REMOTE SENSING APPLICATIONS IN FORESTRY

MULTI-SPECTRAL IMAGERY FOR SPECIES IDENTIFICATION

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By

F. P. Weber

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ABSTRACT

Multispectral imagery, collected over Saginaw Experimental Forest, Ann Arbor, Michigan, in 1963-64 by the Infrared Laboratory of the Michigan Institute of Science and Technology, was quantified with a Welsh Densicron densitometer. Replicated density readings were taken from line-scan imagery of tree plantations of eight commercially important tree species for four diurnal periods and four seasonal periods. Four spectral regions were used in the comparison: (1) 0.32-0.38 microns, (2) 2.0 to 2.6 microns, (3) 4.5 to 5.5 microns, and (4) 8.2 to 14.0 microns.

Standard errors of the mean and coefficients of variation were computed for each species for each wavelength, time of day, and season. The tonal density on the line-scan imagery of each species was ranked by species and the likelihood of separating one tree species from another 19 out of 20 tries ($t = 0.05$) was computed. These results are shown in Appendixes "A" and "B". It was found that all four spectral bands were needed to separate all species, one from another. Some species could not be identified, however, even when the four spectral ranges were used in concert.

The concept of tree species separation by differing density responses in several channels of the electromagnetic spectrum appears feasible from our findings. Because of the lack of control over image making at the time of data collection and the improvements made in instrumentation and computerized signal processors, it is recommended that no further effort be spent on this data.

ACKNOWLEDGEMENTS

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INTRODUCTION

This report describes the results of a multi-spectral tree species identification test conducted over a forested area near Ann Arbor in southeastern Michigan. Although this study considered only a few of the many tree species available in southern Michigan (four coniferous and four deciduous) it does indicate the level of discrimination that can be expected when separating forest types on multi-spectral imagery, as a function of time of day and season.

The identification of tree species on conventional aerial photography requires a talent developed by repeated association between an interpreter's background knowledge and his ability to interpret images as they appear on photographs. To avoid an interpreter's subjective identification of the various tree signatures on this test, a densitometer was used to measure the relative grey-tone densities of the forest imagery.

The concept of multi-spectral identification is clear and direct. Each object or condition in nature has a unique distribution of reflected, emitted or absorbed radiation. If this information is applied wisely on a tree species identification problem, it can be used to distinguish one forest type or condition from another.

The importance of identifying tree species lies in the fact that in many instances the necessary prerequisite in evaluating a forest community, e.g., for detection of forest disturbances, is knowing exactly what species make up the community.

STUDY AREA AND SPECIES

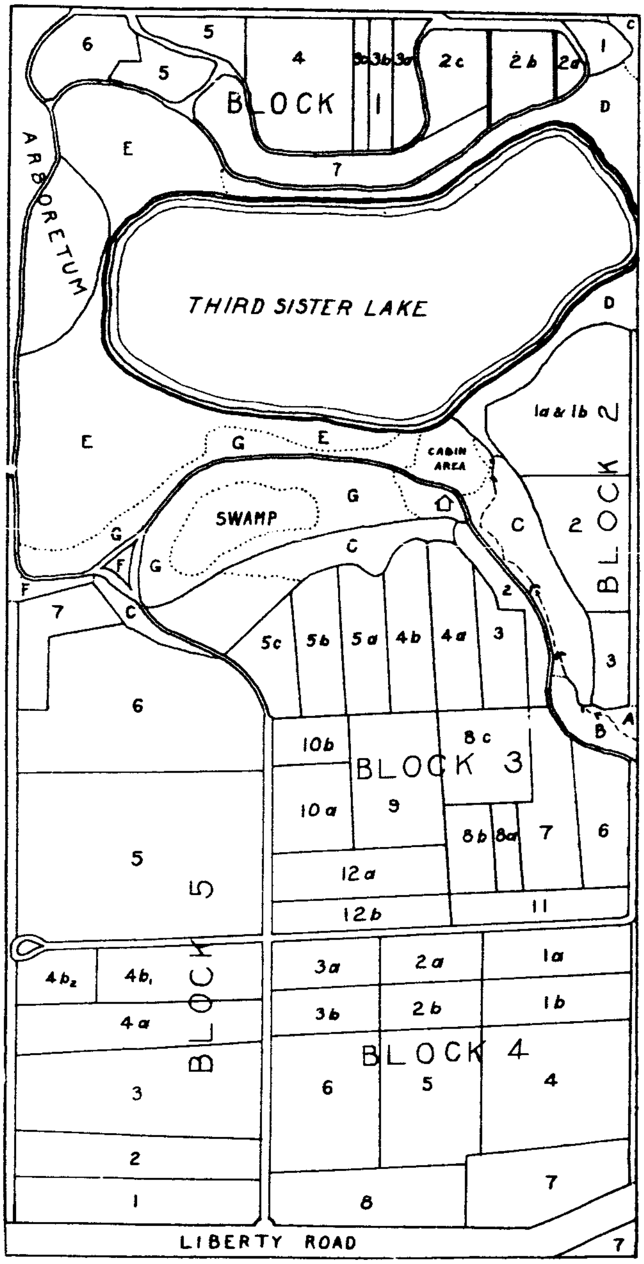
The University of Michigan, School of Natural Resources, manages an eighty-acre tract of timber, referred to as Saginaw Forest, 3 miles west of Ann Arbor, Michigan, which serves as a demonstration area and research laboratory for the faculty and students (Figure 1).

This area was chosen for study from several forested areas in south-eastern Michigan over which a great deal of simultaneous multi-spectral imagery has been collected the last three years. Specifically, it was chosen because of the variety of species available in a small area and because from the vast amount of multi-spectral forest data available, it provided the best continuity of information for considering seasonal and diurnal response variations.

Eight important tree species were selected within the Saginaw Forest for target **response** discrimination. The species involved in the study were:

		Block	Lot	Species Code Ltr *
1. *Pinus strobus* L. - - - - - - - - - - -	eastern white pine	1	4	A
2. *Pinus resinosa* Ait. - - - - - - - - - -	red pine	2	2	B
3. *Pinus ponderosa* Laws. - - - - - - - - -	ponderosa pine	5	5	C
4. *Picea abies* (L.) Karst - - - - - - - -	Norway spruce	4	7	D
5. *Quercus rubra borealis* (Michx. f.) -	northern red oak	4	6	E
6. *Juglans nigra* L. - - - - - - - - - - -	black walnut	3	12a&b	F
7. *Populus deltoides* March. - - - - - - -	cottonwood	5	4a	G
8. *Acer saccharum* Marsh. - - - - - - - -	sugar maple	3	8a&b	H

* code letters refer to species used in Appendices "A" and "B"



SAGINAW FOREST

SCHOOL OF NATURAL RESOURCES
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Scale: 0 100 200 ft.

Block	Lot	Species	Stock	Date	Acres
1	1	Scotch Pine	2-0	Sp.'04	.24
	2a	Austrian Pine	2-0	"	.12
	2b	White Pine	2-0	"	.54
	2c	" "	2-0	"	.57
	3a	Douglas Fir	2-0	"	.37
		Western Y. Pine	2-0	Sp.'08	
	3b	Tulip Poplar	2-0	Sp.'04	.28
		White Pine		Sp.'08	
	3c	Douglas Fir	2-2	Sp.'21	.23
	4	White Pine	2-0	Sp.'04	1.63
	5	Western Y. Pine	2-0	Sp.'08	.75
	6	Scotch, Austrian + W. Y. Pine	2-0	Sp.'06	.61
	7	Scotch Pine	2-0	Sp.'08	.91
		Catalpa	1-0	Sp.'04	
2	1a+1b	Norway Spruce	3-0	Sp.'04	1.68
	2	Norway Pine	3-1	Sp.'23	1.04
	3	Scotch Pine	2-2	Sp.'22	.34
3	1	Black Locust	1-0	Sp.'04	.53
	2	Hickory	1-0	Sp.'07	
		Black Locust			
		Elm			
	3	Scotch Pine	2-2		
		Japanese Red Pine	2-2	Sp.'27	.53
	4a	Scotch Pine	2-2	Sp.'26	.77
	4b	" "	2-2	Sp.'24	.64
		Japanese Red Pine	2-2	Sp.'25	
	5a-5b-5c	Black Locust	1-0	" '06	1.86
		Norway Spruce	2-2	" '15	
	6	Basswood	1-0	" '06	.75
	7	W. Yellow Pine	2-1	" '38	.85
	8a	Sugar Maple	1-0	" '06	.24
	8b	" "	1-0	" '06	.45
	8c	Norway Pine	2-2	" '21	.90
	9	Corsican Pine	2-0	" '30	1.30
	10a	Red Oak	1-0	" '06	.76
	10b	White Oak	1-0	"	.35
	11	Wh. + Burr Oak	Seed	"	.62
	12a	Bl. Walnut	1-0	"	.46
	12b	" "	Seed	Fall '06	.61
4	1a	Wh. Oak	Seed	Fall '06	.74
		Wh. Pine			
	1b	Chestnut	Seed	Fall '06	.74
		Wh. Pine.			
	2a+2b	Red Oak	1-0	Sp.'08	1.02
		Scotch + Wh. Pine			
	3a+3b	Red Oak	Seed	Fall '06	
				Sp.'07	1.08
	4	Bl. Walnut	"	" '09	1.87
		Pine-Oak	2-2		
		Larch-Spruce	2-2		
	5	Red Oak	1-0	Sp.'07	1.45
	6	" "	Seed	"	1.54
	7	Nor. Spruce	2-2	" '14	1.03
	8	Red Oak	1-0	" '08	1.17
5	1	W. Y. Pine	2-0	Sp.'09	1.07
	2	" " "	2-0	" '37	.97
	3	Nor. Spruce	3-0	Fall '11	2.21
	4a	Cottonwood	Cuttings	Sp.'12	1.05
	$4b_1$	W. Y. Pine	2-1	" '15	1.00
	$4b_2$	Nor. Pine	2-2	" '21	.37
	5	W. Y. Pine	2-0	" '09	4.04
	6	" " "	2-0	" '12	2.76
		Filled Douglas Fir		" '18	
	7	Nor. Spruce	2-0	" '37	.64

A = Box Elder B = Douglas Fir C = Oak-Hickory
D = Soft Maple, Willow, Aspen E = Elm, Soft Maple Swamp
F = Nor. + Wh. Spruce G = Wh. Cedar

REVIZED AUG. '53

Figure 1

METHODS

AIRBORN DATA COLLECTION

The University of Michigan through the Institute of Science and Technology, Infrared and Optical Sensor Laboratory at Willow Run, undertook a program of acquiring simultaneous multi-spectral data during 1963 and 1964.[1] The following explanations of data acquisition are pertinent to the tree species identification study.

1. The Project Michigan multi-spectral program obtained pictorial data in several spectral regions simultaneously with a variety of optical sensors over an extensive fixed flight course.

2. The pictorial data were obtained for the fixed course at predetermined intervals throughout a 24-hour period. Each 24-hour period constituted one diurnal mission.

3. Missions were flown at intervals of approximately two weeks throughout the period June 1, 1963, to July 1, 1964.

4. AN/AAS-5(XE2) scanners produced strip maps of the following spectral regions:

Ultraviolet	0.32 to 0.38 microns
Near Infrared	2.0 to 2.6 microns
Middle Infrared	4.5 to 5.5 microns
Far Infrared	8.2 to 14.0 microns

Occasionally, data were collected in the regions 1.5 to 1.9 microns and 3.0 to 4.1 microns. However, due to the seasonal and diurnal discontinuity of these data, they were not used in this study.

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[1] Holter, M. R. and F. C. Polcyn, 1965. Comparative Multispectral Sensing, Report 2900-484-R, IST, U. of M., Ann Arbor (CONFIDENTIAL).

5. A fixed flight path of 50 miles was selected to cover a great variety of objects and object complexes, one of which was an extensive plantation of conifers and hardwoods -- Saginaw Forest (Figure 2).

6. The airborne optical-mechanical scanners were flown at an altitude which produced a scale representation of approximately 1:12,000; a scale which is non-optimal for tree species identification on conventional aerial photography. However, as the discrimination of tree species for this study depended on the variations in grey scale densities, as seen by a densitometer, the small scale was of little concern.

IMAGE INTERPRETATION

Because of the vast amount of seasonal and diurnal data available for the Saginaw Forest over a period of two years, and because of certain discontinuities of data which arose - for one reason or another - at most of the sample times, this study considered data from four sample dates which provided the most complete data. The sample dates were: (1) October 15, 1963, (2) February 5, 1964, (3) April 14, 1964, and (4) June 9, 1964. Diurnal data were analyzed for: (1) 0600, (2) 0900, (3) 1400, and (4) 2000 hours, for each of the seasonal dates.

Values for grey scale densities were read with a Welsh Densicron densitometer, the same instrument used to quantify target-background discrimination data for other Project Michigan multi-spectral programs. Four circular aperture sizes were tested to determine which one gave the least variation in density values for the same forest type. An aperture size of 0.062 inches was found to give the lowest coefficient of variation for density values obtained from the same forest stand.

Five separate density values were obtained for each species at each sampling time, e.g., five density values for red pine at 0900 hours on

Figure 2: Aerial view of Saginaw Forest showing several of the forest stands in Blocks 3, 4, and 5 which were measured with the Welsh densitometer.

June 9, 1964. At the same time, a subjective ranking of image quality was assigned each sampling unit which later helped to explain some of the inconsistencies in the interpretation data.

All image interpretation values were coded and put on special forms before being transferred to punch cards for tabulation and analysis by the University of Michigan 7094 computer.

Data cards were sorted and tabulated by density ordering as a function of wavelength, species, season and time of day. Standard errors of the mean and coefficients of variation were computed for each species within each sampling unit, e.g., wavelength, time of day and season.

RESULTS

The results of rank ordering of species by densities is summarized in Tables 1-15 (Appendix "A"). Perusal of these tables will give the reader an idea of the extent of missing data and why more sophisticated statistical tests could not be made.

The criterion for judging the usefulness of a given spectral region can be based on both the density level (amount of tonal contrast) and the consistency of density values for a particular species when compared with other species. The amount of new information derived by comparing two or more spectral bands usually permitted the positive identification of individual species. The basis for judging the value of additional wavelengths is the tone reversal of a species with respect to the other species.

In Appendix "B" Tables 16-56 present the likelihood of discrimination of tree species, one from another, on the basis of non-overlapping standard errors of the mean at 2-standard deviations (t.05 probability). These 50 tables are assembled by time of day, date, and wavelength that the imagery was obtained.

DISCUSSION AND CONCLUSIONS

It is interesting to note when comparing the rankings and the standard errors of mean separations that the multi-spectral concept must indeed be brought to bear in order to get any significant reliability in the discrimination of tree species. When considering a particular season and time of day, the success of tree species identification is directly related to the number of spectral bands sampled. If a decision were to be made to select two spectral bands, a combination of one short wavelength and one long wavelength band would allow the best chance of success. However, it should be pointed out that in most cases all four bands were needed for complete separation of the tree species, and even with that combination, it was not always possible.

One problem that is obscured by the data is that although a density value might be obtained from the imagery it may not have been representative in density value, with respect to other samples read from the same imagery. This can be caused by a variety of electro-mechanical induced variations or simply that the equipment operator may have changed the image parameters during airborne data collection. This makes the data suspect and can be blamed on the primitive state of the art at the time the data were collected.

It is well for the reader to be cognizant that these variabilities may indeed have come into play in degrading the imagery directly or at least affecting the chances for a nominal species identification test.

Some of these irregularities are of the type that are impossible to completely avoid when applying sophisticated equipment and technology to a complicated biological problem having inherent variation of its own.

Some encouraging developments in equipment and technology have taken place since the data for this study were gathered. A new spectrum-matching technique for enhancing image contrasts of selected objects based on their spectral reflectance or emittance characteristics has been implemented by the Willow Run Laboratories of the University of Michigan.[2] The means of using the multi-element dispersing spectrometer with an optical-mechanical scanner and electronic signal processor have already been demonstrated. Because of this new approach to multi-element or multi-spectral sensing, it is suggested that those responsible for forest resource evaluation will find it profitable to pursue this new technique in the application of species identification. It would appear to be more worthwhile than continuing studies with the present data.

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[2] Lowe, Donald S. and John G. N. Braithwaite, June 1966. Applied Optics, Vol. 5, No. 6, pp. 893-898.

APPENDIX "A"

RANKING OF TREE SPECIES BY DENSITY AND SPECTRAL RANGE

TABLE 1 -- 0600 hours, 10-15-63

	Spectral Range			
	.32-.38	2.0-2.6	4.5-5.5	8.0-14.0
Density Order (increasing)	(NO DATA)		B	C
			A	B
			G	A
			D	H
			C	F
			H	
			F	

TABLE 2 -- 0900 hours, 10-15-63

	.32-.38	2.0-2.6	4.5-5.5	8.0-14.0
Density Order (increasing)	H	H	B	E
	F	E	E	A
	E	A	A	C
	C	F	D	D
	A	B	H	H
	D	D	F	F
	B	C		B

TABLE 3 -- 1400 hours, 10-15-63

	.32-.38	2.0-2.6	4.5-5.5	8.0-14.0
Density Order (increasing)	E	H	H	E
	C	E	B	H
	H	F	A	C
	A	D	D	A
	F	A	E	D
	D	B	F	F
	B	C		B

RANKING OF TREE SPECIES BY DENSITY AND SPECTRAL RANGE

TABLE 4 -- 2000 hours, 10-15-63

	Spectral Range			
	.32-.38	2.0-2.6	4.5-5.5	8.0-14.0
Density Order (increasing)	(NO DATA)		A	A
			D	D
			B	B
			H	E
				H
				G

TABLE 5 -- 0600, 02-05-64

	.32-.38	2.0-2.6	4.5-5.5	8.0-14.0
Density Order (increasing)	(NO DATA)		G	H
			C	G
			D	F
			A	C
			E	B
			B	A
			F	E
			H	

TABLE 6 -- 0900, 02-05-64

	.32-.38	2.0-2.6	4.5-5.5	8.0-14.0
Density Order (increasing)	G	H	F	C
	C	B	H	G
	D	D	C	E
	B	E	E	F
	A	A	G	A
	E	F	B	H
	F	C	D	D
	H	G	A	B

RANKING OF TREE SPECIES BY DENSITY AND SPECTRAL RANGE

TABLE 7 -- 1400, 02-05-64

	Spectral Range			
	.32-.38	2.0-2.6	4.5-5.5	8.0-14.0
Density Order (increasing)	C	H	H	G
	H	E	E	C
	G	F	D	F
	A	A	C	E
	F	C	B	A
	E	G	G	D
			F	H
			A	B

TABLE 8 -- 2000, 02-05-64

	.32-.38	2.0-2.6	4.5-5.5	8.0-14.0
Density Order (increasing)				D
				B
				A
		(NO DATA)		F
				E
				C
				H

TABLE 9 -- 0600, 04-14-64

	.32-.38	2.0-2.6	4.5-5.5	8.0-14.0
Density Order (increasing)	E	H	D	G
	G	D	G	C
	F	E	B	A
	H	B	C	E
	C	F	A	F
	D	G	H	D
	A	A	E	B
		C	F	H

RANKING OF TREE SPECIES BY DENSITY AND SPECTRAL RANGE

TABLE 10 -- 0900, 04-14-64

	Spectral Range			
	.32-.38	2.0-2.6	4.5-5.5	8.2-14.0
Density Order (increasing)	F	H	E	E
	H	E	F	F
	G	F	H	G
	E	D	B	H
	C	B	D	C
	A	A	A	A
	B	G		D
	D	C		B

No data for 1000.

TABLE 11 -- 2000, 04-14-64

Density Order (increasing)			B	G
			D	C
			C	A
	(NO DATA)		A	E
			F	F
			H	B
			E	H
				D

TABLE 12 -- 0600, 06-09-64

Density Order (increasing)	H	D	D	
	G	B	C	
	F	H	H	(NO DATA)
	E	F	B	
	C	A	E	
	B	E	A	
	D		G	
	A		F	

RANKING OF TREE SPECIES BY DENSITY AND SPECTRAL RANGE

TABLE 13 -- 0900, 06-09-64

	Spectral Range			
	.32-.38	2.0-2.6	4.5-5.5	8.2-14.0
Density Order (increasing)	C	C	E	
	G	A	B	
	A	H	D	(NO DATA)
	E	F	A	
	F	E	G	
	H	B	C	
	B	D		
	D			

TABLE 14 -- 1400, 06-09-64

	.32-.38	2.0-2.6	4.5-5.5	8.2-14.0
Density Order (increasing)	H	C		
	E	A		
	B	H	(NO DATA)	
	D	F		
	A	E		
	G	B		
	C	D		
	F			

TABLE 15 -- 2000, 06-09-64

	.32-.38	2.0-2.6	4.5-5.5	8.2-14.0
Density Order (increasing)			B	
			D	
	(NO DATA)		H	(NO DATA)
			C	
			E	
			A	
			F	

APPENDIX "B"

LIKELIHOOD OF DIFFERENTIATING TREE SPECIES (t.05 probability)

TABLE 16 -- 0600 hours, 10-15-63, 4.5-5.5 microns

SPECIES	A	B	C	E	F	G	H	Diff. from Other Species (YES)	(NO)
A	---	YES	NO	NO	YES	NO	YES	3	3
B		---	YES	YES	YES	YES	YES	6	0
C			---	NO	YES	NO	YES	3	3
E				---	YES	NO	NO	2	4
F					---	YES	YES	6	0
G						---	YES	3	3
H							---	5	1

TABLE 17 -- 0600, 10-15-63, 8.2-14.0 microns

SPECIES	A	B	C	F	H		
A	---	NO	NO	YES	YES	2	2
B		---	YES	YES	YES	3	1
C			---	YES	YES	3	1
F				---	NO	3	1
H					---	3	1

LIKELIHOOD OF DIFFERENTIATING TREE SPECIES (t.05 probability)

TABLE 18 -- 0900, 10-15-63, .32-.38 microns

SPECIES	A	B	C	D	E	F	H	Diff. from Other Species (YES)	(NO)
A	---	YES	NO	YES	NO	NO	NO	2	4
B		---	YES	NO	YES	YES	YES	5	1
C			---	YES	NO	NO	NO	2	4
D				---	YES	YES	YES	5	1
E					---	NO	NO	2	4
F						---	NO	2	4
H							---	2	4

TABLE 19 -- 0900, 10-15-63, 2.0-2.6 microns

SPECIES	A	B	C	D	E	F	H		
A	---	NO	YES	YES	YES	NO	YES	4	2
B		---	NO	NO	YES	NO	YES	2	4
C			---	NO	YES	YES	YES	4	2
D				---	YES	NO	YES	3	3
E					---	YES	NO	5	1
F						---	YES	3	3
H							---	5	1

LIKELIHOOD OF DIFFERENTIATING TREE SPECIES (t.05 probability)

TABLE 20 -- 0900, 10-15-63, 4.5-5.5 microns

SPECIES	A	B	D	E	F	H	Diff. from Other Species (YES)	(NO)
A	---	YES	NO	NO	YES	NO	2	3
B		---	NO	NO	NO	NO	4	1
D			---	NO	NO	NO	2	3
E				---	YES	YES	0	5
F					---	NO	3	2
H						---	1	4

TABLE 21 -- 0900, 10-15-63, 8.2-14.0 microns

SPECIES	A	B	C	D	E	F	H		
A	---	YES	NO	NO	NO	YES	NO	2	4
B		---	YES	NO	YES	NO	YES	4	2
C			---	NO	NO	NO	NO	1	5
D				---	NO	NO	NO	0	6
E					---	YES	YES	3	3
F						---	NO	2	4
H							---	2	4

LIKELIHOOD OF DIFFERENTIATING TREE SPECIES (t.05 probability)

TABLE 22 -- 1400, 10-15-63, .32-.38 microns

SPECIES	A	B	C	D	E	F	H	Diff. from Other Species (YES)	(NO)
A	---	YES	NO	NO	NO	NO	NO	1	5
B		---	YES	NO	YES	YES	YES	5	1
C			---	YES	NO	NO	NO	2	4
D				---	YES	YES	YES	4	2
E					---	NO	NO	2	4
F						---	NO	2	4
H							---	2	4

TABLE 23 -- 1400, 10-15-63, 2.0-2.6 microns

SPECIES	A	B	C	D	E	F	H		
A	---	NO	NO	NO	YES	NO	YES	2	4
B		---	NO	NO	YES	YES	YES	3	3
C			---	NO	YES	YES	YES	3	3
D				---	YES	NO	YES	2	4
E					---	NO	NO	4	2
F						---	NO	2	4
H							---	4	2

LIKELIHOOD OF DIFFERENTIATING TREE SPECIES (t.05 probability)

TABLE 24 -- 1400, 10-15-63, 4.5-5.5 microns

SPECIES	A	B	D	E	F	H	Diff. from Other Species (YES)	(NO)
A	---	YES	NO	YES	NO	NO	2	3
B		---	YES	YES	YES	NO	4	1
D			---	NO	NO	NO	1	4
E				---	NO	YES	2	3
F					---	YES	3	2
H						---	2	3

TABLE 25 -- 1400, 10-15-63, 8.2-14.0 microns

SPECIES	A	B	C	D	E	F	H		
A	---	YES	NO	NO	NO	NO	NO	1	5
B		---	YES	NO	YES	NO	YES	4	2
C			---	NO	NO	YES	NO	2	4
D				---	YES	NO	NO	1	5
E					---	YES	NO	3	3
F						---	YES	3	3
H							---	2	4

LIKELIHOOD OF DIFFERENTIATING TREE SPECIES (t.05 probability)

TABLE 26 -- 2000, 10-15-63, 4.5-5.5 microns

SPECIES	A	B	D	H		Diff. from Other Species (YES)	Diff. from Other Species (NO)
A	---	NO	NO	YES		1	2
B		---	NO	NO	(NO DATA)	0	3
D			---	NO		0	3
H				---		1	2

TABLE 27 -- 2000, 10-15-63, 8.2-14.0 microns

SPECIES	A	B	D	E	F	H		
A	---	NO	NO	NO	YES	NO	1	4
B		---	NO	NO	YES	NO	1	4
D			---	NO	YES	NO	1	4
E				---	YES	NO	1	4
F					---	NO	4	1
H						---	0	5

LIKELIHOOD OF DIFFERENTIATING TREE SPECIES (t.05 probability)

TABLE 28 -- 0600, 02-05-64, 4.5-5.5 microns

SPECIES	A	B	C	D	E	F	G	H	Diff. from Other Species (YES)	Diff. from Other Species (NO)
A	---	NO	NO	NO	NO	YES	NO	YES	2	5
B		---	YES	NO	YES	YES	YES	YES	5	2
C			---	NO	YES	YES	NO	YES	4	3
D				---	NO	YES	NO	YES	3	4
E					---	YES	YES	YES	4	3
F						---	YES	NO	6	1
G							---	YES	4	3
H								---	6	1

TABLE 29 -- 0600, 02-05-64, 8.2-14.0 microns

SPECIES	A	B	C	E	F	G	H		
A	---	NO	NO	YES	YES	YES	YES	4	2
B		---	NO	YES	NO	YES	YES	3	3
C			---	YES	NO	YES	YES	3	3
E				---	YES	YES	YES	6	0
F					---	NO	NO	2	4
G						---	NO	4	2
H							---	4	2

LIKELIHOOD OF DIFFERENTIATING TREE SPECIES (t.05 probability)

TABLE 30 -- 0900, 02-05-64, .32-.38 microns

SPECIES	A	B	C	D	E	F	G	H	Diff. from Other Species (YES)	(NO)
A	---	NO	NO	NO	NO	NO	NO	YES	1	6
B		---	NO	NO	NO	NO	NO	NO	0	7
C			---	NO	YES	YES	NO	YES	3	4
D				---	NO	YES	YES	NO	2	5
E					---	NO	YES	NO	3	4
F						---	YES	YES	2	5
G							---	YES	3	4
H								---	4	3

TABLE 31 -- 0900, 02-05-64, 2.0-2.6 microns

SPECIES	A	B	C	D	E	F	G	H		
A	---	YES	YES	YES	NO	NO	YES	YES	5	2
B		---	YES	NO	NO	YES	YES	NO	4	3
C			---	YES	YES	YES	NO	YES	6	1
D				---	NO	YES	YES	NO	4	3
E					---	NO	YES	NO	2	5
F						---	YES	YES	5	2
G							---	YES	6	1
H								---	4	3

LIKELIHOOD OF DIFFERENTIATING TREE SPECIES (t.05 probability)

TABLE 32 -- 0900, 02-05-64, 4.5-5.4 microns

SPECIES	A	B	C	D	E	F	G	H	Diff. from Other Species (YES)	(NO)
A	---	YES	YES	NO	YES	YES	YES	YES	6	1
B		---	NO	NO	NO	NO	NO	NO	1	6
C			---	NO	NO	NO	NO	NO	1	6
D				---	NO	NO	NO	NO	0	7
E					---	YES	NO	NO	2	5
F						---	NO	YES	2	5
G							---	YES	1	6
H								---	1	6

TABLE 33 -- 0900, 02-05-64, 8.2-14.0 microns

SPECIES	A	B	C	D	E	F	G	H		
A	---	YES	YES	YES	NO	NO	YES	YES	5	2
B		---	YES	NO	YES	YES	YES	NO	5	2
C			---	YES	NO	YES	NO	YES	5	2
D				---	YES	YES	YES	NO	5	2
E					---	NO	NO	YES	3	4
F						---	NO	YES	4	3
G							---	YES	4	3
H								---	5	2

LIKELIHOOD OF DIFFERENTIATING TREE SPECIES (t.05 probability)

TABLE 34 -- 1400, 02-05-64, .32-.38 microns

SPECIES	A	C	E	F	G	H	Diff. from Other Species (YES)	(NO)
A	---	NO	NO	NO	NO	NO	5	0
C		---	YES	YES	NO	NO	2	3
E			---	NO	YES	YES	3	2
F				---	NO	NO	1	4
G					---	NO	1	4
H						---	1	4

TABLE 35 -- 1400, 02-05-64, 2.0-2.6 microns

SPECIES	A	C	E	F	G	H		
A	---	YES	YES	NO	YES	YES	4	1
C		---	YES	YES	NO	YES	4	1
E			---	NO	YES	NO	3	2
F				---	YES	YES	3	2
G					---	YES	4	1
H						---	4	1

LIKELIHOOD OF DIFFERENTIATING TREE SPECIES (t.05 probability)

TABLE 36 -- 1400, 02-05-64, 4.5-5.5 microns

SPECIES	A	B	C	D	E	F	G	H	Diff. from Other Species (YES)	(NO)
A	---	NO	NO	NO	YES	NO	NO	YES	2	5
B		---	NO	NO	YES	NO	NO	YES	2	5
C			---	NO	YES	NO	NO	YES	2	5
D				---	NO	NO	NO	NO	0	7
E					---	YES	NO	NO	5	2
F						---	NO	YES	2	5
G							---	YES	1	6
H								---	5	2

TABLE 37 -- 1400, 02-05-64, 8.2-14.0 microns

SPECIES	A	B	C	D	E	F	G	H		
A	---	YES	NO	YES	NO	NO	NO	YES	3	4
B		---	YES	YES	YES	YES	YES	NO	6	1
C			---	YES	NO	NO	NO	YES	3	4
D				---	YES	YES	YES	NO	6	1
E					---	NO	NO	YES	3	4
F						---	NO	YES	3	4
G							---	YES	3	4
H								---	5	2

LIKELIHOOD OF DIFFERENTIATING TREE SPECIES (t.05 probability)

TABLE 38 -- 2000, 02-05-64, 8.2-14.0 microns

SPECIES	A	B	C	D	E	F	H	Diff. from Other Species (YES)	(NO)
A	---	NO	YES	NO	NO	NO	YES	2	4
B		---	YES	NO	NO	YES	YES	3	3
C			---	YES	NO	NO	NO	3	3
D				---	NO	YES	YES	3	3
E					---	NO	NO	0	6
F						---	NO	2	4
H							---	3	3

LIKELIHOOD OF DIFFERENTIATING TREE SPECIES (t.05 probability)

TABLE 39 -- 0600, 04-14-64, .32-.38 microns

SPECIES	A	C	D	E	F	G	H	Diff. from Other Species (YES)	(NO)
A	---	NO	NO	YES	YES	YES	YES	4	2
C		---	NO	YES	NO	NO	NO	1	5
D			---	YES	YES	YES	YES	4	2
E				---	NO	NO	YES	4	2
F					---	NO	NO	2	4
G						---	NO	2	4
H							---	3	3

TABLE 40 -- 0600, 04-14-64, 2.0-2.6 microns

SPECIES	A	B	C	D	E	F	G	H		
A	---	YES	NO	YES	YES	YES	NO	YES	5	2
B		---	YES	NO	NO	NO	NO	NO	2	5
C			---	YES	YES	YES	NO	YES	5	2
D				---	NO	NO	NO	NO	2	5
E					---	NO	NO	NO	2	5
F						---	NO	YES	2	5
G							---	NO	1	6
H								---	3	4

LIKELIHOOD OF DIFFERENTIATING TREE SPECIES (t.05 probability)

TABLE 41 --- 0600, 04-14-64, 4.5-5.5 microns

SPECIES	A	B	C	D	E	F	G	H	Diff. from Other Species (YES)	(NO)
A	---	NO	NO	NO	NO	YES	NO	NO	6	1
B		---	NO	NO	YES	YES	NO	NO	2	5
C			---	NO	YES	YES	NO	NO	2	5
D				---	YES	YES	NO	NO	2	5
E					---	YES	YES	NO	5	2
F						---	YES	YES	7	0
G							---	NO	2	5
H								---	1	6

TABLE 42 -- 0600, 04-14-64, 8.2-14.0 microns

SPECIES	A	B	C	D	E	F	G	H		
A	---	YES	YES	YES	NO	NO	YES	YES	5	2
B		---	YES	NO	YES	YES	YES	NO	5	2
C			---	YES	YES	YES	NO	YES	6	1
D				---	YES	YES	YES	YES	6	1
E					---	NO	YES	YES	5	2
F						---	YES	YES	5	2
G							---	YES	6	1
H								---	6	1

LIKELIHOOD OF DIFFERENTIATING TREE SPECIES (t.05 probability)

TABLE 43 -- 0900, 04-14-64, .32-.38 microns

SPECIES	A	B	C	D	E	F	G	H	Diff. from Other Species (YES)	(NO)
A	---	NO	NO	NO	NO	YES	NO	NO	1	6
B		---	NO	NO	YES	YES	YES	YES	4	3
C			---	YES	NO	YES	NO	YES	3	4
D				---	YES	YES	YES	YES	5	2
E					---	YES	NO	NO	3	4
F						---	NO	NO	5	2
G							---	NO	2	5
H								---	3	4

TABLE 44 -- 0900, 04-14-64, 2.0-2.6 microns

SPECIES	A	B	C	D	E	F	G	H
A	---	NO	YES	NO	YES	YES	NO	YES
B		---	YES	NO	YES	YES	NO	YES
C			---	YES	YES	YES	NO	YES
D				---	YES	YES	NO	YES
E					---	NO	YES	NO
F						---	YES	NO
G							---	YES
H								---

LIKELIHOOD OF DIFFERENTIATING TREE SPECIES (t.05 probability)

TABLE 45 -- 0900, 04-14-64, 4.5-5.5 microns

SPECIES	A	B	D	E	F	H	Diff. from Other Species (YES)	(NO)
A	---	NO	NO	YES	YES	YES	3	2
B		---	NO	YES	YES	NO	2	3
D			---	YES	YES	NO	2	3
E				---	NO	NO	3	2
F					---	NO	3	2
H						---	1	4

TABLE 46 -- 0900, 04-14-64, 8.2-14.0 microns

SPECIES	A	B	C	D	E	F	G	H		
A	---	YES	NO	YES	YES	YES	YES	NO	5	2
B		---	YES	NO	YES	YES	YES	YES	6	1
C			---	YES	YES	YES	YES	YES	6	1
D				---	YES	YES	YES	YES	6	1
E					---	NO	NO	YES	5	2
F						---	NO	YES	5	2
G							---	NO	4	3
H								---	5	2

LIKELIHOOD OF DIFFERENTIATING TREE SPECIES (t.05 probability)

TABLE 47 -- 2000, 04-14-64, 4.5-5.5 microns

SPECIES	A	B	C	D	E	F	H	Diff. from Other Species (YES)	(NO)
A	---	YES	NO	YES	YES	YES	YES	5	1
B		---	YES	NO	YES	YES	YES	5	1
C			---	YES	YES	YES	YES	5	1
D				---	YES	YES	YES	5	1
E					---	NO	NO	4	2
F						---	NO	4	2
H							---	4	2

TABLE 48 -- 2000, 04-14-64, 8.2-14.0 microns

SPECIES	A	B	C	D	E	F	G	H		
A	---	YES	NO	YES	YES	YES	NO	YES	5	2
B		---	YES	NO	YES	YES	YES	NO	5	2
C			---	YES	YES	YES	NO	YES	5	2
D				---	YES	YES	YES	NO	5	2
E					---	NO	YES	YES	6	1
F						---	YES	YES	6	1
G							---	YES	5	2
H								---	5	2

LIKELIHOOD OF DIFFERENTIATING TREE SPECIES (t.05 probability)

TABLE 49 -- 0600, 06-09-64, .32-.38 microns

SPECIES	A	B	C	D	E	F	G	H	Diff. from Other Species (YES)	(NO)
A	---	YES	YES	NO	YES	YES	YES	YES	6	1
B		---	NO	YES	YES	YES	YES	YES	6	1
C			---	YES	NO	YES	NO	YES	4	3
D				---	YES	YES	YES	YES	6	1
E					---	NO	NO	NO	3	4
F						---	NO	NO	4	3
G							---	NO	3	4
H								---	4	3

TABLE 50 -- 0600, 06-09-64, 2.0-2.6 microns

SPECIES	A	B	D	E	F	H		
A	---	YES	YES	NO	NO	YES	3	2
B		---	NO	YES	YES	YES	4	1
D			---	YES	YES	YES	4	1
E				---	YES	YES	4	1
F					---	YES	4	1
H						---	5	0

LIKELIHOOD OF DIFFERENTIATING TREE SPECIES (t.05 probability)

TABLE 51 -- 0900, 06-09-64, .32-.38 microns

SPECIES	A	B	C	D	E	F	H	Diff. from Other Species (YES)	(NO)
A	---	YES	NO	YES	NO	NO	NO	2	4
B		---	YES	NO	NO	NO	YES	3	3
C			---	YES	YES	YES	NO	4	2
D				---	NO	YES	YES	4	2
E					---	NO	NO	1	5
F						---	NO	2	4
H							---	2	4

TABLE 52 -- 0900, 06-09-64, 2.0-2.6 microns

SPECIES	A	B	C	D	E	F	G	H		
A	---	YES	NO	YES	NO	NO	NO	YES	3	4
B		---	YES	NO	YES	NO	YES	NO	4	3
C			---	YES	YES	YES	NO	YES	5	2
D				---	YES	YES	YES	NO	5	2
E					---	NO	NO	NO	3	4
F						---	YES	NO	3	4
G							---	YES	4	3
H								---	3	4

LIKELIHOOD OF DIFFERENTIATING TREE SPECIES (t.05 probability)

TABLE 53 -- 0900, 06-09-64, 4.5-5.5 microns

SPECIES	A	B	C	D	E	G	Diff. from Other Species (YES)	(NO)
A	---	NO	NO	NO	NO	NO	0	5
B		---	YES	NO	NO	NO	1	4
C			---	YES	NO	NO	3	2
D				---	NO	NO	1	4
E					---	NO	1	4
G						---	0	5

TABLE 54 -- 1400, 06-09-64, .32-.38 microns

SPECIES	A	B	C	D	E	F	G	H		
A	---	NO	YES	NO	YES	YES	NO	YES	4	3
B		---	YES	NO	NO	YES	YES	YES	4	3
C			---	YES	YES	YES	NO	YES	6	1
D				---	NO	YES	NO	YES	3	4
E					---	YES	YES	NO	4	3
F						---	YES	YES	7	0
G							---	YES	4	3
H								---	6	1

LIKELIHOOD OF DIFFERENTIATING TREE SPECIES (t.05 probability)

TABLE 55 -- 1400, 06-09-64, 2.0-2.6 microns

SPECIES	A	B	C	D	E	F	H	Diff. from Other Species (YES)	(NO)
A	---	NO	NO	YES	YES	NO	NO	2	4
B		---	YES	YES	NO	NO	YES	3	3
C			---	YES	YES	NO	NO	3	3
D				---	YES	YES	YES	6	0
E					---	NO	NO	3	3
F						---	NO	1	5
H							---	2	4

TABLE 56 -- 2000, 06-09-64, 4.5-5.5 microns

SPECIES	A	B	C	D	E	F	H		
A	---	YES	NO	NO	NO	YES	NO	2	4
B		---	YES	NO	YES	YES	YES	5	1
C			---	NO	NO	YES	NO	2	4
D				---	NO	YES	NO	1	5
E					---	YES	NO	2	4
F						---	YES	6	0
H							---	2	4