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Predicting succession of abandoned agricultural land in the lower Missouri River floodplain

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Introduction

The **1993 flood** of the Missouri River destroyed levees and **ruined farmland** by scouring fields and depositing sands, **leading to the abandonment of agriculture** in many areas in the floodplain.

The Final Environmental Impact Statement of the Big Muddy National Fish and Wildlife Refuge in Missouri, USA, presented the **possibility of incorporating recent abandoned agricultural land into the refuge**, expanding the size of the refuge from 6,729 to ~24,280 ha. It is of interest to the refuge to be able to **project the potential successional trajectory of these abandoned agricultural lands** towards forest or wet prairie habitats, as the wildlife assemblage is expected to differ between these two habitats.

Objective: Examine environmental conditions associated with establishment of young forests vs. wet prairie in abandoned agricultural land subject to flooding.

Hypotheses:

•1) Factors associated with **flooding would preclude succession** of abandoned agricultural sites **to climax forest**.

•2) **Sites closer to the river** would be subjected to greater frequency and severity of flooding and **remain in an early successional state** (i.e., wet prairie) by frequent scouring. Alternatively, sites further from the river would presumably be less affected by flooding and have the potential to succeed to early successional forest conditions.

Study Area

Seven study sites were chosen within the lower Missouri River alluvial floodplain, stretching from northwestern Missouri (near St. Joseph) to east-central Missouri (near St. Louis)(Fig. 1 and Table 1). These seven sites were located in two Fish and Wildlife Service refuges (Big Muddy National Fish and Wildlife Refuge, Squaw Creek National Wildlife Refuge), and three Missouri Department of Conservation Areas (Overton South, Eagle Bluffs, Howell Island). All sites were on public land and all except two (Swan Lake National Wildlife Refuge, Squaw Creek National Wildlife Refuge) were riverward of a levee.

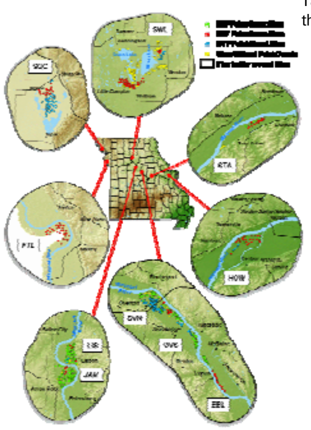


Figure 1. Study site locations along the lower Missouri River. See Table 1 for acronyms

Table 1. Study areas and sample sizes along the lower Missouri River, 2002-2004.

Study Area	*Site Acronym*	*No. of Prairie/ Forest Sites*
Jameson Island	JAM	0/44
Lisbon Bottoms	LIS	3/35
Overton Bottoms North	OVN	22/16
Overton Bottoms South	OVS	24/31
Eagle Bluffs	EBL	0/6
St Aubert Island	STA	0/4
Howell Island	HOW	4/4

Methods

We modeled factors associated with sites that were wet prairie or early successional forest as a **hierarchical Bayesian, mixed effects model** to identify key characteristics that would prove useful for predicting the potential successional direction of the lands acquired by the refuge. The form of the model was:

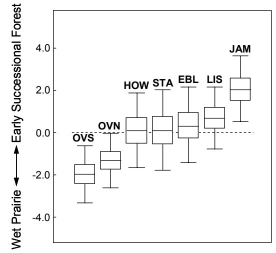
$$\text{logit}(p_{ik}) = \ln(p_{ik}/(1-p_{ik})) = \beta_0 + U_{ok} + \beta_1 x_{1i} + \ldots + \beta_j x_{ji} + \varepsilon i_{jk},$$

where $i = 1\ldots n$, β_j are the slopes for the fixed effects x_{ji}, U_{ok} is the random effect associated with k study area, and $pik = \Pr(Y_{ik} = 1)$. Diffuse or noninformative priors and hyper-priors were assigned to each parameter to represent an initial expectation of the variables on land cover class. Fitting and prediction were conducted in WinBUGS 1.4.1

Results

Study areas differed in their response to whether a site was wet prairie or forest, beyond the effects of the four environmental factors we studied (Fig. 2). Overton Bottoms North and South were predisposed to wet prairie cover whereas Jameson Island was predisposed to forest (Fig. 2); the Jameson Island result was a statistical artifact resulting from no sites occurring in wet prairie at this location.

Figure 2. **Effect of study area on the relationship between wet prairie and early successional floodplain forest**. Boxes represent the inter-quartile ranges bisected by the median study area effect; the arms extend to the 2.5% and 97.5% quantiles. See Table 1 for study area acronyms. Values on the negative side favor the formation of wet prairie whereas values on the positive side favor the creation of early successional forest.



While flood frequency occurred in the best model, it was not credibly different than zero (Fig. 3). There was a **marginal interaction of soil drainage class and elevation** (Figs. 3, 4); it appeared that **wetter, higher sites had a higher probability of occurring as wet prairie** as compared to lower, drier sites (Fig. 4). Ponded soil, or **soils wet to the surface** (Soil Drainage Class 4, Somewhat Poorly Drained soils), **were almost entirely wet prairie** rather than early successional forest (Fig. 4). Some circumspection is required for this interaction term as its credibility interval marginally bounded zero for the parameter estimate (and one for the odds ratio; Fig. 3).

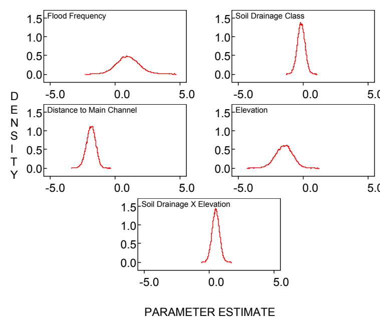
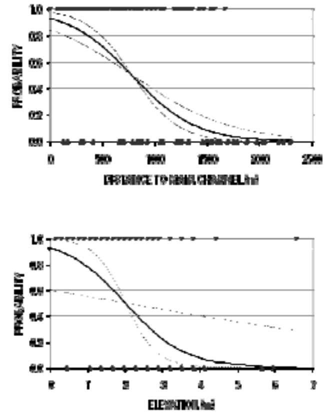
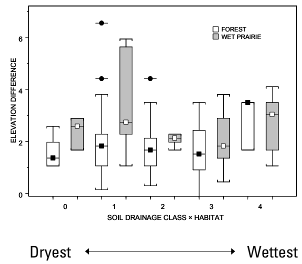


Figure 3. **Posterior marginal sample distributions** of the fixed effects describing the difference between wet prairie and early successional forest along the lower Missouri River. The magnitude, width, and location of the posterior distributions show the effect of the covariates relative to the uninformed or flat prior distribution centered at zero mean that was initially assumed for each covariate.

Figure 4. **Probability** of a lower Missouri River site **being forest** rather than wet prairie **declined with distance from the main channel and an increase in the difference between the site elevation and that of the river.** The interaction of the difference in elevation and soil drainage class (ordered from driest [0] to wettest [4]) had a marginal influence on discriminating between wet prairie and early successional forest.





The **probability of being in forest declined by 15% for every 100 m increase in distance from the main channel,** whereas the **probability of being in forest declined by ~7% for every 0.1 m increase in elevation.**

Conclusions: We found **early successional forest sites were closer to the river and on lower elevation, but occurred on drier soils than wet prairie**. In a regulated river such as the lower Missouri River, wet prairie sites are relatively isolated from the main channel as compared to early successional forest, despite occurring on relatively moister soils. Our results suggest knowledge about natural flood processes should not guide our expectations about successional fate.

Management Implications

Models can be projected onto the landscape, producing spatial predictions of potential successional fate for the agricultural lands that the refuge acquires as a result of its long-term planning process.

When coupled with information regarding the composition of the wildlife community associated with wet prairie and young forest habitat, the ecological value of these land purchases can be elucidated.

In a science-based management framework, such information is essential for efficient stewardship.

Acknowledgments

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