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Some Air-Photo Scale Effects on Douglas-Fir Damage Type Interpretation

Large scale (1:1000) photos are required for interpretation of the subtle strain symptoms, but 1:4000-scale photos will suffice for counts of dead trees.

ABSTRACT: *Interpretations of strain symptoms (damage types) indicative of stress to Douglas-fir [*Pseudotsuga menziesii *(Mirb.) Franco] trees were compared at photo scales of 1:1000 and 1:4000 using color-infrared photos. t-tests indicated no significant differences (p = 0.05) in counts between total numbers of live trees, total numbers of dead trees, and total trees with dead tops. There were significant differences (p = 0.05), however, between counts of photo-visible tree crowns displaying the subtle damage types indicative of chronic levels of stress and between counts of trees not displaying damage types. For the counts of the live damaged trees, 35 percent fewer trees were interpreted as damaged on the 1:4000-scale photos than were interpreted on the 1:1000-scale photos. Conversely, about 84 percent of the trees were interpreted as healthy with the 1:4000 scale whereas only 48 percent were interpreted as healthy with the 1:1000 scale. An interpretation matrix indicates where differences occurred or where information was lost between the 1:1000 and 1:4000-scale photos. It is concluded that for the Douglas-fir stand examined large scale (1:1000) photos are required for interpretation of the subtle strain symptoms, but the 1:4000-scale photos will suffice for counts of dead trees. It is quite possible that the same results would apply to other populations of conifers.*

INTRODUCTION

"WHAT PHOTO SCALE is necessary to detect forest stress?" is a question a resource manager may ask of the remote sensing community. The answer generally involves a compromise among costs, flight safety, and accessible air photo equipment. Very few sources give any recommendation regarding air-photo scales required for photointerpretation for specific strain symptoms.* Thus, the resources manager may end up accommodating other purposes in the project and consequently receive remote sensing products which lack the required detail because the interpretability of the photo product was not considered in the project design. It is the purpose of this paper to report on interpretability differences for selected forest damage types between two large-scale (1:1000 and 1:4000) photos, and to give indications of how much and what information was changed or lost.

LITERATURE REVIEW

Henninger and Hildebrandt (1980) compiled a list of 605 forestry related publications dealing

* *Strain* symptoms are the visual expressions of environmental stress. Remote sensing for stress detection is accomplished through analysis of strain symptoms which permits only inference of stress until positively correlated with ground reference data. In this paper strain symptoms are synonomous with "damage types."

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with the photointerpretation of forest damage. The photo scales reported ranged from "satellite scales" of about 1:1,000,000 and ultra-small-scale air photos of about 1:150,000 to very-large photo scales between 1:1000 to 1:5000. Table 1 presents a number of scale/film combinations used for assessment of various forest stress conditions as they were reported in some selected remote sensing publications. Examination of Table 1 shows that about 16.6 percent of the reports indicated use of very-large scales (= 1:500 to 1:2500) and 27.9 percent indicated use of large scales (= 1:2501 to 1:5000). 55.5 percent of the reports indicated use of scales smaller than 1:5000 for applications ranging from general "stress detection" to dieback, defoliation, discolored foliage, and mortality estimates.

Uses of the very large-scale photos included such applications as *Fomes annosus* root rot analysis, and SO_2 stress detection. The large-scale photos were used for applications ranging from root rot analysis and Tussock moth defoliation to current year mortality. The cited applications of different photographic scales vary considerably and can leave confusion in the minds of resource managers when decisions must be made. Therefore, it was decided to compare the interpretability of the 1:4000 and 1:1000 scale color-infrared photographs for forest strain symptom detection.

Description of Study Stand

The selected forest used in the study was a relatively even-aged, 73 year old Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco] stand growing on an undulating till plain located in the Tranquille Provincial Forest about 15 kilometres north of Kamloops, British Columbia. Among the Douglas-fir there are a few and very scattered stems of ponderosa pine (*Pinus ponderosa* Laws), Engelmann spruce (*Picea engelmannii* Parry), and several small clumps of trembling aspen (*Populus tremuloides* Michx). The Douglas-fir diameters (breast height) range between 28 and 70 cm. The largest diameters belong to scattered old growth (123 year old) Douglas-fir. Fire scars on the old growth Douglas-fir indicate that the younger stand resulted from a forest fire about 80 years ago. Tree heights range between 20 and 40 metres, thus making tree top crown descriptions from the ground very difficult if not impossible in the closed canopy stand. The stand was considered to be healthy because no major insect or disease infestations were reported by the Forest Insect and Disease Survey (Fiddick and Van Sickle, 1979). However, periodic ground checks had shown that scattered Douglas-fir had been attacked by western spruce budworm (*Choristoneura occidentalis* Freeman), but that the budworm feeding was restricted to new leader growth and the infestation never became epiphytotic.

Table 1. Scale: Film Combinations used for Assessment of Forest Stress Conditions as Reported in Selected Remote Sensing Publications. (Film: BW = Black and White Panchromatic; CIR = Color Infrared, NC = Normal Color)

Senior author(s)		Film	Largest scale	Stress type or remark
I. Photogrammetric Engineering and Remote Sensing (1970 to 1980):				
Rohde and Olson	(1970)	NC, CIR, BW	Scale not given	—moisture stress
Hostrap and Kawaguchi	(1971)	NC	1:15,840	—dead trees
Ciesla *et al.*	(1971)	NC, CIR	1: 6,000	—tent caterpillar defoliation
Klein	(1971)	NC	1: 5,000	—bark beetle-killed pine
Ashley *et al.*	(1976)	NC, CIR	1: 9,900	—spruce budworm defoliation
Ulliman and French	(1977)	NC, CIR	1: 5,000	—oak wilt mortality
Telerico *et al.*	(1978)	CIR	1:31,640	—gypsy moth defoliation
II. Internal Archives of Photogrammetry—Vol. 13 (Comm VII); 1980:				
Cagirici		CIR	1: 6,000	—healthy, stressed, dead trees
Ciesla		CIR	1: 6,000(multistage)	—damage appraisal
Lillesand		CIR	1: 6,000	—stress detection in hardwoods
Murtha		CIR	1: 1,200	—SO_2 stress
Sherrer *et al.*		CIR	1:13,000	—pine mortality

III. Proc. Symposium on Remote Sensing for Vegetation Damage; 1978, (Amer. Soc. of Photogramm.)			
Bird *et al.*	NC	1: 2,500	—dieback to scorched crowns
Bradshaw and Chandler	NC	1: 4,000	—Jarrah dieback
Fairweather *et al.*	CIR	1: 9,600	—Dutch elm disease
Gregg *et al.*	CIR	1: 6,000	—Armellaria root rot
Klein *et al.*	NC	1: 6,000	—mountain pine beetle caused mortality
Lee and Wear	CIR	1: 4,500	—Douglas-fir Tussock moth defoliation
Leopold *et al.*	CIR	1: 7,200	—forest stress monitoring
Myers and Bird	NC	1: 4,000	—forest stress detection
Miller and Heller	CIR	1: 4,000	—Douglas-fir Tussock moth susceptibility
Sapp	CIR	1: 2,000	—SO_2 stress
Schultz	NC	1: 8,000	—tree mortality
Williams	CIR	1:12,000	—SO_2 killed foliage
IV. Workshop: Aerial Color Photography in the Plant Sciences (Murtha, 1980):			
7th Workshop:			
Sherrer *et al.*	CIR	1: 1,900	—tree vigor rating
Dillman *et al.*	CIR	1: 7,000	—"faded" pine (bark beetle)
Murtha	CIR	1: 1,200	—incipient tree stress detection
Blazquez *et al.*	CIR	1: 4,000	—stressed citrus trees
6th Workshop:			
Murtha	CIR	1:15,840	—SO_2 mortality—top dieback
5th Workshop: No applicable reports; 1975			
4th Workshop:			
Todhe & Moore	CIR, BW	1: 9,525	—gypsy moth defoliation
Bailey	NC	1: 7,920	—faded and dead pines
3rd Workshop: 1971.			
Murtha	CIR	1: 1,200	—forest stress
Payne *et al.*	CIR	not given	—disease and insect stress
2nd Workshop: 1969.			
Ciesla	CIR	1: 5,940	—bark beetle killed pine
French and Meyer	CIR	1: 9,600	—oak wilt and Dutch elm disease
Hanson and Lautz	CIR	1: 4,000	—current year mortality
Housten	CIR, NC	1: 1,000	—beech bark disease
Murtha	CIR, NC	1: 1,200	—Fomes annosus
Wert *et al.*	BW, BWIR NC, CIR	1: 1,584	—air pollution stress
1st Workshop: 1967.			
Meyer	NC, CIR	1: 5,000	—tree stress detection
Ciesla and Bell	NC, CIR	1: 3,960	—bark beetle killed pine

The same stand was used by Murtha and McLean (1981) in another study where it was reported that the Douglas-fir displayed a range of damage types indicative of low levels of stress. At that time the damage types could not be associated with any specific cause.

METHODS

AIR PHOTOGRAPHY

Details of aerial photography are given in Table 2. Kodak Aerochrome Infrared film, 8443 was exposed by two survey firms through Wratten 12 plus CC20M filters. 1:4000-scale photos with 60 percent forward overlap were obtained by Pacific Survey along a 5-kilometre, north-south transect across the study area.

The 1:1000-scale contiguous photos along the centerline of the five-kilometre transect were obtained by Integrated Resources Photography Inc. using a wingtip 70-mm camera system (Williams, 1978). With the wingtip camera system, stereo overlap is obtained by simultaneous exposures from cameras mounted on the wingtips of a Cessna 180. The fixed distance between the wingtips gives sufficient camera separation to provide excellent stereo viewing of a scene at very-large scales (e.g., 1:1000) without distortion due to excessive parallax. Stereo overlap of the 70-mm photos is about 90 percent. After processing, the stereopairs are matched and mounted in cardboard mounts which facilitates stereo viewing. Film from both photo missions was developed to provide a positive transparency, and the original material was subsequently used in all photointerpretation.

PHOTOINTERPRETATION

A two-kilometre section of the five-kilometre photographic strip was selected for photointerpretation because that section of the Douglas-fir stand was mostly surrounded by open rangeland and the beginning and end of the line were easily located. Only Douglas-fir were examined. The following procedure was used by the author during the photointerpretation, which was accomplished over a period of several weeks:

- Examine each stereo pair of the 1:1000-scale photos with a 2× pocket stereoscope on a light table for a viewing scale of 1:500;
- On each stereopair identify each tree and indicate Damage Type or Types (according to Table 3) for each Douglas-fir;
- Record number of Douglas-fir by damage type;
- Assess each Douglas-fir on only one stereopair; and
- Assess only photo-visible tree crowns.

The interpretation of the 1:1000-scale, 70-mm air photos provided the base-line data against which the 1:4000-scale photos were to be compared. The assessment of all stereoscopically visible tree crowns on the contiguous 70-mm photos gave a ground plot approximately 50 metres wide and 1800 metres long. The area had been ground checked on a number of occasions (e.g., Murtha and McLean, 1981), and this author was confident of the exactness of the photointerpretation of the 1:1000-scale photos. Thus, for purposes of this photointerpretation study in which two scales were compared, the interpretations of the 1:1000-scale photos were known to be correct, and these data were used as the base-line data to which the 1:4000-scale photointerpretation data were compared.

When each tree is assessed according to Damage Types (Table 3), each damage type detected is counted. Thus, if a tree had a dead top (IIA), a thin crown (IIE), with some dead red-brown foliage at the tips of some branchlets (IIIx), and the residual foliage appeared a lighter magenta hue (IIIOb) than foliage on surrounding trees of the same species, then four damage types would be counted. Because a tree crown may display more than one damage type, the total number of individual damage types is greater than the total count of live damaged trees.

After interpretation of the 1:1000-scale photos, the following procedure was used:

- Outline the 1:1000-scale, 70-mm photo coverage of each stereo pair on clear *Mylar* overlay placed over the 1:4000-scale photos (A Bausch and Lomb Zoom 240 stereoscope with 8× magnification was used for a viewing scale of 1:500);
- For each 1:1000-scale photo plot located on the 1:4000-scale photos, assess each Douglas-fir for damage type(s) according to Table 3;

TABLE 2. DETAILS OF AERIAL PHOTOGRAPHY AND CAMERA SYSTEMS USED TO OBTAIN COMPARATED COLOR INFRARED AIR PHOTOS

Scale	Flight Date	Camera	Lens	Exposure	Ave. Flying Height
1:1000	7/29/79	Vinten 492 (70-mm format)	Leitz *f*2/76	1/1000 @ *f*3.8	76 m above terrain
1:4000	8/1/79	Zeiss RMK A 30/32 (23-cm format) or 9 in.	305 mm	1/400 @ *f*6.3	1200 m

TABLE 3. DESCRIPTION OF CONIFEROUS TREE DAMAGE TYPES (AFTER MURTHA, 1972; MURTHA, 1978) USED TO DESCRIBE THE TREE STRAIN SYMPTOMS AS SEEN ON LARGE-SCALE, COLOR-INFRARED AERIAL PHOTOGRAPHS

Damage Type	Description
IA	Tree dead, bark exfoliated, exposed wood bleached whitish through weathering.
IB	Tree recently dead, totally defoliated, limbs and branches maintain bark, and are dark toned.
IIA	Dead defoliated top, may be 10 cm to more than one metre long.
IIC	Top broken off.
IIE	A thin-crowned tree, premature loss of older foliage, inner branches clearly visible, current foliage present.
IIIB	Entire crown yellowed (this damage type appears a mauve hue for the tree crown on color infrared photos).
IIIG	Entire crown shows dead, red-brown foliage (which appears yellow to white-yellow on color-infrared photos).
IIIOa	Tree crowns have a *darker* magenta hue that the normal trees, noted by comparisons (Murtha and McLean, 1981).
IIIOb	Tree crowns have a *lighter* magenta hue than the normal trees, noted by comparisons (Murtha and McLean, 1981).
IIIx	A grouping of several damage types (IIIH, IIII, IIIJ, IIIK, IIIL (Murtha, 1978)) which indicates the presence of dead red-brown foliage on a portion of the tree crown.
HH	Tree crowns which do not display any damage types.

- Record the number of trees by damage type;
- Assess all photo visible tree crowns;
- After the 1:4000-scale photos have been interpreted, begin again and cross-check interpretations using the 1:1000-scale photo data as the base data; and
- Record differences (omission and commission errors) according to trees by damage types.

STATISTICAL ANALYSIS

The photointerpretation of the 38 stereopairs of 1:1000-scale photos yielded a photo plot approximately 50 metres wide and 1800 metres long. Because of a combination of factors including occasional rock outcrops, other trees (e.g., aspen, pine, spruce) within the stand, and natural openings in the forest canopy, the number of photo-visible Douglas-fir on each stereopair varied from a low of 14 crowns to a high of 136 crowns. On the advice of a statistician, the stereopairs with low tree numbers were grouped with adjoining stereopairs in order to increase the total number of crowns per subplot. After re-grouping, the 1:1000-scale photo plot consisted of 22 subplots of variable area, with total tree numbers ranging between 67 and 136 crowns for each subplot. Because the 1:1000-scale photos had been outlined on the 1:4000-scale photos, and crown counts on the 1:4000-scale photos had been maintained on the basis of the 1:1000-scale stereopairs, the groupings of the 1:1000-scale photos were similarly applied to the 1:4000-scale photos. The MIDAS computer package (Fox and Guire, 1976) was used to analyze and compare the 1:1000 and 1:4000, 22 subplots for differences in tree counts, and t-tests were done to determine significance.

RESULTS

Plates 1 and 2 show a comparison of the original contact scales and the comparable enlarged scales as seen during a stereo examination. Example damage types (Table 3) have been illustrated in Plate 1. Many trees showed more than one damage type, and during the counts each damage type was counted. Therefore, the total number of damage types is greater than the total number of damaged trees (Table 4).

Comparisons of the tree counts on the 1:1000 and 1:4000-scale color-infrared air photographs are presented in Table 4. There were no significant differences ($p = 0.05$) between the total count of all live trees [2016 trees at 1:1000 versus 1970 trees at 1:4000], the total count of all dead trees [34 at 1:1000 versus 28 at 1:4000], or the count of Douglas-fir with dead tops (IIA) [19 at 1:1000 versus 5 at 1:4000], although the latter was approaching significance. However, there were significant differences between the counts of the live (HH) trees [972 at 1:1000 versus 1652 at 1:4000], as well as significant differences between counts of trees showing damage types IIC, IIE, IIIB, IIIOa, IIIOb, and IIIx. Damage types IIC, IIIB, and IIIx were not detectable on the 1:4000-scale photographs, whereas 11, 64, and 437 in each category, respectively, were counted on the 1:1000-scale photographs.

Table 5 gives a comparison of the mean percentage and significant difference levels of the live trees as interpreted on the 1:1000 and 1:4000 scale photos. The values were derived from the computer analysis of the 22 subplots. It is emphasized here that the data showed a mean of 51.7 ± 16.2

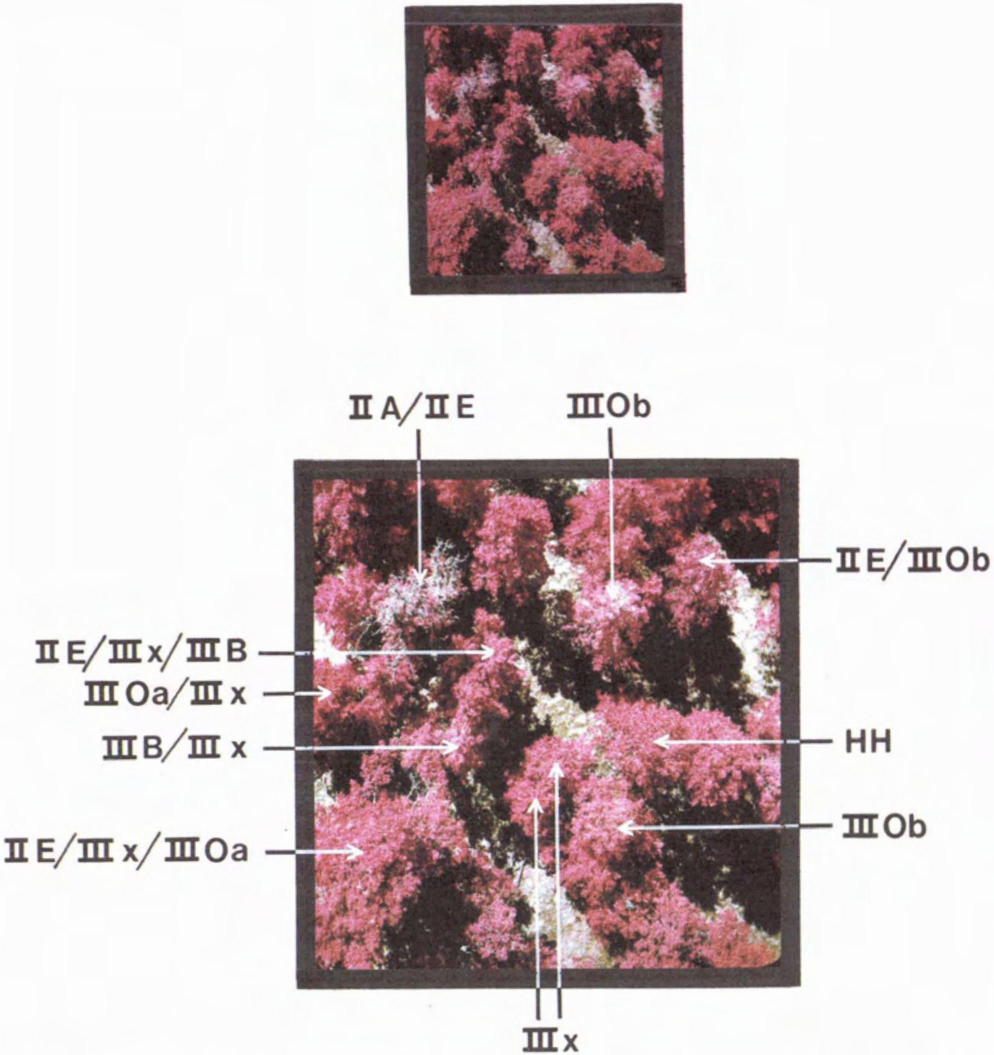

Plate 1. Contact scale (1:1000) (upper photo) and photographic enlargement of the same area to a scale of 1:500 (lower photo). Compare this enlarged view with the enlarged view in Plate 2. Sample Damage Types have been indicated. Note that the 11E/IIIOb tree (upper right) is visible as a IIIOb tree in Plate 2, and the IIE details are lost in Plate 2. Note also that the 11A/IIE tree (upper left) resembles a dead tree (1A) in Plate 2. Details of dead foliage (IIIx) cannot be seen in Plate 2. (Reduced 0.8×.)

Plate 2. Contact scale (1:4000) (upper photo) and photographic enlargement of the same area to a scale of 1:500 (lower photo). This is the same area seen in Plate 1. (Reduced 0.8 ×.)

TABLE 4. COMPARISON OF TREE COUNTS BETWEEN THE 1:1,000 AND 1:4,000-SCALE ORIGINAL COLOR INFRARED POSITIVE TRANSPARENCY, AIR PHOTOGRAPHS [FOR STATISTICAL ANALYSIS, t-TESTS WERE PERFORMED ON DATA FROM 22 ANALYTICAL UNITS (SEE METHODS). TOTALS WITHIN COLUMNS FOLLOWED BY DIFFERENT LETTER ARE SIGNIFICANTLY DIFFERENT ($p < 0.05$).]

Scale	Totals				Damage Types[2]						
	Live	Dead[1]	Damaged	HH	IIA	IIC	IIE	IIIB	IIIOb	IIIOa	IIIx
1:1000	2016a	34a	1044a	972b	19a	11a	253a	64a	438a	196a	437a
1:4000	1970a	28a	318b	1652a	5a	0b	32b	0b	192b	122b	0b

[1] Dead trees include a grouping of damage types IA, IB, and IIIG.
[2] See Table 3 for Damage Type descriptions.

live damaged trees per subplot on the 1:1000-scale photos compared to a mean of 16.7 ± 6.4 on the 1:4000-scale photos (Table 5). These data show a 35 percent difference in the detection and interpretation of the damaged trees between scales. Conversely, about 48 percent of the trees were interpreted as HH trees on the 1:1000-scale photographs, whereas approximately 84 percent of the trees were interpreted as HH on the 1:4000-scale photographs. This represents an approximate 35 percent change in information when scales are decreased from 1:1000 to 1:4000. Because obvious differences were noted between counts on the photographs, it was desirable to know how the information obtained on the 1:1000-scale photos was changed or lost on the 1:4000-scale photos. Figure 1 indicates the result of the 1:4000-scale photointerpretation in terms of the 1:1000-scale photointerpretation. The values for the 1:4000-scale photos are read across the page. The values for the 1:1000-scale photos relative to the 1:4000-scale photos are read down the page and are the sum of the diagonal "box score" (with the percentage value) plus the omission score. The omisssions score (2nd bottom line, Figure 1) represents information known to be present (according to the 1:1000-scale photos) but lost on the 1:4000-scale photos.

If a 1:1 relationship existed, all values would fall in the center diagonal boxes. However, such a situation does not exist. Consider damage type IA: at a scale of 1:1000, 26 trees were counted (Figure 1, bottom line). However, on the 1:4000-scale photos (read across the diagram) only 15 trees were counted (right-side column), and of the 15, only 10 were confirmed as being interpreted correctly according to cross-checking of photo images. Of the remaining five trees seen on the 1:4000-scale photos, two were in fact recently dead trees with dead red brown foliage (IIIG), two were trees with large dead tops (IIA), and one was an image aberration [other] that had no logical counterpart on the 1:1000-scale photos. These five trees are counted as *commission* errors. According to the 1:1000-scale photos, 16 1A trees were entirely overlooked (*omission* errors). Similarly, comparisons can be made for the other damage type categories.

Trees with thin crowns (IIE), as evidenced by premature loss of older foliage, and exposed branches were misinterpreted (Plates 1 and 2). Thirty-two were counted on the 1:4000-scale photos, three were trees with dead tops (IIA), one had lighter magenta foliage (IIIOb), and 28 had thin crowns. The 28 trees correctly interpreted represented only 11 percent of the total number counted with thin crowns; 225 trees were missed entirely in this category. Even McCarthy *et al.* (1982) noted that in their study trees (conifers) with heavy defoliation were incorrectly inter-

TABLE 5. COMPARISON OF MEAN PERCENTAGE AND SIGNIFICANT DIFFERENCE LEVELS OF THE LIVE TREES ON THE 22 SUBPLOTS AS INTERPRETED ON THE 1:1000 and 1:4000-SCALE AIR PHOTOS

Category	1:1000 $\bar{x} \pm \sigma$[1]	1:4000 $\bar{x} \pm \sigma$	Significance level
HH	48.3 ± 16.2	83.9 ± 6.7	<0.001
Live damaged	51.7 ± 16.2	16.7 ± 6.4	<0.001
IIIOa	9.9 ± 4.2	6.4 ± 3.2	<0.004
IIIOb	23.1 ± 24.7	9.9 ± 5.6	<0.02
IIE	13.2 ± 9.9	1.5 ± 2.7	<0.001
IIIB	3.2 ± 2.5	0	—
IIIx	21.2 ± 17.4	0	—
IIA	1.0 ± 1.8	0.2 ± 0.6	N.S.
IIC	0.6 ± 1.3	0	—

[1] $\bar{x} \pm \sigma$ = mean ± standard deviation.

1/1000 (columns); 1/4000 (rows)

	IA	IB	IIIG	IIA	IIC	IIE	IIIB	IIIOb	IIIOa	IIIx	HH	OTHER	Σ
IA	38.4% 10		2	2								1	15
IB	5	100% 4										2	11
IIIG			50% 2										2
IIA				15.6% 3				1		1			5
IIC					0% 0								0
IIE				3		11.1% 28		1					32
IIIB							0% 0						0
IIIOb				2		20	12	27.4% 120	9	16	11	2	192
IIIOa						13	3	23	15.3% 30	17	34	2	122
IIIx										0% 0			0
HH						221	64	246	74	437	62.8% 610		1652
OTHER												0% 0	0
OMISSION	16	0	2	16	11	225	64	318	166	437	362	0	
Σ	26	4	4	19	11	253	64	438	196	437	972	0	2432

FIG. 1. Interpretation matrix of damage type interpretations on the 1:4000-scale airphotos according to interpretations of the 1:1000-scale photos. The 1:4000-scale interpretations are read across the diagram. Total actual counts for the 1:1000-scale photos equals the column box with the percentage value plus omission score. The percentage value relates the correct counts on the 1:4000 to the 1:1000-scale photos. The *omission* score by damage type equals the trees *not* counted on the 1:4000-scale photos, but counted on the 1:1000-scale photos. "Other" (row and column) represents an image aberration that was interpreted to be a damaged tree on the 1:4000-scale photos, but on cross-checking with the 1:1000-scale photos, not one tree crown could be matched to the image pattern.

preted with a 73 percent frequency at a photo scale of 1:4800.

The HH trees were also misinterpreted at the smaller scale, and were subjected to a large number of commission errors. On the 1:4000-scale photos, 1,652 trees were designated as HH and of these 610 were correctly interpreted according to the 1:1000-scale photos. However, 437 were trees with some foliage red brown (IIIx), 221 had thin crowns (IIE), 64 had yellowed foliage (IIIB), 74 had darker magenta-hued foliage (IIIOa), and 246 had lighter magenta-hued foliage (IIIOb). According to Table 2, these counts represent significant differences in tree numbers counted between the 1:1000 and 1:4000-scale photos. The implications here suggest that interpretations of aforementioned damage types are suspect on photos at scales of 1:4000 and smaller.

Conclusions

Analysis and comparison of tree counts on 1:1000 and 1:4000-scale color infrared air photos have indicated no significant difference in counts between total numbers of live trees, total number of dead trees, and total trees with dead tops. There were significant differences ($p = 0.01$) between counts of trees displaying the subtle damage types and between the counts of the trees not displaying damage types. It is concluded that dead trees can be as accurately interpreted on 1:4000-scale photos as they can be on the 1:1000-scale photos. However, the subtle damage types which include thin crowns (IIE), broken tops (IIC), yellowed foliage (IIIB), some foliage red brown (IIIx), and trees with either darker (IIIOa) or lighter magenta (IIIOb) hues cannot be reliably interpreted at the smaller scale of 1:4000. The data in this study suggest that for these latter damage types there are likely to be more misinterpretations (commission errors) than correct interpretations.

Damage type IIE, represented by trees with thin crowns, exposed branches, premature loss of foliage, etc., is noted here. Interpretation on the 1:1000-scale photos was accomplished reliably and quickly, the defoliated branches are easily seen, and 253 trees were counted. At a scale of 1:4000, 32 IIE trees were counted, only 28 correctly, and 225 were omitted. At 1:4000, 221 of the IIE trees appeared to have no damage symptoms (HH), 13 appeared a darker-magenta (IIIOa), and 20 appeared a lighter magenta hue (IIIOb). Thus, image merging (coalescing of detail) at the 1:4000 scale causes misinterpretations. Air photointerpretation for spruce budworm (*Choristoneura fumiferana* Clem.), which can cause both mortality and partial defoliation, would require different scales of photography for evaluation of defoliation and mortality. Mortality can be adequately interpreted on the 1:4000-scale photos; however, estimates of defoliation require larger photographic scales.

Tree mortality caused by the various bark beetles, or other agents, can be assesed with the smaller scale (1:4000) photos; however, damage types which are indicators of low levels of stress should be interpreted only on the larger-scale photos. In this study only two air photo scales were examined. Obviously, there is a definite cut-off point where symptoms are lost. It is suggested here that users of remote sensing data should carefully consider the damage types which need to be interpreted and select the appropriate scale. It is suggested here that air photo scales around 1:4000 be obtained for air photointerpretation of dead trees, either defoliated or with red brown foliage, and 1:1000 for all other damage types. Tests should be conducted to determine the smallest scale for interpretability of single dead trees for the various tree species, and for the scale cut-off point for the interpretability of the other damage types. These data need to be known, in order that resource managers can more precisely select the most suitable photographic scale for the air photo-interpretation of forest strain symptoms, and for dead trees.

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Forthcoming Articles

Lawrence W. Fritz, Moderator, Automated Correlation of Stereo Data.
- *Michael A. Crombie,* Coordination of Stereo Image Registration and Pixel Classification.
- *Bruce K. Opitz,* Advanced Stereo Correlation Research.
- *Berthold K. P. Horn,* Non-Correlation Methods for Stereo Matching.
- *G. A. Wood,* Realities of Automatic Correlation Problems.
- *Alden P. Colvocoresses,* The Relationship of Acquisition Systems to Automated Stereo Correlation.

Peter O. Adeniyi, An Aerial Photographic Method for Estimating Urban Population.

Charles B. Grosch, Determination of Quadric Surfaces from Two Projective Views.

Dierk Hobbie and *Hans W. Faust,* Z-2 ORTHOCOMP, The New High Performance Orthophoto Equipment from Zeiss.

Heinz Hugli and *Werner Frei,* Understanding Anisotropic Reflectance in Mountainous Terrain.

T. S. Kachhwaha, Spectral Signatures Obtained from Landsat Digital Data for Forest Vegetation and Land-Use Mapping in India.

S. Kondo, R. Ohba, and *K. Murata,* Multi-Segments Approximation to a Three-Dimensional Curved Line Using the Least-Squares Locating Method.

W. S. Kowalik, R. J. P. Lyon, and *P. Switzer,* The Effects of Additive Radiance Terms on Ratios of Landsat Data.

Thomas M. Lillesand, Issues Surrounding the Commercialization of Civil Land Remote Sensing from Space.

Brian L. Markham and *John L. Barker,* Spectral Characterization of the Landsat-4 MSS Sensors.

O. W. Mintzer, F. A. Kulacki, and *L. E. Winget,* Measuring Heat Loss from Flat-Roof Buildings with Calibrated Thermography.

Gerald K. Moore and *Frederick A. Waltz,* Objective Procedures for Lineament Enhancement and Extraction.

Gregory B. Pavlin and *Charles A. Langston,* An Integrated Study of Reservoir-Induced Seismicity and Landsat Imagery at Lake Kariba, Africa.

Paul W. Rose and *Peter C. Rosendahl,* Classification of Landsat Data for Application, Everglades National Park.