PROVE 1997 Vegetation Canopy Spectral Reflectance Measurements, Jornada, New Mexico

1. INVESTIGATOR(S)

1.1 Investigators Names and Titles.

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1.2 Title of Investigation.

Determining Vegetation Structural Parameters Amenable to Remote Sensing and Ecological Modeling of Complex 3-D Surfaces

1.3 Contacts (For Data Production Information).

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2. EQUIPMENT

2.1 Instrument Description.

The Spectron Engineering SE590 is a portable battery or A/C operated spectroradiometer consisting of a CE500 data analyzer/logger controller, CE390 spectral detector head and an external battery charger/power supply. The CE500 is a self contained microprocessor based controller which processes the signal from the detector head, amplifying and digitizing it with 12 bit resolution. For each spectral scan, the controller actuates the CE390 shutter, measures and stores the dark current, calculates optimum integration time, acquires the spectrum and automatically subtracts the noise for all 256 spectral elements. A series of scans can be taken and automatically averaged; for our measurements 4 scans were averaged for each measurement. The spectrum is stored in a double precision register which saves the entire 12-bit binary spectra until it is transmitted through the RS-232C port. The spectral detector head uses a diffraction grating as the dispersive element; the spectrum is imaged onto a 256 element photo diode array. Each element integrates simultaneously acquiring the spectrum in a fraction of a second. The interconnect cable from the spectral detector head to the controller couples the spectral signals to the controller, and the timing and control signals to the detector head. A shutter in the detector head, operated by the controller, closes the light path for dark current measurements. For further information consult the SE590 operating manual. Serial Number 1571 was used for canopy and background measurements. Serial Number 1698 was used for reference panel measurement.

2.1.1 Collection Environment

Directional reflected radiation was measured over plots representing selected canopy components (shrubs and individual plants, bare sand and background) at the Jornada Experiment Site near Las Cruses, NM.

2.1.2 Source/Platform

One Spectron Engineering SE590 spectroradiometer detector head was mounted on a mast approximately 0.75 m above a Labsphere Spectralon reference panel. A second SE590 detector head was mounted on a mast that pivoted at the base, so the SE590 could be positioned to view the canopy component at a variety of view zenith angles as the mast pivoted. The mast in the nadir (upright) position placed the SE590 detector head approximately 3.35m vertically above the soil surface and 1.23m horizontally from the pivot point.

2.1.4 Key Variables

Spectral reflectance of canopy components (individual or clusters of shrubs or plants, bare soil and surface background).

2.1.5 Principles of Operation.

The SE590 spectral detector head uses a diffraction grating as the dispersive element; the spectrum is imaged onto a 256 element photo diode array. Each element integrates simultaneously acquiring the spectrum in a fraction of a second.

2.1.6 Manufacturer of Instrument.

Spectron Engineering SE590 Spectroradiometer:
Spectron Engineering, Inc.
25 Yuma Court
Denver, Colorado 80223
(303) 733-1060

Labsphere Spectralon reflective panel
Labsphere, Inc.
P.O. Box 70
North Sutton, NH 03260
(603) 927-4266

3. Calibration.

Each SE590 has a unique wavelength associated with each of its 252 bands. A wavelength characterization was conducted in March and April 1997 using 14 known wavelength sources (lasers and absorption lamps). A radiance calibration was conducted on each instrument in April 1997.

The Labsphere Spectralon panel used in characterizing the incident radiation and simulating a non-Lambertian surface (for reflectance factor calculations) was calibrated by Labsphere.

4. DATA ACQUISITION METHODS.

One SE590 was mounted on a mast to view the Labsphere Spectralon reference panel. The SE590 was automated to take a measurement once every minute during the entire measurement period.

Plots were identified which contained selected shrubs, soils and background features. The mast was positioned so that the SE590 viewed the center of the plot when in the nadir position. The mast was designed to pivot so that the SE590 could be positioned at various viewing angles aligned in a specified plane. Two planes were targeted: the solar principal plane (relative azimuths of 0 and 180 deg) and a plane perpendicular to the solar principal plane (relative azimuths of 90 and 270 deg). In the solar principal plane, viewing angles aligned with the back of the SE590 detector head toward the sun (relative azimuth of 0 deg) were defined as the backscatter angles (designated with a negative view angle) while the viewing angles aligned with the viewed surface between the sun and the SE590 were defined as the forward scatter view angles (designated with a positive view angle). In the plane perpendicular to the solar principal plane, view angles when the SE590 was pivoted to the left of the solar principle plane (when the observer was facing the sun) were designated with negative view angle values; viewing angles to the right of solar principle plane were designated with positive view angle values.

At a particular plot, directional reflected radiation was measured in the solar principal plane; directional reflected radiation in the plane perpendicular to the solar principle plane were measured next (by rotating the mast around the plot so that the pivoting point is 90 deg from the initial pivoting location). View zenith angles of 60, 45, 30 and 15 deg in the back and forward scatter directions of nadir were measured in each plane. Nadir-viewed reflected radiation was measured for each plane as well.

5. DATA DESCRIPTION

5.1 Spatial Characteristics.

5.1.1 Spatial Coverage.

Plots were selected and measured at the Jornada tower and grassland sites. At the tower site the following canopy components were measured: 3 mesquite plants, 2 yucca plants, 2 mormon tea plants, 1 undisturbed background, 1 background after one of the mesquite plants was removed and 1 background after one of the yucca plants was removed. Not all plants were measured each day of measurement. At the grassland site the following plots were selected: 2 grass covered plots, 1 yucca cluster and 1 bare soil surface.

5.1.2 Spatial Resolution.

Each SE590 was installed with a 15 deg field of view lens. The spot size of the SE590 measuring the reference panel was 0.20m in diameter. The spot size of the SE590 on the pivoting mast varied with view angle and height of the plant. A spot size on the soil surface at a nadir view was 0.881m in diameter while at a view zenith angle of 60 degrees the spot size at the soil surface was 1.86m in length and 1.00m in width.

5.2 Temporal Characteristics.

A suite of measurements (all view zenith angles in the solar principal plane and the plane perpendicular to the solar principle plane) required approximately 9 minutes to complete. Generally, 3 plants and a background were measured for an apparent solar zenith angle at a site. On average 50 minutes were required to complete measurements for all canopy component plots (including the travel and setup between plots). Measurements of the canopy components were centered around 2 or 3 solar zenith angles each day.

5.3 Data Description

Data are in a column, comma-delimited format. Row one gives the name of each column. Each of the remaining rows is one measurement at a designated view zenith angle.

Column	Variable	Unit
1	Date	unitless
2	Local Time	decimal time
3	GMTdecimal time	
4	Solar Zenith Angle	degree

5	Solar Azimuth Angle	degree
6	Site: Tower, Grassland	unitless
7	Plant: Mesquite, yucca, mormon tea, sand, grass, background	unitless
8	Plot: Tower Site: 1- Yucca 2 - mesquite 3 - mormon tea 4 - sand (undisturbed background) 5 - mormon tea {destructive plant} 6 - mesquite {destructive plant; high density} 7 - yucca {destructive plant} 8 - mesquite {destructive plant; low density} 9 - background {after dest. yucca removed; same location as plot 7} 10 - background {after dest. mesquite remove; same location as plot 8}) Grassland Site: 1 - yucca 2 - grass 3 - grass 4 - sand (undisturbed background)	unitless
9	View Zenith Angle	degree
10	Relationship to the Principle Plane of Sun Parallel, Perpendicular	unitless
11-112	Bidirectional Reflectance Factor Every 5 nm from 400nm to 900 nm	unitless

6. Data Processing Sequence.

Step 1: Reference panel and canopy reflected measurements were converted to radiance values with appropriate coefficients for each SE590.

Step 2: A cubic splint fit routine was used to smooth and re-sample the panel and canopy reflected radiance values at every 5 nm in order to express the data as a function of the same wavelength bands (each SE590 has a unique wavelength characteristics).

Step 3: Smoothed reference panel radiance values were corrected to account for non-Lambertian characteristics of the panel following the method of Jackson et al. (1987).

Step 4: Smoothed canopy radiance values (Step 2) were ratioed with smoothed corrected reference panel radiance values (Step 3) to yield bidirectional reflectance factors (BRFs) expressed in %. Using the two reference panel measurements closest in time to the canopy reflected measurement, the correct reference panel radiance value is linearly interpolated to match the time of the canopy reflected radiance measurement (following the method of Robinson and Biehl, 1979)

Step 5: Due to problems encountered with the data upon initial processing (see Sec. 7.1), BRF values were modified using a cubic spline fit to smooth the data to every 40 nm from which BRF values were linearly interpolated back to every 5 nm. These modified BRFs are intended to provide data for preliminary analyses.

7. NOTES

7.1 Known Problems With The Data.

Initial inspection of the canopy bidirectional reflectance factors (BRFs) (through processing step 4) varied unexpectedly as a function of wavelength, especially in the near-infrared part of the spectrum. Initially, the wavelength characterization was suspected to have shifted from that characterized in April as a result of the rough transport to and from the Jornada field sites. However, a wavelength analysis of each instrument back in Lincoln, NE did not show any shift of wavelength characterization. As a preliminary "fix", the BRF values at every 5 nm were smoothed to 40 nm data from which BRFs at every 5 nm were linearly interpolated (processing Step 5).

Examples of the original (through Step 4) and modified BRF values (through Step 5) are given below. The sample data is from a nadir-view over a sand plot on 25-May-1997 at 17.6036 GMT.

Wave	Original	Smoothed
400	7.69	7.57
405	7.5	7.71
410	7.47	7.94
415	7.59	8.16
420	7.71	8.39
425	8.23	8.62
430	8.64	8.85
435	9.12	9.08
440	9.39	9.31
445	9.47	9.5
450	9.6	9.67
455	9.8	9.84
460	9.9	10.02
465	10.2	10.19
470	10.37	10.36
475	10.55	10.54
480	10.71	10.71
485	11.01	10.99
490	11.3	11.32

495	11.56	11.65
500	11.75	11.98
505	12.04	12.31
510	12.34	12.64
515	12.68	12.97
520	13.22	13.3
525	13.6	13.76
530	13.9	14.27
535	14.37	14.78
540	14.71	15.29
545	15.33	15.8
550	16.04	16.32
555	16.56	16.83
560	17.23	17.34
565	18.12	17.96
570	18.92	18.61
575	19.86	19.26
580	20.26	19.91
585	20.91	20.56
590	21.67	21.21
595	22.52	21.86
600	22.67	22.51
605	23.08	22.94
610	23.53	23.32
615	24.21	23.7
620	24.76	24.08
625	25	24.46
630	25.25	24.84
635	25.4	25.22
640	25.58	25.6
645	25.7	25.77
650	26.19	25.9
655	26.72	26.03
660	27.34	26.16
665	27.37	26.29
670	27.28	26.43
675	26.97	26.56

680	26.8	26.69
685	27.53	27.2
690	28.68	27.76
695	29.48	28.32
700	29.44	28.88
705	29.25	29.44
710	29.18	30
715	29.54	30.56
720	30.9	31.12
725	32.18	31.45
730	32.81	31.76
735	32.9	32.07
740	32.32	32.39
745	30.86	32.7
750	28.01	33.01
755	28.88	33.32
760	33.43	33.63
765	37.8	33.45
770	36.43	33.24
775	33.87	33.04
780	32.78	32.84
785	32.69	32.63
790	33.16	32.43
795	33.06	32.23
800	32.16	32.02
805	31.48	32.34
810	31.88	32.66
815	33.03	32.97
820	34.43	33.29
825	35.32	33.61
830	35.67	33.93
835	35.32	34.24
840	34.64	34.55
845	34.13	34.49
850	34.38	34.44
855	34.92	34.39

860	35.4	34.33
865	35.2	34.28
870	35.09	34.23
875	34.47	34.17
880	34.26	34.09
885	33.16	33.7
890	32.59	33.3
895	32.69	32.9
900	33.77	32.5
905	34.89	32.1
910	35.68	31.71
915	34.77	31.31
920	30.22	31.18
925	27.46	33
930	29.41	34.82
935	34.15	36.64
940	38.47	38.46
945	39.37	40.27
950	40.27	42.09
955	44.25	43.91
960	45.36	45.29
965	44.17	44.32
970	40.86	43.35
975	39.5	42.37
980	40.64	41.4
985	41.59	40.43
990	39.89	39.46
995	38.16	38.49
1000	37.86	37.91

Modified BRFs increased in the 900nm to 1000nm spectral range. The SE590 sensitivity in this range is lower than in the visible and lower near infrared portions of the spectrum and the sensitivity is not uniform between instruments. Any errors in the radiance calibrations of the instruments may have accentuated differences and caused the increase in BRF values. Thus, BRF values are only reported in the 400 to 900 nm range in this preliminary dataset.

On 28-May-1997, the SE590 measuring reflected radiation from the reference panel stopped working properly after 15.5 GMT. Sky conditions, as determined from the USDA UV-B

Monitoring station MFRSR, were somewhat similar to those on 23-May-1997. As a preliminary solution, reference panel data from 23-May-1997 from 15.5 to 17 GMT were used to calculate BRFs for this period on 28-May-1997.

7.2 Usage Guidance.

Investigation into the variability of the BRF values is underway. BRFs in this dataset should be used with the assumption that the data will be revised at a future date.

8. References

Jackson, R.D., Moran, M.S., Slater, P.N., and Biggar, S.F. 1987. Field calibration of reference reflectance panels. Remote Sensing of Environment 22:145-158.

Robinson, B.F. and Biehl, L.L. 1979. Calibration procedures for measurements of reflectance factor in remote sensing field research, Proc. Soc. Photo-Optical Instrumentation Eng. 23rd Annual Tech. Symp. on Measurements of Optical Radiation, Bellingham, WV p. 16-26.