Canopy Chemistry (OTTER)

Summary:

Canopy characteristics: leaf chemistry, specific leaf area, LAI, PAR, IPAR, NPP, and standing biomass.

Table of Contents:

1. Data Set Overview:

Data Set Identification:

Canopy Chemistry (OTTER)

Data Set Introduction:

The Oregon Transect Ecosystem Research (OTTER) Project was a cooperative effort between NASA and several universities to discern the ecology of western coniferous forests using remote sensing technology supported by gound observations. OTTER is an interdisciplinary project that tested a model that estimated the major fluxes of carbon, nitrogen, and water through a temperate coniferous forest ecosystem.

Six Oregon sites across an elevational and climatic gradient were intensively studied. The transect began at the Pacific coast at the site called Cascade Head, passed through the outskirts of Corvallis, through a dense Douglas fir forest at Scio, through a mountain hemlock/subalpine fir community at Santiam Pass, through a Ponderosa pine community near Metolius, and ended at a site east of Sisters called Juniper. In all, the transect stretched some 300 kilometers west to east.

Goals of the project were to simulate and predict ecosystem processes such as photosynthesis, transpiration, above-ground production, nitrogen transformation, respiration, decomposition, and hydrologic processes; combine field, lab, and remote sensing techniques to estimate key vegetaion and environmental parameters; construct a "geo-referenced" database for extrapolation and testing of principles, techniques, and prediction; and verify the predictions through direct measurements of process rates or controls on processes.

Objective/Purpose:

OTTER was designed to study the ability of remote sensing to detect biophysical characteristics of plant canopies. The data sets correlating to this document contain leaf chemistry data for the six different sites as determined through field investigations and laboratory work.

Summary of Parameters:

Seven parameters were in investigated: emitted radiation, intercepted photosynthetically active radiation, photosynthetically active radiation, leaf area index, leaf chemistry (total nitrogen, phosphorus, amino acids, starch, and chlorophyll a and b), plant above-ground biomass, and net primary production.

Discussion:

Information not available.

Related Data Sets:

Forest-BGC Model Leaf Area Index Data Leaf Reflectances: LICOR Leaf Reflectances: Perkin-Elmer Meteorology Optical Thickness Data: Aircraft Optical Thickness Data: Ground Reflectance Reference Targets SE-590 Field-Measured Reflectances SE-590 Lab-Measured Reflectances SE-590 Landscape Reflectances SE-590 Low Altitude Reflectances Timber Measurements

2. Investigator(s):

Investigator(s) Name and Title:

Name: Dr. Pamela A. Matson Ames Research Center

Addresses: Information not available.

Telephone Numbers: Information not available.

Electronic Mail Address: Information not available.

Title of Investigation:

OTTER Canopy Chemistry Data

Contact (for Data Production Information):

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3. Theory of Measurements:

At each sampling period, five branches were shot from the canopy at random locations within each plot. In general, samples came from middle positions within the canopies; exceptions are noted in the data sets. At site 3 samples were taken along the roads bordering the two plots after December, 1989 (in order to obtain 'sun' foliage from this very dense canopy). Before January 1990 samples from site 3 are probably 'shade' foliage. Samples from all other sites are 'sun' foliage.

4. Equipment:

Sensor/Instrument Description:

- Analysis: The process of an individual examining the information collected during a scientific investigation. Often this takes the form of reviewing and working with output from modeling activities to give meaning to the information.
- Anthrone Colorimeter Process: A procedure used to determine sugars present in plant tissue.
- Leaf Area Meter: A linear light sensor which is used to determine the area of leaves.
- Spectrophotometer: A photometer for measuring the relative intensities of light in different parts of the spectrum.
- Sunfleck Ceptometer: An instrument that measures instantaneous fluxes in solar radiation in the photosynthetically active region (400-700 nm). Often used to determine tree canopy transmittance of photosynthetically active radiation.
- Technicon Autoanalyzer: An instrument used to determine the total nitrogen concentration and total phosphorus concentration in plant tissue.

Collection Environment:

Open-air forest

Source/Platform:

Laboratory

Source/Platform Mission Objectives:

Determine specific leaf area, leaf chemistry, percent of intercepted photosynthetically active radiation, trees per hectare, average basal area, leaf area index, above-ground biomass, and the above-ground net primary production.

Key Variables:

Principles of Operation:

Information not available.

Sensor/Instrument Measurement Geometry:

Information not available.

Manufacturer of Sensor/Instrument:

Sunfleck Ceptometer: Decagon Devices, Inc., Pullman, WA Technicon Autoanalyzer: Technicon Instruments Corporation, 1977. Leaf Area Meter: (LAI-3100; LI-COR Inc., Lincoln, NE) All other information not available.

Calibration:

Calibration information is not available.

5. Data Acquistion Methods:

Leaf Chemistry Data: Foliage was removed from sampled branches and placed on ice after collection. Within a few hours, representative samples were taken for specific leaf area analysis and the remainder of the foliage was frozen at -60 C. Frozen samples were shipped to the Ames Research Center for chemical analysis. At Ames samples were freeze-dried using a cold trap at or below -40 C for 48 to 72 hours and stored at room temperature. The water content of freeze-dried samples was determined by oven-drying at 65 C for hours.

Biochemical Analysis: Reference samples (Standard Reference Material, 1976, 1982) were included in all analyses to ensure uniformity in the methods. At least three references were included in every group of 40 samples analyzed. In addition, 2-4 duplicates of at least three canopy samples were included in all analytical runs; for lignin and cellulose, all samples were run in duplicate. Total nitrogen and total phosphorus were measured with a Technicon Autoanalyzer II after samples were digested in a block digester using a sulfuric acid-mercuric oxide catalyst. Chlorophyll was extracted in acetone buffered by CaCO3 and the concentration was determined by standard spectrophotometric techniques. Free amino acids were determined by a colorimetric method using ninhydrin (Lee and Takahashi, 1966). A potassium permanganate method was used on acid detergent fiber to determine lignin (Van Soest, 1963; Van Soest and Wine, 1968). Cellulose was measured by loss of weight by ashing of lignin-free fiber. Sugars were removed from tissue samples using methanol-chloroform-water, and the residue was analyzed for starch (Matson and Waring, 1984). Sugars isolated in the water-methanol phase were measured using and anthrone colorimetric procedure (Hazid and Neufeld, 1964).

Specific Leaf Area (SLA): Between 20 and 30 cm2 of leaf tissue was removed randomly from the sample and placed on transparent tape. Projected leaf area was determined with a LI-COR

3100 leaf area meter. Then leaf tissue was removed from the tape, dried to a constant weight at 70 C, and weighed.

Intercepted Phtosynthetically Active Radiation (IPAR): IPAR was estimated by measuring the tree canopy transmitted radiance at each site, assuming the remainder was either absorbed or reflected. IPAR for only the trees was measured, with no attempt to estimate the influence of the understory vegetation on radiation interception. To determine tree canopy transmittance of photsynthetically active radiation, a sunfleck ceptometer was used. The instrument measures instantaneous fluxes of solar radiation in the photosynthetically active region (PAR 400-700 nm). Measurements at all sites were made on cloudless days during July-August 1991. To minimize shadow effects, measurements were taken between 1200 and 1400 local solar time. Depending on the variability of the overstory, below canopy PAR was sampled at least 200 to 60 points along north-south and east-west transects. At each sample point the instrument was held level and turned in a circle to collect 20 measurements of PAR at 150 increments. These 20 measurements were then averaged and stored in the instrument's memory. Total incident PAR was measure in a nearby clearing or road at the beginning and end of the sample period and at intervals of approximately every 10 minutes during the sample transects.

Trees per Hectare and Basal Area: To establish patterns of above-ground biomass and productivity, trees were sampled at a study stand at the six sites. 20 circular plots of 50 m2 were randomly selected in each stand. The diameter at breast height (DBH; diameter at 1.37 m) was measured of every tree greater than 5 cm in diameter in each plot. Tree counts and basal area measurements for the plots were used to compute average numbers of trees ha-1, and to estimate the relative contribution of each tree species to the total basal area.

Leaf Area Index (LAI): LAI was estimated after the method of Pierce and Running (1988), which used the relation: LAI = -ln(Qi/Qo)/k, where k is the empirically determined extinction coefficient, which for conifers has been found to range between 0.4 and 0.65 (Jarvis and Leverenz, 1983). In this study, k was assumed to be 0.5, which is a good approximation for conifers (Pierce and Running, 1988). For the alder stand (1A) a k value of 0.6 was used as an average for deciduous canopies (Jarvis and Leverenz, 1983).

Above-Ground Tree Woody Biomass: To establish patterns of above-ground biomass and productivity, trees were sampled at study stands at all sites. 20 circular plots of 50 m2 were randomly selected in each stand. The diameter at breast height (DBH; diameter at 1.37 m) was measured of every tree greater than 5 cm in diameter in each plot. Tree counts and basal area measurements for the plots were used to compute average numbers of trees ha-1 and to estimate the relative contribution of each tree species to the total basal area. Stem, bark, and branch biomass was computed for each species in the sites using allometric relations developed for that species from destructive samples in the Pacific Northwest ((Bormann 1990 (sitka spruce), Gholz et al. 1979 (all other species)). An estimation was derived of total above-ground standing woody biomass by multiplying the measure of average weighted basal area per ha for each species by the biomass regression equations.

Tree Foliage Biomass: To convert from area to foliage biomass, specific leaf areas (cm2/gm dry weight) that were measured on foliage samples collected at the sites were applied. In July five

branches were shot from mid-canopy from dominant representative of all of the major tree species at the 6 sites. Representative samples of needles from each branch were analyzed for fresh needle area (one-sided) with the LI-COR leaf area meter, dryed at 700 C to a constant weight, and then weighed. The average specific leaf area of the five branches was then estimated, and these values were then pooled with the averages for the other trees to provide a site average. Then these values were applied to the LAI estimates from light transmittance (ceptometer, K = 0.5) to yield total foliage biomass (Mg ha-1).

Above-Ground Tree Net Primary Production (ANPP): Woody tree growth was determined by annual tree DBH changes estimated from measurements of growth rings. Increment cores were taken from a random selection of trees in each sample plot beginning with an initial random choice and then every fifth tree in sequence. Measurements were made of the current year's growth (1990) and of the previous five years. No significant difference was found between the current year's-growth increment and the average of the previous five years for any of the sites. As a result, the five year average growth increments were used to compute the average annual increment for each site. These values were then applied to the species regression relationships and average trees per ha to estimate woody biomass production (Mg ha-1 yr-1). In order to gauge patterns of foliage biomass production across the transect, the fraction of new growth was measured in the summer during maximum canopy development. Five branches were collected from each of the species on the sites, and specific leaf areas (cm2/gm1 dry weight) were measured on subsamples of current year age class and on subsamples of all other age classes. These values were then pooled for each site and used to provide an estimate of percent new production. The estimate of percent foliage production was applied to the estimate of total foliage biomass to provide yearly foliage production (Mg ha-1 yr-1). No measurements from Santiam Pass stand (site 4) were collected due to extensive spruce budworm damage. Instead, Gholz's (1982) estimate of new foliage growth fraction for a similar subalpine stand was used to compute total foliage production for site 4. Total annual above-ground net primary production (ANPP) of the trees was calculated by adding the woody biomass increment and foliage production estimates.

6. Observations:

Data Notes:

Leaf samples were taken at all sites within two weeks of each of the five OTTER aircraft data colleciton campaigns for remote sensing data. At site 3, additional samples were taken to provide monthly data.

Field Notes:

Information not available.

7. Data Description:

Spatial Characteristics:

Spatial Coverage:

Site 1: Cascade Head Latitude 44 03' N, Longitude 123 57' 30" W Site 1A: Cascade Head Alder Stand Latitude 44 03' N, Longitude 123 57' 30" W Site 2: Warings Woods Latitude 44 36' N, Longitude 123 16' W Site 3: Scio Control Latitude 44 40' 30" N, Longitude 123 36' 40" W Site 3F: Scio Fertilized Latitude 44 40' 30" N, Longitude 123 36' 40" W Site 4: Santiam Pass Latitude 44 025' 20" N, Longitude 121 50' 20" W Site 5: Metolius Control Latitude 44 25' N, Longitude 121 40' W Site 5: Metolius Fertilized Latitude 44 25' N, Longitude 123 40' W Site 6: Juniper Latitude 44 17' 30" N, Longitude 121 20' W

Spatial Coverage Map:

Maps have been submitted separately by Ames Research Center. Sites 2, 4, and 6 contain one plot each, chosen to represent a uniform and representative sample of the area. Site 1 contains two plots, one containing primarily western hemlock and one containing primarily red alder. Sites 3 and 5 contain one fertilized and one unfertilized plot at each location.

Spatial Resolution:

Not applicable.

Projection:

Not applicable.

Grid Description:

Not applicable.

Temporal Characteristics:

Temporal Coverage:

Data was gathered in two different time periods: 23 August 1989 through 09 October 1990 22 February 1990 through 04 June 1991

Temporal Coverage Map:

Not applicable

Temporal Resolution:

One site monthly, all others quarterly.

Data Characteristics:

Parameter/Variable:

SLA: Specific Leaf Area TN: Total Leaf Nitrogen Concentration TP: Total Leaf Phosphorus Concentration AA: Amino Acid Concentration LIGNIN: Lignin Concentration CELLU: Cellulose Concentration SUGAR: Sugar Concentration STARCH: Starch Concentration CHLA: Chlorophyll a Concentration CHLB: Chlorophyll b Concentration CHLTOT: Total Chlorophyll Concentration

Variable Description/Definition:

Specific Leaf Area: Square amount of leaf per gram. Total Leaf Nitrogen Concentration: Concentration of nitrogen within plant matter. Total Leaf Phosphorus Concentration: Concentration of phosphorus within plant matter. Amino Acid Concentration: Concentration of amino acids within plant matter. Lignin Concentration: Concentration of lignin within plant matter. Cellulose Concentration: Concentration of cellulose within plant matter. Sugar Concentration: Concentration of sugar within plant matter. Starch Concentration: Concentration of starch within plant matter. Chlorophyll a Concentration: Concentration of chlorophyll a within plant matter. Chlorophyll b Concentration: Concentration of cholorophyll b within plant matter. Total Chlorophyll Concentration: Concentration of total chlorophyll within plant matter.

Unit of Measurement:

Specific Leaf Area: cm2/g Total Leaf Nitrogen Concentration: mg/g Total Leaf Phosphorus Concentration: mg/g Amino Acid Concentration: mg/g Lignin Concentration: mg/g Cellulose Concentration: mg/g Sugar Concentration: mg/g Starch Concentration: mg/g Chlorophyll a Concentration: mg/g Chlorophyll b Concentration: mg/g Total Chlorophyll Concentration: mg/g

Data Source:

Laboratory

Data Range:

Information not available.

Sample Data Record:

DATACODE: MS10 MS10 MS10 MS10 MS10 MS10 MS10 MS10 MS10 MS10 FORMAT: 3 3 3 3 3 3 3 3 3 3 OVERFLT: 3 3 3 3 3 3 3 3 3 3 SITE: 1 1 1 1 1 1 1 1 2 2 COLDATE: 900828 900828 900828 900828 900828 900828 900828 900828 900818 900818 SPECIES: ALRU ALRU ALRU TSHE THSE THSE THSE THSE PSME PSME FERT: 0 0 0 0 0 0 0 0 0 0 CANPOS: 2 2 2 2 2 2 2 2 2 2 AGECLS: C C C A A A A A A A ID: 3 4 5 1 2 3 4 5 1 2 SLA: 72.9 84.7 73.2 85.6 61.1 47.7 51.7 TN: 28.41 25.57 27.56 8.80 10.95 10.58 11.46 11.08 12.84 11.76 TP: 1.56 1.50 1.46 1.51 2.05 1.46 2.45 1.30 1.44 1.79 AA: 3.29 3.26 3.32 3.46 3.49 3.40

3.54 3.43 4.12 4.13 LIGNIN: 10.34 12.96 10.59 22.07 20.31 16.95 16.33 15.29 15.40 16.56 CELLU: 15.88 17.87 14.78 21.02 22.21 17.57 22.30 23.04 26.85 22.96 SUGAR: 108.57 112.78 118.99 72.76 69.7165.76 87.07 80.26 91.32 104.19 STARCH: 0.00 0.00 0.00 90.05 11.88 44.30 27.03 30.04 1.71 3.74 CHLA: 4.69 5.06 4.58 1.25 1.53 1.40 1.68 1.51 2.01 1.62 CHLB: 1.58 1.82 2.23 0.39 0.20 0.34 0.63 0.49 0.79 0.56 CHLTOT: 6.27 6.88 6.81 1.64 1.76 1.75 2.30 2.00 2.79 2.17

8. Data Organization:

Data Granularity:

Each file contains at least 15 fields of tabular data. The first six fields give such physical characteristics about the data collection and field site as the data set code, the format number, the date of foliage collection, and the fertilization treatment code. The remaining nine fields of data contain such chemistry information as the specific leaf area, the total leaf nitrogen concentration, the total leaf phosphorus concentration, the amino acid concentration, the sugar concentration, the starch concentration, chlorophyll a and b concentration, and the total chlorophyll concentration. ms103.dat has four additional fields of data which also give such physical characteristics about the data collection and field site as the NASA overflight number, the site location code, the species code, and the age class code of leaves.

Data Format:

There are two ASCII data sets, ms103.dat and ms103.dat, available; these are accompanied by analagous ASCII companion files: ms103.doc and ms104.doc. In addition, a data set companion file, metchem.doc, is also available; this file is included in the complete data set.

9. Data Manipulations:

Formulae:

Derivation Techniques and Algorithms:

Intercepted Phtosynthetically Active Radiation (IPAR): Canopy transmittance (Qi/Qo) was calculated by dividing the average below-canopy PAR (Qi) by the average incident PAR (Qo). Percent intercepted PAR (IPAR) was calculated from the formula: IPAR = (1-Qi/Qo) a 100

Leaf Area Index (LAI): LAI was estimated after the method of Pierce and Running (1988), which used the relation: LAI = -ln(Qi/Qo)/k, where k is the empirically determined extinction coefficient.

Data Processing Sequence:

Data processing information is not available.

Calculations:

Special Corrections/Adjustments:

Information not available.

Calculated Variables:

Qi: Average below-canopy PAR Qo: Average incident PAR k: extinction coefficient

Graphs and Plots:

There is an XY Plot for the ms104.dat data set to show obvious discrepancies. There are 15 columns each containing 129 data points.

10. Errors:

Information about the various errors that may have occurred in the measurement of the canopy characteristics is not available.

11. Notes:

Notes on the data are not available.

12. Application of the Data Set:

The canopy chemistry measurements are a key portion in the OTTER project goals. They give hard, chemical data about the sites in the study. The combination of this laboratory work with field study and remote sensing techniques will help to simulate and predict ecosystem processes.

13. Future Modifications and Plans:

None, the OTTER campaign is complete.

14. Software:

Software Description:

The public domain software package, Imdisp, is provided for image diplay on IBM compatibles. The popular shareware program, Stuffit, is necessary to extract the execution file for the Macintosh image display program, Image4pds.

Software Access:

Software to display most of the OTTER image data (except Aviris and Asas data) on Macintosh and IBM personal computers (and compatibles) is provided on the CD-Rom disc containing the data sets.

15. Data Access:

Contacts for Archive/Data Access Information:

Name: ORNL DAAC User Services Office

Address: ORNL DAAC User Services Office Oak Ridge National Laboratory U.S.A.

Telephone Number: 1-(865)-241-3952

Electronic Mail Address: ornldaac@ornl.gov

Data Center Identification:

ORNL DAAC

Procedures for Obtaining Data:

Contact the ORNL DAAC User Services Office Oak Ridge National Laboratory U.S.A.

Telephone: 1-(865)-241-3952 FAX: 1-(865)-574-4665 Internet: ornldaac@ornl.gov

Data Center Status/Plans:

To be determined.

16. Output Products and Availability:

Available via FTP file or on CD-ROM.

Also available on-line via the World Wide Web at http://daac.ornl.gov.

17. References:

Sugar: Hazid, W.Z. and Neufeld, E.F. 1964. Quantitative determination of starch in plant tissue. In R.L. Whistler, R.J. Smith, and J.N. BeMiller, eds. Methods in Carbohydrate Chemistry. Academic Press, NY.

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Standards: Standard Reference Materials, 1976, 1982. Citrus leaves (SRM # 1572, Dec., 1982) and pine needles (SRM # 1575, Oct., 1976). National Institute of Standards and Technology, United States Department of Commerce, Gaitherburg, Maryland, 20899.

Total Nitrogen/Total Phosphorus: Technicon Instrument Corporation. 1977. Individual/simultaneous determinations of nitrogen and/or phosphorus in BD acid digests. Industrial Method Number 329-74W. Technicon Instrument Corporation, Tarrytown, New York.

Lignin/Cellulose: Van Soest, P.J. 1963. Use of detergents in the analysis of fibrous feeds II. A rapid method for the determination of fiber and lignin. Journal of the Association of Official Chemists 46(5):829-835.

Van Soest, P.J. and R.H. Wine. 1968. Determination of lignin and cellulose in acid-detergent fiber with permanganate. Journal of the Association of Official Analytical Chemists 51:780-785.

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Bormann, B.T. 1990. Diameter-based regression models ignore sapwood-related variation in Sitka spruce. Canadian Journal of Forest Research 20:1098-1104.

Gholz, H.L., C.C. Grier, A.G. Campbell, and A.T. Brown. 1979. Equations and their use for estimating biomass and leaf area of Pacificc Northwest plants. Research Paper 41. Oregon State Univeristy, Forest Research Laboratory, Corvallis, Oregon, U.S.A.

Gholz, H.L. 1982. Environmental limits on above-ground net primary production, leaf area, and biomass in vegetation zones of the Pacific Northwest. Ecology 63:469-481.

18. Glossary of Terms:

Glossary terms can be found in the Glossary list.

19. List of Acronyms:

Additional acronyms can be found in the Acronyms list.

ANPP Above-Ground Tree Net Primary Production DBH Diameter at Breast Height ESD Environmental Sciences Division (Oak Ridge National Laboratory) FTP File Transfer Protocol

IPAR Intercepted Photosynthetically Active Radiation LAI Leaf Area Index NASA National Aeronautics and Space Administration NPP Net Primary Production ORNL Oak Ridge National Laboratories Oak Ridge, Tennessee, U.S.A. OTTER Oregon Transect Ecosystem Research PAR Photosynthetically Active Region SLA Specific Leaf Area

20. Document Information:

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