A New Approach of Using Multiple Composite Fingerprints to Apportion Sediment Sources

X.-C. Zhang[1], B. Liu[2]

Sediment source fingerprinting provides an essential means for estimating sediment source contributions, which are needed not only for soil conservation planning but also for erosion model evaluation and refinement. A single optimum composite fingerprint has been widely used in the literature to estimate sediment provenance. The objectives of this work are to: (1) verify whether an optimum composite fingerprint exists, (2) present a new direction of using multiple composite fingerprints to improve the accuracy and reliability of source contribution estimation, and (3) evaluate and compare the new approach and the optimum composite fingerprint approach using a synthetic sediment mixture. We collected 50 surface samples from overland flow areas in a 15.6 km^2 watershed (Figure 1), 28 subsoil samples from gully banks, and 8 sediment samples at the watershed outlet. We then analyzed 31 elements using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) and a Macro Analyzer. The results show that tracer selection greatly impacts the estimated source contributions. The optimum composite fingerprint may not exist, or at least cannot be identified simply based on a tracer's ability to discriminate sources because of the lack of correlation between the tracer's ability to discriminate and its rigor in estimating source contributions.

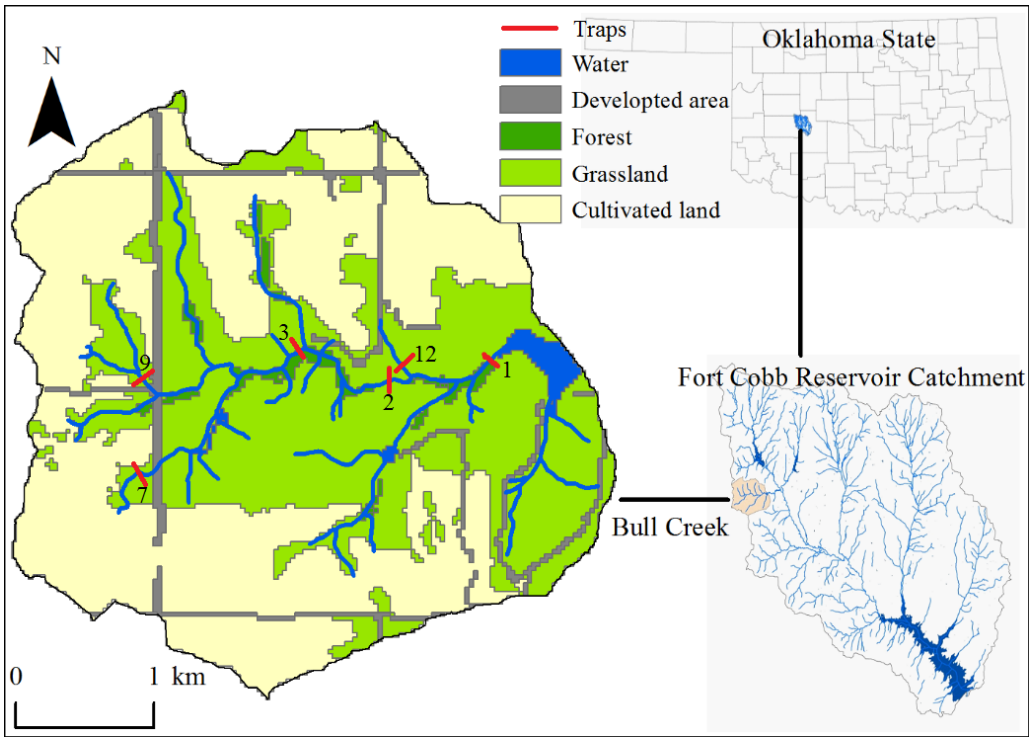

Figure 1. Geographic location and land uses of the study watershed.

[1]Xun-Chang (John) Zhang, Research Hydrologist, USDA-Agricultural Research Service, Grazinglands Research Laboratory, El Reno, Oklahoma, USA; [2]Benli Liu, Associate Professor, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Science, Lanzhou City, Gansu Province, China. Corresponding author: X.C. Zhang, email: John.Zhang@ars.usda.gov.

The weak link is likely caused by (1) tracer conflicts, (2) different levels of tracer measurement errors, and (3) varying degrees of the conservativeness of each tracer or lack of it. To overcome this shortcoming, we propose a new approach of using multiple composite fingerprints. Contrary to the popular tracer reduction strategies, this new approach uses a maximum number of composite fingerprints, which contain non-contradictory tracers in each composite, to maximize the use of all tracer information. The new approach assumes that source proportions averaged over multiple composite fingerprints are more likely to be closer to the population means than any estimates using a single fingerprint alone. Such a 'mean of the means' approach has been shown to not only improve the accuracy but also reduce the uncertainty of the proportion estimates.

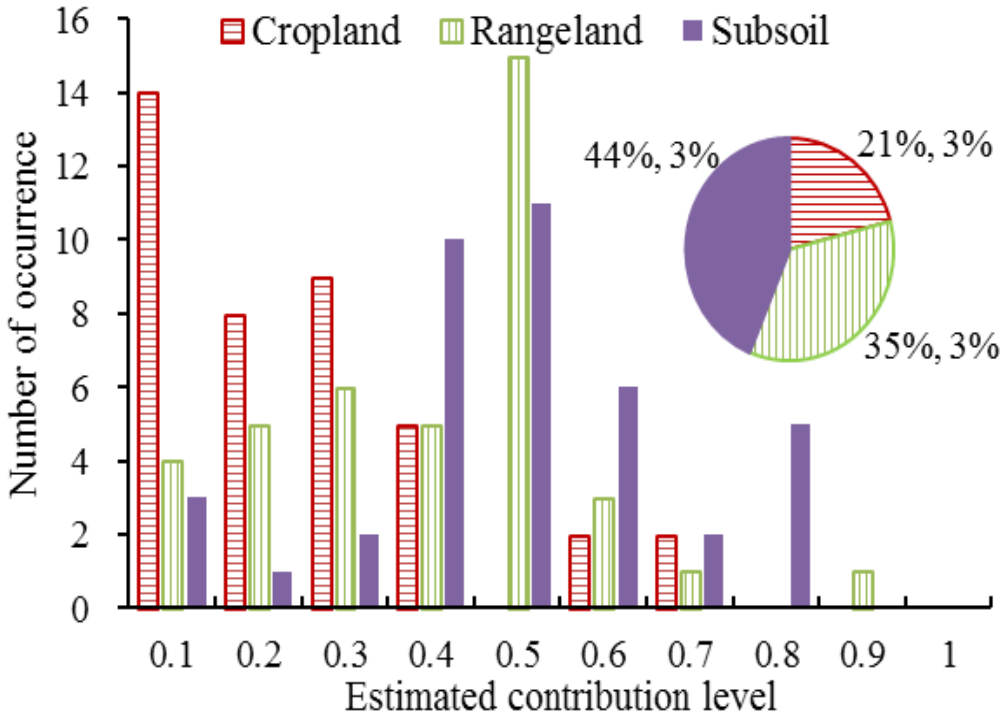

Figure 2. Frequency distributions of the proportional contributions estimated at Trap 1 (Figure 1) for the three sediment sources using analytical solutions to a mixing model for each of the 40 non-contradictory composite fingerprints. The overall frequency-weighted means (standard error) are 44% (3%) for subsoil/gully source, 35% (3%) for rangeland source, and 21% (3%) for cropland source. The fractional proportions estimated by each composite fingerprint varied considerably, but the overall means of the 40 fingerprints were more reliable with small standard errors.