Biomass of Sacrificed Spruce/Aspen (SNF)

Summary:

The purpose of the SNF study was to improve our understanding of the relationship between remotely sensed observations and important biophysical parameters in the boreal forest. A key element of the experiment was the development of methodologies to measure forest stand characteristics to determine values of importance to both remote sensing and ecology. Parameters studied were biomass, leaf area index, above ground net primary productivity, bark area index, and ground coverage by vegetation. Thirty-two quaking aspen and thirty-one black spruce sites were studied.

Aspen is an early successional, shade intolerant species. Aspen stands are essentially even aged, and stand age appears to be the most significant difference among sites in determining stand density, average diameter, and biomass density. Biomass density was highest in stands of older, larger trees and decreased in younger stands with smaller, denser stems. Since all aspen stands had closed canopies, the inverse relationship between biomass density and stem density suggests a series of stands in various stages of self thinning.

Biomass density and projected LAI were much more variable for spruce than aspen. Spruce LAI and biomass density have a tight, nearly linear relationship. Stand attributes are often determined by site characteristics.

Net primary productivity was estimated from the average radial growth over five years measured from the segments cut from the boles and the terminal growth measured as the height increase of the tree. Allometric equations were used to find the height and radial increment as a function of crown height and diameter at breast height. Spruce used an additional parameter of stem density. The models were used to back project five years and determine biomass at that time. The change in biomass over that time was used to determine the productivity.

Measurements of sacrificed trees were used to develop relationships between the biophysical parameters (biomass, leaf area index, bark area index and net primary productivity) and the measurements made at each site (diameter at breast height, tree height, crown depth and stem density). These relationships were then used to estimate biophysical characteristics for the aspen and spruce study sites that are provided in the *Forest Biophysical Parameters (SNF)* data set.

Table of Contents:

1. Data Set Overview:

Data Set Identification:

Biomass of Sacrificed Spruce/Aspen (SNF).

Data Set Introduction:

Aspen is an early successional, shade intolerant species. Aspen stands are essentially even aged, and stand age appears to be the most significant difference among sites in determining stand density, average diameter, and biomass density. Biomass density was highest in stands of older, larger trees and decreased in younger stands with smaller, denser stems. Since all aspen stands had closed canopies, the inverse relationship between biomass density and stem density suggests a series of stands in various stages of self thinning.

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Objective/Purpose:

The purpose of the SNF study was to improve our understanding of the relationship between remotely sensed observations and important biophysical parameters in the boreal forest. A key element of the experiment was the development of methodologies to measure forest stand characteristics to determine values of importance to both remote sensing and ecology. Parameters studied were biomass, leaf area index, above ground net primary productivity, bark area index, and ground coverage by vegetation. Thirty-two quaking aspen and thirty-one black spruce sites were studied.

Summary of Parameters:

Diameter at breast high, depth of crown, tree height, total leaf area, standard deviation of total leaf area, biomass, and standard deviation of biomass.

Discussion:

Site Measurements

Sites were chosen in uniform stands of aspen or spruce. The dominant species in the site constituted over 80 percent, and usually over 95 percent, of the total tree density and basal area. Aspen stands were chosen to represent the full range of age and stem density of essentially pure aspen, of nearly complete canopy closure, and greater than two meters in height. Spruce stands ranged from very sparse stands on bog sites, to dense, closed stands on more productive peatlands.

In each stand a uniform site 60 meters in diameter was laid out. Within this site, five circular plots, 16 meters in diameter, were positioned. One plot was at the center of the site and four were tangent to the center plot, one each in the cardinal directions. In very dense stands, plot radii were decreased so that stem count for the five plots remained around 200 stems. Use of multiple plots within each site allowed estimation of the importance of spatial variation in stand parameters.

Within each plot, all woody stems greater than two meters in height were recorded by species and relevant dimensions were measured. Diameter breast height (dbh) was measured directly. Height of the tree and height of the first live branch were determined by triangulation. The difference between these two heights was used as the depth of crown. The distances between trees and observer were such that no angle exceeded 65 degrees. Most plots were level, small slopes were ignored in calculating heights. Similar measurements were made for shrubs between one and two meters tall in the aspen sites. The *Forest Canopy Composition (SNF)* data set provides the counts of canopy (over two meters tall) tree species and subcanopy (between one and two meters tall) tree species.

For each plot, a two-meter diameter subplot was defined at the center of each plot. Within this subplot, the percent of ground coverage by plants under one meter in height was determined by species. These data, averaged for the five plots in each site, are presented in the *SNF Forest Understory Cover Data (Table)* data set in tabular format (e.g. plant species with a count for that species at each site). The same data are presented in the *SNF Forest Understory Cover Data* data set but are arranged with a row for each species and site and a percent ground coverage for each combination.

In addition, these data sets: canopy, subcanopy, and understory counts have been combined into the *SNF Forest Cover by Species/Strata* data set.

For the aspen sites, in each plot a visual estimation of the percent coverage of the canopy,subcanopy and understory vegetation was made. The site averages of these coverage estimates are presented in the *Aspen Forest Cover by Stratum/Plot (SNF)* data set.

Sacrificed Trees

Dimension analysis of sampled trees were used to develop equations linking the convenience measurements taken at each site and the biophysical characteristics of interest (for example, LAI or biomass). To develop these relations, 32 aspen and 31 spruce trees were sacrificed. The trees were randomly sampled, with stratification by diameter, from stands similar and near to the study sites.

Fifteen mountain maple and fifteen beaked hazelnut trees were also sampled and leaf area determined. These data were used to determine understory leaf area.

For each sampled tree, diameter at breast height, height to first live branch and total height were measured before and after felling. Measurements of all branches included: height of attachment on bole, diameter, length to first secondary branch and total length. Crowns were vertically stratified into three equal sections and six branches were randomly sampled from each stratum. For each sampled branch, all leaves and wood were weighted green and the current year's woody growth was measured. A sample of 200 leaves from each stratum had leaf area measured with a Licor leaf area meter and were dried and weighed. Subsamples from each sampled branch were dried and weighed.

Removal of green spruce needles from branches proved impractical, so needle bearing parts of sampled branches were cut off, separated between current year and older classes, and dried. A sample of 21 needles each from the new and older growth were randomly selected from each canopy stratum. The sampled needles were photographed and green and dry weights were measured. Projected area was determined from the digitized photographs.

Boles were sectioned and weighed green. Four sections five to 20 centimeters long were cut from the base of the bole; half-way between the base and first live branch; just below the first live branch; and half-way between the first live branch and the tree top. Each section was measured and dried and weighed.

Parameter Estimation from Sampled Trees

For each of the sacrificed trees the total above ground biomass was estimated as the sum of the branch and bole biomass. Branch biomass was estimated by finding the dry to green weight ratios for leaves, twigs and wood and using the ratios to convert the green to dry weights for the sampled branches. A regression of branch biomass on branch dimensions was done independently for each tree and used to determine biomass for the unsampled branches. Total branch biomass was the sum of the estimated biomass of the sampled and unsampled branches. Bole biomass was estimated by finding the dry to green weight ratios for each section, converting the green weights and summing. Total biomass is the sum of the branch and bole biomass.

Methods for estimating leaf area were parallel to those for estimating branch biomass. Leaf weights for unsampled branches were estimated using tree-specific, linear regressions on branch dimensions fit with data from sampled branches. For spruce, separate regressions were done for current year and older needles. Measured and estimated foliage weights were summed within strata and, for spruce, age class. The foliage weights were converted to leaf areas using ratios determined from sampled leaves, then totaled for trees. The sacrificied tree statistics for aspen and spruce are provided in this data set [i.e., Biomass of Sacrificed Spruce/Aspen (SNF)].

Bark area in aspen was determined using similar techniques to those for leaf area. Sampled branches were divided into segments, each segment was assumed to be a cylinder and the surface area was calculated. Total branch surface area was the sum of the surface areas of the segments. A regression was developed to determine branch area for the unsampled branches. The sum of the estimated branch areas for the sampled and unsampled branches is the total bark area.

Net primary productivity was estimated from the average radial growth over five years measured from the segments cut from the boles and the terminal growth measured as the height increase of the tree. Allometric equations were used to find the height and radial increment as a function of crown height and diameter at breast height. Spruce used an additional parameter of stem density. The models were used to back project five years and determine biomass at that time. The change in biomass over the surface area was calculated. Total branch surface area was the sum of the surface areas of the segments. A regression was developed to determine branch area for the unsampled branches. The sum of the estimated branch areas for the sampled and unsampled branches is the total bark area.

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Measurements of the sacrificed trees were used to develop relationships between the biophysical parameters (biomass, leaf area index, bark area index and net primary productivity) and the measurements made at each site (diameter at breast height, tree height, crown depth and stem density). These relationships were then used to estimate biophysical characteristics for the aspen and spruce study sites that are provided in the *Forest Biophysical Parameters (SNF)* data set.

Stand Characteristics

Aspen is an early successional, shade intolerant species. Aspen stands are essentially even aged, and stand age appears to be the most significant difference among sites in determining stand density, average diameter, and biomass density. Biomass density was highest in stands of older, larger trees and decreased in younger stands with smaller, denser stems. Since all aspen stands had closed canopies, the inverse relationship between biomass density and stem density suggests a series of stands in various stages of self thinning. Aspen trees do not survive suppression, so that bole diameters tend to be relatively uniform and age-determined and biomass increases with age and diameter while density declines. LAI, however, remains relatively constant once a full canopy is established with aspen's shade intolerance generally preventing development of LAI greater than two to three.

Biomass density and projected LAI were much more variable for spruce than aspen. Spruce LAI and biomass density have a tight, nearly linear relationship. Stand attributes are often determined by site characteristics. Wet, ombrotrophic sites support open, low biomass, mixed age stands. Spruce stands with LAI below about two and biomass densities below about five kilograms per square meter appear to be limited by site characteristics such as nutrient poverty and wetness. Stand quality improves with site richness until canopy closure brings on self thinning. Closed canopies attain maximum LAI at around four, higher than aspen, perhaps because spruce is more shade tolerant (it is often observed growing beneath closed aspen stands in the study area). However, differences between maximum LAI for aspen and spruce may also be related to differences in the leaf distribution within the canopy.

Phenology

Deciduous vegetation undergoes dramatic changes over the seasonal cycle. The varying amount of green foliage in the canopy effects the transpiration and productivity of the forest. Measurements of changes in the canopy and subcanopy green foliage amount over the spring of 1984 have been made. From above the subcanopy, photographs of the aspen canopy were taken, pointing vertically up. The photographs were taken at two locations in sites 16 and 93 on several different days. Foliage coverage was determined by overlaying grids with 200 points onto the photos of the canopy.

The number of points obscured by vegetation were counted. These counts were adjusted for the area of the branches, which had been determined by photos taken before leaf out. The number of foliage points were then scaled between zero, for no leaves, to one, for maximum coverage.

Subcanopy leaf extension was measured for beaked hazelnut and mountain maple, the two most common understory shrubs. For selected branches on trees in sites 16 and 93, the length and width of all leaves were measured on several days. These measurements were used to calculate a total leaf area which was scaled between 0 and 1 as with the aspen. The aspen canopy measurements have been combined with the subcanopy measurements and are available in the *SNF Forest Phenology/Leaf Expansion Data* data set.

These measurements of leafout show that the subcanopy leaf expansion lags behind that of the canopy. Subcanopy leaf expansion only begins in earnest after the canopy has reached nearly full coverage.

Related Data Sets:

- Aspen Forest Cover by Stratum/Plot (SNF)
- Forest Biophysical Parameters (SNF)
- Forest Canopy Composition (SNF)
- SNF Forest Cover by Species/Strata
- SNF Forest Understory Cover Data
- SNF Forest Understory Cover Data (Table)

2. Investigator(s):

Investigator(s) Name and Title:

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Title of Investigation:

Biophysical, Morphological, Canopy Optical Property, and Productivity Data on the Superior National Forest.

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3. Theory of Measurements:

Information not available.

4. Equipment:

Sensor/Instrument Description:

Human observer, analysis, steel measuring tape, and weighing balance.

Collection Environment:

Ground-based.

Source/Platform:

Field investigation.

Source/Platform Mission Objectives:

Information not available.

Key Variables:

Biomass, crown, forest composition/structure, leaf characteristics, and plant characteristics.

Principles of Operation:

Information not available.

Sensor/Instrument Measurement Geometry:

Not applicable.

Manufacturer of Sensor/Instrument:

Information not available.

Calibration:

Not applicable.

5. Data Acquisition Methods:

Information not available.

6. Observations:

Data/Field Notes:

Not available.

7. Data Description:

Spatial Characteristics:

The study area covered a 50 x 50 km area centered at approximately 48 degrees North latitude and 92 degrees West longitude in northeastern Minnesota at the southern edge of the North American boreal forest including a portion of the Superior National Forest (SNF) near Ely, Minnesota, U.S.A.

Temporal Characteristics:

April 1969 to September 1973. Preview data set to check for data gaps, missing values, etc.

Data Characteristics:

	Variable Name/	Long Name	SAS Type	Generic Type	Description
1	dbh	DBH	8	NUMBER(4,1)	"Diameter breast height (cm)"
2	tree_ht	TREE_HEIGHT	8	NUMBER(5,2)	"Total tree height (m)"
3	doc	CROWN_DEPTH	8	NUMBER(5,2)	"Depth of crown (m), measured from the base to the top of the crown"
4	tla	TOTAL_LEAF_AREA	8	NUMBER(9,2)	"Total leaf area (cm2)"
5	sla	STDEV_LEAF_AREA	8	NUMBER(9,2)	"Standard deviation of total leaf area (cm2)"

6	biomass	BIOMASS	8	NUMBER(9,2)
"Total tree biomass (g)"				
7	bio_se	STDEV_BIOMASS	8	NUMBER(9,2)
"Standard deviation of total tree biomass (g)"				
8	species	SPECIES_CODE	$ 12	CHAR(6)
"Plant species (Aspen/Spruce)"				

Sample Data Record:

dbh	**tree_ht**	**doc**	**tla**	**sla**	**biomass**	**bio_se**	**species**
0.9	2.2	1.78	1280.16	0	112.58	2.1	"Aspen"
1.2	2.8	1.77	1766.12	165.46	168.7	24.25	"Aspen"
1.4	3.43	2.14	3677.92	290.14	256.28	8.83	"Aspen"
1.8	3.78	2.62	9708.01	1685.75	598.47	70.36	"Aspen"
2	4.6	2.4	9043.15	814.04	567.4	19.03	"Aspen"
2.2	3.1	1.8	11658.8	1771.7	606.54	16.69	"Aspen"
3.4	5.7	4.43	20256.21	853.54	1909.26	37.94	"Aspen"
3.4	5.35	4.05	32123.67	3891.72	1936.82	59.93	"Aspen"
3.5	5.35	4.15	14072.01	818.25	1532.02	29.73	"Aspen"
7.3	9.2	4.9	102891.09	19216.2	14346.3	621.48	"Aspen"
9.1	9.4	4.42	83769.87	9591.3	11250.38	313.15	"Aspen"
10.5	11.5	5.3	148084.39	11454.91	29413.23	966.04	"Aspen"
13	16.1	5.05	109339.86	12714.04	54486.61	1178.68	"Aspen"
13.7	15.9	4.65	108924.04	8857.67	60834.46	1118.45	"Aspen"
15.1	16.7	6.95	91855.49	4814.76	67338.04	1262.27	"Aspen"
15.4	17.4	7.1	138091.91	8771.01	80391.1	1515.08	"Aspen"
15.8	15.6	5.4	193240.13	8073.15	71016.01	1280.61	"Aspen"
17.3	15.5	8.4	218524.41	6802.89	73012.54	1162.92	"Aspen"
19.4	23	10.3	312907.63	10882.57	171922.24	2513.05	"Aspen"
19.5	19.35	7.4	175246.08	10190.74	107218.69	1803	"Aspen"
21.5	23.1	5.75	182521.34	19549.84	177285.82	2196.16	"Aspen"
22.5	22.5	7.25	500455.06	41004.35	238477.34	3218.93	"Aspen"
22.6	18.1	7.4	287153.53	11609.84	191767.73	2248.49	"Aspen"
22.8	22.4	6.6	422196.53	23861.99	233177.57	2992.33	"Aspen"
23	22.5	8.7	382654.5	12988.99	237964	3036.38	"Aspen"
25.1	23.8	8.85	273654.69	23332.5	274651.8	3343.34	"Aspen"
25.2	22.5	8.8	241456.02	49253.56	270825.85	3766.19	"Aspen"
27.8	23.5	16.25	745781	73361.2	448440.07	6264.33	"Aspen"
30.2	23.5	10.05	743229.75	71937.2	437031.91	5502.92	"Aspen"
32.1	23.8	8.9	531668.81	71937.81	456140.4	4753.74	"Aspen"
32.4	23.5	12.8	1017735.38	91915.13	533887.77	5360.41	"Aspen"
35.4	22.5	11.5	1228601.5	112045.76	559046.9	5050.19	"Aspen"
2.9	2.9	1.66	8303.5	1307.83	957.73	59.84	"Spruce"
4.1	3.7	3.6	28230.51	5520.61	3541.01	230.67	"Spruce"
4.1	4.37	4.24	42984.57	18818.73	5251.89	445.79	"Spruce"
4.4	4.2	2.61	19539.94	2915.01	3286.88	152.28	"Spruce"
4.9	5.6	2.15	13361.46	2415.06	3720.22	320.19	"Spruce"
5.1	4.15	1.9	18259.08	1675.77	4389.37	105.35	"Spruce"
5.5	8.55	5	37405.26	4111.27	6242.02	260.35	"Spruce"
5.7	6	3.1	46803.37	2895.23	6177.99	376.14	"Spruce"
6.9	6.9	5.12	46080.43	6772.37	8869.33	233.97	"Spruce"
8.2	9.35	3.55	34179.43	5821.31	14609.92	377.44	"Spruce"
9.1	10.56	4.82	57286.88	7504.3	16967.75	622.87	"Spruce"
9.2	11.7	3.4	50016.85	6077.54	19912.67	411.31	"Spruce"
11	12.86	5.11	115016.66	12092.5	35581.93	581.85	"Spruce"
11	10.9	7.5	115095.3	18986.75	31188.5	716.32	"Spruce"

11.5	12.6	7.55	160659.06	15806.49	43375.69	942.15	"Spruce"
12.1	11	4	93923.11	14070.42	32544.85	876.03	"Spruce"
12.7	14.7	7.7	77944.05	17154.32	45656.59	1637.72	"Spruce"
14.1	11.94	9.38	165289.27	27741.48	53860.68	2846.02	"Spruce"
14.3	13.9	7.8	335712.03	29299.56	60976.55	1218.13	"Spruce"
14.4	13.1	7.5	119594.65	21101.48	52109.21	1331.45	"Spruce"
15.6	14.4	8	66331.88	6845.71	59780.82	917.52	"Spruce"
15.6	13.1	8.15	115336.13	22047.93	62144.07	1152.5	"Spruce"
16.4	11.8	8.5	438570.81	73382.71	70466.63	1878.4	"Spruce"
18.1	19.9	8.65	214715.11	36310.12	133180.07	2484.47	"Spruce"
18.9	18.8	8.43	241654.33	34868.48	128709.13	2019.3	"Spruce"
19	14.15	12.43	450936.09	69085.73	114136	2979.51	"Spruce"
19.6	14.7	10.47	298449.13	45453.35	114821.05	3087.88	"Spruce"
20.2	14.6	12.4	243767.86	27349.37	128890.17	3164.18	"Spruce"
20.8	15.3	7.27	146029.06	24910.89	104981.92	2439.91	"Spruce"
22.8	17.5	10.1	239635.28	37735.02	137075.67	2088.36	"Spruce"
23	19.95	12.49	492978.78	60853.75	204608.74	6718.3	"Spruce"

Footnote:

For presentation in this document, some padding blanks may have been eliminated between columns in the Sample Data Record. See the *Data Format Section* for conventions used for missing data values in the data file.

8. Data Organization:

Data are sorted by species (Aspen or Spruce) and diameter at breast high (dbh).

Data Granularity:

This data set consists of a single ASCII file containing leaf area, biomass, depth of crown and diameter at breast high for aspen and spruce trees.

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

Data Format:

The data files associated with this data set consist of numeric and character fields of varying lengths aligned in columns.

The first row of each data file contains the 8 character SAS variable name that links to the data format definition file.

Character fields are enclosed in double quotes and numeric fields are listed without quotes.

Missing data values can be of two varieties:

1. Values that were identified as missing in the original data files. Missing numeric values of this type are identified in these data as -999.
2. Those holes that were created as a result of combining files that contained a slightly different variable set. Missing values of this type are identified in these data files as empty double quotes for character fields and a single period, '.' for numeric fields.

9. Data Manipulations:

Not available at this revision.

10. Errors:

Sources of Error:

Information not available.

Quality Assessment:

Data Validation by Source:

Information not available.

Confidence Level/Accuracy Judgment:

Information not available.

Measurement Error for Parameters:

Information not available.

Additional Quality Assessments:

Information not available.

Data Verification by Data Center:

The Superior National Forest data were received from the Goddard Space Flight Center in three media:

- As data dumps from the original Oracle SNF database maintained by GSFC, transferred electronically from the GSFC system to the ORNL system;
- As ASCII files that mirrored the tables published in the Tech Memo; and
- As hard copy (Tech Memo).

Data from both electronic sources were input into SAS by ORNL DAAC data management staff and compared using computer code developed to process the SNF data. In many cases, the data values from both sources were found to be identical. In some cases, however, differences were identified and the providers of the data were consulted to resolve inconsistencies.

Additionally, some variable columns were available in one source, but not the other for various reasons. For example, some calculated variables/columns were provided in the ASCII files (reflecting the Tech Memo tables) that were not stored in the Oracle database for purposes of space conservation.

For similar reasons, coded values were used for many of the site and species identifier variables. A separate reference table was provided to link the coded variable with its definition (e.g., the SPECIES_REF file and the SITE_REF file).

The database produced by the ORNL DAAC is a hybrid product that is a composite of data and information extracted from all three source media. In data sets where coded variables were included, the code definition variables have been added to improve usability of the data set as a stand-alone product.

Therefore the ASCII files that are available through the ORNL DAAC on-line search and order systems are output from a data set that is a product of the essential core of numeric data provided by the data source (GSFC), augmented with additional descriptive information provided by GSFC and reorganized by the ORNL DAAC into a data structure consistent with other similar data sets maintained by the ORNL DAAC.

11. Notes:

Information not available.

12. Application of the Data Set:

Information not available.

13. Future Modifications and Plans:

None available at this revision.

14. Software:

Not available.

15. Data Access:

Contact Information:

ORNL DAAC User Services
Oak Ridge National Laboratory
Telephone: (865) 241-3952
Fax: (865) 574-4665
E-mail: ornldaac@ornl.gov

Data Center Identification:

ORNL Distributed Active Archive Center
Oak Ridge National Laboratory
Telephone: (865) 241-3952
Fax: (865) 574-4665
E-mail: ornldaac@ornl.gov

Procedures for Obtaining Data:

Users may order data by telephone, electronic mail, or fax. Data are availablle via FTP or on CD-ROM. Data are also available via the World Wide Web at http://daac.ornl.gov .

Data Center Status/Plans:

The Superior National Forest 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:

Available via FTP or on CD-ROM.

17. References:

Information not available.

Archive/DBMS Usage Documentation.

Contact the ORNL DAAC, Oak Ridge, Tennessee (see the *Data Center Identification Section*).

18. Glossary of Terms:

A general glossary is located at EOSDIS Glossary.

19. List of Acronyms:

URL Uniform Resource Locator

A general list of acronyms is available at http://cdiac.ornl.gov/pns/acronyms.html.

20. Document Information:

October 10, 1996 (citation revised September 23, 2002)

Document Review Date:

November 5, 1996

Document ID:

ORNL_SNF_BIOMASS

Citation:

Please cite this data set as follows (citation revised September 23, 2002):

Hall, F. G., K. F. Huemmrich, D. E. Strebel, S. J. Goetz, J. E. Nickeson, and K. D. Woods. 1996. Biomass of Sacrificed Spruce/Aspen (SNF). [Biomass of Sacrificed Spruce/Aspen (Superior National Forest)]. Data set. Available on-line [http://daac.ornl.gov] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A. doi:10.3334/ORNLDAAC/141.

Based on F. G. Hall, K. F. Huemmrich, D. E. Strebel, S. J. Goetz, J. E. Nickeson, and K. D. Woods, Biophysical, Morphological, Canopy Optical Property, and Productivity Data from the Superior National Forest, NASA Technical Memorandum 104568, National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Maryland, U.S.A., 1992.

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