ERTS records SO₂ fume damage to forests, Wawa, Ontario

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The Earth Resources Technology Satellite (ERTS) recorded the image shown in Figure 1 and on the front cover on 3 August 1973, from an altitude of about 900 km. The image shows the clarity with which forest damage from SO₂ fumes was recorded on band 5 (red spectral region: 600 to 700 nanometers).

The area covered is a CFS ERTS test-site near Wawa, Ontario (Sayn-Wittgenstein and Moore 1972) which includes an area of known SO₂ damage that has been studied on ultra-small-scale (1:160,000) colour-infrared air photos (Murtha 1972). Four damage zones (Table 1) were recognized and delineated by photo interpretation.

TABLE 1 Criteria used for photo interpretation of the SO₂ fume-damage

Damage zone	Definition	Symbols (Fig. 1)
Total kill	Almost all vegetation is absent, rock outcrops and landforms are prominent; no observable tree growth.	T
Heavy kill	Almost complete mortality of all trees; lesser-vegetation predominates and a few scattered, stunted trees, shrubs and rock outcrops are present.	H
Medium damage	High white birch mortality (greater than 50%), no appreciable mortality of other hardwoods or conifers. There is significant, premature, leaf colour-change ^a of residual birch. Occasional pockets of dense hardwood-sapling growth.	M
Light injury ^b	Low birch mortality and some premature colour change of birch foliage, and yellowing of old-growth white pine.	L

^aLeaf-colour change of birch takes place after fume damage. The leaves appear to take on a yellow cast, although portions of them have been killed and have turned a light straw-brown.

^bOutside the light-injury zone, premature leaf colour-change attributable to fume damage does not occur.

On the band 5 ERTS image, three damage zones were easily delineated (the total-kill, heavy-kill and medium-damage zones) by interpretation of the gray tones (image-density variations) on the black-and-white positive image. The interpretation was augmented by electronic colour enhancement of the density variations. The light-injury zone, recognizable by photo interpretation, could not be delineated on the ERTS image.

The damage was most obvious on the band 5 image obtained during the growing season, for the following major reasons:

- 1/ exposed rock, earth, sand, tree bark and dead foliage have their highest spectral reflectance in the red region (Steiner and Gutermann 1966);
- 2/ chlorophyll of green vegetation absorbs in the red spectral region, and thus, areas of dense forest cover would be dark on band 5.

Analysis of the damage zones shows that:

- the total-kill zone (Fig. 2), where almost no vegetation exists, is brightest on the image;
- the heavy-kill zone, where only patches of lesser-vegetation are found, has a darker tone than the total-kill zone;
- the medium-damage zone (Fig. 3), where some trees are found, is darker in tone than either of the other, but still not as dark as the forested areas outside the damage zones.

Interpretation and image enhancement showed that it was impossible to separate the known light-injury zone from forest areas unaffected by SO₂ but that it was possible to draw a line around the perimeter of the medium-kill zone. It was also shown that at ERTS scale (1:1,000,000) the small variations used to delineate the zone boundaries on air photos are not evident on the satellite image;

For cases where it is difficult to discriminate between the zones of heavy damage and other targets such as clear-cut logging, forest fires, and, in the winter, frozen lakes and bogs, the shape of the area damaged by SO₂ can be used to advantage. The prevailing wind produces a shape which has the following characteristics: a/ there is a strong point-source (e.g. at Wawa in Figure 1); b/ the damage billows (expands) in a given direction coincident

Fig. 1. An enlarged portion of the ERTS image shown on the front cover. Three SO_2 fume-damage zones (T = total kill, H = heavy kill, M = medium damages) are delineated covering about 150 square miles. The light-injury zone (L) could not be seen on the ERTS image but has been transferred from air photos, (ERTS frame no. 1376-16020).

Fig. 2. (Left) The centre of the total-kill zone is characterized by the complete absence of vegetation. The exposed rock, which has a high red spectral reflectance, causes the very light tone of the total-kill zone on satellite image. (Photo by FM).

Fig. 3. (Right) The medium-damage zone is characterized by high white birch mortality, with no significant mortality of other hardwoods and conifers. (Photo by FM)

with the prevailing wind; and c/ damage decreases in intensity as the distance from the source increases. Logging activities and forest fires also have sharply defined boundaries associated with them whereas SO_2 damage does not.

Delineation of damage zones by air-photo (photo scale 1:160,000) and ERTS-imagery interpretation were compared with airborne sketch-mapping. Some shifts in areas between adjoining zones were evident amongst the methods, but since the actual areas of damage were not known exactly, it is impossible to say that one method is more accurate than the others. However, the results were similar and are considered to be of about equal value. The time and effort required to do the interpretation varied appreciably: airborne sketch-mapping was greatest

(one week), photo interpretation (about 2½ days), and ERTS least (one half day, after the image arrived).

In conclusion, ERTS imagery should provide a simple means of mapping and monitoring large forest areas affected by severe SO_2 fume damage.

References

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