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Tree Health Detection Using Thermal Infrared Remote Sensing

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Content

Introduction

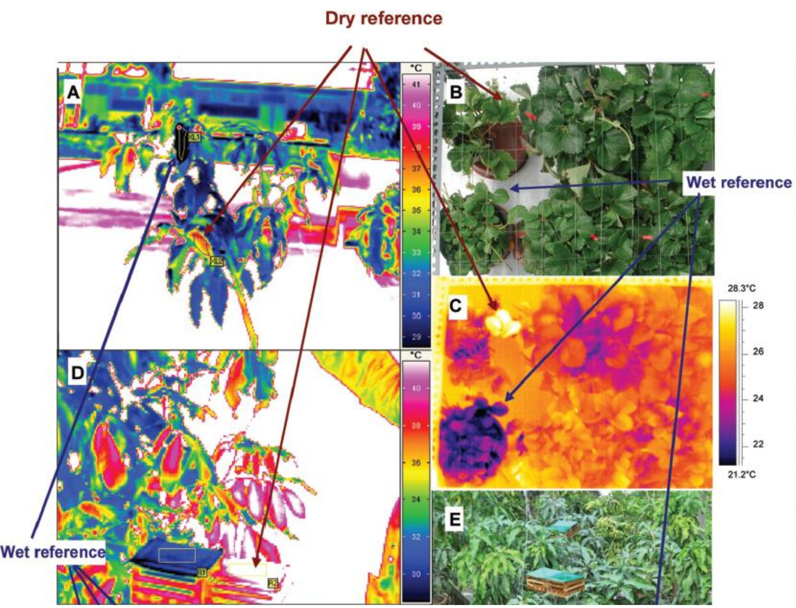
Tree health detection brings significant benefits for pest control and prevention.

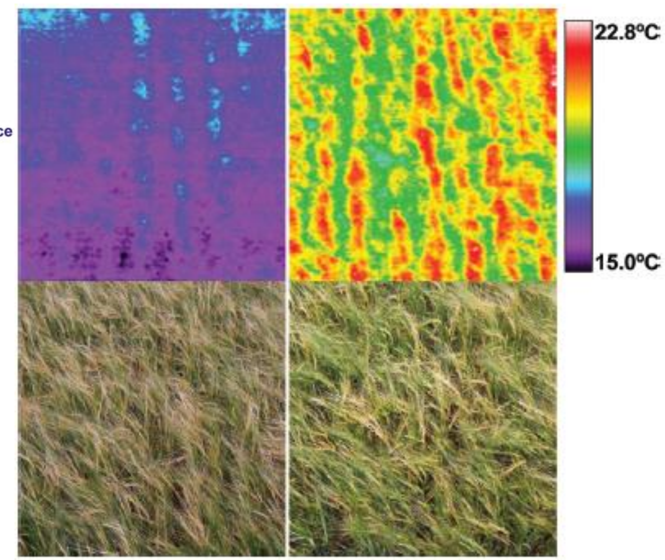
While, traditional approaches in physical methods to detect the health of trees would easily cause irreversible damages.

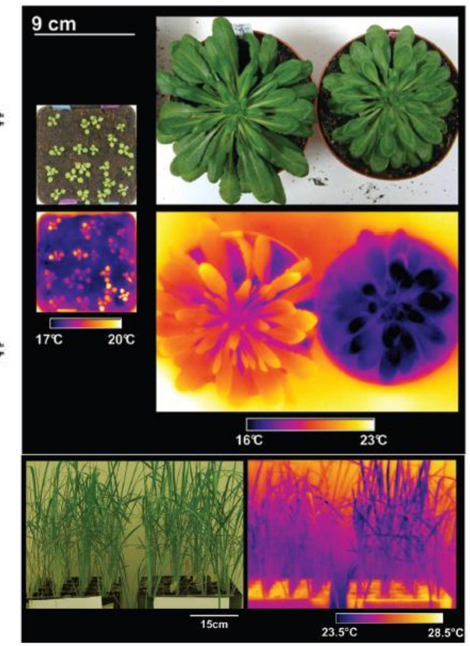
Thermography (i.e. **thermal infrared remote sensing**) which can directly record surface temperatures of trees as thermal infrared images is increasingly known as a scientific **non-invasive method** to identify internal damage of trees.

However, specific relationship between the obtained thermal images and the internal decay / damaged tree trunks or the thickness of tree tissues is still uncertain.

Related Work







Costa,J. M., Grant, O. M., Chaves, M.M.,(2013).Thermography to explore plant–environment interactions. *Journal of Experimental Botany*, Vol. 64, No. 13, pp. 3937-3949.

Thermal imaging can estimate or quantify *water vapour* and *transpiration.*

Related Work

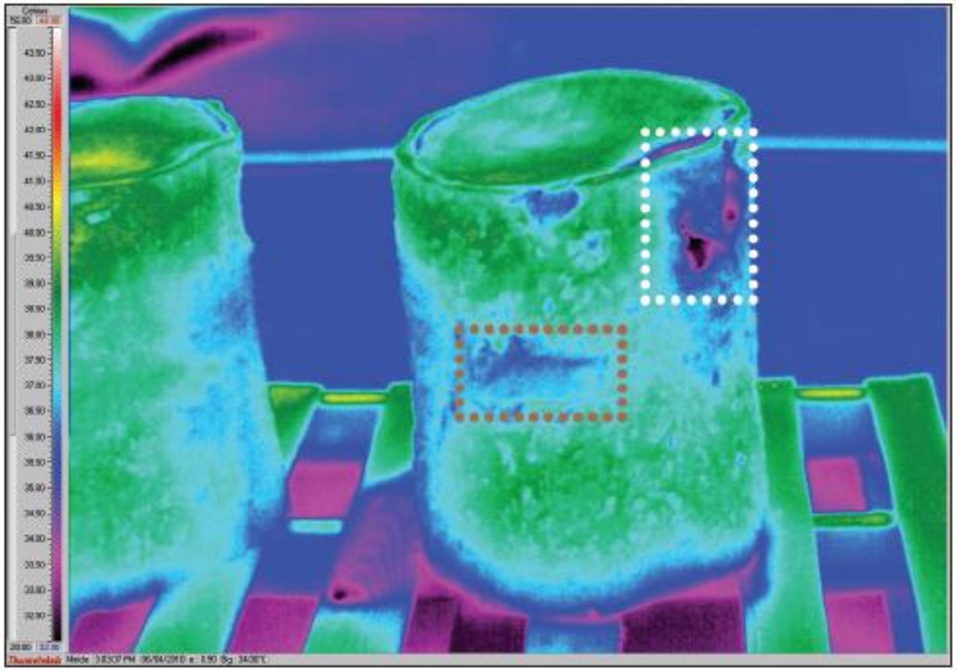


Figure 4. Superficial defects on the trunk, including abrasions (brown box) and detached bark (white box), were consistently associated with lower surface temperatures.

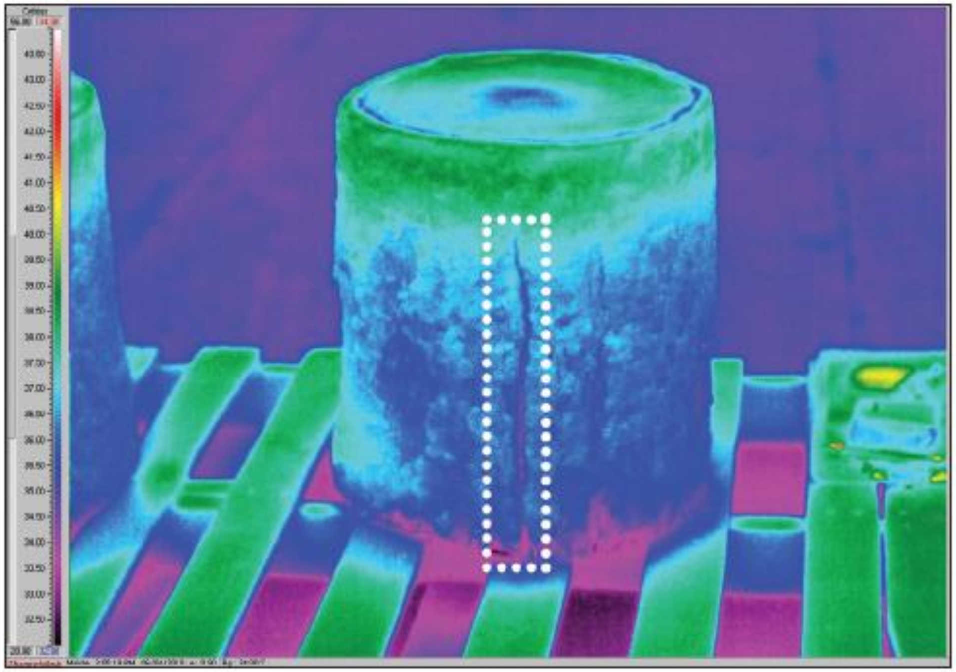


Figure 5. Bark cracks not extending into the stem were related to lower surface temperatures (white box).

Burcham, D. C., Ghosh, S., Choon, L. E., King, F. Y., (2011). Evaluation of an Infrared Camera Technique for Detecting Mechanically Induced Internal Voids in Syzygiumgrande. *Arboriculture & Urban Forestry*, Vol. 37, No. 3, pp. 93-98.

External bark defects were visibly associated with temperature reductions.

Related Work

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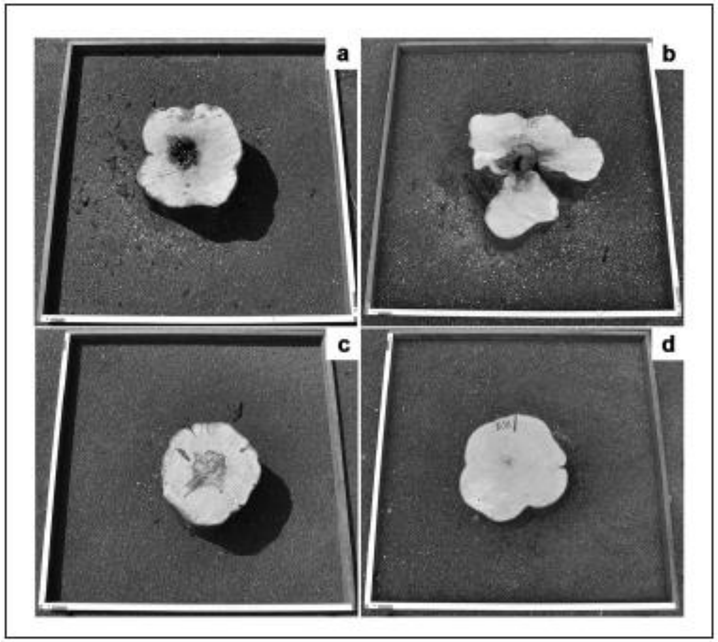
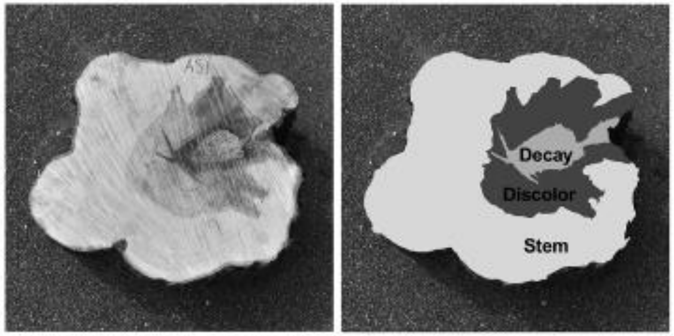


Figure 2. Each cross section was photographed in a 1 m × 1 m frame for visual reference. Among the sampled trees, sections were excised containing: (a) termite-induced cavitations with irregular, smooth-walled voids; (b) decay with irregular color changes, host reaction zones, and dark fungal interaction lines; (c) discoloration with irregular wood color changes and dark fungal interaction lines; and (d) no measurable defects with substantially healthy tissue.



$$\text{Relative defect CSA (\%)} = \frac{\text{Defect CSA (cm}^2\text{)}}{\text{Total stem CSA (cm}^2\text{)}}$$

Figure 3. The relative amount of cross-sectional area occupied by a defect (relative defect CSA), represented as a percentage, was determined by dividing the surface area of the defect by that of the entire stem. In order to determine cross-sectional area, the perimeter of the stem and defect(s) were manually transferred onto a clear PVC transparency sheet, digitized, and analyzed using image processing software.

Burcham, D. C., Leong, E. C., Fong, Y. K., Tan, P.Y., (2012). An Evaluation of Internal Defects and Their Effect on Trunk Surface Temperature in Casuarina equisetifolia L. (Casuarinaceae). *Arboriculture & Urban Forestry*, Vol. 38, No. 6, pp. 277-286.

External features, such as cankers, detached bark, and mechanical damage, were associated with temperature anomalies – **our objective**.

The relationship between the extents of internal defects and surface temperature distributions is still under research – **our objective**.

Research Objectives

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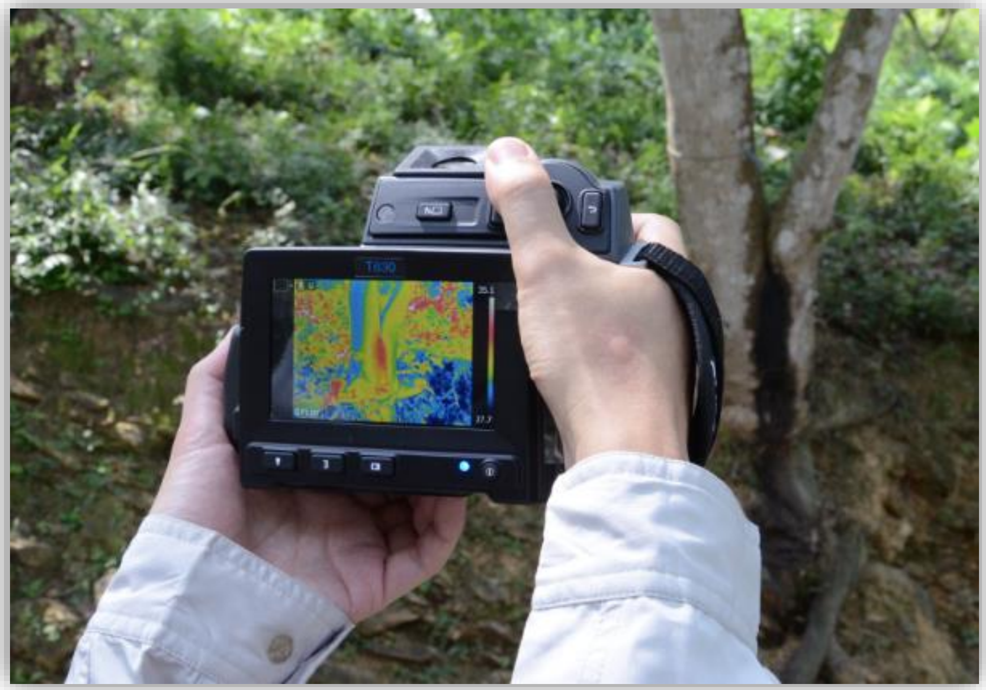
Therefore, our research objectives are:

- Acquire a sufficient number of thermal images for tree trunks in different dates, times, and environmental conditions.
- Design a research method to effectively reveal the damaged areas.
- Discover spatial distribution patterns of the damaged areas and reveal the relationship between the abnormal temperatures and the damaged trunks.

Methodology

1. Pilot study: Acquire thermal Images

- FILR T-Series thermal camera
  sensitivity less than 0.02 degree centigrade
- Distance between the tree and the thermal camera is about 5 to 10 meters
- 172 thermal infrared images + 172 visible wavelength images correspondingly



Study Area

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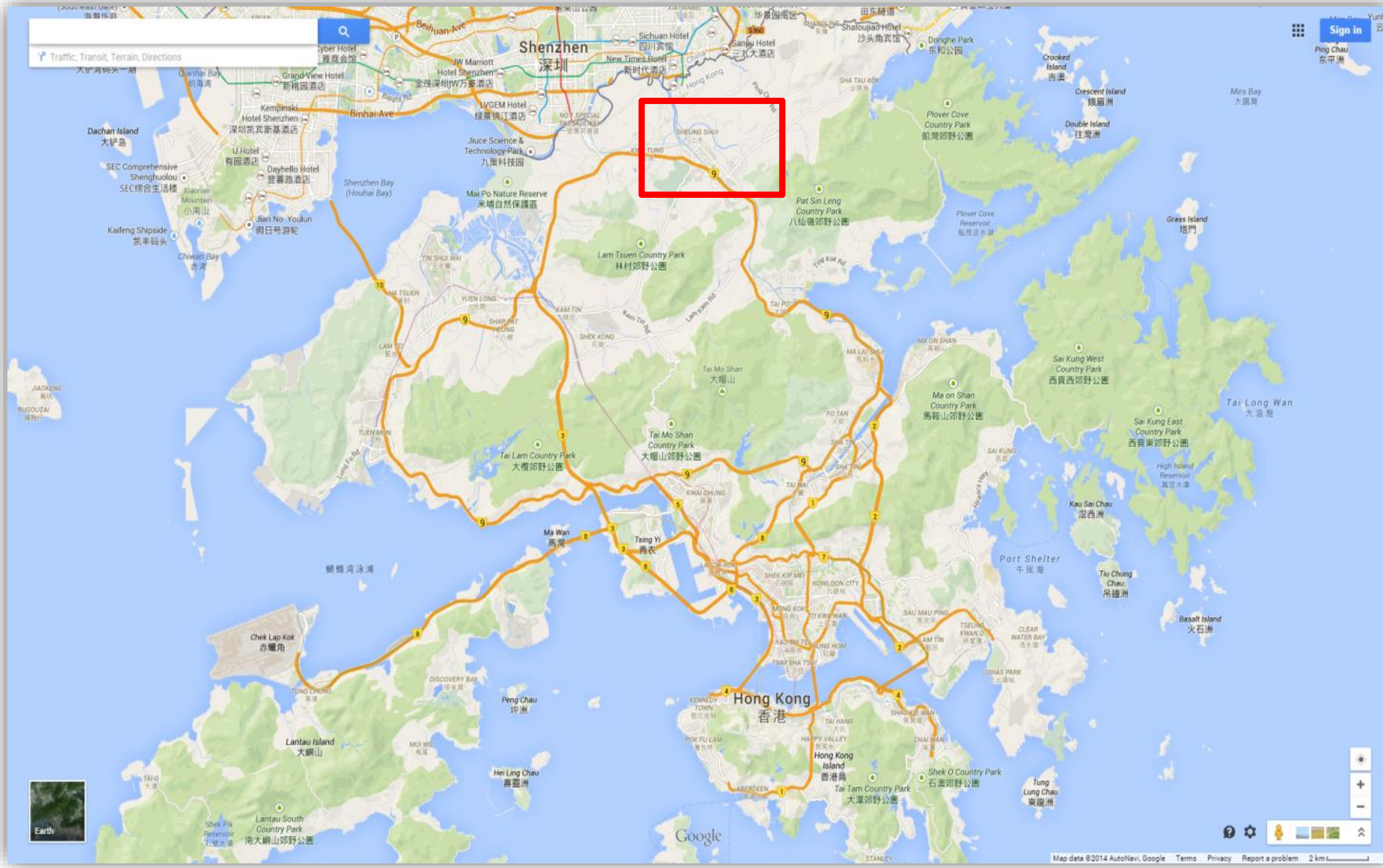


Trees are less protected in this restrict region of Hong Kong.

Methodology

2. Highlighting Potential Damaged Areas

to transfer RGB value to degree Celsius value

red_band

green_band

blue_band

max_t

min_t

sum_band

max_v

min_v

$$\frac{v - min\_v}{max\_v - min\_v} = \frac{t - min\_t}{max\_t - min\_t}$$

v represents any given value in the thermal image

t represents the temperature value in degree centigrade that to be obtained

2. Highlighting Potential Damaged Areas

to calculate the temperature threshold t_thd which is used for extract the low temperature areas (LTA) from the segmented trunks

$$\boxed{r = \frac{t\_thd - min}{max - min}}$$

r is a given value between 0 and 1

max is the maximum temperature in the given segmented trunk image

min is the minimum temperature in the given segmented trunk image

3. Compactness Ratio of the Damaged Area

to measure the compactness of an area determined by its shape (not the size)

$$cr = \frac{A}{\pi R^2}$$

cr adapts the measurement ranging between 0 and 1

a thin and long shape should have a measurement near to 0

an ideal compact shape of the measurement is approaching to 1

A indicates the area of a shape

R represents the radius of the smallest circle that can surround the shape

4. Characteristics of the Potential Damaged Areas

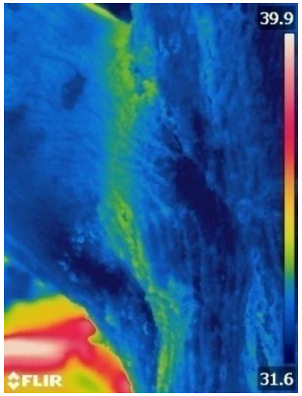
Table 1. Four indices to reveal characteristics of the potential damaged areas of trunks

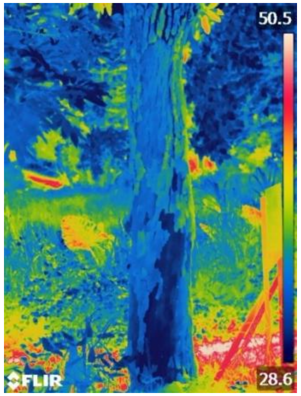
No.	Index	Calculation	Range
1	Temperature difference of the trunk	$TD = \lvert max\_t - min\_t \rvert$	$TD \geq 0$
2	Size Ratio of the polygons	$SizeR = \frac{\sum S(t)}{S}$	$0 \leq SizeR \leq 1$
3	Shape Index to measure complexity of the shape	$ShapeI = \frac{P}{2\sqrt{\pi S(t)}}$	$ShapeI > 0$
4	Shape Similarity of the two polygons in two temperature thresholds	$ShapeS = \frac{ShapeI(t2)}{ShapeI(t1)}$	$ShapeS > 0$

Result Analysis

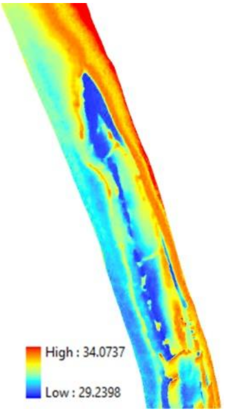
Visible Wavelength Images

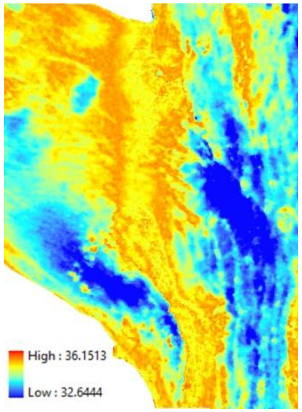
Thermal Infrared Images

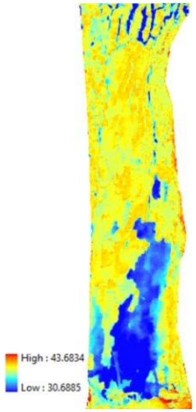




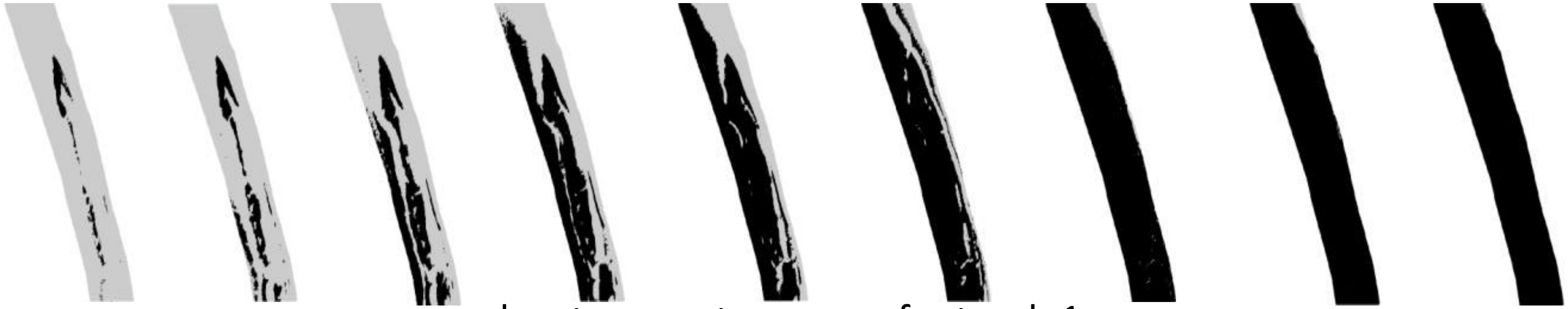
Segmented Trunk Images



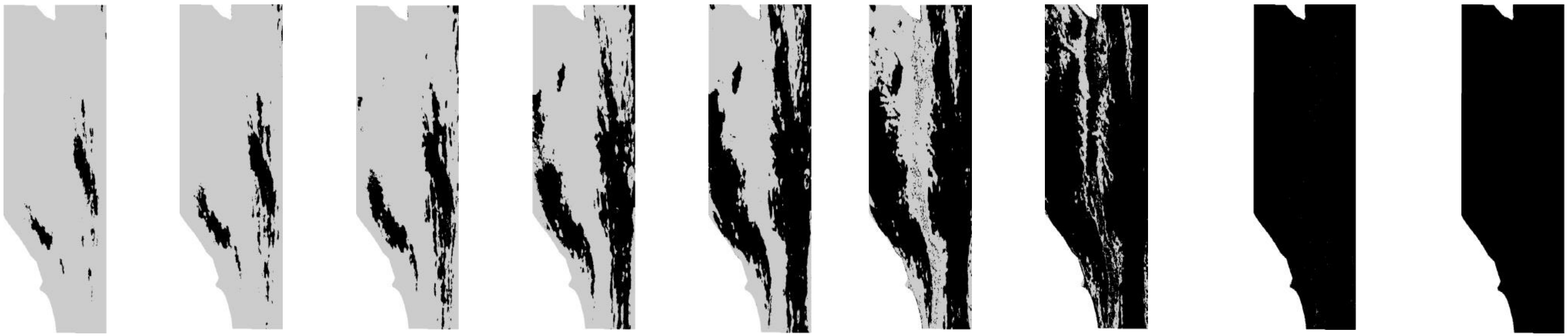




Result Analysis



low temperature areas for trunk-1



low temperature areas for trunk-2

low temperature areas for trunk-3

Result Analysis

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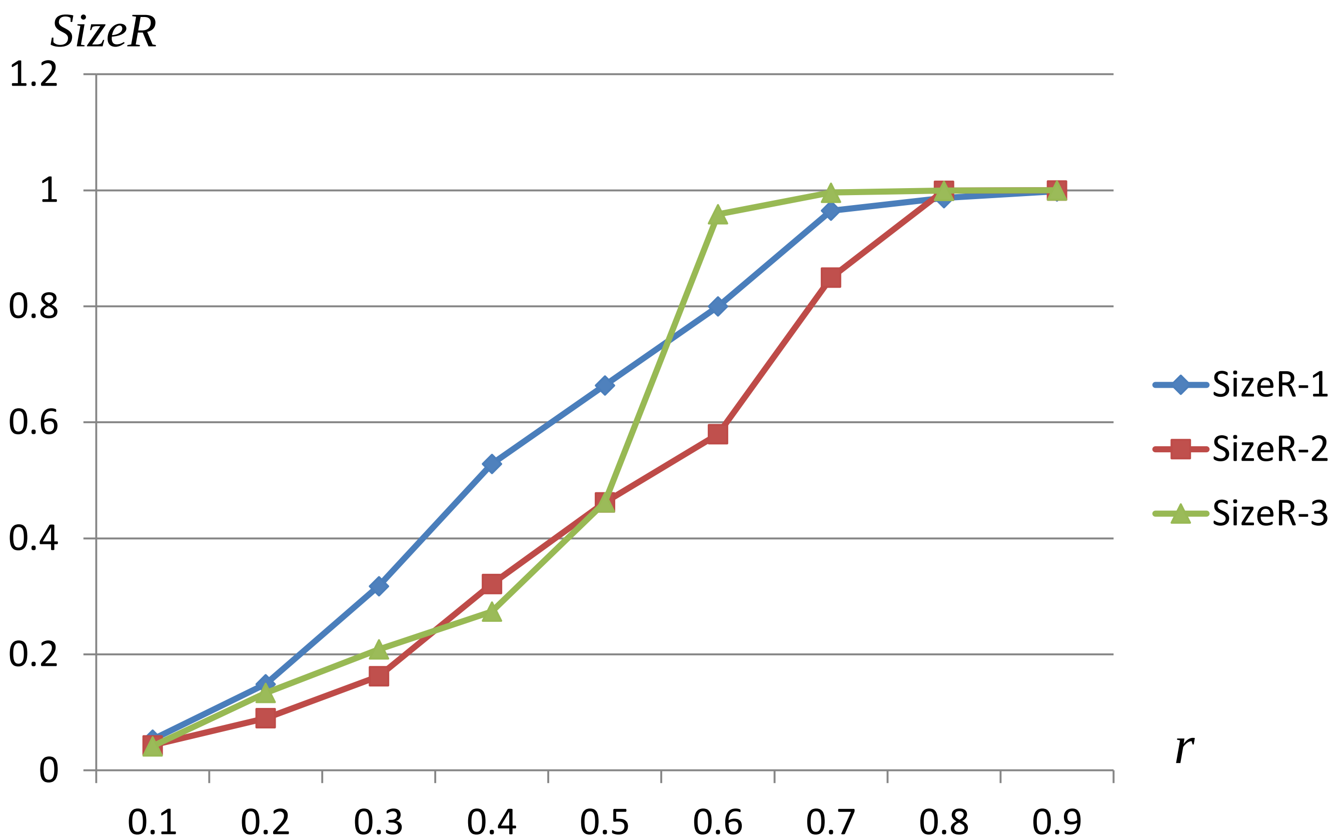
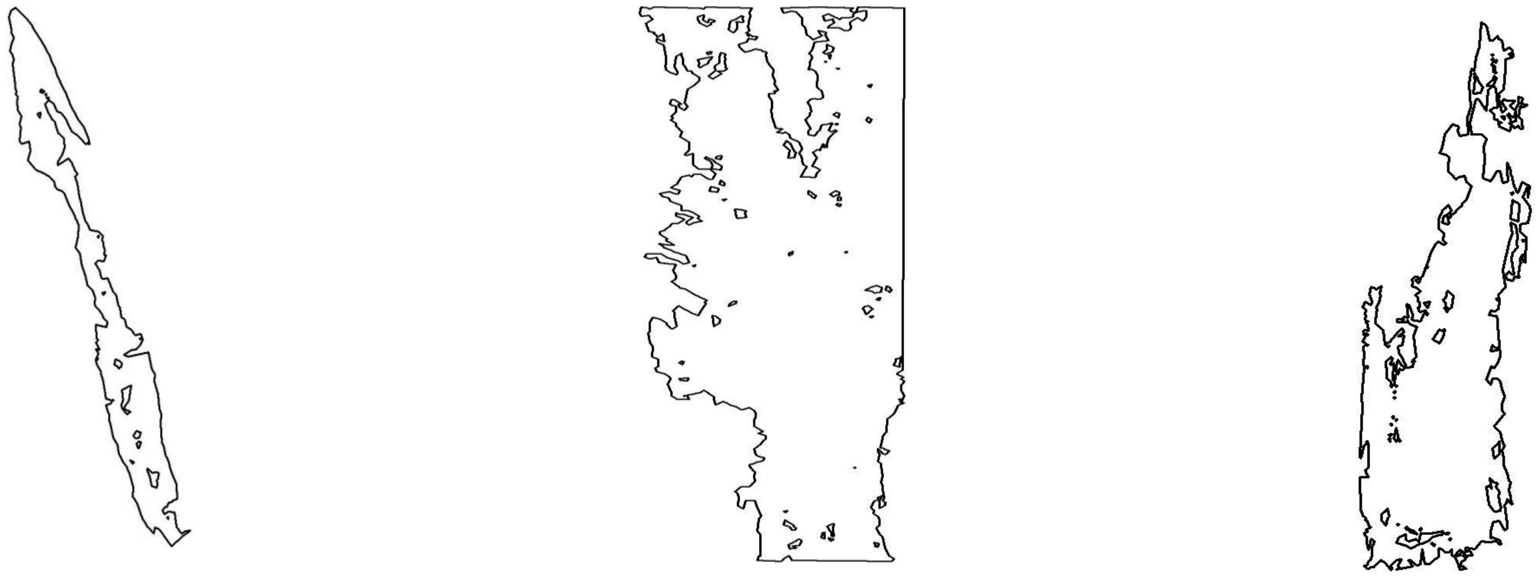


SizeR of the three low temperature areas of segmented trunks

Segmented trunks have the highest possibility of being damaged or decayed when *r* value of each curve reaches the largest slope in this figure, since it indicates huge area difference of polygons between two consecutive groups.

Result Analysis



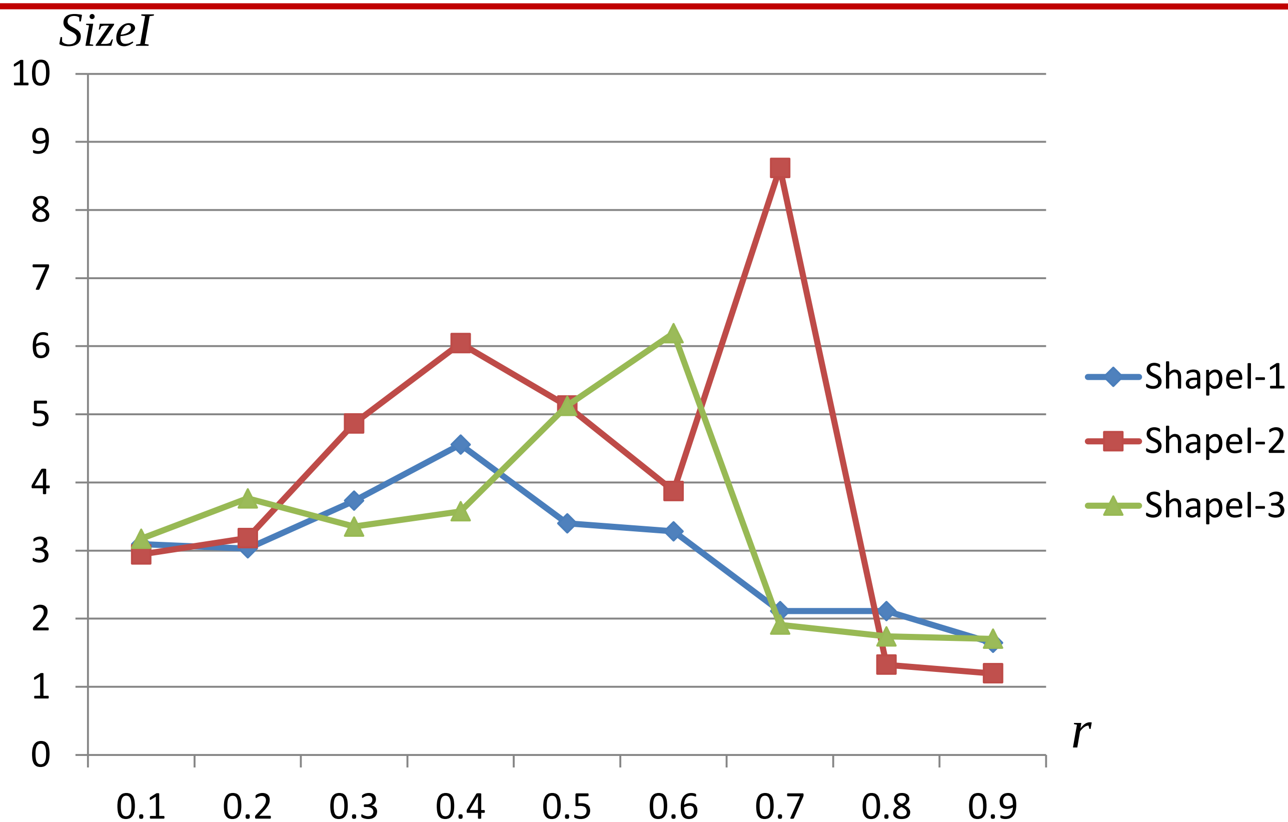
cr = 0.0703 for LTA-1 (*r*=0.3) *cr* = 0.2333 for LTA-2 (*r*=0.6) *cr* = 0.1623 for LTA-3 (*r*=0.5)

Figure 6. Compactness ratio of the maximum size of shape for three trunks

Table 2. DT of the three segmented tree trunks

Name of the trunks	STI-1	STI-2	STI-3
TD	4.8339	3.5069	12.9949

Result Analysis



ShapeI of the three low temperature areas of segmented trunks

The trend of each curve reveals the degree of fragmentation or the complexity of the low temperature areas.

However, the considerable decreasing indicates that almost all the polygons are merged together as one which has a relevant simple shape complexity.

Conclusion and Discussion

The research has discovered some interesting characteristics in view of shape compact with *cr*, size changing with *SizeR*, and shape complexity with *ShapeI* of three tree trunks in the empirical experiment.

Independently using the thermal infrared image is not adequate enough to confidentially determine the damaged areas because it only directly reveals facial temperatures of trunks.

Current research **needs validation analysis by cutting some trees**.

Segmentation accuracy can be improved.

Future Work

Systematically plotting *cr* values for the maximum size of polygon given a full range of *r* values would be possible to find interesting patterns of the potential damaged areas.

To effectively determine damaged internal areas of trunks, acoustic wave theories or other technologies may be used to map the internal structures and densities of trunks.

Physically cutting some tree trunks for the validation analysis.

Construct a systematic database in the relationship between *ShapeI* / *ShapeS* and damaged types of different tree species.

Thank you