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Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS)

Forrest G. Hall and David E. Knapp, Editors

Volume 248

BOREAS TGB-12 Soil Carbon and Flux Data of NSA-MSA in Raster Format

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National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

November 2000

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BOREAS TGB-12 Soil Carbon and Flux Data of NSA-MSA in Raster Format

Gloria Rapalee, Eric Davidson, Jennifer W. Harden, Susan E. Trumbore, Hugo Veldhuis

Summary

The BOREAS TGB-12 team made measurements of soil carbon inventories, carbon concentration in soil gases, and rates of soil respiration at several sites. This data set provides: (1) estimates of soil carbon stocks by horizon based on soil survey data and analyses of data from individual soil profiles; (2) estimates of soil carbon fluxes based on stocks, fire history, drainage, and soil carbon inputs and decomposition constants based on field work using radiocarbon analyses; (3) fire history data estimating age ranges of time since last fire; and (4) a raster image and an associated soils table file from which area-weighted maps of soil carbon and fluxes and fire history may be generated. This data set was created from raster files, soil polygon data files, and detailed lab analysis of soils data that were received from Dr. Hugo Veldhuis, who did the original mapping in the field during 1994. Also used were soils data from Susan Trumbore and Jennifer Harden (BOREAS TGB-12). The binary raster file covers a 733-km^2 area within the NSA-MSA.

Note that some of the files of this data set on the BOREAS CD-ROMs have been compressed using the Gzip program. See Section 8.2 for details.

Table of Contents

1. Data Set Overview

1.1 Data Set Identification

BOREAS TGB-12 Soil Carbon and Flux Data of NSA-MSA in Raster Format

1.2 Data Set Introduction

This data set contains soil properties and classification information, particularly soil carbon stocks and fluxes, time since last fire, and polygon area, over the BOReal Ecosystem-Atmosphere Study (BOREAS) Northern Study Area (NSA)-Modeling Sub-Area (MSA), gridded to a 30-meter pixel resolution. The data were reprojected into the ellipsoidal version of the Albers Equal-Area Conic (AEAC) projection from the original map made by Dr. Hugo Veldhuis (Agriculture and Agri-Food Canada). The original map was then modified by Gloria Rapalee (The Woods Hole Research Center).

1.3 Objective/Purpose

These data are provided by the BOREAS Trace Gas and Biogeochemistry (TGB)-12 team and include pertinent map data in both hardcopy and digital form. This data set has been processed to provide a raster file that can be used for modeling or for comparison purposes. The purpose of this data set is to provide information about the fire history and spatial distribution of soil carbon stocks and fluxes over the NSA-MSA.

1.4 Summary of Parameters

This data set contains information about the spatial distribution of soil classes around the NSA-MSA along with soil class properties such as parent material, texture, slope class, and water table depth, as well as soil carbon stocks and fluxes, time since last fire, and polygon area. A detailed list of parameters is given in Section 7. The polygon numbers in the American Standard Code for Information Interchange (ASCII) table files correspond to pixel values in the binary raster file. The value of each pixel can link to the table described in Section 7 in order to extract these parameters.

1.5 Discussion

The spatial base of this data set is the vector layer by Dr. Hugo Veldhuis of Agriculture and Agri-Food Canada. Using aerial photography and field methods, he identified various soil polygons at a scale of 1:50,000 for the NSA-MSA (what Dr. Veldhuis calls the 'super site'). This data set was also produced from the detailed field soil data collected by Jennifer Harden and Susan Trumbore (TGB-12), plus data from related data sets listed in Section 1.6.

1.6 Related Data Sets

BOREAS AFM-12 1-km AVHRR Seasonal Land Cover Classification
BOREAS Forest Cover Data Layers of the NSA in Raster Format
BOREAS TE-13 Biometry Data
BOREAS TE-18 Landsat TM Maximum Likelihood Classification Image of the NSA
BOREAS TE-20 NSA Soil Lab Data
BOREAS TE-20 Soils Data over the NSA MSA and Tower Sites in Raster Format
BOREAS TE-20 Supplementary Soil & Site Information for NSA MSA and Tower Sites (Grab Bag)
BOREAS TGB-05 Fire History of Manitoba 1980 to 1991 in Raster Format
BOREAS TGB-12 Soil Carbon Data over the NSA

2. Investigator(s)

2.1 Investigator(s) Name and Title

Gloria Rapalee, Graduate Fellow, The Woods Hole Research Center
Eric A. Davidson, Associate Scientist, The Woods Hole Research Center
Jennifer W. Harden, Soil Scientist, United States Geological Survey
Susan E. Trumbore, Associate Professor, University of California, Irvine
Hugo Veldhuis, Senior Pedologist, Agriculture & Agri-Food Canada

2.2 Title of Investigation

Scaling Soil Carbon Stocks and Fluxes of Super Site Northern Study Area Thompson, Manitoba, Canada

Part of: Input, Accumulation, and Turnover of Carbon in Boreal Forest Soils: Integrating ^{14}C Isotopic Analyses with Ecosystem Dynamics

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3. Theory of Measurements

The original soils mapping was performed by using a combination of field samples of the soil and aerial photographs. The original soils map was then modified by Gloria Rapalee using a variety of available data to account for changes in vegetation due to a recent fire. These digital map data provide investigators with a continuous surface of soil parameters plus carbon stock and flux data that can further be used for modeling purposes.

4. Equipment

4.1 Sensor/Instrument Description

Please refer to the separate reports submitted by Drs. Veldhuis and Trumbore et al. regarding equipment used to perform the soils mapping. See Section 1.6.

In addition to field techniques, aerial photography flown in 1978 at 1:50,000 scale was used to map the soils of the NSA-MSA. No additional information is available about this photography.

4.1.1 Collection Environment

The original vector files were received in digital line graph (DLG) format from Dr. Hugo Veldhuis. The modified soil polygon file (this data set) was received in binary raster format.

4.1.2 Source/Platform

Unknown.

4.1.3 Source/Platform Mission Objectives

Unknown.

4.1.4 Key Variables

The key variables of this data set include:

```
POLYNUM = Polygon number
GRIDLOC = Grid location
COMPONT = Polygon component (landscape element)
NUMBER  = Component rank number
PERCENT = Percentage distribution of components
KINDMAT = Kind of rock outcrop or other material at the surface
LANDFRM = Local surface form
PMDEPO1 = Mode of deposition or origin of first (upper) parent material
TXTURE1 = Texture of first (upper) parent material
TXTMOD1 = Texture modifier of first (upper) parent material
PMDEPO2 = Mode of deposition or origin of second (middle) parent material
TXTURE2 = Texture of second (middle) parent material
TXTMOD2 = Texture modifier of second (middle) parent material
PMDEPO3 = Mode of deposition or origin of third (lower) parent material
TXTURE3 = Texture of third (lower) parent material
TXTMOD3 = Texture modifier of third (lower) parent material
COFRAGS = Coarse fragment content in control section of mineral soils
SLOPE   = Slope gradient class
DRAINGE = Drainage class
DEPTHWT = Depth to water table, average
PFDISTR = Permafrost distribution or occurrence
DPTHACT = Depth of active layer (average)
ICECTNT = Ice content of permanently frozen layer
DPTHLFH = Thickness of humus layer (L,F,H)
DPTHORG = Average thickness of peat deposit
SOILDEV = Soil development (soil classification)
VARIANT = Classification variant or phase
SOILTP1 = Dominant soil type associated with polygon component
SOILPH1 = Soil phase or variant associated with dominant soil type
SOILTP2 = Subdominant soil type associated with polygon component
SOILPH2 = Soil phase or variant associated with subdominant soil type
TOTLAREA = Total area (hectares) of each soil polygon
COMPAREA = Area (hectares) of each polygon component
DR_CLASS = Drainage class (numerical code)
STND_AGE = Stand age; time since last fire
ST_AGE_GRP = Stand age; age ranges since last fire
C_SURFACE  = Area-weighted carbon stocks of surface layers, including moss
C_DEEP  = Area-weighted carbon stocks of deep soil horizons
C_TOTAL = Area-weighted total carbon stock for entire profile
         (C_SURFACE + C_DEEP)
FL_SURFACE = Area-weighted carbon fluxes of surface layers, including moss
```

```
FL_DEEP = Area-weighted carbon fluxes of deep soil horizons
FL_NET  = Area-weighted carbon fluxes for entire profile
          (FL_SURFACE + FL_DEEP)
```

4.1.5 Principles of Operation

Unknown.

4.1.6 Sensor/Instrument Measurement Geometry

Unknown.

4.1.7 Manufacturer of Sensor/Instrument

Unknown.

4.2 Calibration

4.2.1 Specifications

Unknown.

4.2.1.1 Tolerance

Unknown.

4.2.2 Frequency of Calibration

Unknown.

4.2.3 Other Calibration Information

Unknown.

5. Data Acquisition Methods

A detailed report of the soils mapping effort, submitted by Dr. Veldhuis, is available. Part 2 of the report (Methodology) provides detailed information about data acquisition methods. Detailed documentation of Trumbore and Harden (TGB-12) field data and methods is also available. See Section 1.6.

6. Observations

6.1 Data Notes

The soils report by Dr. Veldhuis provides observations and descriptions of soils. Additional notes exist in files (not included here) submitted by Dr. Veldhuis. Site and field descriptions of Trumbore and Harden (TGB-12) sampling sites are also available. See Section 1.6.

6.2 Field Notes

Not applicable.

7. Data Description

7.1 Spatial Characteristics

The soil map in this data set covers a 733 km^2 area within the NSA-MSA. Details of spatial coverage and resolution are given in the following sections.

7.1.1 Spatial Coverage

The area mapped is projected in the BOREAS Grid system and is bounded by the following points. These coordinates are based on the North American Datum of 1983 (NAD83).

NSA-MSA (1,420 pixels by 956 lines, 30-meter pixel size)

Point	BOREAS_X	BOREAS_Y	Longitude	Latitude
Northwest	759.33175	630.72800	-98.73055	56.06201
Northeast	801.93175	630.72800	-98.05756	55.99320
Southwest	759.33175	602.04800	-98.81086	55.80873
Southeast	801.93175	602.04800	-98.14207	55.74036

7.1.2 Spatial Coverage Map

The soil map in this data set covers a 733 km^2 area within the NSA-MSA.

7.1.3 Spatial Resolution

The pixel resolution is 30 meters.

7.1.4 Projection

The area mapped is projected in the ellipsoidal version of the AEAC projection. The projection has the following parameters:

```
Datum:  NAD83
Ellipsoid:  GRS80 or WGS84
Origin:   W 111.000 degrees    N  51.000 degrees
Standard Parallels:  N 52 deg 30' 00"
                     N 58 deg 30' 00"
Units of Measure:  kilometers
```

7.1.5 Grid Description

Each pixel represents an area of 30 by 30 meters in the AEAC projection described in Section 7.1.4.

7.2 Temporal Characteristics:

7.2.1 Temporal Coverage

Dr. Veldhuis collected field samples for mapping the MSA and the NSA tower sites in 1994. Air photos taken in 1978 at a scale of 1:50,000 were used for extending the field samples to map the NSA-MSA. Trumbore and Harden collected soil samples in 1993 and 1994. Several data sources (see Section 1.6) that postdate the 1978 air photos were used to generate the fire history data listed in the soils table file. The Landsat Thematic Mapper (TM) image and forest cover images date from 1988. Fire history images date from 1980 to 1991. Data from the AVHRR image are from 1992. Tree core data are from the 1993 biometry inventory of auxiliary sites. Also used was a set of fire history maps dating from 1937 to 1990 produced by Forestry Canada.

7.2.2 Temporal Coverage Map

Not applicable.

7.2.3 Temporal Resolution

Not applicable.

7.3 Data Characteristics

These data are in an image format in which the value of a pixel represents the polygon number from the original vector data, later modified by Gloria Rapalee for this data set. This number can be related to a set of records in the ASCII soils table file. The soils table file contains parameters for the various polygons. Lakes are indicated with a polygon number of 237. Polygons with numbers greater than 237 are split from Dr. Veldhuis's original polygons.

7.3.1 Parameter/Variable

```
POLYNUM
GRIDLOC
COMPONT
NUMBER
PERCENT
KINDMAT
LANDFRM
PMDEPO1
TXTURE1
TXTMOD1
PMDEPO2
TXTURE2
TXTMOD2
PMDEPO3
TXTURE3
TXTMOD3
COFRAGS
SLOPE
DRAINGE
DEPTHWT
PFDISTR
DPTHACT
ICECTNT
DPTHLFH
DPTHORG
SOILDEV
VARIANT
SOILTP1
SOILPH1
SOILTP2
SOILPH2
TOTLAREA
COMPAREA
DR_CLASS
STND_AGE
ST_AGE_GRP
C_MOSS
C_DEEP
C_TOTAL
FL_MOSS
FL_DEEP
FL_TOTAL
```

7.3.2 Variable Description/Definition

Binary Raster Image File

POLYNUM: Number of the map polygon to which the pixel belongs. Unitless but coded value.

ASCII soil table file:

1. POLYNUM = Number of the map polygon.

2. GRIDLOC = An alphanumeric grid to be used to find a particular polygon on the map.

3. COMPONT = Polygon component (landscape element).

The landscape components that make up the area delineated by the polygon. A polygon may have one or many components. They are listed in order of extent.

Code	Class	Description
D	Dominant	The D-components combined cover >50% of the land area of a polygon.
S	Subdominant	The S-components combined cover <50% of the land area of a polygon.
I	Inclusion	Each inclusion covers <15% of the polygon, but the combined area of inclusions may be 25%.
W	Water	Surface water in the form of lakes, ponds or streams may cover between 5 and 100% of a polygon.

4. NUMBER = Component rank number.

Landscape elements with the similar parent material properties are considered to belong to the same general component. Thus, these elements together form the dominant or subdominant component in the polygon, but the individual elements will not be dominant or subdominant. To show the landscape relationship or parent material association, the elements are all considered to belong to the dominant (D) or subdominant (S) group, but are ranked D1, D2, etc., according to their relative importance within the group. For example, three drainage conditions exist on a gently undulating glaciolacustrine blanket. The well-drained portion occupies 30% of the polygon area, imperfectly drained conditions exist in 15% of the polygon, and poorly drained areas with a thin peat cover occupy an additional 10%, for a combined total of 55%. This makes this grouping the dominant component in the polygon. Thus, these three elements will be labeled D1, D2, and D3, respectively.

In the cases of inclusions (I) and water (W), the rank numbers link these components to either the dominant or the subdominant components. The convention is that an uneven rank number (1,3,...) links the inclusion or water to the dominant component(s), while an even rank number links it to the subdominant component(s).

5. PERCENT = Percentage distribution of components.

Percent area is estimated within the nearest 5%. Components <10% are not listed except for W.

6. KINDMAT = Kind of rock outcrop or other material at the surface.

Code	Class	Description
OR	Organic soil	Contains >30% organic matter by weight
R2	Hard rock, acidic	Granite
SO	Mineral soil	Dominant mineral particles, contains <30% organic matter by weight
WA	Water	Water

7. LANDFRM = Local surface form.

Mineral surface forms. Two classes may be combined. For example, "bh" is hummocky blanket; "vi" is inclined veneer.

Code	Class	Description
b	blanket	Unconsolidated surficial materials >1 m thick.
d	dissected	Gullies or valleys dissect the component.
h	hummocky	A complex sequence of slopes extending from concavities of various sizes to knolls or short, discontinuous ridges.
i	inclined	A sloping, unidirectional surface with a generally constant slope not broken by marked irregularity or gullies.
k	knoll and kettle	A very chaotic sequence of knolls, ridges, and kettles.
l	level	A flat or very gently sloping unidirectional surface with a generally constant slope not broken by marked elevations and depressions; slopes are generally <2%.
r	ridged	A long, narrow elevation of the surface, usually distinctly crested with steep sides.
s	steep	Erosional slopes on both consolidated and unconsolidated materials.
u	undulating	A regular sequence of gentle slopes that extends from rounded and, in some places, confined concavities to broad, rounded convexities; low local relief with slopes usually between 2-5%.
v	veneer	Unconsolidated surficial materials <1 m thick. Veneers may be continuous or patchy.
w	beach, strandline	Low ridges with steeper slope on one

		side than on the other.
y	subdued hummocky	A complex sequence of slopes extending from concavities of various sizes to knolls. Local topography is <10 m.

Organic Surface Forms

The classification of landforms is often the case of "best fit." Often the landform encountered does not quite meet all criteria of any class. Organic landforms often are intergrades of one form to another.

Code	Class	Description
Ba	Palsa bog	A bog composed of individual or coalesced palsas, occurring in an unfrozen peatland. Palsas are mounds of perennially frozen peat and mineral soil, up to 5 m high, with a maximum diameter of 100 m. The surface is highly uneven, often containing collapse scar bogs.
Bc	Collapse scar bog	A circular or oval-shaped wet depression in a perennially frozen peatland; the collapse scar bog was once part of the perennially frozen peatland, but the permafrost thawed, causing the surface to subside; the depression is poor in nutrients, as it is not connected to the minerotrophic fens in which the palsa or peat plateau occurs.
Bt	Peat plateau bog	A bog composed of perennially frozen peat, rising abruptly about 1 m from the surrounding unfrozen fen; the surface is relatively flat and even, and the bog commonly covers large areas; the peat was originally deposited in a nonpermafrost environment and is associated in many places with collapse bogs or fens.
Bv	Veneer bog	A bog occurring on gently sloping terrain underlain by generally discontinuous permafrost; although drainage is predominantly below the surface, overland flow occurs in poorly defined drainage-ways during peak runoff; peat thickness is usually less than 1.5 m.
Fb	Basin fen	A fen occupying a topographically defined basin; however, the basins do not receive drainage from upstream and the fens are thus influenced mainly by local hydrological conditions; the depth of peat increases toward the center.
Fc	Collapse scar fen	A fen with circular or oval depressions, up to 100 m, occurring in larger fens, marking the subsidence of thawed permafrost peatlands. Dead trees,

		remnants of the subsided vegetation of permafrost peatlands, are often evident.
Fh	Horizontal fen	A fen with a very gently sloping featureless surface; this fen occupies broad, often ill-defined depressions, and may be interconnected with other fens; peat accumulation is generally uniform.
Fs	Stream fen	A fen located in the main channel or along the banks of permanent or semi-permanent streams. This fen is affected by the water of the stream at normal and flood stages.

8. PMDEPO1 = Mode of deposition or origin of first (upper) parent material.

Code	Class	Description
AN	Anthropogenic	Materials modified by human activity so that their physical properties have been drastically altered; they include borrow pits, gravel pits, road beds.
B	Bog	Bogs consist of unspecified organic materials associated with an ombrotrophic environment because the slightly elevated nature of the bog dissociates it from nutrient-rich ground water or surrounding mineral soils; near the surface, materials are usually not or very little decomposed (fibric), yellowish to pale brown, loose and spongy in consistence, and entire sphagnum plants are readily identified; these materials are extremely acid, with low bulk density and high fiber content; at depths they become darker, compacted, and somewhat layered; bogs are associated with slopes or depressions on topography with a water table at or near the surface in the spring and slightly below it during the rest of the year; they are usually covered with sphagnum mosses, but sedges may also grow on them; bogs may be treed or treeless, and many are characterized by a layer of ericaceous shrubs.
F	Fluvial	Sediment generally consisting of silt and clay with a minor fraction of sand and gravel; gravels are typically rounded; alluvial sediments are commonly moderately to well sorted and display stratification.
FN	Fen	Fens consist of unspecified organic materials formed in a minerotrophic environment because of the close association of the material with mineral-rich waters; it is usually moderately well to well decomposed, dark brown to black,

		with fine- to medium-sized fibers; decomposition commonly becomes greater at lower depths; the materials are covered with a dominant component of sedges or brown mosses, but grasses reeds, sphagnum mosses, shrubs and trees may be associated.
GF	Glaciofluvial	Material moved by glaciers and subsequently sorted and deposited by streams flowing from the melting ice; deposits are stratified and may occur in the form of outwash plains, deltas, kames, eskers, and kame terraces.
GL	Glaciolacustrine	Sediment generally consisting of either stratified fine sand, silt, and clay deposited on the glacial lake bed or moderately well sorted and stratified sand and coarser materials that are beach and other near-shore sediments transported and deposited by wave action; these materials either have settled from suspension in bodies of standing fresh water or have accumulated at their margins through wave action.
O	Organic	A layered sequence of more than three types of organic undifferentiated material (>30% organic matter by weight).
R	Residual	Unconsolidated, weathered, or partly weathered soil mineral materials that accumulates by disintegration of bedrock in place.
T	Till (Morainal)	Sediment generally consisting of well-compacted material that is nonstratified and contains a heterogeneous mixture of sand, silt, and clay particle sizes and coarse fragments in a mixture that has been transported beneath, beside, on, within, or in front of a glacier and not modified by any intermediate agent.
RK	Rock	A consolidated bedrock layer that is too hard to break with the hands (>3 on Mohs' scale) or to dig with a spade when moist.

9. TXTURE1 = Texture of first (upper) parent material.

Soil texture indicates the relative proportions of the various soil separates in a soil. Soil separates are mineral particles, <2.0 mm in equivalent diameter, ranging between specified size limits:

Soil separate	Diameter (mm)
Very coarse sand	2.0-1.0
Coarse sand	1.0-0.50
Medium sand	0.50-0.25
Fine sand	0.25-0.10
Very fine sand	0.10-0.05
Silt	0.05-0.002
Clay	<0.002

Coarse fragments are rock or mineral fragments >2.0 mm in diameter:

Coarse fragment	Diameter (cm)
Gravel	0.2-7.5
Cobble	7.5-25.0

Sands
Sand is a soil material that contains 85% or more sand; the percentage of silt plus 1.5 times the percentage of clay, does not exceed 15.

Code	Class	Description
VCS	Very Coarse Sand	25% or more very coarse sand, and less than 50% any other one grade of sand.
CS	Coarse Sand	25% or more very coarse and coarse sand, and less than 50% any other grade of sand.
S	Sand	25% or more very coarse, coarse, and medium sand (but less than 25% very coarse and coarse sand), and less than 50% of either fine or very fine sand.
FS	Fine Sand	50% or more fine sand, or less than 25% very coarse, coarse, and medium sand and less than 50% very fine sand.
VFS	Very Fine Sand	50% or more very fine sand.

Loamy Sands

Loamy sand is a soil material that contains at the upper limit 85-90% sand, and the percentage of silt plus 1.5 times the percentage of clay is not less than 15; at the lower limit it contains not less than 70-85% sand, and the percentage of silt plus twice the percentage of clay does not exceed 30.

Code	Class	Description
LCS	Loamy Coarse Sand	25% or more very coarse and coarse sand, and less than 50% any other one grade of sand.
LS	Loamy Sand	25% or more very coarse, coarse, and medium sand (but less than 25% very coarse and coarse sand), and less than 50% fine or very fine sand.
LFS	Loamy Fine Sand	50% or more fine sand, or less than 50% very fine sand and less than 25% very coarse, coarse, and medium sand.
LVFS	Loamy Very Fine Sand	50% or more very fine sand.

Sandy Loams

Sandy loam is a soil material that contains either 20% clay or less, with the percentage of silt plus twice the percentage of clay exceeding 30, and 52% or more sand; or less than 7% clay, less than 50% silt, and 43-52% sand.

Code	Class	Description
CSL	Coarse Sandy Loam	25% or more very coarse and coarse sand and less than 50% any other one grade of sand.
SL	Sandy Loam	30% or more very coarse, coarse, and medium sand (but less than 25% very coarse and coarse sand), and less than 30% of either very fine or fine sand.
FSL	Fine Sandy Loam	30% or more fine sand and less than 30% very fine sand; or between 15-30% very coarse, coarse, and medium sand; or more than 40% fine and very fine sand, at least half of which is fine sand, and less than 15% very coarse, coarse, and medium sand.
VFSL	Very Fine Sandy Loam	30% or more very fine sand, or more than 40% fine and very fine sand, at least half of which is very fine sand, and less than 15% very coarse, coarse, and medium sand.

Textures finer than sandy loams:

Code	Class	Description
L	Loam	7-27% clay, 28-50% silt, and less than 52% sand.
SIL	Silt Loam	50% or more silt and 12-27% clay, or 50-80% silt and less than 12% clay.
SI	Silt	80% or more silt and less than 12% clay.
SCL	Sandy Clay Loam	20-35% clay, less than 28% silt, and 45% or more sand.
CL	Clay Loam	27-40% clay and 20-45 sand.
SICL	Silty Clay Loam	27-40% clay and less than 20% sand.
SC	Sandy Clay	35% or more clay and 45% or more sand.
SIC	Silty Clay	40% or more clay and 40% or more silt.
C	Clay	40% or more clay, less than 45% sand, and less than 40% silt.
HC	Heavy Clay	More than 60% clay.
O	Organic	Fiber content undifferentiated.
F	Fibric	40% or more rubbed fiber content by volume.
M	Mesic	10% or more and less than 40% fiber content by volume.
H	Humic	<10% rubbed fiber content by volume.

10. TXTMOD1 = Texture modifier of first (upper) parent material.

Code	Class	Description
GR	Gravelly	15-35% gravel by volume
VG	Very gravelly	35-60% gravel by volume
EG	Extremely gravelly	>60% gravel by volume
MU	Mucky	9-17% organic carbon
GY	Gritty	Sharp edged particles present
AY	Ashy	Quantities of volcanic or organic ash present
WY	Woody	Quantities of woody fragments present (organic soils)

11. PMDEPO2 = Mode of deposition or origin of second (middle) parent material.

12. TXTURE2 = Texture of second (middle) parent material.

13. TXTMOD2 = Texture modifier of second (middle) parent material.

14. PMDEPO3 = Mode of deposition or origin of third (lower) parent material.

15. TXTURE3 = Texture of third (lower) parent material.

16. TXTMOD3 = Texture modifier of third (lower) parent material.

17. COFRAGS = Coarse fragment content in control section of mineral soils.

Code	Class	Description
A	<1% by volume	Rounded, subrounded, flat, angular, or irregular rock fragment from 2 mm to 60 cm or more in size.
B	1-15%	
C	16-35%	
D	36-60%	
E	>60%	
#	Not applicable	

18. SLOPE = Slope gradient class.

The slope is generally the average or common slope of the unit, but in the case of complex topography the steepest slope class is listed.

Code	Class
1	1-2%
4	3-5%
8	6-9%
13	10-15%
25	16-30%
45	31-60%

19. DRAINGE = Drainage class.

Code	Class	Description
VR	Very rapid	Water is removed from the soil very rapidly in relation to supply; excess water flows downward very rapidly if underlying material is pervious; subsurface flow may be very rapid during heavy rainfall provided the gradient is steep; source of water is precipitation.
R	Rapid	Water is removed from the soil rapidly in relation to supply; excess water flows downward if underlying material is pervious; subsurface flow may occur on steep gradients during heavy rainfall; source of water is precipitation.
W	Well	Water is removed from the soil readily but not rapidly; excess water flows downward readily into underlying pervious material or laterally as subsurface flow; these soils commonly retain optimum amounts of moisture for plant growth after rains or addition of irrigation water.
MW	Moderately well	Water is removed from the soil

		somewhat slowly in relation to supply; excess water is removed somewhat slowly because of low perviousness, shallow water table, lack of gradient, or some combination of these; precipitation is the dominant source of water in medium-to-fine textured soils; precipitation and significant additions by subsurface flow are necessary in course textured soils.
I	Imperfect	Water is removed from the soil sufficiently slowly in relation to supply to keep the soil wet for a significant part of the growing season; excess water moves slowly downward if precipitation is the major supply; if subsurface water or groundwater, or both, is the main source, the flow rate may vary but the soil remains wet for a significant part of the growing season.
P	Poor	Water is removed so slowly in relation to supply that the soil remains wet from a comparatively large part of the time the soil is not frozen; excess water is evident in the soil for much of the time; subsurface flow or groundwater flow, or both, in addition to precipitation are the main sources of water; there may also be a perched water table.
VP	Very poor	Water is removed from the soil so slowly that the water table remains at or near the surface for most of the time the soil is not frozen; groundwater flow and subsurface flow are the major sources of water; precipitation is less important except where there is a perched water table.
#	Not applicable	

20. DEPTHWT = Average depth to water table.

Code	Class	Description
10	0-20 cm	Most shallow water table during growing season.
50	20-75 cm	
125	75-150 cm	
200	>150 cm	
*	0-100 cm	With perennially frozen subsoil.
#	Not applicable	(Water, ice, rock).

21. PFDISTR = Permafrost distribution or occurrence.

Code	Class	Description
V	Very sporadic	Sparse patches of permafrost are associated with the component.
S	Sporadic	Isolated patches or islands of permafrost occur within the component.
D	Discontinuous	Widespread permafrost occurs within the component.
C	Continuous	Permafrost underlies all or almost all of the component.
#	Not applicable	

22. DPTHACT = Depth of active layer (average).

Code	Class	Description
50	35-75 cm	Top layer of ground subject to annual thawing and freezing
100	>75 cm	in areas underlain by permafrost.
#	Not applicable	

23. ICECTNT = Ice content of permanently frozen layer.

Code	Class	Description
L	Low	Ice content (volume) less than available pore space in nonfrozen soil.
M	Medium	No excess ice; ice content (volume) equal to pore space of nonfrozen soil.
H	High	Excess ice: ice content greater than pore space in nonfrozen soil; ice usually in the form of lenses, vein ice, or massive ground ice.

24. DPTHLFH = Thickness of humus layer (L,F,H).

The thickness of the humus layer is estimated and based on observations in the field. However, the frequency of forest fires in the area may reduce deep LFH layers to nil from one year to the next.

Code	Class
0	<5 cm
1	5-10 cm
2	11-20 cm
3	21-40 cm
4	>40 cm
#	Not applicable (e.g., borrow pit, organic deposits)

25. DPTHORG = Average thickness of peat deposit.

Peat consist of organic material that accumulated under very wet or saturated conditions.

Code	Class	Description
0	<0.2 m	Peat development has just started (paludification), or depth of peat layer has been reduced by fire.
1	0.2-0.6 m	Peat depth generally less than 40 cm if peat depth is rather uniform; or peat depth is on average about 40 cm but varies strongly over short distances due to sphagnum hummock formation.
2	0.6-1.6 m	Shallow peat (fens and bogs).
3	1.6-3.0 m	Deep peat.
4	>3.0 m	Very deep peat.

26. SOILDEV = Soil development (soil classification).

The dominant soil development associated with the polygon component. Other kinds of soil development are usually present, but only as inclusions.

Code	Class
Brunisolic	
EDYB	Eluviated Dystric Brunisol
GLEDYB	Gleyed Eluviated Dystric Brunisol
EEB	Eluviated Eutric Brunisol
GLEEB	Gleyed Eluviated Eutric Brunisol
Gleysolic	
OHG	Orthic Humic Gleysol
RHG	Rego Humic Gleysol
OG	Orthic Gleysol
FEG	Ferric Gleysol
OLG	Orthic Luvic Gleysol
HULG	Humic Luvic Gleysol
Luvisolic	
OGL	Orthic Gray Luvisol
DGL	Dark Gray Luvisol
GLGL	Gleyed Gray Luvisol
GLDGL	Gleyed Dark Gray Luvisol
Organic	
TYF	Typic Fibrisol
MEF	Mesic Fibrisol
TF	Terric Fibrisol
TMEF	Terric Mesic Fibrisol
HYF	Hydric Fibrisol
TYM	Typic Mesisol
FIM	Fibric Mesisol

TM	Terric Mesisol
TFIM	Terric Fibric Mesisol
THUM	Terric Mesic Humisol
TH	Terric Humisol
TFIH	Terric Fibric Humisol
TMEH	Terric Mesic Humisol

Cryosolic

OSC	Orthic Static Cryosol
RSC	Regosolic Static Cryosol
OTC	Orthic Turbic Cryosol
RTC	Regosolic Turbic Cryosol
FIOC	Fibric Organic Cryosol
MEOC	Mesic Organic Cryosol
HUOC	Humic Organic Cryosol
TFIOC	Terric Fibric Organic Cryosol
TMEOC	Terric Mesic Organic Cryosol
THUOC	Terric Humic Organic Cryosol

27. VARIANT = Classification variant or phase.

Code	Class	Description
c	Cryic	This designation has been used to identify Luvisolic soils with permafrost within the control section. These soils are at present not recognized in the Canadian System of Soil Classification.
l	Lithic	A soil that has a lithic contact within the control section.
p	Peaty	A soil that has a peaty layer 15-40 cm thick.

28. SOILTP1 = Dominant soil type associated with polygon component.

The dominant soil type listed represents the soils that occupy >50% of the component. The soil type may be a soil series, which is a soil type defined within narrow limits, or a group of soils that vary to some extent in texture, depth of profile, etc. The soil type used to identify organic landscape components is the soil that best represents the group or complex of soils that are associated with that particular landscape component. The organic soil type usually represents related, but sometimes quite different, soils. These variations may include peat depth, presence or absence of certain peat layers, variation in peat decomposition, etc.

29. SOILPH1 = Soil phase or variant associated with dominant soil type.

The soil phase or variant is used to identify more specifically the dominant soil type. These soils vary to some degree from the model due to differences in parent material (stratification, texture), depth of the LFH layer, peaty surface, coarse fragment content, etc.

Code	Class	Description
d	Deep	A soil that is relatively deep.
h	humus	A soil with a relatively deep duff layer.
s	Shallow	A soil that is relatively shallow.
v	Very deep	A soil that is very deep.
w	Very shallow	A soil that is very shallow.
x	complex	A soil that varies in a number of properties from the model (series concept)
1,2,3	Variant number	A soil that varies in one or more specific properties from the series concept.

30. SOILTP2 = Subdominant soil type associated with polygon component.

The subdominant soil type listed represents the soils that occupy <50% of the component. The soil type may be a soil series, which is a soil type defined within narrow limits, or a group of soils that vary to some extent in texture, depth of profile, etc. The soil type used to identify organic landscape components is the soil that best represents the group or complex of soils that are associated with that particular landscape component. The organic soil type usually represents related, but sometimes quite different, soils. These variations may include peat depth, presence or absence of certain peat layers, variation in peat decomposition, etc.

31. SOILPH2 = Soil phase or variant associated with subdominant soil type.

The soil phase or variant is used to identify more specifically the subdominant soil type component. (See no. 29 for codes.)

32. TOTLAREA = Total area (hectares) of soil polygon.

33. COMPAREA = Area (hectares) of polygon component.

34. DR_CLASS = Drainage class (numerical code used for modeling carbon stocks and fluxes).

Code	Class	
1	Rock	
2	VR	Very Rapid
3	R	Rapid
4	W	Well
5	MW	Moderately Well
6	I	Imperfect
7	P	Poor
8	VP	Very Poor
9	Water	
10	Lake	

35. STND_AGE = Age (years) since last fire of each soil polygon component. 1994 is the reference year. Some are age ranges. Data are from a variety of sources. (See Sections 1.6 and 7.2.1.)

13	1981 burn scar from Landsat TM image and Terrestrial Ecology (TE)-05 fire history images.
30	1964 burn scar from Forestry Canada fire history maps and Manitoba Natural Resources 1988 forest inventory data.
38	1956 burn scar from Forestry Canada fire history maps and Natural Resources Manitoba 1988 forest inventory data.
43 +/- 7	Mean age +/- 1 std deviation from TE-13 tree core data.
45	Manitoba Natural Resources 1988 forest inventory data.
50	Estimate from Landsat TM image and Natural Resources Manitoba 1988 forest inventory data.
59 +/- 15	Mean age +/- 1 std deviation from TE-13 tree core data of forest stands along Hwy 391.
70	Natural Resources Manitoba 1988 forest inventory data - high end of age range 56 +/- 20 yrs.
86 +/- 10	Manitoba Natural Resources 1988 forest inventory data.
89 +/- 14	Mean age +/- 1 std deviation from TE-13 tree core data of forest stands near and around OJP tower site.
104 +/- 20	Natural Resources Manitoba 1988 forest inventory data.
120	Stand age of OBS near and around tower.
146 +/- 20	Natural Resources Manitoba 1988 forest inventory data.
199	Fen.
299	Lake.

36. ST_AGE_GRP = Stand age groupings used for estimating carbon stocks and modeling fluxes. Note: We assumed that the fens do not burn and therefore did not assign age since last fire for those polygon components that are fens.

13	1981 burn scar from Landsat TM image and TE-05 fire history images.
30	1964 burn scar from Forestry Canada fire history maps and Natural Resources Manitoba 1988 forest inventory data.
38	1956 burn scar from Forestry Canada fire history maps and Natural Resources Manitoba 1988 forest inventory data.
43 +/- 7	Mean age +/- 1 std deviation from TE-13 tree core data.
60	50 - 65 grouped.
70	Natural Resources Manitoba 1988 forest inventory data - high end of age range 56 +/- 20 yrs.
90	OJP tower site and other stands designated by Natural Resources Manitoba 1988 forest inventory as 86 yrs and older.
120	OBS tower site and other stands designated by Natural Resources Manitoba 1988 forest inventory as 104 yrs and older.
1	Fen.
0	Lake.

37. C_SURFACE = Area-weighted score (kg C/m^2) of carbon stock for surface horizons (including moss). Note: Stock = 0 for rock outcrops, open water, and lakes. Stock = 13 for fens and bog collapse.

38. C_DEEP = Area-weighted score (kg C/m^2) of carbon stock for deep soil horizons - humic and mineral A and B layers. Scores computed from average C stock of soil series. Note: Stock = 0 for rock outcrops, open water, and lakes.

39. C_TOTAL = Area-weighted score (kg C/m^2) of carbon stock for entire soil profile (C_SURFACE + C_DEEP). Note: Stock = 0 for rock outcrops, open water, and lakes.

40. FL_SURFACE = Area-weighted score (kg $C/m^2/yr$) of carbon flux for surface horizons (including moss). Note: Flux = 0 for rock outcrops, open water, lakes, fens, and collapse bogs.

41. FL_DEEP = Area-weighted score (kg $C/m^2/yr$) of carbon flux for deep soil horizons - humic and mineral A and B layers. Note: Flux = 0 for rock outcrops, open water, lakes, collapse bogs, and palsa bogs.

42. FL_NET = Area-weighted score (kg $C/m^2/yr$) of carbon flux for entire soil profile (F_SURFACE + F_DEEP). Note: Flux = 0 for rock outcrops, lakes, and open water.

NOTE: Negative (<0) flux denotes carbon released from the soil or surface horizons to the atmosphere (source). Positive (>0) flux denotes carbon stored in the soil or surface horizons (sink).

7.3.3 Unit of Measurement

See Section 7.3.2.

7.3.4 Data Source

This data product is derived from the soil maps that were produced by Dr. Hugo Veldhuis of Agriculture and Agri-Food Canada. See Section 1.5 for more information.

7.3.5 Data Range

Each pixel in the image file contains the polygon number value. This value is matched to the polygon number listed in the corresponding ASCII soils table file. The values for that polygon number apply to that polygon.

7.4 Sample Data Record

Not applicable.

8. Data Organization

8.1 Data Granularity

The smallest unit of data for this data set is the data set itself.

8.2 Data Format

8.2.1 Uncompressed Data Files

The image file contains binary 16-bit (2-byte) values with the low order byte The overall content of this product is:

```
File 1   ASCII text file listing files on tape
File 2   NSA-MSA Binary Soil Map
File 3   NSA-MSA Soils Polygon Data Table (ASCII)
```

The binary raster file that covers the NSA-MSA is distributed as 16-bit integers with the low-order byte first. The soils table file that indicates the soil parameters for the polygons in the map is distributed as an ASCII text file. The files have the following characteristics:

File	Record Size (Bytes)	Bytes/Pixel	# Records
File 1	80	ASCII text	8
File 2	2840	2	956
File 3	350	ASCII text	690

8.2.2 Compressed CD-ROM Files

On the BOREAS CD-ROMs, files 1 and 3 listed above are stored as ASCII text; however, file 2 has been compressed with the Gzip compression program (file name *.gz). These data have been compressed using gzip version 1.2.4 and the high compression (-9) option (Copyright (C) 1992-1993 Jean-loup Gailly). Gzip (GNU zip) uses the Lempel-Ziv algorithm (Welch, 1994) used in the zip and PKZIP programs. The compressed files may be uncompressed using gzip (-d option) or gunzip. Gzip is available from many Web sites (for example, ftp site prep.ai.mit.edu/pub/gnu/gzip-*.*) for a variety of operating systems in both executable and source code form. Versions of the decompression software for various systems are included on the CD-ROMs.

9. Data Manipulations

9.1 Formulae
See Section 9.1.1.

9.1.1 Derivation Techniques and Algorithms
The reader is referred to the detailed report submitted by Dr. Veldhuis for details on the derivation of the original maps (see Section 1.6). Refer to Davidson (1995) and Davidson and Lefebvre (1993) for methodology on calculating area-weighted scores for carbon stocks and fluxes. Refer to Trumbore and Harden (1997) and Harden et al. (1997) for details on algorithms and their derivation for modeling carbon stocks and fluxes.

9.2 Data Processing Sequence

9.2.1 Processing Steps
BOREAS Information System (BORIS) personnel processed the data by:

- Visually reviewing the data file contents.
- Copying the ASCII and compressing the binary files for release on CD-ROM.

9.2.2 Processing Changes
None.

9.3 Calculations
Refer to Davidson (1995) and Davidson and Lefebvre (1993) for methodology on calculating area-weighted scores for carbon stocks and fluxes. Refer to Trumbore and Harden (1997) and Harden et al. (1997) for details on algorithms and their derivation for modeling carbon stocks and fluxes.

9.3.1 Special Corrections/Adjustments
None.

9.3.2 Calculated Variables
None.

9.4 Graphs and Plots
None.

10. Errors

10.1 Sources of Error
Errors could result from the change in format from vector to raster. However, the original raster image was thoroughly checked and compared to the original vector data to avoid such problems. The vector data were an original mapping using data collected directly from the field along with air photos. Errors could arise from a typographical error in the field notes.

10.2 Quality Assessment

10.2.1 Data Validation by Source
Any data validation or accuracy assessment would have to have been made by the original sources. Please refer to the reports mentioned in Section 5.

10.2.2 Confidence Level/Accuracy Judgment
The spatial accuracy of these data is considered very good.

10.2.3 Measurement Error for Parameters

Unknown.

10.2.4 Additional Quality Assessments

None.

10.2.5 Data Verification by Data Center

BORIS personnel viewed and compared the images with the original vector data to identify any possible discrepancies.

11. Notes

11.1 Limitations of the Data

The reports by Dr. Hugo Veldhuis and TGB-12 may indicate some limitations of the soil mapping. See Section 1.6.

Some of the stand age/fire history data are estimates and assumptions for those areas within the study area for which no data were available. Also, in other areas, estimates are at the high end of the age ranges listed in the Natural Resources Manitoba forest inventory field manual. (See Section 17.2.)

Carbon stocks and fluxes are area-weighted averages for each polygon component. Moss stocks and fluxes and deep carbon fluxes were calculated by applying algorithms for soil carbon inputs (I) and decomposition rates (k) based on field work using radiocarbon analyses. Reference I's and k's are in the middle of the range for each drainage/vegetation type. They may be under or over estimated. For further details see Trumbore and Harden (1997),Harden et al. (1997), and Rapalee et al. (in preparation).

Carbon stocks for the deep soil horizons are also area-weighted averages. That is, the average stock for a particular soil series for the deeper layers of the soil profile. In some cases, however, there was only one soil pit for a particular soil series. Also, since many of the profile descriptions of the study area were missing data on bulk density, we developed a nonlinear regression relating bulk density to carbon content for the soil profile descriptions that had both. Errors in average C stocks for the soil series may have arisen from our estimates of bulk density.

11.2 Known Problems with the Data

None.

11.3 Usage Guidance

Before uncompressing the Gzip files on CD-ROM, be sure that you have enough disk space to hold the uncompressed data files. Then use the appropriate decompression program provided on the CD-ROM for your specific system.

11.4 Other Relevant Information

For more information, please consult the soils report by Dr. Hugo Veldhuis and the documentation by Harden and Trumbore (TGB-12). See Section 1.6.

12. Application of the Data Set

This data set was created for BOREAS investigators who need soils data in the vicinity of the MSA for further modeling and to generate maps of area-weighted carbon stocks and fluxes.

13. Future Modifications and Plans

None.

14. Software

14.1 Software Description

IDRISI GIS software was used to modify the gridded soil polygon file produced from Dr. Veldhuis's original soil map. Gzip (GNU zip) uses the Lempel-Ziv algorithm (Welch, 1994) used in the zip and PKZIP commands.

14.2 Software Access

IDRISI is proprietary software with copyright protection. This software is a product of the IDRISI Project at Clark University, Worcester, MA. Gzip is available from many Web sites across the Internet (for example, ftp site prep.ai.mit.edu/pub/gnu/gzip-*.*) for a variety of operating systems in both executable and source code form. Versions of the decompression software for various systems are included on the CD-ROMs.

15. Data Access

The raster format soil carbon and flux data from the NSA-MSA are available from the Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

15.1 Contact Information

For BOREAS data and documentation please contact:

ORNL DAAC User Services
Oak Ridge National Laboratory
P.O. Box 2008 MS-6407
Oak Ridge, TN 37831-6407
Phone: (423) 241-3952
Fax: (423) 574-4665
E-mail: ornldaac@ornl.gov or ornl@eos.nasa.gov

15.2 Data Center Identification

Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC) for Biogeochemical Dynamics http://www-eosdis.ornl.gov/.

15.3 Procedures for Obtaining Data

Users may obtain data directly through the ORNL DAAC online search and order system [http://www-eosdis.ornl.gov/] and the anonymous FTP site [ftp://www-eosdis.ornl.gov/data/] or by contacting User Services by electronic mail, telephone, fax, letter, or personal visit using the contact information in Section 15.1.

15.4 Data Center Status/Plans

The ORNL DAAC is the primary source for BOREAS field measurement, image, GIS, and hardcopy data products. The BOREAS CD-ROM and data referenced or listed in inventories on the CD-ROM are available from the ORNL DAAC.

16. Output Products and Availability

16.1 Tape Products

These data can be made available on 1600 or 6250 Bytes Per Inch (BPI) 8 mm, Digital Archive Tape (DAT), or 9-track tapes.

16.2 Film Products

None.

16.3 Other Products

These data are available on the BOREAS CD-ROM series.

17. References

17.1 Platform/Sensor/Instrument/Data Processing Documentation

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17.3 Archive/DBMS Usage Documentation

None.

18. Glossary of Terms

None.

19. List of Acronyms

```
AEAC      - Albers Equal-Area Conic
ASCII     - American Standard Code for Information Interchange
BOREAS    - BOReal Ecosystem-Atmosphere Study
BORIS     - BOREAS Information System
BPI       - Bytes Per Inch
CD-ROM    - Compact Disk-Read-Only Memory
DAAC      - Distributed Active Archive Center
DAT       - Digital Archive Tape
DLG       - Digital Line Graph
EOS       - Earth Observing System
EOSDIS    - EOS Data and Information System
GIS       - Geographic Information System
GMT       - Greenwich Mean Time
GPS       - Global Positioning System
GSFC      - Goddard Space Flight Center
MSA       - Modeling Sub-Area
NAD27     - North American Datum of 1927
NAD83     - North American Datum of 1983
NASA      - National Aeronautics and Space Administration
NSA       - Northern Study Area
OBS       - Old Black Spruce
OJP       - Old Jack Pine
ORNL      - Oak Ridge National Laboratory
PANP      - Prince Albert National Park
SSA       - Southern Study Area
TE        - Terrestrial Ecology
TGB       - Trace Gas Biogeochemistry
TM        - Thematic Mapper
URL       - Uniform Resource Locator
UTM       - Universal Transverse Mercator
WWW       - World Wide Web
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13. ABSTRACT *(Maximum 200 words)*

The BOREAS TGB-12 team made measurements of soil carbon inventories, carbon concentration in soil gases, and rates of soil respiration at several sites. This data set provides: (1) estimates of soil carbon stocks by horizon based on soil survey data and analyses of data from individual soil profiles; (2) estimates of soil carbon fluxes based on stocks, fire history, drainage, and soil carbon inputs and decomposition constants based on field work using radiocarbon analyses; (3) fire history data estimating age ranges of time since last fire; and (4) a raster image and an associated soils table file from which area-weighted maps of soil carbon and fluxes and fire history may be generated. This data set was created from raster files, soil polygon data files, and detailed lab analysis of soils data that were received from Dr. Hugo Veldhuis, who did the original mapping in the field during 1994. Also used were soils data from Susan Trumbore and Jennifer Harden (BOREAS TGB-12). The binary raster file covers a 733-km^2 area within the NSA-MSA.

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