Research Brief

Environmental Determinants of Student Achievement in North Carolina

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January 2026

The Issue

The relationship between environmental factors and student achievement has been a topic of increasing interest in education research. Understanding how various environmental exposures impact student achievement outcomes is crucial for developing effective education policies and interventions (Koçak et al., 2020; Li & Li, 2022; Omolo et al., 2020).

This study integrates student achievement data from the North Carolina Department of Education with 229 environmental variables from 10 sources to examine how environmental exposures at school locations affect academic performance. Using a Bayesian modeling framework, the analysis adjusts for student- and school-level characteristics while accounting for spatial and temporal dependencies (Besag & Green, 1993; Blangiardo et al., 2013; Rue et al., 2009).

The study focuses on standardized test scores (e.g., 3rd- and 8th-grade reading and math, Algebra I, English II), graduation indicators, and advanced coursework participation. Environmental data—including air quality (from the EPA and PurpleAir), vegetation indices (from NASA MODIS), food access (from the U.S. Department of Agriculture), and community resilience (from the U.S. Census Bureau)—were merged at the school level.

A secondary assessment was used to reduce the number of environmental variables and identify those most strongly associated with spatial variation in student outcomes (Carroll & Zhao, 2018). Of the 229 variables considered, 129 were selected across all outcomes, with 35 ultimately retained in the final models.

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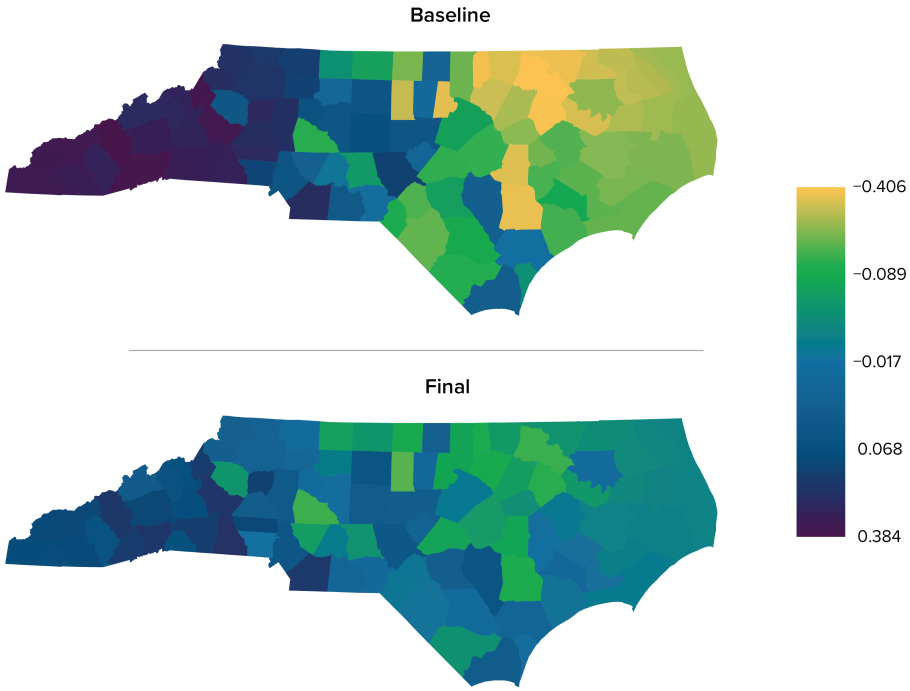
The Findings

Common predictors included food access, area deprivation, and sociodemographic composition. For example, schools in areas with poor food access and worse community resilience had lower 3rd-grade math scores. Conversely, higher mean family income (as measured by the Area Deprivation Index) was associated with increased student absences, suggesting complex interactions between wealth and engagement. The findings suggest that interventions aimed at improving academic outcomes should consider place-based strategies, such as enhancing food environments, addressing economic deprivation, and mitigating racial segregation.

Spatial plots of county-level random effects showed that environmental variables reduced unexplained geographic variation in student outcomes. Of the 13 models, 10 showed a reduction in spatial heterogeneity (Moran's I), and a similar number showed improved model fit. Figure 1 displays a comparison of the spatial random effect estimates from the baseline and final models for the 3rd-grade math outcome. These findings suggest that environmental variables help explain residual spatial variation not captured by school-level characteristics. Temporal effects remained stable, indicating that environmental variables primarily explain spatial—not temporal—variation (Schrödle & Held, 2010; Sørbye, 2013).

Figure 1: Comparison of baseline and final model spatial random effect estimates for 3rd-grade math scores.



Note. Estimates for county retention rates are available in a tabular format in **Figure 1 Supplement**.

The Implications

Environmental disadvantage—particularly related to food access, economic hardship, and community resilience—has a measurable impact on student achievement in North Carolina. Addressing these factors through interdisciplinary, data-driven strategies is essential for promoting educational equity and improving outcomes for all students.

Future research should explore causal mechanisms using longitudinal data and consider additional variables such as teacher quality and curriculum. More granular data at the household or neighborhood level could further clarify how environmental risks are experienced across student populations.

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