Remotely-sensed Urban Wet-landscapes: An Indicator of Coupled Effects of Human Impact and Climate Change

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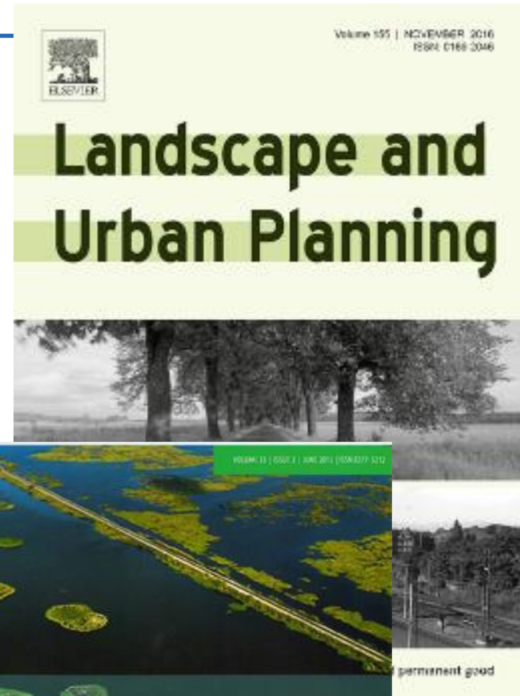
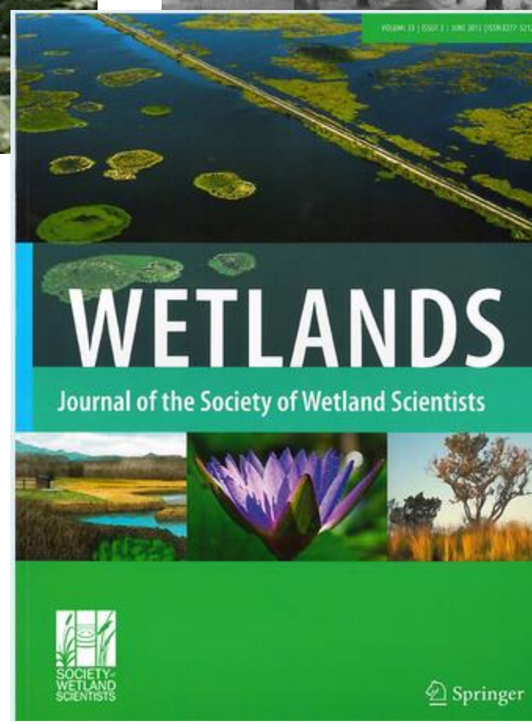
My recent research interests:
Geospatial methods for assessing wetlands and urban landscape changes





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Project History and Acknowledgements

- This study was conducted in the Kansas City metropolitan area
- The remote sensing of land cover changes in this area spanned over four decades from 1972 through 2010.
- The first stage focused on detection of long-term trends of urban land cover change from 1972 through 2001 (US EPA MM98705401 and MM98735701)
- The second stage examined how to detect the coupled effects of human impact and climate change on urban landscapes (US EPA CD 97701501)
- K. Underhill, J. Ma, D. Murambadoro, and X. Xu worked on the projects as part of their dissertation or thesis research.

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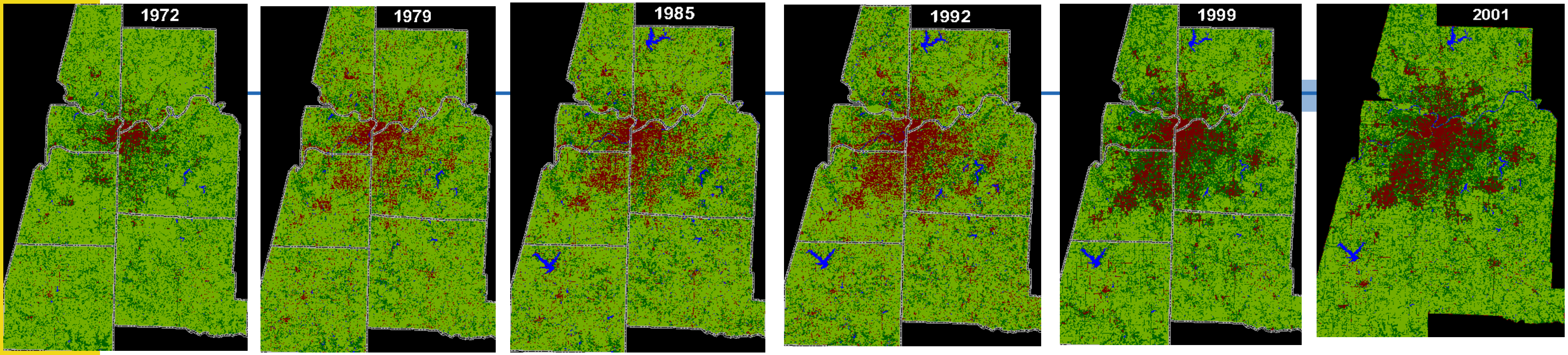
Kansas City area experienced significant urban sprawl in recent decades



Metro Area	1972	1979	1985	1992	1999	2001
Built-up	8.65%	10.38%	12.03%	15.41%	18.69%	19.19%
Forest	16.36%	16.44%	16.81%	16.58%	16.71%	17.36%
Non-Forest	73.93%	71.96%	69.06%	66.03%	62.70%	61.24%
Surface water	1.05%	1.22%	2.10%	1.99%	1.90%	2.21%

(1) Have human activities and precipitation variation jointly impacted surface water cover?

(2) How can we detect such coupled impacts through remote sensing analysis?

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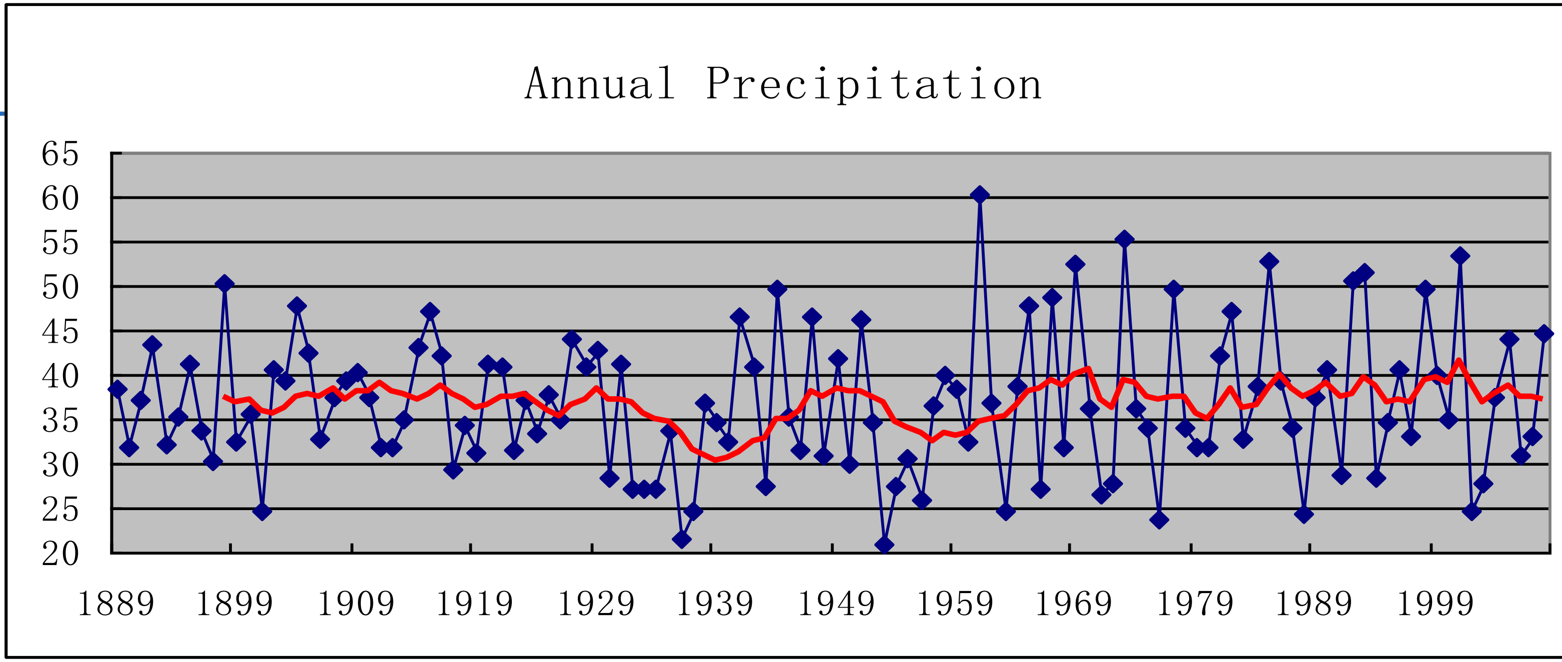

According to US EPA (1997; 1998), both Missouri and Kansas states have seen 10-20 % increase of precipitation in the recent decades

Recent observations and studies indicate that in many metropolitan areas, urban landscapes might have been shaped by climate impacts (e.g. precipitation variation) (Ji and Murambadoro 2010; Kaplan 2012; Mezösi et al. 2013; Mitsch and Hernandez 2013).

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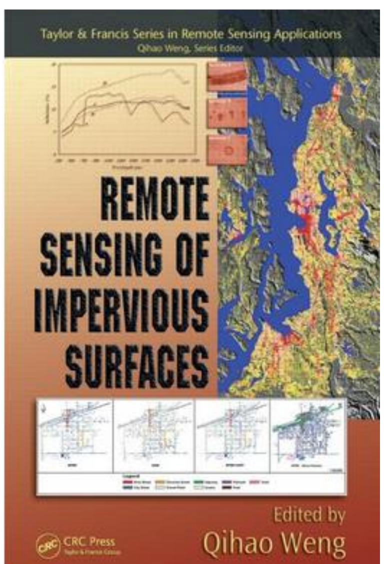
Reconsider indicators for urban remote sensing: “**Dryscape**” vs. “**Wetscape**”?

Built-up lands – impervious surfaces (Dry-landscapes or “Dryscape”)

Urban surface waters or loosely-defined **wetlands** (Wet-landscapes or “Wetscape”)



Major drivers of urban land transformation: **human impact** and **climate change** (e.g. precipitation)

“Dryscape” is a good indicator of human impacts but **less effective** to represent climate (e.g. precipitation) change

Is “Wetscape” an effective indicator of **the coupled effects** of human disturbance and climate impact?

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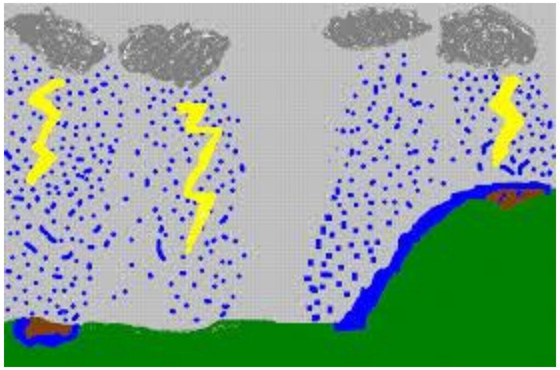
Wetscape indicator for linking two driving forces of urban land transformation: a new understanding of urbanization process in relation to climate change



Human activities

Precipitation change

Research Objectives	Research Challenges	Research Approaches
Verify the effectiveness of the wetscape indicator through remote sensing analysis	Must be able to detect fine-scale wetlands that traditional image classification methods cannot do	Develop a knowledge-based image classification algorithm on urban wetland detection
Develop a new understanding of urban landscape change based on the wetscape indicator	Must be able to analyze the wetscape change in relation to human activities at various scales	Across spatial & temporal scales in wetscape analysis
	Must be able to link wetscape indicator change to precipitation variation in analysis	Analyze size effects of wetscapes
		Analyze long-term precipitation trend

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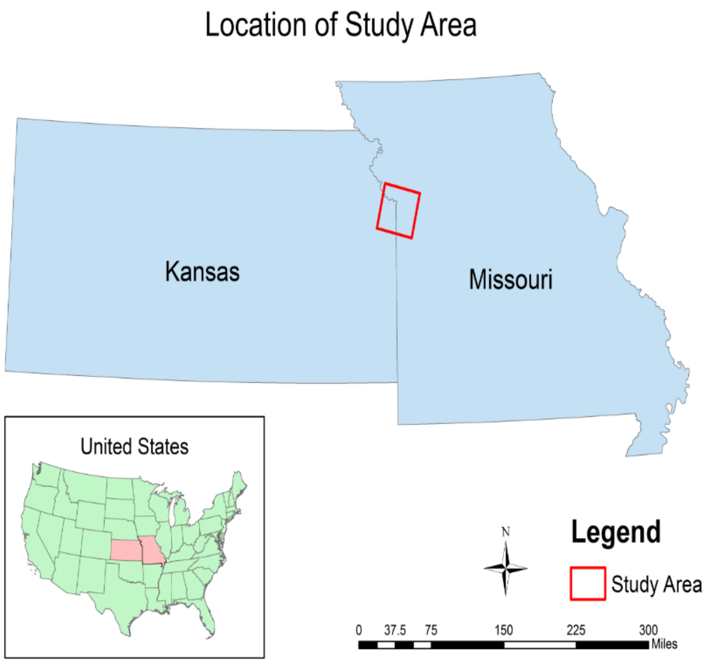
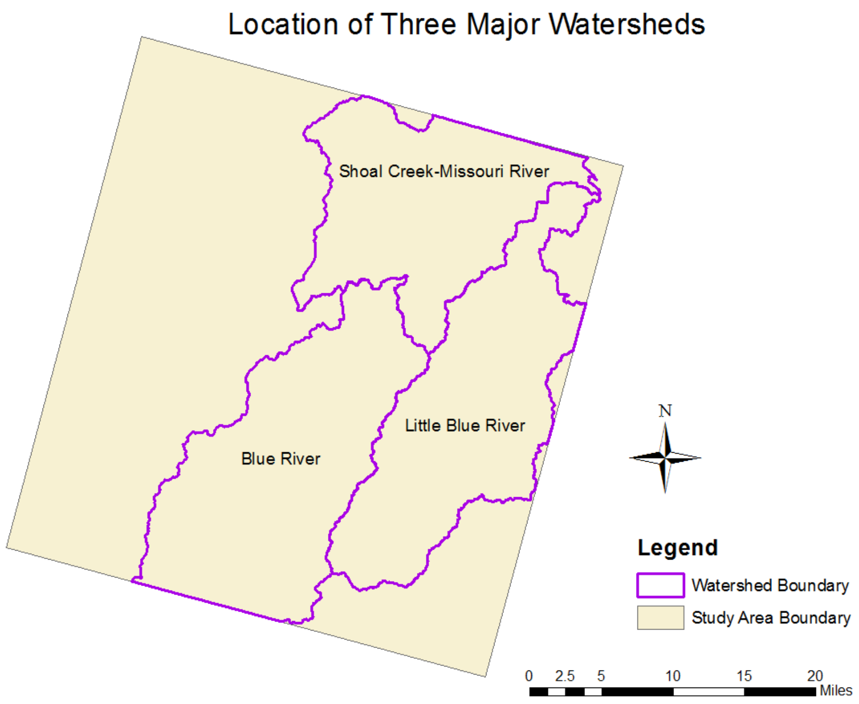
Study Area

- The Kansas City metropolitan area





Methodology: General Procedures

(1) Conduct traditional supervised classifications (base maps):

- Wetlands
- Farmland/grassland
- Impervious surface
- Forestland

(2) Create a knowledge base

(3) Conduct the knowledge-based classifications to fine-tune wetland features of the base maps

(4) Verify the effectiveness of new method by quantitative comparison

(5) Analyze urban wetscape dynamics in relation to driving forces

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Data used (examples)

Data	Description
SPOT -2 images	(band 1-3) 1992, 20m spatial resolution
SPOT -5 images	(band 1-4) 2008 and 2010, 10m spatial resolution
Historical images	Base maps for accuracy assessment
Watershed boundaries	Determine the boundaries of sub study areas
Agricultural field polygons	Photo-interpreted – unique for all years
River polylines	As the background for river wetland
Land cover classification	Via maximum likelihood (ML) algorithm; served as baseline classification
Digital elevation model	Resolution =3m for XY and =around 0.1m for Z
Slope model	Calculated from DEM
NDVI	Calculated from satellite imagery
Hydric soil surface	Indicator of potential wetlands
Wetland vegetation	Distribution and density of comprehensive wetland vegetation

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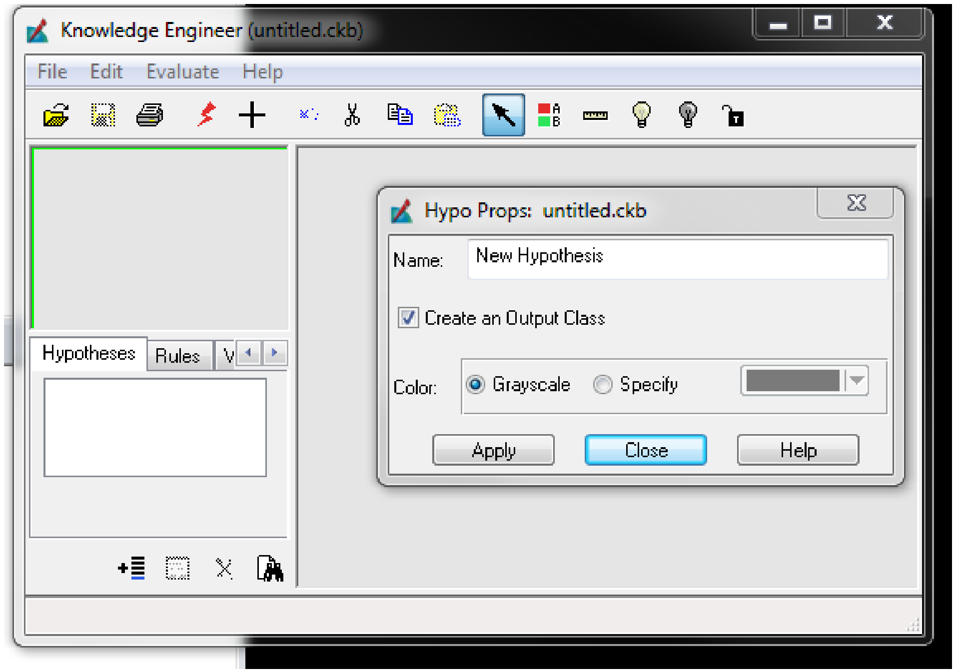
Methodology: Creating Knowledge Base

- Use the ERDAS IMAGINE **Knowledge Engineer** software to create the knowledge base
- In this process, two "hypotheses" have been set to indicate two urban wetland types:
  - Open wetlands
  - Vegetated wetlands



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Methodology: Creating Knowledge Base

- Variables used in the knowledge base

Property	Variables	Description
Terrain	Elevation	Urban wetlands are typically located in low-lying places
	Slope	Help define the concentration of urban waters
Spatial adjacencies	Distance from River	Veg. wetlands are typically not far away from large water bodies
	Distance from impervious surface	Open wetlands are typically kept in distance from artificial constructions
Habitat conditions	NDVI	The NDVI of wetlands are usually lower than other urban features
	Wetland Vegetation	The distribution and density of wetland vegetation can help define the urban wetlands
Hydrogeomor-phological characteristics	Ag. Polygon Surface	Agricultural lands are typically formed as regular polygons, while wetlands are not
	Hydric Soil Surface	Help define the potential locations of urban wetlands
	Area	Open wetlands are typically larger than a specific size value
Relevant geostatistics	ML Class	Classified by using maximum likelihood (ML) algorithm and are kept intact

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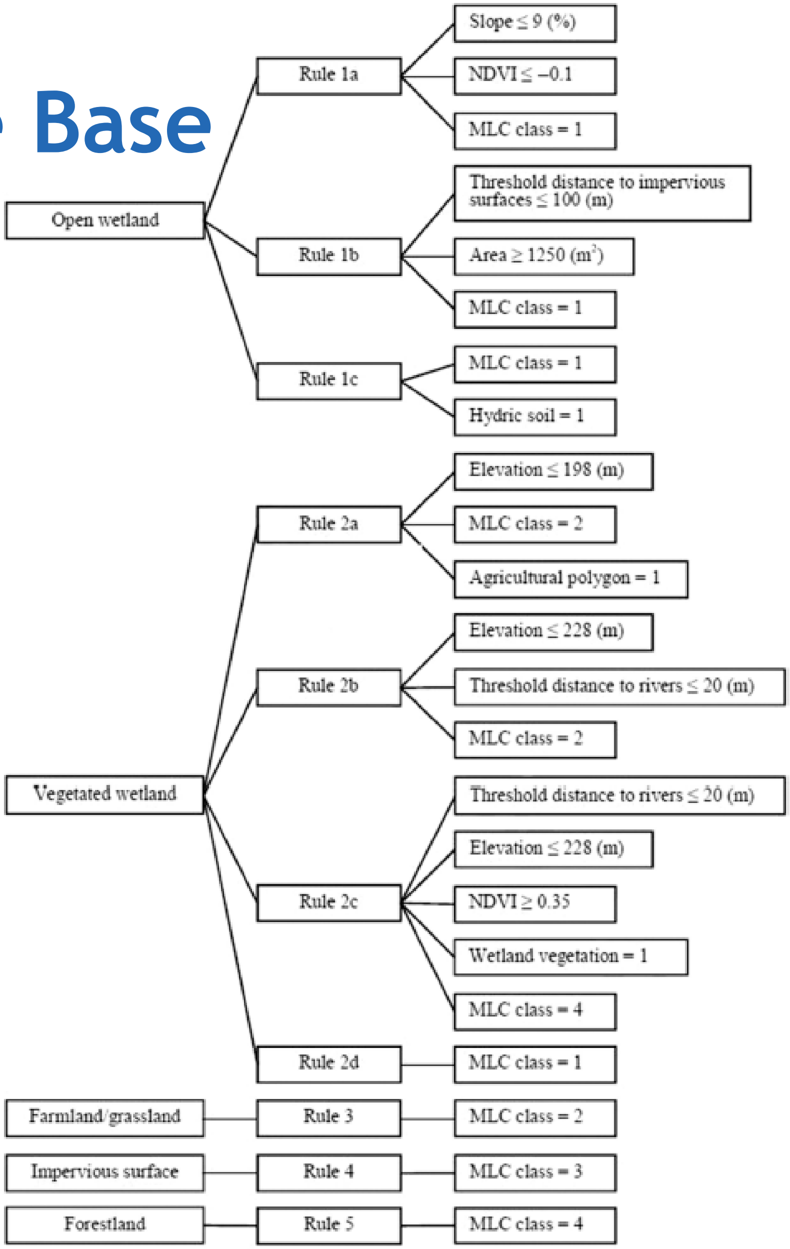
Creating Knowledge Base

- Decision tree for knowledge-based classification of wetlands



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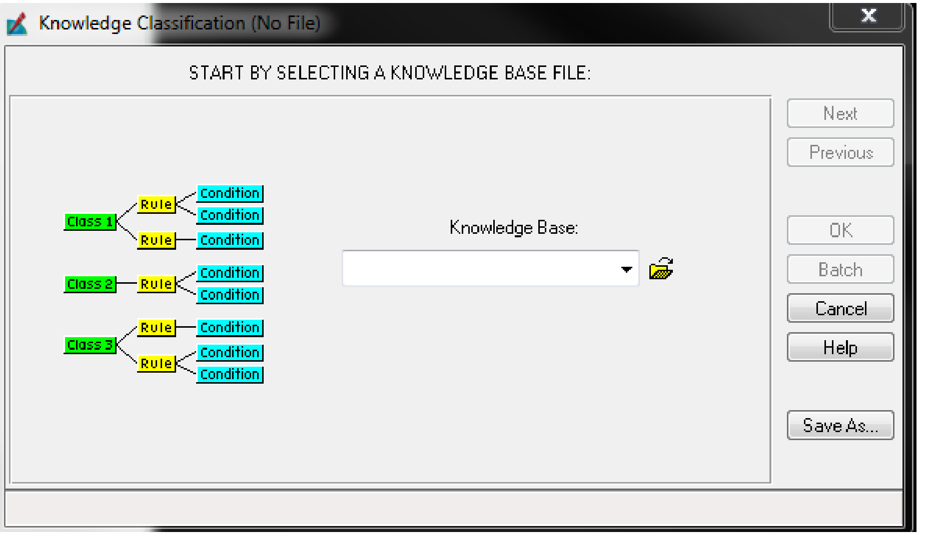
Methodology: Knowledge-based Classification

- After the knowledge bases have been created, the **Knowledge Classifier** applies the knowledge base to the base maps to re-map wetlands



- Three other land covers created by the traditional classification were kept intact in the knowledge-based classification:
  - Farmland/grassland
  - Impervious surface
  - Forestland

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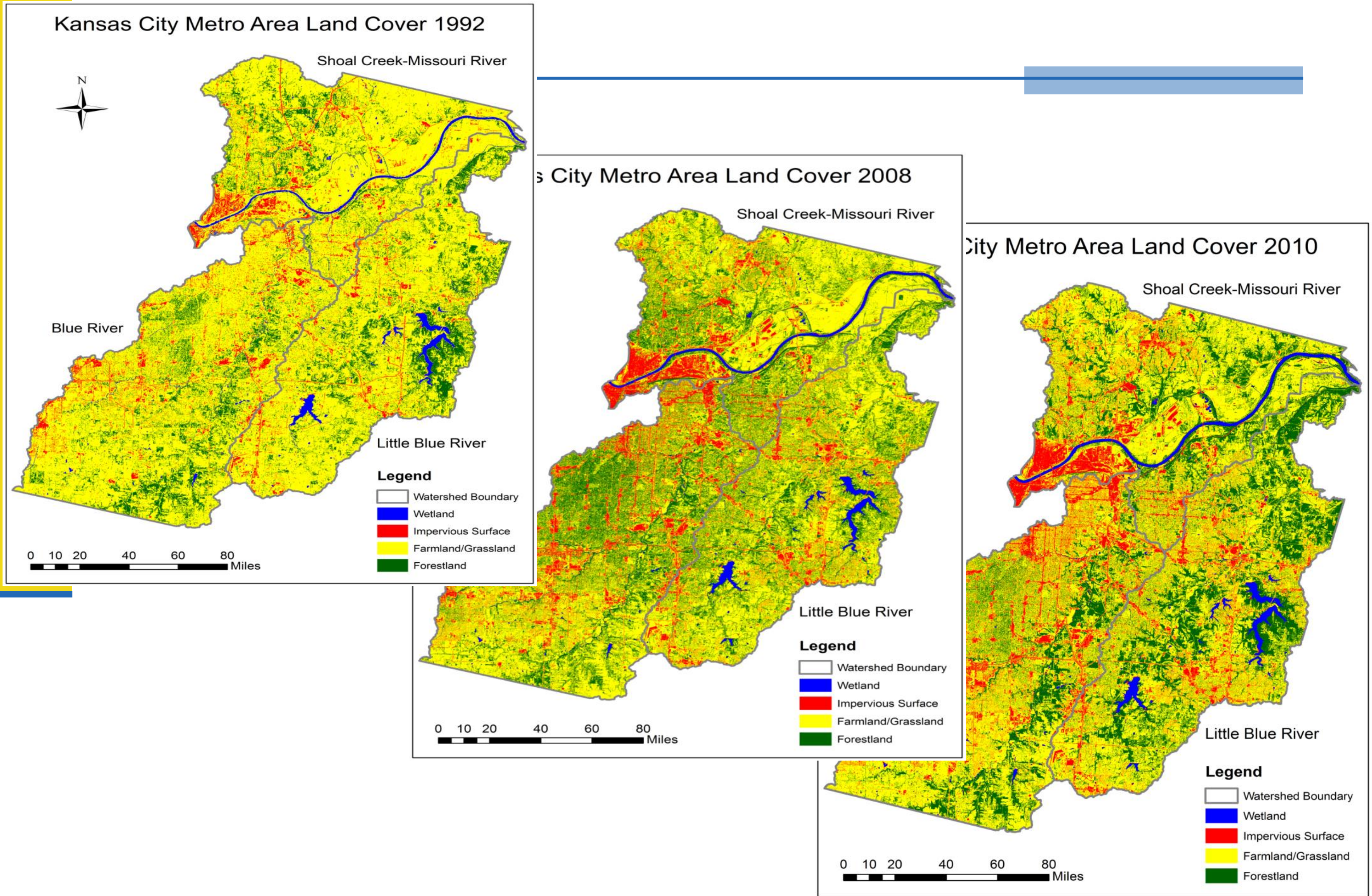
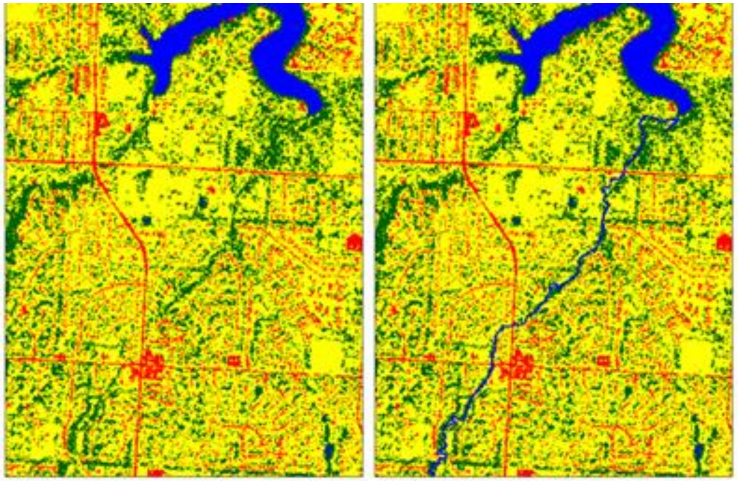
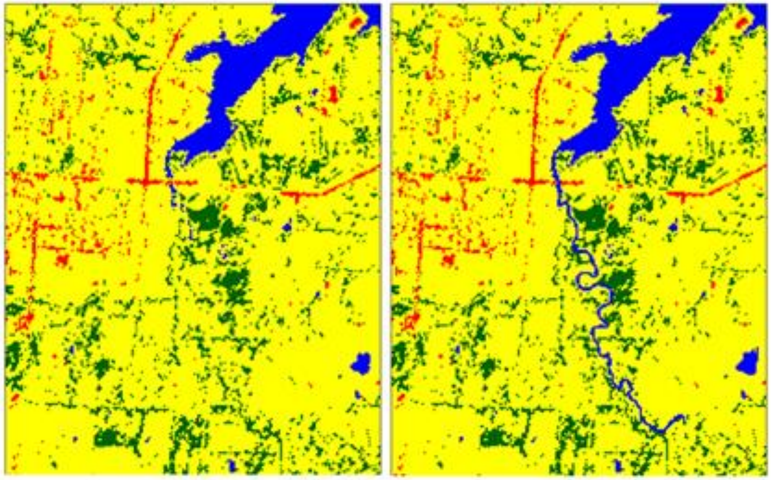
Classification Results



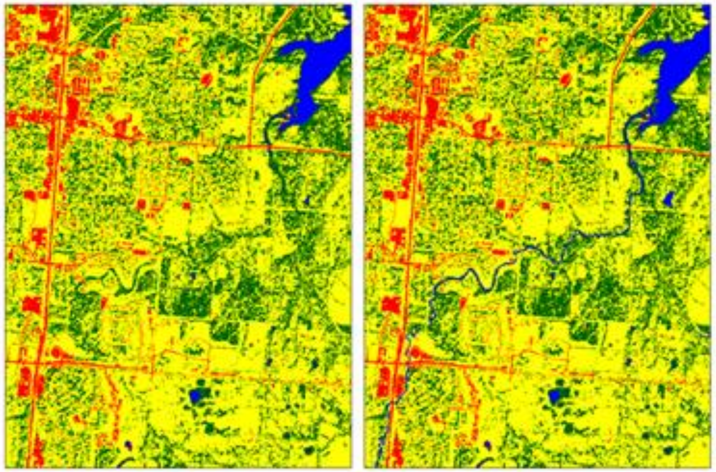
Improved Detection



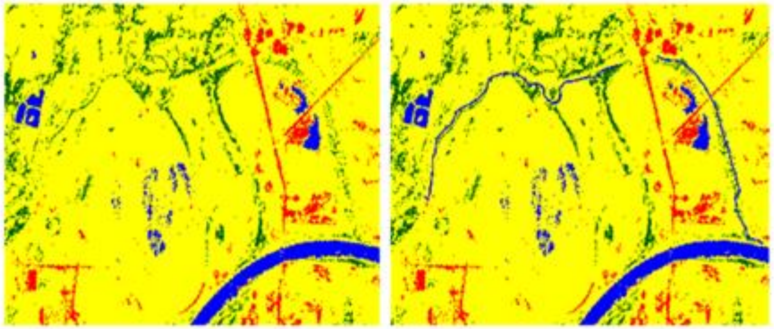
East Fork Little Blue River, Little Blue River Watersheds 2008



Lumpkins Fork, Little Blue River Watersheds 1992

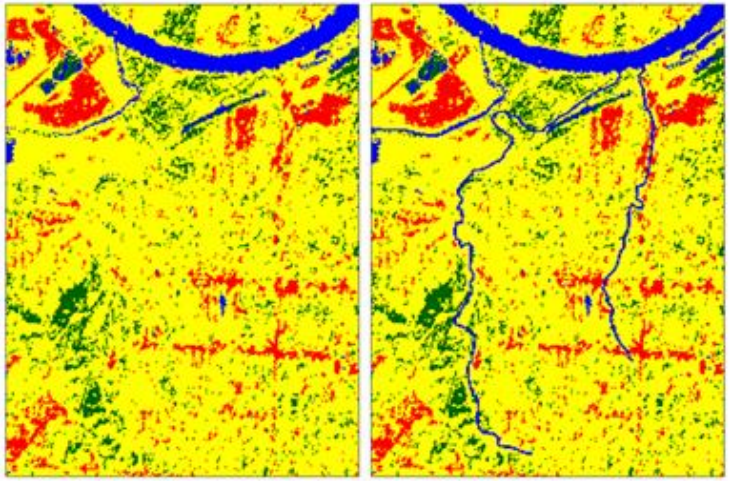


Little Blue River, Little Blue River Watersheds 2008

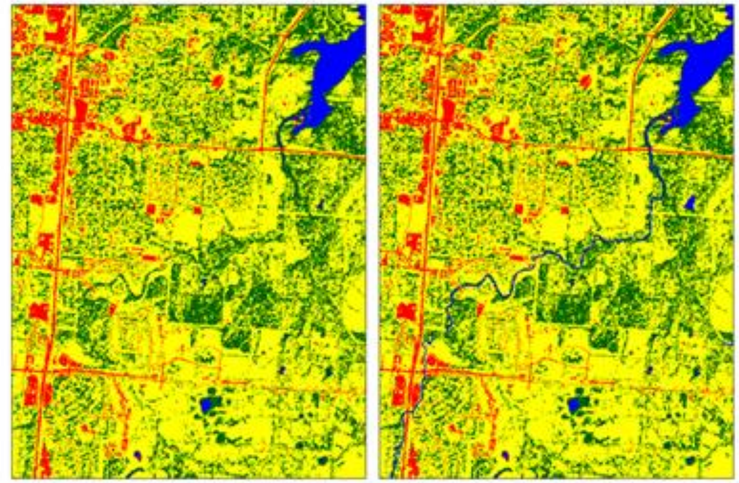


Shoal Creek, Shoal Creek-Missouri River Watersheds 1992

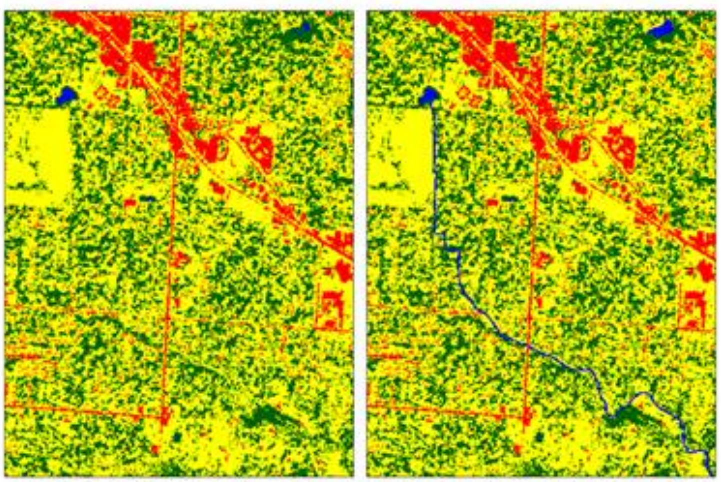
Improved Detection



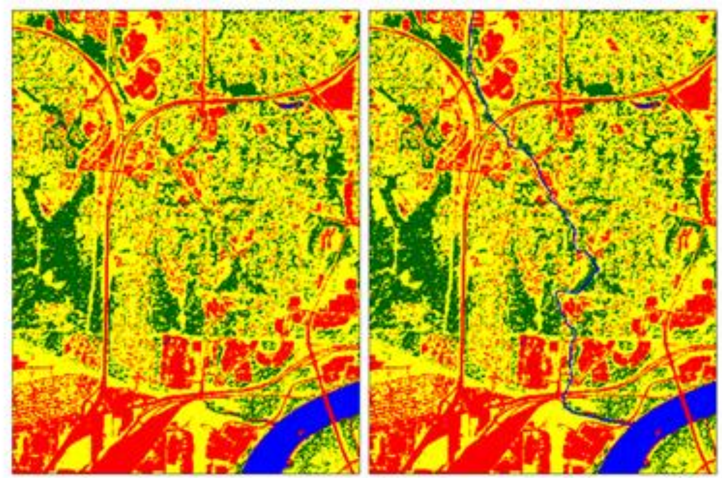
Rock Creek & Sugar Creek, Shoal Creek-Missouri River Watersheds 1992



Little Blue River, Little Blue River Watersheds 2008



White Oak Creek, Little Blue River Watersheds 2008



Rock Creek, Shoal Creek-Missouri River Watersheds 2010

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Methodology: Other procedures

- Assessing classification accuracies and comparing two classification methods
- Verifying the effectiveness of knowledge-based approach used for urban wetland detection
- Analyzing Urban Wetscape Dynamics in relation to driving forces

Accuracy Assessment & Analysis

Land cover class	1992		2008		2010	
	Producer's	User's	Producer's	User's	Producer's	User's
Wetland	84.6	68.5	91.3	72.9	88.1	73.1
Farmland/ Grassland	87.2	90.3	86.9	92.4	84.9	94.5
Impervious surface	92.8	87.2	91	93.8	93.3	92.7
Forestland	94.3	86.9	97.4	90.2	95.8	89.2
Total	87.5		89.4		90.1	

Traditional approach

Land cover class	1992		2008		2010	
	Producer's	User's	Producer's	User's	Producer's	User's
Wetland	92.1	90.3	96.2	91.7	94.9	93
Farmland/ Grassland	88.7	93.4	88.1	95.3	87.8	94.3
Impervious surface	91.5	86.1	94.9	97.4	95.2	97.2
Forestland	94.8	87.3	97	87.9	96.4	84
Total	90.1		91.6		91.8	

Knowledge-based approach

- The accuracy on wetland cover improves significantly
- The producer's and the user's accuracies are both higher than 90%

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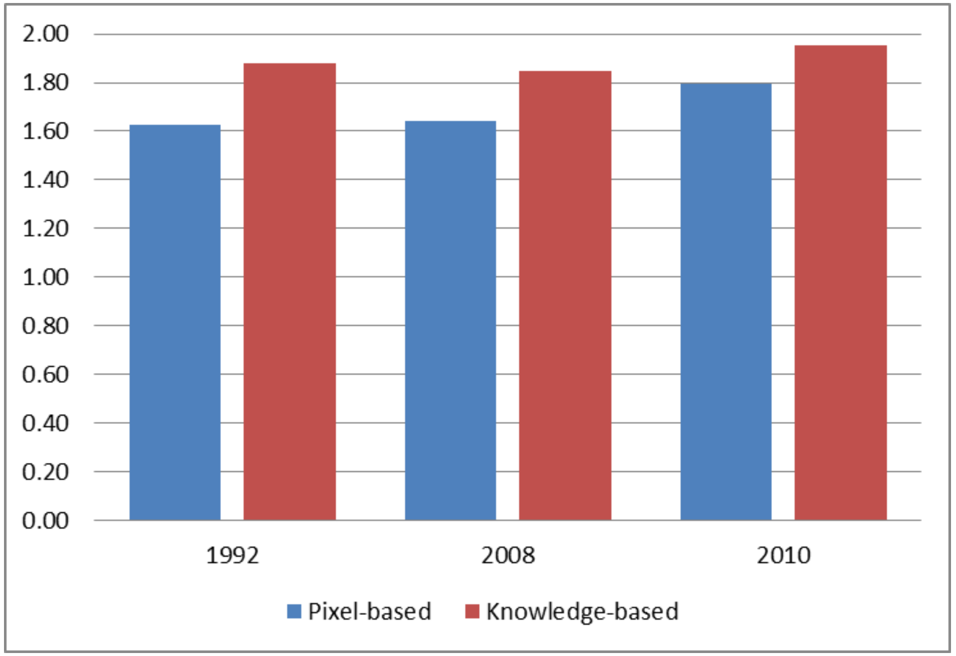
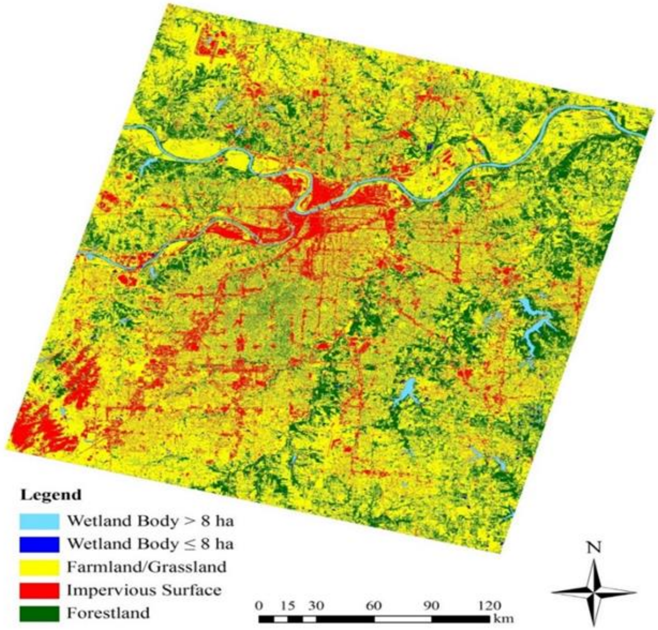
Urban Wetscape Dynamics Analysis

- The new knowledge-based classification can help detect around 10% more urban wetlands on average





Urban Wetland Dynamics at the metropolitan level

Knowledge-based classification results in terms of the area and percentage of detected land cover in all study years

	1992		2008		2010		
Land-cover type	Area (km^2)	Cover (%)	Area (km^2)	Cover (%)	Area (km^2)	Cover (%)	Total change (%)
Wetland	53.79	1.76	54	1.77	58.16	1.91	+8.52
Farmland/grassland	2362.66	77.52	1949.07	63.89	1883.84	61.8	−20.27
Impervious surface	220.44	7.23	330.69	10.84	430.65	14.13	+95.43
Forestland	410.3	13.46	716.55	23.49	675.5	22.16	+64.63

- Wetland
  - increased
- Farmland/grassland
  - large decline
- Impervious surfaces
  - Almost doubled
- Forestlands
  - increased

At the metropolitan level, both wetlands and impervious surface increased

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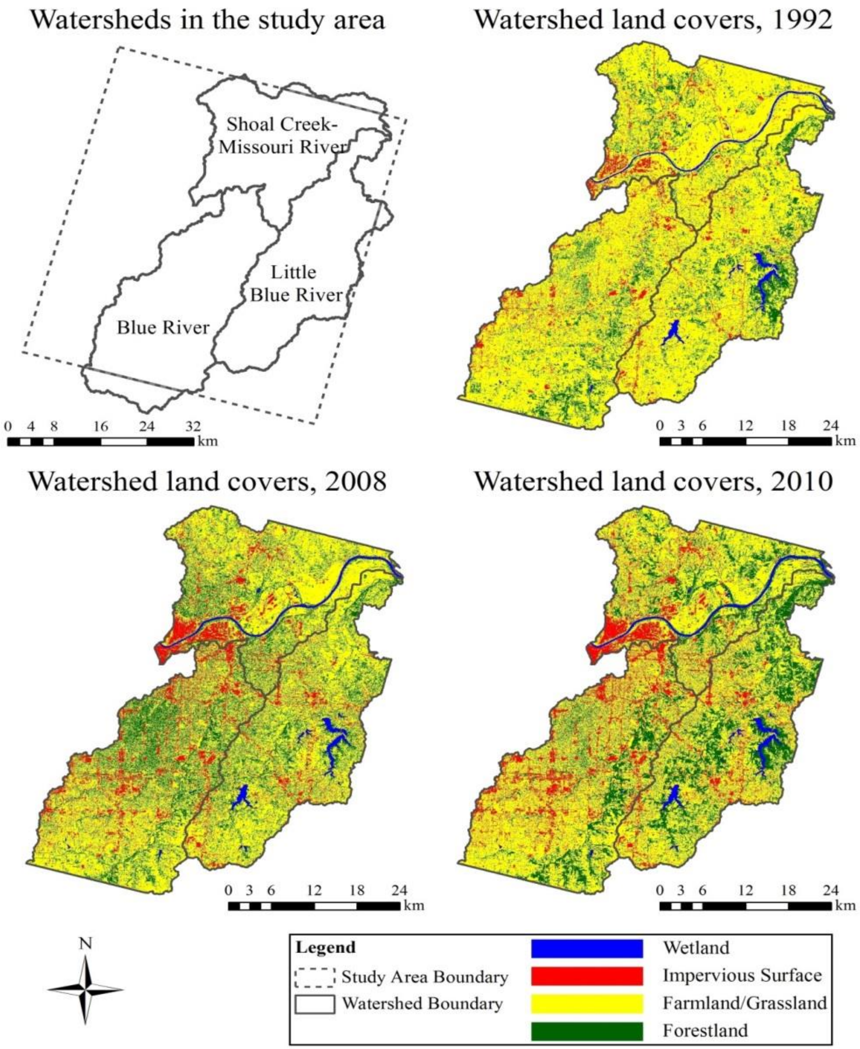
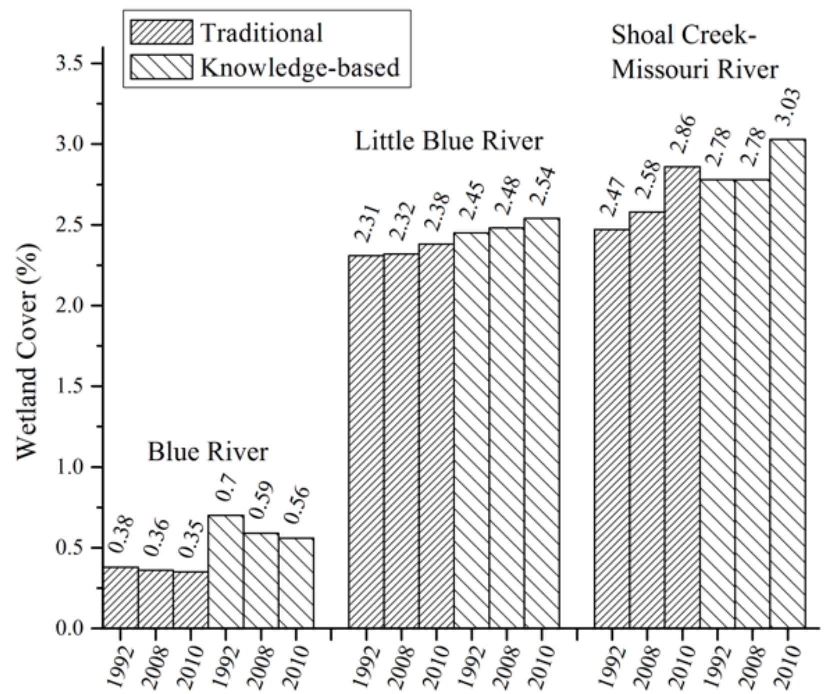
Wetland Cover Changes at Watershed Level





The decrease in wetlands was well correlated with the increase in impervious surfaces in **the Blue River watershed**: human builtup impact on the smaller wetlands? In contrast, in **the Little Blue River watershed** and in **the Shoal Creek – Missouri River watershed** wetland cover gained: suggesting swelling of the larger wetlands in response to precipitation increase?

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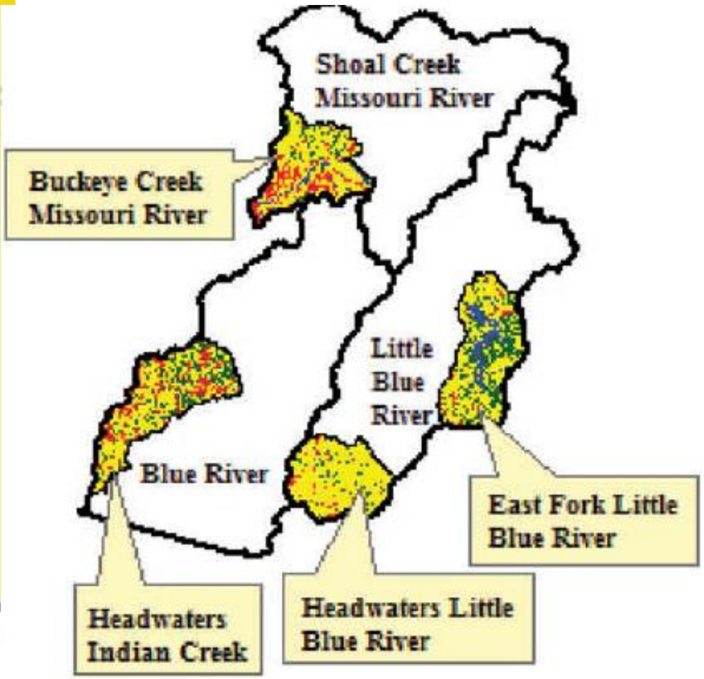
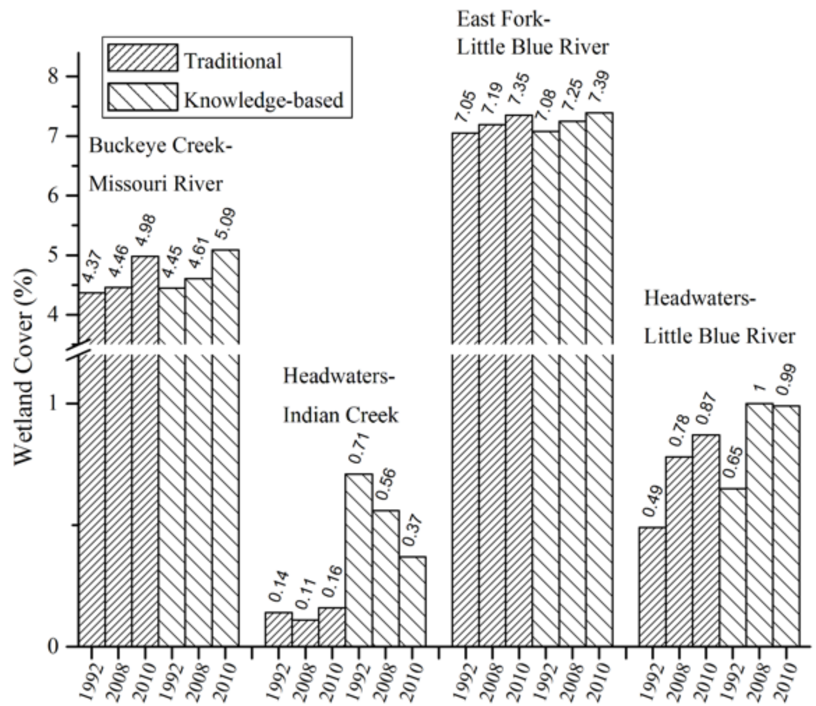
Wetland cover changes in selected sub-watersheds

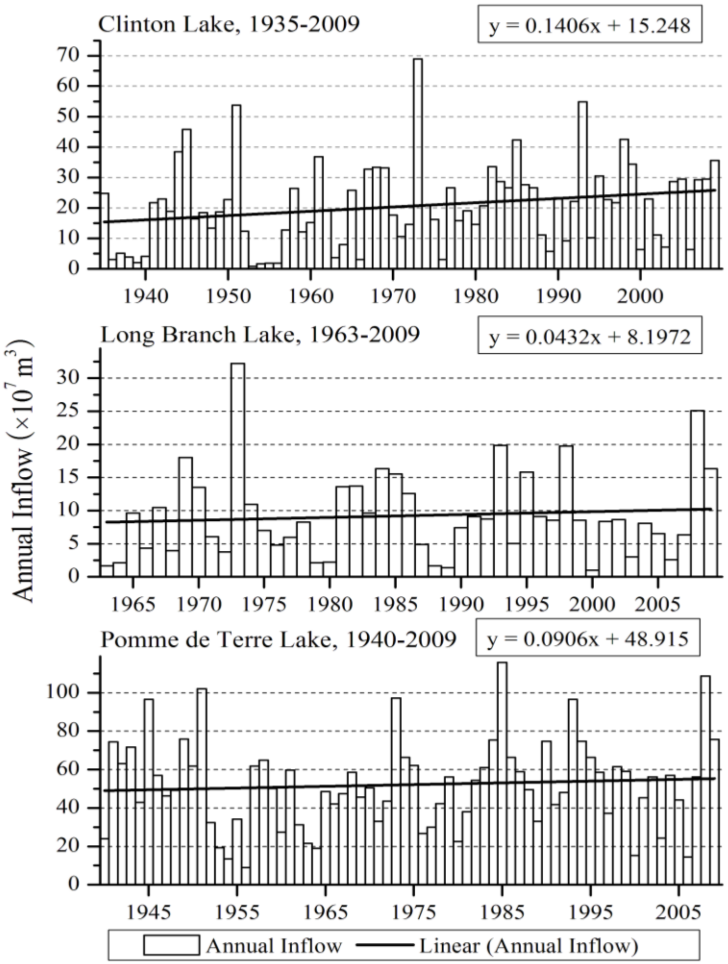


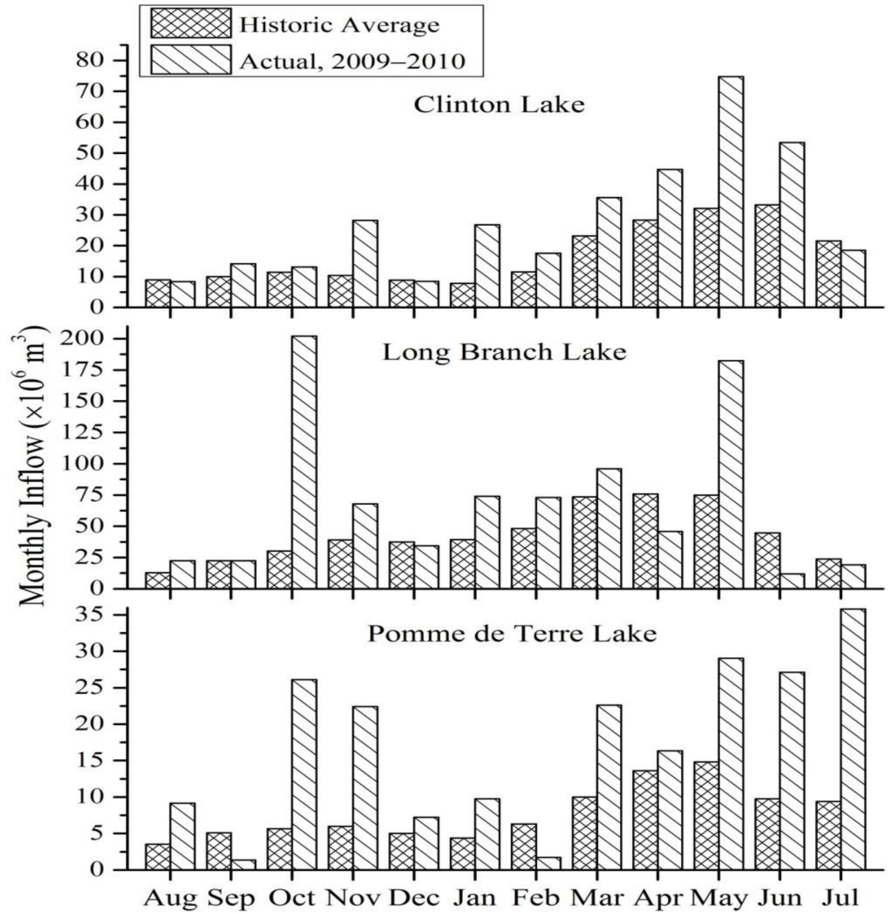


At sub-watershed level, wetland changes were not necessarily the same as their parent watersheds.

The urban wetland change trends tend to vary or differ more at the sub-watershed level, suggesting the impacts of driving forces are highly location dependent at a fine scale level.

Precipitation Impact Analysis





(1) A long-term rising trend of inflow to the study lakes in the region confirms an increase in precipitation in the region in recent decades; (2) The 2009-2010 inflow to the study lakes far exceeded historical monthly mean, which explained the relatively sharp increase in wetland cover in this period.

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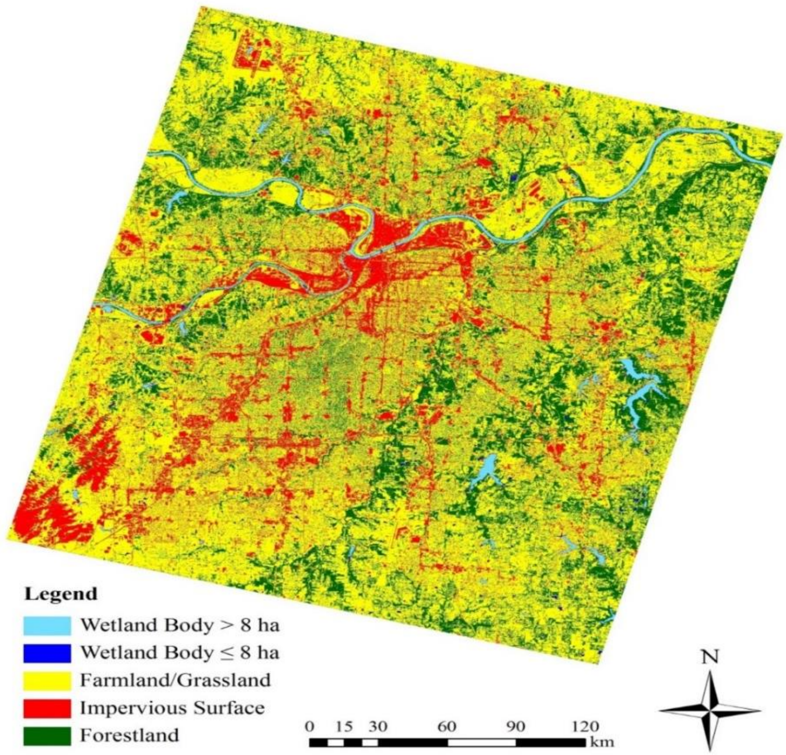
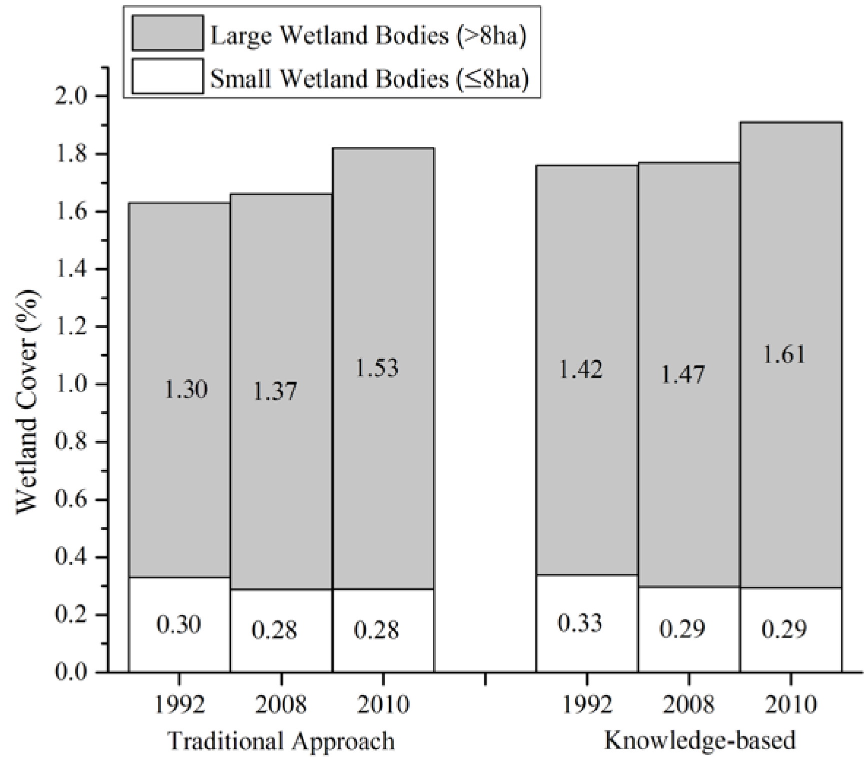
Wetland Size Impact Analysis





At the metropolitan level, there were consecutive increases in wetland cover in the study years when all wetlands were combined in the analysis. However, when excluding the larger wetland bodies from analysis, the study area registered a decline in wetland cover, suggesting that the two size groups had different underlying trends: **gain in the larger wetlands vs. loss in the smaller ones**.

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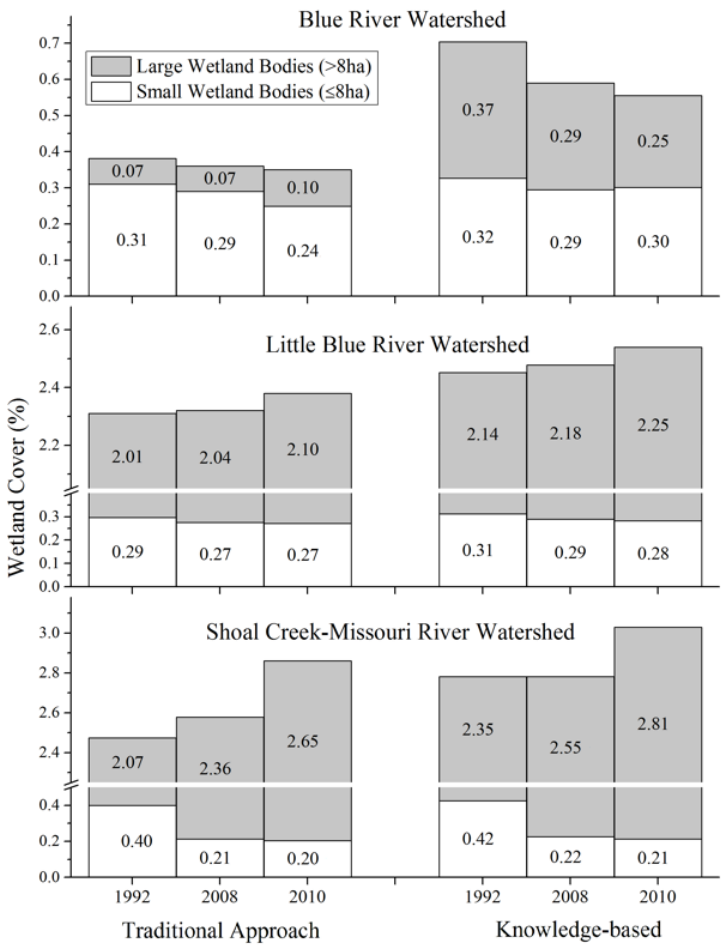
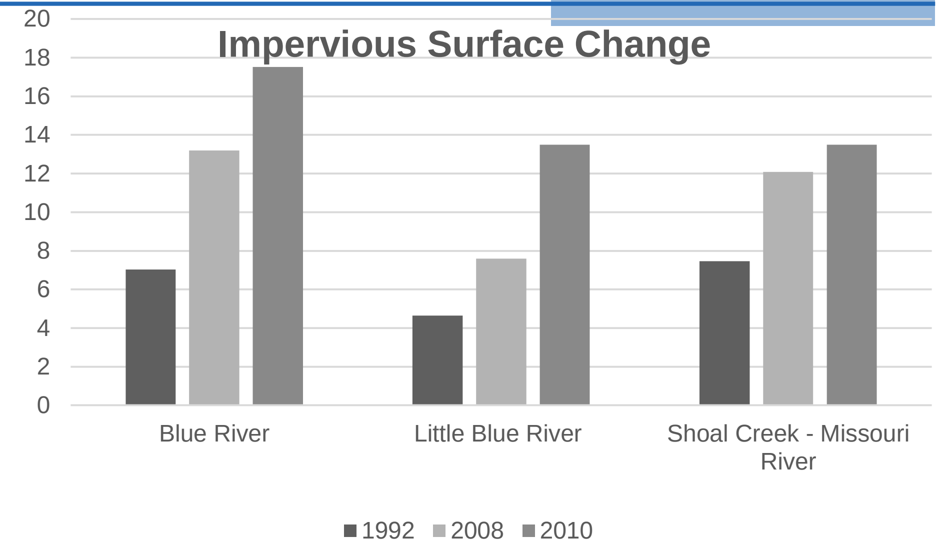
Wetland Size Impact Analysis





The wetland size comparison analysis suggests that the wetland-gaining trends directly detected by remote-sensing methods would be largely caused by the swelling effect of increased precipitation, which is more noticeable in the larger wetlands.

This analysis also indicates that the study area experienced a general decline in the cover of the smaller wetlands, which was in correlation with the significant expansion of impervious surfaces in the region.

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Conclusions

- The study suggests that urban wetscapes are subject to coupled impacts of human built-up activities and precipitation variation. Such impacts vary at different scales and based on the sizes of urban wetlands.

- The cover change of smaller wetlands is more closely related to human built-up impacts, whereas that of larger ones is more responsive to precipitation influences.

- Increased precipitation could swell wetlands, particularly larger ones, which may inflate the remote sensing findings on urban wetland change trend.

- With all of the findings, the study confirms that the wetscape dynamics is an effective indicator of coupled effects of human disturbances and climate change on urban landscapes. The study of the indicator dynamics provides a new understanding of the urban land change – driving force relationships.

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Conclusion

- The integrated knowledge-based classification algorithm can improve urban wetland mapping capabilities

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Characterizing urban sprawl using multi-stage remote sensing images and landscape metrics

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Understanding urban wetland dynamics: cross-scale detection and analysis of remote sensing

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(*Received 25 March 2014; accepted 14 January 2015*)

This study aimed to detect and understand remotely sensed urban wetland dynamics as a sensitive indicator of the combined effects of human disturbances and climate impacts in the course of global change. To address this objective, the study developed technical approaches to detect and interpret wetland changes across spatial scales in complex urban landscapes. Using a series of Satellite Pour l'Observation de la Terre (SPOT) images covering 1992–2010, the study was conducted in the Kansas City metropolitan area of the USA, which has experienced significant urban sprawl in

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Thank You!

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