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Rainforest Species on Large-Scale Color Photos

1:2000 scale color aerial photographs enabled accurate identification of many tree species in the tropical rainforests of Australia.

Abstract: *The extreme variability and complexity of tropical rainforests preclude any detailed floristic classification from conventional small-scale black-and-white aerial photographs. This paper describes a study conducted in north Queensland of the use of large-scale color, color infrared, and black-and-white aerial photographs for the identification of tree species as a basis for rainforest classification. Normal color transparency film at 1:2000 scale was the best combination of film and scale for species identification. Six forest areas studied by five interpreters had a total of 111 different dominant and codominant species. In the test stands, 55 different rainforest species were correctly identified at least once. Twenty-four species were identified with more than 75 percent accuracy and 11 of these were correctly identified in every case examined by the five interpreters. Directions for future research are suggested.*

Introduction

Classification of the tropical rainforests in north Queensland, Australia, has been a perplexing challenge to foresters and ecologists for many years. The approaches and methods considered for classification have been as diverse as the information sought and the management objectives of the investigators. Conservationists have sought a form of ecosystem classification which would enable them to assess, among other things, whether natural ecosystems are adequately represented in national parks. Management foresters have sought a classification which would allow estimation of current timber volumes, likely volumes available at the next cutting cycle, or the forest's potential productivity.

It is unlikely that any single method of rainforest classification will satisfy all requirements. Tracey and Webb (1975) published a series of maps at 1:100 000 scale of the vegetation of the humid tropical region of north Queensland on which the rainforests were classified, first into structural units and then into broad communities correlated with climatic zones and soil parent material. The physiognomic-structural classification used for these maps has been the subject of several papers (Webb, 1959; Webb *et al.*, 1970; Webb *et al.*, 1976). The maps were based on 25 years of field experience, interpretation of conventional small-scale black-and-white aerial photographs, and several aerial observation flights (J. G. Tracey, pers. comm.).

The management forester, on the other hand, whose aim is to locate, log, and silviculturally treat the areas growing valuable species requires a floristic approach to rainforest classification. Volck (1975) described the broad classes required for management purposes as:

- Rainforests which have a 'reasonable' stocking of valuable species in a range of size classes;
- Rainforests which either have had (prior to logging), or still have, a small proportion of the valuable species, and are considered capable of growing valuable species either by light or intensive enrichment plantings;
- Rainforests that are deficient in the valuable species, but contain reasonable stockings of acceptable commercial species; and
- Rainforests that are deficient in valuable species and acceptable commercial species.

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Efforts to map such classes were made by the Queensland Department of Forestry during the 1960s using inventory surveys in which strip lines were assessed on the ground. However, this method was very expensive due to the difficulty of ground access, and less than 20 percent of the rainforest in the State was sampled. Information on species and regeneration which is collected after logging has been unsatisfactory for demarcating floristic classes.

Aerial photographs have been widely used throughout the world for classifying forests into associations and identifying tree species (Myers, 1976). Most modern temperate forest inventories incorporate, at least to some degree, species identification from aerial photographs, but photo identification of tree species in tropical rainforest inventories has been less successful. The basic problem is the degree of floristic diversity which exists in rainforests. In temperate forest surveys an interpreter is seldom required to identify more than a dozen or so species in an area and often far fewer, while in the tropical rainforest several hundred tree species may occur within a small area. Whitmore (1975) shows examples of tree species diversities for tropical rainforests from different parts of the world ranging from about 50 per hectare to over 300 per hectare. Tree species diversity in north Queensland (approximately 80 to 170 per hectare) appears to be greater than forests in comparable parts of the Americas and Africa but less than other Indo-Malayan forests. Nyyssonen (1962) reviewed investigations in the 1950s into the identification of tree species in the tropics. In the studies quoted, medium- to small-scale black-and-white prints were used and, invariably, few species could be identified. The trend was for only one or two species to be identifiable on the basis of emergence or very distinctive crown shape. For this reason, and since small-scale photographs are usually all that are available, the use of aerial photographs in tropical forest surveys has been confined almost exclusively to mapping forest classes based on gross structural differences.

Since the early 1970s, however, there have been several reports of attempts to apply some of the more recent aerial photographic developments, such as color and color infrared films and very large scales, to the specific problems of tropical rainforest inventory. Versteegh (1974) found that, while 1:5000 scale photographs offered some possibilities for assessing the timber potential of tropical forests in Surinam by means of crown counts, tree species were difficult to identify on either color or black-and-white films, even at this large scale, except when they were emergent. Crown shape and tone were too variable within a species to be used for species separation and color offered little advantage over black and white for species identification. Clément and Guellec (1974) had more success using 1:5000 scale color diapositives to locate trees of a single important species in the tropical forest of Gabon. Seventy-three percent of the okoumé (*Aucoumea klaineana* Pierre) were identifiable by crown structure, texture, and color, although confusion with certain other species was possible.

Sayn-Wittgenstein *et al.* (1978) found that a number of species in the tropical rainforest in Surinam could be "identified with a reasonable degree of success or exhibit characteristics that indicate that identification guidelines could be drawn up following a moderate amount of further study," using high quality color photographs at 1:4000 scale or larger. An attempt to construct a dichotomous key for species identification was unsuccessful. Emphasis in the study was placed on attempting to identify characteristics which appear promising for species identification. The most useful features were crown size and shape, dominance, branching habit, texture, foliage characteristics, and color. Normal color film was considered essential for species identification.

This paper describes a study designed to test the use of large-scale color aerial photography for species identification in a range of north Queensland rainforest types. The objectives were

- to determine if rainforest species exhibit features which are sufficiently consistent and characteristic to enable reliable identification on large-scale aerial photographs, and
- to study the relative merits of various films and scales of photography for species identification.

An interpretation guide to the distinctive characteristics of the identifiable species which were countered in this study has been prepared for publication elsewhere (Myers, 1981).

Throughout this paper scientific names of species are used. The corresponding standard trade names and common names may be found in Hyland (1971).

Study Areas

A series of 0.5 ha reference plots was established by the North Queensland Regional Station of the Division of Forest Research to examine forest structure, species composition, and tree growth in rainforest communities of Australia's eastern tropical coast. Six of these plots and the adjacent forests in the vicinity of Cairns and the Atherton Tableland in north Queensland (Fig. 1) were selected for aerial photography because of the range of forest types and species they exhibited and the ease of location from the air.

The plots are 100 m by 50 m. All trees greater than 10 cm diameter at breast height have been identified, labeled, and mapped. The types of rainforest sampled by the plots are classified in

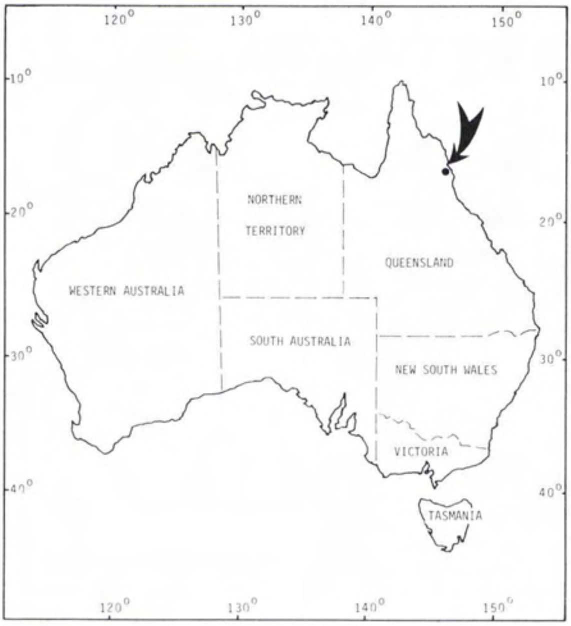

FIG. 1. Map of Australia showing the study area in north Queensland.

Table 1 according to the physiognomic system of Webb (1959).

The previously identified dominant and codominant trees on the plots which were visible on the photographs were used as training sets for the photo interpreters. Subsequently, attempts were made to locate and identify further examples of the same species in test stands outside the plots. Many of the trees on the plots were not visible on the vertical aerial photographs due to overtopping dominants or dense shadow. The training set therefore consisted solely of the dominant and codominant crowns which were large enough when viewed vertically to provide an image on the photographs which could be examined separately. The plot boundaries were located on the photographs. Each visible tree within the plot was then located on the photographs and identified in the field.

PHOTOGRAPHY

The photographs were exposed on 24 and 25 July 1976 from a Cessna 182 aircraft using Vinten and Hasselblad 70 mm cameras. Color transparencies on Kodak Aerochrome MS Film 2448 (Estar Base) were exposed at four scales (1:2000, 1:3000, 1:4000, and 1:6000) over each of the six plots. In addition, over one plot, color infrared transparencies on Kodak Aerochrome Infrared Film 2443 (Estar Base) were exposed at the same four scales, color negatives on Kodak Aerocolor Negative Film 2445 (Estar Base) were exposed at two scales (1:2000 and 1:4000), and black-and-white negatives on Kodak Plus-X Aerographic Film 2402 (Estar Base) were exposed at the same two scales. An example of the Kodak Aerochrome MS Film 2448, enlarged 2×, is reproduced on the cover.

PHOTO INTERPRETATION

Two interpretation methods were tested in this study. The first, referred to as 'individual in-

TABLE 1. ENVIRONMENTAL AND STRUCTURAL CHARACTERISTICS OF TROPICAL RAINFOREST COMMUNITIES IN THE REFERENCE PLOTS

	Plot					
Characteristic	Curtain Fig	Mt Haig	Tinaroo	Gordonvale	Woopen Ck	Mt Lewis
Altitude (m)	720	1100	720	20	80	1000
Latitude	17°18′S	17°09′S	17°10′S	17°00′S	17°31′S	16°30′S
Longitude	145°34′E	145°38′E	145°37′E	145°50′E	145°50′E	145°16′E
Av. annual rainfall (mm)	1500	2000	1200	2200	4000	3000
Parent material	basalt	granite	granite	metamorphic and granite	metamorphic	granite
Physiognomic description*	complex notophyll vine forest	simple micro-phyll vine-fern forest	complex notophyll vine forest with emergent *Agathis robusta*	mesophyll vine forest	complex mesophyll vine forest	simple micro-phyll vine-fern forest
No. of tree species	44	63	35	68	43	82
No. of trees	313	507	453	486	238	449
Tree basal area (m^2)	31.3	32.8	14.2	17.9	20.5	29.7
Canopy height (m)	35–42	30–36	15–23	10–29	22–24	24–32

* Physiognomic description of forest types by Webb (1959) and Tracey and Webb (1975).

terpretation,' examined the possibility of interpreters independently recognizing specimens of a species based on the appearance of known examples in a training set. The second, referred to as 'group classification,' examined the possibility of using a classification analysis to discriminate species on the basis of characteristics determined by a group of interpreters making decisions by consensus.

INDIVIDUAL PHOTO INTERPRETATION

Four interpreters independently studied the photographs of all six reference plots and adjacent test stands while a fifth interpreter examined only three sites. A 4× Abrams lens stereoscope was used for interpretation. All films and scales were available to the interpreters. Each visible individual of a species within a plot was examined to determine the diagnostic features of the species; then the identification of additional examples in the test stand outside the plot was attempted. This process was repeated for all species on each reference plot. Identified individuals in the test stands were marked on transparent overlays and the trees were subsequently located in the field to verify the identifications.

The features which were used by interpreters in identifying the trees on the photographs were color, crown size and dominance, crown shape, crown texture, branching habit, branch visibility, foilage density, and presence or absence of fruiting or flowering.

The study was carried out over two field seasons. In the first season, interpreters were asked to limit their identifications to about five examples of each species. As the field work showed that this limit was unnecessarily restrictive, in the second season the interpreters were asked to identify up to 15 examples of each species for the remaining sites. The Curtain Fig, Mt. Haig, and Tinaroo sites were studied in the first year; the Gordonvale, Woopen Creek, and Mt. Lewis sites in the second.

GROUP CLASSIFICATION

A stereo-projection setup was developed to enable a group of interpreters collectively to examine the photographs. The setup consisted of two 70-mm slide projectors modified to allow the insertion of a polarizing filter in the light path between the slide and the projection lens. The axis of polarization on one projector was set at 90° to the other. The photographs were then projected onto a highly reflective daylight or silver lenticular projection screen and viewed through polarizing spectacles. The axis of polarization of the eye pieces was set at 90° to each other and complementary to the projection filters so that the left eye saw only the left photograph and the right eye saw only the right photograph. In this way a greatly enlarged stereo model could be viewed on the screen by any number of interpreters at one time. A similar set up was described by Kiefer (1977).

Using the stereo-projection setup, a group of four interpreters classified the same attributes as mentioned above for each visible crown on the plots. Test stands outside the plots were not interpreted in this method. The scale used for the group classification was 1:3000. Since this did not require as many stereo models to cover the complete plot as the 1:2000 scale, consistent interpretation standards were more easily maintained, whereas it provided a more detailed image than did the two smaller scales. The stereo-projection system provided a 24× linear enlargement, resulting in a projected viewing scale of about 1:120.

COLOR ANALYSIS

Densitometric measurements were made of the crown image of each tree in the training sets on 1:3000 scale color transparencies to provide data for a quantitative assessment of the contribution of crown color to the separation of rainforest species. The instrument used was a Macbeth Expediter Transmission Densitometer TD-504 with digital readout. A circular aperture of 0.7-mm diameter was used. The filters were Wratten gelatin filters numbers 92 in the red, 93 in the green, 94 in the blue, and 106 in the visual for measuring the cyan, magenta, and yellow dye layer densities and the overall film density, respectively. The pass bands of the colored filters approximate the spectral bands of the peak densities of the three dye layers in standard color film. The relative density levels, which were calculated by subtracting the visual density from the three dye layer densities, are an approximation of the spectral signature of the tree. The spectral data were subjected to both graphical and canonical analyses.

RESULTS AND DISCUSSION

A total of 1109 interpretations were made by the five interpreters of which 73 percent were correct. Fifty-five of the 111 dominant and codominant species of the reference plots were also found and correctly identified in the test stands at least once. It is estimated that in stands of identical composition to the reference plots about 51 percent of the dominant and codominant trees would be identified. This estimate was derived by applying the appropriate rate of successful identification to each species in the reference plots.

There was wide variation between species in the accuracy of their identification and the frequency with which the identification was attempted. Those species which were correctly identified in the test stands at least once may be conveniently divided into *frequently identified* species, which were correctly identified more than once by more than one interpreter (i.e., at least four times) and *less frequently identified* species, which were correctly identified less than four times. The *frequently identified* species, which comprised 81 percent (896) of all interpretations, were 85 per cent correctly identified. The *less frequently identified* species, which represented 19 percent (213) of all interpretations, were only 26 percent correctly identified. Fifty percent of the latter interpretations were made by the only interpreter who had not had any experience using the rainforest photographs in the field prior to interpretation. An interpreter with substantial field experience could be expected to achieve better results through familiarity with ground identifying features of the species and ecological clues such as normal aspect and slope-position preference of a species.

Table 2 shows the interpreters' performance for the *frequently identified* species at each site. The difference between interpreters was significant ($P < 0.001$) only at the Tinaroo site. The poor performance of interpreter No. 1 accounts for this difference, and it can be seen that he achieved the lowest accuracy of all interpreters in each of the three sites studied in the first season. This was due in part to his need for corrective lenses, which he obtained and used for interpretation of the last three sites. In general the interpreter performance reflected the degree of experience of each person with species identification, with interpreter No. 1 (77 percent of identifications correct) being least experienced and interpreter No. 5 (90 percent) having the most experience, but the differences overall are not statistically significant.

The results of the photo interpretation for the *frequently identified* species are presented in Table 3 and for the *less frequently identified* species in Table 4. The data are presented in this way because interpreter confidence was low for the latter species and interpretation accuracy could not reasonably be determined based on so few trees. Table 3 shows that 24 of the *frequently identified* species were correctly identified more than 75 percent of the time and 11 of these were interpreted correctly in every case. In all, at least one individual of 55 different species was correctly identified on the photographs. Of the 32 different species which were *frequently identified*, seven were in merchantability class A (most valuable cabinet species), 19 were acceptable commercial species, and six were non-commercial.

Comparisons between the number of trees correctly identified in each location are confounded by the different interpretation guidelines used for the first three versus the last three study sites as mentioned previously, and by the relatively poor quality of the photographs of the Mt. Lewis site. These photographs were exposed at a low solar altitude (41°), which resulted in increased areas of

TABLE 2. INTERPRETERS' PERFORMANCE FOR *FREQUENTLY IDENTIFIED** SPECIES IN TEST STANDS

Study site	Interpreter 1			Interpreter 2			Interpreter 3			Interpreter 4			Interpreter 5		
	Number of trees	Correct identifications No.	%	Number of trees	Correct identifications No.	%	Number of trees	Correct identifications No.	%	Number of trees	Correct identifications No.	%	Number of trees	Correct identifications No.	%
Curtain Fig	29	20	69	28	26	93	32	24	75	41	34	83	34	28	82
Mt. Haig	41	25	61	38	30	79	29	21	72	36	27	75	37	31	84
Tinaroo	32	20	62	18	17	94	23	21	91	19	18	94	39	38	97
Gordonvale	54	47	87	—	—	—	66	55	83	56	51	91	68	63	93
Woopen Creek	34	34	100	—	—	—	34	33	97	34	32	94	30	29	97
Mt. Lewis	4	3	75	—	—	—	17	11	65	8	8	100	15	12	88
Totals/Means	194	149	77	84	73	87	201	165	82	194	170	88	223	201	90

* *Frequently identified* species—one correctly identified more than once by more than one interpreter.

TABLE 3. INTERPRETATION RESULTS FOR *FREQUENTLY IDENTIFIED** SPECIES

Study site	No. of interpreters	Species	Number of trees	Correct identifications No.	Correct identifications %
Curtain Fig	5	*Toona australis*	25	25	100
		Endiandra cowleyana	16	16	100
		Aleurites moluccana	27	26	96
		Dysoxylum pettigrewianum	20	16	80
		Argyrodendron peralatum	24	18	75
		Castanospermum australe	30	21	70
		Flindersia brayleyana	22	10	45
			164	132	80
Mt. Haig	5	*Agathis atropurpurea*	30	30	100
		Flindersia bourjotiana	32	29	91
		Ceratopetalum succirubrum	15	13	87
		Elaeocarpus sp.	23	19	83
		Flindersia pimenteliana	26	17	65
		Musgravea stenostachya	14	8	57
		Balanops australiana	31	14	45
		Elaeocarpus sericopetalus	10	4	40
			181	134	74
Tinaroo	5	*Austromyrtus hillii*	24	24	100
		Alstonia muellerana	21	20	95
		Croton insularis	20	19	95
		Acacia aulacocarpa	10	10	100
		Argyrodendron peralatum	10	10	100
		Cleistanthus semiopacus	22	18	82
		Euroschinus falcata	10	6	60
		Flindersia schottiana	14	7	50
			131	114	87
Gordonvale	4	*Flindersia bourjotiana*	11	11	100
		Acacia aulacocarpa	60	58	97
		Blepharocarya involucrigera	60	58	97
		Flindersia pimenteliana	24	23	97
		Carnarvonia araliifolia	42	35	83
		Alstonia muellerana	35	25	71
		Elaeocarpus bancroftii	12	6	50
			244	216	89
Woopen Creek	4	*Schefflera actinophylla*	59	59	100
		Backhousia bancroftii	60	57	95
		Ficus leptoclada	6	6	100
		Castanospermum australe	7	6	86
			132	128	97
Mt. Lewis	4	*Eugenia* sp. aff. *E. smithii* (RESA)	9	9	100
		Eugenia sp. aff. *E. smithii* (WESA)	6	6	100
		Balanops australiana	11	9	82
		Eugenia sp. aff. *E. luehmanii*	8	5	62
		Elaeocarpus largiflorens	10	5	50
			44	34	77

* *Frequently identified* species—one correctly identified more than once by more than one interpreter.

shadow in the crowns and a loss of interpretable information. In addition, surface wind had moved the trees between exposures, making detailed analysis of the stereo model very difficult. Although the solar altitude (31°) for the Woopen Creek photographs was even lower than that for Mt. Lewis, the interpretation results were better. This outcome was due to the simplicity of the Woopen Creek forest, which was characterized by the predominance of one tree species, *Backhousia*

TABLE 4. INTERPRETATION RESULTS FOR *LESS FREQUENTLY IDENTIFIED** SPECIES

Study site	Species	No. of trees	No. correct identifications
Curtain Fig	*Tetrasynandra laxiflora*	6	1
	Doryphora aromatica	7	3
	Terminalia sericocarpa	2	2
	Endiandra pubens	4	1
	Dendrocnide photinophylla	4	1
	Myristica insipida	5	1
Mt. Haig	*Elaeocarpus foveolatus*	8	3
	Eugenia sp. aff. *E. angophoroides*	4	2
	Cryptocarya angulata	3	1
	Beilschmedia sp. aff. *B. obtusifolia*	2	1
Tinaroo	*Cerbera inflata*	5	4
	Pseudoweinmannia lachnocarpa	8	3
	Melicope erythrococa	2	1
	Blepharocarya involucrigera	3	1
	Ficus spp.	6	1
	Glochidion ferdinandii	3	1
Gordonvale	*Commersonia bartramia*	6	6
	Podocarpus neriifolius	3	2
	Sterculia laurifolia	7	2
Mt. Lewis	*Ficus* spp.	5	5
	Flindersia bourjotiana	15	3
	Ceratopetalum succirubrum	6	1
	Flindersia brayleyana	5	3
	Darlingia darlingiana	9	2
	Argyrodendron sp.	6	1
	Stenocarpus sp.	1	1
	Elaeocarpus sp.	1	1
	Cryptocarya sp.	1	1

* *Less frequently identified* species—one not correctly identified more than once by more than one interpreter.

bancroftii, and one epiphyte, *Schefflera actinophylla*. These two species made up 90 percent of the interpreted individuals, and both had very distinctive appearances. In general, however, there was a correlation between ease and accuracy of interpretation, and solar altitude. Aside from Woopen Creek, the easiest and most accurate interpretation was carried out at the Tinaroo, Gordonvale, and Curtain Fig sites, which were photographed at the highest solar altitudes: 48°, 48°, and 50°, respectively. Therefore, any future photography of rainforest for the purpose of detailed interpretation of species should be conducted at the highest solar altitudes possible, certainly not lower than 45°.

The results of this study indicate that there is potential to identify rainforest species in north Queensland, but the full extent of this potential has not been tested since

- Slightly fewer than 30 percent of the total of about 800 Australian tropical rainforest tree species were represented in the reference plots, and only 48 percent of those were represented in the dominant and codominant crown classes which comprised the training sets;
- Sixty-seven percent of the species in the training sets were represented by three or fewer individuals, which in most cases was too few to enable the variation which existed in the appearance of the species to be assessed; and
- Individuals in the training sets may have been atypical of the general range of appearance of the species (i.e., the crowns may have been small or unhealthy).

The species successfully identified in this study may not always be identifiable on large-scale color aerial photographs. The accuracy of identification will be influenced by phenological processes such as flowering, leaf flush, or leaf shed and may be affected by elevation, aspect and edaphic factors. Future work should aim to test the repeatability of the results for the same species under different conditions. The time of year of photography is not very flexible due to the short period of weather suitable for obtaining aerial photographs in the seasonally wet tropics.

An examination of the erroneous identifications made in the study revealed some common mistakes which indicate a strong similarity between the photo appearances of pairs or groups of species. Some errors were unique, that is, they were made only once and as such were of little importance. Others were made by more than one interpreter but only one tree was involved. These demonstrated that one tree of a species possessed the common appearance of another species at the time of photography. Another type of error occurred where an interpreter consistently repeated the same misidentification and indicated that the species had a consistent appearance but the interpreter was misnaming it. The most important type of error was where several interpreters made the same mistake on several different trees, indicating that the two species showed sufficiently similar characteristics on at least some occasions to warrant special attention when identifying rainforest species on large-scale photographs.

SCALE COMPARISON

The evaluation of the merits of the four scales used in this study for rainforest species identification was subjective and based on both the group and individual interpretations. The categories used to classify the tree crown images on 1:3000 scale were not suitable for the other three scales. The interpretability of relative crown area and relative tree height were not affected by scale but all other features were influenced. The amount of detail visible on 1:2000 was far greater than on 1:3000 scale with the result that it was possible to describe the texture of smaller portions of the crown, and an extra class of texture could be reliably recognized. The texture of the entire crown and of the individual crown segments could be described separately. More trees appeared to have crowns composed of discrete segments. Frequently, individual large leaves were resolved, and leaf arrangement was also visible on some species. In some instances it was possible to identify positively distinctive features such as flowering or fine branch visibility on 1:2000 or 1:3000 scale but, on the smaller scales, these features blended with the foliage to form an overall crown color. Some species which display a prominent distinctive characteristic such as deciduousness, strong apical dominance, or emergence were equally identifiable on the smaller scales or on the large scale, but accurate identification of most of the species relies on the interpretation and combination of a number of features, many of which were interpretable only on the 1:2000 scale.

On the 1:4000 and 1:6000 scales less information was interpretable on crown texture and structure. There was also a decrease in the range of colors visible on the small scales. On the largest scale, subtle variations in color within a crown were often visible but were missing on smaller scales. Therefore, 1:2000 is the scale recommended for Queensland rainforest species identification unless it is desirable to locate only one species and that species displays a distinctive characteristic to the vertical view, in which case a smaller scale may suffice.

FILM COMPARISON

The evaluation of the four films used in this study was also subjective, and was done by the group interpretation method. The black-and-white diapositives showed the highest resolution and allowed the most detailed classification of texture, but the lack of color was severely limiting for overall identification of species. The color infrared transparencies were slightly poorer in resolution than the true color transparencies and the range of colors was greatly reduced. No more than five or six categories of red and pink could be separated on the color infrared film, while it was difficult to name sufficient descriptive categories to cover the range of colors occurring on the true color film. Also, due to the higher contrast of the color infrared film, shaded portions of crowns were not visible, while they were on true color. The color diapositives from color negatives were also high in contrast and had poorer resolution and reduced color range compared to the color transparencies. These considerations combined with the greater cost of printing from color negatives (the cost ratio between color transparencies and color diapositives is about 1:10 and between color transparencies and color paper prints is about 1:4) lead to the recommendation that color transparencies be used for rainforest species identification, particularly in 70-mm format. The use of a light-weight field transparency viewer (Myers and Van der Duys, 1975) or a small-format light table greatly facilitates handling and viewing small-format transparencies in the field.

GROUP CLASSIFICATION

An attempt was made to develop discriminant functions whereby unknown individuals could be assigned to their correct species. Data inputs for this analysis included crown characteristics and color density values obtained from known individuals in the training sets. The analysis techniques used included MULCLAS, MULTBET, and GOWER (Williams, 1976). The analyses were not successful in separating species with the exception of *Toona australis* which, by virtue of being the only leafless species, always showed a distinct separation from the other groups. In view of the unpromising results of the exploratory work with the group classification technique and the success of the individual interpretation method, group classification for rainforest species identification was not pursued further.

COLOR ANALYSIS

Densitometric data showed a high degree of overlap of densities between species and a wide range of densities within species. With the exception of *Austromyrtus hillii* on the Tinaroo plot and *Elaeocarpus* sp. on the Mt. Haig plot, no species showed a spectral signature which alone would positively separate it from its associated species. However, all interpreters agreed that far fewer species would have been correctly identified without the use of color as one discriminating factor in the photo interpretation process.

Conclusions

This study has demonstrated the potential to identify species on large-scale color aerial photographs of the north Queensland tropical rainforest. Many species exhibit photo-interpretable features which are sufficiently consistent and characteristic to enable accurate identification on large-scale photographs. These were recorded by Myers (1981). Fifty percent of the dominant and codominant species of the reference plots were also found and correctly identified in the test stands at least once. It is estimated that in stands of identical composition to the reference plots about 51 percent of the dominant and codominant trees would be identified. To achieve the best results, it is essential that the interpreter have a thorough field knowledge of the various species, their identifying features, and their habits. Color transparencies should be used at 1:2000 scale in 70-mm format, and photographs should not be exposed at solar altitudes of less than 45-50 degrees.

The study has given reason for optimism for future work but more needs to be done to develop the method to a stage where it is fully operational and can be applied in a broad-scale classification of the rainforest. Future studies should aim to investigate

- the full range of species which are identifiable on large-scale color aerial photographs;
- the proportion of each species which can be identified and the proportion of the stands comprised of identifiable species;
- the repeatability of the results for the same species at different times and at different locations; and
- the incorporation of the method into an overall inventory system.

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