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Tracking sediment through the Holocene: Determining anthropogenic contributions to a sediment-rich agricultural system, north-central USA

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Management and restoration of sediment-impaired streams requires quantification of sediment sources and pathways of transport. Addressing the role of humans in altering the magnitude and sources of sediment supplied to a catchment is notoriously challenging. Here, we explore how humans have amplified erosion in geomorphically-sensitive portions of the predominantly-agricultural Minnesota River basin in north-central USA. In the Minnesota River basin, the primary sources of sediment are classified generally as upland agricultural field vs. near-channel sources, with near-channel sources including stream banks, bluffs, and ravines. Using aerial lidar data, repeat terrestrial lidar scans of bluffs, ravine monitoring, historic air photo analyses, and sediment fingerprinting, we have developed a sediment budget to determine the relative importance of each source in a tributary to the Minnesota River, the Le Sueur River. We then investigate how these sources have changed through time, from changes evident over the past few decades to changes associated with valley evolution over the past 13,400 years.

The Minnesota River valley was carved ∼13,400 years ago through catastrophic drainage of glacial Lake Agassiz. As the Minnesota River valley incised, knickpoints have migrated upstream into tributaries, carving out deep valleys where the most actively eroding near-channel sediment sources occur. The modern sediment budget, closed for the time period 2000 to 2010, shows that the majority of the fine sediment load in the Le Sueur River comes from bluffs and other near-channel sources in the deeply-incised knick zone. Numerical modeling of valley evolution constrained by mapped and dated strath terraces cut into the glacial till presents an opportunity to compare the modern sediment budget to that of the river prior to anthropogenic modification. This comparison reveals a natural background or "pre-agriculture" rate of erosion from near-channel sources to be 3-5 times lower than modern near-channel erosion rates.

Notably, depositional records from a naturally-dammed lake downstream on the upper Mississippi River show a more dramatic 10-fold increase in deposition rates from pre-agricultural times to the present. Sediment fingerprinting shows that pre-agriculture sediment loads were dominated by near-channel sediment sources. As deposition rates rose in the late 1800s and early 1900s, the sources shifted increasingly to agricultural soil erosion. In the past few decades, deposition rates have remained high, but sediment fingerprinting indicates yet another significant shift back to near-channel sources. On-going changes in basin hydrology, from both installation of agricultural drainage systems and on-going climate change have put more water in the rivers, increasing rates of near-channel bank and bluff erosion. This most recent shift in sediment sources has significant implications for turbidity management in the Minnesota River basin.