

DETECTING STRESSED TREES WITH MULTISPECTRAL IMAGERY AFTER ATMOSPHERIC COMPENSATION

See a better world.®



Detecting Stressed Trees with Satellite Imagery

Geocarto International Centre Limited & DigitalGlobe

The health of individual trees can now be determined without field visits. A new early detection system allows researchers to use high-resolution satellite data from DigitalGlobe's WorldView-2 and WorldView-3 satellites to diagnose tree health remotely—making field visits necessary only if there is a need to verify the tree location or to carry out field diagnosis and treatment. This innovative technology is based on spectral reflectance analysis of the satellite data collected from individual trees.

Enabled by DigitalGlobe AComp

The availability of DigitalGlobe Atmospheric Compensation (AComp) greatly accelerates the pace of this process. With just the raw satellite data, we have to go through the process of converting DN to Radiance to Reflectance before we can undertake analysis of individual pixels. This conversion requires an additional calibration algorithm to get the surface reflectance. AComp facilitates this process by automatically compensating for atmospheric variability from pixel to pixel within a scene—ensuring consistent and reliable results. We can now use the surface reflectance data directly to generate spectral reflectance for tree stress study.

This technique reveals internal tree health warning indicators before any external symptoms can be observed. The early objective information they provide helps arborists and tree management teams carry out remedial measures expeditiously. This technique is not intended to diagnose the cause of the stress, which still has to be investigated in the field.

Tree Stress Warning Signs

From our study of banyan trees (*Ficus microcarpa*), we have found three warning indicators revealed by a stressed tree before collapse: a drop in reflectance in the near-infrared band; reduced absorption in the red band; and a drop in red edge band/shift of red edge to shorter wave length, as shown in **Figure 1**.

Near-infrared spectral reflectance indicates the condition of leaf cellular structure, while the red edge shift, red edge reflectance and red band absorption reveal the variation in chlorophyll content. Spectral reflectance will reveal subtle changes in chlorophyll content and leaf cellular structure caused by biotic and abiotic factors.

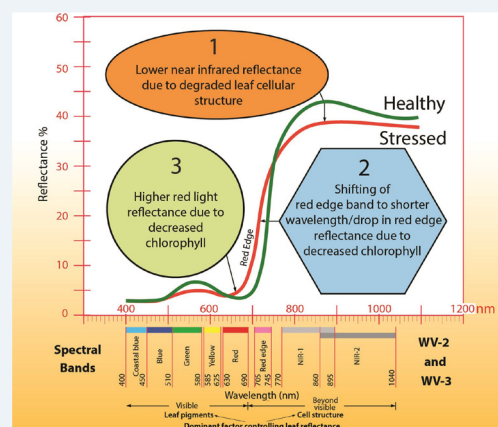


Figure 1. Internal Warning Indicators



Banyan Trees, Hawaii, United States
before and after AComp processing

When the leaf cellular structure is degrading, the near-infrared reflectance drops. If the red edge drops in reflectance and the absorption in the red band reduces, the indication is decreased chlorophyll content. These are warning indicators of a stress condition. If all are present, the tree is seriously stressed and structurally unstable, as illustrated in **Figure 2**.

Results of the Spectral Reflectance Analysis

Our interpretation is based on a comparison of the spectral reflectance of the same tree on different dates. This comparison can be also made for different trees, assuming the trees are the same species and the satellite data was collected on the same date. Comparison of spectral reflectance is relative: amelioration or deterioration of stress conditions refers to the changes observed over two and more dates.

We have studied three fallen trees grown in three different locations on Hong Kong Island—namely, on stone wall, steep slope and level ground, as illustrated in **Figure 3**.

For our analysis, we used the red, red edge and near-infrared spectral bands of WorldView-2 satellite images acquired on two different dates. The first satellite image was collected on 2010-02-25, and the second on 2015-04-17. Over the period of 5 years, the drop in the reflectance of the near infrared band for tree (3) was over 7%, for tree (2) 3.5%, and for tree (1) 4%. They all showed the three warning indicators. Tree 3 collapsed two days after the image was taken, while trees (2) and (1) collapsed after 96 and 94 days, respectively.

We can therefore conclude that there is a direct correlation between the drop in spectral reflectance and the closeness to the date of collapse—e.g., two days for tree (3) compared to 94 days for tree (2) and 96 days for tree (1). Since all the three warning indicators were present, these three trees were seriously stressed and structurally unstable. Their state of health deteriorated as the drop of the spectral reflectance increased—leading to their eventual collapse.

Case Study: Retrospective of a Declining Tree

In November 2014, a 14-meter *Scolopia saeva* tree located at Lei Yue Mun Park on Hong Kong Island was confirmed to have brown root rot (BRR) disease. Despite regular maintenance, the tree continued to decline. As it posed a potential risk of collapse, this seriously infected tree was removed on February 17, 2017 for public safety.

Using AComp WV-2 data, we undertook a retrospective study of this tree dating back to 2012. The results are presented in **Figure 4**.

The spectral reflectance of this tree showed continual drop over the period from 2012 to 2017, indicating that its health condition was progressively deteriorating. The deterioration was immense within just two months from 2014-11-19 to 2015-01-09, as indicated by the marked drop in NIR and red edge reflectance, as well as the reduction in red band absorption. As all the three warning indicators were present, this tree was severely stressed and structurally unstable on 2017-01-21. The study of this one declining tree shows how this technology can provide early and complementary information to arborists and tree management teams to implement remedial measures.

Case Study: A Tree Falls in Oslo

On August 10, 2016, the Norwegian Aftenpost (Evening Post) reported that a giant, 100-year-old elm tree had suddenly collapsed in downtown Oslo, Norway. Prompted by this intriguing incident, we immediately located the tree and found two cloud-free WorldView-2 images covering that area in DigitalGlobe’s image library. These two images were collected on 2014-09-02 and 2015-09-08—the latter about one year before the tree collapsed.

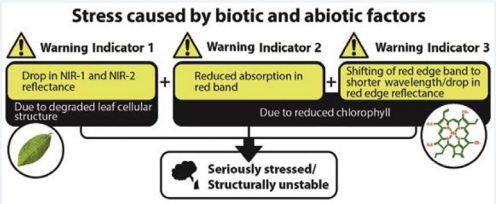


Figure 2. Implications of Internal Warning Indicators.

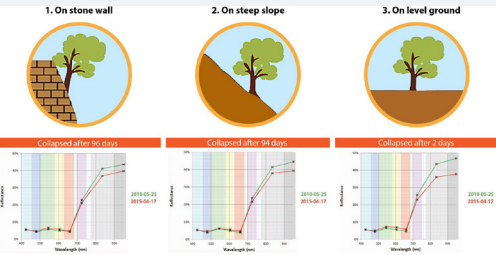


Figure 3. Trees Grown in Different Locations and Collapsed Subsequently

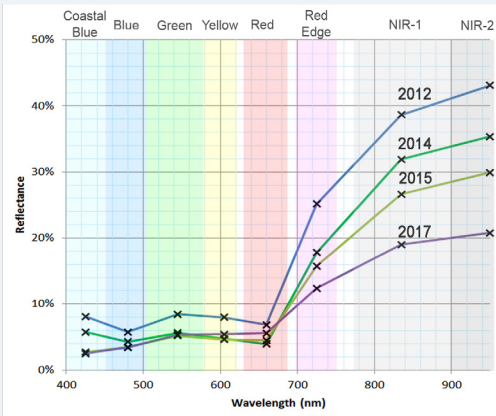


Figure 4. Spectral reflectance curves



Lei Yue Mun, Hong Kong before and after AComp processing

We used the AComp data of these two dates to generate spectral reflectance curves of this tree (1) and two adjacent trees (2) and (3) for comparison study, as shown in **Figure 5**.

Our study provided startling results. Within just one year, the spectral reflectance of tree (1) showed a **5%** drop in the near-infrared region, a **1%** drop in red edge band and a **2.6%** reduction in red band absorption. Such significant drops indicated that the tree was seriously stressed. Hence, it can be interpreted that tree (1) was already seriously stressed on 2015-09-08 when the satellite image was taken—a year before its subsequent collapse

On the other hand, the two adjacent trees did not show much variation in spectral reflectance over the same period. Their health condition was therefore judged to be stable, and both are still standing—which confirms the practical application of this new technology.

Case Study: Hong Kong Tree Health

In January 2017, we undertook a monitoring project for a department of the Hong Kong government. The objective was to study 10 old and valuable trees plus 100 more individual trees in five public parks in Hong Kong. We used archive data collected in January 2014 and 2015 as well as tasking data acquired in 2017 for our study of each tree. From our study of over 300 spectral reflectance curves, we have identified 4 categories of tree health condition, as shown in **Figure 6**.

Improving. If the reflectance in NIR and red edge increases, and the absorption in the red band also increases over a period, the indication is improvement over that period.

Stable. When there is little variation in the spectral reflectance of the same tree over a period, a stable condition is indicated over that period.

Fluctuating. If the spectral reflectance rises and drops or drops and rises over a period, the indication is fluctuating.

Declining. When the spectral reflectance and red band absorption continues to drop over a period, the indication is deterioration over that period.

Conclusion: Advantages

This new technology promises five distinct advantages:

- (1) It provides a non-invasive, time-saving and cost-effective method of monitoring tree stress conditions over any period for which WorldView-2 or Worldview-3 satellite data exists.
- (2) It presents more objective and quantitative means to measure the stress condition of an individual tree.
- (3) It can detect tree stress before any external symptoms are shown by analyzing internal warning indicators like subtle changes in chlorophyll content and leaf cellular structure.
- (4) When this technology is integrated with conventional field inspection and diagnosis, it will greatly enhance the monitoring and management of an individual tree to expedite implementation of timely remedial measures.
- (5) A vast archive of WorldView-2 and Worldview-3 satellite data is available for retrospective study of the changes in the health conditions of an individual tree.

If you are interested in exploring more about this innovative tree monitoring technology, we cordially invite you to visit this website: <http://www.geocarto.hk>

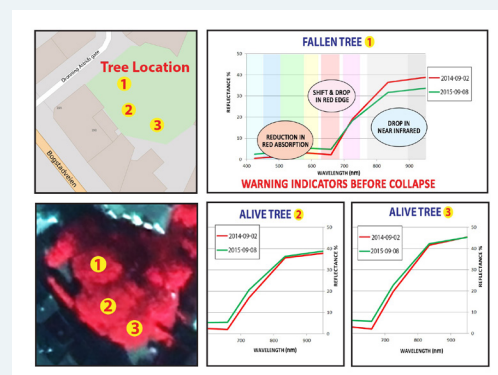


Figure 5. Fallen Tree and Alive Trees

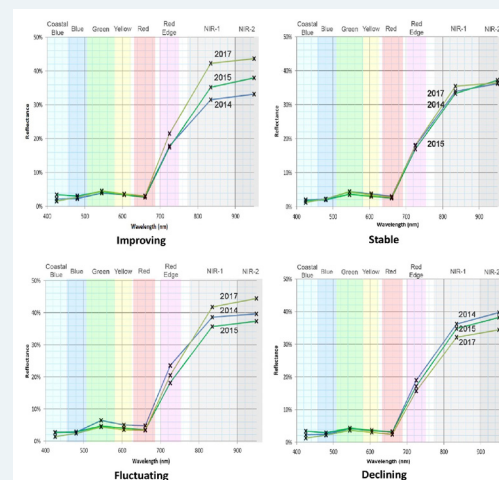
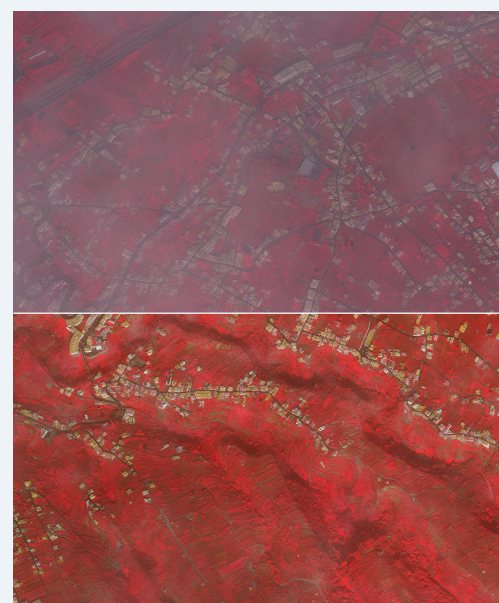


Figure 6. Spectral reflectance curves



Canary Islands, Spain
before and after AComp processing

WP-ACOMP 08/17