Paper A 9

SO_2 DAMAGE TO FORESTS RECORDED BY ERTS-1

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ABSTRACT

SO_2 fumes have been affecting the forests around Wawa, Ontario, which have been under surveillance for a number of years and were recently covered by ultra-small-scale (1:160,000) air photography for damage-assessment purposes. The area was selected as a Canadian Forestry Service ERTS test site and was imaged on four successive ERTS-1 passes during the summer of 1973.

Image interpretation supported by electronic colour enhancement was used to delineate on ERTS imagery three damage zones (total-kill, heavy-kill and medium-damage zones). The zones delineated on ERTS imagery are similar to the results of aerial sketch-mapping and air photo interpretation. Band 5 provided the greatest detail for assessing the damage to the forests, followed in successive order by bands 4, 6 and 7. Comparision with ERTS images obtained in the winter showed that even though the total-kill could be separated from heavy-kill damage zones, total-kill could not be consistently separated from clear-cut logging, burned areas, frozen lakes and bogs.

INTRODUCTION

Between May 4 and September 8, 1973, a CFS test site near Wawa, Ontario (Sayn-Wittgenstein and Moore, 1972) was imaged six times (twice in the spring and four times in the summer); each time virtually cloud-free conditions existed. The best images were obtained on August 3, and September 8; this paper deals with these images.

SUMMARY OF RESULTS

Band 5 was the best band to delineate the extent of vegetation damage on both dates. The boundaries of damage on the August 3, band-5 image (Figure 1) coincided most closely with the results of the photo interpretation and aerial sketch-mapping. Figure 2 depicts the image for band 4: Figures 3 and 4 are the corresponding imagery for September 8. Figure 5 and 6 are photos of the total-kill and medium-damage zones.

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[1] This paper is the synthesis of 2 previous publications (Murtha 1972 and 1973).

The SO_2 fume damage to the vegetation was the most obvious on the band 5, August 3 image for the following reasons:

(i) exposed rock, sand, tree bark, and dry, dead foliage have their highest spectral reflectance in the red spectral region (Steiner and Gutermann, 1966);

(ii) chlorophyll of green vegetation absorbs in the red spectral region, thus vegetated areas would be "dark" on band 5.

Analysis of the damage zones showed that:

(i) the total-kill zone (Figure 5) where almost no vegetation exists, is "brightest" on the image;

(ii) the heavy-kill zone, where only patches of less vegetation are found, has a darker tone than does the total-kill zone;

(iii) the medium-damage zone (Figure 6) where some of the trees have been killed, is darker in tone than either of the others, but is still not as dark as the forested areas outside the damage zones;

(iv) it was impossible to delineate the area of light injury on the ERTS-1 image;

(v) at ERTS-1 scale (1:1,000,000) the small variations in the boundaries of the damage zones are not evident;

(vi) as the growing season ended and autumnal coloration occurred, it was increasingly difficult to delineate the perimeters of the damage zones.

Discrimination between the SO_2 fume damage zones and other forest "disturbances", such as fire and logging, was facilitated because of the particular characteristics of the SO_2 pollutant damage, and was influenced to a great extent by the prevailing wind. Thus,

(i) there is a strong point-source (e.g. factory location at Wawa. *See arrows* Figures 1 to 4);

(ii) the damage billows (expands) in a direction coincident with the prevailing winds; and

(iii) the damage decreases in intensity as the distance from the point-source increases.

Logging activities and forest fires have sharply defined boundaries associated with them whereas the areas of SO_2 damage did not.

If the total-kill and heavy-kill damage zones had not been present, it would have been virtually impossible to delineate the medium-damage zone, let alone designate the cause of damage as an air pollutant. It was only because of *a priori* knowledge that the Wawa damage was attributed to SO_2. The only interpretation possible from the ERTS-1 image was to indicate that the damage was wind-associated.

The sequence of the dates and bands indicates that there is an optimum date during the growing season at which to delineate the damage. Obviously any date prior to the growing season is unsuitable because of the large component of leafless, perfectly healthy trees and "exposed terrain". In the latter part of the growing season, autumnal coloration "colours" the interpretation of results. The best results would then come during the early part of August.

In conclusion, it seems that ERTS-1 imagery should provide a simple means of mapping and monitoring large forest areas affected by severe SO_2 fume damage, provided sufficient time has elapsed for the damaged forest region to take on the characteristics of the air pollutant (SO_2) damage. It is impossible to map areas of "light injury" from the satellite imagery.

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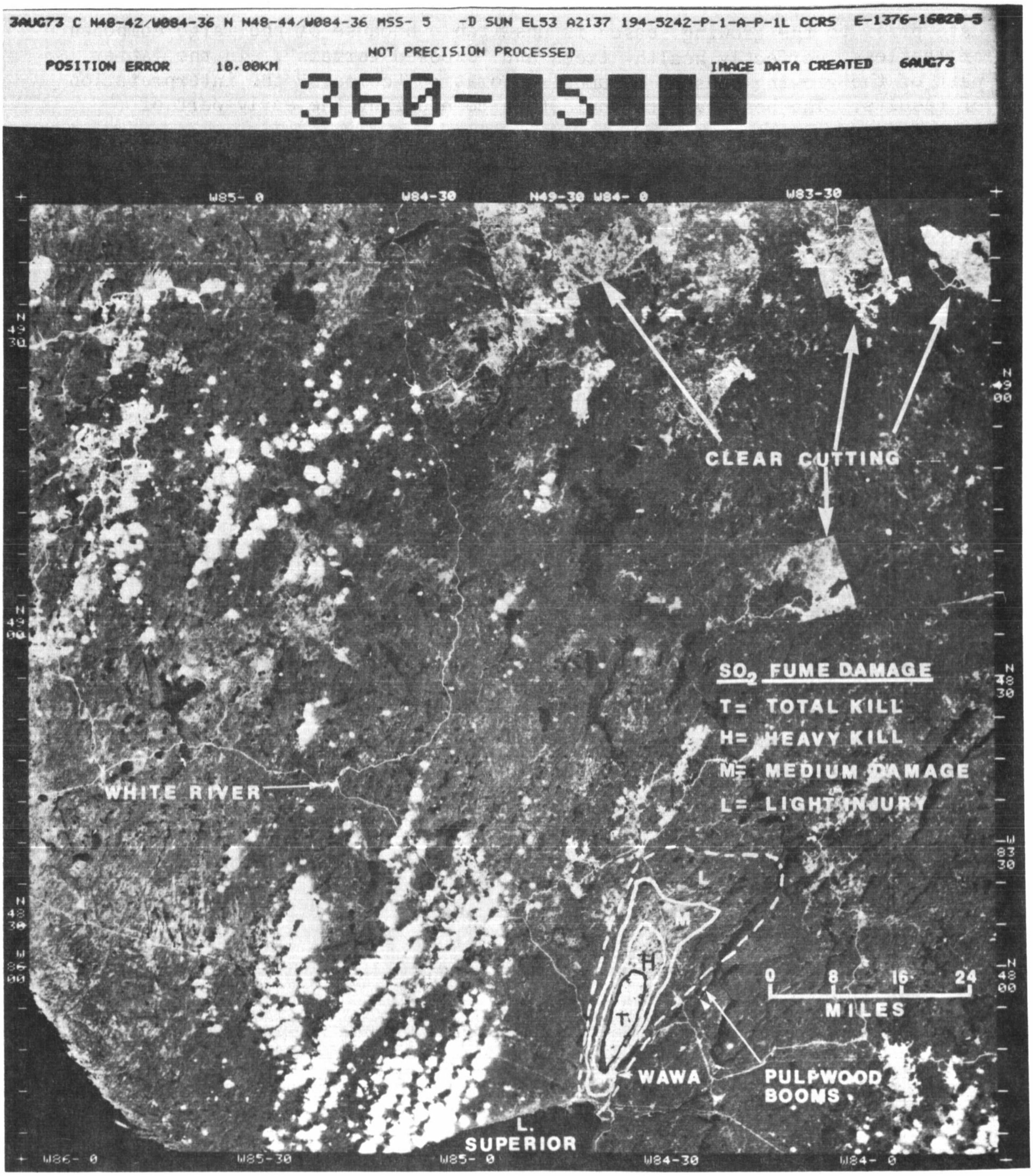

Figure 1. ERTS-1 frame no. 1376-16020; band 5; 3 August, 1973. Three SO_2 fume-damage zones are delineated covering about 390 square kilometers. (Refer to Murtha (1972) for definitions of the damage zones.) Total-kill = T; Heavy-kill = H; Medium-damage = M; and light-injury = L. The light-injury zone was not interpreted from the ERTS-1 image but was transferred from air photos. The T, H, and M zones are consistent with the photo-interpretation results.

Figure 2. ERTS-1 frame no. 1376-16020; band 4; 3 August 1973. Note the decreased detail and size of damage area when compared with Figure 1.

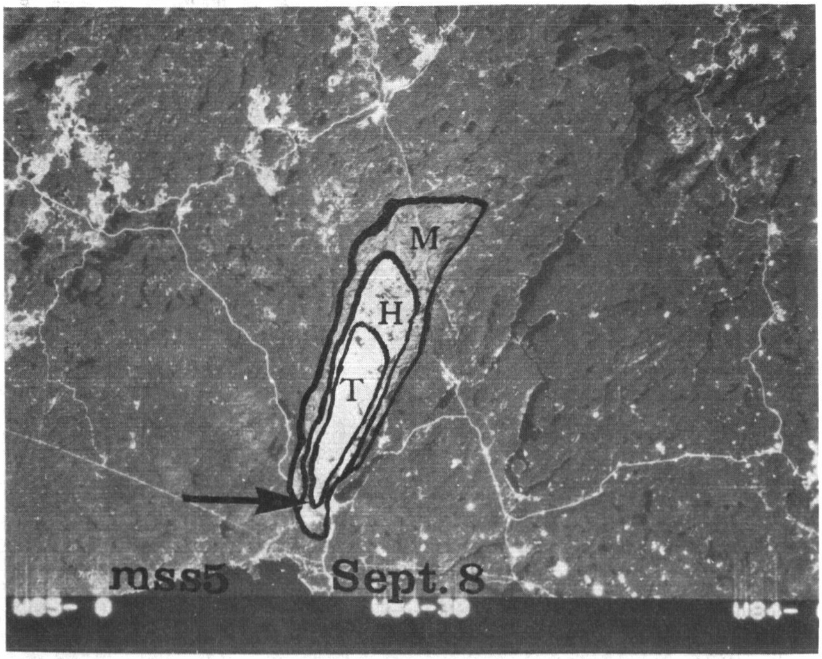

Figure 3. ERTS-1 frame no. 1412-16013; band 5; 8 September 1973. Although the damage zones may be delineated, the size of the medium-damage zone is not as large as the zone delineated in Figure 1. The other two zones are virtually the same as that shown in Figure 1.

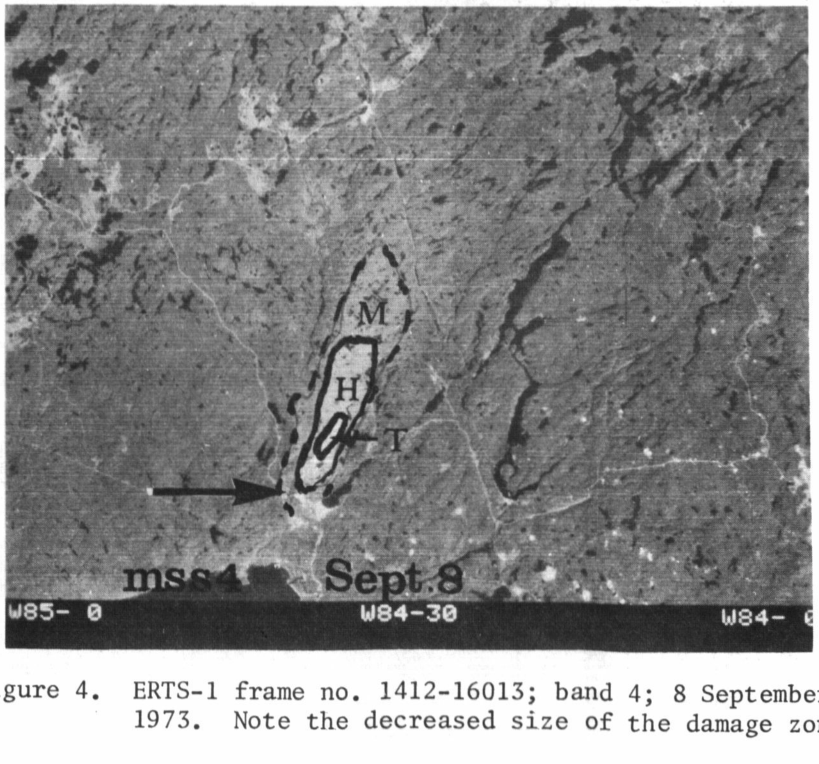

Figure 4. ERTS-1 frame no. 1412-16013; band 4; 8 September 1973. Note the decreased size of the damage zones.

Figure 5. 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 FMI).

Figure 6. The medium-damage zone is characterized by high white birch (*Betula papyrifera* Marsh) mortality, with no significant mortality of other hardwoods and conifers. (Photo by FMI).