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Historical cause and effect: Are changes in lake chemistry drivers of or driven by changes in land-use?

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Land-use decisions both respond to and influence patterns in abiotic and biotic variables. This interaction can make it difficult to determine whether a current association between land use and environmental conditions is due to the environment changing in response to development (e.g. higher nutrient loads in lakes with many cottages) or variation in the environment guiding the location of humans (e.g. more cottages on nutrient-rich lakes with good fishing). We coupled a 57-year record of limnological data with land-use/land-cover data derived from aerial photos to ask “Are changes in lake chemistry drivers of or driven by changes in land-use?" for the region around the North-Temperate Lakes LTER site. Land cover data were digitized from aerial photos taken in 1939, 1961 and 1996 for 100-meter buffers around 50 lakes and compared to lake chemistry data from the 1930s and 1980s, using ordination techniques to reduce the dimensionality of both the land-use and the environmental data. Although the dominant land covers throughout the study period were deciduous, mixed, and evergreen forest, the human component of the landscape changed substantially across the time series. Low-density residential development increased 107% from 1939 to 1961 while high-density development increased by 55%. The rate of increase between 1961 and 1996 was more moderate (69% and 6.4%). In 1939, lakes with a higher pH were more likely to have low-density development (odds ratio = 4.203 (1.478-11.948), Likelihood Ratio Test X2 = 9.5, p= 0.002), however this pattern did not hold for the presence of low-density development in later time-steps. Additionally, high-density development in 1939 was unrelated to the environmental variables tested, indicating that decisions about the location of high- and low-density development are made with different metrics. Lake chemistry in the 1980s was generally not explained by land cover patterns in either 1939 or 1961, with the notable exception of ammonia, which was partially explained by the abundance of low-density residential development in 1939 ($R2 = 0.15$, $p < 0.0001$).