

## Overview of Thermal Imaging for Tree Assessment

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### Summary

The value of Thermography to assess trees is reviewed in relation to the needs of inspectors and diagnosticians in the fields of urban forestry, arboriculture and veteran tree management. Images obtained with an infrared camera allow the early detection of various kinds of alteration in trees, including decay/cavity and the onset of adaptive growth in response to damage or mechanical stress. Advantages include total non-invasiveness, rapidity of use, the provision of ‘real-time’ information and the possibility to store images: comparing them with images taken at a later stage, it is possible to quantitatively determine the evolution of damage. In order to assess trees, however, the surfaces must be out of direct sunlight, not wet and unobscured. The images do not distinguish between different kinds of rots, but they can usually be correctly interpreted in the light of appropriate knowledge and experience. The technique does not allow a truly quantitative assessment of the relative extent of decayed and sound wood, but it appears to be accurate enough to identify trees which merit either remedial action or more precise assessment.

Keywords: Thermography, Tree assessment, Veteran trees management, Habitat assessment, Infrared photography, Tree decay, Tree hazard assessment, *Phytophthora* spp.

### Introduction

Thermography is a well established technique in a range of disciplines, including engineering and medicine. The use of an infrared (IR) camera system for the thermographic detection of cavities in trees has been described and reviewed (G. CATENA, 1990; G. CATENA, 1992; A. CATENA and G. CATENA, 2001). The resulting thermal images represent only the pattern of temperature at the bark surface but this pattern depends on the differing thermal properties of underlying zones of sound and decayed wood, which produce steady-state temperature gradients across the tree surface. The pattern appears as a black-and-white or pseudo-colour ‘thermal map’, in which the area overlying decayed wood or a cavity is usually cooler than the surrounding area.

Compared with other methods for decay detection, IR imaging has the clear advantages of being totally non-invasive. As such, it allows data to be collected at intervals without disturbing the tree internally, thus aiding the investigation and accurate monitoring of a potential or confirmed deterioration in health or mechanical integrity. A further advantage is that it can operate at a distance of up to 20 or 25 metres (CATENA *et al.* 1990) and therefore allows the detection of cavities that would otherwise be accessible only by climbing or via hydraulic platforms. Also, the information is provided in ‘real-time’. These characteristics can clearly save users inconvenience, personal risk and time. Indeed, the technique is less time-consuming in its use than any other

technologically advanced system. As with any system, however, practitioners require information about accuracy, reliability, and cost (LONSDALE, 1999). The present article considers these questions and also considers the value of the technique for the assessment of trees as habitats for wildlife associated with cavities.

### **The specificity of the system for decay detection**

The thermal properties of stems and branches in standing trees may be affected by a number of factors, of which decay is not the only one. For example, as discussed below, bark lesions caused by pathogens such as *Phytophthora* spp. can be detected by thermal imaging while not yet externally visible, even if they overlie sound wood. (A. CATENA, 2003). On balance, it seems useful that thermal imaging can detect a range of possible defects in addition to decay, or that it can detect decay (in the root system) beyond the direct range of the image. Although it does not provide a specific diagnosis for different types of decay, there will in most cases be other visual evidence that can be used. Being a noncontact investigation system, correct interpretation of IR imaging may, however, require the use of other specialised techniques in some instances.

### **Qualitative and quantitative assessment of decay**

Numerous case studies have been cited to show that extensive zones of decay are represented by correspondingly extensive 'cool zones' on thermal images. This relationship has not been investigated completely to date, but it has been broadly verified by 300 general comparisons between thermal images and data obtained using invasive tools and felling (A. CATENA, 2004). It is, however, of interest to note that the technique appears able to detect decay caused by *Kretzschmaria* (= *Ustulina*) *deusta* (CATENA, unpublished data). This kind of decay has proved difficult to detect using certain other devices (SCHWARZE *et al.* 1995) and has therefore come to be regarded as a test of sensitivity (RABE *et al.*, 2004). As is usually the case with decay, the area of bark overlying the decay caused by this fungus was colder than the surrounding bark.

In tree risk assessment, it is often necessary to estimate the extent of decay, so as to determine whether it represents a significant weakness, for example by calculating the relative thickness of a residual wall of sound wood in the form of the 't/R ratio' (MATTHECK and BRELOER, 1994). As pointed out by A. CATENA (2003), thermal images cannot always provide such measurements precisely. Also, in certain cases, large cool zones have been found on stem bases that, after felling the trunk, showed only small volumes of decay. Measurements taken with a Dendrodensitometre inclined downwards showed the presence of large cavities below ground-level. It appears, therefore, that the decay was more extensive below ground-level (A. CATENA 2003). This indicates that thermography provides the only technologically advanced method of detecting decay in the root system.

Despite some exceptions, most investigations to date have shown a direct relationship between thermal images and the relative extent of the underlying zones of sound and decayed wood. For example, the large tree shown in Fig. 1 contains a wide cavity from the base to the bifurcation; this was evident from a cavity-opening on the opposite side. However, the thermal image shows several yellow strips, representing substantial zones of functional tissue, surrounding the cavity which is represented in blue. Thus, the image correctly indicated that the tree's mechanical integrity was not significantly compromised. Generally, it appears that thermal imaging provides a good basis for deciding whether the t/R ratio is either well above or well below a threshold at which other methods might be needed to obtain comparative information.

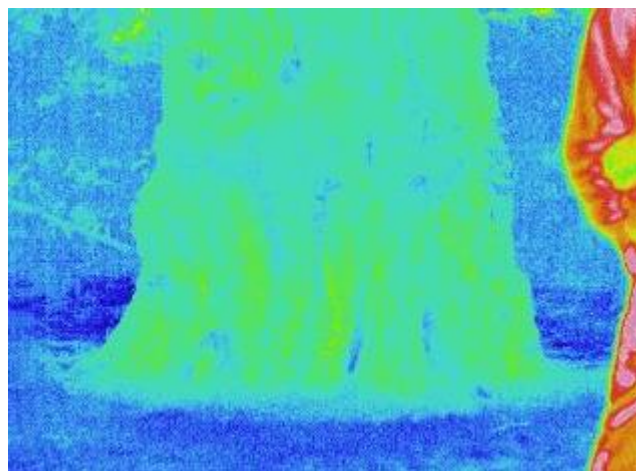


Fig. 1 – This Horse chestnut is hollow, but a thick wall of sound wood provides good mechanical support

### Assessment of features other than decay

Any feature that substantially alters the thermal properties of wood or bark can be detected by thermography. This might cause uncertainty in the interpretation of thermal images, but it is possible to distinguish between decay and other features if the assessment is made in the light of other evidence and of appropriate knowledge and experience. For example, the formation of new functional tissue by adaptive growth of the cambium can be detected by its thermal properties before its presence is otherwise obvious. For prognosis of the tree's condition, it is important to know whether such tissues are forming in response to damage and/or to mechanical stress. The thermal image in Fig. 2 shows a *Sophora japonica* with a light yellow strip of colouration running the full length of the trunk. The blue colour indicates a cavity also running along the trunk. Analysis of this image, together with dissection of the tree, showed that the yellow strip corresponded to a strip of increased wood formation, running parallel to the cavity, as clearly showed in Fig. 3, which shows the stump of the *Sophora*.

A further application of thermography is the detection of bark lesions (e.g. bleeding cankers caused by *Phytophthora* spp.) at a stage before such damage becomes visible to the naked eye. Fig. 4, taken in Holland in October 2004, shows an *Aesculus*

*hippocastanum* with no visible signs of damage. On the contrary, the thermal image of Fig. 5 showed that the tree was affected by delimited bark lesions, the presence of



Fig. 2 – Thermal images can reveal newly forming strips of functional tissue in veteran trees even when these are not externally visible. The case of a *Sophora Japonica* whose trunk is completely hollow, from the base to the broken ends of the main branches: the yellow strip towards the observer point out the presence of new functional tissue too



Fig. 3 – The stump of the *Sophora Japonica* confirms the presence of the axial cavity and of the newly formed tissue in the area of the yellow strip

which was confirmed by cutting the bark in the area corresponding to the dark blue spot pointed out by a black arrow in the image. Although these lesions were of the type caused by *Phytophthora* spp. they were in this instance not identified.

To date, there have been no studies to investigate the application of thermography for the detection of bark lesions caused by *Phytophthora* spp. However, in view of experience with bark lesions so far, it seems highly likely that the technique has considerable value in this context.



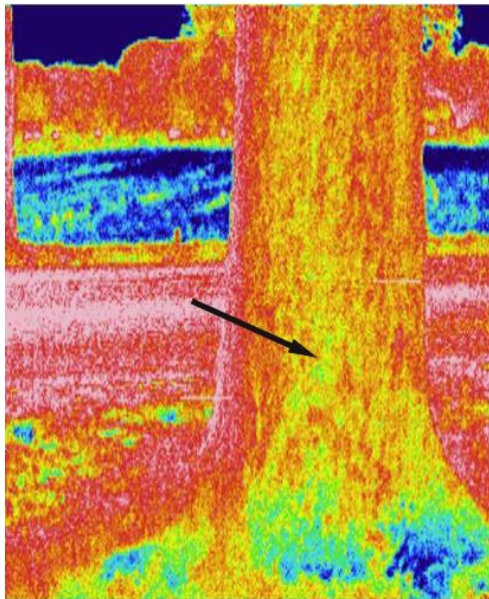


Fig. 4 – In this thermal image of *Aesculus hippocastanum*, the black arrow points out in light blue the presence of internal decay (bark necrosis). Its presence was not visible from the outside, but was confirmed by cutting away the outer bark. Grass growing at its collar is responsible for the blue-bluish colours at the collar



Fig. 5 – The picture of the same tree shows no damage on the surface of the trunk

Thermography of bark is a relatively new development, compared with the use of IR imaging of the crowns of trees, using monochrome and false colour films. This has been done for many years in aerial surveillance so as to detect the distribution and spread of damage in forests. Also, when applied to the foliage of individual trees, IR photography can make a significant contribution to disease detection (BAWDEN, 1933; CATALANO *et al.* 1986; CATALANO *et al.* 1988; CATENA *et al.* 1991), often before damage becomes visible to the naked eye.

## Applications for habitat assessment

Over recent years, arboriculture has increasingly embraced new fields of interest and assessment. A particularly important development has been the recording and investigation of veteran trees, which has been promoted in the UK largely through initiatives involving the Ancient Tree Forum (ATF)<sup>1</sup>. Thanks to these initiatives, there are numerous sites where trees of significant interest for landscape and biodiversity are valued and have been recorded and studied. Decaying wood and cavities within these trees, often formerly regarded only as potentially hazardous, are recognised for their habitat value as well as for the need to undertake risk assessments where appropriate. Thermography should be of value for identifying these features, particularly in cases where other methods would involve the need for tree climbing or the use of hydraulic platforms. Invasive methods might also disturb animals that are nesting, roosting or hibernating within cavities. These may include legally protected species, the disturbance of which could infringe laws such as the Wildlife and Countryside Act (1981) and the Countryside and Rights of Way Act (2000), in the case of the UK.

Figure 6 shows a black-and-white picture of a relatively young Plane Tree: it was of some interest as there were two small woodpecker holes on the trunk (one is pointed out by a black arrow), but no others signs of decay are visible.



Fig. 6 – Young Plane tree with no external sign of damage but two Woodpecker holes. One is pointed out by a black arrow

The monochrome thermal image, Figure 7, taken with an early form of the apparatus shows a wide cavity in dark grey, at the bifurcation, going up along the two branches but mainly in the one on the left side of the image. of a relatively young plane tree taken with an early form of the apparatus. The tree was of some interest as there were two

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<sup>1</sup> The ATF is a UK multidisciplinary non-governmental agency, whose aim is to improve the scientific knowledge about ancient trees, for the benefit of their effective sustainable management and protection.



Fig. 7 – Black-and-white thermal image of the Plane-tree in Figure 6, taken with an old less performing apparatus. It shows a large cavity at the bifurcation level going up mainly along the left-side branch

small woodpecker holes on the trunk, but no other signs of decay. The thermal image shows a wide cavity in dark grey, at the bifurcation going up along the two branches. The same apparatus showed the presence of a substantial cavity, shown in dark grey, in a *Casuarina* from which a Tawny Owl (*Strix aluco*) was later seen to fly (Fig. 8). The cavity was not visible from ground level. From the thermal image it is impossible to identify the large bird. This is because both the high insulating power of its feathers and of the wood prevent the detection of a living, warm body inside the trunk. In the case of large colonies of bats, it could be possible that the heat they produce could be recognized flowing out of the cavity.



Fig. 8 – The large cavity at the bifurcation of this *Casuarina*, shown in this thermal image (same apparatus as Figure 7) was not visible from ground level: it harboured the nest of a tawny owl that flew away after the image was made

### **Limitations: surfaces that are unsuited for thermography**

For the reasons stated by A. CATENA (2003), thermography will be unsatisfactory if the bark surface is obscured by anything such as moss or other vegetation, or if it is wet or has been heated by direct exposure to sunlight. The latter limitation can, however, be avoided in many cases, by obtaining images from a shaded portion of the stem or branch. Also, the system has been found to perform well over a wide range of ambient temperature (from +2 to +35°C in tests so far), by day or by night, all year round. It might be argued that the sensitivity or accuracy of the system might be affected by the thickness or the insulating properties of the bark of various tree species. To date, a few thousand trees of many different species have been satisfactorily assessed, including broadleaved, coniferous and palm trees (A. CATENA, 2004): therefor there is no evidence to support the above argument.

### **Potential for further development of thermography of trees**

There is a need to go depth in the mechanisms whereby thermography reveals decay and other alterations in trees even if the present understanding of these mechanisms and of the extent to which thermography can reveal the nature and dimensions of alterations is sufficient to assess trees and to assist users in interpreting the images that it provides

### **Type of Apparatus and Specifications**

Almost any type of currently available IR camera can be used for the thermal imaging of trees, provided that it has high geometric resolution and thermal sensitivity and includes a monitor for visualising the images of the area being filmed (A. CATENA, 2003). At present, the apparatus is sold at reasonable prices (€ 4.000 – € 8.000): in the UK it can even be rented on a daily basis

### **Conclusions**

Thermography of trees provides a means of detecting alterations relating to mechanical integrity, physiological function, tree vitality, disease and habitat conservation. In particular, it appears to have special value for detecting the early stages of such alterations, including those that involve the root system. The technique does not automatically distinguish between different kinds of alteration, but a correct diagnosis is usually possible in the light of appropriate technical knowledge and experience (G. CATENA, 2003) and occasionally with the use of other methods. Although, with current knowledge, thermal images do not always precisely measure the dimensions of features such as cavities, they provide enough information to help decide whether there is a need for remedial action or a more detailed kind of assessment. The main advantages of thermography over other diagnostic techniques are that it is totally non-destructive, rapid in its use and capable of use at a distance from the object.



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