LAI (Indirect): Light Wand - KSU (FIFE)

Summary:

The prairie is inherently variable and large numbers of samples are needed to obtain reliable estimates of the prairie agronomic characteristics. For the Indirect Leaf Area Index Obtained from the KSU Light Wand Study a limited number of destructive samples were supplemented by large numbers of rapid non-destructive estimates. For the non-destructive measurements the LI-COR Inc. LAI-2000 Plant Canopy Analyzer (light-wand) was used. This instrument measures transmittance of the canopy in the blue region of the spectrum, at five different zenith angles. These measurements were inverted to provide estimates of leaf area index, and mean inclination angle of the leaves to the zenith.

Verification studies conducted by LI-COR Inc. indicated that the LAI-2000 Canopy Analyzer measurements were generally within 15% of values obtained by destructive sampling and measurement with a leaf area meter. As a rough guess even the destructive measurements are accurate only to within about 25% of the true sample leaf area value. In the opinion of the study team, the non-destructive measurements with the LAI-2000 are as good as the destructive measurements, and provide a better estimate of the site mean, because many more non-destructive measurement can be made.

Table of Contents:

1. Data Set Overview:

Data Set Identification:

LAI (Indirect): Light Wand - KSU (FIFE).
(Indirect Leaf Area Index Obtained from the KSU Light Wand).

Data Set Introduction:

The Indirect Leaf Area Index Obtained from the KSU Light Wand Data Set contains leaf area index, mean angle of leaf inclination, and diffuse transmittance data.

Objective/Purpose:

Provide large numbers of rapid non-destructive estimates of leaf area index (LAI), in support of the more labor-intensive destructive sampling methods of acquiring measurements of LAI.

Summary of Parameters:

Leaf area index, mean angle of leaf inclination, and diffuse transmittance.

Discussion:

The prairie is inherently variable and large numbers of samples are needed to obtain reliable estimates of the prairie agronomic characteristics. Since destructive sampling is very time consuming and expensive, it was decided that a limited number of destructive samples should be supplemented by large numbers of rapid non-destructive estimates. For the non-destructive measurements the LI-COR Inc. LAI-2000 Plant Canopy Analyzer (light-wand) was used. This instrument measures transmittance of the canopy in the blue region of the spectrum, at five different zenith angles. These measurements are inverted to provide estimates of leaf area index, and mean inclination angle of the leaves to the zenith.

Verification studies conducted by LI-COR Inc. have shown that the LAI-2000 Canopy Analyzer performs well. LAI-2000 measurements were generally within 15% of values obtained by destructive sampling and measurement with a leaf area meter. In our own experience we found that even the destructive measurements are subject to large error. Prairie grass leaves tend to curl and fold as they are fed into the belts of a standard leaf area meter. The values obtained depended on how much care the operator takes when feeding in the leaves into the leaf area meter. As a rough guess even the destructive measurements are accurate only to within about 25% of the true sample leaf area value. In our opinion the non-destructive measurements with the LAI-2000 are as good as the destructive measurements, and provide a better estimate of the site mean, because many more non-destructive measurement can be made.

Related Data Sets:

- Leaf Area Index and PAR Determined from KSU Light Bar Measurements. This data set contains data from the light bar collected by KSU staff science. Leaf Area Index and photosynthetically active radiation above and below the canopy were measured.
- Leaf Area Index and PAR Determined from UNL Light Bar Measurements. This data set contains data from the light bar (LICOR LI-191SA) collected by University of Nebraska group. The variables collected were photosynthetically active radiation, Absorbed photosynthetically active radiation, Intercepted photosynthetically active radiation and Leaf Area Index.
- Surface Reflectance Measured with a Mast-borne MMR. This data set contains reflected radiance and reflectance values from Barnes MMR.
- SE-590 Reflectance Factors and Radiances from UNL. This data set contains nadir and off-nadir SE-590 (ground measured) spectrometer radiances and reflectances measurements from the University of Nebraska group.
- SE-590 Reflectance Factors and Radiances Measured from a Helicopter. This data set contains reflectance measured with the helicopter mounted SE-590 spectrometer.
- SE-590 Spectroradiometer Reflectance Factors from GSFC. This data set contains nadir and off-nadir SE-590 (ground measured) spectrometer radiances and reflectances measurements from the Goddard Space Flight Center SRB group.
- Surface Reflectances Measured by the PARABOLA. This data set contains Don Deerings PARABOLA data; sky and ground radiance values collected using a sphere-scanning radiometer. This data has been averaged to give equal intervals of viewing angles.
- Leaf Angle Data. This data set contains data on the orientation of leaves of 10 different species.
- Biophysical Properties of Vegetation. This data set contains measurements of leaf area index and biomass of difference canopy components.
- Vegetation Species and Cover Abundance. This data set contains the Species Composition data, by site and data.
- Vegetation Species Reference. Konza LTER species names, codes, types and other reference information.

FIS Data Base Table Name:

LIGHT_WAND_DATA.

2. Investigator(s):

Investigator(s) Name and Title:

Dr. Tanvir Shah
Alabama A & M University

Dr. E.T. Kanemasu (Head)
University of Georgia

Title of Investigation:

Non-Destructive Vegetation Canopy Analysis at the FIFE Site.

Contact Information:

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Requested Form of Acknowledgment.

The Indirect Leaf Area Index Obtained from the KSU Light Wand data were collected by staff of Kansas State University under the direction of T. Shaw and E.T. Kanemasu. The contribution of these data is appreciated.

3. Theory of Measurements:

For a thorough explanation of the theory of the interception method for estimating leaf area index and other canopy characteristics, please refer to the manufacturers technical notes, and other references given in the *References Section*.

Very briefly, the LAI-2000 Plant Canopy Analyzer measures the interception fraction (at wavelength shorter than 490 nm) at five zenith angles. For calculating leaf area index and mean leaf inclination angle, the following assumptions are made:

1. The foliage is black, i.e., no radiation is reflected off or is transmitted through the leaves, in the wavelength band sensed by the instrument,
2. The foliage elements are small compared to the area of view of the sensors,
3. The foliage is randomly distributed within the canopy volume,
4. The leaves are randomly oriented in the azimuth, i.e., the leaves do not tend to face a certain compass bearing.

As a beam of light passes through a canopy, the probability that it will hit a foliage element is a function of foliage density (leaf area per unit canopy volume, **mu**, and fraction of leaf area which is projected perpendicularly to the beam, **G(theta, phi)**. Where theta and phi are given zenith and azimuth directions. Thus for a canopy with a random leaf angle distribution **G(theta, phi) = 0.5.** From Beer's law transmittance, **T(theta, phi)** is given by:

T(theta, phi) = exp (-G(theta,phi) mu S(theta,phi)|

where:

S(theta, phi) is the pathlength through the canopy.

Assuming uniform sky illumination and a random distributions of leaf azimuth angles, we can drop the suffix, **phi**, and re-write the above equation as:

G(theta) mu = K(theta) = -ln(T(theta)) / S(theta).

Miller (1967) refers to **K(theta)** as the contact frequency, number of hits made with foliage per unit length traveled through the canopy.

Miller gives an exact solution for **mu** as:

mu = 2 integral (K(theta) sin (theta), d.theta)

for **theta** = 0 to pi/2.

Since for a given canopy height of **z**, leaf area index, **L = muz**, and the pathlength is given by:

S(theta) = z / cos(theta).

Substituting into Miller's solution for **mu** gives:

L = 2 integral (Kh(theta) sin(theta) d.theta)

for **theta** = 0 to pi/2

where:

Kh(theta) is **K(theta)** times canopy height **z**, and is referred to by Lang (1987) as contact number.

Thus,

Kh(theta) = -ln(T(theta)) cos(theta).

The mean inclination angle of the canopy leaves (MTA in data table) can be calculated using a relationship between **d.G(theta) / d.theta** and the mean leaf inclination angle using a polynomial relationship derived from idealized canopies (see Lang 1986).

4. Equipment:

Sensor/Instrument Description:

The LAI-2000 Plant Canopy Analyzer (LI-COR Inc.), or 'light-wand' was used for non-destructive estimation of LAI during FIFE 1989. Refer to manufacturer's manual for a complete description (Anonymous 1989).

Collection Environment:

Ground-based.

Source/Platform:

Ground-based measurements.

Source/Platform Mission Objectives:

The primary objectives were to provide estimates of leaf area index at the FIFE sites. Leaf area values are important in land surface-atmosphere exchange processes and for interpreting satellite measurements.

Key Variables:

Leaf area index, mean inclination angle of the leaves, diffuse canopy transmittance.

Principles of Operation:

The LAI-2000 estimates LAI and mean leaf angle (MTA) from measurements of canopy transmittance at 5 different zenith angles (7, 23, 38, 53, and 68 degrees). The sensor head has an approximate cross-sectional area of 2.5 x 2.5 (cm2), and is placed above and below the canopy to take transmittance readings. The detectors inside the optical head are filtered to receive radiation less than 490 nm. This is the blue end of the spectrum where foliage has very low transmittance. The basic data collected by the LAI-2000 consists of 10 numbers; 5 of the numbers are the signals from the 5 detector-rings of the instrument when the optical head was above the vegetation canopy; while the remaining 5 numbers are the detector outputs with the head below the canopy. For both readings the sensor looks up at the sky. From these 10 numbers it is possible to calculate five values of transmittance at the 5 zenith angles. These values are then used to calculate LAI and mean leaf angle (MTA). Several sets of pairs of above and below canopy readings are taken to obtain a spatial average. Various assumptions are made when calculating LAI and MTA and the reader should refer to the LAI-2000 operating manual for further information.

Sensor/Instrument Measurement Geometry:

A wide-angle lens looks up at the sky sequentially from above the canopy and from the base of the canopy. The detectors limit the view to five zenith angles, the largest angle being about 68 degree form the vertical. The instrument head is about 2.5 cm in cross-section, so that any plant material shorter than 2.5 cm is not detected. On sites grazed by animals, there may be substantial amounts of short grass which is not detected.

Manufacturer of Sensor/Instrument:

LI-COR Inc.
P.O. Box 4425
4421 Superior Street
Lincoln, Nebraska
68504, U.S.A.
Phone: (402) 467-3576
FAX: (402)467-2819

Calibration:

The LAI-2000 Plant Canopy Analyzer does not require calibration when used with only one head (as in this case).

Specifications:

See the *Principles of Operation Section*.

Tolerance:

Integration time can be increased under low light. Scattered radiation within the canopy being measured, and non-uniform sky brightness, cause error in estimation of leaf area index.

Frequency of Calibration:

Not available at this revision.

Other Calibration Information:

Not applicable in this study.

5. Data Acquisition Methods:

Usually three pairs of above and below canopy readings were taken at each plot. The instruments azimuthal field-of-view was restricted to 180 degrees. The sun and the operator were on the side not being viewed by the sensor. An umbrella was also used during sunshine to shade an area of about 80 cm diameter around the sensor. The purpose of shading the sensor and foliage around the sensor was to reduce the amount of reflected radiation reaching the sensor which causes an under-estimation of LAI. The instruments assumes azimuthal symmetry and integrates over its entire azimuthal field-of-view. A uniformly bright sky hemisphere therefore is desirable. However because of time constraints measurements were taken regardless of sky conditions.

6. Observations:

Data Notes:

Not available.

Field Notes:

INFORMATION ON LIGHT WAND DATA

DATE	SITE SAMPLED	1989 WHERE	APPROX. # OF PLOTS AND REPS	REMARKS
906	7/03	behind WAB	4 plots 3 readings/plot	well-watered before measurements, destructively sampled after measurements
910	7/04	behind WAB	4 plots 3 readings/plot	well-watered before measurements, destructively sampled after measurements
911	7/05	behind WAB	4 plots 3 readings/plot	well-watered before measurements, destructively sampled after measurement
944	7/06	behind WAB	4 plots 3 readings/plot	well-watered before measurements, destructively sampled after measurement
921	7/07	behind WAB	4 plots 3 readings/plot	well-watered before measurements, destructively sampled after measurement
906	7/10	in WAB	50 plots 3 readings/plot	
919	7/11	in WAB	12 plots 3 readings/plot	data set not complete
921	7/11	in WAB	98 plots 3 readings/plot	
902	7/12	in WAB	50 plots 3 readings/plot	
911	7/12	in WAB	100 plots 3 readings/plot	
910	7/13	in WAB	50 plots 3 readings/plot	
912	7/13	in WAB	50 plots 3 readings/plot	
936	7/13	in WAB	44 plots 3 readings/plot	
913	7/14	in WAB	22 plots 3 readings/plot	
944	7/14	in WAB	25 plots 3 readings/plot	
925	7/14	in WAB	34 plots 3 readings/plot	
938	7/14	in WAB	15 plots 3 readings/plot	
944	7/18	behind	20 plots	destructively

WAB 3 readings/plot sampled after
measurement
944 7/18 in WAB 50 plots
3 readings/plot
911 7/19 behind 20 plots destructively
WAB 3 readings/plot sampled after
measurement
911 7/19 in WAB 100 plots
3 readings/plot
906 7/20 behind 20 plots destructively
WAB 3 readings/plot sampled after
measurement
906 7/20 in WAB 100 plots
3 readings/plot
921 7/21 behind 20 plots destructively
WAB 3 readings/plot sampled after
measurement
921 7/21 in WAB 100 plots
3 readings/plot
908 7/24 in WAB 50 plots
3 readings/plot
910 7/24 in WAB 50 plots
3 readings/plot
902 7/24 in WAB 50 plots
3 readings/plot
938 7/25 in WAB 50 plots
3 readings/plot
936 7/25 in WAB 50 plots
3 readings/plot
944 7/25 in WAB 36 plots incomplete data set
3 readings/plot
921 7/26 in WAB 50 plots
3 readings/plot
912 7/26 in WAB 50 plots
3 readings/plot
913 7/27 in WAB 50 plots
3 readings/plot
925 7/27 in WAB 50 plots
3 readings/plot
906 7/27 in WAB 100 plots
3 readings/plot
919 7/28 in WAB 50 plots
3 readings/plot
911 7/28 in WAB 100 plots
3 readings/plot
911 7/28 in 15 plots,
Parabola 3 readings/plot
944 7/31 behind 10 plots destructively
WAB 3 readings/plot sampled after
measurement
944 7/31 in WAB 50 plots
3 readings/plot
910 8/01 behind 10 plots destructively
WAB 3 readings/plot sampled after
measurement
910 8/01 in WAB 50 plots
3 readings/plot

921 8/02 behind 10 plots destructively
WAB 3 readings/plot sampled after
measurement
921 8/02 in WAB 100 plots
3 readings/plot
906 8/04 behind 10 plots destructively
WAB 3 readings/plot sampled after
measurement
906 8/04 in 15 plots
Parabola 3 readings/plot
906 8/04 in WAB 100 plots
3 readings/plot
911 8/04 behind 10 plots destructively
WAB 3 readings/plot sampled after
measurement
911 8/05 in WAB 100 plots
3 readings/plot
910 8/07 behind 4 plots well-watered before
WAB 3 readings/plot measurements,
destructively sampled
after measurements
906 8/07 behind 4 plots well-watered before
WAB 3 readings/plot measurements,
destructively sampled
after measurements
902 8/07 in WAB 50 plots
3 readings/plot
921 8/08 behind 4 plots well-watered before
WAB 3 readings/plot measurements,
destructively sampled
after measurements
911 8/08 behind 4 plots well-watered before
WAB 3 readings/plot measurements,
destructively sampled
after measurements
944 8/08 behind 4 plots well-watered before
WAB 3 readings/plot measurements,
destructively sampled
after measurements
908 8/08 in WAB 50 plots
3 readings/plot
938 8/09 in WAB 50 plots
3 readings/plot
936 8/09 in WAB 40 plots incomplete data set
3 readings/plot
912 8/10 in WAB 50 plots
3 readings/plot
925 8/10 in WAB 50 plots
3 readings/plot
913 8/11 in WAB 50 plots
3 readings/plot
919 8/11 in WAB 50 plots
3 readings/plot
906 8/14 behind 20 plots destructively
WAB 3 readings/plot sampled after
measurement
906 8/14 in WAB 100 plots

```
3 readings/plot
906   8/14   in       30 plots         plot numbers 13-20
Parabola  3 readings/plot were also
destructively sampled
- see destructive
data set
921   8/15   behind   20 plots         destructively
WAB      3 readings/plot  sampled after
measurement
921   8/15   in WAB   100 plots
3 readings/plot
921   8/15   in       30 plots         plot numbers 1 - 9
Parabola  3 readings/plot were also
destructively sampled
- see destructive
data set
911   8/16   behind   20 plots         destructively
WAB      3 readings/plot  sampled after
measurement
911   8/16   in WAB   100 plots
3 readings/plot
911   8/16   in       30 plots         plot numbers 13-20
Parabola  3 readings/plot were also
destructively sampled
- see destructive
data set
910   8/17   behind   20 plots         destructively
WAB      3 readings/plot  sampled after
measurement
910   8/17   in WAB   50 plots
3 readings/plot
944   8/18   behind   20 plots         destructively
WAB      3 readings/plot  sampled after
measurement
944   8/18   in WAB   50 plots
3 readings/plot
```

7. Data Description:

Spatial Characteristics:

The FIFE study area, with areal extent of 15 km by 15 km, is located south of the Tuttle Reservoir and Kansas River, and about 10 km from Manhattan, Kansas, USA. The northwest corner of the area has UTM coordinates of 4,334,000 Northing and 705,000 Easting in UTM Zone 14.

Spatial Coverage:

This is point data collected at specific sitegrid's within the FIFE study area. Measurements were taken at all 13 surface flux stations during FIFE 1989. The location of the stations are listed below.

SITEGRID	STN_ID	NORTHING	EASTING	LATITUDE	LONGITUDE	ELEV
1478-LWK	938	4331223	720664	39 06 15	-96 26 53	375
1916-LWK	902	4330282	708259	39 05 55	-96 35 30	351
1942-LWK	944	4330133	713414	39 05 46	-96 31 56	422
2133-LWK	906	4329726	711604	39 05 34	-96 33 12	443
2330-LWK	908	4329314	711066	39 05 22	-96 33 35	424
2655-LWK	936	4328787	716070	39 05 00	-96 30 07	367
3129-LWK	912	4327822	710820	39 04 33	-96 33 47	431
3317-LWK	910	4327395	708485	39 04 22	-96 35 24	427
4168-LWK	925	4325704	718646	39 03 18	-96 28 24	438
4439-LWK	911	4325219	712795	39 03 07	-96 32 27	445
6735-LWK	913	4320652	712073	39 00 40	-96 33 03	385
6912-LWK	919	4320178	707307	39 00 29	-96 36 21	385
8639-LWK	921	4316771	712827	38 58 33	-96 32 36	440

SITEGRID	SLOPE	ASPECT
1478-LWK	2	N
1916-LWK	2	N
1942-LWK	1	TOP
2133-LWK	1	TOP
2330-LWK	5	E
2655-LWK	4	E
3129-LWK	14	E
3317-LWK	15	W
4168-LWK	1	TOP
4439-LWK	2	N
6735-LWK	1	BOTTOM
6912-LWK	2	N
8639-LWK	1	TOP

The number of plots measured at each site (by date) and their position in relation to the Wind Aligned Blobs (WAB) are listed in the *Field Notes Section*.

The permanent (140-240 degree) WABs at the super-sites (sites 906, 911, and 921) were marked with 100 flags with the density of flags varying with distance from the flux station as follows:

Radial Distance (m):	10	20	30	40	50	60	70	80	90	100
Sample Frequency:	2	7	10	12	13	13	13	12	10	8

These flag positions are referred to as plots within the sites. The positions of these plots within the permanent WABs were fixed throughout the duration of FIFE 89. These plots were numbered sequentially. Plot 1 was the first plot just in from the 240 degree compass bearing on the 10 m arc from the apex of the WAB, and plot 100 was 100 m away from the apex on the 240 degree compass bearing. Plots at the non-supersites (all other flux sites) were marked out at half the density of plots at the super- sites (i.e., 50 plots in the 140-240 degree WAB). PAR readings in the WAB were taken at odd numbered plots while light-wand readings were taken at every plot in the WAB. A given plot number in any data set corresponds to the same location at the site. In the case of in-WAB measurements these locations were fixed throughout the duration of

FIFE 89. In addition to readings in the WABs PAR and light-wand readings were also taken behind the WABs at positions where destructive samples (for LAI and biomass) were due to be taken. The non-destructive measurements were always taken just before (less than ½ hour prior to) destructive sampling. The destructive plots were usually positioned 5-10 m apart along a linear east-west transect about 20 m or so behind the WAB apex, i.e., within the 270-90 degree compass bearings from the flux measuring apparatus. The plots were labeled sequentially. Also a limited number of PAR and LAI-2000 readings were taken in the PARABOLA areas at the super-sites. These measurements have SAMPLE_TYPE of 'PBA'. On August 14, 15, and 16 the transects for the destructive samples were made to pass through the PARABOLA areas. For these plots, a full set of destructive and non-destructive measurements is available. On August 14 at site 906 destructive plots 13-20 were in the PARABOLA area. On August 15 at site 921 destructive plots 1-9 were in the PARABOLA area. On August 16 at site 911 destructive plots 13-20 were in the PARABOLA area.

Spatial Coverage Map:

Not available.

Spatial Resolution:

Depends on the height (**h**) of the canopy (usually < 0.5m).

Spatial resolution = 2h (TAN 68).

Projection:

Not available.

Grid Description:

Not available.

Temporal Characteristics:

Temporal Coverage:

Data were collected from July 3, 1989 through August 18, 1989, during IFC-5.

Temporal Coverage Map:

Not available.

Temporal Resolution:

Measurements were made every day during the overall data collection period but measurements at an individual location were made about once a week (see the *Field Notes Section* for exact dates).

Data Characteristics:

The SQL definition for this table is found in the LIGHTWND.TDF file located on FIFE CD-ROM Volume 1.

Parameter/Variable Name

Parameter/Variable Description	**Range**	**Units**	**Source**
SITEGRID_ID This is a FIS grid location code. Site grid codes (SSEE-III) give the south (SS) and east (EE) cell number in a 100 x 100 array of 200 m square cells. The last 3 characters (III) are an instrument identifier.			
STATION_ID The station ID designating the location of the observations.			
OBS_DATE The date of the observations, in the format (DD-MMM-YY).			
OBS_TIME The time that the observation was taken in GMT. The format is (HHMM).		[GMT]	
PI_NAME The name of the Principal Investigator who oversaw the collection of the data.	$		
PLOT_NUM The plot number at the site where the observations were made.			

SAMPLE_TYPE #
The information about the
treatment of the plot where the
data were collected, such as if
the plot was watered or
destructively sampled.

LAI_2000_LAI
The leaf area index as calculated
by the LAI-2000.

LAI_ST_ERR
The standard error of the leaf
area index measurement.

MEAN_LEAF_INCL_ANG
The mean inclination angle of the [degrees]
leaves in the canopy as determined
by the LAI-2000.

LEAF_INCL_ANG_ST_ERR
The standard error of the mean
inclination angle.

DIFFUSE_TRNSMTNC
The diffuse transmittance of the
canopy. This is the probability
of diffuse radiation from above
penetrating the canopy to a
particular location.

NUM_OBS
The number of pairs of above and
below canopy observations used in
the calculations.

FIFE_DATA_CRTFCN_CODE *
The FIFE Certification Code for
the data, in the following format:
CPI (Certified by PI), CPI-???
(CPI - questionable data).

LAST_REVISION_DATE
data, in the format (DD-MMM-YY).

Footnotes:

$ For this data set the PI_NAME = T. SHAH

Decode the SAMPLE_TYPE field as given below: DS Destructively sampled DSWW Destructively sampled and well watered PBA PARABOLA sites

* Decode the FIFE_DATA_CRTFCN_CODE field as follows

The primary certification codes are: EXM Example or Test data (not for release). PRE Preliminary (unchecked, use at your own risk). CPI Checked by Principal Investigator (reviewed for quality). CGR Checked by a group and reconciled (data comparisons and cross-checks).

The certification code modifiers are: PRE-NFP Preliminary - Not for publication, at the request of investigator. CPI-MRG PAMS data that are "merged" from two separate receiving stations to eliminate transmission errors. CPI-??? Investigator thinks data item may be questionable.

Sample Data Record:

SITEGRID_ID	STATION_ID	OBS_DATE	OBS_TIME	PI_NAME	PLOT_NUM	SAMPLE_TYPE
6912-LWK	919	28-JUL-89	1433	T. SHAH	35	
6912-LWK	919	28-JUL-89	1434	T. SHAH	36	
6912-LWK	919	28-JUL-89	1434	T. SHAH	37	
6912-LWK	919	28-JUL-89	1435	T. SHAH	38	

LAI_2000_LAI	LAI_ST_ERR	MEAN_LEAF_INCL_ANG	LEAF_INCL_ANG_ST_ERR
.570	.030	90	272
.550	.040	64	2
1.540	.060	73	8
1.590	.170	60	4

DIFFUSE_TRNSMTNC	NUM_OBS	FIFE_DATA_CRTFCN_CODE	LAST_REVISION_DATE
.662	3	PRE	31-AUG-89
.660	3	PRE	31-AUG-89
.336	3	PRE	31-AUG-89
.296	3	PRE	31-AUG-89

8. Data Organization:

Data Granularity:

This is point data collected at specific sitegrid's within the FIFE study area.

A general description of data granularity as it applies to the IMS appears in the EOSDIS Glossary.

Data Format:

The CD-ROM file format consists of numerical and character fields of varying length separated by commas. The character fields are enclosed with a single apostrophe. There are no spaces between the fields. Each file begins with five header records. Header records contain the following information: Record 1 Name of this file, its table name, number of records in this file, path and name of the document that describes the data in this file, and name of principal investigator for these data. Record 2 Path and filename of the previous data set, and path and filename of the next data set. (Path and filenames for files that contain another set of data taken at the same site on the same day.) Record 3 Path and filename of the previous site, and path and filename of the next site. (Path and filenames for files of the same data set taken on the same day for the previous and next sites (sequentially numbered by SITEGRID_ID)). Record 4 Path and filename of the previous date, and path and filename of the next date. (Path and filenames for files of the same data set taken at the same site for the previous and next date.) Record 5 Column names for the data within the file, delimited by commas. Record 6 Data records begin.

Each field represents one of the attributes listed in the chart in the *Data Characteristics Section* and described in detail in the TDF file. These fields are in the same order as in the chart.

9. Data Manipulations:

Formulae:

See the *Theory of Measurements Section*.

Derivation Techniques and Algorithms:

See the *Theory of Measurements Section*.

Data Processing Sequence:

Processing Steps:

All basic calculations were performed by the software of the LAI-2000. For complete details of the LAI-2000 implementation refer to the LAI-2000 operating manual.

T(theta) values are calculated for each pair of above-below readings. These values are divided by the corresponding values for S(theta), i.e., 1/cos(theta) to yield the contact numbers Kh(theta). Integration of the equation of Miller (1967) is achieved by summing the products of Kh(theta) and the weighting factors, sin(theta)d.(theta).

After calculating leaf area index, five values of G(theta) can be calculated. These values are regressed against values of theta to obtain a mean value for d.G(theta) / d.Theta. This value is used in conjunction with a fifth order polynomial which describes the average values of

d.G(theta) / d.theta versus leaf inclination angles of a set of idealized canopies, to calculate the mean leaf inclination angle for the canopy being measured.

Diffuse transmittance, was calculated by summing the weighted transmittances at the 5 zenith angles. The weighting factors are proportional to sin(theta)cos(theta). Values used were, 0.06, 0.19, 0.25, 0.25, and 0.25 for the 7, 23, 38, 53 and 68 degree at which the five sensors view the sky.

Processing Changes:

None.

Calculations:

Special Corrections/Adjustments:

None.

Calculated Variables:

- Leaf area index, and
- Diffuse transmittance.

Graphs and Plots:

None.

10. Errors:

Sources of Error:

Scattered radiation within the canopy being measured, and non-uniform sky brightness, cause error in estimation of leaf area index.

Quality Assessment:

Not available at this revision.

Data Validation by Source:

Not available at this revision.

Confidence Level/Accuracy Judgment:

Verification studies conducted by LI-COR Inc. have shown that the LAI-2000 Canopy Analyzer performs well. LAI-2000 measurements were generally within 15% of values obtained by destructive sampling and measurement with a leaf area meter. In our own experience we found that even the destructive measurements are subject to large error. Prairie grass leaves tend to curl and fold as they are fed into the belts of a standard leaf area meter. The values obtained depended on how much care the operator takes when feeding in the leaves into the leaf area meter. As a rough guess even the destructive measurements are accurate only to width about 25% of the true sample leaf area value. In our opinion the non-destructive measurements with the LAI-2000 are as good as the destructive measurements, and provide a better estimate of the site mean, because many more non-destructive measurement can be made.

The optical head of the LAI-2000 Plant Canopy Analyzer is about 2.5 cm in cross-section, so that any plant material shorter than 2.5 cm is not detected. On sites grazed by animals, there may be substantial amounts of short grass which is not detected.

Measurement Error for Parameters:

Not available at this revision.

Additional Quality Assessments:

None.

Data Verification by Data Center:

The data verification performed by the ORNL DAAC deals with the quality of the data format, media, and readability. The ORNL DAAC does not make an assessment of the quality of the data itself except during the course of performing other QA procedures as described below.

The FIFE data were transferred to the ORNL DAAC via CD-ROM. These CD-ROMs are distributed by the ORNL DAAC unmodified as a set or in individual volumes, as requested. In addition, the DAAC has incorporated each of the 98 FIFE tabular datasets from the CD-ROMs into its on-line data holdings. Incorporation of these data involved the following steps:

- Copying the entire FIFE Volume 1, maintaining the directory structure on the CD-ROM;
- Using data files, documentation, and SQL code provided on the CD-ROM to create a database in Statistical Analysis System (SAS); and
- Creating transfer files to transfer the SAS metadata database to Sybase tables.

Each distinct type of data (i.e. "data set" on the CD-ROM), is accompanied by a documentation file (i.e., .doc file) and a data format/structure definition file (i.e., .tdf file). The data format files on the CD-ROM are Oracle SQL commands (e.g., "create table") that can be used to set up a relational database table structure. This file provides column/variable names, character/numeric type, length, and format, and labels/comments. These SQL commands were converted to SAS code and were used to create SAS data sets and subsequently to input data files directly from the CD-ROM into a SAS dataset. During this process, file names and directory paths were captured

and metadata was extracted to the extent possible electronically. No files were found to be corrupted or unreadable during the conversion process.

Additional Quality Assurance procedures were performed as follows:

- Statistical operations were performed to calculate minimum and maximum values for all numeric fields and to create a listing of all values of the character fields. During this process, it was determined that various conventions were used to represent missing values. (Note: no modifications were made to any data by the DAAC). In most cases, missing value identification conventions were discussed in the accompanying .doc file. Based on a visual check of the minimum and maximum values, no glaring errors or holes were identified that might indicate errors introduced during CD-ROM mastering by the FIFE project or data ingest by the DAAC.
- Some minor inconsistencies and typographical errors were identified in some of the character fields and column labels, however, no modifications were made to the data by the DAAC.
- Some conversions of ASCII data were necessary to move the data from a DOS platform to a UNIX platform. Standard operating system conversion utilities were used (e.g., dos2unix).
- Much of the metadata required for archival is imbedded in the narrative documentation accompanying the data sets and extracted manually by DAAC staff who have read the .doc files provided on the CD-ROM and have hand entered this information into the metadata database maintained by the DAAC. QA procedures have been performed on these metadata to identify and eliminate typographical errors and inconsistencies in naming conventions, to ensure that all required metadata is present, and to ensure the accuracy of file names and paths for retrieval.
- Data requested for distribution to users are checked to verify that files copied from disk to other media remain uncorrupted.

As errors are discovered in the on-line tabular data by investigators, users, or DAAC staff, corrections are made in cooperation with the principal investigators. These corrections are then distributed to users. CD-ROM data are corrected when re-mastering occurs for replenishment of CD-ROM stock.

11. Notes:

Limitations of the Data:

Not available.

Known Problems with the Data:

None.

Usage Guidance:

Use as rough estimates of leaf areas at the FIFE sites. True site means (accurate to within about 5%) would be very difficult and time-consuming to obtain.

Any Other Relevant Information about the Study:

Not available at this revision.

12. Application of the Data Set:

This data set can be used as rough estimates of leaf areas at the FIFE sites.

13. Future Modifications and Plans:

The FIFE field campaigns were held in 1987 and 1989 and there are no plans for new data collection. Field work continues near the FIFE site at the Long-Term Ecological Research (LTER) Network Konza research site (i.e., LTER continues to monitor the site). The FIFE investigators are continuing to analyze and model the data from the field campaigns to produce new data products.

14. Software:

Software to access the data set is available on the all volumes of the FIFE CD-ROM set. For a detailed description of the available software see the *Software Description Document*.

15. Data Access:

Contact Information:

ORNL DAAC User Services
Oak Ridge National Laboratory

Telephone: (865) 241-3952
FAX: (865) 574-4665

Email: ornldaac@ornl.gov

Data Center Identification:

ORNL Distributed Active Archive Center
Oak Ridge National Laboratory
USA

Telephone: (865) 241-3952
FAX: (865) 574-4665

Email: ornldaac@ornl.gov

Procedures for Obtaining Data:

Users may place requests by telephone, electronic mail, or FAX. Data is also available via the World Wide Web at http://daac.ornl.gov.

Data Center Status/Plans:

FIFE data are available from the ORNL DAAC. Please contact the ORNL DAAC User Services Office for the most current information about these data.

16. Output Products and Availability:

The Indirect Leaf Area Index Obtained from the KSU Light Wand data are available on FIFE CD-ROM Volume 1. The CD-ROM filenames is as follows:

\DATA\SUR_REFL\LIGHTWND\GRIDxxxx\ydddgrid.LWK

Where *xxxx* is the four digit code for the location within the FIFE site grid. Note: capital letters indicate fixed values that appear on the CD-ROM exactly as shown here, lower case indicates characters (values) that change for each path and file.

The format used for the filenames is: *ydddgrid.sfx*, where *grid* is the four-number code for the location within the FIFE site grid, *y* is the last digit of the year (e.g., 7 = 1987, and 9 = 1989), and *ddd* is the day of the year (e.g., 061 = sixty-first day in the year). The filename extension (*.sfx*), identifies the data set content for the file (see the *Data Characteristics Section*) and is equal to .LWK for this data set.

17. References:

Satellite/Instrument/Data Processing Documentation.

Anonymous. 1989. LAI-2000 Plant Canopy Analyzer, Operating Manual, June 1989. Published by LI-COR, Inc. Box 4425. 4421 Superior Street. Lincoln, Nebraska 68504, USA.

Journal Articles and Study Reports.

Warren Wilson, J. and Reeve, J.E. 1959. Analysis of the spatial distribution of foliage by two-dimensional point quadrats. New Phytol. (58) 92-101.

Miller, J.B. 1967. A formula for average foliage density. Aust. J. Bot. (15) 141-144.

Lang, A.R.G. 1986. Leaf area and average leaf angle from transmittance of direct sunlight. Aust. J. Bot. (34) 349-355.

Archive/DBMS Usage Documentation.

Contact the EOS Distributed Active Archive Center (DAAC) at Oak Ridge National Laboratory (ORNL), Oak Ridge, Tennessee (see the *Data Center Identification Section*). Documentation about using the archive and/or on-line access to the data at the ORNL DAAC is not available at this revision.

18. Glossary of Terms:

A general glossary for the DAAC is located at Glossary.

19. List of Acronyms:

APAR Absorbed Photosynthetically Active Radiation DAAC Distributed Active Archive Center DSWW Destructively Sample After Watering EOSDIS Earth Observing System Data and Information System FIFE First ISLSCP Field Experiment FIS FIFE Information System IPAR Intercepted Photosynthetically Active Radiation IRT Infrared Thermometer ISLSCP International Satellite Land Surface Climatology Project KSU Kansas State University LAI Leaf Area Index MMR Modular Multiband Radiometer MTA Mean Leaf Angle NMLR Nebraska Multiband Leaf Radiometer ORNL Oak Ridge National Laboratory PAR Photosynthetically Active Radiation PARABOLA Portable Apparatus for Rapid Acquisition of Bi-directional Observations of the Land and Atmosphere PBA Measurements Taken in the PARABOLA Area SEL Standard Error of Leaf Area Index Estimate SEM Standard Error of Mean Leaf Angle Estimate UNL University of Nebraska - Lincoln URL Uniform Resource Locator WAB Wind Aligned Blob

A general list of acronyms for the DAAC is available at Acronyms.

20. Document Information:

May 9, 1994 (citation revised on October 16, 2002).

Warning: This document has not been checked for technical or editorial accuracy by the FIFE Information Scientist. There may be inconsistencies with other documents, technical or editorial errors that were inadvertently introduced when the document was compiled or references to preliminary data that were not included on the final CD-ROM.

Previous versions of this document have been reviewed by the Principal Investigator, the person who transmitted the data to FIS, a FIS staff member, or a FIFE scientist generally familiar with the data.

Document Review Date:

August 1, 1996.

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ORNL-FIFE_LIGHTWND.

Citation:

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