Forest Biophysical Parameters (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.

Sites were chosen in uniform stands of aspen or spruce. 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. Diameter breast height (dbh), height of the tree and height of the first live branch were measured. 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. For the aspen sites, a visual estimation of the percent coverage of the canopy, subcanopy, and understory vegetation was made in each plot.

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). Fifteen mountain maple and fifteen beaked hazelnut trees were also sampled and leaf area determined. These data were used to determine understory leaf area. The total above-ground biomass was estimated as the sum of the branch and bole biomass for a set of sacrificed trees. Total branch biomass was the sum of the estimated biomass of the sampled and unsampled branches. Total biomass is the sum of the branch and bole biomass.

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. 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 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 this data set.

Biomass density was highest in stands of older, larger Aspen trees and decreased in younger stands with smaller, denser stems. LAI 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. However, differences between maximum LAI for aspen and spruce may also be related to differences in the leaf distribution within the canopy.

Table of Contents:

1. Data Set Overview:

Data Set Identification:

Forest Biophysical Parameters (SNF).

Data Set Introduction:

The Forest Biophysical Parameters (SNF) Data Set contains diameter at breast high, depth of crown, tree height, total leaf area, standard deviation of total leaf area, biomass, and standard deviation of biomass data from sites of aspen and spruce.

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 data set *Forest Canopy Composition (SNF)* 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 sacrificed tree statistics for aspen and spruce are provided in the *Biomass of Sacrificed Spruce/Aspen (SNF)* Data Set.

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 that time was used to determine the productivity.

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 this data set (i.e., Forest Biophysical Parameters (SNF)).

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 *Forest Phenology/Leaf Expansion Data (SNF)* 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)
- Biomass of Sacrificed Spruce/Aspen (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:

Not available.

4. Equipment:

Sensor/Instrument Description:

Collection Environment:

Ground-based.

Source/Platform:

Field Investigation.

Source/Platform Mission Objectives:

Not available.

Key Variables:

Biomass, leaf area index, above ground net primary productivity, bark area index, and ground coverage by vegetation.

Principles of Operation:

Not available.

Sensor/Instrument Measurement Geometry:

Not applicable.

Manufacturer of Sensor/Instrument:

Not applicable.

Calibration:

Not applicable.

5. Data Acquisition Methods:

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:

The data was collected during the summers of 1983 and 1984.

Data Characteristics:

Variable Name/ Long Name Description	SAS Type	Generic Type
1 site_id SITE_ID "Site ID"	8	NUMBER(4,0)
2 n_trees NUM_TREES "Number of trees in the plot used in the sample"	8	NUMBER(4,0)
3 areasite SAMPLED_AREA "Sampled area in site (m2), usually made up of several plots"	8	NUMBER(4,0)
4 dbh_avg DBH_AVERAGE "Average DBH of sampled trees at site (cm)"	8	NUMBER(4,2)
5 dbh_sd DBH_SD "Standard deviation of DBH at site(cm)"	8	NUMBER(4,2)
6 stem_m2 STEM_DENSITY "Number of trees per square meter"	8	NUMBER(4,3)
7 basal BASAL_AREA "Ratio of bole area to surface area"	8	NUMBER(4,2)
8 bmi BIOMASS_AVERAGE "Average biomass index (kg/m2)"	8	NUMBER(4,3)
9 bmi_sd BIOMASS_SD "Standard deviation of biomass index (kg/m2)"	8	NUMBER(4,3)
10 npp AVG_NPP "Net primary production	8	NUMBER(4,3)

(kg/m2/year)"

---

11 lai   8
"One-sided leaf area index"

---

12 lai_sd   8
"Standard deviation of LAI"

---

13 bai   BAI_AVG   8   NUMBER(4,3)
"Bark area index (ratio of
the entire surface of boles
and branches to the surface
area of the site)"

---

14 bai_sd   BAI_SD   8   NUMBER(4,3)
"Standard deviation of BAI"

---

15 sub_lai   8
"Subcanopy leaf area index"

---

16 species $ 12
"Plant species"

---

17 tree_ht   TREE_HEIGHT   8   NUMBER(4,1)
"Average tree height of
stand (m)"

---

18 stndagex   MAX_STAND_AGE 8   NUMBER(3,0)
"Apparent maximum stand age
(yrs)"

---

19 baslarea   BASAL_AREA   8   NUMBER(4,3)
"Basal area of the site,
defined as the cross sectional
area of trees in cm2/m2 of total
sampled area"

---

20 npp_sd   SD_NPP   8   NUMBER(4,3)
"NPP standard deviation
(kg/m2/yr)"

---

21 laicanav   LAI_CANOPY_AVG 8   NUMBER(4,3)
"Average canopy overstory
LAI(ratio of green leaf to
surface area of the site)"

---

22 laicansd	LAI_CANOPY_SD	8	NUMBER(4,3)

"Standard deviation of the
average canopy overstory LAI"

---

23 laisubav	LAI_SUBCAN_AVG	8	NUMBER(4,3)

"Subcanopy LAI average"

---

24 laisubsd	LAI_SUBCAN_SD	8	NUMBER(4,3)

"Subcanopy LAI standard
deviation"

Sample Data Record:

site_id	n_trees	areasite	dbh_avg	dbh_sd	stem_m2	basal
bmi	bmi_sd	npp	lai	lai_sd	bai	bai_sd
sub_lai	species	tree_ht	stndagex			

2	176	1005	14.52	4.43	0.17507	0.00317
12.378	0.83	0.3248	2.884	0.34	.	.
.	"Spruce"	50	146			
3	95	1005	15.22	9.56	0.0945	0.00239
13.705	1.388	0.563	2.524	0.253	1.286	0.353
0.201	"Aspen"	80	49			
12	165	1005	4.54	2.11	0.16413	0.00032
0.678	0.127	0.0394	0.484	0.181	.	.
.	"Spruce"	20	101			
14	248	1005	13.22	4.13	0.24669	0.00372
13.643	0.587	0.4323	3.266	0.427	.	.
.	"Spruce"	60	110			
15	225	1005	12.21	3.83	0.22381	0.00288
10.68	0.675	0.3476	2.692	0.383	.	.
.	"Spruce"	60	107			
16	100	1005	16.42	8.87	0.09947	0.00272
13.433	1.034	0.667	2.427	0.235	1.498	0.278
1.08	"Aspen"	60	47			
18	262	1005	4.24	2.06	0.26062	0.00046
1.093	0.192	0.0632	0.739	0.254	.	.
.	"Spruce"	25	91			
19	257	1005	4.05	1.98	0.25564	0.00041
1.032	0.2	0.0582	0.692	0.242	.	.
.	"Spruce"	25	91			
20	231	1005	8.48	7.16	0.22978	0.00222
10.34	1.698	0.736	2.464	0.436	1.144	0.466
0.5	"Aspen"	45	64			
21	144	1005	10.11	8.48	0.14324	0.00195
11.122	1.842	0.59	3.118	0.789	1.096	0.336
1.393	"Aspen"	65	70			
36	236	1005	6.36	6.85	0.23475	0.00161
8.106	0.98	0.538	2.056	0.236	1.02	0.221
0.193	"Aspen"	-999	69			
38	472	1005	7.33	3.35	0.46951	0.0024
6.79	0.6	0.2951	2.691	0.644	.	.
.	"Spruce"	30	155			
39	379	1005	5.15	2.5	0.377	0.00097
2.373	0.421	0.1176	1.319	0.455	.	.
.	"Spruce"	20	76			
41	184	1005	13.49	5.73	0.18303	0.00308
11.135	0.517	0.3492	2.842	0.313	.	.
.	"Spruce"	60	130			

```
42          260          1005         8.6          5.8          0.25863      0.00218
7.314       0.455        0.2584       2.279        0.283        .            .
.           "Spruce"        60          119
43          284          782          8.44         4.79         0.36305      0.00268
8.696       0.716        0.3303       2.791        0.476        .            .
.           "Spruce"        60          127
45          265          496          7.28         3.65         0.53387      0.00278
8.446       1.253        0.3575       3.085        0.761        .            .
.           "Spruce"        40           52
47          269          462          5.29         2.5          0.58249      0.00156
3.527       0.465        0.1799       1.996        0.757        .            .
.           "Spruce"        35           53
48          224          660          9.83         3.19         0.33953      0.00285
9.149       1.665        0.4044       2.7          0.795        .            .
.           "Spruce"        50           54
```

Footnote:

> For presentation in this document, some padding blanks may have been eliminated between columns in the Sample Data Record. Due to the many fields in this data file, these columns will wrap while viewing. The actual data files, however, are column delimited with an adequate record length to prevent wrapping. See the *Data Format Section* for conventions used for missing data values in the data file.

8. Data Organization:

Data are sorted by study site (site_id). Key fields in each record are site_id and species.

Data Granularity:

This data set consists of a single ASCII file containing counts of trees, average DBH, stem diameter, basal area, bark area index, net primary productivity, apparent stand age and biomass at each site for Spruce and Aspens.

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.

10. Errors:

Sources of Error:

Not available.

Quality Assessment:

Not available.

Data Validation by Source:

Not available.

Confidence Level/Accuracy Judgment:

Not available.

Measurement Error for Parameters:

Not available.

Additional Quality Assessments:

Not available.

Data Verification by Data Center:

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

1. As data dumps from the original Oracle SNF database maintained by GSFC, transferred electronically from the GSFC system to the ORNL system;
2. As ASCII files that mirrored the tables published in the Tech Memo; and
3. 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:

Limitations of the Data:

Not available.

Known Problems with the Data:

None known at this revision.

Usage Guidance:

Not available.

Any Other Relevant Information about the Study:

None.

12. Application of the Data Set:

This data set can be used to estimate biophysical characteristics for the aspen and spruce study sites.

13. Future Modifications and Plans:

None known 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 available 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:

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:

January 20, 1997

Document ID:

ORNL-SNF_BIOPHYS

Citation:

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. Forest Biophysical Parameters (SNF). [Forest Biophysical Parameters (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/142.

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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