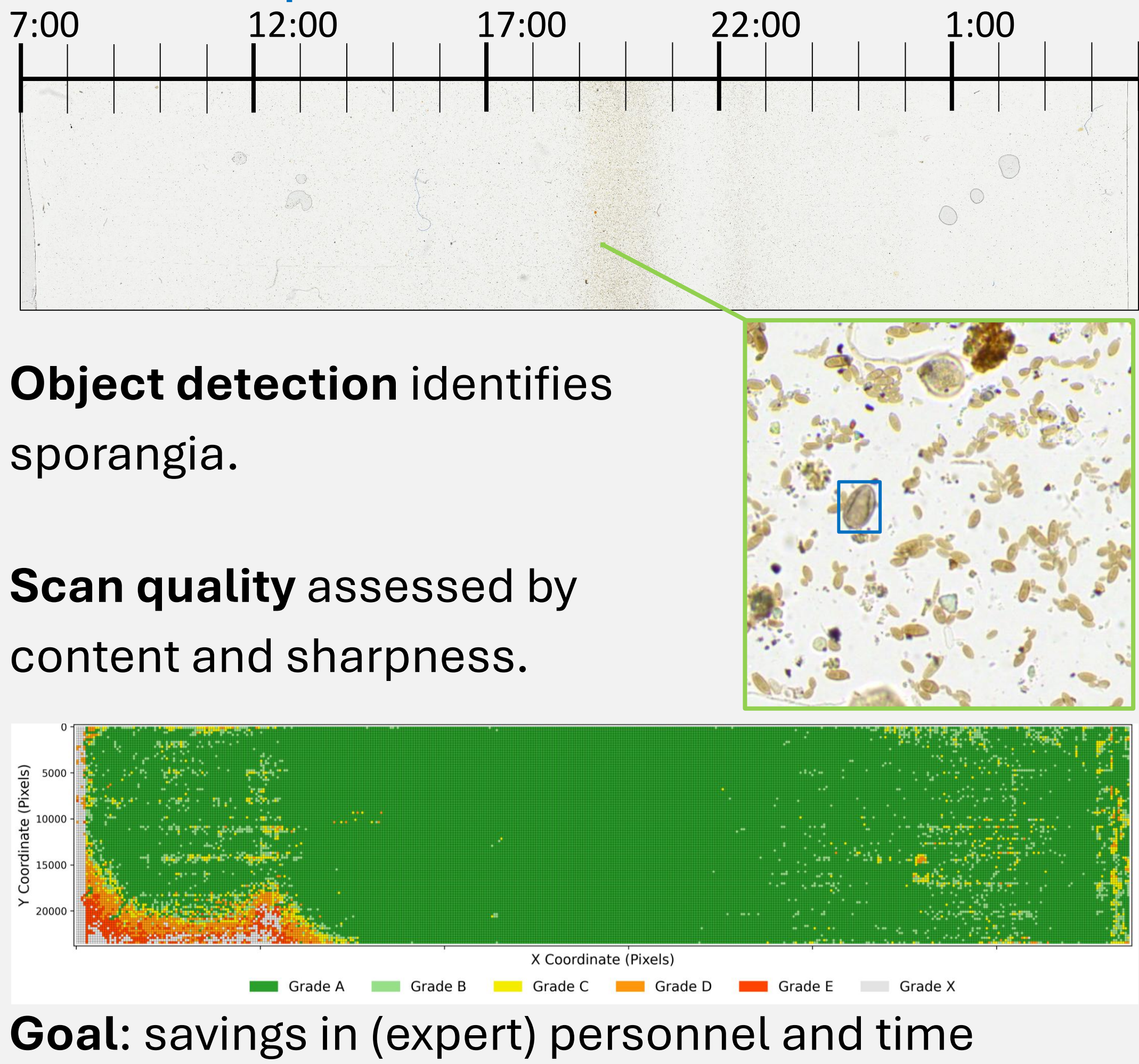
Sebold & LfL (2025)

Forster et al. (2023)

Project Overview

Peronospora Warning Service 2.0

Implementation of AI-based Digital Microscopes



Object detection identifies sporangia.

Scan quality assessed by content and sharpness.

Goal: savings in (expert) personnel and time

Peronospora Warning Service 3.0

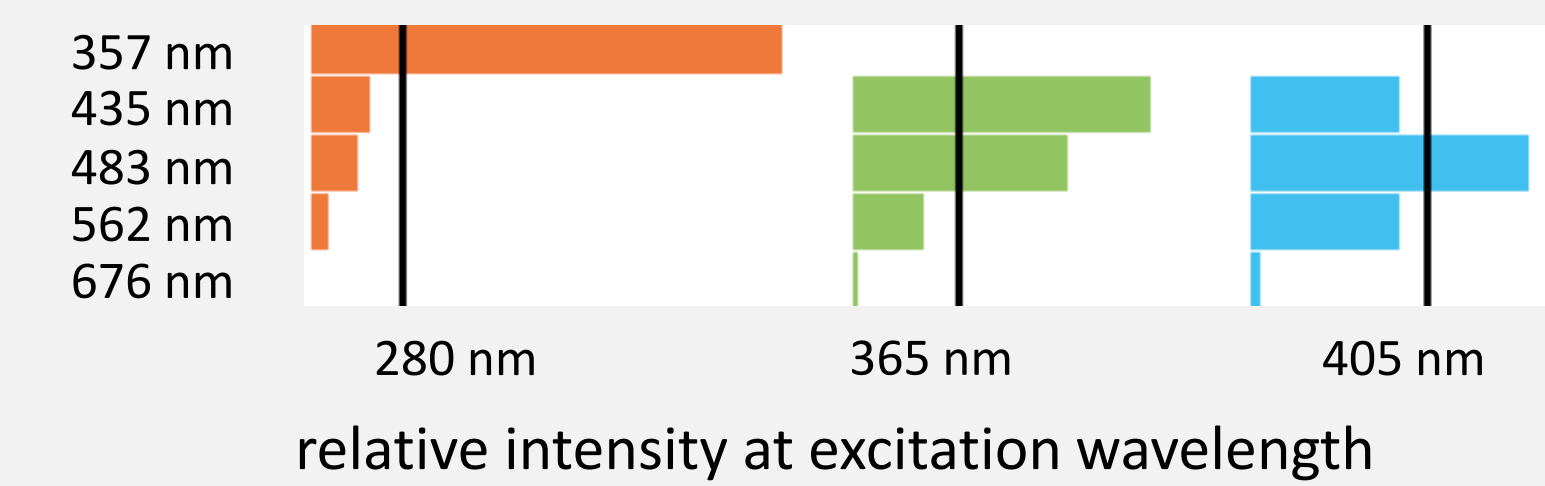
Use of Real-Time Spore Traps

Holographic images



© Swisens

Fluorescence spectrum

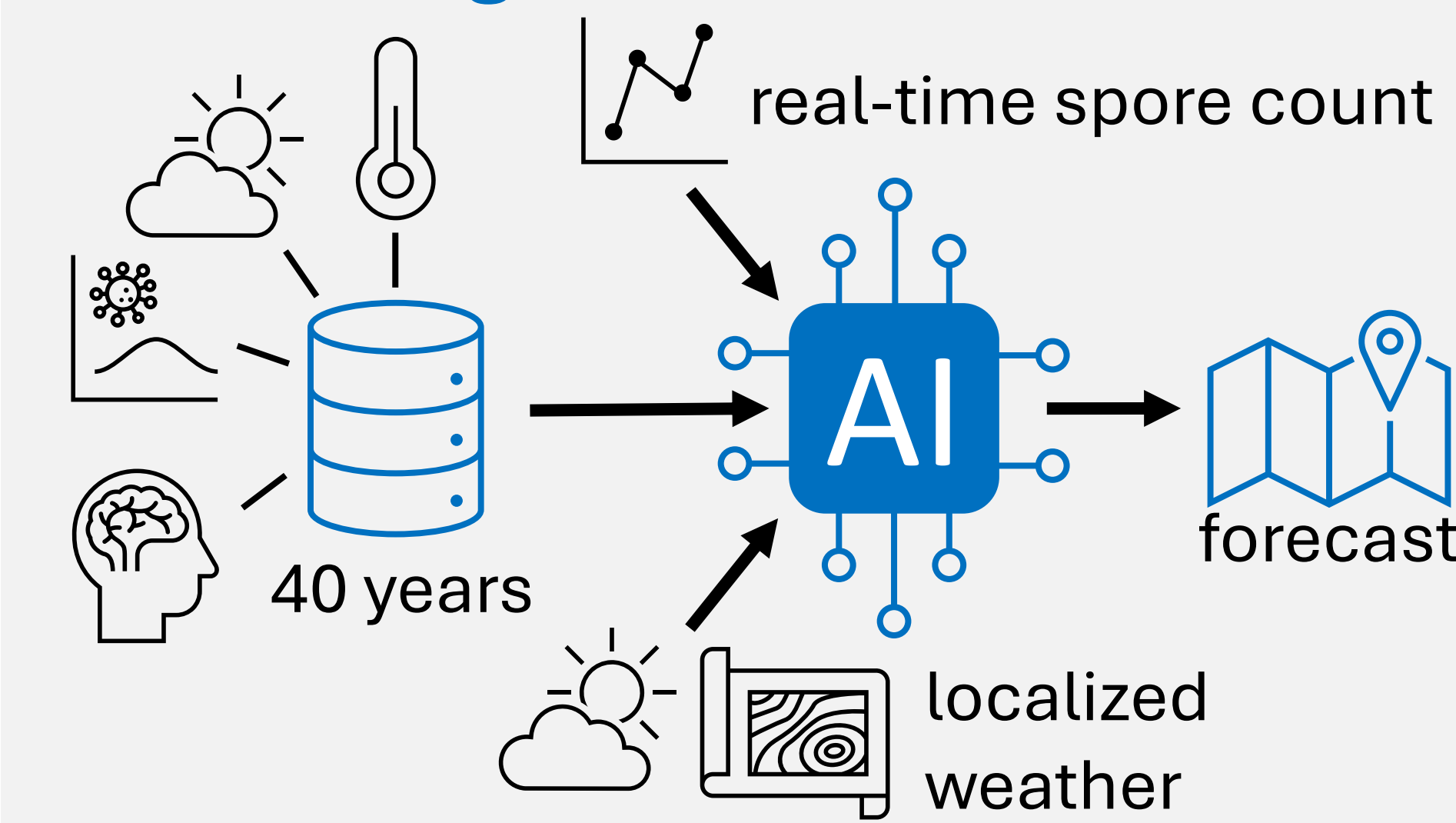


Feature-based classifier for real-time particle identification.

Goal: real-time counts, low maintenance

Peronospora Warning Service 4.0

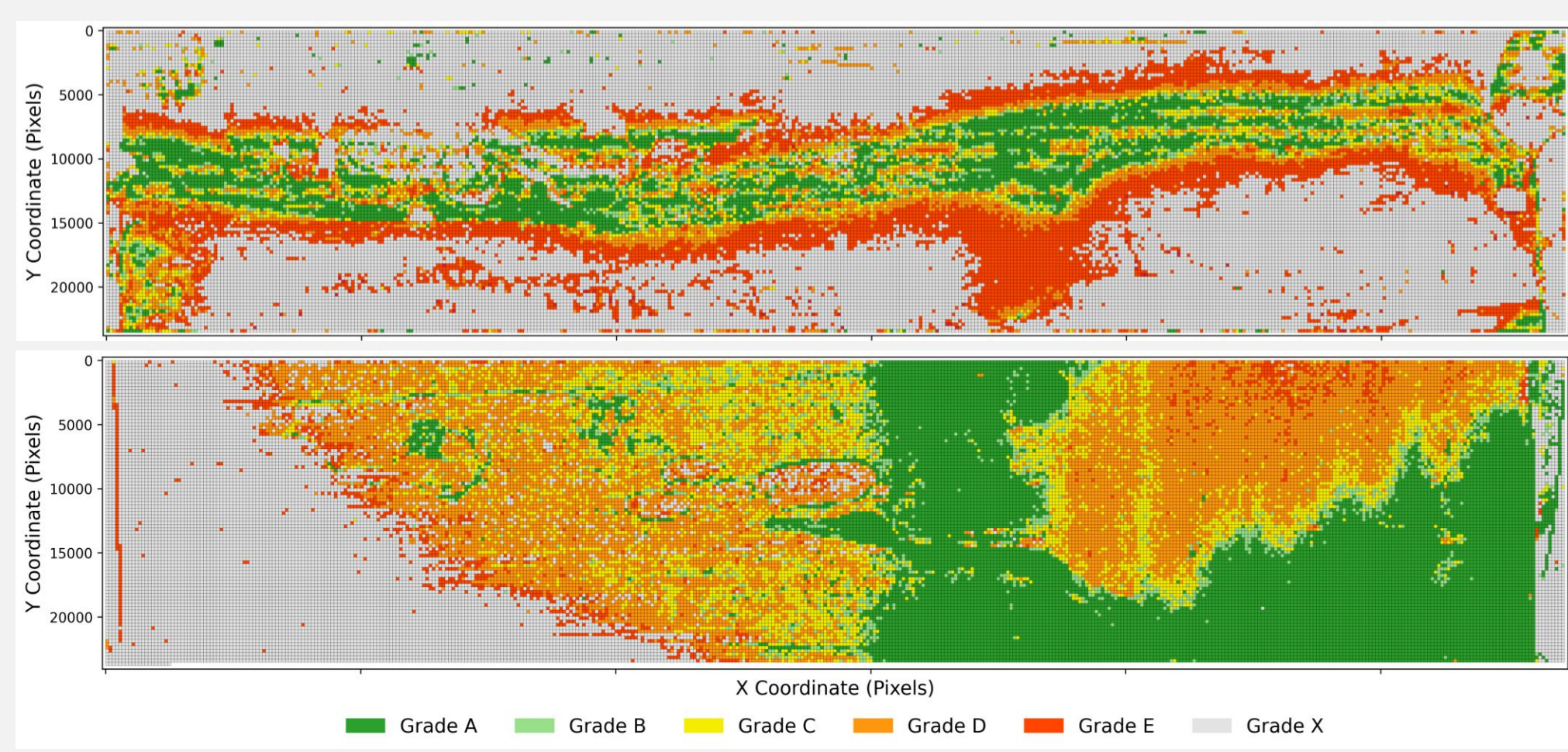
Development of a Regionalized Forecasting Model



Goal: localized, two-day forecast and potential evaluation for powdery mildew

Findings and Challenges

Quality and Sharpness Varies Inside and Across Slides

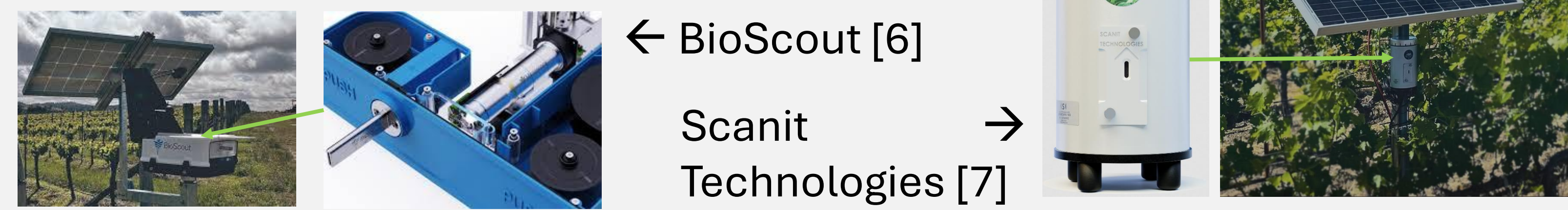


- Low quality areas:
- Air bubbles, uneven prep
- No content areas:
- No particles, too blurry

Tradeoff: High resolution scan mode vs. scan times.

Different Smart Trap Systems

Idea: Apply digital microscopy directly in the field



← BioScout [6]

Scanit Technologies [7]

Project Outlook

Securing and improving the **Peronospora warning service** for the future by:

- digitalizing knowledge
- improving efficiency
- ensuring high quality

Contributing to improvement in integrative plant protection.

References

- Peronospora Warndienst. (2026, May 26). <https://www.lfl.bayern.de/ipz/hopfen/030222/index.php>
- Krentheller et al. (1983), Epidemiology and forecasting of hop downy mildew (*Pseudoperonospora humuli*)
- Purayannur, Set al. (2021). The hop downy mildew pathogen *Pseudoperonospora humuli*. *Mol. Plant Pathol.*, 22(7), 755. doi: 10.1111/mp.13063
- Pflanzenforschung (2026, May 26). <https://www.pflanzenforschung.de/de/pflanzenwissen/pflanzensteckbriefe/hopfen>
- Botanik des Hopfens. (2026, May 26). <https://tettmanger-hopfen.de/alles-uber-hopfen/botanik-des-hopfens/>
- BioScout. (2026, May 26). <https://www.bioscout.com.au>
- AI-Enhanced Crop Disease Detection & Airborne Insights | Scanit Technologies. (2026, May 26). <https://www.scanittech.com>

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