

Metadata

Dataset Title

Monthly lake water quality data (May-September 2022) following the Greenwood Fire in northeastern Minnesota v1.0

Abstract

This repository contains lake water quality responses to the 2021 Greenwood Fire in Superior National Forest, Minnesota, USA (near Isabella, MN in northeastern MN). Thirty lakes (15 burned watershed, 15 control) were sampled monthly from May-September 2022 along various fire disturbance gradients (e.g., % watershed burned) and in relation to hydrologic connectivity (i.e., drainage vs. isolated lakes). Much of the non-water quality data we used came from published sources, which are described and referenced below. This repository also contains R code used to analyze and visualize data, as well as some output figures.

Investigators

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Other personnel names and roles

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License

Keywords

lakes, water quality, wildfire, Minnesota, burn severity, hydrologic connectivity, watershed

Funding of this work:

Add rows to table if several grants were involved, list only the main PI, start with main grant first:

PI First Name	PI Middle Initial	PI Last Name	PI ORCID ID (optional)	Title of Grant	Funding Agency	Funding Identification Number
Ian	M	McCullough	0000-0002-6832-674X	Collaborative Research: RAPID: lake ecosystem responses to fire along gradients of burn characteristics and hydrologic connectivity	US National Science Foundation Division of Environmental Biology	2212082
Christopher	T	Filstrup	0000-0003-3812-2831	Collaborative Research: RAPID: lake ecosystem responses to fire along gradients of burn characteristics	US National Science Foundation Division of Environme	2212083

				and hydrologic connectivity	ntal Biology	
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Timeframe

- Begin date: 2022
- End date: 2022
- Data collection ongoing/completed: completed

Taxonomic species or groups

N/A

Methods

The methods used to analyze and/or generate the data tables below can be found in the R scripts in this repository and/or associated manuscripts (see Notes and Comments).

Data Table

Table name: Data/BurnSeverity/Ian_calculations/all_burn_severity_variables.csv

Table description: Burn severity (vegetation and soil) metrics calculated at watershed and shoreline (100 m lake buffer) scales. This table is a combination of other tables in the same folder (burned_buff100m_sbs_pct, burned_buff100m_vbs_pct, burned_ws_sbs_pct, burned_buff100m_vbs_pct).

Column name	Description	Unit or code explanation or date format	Empty value code
lagoslakeid	Unique lake ID in LAGOS database	NA	
ws_vbs_Unburned_pct	Percentage of watershed that is unburned	NA	
ws_vbs_Low_pct	Percentage of watershed burned at low severity based on vegetation	NA	
ws_vbs_ModerateLow_pct	Percentage of watershed burned at moderate-low severity based on vegetation	NA	
ws_vbs_ModerateHigh_pct	Percentage of watershed burned at moderate-high severity based on vegetation	NA	
ws_vbs_High_pct	Percentage of watershed burned at high severity based on vegetation	NA	
ws_vbs_total_burn_pct	Percentage of watershed burned	NA	
net_id	Network unique identifier	NA	

Note: additional columns are similar to above. 'vbs' and 'sbs' indicate burn severity based on vegetation and soil, respectively and ws and buff100m indicate watershed and shoreline scales.

Table name: Data/LAGOS/LAGOS_LOCUS_GEO_DEPTH_combined.csv

Table description: Ancillary lake and watershed data from LAGOS-US (lagoslakes.org). The LOCUS_GEO_DEPTH table includes columns also in the standalone GEO and LOCUS tables. Note that 'zone' refers to lake watershed in descriptions.

Column name	Description	Unit or code explanation or date format	Empty value code
lagoslakeid	Unique lake ID in LAGOS database	NA	
Site	Lake name	NA	
climate8110norm_ppt_m mperyr	Average annual precipitation from 1981- 2010	Mm	
lakes1ha_all_ha	total water area of lakes greater than or equal to 1 ha within the zone; because lake polygons are clipped to the zone boundary, the summed lake area does not include lake area located outside of the zone	Hectares	
lakes1ha_all_n	count of all lakes greater than or equal to 1 ha within the zone		
lakes1ha_all_nperha	density of lakes greater than or equal to 1 ha within the zone expressed as number per hectare		
lakes1ha_all_pct	percent of the zone area comprised of lakes greater than or equal to 1 ha; because lake polygons are clipped to the zone boundary, the summed lake area does not include lake area located outside of the zone		
streams_all_mperha	density of all streams within the zone, calculated as the sum of the stream length divided by the zone area; the artificial lines through non-riverine waterbodies are not counted in the stream length		
roads_mperha	road density within the zone, calculated as sum of the length of roads in the zone divided by the area of the zone		
area_ha	watershed area	Hectares	
perimeter_m	perimeter of watershed polygon including the perimeter of any internal holes	m	
soil_clay_pct	average percentage mass fraction of clay, 0 to 2 micrometers, in the 0 to 5 cm depth soil layer within the zone		

soil_coarse_pct	average percentage by volume of coarse fragments in the 0 to 5 cm soil depth layer within the zone		
soil_depthtobedrock_cm	average absolute depth to bedrock within the zone	cm	
soil_kffact	average soil erodibility factor, not adjusted for the effect of rock fragments, within the zone	NA	
soil_orgcarbon_gperkg	average organic carbon content, fine earth fraction, in the 0 to 5 cm soil layer within the zone	g/kg	
soil_sand_pct	average percentage mass fraction of sand, 50 to 200 micrometers, in the 0 to 5 cm depth soil layer within the zone		
soil_silt_pct	average percentage mass fraction of silt, 2 to 50 micrometers, in the 0 to 5 cm depth soil layer within the zone		
elevation_max_m	maximum elevation in the zone referenced to the North American Vertical Datum of 1988, NAVD88	m	
elevation_mean_m	mean elevation in the zone referenced to the North American Vertical Datum of 1988, NAVD88	m	
elevation_min_m	minimum elevation in the zone referenced to the North American Vertical Datum of 1988, NAVD88	m	
elevation_sd_m	Standard deviation of elevation in the zone referenced to the North American Vertical Datum of 1988, NAVD88	m	
reliefratio	an index of topographic relief within a watershed calculated as the difference between mean and minimum elevation divided by the difference between maximum and minimum elevation	NA	
topographicwetness	mean topographic wetness index of cells within the zone	NA	
tri_m	mean terrain ruggedness index, TRI, of cells within the zone using the Riley algorithm (1999), where TRI at each cell is the absolute difference in meters between the elevation of the focal cell and its immediate neighbors; the cell size is 10 m square.	NA	
nlcd_fordec41_pct	percent of zone classified as deciduous forest		
nlcd_forcon42_pct	percent of zone classified as evergreen forest		
nlcd_formix43_pct	percent of zone classified as mixed forest		
nlcd_wetwood90_pct	percent of zone classified as woody wetlands		

nlcd_wetemerg95_pct	percent of zone classified as emergent herbaceous wetlands		
lake_waterarea_ha	surface area of lake waterbody polygon from NHD comprised of open water; islands are excluded	Hectares	
lake_totalarea_ha	total area of the lake waterbody polygon from the NHD; includes combined area of open water and any islands within the outer boundary	Hectares	
lake_islandarea_ha	surface area of any islands contained within the outer boundary of the lake waterbody polygon from NHD	Hectares	
lake_perimeter_m	perimeter of outer boundary of lake waterbody polygon from the NHD; excludes perimeter of any islands	m	
lake_islandperimeter_m	perimeter of islands contained within the outer boundary of the lake waterbody polygon from the NHD	m	
lake_shorelinedevfactor	shoreline development factor; calculated as lake_perimeter_m divided by the product of 2 times the square root of pi times lake_waterarea_ha	NA	
lake_connectivity_class	maximum hydrologic connectivity class of the focal lake determined from the NHD network considering both permanent and intermittent-ephemeral flow	NA	
lake_connectivity_fluctuates	indicates whether the lake connectivity classification depends on non-permanent flow	Y=yes, N=no	
lake_connectivity_permanent	hydrologic connectivity class of the focal lake determined from the NHD network considering only permanent flow	NA	
lake_lakes1ha_upstream_ha	total area of lakes greater than or equal to 1 ha upstream of the focal lake, connected via surface streams	Hectares	
lake_lakes4ha_upstream_ha	total area of lakes greater than or equal to 4 ha upstream of the focal lake, connected via surface streams	Hectares	
lake_lakes10ha_upstream_ha	total area of lakes greater than or equal to 10 ha upstream of the focal lake, connected via surface streams	Hectares	
lake_lakes1ha_upstream_n	count of lakes greater than or equal to 1 ha upstream of the focal lake, connected via surface streams		
lake_lakes4ha_upstream_n	count of lakes greater than or equal to 4 ha upstream of the focal lake, connected via surface streams		

lake_lakes10ha_upstream_n	count of lakes greater than or equal to 10 ha upstream of the focal lake, connected via surface streams		
lake_elevation_m	the elevation of the lake polygon central point, in meters; referenced to the North American Vertical Datum of 1988 or NAVD88 and obtained from the National Elevation Dataset	m	
ws_subtype	watershed subtype class for the watershed; LC equals local catchment, DWS equals drainage-watershed, IDWS equals inter-drainage-lake watershed	NA	
ws_focallakewaterarea_ha	surface area of focal lake for which the WS is calculated	Hectares	
ws_area_ha	area of watershed polygon	Hectares	
ws_perimeter_m	perimeter of watershed polygon including perimeter of any internal holes	m	
ws_lake_arearatio	ratio between watershed area and lake water area	NA	
lake_meanwidth_m	Average width of lake	m	
lake_maxdepth_m	The maximum depth in meters of a lake based on existing sources, not based on field measurements	m	
type	Burned watershed or control group lake	NA	
source	Drainage (inflowing streams) or isolated lake (no inflow our outflows)	NA	

Table name: Data/VariancePartitioning/burned_v_control.csv

Table description: Each of the tables in this folder represents output from a variance partitioning analysis. The difference is the fire variable used. ConnClass=permanent hydrologic connectivity class, mean depth=average of maximum depths measured at each lake in the field, Random:lake=random lake effect, Month=random month effect. See LAGOS table above for descriptions of predictor variables.

burned_v_control.csv: based on simple burned vs. control groups

pct_buffer_burned.csv: based on percent shoreline (100m lake buffer) burned

pct_buffer_burned_HSsoil.csv: based on percent shoreline (100m lake buffer) burned at high severity based on soil

pct_buffer_burned_HSveg.csv: based on percent shoreline (100m lake buffer) burned at high severity based on vegetation

pct_ws_burned: based on percent watershed burned

pct_ws_burned_HSsoil.csv: based on percent watershed burned at high severity based on soil

pct_ws_burned_HSveg.csv: based on percent watershed burned at high severity based on vegetation

Column name	Description	Unit or code explanation or date format	Empty value code
predictor	Lake or watershed predictor variable	Variable; see LAGOS table above	
variable	Water quality response variable	Variable; see water quality tables below	
variance	Variance explained	NA	

Table name: Data/WaterQuality/burned_control_change_summary.csv and
burned_control_change_summary_conn.csv.

Table description: Monthly summaries of lake water quality in burned vs. control lakes from 2022. The table with 'conn' in the title contains columns for burned vs. control drainage and isolated lakes, whereas the other is all burned vs. control lakes. Measurements are lake surface samples.

Column name	Description	Unit or code explanation or date format	Empty value code
Month	Sampling month	NA	
TP_burned	Total phosphorus in burned lakes (first number is concentration, second is number of lakes sampled)	ppb	
TP_control	Total phosphorus in control lakes (first number is concentration, second is number of lakes sampled)	ppb	
TP_diff	Total phosphorus difference in burned vs. control lakes (first number is concentration, second is percentage)	ppb	
TN_burned	Total nitrogen in burned lakes (first number is concentration, second is number of lakes sampled)	ppb	
TN_control	Total nitrogen in control lakes (first number is concentration, second is number of lakes sampled)	ppb	

TN_diff	Total nitrogen difference in burned vs. control lakes (first number is concentration, second is percentage)	ppb	
DOC_burned	Dissolved organic carbon in burned lakes (first number is concentration, second is number of lakes sampled)	ppm	
DOC_control	Dissolved organic carbon in control lakes (first number is concentration, second is number of lakes sampled)	ppm	
DOC_diff	Dissolved organic difference in burned vs. control lakes (first number is concentration, second is percentage)	ppm	
TSS_burned	Total suspended solids in burned lakes (first number is concentration, second is number of lakes sampled)	mg/L	
TSS_control	Total suspended solids in control lakes (first number is concentration, second is number of lakes sampled)	mg/L	
TSS_diff	Total suspended solids difference in burned vs. control lakes (first number is concentration, second is percentage)	mg/L	
Chloro_burned	Chlorophyll-a in burned lakes (first number is concentration, second is number of lakes sampled)	ppb	
Chloro_control	Chlorophyll-a in control lakes (first number is concentration, second is number of lakes sampled)	ppb	
Chloro_diff	Chlorophyll-a difference in burned vs. control lakes (first number is concentration, second is percentage)	ppb	
Secchi_burned	Secchi depth in burned lakes (first number is value, second is number of lakes sampled)	m	
Secchi_control	Secchi depth in control lakes (first number is value, second is number of lakes sampled)	m	
Secchi_diff	Secchi depth difference in burned vs. control lakes (first number is value, second is percentage)	m	
pH_burned	pH in burned lakes (first number is value, second is number of lakes sampled)		
pH_control	pH in control lakes (first number is value, second is number of lakes sampled)		
pH_diff	pH difference in burned vs. control lakes (first number is value, second is percentage)		
ANC_mgCaCO3L_burned	Acid neutralizing capacity in burned lakes (first number is concentration, second is number of lakes sampled)	mg/L as CaCO3	

ANC_mgCaCO3L_control	Acid neutralizing capacity in control lakes (first number is concentration, second is number of lakes sampled)	mg/L as CaCO3	
ANC_mgCaCO3L_diff	Acid neutralizing capacity difference in burned vs. control lakes (first number is concentration, second is percentage)	mg/L as CaCO3	
SpecCond_uScm_burned	Specific conductivity in burned lakes (first number is conductivity, second is number of lakes sampled)	uS/cm	
SpecCond_uScm_control	Specific conductivity in control lakes (first number is conductivity, second is number of lakes sampled)	uS/cm	
SpecCond_uScm_diff	Specific conductivity difference in burned vs. control lakes (first number is conductivity, second is percentage)	uS/cm	
NH4N_burned	NH4 in burned lakes (first number is concentration, second is number of lakes sampled)	ppb	
NH4N_control	NH4 in control lakes (first number is concentration, second is number of lakes sampled)	ppb	
NH4N_diff	NH4 difference in burned vs. control lakes (first number is concentration, second is percentage)	ppb	
WaterTemp_C_burned	Water temperature in burned lakes (first number is value, second is number of lakes sampled)	degC	
WaterTemp_C_control	Water temperature in control lakes (first number is value, second is number of lakes sampled)	degC	
WaterTemp_C_diff	Water temperature difference in burned vs. control lakes (first number is value, second is percentage)	degC	

Table name: Data/WaterQuality/combined_lab_field_may_sep.csv

Table description: Combined lab and field lake water quality results from May to September 2022.

Column name	Description	Unit or code explanation or date format	Empty value code
Site	Lake name	NA	
Month	Sample month	Numeric	
Date	Sample date	Month/day/year	
Chloro_ppb	Chlorophyll-a	ppb	

TP_ppb	Total phosphorus	ppb	
TN_ppb	Total nitrogen	ppb	
NH4N_ppb	NH4N	ppb	
NO2NO3_ppb	NO2NO3	ppb	
ANC_mgCaCO3L	Acid neutralizing capacity	mg/L as CaCO3	
TSS_mgL	Total suspended solids	mg/L	
DOC_ppm	Dissolved organic carbon	ppm	
lagoslakeid	Unique lake ID in LAGOS database	NA	
Type	Burned or control lake	NA	
lake_connectivity_class	maximum hydrologic connectivity class of the focal lake determined from the NHD network considering both permanent and intermittent-ephemeral flow	NA	
ConnClass	hydrologic connectivity class of the focal lake determined from the NHD network considering only permanent flow	NA	
Group	Control drainage, control isolated, burned drainage or burned isolated lake groups	NA	
Month_factor	Month as a factor (e.g., May, Jun)	NA	
SecchiDepth_m	Secchi depth	m	
zMax_m	Maximum lake depth	m	
ProfileDepth_m	Sample depth	m	
WaterTemp_C	Water temperature	degC	
SpecCond_uScm	Specific conductivity	uS/cm	
LDO_mgL	Dissolved oxygen	mg/L	
LDO_pct	Dissolved oxygen	Percentage	
pH	pH		
Lake	Lake name without the word "lake" for easier plotting	NA	

Table name: Data/WaterQuality/minmedianmaxWQ_summary.csv

Table description: Summary statistics for water quality in burned and control lakes in 2022. See previous table for descriptions and units of water quality variables.

Column name	Description	Unit or code explanation or date format	Empty value code
Variable	TP, TN, DOC, TSS, Secchi, Chlorophyll-a, pH, Water temperature, Acid neutralizing capacity	NA	
MayBurned	First number is minimum, second number is median, third number is maximum measured in May among burned lakes.	Variable	

MayControl	First number is minimum, second number is median, third number is maximum measured in May among control lakes.	Variable	
JunBurned	First number is minimum, second number is median, third number is maximum measured in June among burned lakes.	Variable	
JunControl	First number is minimum, second number is median, third number is maximum measured in June among control lakes.	Variable	
JulBurned	First number is minimum, second number is median, third number is maximum measured in July among burned lakes.	Variable	
JulControl	First number is minimum, second number is median, third number is maximum measured in July among control lakes.	Variable	
AugBurned	First number is minimum, second number is median, third number is maximum measured in August among burned lakes.	Variable	
AugControl	First number is minimum, second number is median, third number is maximum measured in August among control lakes.	Variable	
SepBurned	First number is minimum, second number is median, third number is maximum measured in September among burned lakes.	Variable	
SepControl	First number is minimum, second number is median, third number is maximum measured in September among control lakes.	Variable	
AllMonthsBurned	First number is minimum, second number is median, third number is maximum measured among all months combined among burned lakes.	Variable	
AllMonthsControl	First number is minimum, second number is median, third number is maximum measured among all months combined among control lakes.	Variable	

Table name: Data/weatherstation/ambient-weather-20220524-20220926.csv

Table description: Weather station data measured from May through September 2022 (47.709624, -91.663992).

Column name	Description	Unit or code explanation or date format	Empty value code
Date	Date and time	Year/month/day	

		, military time + seconds	
Simple Date	Simplified date and time	Month/day/year , military time	
Outdoor Temperature (°F)	Air temperature	degF	
Feels Like (°F)	Feels like air temperature	degF	
Dew Point (°F)	Dew point	degF	
Wind Speed (mph)	Wind speed	miles/hour	
Wind Gust (mph)	Wind gust	miles/hour	
Wind Direction (°)	Wind direction	Degrees	
Hourly Rain (in/hr)	Rain	inches/hour	
Daily Rain (in)	Rain	inches/day	
24 Hour Rain (in)	Rain	inches in last 24 hours	
Relative Pressure (inHg)	Relative pressure	inHg	
Outdoor Humidity (%)	Humidity	Percentage	
Absolute Pressure (inHg)	Absolute pressure	inHg	

Table name: Data/lake_locations.csv

Table description: Table with lake latitude and longitude coordinates

Column name	Description	Unit or code explanation or date format	Empty value code
lagoslakeid	Unique lake ID in LAGOS database	NA	
lake_lat_decdeg	Latitude	Decimal degrees	
lake_lon_decdeg	Longitude	Decimal degrees	
Site	Lake name	NA	

Scripts/code (software) (in the Rcode folder)

File name	Description	Scripting language
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This repository will be published on Zenodo as “Monthly lake water quality data (May-September 2022) following the Greenwood Fire in northeastern Minnesota v1.0”	https://github.com/contlimno/SplashNBurn	R
BurnSeverity_byLake.R	Burn severity plots by lake (figure 1 and supplemental figures)	R
Check_WQdata_inLAGOS.R	Check for availability of pre-fire lake water quality data in LAGOS database	R
ComparingBurnedControlLakeCharacteristics.R	Comparison of lake and watershed characteristics in burned vs. control lakes	R
ExploringWaterQuality_IMM.R	Initial exploratory water quality data analysis	R
GetLatLonCoordinates.R	Obtain latitude and longitude for study lakes	R
HMSC_water_chem_model.R	Variance partitioning analysis	R
LakeProfiles-JAB	Analysis of lake profile data	R
MultipanelVariancePartitioningPlot.R	Creation of summary plot for variance partitioning analysis (figure 5)	R
NOAA_climatedata.R	Analysis of historical climate data (supplemental figures)	R
WaterQuality_Boxplots.R	Creation of summary plot for monthly water quality data (figure 3)	R
WaterQuality_BurnGradients.R	Creation of summary plot for water quality along burn gradients (figure 4)	R
WaterQuality_DensityHistograms.R	Creation of summary plot for water quality in burned vs. control lakes (figure 2)	R
WaterQuality_PercentChange.R	Calculate percent change in burned vs. control lakes	R
WaterQuality_SummaryTables.R	Generate summary tables for lake water quality	R
WeatherStation.R	Analysis of weather station data for the 2022 sampling season	R

Data provenance

Dataset title	Dataset DOI or URL	Creator (name & email)	Contact (name & email)
LAGOS-US-LOCUS v1.0	https://doi.org/10.6073/pasta/e5c2fb8d77467d3f03de4667ac2173ca	Nicole Smith (smithn78@msu.edu)	Nicole Smith (smithn78@msu.edu)
LAGOS-US-GEO v1.0	https://doi.org/10.6073/pasta/53ae2afd051a6a082a2ab129e4281e13	Nicole Smith (smithn78@msu.edu)	Nicole Smith (smithn78@msu.edu)
LAGOS-US-DEPTH v1.0	https://doi.org/10.6073/pasta/64ddc4d04661d9aef4bd702dc5d8984f	Jemma Stachelek (stachel2@msu.edu)	Jemma Stachelek (stachel2@msu.edu)

Notes and Comments

This is the manuscript associated with this repository:

McCullough, I. M., Brentrup, J. A., Wagner, T., Lapierre J., Henneck, J, Paul, A. M., Belair, M., Moritz, M. A. and C. T. Filstrup. (Accepted). Fire characteristics and hydrologic connectivity influence short-term responses of north temperate lakes to wildfire. *Geophysical Research Letters*.

Other data in this repository:

Data/GreenwoodFirePolygon/GreenwoodFirePolygon.shp

A shapefile of the Greenwood Fire burn area in NAD 1983/CONUS Albers (EPSG: 5070)

Data/GTAC

Satellite images from before and after the fire, dNBR rasters (for burn severity), soil burn severity raster (sbs)

4-22-22: downloaded from: <https://burnseverity.cr.usgs.gov/baer/baer-imagery-support-data-download>

<https://www.fs.usda.gov/about-agency/gtac>

<https://www.fs.usda.gov/inside-fs/out-and-about/greenwood-fire-post-wildfire-assessments-provide-key-information-and>

5-11-22: downloaded soil burn severity (sbs) data from:

<https://burnseverity.cr.usgs.gov/baer/baer-imagery-support-data-download>

As of this date, no updates to other data downloaded on 4-22

Data/Minnesota_outline/Minnesota.shp

A shapefile of Minnesota in NAD 1983 USGS Continuous USA Albers (EPSG: 102039)

Data/NOAA_climate

Historical climate data for northeastern Minnesota. Downloaded NOAA climate data for Lake County, MN on 8-25-22. Changed based period to 1991-2020. They have city data for Duluth or International Falls going back to 1940s. Palmer Drought Index not available for cities or counties

NOAA National Centers for Environmental information, Climate at a Glance: County Time Series, published August 2022, retrieved on August 25, 2022 from <https://www.ncei.noaa.gov/cag/>

The 3386547_Duluth_precip_1948_2023.csv file is for the Duluth airport, whereas the other files are for Lake County. Please see the original source for column explanations.

National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information. (2023). Daily Summaries Station Details: Duluth International Airport, MN, US. <https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USW00014913/detail>. 472 Accessed 7-10-23.