025761-1-T

LEAF AREA INDEX DATA FOR THE MICHIGAN FOREST TEST SITES (1990-1991)

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Work Funded by NASA under Grant No. NAGW-1362

January, 1992

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UMR Ø473

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1.0 INTRODUCTION

In preparation for studies using orbital SAR data from SIR-C/X-SAR and ERS-1, several test sites in northern Michigan have been overflown by the Jet Propulsion Laboratory's 3-frequency, polarimetric AIRSAR. To date, the NASA-Ames DC-8 with the AIRSAR has obtained data over these areas on April 1, July 8 and July 10, 1990 and also on June 6, 1991. The purposes of these flights have been to obtain radar imagery suitable for development and testing of approaches to (1) discriminate forest communities, (2) estimate above-ground biomass and (3) infer near-surface soil moisture. Two main test sites have been established for these purposes: (1) around the University of Michigan Biological Station (UMBS), at Douglas Lake and (2) at the eastern end of Michigan's Upper Peninsula (centered near the village of Raco).

In addition to the airborne SAR data, data were obtained at ground-level to describe many forest properties. These data include observations required to estimate biomass such as stand level descriptions of tree height, diameter and density (by species) and also leaf area index (LAI). Additional measurements were made to quantify the moisture conditions and dielectric properties of selected forest stands during the time of airborne or orbital SAR observations. This report details the methodology and results of LAI measurements made during 1990 and 1991. Other measurements are the subject of separate technical reports. This report details the methods used in estimating the LAI of the forest stands, methods used to evaluate the reliability of the data set and a summary of the results.

The leaf area index (LAI) is defined by Ulaby et al. (1986) as the total single-sided surface area of all the leaves within the canopy over a unit area of ground. Leaf area index is useful in calculating the biomass present in the crown of a forest stand. The units of LAI are square meter per square meter.

Sites near the University of Michigan Biological Station at Pellston, Michigan and sites near Raco, Michigan, in the Hiawatha National Forest, were chosen for the wide variety of both conifer and hardwood species present.

The data from the measured stands were processed and evaluated to determine their accuracy. When possible, correction factors were used to account for instrument bias. A large portion of this report will deal with how the data was evaluated and what corrections were used.

The Li-Cor LAI-2000 (Li-Cor Inc, Lincoln, NE) device was used to estimate the LAIs of the various stands. This device was chosen because of it's portability and ease of use. The Li-Cor device, which was designed for agricultural canopies, has been shown to be an accurate estimator of both conifer and deciduous LAI as per Gower and Norman (1990). The LAI-2000 is an optical instrument that estimates LAI by comparing the amount of light incident on the forest canopy to the amount of light that penetrates the canopy.

The instrument uses a fisheye lens that projects the sky image onto five light sensitive rings. Each ring is centered around a zenith angle (7°,22°,38°,52°,68°). The incident light at each of the five zenith angles is averaged over the azimuth, to produce a reading. The device is meant to measure only ambient light, not reflected or direct sunlight. Therefore, care must be taken to (1) use the instrument under diffuse illumination conditions or (2) use view restrictors, in front of the lens, to block both direct sunlight and specular scattering by the canopy. Radiation with a wavelength greater than 490nm tends to be reflected by the foliage. Therefore, the device responds only to radiation of

wavelength less then 490nm, so that the foliage appears black. For more information see Welles and Norman (1991).

In addition to Leaf Area Index the LAI-2000 also provides useful information about the orientation of objects in the crown of the forest. Along with each LAI reading there is a corresponding mean tip angle (average orientation angle of the crown constituents) reading. This report focuses primarily on LAI; however, the MTA has been included in the data summary for completeness.

2.0 METHODOLOGY

The LAI of a stand of trees was found by sampling the LAI at various points (called plots), within the stand. Each stand in the UMBS forest is 1 hectare (100mx100m) and each stand at Raco is 4 hectares (200mx200m). The plots are located at even intervals along five parallel transects. These transects are separated by 20m (40m at Raco) and are perpendicular[1] to the baseline. The baseline must be a distance of at least two times the height of the trees into the stand, so that the LAI readings are not effected by the stand edge. The first transect is located a random number (1 to 20m at UMBS and 1 to 40m at Raco) of meters along the baseline. There are two plots along each transect in the UMBS stands and eight plots along each transect in the Raco forest.[2] Each plot along a transect is separated by 50m (25m at Raco) with the first plot located a random number of meters along the transect. At each plot there are three flagged locations. These flags are on a line perpendicular to the transect and are separated by 2m. It is at each of these flags that a measurement is taken. The LAI for each plot is the average of these three readings. The LAI of each stand is the average of all plot LAIs sampled in that stand.

Estimating the LAI of a forest stand required two LAI instruments. In order to measure the light incident upon the top of the canopy, one Li-Cor machine was left in a clearing in automatic mode, while another one was carried around, taking readings under the canopy. Two types of readings were taken under the canopy. The first, called "full canopy" observation, is measured at ground level so as to include all understory LAI. The second, called the "crown" observation, is measured at 1m or above the shrubs, whichever is higher. The data recorded by the instrument left in the clearing is called the "sky background reference". For more information on "sky background" see section 2.1.

Before a stand can be measured, a location must be found for the sky background instrument. The sky background must be determined at a location as close to the stand as possible, in a clearing, and in a position at least two times the average tree height away from the nearest tree, so that the instrument has a completely unobstructed view of the sky. The time and location of all stands measured, as well as the location of the sky background instrument, is given in section 3. Maps of the UMBS and Raco sites are in Figures 1 and 2.

At the beginning of each day, all of the LAI instruments involved were calibrated together. In addition, on September 18th, 1990 and September 20th, the LAI instruments were positioned next to each other for a couple minutes, several times during the day. This was done to check for any drift in the calibration. No significant drift was found, and calibration for the rest of the measurement days was done only in the morning.

Finally, the data were processed and evaluated. For details on this process see sections 2.1, 2.2 and 2.3.

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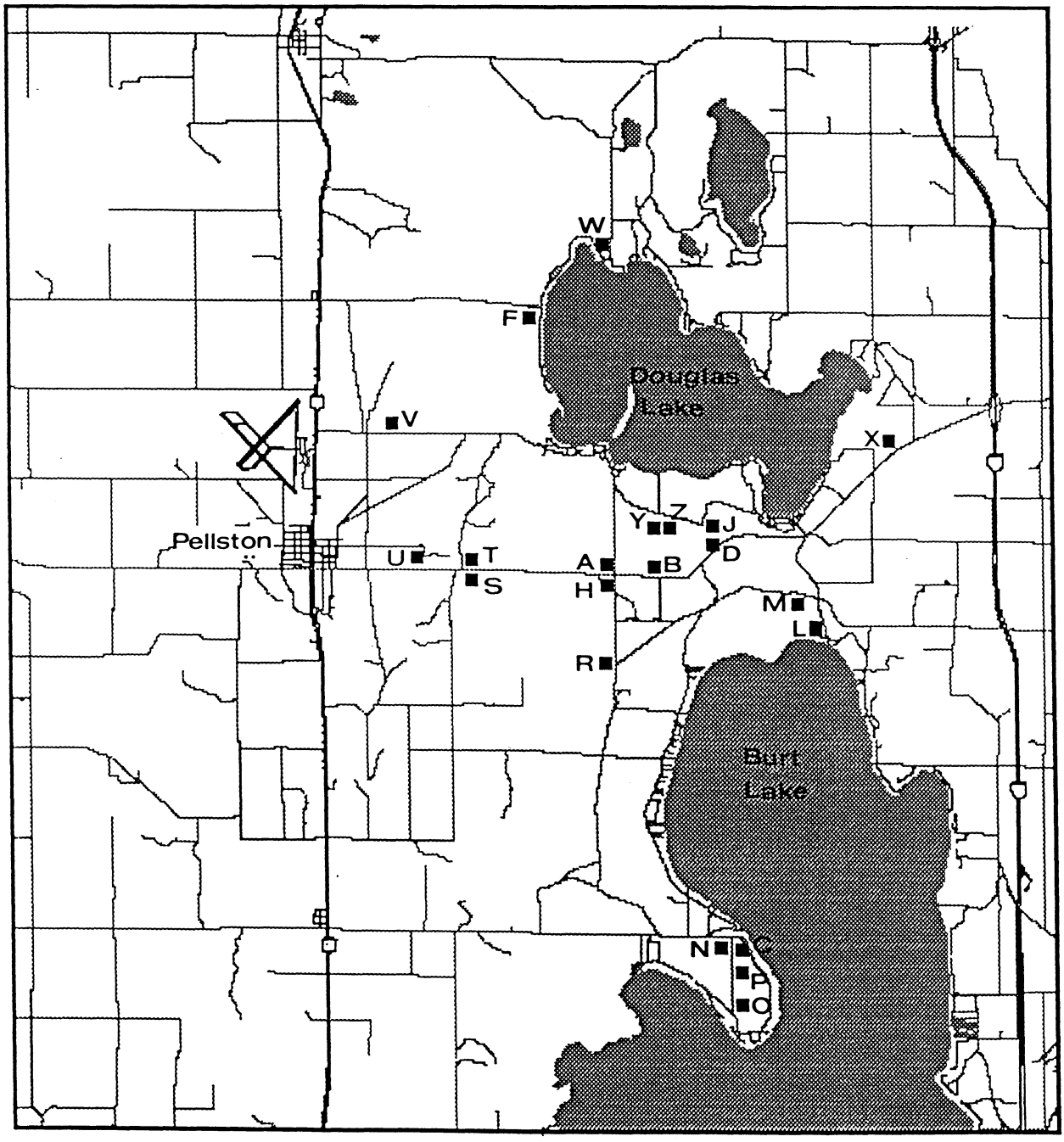
[1] in plantation stands transects are angled to avoid paralleling tree rows

[2] in the Raco stands, readings were not taken at all plots, for the sake of speed

ure 1.

STAND LOCATION MAP
UMBS SITE
1992



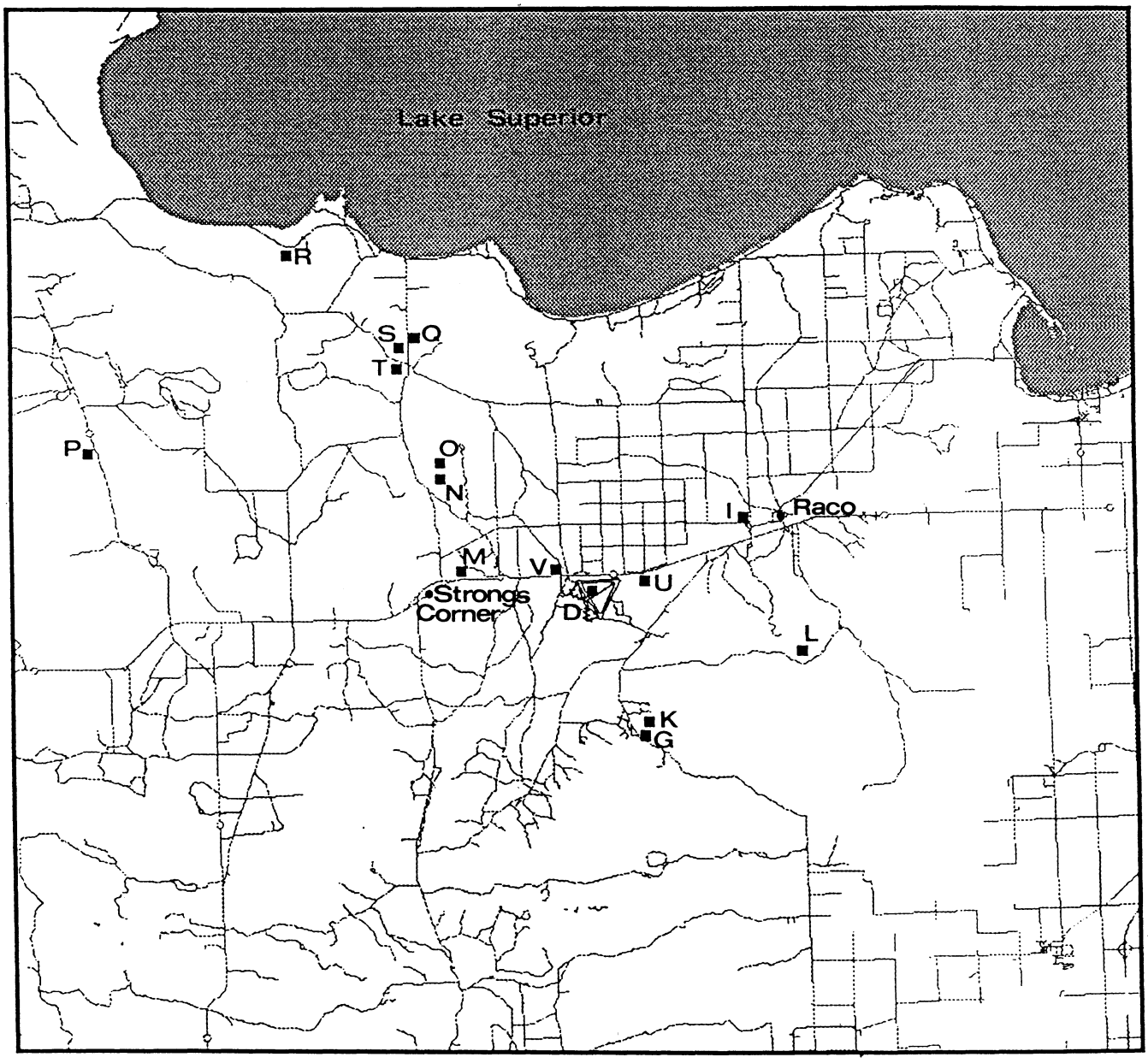
0 1 2 5

Scale in Kilometers

The University of Michigan
Microwave Image Processing Laboratory

ure 2.

STAND LOCATION MAP
RACO SITE
1992



0 1 2 5

Scale in Kilometers

The University of Michigan
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We were originally interested in LAI of the leaves in a forest canopy. However, The trunks and branches also block incident light. Therefore, we define the actual LAI of a stand, for deciduous trees, as follows:

$$LAI_{actual} = LAI_{foliated} - LAI_{defoliated}$$

The foliated measurements were made during the summer or early fall and the defoliated measurements were made during the winter or early spring. For evergreen conifers, there is no way to measure a defoliated LAI. In fact, according to Gower and Norman (1990,p. 6), the error in LAIs computed by the Li-Cor device, for conifers, is to underestimate LAI due to the needle shoot geometry of conifers. Therefore, the actual LAI for conifers is:

$$LAI_{actual} = C_s * LAI_{foliated}$$

Where C_s is a constant, specific to the specie of conifer, as per Gower and Norman (1990, p. 6), given in Table 1.

Table 1: LAI Correction Coefficients for Evergreen Conifers

Specie	C_s
Red Pine	1.50
White Pine	1.67
European Larch	1.49
Norway Spruce	1.60

2.1 Sky Background & Measuring Forest LAI

The Li-Cor device was designed primarily for situations where the operator could measure the light incident upon the canopy (sky background) and the light penetrating the canopy, with one instrument (i.e. taking the Leaf Area Index of a field of corn). However, a forest canopy presents obvious problems in measuring the sky background at the same location in space and time as the canopy reading. Therefore, it was necessary to find a suitable location to measure sky background. The nearest suitably sized clearing or open field was used for this purpose. One instrument was left in a clearing and recorded the sky background every 15 seconds, while the second instrument moved around and took readings below the canopy. The two files generated by these instruments were later merged to produce the actual LAI readings. The time of every measurement was recorded by the Li-Cor device. Readings from under the canopy were correlated with the sky background readings that were nearest to them, in time, using the Li-Cor software. Both clocks were synchronized to within one second.

The problem with this method is that the sky background is no longer an exact representation of the ambient light over the canopy instrument, in the forest stand. The farther the sky background instrument is from the stand, the more this becomes a problem. If conditions are clear or uniformly overcast, then the sky background will not vary much in either time or space, which will solve this problem (Gower and Norman,1990). However, conditions such as scattered low clouds cause local variations in the ambient light over a stand that may either (1) not be detected by the sky background instrument or (2) be offset in time and/or magnitude from the from the readings of the sky background instrument, if it is located too far away.

In order to determine whether or not a set of sky background readings are reliable, they were plotted versus time and objectively evaluated. Two examples of sky background

Fig 3a: LAI Sky Background-August 12, 1991
Reliable Sky Background File

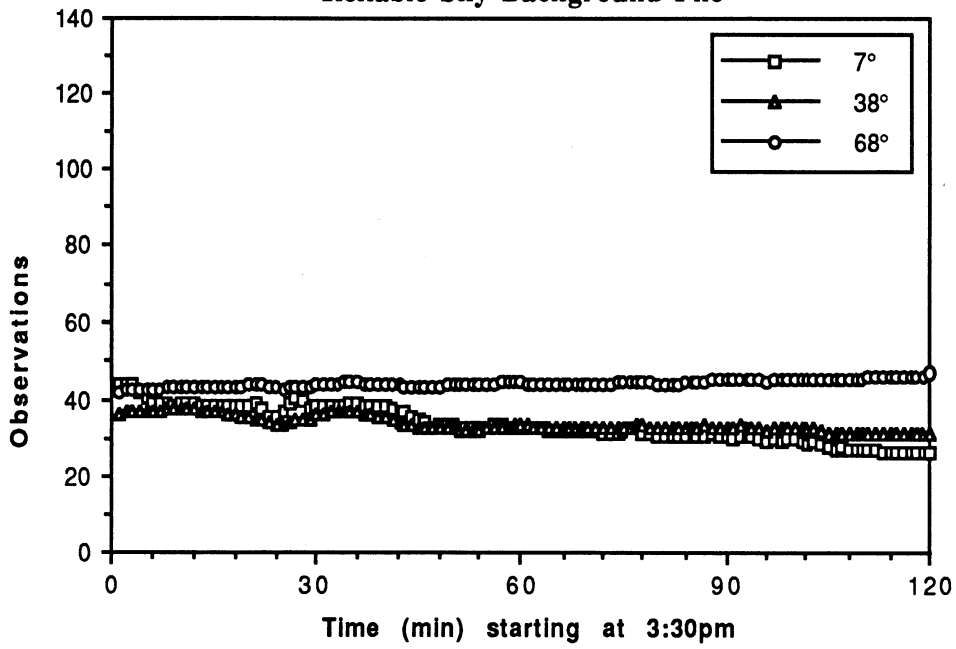
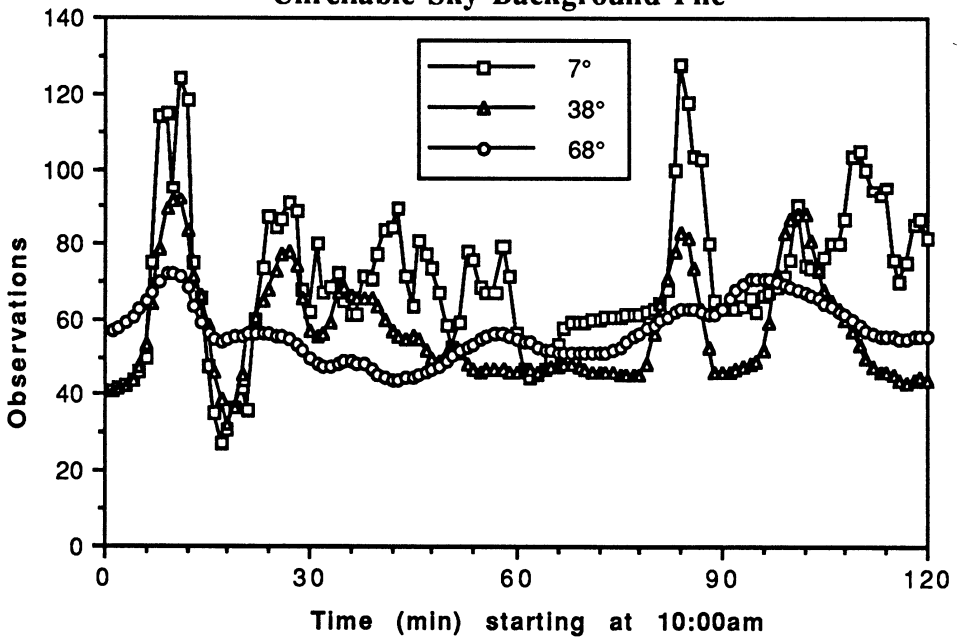


Fig 3b: LAI Sky Background-August 15, 1991
Unreliable Sky Background File



plots are shown in Figure 3. The first plot is an example of a "good" or time-invariant sky background file, from a clear sunny afternoon. There is little change in the incident light intensity at any of the zenith angles over a span of two hours. This sky background file is a reliable representation of the incident light on any stand within several kilometers. The second plot is an example of a "bad" or time-variant sky background file. This file was generated while several squall lines were passing through the area. The readings vary sharply over a span of minutes. Even, the low zenith angle readings, which are generally stable, vary widely over the time shown. This file would be unreliable for any stand that was not very close to the location of the sky background instrument. Sky background instruments were placed as close as possible to the measured stands, typically within 500m, in order to minimize this problem.

"Bad" sky background data was a problem on several of the days that data were recorded. These days are noted in the data tables, in the Appendix, by an uncertainty measure. For a definition of uncertainty measure see section 2.2.

2.2 Calibration

In order to determine the extent to which a time-variant sky background file can introduce uncertainty into the reported LAI measurements, the following procedure was used. LAIs were computed using a time-variant sky background file, such as that in figure 3b. Then these LAIs were compared to LAIs computed using the same canopy readings but with a different sky reference file. This second sky reference file was generated by having two sky background instruments running simultaneously, at two widely different locations. The differences in computed LAI resulting from choice of sky reference file give an estimate of measurement uncertainty related to spatial variation in solar illumination. In cases where there were not enough Li-Cor instruments to continuously have two sky reference measurements at different locations, then a second one could be simulated; this was done by shifting the time scale in the original sky reference file by some arbitrary time (i.e. five minutes). Essentially, we are trading time for distance. The assumption is that the clouds were moving uniformly in one direction. If this is true, then the generated file should be a good estimate of what another Li-Cor instrument, located five minutes down wind of the first, would observe.

The results of comparing many of these sets of LAIs seems to indicate that the uncertainty generated by a "bad sky cal" is often a zero-mean random process, at least for the limited sample of meteorologic conditions examined. In other words, The average of a statistically large number of LAI points is not affected by a randomly, time-variant sky reference file, provided that many points are averaged. However, the individual points themselves may be greatly affected. Table 2 is an example of this effect. A time-variant sky reference file is synchronized with the below-canopy readings to calculate the "original" LAI. The "time-shifted" LAI is also shown and assumes that the below-canopy and sky reference measurement are separated in space by 5 minutes of cloud motion. The change induced in the average LAI of the two stands, by shifting the time scale, was only 0.2%, whereas the average change to the LAI of an individual point was 7.57%. In determining what a sufficient sample size of LAI points was, we found that the average LAI over an hour and a half, or greater, was not effected by poor sky reference data.

We define the standard deviation of the point to point differences between the two LAI files to be the uncertainty measure generated by "bad" sky reference. In other words, the uncertainty measure is the average error introduced to any single LAI plot sample by a poor sky reference file. This is denoted by u= 0.### in the data tables of the appendix. We take this uncertainty to be significant if it is on the order of 0.1 or larger. If no uncertainty measure is listed in the data table, then it can be assumed to be negligible. (note: The stands at the U of M Biological station, usually took about twenty minutes to

measure. Therefore, the uncertainty for these stands had to be calculated over several stands, so that the statistical criteria were met.)

Table 2: Stand Uncertainty Calculation: April 19th

UMBS stands O&F

	LAI			
	original	time-shifted	difference	% difference
	1.28	1.32	0.04	3.13%
	0.98	0.97	-0.01	-1.02%
	1.16	1.06	-0.1	-8.62%
	1.51	1.41	-0.1	-6.62%
	1.16	1.06	-0.1	-8.62%
	0.92	0.98	0.06	6.52%
	0.88	0.98	0.1	11.36%
	1	1.1	0.1	10.00%
	0.98	1.05	0.07	7.14%
	0.71	0.72	0.01	1.41%
	0.68	0.66	-0.02	-2.94%
	0.82	0.74	-0.08	-9.76%
average	1.007	1.004	-0.0025	0.17%
std dev	0.239	0.224	0.0781	7.58%

3.0 DATA

A timetable of LAI observations at Raco and UMBS is given in Table 3 along with the ID's of the Li-Cor instruments used.

Table 3: Measurement Time Table

date	stand	time	sky cal location	sky cal inst	canopy instrument
18-Sep-90	umbs Z	10:26-11:25	umbs softball	wisconsin-	erim-A, wisconsin-B
	umbs Y	11:38-12:04	"	"	"
	umbs J	12:26-12:47	"	"	"
	umbs D	13:02-13:23	"	"	"
	umbs X	14:21-14:42	"	"	"
	umbs B	14:55-15:14	"	"	"
	umbs A	15:25-16:00	"	"	"
	umbs H	16:01-16:19	"	"	"
	umbs R	16:39-16:54	"	"	"
20-Sep-90	umbs C	10:11-10:28	Burt Lake	wisconsin-A	wisconsin-B
	umbs N	10:41-10:58	"	"	"
	umbs P	11:11-11:30	"	"	"
	umbs O	11:53-12:32	"	"	"
	umbs T	14:55-15:17	Plains rd.	"	"
	umbs S	15:25-15:45	"	"	"
	umbs U	15:57-16:14	"	"	"
	umbs V	16:45-17:07	"	"	"
	umbs F	17:37-17:55	"	"	"
	umbs W	18:13-18:33	"	"	"
26-Sep-90	raco S	12:28-13:31	raco ASP	MTU-B	wisconsin:A&B, erim:A
	raco T	14:11-14:36	"	"	"
	raco Q	14:52-15:14	"	"	"
	raco N	15:47-16:15	"	"	"
	raco O	16:23-16:53	"	"	"
	raco V	17:43-18:05	raco airport	MTU-A	"
27-Sep-90	raco D	10:17-10:50	raco airport	MTU-A	wisconsin:A&B, erim:A
	raco U	11:04-11:33	"	"	"
	raco M	12:06-12:35	"	"	"
	raco I	13:47-14:51	raco I	"	"
	raco G	15:25-16:09	raco G	"	"
	raco K	16:22-16:58	"	"	"
18-Apr-91	raco S	15:24-16:15	raco ASP	erim-A	wisconsin-A&B
	raco T	16:24-16:48	"	"	"
	raco Q	17:03-17:29	"	"	"
19-Apr-91	umbs Y	13:20-13:39	umbs softball	erim -A	wisconsin B
	umbs J	13:58-14:15	"	"	"
	umbs H	15:01-15:21	"	"	"
	umbs X	15:24-15:29	"	"	wisconsin A&B
	umbs Z	13:30-13:40	"	"	wisconsin A
	umbs D	14:04-14:30	"	"	"
	umbs A	14:56-15:13	"	"	"
	umbs C	16:21-16:27	"	"	wisconsin A&B
	umbs N	16:40-16:48	Burt Lake	"	"

	umbs P	16:52-16:59	"	"	"
	umbs O	17:10-17:18	"	"	"
	umbs F	18:24-18:42	"	"	"
12-Aug-91	raco T	15:50-17:45	raco ASP	UM-A	UM-B
13-Aug-91	raco S	10:15-12:35	raco ASP	UM-A	UM-B
	raco Q	13:36-15:22	"	"	"
	raco R	17:43-18:51	Lake Sup shore	"	"
14-Aug-91	raco I	9:30-10:46	raco I	UM-A	UM-B
	raco G	11:51-12:52	raco G	"	"
	raco K	13:54-15:04	"	"	"
	raco L	15:49-17:19	"	"	"
	raco M	18:59-19:40	raco M	"	"
15-Aug-91	raco V	9:35-10:32	raco airport	UM-A	UM-B
	raco D	10:44-11:32	"	"	"
	raco U	13:32-14:24	"	"	"
16-Aug-91	raco N	9:44-10:51	raco N	UM-A	UM-B
	raco O	11:02-12:25	"	"	"

3.1 Example of Data from Appendix

A full listing of the calculated LAI and MTA values for each location at each stand listed in Table 3 are given in the Appendix. An example is given in Table 4, for a Jack Pine stand. The table lists LAI and MTA at each location as the average of 3 samples (per location). In this case, 2 instruments (Erim-A and Wisc-B) were used to make the below canopy readings. The two instruments generally agree to within 1%. This small difference shows that the measurements are repeatable and not heavily dependent upon instrument, operator, or time of observation. The stand averages and standard deviations are reported as well as an uncertainty estimate, if the sky background file was time-variant.

Table 4: UMBS Stand B: Jack Pine

Transect	location	September '90			
		erim-A		wisc-B	
		LAI	MTA	LAI	MTA
1	1	3.03	49	3.04	53
1	2	2.48	52	2.52	51
2	1	3.04	46	3.03	46
2	2	2.24	52	2.28	47
3	1	2.03	58	2.01	53
3	2	2.96	56	3.05	57
4	1	2.02	58	1.94	59
4	2	2.28	63	2.15	62
5	1	2.2	57	2.19	57
5	2	2.47	58	2.43	55
MEAN:		2.48	54.90	2.46	54.00
STD DEV:		0.40	5.07	0.43	5.08

3.2 Summary of Results

The stand average values of LAI and MTA are given in Tables 5 to 8 for both the UMBS and Raco stands. Please note that deciduous trees were not foliated during the April 1991 measurement period. Hence, for deciduous stands:

$$LAI_{actual} = LAI_{foliated} - LAI_{April\ '91}$$

For coniferous species, the LAI values given in Tables 5 and 7 should be adjusted for shoot geometry as indicated in Table 1. Note that on dates where no "full canopy" results are shown, only "crown" measurements were made.

Table 5: Leaf Area Index Summary: UMBS

Specie	stand	September '90 A		September '90 B		April '91	
		LAI	std dev	LAI	std dev	LAI	std dev
Red Pine	V	3.06	0.26				
Red Pine Plant.	T	2.52	0.23				
Red Pine Plant.	U	3.45	0.24				
Jack Pine	B	2.48	0.40	2.46	0.43		
Jack Pine Plant.	S	2.79	0.34				
Hardwood Swamp	F	3.85	0.54			0.84	0.13
Hardwood Swamp	W	2.65	0.28				
Hardwood	C	4.72	0.29			1.13	0.09
Hardwood	N	4.54	0.36			1.14	0.16
Red Oak	O	4.27	0.33			1.20	0.14
Red Oak	P	4.73	0.23			1.12	0.16
Good Site Aspen	A	4.16	0.61	4.18	0.61	1.09	0.14
Good Site Aspen	H	3.57	0.49	3.49	0.51	0.93	0.11
Mod. Site Aspen	R	3.52	0.41	3.48	0.37		
Mod. Site Aspen	X	2.81	0.48	2.80	0.53	0.75	0.15
Mod. Site Aspen	Z	2.21	0.25	2.16	0.30	1.05	0.21
Good Site Aspen	H						
Poor Site Aspen	D	2.04	0.34	1.99	0.27	0.84	0.28
Poor Site Aspen	J	2.70	0.49	2.66	0.53	0.63	0.14
Aspen Saplings	Y	1.16	0.60	1.12	0.59	0.37	0.17

Table 6: Mean Tip Angle Summary: UMBS

Specie	stand	September '90 A		September '90 B		April '91	
		MTA	std dev	MTA	std dev	MTA	std dev
Red Pine	V	50.80	6.41				
Red Pine Plant.	T	52.30	7.70				
Red Pine Plant.	U	56.10	3.38				
Jack Pine	B	54.90	5.07	54.00	5.08		
Jack Pine Plant.	S	54.20	3.43				
Hardwood Swamp	F	45.70	6.04			49.90	9.19
Hardwood Swamp	W	53.60	5.48				
Hardwood	C	42.10	2.73			51.90	4.98
Hardwood	N	39.80	2.82			39.90	21.50
Red Oak	O	42.30	5.64			43.10	21.02
Red Oak	P	42.00	2.75			52.50	4.30
Good Site Aspen	A	44.50	5.10	46.30	5.48	67.10	14.29
Good Site Aspen	H	45.90	7.77	44.60	6.93	0.93	0.11
Mod. Site Aspen	R	46.40	6.04	46.40	4.53		
Mod. Site Aspen	X	46.00	5.27	44.80	4.85	58.60	5.74
Mod. Site Aspen	Z	52.00	7.33	51.00	7.45	48.14	8.15
Poor Site Aspen	D	48.80	6.20	47.30	7.60	59.60	11.93
Poor Site Aspen	J	46.50	9.30	46.00	8.67	67.90	12.29
Aspen Saplings	Y	48.70	11.14	50.40	7.60	45.40	22.69

Table 7: Leaf Area Index Summary: Raco

Specie	stand	September '90		April '91		August'91 Crown		August'91 Full Canopy	
		LAI	std dev	LAI	std dev	LAI	std dev	LAI	std dev
Red Pine	D	2.10	0.63			2.16	0.61	2.58	0.44
Red & White Pine	G	3.09	0.44			2.93	0.47	4.00	0.44
Red & White Pine	K	3.00	0.51			2.89	0.51	4.19	0.33
Jack Pine	I	1.93	0.21			2.14	0.25	4.00	0.61
Jack Pine	M	2.23	0.26			2.30	0.25	3.36	0.47
Mature Jack Pine	U	1.13	0.43			1.34	0.65	1.98	0.74
Young Jack Pine	V	0.70	0.42			0.82	0.54	1.39	0.72
Mixed Hardwood	N	4.42	0.43			4.96	0.5	5.33	0.5
Mixed Hardwood	O	4.52	0.44			4.59	0.56	4.99	0.47
Young Hardwood	Q	3.44	0.24	0.96	0.1	4.19	0.31	4.68	0.37
Aspen/Maple	T	3.66	0.33	1.06	0.17	4.31	0.43	4.86	0.45
Young Aspen	S	2.45	0.6	0.70	0.15	2.91	0.52	4.06	0.62
Cedar	R					4.53	0.51	4.88	0.36
Spruce	L					2.00	0.59	3.56	0.59

Table 8: Mean Tip Angle Summary: Raco

Specie	stand	September '90		April '91		August'91			
						Crown		Full Canopy	
		MTA	std dev	MTA	std dev	MTA	std dev	MTA	std dev
Red Pine	D	54.60	10.32			46.94	14.11	48.69	7.58
Red & White Pine	G	50.13	6.59			44.69	5.88	41.78	9.09
Red & White Pine	K	50.18	7.25			45.59	7.92	39.66	8.18
Jack Pine	I	59.88	9.93			58.81	11.11	42.25	4.32
Jack Pine	M	57.00	5.19			59.94	4.63	51.28	7.06
Mature Jack Pine	U	57.74	18.26			46.65	23.83	43.13	18.34
Young Jack Pine	V	68.53	16.36			48.21	20.51	50.30	13.06
Mixed Hardwood	N	42.45	3.43			39.31	6.82	40.27	5.58
Mixed Hardwood	O	43.48	3.84			40.38	8.48	41.17	4.62
Young Hardwood	Q	45.18	3.08	63.55	2.04	46.50	4.89	44.95	4.21
Aspen/Maple	T	41.91	3.56	59.68	4.31	43.35	3.37	43.05	2.55
Young Aspen	S	48.79	5.64	64.07	3.58	55.73	7.70	49.77	7.05
Cedar	R					54.50	6.21	54.30	6.25
Spruce	L					52.59	18.98	46.34	6.44

4.0 REFERENCES

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5.0 APPENDIX

Stands are listed alphabetically by letter name as seen in the Summary. UMBS stands are listed first.

Raco Stand D: Young Red Pines

Transect	Location	September '90		August'91 ***			
		u=0.103		Crown *,**		Full Canopy *	
		LAI	MTA	LAI	MTA	LAI	MTA
1	1	2.07	48	2.76	41	2.58	42
1	2	2.34	57	2.28	60	2.25	61
1	3	2.61	62	2.73	51	2.77	51
1	4	2.76	45	2.89	41	2.95	41
1	5	1.53	58	1.78	46	2.25	45
1	6	2.32	50	2.56	43	2.91	43
1	7	2.42	42	2.41	0	2.85	36
1	8	1.8	63	1.71	40	2.41	49
2	1	1.89	64	2.29	62	2.39	60
2	2	3.19	43	2.85	43	3.09	41
2	3	2.67	59	2.68	57	2.83	53
2	4	2.73	51	2.85	47	3.00	45
2	5	2.62	46	2.75	42	2.96	51
2	6	1.36	45	1.17	39	2.21	42
2	7	2.03	65	2.16	61	2.51	60
2	8	2.28	54	1.98	56	2.31	53
3	1	2.95	38				
3	2	3.35	44				
3	3	2.61	58				
3	4	1.86	43				
3	5	2.27	63				
3	6	2.4	63				
3	7	3.11	42				
3	8	1.97	47				
4	1	1.77	72	2.2	62	2.84	47
4	2	2.45	60	2.37	57	2.8	54
4	3	2.19	59	2.56	54	2.8	47
4	4	1.86	62	1.82	43	2.38	58
4	5	1.97	66	2.88	44	3.26	45
4	6	1.58	74	1.99	72	2.4	58
4	7	1.49	46	2.22	30	2.47	37
4	8	1.10	63	1.49	44	1.99	43
5	1	2.57	43	2.86	37	3.08	39
5	2	1.53	48	1.65	51	2.95	48
5	3	1.71	39	1.94	42	2.22	46
5	4	2.59	40	2.94	37	3.24	40
5	5	0.69	67	0.91	42	1.76	57
5	6	0.74	73	0.93	64	1.3	48
5	7	1.33	63	1.13	70	2.35	64
5	8	1.39	59	1.51	24	2.39	54
MEAN:		2.10	54.60	2.16	46.94	2.58	48.69
STD DEV:		0.63	10.32	0.61	14.11	0.44	7.58

* Full Canopy uncertainity measure = 0.122, Crown uncertianity = 0.255

** Crown LAI determined by measuring 1 meter above ground-cover

*** Only stand means are useful due to time variations in sky calibration.

Raco Stand G: Mature Red & White Pines

Transect	Location	September '90		August'91			
				Crown		Full Canopy	
		LAI	MTA	LAI	MTA	LAI	MTA
1	1	2.65	60	2.32	56	4.09	48
1	2	2.5	47	2.63	44	3.41	43
1	3	2.93	51	2.68	44	3.35	42
1	4	2.57	47	3.01	49	4.05	42
1	5	2.46	57	2.79	43	5.1	35
1	6	2.94	51	2.97	43	4.08	41
1	7	3.05	44	3.21	43	4.81	40
1	8	2.84	45	2.5	43	3.62	48
2	1	2.72	51	2.97	40	4.06	48
2	2	3.04	53	3.34	57	3.75	56
2	3	2.62	44	2.51	44	3.4	46
2	4	2.39	73	2.76	44	4.03	43
2	5	2.74	49	2.1	41	3.78	45
2	6	2.85	52	2.29	44	3.67	0
2	7	3.85	57	2.19	44	3.06	47
2	8	3.21	47	2.65	42	4.06	38
3	1	3.08	47				
3	2	2.80	46				
3	3	3.18	59				
3	4	2.56	61				
3	5	2.86	57				
3	6	3.2	43				
3	7	3.6	53				
3	8	2.83	48				
4	1	3.12	51	2.86	47	4.12	41
4	2	3.15	48	2.81	44	3.41	47
4	3	3.34	51	3.24	48	4.19	36
4	4	3.34	43	2.9	39	4.2	43
4	5	2.81	54	2.63	44	4.16	41
4	6	3.26	59	2.88	58	3.86	46
4	7	3.67	45	3.49	41	4.04	41
4	8	3.10	47	3.25	39	4.43	39
5	1	3.01	46	3.74	38	4.54	43
5	2	3.41	55	3.69	46	4.3	47
5	3	3.86	42	4.16	35	4.38	38
5	4	3.54	48	2.85	44	3.92	38
5	5	2.91	43	3.3	38	4.14	37
5	6	4.12	40	3.47	38	4.48	40
5	7	3.57	47	3.15	56	3.56	56
5	8	4.06	44	2.48	54	3.89	42
MEAN:		3.09	50.13	2.93	44.69	4.00	41.78
STD DEV:		0.44	6.59	0.47	5.88	0.44	9.09

Raco Stand I: High Density Jack Pines

Transect	Location	September '90		August'91 ***			
				Crown		Full Canopy	
		LAI	MTA	LAI	MTA	LAI	MTA
1	1	2.02	43	2.1	42	2.78	34
1	2	1.76	63	1.57	64	3.27	42
1	3	1.91	65	1.9	70	4.51	47
1	4	1.9	59	2.08	59	3.83	38
1	5	1.9	63	1.93	65	4.43	42
1	6	1.66	76	2.02	61	3.97	44
1	7	2.05	54	2.19	49	3.83	41
1	8	1.94	46	1.95	41	3.28	42
2	1	1.97	60	1.78	63	3.87	44
2	2	1.8	62	2.08	55	4.06	42
2	3	1.59	90	2.13	90	3.77	50
2	4	1.85	60	2.01	52	3.69	36
2	5	1.47	64	1.65	66	4.82	41
2	6	1.8	60	2.31	53	4.55	41
2	7	1.81	63	2.34	62	6.1	41
2	8	2.02	69	1.88	90	4.28	51
3	1	1.89	68				
3	2	1.52	67				
3	3	2.17	44				
3	4	1.56	64				
3	5	1.96	52				
3	6	1.98	57				
3	7	1.97	47				
3	8	1.52	80				
4	1	1.99	64	2.08	72	3.84	40
4	2	2.07	58	2.42	57	4.43	40
4	3	2.29	53	2.7	50	4.69	39
4	4	2.20	50	2.38	55	3.65	44
4	5	2.17	58	2.49	52	4.38	46
4	6	1.84	60	1.96	59	3.84	43
4	7	1.95	55	2.23	44	3.86	42
4	8	1.90	60	2.04	55	4.79	30
5	1	1.74	58	2.22	61	3.64	44
5	2	2.01	55	2.29	67	3.31	45
5	3	2.26	53	2.53	49	3.92	41
5	4	2.12	54	2.12	57	3.63	43
5	5	2.1	52	2.19	51	3.49	42
5	6	2.35	49	2.14	53	4.05	42
5	7	1.84	82	2.21	59	3.96	51
5	8	2.15	58	2.43	59	3.49	44
MEAN:		1.93	59.88	2.14	58.81	4.00	42.25
STD DEV:		0.21	9.93	0.25	11.11	0.61	4.32

** only stand means are useful due to time variations in sky calibration.

Raco Stand K: Mature Red & White Pines

Transect	Location	September '90		August'91			
				Crown		Full Canopy	
		LAI	MTA	LAI	MTA	LAI	MTA
1	1	2.8	51	2.31	48	3.63	39
1	2	3.28	53	3.33	50	3.8	48
1	3	3.28	48	3.07	51	4.51	44
1	4	4.16	43	4.25	28	4.71	40
1	5	2.69	48	2.73	40	3.98	15
1	6	2.95	42	2.89	48	3.83	42
1	7	2.62	57	2.34	61	3.69	54
1	8	2.85	46	2.26	43	4.28	27
2	1	2.98	53	2.81	53	4.46	35
2	2	3.38	49	3.07	41	4.11	33
2	3	3.25	49	2.46	53	3.53	55
2	4	3.82	42	3.76	37	4.24	36
2	5	3.61	46	3.78	40	4.63	42
2	6	2.97	52	2.38	43	3.97	49
2	7	3.12	46	2.9	31	4.4	37
2	8	2.55	61	2.15	56	4.09	41
3	1	2.23	66				
3	2	2.43	60				
3	3	2.80	49				
3	4	3.19	40				
3	5	2.81	56				
3	6	3.26	44				
3	7	2.85	44				
3	8	3.16	49				
4	1	3.42	42	3.04	38	4.07	35
4	2	1.89	62	2.02	55	4.54	38
4	3	2.99	52	2.71	44	4.26	36
4	4	3.17	49	2.93	43	4.25	43
4	5	2.78	62	3.07	55	4.4	43
4	6	4.30	41	3.66	37	3.99	38
4	7	3.50	48	3.09	41	3.99	39
4	8	3.11	44	2.71	41	4.28	25
5	1	2.01	70	2.57	60	3.79	53
5	2	2.74	44	3.29	43	4.91	32
5	3	2.59	49	2.37	43	4.08	39
5	4	3.16	42	3.12	41	4.57	42
5	5	2.51	58	2.7	43	4.17	39
5	6	2.42	51	2.51	45	4.52	39
5	7	3.55	52	3.12	53	4.38	46
5	8	3.01	47	3.01	54	3.97	45
MEAN:		3.00	50.18	2.89	45.59	4.19	39.66
STD DEV:		0.51	7.25	0.51	7.92	0.33	8.18

Raco Stand L: Black Spruce Wetland

Transect	Location	August'91			
		Crown		Full Canopy	
		LAI	MTA	LAI	MTA
1	1	1.69	57	2.4	49
1	2	2.49	43	3.13	38
1	3	1.29	90	3.42	45
1	4	2.14	39	2.63	46
1	5	1.28	67	3.28	44
1	6	2.07	51	4.25	45
1	7	1.46	65	3.81	45
1	8	1.65	0	4.21	44
2	1	1.7	66	3.08	44
2	2	2.42	42	3.28	41
2	3	1.92	33	2.97	34
2	4	1.73	42	3.58	43
2	5	1.91	57	3.88	47
2	6	1.82	71	3.57	48
2	7	2.14	16	3.95	41
2	8	1.17	46	2.97	54
3	1				
3	2				
3	3				
3	4				
3	5				
3	6				
3	7				
3	8				
4	1	2.47	66	3.91	40
4	2	0.77	58	2.62	57
4	3	1.51	54	3.05	44
4	4	1.81	90	3.38	56
4	5	2.33	65	3.53	63
4	6	2.58	64	3.91	42
4	7	3.38	45	3.91	44
4	8	2.24	63	4.26	46
5	1	1.74	58	3.2	56
5	2	1.32	60	2.9	45
5	3	2.14	56	3.65	48
5	4	3.35	41	4.95	37
5	5	3.08	53	3.98	48
5	6	1.98	15	4.5	42
5	7	2.14	62	3.8	58
5	8	2.16	48	4.1	49
MEAN:		2.00	52.59	3.56	46.34
STD DEV:		0.59	18.98	0.59	6.44

Raco Stand M: Jack Pine Plantation

Transect	Location	September '90		August'91			
		u=0.096		Crown		Full Canopy	
		LAI	MTA	LAI	MTA	LAI	MTA
1	1	2.48	62	2.21	64	3.61	40
1	2	2.59	59	2.1	60	3.92	44
1	3	2.21	62	2.19	65	3.86	55
1	4	2.36	57	2.11	61	3.22	51
1	5	2.3	63	2.36	62	3.31	48
1	6	2.2	55	2.23	59	3	62
1	7	2.61	54	2.11	58	3	42
1	8	2.55	63	2.56	58	3.59	46
2	1	2.27	48	2.09	53	3.12	58
2	2	2.63	61	2.53	62	3.93	58
2	3	1.96	56	2.23	59	2.68	59
2	4	1.89	60	1.84	63	2.71	49
2	5	2.08	60	2.33	61	3.36	55
2	6	2.65	48	3	49	3.92	50
2	7	2.49	44	2.78	42	3.27	47
2	8	2.22	58	2.6	63	3.73	58
3	1	2.00	57				
3	2	2.06	60				
3	3	1.83	63				
3	4	2.07	60				
3	5	2.69	43				
3	6	2.36	60				
3	7	2.9	46				
3	8	2.16	60				
4	1	2.28	53	2.51	58	3.25	51
4	2	2.02	53	2.4	60	2.96	48
4	3	2.24	60	2.44	61	3.94	61
4	4	2.06	55	2.17	61	3.12	53
4	5	1.82	57	1.9	62	3.79	42
4	6	2.00	59	2.37	66	3.51	41
4	7	2.15	58	2.38	61	3.67	48
4	8	2.15	54	2.14	58	2.47	60
5	1	2.11	60	2.29	62	3.71	44
5	2	2.05	56	2.05	60	3	47
5	3	2.19	58	2.33	62	2.95	61
5	4	1.97	60	1.99	62	4.18	44
5	5	2.11	57	2.45	61	2.79	61
5	6	1.93	63	2.07	63	2.92	57
5	7	2.36	55	2.59	58	2.96	59
5	8	2.27	63	2.34	64	4.19	42
MEAN:		2.23	57.00	2.30	59.94	3.36	51.28
STD DEV:		0.26	5.19	0.25	4.63	0.47	7.06

Raco Stand N: Mature Northern Hardwoods

Transect	Location	September '90		August'91 ***			
				Crown u=0.165		Full Canopy *	
		LAI	MTA	LAI	MTA	LAI	MTA
1	1	4.25	42	4.58	44	5	43
1	2	4.71	43	4.78	37	4.89	39
1	3	4.56	42	5.52	44	5.59	44
1	4	4.8	44	5.4	47	5.67	45
1	5	3.97	35	4.71	38	5.75	42
1	6	4.63	49	5.59	43	5.86	43
1	7	4.25	46				
1	8	4.56	38				
2	1	4.85	42	4.78	37	5.27	39
2	2	4.51	42	4.95	41	4.96	43
2	3	5.29	41	5.65	40	6.26	40
2	4	4.74	47	4.87	46	5.19	48
2	5	4.77	43	4.87	35	5.2	35
2	6	5.11	41	5.26	43	5.65	39
2	7	4.99	45	5.48	39	5.79	43
2	8	5.19	41				
3	1	4.49	41				
3	2	4.86	41				
3	3	4.82	40				
3	4	4.61	41				
3	5	3.91	47				
3	6	4.66	41				
3	7	4.67	40				
3	8	4.72	45				
4	1	4.41	36	5.16	30	5.71	34
4	2	3.94	45	4.96	40	5.22	43
4	3	4.51	43	5.87	32	5.88	18
4	4	4.19	36	4.27	13	4.5	37
4	5	4.09	41	5.11	40	5.11	37
4	6	3.98	41	4.45	41	4.52	41
4	7	3.80	43				
4	8	4.51	48				
5	1	3.56	41	4.36	39	5.19	41
5	2	4.19	42	4.92	38	5.57	40
5	3	3.91	42	3.85	41	4.04	41
5	4	3.81	50	4.18	45	5.04	47
5	5	3.63	45	4.89	40	5.46	42
5	6	4.07	48	4.97	48	5.7	42
5	7	4.24	38	5.59	41	5.63	41
5	8	4.20	42				
MEAN:		4.42	42.45	4.96	39.31	5.33	40.27
STD DEV:		0.43	3.43	0.50	6.82	0.50	5.58

* Full Canopy uncertainty measure = 0.146

*** only stand means are useful due to time variations in sky calibration.

Raco Stand O: Mature Northern Hardwoods

Transect	Location	September '90		August'91 ***			
				Crown u=0.125		Full Canopy *	
		LAI	MTA	LAI	MTA	LAI	MTA
1	1	4.54	49	4.28	6	4.6	33
1	2	4.4	42	5.34	36	5.55	34
1	3	4.34	49	4.72	44	5.44	45
1	4	4.08	43	4.03	48	4.43	46
1	5	4.07	43	4.04	47	4.09	44
1	6	3.99	50	4.42	44	4.79	43
1	7	4.87	41				
1	8	3.78	42				
2	1	4.41	53	4.11	49	4.89	44
2	2	4.7	42	4.01	37	4.59	41
2	3	4.68	43	3.85	45	4.23	47
2	4	4.38	47	3.64	51	4.18	49
2	5	4.66	40	5.07	42	5.56	44
2	6	4.7	41	4.9	36	5.31	38
2	7	5.15	42				
2	8	4.71	44				
3	1	4.52	43				
3	2	4.85	56				
3	3	5.23	41				
3	4	5.07	44				
3	5	5.07	38				
3	6	4.86	41				
3	7	4.8	39				
3	8	4.8	43				
4	1	4.43	43	5.01	43	5.04	41
4	2	4.18	40	4.56	42	4.82	41
4	3	4.77	40	5.21	40	5.53	40
4	4	4.21	43	4.61	42	5	44
4	5	4.19	42	4.4	41	4.89	41
4	6	5.39	41	5.05	41	5.45	41
4	7	4.33	43				
4	8	3.93	42				
5	1	4.04	44	4.68	42	5.23	42
5	2	5.08	40	5.02	37	5.12	38
5	3	4.08	43	4.24	36	5.21	28
5	4	3.61	45	3.95	43	4.66	42
5	5	4.85	43	5.9	42	5.62	39
5	6	4.99	42	5.1	35	5.52	43
5	7	4.20	41				
5	8	3.75	51				
MEAN:		4.52	43.48	4.59	40.38	4.99	41.17
STD DEV:		0.44	3.84	0.56	8.48	0.47	4.62

* Full Canopy Uncertainty Measure = 0.143

*** only stand means are useful due to time variations in sky calibration.

Raco Stand Q: Young Northern Hardwoods*

Transect	Location	September '90		April '91		August'91			
						Crown		Full Canopy	
		LAI	MTA	LAI	MTA	LAI	MTA	LAI	MTA
1	1	3.57	42	1.04	62	4.87	41	4.66	41
1	2	3.55	45	1.05	65	4.89	44	5.52	44
1	3	3.42	49	1.06	65	4.52	54	5.12	56
1	4	3.55	46	0.92	64	4.32	44	4.58	45
1	5	3.52	48	1.04	64	4.45	52	5.09	52
1	6	3.44	44	0.89	64	4.24	43	4.44	44
1	7	3.54	41	0.89	65	4.48	40	5.46	42
1	8	3.4	42	0.9	62	4.32	38	4.59	37
2	1	3.36	49	0.98	64	3.79	48	4.58	43
2	2	4.06	42	0.77	62	4.11	45	5.41	41
2	3	3.45	46	1.01	65	4.02	50	4.6	51
2	4	3	48	1.02	68	3.94	45	4.85	41
2	5	3.18	43	1.06	63	4.21	42	4.8	42
2	6	3.47	42	0.97	66	4.44	42	4.84	41
2	7	3.08	44	0.94	68	3.67	49	3.81	42
2	8	4.07	41	0.81	65	4.35	42	4.87	43
3	1	3.61	46	0.95	64	3.53	58	4.36	51
3	2	3.81	44	0.94	63	3.86	46	4.38	42
3	3	3.63	43	1.03	65	4.48	42	4.61	44
3	4	3.61	50	0.82	64	4.32	53	4.91	50
3	5	3.13	48	0.96	65	4.19	47	5.25	42
3	6	3.16	48	0.83	63	4.29	49	4.21	48
3	7	3.27	46	0.81	66	3.9	54	4.82	48
3	8	3.17	50	0.69	67	4.03	50	4.98	40
4	1	3.25	45	1.00	62	4.01	43	4.64	43
4	2	3.48	43	0.93	63	4.76	42	4.94	44
4	3	3.43	41	0.94	62	4.38	41	4.45	41
4	4	3.18	44	0.96	63	4.31	42	4.92	47
4	5	3.38	54	1.01	65	4.03	58	4.52	53
4	6	3.21	44	0.94	63	3.83	47	4.39	44
4	7	3.31	47	0.99	58	4.01	49	4.29	48
4	8	3.23	48	0.86	60	4.24	50	4.75	47
5	1	3.59	44	1.11	62	4.3	47	4.51	47
5	2	3.29	50	0.94	64	3.86	53	4.31	51
5	3	3.27	46	0.98	62	3.74	47	4.31	40
5	4	3.62	43	1.06	63	4.21	47	4.69	47
5	5	3.43	44	1.06	62	3.99	45	4.15	43
5	6	3.46	42	1.12	62	3.97	42	4.15	42
5	7	3.63	43	1.09	61	4.52	47	4.66	48
5	8	3.68	42	1.01	61	4.39	42	4.74	43
MEAN:		3.44	45.18	0.96	63.55	4.19	46.50	4.68	44.95
STD DEV:		0.24	3.08	0.10	2.04	0.31	4.89	0.37	4.21

* For deciduous trees, actual LAI = observed LAI - April '91 LAI

Raco Stand R: Cedar Wetland

Transect	Location	August'91			
		Crown		Full Canopy	
		LAI	MTA	LAI	MTA
1	1	4.73	62	5.21	60
1	2	4.41	49	4.41	49
1	3	4.58	60	4.58	60
1	4	5.57	52	5.57	52
1	5	4.4	56	4.4	56
1	6	4.27	52	4.27	52
1	7	5.26	61	5.26	61
1	8	4.09	41	4.66	39
2	1	4.87	61	5.48	62
2	2	3.91	50	4.7	52
2	3	5.51	52	5.65	50
2	4	3.58	40	5.03	42
2	5	4.29	49	4.44	55
2	6	4.04	60	4.65	67
2	7	3.72	42	5.06	45
2	8	3.63	62	4.15	64
3	1	4.77	54	4.66	54
3	2	4.12	52	5.09	49
3	3	4.18	45	4.67	45
3	4	5.15	59	5.09	54
3	5	4.53	48	4.77	49
3	6	3.5	53	4.83	46
3	7	4.58	52	5.07	50
3	8	4.77	58	4.95	55
4	1	4.68	58	4.64	60
4	2	4.57	58	4.52	58
4	3	4.48	50	4.52	52
4	4	4.2	59	4.77	60
4	5	4.84	53	4.97	50
4	6	4.49	65	5.29	57
4	7	4.97	55	5.04	56
4	8	4.76	58	4.81	58
5	1	4.33	52	4.44	52
5	2	3.84	67	4.53	67
5	3	4.53	55	5.21	55
5	4	4.69	55	5.09	55
5	5	5.14	56	5.19	56
5	6	4.69	53	4.86	54
5	7	5.31	54	5.44	54
5	8	5.07	62	5.06	60
MEAN:		4.53	54.50	4.88	54.30
STD DEV:		0.51	6.21	0.36	6.25

Raco Stand S: Aspen Saplings (good site)*

Transect	Location	September '90		April '91		August'91			
						Crown		Full Canopy	
		LAI	MTA	LAI	MTA	LAI	MTA	LAI	MTA
1	1	0.71	41	0.27	70	2.63	50	3.41	52
1	2	1.35	56	0.47	69	2.95	49	3.65	54
1	3	1.47	59	0.54	70	2.48	59	3.23	62
1	4	1.52	53	0.87	61	3.48	50	4.46	43
1	5	2.04	48	0.74	64	2.64	64	4.21	39
2	1	2.06	55			3.25	55	4.36	52
2	2	2.10	59			2.83	45	4.26	42
2	3	2.12	48			3.44	43	4	46
2	4	2.17	58	0.85	61	3.4	55	4.67	44
2	5	2.23	56			3.35	53	3.56	56
3	1	2.35	42	0.81	61	3.22	52	4.28	45
3	2	2.33	52			2.76	62	3.92	61
3	3	2.33	52	0.75	63	3.24	58	4.46	44
3	4	2.26	56			3.06	46	4.22	53
3	5	2.25	52			3.26	60	4.41	42
4	1	2.42	50	0.69	70				
4	2	2.38	51	0.5	70	2.8	61	3.38	57
4	3	2.39	40	0.90	67	2.9	66	3.95	56
4	4	2.40	44	0.90	62	2.75	64	4.2	54
4	5	2.41	45			2.66	63	3.53	46
5	1	2.43	44	0.69	62	2.9	57	4.59	50
5	2	2.45	47	0.55	66	3.05	43	4.98	39
5	3	2.47	49	0.78	65	1.7	61	3.71	46
5	4	2.5	55	0.68	65	1.45	37	2.4	55
5	5	2.50	42	0.79	63	1.81	66	2.74	67
7	1	2.52	54	0.88	61				
7	2	2.51	41	0.7	59				
8	1	2.59	52	0.73	57				
8	2	2.63	44	0.96	63				
8	3	2.94	49	0.72	62				
9	1	3.25	43	0.57	62	2.72	63	4.06	47
9	2	3.38	43	0.74	64	3.38	59	5.04	47
9	3	3.39	44	0.63	66	3.13	62	4.47	54
9	4	3.78	46	0.73	59				
10	1	3.03	44	0.66	69	3.56	53	4.5	53
10	2	3.15	45	0.67	64	3.29	63	4.89	43
10	3	3.19	52	0.63	65	3.23	53	4.12	44
10	4	3.21	43	0.71	62				
MEAN:		2.45	48.79	0.70	64.07	2.91	55.73	4.06	49.77
STD DEV:		0.60	5.64	0.15	3.58	0.52	7.70	0.62	7.05

* For deciduous trees, actual LAI = observed LAI - April '91 LAI

Raco Stand T: Mature Aspen/Maple (good site) *

Transect	Location	September '90		April '91		August'91			
						Crown		Full Canopy	
		LAI	MTA	LAI	MTA	LAI	MTA	LAI	MTA
1	1	3.7	32	0.8	58	4.18	41	5.19	43
1	2	3.43	41	0.92	63	4.49	41	4.84	45
1	3	3.12	43	0.96	60	4.15	42	4.78	44
1	4	3.81	41	1.34	45	5.36	40	5.67	42
1	5	3.64	44	0.94	58	4.18	43	5.02	43
1	6	3.16	45	1.03	56	4.26	46	5.21	44
1	7	2.81	45	0.83	60	3.35	50	4.11	46
1	8	4.12	40	0.87	56	3.52	41	3.94	41
2	1	3.86	40	0.93	62	4.34	43	4.37	41
2	2	3.44	45	1.11	55	4.21	46	5.29	48
2	3	3.09	49	0.92	65	3.67	44	4.87	41
2	4	3.47	49	1.13	62	4.14	49	4.81	50
2	5	3.89	38	1.24	53	5.01	37	5.41	41
2	6	4.06	41	0.91	66	5.1	44	5.47	46
2	7	3.78	40	0.84	62	4.31	41	4.43	42
2	8	3.94	42	0.99	63	4.11	48	4.51	49
3	1	3.96	40	0.90	59	4.32	42	4.7	44
3	2	4.01	41	0.85	59	4.76	41	4.89	42
3	3	3.78	45	1.08	61	4.73	43	4.98	43
3	4	3.79	41	1.05	57	4.7	40	5.22	42
3	5	4.05	40	1.31	58	5.23	42	5.68	43
3	6	3.13	45	1.09	55	4.29	45	5.15	40
3	7	4.08	37	1.07	60	4.37	42	4.73	42
3	8	4.08	34	1.05	52	4.34	40	4.54	39
4	1	3.74	43	1.17	63	4.61	49	4.7	47
4	2	3.55	40	1.15	61	3.81	41	4.09	42
4	3	3.79	39	1.27	61	4.21	41	4.75	42
4	4	3.53	42	1.54	61	4.32	41	4.96	43
4	5	3.68	45	1.22	62	4.31	47	5.03	43
4	6	3.32	45	1.23	66	4.29	48	5.69	42
4	7					4.01	41	4.39	41
4	8					4.39	38	4.58	39
5	1	3.45	44	0.94	63	3.81	44	4.2	45
5	2	3.67	44	1.21	62	3.97	45	4.59	42
5	3	3.77	43	1.12	61	4.31	50	5.1	43
5	4	3.80	42	1.16	64	4.16	47	5.33	43
5	5					4.17	41	4.72	40
5	6								
5	7								
5	8								
MEAN:		3.66	41.91	1.06	59.68	4.31	43.35	4.86	43.05
STD DEV:		0.33	3.56	0.17	4.31	0.43	3.37	0.45	2.55

* For deciduous trees, actual LAI = observed LAI - April '91 LAI

Raco Stand U: Mature Jack Pines

Transect	Location	September '90		August'91 ***			
				Crown u=0.292		Full Canopy *	
		LAI	MTA	LAI	MTA	LAI	MTA
1	1	1.87	51	1.75	51	2.51	38
1	2	0.96	45	0.57	11	0.74	28
1	3	0.61	87	0.31	62	0.69	54
1	4	1.22	60	1	63	1.83	40
1	5	0.48	63	0	x	1.08	41
1	6	1.2	45	2.01	40	1.54	41
1	7	1.35	72	1.71	66	1.72	71
1	8	0.68	71	0.55	57	0.71	40
2	1	1.25	71				
2	2	1.52	40				
2	3	0.91	63				
2	4	0.75	58				
2	5	1.37	63				
2	6	1.16	43				
2	7	0.74	52				
2	8	0.89	45				
3	1	1.34	68	1.46	56	2.2	57
3	2	0.94	90	1.21	64	1.69	55
3	3	0.50	90	0.71	49	1.03	53
3	4	1.00	90	1.07	67	1.28	65
3	5	0.61	71	0.67	90	1.76	69
3	6	1.08	60	1.44	59	1.83	52
3	7	1.48	0	1.42	0	2.14	0
3	8	0.84	45	1.42	59	2.39	38
4	1	2.23	53	1.53	41	2.56	40
4	2	0.96	46	1.26	34	2.09	41
4	3	1.66	31	1.79	0	2.91	0
4	4	1.91	48	2.89	55	2.87	44
4	5	1.25	66	1.61	57	1.88	55
4	6	0.72	66	0.81	48	1.7	18
4	7	0.86	64	1.5	54	1.99	45
4	8	1.81	46	1.78	43	2.39	47
5	1	1.51	38	2.42	30	3.76	38
5	2	1.23	41	2.53	0	2.91	18
5	3	0.56	67	0.84	90	1.22	90
5	4	0.64	84	1.43	37	1.55	43
5	5	1.1	51	1.51	55	2.36	49
5	6	1.61	50	2.03	45	2.61	34
5	7			0.73	0	3.11	41
5	8	0.90	43	1.06	63	2.36	35
MEAN:		1.13	57.74	1.34	46.65	1.98	43.13
STD DEV:		0.43	18.26	0.65	23.83	0.74	18.34

* Full Canopy u=0.180

x: LAI of zero invalidates mean tip angle information

*** only stand means are useful due to variations in sky calibration.

Raco Stand V: Young Jack Pines

Transect	Location	September '90		August'91 ***			
				Crown u=0.370		Full Canopy *	
		LAI	MTA	LAI	MTA	LAI	MTA
1	1	0.56	64	0.63	63	1.06	56
1	2	0.86	66	1.07	47	1.15	28
1	3	0.64	26	1.48	41	2.31	42
1	4	0.23	52	0.78	45	1.43	56
1	5	0.1	53	0.38	1	0.71	40
1	6	1.02	59	1	58	1.6	55
1	7	0.17	62	0.43	90	1.23	61
1	8	0.5	90	0	x	0	x
2	1	0.59	76	1.16	30	1.34	39
2	2	0.83	83	0.97	56	2.16	42
2	3	0.39	90	0.55	0	1.21	47
2	4	0.98	62	1.13	43	2.07	41
2	5	0.39	74	0	x	0.8	59
2	6	0.49	90	0	x	0	x
2	7	0.64	87	0	x	1.48	50
2	8	0.89	51	2.03	54	2.62	43
3	1	1.11	60				
3	2	1.84	42				
3	3	1.62	66				
3	4	1.10	61				
3	5	1.1	63				
3	6	0.36	74				
3	7	0.37	83				
3	8	0.34	77				
4	1	1.14	59	1.55	42	2.68	46
4	2	0.46	58	0.81	20	0.99	5
4	3	1.22	65	1.27	63	2.47	51
4	4	0.48	61	0.95	50	1.52	63
4	5	0.14	90	0.13	39	0.44	53
4	6	1.30	43	1.29	43	2.44	54
4	7	0.60	90	0.72	70	0.97	70
4	8	0.52	59	0.59	47	1.53	47
5	1	0.46	90	1.17	40	1.41	44
5	2	0.18	90	1.74	43	2.42	47
5	3	0.27	90	1.26	73	1.71	66
5	4	1.13	58	1.3	52	1.44	56
5	5	1.18	61	0.71	44	0.92	60
5	6	1.03	49	0.34	48	0.92	66
5	7	0.62	77	0.26	90	0.48	68
5	8	0.28	90	0.59	58	0.89	54
MEAN:		0.70	68.53	0.82	48.21	1.39	50.30
STD DEV:		0.42	16.36	0.54	20.51	0.72	13.06

* Full Canopy u=0.410

x: LAI of zero invalidates mean tip angle information

*** only stand means are useful due to time variations in sky calibration.

UMBS Stand A: Good Site Aspen *

Transect	Location	September '90 u=0.131				April '91	
		erim-A		wisc-B		u=0.107	
		LAI	MTA	LAI	MTA	LAI	MTA
1	1	5.33	40	5.32	40	1.37	57
1	2	3.78	48	3.51	52	1.22	64
2	1	4.3	40	4.39	57	1	75
2	2	4.41	55	4.41	42	1.2	49
3	1	4.42	45	4.46	49	1	90
3	2	4.51	39	4.57	41	1.13	57
4	1	3.24	41	3.9	48	0.9	90
4	2	3.86	46	3.33	44	1.03	56
5	1	4.38	42	4.4	42	0.98	72
5	2	3.41	49	3.5	48	1.02	61
MEAN:		4.16	44.50	4.18	46.30	1.09	67.10
STD DEV:		0.61	5.10	0.61	5.48	0.14	14.29

UMBS Stand B: Jack Pine

Transect	Location	September '90			
		erim-A		wisc-B	
		LAI	MTA	LAI	MTA
1	1	3.03	49	3.04	53
1	2	2.48	52	2.52	51
2	1	3.04	46	3.03	46
2	2	2.24	52	2.28	47
3	1	2.03	58	2.01	53
3	2	2.96	56	3.05	57
4	1	2.02	58	1.94	59
4	2	2.28	63	2.15	62
5	1	2.2	57	2.19	57
5	2	2.47	58	2.43	55
MEAN:		2.48	54.90	2.46	54.00
STD DEV:		0.40	5.07	0.43	5.08

* For deciduous trees, actual LAI = observed LAI - April '91 LAI

UMBS Stand C: Northern Hardwoods *

Transect	Location	September '90		April '91	
		LAI	MTA	LAI	MTA
1	1	4.74	41	0.95	58
2	1	4.41	49	1.14	54
2	2	5.26	41	1.12	57
2	3	4.81	42	1.2	52
3	1	4.99	41	1.21	44
3	2	4.41	42	1.09	54
4	1	4.48	44	1.27	53
4	2	4.46	41	1.13	54
5	1	4.66	41	1.1	43
5	2	4.99	39	1.13	50
MEAN:		4.72	42.10	1.13	51.90
STD DEV:		0.29	2.73	0.09	4.98

UMBS Stand D: Poor Site Aspen *

Transect	Location	September '90				April '91	
		erim-A		wisc-B		u=0.134	
		LAI	MTA	LAI	MTA	LAI	MTA
1	1	2.57	45	2.33	42		
1	2	1.6	47	1.67	45		
2	1	2.18	50	2.08	48		
2	2	2.33	50	2.15	44		
3	1	2.38	43	2.41	43		
3	2	2.13	39	2.09	33	0.96	42
4	1	1.62	56	1.7	56	0.59	75
4	2	1.92	46	1.89	53	1.25	58
5	1	1.92	52	1.89	50	0.6	59
5	2	1.71	60	1.66	59	0.81	64
MEAN:		2.04	48.80	1.99	47.30	0.84	59.60
STD DEV:		0.34	6.20	0.27	7.60	0.28	11.93

* For deciduous trees, actual LAI = observed LAI - April '91 LAI

UMBS Stand F: Hardwood Swamp *

Transect	Location	September '90		April '91	
				u=0.078	
		LAI	MTA	LAI	MTA
1	1	3.15	47	0.9	44
1	2	3	41	0.9	53
2	1	3.45	58	0.98	51
2	2	3.54	48	0.75	65
3	1	4.06	52	0.71	60
3	2	3.92	39	0.72	40
4	1	4.08	48	0.68	37
4	2	4.57	41	1.07	52
5	1	4.48	42	0.82	41
5	2	4.23	41	0.85	56
MEAN:		3.85	45.70	0.84	49.90
STD DEV:		0.54	6.04	0.13	9.19

UMBS Stand H: Good Site Aspen *

Transect	Location	September '90				April '91	
		erim-A		wisc-B		u=0.134	
		LAI	MTA	LAI	MTA	LAI	MTA
1	1	3.26	54	3.32	51	0.82	90
1	2	3.33	60	3.11	57	0.76	87
2	1	3.92	41	3.86	42	1.03	59
2	2	4	56	3.93	54	0.94	76
3	1	3.56	42	3.52	40	1.12	53
3	2	4.31	38	4.22	36	0.95	59
4	1	3.36	45	3.33	43	0.93	57
4	2	3.45	42	3.32	42	1.03	52
5	1	2.59	41	2.43	42	0.81	52
5	2	3.93	40	3.86	39	0.91	49
MEAN:		3.57	45.90	3.49	44.60	0.93	63.40
STD DEV:		0.49	7.77	0.51	6.93	0.11	15.20

* For deciduous trees, actual LAI = observed LAI - April '91 LAI

UMBS Stand J: Poor Site Aspen *

Transect	Location	September '90				April '91	
		erim-A		wisc-B		u=0.134	
		LAI	MTA	LAI	MTA	LAI	MTA
1	1	3.04	42	2.84	44	0.64	59
1	2	2.07	62	1.99	62	0.51	68
2	1	2.59	41	2.5	39	0.58	63
2	2	3.01	44	2.96	42	0.98	63
3	1	3.12	41	3.16	40	0.68	70
3	2	2.62	51	2.54	49	0.52	55
4	1	2.28	62	2.31	60	0.63	90
4	2	1.94	44	1.85	43	0.55	65
5	1	2.84	45	2.9	45	0.52	89
5	2	3.46	33	3.56	36	0.73	57
MEAN:		2.70	46.50	2.66	46.00	0.63	67.90
STD DEV:		0.49	9.30	0.53	8.67	0.14	12.29

UMBS Stand N: Northern Hardwoods *

Transect	Location	September '90		April '91	
		LAI	MTA	LAI	MTA
1	1	4.75	38	1.34	0
1	2	5	39	1.16	47
2	1	4.25	38	1.07	51
2	2	4.8	41	1.25	47
3	1	4.99	36	1.16	54
3	2	4.64	43	1.1	49
4	1	4.22	38	1.39	0
4	2	4.16	45	0.95	59
5	1	3.98	38	0.89	50
5	2	4.6	42	1.06	42
MEAN:		4.54	39.80	1.14	39.90
STD DEV:		0.36	2.82	0.16	21.50

* For deciduous trees, actual LAI = observed LAI - April '91 LAI

UMBS Stand O: Northern Red Oak *

Transect	Location	September '90		April '91	
		LAI	MTA	LAI	MTA
1	1	3.69	43	1.16	50
1	2	3.92	43	1.28	0
2	1	4.18	50	1.22	59
2	2	3.89	47	0.98	46
3	1	4.43	42	1.16	57
3	2	4.45	41	1.16	8
4	1	4.41	43	1.13	55
4	2	4.69	29	1.51	50
5	1	4.56	46	1.24	53
5	2	4.47	39	1.16	53
MEAN:		4.27	42.30	1.20	43.10
STD DEV:		0.33	5.64	0.14	21.02

UMBS Stand P: Northern Red Oak *

Transect	Location	September '90		April '91	
		u=0.110			
		LAI	MTA	LAI	MTA
1	1	5.22	38	1.01	45
1	2	4.71	40	1.5	54
2	1	4.58	40	1.04	47
2	2	4.52	47	1.18	54
3	1	5.04	45	1.12	56
3	2	4.63	41	1.05	55
4	1	4.67	43	1.07	49
4	2	4.59	44	1.09	54
5	1	4.8	42	0.91	52
5	2	4.52	40	1.2	59
MEAN:		4.73	42.00	1.12	52.50
STD DEV:		0.23	2.75	0.16	4.30

* For deciduous trees, actual LAI = observed LAI - April '91 LAI

UMBS Stand R: Moderate Site Aspen *

Transect	Location	September '90			
		erim-A		wisc-B	
		LAI	MTA	LAI	MTA
1	1	3.82	46	3.69	43
1	2	3.31	37	3.31	46
2	1	3.34	49	3.59	48
2	2	2.56	49	2.57	46
3	1	4.07	44	3.84	47
3	2	3.44	59	3.34	57
4	1	3.79	48	3.77	45
4	2	3.71	40	3.56	42
5	1	3.72	49	3.75	49
5	2	3.46	43	3.36	41
MEAN:		3.52	46.40	3.48	46.40
STD DEV:		0.41	6.04	0.37	4.53

UMBS Stand S: Jack Pine Plantation

Transect	Location	September '90	
		LAI	MTA
1	1	3.08	50
1	2	2.8	51
2	1	3.1	56
2	2	2.67	51
3	1	3.07	56
3	2	2.03	61
4	1	3.11	56
4	2	2.5	55
5	1	2.85	51
5	2	2.72	55
MEAN:		2.79	54.20
STD DEV:		0.34	3.43

* For deciduous trees, actual LAI = observed LAI - April '91 LAI

UMBS Stand T: Red Pine Plantation

Transect	Location	September '90	
		LAI	MTA
1	1	2.42	52
1	2	2.94	38
2	1	2.29	57
2	2	2.85	42
3	1	2.53	57
3	2	2.4	60
4	1	2.54	48
4	2	2.34	62
5	1	2.66	52
5	2	2.24	55
MEAN:		2.52	52.30
STD DEV:		0.23	7.70

UMBS Stand U: Red Pine Plantation

Transect	Location	September '90	
		LAI	MTA
1	1	3.49	56
1	2	3.24	54
2	1	3.77	59
2	2	3.51	54
3	1	3.72	59
3	2	3.4	56
4	1	3.49	57
4	2	3.68	54
5	1	3.05	62
5	2	3.17	50
MEAN:		3.45	56.10
STD DEV:		0.24	3.38

UMBS Stand V: Red Pine

Transect	Location	September '90	
		LAI	MTA
1	1	3	52
1	2	3.06	55
2	1	2.9	59
2	2	2.89	53
3	1	2.82	52
3	2	3.07	60
4	1	3.63	42
4	2	3.42	43
5	1	2.84	44
5	2	2.95	48
MEAN:		3.06	50.80
STD DEV:		0.26	6.41

UMBS Stand W: Hardwood Swamp

Transect	Location	September '90	
		u=0.152	
		LAI	MTA
1	1	2.72	49
1	2	2.3	48
2	1	2.46	63
2	2	2.73	48
3	1	2.52	56
3	2	2.61	48
4	1	2.71	61
4	2	2.95	56
5	1	3.2	54
5	2	2.32	53
MEAN:		2.65	53.60
STD DEV:		0.28	5.48

UMBS Stand X: Moderate Site Aspen *

Transect	Location	September '90				April '91	
		erim-A		wisc-B		u=0.134	
		LAI	MTA	LAI	MTA	LAI	MTA
1	1	2.96	41	2.98	41	0.8	64
1	2	2.43	51	2.36	50	0.57	65
2	1	2.34	56	2.31	55	0.84	61
2	2	1.91	44	1.86	43	0.5	50
3	1	3.37	41	3.38	41	0.98	54
3	2	2.61	48	2.45	45	0.62	58
4	1	3.13	41	3.3	40	0.89	62
4	2	3.38	42	3.42	41	0.75	49
5	1	3.03	45	3.06	44	0.84	63
5	2	2.93	51	2.9	48	0.67	60
MEAN:		2.81	46.00	2.80	44.80	0.75	58.60
STD DEV:		0.48	5.27	0.53	4.85	0.15	5.74

UMBS Stand Y: Aspen Saplings (1980 burn) *

Transect	Location	September '90				April '91	
		erim-A		wisc-B		u=0.134	
		LAI	MTA	LAI	MTA	LAI	MTA
1	1	1.57	43	1.27	51	0.38	59
1	2	0.96	62	1	63	0.44	42
2	1	1.02	62	0.92	45	0.3	73
2	2	1.99	42	2.02	41	0.5	0
3	1	0	57	0	57	0.11	62
3	2	1.12	50	1.06	60	0.5	32
4	1	0.42	26	0.4	48	0.09	73
4	2	1.74	55	1.67	52	0.51	41
5	1	1.51	49	1.49	42	0.27	46
5	2	1.29	41	1.33	45	0.56	26
MEAN:		1.16	48.70	1.12	50.40	0.37	45.40
STD DEV:		0.60	11.14	0.59	7.60	0.17	22.69

* For deciduous trees, actual LAI = observed LAI - April '91 LAI

UMBS Stand Z: Moderate Aspen (1948 burn) *

Transect	Location	September '90				April '91	
		erim-A		wisc-B		u=0.134	
		LAI	MTA	LAI	MTA	LAI	MTA
2	1	1.95	59	1.95	57	0.75	58
2	2	2.28	45	2.26	43	0.94	46
2	3						
3	1	2	57	1.82	59	1.01	43
3	2	2.42	43	2.31	42	1.43	37
3	3	1.92	61	1.83	58		
4	1	2.12	55	2.09	54	0.95	56
4	2	2.64	43	2.72	42	1.08	42
4	3	2.34	53	2.28	53	1.16	55
MEAN:		2.21	52.00	2.16	51.00	1.05	48.14
STD DEV:		0.25	7.33	0.30	7.45	0.21	8.15

* For deciduous trees, actual LAI = observed LAI - April '91 LAI