Measurements of Soil Carbon Dioxide and Methane Concentrations and Fluxes, and Soil Properties at Four Ages of Jack Pine Forest in the Southern Study Area of the Boreal Ecosystem Atmosphere Study, Saskatchewan, Canada, 1993-95

By Kimberly P. Wickland *and* Robert G. Striegl

U.S. GEOLOGICAL SURVEY
Open-File Report 97-49

Denver, Colorado
1997

U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

Gordon P. Eaton, Director

.

For additional information write to:

Chief, Branch of Regional Research
U.S. Geological Survey
Box 25046, MS 418
Denver Federal Center
Denver, CO 80225

Copies of this report can be purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
Denver Federal Center
Denver, CO 80225

CONTENTS

FIGURE

TABLES

CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To obtain
kilometer (km)	0.6214	mile
centimeter (cm)	0.394	inch
gram (g)	0.03527	ounce
liter (L)	0.946	quart
meter (m)	3.281	foot
milligram (mg)	0.00004	ounce
millimeter (mm)	0.03937	inch
square meter (m^2)	10.76	square foot
moles of carbon	12.011	grams of carbon

The following terms are also used in this report:

micromoles per square meter per second ($\mu moles/m^2/sec$)
micromoles per square meter per day ($\mu moles/m^2/day$)
microsiemens per centimeter ($\mu siemens/cm$)
microequivalents per liter ($\mu eq/L$)
milligrams per liter (mg/L)
parts per million by volume (ppm)
permil content of ^{13}C relative to Pee Dee belemnite standards ($\delta\ ^{13}C$)
permil content of ^{18}O relative to Standard Mean Ocean Water ($\delta\ ^{18}O$)
weight percent (weight %)

Degree Celsius (°C) may be converted to degree Fahrenheit (°F) by using the following equation:

$$°F = 9/5\ (°C) + 32$$

Central Standard Time (CST) may be converted to Greenwich Mean Time (GMT) by using the following equation:

$$GMT=CST+6\ hours$$

Measurements of Soil Carbon Dioxide and Methane Concentrations and Fluxes, and Soil Properties at Four Ages of Jack Pine Forest in the Southern Study Area of the Boreal Ecosystem Atmosphere Study, Saskatchewan, Canada, 1993-95

By Kimberly P. Wickland *and* Robert G. Striegl

Abstract

Fluxes of carbon dioxide (CO_2) and methane (CH_4) across the soil-air interface were measured in four ages of jack pine forest at the Southern Study Area of the Boreal Ecosystem Atmosphere Study during August 1993 to March 1995. Gross and net flux of CO_2 and flux of CH_4 between soil and air are presented for 24 chamber sites in mature jack pine forest, 20-year old and 8-year old planted stands, and a clear cut area. Distributions of CO_2 and CH_4 concentrations are presented for the upper 5 meters (m) of soil and unsaturated zone at the mature stand, the upper 6 m at the 20-year old stand, and the upper 1 m at the 8-year old stand and clear cut area. Particle size and carbon content of the unsaturated deposits, precipitation, soil temperature and moisture, carbon and oxygen isotopes of soil CO_2, and soil water chemistry are also presented.

INTRODUCTION

The Boreal Ecosystem Atmosphere Study (BOREAS) is a large scale international investigation focused on improving the understanding of the exchanges of radiative energy, sensible heat, water, carbon dioxide (CO_2) and trace gases between boreal forests and the lower atmosphere. A primary objective of BOREAS is to collect the data needed to improve computer simulation models of the important processes controlling these exchanges so that scientists can anticipate the effects of climate change on the biome. Ground-based measurements for BOREAS are focused in the vicinity of 10 tower flux sites in Canada; six at the Southern Study Area in the proximity of Prince Albert, Saskatchewan, and four at the Northern Study Area near Thompson, Manitoba. Data presented in this report were collected at the Old Jack Pine and Young Jack Pine tower flux sites and nearby clear cut areas at the Southern Study Area (figure 1). A variety of aircraft, tower flux, and ecological data collected at these sites will ultimately be available through the BOREAS information system, as will the data tabulated here. More extensive site information on BOREAS is available through the BOREAS information system on the World Wide Web (http://boris.gsfc.nasa.gov/BOREAS).

Purpose and Scope

This report presents data relevant to understanding the transfer and storage of carbon among soil, the unsaturated zone, ground cover vegetation, and understory air in jack pine forest at the Southern Study

Area. The data were collected continuously from May through September, 1994 and during separate field trips in August 1993 and March 1995.

Site Descriptions

The Southern Study Area of the Boreal Ecosystem Atmosphere Study encompasses a 130 kilometer (km) by 90 km area in Saskatchewan bounded on the west by Prince Albert National Park and on the east by Narrow Hills Provincial Park (fig. 1). Four different jack pine forest settings in the Southern Study Area were selected as sampling sites: undisturbed mature forest or "Old Jack Pine", an approximately 20-year old stand or "Young Jack Pine", an approximately 8-year old stand or "Recent Cut", and a mature stand that was clear cut during the fall and winter of 1993-1994 or "Clear Cut". The sites are located on the east side of the Southern Study Area within 4 km west of Road 106 and 10 km south of its intersection with Road 120. They are set in sandy glacial outwash with a water table that varies among sites from about 4 to 8 meters below the surface. Gas flux was measured at six locations within each of the four sites for a total of 24 sample locations. Each site contained a linear transect having three pairs of permanently installed chamber collars spaced 30 m apart. Collars within pairs were spaced 1 m apart, and each chamber was designated a letter. Chambers A-F were at the Young Jack Pine site, chambers G-L were at the Old Jack Pine site, chambers M-R were at the Recent Cut site, and chambers S-X were at the Clear Cut site.

The Old Jack Pine soil gas transect is located about 150 m southeast of the Old Jack Pine tower flux site (53.916 N latitude, 104.691 W longitude). The forest was established by fire, reportedly in the 1890's, and is comprised entirely of jack pine *(Pinus banksiana)* having an occasional alder in the understory. The soil is almost completely covered with reindeer lichen (*Cladina*) and includes some bearberry (*Arctostaphylos uvu-ursi*) and deadfall jackpine.

The Young Jack Pine transect is approximately 40 m north of the Young Jack Pine tower flux site (53.875 N latitude, 104.647 W longitude). The site was clear cut in the late 1970's and the regrowth forest is jack pine with an occasional aspen. Sample trees harvested at the site in 1994 ranged in age from about 16 to 20 years and in height from about 5 to 6 m. The soil is approximately 50 percent covered with vegetation, including grasses, wild rose (*Rosa spp*), blueberry (*Vaccinium canadense*) and bearberry. The remaining soil is covered with pine needles and woody debris, primarily slash left from the clear cutting.

The Recent Cut transect is located about 2 km southeast of the Old Jack Pine tower in an area that was formerly a forest stand continuous with the stand currently encompassing the Old Jack Pine tower. The area surrounding the Recent Cut transect was clear cut in the mid 1980's and the regrowth stand was about 8 years old in 1994, with trees ranging in height from 2 to 3 m. The soil is mostly covered with woody debris, primarily slash left from the clear cutting. Ground cover vegetation is mostly grasses, with wild rose, blueberry and bearberry.

The Clear Cut transect is located approximately 3 km SE of the Old Jack Pine tower. The surrounding area was formerly in a forest stand that was continuous with the stand currently encompassing the Old Jack Pine tower and was clear cut during the fall and winter of 1993-94. During the summer of 1994, the soil at the Clear Cut transect was either stripped bare or was covered with slash and dead and dying vegetation.

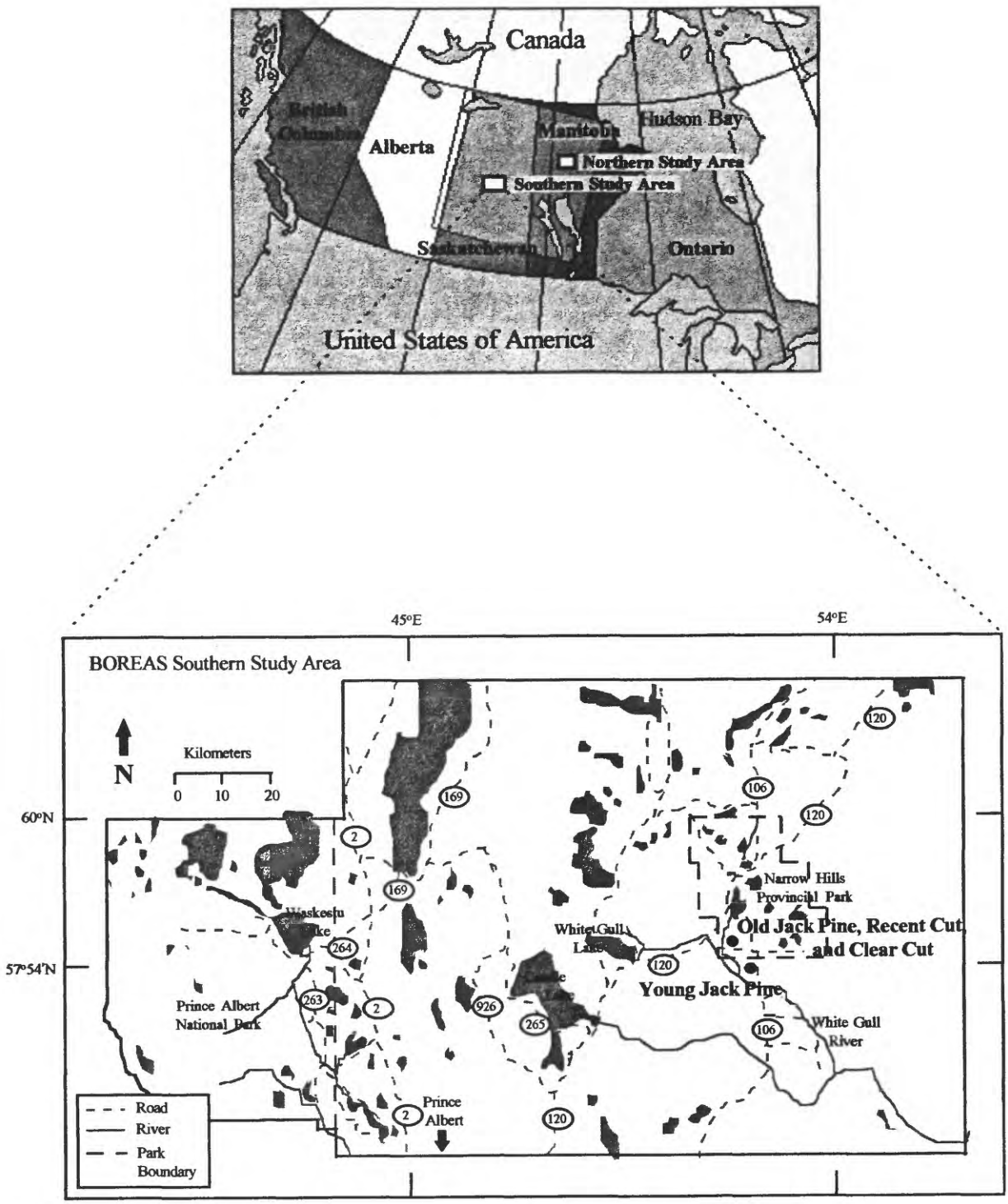

Figure 1. Maps showing location of the Boreal Ecosystem Atmosphere Study Southern Study Area and study sites. (map adapted from BOREAS World Wide Web page, http:// boris.gsfc.nasa.gov/BOREAS)

Acknowledgments

Collection of these data was a combined effort by the authors and D. Anderson, P. Cutrone, J. Heiny, P. Hern, M.A. Mast, C. Michmerhuizen, M. Sierszen, and D. Stannard. Funding was provided by a BOREAS grant from National Aeronautics and Space Administration and the United States Geological Survey Global Change Hydrology Program.

METHODS AND DATA

The data in this report are presented in tables that immediately follow descriptions of the field and analytical method(s) used to obtain them. Basic site and environmental data precede data summaries on gas concentration and flux.

Surficial Deposits

Vertical pits 2 m deep were dug at two sites for detailed soil descriptions and sample collection. Field descriptions of the soil pits at each site are provided in table 1. Samples were collected in each soil horizon, at approximately every 0.1 m. Additionally, soils were described and sampled in shallow pits and at road cuts and borrow pits. Samples were analyzed for particle size (Folk, 1980) and percent carbon. Soil colors were determined using the Munsell soil color charts (1992). These soils were formed in forested, sandy, glaciofluvial parent material of the Saskatchewan Plains and are classified as Humo-Ferric Podzols (Clayton and others, 1977).

Old Jack Pine

All soils described at this site were formed in medium grained sand, 0.25 - 0.50 millimeters (mm) diameter. The average percent moisture at the soil surface was 8.40 percent (range 5.01 to 12.2 percent) for 12 samples collected from June 24 to July 26, 1994. Six soil profiles were described in detail and sampled. The descriptions that follow and are presented in table 1 are averages from those profiles.

The O (organic) horizon ranges from 25 to 60 mm thick. It is black to very dark gray to dark reddish brown in color, with mean grain diameters ranging from 0.32 to 0.38 mm. Silt and clay content varies from 1.34 to 4.40 percent, and the amount of material greater than sand size (2.0 mm) ranges from 0.43 to 23 percent.

The Ah (humic) horizon ranges from 40 to 50 mm thick. The color varies from very dark gray to dark reddish brown, with mean grain diameters ranging from 0.32 to 0.40 mm. Silt and clay content ranges from 0.97 to 3.02 percent, and the amount of material greater than sand size varies from 0.10 to 1.28 percent.

The Ae (eluviated) horizon, where present, ranges from 30 to 190 mm thick, having undulating, irregular, but distinct boundaries with the overlying Ah horizon and underlying B horizon. The color is pinkish gray to reddish brown, with silt coatings on the sand grains. The mean grain diameters range from 0.31 to 0.40 mm, silt and clay content varies from 2.14 to 3.36 percent, and the amount of material greater than sand size varies from 0.11 to 1.03 percent.

The Bf (ferric) horizon ranges from 70 to 800 mm thick. The color is yellowish red with iron staining. The mean grain diameter ranges from 0.32 to 0.43 mm, and grains vary in shape from moderately-well to sub-rounded. Silt and clay content ranges from 1.6 to 5.45 percent, and the amount of material greater than sand size ranges from 0.02 to 45 percent. Pebbles (2.00 to 4.00 mm diameter) are occasionally found in the B horizon along distinct laminae.

The C horizon is found at the bottom of the soil pit and varies from at least 110 mm to greater than 1200 mm thick. Color varies from light red brown to red brown and yellow red to pinkish white. Mean grain diameters range from 0.34 to 0.42 mm, with 0.19 to 3.50 percent silt and clay and 0.10 to 2.30 percent material greater than sand size. Cobbles (16.0 to 64.0 mm), gravel (4.00 to 16.0 mm), and pebbles (2.00 to 4.00 mm) are common in the C horizon and are oriented along distinct laminae.

Young Jack Pine

Soils described at this site were formed in fine to coarse-grained sand (0.125 to 1.00 mm diameter). The average percent soil moisture at the soil surface was 10.4 percent (range 3.99 to 23.5 percent) for 16 samples collected from June 25 to July 25, 1994. Seven soil profiles were described and sampled. The descriptions that follow and are presented in table 1 are averages from these profiles.

The O horizon ranges from 20 to 50 mm thick, and the color varies from black to gray to dark reddish brown. The mean grain diameter ranges from 0.29 to 0.44 mm, with 0.08 to 6.80 percent silt and clay and 0.69 to 18.0 percent material greater than sand size.

The Ah horizon ranges from 20 to 40 mm thick, and the color varies from dark red brown to black. Mean grain diameter ranges from 0.29 to 0.42 mm. Silt and clay (1.74 to 5.76 percent) and organic matter are present in the Ah horizon, as well as 0.74 to 2.20 percent material greater than sand size.

The Ae horizon, where present, ranges from 10 to 110 mm thick. The color is reddish brown to gray, with silt coatings on the sand grains. The mean grain diameter ranges from 0.24 to 0.42 mm, silt and clay content varies from 2.78 to 5.82 percent, and the amount of material greater than sand size varies from 0.46 to 2.83 percent.

The Bf horizon ranges from 60 to 620 mm thick, and the color varies from reddish brown to yellowish red with iron staining on the sand grains. The mean grain diameter varies from 0.31 to 0.55 mm, and grains vary in shape from are subangular to subrounded or moderately well rounded. Silt and clay content ranges from 0.43 to 7.34 percent and the amount of material greater than sand size varies from 0.47 to 54.0 percent. Occasional lenses of pebbles are oriented along horizontal laminae.

The C horizon varies from at least 20 mm to greater than 540 mm thick with color varying from light reddish brown to pinkish gray. The mean grain diameter ranges from 0.56 to 0.67 mm, and grains are subangular to subrounded. Silt and clay content varies from 0.31 to 3.21 percent, and the amount of material greater than sand size ranges from 0.09 to 56.0 percent. Pebbles are commonly found in distinct laminae.

Table 1 . Soil descriptions at the Old Jack Pine and Young Jack Pine sites, BOREAS Southern Study Area, Saskatchewan, Canada, 1994. Numbers given are averages taken from detailed descriptions of six Old Jack Pine and seven Young Jack Pine soil profiles.

[mm, millimeters; %, percent; OJP, Old Jack Pine; YJP, Young Jack Pine]

Site	Soil horizon	Depth from surface (mm)	Average thickness (mm)	Color (Munsell soil color chart, 1992)	Average description
OJP	O	+36	36	5YR 2.5/2	Medium sand (average grain diameter 0.36 mm), with 1.66% silt and clay; 14.0% greater than sand size (2.00 mm); lichens, moss, roots, twigs, vegetation, decaying organic material, burned material.
OJP	Ah	0 - 45	45	5YR 3/3	Medium sand (0.36 mm), 2.90% silt and clay; and 0.62% greater than sand size; moderately well to subrounded, poorly sorted, organic material.
OJP	Ae	45 - 95	50	5YR 6/2	Medium sand (0.36 mm); 2.67% silt and clay; 0.44% greater than sand size; subrounded to moderately well rounded, poorly sorted, silt coating on grains.
OJP	Bf	95 - 370	270	5YR 4/6	Medium sand (0.35 mm); 3.54% silt and clay; 9.43% greater than sand size; subrounded to moderately well rounded; moderately well sorted, iron staining on grains.
OJP	C	370 - 740	370	5YR 5/3-5/6	Medium sand (0.38 mm); 1.36% silt and clay; 0.35% greater than sand size; subangular to moderately well rounded, moderately well to well sorted, calcareous.
YJP	O	+34	34	5YR 2.5/1	Medium sand (0.39 mm); 2.92% silt and clay; 12% greater than sand size; lichens, moss, roots, small twigs, vegetation, decaying organic material.
YJP	Ah	0 - 27	27	5YR 3/3	Medium sand (0.36 mm); 2.86% silt and clay; 1.18% greater than sand size; subrounded to moderately well rounded, poorly sorted, organic material.
YJP	Ae	27 - 97	70	5YR 4/3	Medium sand (0.34 mm); 4.61% silt and clay; 1.62% greater than sand size; subangular to subrounded , poorly sorted, silt coatings on grains.
YJP	Bf	97 - 390	290	5YR 5/6-6/6	Medium to coarse sand (0.42 mm); 4.30% silt and clay; 4.16% greater than sand size; subangular to subrounded, poorly sorted, iron staining, pebbles (2.00-4.00 mm diameter) in laminae at base of profile.
YJP	C	390 - 930	280	5YR 6/1-6/3	Coarse sand (0.59 mm); 1.09% silt and clay; 12.7% greater than sand size; subangular to subrounded, poorly sorted, 10 mm thick laminae.

Carbon Content of Soils

Soils were collected from various depth intervals in augured holes at the Old Jack Pine and Young Jack Pine sites. The soil samples were analyzed for total carbon content and/or inorganic carbon content using a UIC Coulometrics, Inc. model 5012 coulometer. Total carbon was determined by combusting an 80 to 100 mg soil sample (dry weight) at 900° C and measuring the amount of evolved carbon dioxide gas. Inorganic carbon was determined by acidifying a 100 to 120 mg soil sample with perchloric acid and measuring the amount of evolved carbon dioxide gas. Total and inorganic carbon content are expressed as weight percent carbon per unit weight of soil sample. Both total and inorganic carbon content for Old Jack Pine soils are listed in table 2. Inorganic carbon content for two soil profiles at Young Jack Pine are listed in table 3.

Table 2. Soil carbon content at the Old Jack Pine site, BOREAS Southern Study Area, Saskatchewan, Canada, collected on August 20 (day 232), 1993.
[m, meters; weight %, weight of carbon in sample/total dry weight of sample x 100]

Depth (m)	Total carbon (weight %)	Inorganic carbon (weight %)
0 - 0.02	1.1932	0.0094
0 - 0.1	0.3754	0.0040
0.1 - 0.3	0.0762	0.0008
0.3 - 0.6	0.0410	0.0006
0.6 - 0.9	0.0351	0.0001
0.9 - 1.2	0.0310	0.0001
1.2 - 1.5	0.0242	0.0000
1.5 - 1.8	0.0236	0.0001
1.8 - 2.1	0.0260	0.0002
2.1 - 2.4	0.0280	0.0004
2.4 - 2.7	0.0252	0.0012
2.7 - 3.0	0.4244	0.3990
3.0 - 3.4	0.4812	0.2850
3.4 - 3.7	0.3300	0.2980
3.7 - 4.0	0.2484	0.2690

Table 3. Soil carbon content at two Young Jack Pine site profiles, BOREAS Southern Study Area, Saskatchewan, Canada, collected on August 20 and 21 (days 232 and 233), 1993.
[m, meters; weight %, weight of carbon in sample/total dry weight of sample x 100; --, no data]

Depth (m)	Inorganic carbon (weight %) Profile 1	Inorganic carbon (weight %) Profile 2
0.6	0.0008	--
1.2	0.0002	--
2.4	0.1725	--
3.0	0.6090	--
3.7	0.4189	0.7097
4.3	0.7587	0.4652
4.9	0.5543	1.1590
5.5	0.9423	0.7436
6.1	0.5037	--
6.7	0.4482	--
8.5	0.4692	--
9.1	0.6573	--
10.0	0.9074	--

Precipitation

Daily precipitation was measured at the Young Jack Pine site in 1994 using a Weathertronics 6010 tipping bucket rain gauge (one tip=0.25 mm) located in a clearing approximately 10 m in diameter near the Young Jack Pine tower. Data are presented in table 4.

Table 4. Daily precipitation at the Young Jack Pine site, BOREAS Southern Study Area, Saskatchewan, Canada, 1994.

[mm, millimeters]

Date (day of year)	Precipitation (mm)	Date (day of year)	Precipitation (mm)
May 16 (136)	20.25	June 13 (164)	0.00
May 17 (137)	5.25	June 14 (165)	19.75
May 18 (138)	8.00	June 15 (166)	3.50
May 19 (139)	0.00	June 16 (167)	2.75
May 20 (140)	0.00	June 17 (168)	0.00
May 21 (141)	8.50	June 18 (169)	0.00
May 22 (142)	2.25	June 19 (170)	2.50
May 23 (143)	0.00	June 20 (171)	2.50
May 24 (144)	10.50	June 21 (172)	0.00
May 25 (145)	0.00	June 22 (173)	0.00
May 26 (146)	0.00	June 23 (174)	0.00
May 27 (147)	0.00	June 24 (175)	0.00
May 28 (148)	16.25	June 25 (176)	4.25
May 29 (149)	0.00	June 26 (177)	0.00
May 30 (150)	5.25	June 27 (178)	0.00
May 31 (151)	0.00	June 28 (179)	5.00
June 1 (152)	0.00	June 29 (180)	2.75
June 2 (153)	0.00	June 30 (181)	19.25
June 3 (154)	1.50	July 1 (182)	0.00
June 4 (155)	0.00	July 2 (183)	0.00
June 5 (156)	0.50	July 3 (184)	1.25
June 6 (157)	0.75	July 4 (185)	3.25
June 7 (158)	0.00	July 5 (186)	36.00
June 8 (159)	0.00	July 6 (187)	0.25
June 9 (160)	0.00	July 7 (188)	0.00
June 10 (161)	0.00	July 8 (189)	0.25
June 11 (162)	0.00	July 9 (190)	0.00
June 12 (163)	0.00	July 10 (191)	2.50

Table 4. (continued)

Date (day of year)	Precipitation (mm)	Date (day of year)	Precipitation (mm)
July 11 (192)	1.25	Aug. 9 (221)	0.00
July 12 (193)	9.75	Aug. 10 (222)	0.75
July 13 (194)	0.25	Aug. 11 (223)	1.00
July 14 (195)	0.00	Aug. 12 (224)	3.25
July 15 (196)	3.50	Aug. 13 (225)	0.00
July 16 (197)	0.00	Aug. 14 (226)	0.00
July 17 (198)	0.00	Aug. 15 (227)	0.00
July 18 (199)	3.00	Aug. 16 (228)	0.00
July 19 (200)	100.50	Aug. 17 (229)	0.00
July 20 (201)	10.25	Aug. 18 (230)	0.25
July 21 (202)	0.00	Aug. 19 (231)	3.75
July 22 (203)	2.50	Aug. 20 (232)	0.00
July 23 (204)	0.00	Aug. 21 (233)	0.00
July 24 (205)	0.00	Aug. 22 (234)	1.75
July 25 (206)	0.00	Aug. 23 (235)	0.00
July 26 (207)	0.00	Aug. 24 (236)	0.00
July 27 (208)	0.00	Aug. 25 (237)	0.00
July 28 (209)	0.00	Aug. 26 (238)	0.00
July 29 (210)	10.00	Aug. 27 (239)	0.00
July 30 (211)	0.00	Aug. 28 (240)	0.00
July 31 (212)	0.00	Aug. 29 (241)	2.50
Aug. 1 (213)	3.25	Aug. 30 (242)	0.00
Aug. 2 (214)	0.00	Aug. 31 (243)	0.00
Aug. 3 (215)	0.00	Sep. 1 (244)	0.00
Aug. 4 (216)	0.00	Sep. 2 (245)	0.00
Aug. 5 (217)	0.00	Sep. 3 (246)	0.00
Aug. 6 (218)	0.25	Sep. 4 (247)	18.25
Aug. 7 (219)	0.00	Sep. 5 (248)	0.75
Aug. 8 (220)	0.00		

Soil Surface Temperature and Water Content

Soil surface temperature was measured using a Fluke model 51 K thermometer at 3 depths (0.05, 0.10, and 0.15 m) at each pair of chambers in conjunction with flux measurements.

Soil water content was determined from soil samples collected at each pair of chambers concurrent with flux measurements. Each sample included the top 0.05 m of soil and was sealed in an air-tight container until analysis. The samples were weighed, oven-dried at 105°C for approximately 24 hours, and weighed again. After subtracting the container weight, percent water content was calculated as the difference of the original sample weight and the dried sample weight divided by the original sample weight and multiplied by 100 (Klute, 1986).

Tables 5-8 list collection date, time of measurement, air temperature, soil temperatures at depth, and soil water content for each site in 1994.

Table 5. Soil temperature and soil water content at the Old Jack Pine site, BOREAS Southern Study Area, Saskatchewan, Canada, 1994.
[CST, Central Standard Time; °C, degrees Celsius; m, meters; weight %, weight of water in sample/total weight of sample x 100; --, no data]

Date (day of year)	Time of day (CST)	Location (chamber pair)	TEMPERATURE (°C)				Water content (weight %) 0 - 0.05 m
			Air	-0.05 m	-0.10 m	-0.15 m	
May 22 (142)	13:30	GH	--	--	--	--	9.61
May 26 (146)	14:00	GH	--	11.2	8.7	7.5	9.22
May 26 (146)	14:30	IJ	--	12.8	9.9	7.6	4.94
May 26 (146)	15:00	KL	--	10.7	8.6	6.7	10.71
June 1 (152)	12:00	GH	--	11.6	9.0	7.9	9.24
June 1 (152)	12:30	IJ	--	10.5	8.6	8.0	11.73
June 1 (152)	13:00	KL	--	10.2	8.4	7.1	8.95
June 4 (155)	15:00	GH	--	14.8	13.1	11.8	4.22
June 4 (155)	15:30	IJ	--	14.6	12.1	10.6	11.35
June 4 (155)	16:00	KL	--	12.1	10.5	9.3	8.73
June 8 (159)	11:00	KL	--	10.5	9.6	9.0	13.44
June 8 (159)	13:00	GH	--	13.5	11.7	10.8	11.70
June 8 (159)	14:00	IJ	--	13.5	11.6	10.4	9.44
June 18 (169)	11:00	KL	20.5	9.1	8.3	7.7	10.98
June 18 (169)	12:00	IJ	20.6	9.5	8.8	8.3	10.52
June 18 (169)	13:00	GH	21.7	13.5	12.0	10.3	8.97
June 24 (175)	12:00	GH	26.8	17.0	14.3	13.3	5.86
June 24 (175)	12:30	IJ	23.6	17.6	14.2	12.6	5.07

Table 5. (continued)

Date (day of year)	Time of day (CST)	Location (chamber pair)	TEMPERATURE (°C)				Water content (weight %) 0 - 0.05 m
			Air	-0.05 m	-0.10 m	-0.15 m	
June 24 (175)	13:00	KL	25.6	14.5	13.2	12.6	9.09
July 4 (185)	11:00	GH	14.6	13.0	12.6	12.4	12.01
July 4 (185)	12:00	IJ	13.6	13.2	12.7	12.3	--
July 7 (188)	12:00	GH	18.2	13.4	12.5	12.1	9.96
July 7 (188)	13:00	IJ	17.8	13.9	12.6	12.0	9.49
July 7 (188)	13:00	KL	17.8	13.3	12.5	11.8	12.19
July 10 (191)	10:00	GH	20.9	14.2	13.5	13.3	7.66
July 10 (191)	11:00	IJ	19.3	16.1	14.5	13.7	6.84
July 21 (202)	15:00	GH	28.5	19.7	18.7	17.5	9.07
July 21 (202)	15:30	IJ	29.7	21.5	19.6	17.6	--
July 21 (202)	16:00	KL	27.2	20.0	17.7	16.5	--
July 22 (203)	09:00	GH	--	--	--	--	8.53
July 26 (207)	12:00	GH	35.1	15.7	14.8	14.5	5.01
July 26 (207)	13:30	IJ	34.6	16.6	15.3	14.7	--
July 26 (207)	14:00	KL	34.3	18.0	16.3	15.0	--
Aug. 2 (214)	16:00	GH	28.5	21.3	19.1	17.9	--
Aug. 2 (214)	16:00	IJ	28.6	21.0	18.6	17.3	--
Aug. 8 (220)	15:00	GH	22.4	15.5	15.0	14.7	--
Aug. 8 (220)	16:00	IJ	19.9	15.8	15.0	14.4	--

Table 5. (continued)

Date (day of year)	Time of day (CST)	Location (chamber pair)	TEMPERATURE (°C)				Water content (weight %) 0 - 0.05 m
			Air	-0.05 m	-0.10 m	-0.15 m	
Aug. 8 (220)	17:00	KL	20.1	14.9	14.4	14.0	--
Aug. 10 (222)	12:30	GH	25.0	16.4	15.1	14.6	--
Aug. 10 (222)	13:00	IJ	24.8	16.8	15.8	14.9	--
Aug. 10 (222)	14:00	KL	24.9	17.2	16.0	14.7	--
Aug. 15 (227)	14:00	GH	30.7	19.9	16.1	14.4	2.28
Aug. 15 (227)	14:30	IJ	32.2	20.4	17.4	15.3	2.43
Aug. 15 (227)	15:00	KL	29.7	18.8	16.3	14.7	6.19
Aug. 20 (232)	08:00	GH	12.3	12.2	12.7	13.2	4.53
Aug. 20 (232)	10:00	GH	20.8	13.1	12.8	13.0	5.32
Aug. 20 (232)	12:00	GH	26.9	16.1	13.4	12.6	3.30
Aug. 20 (232)	14:00	GH	28.4	19.9	17.3	15.4	3.60
Aug. 20 (232)	16:00	GH	27.6	18.5	16.9	15.9	3.06
Aug. 20 (232)	18:00	GH	27.3	17.5	16.6	16.0	5.81
Aug. 20 (232)	20:00	GH	21.1	16.9	16.6	15.8	5.02
Aug. 20 (232)	22:00	GH	15.5	16.3	16.4	16.1	6.95
Aug. 21 (233)	00:00	GH	14.0	15.5	15.7	15.6	4.89
Aug. 21 (233)	02:00	GH	12.7	14.9	15.4	15.5	5.97
Aug. 21 (233)	04:00	GH	11.5	14.3	14.5	14.7	4.45
Aug. 21 (233)	06:00	GH	12.2	13.9	14.3	14.6	4.83

Table 5. (continued)

Date (day of year)	Time of day (CST)	Location (chamber pair)	TEMPERATURE (°C)				Water content (weight %) 0 - 0.05 m
			Air	-0.05 m	-0.10 m	-0.15 m	
Aug. 21 (233)	08:00	GH	13.4	14.0	14.1	14.2	--
Aug. 22 (234)	11:00	GH	23.2	16.7	15.2	14.8	3.21
Aug. 22 (234)	12:00	IJ	21.8	16.4	15.2	14.9	2.73
Aug. 22 (234)	12:00	KL	21.5	15.5	14.8	14.7	8.58
Aug. 25 (237)	15:00	GH	19.4	15.7	14.3	13.6	2.59
Aug. 25 (237)	16:00	IJ	19.8	15.8	14.2	13.6	--
Aug. 25 (237)	17:00	KL	17.4	15.3	14.6	14.0	--
Sep. 9 (252)	10:00	GH	18.9	12.1	12.0	12.0	5.84
Sep. 9 (252)	11:00	IJ	18.9	12.1	11.6	11.6	--
Sep. 9 (252)	11:30	KL	20.3	12.1	11.6	11.6	--
Sep. 11 (254)	14:00	GH	19.1	12.7	12.0	11.0	--
Sep. 11 (254)	14:30	IJ	14.9	11.8	11.5	11.1	6.66
Sep. 11 (254)	15:00	KL	13.4	11.7	11.3	11.2	--
Sep. 12 (255)	11:00	GH	23.3	10.1	9.8	10.1	--
Sep. 14 (257)	12:00	GH	23.3	10.1	9.8	10.1	4.90
Sep. 14 (257)	12:30	IJ	28.0	10.4	9.3	9.5	3.90
Sep. 14 (257)	13:00	KL	24.3	12.0	10.4	10.2	6.42

Table 6. Soil temperature and soil water content at the Young Jack Pine site, BOREAS Southern Study Area, Saskatchewan, Canada, 1994.
[CST, Central Standard Time; °C , degrees Celsius; m, meters; weight %, weight of water in sample/total weight of sample x 100; --, no data]

Date (day of year)	Time of day (CST)	Location (chamber pair)	TEMPERATURE (°C)				Water content (weight %) 0 - 0.05 m
			Air	-0.05 m	-0.10 m	-0.15 m	
May 26 (146)	11:00	AB	--	--	--	8.1	10.08
May 26 (146)	11:30	CD	--	--	--	8.6	9.01
May 26 (146)	12:00	EF	--	--	--	9.0	8.05
June 3 (154)	09:30	AB	--	12.4	11.7	11.3	15.11
June 4(155)	11:00	AB	--	13.1	11.3	10.5	11.81
June 4 (155)	11:30	CD	--	14.5	12.7	12.1	7.51
June 4 (155)	12:00	EF	--	18.5	13.5	12.1	7.47
June 8 (159)	16:00	AB	--	14.6	13.6	12.8	9.42
June 8 (159)	17:30	CD	--	16.8	14.7	13.5	2.83
June 9 (160)	11:30	AB	--	12.6	11.9	11.4	8.18
June 9 (160)	12:00	CD	--	14.4	12.4	11.8	5.13
June 9 (160)	13:00	EF	--	15.5	12.8	12.2	2.07
June 10 (161)	16:00	AB	--	16.8	14.7	13.4	4.25
June 10 (161)	16:30	CD	--	20.4	16.9	15.3	3.05
June 10 (161)	17:00	EF	--	18.8	16.7	15.1	1.90
June 11 (162)	11:30	AB	--	--	--	--	12.56
June 11 (162)	13:30	AB	28.3	15.3	13.2	12.2	9.84
June 11 (162)	16:00	AB	25.0	16.8	15.0	13.7	6.49

Table 6. (continued)

Date (day of year)	Time of day (CST)	Location (chamber pair)	TEMPERATURE (°C)				Water content (weight %) 0 - 0.05 m
			Air	-0.05 m	-0.10 m	-0.15 m	
June 11 (162)	18:30	AB	22.2	16.0	15.2	14.2	3.27
June 11 (162)	20:00	AB	19.0	14.9	14.2	13.6	6.21
June 11 (162)	23:30	AB	5.4	13.8	15.1	14.8	12.51
June 12 (163)	01:30	AB	4.0	11.7	13.0	13.4	4.66
June 12 (163)	03:30	AB	2.4	11.8	12.9	13.3	5.85
June 12 (163)	05:30	AB	9.5	12.1	12.6	13.3	4.61
June 12 (163)	07:30	AB	13.1	11.7	11.8	11.9	4.54
June 12 (163)	09:30	AB	17.5	12.8	11.8	11.8	4.00
June 12 (163)	11:30	AB	14.4	15.5	14.4	13.6	14.64
June 20 (171)	10:30	EF	25.2	11.9	10.7	10.6	11.11
June 20 (171)	11:00	CD	25.1	14.1	12.4	11.7	10.18
June 20 (171)	12:30	AB	22.7	13.4	11.7	10.7	17.45
June 25 (176)	12:30	EF	15.7	15.5	14.8	14.4	--
June 25 (176)	13:00	CD	16.5	14.2	13.5	13.3	--
June 25 (176)	14:00	AB	18.6	16.5	15.1	14.6	--
July 3 (184)	10:30	AB	20.4	14.4	13.5	13.3	9.92
July 3 (184)	11:30	CD	15.5	16.3	14.6	13.7	8.59
July 6 (187)	12:00	AB	16.1	14.6	13.5	13.0	10.92
July 6 (187)	13:00	CD	20.9	14.6	13.1	12.7	9.73

Table 6. (continued)

Date (day of year)	Time of day (CST)	Location (chamber pair)	TEMPERATURE (°C)				Water content (weight %) 0 - 0.05 m
			Air	-0.05 m	-0.10 m	-0.15 m	
July 6 (187)	13:30	EF	16.0	17.1	14.8	14.1	10.26
July 9 (190)	13:30	AB	23.4	19.2	15.8	14.1	23.50
July 9 (190)	14:30	CD	25.3	19.9	16.8	15.4	5.73
July 20 (201)	15:00	AB	26.6	20.5	18.4	17.5	16.96
July 20 (201)	16:00	CD	28.0	22.7	19.3	18.1	6.77
July 20 (201)	16:30	EF	30.5	27.3	21.4	19.0	4.79
July 25 (206)	11:00	AB	--	15.3	13.8	13.6	18.57
July 25 (206)	11:30	CD	--	15.3	14.3	13.9	4.97
July 25 (206)	12:30	EF	--	21.1	17.6	14.9	3.99
Aug. 1 (213)	15:30	AB	26.3	21.2	19.4	18.5	--
Aug. 4 (216)	14:00	AB	29.7	18.3	16.7	15.0	--
Aug. 4 (216)	14:30	CD	29.2	18.8	17.4	15.5	--
Aug. 4 (216)	15:00	EF	27.0	18.0	17.0	16.0	--
Aug. 8 (220)	10:30	AB	21.4	13.9	13.7	14.7	--
Aug. 8 (220)	11:00	CD	21.2	14.2	13.7	13.2	--
Aug. 8 (220)	12:00	EF	19.4	16.2	15.2	15.1	--
Aug. 10 (222)	08:30	AB	17.6	14.3	13.6	13.5	--
Aug. 10 (222)	09:30	CD	20.3	14.4	14.0	13.8	--
Aug. 10 (222)	10:30	EF	23.1	16.6	15.2	14.2	--

Table 6. (continued)

Date (day of year)	Time of day (CST)	Location (chamber pair)	TEMPERATURE (°C)				Water content (weight %) 0 - 0.05 m
			Air	-0.05 m	-0.10 m	-0.15 m	
Aug. 11 (223)	12:00	AB	17.1	15.4	14.8	14.2	6.22
Aug. 11 (223)	13:30	AB	26.3	18.8	16.2	14.9	3.95
Aug. 11 (223)	16:30	AB	20.9	17.9	17.3	16.8	3.70
Aug. 11 (223)	18:30	AB	20.3	17.8	16.9	16.1	2.87
Aug. 11 (223)	20:30	AB	20.3	18.2	17.5	16.9	3.49
Aug. 11 (223)	22:30	AB	12.9	15.0	16.0	17.4	3.27
Aug. 12 (224)	00:00	AB	11.3	14.8	15.6	16.0	2.86
Aug. 12 (224)	04:30	AB	11.2	13.1	14.0	14.4	3.43
Aug. 12 (224)	06:30	AB	14.9	13.4	14.0	14.0	4.03
Aug. 12 (224)	09:00	AB	14.6	14.0	14.0	14.0	5.62
Aug. 12 (224)	15:00	AB	15.5	14.6	14.0	--	10.01
Aug. 18 (230)	11:30	AB	22.2	15.3	14.1	13.7	4.39
Aug. 18 (230)	12:30	CD	22.0	17.3	14.4	13.9	2.04
Aug. 18 (230)	13:30	EF	21.8	18.6	16.4	15.4	2.54
Aug. 23 (235)	11:00	AB	26.0	15.0	13.9	14.1	4.28
Aug. 23 (235)	11:30	CD	24.5	15.5	14.5	14.0	3.37
Aug. 23 (235)	11:30	EF	23.5	17.2	15.0	--	--
Aug. 26 (238)	13:00	AB	18.2	13.1	11.3	11.2	4.09
Aug. 26 (238)	13:30	CD	18.8	13.5	12.1	12.0	3.07

Table 6. (continued)

Date (day of year)	Time of day (CST)	Location (chamber pair)	TEMPERATURE (°C)				Water content (weight %) 0 - 0.05 m
			Air	-0.05 m	-0.10 m	-0.15 m	
Aug. 26 (238)	14:30	EF	20.1	14.9	12.9	12.6	1.52
Sep. 8 (251)	14:30	AB	24.4	14.6	13.1	12.7	7.95
Sep. 8 (251)	15:30	CD	24.8	14.8	13.2	12.6	--
Sep. 8 (251)	16:30	EF	24.1	14.4	13.1	12.6	--
Sep. 12 (255)	16:00	AB	16.1	12.7	11.9	11.2	--
Sep. 12 (255)	17:00	CD	17.3	12.6	11.5	11.0	3.75
Sep. 12 (255)	17:30	EF	17.3	14.4	13.3	13.2	
Sep. 15 (258)	11:00	AB	17.4	12.6	11.6	11.4	3.37
Sep. 15 (258)	11:30	CD	19.0	12.8	11.5	11.2	5.27
Sep. 15 (258)	12:00	EF	18.7	13.1	12.2	11.8	4.11
Sep. 18 (261)	06:30	CD	--	--	--	--	1.80

Table 7. Soil temperature and soil water content at the Recent Cut site, BOREAS Southern Study Area, Saskatchewan, Canada, 1994.
[CST, Central Standard Time; °C, degrees Celsius; m, meters; weight %, weight of water in sample/total weight of sample x100; --, no data]

Date (day of year)	Time of day (CST)	Location (chamber pair)	TEMPERATURE (°C)				Water content (weight%) 0-0.5 m
			Air	-0.05 m	-0.10 m	-0.15 m	
May 26 (146)	15:00	MN	--	18.5	14.6	12.0	7.96
May 26 (146)	16:00	OP	--	15.1	12.9	11.0	24.58
May 26 (146)	17:00	QR	--	17.3	11.7	10.0	9.45
June 5 (156)	12:00	MN	--	15.7	13.8	12.6	12.93
June 5 (156)	12:30	OP	--	13.2	12.1	11.2	9.19
June 5 (156)	13:00	QR	--	14.3	13.0	12.2	22.46
June 10 (161)	08:00	MN	--	13.3	12.9	12.7	3.97
June 10 (161)	08:30	OP	--	11.9	11.2	11.2	13.02
June 10 (161)	09:00	QR	--	12.7	11.5	11.5	12.40
June 27 (178)	10:00	MN	18.6	15.2	14.1	--	4.80
June 27 (178)	10:00	OP	22.4	16.4	13.4	12.2	21.44
June 27 (178)	11:00	QR	21.2	15.3	13.4	12.8	8.34
June 28 (179)	11:30	MN	21.0	19.8	16.7	15.0	6.85
June 28 (179)	11:30	OP	21.9	17.7	15.8	14.2	19.97
July 3 (184)	13:00	MN	17.9	17.8	16.2	15.4	7.91
July 8 (189)	15:00	MN	20.2	18.9	16.9	15.5	3.38
July 8 (189)	15:30	OP	20.9	17.8	15.9	14.8	14.45
July 9 (190)	11:00	MN	20.0	15.4	13.7	13.3	9.29

Table 7. (continued)

Date (day of year)	Time of day (CST)	Location (chamber pair)	TEMPERATURE (°C)				Water content (weight%) 0-0.5 m
			Air	-0.05 m	-0.10 m	-0.15 m	
July 21 (202)	10:00	MN	31.0	24.4	8.4	15.9	8.94
July 21 (202)	10:30	OP	28.8	19.0	16.0	15.1	--
July 29 (210)	15:30	MN	25.4	21.4	20.4	19.7	--
July 29 (210)	16:00	OP	31.5	19.4	18.2	17.1	--
July 31 (212)	11:30	MN	29.3	19.6	17.2	16.5	--
Aug. 9 (221)	15:30	MN	26.4	20.2	19.1	16.9	--
Aug. 9 (221)	16:00	OP	25.9	19.2	17.5	15.9	--
Aug. 9 (221)	16:30	QR	25.3	19.1	17.3	15.6	--
Aug. 13 (225)	10:00	MN	15.0	12.8	9.9	--	5.23
Aug. 13 (225)	10:30	OP	18.3	12.9	11.5	11.2	14.59
Aug. 13 (225)	11:00	QR	17.5	12.8	11.8	11.8	8.50
Aug. 19 (231)	12:00	MN	23.7	18.5	16.6	--	5.48
Aug. 19 (231)	13:00	OP	24.2	15.9	15.1	14.6	9.30
Aug. 19 (231)	13:30	QR	21.3	17.6	15.3	14.1	3.84
Aug. 22 (234)	10:00	MN	16.9	16.8	16.7	--	2.91
Aug. 22 (234)	10:00	OP	16.8	15.8	15.4	15.2	3.91
Aug. 25 (237)	10:00	MN	19.3	15.0	13.6	--	0.89
Aug. 25 (237)	11:00	OP	22.5	14.6	13.1	12.6	3.42
Aug. 25 (237)	12:00	QR	20.7	15.6	13.1	12.9	--

Table 7. (continued)

Date (day of year)	Time of day (CST)	Location (chamber pair)	TEMPERATURE (°C)				Water content (weight%) 0-0.5 m
			Air	-0.05 m	-0.10 m	-0.15 m	
Sep. 9 (252)	16:00	MN	22.4	15.3	14.5	14.1	4.78
Sep. 9 (252)	16:30	OP	22.6	15.5	14.0	13.4	--
Sep. 10 (253)	15:00	OP	13.7	15.1	14.4	13.9	--
Sep. 15 (258)	10:00	MN	13.2	11.6	11.7	11.8	3.80
Sep. 15 (258)	10:00	OP	13.5	11.2	10.9	10.8	8.59
Sep. 15 (258)	10:00	QR	14.4	11.3	10.9	10.9	2.59

Table 8. Soil temperature and soil water content at the Clear Cut site, BOREAS Southern Study Area, Saskatchewan, Canada, 1994.
[CST, Central Standard Time; °C, degrees Celsius; m, meters; weight %, weight of water in sample/total weight of sample x 100; --, no data]

Date (day of year)	Time of day (CST)	Location (chamber pair)	TEMPERATURE (°C)				Water content (weight%) 0-0.5 m
			Air	-0.05 m	-0.10 m	-0.15 m	
May 26 (146)	18:00	ST	--	16.5	13.3	11.3	8.83
May 26 (146)	18:00	UV	--	15.1	13.7	11.5	11.91
May 26 (146)	18:00	WX	--	16.5	14.4	12.5	2.10
June 5 (156)	14:00	UV	--	--	--	--	6.33
June 5 (156)	14:00	WX	--	13.5	12.3	11.6	14.09
June 10 (161)	10:00	UV	--	13.9	11.8	10.9	12.08
June 10 (161)	10:00	ST	--	16.3	14.1	11.8	7.14
June 10 (161)	10:00	WX	--	--	--	--	7.12
June 25 (179)	13:00	ST	22.5	17.6	15.9	13.7	9.43
June 25 (179)	13:00	UV	20.7	17.4	15.1	13.5	14.83
June 25 (179)	13:00	WX	20.5	19.1	16.8	14.8	11.99
July 4 (185)	13:00	ST	15.3	13.9	13.3	12.9	--
July 7 (188)	14:00	ST	19.7	16.9	15.2	13.6	11.77
July 7 (188)	14:00	UV	21.4	15.2	13.4	12.3	10.41
July 10 (191)	12:00	ST	17.9	18.4	16.9	15.3	8.27
July 21 (202)	12:00	ST	30.0	22.6	19.2	18.0	8.49
July 21 (202)	12:00	UV	31.5	23.0	18.9	17.0	--
July 28 (209)	15:00	ST	27.2	21.3	20.4	19.1	--

Table 8. (continued)

Date (day of year)	Time of day (CST)	Location (chamber pair)	TEMPERATURE (°C)				Water content (weight%) 0-0.5 m
			Air	-0.05 m	-0.10 m	-0.15 m	
July 28 (209)	15:00	UV	25.0	19.4	18.6	18.0	--
July 29 (210)	11:00	ST	22.4	18.9	18.3	17.9	--
July 31 (212)	11:00	ST	--	22.0	18.2	17.6	--
July 31 (212)	11:00	WX	27.9	21.7	19.3	17.8	--
Aug. 9 (221)	13:00	ST	24.0	18.3	16.8	1.54	--
Aug. 9 (221)	13:00	UV	22.9	17.1	15.8	14.9	--
Aug. 9 (221)	13:00	WX	23.7	16.9	16.0	14.5	--
Aug. 10 (222)	16:00	ST	23.0	19.1	18.4	17.8	--
Aug. 10 (222)	16:00	UV	19.9	17.6	17.2	16.8	--
Aug. 10 (222)	16:00	WX	24.2	18.6	17.3	16.9	--
Aug. 13 (225)	14:00	ST	19.5	17.4	14.8	13.7	--
Aug. 13 (225)	14:00	UV	19.8	17.7	15.4	13.9	8.14
Aug. 13 (225)	14:00	WX	18.8	17.0	15.4	14.0	5.78
Aug. 15 (227)	11:00	ST	25.8	16.7	15.4	14.8	5.41
Aug. 15 (227)	11:00	UV	29.0	16.3	15.2	14.4	6.49
Aug. 15 (227)	11:00	WX	29.4	19.0	16.6	15.8	5.90
Aug. 18 (230)	15:00	ST	22.7	19.5	17.5	16.7	--
Aug. 18 (230)	15:00	UV	22.8	19.5	17.7	16.6	--
Aug. 18 (230)	15:00	WX	21.8	20.9	18.9	17.5	--

Table 8. (continued)

Date (day of year)	Time of day (CST)	Location (chamber pair)	TEMPERATURE (°C)				Water content (weight%) 0-0.5 m
			Air	-0.05 m	-0.10 m	-0.15 m	
Aug. 23 (235)	09:00	ST	21.6	16.4	15.4	15.0	5.11
Aug. 23 (235)	09:00	UV	22.9	15.1	14.3	14.3	7.58
Aug. 25 (237)	14:00	ST	18.8	18.5	16.4	15.2	3.95
Aug. 25 (237)	14:00	UV	20.3	17.8	16.3	15.3	5.80
Aug. 25 (237)	14:00	WX	19.4	18.3	17.1	16.0	--
Sep. 9 (252)	15:00	ST	28.0	15.1	14.1	13.6	--
Sep. 9 (252)	15:00	UV	23.8	14.9	14.0	13.4	8.99
Sep. 9 (252)	15:00	WX	22.4	14.8	14.1	13.5	--
Sep. 11 (254)	11:00	ST	20.7	10.5	10.6	10.9	--
Sep. 11 (254)	11:00	UV	20.6	11.3	10.9	11.3	7.15
Sep. 11 (254)	11:00	WX	16.0	12.1	11.6	11.6	--
Sep. 14 (257)	11:00	ST	22.4	14.9	13.5	12.8	5.28
Sep. 14 (257)	11:00	UV	28.6	15.3	13.8	12.8	6.15
Sep. 14 (257)	11:00	WX	26.9	15.5	14.1	13.4	2.95

Soil Carbon Dioxide and Methane

Gas Analyses

Traceable gas calibration standards for all CO_2 and CH_4 analyses were provided by BOREAS operations. Carbon dioxide concentrations were measured using non-dispersive infrared gas analyzers (IRGAs) calibrated to span the expected concentration range. Three different IRGAs were used for measuring CO_2 concentration at the jack pine soil gas transects. Accumulation of CO_2 in soil gas flux chambers was measured using a LI-COR model 6200. *In situ* soil CO_2 concentrations exceed the range of the LI-COR 6200, so two PP Systems model EGM IRGAs were used, one having a range up to 5000 parts per million (ppm) CO_2 and the second having a range up to 10,000 ppm CO_2.

Methane concentrations were measured using a Chrompack model 438A gas chromatograph (GC) having a 2 meter 80-100 mesh Porapak-N column and a flame ionization detector. Carrier gas was nitrogen and the oven temperature was maintained at 38°C. Methane concentrations were calculated from standards curves established from a series of CH_4 standards run between every 8 to 10 samples. Concentrations smaller than 0.49 ppm were calculated by linear extrapolation of integrator response between a 0.49 ppm CH_4 standard and a nitrogen blank.

Gas Concentration Profiles

Concentration of CO_2 and CH_4 in soil gas were measured at chamber pairs at each of the four transects using 2.0 mm inside diameter stainless steel probes. The probes were inserted to soil depths ranging from 0.02 m to 0.50 m, and soil gas was collected using nylon syringes. CO_2 concentration was analyzed on-site using a PP Systems model EGM IRGA, and CH_4 concentration was analyzed by gas chromatography using methods described above. Soil gas collection was concurrent with chamber measurements.

In addition to the chamber pair probe measurements, each site had a series of permanent probes installed for soil gas collection. The Old Jack Pine site had permanent probes installed within 10 m of the first chamber pair (GH) to a maximum depth of 3.4 m. The Young Jack Pine site had permanent probes installed within 10 m of the first chamber pair (AB) to a maximum depth of 6.0 m. Additional probes were located 5 m south of the Young Jack Pine instrument shelter.

Tables 9-12 list CO_2 concentration profiles at the Old Jack Pine and Young Jack Pine sites in 1994-95, and the Recent Cut and Clear Cut sites in 1994. "Location" indicates chamber pair where measurements were taken; an entry of "PP" indicates measurements taken from the permanent probes.

Tables 13-16 list CH_4 concentration profiles at all sites. Old Jack Pine and Young Jack Pine profiles were measured in 1994-95, and Recent Cut and Clear Cut profiles were measured in 1994. "PP" indicates measurements taken from the permanent probes.

Table 9. Soil carbon dioxide concentration profiles at the Old Jack Pine site, BOREAS Southern Study Area, Saskatchewan, Canada, 1994-95.
[m, meters; --, no data; all concentrations are in parts per million by volume]

Date (day of year)	1994	May 26 (146)	May 27 (147)	Jun 9 (160)	Jun 15 (166)	Jun 29 (180)	Jul 7 (188)	Jul 8 (189)	Jul 22 (203)	Aug 10 (222)	Aug 14 (226)	Aug 19 (231)
Depth (m)	Location:	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP
0.02		--	--	--	--	--	--	--	--	--	--	--
0.05		--	--	1008	606	1086	--	1242	1524	775	804	910
0.10		696	1017	1227	892	1392	--	1621	2012	1068	1087	1195
0.15		--	--	1406	1252	1578	--	1801	2345	1229	1241	1352
0.20		--	--	1218	1171	1678	--	1727	2562	1369	1306	1467
0.25		1168	786	362	542	1736	--	1670	--	--	--	--
0.30		--	--	1508	1368	1806	--	1923	2840	1587	1526	1653
0.35		--	--	--	--	--	--	--	--	--	--	--
0.40		--	--	1544	1432	1885	--	2272	3010	1748	1667	1794
0.45		--	--	--	--	--	--	--	--	--	--	--
0.50		1182	1162	1526	1358	1885	--	2257	2990	1810	1717	1824
0.55		--	--	--	--	--	--	--	--	--	--	--
0.60		--	--	1175	1354	1823	--	2192	2840	1892	1802	1856
0.65		--	--	--	--	--	--	--	--	--	--	--
0.68		--	--	--	--	--	--	--	--	--	--	--
0.75		1140	1129	1513	1368	1905	--	2319	2988	2063	1962	1996
0.90		1516	1424	1822	--	2461	2967	--	3614	2012	1965	2119
0.96		1122	1103	--	--	--	--	--	--	--	--	--
1.00		--	--	1381	1376	1954	--	2380	3017	2340	2242	2194
1.20		1362	1290	1703	--	2210	2720	--	3296	2079	2043	2120
2.00		987	945	1335	--	1684	1976	--	2378	2364	2300	2255
2.50		844	805	1143	--	1496	1760	--	2102	2457	2382	2313
3.00		--	--	--	--	--	--	--	--	--	--	--
3.40		564	515	574	--	760	898	--	--	--	--	--
4.00		--	--	--	--	--	--	--	--	--	--	--
5.00		--	--	--	--	--	--	--	--	--	--	--

Table 9. (continued)

Date (day of year)	1994	Sep 9 (252)	Sep 9 (252)	Sep 9 (252)	Sep 9 (252)	Sep 9 (252)	Sep 18 (261)	1995	Mar 19 (78)	Mar 20 (79)	Mar 21 (80)
Depth (m)	Location:	PP	GH	IJ	I	J	PP		PP	PP	PP
0.02		--	500	607	642	490	--		--	--	--
0.05		862	680	718	1126	757	742		436	499	--
0.10		1215	970	900	1441	1128	985		486	553	--
0.15		1416	1155	1104	1833	1417	1157		507	--	--
0.20		1515	1307	1274	2085	1625	1230		523	557	--
0.25		--	1404	1399	2268	1811	--		--	--	--
0.30		1697	1468	1527	2376	1918	1440		538	620	--
0.35		--	1520	1602	2417	2010	--		--	--	--
0.40		1825	1568	1685	2432	2038	1585		546	600	--
0.45		--	1622	1760	2437	2078	--		--	--	--
0.50		1836	1677	1804	2433	2112	1622		534	641	--
0.55		--	1718	1854	--	--	--		--	--	--
0.60		1813	1750	1895	--	--	1655		566	652	--
0.65		--	1780	1919	--	--	--		--	--	--
0.68		--	1801	--	--	--	--		--	--	--
0.75		1932	--	--	--	--	1710		559	636	--
0.90		2205	--	--	--	--	1867		--	--	--
0.96		--	--	--	--	--	--		--	--	--
1.00		2035	--	--	--	--	1965		578	696	632
1.20		2160	--	--	--	--	1931		--	--	--
2.00		2131	--	--	--	--	21110		594	722	625
2.50		--	--	--	--	--	--		--	--	--
3.00		2131	--	--	--	--	2175		589	763	641
3.40		--	--	--	--	--	--		--	--	--
4.00		--	--	--	--	--	--		622	747	648
5.00		--	--	--	--	--	--		359	381	391

Table 10. Soil carbon dioxide profiles at the Young Jack Pine site, BOREAS Southern Study Area, Saskatchewan, Canada, 1994-95.
[m, meters; --, no data; all concentrations are in parts per million by volume; all measurements are at permanent probes]

Date (day of year)	1994	May 27 (147)	May 28 (148)	Jun 1 (152)	Jun 9 (160)	Jun 15 (166)	Jun 29 (180)	Jul 6 (187)	Jul 8 (189)	Jul 23 (204)	Aug 1 (213)	Aug 4 (216)	Aug 9 (221)	Aug 13 (225)	Aug 25 (237)
Depth (m)															
0.05		--	1530	1497	1503	1575	2098	--	2874	1960	1820	2140	1497	1446	1080
0.10		--	2274	2228	2204	1925	3054	--	4857	3485	2892	3570	2524	2349	--
0.15		--	2091	1956	1846	2003	2638	--	4558	4715	3875	2860	2084	1966	1392
0.20		--	2000	1844	1847	1896	2547	--	4211	5675	4160	2760	2005	1902	1284
0.25		--	2253	2210	2172	2259	2949	--	4783	6225	4690	3445	2422	2251	1723
0.30		--	2258	2318	2378	2368	3248	--	4965	6750	5082	4150	2958	2726	2186
0.40		--	2266	2318	2373	2357	3213	--	4963	7070	5400	4000	2861	2632	2086
0.50		--	2384	2483	2633	2469	3420	--	5012	7150	5576	4580	3300	3040	2512
0.60		--	2195	2356	2635	2407	3443	--	4990	--	5730	4415	3777	3385	2964
0.75		--	1925	2109	2277	2277	3325	--	4564	--	--	5400	4138	3641	3326
1.00		2295	2062	2126	2488	2586	3358	--	4597	6945	6014	5515	4110	3754	3314
1.50		1958	--	--	--	--	--	4441	--	5883	5716	--	4405	4089	3662
2.00		1708	1557	--	--	1676	2716	3863	--	4503	5184	--	4428	4119	3768
2.50		1593	--	--	--	--	--	3289	--	3650	4550	--	4154	3941	3728
3.00		1380	1403	--	1622	1622	2157	2440	--	2529	3204	--	3502	3260	3164
4.00		1398	1401	--	--	1435	1820	2017	--	2362	2648	--	3013	2959	3052
5.00		1423	1423	--	--	1336	1672	1807	--	2194	2393	--	2708	2723	2948
6.00		1451	1454	--	--	1460	1574	1645	--	2033	2234	--	2479	2525	2835

Table 10. (continued)

Date (day of year)	Sep 10 (253)	Sep 17 (260)	Sep 18 (261)	1995	Mar 19 (78)	Mar 20 (79)	Mar 21 (80)
Depth (m)							
0.05	1446	1099	1283		683	713	--
0.10	--	1724	1887		832	804	--
0.15	1822	1392	1605		780	--	--
0.20	1700	1293	1475		753	778	--
0.25	2130	1567	1836		826	--	--
0.30	2488	2018	2102		922	888	--
0.40	2418	1952	2048		901	880	--
0.50	2791	2310	2360		963	931	--
0.60	3104	2640	2599		1064	1028	--
0.75	3260	2876	2775		1162	1128	--
1.00	3216	2828	2790		1158	1148	949
1.50	3367	3124	--		1170	1206	1014
2.00	3399	3276	--		1367	1328	1108
2.50	3223	3354	--		1471	1447	1189
3.00	3100	3100	--		1576	1355	1254
4.00	3142	3144	--		1740	1296	1365
5.00	3147	3156	--		1840	1845	1439
6.00	3140	3163	--		1902	1910	1505

Table 11. Soil carbon dioxide concentration profiles at the Recent Cut site, BOREAS Southern Study Area, Saskatchewan, Canada, 1994.
[m, meters; --, no data; all concentrations are in parts per million by volume]

Date (day of year)		Jun 5 (156)	Jun 29 (180)	Jul 8 (189)	Jul 23 (204)	Aug 10 (222)	Aug 14 (226)	Aug 19 (231)	Sep 9 (252)	Sep 10 (253)	Sep 10 (253)	Sep 10 (253)	Sep 10 (253)	Sep 10 (253)
Depth (m)	Location:	QR	QR	QR	QR	QR	QR	QR	QR	QR	MN	OP	QR	QR
0.02		--	--	--	--	--	--	--	1000	--	796	541	540	--
0.05		1270	2550	--	2560	--	--	--	3250	--	1500	646	1060	--
0.10		1820	3310	2710	3710	--	925	866	3180	1080	2870	1030	1360	1080
0.15		--	3650	--	4280	--	--	--	4080	--	2870	1220	1610	--
0.20		2310	3790	3970	4550	1110	1200	1140	--	1560	--	1350	1720	1560
0.25		--	3820	--	4950	--	--	--	--	--	--	1510	1840	--
0.30		2700	3800	4430	5100	1410	1420	1390	--	1800	--	1670	1920	1800
0.35		--	--	--	5320	--	--	--	--	--	--	1780	1970	--
0.40		--	--	--	5440	--	--	--	--	--	--	1870	2020	--
0.45		--	--	--	5540	--	--	--	--	--	--	1950	2060	--
0.50		--	--	--	--	--	--	--	--	--	--	2060	2110	--
0.60		2960	3670	5060	5730	1800	1700	1670	--	--	--	--	--	2090
0.90		3020	3720	5040	6040	2190	2090	2010	--	--	--	--	--	2360

Table 12. Soil carbon dioxide concentration profiles at the Clear Cut site, BOREAS Southern Study Area, Saskatchewan, Canada, 1994.
[m, meters; --, no data; all concentrations are in parts per million by volume]

Date (day of year)		Jun 5 (156)	Jun 29 (180)	Jul 7 (188)	Jul 23 (204)	Aug 14 (226)	Aug 19 (231)	Sep 9 (252)	Sep 9 (252)	Sep 9 (252)	Sep 15 (258)
Depth (m)	Location:	ST	ST	ST	ST	ST	ST	ST	UV	WX	ST
0.02		--	--	--	--	--	--	368	398	407	--
0.05		570	601	--	636	--	--	536	538	552	--
0.10		621	747	--	1060	--	--	749	912	808	--
0.15		--	885	--	1400	--	--	862	1110	968	--
0.20		826	939	965	1590	888	923	883	1230	1170	726
0.25		--	1000	--	1720	--	--	930	1360	1290	--
0.30		963	1050	1130	1770	1050	1100	1000	1500	1410	878
0.35		--	--	--	1840	--	--	1010	1580	1510	--
0.40		--	--	--	1880	--	--	1050	1670	1590	--
0.45		--	--	--	1890	--	--	1070	1750	1650	--
0.50		--	--	--	--	--	--	1100	1800	1710	--
0.60		1020	1140	1220	1570	1130	1200	1130	--	--	1000
0.65		--	--	--	--	--	1230	--	--	--	--
0.90		--	1180	1300	1450	1130	--	--	--	--	--

Table 13. Soil methane concentration profiles at the Old Jack Pine site, BOREAS Southern Study Area, Saskatchewan, Canada, 1994-95.
[m, meters; --, no data; nd, not determined (detected but not quantified); all concentrations are in parts per million by volume]

Date (day of year)	1994	May 27 (147)	Jun 8 (159)	Jun 8 (159)	Jun 8 (159)	Jun 9 (160)	Jun15 (166)	Jun 18 (169)	Jun 18 (169)	Jun 18 (169)	Jul 2 (183)	Jul 4 (185)	Jul 4 (185)
Depth (m)	Location:	PP	GH	IJ	KL	PP	PP	GH	IJ	KL	PP	GH	IJ
0.02		--	--	--	--	--	--	--	--	--	--	--	--
0.05		--	1.82	1.62	1.34	1.54	1.39	1.35	1.23	1.58	1.45	1.54	1.49
0.08		1.15	--	--	--	--	--	--	--	--	--	--	--
0.10		--	2.58	1.31	nd	1.26	1.18	1.21	1.11	1.34	1.20	1.18	1.12
0.15		--	1.18	1.00	0.74	1.24	0.63	1.74	0.44	0.99	0.68	0.99	0.79
0.20		--	--	--	--	0.68	0.82	--	--	--	0.26	0.71	0.39
0.25		--	--	--	--	1.96	1.82	--	--	--	0.13	nd	0.16
0.27		0.09	--	--	--	--	--	--	--	--	--	--	--
0.30		--	--	--	--	0.37	1.80	--	--	--	0.04	0.25	0.18
0.35		--	--	--	--	--	--	--	--	--	--	--	--
0.40		--	--	--	--	0.69	0.21	--	--	--	--	--	--
0.45		--	--	--	--	--	--	--	--	--	--	--	--
0.50		--	--	--	--	0.29	0.56	--	--	--	0.17	--	--
0.60		--	--	--	--	0.16	1.01	--	--	--	0.34	--	--
0.75		0.03	--	--	--	0.15	--	--	--	--	0.61	--	--
0.90		0.08	--	--	--	0.19	0.89	--	--	--	nd	--	--
0.96		0.03	--	--	--	--	--	--	--	--	--	--	--
1.00		--	--	--	--	0.47	0.36	--	--	--	0.02	--	--
1.20		nd	--	--	--	--	1.32	--	--	--	nd	--	--
2.00		0.06	--	--	--	0.08	1.14	--	--	--	0.29	--	--
2.50		0.02	--	--	--	0.14	0.95	--	--	--	0.04	--	--
3.40		0.08	--	--	--	0.07	1.15	--	--	--	nd	--	--

Table 13. (continued)

Date (day of year)	1994	Jul 10 (191)	Jul 10 (191)	Jul 10 (191)	Jul 26 (207)	Aug 4 (216)	Aug 15 (227)	Aug 19 (231)	Aug 22 (234)	Sep 12 (255)	Sep 12 (255)	1995	Mar 21 (80)
Depth (m)	Location:	PP	GH	iJ	GH	GH	GH	PP	GH	PP	PP		PP
0.02		--	--	--	1.77	1.47	1.84	--	1.89	--	1.84		1.86
0.05		--	1.81	--	1.62	1.34	1.84	1.59	1.56	1.55	1.48		--
0.08		--	--	--	--	--	--	--	--	--	--		--
0.10		--	1.32	1.55	1.24	1.07	1.51	nd	1.31	1.24	0.96		1.45
0.15		--	1.24	--	0.87	0.96	1.33	0.87	1.10	0.70	0.53		--
0.20		--	0.69	1.16	0.68	0.85	0.92	0.32	0.85	0.27	0.20		1.08
0.25		--	0.50	--	0.47	0.62	0.76	--	0.73	--	0.23		--
0.27		--	--	--	--	--	--	--	--	--	--		--
0.30		--	0.49	0.64	0.39	0.52	0.51	0.08	0.57	0.22	0.17		0.91
0.35		--	--	--	--	--	0.35	--	0.42	--	0.14		--
0.40		--	--	--	--	--	0.24	0.22	0.34	0.17	0.13		--
0.45		--	--	--	--	--	0.16	--	0.30	--	0.13		--
0.50		--	--	--	--	--	0.08	0.16	0.31	0.16	0.12		0.75
0.60		--	--	--	--	--	--	0.14	--	0.13	--		--
0.75		--	--	--	--	--	--	0.12	--	0.12	--		--
0.90		0.03	--	--	--	--	--	0.08	--	0.06	--		0.16
0.96		--	--	--	--	--	--	--	--	--	--		--
1.00		--	--	--	--	--	--	0.19	--	0.10	--		0.34
1.20		0.26	--	--	--	--	--	0.07	--	0.03	--		0.12
2.00		0.03	--	--	--	--	--	0.03	--	0.02	--		1.04
2.50		0.03	--	--	--	--	--	0.05	--	0.02	--		0.11
3.40		0.15	--	--	--	--	--	--	--	0.08	--		--

Table 14. Soil methane concentration profiles at the Young Jack Pine site, BOREAS Southern Study Area, Saskatchewan, Canada, 1994-95.
[m, meters; --, no data; nd, not determined (detected but not quantified); all concentrations are in parts per million by volume]

Date (day of year)	1994	Jun 2 (153)	Jun 4 (155)	Jun 9 (160)	Jun 15 (166)	Jun 20 (171)	Jun 20 (171)	Jun 20 (171)	Jul 1 (182)	Jul 3 (184)	Jul 3 (184)	Jul 9 (190)	Jul 9 (190)
Depth (m)	Location:	PP	PP	PP	PP	AB	CD	EF	PP	AB	CD	PP	CD
0.02		--	--	--	--	--	--	--	--	--	--	--	--
0.05		0.88	1.45	1.26	1.08	1.29	1.63	1.48	1.13	1.58	1.62	1.57	1.70
0.10		0.22	1.00	0.48	0.35	1.26	1.78	1.35	0.29	1.24	1.27	1.39	1.40
0.15		0.50	1.00	0.84	0.68	1.28	--	--	0.65	1.06	0.90	1.14	1.08
0.20		0.62	0.84	1.07	0.74	--	--	--	0.82	0.60	--	0.63	0.47
0.25		0.28	0.36	0.56	0.66	--	--	--	0.39	nd	--	0.59	--
0.30		0.14	0.18	0.34	0.38	--	--	--	0.13	0.19	--	0.41	--
0.35		--	--	--	--	--	--	--	--	--	--	--	--
0.40		0.10	0.14	0.27	0.23	--	--	--	0.24	--	--	--	--
0.45		--	--	--	--	--	--	--	--	--	--	--	--
0.50		0.13	0.12	0.57	0.26	--	--	--	0.36	--	--	--	--
0.60		nd	0.03	0.15	1.53	--	--	--	--	--	--	--	--
0.75		nd	--	1.93	0.88	--	--	--	0.01	--	--	--	--
1.00		0.06	--	0.10	0.20	--	--	--	0.50	--	--	0.08	--
1.50		0.05	--	0.31	0.50	--	--	--	nd	--	--	--	--
2.00		0.06	--	0.20	0.40	--	--	--	nd	--	--	0.09	--
2.50		--	--	0.32	0.17	--	--	--	nd	--	--	--	--
3.00		0.06	--	0.09	0.07	--	--	--	nd	--	--	0.04	--
4.00		0.06	--	0.37	0.02	--	--	--	nd	--	--	0.04	--
5.00		0.07	--	0.11	nd	--	--	--	nd	--	--	--	--
6.00		0.06	--	--	nd	--	--	--	nd	--	--	--	--

Table 14. (continued)

Date (day of year)	1994	Jul 25 (206)	Jul 25 (206)	Aug 15 (227)	Aug 17 (229)	Aug 23 (235)	Aug 26 (238)	Sep 11 (254)	Sep 11 (254)	Sep 11 (254)	Sep 11 (254)	1995	Mar 21 (80)
Depth (m)	Location:	PP	PP	AB	AB	AB	PP	PP	PP	PP	AB		PP
0.02		--	1.73	1.77	1.91	1.89	--	--	--	--	1.82		1.87
0.05		1.09	1.58	1.80	1.63	1.67	1.64	1.26	--	--	1.77		--
0.10		0.37	1.21	1.48	1.30	1.43	1.25	0.42	--	--	1.71		1.86
0.15		0.70	0.82	1.23	1.11	1.27	0.66	0.88	--	--	1.09		--
0.20		nd	0.50	1.16	0.94	1.05	1.10	0.98	--	--	0.81		1.36
0.25		0.40	0.39	0.85	0.78	0.84	0.79	0.51	--	--	0.63		--
0.30		0.11	0.30	0.89	0.81	0.74	0.20	0.54	--	--	--		1.37
0.35		--	--	0.70	0.58	0.78	--	--	--	--	--		--
0.40		0.14	--	0.75	0.51	0.91	0.42	0.21	--	--	--		--
0.45		--	--	0.55	0.36	0.45	--	--	--	--	--		--
0.50		0.11	--	0.81	0.37	0.43	0.18	0.11	--	--	--		0.88
0.60		0.06	--	--	--	--	0.03	0.16	--	--	--		--
0.75		0.10	--	--	--	--	0.11	0.09	--	--	--		--
1.00		0.09	--	--	--	--	nd	0.09	0.08	0.06	--		1.90
1.50		--	--	--	--	--	0.17	--	--	--	--		--
2.00		--	--	--	--	--	nd	--	0.20	0.04	--		1.50
2.50		--	--	--	--	--	0.11	--	--	--	--		--
3.00		--	--	--	--	--	0.06	--	0.03	0.02	--		0.50
4.00		--	--	--	--	--	nd	--	0.02	0.02	--		--
5.00		--	--	--	--	--	0.04	--	0.02	--	--		1.02
6.00		--	--	--	--	--	0.05	--	0.02	--	--		--

Table 15. Soil methane concentration profiles at the Recent Cut site, BOREAS Southern Study Area, Saskatchewan, Canada, 1994.
[m, meters; --, no data; nd, not determined (detected but not quantified); all concentrations are in parts per million by volume]

Date (day of year)		Jun 5 (156)	Jun 10 (161)	Jun 10 (161)	Jun 15 (166)	Jun 27 (178)	Jun 27 (178)	Jun 27 (178)	Jul 3 (184)	Jul 9 (190)	Jul 29 (210)	Aug 13 (225)	Aug 19 (231)	Aug 22 (234)	Sep 12 (255)	Sep 12 (255)
Depth (m)	Location:	QR	MN	OP	QR	MN	OP	QR	MN	QR	MN	QR	QR	QR	QR	QR
0.02		--	--	--	--	--	--	--	--	--	1.82	1.42	--	1.64	--	1.78
0.05		1.31	1.41	1.13	1.28	1.67	1.67	1.40	1.51	1.69	1.62	1.04	--	1.53	--	1.57
0.10		0.94	1.55	1.16	1.05	1.47	1.19	1.12	1.18	1.16	1.50	0.83	1.48	1.24	1.25	1.15
0.15		--	1.28	0.93	--	1.14	0.74	--	0.38	0.77	--	0.69	--	0.94	--	0.71
0.20		0.42	--	--	0.40	--	0.49	0.54	0.09	0.79	--	0.52	0.82	0.78	0.53	0.61
0.25		--	--	--	--	--	0.22	--	0.07	0.33	--	0.43	--	0.60	--	0.39
0.30		0.13	--	--	0.15	--	--	0.24	0.15	0.21	--	0.47	0.45	0.48	0.13	0.29
0.35		--	--	--	--	--	--	--	--	--	--	0.35	--	0.51	--	0.20
0.40		--	--	--	--	--	--	--	--	--	--	0.24	--	0.38	--	0.17
0.45		--	--	--	--	--	--	--	--	--	--	0.26	--	0.38	--	0.18
0.50		--	--	--	--	--	--	--	--	--	--	0.27	--	0.39	--	0.18
0.60		0.23	--	--	0.05	--	--	nd	--	0.10	--	--	0.21	--	0.14	--
0.90		nd	--	--	0.22	--	--	nd	--	0.62	--	--	0.12	--	0.08	--

Table 16. Soil methane concentration profiles at the Clear Cut site, BOREAS Southern Study Area, Saskatchewan, Canada, 1994.

[m, meters; --, no data; nd, not determined (detected but not quantified); all concentrations are in parts per million by volume]

Date (day of year)		Jun 5 (156)	Jun 15 (166)	Jun28 (179)	Jul 4 (185)	Jul 10 (191)	Jul 29 (210)	Jul 29 (210)	Aug 13 (225)	Aug 19 (231)	Aug 23 (235)	Sep 12 (255)	Sep 12 (255)
Depth (m)	Location:	ST	ST	ST	ST	ST	ST	UV	ST	ST	ST	ST	ST
0.02		--	--	--	--	--	1.79	1.69	1.75	--	1.82	--	1.82
0.05		1.56	1.51	1.50	--	1.69	1.62	1.49	1.56	--	1.82	--	1.66
0.10		1.36	1.40	1.23	1.24	1.46	1.51	1.14	1.25	--	1.11	--	1.30
0.15		--	--	0.82	--	0.87	0.88	0.93	0.95	--	0.91	--	nd
0.20		0.64	0.62	0.61	0.42	0.62	0.63	0.69	0.63	0.65	0.49	0.53	0.65
0.25		--	--	0.41	--	0.45	0.53	--	0.39	--	0.33	--	0.44
0.30		0.58	0.20	0.20	0.07	0.30	0.35	--	0.23	0.17	0.22	0.23	0.31
0.35		--	--	--	--	--	--	--	0.16	--	0.14	--	0.12
0.40		--	--	--	--	--	--	--	0.11	0.29	0.16	0.08	0.13
0.45		--	--	--	--	--	--	--	0.08	--	0.14	--	0.10
0.50		--	--	--	--	--	--	--	0.08	--	0.12	--	0.08
0.60		0.20	0.06	--	--	0.02	--	--	--	0.06	--	0.04	--
0.90		--	--	--	--	nd	--	--	--	--	--	--	--

Fluxes

Carbon dioxide and CH_4 fluxes were measured by the static chamber technique, which involves measuring the accumulation or loss of gas concentration within chambers placed on the soil surface versus time (Healy and others, 1996). The chambers, which are cylindrical with an open bottom and a closed top, are constructed from 0.30 m inside diameter PVC (polyvinylchloride) irrigation pipe. To prevent gas leakage to or from the chambers during measurement, they were affixed by a gasket to a collar, constructed from the same pipe material, that was inserted permanently into the soil to a depth of 0.10 m. When deployed, the collars and chambers had a combined height of 0.28 to 0.30 m. The chambers have a coiled 1.6 mm inside diameter aluminum tube installed through the sidewall near the top to equalize inside and outside pressure and are fitted with various gas ports for air circulation and sample collection. Gross soil CO_2 flux is the total amount of CO_2 that passes across the soil-groundcover/air interface in the absence of photosynthesis. Chambers for measurement of gross CO_2 flux and CH_4 flux have opaque PVC tops that create a dark chamber environment. Net soil CO_2 flux is gross flux minus CO_2 uptake by groundcover photosynthesis. Chambers used for measurement of net CO_2 flux have clear polycarbonate tops that are optically transparent across the window of photosynthetically active radiation, allowing plant photosynthesis to occur. Air is recirculated inside the chambers at a rate of 0.25 chamber volume per minute to ensure mixing.

Gross and net CO_2 flux were measured by continuously monitoring the CO_2 concentration in air circulating in a chamber placed on the soil surface. CO_2 concentrations were recorded at 20-second intervals for 8 minutes using a LI-COR 6200 IRGA.

Soil CH_4 flux was measured by GC analysis of a time series of six syringe samples of air collected from the center of volume of the chamber. Deployment times ranged from 24 to 40 minutes, depending on the anticipated flux rate.

Rates of gas emission or consumption were determined by the equation:

$$J = dC/dt\ h,$$

where J is the rate of gas flux across the soil surface (moles $m^{-2}\ t^{-1}$); C is the concentration of the gas of interest in the chamber at ambient temperature and pressure (moles m^{-3}); t is time; h is chamber height (m); dC/dt is the slope of the best fit of the time series of concentration in the chamber as time approaches zero (Healy and others, 1996).

Tables 17-20 show gross and net CO_2 flux at all four sites during 1994 and spring 1995. A positive value represents CO_2 emission from the soil to the atmosphere, and a negative value represents consumption of atmospheric CO_2.

Tables 21 and 22 show gross and net CO_2 flux at the Old Jack Pine and Young Jack Pine sites measured regularly over one or more 24-hour periods.

Tables 23-26 show CH_4 flux at all sites during 1994 and spring 1995. Positive and negative values represent CH_4 emission and consumption, respectively.

Table 17. Soil carbon dioxide flux at the Old Jack Pine site, BOREAS Southern Study Area, Saskatchewan, Canada, 1994-95.

[CST, Central Standard Time; µmoles/m^2/sec, micromoles per square meter per second; --, no data]

Date (day of year)	Chamber	Time of day (CST)	Gross flux (µmoles/m^2/sec)	Time of day (CST)	Net flux (µmoles/m^2/sec)
1994					
May 26 (146)	G	13:57	1.44	--	--
May 26 (146)	H	14:08	1.51	--	--
May 26 (146)	I	14:30	2.36	--	--
May 26 (146)	J	14:44	1.90	--	--
May 26 (146)	K	14:56	1.75	--	--
May 26 (146)	L	15:07	1.29	--	--
June 4 (155)	G	15:00	1.63	--	--
June 4 (155)	H	14:50	1.93	--	--
June 4 (155)	I	15:14	2.40	--	--
June 4 (155)	J	15:27	1.85	--	--
June 4 (155)	K	15:41	2.04	--	--
June 4 (155)	L	15:54	1.29	--	--
June 8 (159)	G	11:41	1.05	12:10	1.12
June 8 (159)	H	11:28	1.53	11:57	1.20
June 8 (159)	I	12:23	2.13	--	--
June 8 (159)	J	12:36	1.52	--	--
June 8 (159)	K	13:05	1.60	--	--
June 8 (159)	L	12:51	1.10	--	--
June 24 (175)	G	11:33	2.13	12:12	1.42
June 24 (175)	H	--	--	12:25	1.84
June 24 (175)	I	12:38	2.92	--	--
June 24 (175)	J	12:50	2.11	--	--
June 24 (175)	K	13:03	1.79	--	--
July 7 (188)	G	11:51	2.15	12:19	1.83
July 7 (188)	H	12:04	2.83	12:31	2.07
July 7 (188)	I	12:45	4.09	--	--
July 7 (188)	J	12:54	2.67	--	--

Table 17. (continued)

Date (day of year)	Chamber	Time of day (CST)	Gross flux (μmoles/m^2/sec)	Time of day (CST)	Net flux (μmoles/m^2/sec)
July 7 (188)	K	13:07	3.06	--	--
July 7 (188)	L	13:18	2.58	--	--
July 21 (202)	G	14:57	3.46	14:37	3.52
July 21 (202)	H	15:11	4.87	14:47	4.68
July 21 (202)	I	15:20	9.15	--	--
July 21 (202)	J	15:30	4.75	--	--
July 21 (202)	K	15:44	5.86	--	--
July 21 (202)	L	15:54	3.79	--	--
July 22 (203)	G	10:13	2.48	--	--
July 22 (203)	H	10:25	3.36	--	--
July 22 (203)	I	10:34	6.42	--	--
July 22 (203)	J	10:44	3.26	--	--
July 22 (203)	K	10:55	4.28	--	--
July 22 (203)	L	11:07	3.69	--	--
Aug. 2 (214)	G	16:13	2.21	15:52	2.44
Aug. 2 (214)	H	16:23	3.14	16:03	2.96
Aug. 2 (214)	I	16:54	6.12	16:34	6.63
Aug. 2 (214)	J	17:04	3.27	16:44	2.32
Aug. 8 (220)	G	15:15	1.19	15:34	1.26
Aug. 8 (220)	H	15:19	1.50	15:44	1.21
Aug. 8 (220)	I	15:55	3.03	16:15	3.18
Aug. 8 (220)	J	16:06	2.07	16:25	0.87
Aug. 8 (220)	K	16:37	3.06	16:57	2.45
Aug. 8 (220)	L	16:47	1.86	17:08	1.35
Aug. 10 (222)	G	12:10	1.58	12:30	1.05
Aug. 10 (222)	K	13:33	3.48	13:51	1.97
Aug. 10 (2220	L	13:42	1.80	14:01	1.33
Aug. 25 (237)	G	15:29	1.00	15:49	0.91
Aug. 25 (237)	H	15:39	1.29	15:59	0.90

Table 17. (continued)

Date (day of year)	Chamber	Time of day (CST)	Gross flux (μmoles/m^2/sec)	Time of day (CST)	Net flux (μmoles/m^2/sec)
Aug. 25 (237)	I	16:10	2.25	16:30	2.66
Aug. 25 (237)	J	16:20	1.65	16:40	1.07
Aug. 25 (237)	K	16:51	2.21	--	--
Aug. 25 (237)	L	17:01	1.46	--	--
Sep. 9 (252)	G	09:52	1.09	10:13	0.89
Sep. 9 (252)	H	10:03	1.44	10:24	0.69
Sep. 9 (252)	I	10:38	3.42	10:59	3.09
Sep. 9 (252)	J	10:49	1.75	11:11	0.78
Sep. 9 (252)	K	11:23	2.99	11:43	1.58
Sep. 9 (252)	L	11:32	2.11	11:53	0.91
Sep. 14 (257)	G	11:36	0.97	11:56	0.97
Sep. 14 (257)	H	11:27	1.45	11:45	0.36
Sep. 14 (257)	I	12:08	2.25	12:28	2.62
Sep. 14 (257)	J	12:18	1.85	12:38	1.22
Sep. 14 (257)	K	12:59	2.42	13:20	1.42
Sep. 14 (257)	L	12:50	1.61	13:09	0.87
1995					
Mar. 19 (78)	G	--	--	18:00	-0.01
Mar. 19 (78)	H	18:13	0.15	--	--
Mar. 19 (78)	I	--	--	17:33	0.19
Mar. 19 (78)	J	17:16	0.11	--	--
Mar. 19 (78)	K	--	--	16:40	0.15
Mar. 19 (78)	L	16:22	0.14	--	--

Table 18. Soil carbon dioxide flux at the Young Jack Pine site, BOREAS Southern Study Area, Saskatchewan, Canada, 1994-95.

[CST, Central Standard Time; μmoles/m^2/sec, micromoles per square meter per second; --, no data]

Date (day of year)	Chamber	Time of day (CST)	Gross flux (μmoles/m^2/sec)	Time of day (CST)	Net flux (μmoles/m^2/sec)
1994					
May 26 (146)	A	10:46	1.92	--	--
May 26 (146)	B	11:01	2.16	--	--
May 26 (146)	C	11:18	1.38	--	--
May 26 (146)	D	11:30	1.03	--	--
May 26 (146)	E	11:46	2.60	--	--
May 26 (146)	F	11:59	1.69	--	--
June 2 (153)	A	13:45	1.89	--	--
June 2 (153)	B	--	--	14:00	1.71
June 3 (154)	A	09:30	2.06	--	--
June 3 (154)	A	09:52	2.56	--	--
June 3 (154)	B	09:41	2.10	10:05	1.65
June 4 (155)	A	10:10	2.49	10:54	0.29
June 4 (155)	B	10:38	2.62	11:05	2.47
June 4 (155)	C	11:25	1.91	--	--
June 4 (155)	D	11:38	1.75	--	--
June 4 (155)	E	11:53	3.42	--	--
June 4 (155)	F	12:06	2.38	--	--
June 9 (160)	A	11:11	2.48	11:41	-0.37
June 9 (160)	B	11:28	2.21	11:53	1.49
June 9 (160)	C	12:17	1.64	--	--
June 9 (160)	D	12:32	1.70	--	--
June 9 (160)	E	12:47	3.25	--	--
June 9 (160)	F	12:59	2.11	--	--
June 10 (161)	A	15:16	3.39	--	--
June 10 (161)	C	16:15	1.81	--	--
June 10 (161)	D	16:22	2.04	--	--
June 10 (161)	E	16:43	3.34	--	--

Table 18. (continued)

Date (day of year)	Chamber	Time of day (CST)	Gross flux (μmoles/m^2/sec)	Time of day (CST)	Net flux (μmoles/m^2/sec)
June 10 (161)	F	16:55	2.16	--	--
June 25 (176)	A	13:52	2.69	14:31	1.44
June 25 (176)	B	13:40	3.52	14:06	2.56
June 25 (176)	C	13:26	3.39	--	--
June 25 (176)	D	12:54	2.43	--	--
June 25 (176)	E	12:40	4.48	--	--
June 25 (176)	F	12:27	3.58	--	--
July 6 (187)	A	11:59	4.20	12:22	0.33
July 6 (187)	B	12:10	4.09	12:32	2.09
July 6 (187)	C	12:49	3.92	--	--
July 6 (187)	D	13:03	2.76	--	--
July 6 (187)	E	13:20	4.93	--	--
July 6 (187)	F	13:30	4.35	--	--
July 20 (201)	A	15:40	5.91	14:50	2.69
July 20 (201)	B	15:25	5.49	15:00	3.66
July 20 (201)	C	15:50	4.96	--	--
July 20 (201)	D	16:02	4.37	--	--
July 20 (201)	E	16:14	7.08	--	--
July 20 (201)	F	16:24	4.52	--	--
July 31 (212)	A	15:04	5.09	15:27	3.41
July 31 (212)	A	20:08	3.87	20:45	4.72
July 31 (212)	B	--	--	15:39	4.64
July 31 (212)	B	15:16	5.02	20:34	-0.56
July 31 (212)	B	20:21	3.55	03:24	3.51
Aug. 1 (213)	A	06:05	1.86	03:13	3.45
Aug. 1 (213)	A	--	--	05:53	2.62
Aug. 1 (213)	A	15:47	6.86	15:25	4.31
Aug. 1 (213)	B	06:17	3.99	05:42	2.69
Aug. 1 (213)	B	15:57	6.18	15:35	4.45
Aug. 2 (214)	A	14:52	6.15	14:32	2.58

Table 18. (continued)

Date (day of year)	Chamber	Time of day (CST)	Gross flux (μmoles/m^2/sec)	Time of day (CST)	Net flux (μmoles/m^2/sec)
Aug. 2 (214)	B	15:03	5.73	14:42	2.99
Aug. 2 (214)	C	13:26	5.86	13:04	4.97
Aug. 2 (214)	D	13:35	4.64	13:14	2.78
Aug. 2 (214)	E	14:09	6.64	13:47	3.55
Aug. 2 (214)	F	14:20	3.96	13:58	3.79
Aug. 4 (216)	A	13:42	4.93	13:28	-0.42
Aug. 4 (216)	B	14:05	4.65	13:40	2.98
Aug. 4 (216)	C	14:43	4.23	14:17	3.77
Aug. 4 (216)	D	14:55	3.00	14:30	2.07
Aug. 4 (21)6	E	15:32	4.57	15:09	2.97
Aug. 4 (216)	F	15:43	2.72	15:17	2.56
Aug. 8 (220)	A	10:15	2.19	10:36	-0.34
Aug. 8 (220)	B	10:25	2.82	10:46	-0.76
Aug. 8 (220)	C	11:02	2.54	11:35	2.24
Aug. 8 (2200	D	11:14	2.00	11:20	1.00
Aug. 8 (220)	E	11:49	2.95	12:11	1.70
Aug. 8 (220)	F	12:00	1.93	12:21	1.64
Aug. 10 (222)	A	08:30	2.93	08:51	0.74
Aug. 10 (222)	B	08:41	3.00	09:02	1.33
Aug. 10 (222)	C	09:14	3.13	09:45	2.09
Aug. 10 (222)	D	09:24	3.13	09:56	1.68
Aug. 10 (222)	E	10:07	3.22	10:29	1.16
Aug. 10 (222)	F	10:17	2.77	10:40	1.98
Aug. 18 (230)	A	11:30	2.97	11:57	-1.27
Aug. 18 (230)	B	11:46	3.05	12:07	-0.10
Aug. 18 (230)	C	12:18	2.10	12:40	1.76
Aug. 18 (230)	D	12:28	1.98	12:50	1.22
Aug. 18 (230)	E	13:24	3.17	13:45	1.18
Aug. 18 (230)	F	13:14	1.67	13:35	1.50

Table 18. (continued)

Date (day of year)	Chamber	Time of day (CST)	Gross flux (μmoles/m^2/sec)	Time of day (CST)	Net flux (μmoles/m^2/sec)
Aug. 26 (238)	A	12:43	1.72	13:03	-1.24
Aug. 26 (238)	B	12:53	1.86	13:15	-0.38
Aug. 26 (238)	C	13:26	1.25	13:46	0.92
Aug. 26 (238)	D	13:36	0.99	13:57	0.52
Aug. 26 (238)	E	14:07	1.82	14:29	0.52
Aug. 26 (238)	F	14:17	0.98	14:39	0.92
Sep. 8 (251)	A	14:23	3.19	14:43	0.93
Sep. 8 (251)	B	14:32	2.12	14:55	1.75
Sep. 8 (251)	C	15:12	2.28	15:50	2.07
Sep. 8 (251)	D	15:36	1.73	16:03	1.33
Sep. 8 (251)	E	16:17	2.75	16:41	2.21
Sep. 8 (251)	F	16:29	1.79	16:52	1.74
Sep. 15 (258)	A	14:50	1.77	15:07	0.69
Sep. 15 (258)	B	14:58	1.56	15:17	1.18
Sep. 15 (258)	C	15:28	1.57	15:47	1.56
Sep. 15 (258)	D	15:37	1.25	15:57	1.09
Sep. 15 (258)	E	16:10	2.03	16:30	1.93
Sep. 15 (258)	F	16:19	1.11	16:40	1.26
1995					
Mar. 19 (78)	A	11:10	0.16	--	--
Mar. 19 (78)	B	12:06	0.30	--	--
Mar. 19 (78)	C	12:45	0.08	--	--
Mar. 19 (78)	D	--	--	13:06	-0.18
Mar. 19 (78)	E	13:51	0.21	--	--
Mar. 19 (78)	F	--	--	14:13	0.07

Table 19. Soil carbon dioxide flux at the Recent Cut site, BOREAS Southern Study Area, Saskatchewan, Canada, 1994-95.

[CST, Central Standard Time; μmoles/m^2/sec, micromoles per square meter per second; --, no data]

Date (day of year)	Chamber	Time of day (CST)	Gross flux (μmoles/m^2/sec)	Time of day (CST)	Net flux (μmoles/m^2/sec)
1994					
May 26 (146)	M	15:35	2.55	--	--
May 26 (146)	N	15:47	2.36	--	--
May 26 (146)	O	16:26	2.29	--	--
May 26 (146)	P	16:38	2.49	--	--
May 26 (146)	Q	16:52	4.42	--	--
May 26 (146)	R	17:05	1.99	--	--
June 5 (156)	M	11:58	3.58	--	--
June 5 (156)	N	11:30	1.26	11:44	1.78
June 5 (156)	O	12:22	2.61	12:10	2.08
June 5 (156)	P	12:35	2.27	--	--
June 5 (156)	Q	13:11	3.69	--	--
June 5 (156)	R	12:55	2.23	--	--
June 28 (179)	M	11:30	6.85	12:05	3.23
June 28 (179)	N	11:50	3.16	12:20	2.03
June 28 (179)	O	12:35	4.32	--	--
June 28 (179)	P	12:45	4.85	--	--
June 28 (189)	M	14:51	5.84	15:13	1.50
July 8 (189)	N	15:03	3.29	15:26	2.05
July 8 (189)	O	15:38	4.16	--	--
July 8 (189)	P	15:48	4.01	--	--
July 11 (192)	M	13:36	5.49	--	--
July 21 (202)	M	10:35	4.67	10:10	-0.10
July 21 (202)	N	10:46	3.08	10:26	1.26
July 21 (2020	0	10:57	5.21	11:15	0.87
July 21 (202)	P	10:07	6.49	--	--
July 31 (212)	M	11:30	4.24	11:50	1.09
July 31 (212)	N	11:40	3.07	12:01	1.69

Table 19. (continued)

Date (day of year)	Chamber	Time of day (CST)	Gross flux (μmoles/m^2/sec)	Time of day (CST)	Net flux (μmoles/m^2/sec)
July 31 (212)	O	12:11	4.95	12:25	-0.72
July 31 (212)	P	12:46	6.09	12:35	1.03
July 31 (212)	Q	12:59	7.63	--	--
Aug. 9 (221)	M	15:06	2.77	15:27	1.04
Aug. 9 (221)	N	15:16	1.44	15:38	1.09
Aug. 9 (221)	O	15:49	3.14	16:07	-0.87
Aug. 9 (221)	P	15:59	2.97	16:18	0.35
Aug. 9 (221)	Q	16:30	3.59	16:51	0.32
Aug. 9 (221)	R	16:36	1.83	17:02	0.46
Aug. 19 (231)	M	12:07	4.46	12:28	3.70
Aug. 19 (231)	N	12:16	2.65	12:39	0.39
Aug. 19 (231)	O	12:50	3.65	13:13	0.35
Aug. 19 (231)	P	13:03	3.37	13:23	0.60
Aug. 19 (231)	Q	13:34	3.71	13:54	-1.65
Aug. 19 (231)	R	13:44	2.75	14:04	-0.20
Aug. 25 (237)	M	10:18	2.66	10:42	1.75
Aug. 25 (237)	N	10:31	1.34	10:52	1.17
Aug. 25 (237)	O	11:14	1.55	11:34	-0.77
Aug. 25 (237)	P	11:24	1.36	11:44	-0.67
Aug. 25 (237)	Q	11:55	2.10	12:15	-1.63
Aug. 25 (237)	R	12:05	1.13	12:25	0.37
Sep. 9 (252)	M	15:48	4.37	16:10	3.47
Sep. 9 (252)	N	15:59	2.67	16:20	2.27
Sep. 9 (252)	O	16.32	2.08	16:50	0.50
Sep. 9 (252)	P	16:41	2.15	17:00	1.29
Sep. 15 (258)	M	09:50	2.08	10:34	2.08
Sep. 15 (258)	N	10:00	1.40	10:24	1.34
Sep. 15 (258)	O	10:46	1.10	11:05	-0.42
Sep. 15 (258)	P	10:55	1.18	11:14	0.23
Sep. 15 (258)	Q	11:31	1.50	11:51	-1.82

Table 19. (continued)

Date (day of year)	Chamber	Time of day (CST)	Gross flux (μmoles/m^2/sec)	Time of day (CST)	Net flux (μmoles/m^2/sec)
Sep. 15 (258)	R	11:40	1.71	11:59	-0.64
1995					
Mar. 20 (79)	M	--	--	15:22	0.05
Mar. 20 (79)	N	15:03	0.12	--	--
Mar. 20 (79)	O	14:25	0.15	--	--
Mar. 20 (79)	P	--	--	13:49	0.10
Mar. 20 (79)	Q	13:12	0.05	--	--
Mar. 20 (79)	R	--	--	13:30	0.14

Table 20. Soil carbon dioxide flux at the Clear Cut site, BOREAS Southern Study Area, Saskatchewan, Canada, 1994-95.

[CST, Central Standard Time; μmoles/m^2/sec, micromoles per square meter per second; --, no data]

Date (day of year)	Chamber	Time of day (CST)	Gross flux (μmoles/m^2/sec)	Time of day (CST)	Net flux (μmoles/m^2/sec)
1995					
May 26 (146)	S	18:24	0.74	--	--
May 26 (146)	T	18:12	0.74	--	--
May 26 (146)	U	18:01	1.64	--	--
May 26 (146)	V	17:50	1.51	--	--
May 26 (146)	W	17:26	1.75	--	--
May 26 (146)	X	17:38	1.55	--	--
May 27 (147)	S	17:45	0.73	--	--
May 27 (147)	T	17:00	0.74	--	--
May 27 (147)	U	16:15	1.64	--	--
May 27 (147)	V	15:30	1.45	--	--
May 27 (147)	W	14:00	1.75	--	--
May 27 (147)	X	14:45	1.55	--	--
June 5 (156)	W	14:24	1.28	--	--
June 5 (156)	X	14:09	1.10	--	--
June 28 (179)	S	13:05	1.22	13:24	1.37
June 28 (179)	T	13:12	1.42	13:40	1.87
June 28 (179)	U	13:55	2.52	--	--
June 28 (179)	V	14:07	2.20	--	--
July 7 (188)	S	13:45	1.08	14:05	1.22
July 7 (188)	T	13:53	1.11	14:14	1.48
July 7 (188)	U	14:48	2.63	--	--
July 7 (188)	V	14:28	1.88	--	--
July 21 (202)	S	11:50	1.17	11:34	1.83
July 21 (202)	T	12:00	1.46	11:42	1.95
July 21 (202)	U	12:11	3.00	--	--
July 21 (202)	V	12:20	1.49	--	--
July 31 (212)	S	09:55	0.91	10:16	1.00

Table 20. (continued)

Date (day of year)	Chamber	Time of day (CST)	Gross flux (μmoles/m^2/sec)	Time of day (CST)	Net flux (μmoles/m^2/sec)
July 31 (212)	T	10:05	1.02	10:26	1.16
July 31 (212)	U	10:40	1.65	--	--
July 31 (212)	V	10:50	1.59	--	--
July 31 (212)	W	11:01	1.59	--	--
July 31 (212)	X	11:11	1.21	--	--
Aug. 9 (221)	S	11:50	0.49	12:11	0.62
Aug. 9 (221)	T	12:01	0.53	12:23	0.71
Aug. 9 (221)	U	12:35	0.91	12:55	1.04
Aug. 9 (221)	V	12:45	0.82	13:06	0.87
Aug. 9 (221)	W	13:16	0.89	13:37	1.37
Aug. 9 (221)	X	13:26	0.63	13:48	1.07
Aug. 10 (222)	S	15:20	0.48	15:41	0.62
Aug. 10 (222)	T	15:30	0.51	15:50	0.76
Aug. 10 (222)	U	16:01	1.02	16:20	1.14
Aug. 10 (222)	V	16:10	0.86	16:29	0.97
Aug. 10 (222)	W	16:40	1.22	16:59	1.23
Aug. 10 (222)	X	16:50	0.89	17:07	0.96
Aug. 15 (227)	S	10:00	0.62	10:20	0.65
Aug. 15 (227)	T	10:10	0.69	--	--
Aug. 15 (227)	U	10:41	0.87	11:01	1.14
Aug. 15 (227)	V	10:51	0.82	11:11	1.08
Aug. 15 (227)	W	11:21	1.04	11:45	1.23
Aug. 15 (227)	X	11:35	1.09	11:50	1.14
Aug. 18 (230)	S	14:45	0.64	15:05	0.65
Aug. 18 (230)	T	14:55	0.67	15:15	0.73
Aug. 18 (230)	U	15:26	0.95	15:46	1.12
Aug. 18 (230)	V	15:36	0.75	15:57	0.94
Aug. 18 (230)	W	16:07	0.86	--	--
Aug. 18 (230)	X	16:17	0.82	--	--

Table 20. (continued)

Date (day of year)	Chamber	Time of day (CST)	Gross flux (μmoles/m^2/sec)	Time of day (CST)	Net flux (μmoles/m^2/sec)
Aug. 25 (237)	S	12:45	0.33	13:05	0.63
Aug. 25 (237)	T	12:55	0.39	13:15	0.63
Aug. 25 (237)	U	14:15	0.92	14:35	0.80
Aug. 25 (237)	V	14:25	0.62	14:45	0.68
Aug. 25 (237)	W	14:56	0.76	--	--
Aug. 25 (237)	X	15:06	0.51	--	--
Sep. 9 (252)	S	14:15	0.47	14:35	0.55
Sep. 9 (252)	T	14:25	0.55	14:45	0.61
Sep. 9 (252)	U	15:01	0.90	--	--
Sep. 9 (252)	V	15:11	0.72	--	--
Sep. 9 (252)	W	15:22	0.38	--	--
Sep. 9 (252)	X	15:32	0.55	--	--
Sep. 14 (257)	S	14:31	0.45	15:51	0.53
Sep. 14 (257)	T	14:42	0.43	15:00	0.54
Sep. 14 (257)	U	15:50	0.82	15:30	0.95
Sep. 14 (257)	V	15:20	0.64	15:50	0.72
Sep. 14 (257)	W	16:03	0.53	16:22	0.92
Sep. 14 (257)	X	16:12	0.64	16:32	0.77
1995					
Mar. 20 (79)	S	09:43	0.06	--	--
Mar. 20 (79)	T	--	--	10:01	-0.09
Mar. 20 (79)	U	--	--	08:29	0.22
Mar. 20 (79)	V	09:06	0.13	--	--
Mar. 20 (79)	W	07:47	0.20	--	--
Mar. 20 (79)	X	--	--	08:05	0.16

Table 21. Soil carbon dioxide flux over a 24-hour period at the Old Jack Pine site, BOREAS Southern Study Area, Saskatchewan, Canada, 1994.

[CST, Central Standard Time; µmoles/m^2/sec, micromoles per square meter per second; --, no data]

Date (day of year)	Time of day (CST)	Gross flux (µmoles/m^2/sec)	Net flux (µmoles/m^2/sec)
Aug. 20 (232)	08:00	1.65	--
Aug. 20 (232)	08:30	--	0.84
Aug. 20 (232)	10:00	2.43	--
Aug. 20 (232)	10:30	--	1.63
Aug. 20 (232)	12:00	3.16	--
Aug. 20 (232)	12:30	--	2.81
Aug. 20 (232)	14:00	2.28	--
Aug. 20 (232)	14:30	--	2.06
Aug. 20 (232)	16:00	2.54	--
Aug. 20 (232)	16:30	--	2.29
Aug. 20 (232)	17:30	2.36	--
Aug. 20 (232)	18:00	--	2.22
Aug. 20 (232)	20:00	2.62	--
Aug. 20 (232)	20:30	--	2.28
Aug. 20 (232)	22:00	2.45	--
Aug. 20 (232)	22:30	--	2.25
Aug. 21 (233)	00:00	2.21	--
Aug. 21 (233)	00:30	--	1.91
Aug. 21 (233)	02:00	1.48	--
Aug. 21 (233)	02:30	--	2.00
Aug. 21 (233)	04:00	2.05	--
Aug. 21 (233)	04:30	--	1.65
Aug. 21 (233)	06:00	1.88	--
Aug. 21 (233)	06:30	--	1.44
Aug. 21 (233)	08:00	1.58	--
Aug. 21 (233)	08:30	--	1.24

Table 22. Soil carbon dioxide flux over 24-hour periods at the Young Jack Pine site, BOREAS Southern Study Area, Saskatchewan, Canada, 1994.

[CST, Central Standard Time; μmoles/m^2/sec, micromoles per square meter per second; --, no data]

Date (day of year)	Time of day (CST)	Gross flux (μmoles/m^2/sec)	Net flux (μmoles/m^2/sec)
June 11 (162)	13:30	3.01	--
June 11 (162)	14:00	--	2.11
June 11 (162)	16:00	2.72	--
June 11 (162)	16:30	--	1.45
June 11 (162)	18:30	2.32	--
June 11 (162)	19:00	--	1.92
June 11 (162)	20:30	2.40	--
June 11 (162)	21:00	--	2.19
June 11 (162)	23:30	2.23	--
June 12 (163)	00:00	--	2.00
June 12 (163)	01:30	2.03	--
June 12 (163)	02:00	--	2.13
June 12 (163)	03:30	1.97	--
June 12 (163)	04:00	--	1.63
June 12 (163)	05:30	1.84	--
June 12 (163)	06:00	--	1.49
June 12 (163)	07:30	1.78	--
June 12 (163)	08:00	--	1.00
June 12 (163)	09:30	2.16	--
June 12 (163)	10:00	--	0.68
June 12 (163)	11:30	2.02	--
June 12 (163)	12:00	--	1.13
June 12 (163)	12:30	2.82	2.05
Aug. 11 (223)	11:30	3.05	--
Aug. 11 (223)	12:00	--	0.09
Aug. 11 (223)	13:30	4.04	--
Aug. 11 (223)	14:00	--	1.27
Aug. 11 (223)	15:00	3.07	0.03

Table 22. (continued)

Date (day of year)	Time of day (CST)	Gross flux (μmoles/m^2/sec)	Net flux (μmoles/m^2/sec)
Aug. 11 (223)	16:30	3.55	--
Aug. 11 (223)	17:00	--	2.86
Aug. 11 (223)	18:30	2.38	--
Aug. 11 (223)	20:30	3.10	--
Aug. 11 (223)	21:00	--	2.57
Aug. 11 (223)	22:30	2.98	--
Aug. 11 (223)	23:00	--	2.41
Aug. 12 (224)	00:30	2.77	--
Aug. 12 (224)	01:00	--	2.12
Aug. 12 (224)	04:30	2.83	--
Aug. 12 (224)	05:00	--	2.34
Aug. 12 (224)	06:30	2.25	--
Aug. 12 (224)	07:00	--	1.97
Aug. 12 (224)	09:00	2.80	--
Sep. 17 (260)	16:00	1.80	--
Sep. 17 (260)	16:30	1.60	--
Sep. 17 (260)	17:00	--	1.25
Sep. 17 (260)	18:00	1.47	--
Sep. 17 (260)	18:30	--	1.28
Sep. 17 (260)	20:30	1.54	--
Sep. 17 (260)	22:00	1.39	--
Sep. 18 (261)	00:00	1.32	--
Sep. 18 (261)	04:30	1.13	--
Sep. 18 (261)	05:30	1.13	--
Sep. 18 (261)	06:30	1.12	--
Sep. 18 (261)	08:30	1.20	--
Sep. 18 (261)	09:00	1.30	--
Sep. 18 (261)	10:30	1.76	--
Sep. 18 (261)	11:00	1.90	--

Table 22. (continued)

Date (day of year)	Time of day (CST)	Gross flux (μmoles/m^2/sec)	Net flux (μmoles/m^2/sec)
Sep. 18 (261)	13:00	1.92	--
Sep. 18 (261)	14:30	2.11	--
Sep. 18 (261)	15:00	--	1.45

Table 23. Soil methane flux at the Old Jack Pine site, BOREAS Southern Study Area, Saskatchewan, Canada, 1994-95.

[CST, Central Standard Time; µmoles/m^2/day, micromoles per square meter per day]

Date (day of year)	Chamber	Time of day (CST)	Methane flux (µmoles/m^2/day)
1994			
June 1 (152)	G	10:00	-386
June 1 (152)	H	10:00	-180
June 1 (152)	I	11:00	-643
June 1 (152)	J	11:00	-422
June 1 (152)	L	12:00	-68
June 4 (155)	G	15:00	-177
June 8 (159)	G	12:45	-87
June 8 (159)	H	12:45	-311
June 8 (159)	I	14:15	-142
June 8 (159)	J	14:15	-149
June 8 (159)	K	11:00	-133
June 8 (159)	L	11:00	-110
June 18 (169)	G	13:35	-107
June 18 (169)	H	13:36	-70
June 18 (169)	I	12:00	-86
June 18 (169)	J	12:01	-87
June 18 (169)	K	11:11	-57
June 18 (169)	L	11:10	-87
July 4 (185)	G	11:00	-142
July 4 (185)	H	11:01	-50
July 4 (185)	I	11:50	-90
July 4 (185)	J	11:51	-80
July 10 (191)	G	10:00	-61
July 10 (191)	H	10:01	-147
July 10 (191)	I	10:42	-122
July 10 (191)	J	10:43	-94
July 26 (207)	G	12:01	-58

Table 23. (continued)

Date (day of year)	Chamber	Time of day (CST)	Methane flux (μmoles/m^2/day)
July 26 (207)	I	13:40	-104
July 26 (207)	J	13:40	-152
July 26 (207)	K	14:20	-162
July 26 (207)	L	14:20	-122
Aug. 15 (227)	G	14:25	-105
Aug. 15 (227)	H	14:25	-104
Aug. 15 (227)	I	14:25	-138
Aug. 15 (227)	J	15:04	-164
Aug. 15 (227)	K	15:04	-154
Aug. 15 (227)	L	15:04	-156
Aug. 22 (234)	G	11:25	-90
Aug. 22 (234)	H	11:25	-112
Aug. 22 (234)	I	12:08	-161
Aug. 22 (234)	J	12:08	-85
Aug. 22 (234)	K	12:09	-121
Aug. 22 (234)	L	12:09	-213
Sep. 11 (254)	G	13:35	-62
Sep. 11 (254)	H	13:35	-51
Sep. 11 (254)	I	14:13	-68
Sep. 11 (254)	J	14:13	-82
Sep. 11 (254)	K	14:50	-65
Sep. 11 (254)	L	14:50	-88
1995			
Mar. 21 (80)	G	13:05	-126
Mar. 21 (80)	H	13:05	-60
Mar. 21 (80)	I	13:05	-85
Mar. 21 (80)	K	13:05	-81
Mar. 21 (80)	L	13:05	-60

Table 24. Soil methane flux at the Young Jack Pine site, BOREAS Southern Study Area, Saskatchewan, Canada, 1994-95.

[CST, Central Standard Time; μmoles/m^2/day, micromoles per square meter per day]

Date (day of year)	Chamber	Time of day (CST)	Methane flux (μmoles/m^2/day)
1994			
May 31 (151)	A	11:10	-125
May 31 (151)	B	11:10	-47
May 31 (151)	C	14:18	-53
May 31 (151)	D	14:18	-150
May 31 (151)	E	14:55	-110
May 31 (151)	F	14:55	-79
June 8 (159)	B	16:23	-121
June 8 (159)	C	17:40	-80
June 8 (159)	D	17:41	-110
June 20 (171)	A	12:30	-56
June 20 (171)	B	12:31	-58
June 20 (171)	C	11:18	-54
June 20 (171)	D	11:19	-56
June 20 (171)	E	10:30	-45
June 20 (171)	F	10:31	-76
July 3 (184)	A	10:40	-59
July 3 (184)	B	10:41	-53
July 3 (184)	C	11:30	-42
July 3 (184)	D	11:31	-28
July 9 (190)	A	13:26	-89
July 9 (190)	B	13:27	-57
July 9 (190)	C	14:16	-81
July 9 (190)	D	14:17	-43
July 25 (206)	A	10:45	-110
July 25 (206)	B	10:45	-116
July 25 (206)	C	11:33	-63
July 25 (206)	D	11:33	-66

Table 24. (continued)

Date (day of year)	Chamber	Time of day (CST)	Methane flux (μmoles/m^2/day)
July 25 (206)	E	12:33	-26
July 25 (206)	F	12:33	-69
Aug. 11 (223)	A	11:25	-49
Aug. 11 (223)	B	11:41	-108
Aug. 15 (227)	A	10:00	-64
Aug. 15 (227)	B	10:00	-91
Aug. 15 (227)	C	10:01	-129
Aug. 15 (227)	D	10:58	-98
Aug. 15 (227)	E	10:57	-80
Aug. 15 (227)	F	10:57	-79
Aug. 23 (235)	A	10:48	-153
Aug. 23 (235)	B	10:48	-105
Aug. 23 (235)	C	11:29	-130
Aug. 23 (235)	D	11:29	-199
Aug. 23 (235)	E	11:30	-189
Aug. 23 (235)	F	11:30	-138
Sep. 12 (255)	A	15:55	-43
Sep. 12 (255)	B	15:55	-55
Sep. 12 (255)	C	14:35	-53
Sep. 12 (255)	D	14:35	-54
Sep. 12 (255)	E	17:12	-40
Sep. 12 (255)	F	17:12	-82
1995			
Mar. 21 (80)	A	09:15	-51
Mar. 21 (80)	B	09:15	0
Mar. 21 (80)	C	09:15	0
Mar. 21 (80)	D	09:15	-26

Table 25. Soil methane flux at the Recent Cut site, BOREAS Southern Study Area, Saskatchewan, Canada, 1994-95.
[CST, Central Standard Time; μmoles/m^2/day, micromoles per square meter per day]

Date (day of year)	Chamber	Time of day (CST)	Methane flux (μmoles/m^2/day)
1994			
June 5 (156)	M	11:58	-87
June 5 (156)	N	11:30	-63
June 10 (161)	M	08:20	0
June 10 (161)	N	08:21	-44
June 10 (161)	O	08:28	-62
June 10 (161)	P	08:27	-28
June 10 (161)	Q	09:16	-169
June 10 (161)	R	09:15	-125
June 27 (178)	M	09:43	-21
June 27 (178)	N	09:44	-105
June 27 (178)	O	09:42	-70
June 27 (178)	P	09:40	-120
June 27 (178)	Q	10:43	-130
June 27 (178)	R	10:44	-74
July 3 (184)	M	12:57	-88
July 3 (184)	N	12:58	-123
July 9 (190)	M	10:27	-56
July 9 (190)	N	11:28	-30
July 29 (210)	M	15:35	-41
July 29 (210)	N	15:35	-127
July 29 (210)	O	16:17	-90
July 29 (210)	P	16:17	-85
Aug. 13 (225)	M	10:00	-93
Aug. 13 (225)	N	10:00	-72
Aug. 13 (225)	O	10:42	-142
Aug. 13 (225)	P	10:42	-133
Aug. 13 (225)	Q	11:22	-102
Aug. 13 (225)	R	11:22	-134

Table 25. (continued)

Date (day of year)	Chamber	Time of day (CST)	Methane flux (μmoles/m^2/day)
Aug. 22 (234)	M	10:07	-60
Aug. 22 (234)	N	10:07	-137
Aug. 22 (234)	O	10:08	-194
Aug. 22 (234)	P	10:08	-125
Sep. 10 (253)	M	14:00	-12
Sep. 10 (253)	N	14:00	-66
Sep. 10 (253)	O	14:45	-67
Sep. 10 (253)	P	14:45	-61
1995			
Mar. 21 (80)	N	15:07	-62
Mar. 21 (80)	O	15:07	-47
Mar. 21 (80)	Q	15:07	-30
Mar. 21 (80)	R	15:07	0

Table 26. Soil methane flux at the Clear Cut site, BOREAS Southern Study Area, Saskatchewan, Canada, 1994-95.
[CST, Central Standard Time; μmoles/m^2/day, micromoles per square meter per day]

Date (day of year)	Chamber	Time of day (CST)	Methane flux (μmoles/m^2/day)
1994			
June 10 (161)	S	10:20	-101
June 10 (161)	T	10:21	-172
June 10 (161)	U	10:44	-76
June 10 (161)	V	10:43	-158
June 10 (161)	W	11:10	-94
June 10 (161)	X	11:11	-49
June 28 (179)	S	13:05	-134
June 28 (179)	T	13:12	-103
June 28 (179)	U	13:55	-93
June 28 (179)	V	14:07	-85
June 28 (179)	W	14:30	-62
July 4 (185)	S	12:55	-145
July 4 (185)	T	12:56	-114
July 10 (191)	S	11:36	-89
July 10 (191)	T	11:37	-120
July 28 (209)	S	14:34	-67
July 28 (209)	S	15:00	-61
July 28 (209)	T	14:35	-87
July 28 (209)	U	15:28	-79
July 28 (209)	V	15:29	-93
July 29 (210)	T	10:18	-138
Aug. 13 (225)	S	13:30	-133
Aug. 13 (225)	T	13:30	-119
Aug. 13 (225)	U	13:30	-164
Aug. 13 (225)	V	14:15	-125
Aug. 13 (225)	W	14:15	-79
Aug. 13 (225)	X	14:15	-99
Aug. 23 (235)	S	9:27	-111

Table 26. (continued)

Date (day of year)	Chamber	Time of day (CST)	Methane flux (μmoles/m^2/day)
Aug. 23 (235)	T	9:27	-136
Aug. 23 (235)	U	9:28	-118
Aug. 23 (235)	V	9:28	-81
Sep. 11 (254)	S	10:00	-86
Sep. 11 (254)	T	10:00	-85
Sep. 11 (254)	U	10:40	-62
Sep. 11 (254)	V	10:40	-97
Sep. 11 (254)	W	11:20	-67
Sep. 11 (254)	X	11:20	-42
1995			
Mar. 21 (80)	S	17:08	-74
Mar. 21 (80)	T	17:08	-102
Mar. 21 (80)	U	17:08	-38
Mar. 21 (80)	V	17:08	-23

Stable Isotopes in Gases

Soil gas was collected from three series of depths in the unsaturated zone at Young Jack Pine. Carbon dioxide, extracted from the gas by cryogenic trapping, was analyzed for ^{13}C and ^{18}O content using mass spectrometry at the U.S. Geological Survey gas isotope laboratory in Denver, Colorado. Values in Table 27 were obtained from samples collected on one occasion. Stable isotope values are presented in delta notation in units of the parts per thousand relative difference (permil) between the ratios of ^{13}C to ^{12}C and ^{18}O to ^{16}O in the samples and Pee Dee belemnite for ^{13}C and Standard Mean Ocean Water for ^{18}O (Friedman and O'Neill, 1977; Fritz and Fontes, 1980).

Table 27. Carbon and oxygen isotopes in soil gas collected from three locations at the Young Jack Pine site, BOREAS Southern Study Area, Saskatchewan, Canada, on August 23 (day 235)1994.

[m, meters; ^{13}C content is in permil relative to Pee Dee belemnite standards; ^{18}O content is in permil relative to Standard Mean Ocean Water (Friedman and O'Neill, 1977; Fritz & Fontes, 1980)]

Location	Depth (m)	delta ^{13}C CO_2	delta ^{18}O CO_2	CO_2 (ppm)
1	1.0	-10.10	27.73	4232
1	2.0	-20.41	20.68	4057
1	3.0	-20.47	23.57	3547
1	4.0	-20.50	22.68	3150
1	5.0	-20.40	23.09	2890
1	6.0	-20.44	23.57	2654
2	1.0	-20.99	22.25	5980
2	1.5	-20.85	22.12	5912
2	2.0	-21.29	28.94	5500
2	2.5	-20.62	23.28	4820
3	0.1	-18.82	23.77	1941
3	0.2	-20.12	20.65	2928
3	0.3	-19.94	23.25	3302

Soil Water Chemistry

Gravity drainage lysimeters were installed at the Young Jack Pine and Old Jack Pine sites to collect liquid water percolating through the unsaturated sands to a maximum depth of 1.00 m. Only one rainfall event (day 200, 1994) was large enough to initiate sufficient percolation at the Young Jack Pine site for water sample collection and analysis. Sufficient water volume was never collected at the Old Jack Pine site. Table 28 lists chemistry of soil water collected at Young Jack Pine site. Analyses were according to Fishman and Friedman (1985).

Table 28. Water chemistry of soil water collected at the Young Jack Pine site, BOREAS Southern Study Area, Saskatchewan, Canada, July 19 (day 200), 1994.
[m, meters; mg/L, milligrams per liter; µeq/L, microequivalents per liter; µsiemens/cm, microsiemens per centimeter; --, no data]

Depth (m)	Total organic carbon (mg/L)	Total inorganic carbon (mg/L)	Acid neutralizing capacity (µeq/L)	Specific conductance (µsiemens/cm)
0.10	9.05	--	452	58.3
0.30	74.0	0.94	421	72.6
0.75	36.6	8.60	1408	158
1.00	35.9	15.6	2495	238

Depth (m)	Sodium (µeq/L)	Ammonium (µeq/L)	Potassium (µeq/L)	Magnesium (µeq/L)	Calcium (µeq/L)	Chloride (µeq/L)	Nitrate (µeq/L)	Sulfate (µeq/L)
0.10	23.1	1.71	7.22	18.8	42.5	6.58	1.24	4.28
0.30	24.0	2.52	7.26	19.8	53.0	5.45	0.91	5.79
0.75	21.0	0.746	4.35	40.5	107	9.42	0.88	14.1
1.00	36.2	1.33	9.58	67.9	159	9.41	0.89	10.2

REFERENCES

Clayton, J.S., Ehrlich, W.A., Cann, D.B., Day, J.H., and Marshall, I.B., 1977, Soils of Canada, Volume II Soil Inventory: Research Branch, Canada Department of Agriculture, 239 p.

Fishman, M.J. and Friedman, L.C., 1985, Methods of determination of inorganic substances in water and fluvial sediments, Techniques of Water Resources Investigations of the U.S. Geological Survey, Book 5, chapter A1; 545 p.

Folk, R.L., 1980, Petrology of sediment rocks: Austin, Texas, Hemphill Publishing Company, 182 p.

Friedman, I., and O'Neil, J.R., 1977, Compilation of stable isotope fractionation factors of geochemical interest (sixth ed.): U.S. Geological Survey Professional Paper 440-KK, 12 p.

Fritz, P., and Fontes, J. Ch., 1980, Handbook of environmental isotope geochemistry, vol. 1, The terrestrial environment, A: Amsterdam, Elsevier Scientific Publishing Company, 543 p.

Healy, R.W., Striegl, R.G., Russell, T.F., Hutchinson, G.L., and Livingston, G.P., 1996, Numerical evaluation of static-chamber measurements of soil-atmosphere gas exchange: Identification of Physical Processes: Soil Science Society of America Journal, v. 60, no. 3, p. 740-747.

Klute, A., 1986, Methods of soil analysis, part 1, Physical and mineralogical methods, (2nd ed.): Madison, Wisconsin, American Society of Agronomy, Inc., Soil Science Society of America, Inc., 1188p.

Munsell soil color charts, 1992: Newburgh, New York, Macbeth Division of Kollmorgen Instruments Corporation.