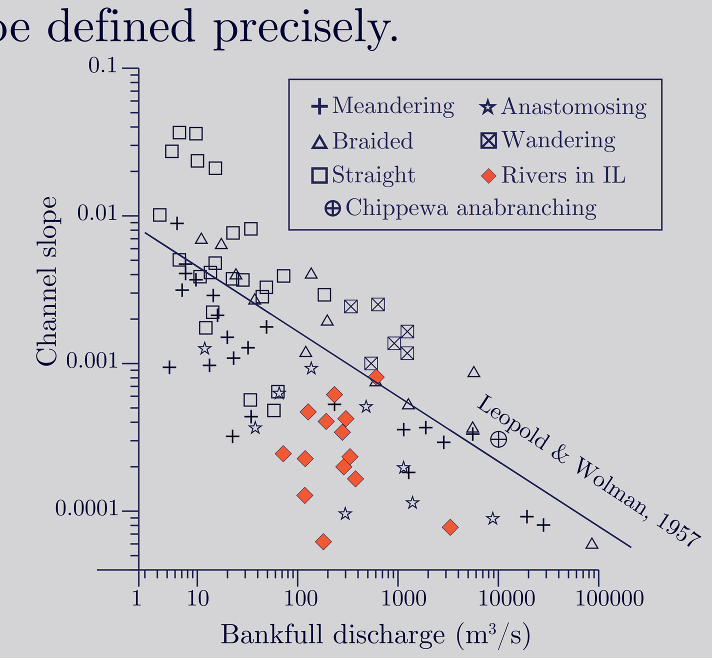
Prevalence and morphological characteristics of anabranching reaches juxtaposed with lowland meandering rivers in the Midwestern US

Tanya Shukla, Bruce Rhoads
Department of Geography & GIS, University of Illinois at Urbana Champaign, IL, 61801
E-mail: tshukla2@illinois.edu, brhoads@illinois.edu

Paper number: EP45D-1543

1. Introduction: spatial variablity in channel planform

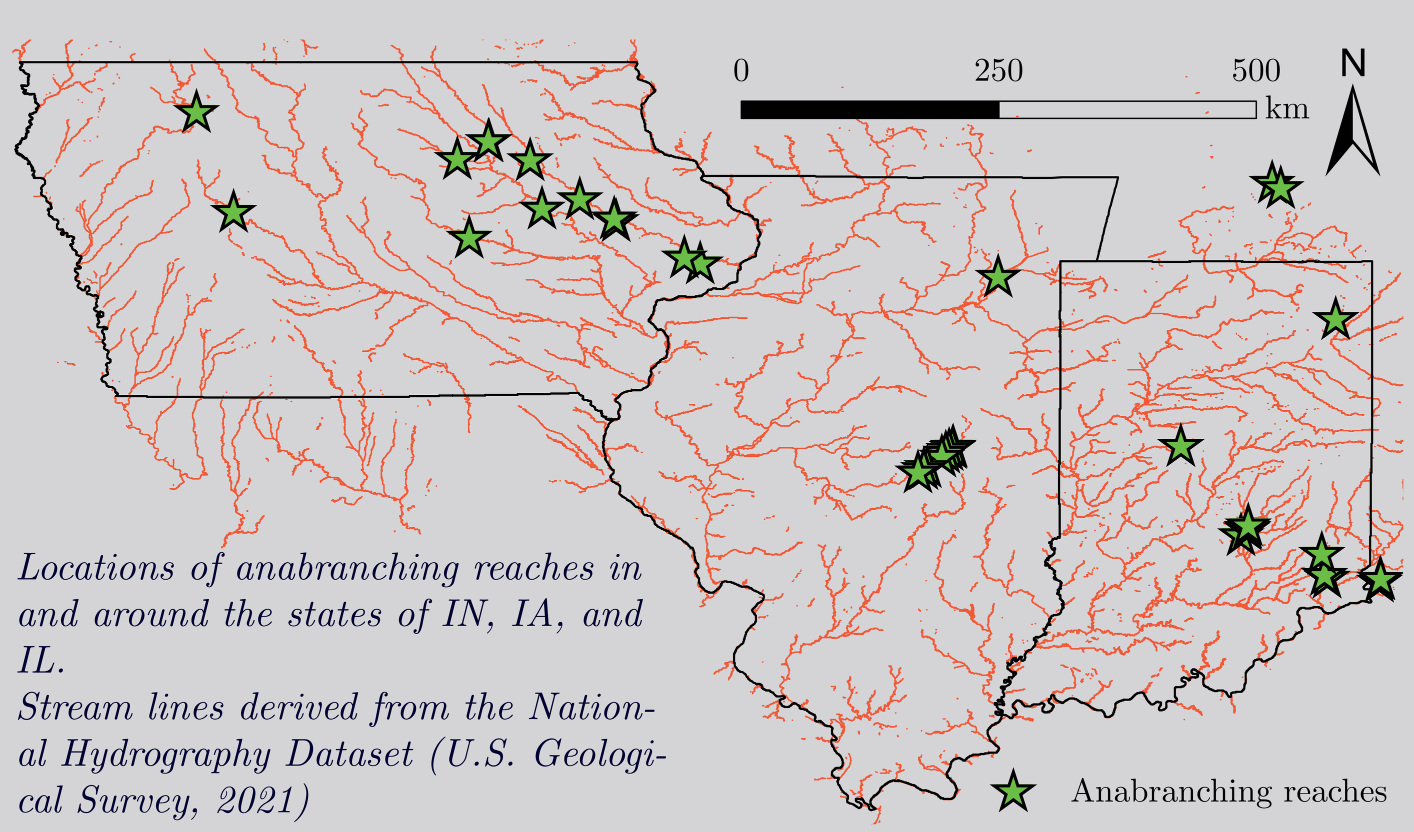
- Variability in channel planform indicates differing boundary conditions, evolution trajectories and underlying processes.
- Plotting the channel slope with bankfull discharge for different river types separated meandering and braided rivers, indicating they occur in distinct energy regimes (Leopold & Wolman, 1957). However, the energy domain of anabranching rivers (Nanson & Knighton, 1996) is yet to be defined precisely.



- Quantification of channel planform using reach scale metrics gives an indication of the (self-) similarities or differences in underlying processes between rivers of different character (Kelly, 2006; Hundey & Ashmore, 2009; Meshkova & Carling, 2013).
- The purpose of this paper is to capture the diversity of anabranching forms in midwestern US, where spatial transitions in planform occur without associated changes in valley width.

2. Regional setting

- This study focuses on anabranching reaches found in Illinois, Indiana, and Iowa. This region has gone through cycles of glaciation and is currently under intensive agriculture.
- The topography is relatively flat and end moraines are distributed throughout the landscape - an indication of the region's glacial past. Windblown loess overlies most glacial deposits.
- An extensive search for anabranching reaches along meandering rivers is being conducted using Google Earth Imagery (leaf-off). As of now we have identified 16 rivers containing a total of 38 anabranching reaches. The dataset is growing and more locations will be added as we search other midwestern states.



Locations of anabranching reaches in and around the states of IN, IA, and IL.
Stream lines derived from the National Hydrography Dataset (U.S. Geological Survey, 2021)

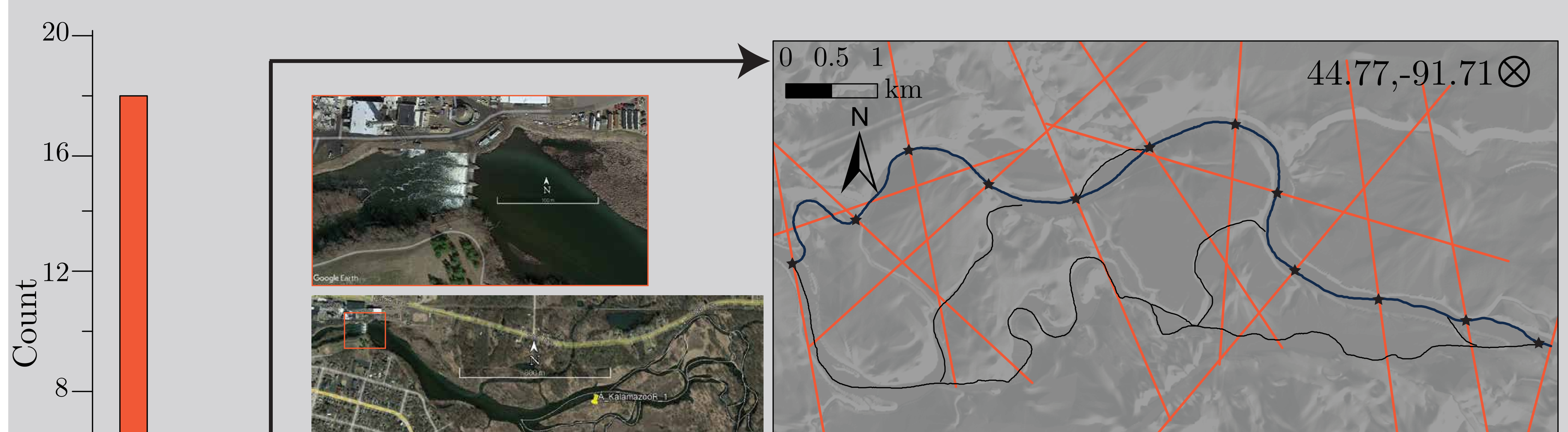
3. Methods: Planform metrics and slope-discharge plots

- Main channel centerline and island polygons were manually digitized on Google Earth and imported into ArcMap 10.8 for further analysis.
- Channel slope was calculated using LiDAR elevation data and bankfull discharge was estimated at USGS gage stations as 2 year flood. Channel slope was plotted as a function of discharge to quantify energy conditions

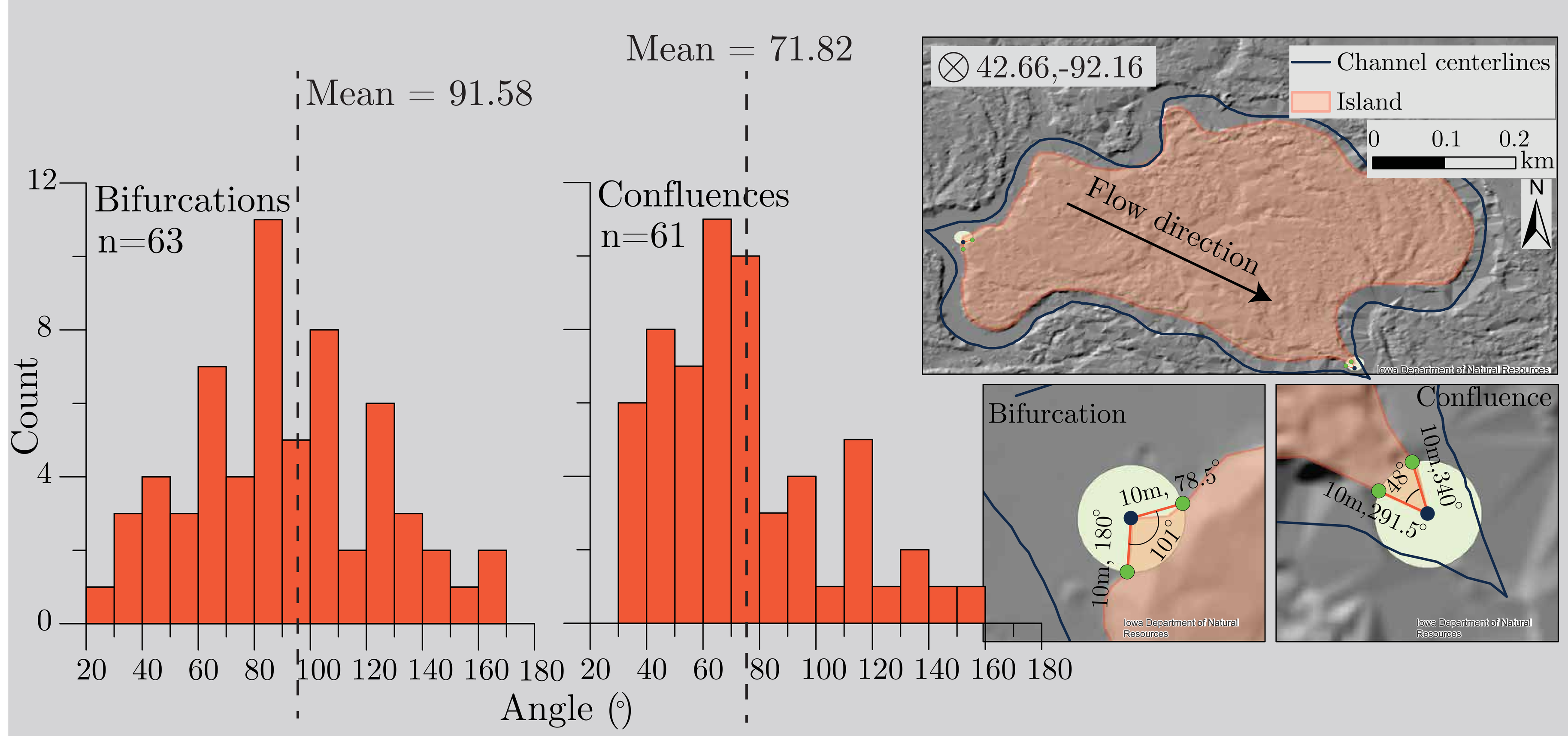
Metric	Physical significance	References	Method
Channel count index	Measure of multiplicity of channels in a reach	Egozi & Ashmore, 2008; Meshkova & Carling, 2013	Number of channels intersecting a transect were measured within an anabranching reach
Island shape and scaling relationships	Similarity or difference in island formative processes	Kelly, 2006; Hundey & Ashmore, 2009	Scaling relationship quantified as power law fit between length and width as well as perimeter and area of islands
Bifurcation and confluence angle	Channel flow and sediment transport patterns	Coffey & Shaw, 2017; Hasthorpe & Mount, 2012	Difference in the bearing of channels on both sides o an island vertex

4. Results: Planform metrics

- Median channel count for all anabranching reaches studied is two. More than 50% of anabranching reaches have two channels, when averaged over the number of transects.
- Some reaches, however, are highly dissected, for example a reach of the Chippewa River, WI where the channel count is 2.4.
- Mean bifurcation angle is 91°±33°), and is not consistent with the theoritical critical bifurcation angle of 72° calculated for stream networks through hydraulic principles (Devauchelle et. al., 2012).

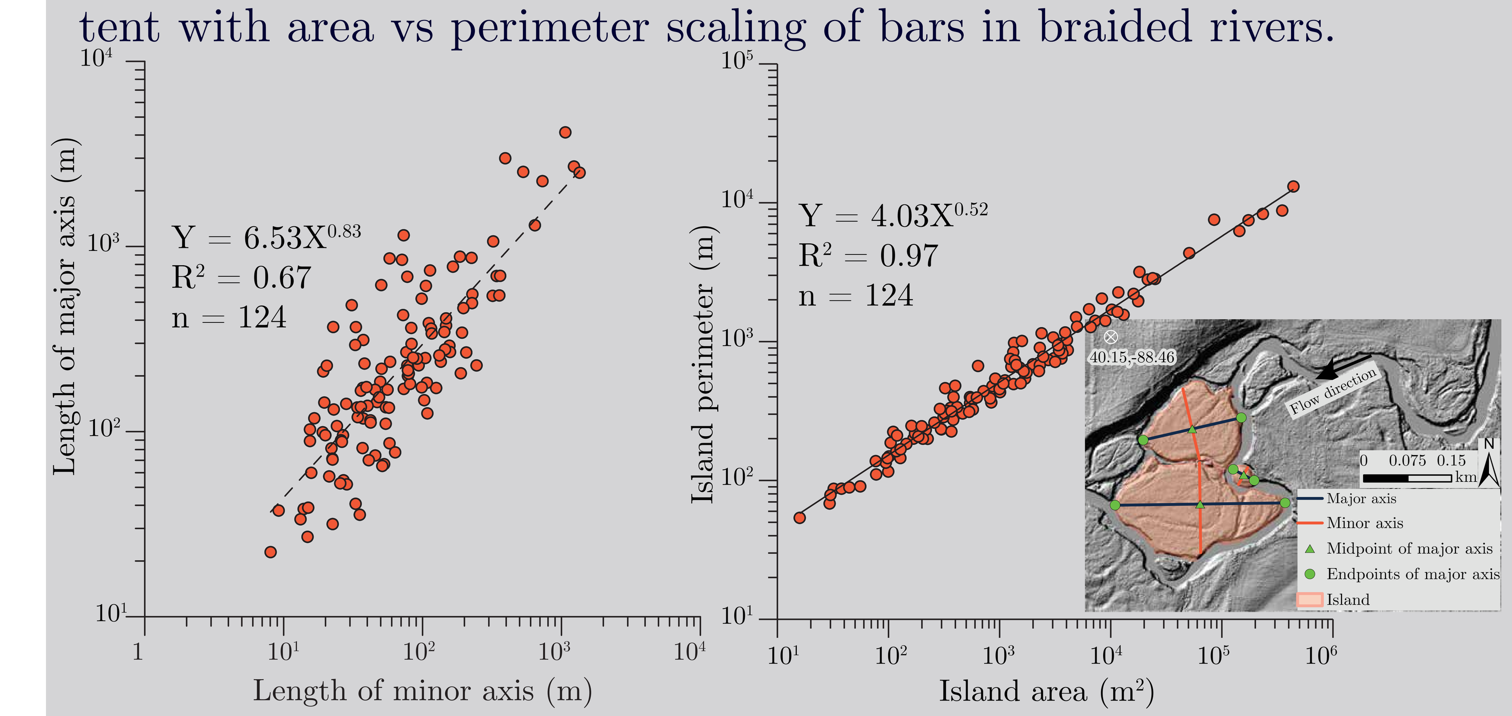


(Top) Anabranching reach in the Chippewa R., Wisconsin. Channel count calculated as ratio of number of times each transect is intersected by a channel centerline per unit number of transects.(Bottom) Bifurcation and confluence angle calculation procedure. The bearings of each line were subtracted to compute the inner acute angle.



5. Results: Planform scaling relationships

- Exponent of width-length scaling for bars in braided rivers is close to unity for major axis length varying over six orders of magnitude, implying a self similar form across scales.
- In anabranching case, the exponent for length scaling is less than unity. Area vs perimeter scaling of anabranching islands is consistent with area vs perimeter scaling of bars in braided rivers.



6. Conclusions

- Otherwise meandering rivers (according to plotting position on slope discharge plot) containing anabranching reaches were identified in and around the states of Illinois, Indiana, and Iowa.
- Channel count (average number of channels per cross section) ranged between 2-3.8, agreeing well with theoretical estimates of two to four channels (Huang & Nanson, 2007; Eaton et. al., 2010) as well as being within the range of recent measurements for large anabranching rivers (Meshkova & Carling, 2013).
- Bifurcation angle estimates (91°±33°), however, are larger than theoretical calculations of 72°, those for large anabranching rivers with bifurcation angle values between 50°-85° (Meshkova & Carling, 2013), as well as for deltaic networks (70.4°±2.6°) (Coffey & Shaw, 2017).
- The study is a first attempt at characterizing juxtaposed anabranching-meandering systems and provides a basis to explore the role of natural versus human induced processes on formation and evolution of mixed planform river characteristics in intensively managed agricultural landscapes.

7. References

Coffey, T. S., & Shaw, J. B. (2017). Congruent bifurcation angles in river delta and tributary channel networks. Geophysical Research Letters, 44(22), 11-427.

Devauchelle, O., Petroff, A. P., Seybold, H. F., & Rothman, D. H. (2012). Ramification of stream networks. Proceedings of the National Academy of Sciences, 109(51), 20832-20836.

Eaton, B. C., Millar, R. G., & Davidson, S. (2010). Channel patterns: Braided, anabranching, and single-thread. Geomorphology, 120(3-4), 353-364.

Egozi, R., & Ashmore, P. (2008). Defining and measuring braiding intensity. Earth surface processes and landforms, 33(14), 2121-2138.

Hasthorpe, J., & Mount, N. (2012). Automatic computation of river channel bifurcation angles.

Huang, H. Q., & Nanson, G. C. (2007). Why some alluvial rivers develop an anabranching pattern. Water Resources Research, 43(7).

Hundey, E. J., & Ashmore, P. E. (2009). Length scale of braided river morphology. Water Resources Research, 45(8).

Kelly, S. E. A. N. (2006). Scaling and hierarchy in braided rivers and their deposits: examples and implications for reservoir modelling. Braided rivers: Process, deposits, ecology and management, 36, 75-106.

Leopold, L. B., & Wolman, M. G. (1957). River channel patterns: braided, meandering, and straight. US Government Printing Office.

Meshkova, L. V., & Carling, P. A. (2013). Discrimination of alluvial and mixed bedrock–alluvial multichannel river networks. Earth Surface Processes and Landforms, 38(11), 1299-1316.

Nanson, G. C., & Knighton, A. D. (1996). Anabranching rivers: their cause, character and classification. Earth surface processes and landforms, 21(3), 217-239.

8. Acknowledgement

The presenting author acknowledges Samuel, Berle D. and Jeffrey A. Schlesinger Travel Grant from the School of Earth, Society and Environment (SESE), University of Illinois for supporting AGU travel and registration costs. Both the authors acknowledge the NSF IML-CZO and CINet projects.