Statistical Analysis of the GLOBOCARB Dataset (1900–2000)

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Abstract. We tested whether organic carbon accumulation rates (OCAR) in the GLOBOCARB dataset (143 biome-decade means from 516 ^{210}Pb-dated cores) increased over the 20th century (H1) and more steeply in tropical than boreal regions (H2). Lake C burial rose 2.5-fold (49.0–121.1 Tg C yr^{-1}); post-1950 OCAR was 68.7% higher than pre-1950 ($p = 0.004$), supporting H1. A mixed-effects interaction model confirmed steeper tropical slopes (8.6× boreal), supporting H2. Including reservoirs, total burial reached 139.2 ± 18 Tg C yr^{-1} by 2000, sequestering ~9.3 Pg C across the 20th century.

1 Introduction

Inland waters cover <4% of non-glaciated land but bury ~0.2 Pg C yr^{-1} in lake sediments- three times the per-area rate of ocean sediments (Cole et al., 2007; Tranvik et al., 2009). During the 20th century, reactive nitrogen deposition increased tenfold (Galloway et al., 2008) and phosphorus fertilizer use surged post-WWII. Anderson et al. (2020) synthesized 516 lake records and attributed burial increases primarily to nutrient enrichment rather than temperature. We test: **H1**: OCAR increased over the 20th century, with post-1950 rates exceeding pre-1950 rates. **H2**: The increase was steeper in tropical than boreal biomes, consistent with nutrient enrichment as the primary driver.

1.1 Data Provenance

The GLOBOCARB dataset was produced by a consortium led by N.J. Anderson (Loughborough University) with A.J. Heathcote and D.R. Engstrom (Science Museum of Minnesota), published in *Science Advances* (Anderson et al., 2020). The supplementary data is hosted on Mendeley Data (DOI: 10.17632/34hsd2jygc.1) under CC BY-NC 4.0. Lake areas derive from the Global Lakes and Wetlands Database (GLWD; Lehner & Döll, 2004); reservoir areas from GRanD (Lehner et al., 2011).

1.2 Connections to Other Datasets

GLOBOCARB complements the Global Carbon Budget (Friedlingstein et al., 2023), which tracks terrestrial/oceanic sinks but excludes inland-water burial. HydroLAKES (Messager et al., 2016) could disaggregate biome-level means to individual lakes. Nitrogen deposition datasets (e.g., Ackerman et al., 2019) would enable direct testing of the nutrient-enrichment mechanism.

2 Material and Methods

The dataset contains decadal OCAR means (g C m^{-2} yr^{-1}) for 13 biomes spanning 1900–2000 (143 observations). Two biomes- Large Lakes (OCAR = 10.43, SD = 0) and Flooded Grasslands (OCAR = 31.00, SD = 0) -have zero temporal variance, indicating placeholder data; these were included in total burial but excluded from trends (reliable $n = 121$). Analyses used R v4.5.2. Total C burial = OCAR × Lake Area × 10^6 / 10^{12}; reservoir burial computed analogously. Temporal trends were assessed via linear regression, Welch's t-test (pre-/post-1950), and mixed-effects models with random intercepts and slopes per biome (lme4). ANOVA assumptions failed (Shapiro-Wilk and Levene's $p < 0.001$); we report Welch's ANOVA with Games-Howell post-hoc tests. The tropical–boreal slope difference was tested via fixed-effects and mixed-effects interaction models. Sensitivity of total burial to suspect-biome exclusion was assessed.

3 Results

3.1 Biome Differences and Temporal Patterns

OCAR is right-skewed (mean = 28.84, median = 17.85 g C m^{-2} yr^{-1}; range 1.86–145.67). Mangroves show the highest mean (92.9 ± 33.2), Tundra the lowest (3.6 ± 1.2). Welch's ANOVA confirms biome differences ($F = 42.6$, df = 10/42.5, $p < 2.2\times10^{-16}$, $\eta^2 = 0.78$); Games-Howell tests show Mangroves differ from all other biomes ($p < 10^{-13}$). Fig. 1 indicates temporal shifts from blue (1900) to red (2000), with suspect biomes flagged.

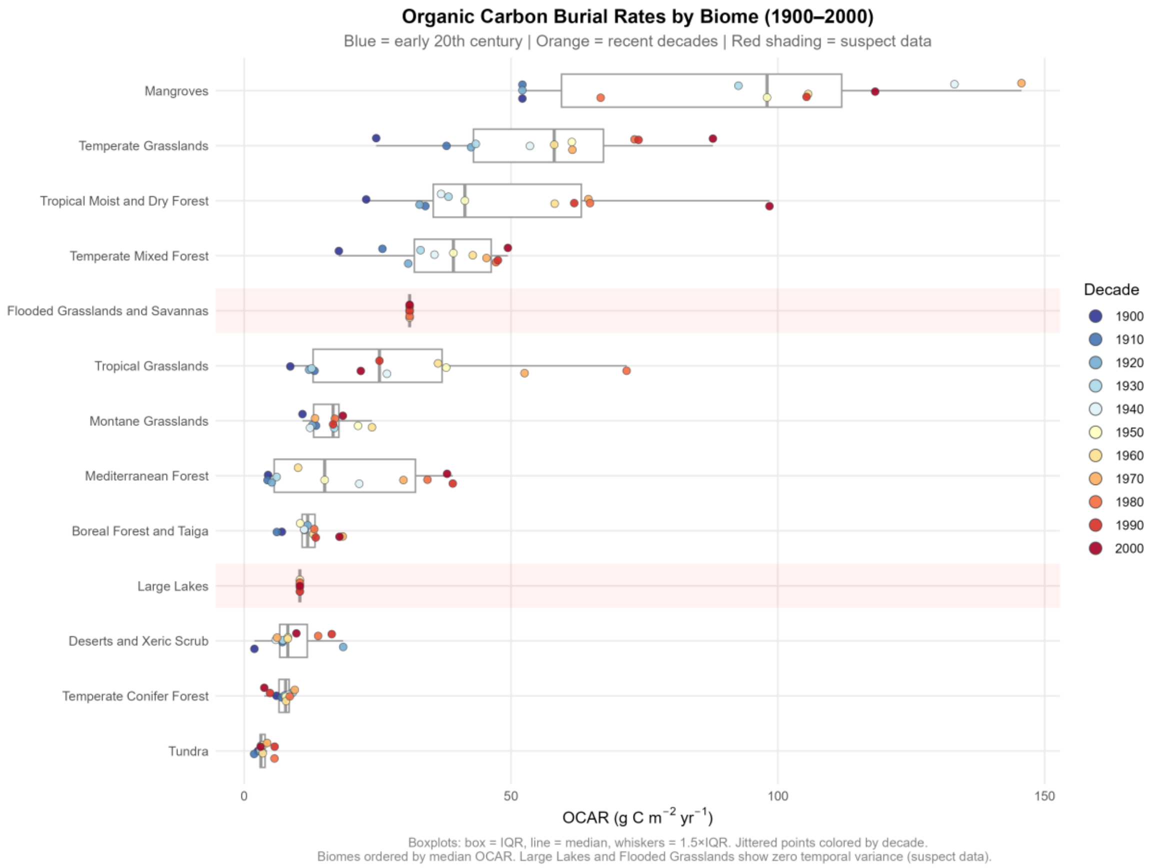

Fig. 1. OCAR by biome (1900–2000. Data: Anderson et al. (2020).

3.2 Temporal Trends and the Anthropocene Signal

Global OCAR increased (slope = 0.273 g C m^{-2} yr^{-1} per decade, $R^2 = 0.084$, $p = 0.001$). The low R^2 reflects inter-biome variation; a random-intercept/random-slope mixed-effects model (OCAR ~ Decade + (Decade | Biome)) confirms a significant global upward trend after absorbing biome-level heterogeneity. The steepest increases occurred in Tropical Moist/Dry Forest (0.599/decade, $R^2 = 0.85$) and Temperate Grasslands (0.538, $R^2 = 0.95$). Post-1950 mean OCAR was 68.7% higher than pre-1950 (37.21 vs. 22.06; Welch's $t = 2.94$, $p = 0.004$, Cohen's $d = 0.55$), supporting H1. After Bonferroni correction ($m = 11$), only Temperate Grasslands ($p_{corr} = 0.019$) and Temperate Mixed Forest ($p_{corr} = 0.038$) remain individually significant.

3.3 Tropical vs. Boreal Trajectories

Tropical biomes show a linear slope of 0.518 g C m^{-2} yr^{-1} per decade vs. 0.060 for boreal (8.6× difference). A fixed-effects interaction model yields $p = 0.048$; a mixed-effects model with biome as random intercept confirms the divergence ($t > 2$ for interaction term), supporting H2 (Fig. 2). This divergence indicates higher tropical sensitivity to nutrient-enhanced primary production and intensified allochthonous C delivery via accelerated hydrological cycles (Amora-Nogueira et al., 2022).

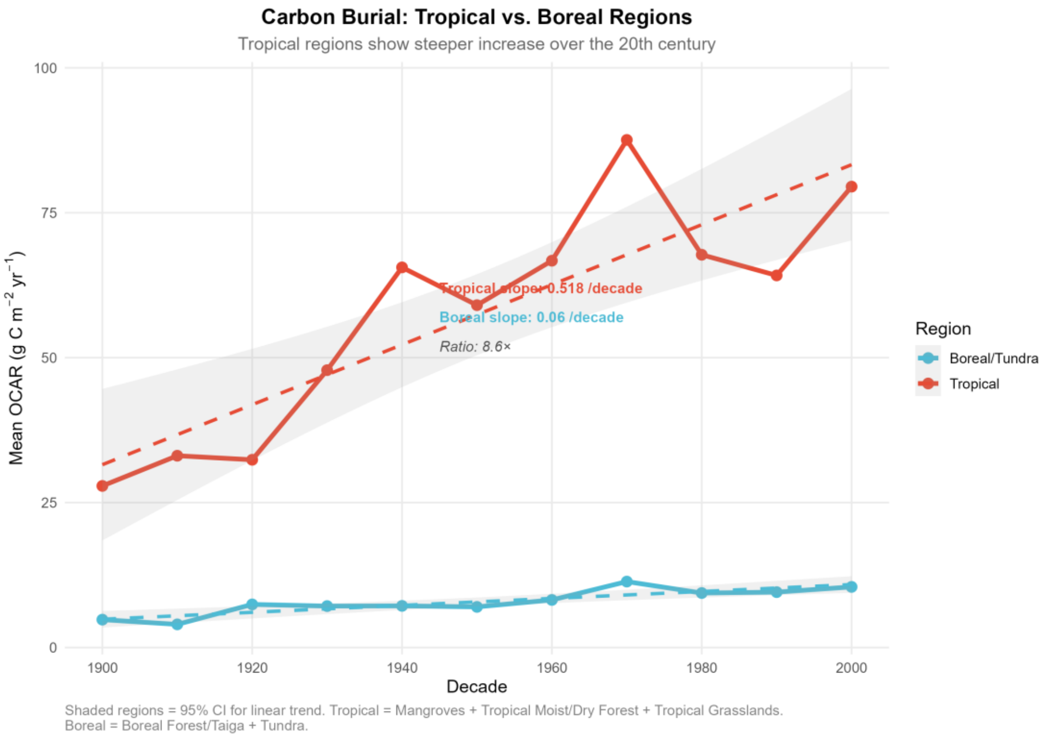

Fig. 2. Tropical vs. boreal OCAR trajectories (1900–2000). Data: Anderson et al. (2020).

3.4 Total Carbon Burial and Reservoir Contribution

Lake C burial rose from 49.0 to 121.1 Tg C yr^{-1} (2.5-fold; Fig. 3). In 2000, Boreal Forest/Taiga contributed 24.2% despite low OCAR (lake area: 1.64 × 10^{6} km^{2}); Tropical Moist/Dry Forest 21.9%; Mangroves only 3.1% - total burial is governed by spatial extent. Reservoir burial grew from 0.4 to 18.1 Tg C yr^{-1} (13.0% of combined total: 139.2 Tg C yr^{-1} in 2000). Applying lake OCAR to reservoirs is likely conservative, as reservoirs exhibit higher watershed-to-lake area ratios and act as more efficient sediment traps (Vörösmarty et al., 2003). The Spearman correlation between reservoir area and OCAR ($\rho = 0.167$, $p = 0.067$) vanishes after detrending ($\rho = -0.04$, $p > 0.6$), indicating shared temporal trends drove the raw association. Sensitivity analysis confirms the two suspect biomes contribute a constant ~14% of total burial. Twhile emporal trends are unaffected by their exclusion.

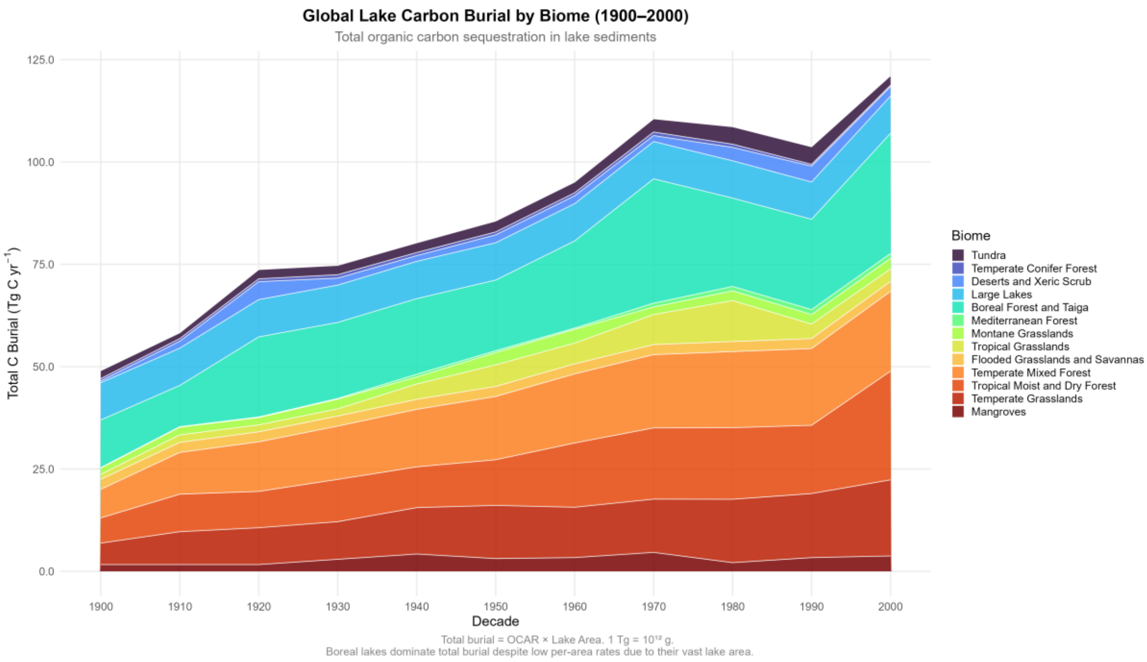

Fig. 3. Global lake carbon burial by biome (1900–2000). Data: Anderson et al. (2020).

4 Discussion

The 2.5-fold burial increase is consistent with independent estimates: Mendonça et al. (2017) estimated global inland-water C burial at 0.15 Pg C yr^{-1} via mass-balance, and Kastowski et al. (2011) reported 0.05–0.07 Pg C yr^{-1} for lakes- our 2000 estimate of 0.12 Pg C yr^{-1} falls within this range. Heathcote et al. (2015) found 3–5× higher contemporary burial in northern lakes versus Holocene baselines, implicating nitrogen deposition. The tropical–boreal divergence is consistent with Amora-Nogueira et al. (2022), who showed tropical lakes bury carbon at ~3× boreal rates due to greater allochthonous inputs.

Two caveats deserve emphasis. First, each observation is a biome-decade mean; the 121 “independent” observations contain within-biome temporal autocorrelation that pooled regressions ignore. The mixed-effects model partially addresses this but standard errors remain underestimated without lake-level data. Second, the tropical time series (Fig. 2) suggests a possible leveling in the 1980s–1990s; GAMs or changepoint analysis could identify acceleration phases. The additional ~72 Tg C yr^{-1} offsets 20–30% of freshwater CO_2 emissions (Anderson et al., 2020) and, equivalent to ~5% of the ocean sink (~2.8 Pg C yr^{-1}; Friedlingstein et al., 2023), represents storage on 10^2–10^4 year timescales.

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Supplementary Material. All source code, statistical output, and additional figures are available on GitHub (github.com/michi-sxc/biogeochem).

Declaration of Authorship

I hereby confirm that I have written this report independently and have not used any sources and aids other than those specified. The manuscript’s language and style were partly refined using DeepL Write (DeepL SE, 2026). This AI-assisted writing tool was employed for grammar correction and language enhancement while maintaining the original scientific content and meaning.

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