ABoVE: Landsat Vegetation Greenness Trends, Boreal Forest Biome, 1985-2019

Get Data

Documentation Revision Date: 2022-04-30

Dataset Version: 1

Summary

This dataset provides information on interannual trends in annual maximum vegetation greenness from 1985 to 2019 for recently undisturbed areas in the boreal forest biome. Multi-decadal changes in remotely sensed vegetation greenness provide evidence of an emerging boreal biome shift driven by climate warming. Annual maximum vegetation greenness was assessed at about 100,000 random sample locations using an ensemble of spectral vegetation indices (NDVI, EVI2, kNDVI, and NIRv) derived from Landsat products. The dataset provides raster data summarizing vegetation greenness trends for sample locations stratified by Ecological Land Unit in GeoTIFF format. These raster data span the circum-hemispheric boreal forest biome between 45 to 70 degrees north at 300 m resolution. Estimates of uncertainty were generated using Monte Carlo simulations. Interannual trends in annual maximum vegetation greenness from 1985 to 2019 and 2000 to 2019 are provided for sample locations with adequate data for time series analysis; these data are in comma-separated values (CSV) format.

There are 21 data files included in this dataset: 20 files in GeoTIFF (*.tif) format and one file in comma-separated values (*.csv) format.

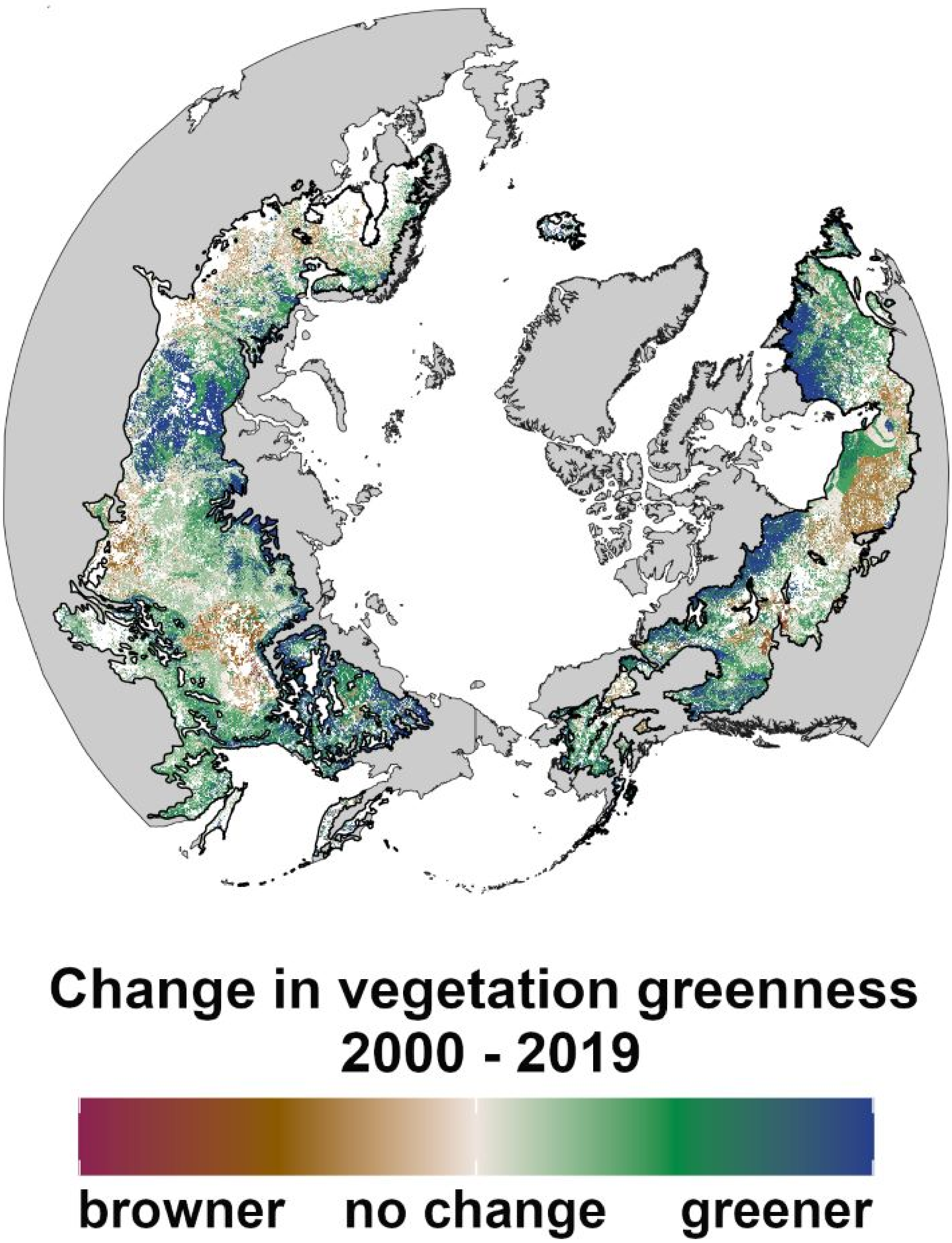

Figure 1. Change in greenness of boreal forest across the northern hemisphere between 2000 to 2019, estimated from an ensemble of vegetation indices derived from Landsat imagery. Source: boreal_greenness_median_percent_change_2000to2019_p500.tif

Citation

Berner, L.T., and S.J. Goetz. 2022. ABoVE: Landsat Vegetation Greenness Trends, Boreal Forest Biome, 1985-2019. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/2023

Table of Contents

1. Dataset Overview

This dataset provides information on interannual trends in annual maximum vegetation greenness from 1985 to 2019 for recently undisturbed areas in the boreal forest biome. Multi-decadal changes in remotely sensed vegetation greenness provide evidence of an emerging boreal biome shift driven by climate warming. Annual maximum vegetation greenness was assessed at about 100,000 random sample locations using an ensemble of spectral vegetation indices (NDVI, EVI2, kNDVI, and NIRv) derived from Landsat products. The dataset provides raster data summarizing vegetation greenness trends for sample locations stratified by Ecological Land Unit in GeoTIFF format. These raster data span the circum-hemispheric boreal forest biome between 45 to 70 degrees north at 300 m resolution. Estimates of uncertainty were generated using Monte Carlo simulations. Interannual trends in annual maximum vegetation greenness from 1985 to 2019 and 2000 to 2019 are provided for sample locations with adequate data for time series analysis; these data are in comma-separated values (CSV) format.

Project: Arctic-Boreal Vulnerability Experiment

The Arctic-Boreal Vulnerability Experiment (ABoVE) is a NASA Terrestrial Ecology Program field campaign being conducted in Alaska and western Canada, for 8 to 10 years, starting in 2015. Research for ABoVE links field-based, process-level studies with geospatial data products derived from airborne and satellite sensors, providing a foundation for improving the analysis, and modeling capabilities needed to understand and predict ecosystem responses to, and societal implications of, climate change in the Arctic and Boreal regions.

Related Publication

Berner, L.T. and S.J. Goetz. 2022. Satellite observations document trends consistent with a boreal forest biome shift. Global Change Biology, 28(10), 3275-3292. https://doi.org/10.1111/gcb.16121

Related Dataset

Berner, L.T., R. Massey, and S.J. Goetz. 2021. ABoVE: Landsat Tundra Greenness and Summer Air Temperatures, Arctic Tundra, 1985-2016. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1893

- The current dataset is based on similar Landsat data processing and analyses but focuses on the boreal biome instead of the Arctic tundra biome.

Acknowledgments

This project was supported by NASA's ABoVE program (grants NNX17AE44G, 80NSSC19M0112) and Carbon Cycle Science Program (grant NNX17AE13G).

2. Data Characteristics

Spatial Coverage: Distribution of boreal forest in northern hemisphere between 45 to 70 degrees north.

Spatial Resolution: 300 m

Temporal Coverage: 1985-06-01 to 2019-08-31

Temporal Resolution: annual

Study Area: Latitude and longitude are given in decimal degrees.

Site	Westernmost longitude	Easternmost longitude	Northernmost latitude	Southernmost latitude
Boreal forest biome of northern hemisphere	-180	180	70	45

Data File Information

There are 21 data files included in this dataset: 20 files in GeoTIFF (*.tif) format and one file in comma-separated values (*.csv) format. The GeoTIFF files with annual greenness trends are named boreal_greennness_*AAAA_BBBB_CCCC*.tif, where

- *AAAA* is "median_percent_change", "percent_browning" or "percent_greening" indicating the mapped variable.
- *BBBB* is "1985to 2019" or "2000to2019" indicating the time period.
- *CCCC* is "p025", "p500", or "p975"; indicating 2.5 th, 50th (median), or 97.5th percentile, respectively, of the mapped variable. These percentiles represent a 95% confidence interval for the mapped variable and were derived using Monte Carlo simulations.

Table 1. File names and descriptions.

File Name	Units	Description
boreal_greenness_median_percent_change_*BBBB_CCCC*.tif	percent	Median percent change in annual maximum vegetation greenness for time period across all sample locations within each ecological land unit. Percent change was computed as the change in vegetation greenness during the time period divided by initial vegetation greenness and then multiplied by 100.
boreal_greenness_percent_browning_*BBBB_CCCC*.tif	percent	Percent of sample locations in each ecological land unit that had a significant (α=0.10) negative trend in annual maximum vegetation greenness for the time period.
boreal_greenness_percent_greening_*BBBB_CCCC*.tif	percent	Percent of sample locations in each ecological land unit that had a significant (α=0.10) positive trend in annual maximum vegetation greenness for the time period.
boreal_sample_frame.tif	1	Binary raster identifying grid cells that were part of the boreal forest sampling frame.
boreal_ecounits.tif	1	Numerical identifier for each ecological land unit in the boreal sampling frame.

boreal_greenness_trend_summary.csv	-	Tabular data including trends in annual maximum vegetation greenness for sample locations during two time periods derived using an ensemble of spectral vegetation indices. See Table 2 for variables and descriptions.

Data File Details

Each GeoTIFF has a spatial domain covering the circum-hemispheric distribution of the boreal forest biome between 45 to 70 degrees north at 300 m spatial resolution in the North Pole Lambert Azimuthal Equal Area (LAEA) spatial projection (EPSG:3571).

Table 2. Variables in the file boreal_greenness_trend_summary.csv. Each trend metric includes a best-estimate (50^{th} percentile) as well as a lower bound (2.5^{th} percentile) and upper bound (97.5^{th} percentile) of a 95% confidence interval derived from Monte Carlo simulations.

Variable	Units	Description
site	-	Unique alphanumeric identifier for each sample location.
latitude	degree_north	Latitude in decimal degrees of site; WGS84 datum.
longitude	degree_east	Longitude in decimal degrees of site; WGS84 datum.
ecounit	1	Numerical identifier for the Ecological Land Unit in which each site is located.
trend.period	-	Time period over which the trend in vegetation greenness was assessed (“1985 to 2019” or “2000 to 2019").
tau.p025	1	Mann-Kendall’s tau statistic (2.5^{th} percentile).
tau.p500	1	Mann-Kendall’s tau statistic (50^{th} percentile).
tau.p975	1	Mann-Kendall’s tau statistic (97.5^{th} percentile).
percent.change.p025	percent	Percent change in vegetation greenness (2.5^{th} percentile).
percent.change.p500	percent	Percent change in vegetation greenness (50^{th} percentile).
percent.change.p975	percent	Percent change in vegetation greenness (97.5^{th} percentile).

3. Application and Derivation

The boreal forest biome is a major component of Earth’s terrestrial biosphere and climate system (Bonan, 2008), yet vulnerable to a geographic shift as the climate continues to change (Baltzer et al., 2021; Beck et al., 2011). Remotely sensed metrics of vegetation greenness (e.g., Normalized Difference Vegetation Index [NDVI]) are indicators of vegetation productivity and mortality (Berner et al., 2020; Boyd et al., 2021; Camps-Valls et al., 2021) and thus long-term changes in vegetation greenness could provide evidence of an emerging boreal biome shift (Beck et al., 2011). To shed light on the extent that which a boreal biome shift is underway, multi-decadal changes in vegetation greenness were assessed at sample locations across the boreal biome using Landsat satellite observations (Berner and Goetz, 2022).

4. Quality Assessment

Multiple sources of uncertainty can impact estimates on annual maximum vegetation greenness and its changes over time when using Landsat satellite observations. Therefore, uncertainty associated with measurement error, cross-sensor calibration, data availability, and phenological modeling were propagated through the analysis using Monte Carlo simulations (n=1,000). Each trend metric in this dataset includes a best-estimate (50^{th} percentile), as well as the lower (2.5^{th} percentile) and upper (97.5^{th} percentile) limits of a 95% confidence interval.

5. Data Acquisition, Materials, and Methods

This dataset provides information on vegetation greenness trends for recently undisturbed areas with natural vegetation and little to no human pressure in the boreal forest biome. The spatial extent of the boreal forest biome (~15.1 million km^2) was delineated using the World Wildlife Fund’s Terrestrial Ecoregions of the World dataset (Olson et al., 2001) gridded at 300 m resolution. Grid cells without natural vegetation (e.g., barren, developed, crops) were masked using a satellite land cover dataset (ESA, 2017), as were grid cells with evidence of more than minimal human pressure (Venter et al., 2016). Grid cells were additionally masked if there was evidence of disturbance since the mid-1980s, as determined using regional to global forest disturbance datasets (Giglio et al., 2018; Guindon et al., 2017; Hansen et al., 2013; Kasischke et al., 2002; Loboda and Chen, 2016).

Sample locations (n=100,000) were then randomly selected from this sampling frame, which comprised 56% (8.43 million km^2) of the boreal forest biome. Annual maximum vegetation greenness was estimated at each sample location using 30 m resolution Landsat data. The sample locations were stratified by Ecological Land Unit (ELU; Sayre et al., 2014) at 300 m resolution and trends were summarized across sample locations within each ELU. The ELUs demarcate areas with distinct combinations of bioclimate, landform, lithography, and land cover, thus providing a way to summarize vegetation greenness trends in an ecologically meaningful manner. Overall, the raster data cover recently undisturbed natural vegetation in the boreal forest biome at 300 m resolution.

To measure greenness trends, estimates of annual maximum vegetation greenness for the periods 1985 to 2019 and 2000 to 2019 were derived from Landsat data. Two time periods were used to take advantage of the improved spatial coverage of Landsat data from 2000 to 2019 and to minimize the potential effects of greening due to succession after disturbances prior to the early 1980s.

Annual maximum vegetation greenness was estimated using clear-sky Landsat data sporadically acquired each year from June through August (day of year 152 to 243). Annual maximum vegetation greenness was characterized using phenological modeling and an ensemble of spectral vegetation indices (NDVI, EVI2, NIRv, and kNDVI) derived from surface reflectance measured by sensors on the Landsat satellites (5,7, and 9). Interannual trends were then assessed using non-parametric Mann-Kendall trend tests and Theil-Sen slope indicators after pre-whitening each time series. Each trend component of this dataset includes estimates of uncertainty that were generated using Monte Carlo simulations (n=1,000). The median estimate (50^{th} percentile) along with 95% confidence limits (2.5th and 97.5th percentiles) are included.

The data file boreal_greenness_trend_summary.csv includes tabular data on interannual trends in annual maximum vegetation greenness from 1985 to 2019 and 2000 to 2019 for each sample location. The raster data (*.tif) summarize interannual trends in annual maximum vegetation greenness during each time period for sample locations stratified by Ecological Land Unit (ELU) within the boreal biome (Table 1).

See Berner and Goetz (2022) for details of this analysis. The code repository https://github.com/logan-berner/boreal_biome_shift includes scripts developed for this analysis.

6. Data Access

These data are available through the Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

ABoVE: Landsat Vegetation Greenness Trends, Boreal Forest Biome, 1985-2019

Contact for Data Center Access Information:

- E-mail: uso@daac.ornl.gov
- Telephone: +1 (865) 241-3952

7. References

Baltzer, J.L., N.J. Day, X.J. Walker, D. Greene, M.C. Mack, H.D. Alexander, D. Arseneault, J. Barnes, Y. Bergeron, Y. Boucher, L. Bourgeau-Chavez, C.D. Brown, S. Carrière, B.K. Howard, S. Gauthier, M.-A. Parisien, K.A. Reid, B.M. Rogers, C. Roland, L. Sirois, S. Stehn, D.K. Thompson, M.R. Turetsky, S. Veraverbeke, E. Whitman, J. Yang, and J.F. Johnstone. 2021. Increasing fire and the decline of fire adapted black spruce in the boreal forest. Proceedings of the National Academy of Sciences 118:e2024872118. https://doi.org/10.1073/pnas.2024872118

Beck, P.S. A., G.P. Juday, C. Alix, V.A. Barber, S.E. Winslow, E.E. Sousa, P. Heiser, J.D. Herriges, and S.J. Goetz. 2011. Changes in forest productivity across Alaska consistent with biome shift. Ecology Letters 14:373–379. http://doi.org/10.1111/j.1461-0248.2011.01598.x

Berner, L.T. and S.J. Goetz. 2022. Satellite observations document trends consistent with a boreal forest biome shift. Global Change Biology, 28(10), 3275-3292. https://doi.org/10.1111/gcb.16121

Berner, L.T., R. Massey, and S.J. Goetz. 2021. ABoVE: Landsat Tundra Greenness and Summer Air Temperatures, Arctic Tundra, 1985-2016. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1893

Berner, L.T., R. Massey, P. Jantz, B.C. Forbes, M. Macias-Fauria, I. Myers-Smith, T. Kumpula, G. Gauthier, L. Andreu-Hayles, B.V. Gaglioti, P. Burns, P. Zetterberg, R. D'Arrigo, and S.J. Goetz. 2020. Summer warming explains widespread but not uniform greening in the Arctic tundra biome. Nature Communications 11:4621. https://doi.org/10.1038/s41467-020-18479-5

Bonan, G.B. 2008. Forests and climate change: forcings, feedbacks, and the climate Benefits of forests. Science 320:1444–1449. http://doi.org/10.1126/science.1155121

Boyd, M.A., L.T. Berner, A.C. Foster, S.J. Goetz, B.M. Rogers, X.J. Walker, and M.C. Mack. 2021. Historic declines in growth portend trembling aspen death during a contemporary leaf miner outbreak in Alaska. Ecosphere 12:e03569. https://doi.org/10.1002/ecs2.3569

Camps-Valls, G., M. Campos-Taberner, Á. Moreno-Martínez, S. Walther, G. Duveiller, A. Cescatti, M.D. Mahecha, J. Muñoz-Marí, F.J. García-Haro, L. Guanter, M. Jung, J.A. Gamon, M. Reichstein, and S.W. Running. 2021. A unified vegetation index for quantifying the terrestrial biosphere. Science Advances 7:eabc7447. https://doi.org/10.1126/sciadv.abc7447

ESA. 2017. Land Cover CCI Product User Guide Version 2. Technical Report. http://maps.elie.ucl.ac.be/CCI/viewer/download/ESACCI-LC-Ph2-PUGv2_2.0.pdf

Giglio, L., L. Boschetti, D.P. Roy, M.L. Humber, and C.O. Justice. 2018. The Collection 6 MODIS burned area mapping algorithm and product. Remote Sensing of Environment 217:72–85. https://doi.org/10.1016/j.rse.2018.08.005

Guindon, L., P. Villemaire, R. St-Amant, P.Y. Bernier, A. Beaudoin, F. Caron, M. Bonucelli, and H. Dorion. 2017. Canada Landsat Disturbance (CanLaD): a Canada-wide Landsat-based 30-m resolution product of fire and harvest detection and attribution since 1984. Natural Resources Canada. https://doi.org/10.23687/add1346b-f632-4eb9-a83d-a662b38655ad

Hansen, M.C., P.V. Potapov, R. Moore, M. Hancher, S.A. Turubanova, A. Tyukavina, D. Thau, S.V. Stehman, S.J. Goetz, T.R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C.O. Justice, and J.R. G. Townshend. 2013. High-Resolution Global Maps of 21st-Century Forest Cover Change. Science 342:850–853. https://doi.org/10.1126/science.1244693

Kasischke, E.S., D. Williams, and D. Barry. 2002. Analysis of the patterns of large fires in the boreal forest region of Alaska. International Journal of Wildland Fire 11:131-144. https://doi.org/10.1071/WF02023

Loboda, T.V., and D. Chen. 2016. Distribution of Young Forests and Estimated Stand Age across Russia, 2012. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1330

Olson, D.M. E. Dinerstein, E.D. Wikramanayake, N.D. Burgess, G.V.N. Powell, E.C. Underwood, J.A. D'amico, Il. Itoua, H.E. Strand, J.C. Morrison, C.J. Loucks, T.F. Allnutt, T.H. Ricketts, Y. Kura, J.F. Lamoreux, W.W. Wettengel, P. Hedao, and K.R. Kassem. 2001. Terrestrial Ecoregions of the World: A New Map of Life on Earth: A new global map of terrestrial ecoregions provides an innovative tool for conserving biodiversity. BioScience 51:933–938. https://doi.org/10.1641/0006-3568(2001)051[0933:TEOTWA]2.0.CO;2

Sayre, R., J. Dangermond, C. Frye, R. Vaughan, P. Aniello, S. Breyer, D. Cribbs, D. Hopkins, R. Nauman, W. Derrenbacher, D. Wright, C. Brown, C. Convis, J. Smith, L. Benson, D. Paco VanSistine, H. Warner, J. Cress, J. Danielson, S. Hamann, T. Cecere, A. Reddy, D. Burton, A. Grosse, D. True, M. Metzger, J. Hartmann, N. Moosdorf, H. Dürr, M. Paganini, P. DeFourny, O. Arino, S. Maynard, M. Anderson, and P. Comer. 2014. A New Map of Global Ecological Land Units — an ecophysiographic stratification approach. Washington, DC: Association of American Geographers. http://aag.org

Venter, O., E.W. Sanderson, A. Magrach, J.R. Allan, J. Beher, K.R. Jones, H.P. Possingham, W.F. Laurance, P. Wood, B.M. Fekete, M.A. Levy, and J.E. M. Watson. 2016. Global terrestrial Human Footprint maps for 1993 and 2009. Scientific Data 3:160067. https://doi.org/10.1038/sdata.2016.67