A Resource Recovering Landscape for Sustainable Bioenergy

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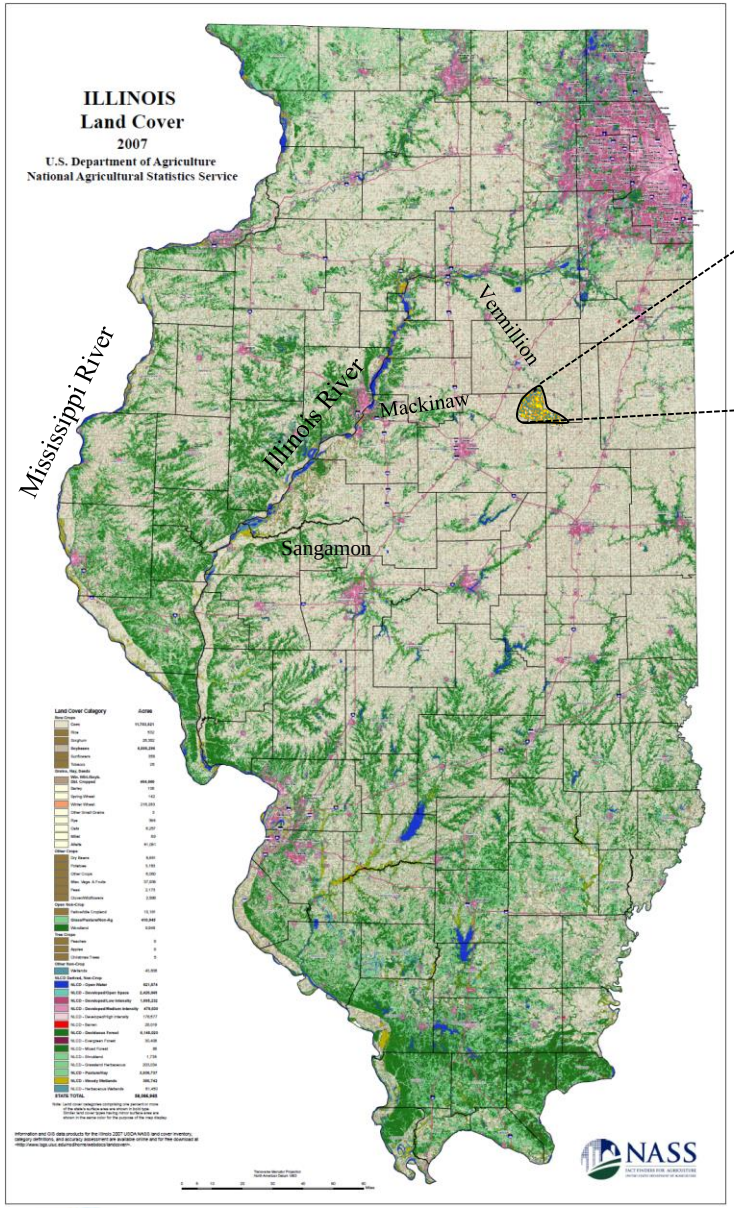
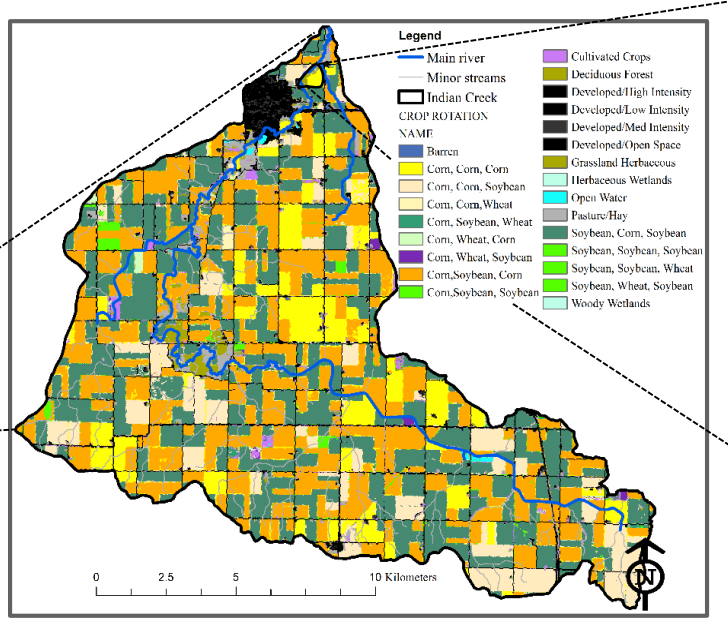
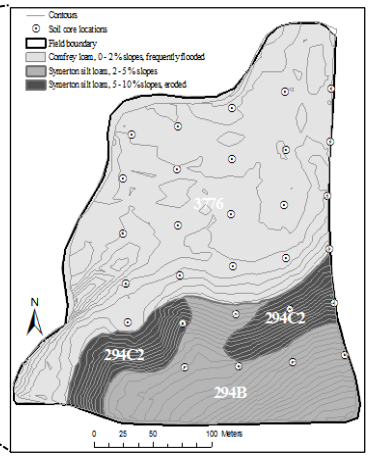
Rethinking the Agricultural Landscape





Indian Creek watershed, IL

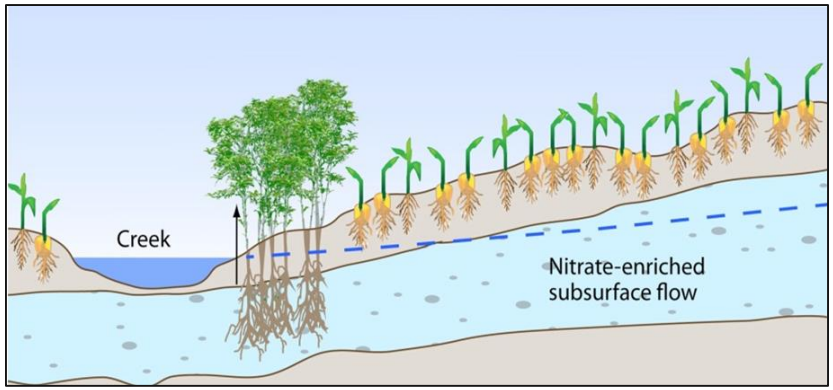


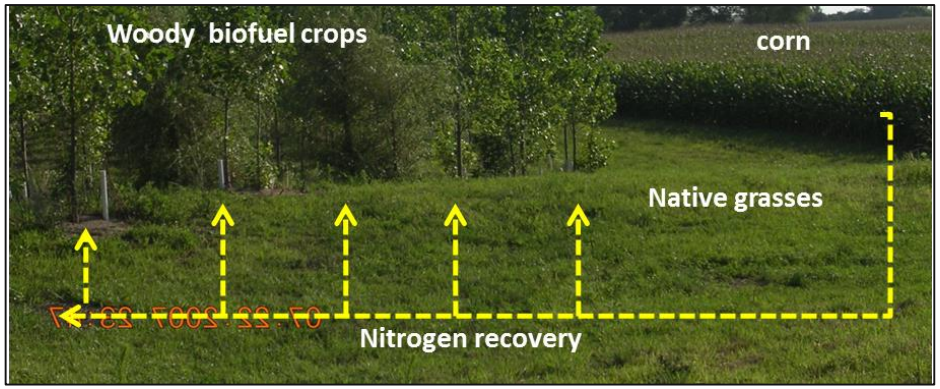
Fairbury site, IL

Designing the agricultural landscape to address multiple goals:

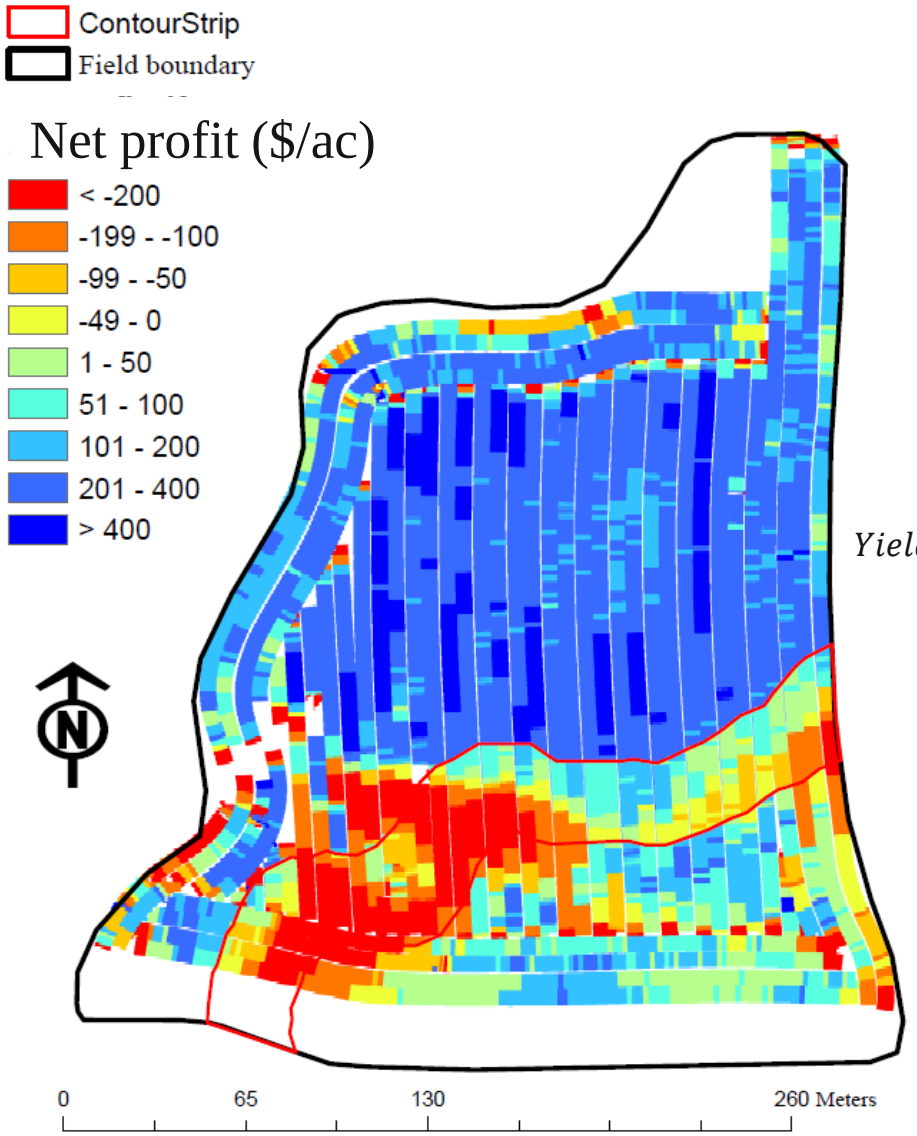
	Business as Usual (BAU)	Landscape Design
Provisioning Services	Yields, profit	Optimize yields of food, feed, fiber, bioenergy, bioproducts
Regulating Services	Not factored in the economics, called externalities	Water quality, habitat, C sequestration, GHG reduction, flood control, etc. are part of the design. Economic models accounts for both
Conceptual Focus	How to mitigate the impacts retroactively	Focuses beyond mitigating impacts, on “how to design” so that all services are incorporated and desirable externalities are obtained

Bioenergy Crop integration at the field scale: Nutrient Recovery





Spatial variability of net profits



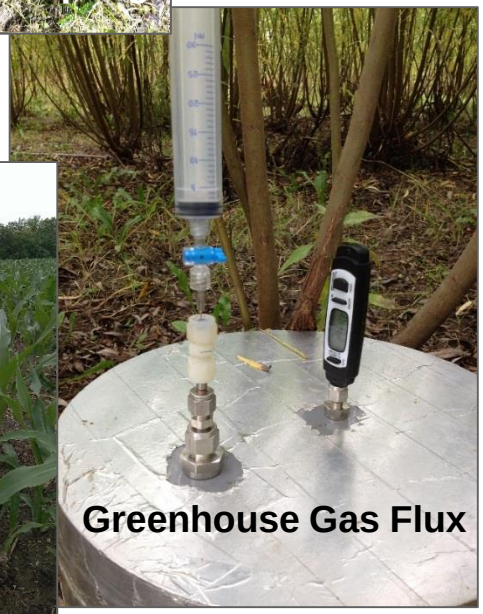
Net profit ($/acre)

$$Yield\left[\frac{bushel}{acre}\right] \times Corn\ price\left[\frac{\$}{bushel}\right] - Non_land\ costs\left[\frac{\$}{acre}\right] - Cash\ rent\left[\frac{\$}{acre}\right]$$

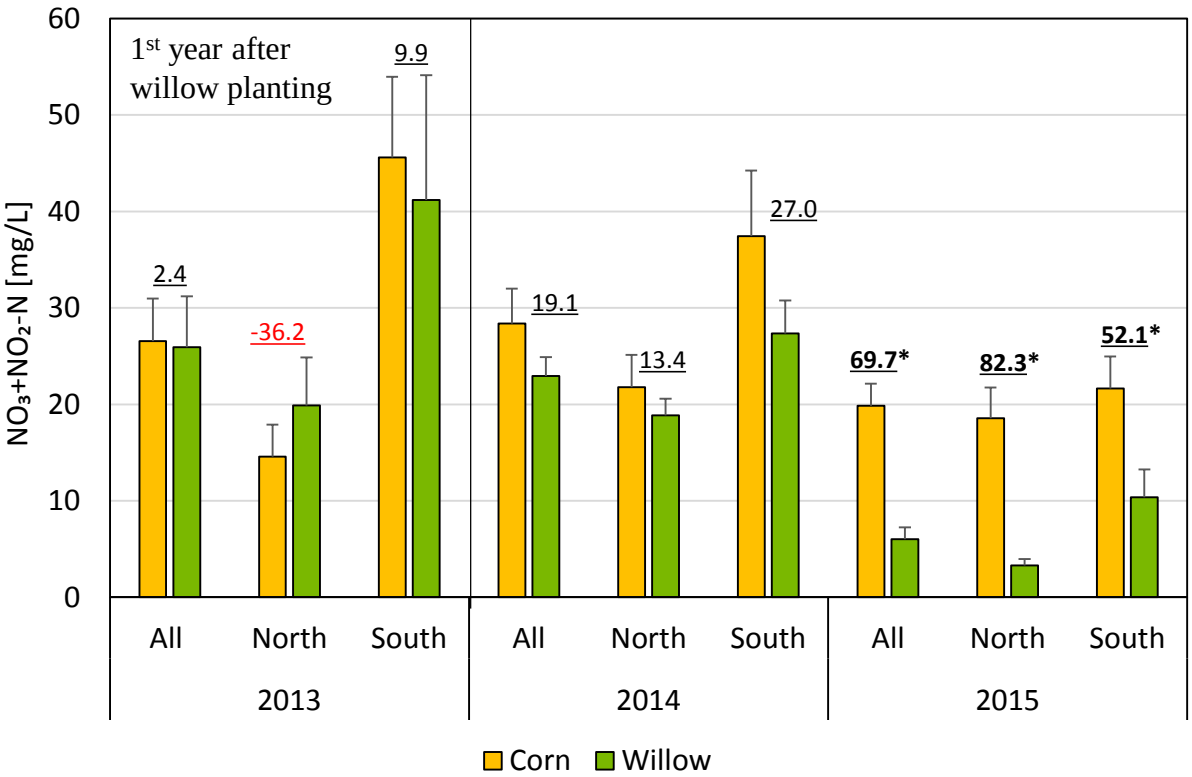
AVG ($/acre) = 153

STD ($/acre) = 230

Field-Scale Monitoring

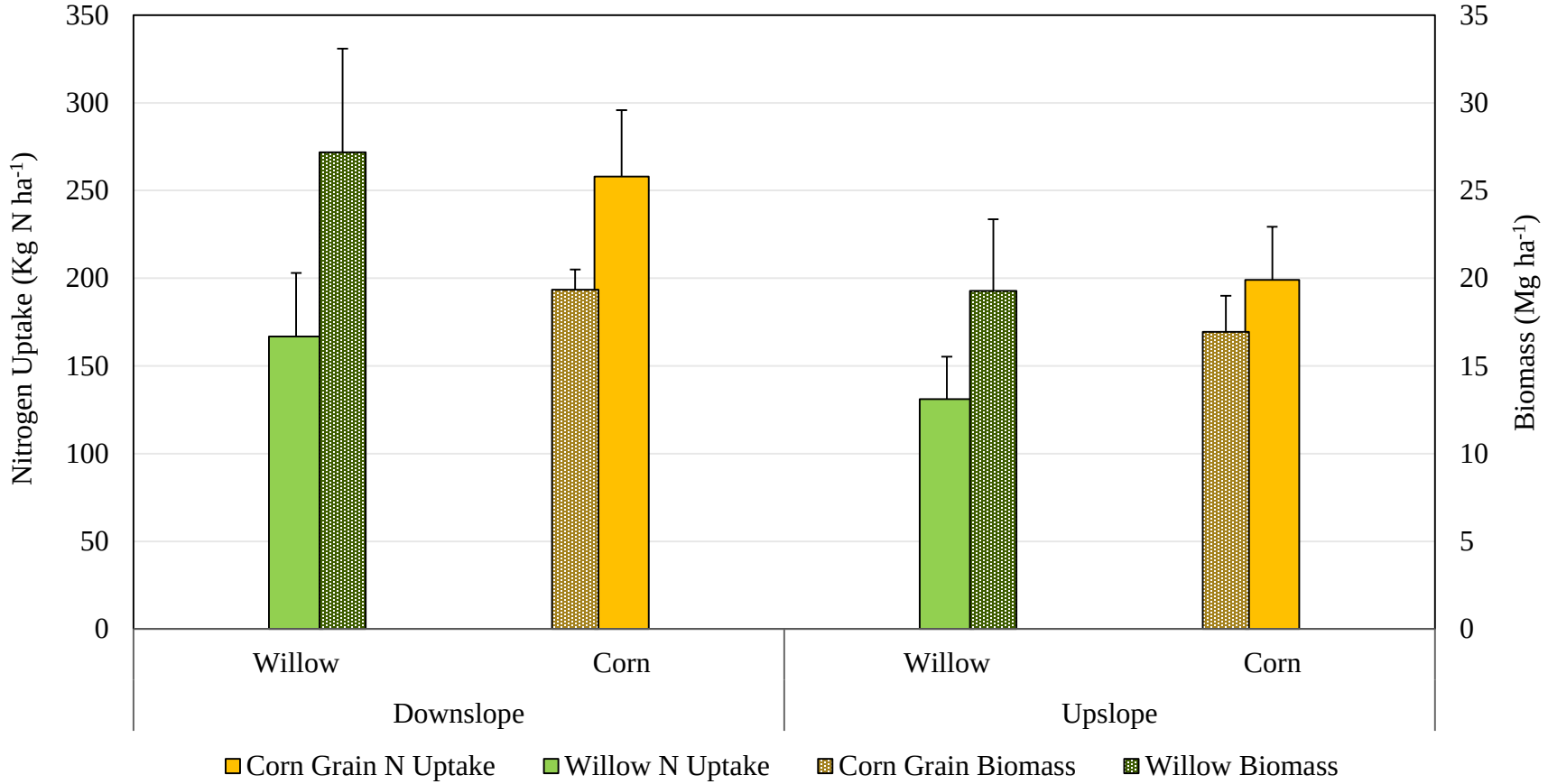


Nitrogen Reduction



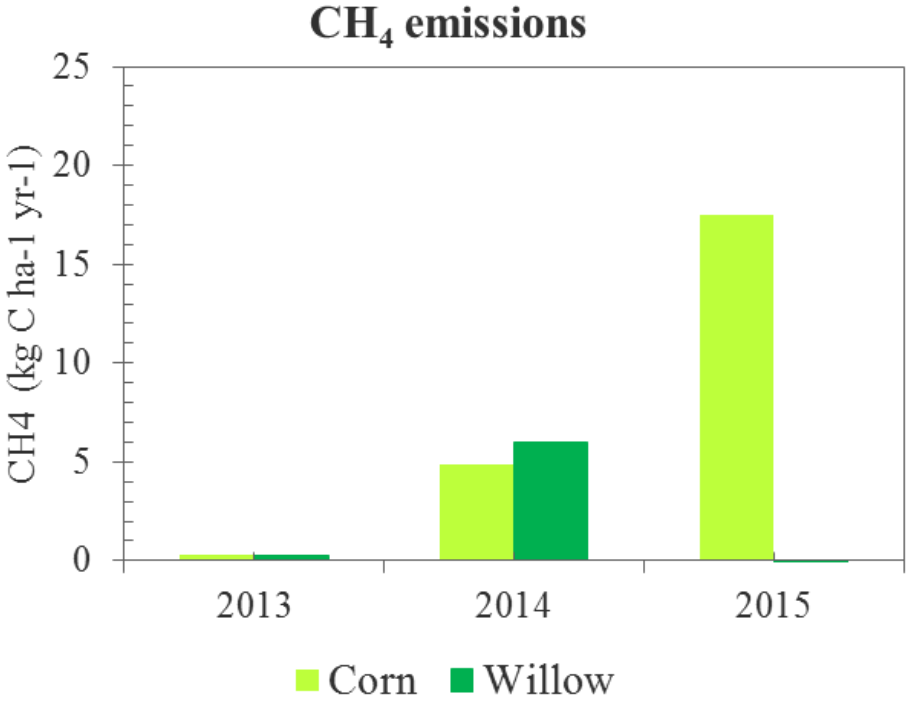
2013-2015 Mean NO_3+NO_2-N concentrations in soil water under different crop covers and soil conditions. Reductions in nitrate under willow crop cover is shown. Asterisk indicates significant difference between crop covers

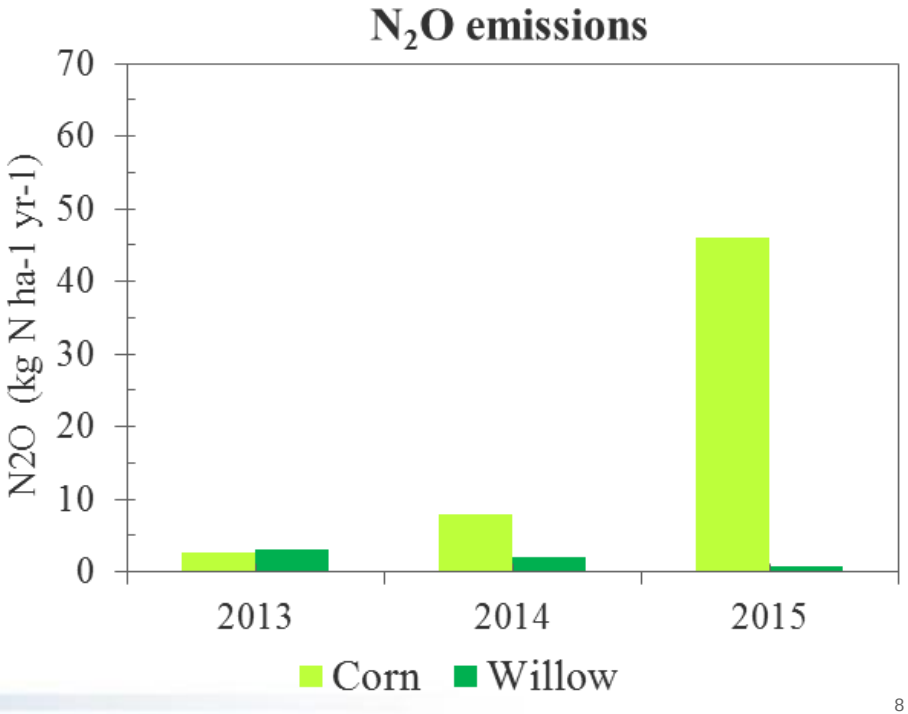
In-situ Recovery of Nitrogen: Fertilizer Leachate from Corn Application



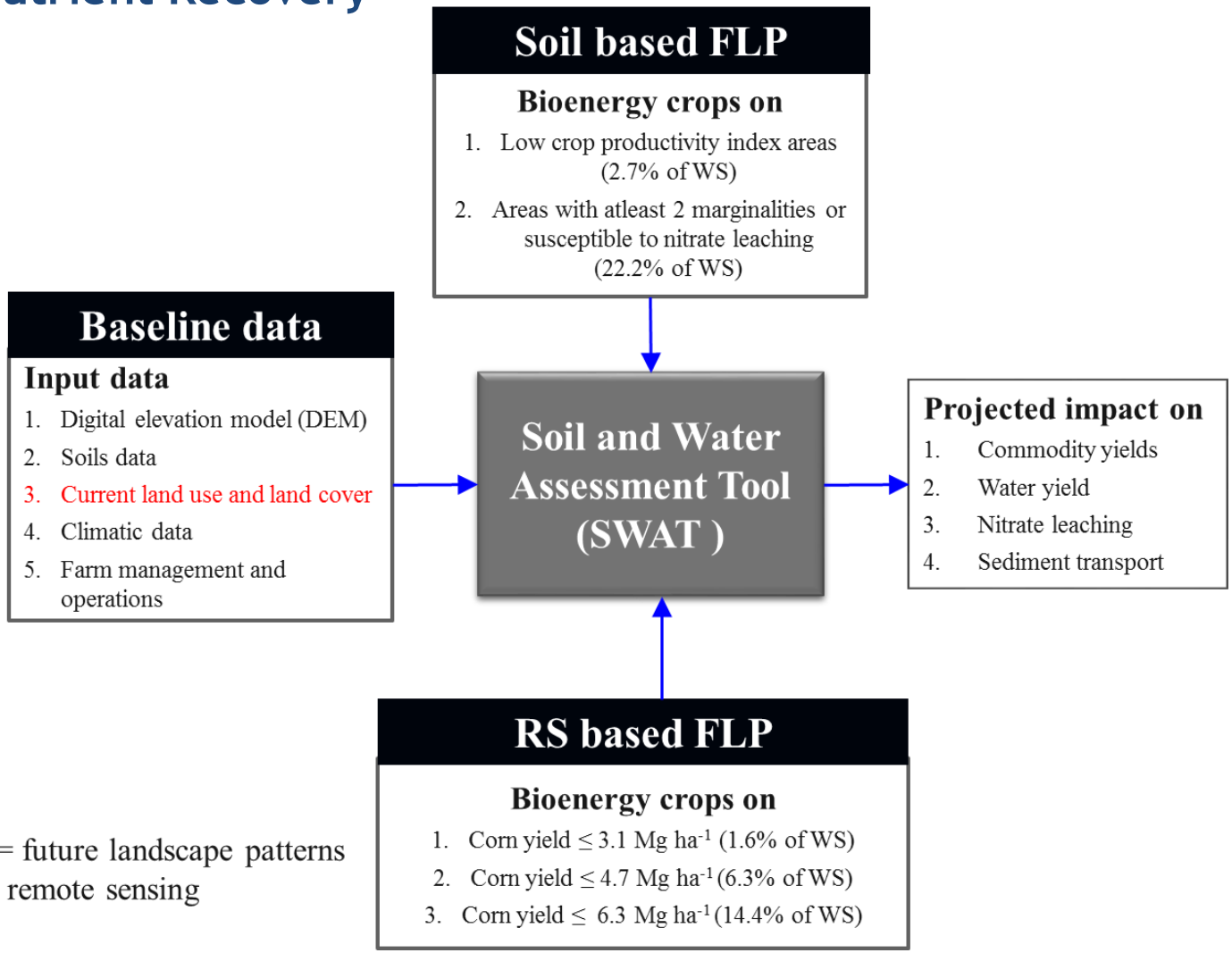
End of the 2015 growing season, average nitrogen uptake by harvestable biomass (corn grain, willow branches) with standard error.

Greenhouse Gas Emissions



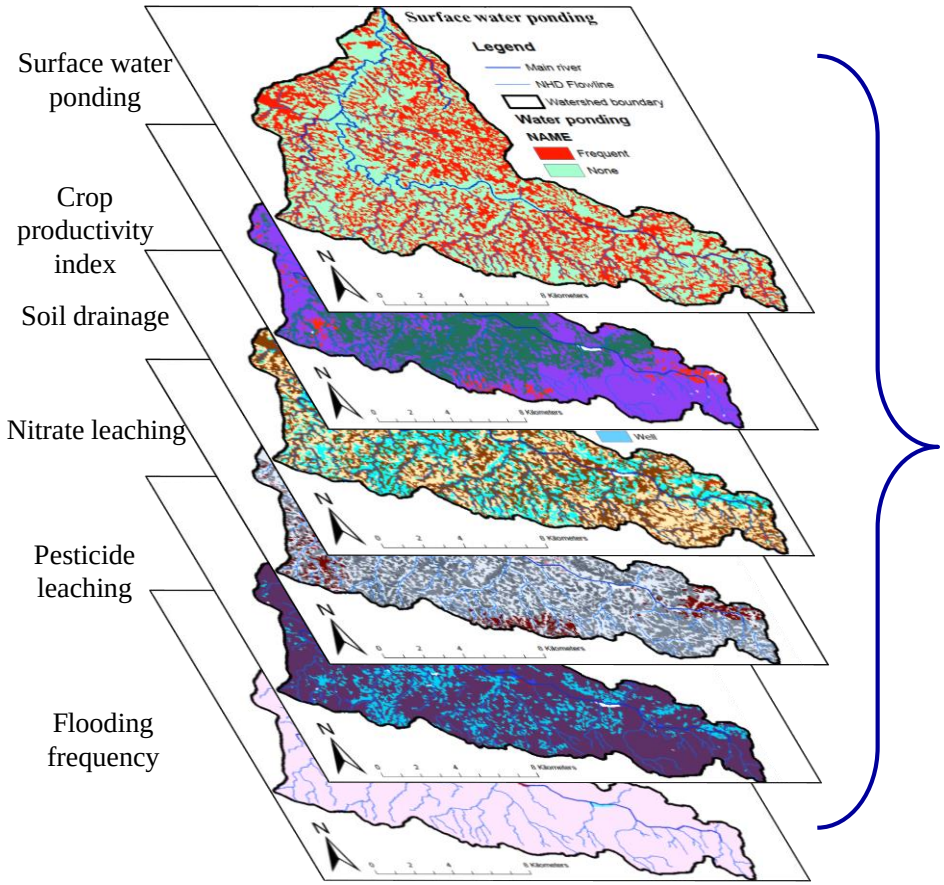


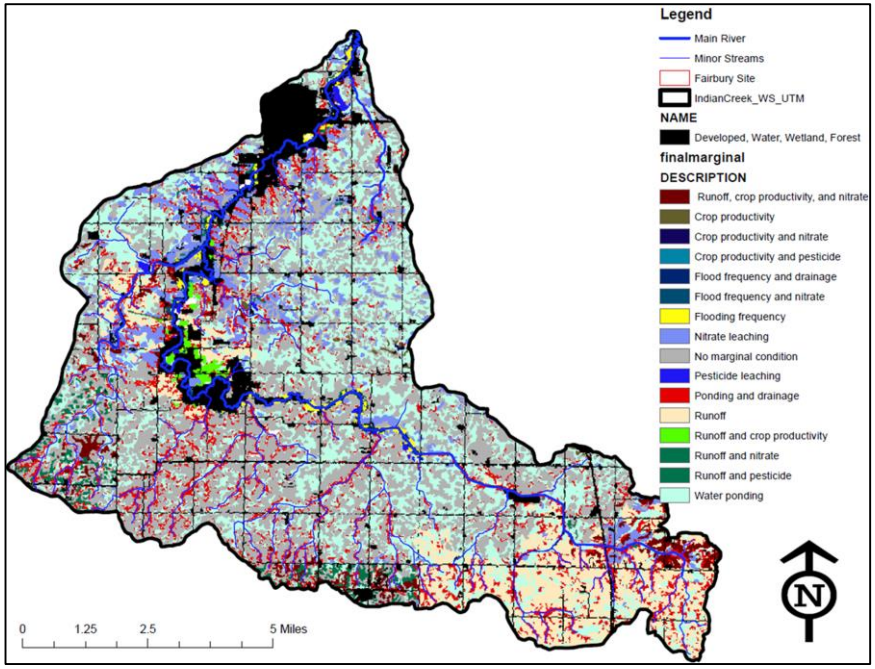
Bioenergy Crop Integration at the Watershed Scale: Nutrient Recovery



FLP = future landscape patterns
RS = remote sensing

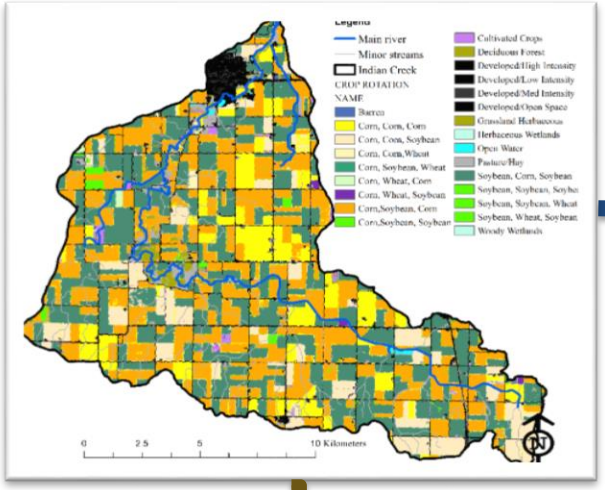
Marginal classification using SSURGO data





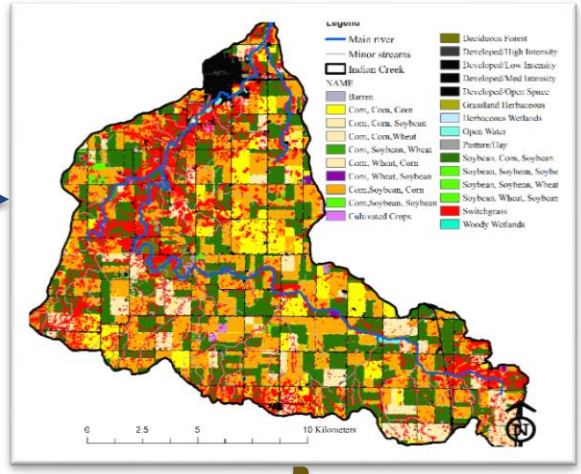
Watershed Design for Ecosystem Services on “marginal land”

Current land use

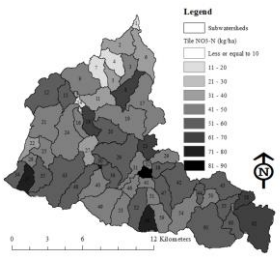


Watershed landscape designs that improve water quality also seem to improve pollinator nesting index (InVEST model)

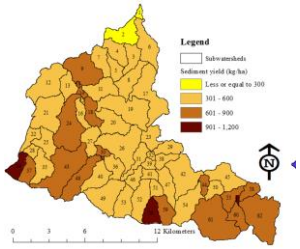
Design including bioenergy and water quality



Tile- nitrate leachate

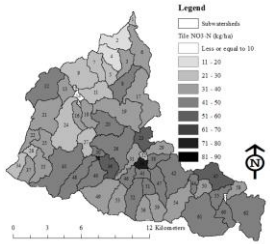


Sediment yield

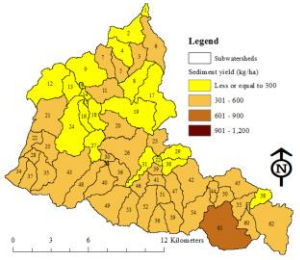


Pollinator nesting index

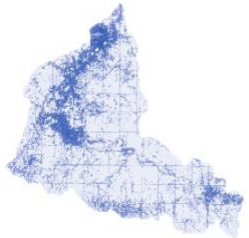
Tile- nitrate leachate



Sediment yield

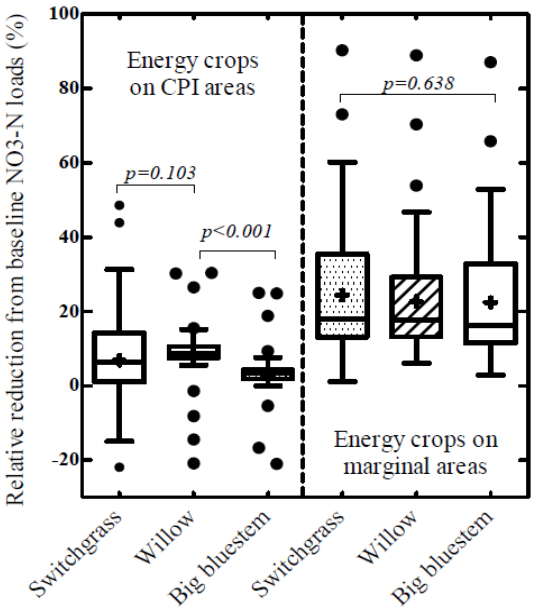


Pollinator nesting index

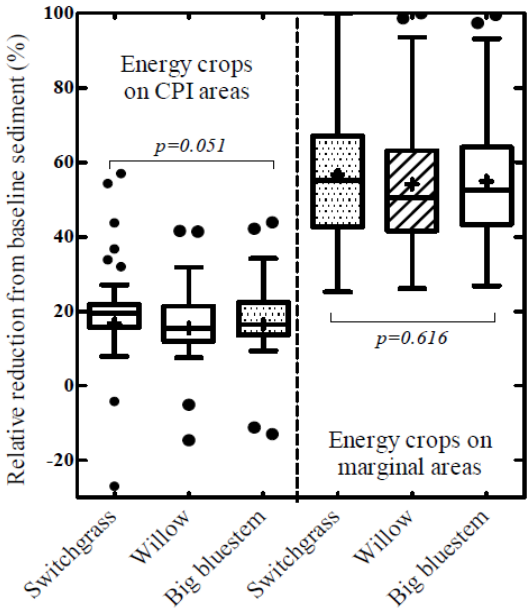


Results of Soil Data Based Analysis

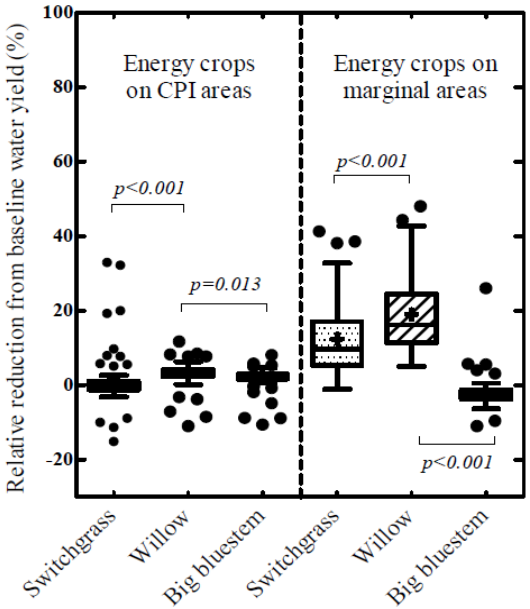
NO_3-N reduction (%)



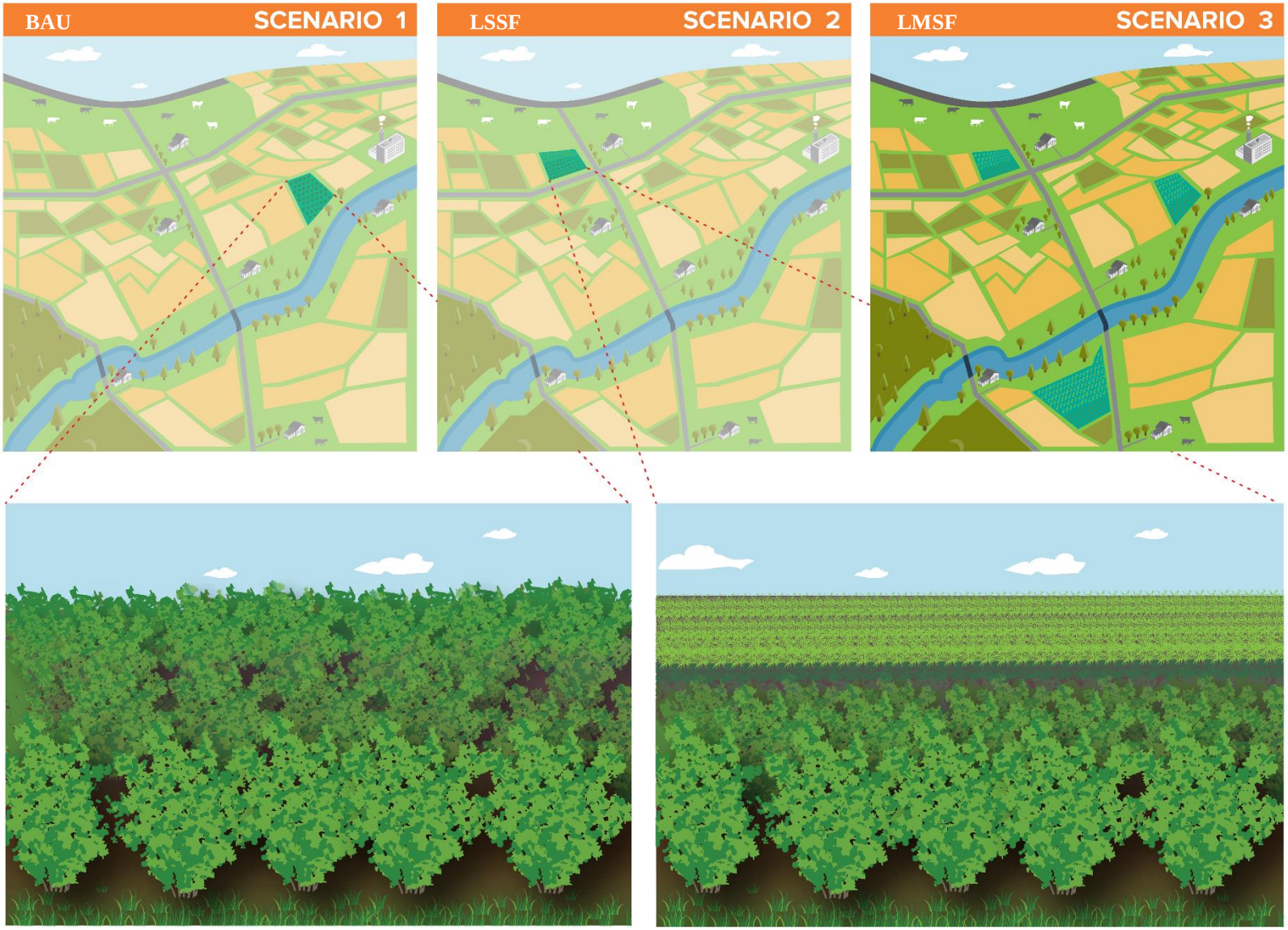
Sediment reduction (%)



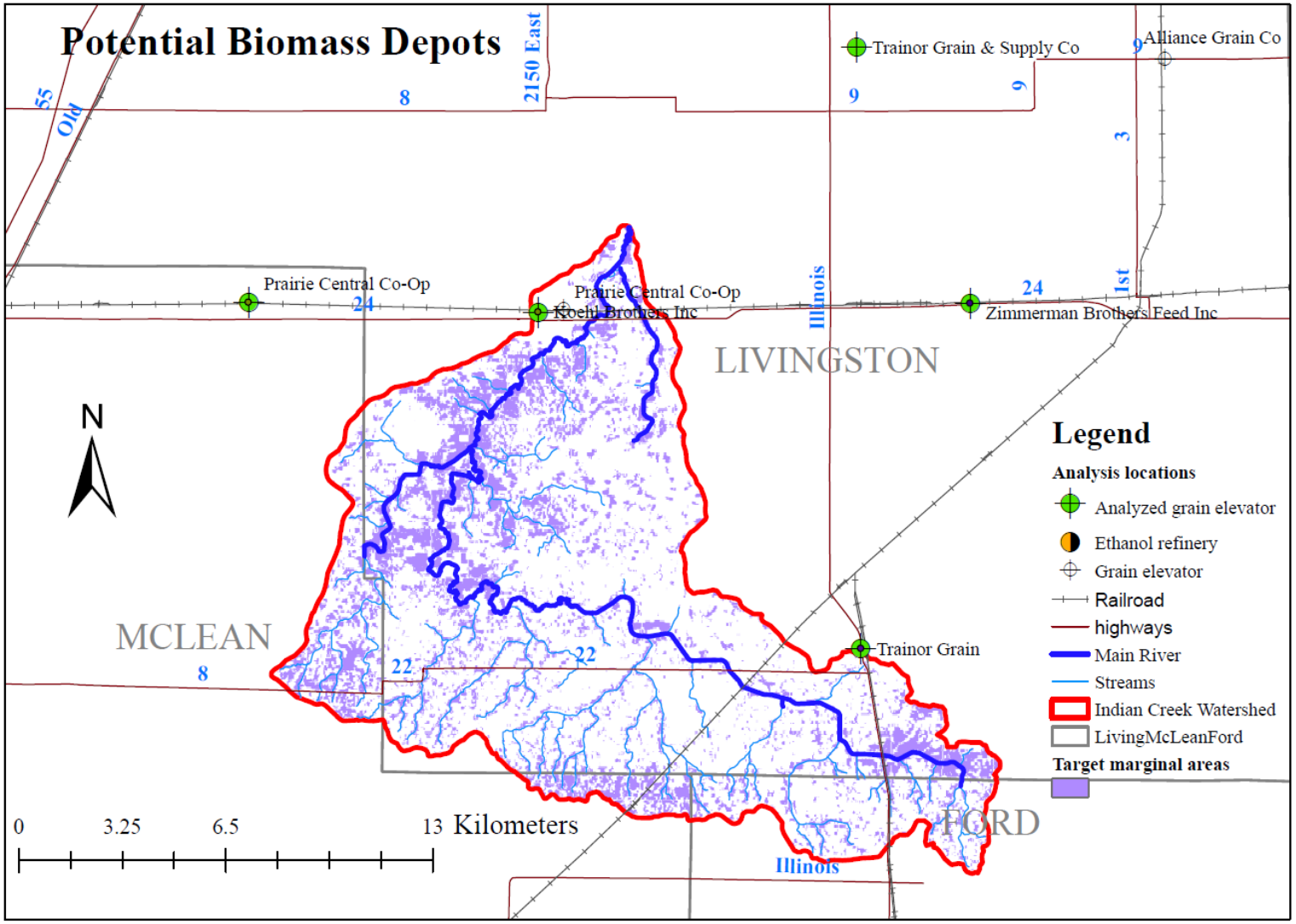
Water yield reduction (%)



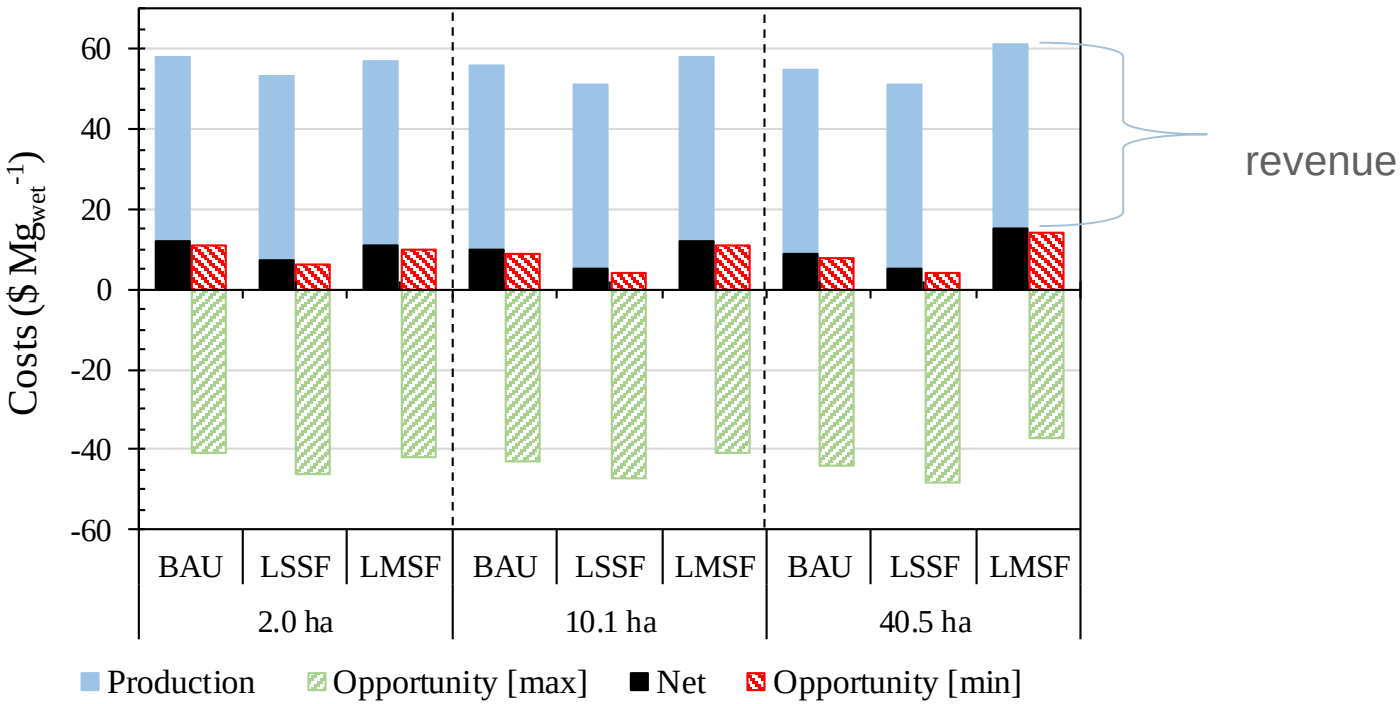
Landscape Design: Economic Analysis



Marginal subfields locations within the watershed



Comparison of production, net, and opportunity costs (to depot)



Comparison of production, net, and opportunity costs of willow under business as usual (BAU) and two landscape scenarios(LSSF: single subfield and LMSF: multiple subfields) across three production scales (2.0, 10.1, and 40.5 ha). Net costs are differences between production costs and revenue from sale of biomass. Opportunity costs are costs of growing willow instead of growing corn (willow revenue – corn revenue) on the same marginal land. Maximum and minimum reflect variability in corn yields on marginal land.

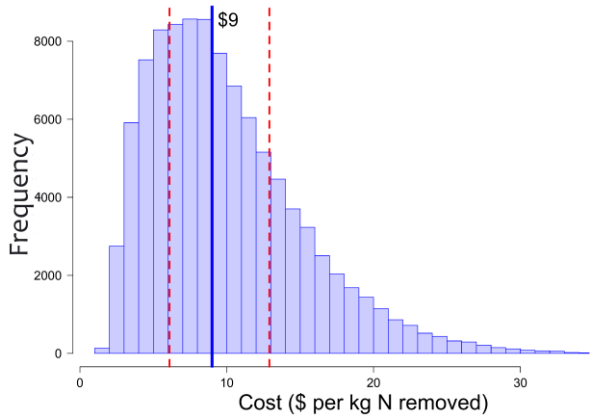
Lifecycle cost distribution

Life Cycle Costs	Case 1					Case 2					Case 3				
	BAU		Landscape: single subfield		Landscape: multiple subfield	BAU		Landscape: single subfield		Landscape: multiple subfield	BAU		Landscape: single subfield		Landscape: multiple subfield
	Min (%)	Max (%)	Min (%)	Max (%)	Most Likely (%)	Min (%)	Max (%)	Min (%)	Max (%)	Most Likely (%)	Min (%)	Max (%)	Min (%)	Max (%)	Most Likely (%)
Land Costs	55	54	57	56	52	57	55	59	57	51	58	56	59	58	48
Admin.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Establishment	11	10	11	10	10	10	10	10	10	9	10	10	10	10	9
Fertilizer	2	2	0	0	0	2	2	0	0	0	2	2	0	0	0
Harvest	21	20	21	21	25	21	20	21	21	25	19	19	20	19	22
Transport	6	9	6	8	8	4	7	5	8	10	5	7	5	7	16
Stock Removal	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Total	**100%**														

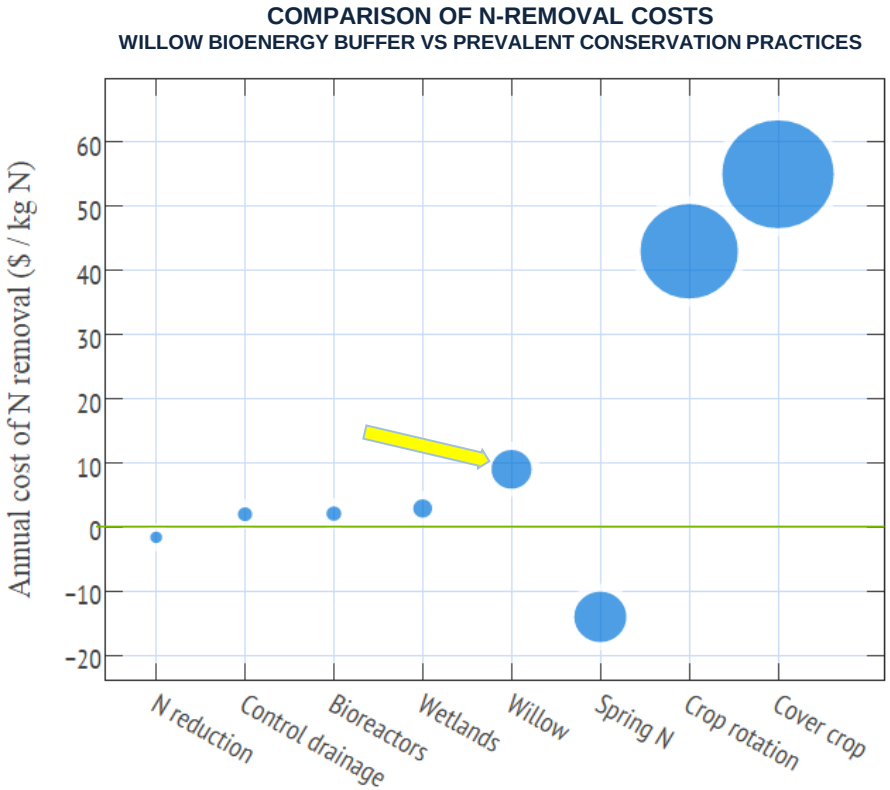
Estimated Cost of removing 1 kg N using willows in landscape positions – comparing with other conservation practices

Costs vary based on:

- N removal % [range from literature 40-80%]
- fertilizer use/headland [net revenues from Ecowillow]
- transport distance between depot and subfields: [net revenues from Ecowillow]
- Nitrate leachate [range from literature: 20-50 kg N/ ha]
- Assumes for now local distributed biomass use (no biorefinery)
  - Min: $1.80
  - Max: $37.00
  - Mean: $9.00
  - STD: $1.70
  - 25% percentile $6.00
  - 75% percentile $13.00



Cost N removed = Revenue/leachate loading * reduction %



[Christianson et al., 2013]

THE FARMER'S PERSPECTIVE

Questions?