Validation of ASTER and MODIS Surface-temperature and Vegetation Products with Surface Flux Applications

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Annual Report

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The ASTER/MODIS products to be directly validated in this program are;

- Land surface temperature (LST) and emissivity at the scale of ASTER and MODIS pixels;
- Leaf Area Index (LAI);
- Fraction Intercepted Photosynthetically Active Radiation (FIPAR);
- Above-Ground Net Primary Production (NPP) and the net ecosystem CO_2 exchange (NEE);
- Snow and land cover

These objectives were obtained using a combination of field measurements, Geostatistics, ecosystem modeling and remote sensing. It is unfortunate that much of the planned comparisons between ground based measurements and remotely sensed products has been hampered by lack of remotely sensed products.

1. Land surface temperature (LST) and emissivity at the scale of ASTER and MODIS pixels

We successfully designed and tested an automated self-calibrating differential infrared thermometer (Figure 1) and installed it on the tall tower in 2001; however there were no suitable ASTER data for comparison. Frankly, we experienced a large amount of frustration trying to coordinate data needs with the ASTER team.

2. Leaf Area Index (LAI)

A second objective of this study was to characterize the vegetation cover and LAI of a 10-km^2 area around a 447-m eddy flux tower in northern Wisconsin using a cyclic sampling design to validate LAI products derived from remote sensing. The vegetation surrounding the tower was comprised (> 80%) of four major forest cover types: forested wetlands, upland aspen forests, upland northern hardwood forests, and upland pine forests, and a fifth, non-forested cover type, grass (open meadow) (Figure 2). LAI differed significantly among the five cover-types and averaged 3.45, 3.57, 3.82, 3.99 and 1.14 for northern hardwoods, aspen, forested wetlands, upland conifers, and grass, respectively (Figure 3). The range of spatial autocorrelation for LAI was 147 m, but was decreased to 117 m when vegetation cover was included as a covariate (Table 1).

Another objective of this study was to measure LAI and to correlate these measurements to management activities, soil characteristics, topography, and vegetation types. Maximum LAI differed significantly between years; LAI values were 17% higher in 2000 than in 1999 ($p<0.001$) (Figure 4). We estimated a mean LAI of 4.11 and a standard error of 0.0050 for the current stand structure and we estimated a mean LAI of 4.47 and a standard error of 0.25 for the estimated pre-settlement stand structure. Recent management activities can dramatically alter LAI values for a stand. Clear-cutting, within the last 5 years, reduces LAI by 2.0. We found that the following factors were significantly correlated to LAI measured over a two-year period: year (inter-annual variations), elevation, vegetation cover-type, roads, management, aspect, slope, soil texture. There are several second and third order interactions that are significant: elevation*management, elevation*texture, vegetation cover-type*aspect, vegetation cover-type*texture, road*management, aspect*texture, vegetation cover-type*aspect*texture, elevation*year, year*management. With the combined management and environmental LAI model, the spatial patterns have almost been fully explained, with a spatial autocorrelation range of only 18 meters.

We used geostatistics to develop a spatial LAI map based on the field measurements and compared it to the MODIS-derived LAI map (Figure 5). In general there was poor correlation between the two spatial LAI maps.

3. Fraction Intercepted Photosynthetically Active Radiation (FIPAR) and Above-Ground Net Primary Production (NPP)

Aboveground net primary production ranged from 125 to 225 gC m-2 yr, with alder having the lowest ANPP and conifers and wertlands having the highest ANPP (Figure 6).

Northern hardwood forests, primarily consisting of sugar maple, had the highest light use efficiency (LUE) each year followed by aspen, red pine, forested wetlands, and upland conifer. Average growing season LUE (all forest cover types) increased significantly from 0.42 to 0.47 (g C MJ-1) for 1999 and 2000, respectively (Table 3). Average annual LUE (all forest cover types) increased significantly from 0.33 to 0.36 (g C MJ-1) for 1999 and 2000 respectively. LUE was significantly different among forest cover types each year. Differences in comparisons and interpretations thereof may arise when using absorbed light based on growing season conditions versus that of the whole year. Future work on LUE should consider variations among mixtures of many land cover types especially forested wetlands. Results from this study suggest that NPP modeling with LUE should consider site-specific efficiency factors rather than biome specific factors.

We examined the aggregation effects of using different spatial scales of leaf area index (LAI) and land cover products, derived from sensors differing in resolution from 15m to 1000m, in a light use efficiency (LUE) model to estimate NPP in a heterogeneous region. The coarsest resolution (1000m) NPP estimate (430 gC m-2 year-1) was 7% greater than the finest resolution (15m) NPP estimate (402 gC m-2 year-1) (Figure 7).. Results from this study show that land cover classification scheme has a significant influence on NPP estimates in this region. Future work on estimating NPP in this region should consider proportional land cover estimates within mixed pixels (>1km).

Papers published in, or accepted by refereed journals

Burrows, S.N., S.T. Gower, M.K. Clayton, D.S. Mackay, D.E. Ahl, J.M. Norman, and G. Diak. (2002). Application of geostatistics to characterize LAI for flux towers to landscapes. ***Ecosystems***. (in press)

Papers submitted to refereed journals

Ahl, D.E., D.S. Mackay, B.E. Ewers, S.T. Gower, S. Samanta, and S.N. Burrows. (200X). Stand level modeling of transpiration in northern Wisconsin. ***Global Change Biology***. (Submitted.)

Gower, S.T., K.S. Fassnacht, D.J. Mladenoff and S.N. Burrows. (200X). Landscape patterns of leaf area index, aboveground net primary production, and light use efficiency of forests in northern Wisconsin. ***Global Change Biology***. (Submitted.)

Mackay, D.S., D.E. Ahl, B.E. Ewers, S.T. Gower, S.N. Burrows, S. Samanta, and K.J. Davis. (200X). Aggregation effects of remotely sensed vegetation cover on estimates of evapotranspiration in a northern Wisconsin forest. ***Global Change Biology***. (Submitted.)

Ewers, B.E., D.S. Mackay, D.E. Ahl, S.N. Burrows, S. Samanta, S.T. Gower. (200X). Influence of forest cover type on diurnal and daily patterns of canopy transpiration. ***Water Resources Research***. (Submitted.)

Papers in preparation

TECHNICAL PAPERS, BOOKS, CHAPTERS ACCEPTED IN 2001

Burrows, S.N., S. T. Gower, M. K. Clayton, D. S. Mackay, D. E. Ahl, John M. Norman, and George Diak. 2001. Application of geostatistics to characterize LAI for flux towers to landscapes. Ecosystems. (accepted).

Ewers. BE, DS Mackay, ST Gower, DE Ahl, SN Burrows, S Samanta. 2001. Tree species effects on stand transpiration in northern Wisconsin. Water Resources Research. (accepted).

TECHNICAL PAPERS, BOOKS, CHAPTERS SUBMITTED IN 2001

Ahl, DE, DS Mackay, BE Ewers, ST Gower, S Samanta, and SN Burrows. 2001. Stand level modeling of transpiration in northern Wisconsin. Global Change Biology. (submitted).

Mackay, D.S., D.E. Ahl, B.E. Ewers, S.T. Gower, S.N. Burrows, S. Samanta, and K.J. Davis. 2001. Aggregation effects of remotely sensed vegetation cover on estimates of evapotranspiration in a northern Wisconsin forest. ***Global Change Biology***. (sumitted).

TECHNICAL PAPERS IN PREPARATION IN 2002

Ahl, D. E., Gower, S. T., Mackay, D. S., Burrows, S. N., Norman, J. M., and Diak, G. (2002), Light use efficiency of a heterogeneous forest in northern Wisconsin: Implications for remote sensing and modeling net primary production. (In preparation)

Ahl, D. E., Gower, S. T., Mackay, D. S., Burrows, S. N., Norman, J. M., and Diak, G. (2002), Aggregation effects of leaf area index and land cover on estimated net primary production in northern Wisconsin. (In preparation).

Burrows, S.N., D.E. Ahl, S.T. Gower, M.K. Clayton, D.S. Mackay, J.M. Norman, and G. Diak. (200X). Influence of anthropogenic and natural sources on spatial-temporal variations of leaf area index in northern Wisconsin. To be submitted to ***Landscape Ecology.***

Burrows, S.N. and M.K. Clayton. (200X). Bayesian estimation of spatial variation on a northern Wisconsin landscape.

Burrows, S.N., ***et al.*** (200X). Estimations of net primary productivity around a very tall eddy-flux tower in northern Wisconsin.

Burrows, S.N., ***et al.*** (200X). Variations of leaf area index and net primary productivity of five North American biomes.

RESEARCH PRESENTATION

Ewers, BE, DS Mackay, DE Ahl, S Samanta, SN Burrows, and ST Gower. 2001. Impact of canopy coupling on canopy average stomatal conductance across seven tree species in Northern Wisconsin. American Geophysical Union Annual Meeting, San Francisco, CA.

Ewers, BE, DS Mackay, DE Ahl, S Samanta, SN Burrows, and ST Gower. 2001. The impact of heterogeneous forest cover on water fluxes at the tree, stand, and regional scales. Ecological Society of America Annual Meeting, Madison, WI.

Burrows, S, ST Gower, DS Mackay, DE Ahl, JM Norman, GD Diak, M Clayton. 2001. Spatial-temporal variation of leaf area index (LAI) and aboveground net primary productivity (ANPP) of a northern Wisconsin forested landscape. Ecological Society of America Annual Meeting, Madison, WI.

Mackay, DS, B Ewers, DE Ahl, S Samantha, ST Gower. 2001. Short-term prediction of transpiration from managed forests in northern Wisconsin. Ecological Society of America Annual Meeting, Madison, WI.

Table 1. Summary of July 1999 leaf area index estimates by dominant cover-type, with a spherical spatial covariance structure. The sill is the estimated variance ($\hat{\sigma}^2$) as $\lim_{h \to \infty} \gamma(h)$. The nugget is the estimated variance at distance zero. The range is the estimated distance at which the sill begins. SE is the standard error of the estimated mean.

Vegetation Cover-type	Mean	SE	5th percentile	95th percentile	Range (m)	Sill	Nugget
Aspen	3.57	0.19	0.51	5.72	80.20	1.90	0.2585
Forested Wetlands	3.82	0.12	1.32	5.66	158.99	1.29	0.5144
Grass	1.14	0.35	0.10	3.80	22.49	1.23	0.3431
Northern Hardwoods	3.45	0.16	1.31	5.44	90.63	1.61	0.2268
Upland Conifers	3.99	0.23	0.98	6.57	53.19	2.37	0.3240

Table 2. Combined management and environmental LAI model

Effect	Num DF	Den DF	F Value	Pr > F
year	1	1392	28.24	<.0001
elevation	1	1392	1.48	0.2247
cover-type	7	1392	20.02	<.0001
road	1	1392	20.55	<.0001
management	2	1392	5.62	0.0037
aspect	8	1392	3.97	0.0001
slope	1	1392	14.82	0.0001
texture	6	1392	6.6	<.0001
elevation*management	2	1392	5.68	0.0035
elevation*texture	8	1392	6.02	<.0001
cover-type*aspect	24	1392	5.99	<.0001
cover-type*texture	17	1392	2	0.0088
road*management	1	1392	6.89	0.0088
aspect*texture	26	1392	10.19	<.0001
cover-type*aspect*texture	6	1392	3.38	0.0026
elevation*year	1	1392	26.62	<.0001
year*management	2	1392	10.68	<.0001

Table 3. Annual and growing season light use efficiency (LUE) (gC MJ^{-1}) for the five major forest cover types. One standard error in parentheses (s.e.). Results are from a mixed linear model, NPP=APAR, using net primary production (NPP) as the dependant variable with absorbed photosynthetically active radiation (APAR), year, and plot classification as effects. The slope of the model with no intercept was used to determine LUE.

	1999				2000			
	Annual		Growing Season		Annual		Growing Season	
Forest Cover Type	LUE	s.e.	LUE	s.e.	LUE	s.e.	LUE	s.e.
Aspen	0.42	(0.04)	0.47	(0.04)	0.45	(0.05)	0.51	(0.05)
Forested Wetland	0.28	(0.03)	0.37	(0.04)	0.31	(0.04)	0.41	(0.05)
Hardwood	0.49	(0.07)	0.52	(0.08)	0.53	(0.09)	0.56	(0.10)
Red Pine	0.27	(0.05)	0.46	(0.08)	0.30	(0.05)	0.50	(0.09)
Upland Conifer	0.18	(0.04)	0.31	(0.06)	0.21	(0.04)	0.35	(0.08)

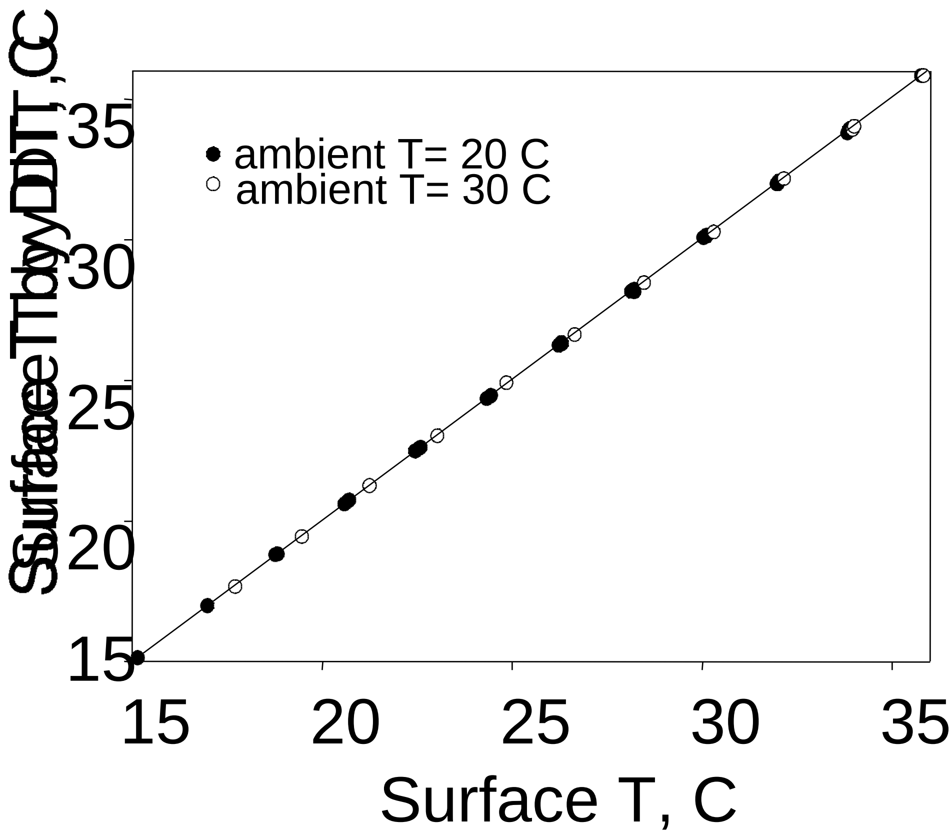

Figure 1: Comparison of surface temperature and surface temperature measured using differential infrared thermometer for two ambient temperatures.

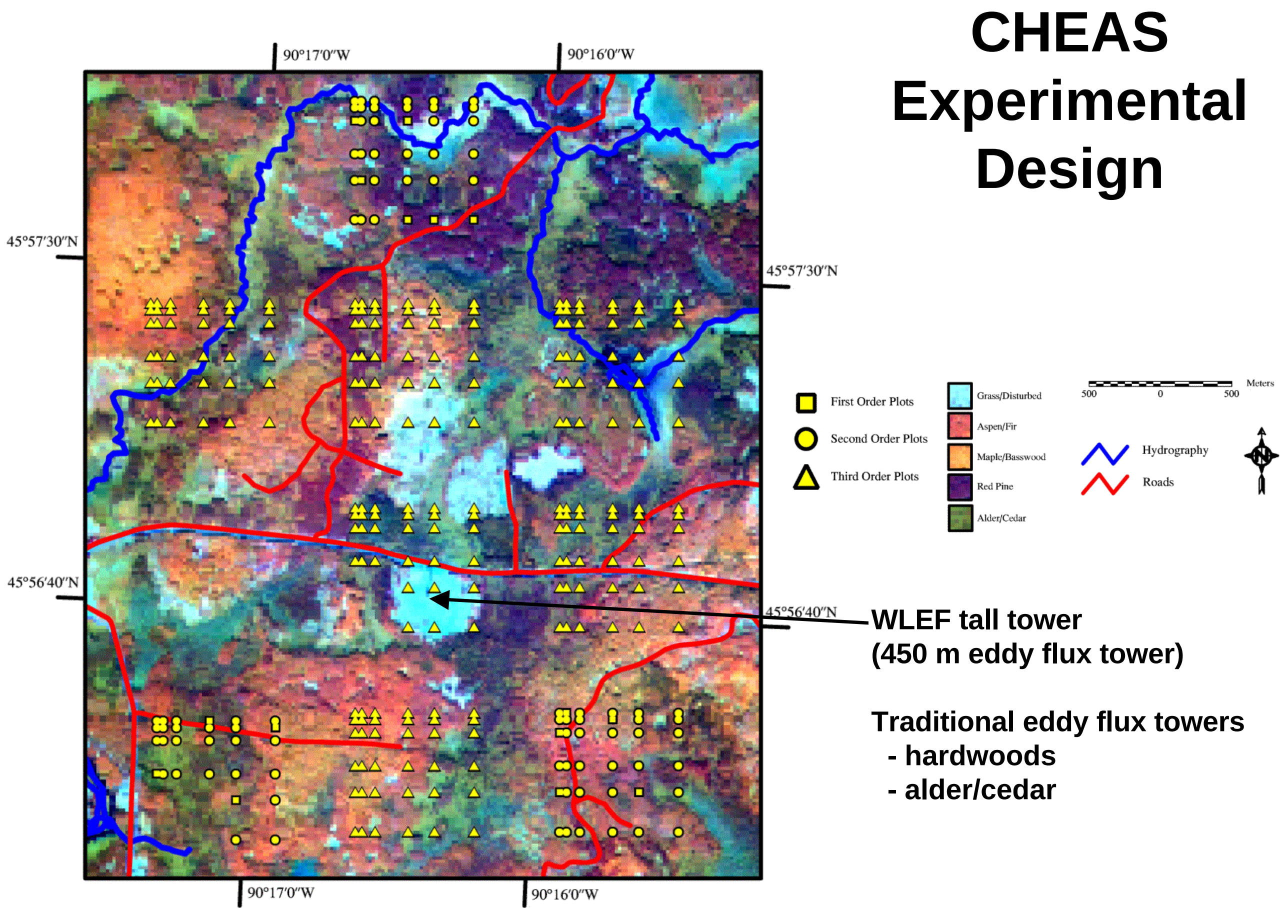

Figure 2: Major land cover types for the WLEF EOS-Validation site. Land cover map prepared from Atlas imagery.

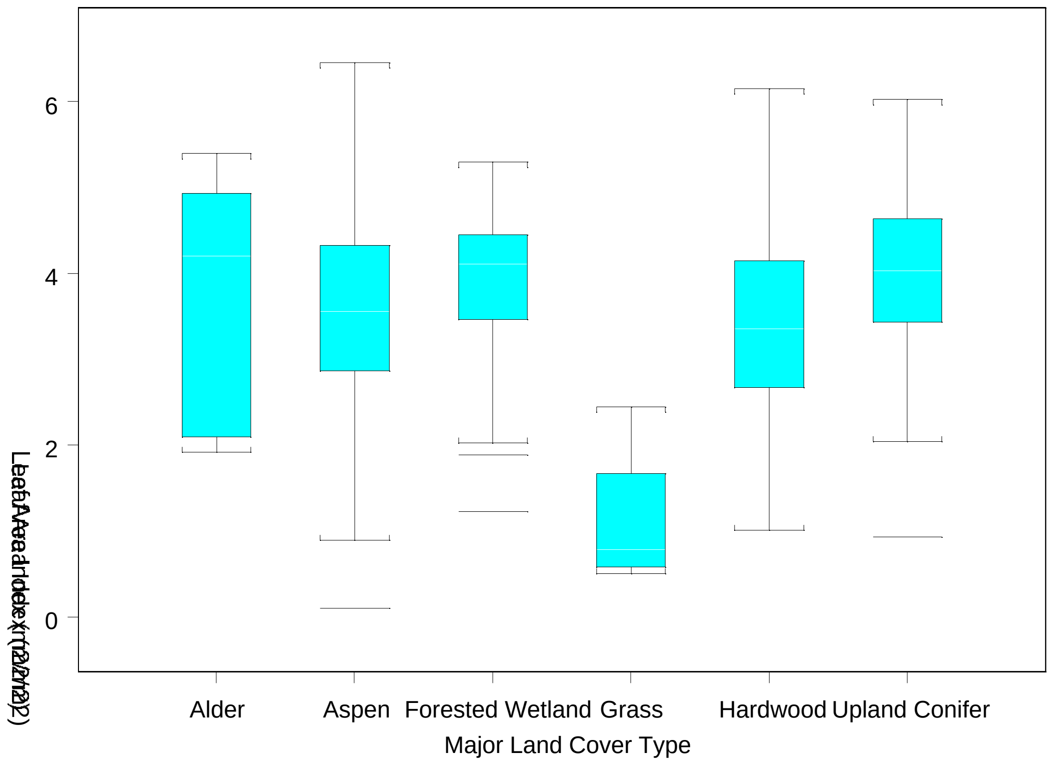

Figure 3: Box plots of average LAI for the major vegetation cover types at the WLEF EOS-VAL study site.

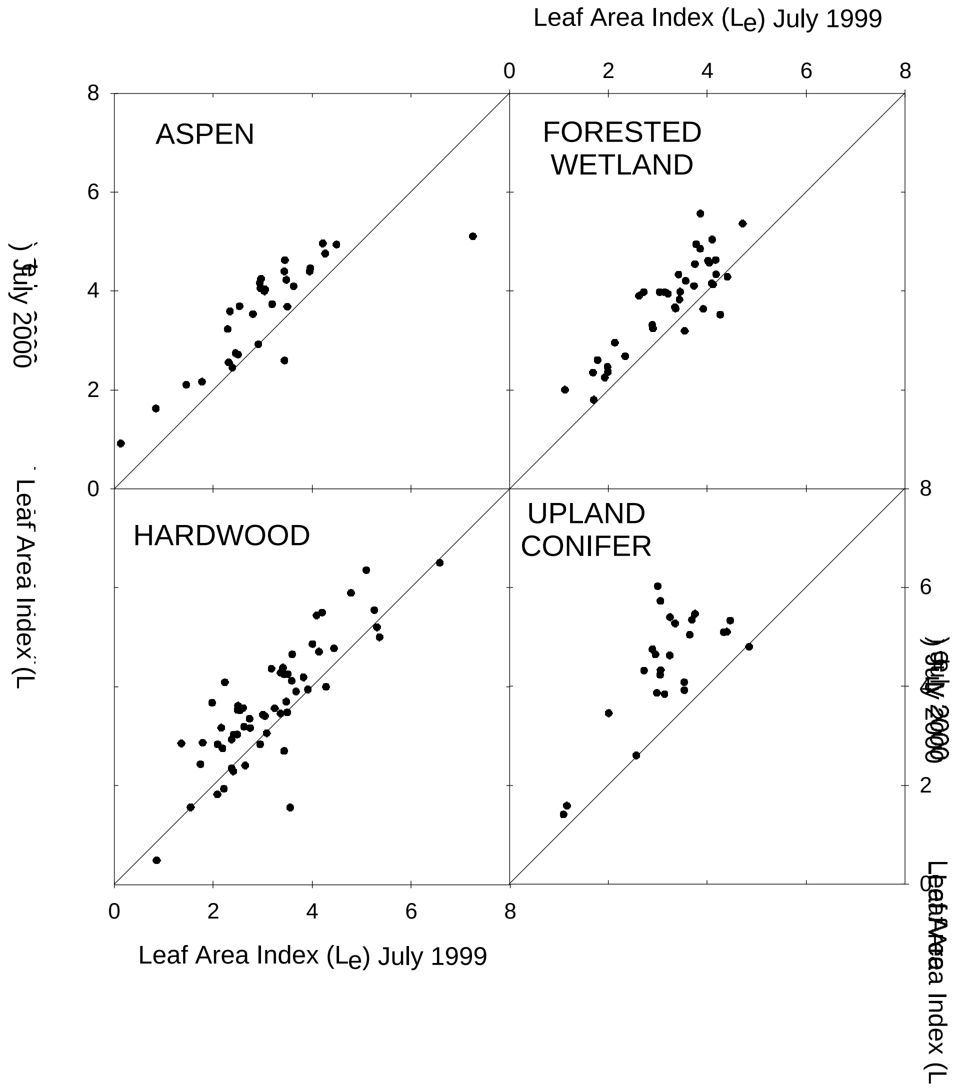

Figure 4: Comparison of LAI for 199 and 2000. Results show consistent between year difference, emphasizing the need for field measurements to validate MODIS data.

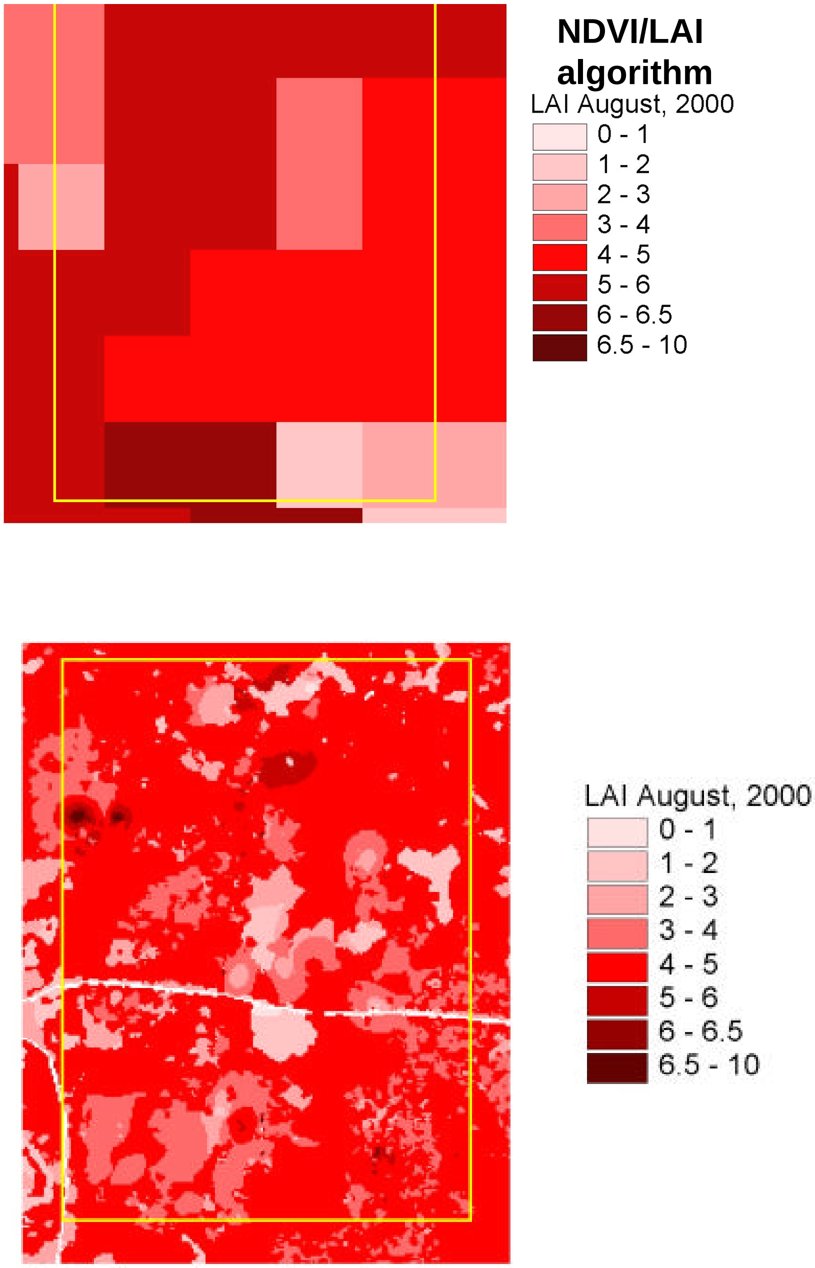

Figure 5: Comparison of MODIS LAI map (upper panel) and co-kriged LAI map (lower map) derived from field measurements for the WLEF study site.

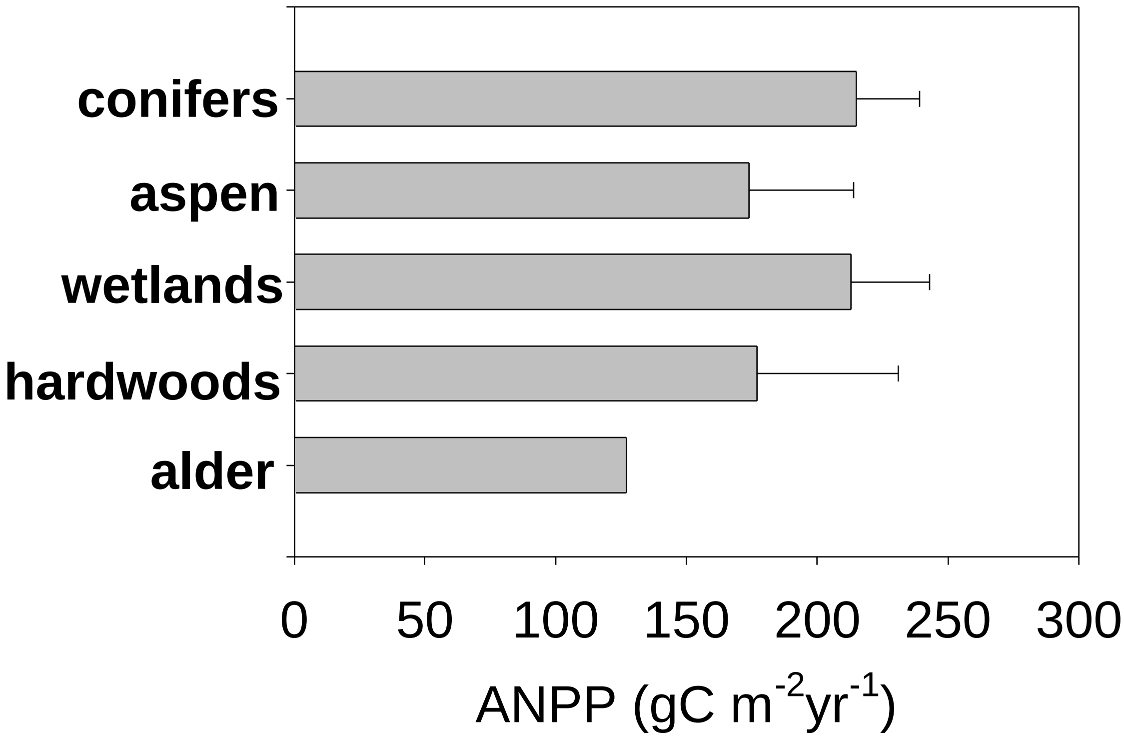

Figure 6: Average (+ one standard deviation) aboveground net primary production (ANPP) for the dominant vegetation types at the WLEF EOS-VAL study site.

Figure 7: Comparison of ANPP estimates based on three different land cover schemes and co-kriged and co-kriged _ NDVI information used as covariates.