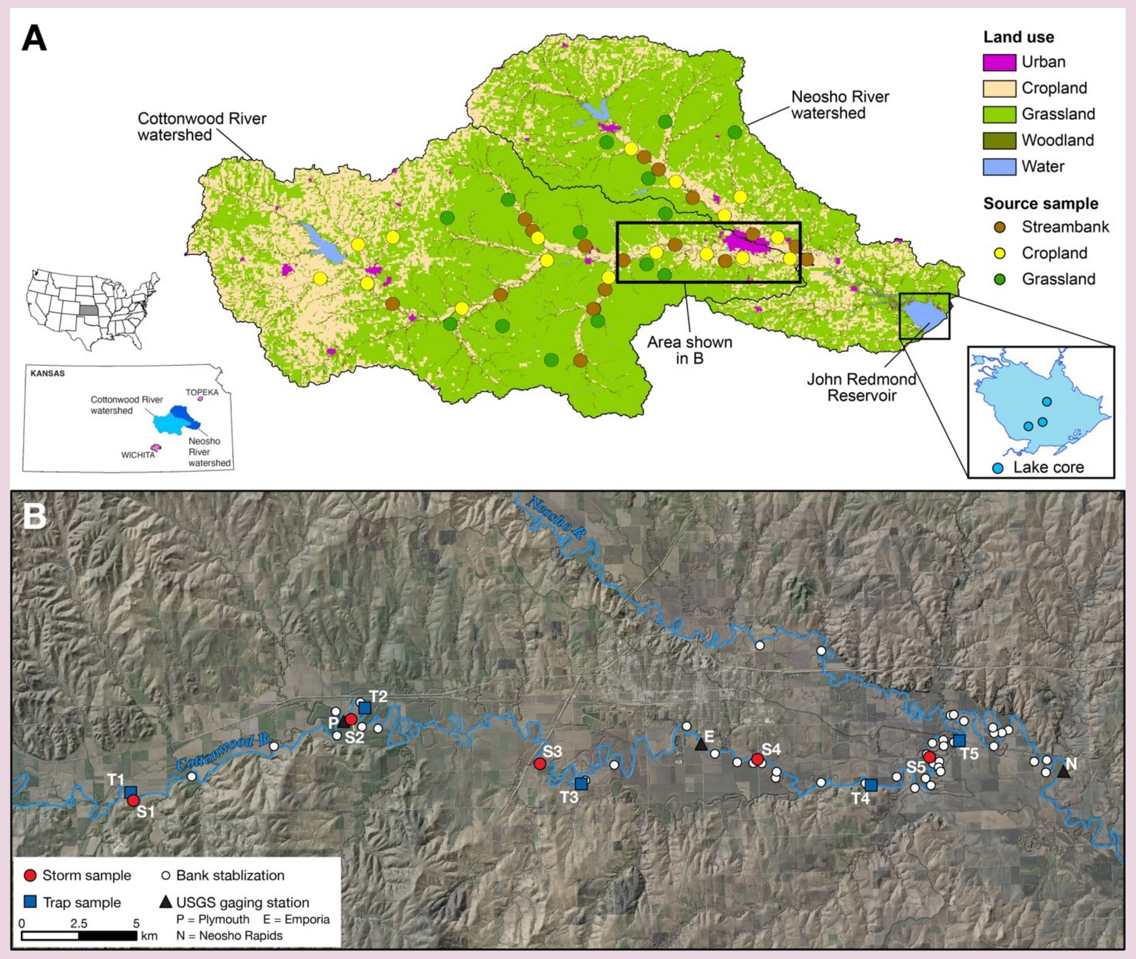
EVENT-DRIVEN SHIFTS IN RIVER AND RESERVOIR SEDIMENT SOURCES: COTTONWOOD RIVER AND JOHN REDMOND RESERVOIR, USA

Cayden E. Lloyd[1], Anthony L. Layzell[2], Abigal Percich[3], Ted D. Harris[4], Michael Ketterer[5], Admin Husic[3]

1. Department of Civil, Environmental & Architectural Engineering, University of Kansas, Lawrence, KS US ; 2. Kansas Geological Survey, University of Kansas, Lawrence, KS, USA ; 3. Department of Civil & Environmental Engineering, Virginia Tech, Blacksburg, VA, USA ; 4. Kansas Biological Survey, University of Kansas, Lawrence, KS, USA ; 5. Department of Chemistry and Biochemistry, Northern Arizona University, Flagstaff, AZ, USA

Introduction

Reservoir sedimentation is a global issue. In the United States, reservoir storage capacity over the past 30 years has continually declined due to sedimentation and, in Kansas, multiple large reservoirs are expected to become more than 50% infilled over the coming decades. Regionally, it is understood that streambank erosion is the main source of sediment to downstream reservoirs. Hence, streambank stabilization projects have received considerable attention as a management solution. Here, we conduct a sediment fingerprinting study to identify the relative contribution of streambank, cropland, and grassland sediment sources to the Cottonwood River and John Redmond Reservoir.



(A) Study area location showing land use and sampling sites for streambank, cropland, and grassland samples in the Cottonwood and Neosho River watersheds. Inset map shows reservoir coring locations. (B) Storm and trap sampling locations along the Cottonwood River. Locations of streambank stabilization sites are also shown.

Source 1: Streambanks

Source 2: Cropland

Source 3: Grassland

(A) Collection of lakebed samples from John Redmond Reservoir via sediment coring. (B) Deployment of 1-L Van Dorn sampler from bridge at site S2 to sample suspended sediment during a flood event. (C) Time-integrated sediment trap at site T5. The trap is positioned such that sediment collection only occurs during storm conditions.

Model

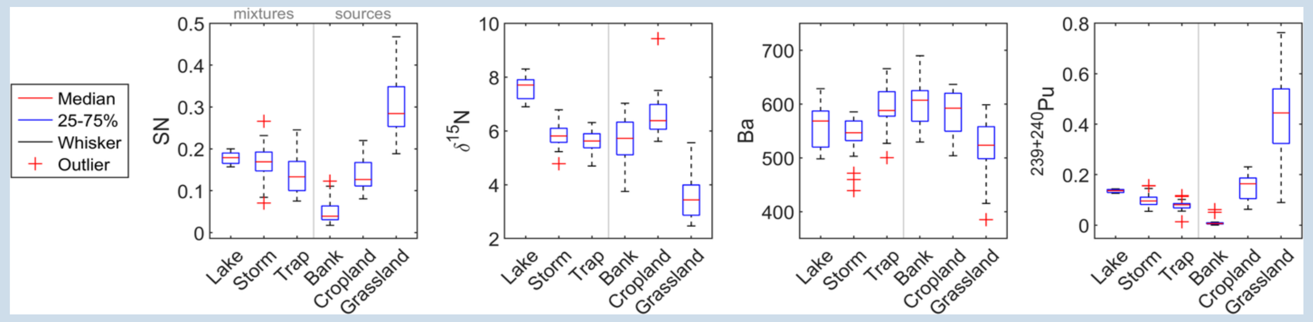
Sediment fingerprinting models can take many forms, from fully frequentist to fully Bayesian (Cooper et al., 2014). Irrespective of the modeling framework selected, both approaches typically solve the following mass balances for sediment (1) and each tracer (2) as:

$$\sum_{i=1}^{n} \pi_i = 1, \qquad \pi_i \geq 0 \; for\; all\; i = 1, 2, \ldots, n \qquad (1)$$

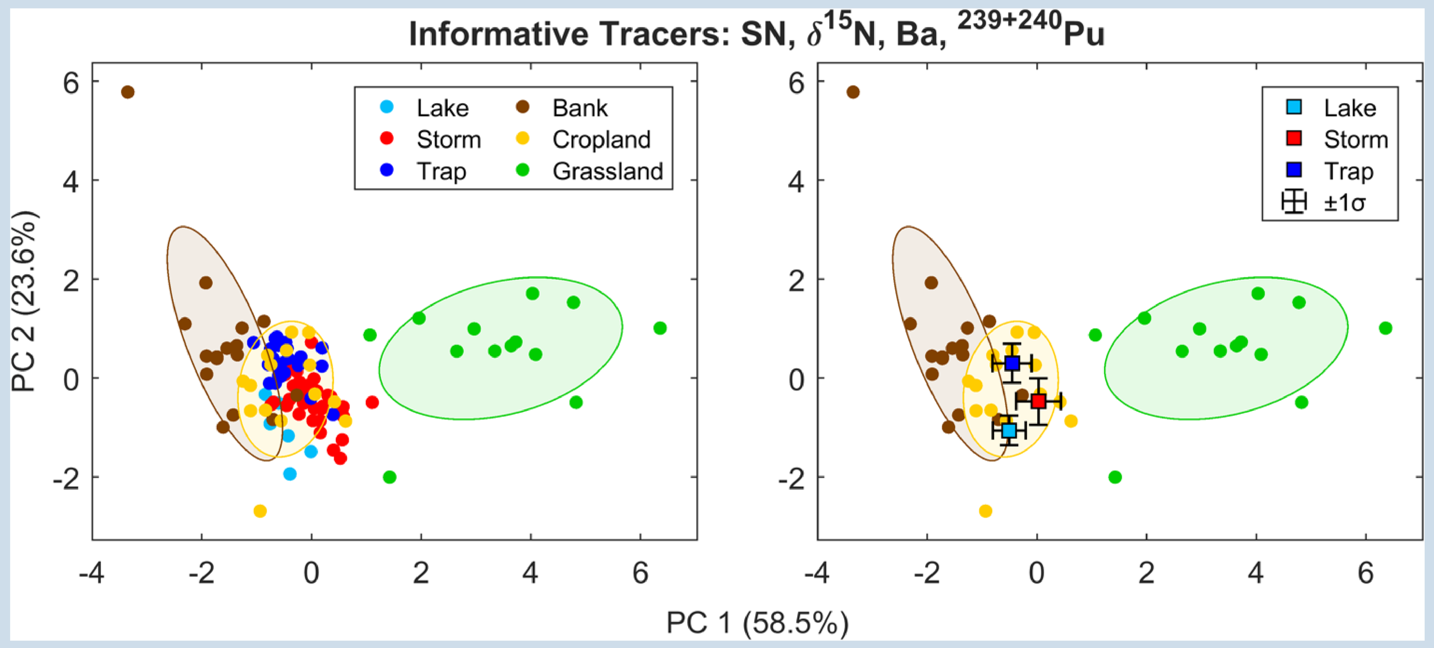
and

$$\sum_{i=1}^{n} \pi_i S_{ij} = M_j, \qquad for\; j = 1, 2, \ldots, m \qquad (2)$$

where π_i is the fractional contribution from the *i*-th source, *n* is the number of sediment sources, *m* is the number of tracers, S_{ij} is the *j*-th tracer concentration of the *i*-th source, and M_j is the concentration of the mixture for the *j*-th tracer.



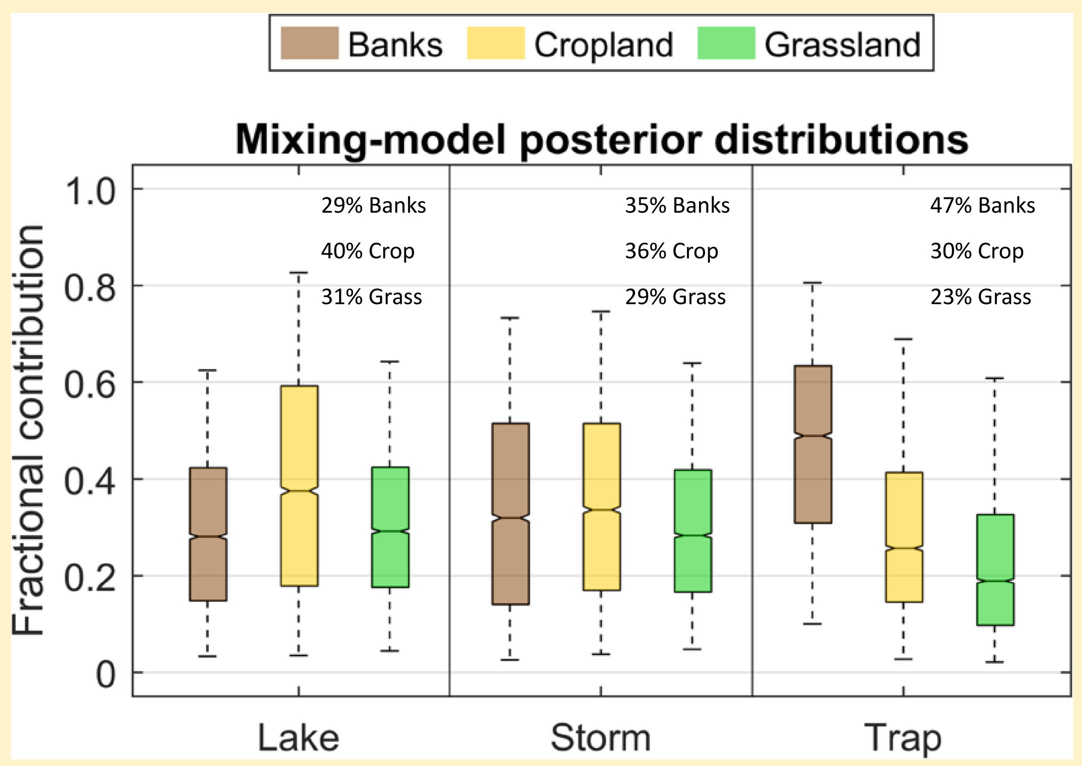
Informative tracer distributions for the mixture and source samples. $\delta^{15}N$ was an informative tracer for storm and trap mixtures, but not lake mixtures.



Principal components analysis of tracers for the three mixtures (lake, storm, and trap) and the three sources (banks, cropland, and grassland).

Results

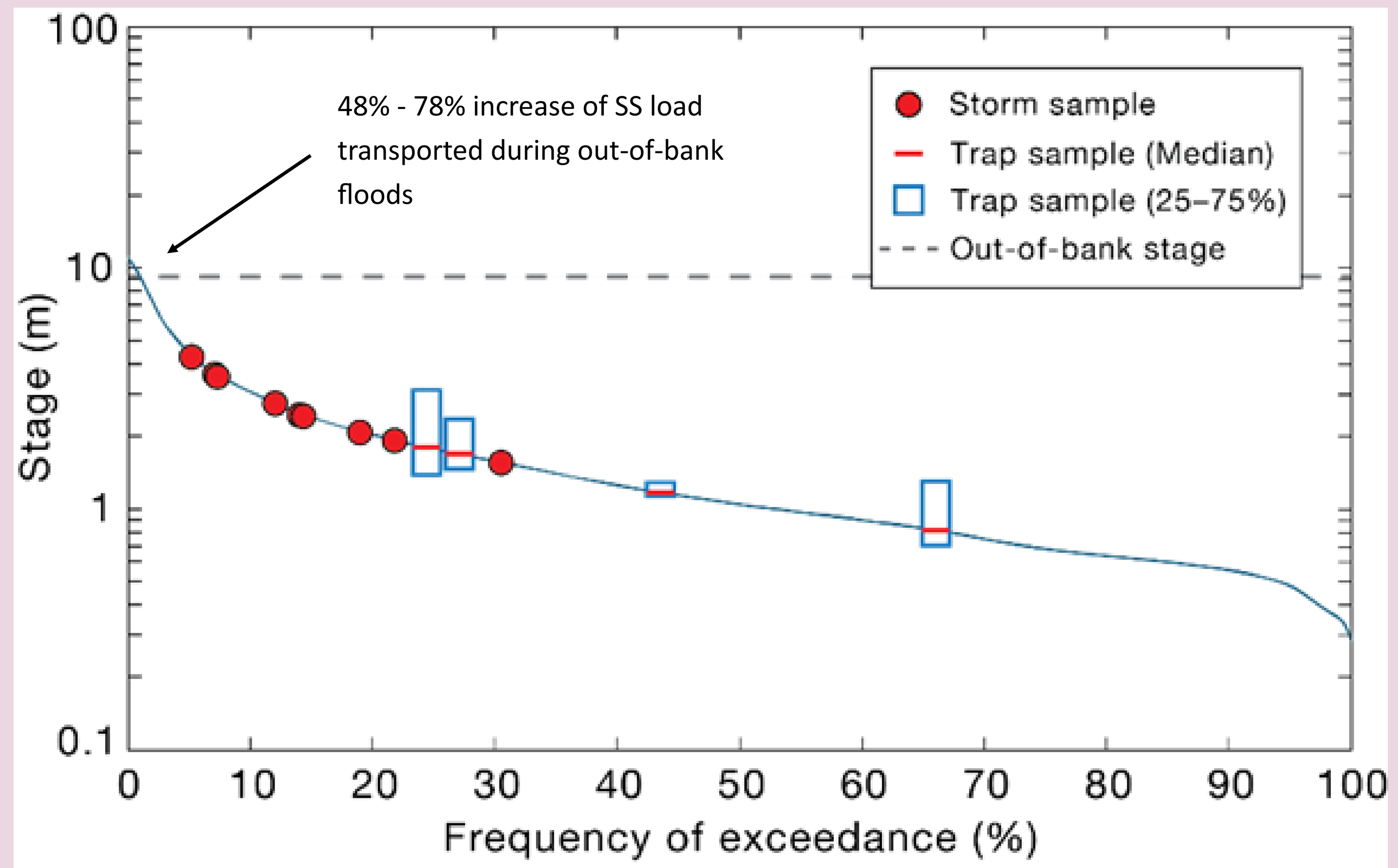
Lakebed sediment is most representative of material transported during large, infrequent flood events and our results indicate that this sediment is primarily derived from cropland sources (40%) not streambanks (29%). Discrete sampling of moderately sized storm events, which occur multiple times per year, indicated a drop in the relative proportion of cropland sediment (36%) and an increase in bank material (35%). Time-integrated traps, which collect sediment during storm events as well as low-flow periods, were found to have the lowest cropland (30%)



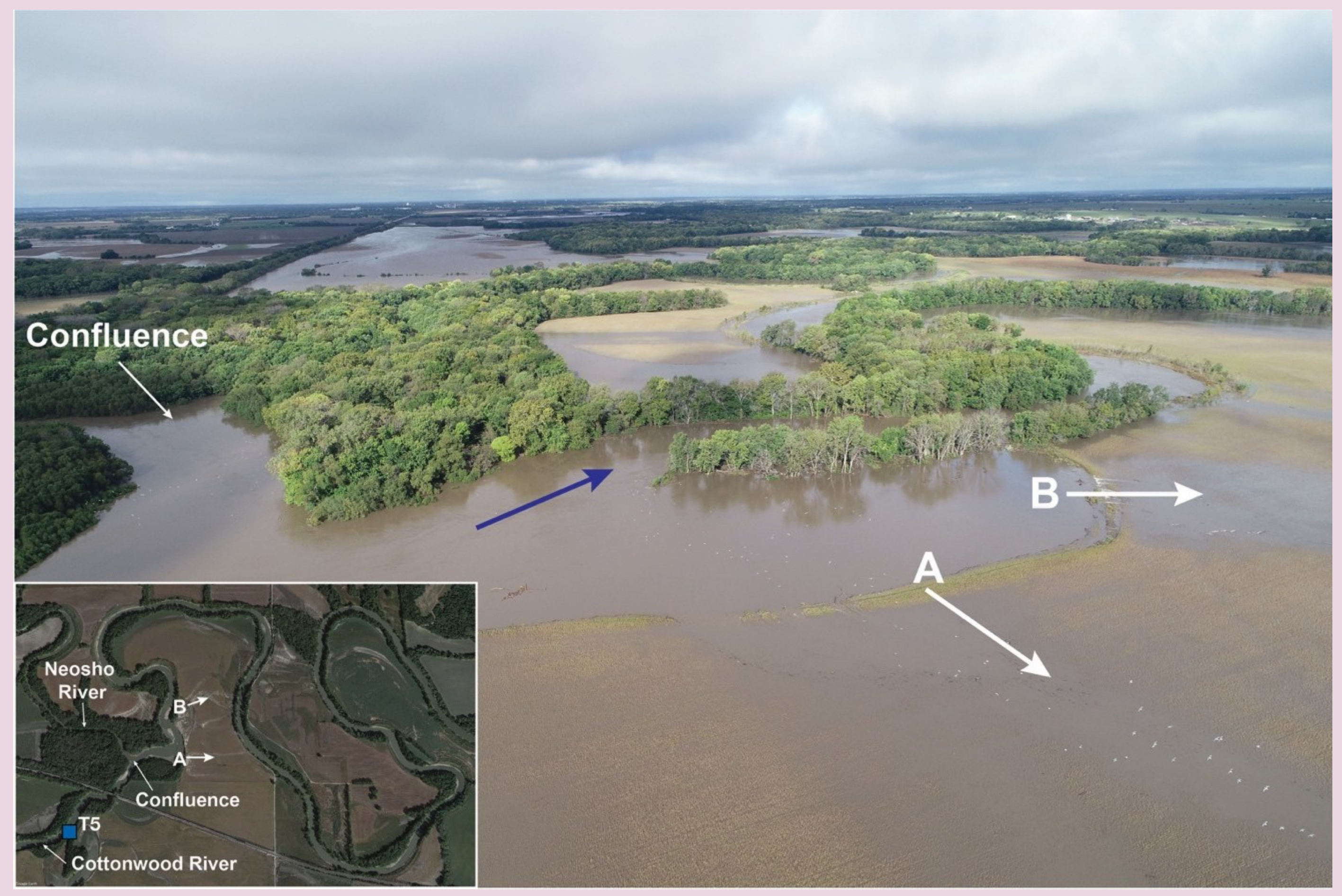
Posterior source contributions for three types of sediment mixtures: reservoir bed deposits (lake), discrete storm-event samples (storm), and time-integrated trap samples (trap).

Discussion

The shift from in-channel bank-dominated sourcing, for time-integrated traps, to cropland-dominated sediment sourcing, for lakebed material, reflects the enhanced connectivity of upland sources during high-magnitude, out-of-bank floods. In particular, the valley floor of the Cottonwood River is heavily cultivated, thus cropland sediment is likely entrained from floodplain chutes that cut across meander bends and create erosional pathways during out-of-bank events.



Stage-frequency curve for the Cottonwood River at Plymouth (USGS gage 07182250). The instantaneous stage associated with discrete storm-event sampling and the range of stages during time-integrated trap deployment are indicated. The out-of-bank stage indicates the connection of the river channel to the surrounding floodplain (see Figure 10 for an example of an out-of-bank event).



Flooding on the Cottonwood and Neosho Rivers (October 10, 2018).

Conclusion

Our study demonstrates that sediment fingerprinting provides valuable insights into sediment sourcing, highlighting the complexity of interactions between streambank and upland sediment sources. Consequently, management strategies should not solely target streambank stabilization but must integrate measures addressing upland erosion, particularly from cropland areas.