From Drainage to Denitrification: Identification and Characterization of Historic-Depressional Wetlands for Agricultural Nitrate Removal

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Loss of Historic Wetlands in the UMRB

Previous studies found that more than 90% of the wetlands in the Upper Mississippi River Basin (UMRB) have been lost since the arrival of European settlers [8]. This region serves as a significant contributor of nitrogen (N) to the Gulf of Mexico, playing a critical role in the Gulf's excessive nitrogen load and the formation of its substantial summer "dead zone" [4, 13]. Restoring these wetlands could mitigate N pollution, but successful efforts necessitates an understanding of their size distribution and spatial arrangement within the landscape mosaic [9, 14].

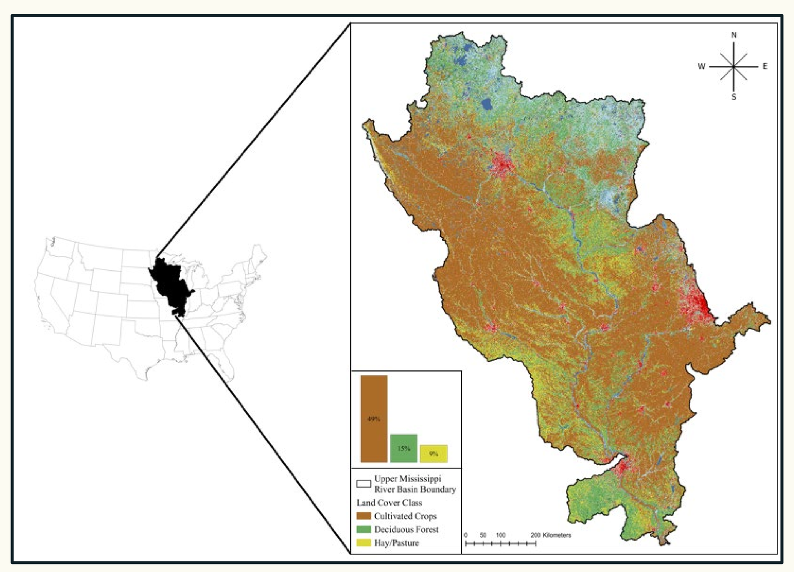


Fig. 2. Land use classifications within the UMRB (492,000 km²). Tile-drained cropland (49% of UMRB land area) accounts for some of the most productive agricultural land in the world.

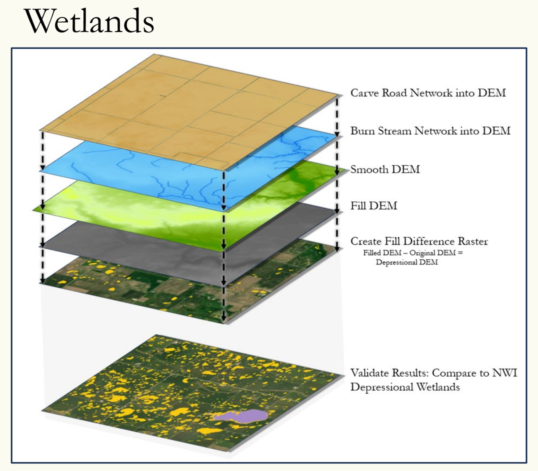
Identifying Historic-Depressional Wetlands in the UMRB

Datasets

10m DEMs | TIGER Lines | Watershed Boundaries | NHD Flowlines | NWI Wetlands

Preprocessing and Analysis

Identifying Historic-Depressional Wetlands



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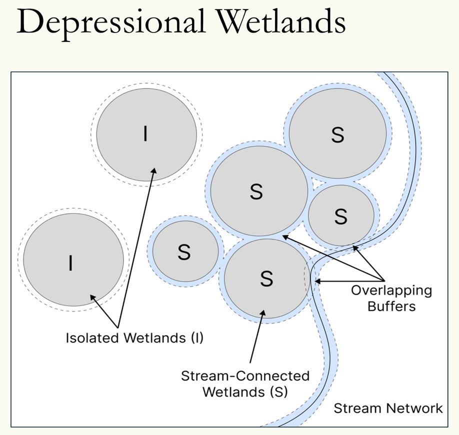
Sub-setting Current-Depressional Wetlands



Output

Vector dataset of historic-depressional wetlands

Vector dataset of current-depressional wetlands

What was the total area of historic-depressional wetland across the UMRB?

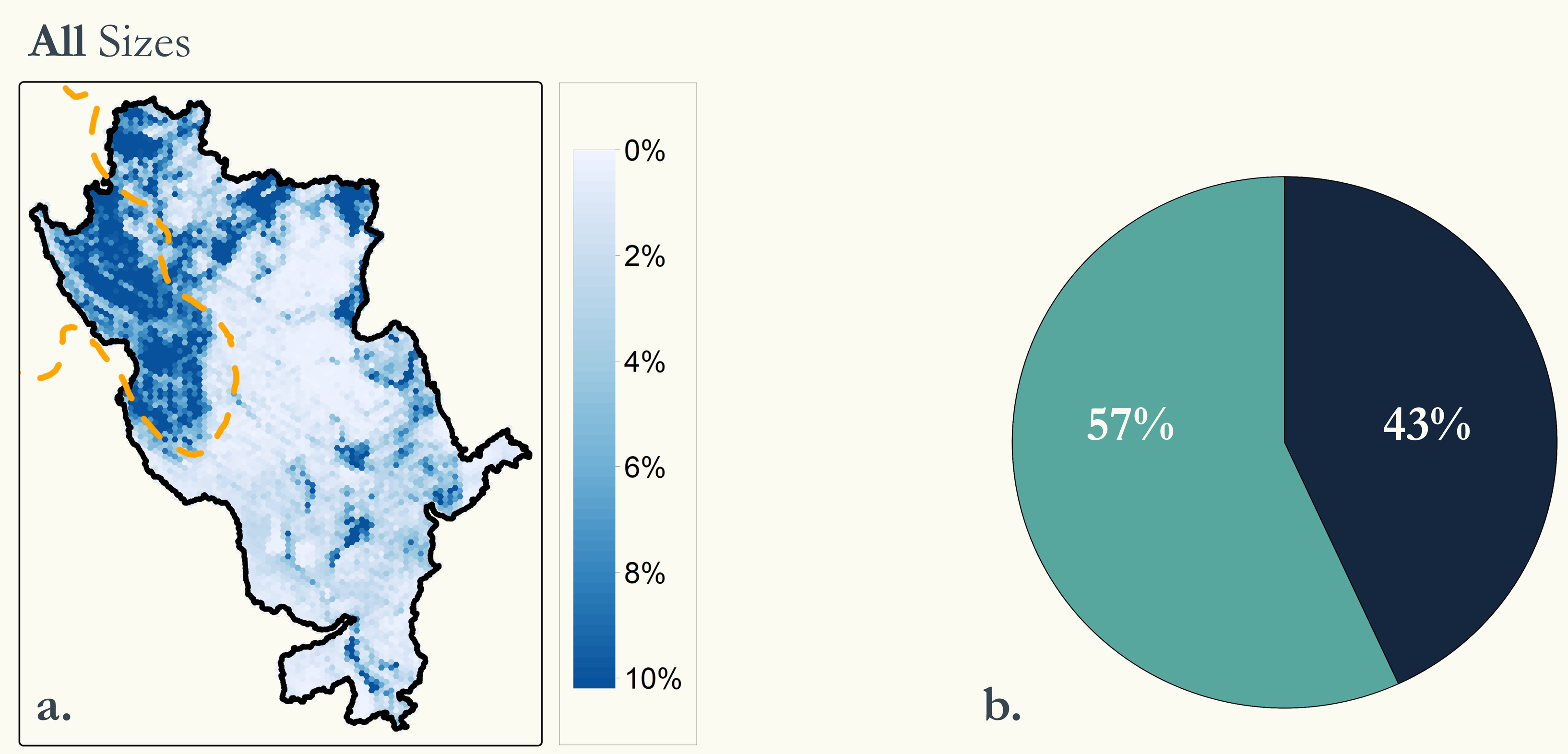


Fig. 2. (a) **Percent area (m²). of grid covered by historic-depressional wetland.** Notably, there is a substantial **concentration** of these historic wetland area within the Prairie Pothole Region (PPR, **orange** dashed outline), whose unique geomorphology is characterized by a dominance of depressional wetlands. (b) **Percent area by size class of historic-depressional wetlands.** Of the 4,450,374 historic-depressional wetlands identified, 43% of all historic-depressional wetlands are **small** (500 – 3k sq. m) wetlands.

What is the magnitude of depressional wetland loss across the UMRB?

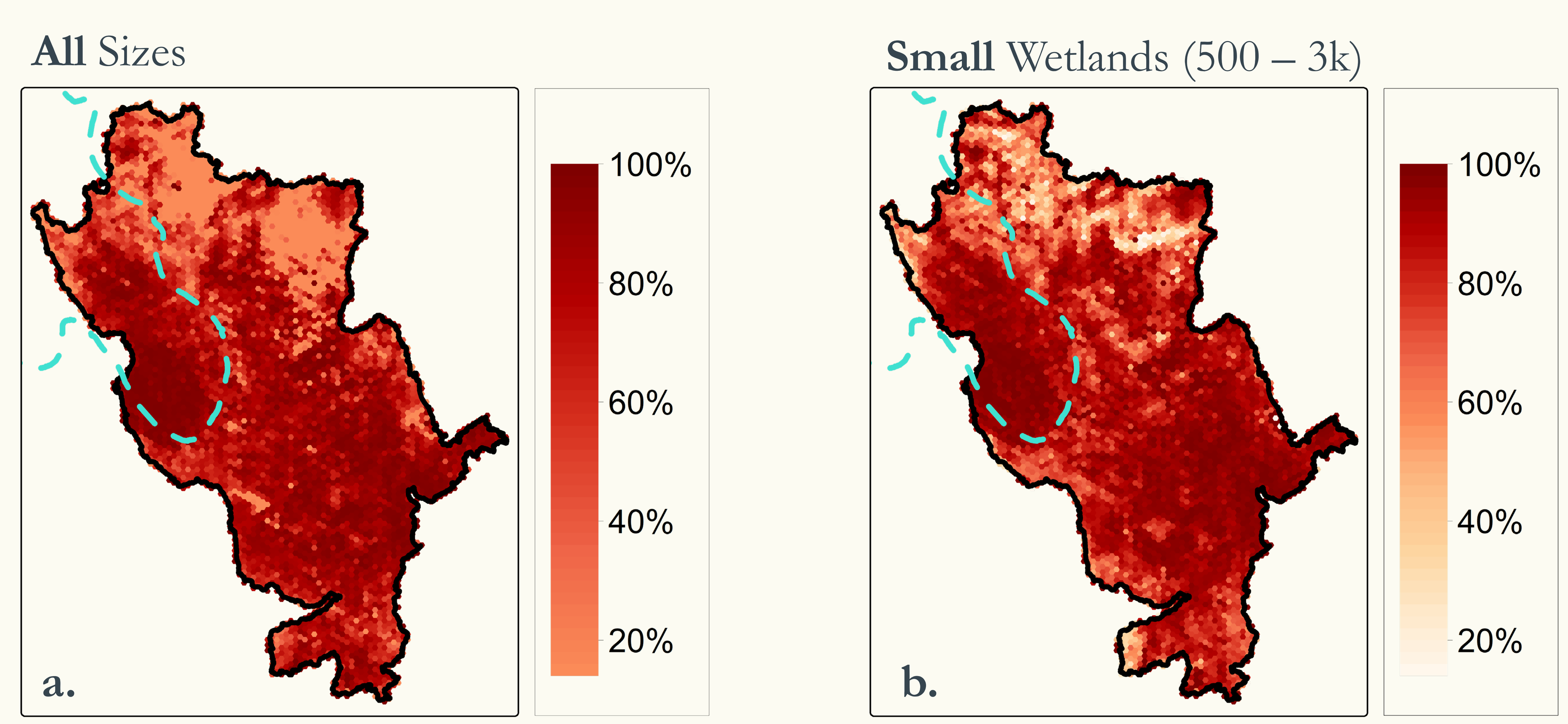


Fig. 3. Percent loss in depressional wetland area (m²). Loss estimations were calculated for all wetland size classes (**a**), and for a subset of small wetlands (**b**). The results returned high rates (>**80**% for all class sizes, >**90**% for small wetlands) of loss throughout the UMRB. We observed a marked pattern of loss where the UMRB and the PPR (**cyan** dashed outline) overlap.

How has their spatial distribution evolved over time?

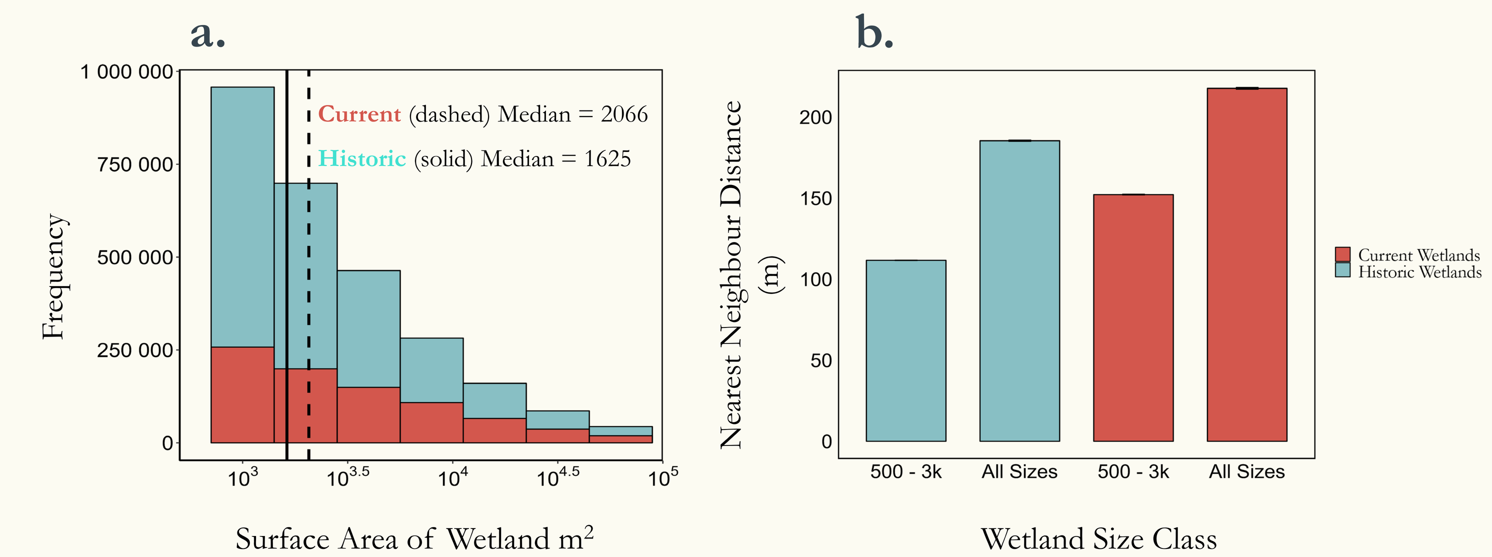


Figure 4. (a) **Size-frequency of historic and current depressional wetlands.** Historic wetlands exhibit a lower median value, indicating a preferential loss of smaller wetlands. (b) **Average nearest neighbour distances (NND) between historic and current depressional wetlands.** Mean NND increased from 152 m to 218 m, which arises directly from the large loss of wetland area (**Figure 3**), which left many wetlands geographically isolated from the others.

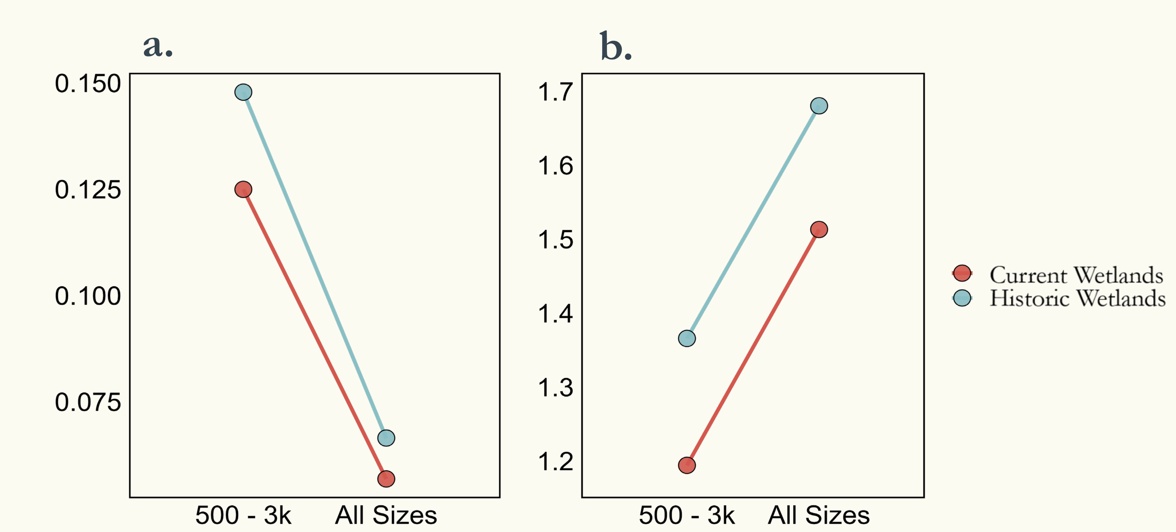


Figure 5. (a) **Average Perimeter-to-Area ratio between historic and current wetlands.** In both the all and small size classes, historic wetlands had a higher P:A than current wetlands, as well as a **Shoreline Irregularity Index** (**b**), reflective of the greater complexity and greater variability in their perimeters compared to current wetlands.

Conclusion & Future Directions

The results indicate significant wetland area loss across all size classes in the UMRB, with >**80**% average loss for all sizes, and >**90** % for small wetlands specifically, a trend evident in **Fig. 3a**. This disproportionate loss of smaller wetlands coincides with the findings in **Figs. 4 & 5**, that found increased mean distances between wetlands (which restricts species migration thus negatively impacting biodiversity) [5], and a decrease in P:A, where smaller wetlands with larger P:A have been shown to produce higher rates of groundwater recharge [6, 11]. These patterns of loss can result in disproportionate losses of ecosystem services [1, 2, 3, 7, 12]. This work marks an initial phase of investigating tradeoffs linked to the targeted restoration of historic depressional wetlands in the UMRB, whose findings will assist watershed managers and natural resource agencies to ensure water bodies meet quality standards, both within and beyond the UMRB.

[1] Cheng et al., 2023 [2] Cheng et al., 2020 [3] Cheng & Basu 2017 [4] Díaz & Rosenberg, 2011 [5] Gibbs, 1993 [6] LaBaugh et al., 1998 [7] Ligi et al., 2014 [8] Mitsch & Day, 2006 [9] Pierce et al., 2012 [10] Semlitsch, 2000 [11] Tiner, 2003 [12] Van Meter & Basu, 2015 [13] Van Meter et al., 2017 [14] Zedler, 2003.