Tree Health Assessments Using Infrared (IR) Cameras

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Background

We plant trees for the countless benefits they provide to our communities, including clean air, visual beauty, and shade from the hot sun. Mature trees, in particular, contribute meaningfully to our landscapes and captivate our attention. They contribute to our sense of place and sustain our connection to the natural world. Although these trees appear to be permanent fixtures of a landscape, they are all vulnerable to stress and may eventually decline and subside. Arborists mitigate these problems by regularly inspecting the biological health and physical stability of trees to preserve their condition. In practice, they often use a visual inspection process, supplemented by their knowledge and experience, to search for signs and symptoms of hazardous conditions that need attention. These inspections help ensure that everyone enjoys the benefits of trees while minimizing the costs.

Occasionally, special instruments can be applied to assist arborists with the detection and diagnosis of specific problems. For example, the penetration resistance drill and sonic tomograph are two devices frequently used by arborists locally. These identify and assess internal defects by measuring material property changes associated with damaged wood. Similar commercial devices evaluating a range of material properties, including acoustic wave velocity, gamma-ray transmissivity, and electrical resistivity, have been developed for practical use in the field. Although it may be tempting to assume these devices are infallible, their results should always be carefully interpreted by experienced arborists. Reliable guidelines are not available to describe acceptable limits for many tree health problems, and arborists often must rely on their training, experience, and available reports to form a prognosis and develop options for treatment. There is also a scarcity of information about these devices' expected performance and practical limitations under a range of field conditions. Ultimately, research and development of new, potentially useful devices can enhance the tree inspection process by increasing the quality of information available to arborists in the field.

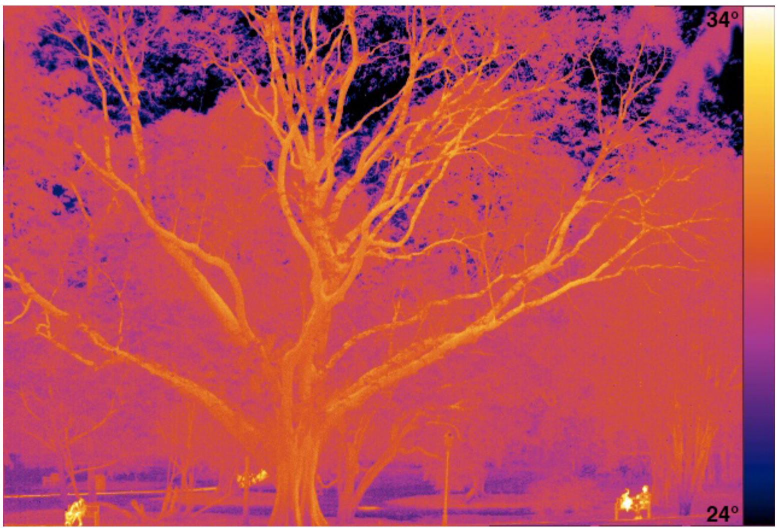

Figure 1 An IR image (left) showing stem, branch, and leaf surface temperatures of an angsana (*Pterocarpus indicus*) in the Singapore Botanic Gardens captured by a handheld IR camera (right).

Recently, CUGE Research completed an evaluation of infrared (IR) cameras applied similarly during tree inspections. IR cameras work almost the same as digital visible light cameras except that they are sensitive to long-wave (8–14 µm) IR radiation, and the images produced by the camera display the surface temperatures of objects in their field of view (Fig. 1). In many industries, an object's surface temperature offers a valuable benchmark of its condition when evaluated by an IR camera. For example, IR cameras have frequently been used to identify travelers with a high fever and control the spread of communicable diseases, such as SARS and Avian Flu. In a similar way, leaf and stem temperatures may reveal useful information about a tree's health and stability. Guided by existing research, the IR camera can be used to evaluate the relationship between a tree's surface temperature and some common afflictions, including trunk defects, drought stress, and sap flow disruption. Guidelines are included below for arborists interested in using these techniques.

Guidelines

Basic measurement principles

Overall, the IR camera is a user-friendly instrument that many can use confidently with the right training and guidance. Like many other instruments, there are a few important points to remember in order to successfully use this device to assess trees in the field. The following principles will help arborists confidently use this device for the first time:

1. Always take several measurements of your target subject. Tree temperatures are constantly changing in relation to the weather and average readings collected across space and time will smooth out much of this fluctuation.

2. Set up the camera at an appropriate distance from the target (Fig. 2). Small subjects should be measured at closer distances to obtain accurate results. For example, this means that you can't measure yellow flame (*Peltophorum pterocarpum*) leaflets accurately from the ground.

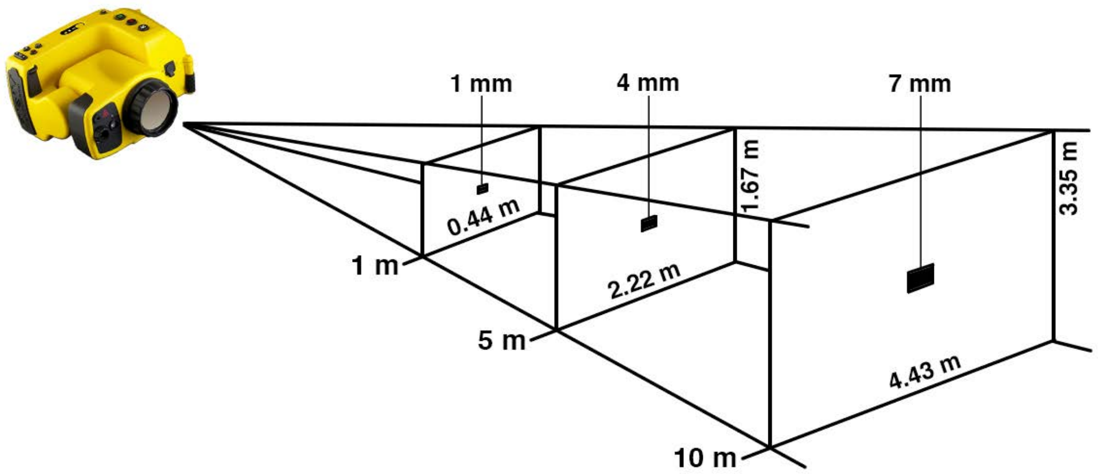

Figure 2 The camera's field of view (black outline) and smallest measurable object (black box) vary depending on the distance between the lens and target subject (Note: These dimensions are only accurate for the Thermoteknix VisIR 640-P infrared camera.)

3. Calibrate the camera with information about your subject. The target subject's emissivity (ε), a measure of its ability to radiate energy, and the current temperature need to be entered at this stage. Reference emissivity values for common natural materials can be found in Table 1.

Table 1 Emissivity Values for Common Materials in the Natural Environment

Material	Emissivity (ε)
Green foliage	0.96 ± 0.01
Lichens	0.97 ± 0.01
Senescent foliage	0.87 ± 0.06
Soil	0.97 ± 0.01
Tree bark	0.94 ± 0.02
Water	0.99 ± 0.07

Source: Salisbury and D'Aria (1992)

4. Avoid taking measurements of sunlit areas with an IR camera. Instead, choose shaded parts of your target subject where temperatures won't be distorted by sunlight.

5. Compare your measurements with reference values collected in the same way from a healthy tree nearby. This can clarify whether your target subject's temperatures are typical or abnormal.

Trunk defects

One of the useful ways in which the IR camera can be applied is to help identify structural defects. The presence of internal defects, such as decay, cavities, and insect borer galleries, dramatically alter trunk anatomy, and these defects can affect the ability of trees to resist physical loads. Our studies show that the camera reveals the position and extent of internal defects only when relatively large areas, exceeding 75% of the stem cross-section, are significantly degraded inside the trunk. The IR camera is not able to detect internal defects below this size, nor is it able to reveal incipient wood decay lesions located just underneath the bark surface.

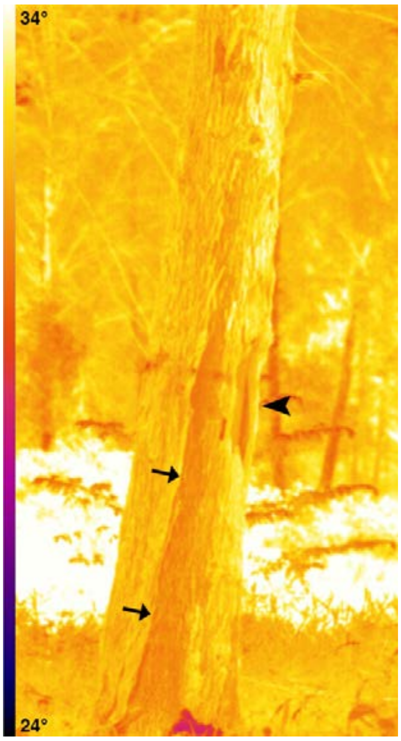

Figure 3 IR images reveal external defects, such as detached bark (arrows) and mechanical damage (pointer), more reliably than internal defects.

In contrast, the IR camera provides comparatively more information about the health of bark and cambial tissues than internal wood. The camera often clearly highlights the existence of external defects, such as mechanical damage, cankers, and cracks (Fig. 3). These defects may be visually apparent during tree inspections or just out of sight below the bark.

To evaluate trees for defects using an IR camera, place a 1.5 m tall canvas screen around the trunk to block direct sunlight during the day. Remove the screen from the target subject just before sunset. Afterwards, measure trunk surface temperatures and look for distinct areas of abnormal temperatures. These areas will be associated with the general position and extent of defects. This process should be repeated over at least three days for confirmation.

Drought stress

The IR camera can also be used to look for symptoms of drought stress. Plants routinely lose large amounts of water through their leaves during gas exchange with the surrounding air. During this process, the phase change of water from a liquid to vapor as it evaporates cools the leaf surface. If a tree doesn't have enough water, they often respond by closing their leaf pores (stomata) to conserve water and, as a result, stop evaporative cooling of the leaf surface. This almost always causes leaf temperatures to rise measurably. In these cases, IR cameras can be used to confirm drought stress by measuring canopy leaf temperatures.

To evaluate trees for drought stress using an IR camera, measure canopy leaf temperatures periodically for at least three days. These regular measurements should be recorded as the difference between leaf and air temperatures at the time of image collection. Compare your average measurements with those from a nearby healthy tree. Based on our studies, drought stressed canopies should be approximately 0.5°C warmer than a well-watered reference (Fig. 4).

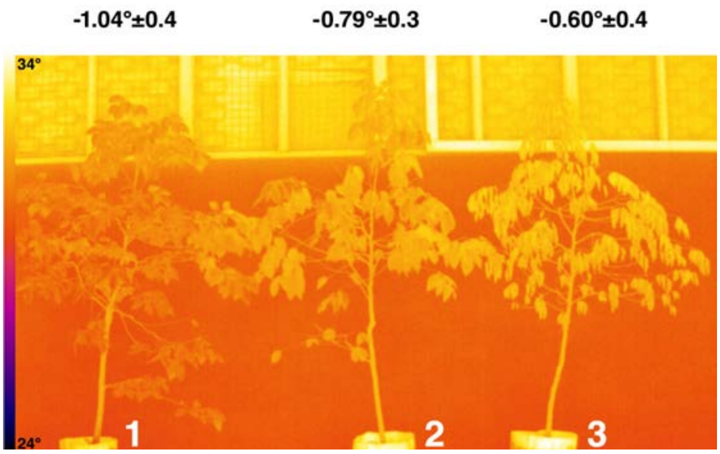

Figure 4 Average leaf temperatures (mean±SD) of chengal pasir (*Hopea odorata*) were significantly warmer for drought stressed trees (Plants 2 and 3) than a well-watered reference (Plant 1). (Note: Temperature values are the difference between leaf and air temperatures at the time of IR image collection.)

These canopy temperature measurements can provide a confirmation of drought stress, but they should be supported by other visual symptoms, such as the loss of interior foliage and drooping, curled leaves (Fig. 5). At more advanced stages of drought stress, it is common to see an even area of dead, brown tissue at the leaf margin. For a low cost alternative, non-contact infrared thermometers can also be used to measure leaf temperatures in this application.

Figure 5 Drought-stressed leaves with lower turgor pressure (right) lose stiffness and curl inwards compared with normal leaves (left).

Trunk sap flow disruption

The IR camera also reveals useful information about tree root systems. During the day, xylem water gradually warms as it passes from the cool root system into the warm trunk, and this water conduction produces vertical temperature gradients on the trunk close to the soil surface (Fig. 6). These gradients can be clearly seen with the IR camera and provide a useful way to check for sap flow disruptions originating in the root system. This condition can have serious implications for tree health and stability when they are caused by mechanical damage in the root system. Root systems are often damaged in this way during construction or excavation work, and this technique provides a non-destructive means of screening trees for such problems.

Figure 6 The natural temperature gradient at the trunk base (pointer, plant 1) is caused when cool water from the root system gradually warms as it's conducted upwards, and its absence from the same location (pointer, plant 2) suggests a disruption of sap flow.

To evaluate trees for sap flow disruptions using an IR camera place, a 1.5 m tall canvas screen around the trunk to block direct sunlight during the day. Remove the screen from the target subject just before sunset. Measure trunk surface temperatures and look for the presence (or absence) of this temperature gradient near the ground. Trunk surfaces without this gradient should correspond with the location of a root system disruption. This process should be repeated over at least three days for confirmation.

As one advantage, this non-destructive assessment allows arborists to screen for the problem without removing soil from the root zone. The technique can easily be used to evaluate preserved trees within construction sites as well as those affected by excavation in the roadside verge. Once identified, the results can be used to guide subsequent soil excavation to confirm and further assess the extent of the problem. As before, these measurements should provide supporting evidence of root damage that complements other observations, and the implications of the damage should be carefully assessed by experienced arborists. Existing guidelines about the consequences of root pruning on tree health and stability can be found in many publications (e.g. Hamilton 1988; Smiley 2008).

Further reading

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