THE POTENTIAL FOR REMOTELY SENSING LEAF AREA INDEX IN THE JARRAH FOREST

K. R. Whitford
Department of Conservation and Land Management,
Research Centre, Dwellingup, Western Australia
1988

CONTENTS

A REPORT ON THE POTENTIAL FOR REMOTELY SENSING LAI IN THE JARRAH FOREST

The potential for applying remote sensing technology to the measurement of leaf area index (LAI) has been established by a variety of research work. This research can be divided into theoretical studies demonstrating the causal relationship between spectral reflectance and LAI, and empirical scanning exercises demonstrating the application of this technology to the measurement of LAI. (LAI is defined as the single side leaf surface area per unit ground area.)

This report examines the applied research into this technology to determine if remote sensing can provide an effective means of measuring LAI in the jarrah forest. As part of this examination, the results from 2 trial scans of a group of forest plots are presented and discussed.

1. Why use remote sensing?

There are 3 reasons for using Remote Sensing to measure LAI.

i. The suitability of the measurement scale.
ii. Indications from supporting research of the likely success.
iii. The absence of other methods likely to prove successful.

i. Scale of Measurement

The use of a suitable measuring device is essential to all measurement. Just as it is inappropriate to use a 1 metre rule to measure a distance of kilometres, the measurement of leaf area on individual trees is unsuited to determining the LAI of catchment areas.

Broad scale LAI measurement requires the use of some broad-scale measuring device. Alternately, catchment LAI could be estimated using sampling techniques and measurements of LAI on small plots (e.g. 20m x 20m). Apart from measurements techniques for individual trees, there is presently no proven technique available for measuring LAI on areas of this size (20m x 20m).

Remote sensing provides a measurement at an appropriate scale.

ii. Relevant supporting research

Several researchers are currently applying remote sensing to the problem of determining LAI. The progress in this area provides some background on which to base the development and application of this technique in the jarrah forest. This work also provides some indication of the likely success of this technique, and the difficulties that must be overcome.

iii. The absence of other proven methods

A variety of techniques for measuring LAI have been proposed and are being developed by forest researchers. The two most promising methods have been trialed by the author and further examination of one technique is presently being undertaken. If successful, this technique could be applied to circular plots of approximately 50m. in diameter. However, there are limitations in this technique which may reduce the value of the information obtained.

Remote Sensing could become the remaining option for determining broad scale LAI.

2. Existing research, a brief review.

Research into measuring LAI using remote sensing can be divided into 2 categories.

i. Research into the factors affecting the reflectance response recorded from vegetation.
ii. Application of this theory to the determination of LAI within a remotely sensed scene.

i. Research into the spectral reflectance of vegetation.

Reflectance is the ratio of incoming radiation to reflected radiation in a particular waveband.

$$\text{Reflectance} = \frac{\text{Radiant Exitance}}{\text{Irradiance}}$$

The spectral reflectance of a surface can be measured continuously throughout the spectrum. In application, the response is usually measured as bidirectional reflectance in discrete wave bands across the spectrum. Bidirectional reflectance is the reflectance measured under a specific configuration of sun position and sensor viewing angles, relative to the scene. In this discussion, reflectance refers to bidirectional reflectance.

The typical spectral reflectance curve of vegetation is described by Hoffler (1978). The reflectance of vegetated surfaces departs markedly from the reflectance of other land cover types in several intervals across the spectrum (fig. 1.). These spectral intervals are regularly used in remote sensing to distinguish vegetation from other land use classifications. The placement of scanner bands is consistent with the location of these distinguishing spectral intervals and has resulted in the visible and near infra-red (NIR) areas of the spectrum being commonly used to classify vegetation types. See Fig. 1.

Theoretical research has covered both the spectral reflectance of leaves and the response of canopies composed of many such leaves.

For individual leaves, it has been shown that this spectral reflectance curve is sensitive to pigmentation, the presence or absence of chlorophyll and anthocyanin, and the internal structure of the leaves. (Hoffler and Johannsen 1969) Leaf moisture content also affects the spectral reflectance signature (Hoffler and Johannsen 1969).

A naturally occurring canopy is far more complex than an individual leaf. A canopy consists of layers of leaves and stems oriented in a variety of directions. In addition to the reflectance properties of the components, the quantities and orientations of these components determine what proportions of the incoming radiation are reflected, transmitted and absorbed as they pass through the canopy volume (Suits 1972). Consequently the spectral response from the vegetation scene is strongly influenced by both the structure of the canopy volume and the reflectance properties of the canopy components.

It would be expected that, for the component leaves and stems, variations in reflectance between species would be much greater than within a species. Hence, across a forest canopy, variations in the reflectance properties of these components should primarily occur with variations in the stand species composition. Other factors may be responsible for secondary variations in the reflectance of these components. Variations in the orientation and amount of these components should be primarily related to variations in the stand density and LAI, as well as the species composition of the stand.

For the fixed species composition of a particular plant community, the reflectance properties of the component leaves and stems should not change greatly.

However, the quantities and orientations of these components would change with variations in stand density and LAI.

Similarly, flowering and fruiting changes the vegetation structure and the composition of reflecting components. Leaf age could also be expected to change the reflectance properties of leaves.

Beneath the vegetated layer of a site is the soil. This soil reflects the radiation that is transmitted through the vegetation layer. Different soil types have their own distinctive spectral signatures which are influenced by the soil moisture content. Hence variations in the underlying soil type and moisture content affect the reflectance from a vegetated scene.

Finally, one must consider the effects of sun and sensor geometry on the spectral response recorded from a vegetated area. The spectral reflectance measured from a surface is affected both by the angle from which the surface is illuminated, and by the angle that the surface is viewed. Aircraft scanners such as the one discussed here look vertically down while scanning across the landscape. This results in a range of pixel viewing angles across each scanning line and a scene composed of many successive lines. Within a small portion of a scanner line the effect of this variation of viewing angle is minimized, particularly when the scanning aircraft is flown toward or away from the sun.

In summary, following factors are likely to affect the spectral response from a forest scene.

a) Stand LAI (Through both the reflective surface area and the structure of the stand)
    under-storey LAI
    over-storey LAI

b) Stand species composition
    over-storey composition
    under-storey composition

c) Soil type

d) Soil moisture

e) Angle of sun illumination (ie. Sun altitude)

f) Angle of flight line relative to the Suns azimuth

g) Stand moisture status

h) Leaf age

i) Flowering of under-storey and over-storey

ii. Applications of this theory to measuring LAI

Given the potential complexity of any model that considers the possible combinations of the above variables, the applied research that has been done into measuring LAI using remote sensing has been empirical and superficial. It is presently difficult to measure LAI by **any** method. Hence, applied research aimed at establishing the role of these factors would involving massive amounts of field work. This task has not yet been tackled. In fact field based research in this area may be inappropriate.

However, theoretical and empirical research has established some basic relationships for estimating LAI. A variety of ratios and subtractions have been proposed and are summarised by Curran (1981)(see table 1). These ratios and subtractions are based on the strong shift in reflectance that occurs from the visible red to NIR in the vegetation spectral signature (fig. 1.). Changes in the slope of this edge have been related to chlorophyll concentration (Horler et al 1983), while changes in the height of this step can be related to LAI (Myers 1970). This shift enables the separation of soil and vegetation. The subtraction, IR - R, provides a measure of this step height, as does the IR/R ratio and the normalized difference ratio. Such ratios are not unique and the concentration of analysis on this area may be influenced by the availability of reflectance measurements in these band widths. Theory indicates that other areas of the vegetation spectrum could be equally useful for determining LAI.

The most notable examples of the remote sensing of LAI are those of Curran and Williamson (1987) and Peterson et al. (1987). Similar methodology was used in both studies. Airborne scans were taken concurrently with ground based measurement of LAI on sample plots spread over the scanned areas. These LAI measurements, taken on a small part of the scene, were then related to the scanned data to produce a regression equation. This regression equation was used to determine the LAI throughout the scene. Once LAI had been estimated over the scene, test sites of known LAI within the scene could then be used to assess the accuracy of the regressions in predicting LAI. Alternately, with a limited data set a roll-over technique can be used.

Curran and Williamsons work studied the LAI of grasslands ranging in LAI from 0.1 to 3.0. Peterson et al. measured the LAI of coniferous forests ranging in LAI from 0.6 to 16.1. Both papers concentrate their analysis on the NIR/R ratio and normalized difference vegetation indices applied to data collected by an Airborne Thematic

Mapper. Both authors conclude that these indices are valid for determining LAI **within** a scanner scene.

3. The Inglehope data analysis exercise

The study area consists of 30 square plots, 40m. x 40m. These 30 plots are spread over an area of jarrah pole stand approximately 500m. x 500m. The plots form a thinning trial in which a range of stand densities have been artificially created.

These stand densities range in basal area from 5.5m^2/ha to 28.5 m^2/ha and create a range of LAI from 0.4 to 2.0. The LAI of 20 of these plots has been determined using a technique developed by the author (WHITFORD 1991). This measurement technique uses regressions that relate individual tree dimensions and crown assessments to tree leaf area. From the ground area of the plots, and the leaf area of the trees, the plot LAI can be calculated.

To calculate LAI, measurements were taken on all trees in winter/spring 1987 prior to the commencement of leaf flush. Two scans of the plot area were taken using the Geoscan 13 band MSS. The band values collected are uncalibrated intensities (counts) that are linearly related to the reflectance value of each waveband. The band positions are shown on the attached figure from Richards (Fig 1.).

The first scan was in mid November and the second scan on December 2nd. when leaf flush had just commenced on some plots. In separate analysis exercises, both of these scans were related to the pre-flush estimations of LAI made by the author.

Two different methods of locating and extracting the plot pixels were used in the 2 scans. For the November scan, the plot locations in the scene were estimated. This was possible because the thinning treatments create a clear picture of the plot layout that can be related to existing maps. Plots were visually located on the scan and the mean pixel value for each of the 13 bands was obtained from pixels within each plot area. This procedure is crude but enables the extraction of a small area of data from within the plot boundary.

For the December 2nd. scan, ground markers were placed about the trial area at surveyed locations. By identifying the line and pixel locations of these markers on the scan, it was possible to calculate a mean line and pixel size to be used across the 500m x 500m thinning trial area (pixel size approx. 4.5m). From these dimensions and the surveyed locations of the plot corners, the line and pixel locations of the plot corners could be calculated to within $^+/_-1$ pixel and $^+/_-$ 1 line. Once the corners of all 20 plots were accurately located, an area of pixels was extracted to determine the mean band reflectances for each plot.

The pixel extraction procedure applied to the 2 scans produced a set of scanner data for each scan. These 2 data sets were separately related to the one set of LAI measurements taken prior to the spring leaf flush of 1987.

4. Results and Discussion from Inglehope

This work was considered to be a preliminary exploration. A correlation matrix was produced for the November and for the December scans. See Table 2 for the correlation matrix from the December scan. Both matrices showed similar trends. As the pixel extraction process applied to the December scene was more detailed and accurate, subsequent data analysis and discussion concentrates on this scan.

As is commonly observed in remotely sensed data, there is a strong correlation between bands that are within a spectral group. e.g. The NIR wave-bands 4 and 5 were correlated as were the middle infra-red (MIR) group, 6, 7, 8, and 9; the far infra-red (FIR), 10, 11, 12; and the visible, 1, 2, and 3. There were also good correlations between the MIR and FIR bands.

All bands except 4 and 5 showed a strong negative correlation with LAI. This is due to the increasing absorption and scattering of radiation that occurs as LAI increases. Denser leafy canopies absorb more radiation. Radiation that strikes the top of the canopy is either absorbed, reflected or transmitted. Much of the reflected and transmitted radiation is scattered into the canopy and strikes other leaf surfaces where it is absorbed. When reflected from the ground below, it must once again pass through the trunk and leaf layer and is further scattered and absorbed. Hence, in most wave-bands, denser stands with more leaf and trunk area absorb the radiation more effectively than thinner stands and bare soil.

The range of vegetation indices presented by Curran (Table 1) were applied to the November and December scans. The infrared/red ratio (band 5/band 3) and the normalized difference ratio ((band 5-band 3)/(band 5 + band 3)) were the best of these standard indices. None of these standard indices were as highly correlated with LAI as the single bands. For instance, in the December scan, band 2 (green) has an r^2 of 0.83 with LAI compared to an r^2 of 0.37 for the normalized difference ratio.

Plots of LAI against these single bands showed an even spread of data points and linear relationships with LAI. A stepwise multiple linear regression analysis was applied to the December scan data. Empirical relationships between LAI and band combinations were produced. These are presented in table 3. These relationships may be specific to this scan.

Field vegetation scenes consist of a combination of soil and vegetation components. The soil reflectance signature is markedly different from the vegetation signature in several wave-bands. Figure 1. shows how these 2 signatures usually separate noticeably in the visible red, the NIR around 0.8 microns, and in the MIR beyond 1.2 microns. As vegetation cover increases, the reflectance from a scene tends toward the pure vegetation signature.

Figure 2 shows the average reflectance signatures for each of the 5 thinning levels applied to the 30 plots in the trial. Because of the relationship between leaf area and basal area, each thinning treatment corresponds to a mean LAI. The mean LAI for each thinning treatment is given on figure 2. Each signature was compiled from the average reflectances of 4 plots. This figure shows the separation of these signatures as LAI increases. The trend is most noticeable for wavelengths beyond 2.0 microns (bands 6,7,8, and 9), where the reflectance decrease with increasing LAI. The distinctive features of these graphs are first the upward movement of the graphs with decreasing LAI and second the marked upward swing of the "tail" of the graph (wavelengths beyond 2 um) with decreasing LAI. The characteristics of the soil and vegetation signatures beyond 1.2 microns have not previously been applied to determining LAI and are possibly not as reliable as the Red-NIR shift for distinguishing soil and vegetation.

It should be noted that within a thinning treatment there is considerable variation in this reflectance signature. However this variation is less than the variation between thinning treatments.

5. Concluding discussion of results from Inglehope scans

The reflectance of vegetation is affected by a combination of factors. This report has considered only the relationship with LAI, and the effects of soil background, under-storey and canopy structure have not been considered. It is unlikely that variations in vegetation moisture status or the presence of senescent vegetation would be relevant to this scene. Similarly the soil types and soil moisture across this scene are uniform and were not considered. The major factors that varied across the thinning plots were plot basal area, over-storey and under-storey LAI, and under-storey species composition.

In this analysis, all of the variability in the reflectance data was attributed to variations in LAI. This is not entirely correct. Some should be related to under-storey variations and the other sources of variability. The sources of variability that were not considered would account for some of the error in the relationships presented here.

Across the 20 plots, much of the variation in LAI is correlated with thinning intensity (measured as plot basal area). For these plots, canopy structure may also be related to plot basal area. Tree thinning exposes the ground surface and consequently, for these plots, canopy cover is likely to be well correlated with basal area. Consequently, it is not known if the relationships found in this data are relationships between LAI and reflectance, or between some variable related to LAI, such as canopy cover, and reflectance.

In unthinned forest stands, a relationship does exists between basal area and LAI. However, site moisture and fertility could allow LAI to vary independently from stand basal area. At Inglehope in December there would have been little variation in site fertility or soil moisture and the major factor affecting LAI on those 20 plots would have been stand density. This is not consistent with the causes of natural variation that would be seen across the forest. The shift in the spectral signatures of the different thinning treatments may be caused by the variations in ground coverage with LAI. The strong correlation between LAI and basal area (or ground coverage) is a weakness of this data set and limits the conclusions that can be made regarding relationship between LAI and reflectance in unthinned forest.

6. Conclusions on the potential application of results

The r^2 of the regressions produced in this analysis indicate that these equations could be successfully applied to predicting the LAI of thinning plots within this scene. These equations may also be used, though with less certainty, to predict the LAI of other native forest sites within the scene. However these relationships are definitely specific to this single scanner run and could not be applied to other scans. This is a major shortcoming of this methodology.

Ideally an experiment such as this could produce a relationship between LAI and spectral response that could be applied to any scan of this forest type. Before further progress can be made towards this goal certain technical problems need to be resolved. These are;

i. Reflectance

The geoscan data used in this analysis is not true reflectance data. The scanner measures the radiant exittance, as a count, and this count is linearly related to the actual radiant exittance. However, this relationship is not known. Hence, the true radiant exittance cannot be determined. As this scanner does not measure incoming radiation (irradiance), the percentage reflectance also cannot be determined. This limits the treatments that can be applied to the data. A scanner that measured the irradiance at the aircraft altitude would enable a rough calculation of reflectance. Alternately ground measurements with a radiometer could supply this information. Reflectance is assumed to be independent of irradiance and is consequently a more useful measurement than radiant exittance.

ii. Bidirectional Reflectance

The term reflectance is often loosely applied to MSS scenes. In this discussion it refers to bidirectional reflectance. Bidirectional reflectance is the reflectance measured under a specific configuration of sun position and sensor viewing angles, relative to the scene.

A vegetation scene under fixed conditions of illumination will have differing reflectances when viewed from different angles. Conversely a scene viewed from one angle will show differing reflectance under different angles of illumination.

A specific arrangement of sun angle and sensor angles exists in any MSS data set and should be considered as one of the variables in the data set. This analysis has not consider these angles and consequently any conclusions drawn from the data are only relevant to the existing arrangement of sun, scene and sensor. They may not apply to other scans.

iii. Atmospheric effects.

To produce a correct value for reflectance the atmosphere beneath the aircraft must also be considered. Aerosols and particles in the atmosphere beneath the aircraft scatter both the incoming and reflected radiation. Hence the measurements taken from the aircraft must be corrected for the atmosphere existing at the time of the scan. This requires measurements, close to the ground, of the irradiance, radiant exittance, or both, so that the aircraft measurements can be corrected for existing atmospheric conditions.

If the 3 problems discussed above could be corrected, i.e. if the scanner could collect measurements of the irradiance under a specific set of sun scene and sensor angles while concurrent ground measurements of reflectance were recorded above some point of the scene, then this data could be used to produce relationships for predicting LAI on any similar scanner data set with similar sun scene and sensor angles.

iv. Data handling.

The data collection technique used in this experiment involved the extraction of a small rectangular area of pixels from within the plot boundaries. Although these plots are square, most were not oriented to the flight line of the scanner. The software available for pixel extraction is unable to extract all of the data from these non-aligned plots. Consequently some data is lost and an unnecessary source of error is introduced.

Improvements in this pixel extraction procedure are necessary. At present the extracted data is manually transferred onto another computer for analysis. This limits the amount of data that can be handled. Removing this manual step would speed up and improve the data analysis.

Further development of this technique is dependant on solving these technical problems. Once these problems are addressed, future experiments can concentrate on identifying the factors that must be considered when scanning for LAI.

Literature Cited

Curran P.J. 1981. Multispectral remote sensing for estimating biomass and productivity. in Plants and the daylight spectrum. Academic Press 65-99

Curran P.J. and Williamson H.D. 1987. GLAI estimation using measurements of red and near infrared radiance. Photogrammetric Eng. & Rem. Sen. Vol. 53, no. 2. pp 181-186

Hoffler R.M. 1978. Biological and physical considerations of applying computer aided analysis techniques to remote sensor data. In R.H. Swain & S.M. Davis Eds. Remote Sensing: The quantitative approach. p231-240 N.Y. McGraw-Hill

Hoffler R.M. and C.J. Johannsen. Ecological Potentials in Spectral Signature Analysis, in P.L. Johnsen(Ed.) Remote Sensing in Ecology, University of Georgia Press, Athens, Ga. 1969

Meyers V. I. 1970. Soil, Water, and Plant Relations, in "Remote Sensing with Special Reference to Agriculture and Forestry". National Academy of Sciences, Washington D.C. pp 253-297.

Peterson D.L., Spanner M.A., Running S.W. and Teuber K.B. Relationship of TM simulator data to LAI of temperate coniferous forests. Rem. Sen. Env.?

Richards J.A. 1986. Remote sensing digital image analysis. p 3. Springer-Verlag

TABLE 1

Seven of the more commonly used bidirectional reflectance ratios, where G = green, R = red and IR = near infrared

NAME	FORMULA	EXAMPLE
Simple subtraction	$IR - R$	Pearson *et al.* (1976)
Simple division	$\frac{IR}{R}$	Curran and Milton (1981)
Complex division	$\frac{IR}{R + \text{other wavelengths}}$	Curran (1980c)
Simple multiratio (vegetation index or normalised difference)	$\frac{IR - R}{IR + R}$	Tomlins and Thompson (1980)
Complex multiratio (transformed vegetation index or normalised difference)	$\sqrt{\frac{IR - R}{IR + R} + 0.5}$	Rouse *et al.* (1973)
Perpendicular vegetation index (vegetation bidirectional reflectance departure from soil background)	$\sqrt{(R_{soil} - R_{veg})^2 + (IR_{soil} - IR_{veg})^2}$	Richardson and Wiegand (1977)
Green vegetation index (as above for use with Landsat satellite wavebands)	$-0.29(G) - 0.56(R) + 0.60(IR) + 0.49(IR)$	Kauth and Thomas (1976)

TABLE 2

Correlation matrix for LAI and Geoscan bands Dec. 2nd 1987

		Blue	Green	Red	NIR	NIR	IR	IR	IR	IR	FIR	FIR	FIR
CORR	LAI	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12
LAI	1.00												
B1	-0.84	1.00											
B2	-0.91	0.96	1.00										
B3	-0.87	0.97	0.97	1.00									
B4	-0.51	0.18	0.35	0.21	1.00								
B5	-0.61	0.33	0.49	0.35	0.96	1.00							
B6	-0.87	0.95	0.95	0.97	0.15	0.29	1.00						
B7	-0.89	0.96	0.95	0.97	0.19	0.32	0.99	1.00					
B8	-0.89	0.95	0.95	0.97	0.20	0.33	0.99	0.99	1.00				
B9	-0.89	0.95	0.95	0.97	0.22	0.36	0.99	0.99	0.99	1.00			
B10	-0.79	0.83	0.82	0.85	0.11	0.23	0.90	0.91	0.91	0.92	1.00		
B11	-0.81	0.87	0.84	0.87	0.10	0.23	0.93	0.93	0.94	0.94	0.98	1.00	
B12	-0.84	0.90	0.89	0.90	0.15	0.28	0.95	0.96	0.96	0.96	0.98	0.98	1.00
B13	-0.84	0.88	0.87	0.89	0.16	0.28	0.94	0.95	0.95	0.96	0.98	0.99	0.99

TABLE 3

REGRESSIONS

Best fit empirical regressions

December 2nd scan

1. $LAI = -0.0289 * BAND\ 2 - 0.0059 * BAND\ 4 + 5.57$

   $r^2 = 0.89 \qquad n = 20$

2. $LAI = -0.0096 * BAND\ 4 - 0.0126 * BAND\ 8 + 3.94$

   $r^2 = 0.92 \qquad n = 20$

November scan

3. $LAI = -0.0225 * BAND8 + 0.01365 * BAND10 - 0.01866 * BAND13 + 4.17$

   $r^2 = 0.76 \qquad n = 21$

TABLE 4

Correlation between bands or combinations and LAI for November and December scans.

LAI Correlation

Variable	November scan n = 21	December scan n = 20	
B1	-0.69	-0.84	
B2	-0.55	-0.91	
B3	-0.70	-0.87	
B4	0.35	-0.51	
B5	0.17	-0.61	
B6	-0.78	-0.87	
B7	-0.79	-0.89	
B8	-0.80	-0.89	
B9	-0.80	-0.89	
B10	-0.67	-0.79	
B11	-0.73	-0.81	
B12	-0.75	-0.84	
B13	-0.75	-0.84	
LAI	1.00	1.00	
CURRAN1	0.72	0.36	curran1 = B4/B3
PEAR	0.67	0.21	pear = B4 - B3 ;
CURRAN12	0.66	0.61	curran12 = B5/B3 ;
CURRAN13	0.70	0.48	curran13 = (B4 + B5)/B3 ;
CURRAN2	0.69	0.21	curran2 = B4/(B3 + B1) ;
TOMLINS1	0.74	0.38	tomlins1 = (B4 - B3)/(B4 + B3);
TOMLINS2	0.67	0.61	tomlins2 = (B5 - B3)/(B5 + B3);
TOMLINS3	0.72	0.49	tomlins3 = (B5+B4 - B3)/(B5+B4 + B3);
KAUTH	0.63	0.18	Kauth = -0.29*B2 - 0.56*B3 + 0.60*B4 + 0.49*B5

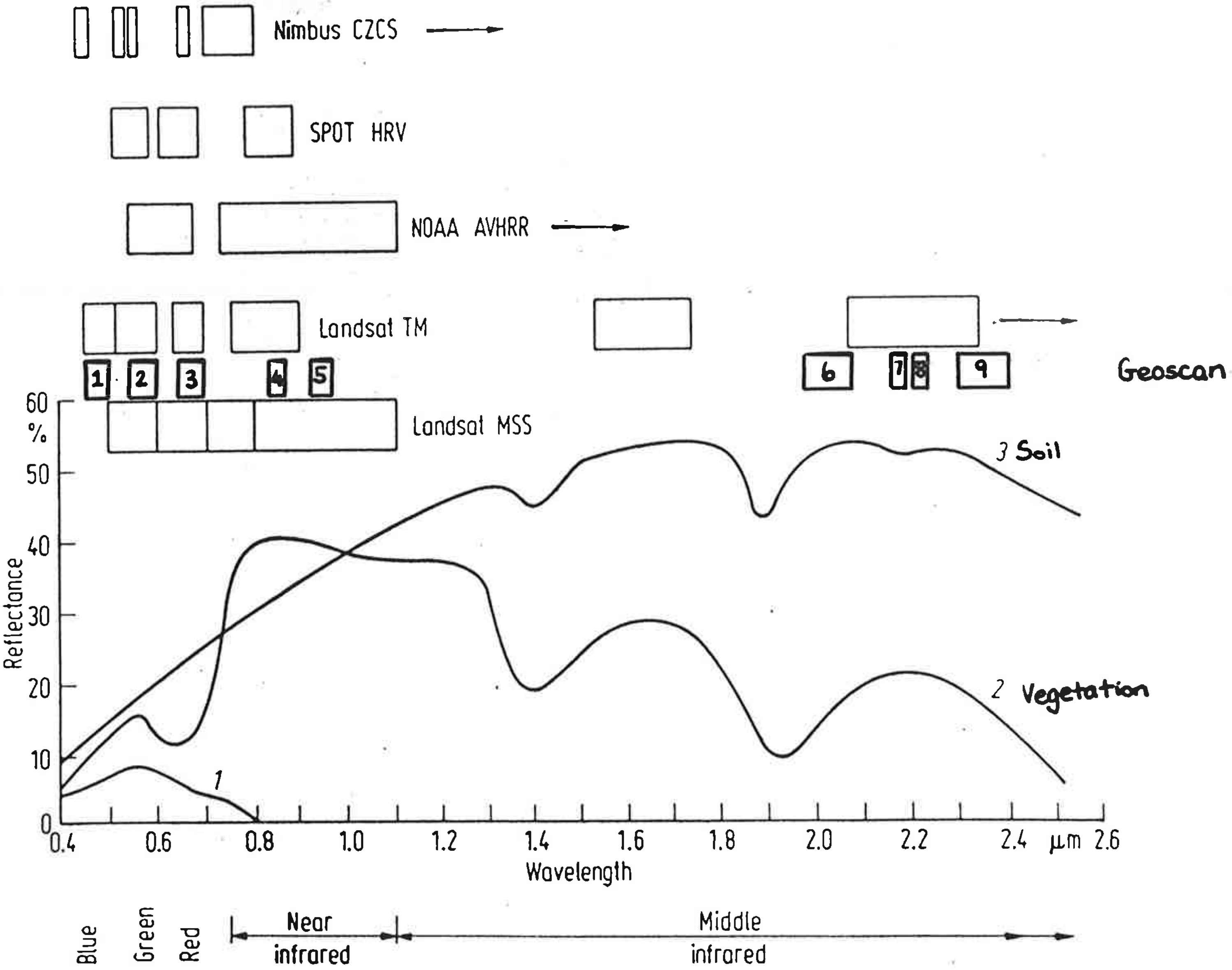
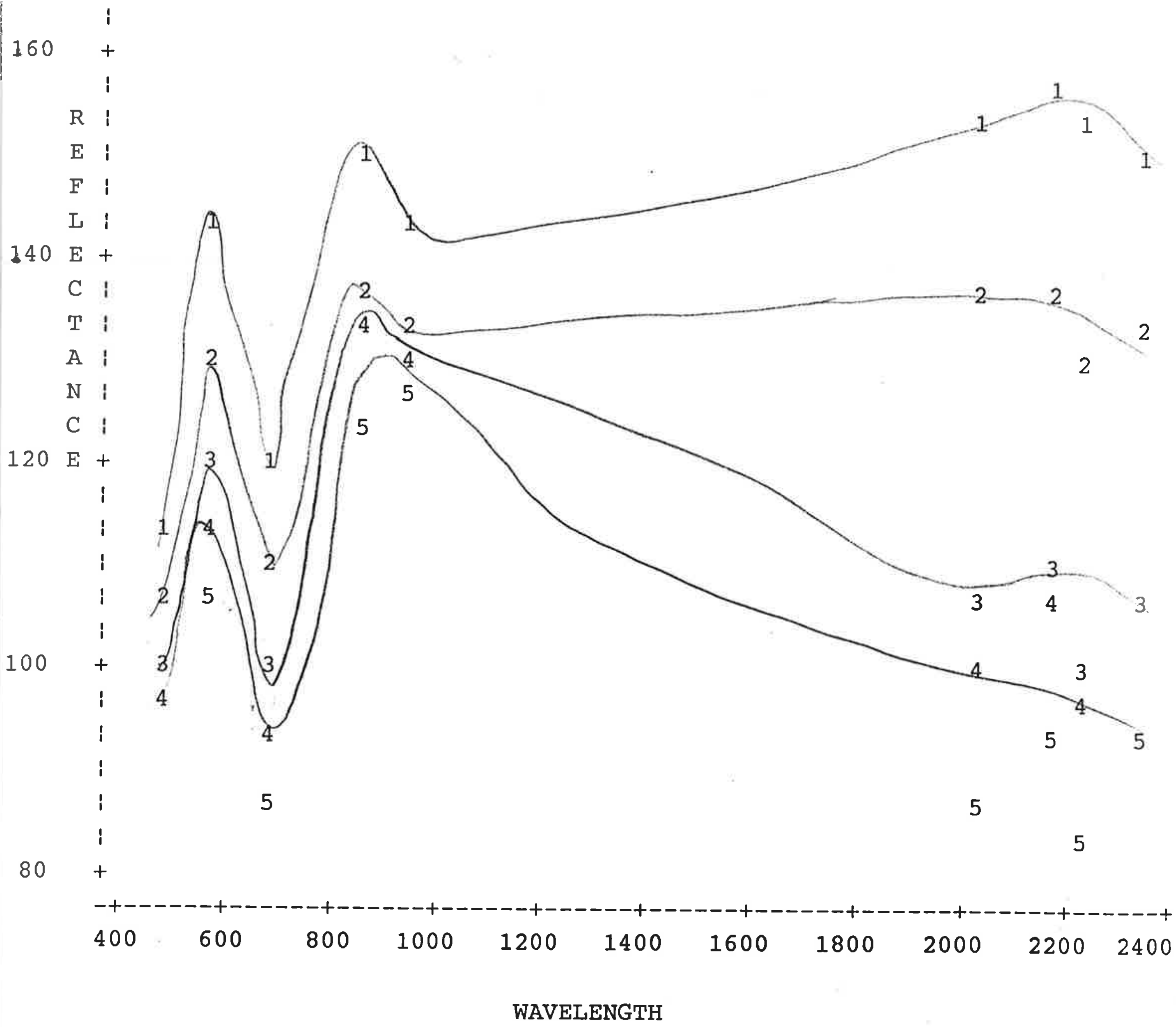


Fig. 1. Spectral reflectance characteristics of common earth surface materials in the visible and near-to-mid infrared range. *1* Water, *2* vegetation, *3* soil. The positions of spectral bands for common remote sensing satellites are indicated.

Figure 2

Plot of Reflectance vs Wavelength

Symbol is thinning class



WLM 1294

Kim Whitford,
*C.A.L.M.
Research Centre,
Dwellingup, W.A. 6213
Phone 09 538 1105
Fax 09 538 1206
January 21st 1994

Lachlan McCaw,
Manjimup Research Centre
CALM Manjimup

Dear Lachlan,

Enclosed is a copy of a draft report that Geoff said you may be interested in. It discusses my use of the Geoscan 13 band scanner to remotely sense leaf area index (LAI). At the time I was interested in developing a general relationship between reflectance and LAI, and the report is probably a bit pessimistic. I found strong discrimination, within a scanner scene, of the amount of foliage cover. I have no doubt that remote sensing could be effectively applied to mapping fire (with its strong qualitative differences) especially if the fire history of some locations in the scene were well known.

Please excuse the rough structure of this report.

There is an excellent reference, that I purchased, in the CALM library. It is

Richards J. A. 1986 Remote sensing digital image analysis. Springer-Verlag.

I have also included some ALCOA funded research. This work, done in 1992, found similar responses and reached similar conclusions to mine.

Yours sincerely

Kim Whitford

Kim Whitford