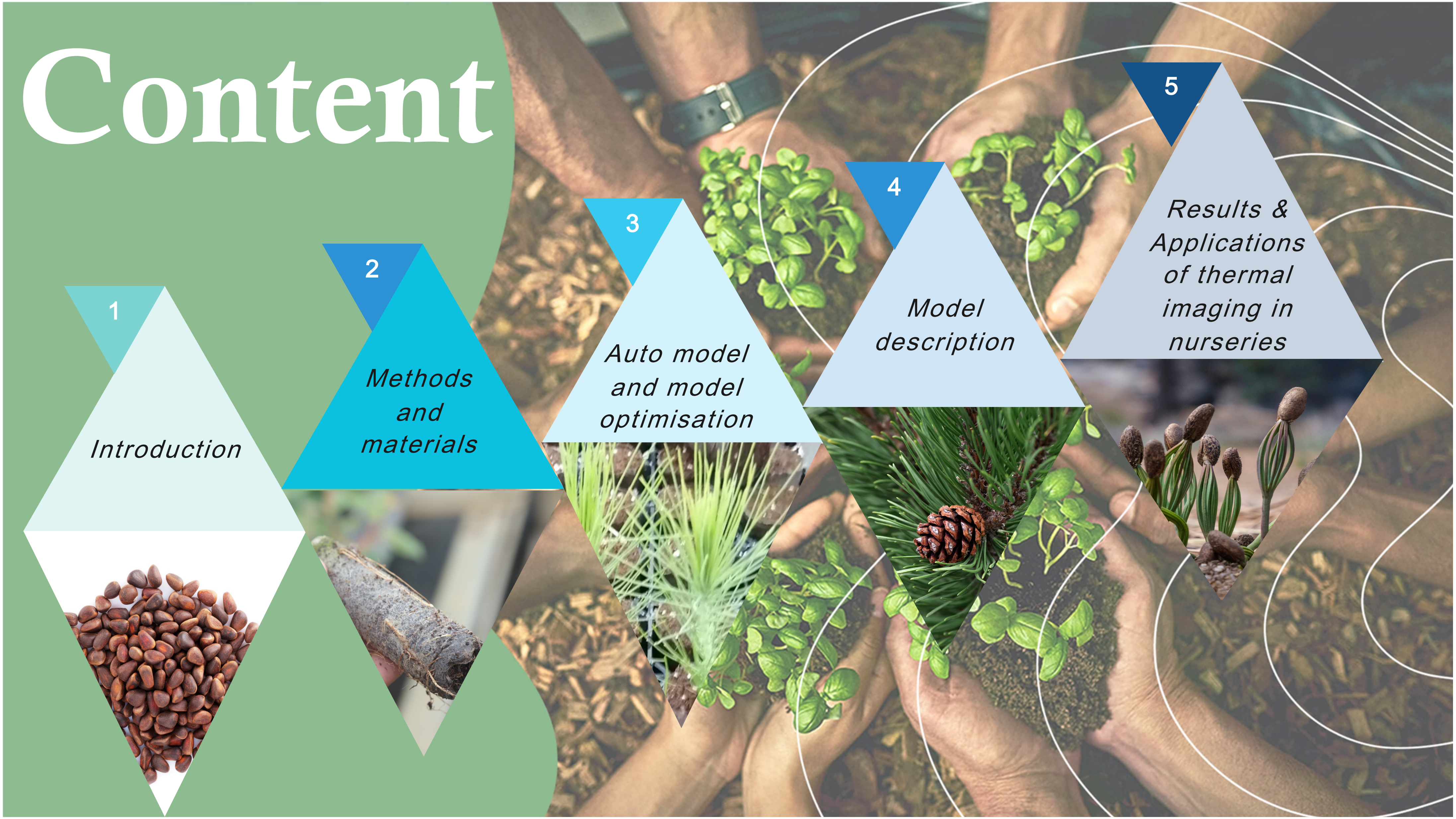
Modern technologies in horticulture – Integrating remote sensing at a nursery level.

IPPS Southern Africa Region 27th annual conference.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Introduction

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- Forestry nurseries are the starting point for large-scale timber and reforestation projects.
- Any stress or disease that compromises plant health which can delay production.
- Nurseries rely on visual inspection to detect stress.

Why Thermal Imaging?

- Thermal remote sensing offers a powerful, non-destructive means to detect sub-visual temperature changes that correlate with plant stress.
- Stressed hedges display elevated temperatures due to reduced transpiration and altered physiological processes.
- Detecting these temperature anomalies well before visible symptoms appear allows for targeted interventions, such as adjusting irrigation or applying nutrients potentially saving hundreds of plants.

Scope of this study

- Our research focused on *Pinus patula* × *Pinus tecunumanii* (PPTL) stock plant hedges grown in sand beds.
- Compared stressed vs healthy hedges utilizing their temperature profiles with machine learning techniques.
- To facilitate timely interventions to enhance plant health and reduce hedge losses.

Methods and materials

Sandbed establishment:

- ✓ Sandbeds were constructed with fiberglass (Figure 1).
- ✓ The fibreglass tray was mounted on a steel frame at a slope to facilitate drainage (Figure 2).
- ✓ A layer of gravel was added to the fibreglass and covered by bidim cloth.
- ✓ Washed sand was added on top to form the main growing medium (Figure 3).

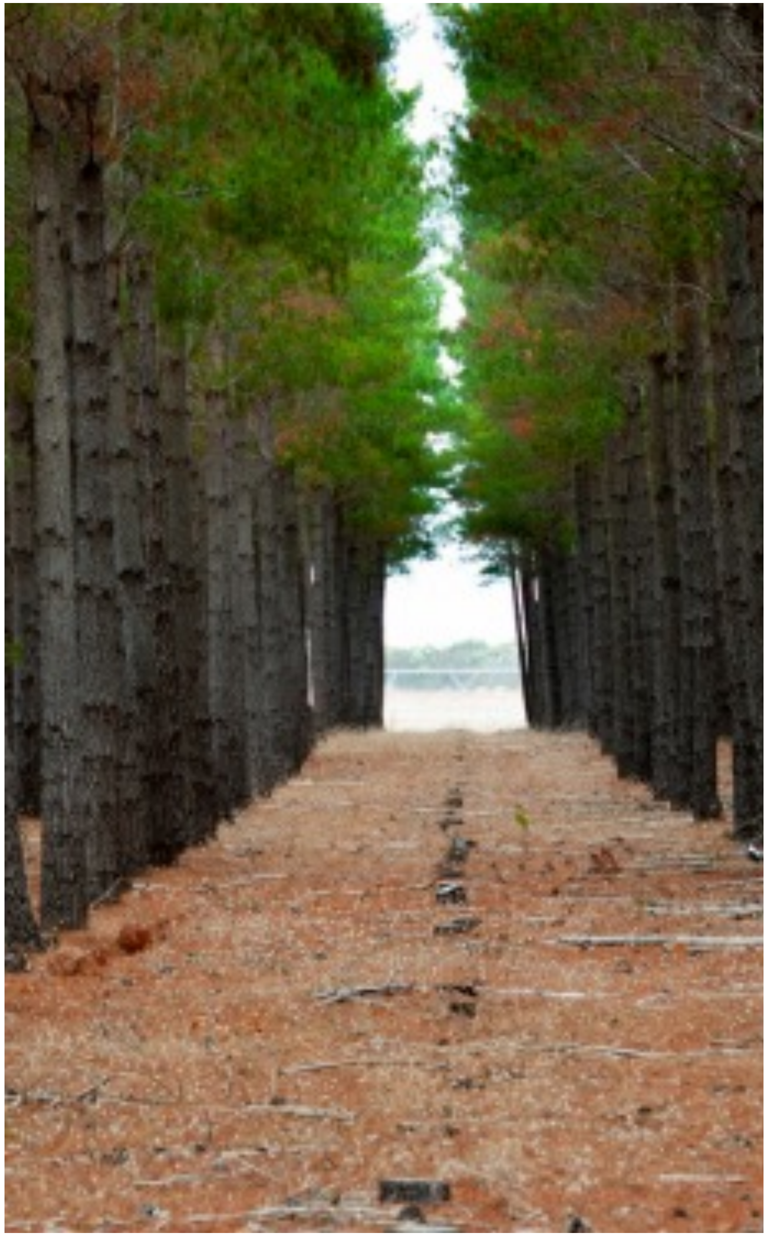
Watering and fertigation:

- ✓ Drip lines were installed on top of the sand, each equipped with emitters.
- ✓ Spacing between drippers ensured even coverage across the sandbed surface.
- ✓ Hedges were watered twice a day at 9am and 2pm for 30 minutes.
- ✓ Hedges were fertigated twice a week.

Figure 1: Fiberglass filled with gravel stones.

Figure 2: Steel frame.

Figure 3: Sandbed with PPTL hedges.



Methods and materials

Thermal Imaging Equipment:

✓ Cat Smartphone S60 with FLIR thermal imaging camera.

- 13-megapixel sensor.
- 8–14 µm spectral range.

Image capture details:

✓ Frequency: Once a week for 13 months.

✓ Height: Approximately 1.5 meters above the sandbed.

Data Processing:

✓ Temperature readings extracted using FLIR software 6.4.

✓ Data processed using RapidMiner Studio 9.10.

Figure 4: Cat Smartphone.

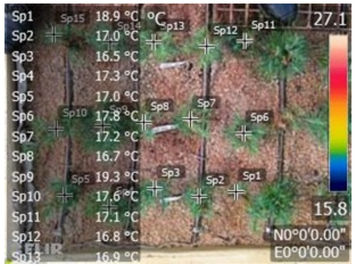
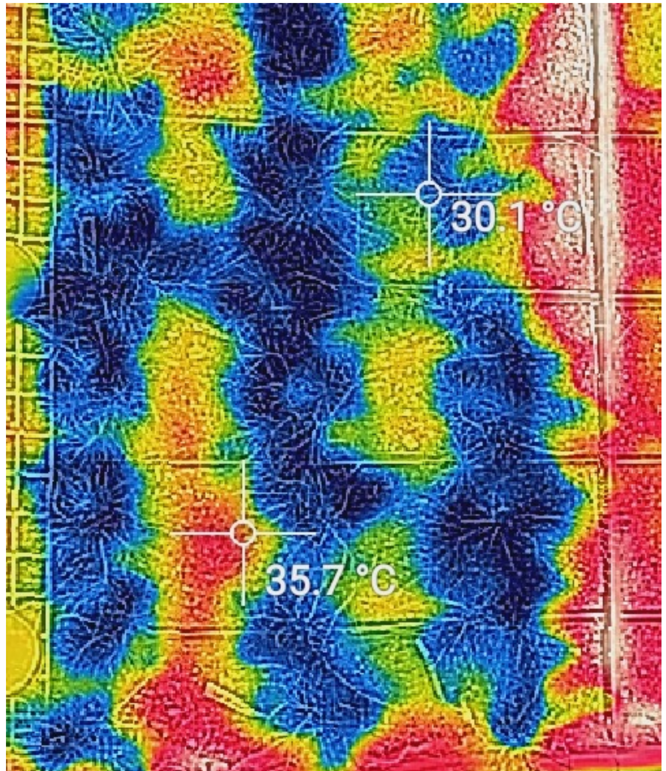


Figure 5: Thermal image showing the temperatures of PPTL hedges.

ALTAIR

RAPIDMINER

Figure 6: Software used for data extraction and processing.



Auto model and model optimisation

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Automates Machine Learning: No coding required.

Data Preparation: Detects variable types, handles missing values, and suggests transformations.

Target Selection: Identifies classification or regression problems.

Model Training & Selection: Tests multiple algorithms and optimizes performance.

Evaluation & Comparison: Ranks models using key metrics (accuracy, RMSE, ROC curves, etc.).

Deployment: Exports models for real-time use.

Key Benefits

✅ Fast & user-friendly

✅ Automates best practices

✅ Provides clear visual insights

✅ Easy model deployment

We used eight models in this study.

Optimizing & choosing the best model

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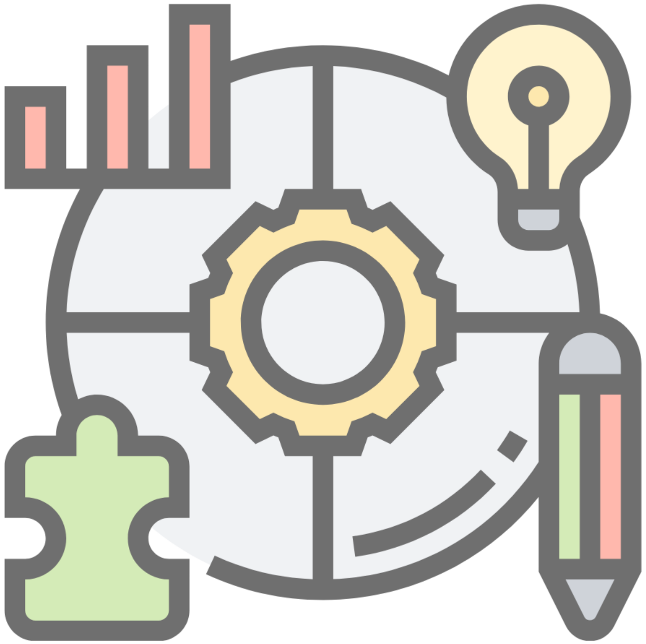

Optimizations techniques:

- Hyperparameter tuning for better performance
- Feature selection to remove irrelevant data
- Cross-validation to prevent overfitting

Model Comparison:

- Classification: Accuracy, Precision, Recall, F1-Score, ROC Curve

Choosing the Best Model:

- Auto model ranks models based on performance metrics
- Users can manually compare models for specific needs
- Best model can be exported, fine-tuned, or deployed

Results of the study

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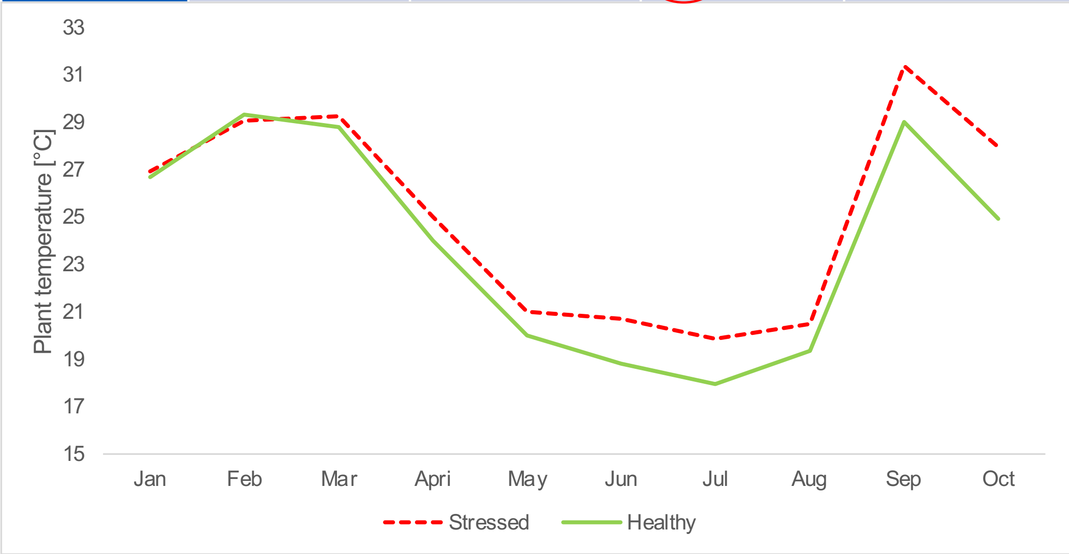
- Temperatures declined from January (27°C) to July (17°C).
- Standard deviations (1.05–1.72) indicate moderate temperature variability across hedges.
- Both stressed and healthy hedges follow a seasonal cooling trend from March to July.
- Stressed hedges were **0.5–1.5 °C** higher than healthy hedges.
- During cool months **(June–July)** stressed hedges maintained higher temperatures.
- This difference suggests early detection is possible before visible symptoms appear.
- Detecting a **1 °C** offset in March may allow nursery managers to intervene (adjust watering/fertilization) weeks before any visible symptoms.

Months	Minimum	Maximum	Average	Std Deviation
Jan	22	35	27	1.63
Feb	26	32	30	1.39
Mar	25	34	29	1.54
Apr	14	23	20	1.54
May	15	26	17	1.05
Jun	19	20	22	1.13
Jul	13	21	17	1.72



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Model evaluation metrics

To determine the best model, we assessed the following metrics:

Accuracy: The percentage of correctly classified instances.

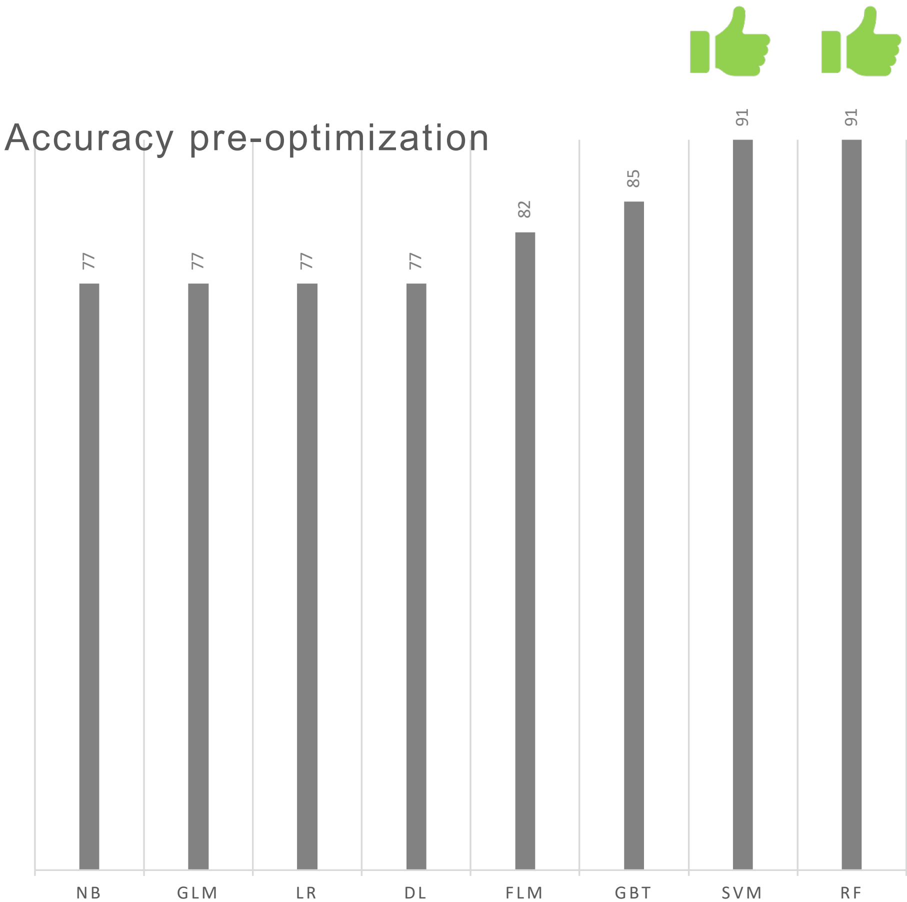
Recall : The model's ability to correctly identify stressed plants.

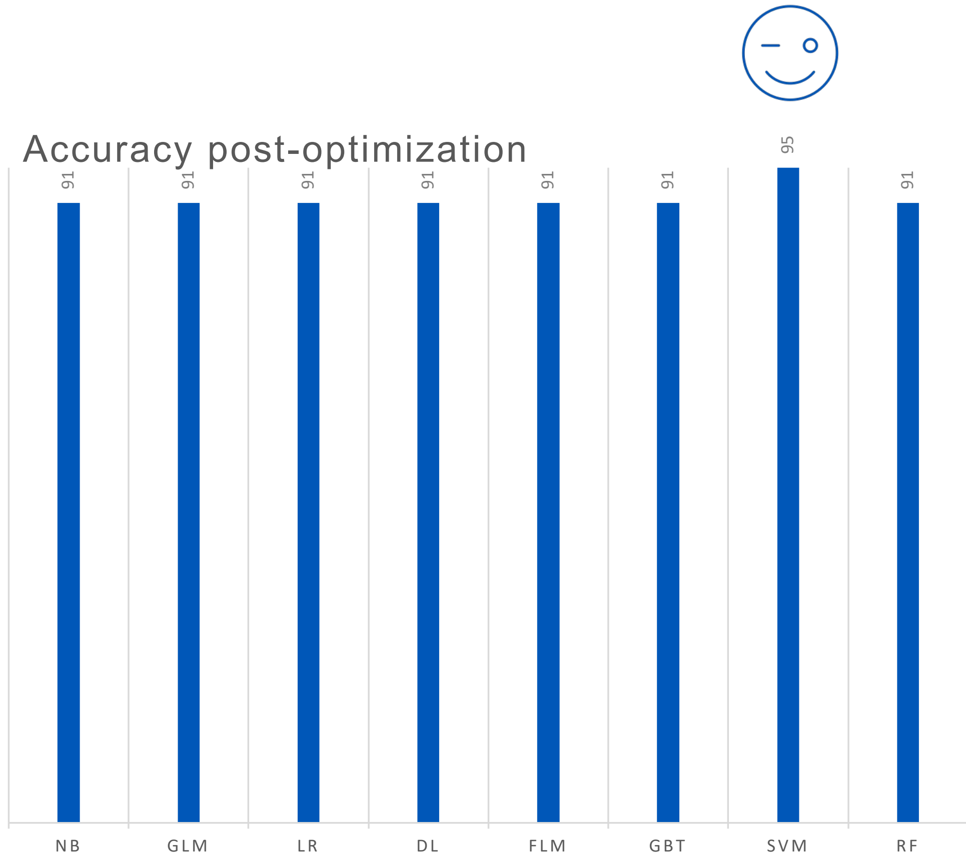
Area Under the Curve (AUC): Measures how well the model distinguishes between classes (Health vs stressed plants).

Specificity: Ability to correctly classify healthy plants.

Standard Deviation: Measures variability in predictions.

Results of the study





Naive Bayes **(NB),** Logistic Regression (**LR**)**,** Fast Large Margin **(FLM),** Deep Learning **(DL),**Decision Tree **(DT),** Gradient Boosted Trees **(GBT),**Support Vector Machine**(SVM),** Random Forest **(RF).**

Results of the study

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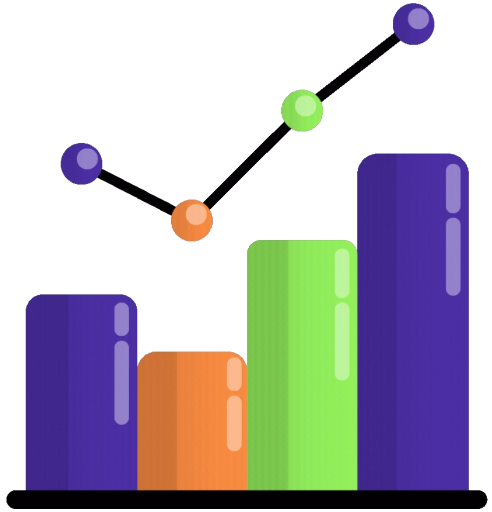
Model description	Recall	Specificity	AUC	Std. Dev.	Accuracy
Support Vector Machine	**0.92**	**0.93**	**0.98**	**±1.0%**	**95%**
Random Forest	0.9	0.91	0.96	±1.5%	92%
Gradient Boosted Trees	0.88	0.92	0.95	±2.0%	91%
Logistic Regression	0.86	0.88	0.92	±1.2%	90%



- **SVM as the top choice:** Proven effective in identifying plant stress based on performance results.
- **Accurate stress detection:** Successfully distinguished between stressed and healthy hedges.
- **Fewer missed issues**: High recall values meant fewer cases of undetected plant stress, allowing timely treatment.
- **Reduced unnecessary action:** High specificity minimized false positives, preventing unnecessary interventions and saving resources e.g. fertilizer application.

Applications of thermal imaging in nurseries

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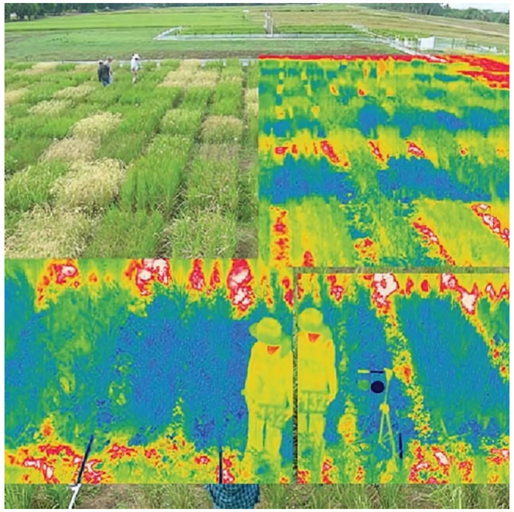
- ✓ Identify plant stress due to factors like water deficiency, nutrient imbalances, or disease onset.
- ✓ Monitors temperature distribution with plants.
- ✓ Early detection of stressed plants which allows corrective actions.
- ✓ Cost savings associated with replacing hedges.



Blackview, 2024

Practical implementation in the nurseries

Pilot testing and calibration

Installing a few thermal cameras in key nursery areas (e.g., greenhouses or outdoor sandbed sections).

01

Integration with irrigation & climate systems

Connect thermal imaging systems with the nursery's existing irrigation systems. The temperature data can help determine when and where water is needed most, optimizing water usage and preventing over- or under-irrigation.

02

Automated data processing & alert system

Implement SVM model that processes the thermal images to detect early signs of stress. The model should automatically flag plants that deviate from normal temperature profiles, allowing nursery managers to take action before visual symptoms develop.

03

Practical implementation in the nurseries

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Staff training & standard operating procedures

Develop SOPs for responding to early stress signals, such as adjusting irrigation schedules, checking for disease outbreaks, or modifying fertilizer applications.

04

Regular maintenance & system updates

Periodically review system performance to incorporate feedback and improve the detection algorithms.

05

Scalability & integration with other technologies

Once the pilot proves successful, expand the thermal imaging system to cover more areas of the nursery

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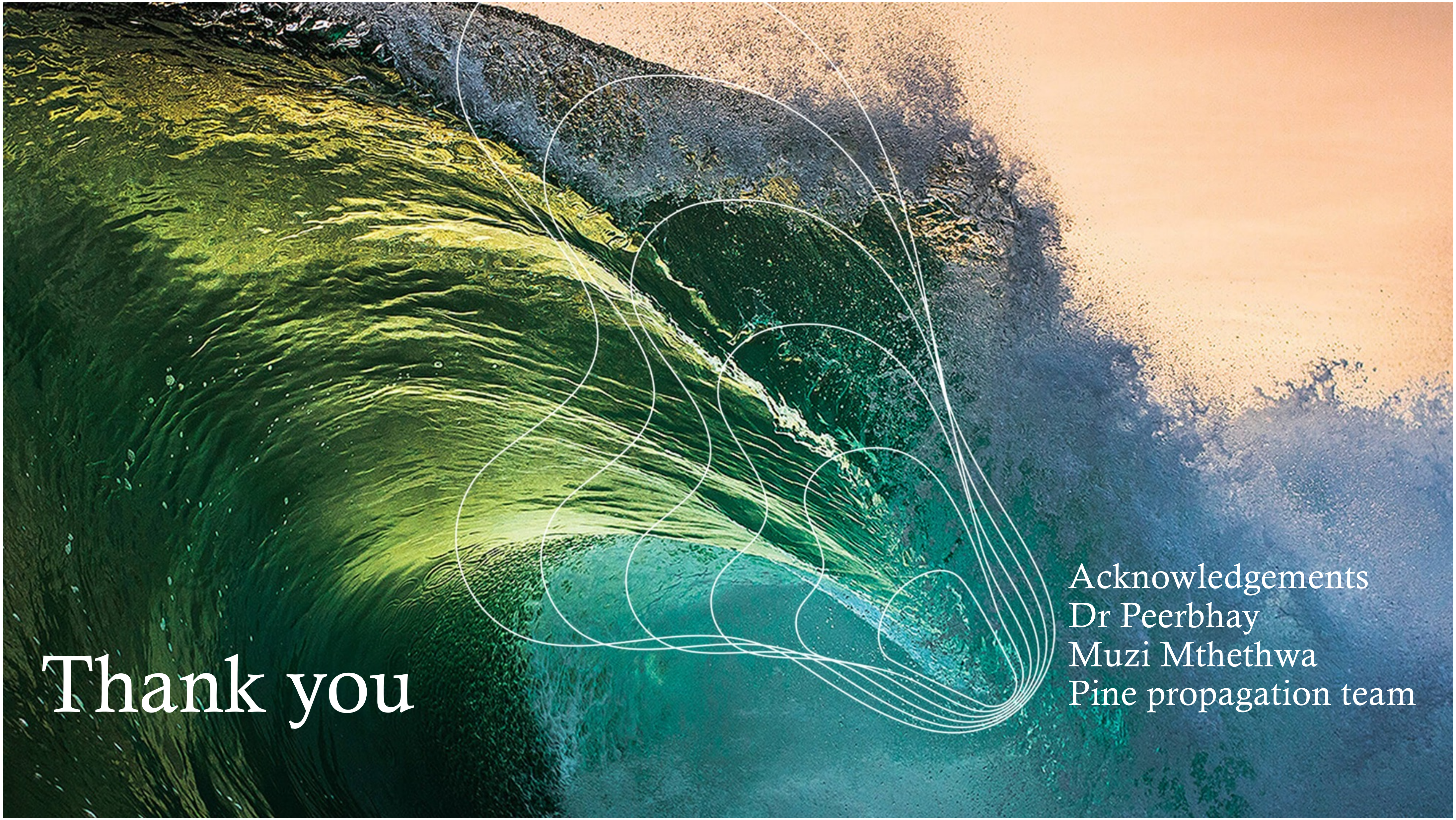
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