Simulating the future impacts of urban land cover change on surface water quality within the Chicago Metropolitan Statistical Area, Illinois

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Outline

- Introduction
- Objectives
- Study area
- Methods
- Results
- Conclusions
- Further research

Introduction

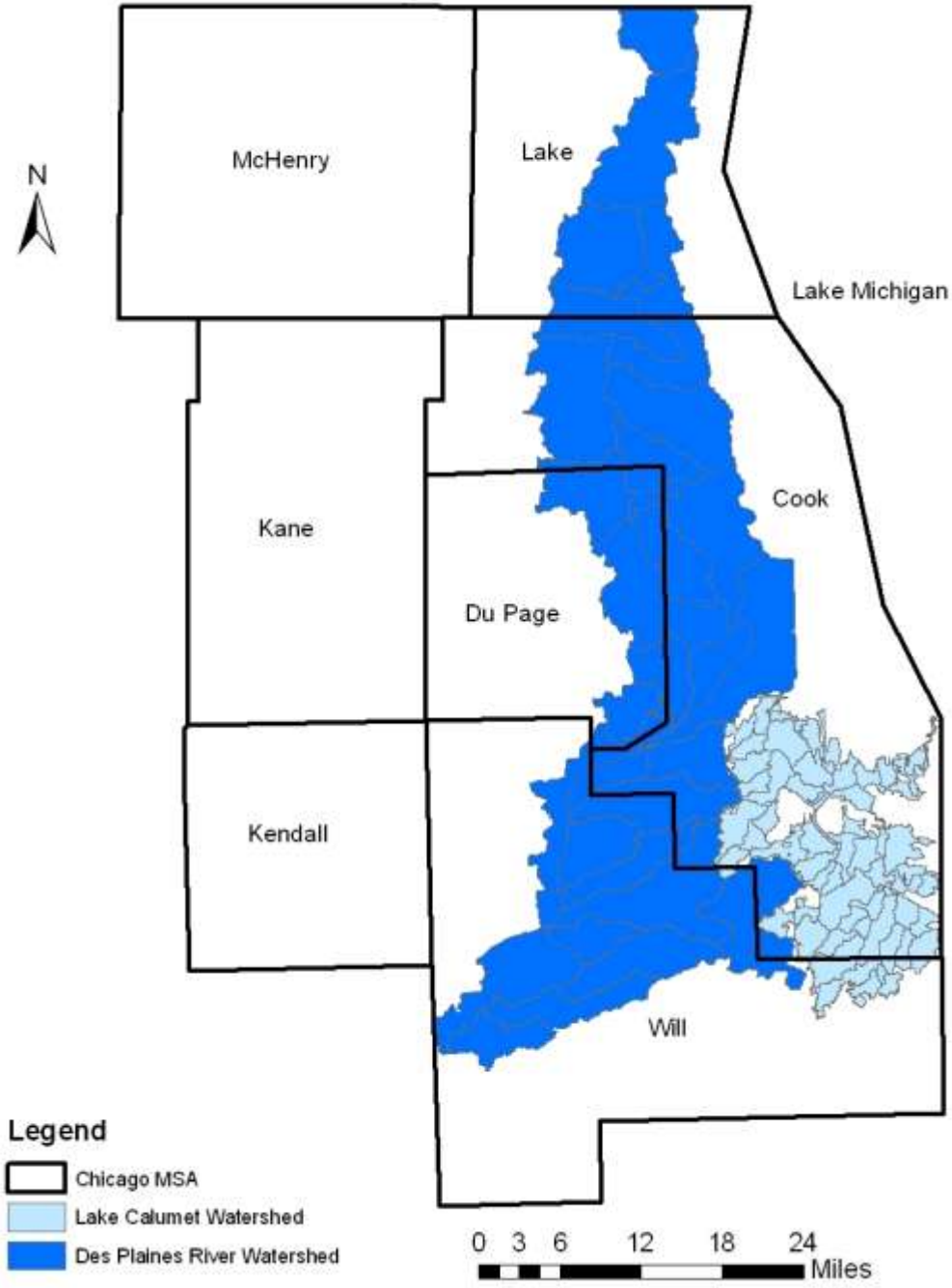
- Anthropogenic sources are the major causes of impurities in surface water (Vieux 1991, Bloesh 2004).
- Load, concentration levels, and types of nonpoint source pollutants depend on the land use varieties within a watershed (Young et al. 1996; Lindgren 2001; Goonetilleke et al. 2005).
- Urban watershed produce greater number of pollutants and higher concentration compared to rural watersheds (Coulter et al. 2004; Ahn et al. 2005).
- Surface water quality depends on the rate of land use and land cover change, and also the extent of hydrologically active areas within a watershed (Wilson and Weng 2010).
- Simulation models provide a framework to gauge nonpoint source pollution load and concentration within a watershed (Arnold et al. 1998; Tague and Costello 2008).

Objectives

- To predict the spatial extent of land use and land cover within Des Plaines River watershed and Lake Calumet watershed by 2020 and 2030.
- To assess the influence of change in land use and land cover between 2010 and future dates on nonpoint source pollution concentration within the watersheds.

Location of Study Area

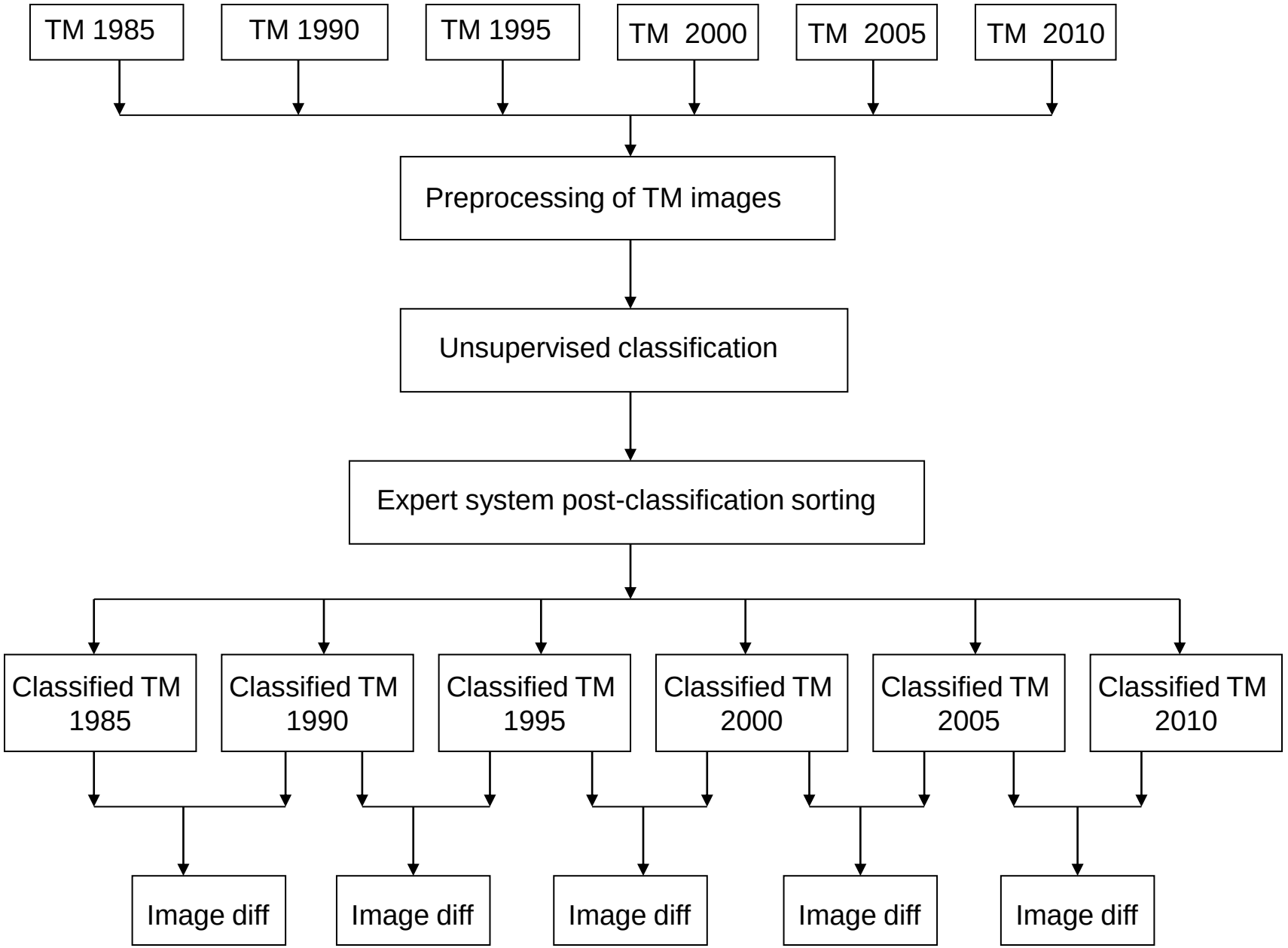
Location of Study Area Watersheds



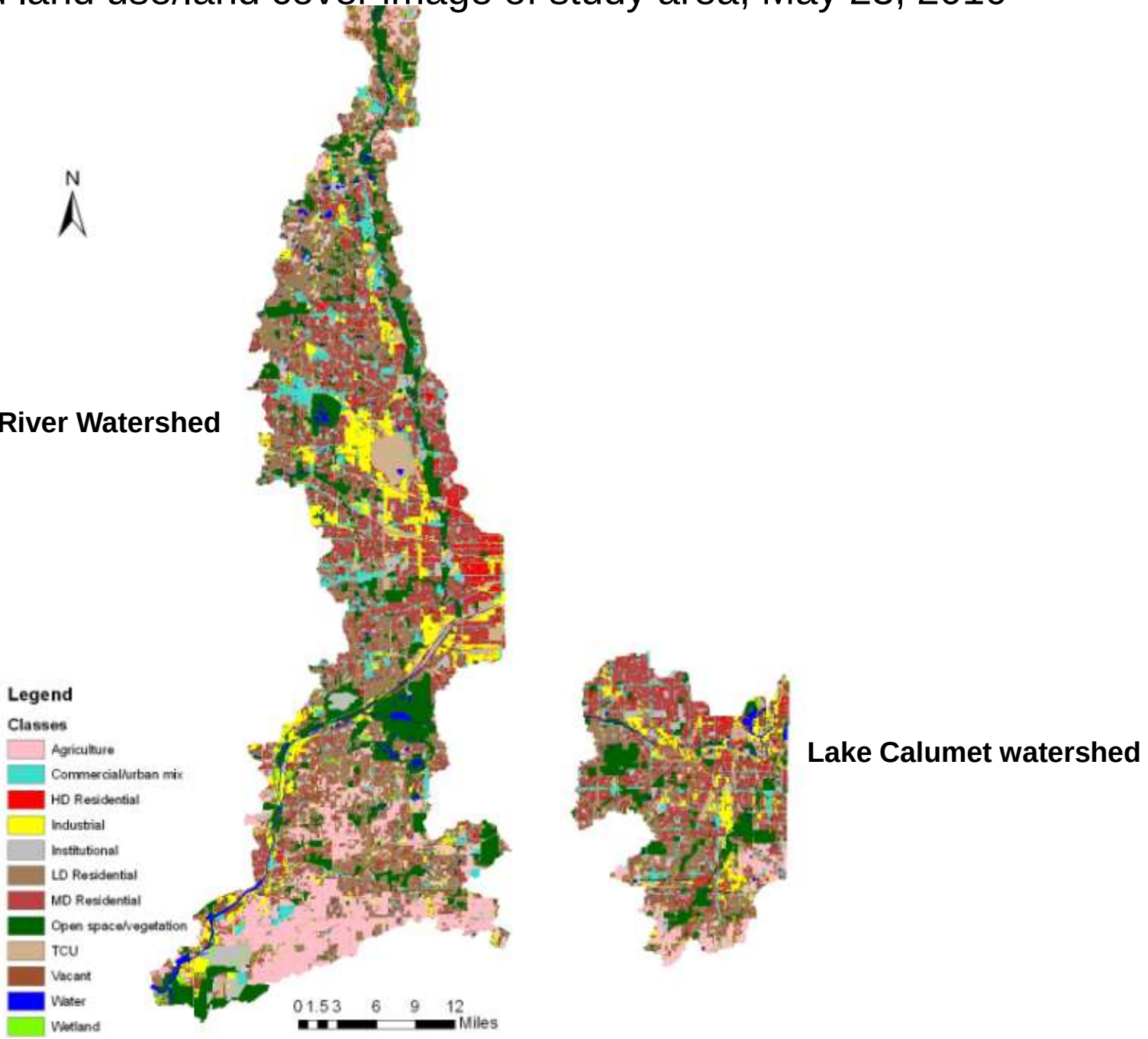
A section of Des Plaines River by Joliet, IL

Methods

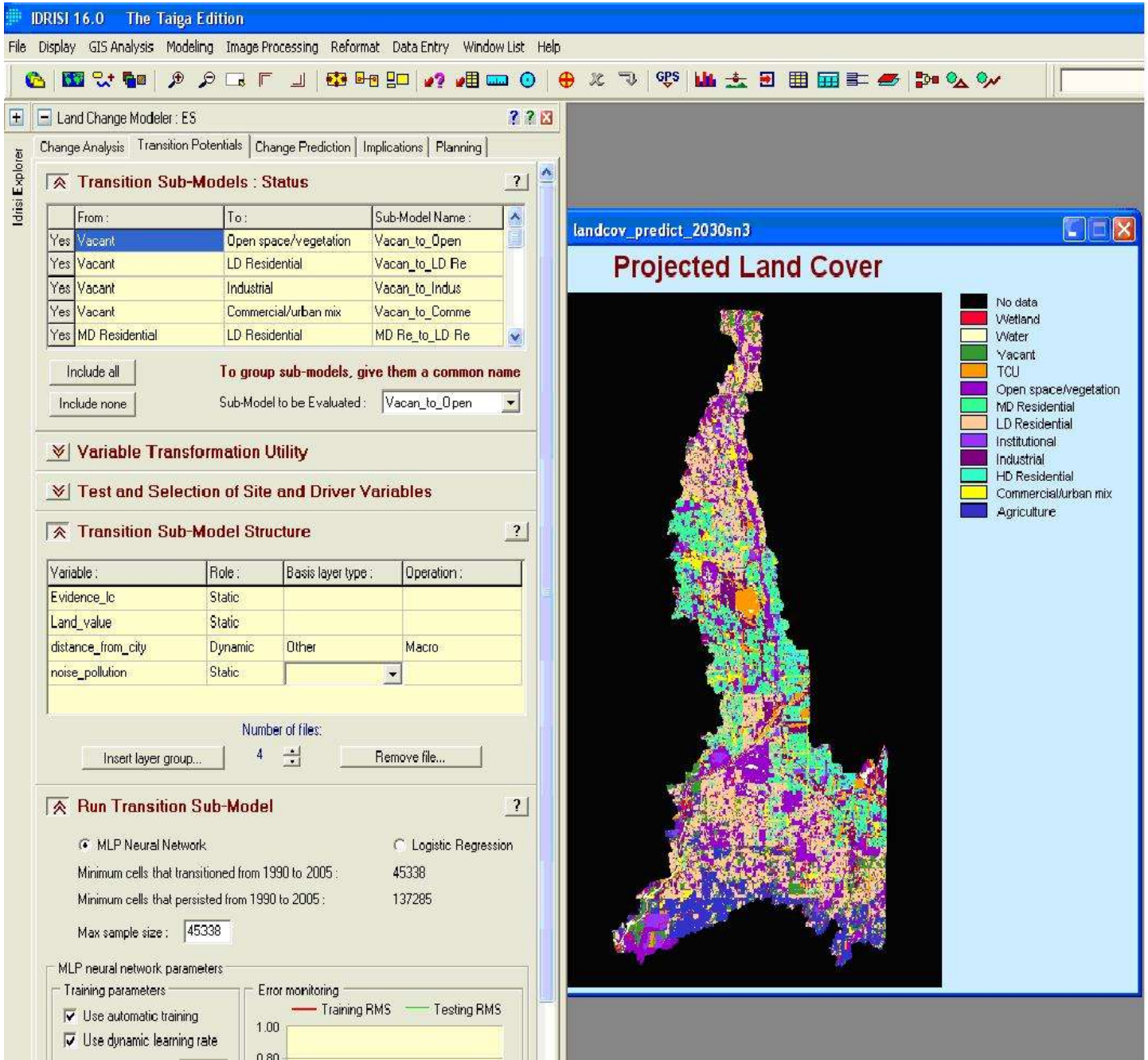
Landsat Thematic Mapper image processing flow chart



Classified land use/land cover image of study area, May 23, 2010



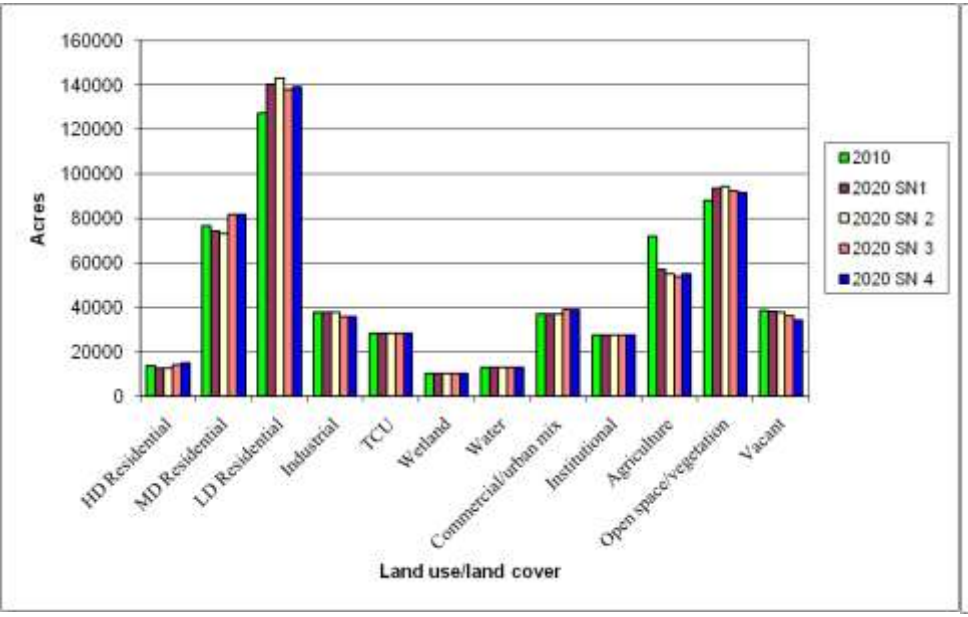
Predicting future land cover change in study area

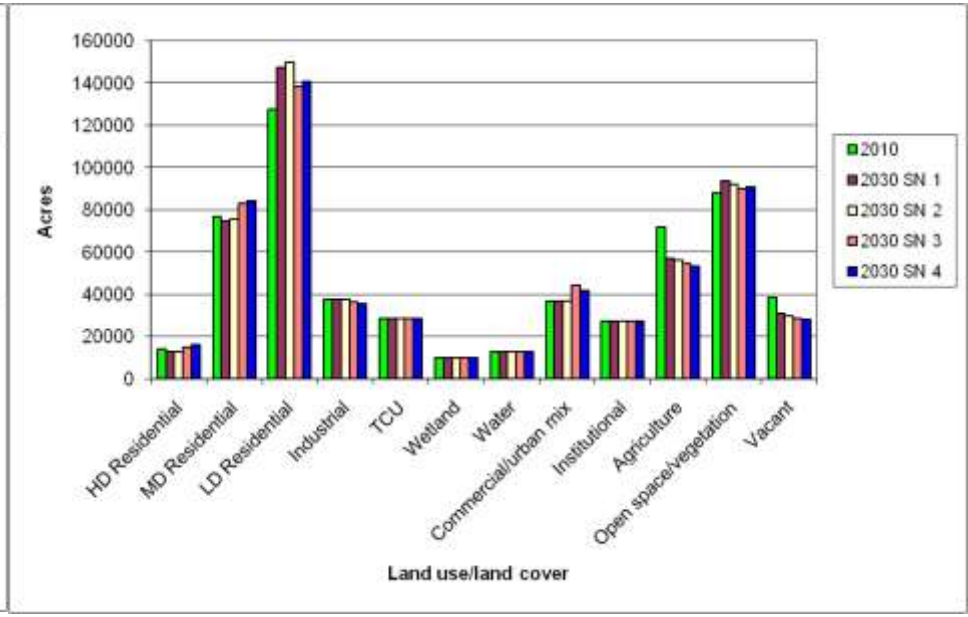


Land cover change planning scenarios

- Scenario 1
  - Incentive for low density residential and open space/vegetation land covers.
- Scenario 2
  - Higher incentive for low density residential and open space/vegetation land covers.
- Scenario 3
  - Minimum incentive for commercial/urban mix land cover and lower incentive for open space/vegetation land cover compared to SN 1 and 2. Removal of incentive for low density residential land cover.
- Scenario 4
  - Higher incentive for the growth of commercial/urban mix land cover. All other incentives removed.

Projected land cover change between 2010 and future in Des Plaines River Watershed

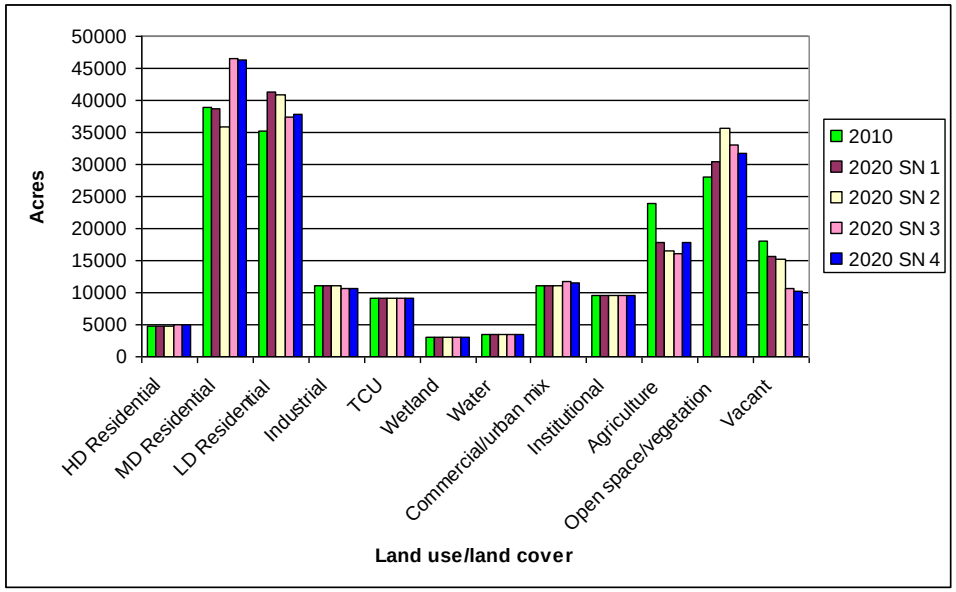


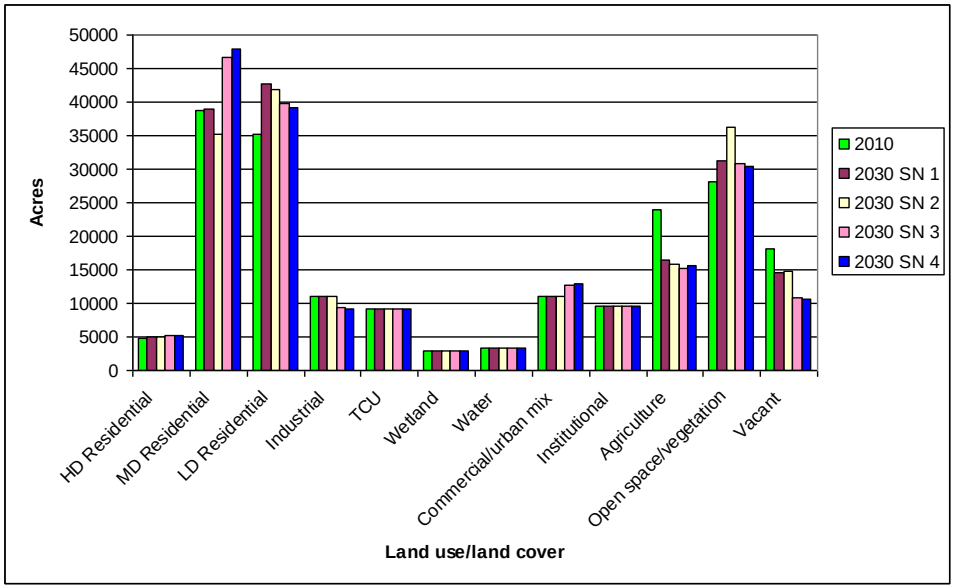


Land use	SN1	SN2	SN3	SN4
HD Residential	-8.9	-8.7	0.5	6.2
MD Residential	-3.2	-4.7	6.5	6.6
LD Residential	10.1	12.3	8.3	9.3
Industrial	0	0	-5.5	-5.5
TCU	0	0	0	0
Wetland	0	0	0	0
Water	0	0	0	0
Commercial/urban mix	0	0	5.8	5.2
Institutional	0	0	0	0
Agriculture	-20.3	-23.1	-24.7	-23.5
Open space/vegetation	6.4	7.3	4.8	3.9
Vacant	-1	-1.7	-5.9	-11

Land use	SN1	SN2	SN3	SN4
HD Residential	-6.8	-6.5	8.6	14.8
MD Residential	-2.9	-1.5	8.1	9.7
LD Residential	15.5	17.5	8.7	10.5
Industrial	0	0	-5.5	-5.7
TCU	0	0	0	0
Wetland	0	0	0	0
Water	0	0	0	0
Commercial/urban mix	0	0	15	13.9
Institutional	0	0	0	0
Agriculture	-20.6	-21.9	-23.7	-25.7
Open space/vegetation	6.4	4.6	2.4	3.2
Vacant	-19.3	-22.5	-26.1	-26.7

Projected land cover change between 2010 and future in Lake Calumet Watershed





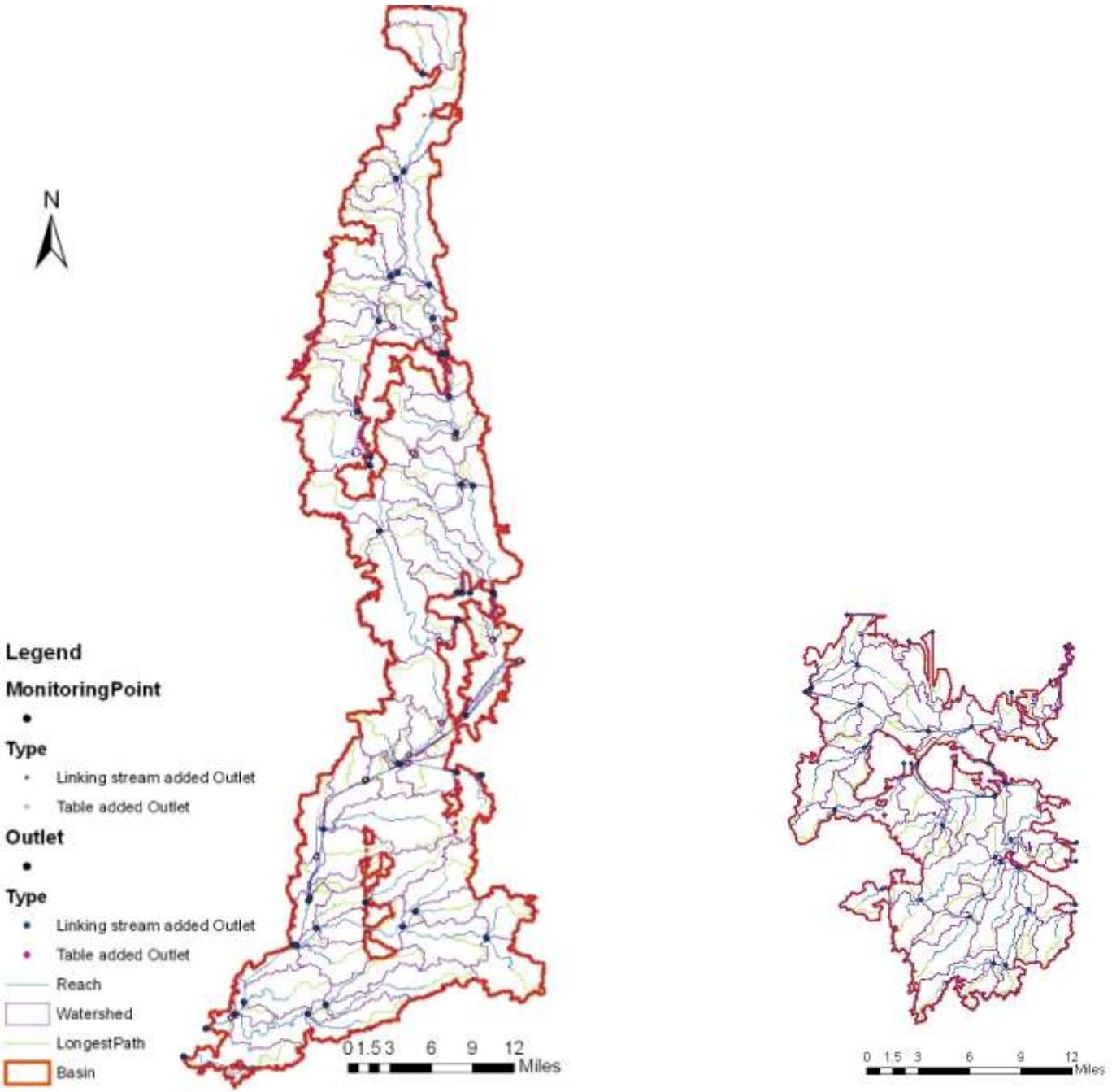
Land use	SN1	SN2	SN3	SN4
HD Residential	0.6	-0.3	2.1	2.7
MD Residential	-0.2	-7.7	19.9	19.3
LD Residential	17.7	16.6	6.6	7.7
Industrial	0	0	-4	-3.9
TCU	0	0	0	0
Wetland	0	0	0	0
Water	0	0	0	0
Commercial/urban mix	0	0	6.3	3.5
Institutional	0	0	0	0
Agriculture	-25.2	-31.2	-33.2	-25.5
Open space/vegetation	8.4	26.8	17.6	13.4
Vacant	-13.8	-16	-41	-44

Land use	SN1	SN2	SN3	SN4
HD Residential	1.2	1.4	8.6	7.8
MD Residential	0.3	-9.2	20.2	23.3
LD Residential	21.4	19.5	13.3	11.4
Industrial	0	0	-15.4	-16.4
TCU	0	0	0	0
Wetland	0	0	0	0
Water	0	0	0	0
Commercial/urban mix	0	0	16	16.2
Institutional	0	0	0	0
Agriculture	-31.1	-33.7	-36.2	-35.2
Open space/vegetation	11.3	29	10.2	8.6
Vacant	-18.9	-18.6	-39.7	-41

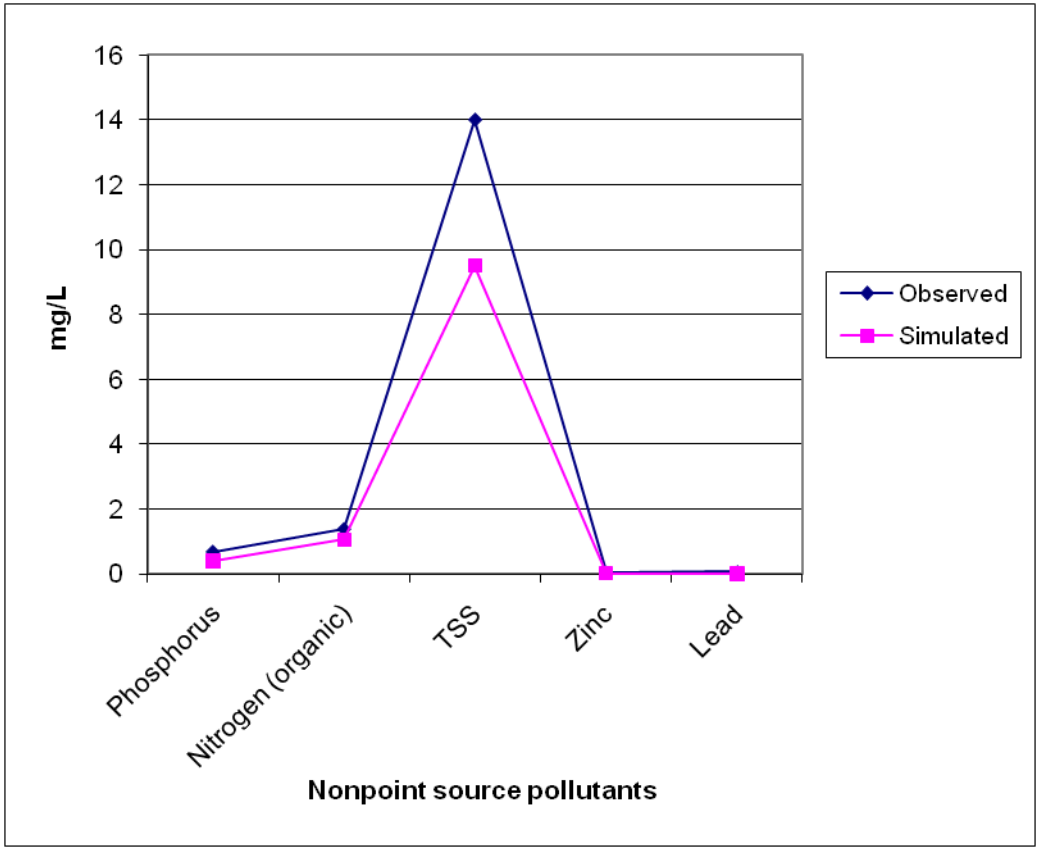
Water quality simulation models used in study

- Soil and Water Assessment Tool (SWAT) version 2009.
- A customized Nonpoint Source Pollution and Erosion Comparison Tool (N-SPECT) version 1.5.1.

Water quality modeling of watersheds



Calibration of SWAT model for study area 2000



$$E_{rel} = 1 - \frac{\sum_{i=1}^{n}\left(\frac{O_i - P_i}{O_i}\right)^2}{\sum_{i=1}^{n}\left(\frac{O_i - \overline{O}}{\overline{O}}\right)^2} = 0.86$$

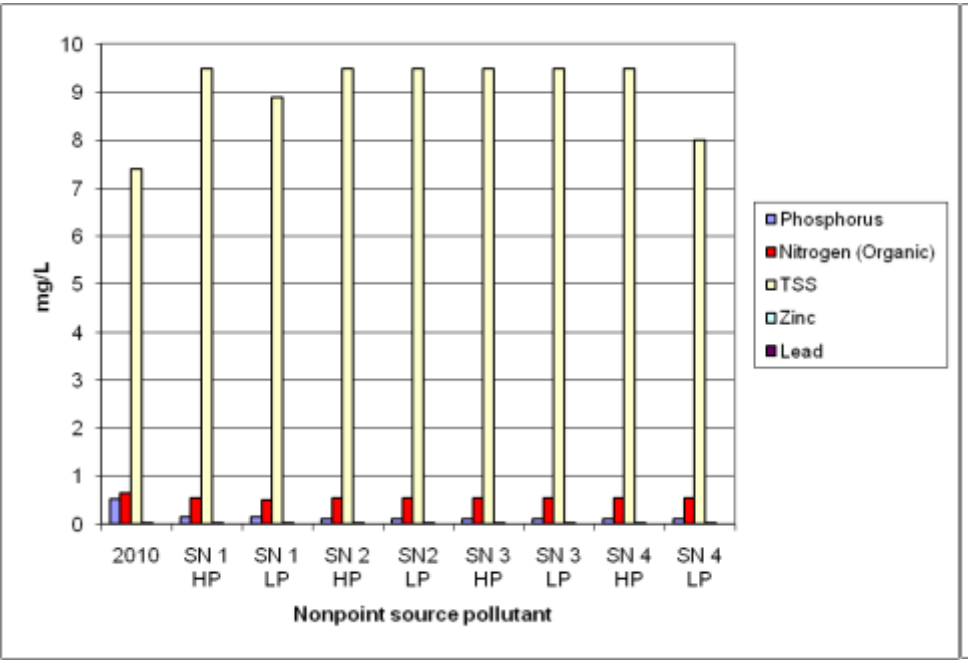
$$d_{rel} = 1 - \frac{\sum_{i=1}^{n}\left(\frac{O_i - P_i}{O_i}\right)^2}{\sum_{i=1}^{n}\left(\frac{\left|P_i - \overline{O}\right| + \left|O_i - \overline{O}\right|}{\overline{O}}\right)^2} = 0.95$$

Calibration criteria	Threshold	Result
E_{rel}	0.75	0.86
d_{rel}	0.85	0.95

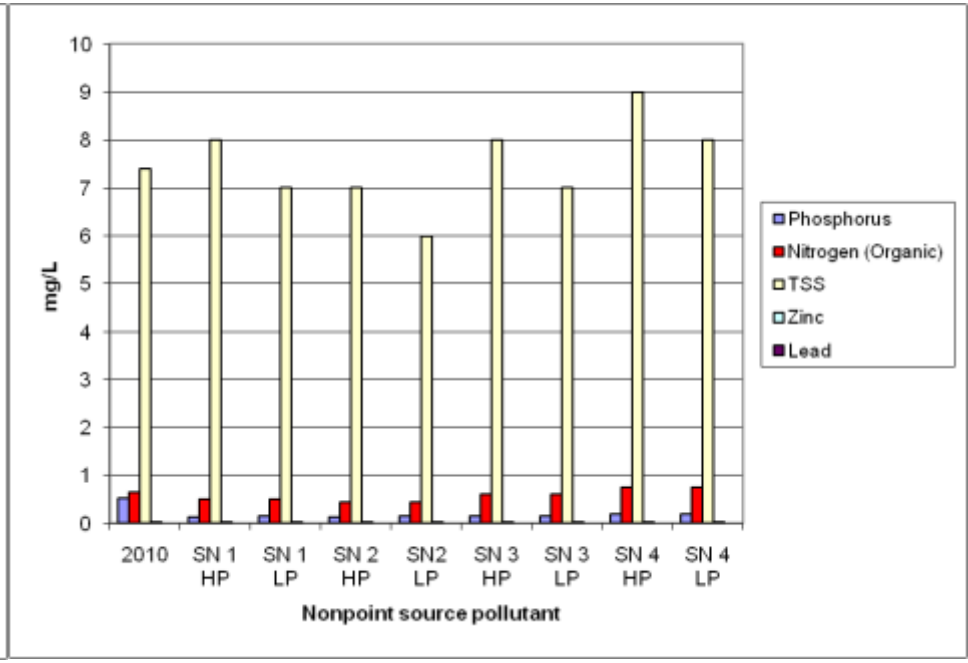
E_{rel} = Nash-Sutcliffe relative (modified) simulation efficiency coefficient.
d_{rel} = relative (modified) index of agreement coefficient of simulation efficiency

Results

Future nonpoint source pollution concentration for Des Plaines River Watershed



2020



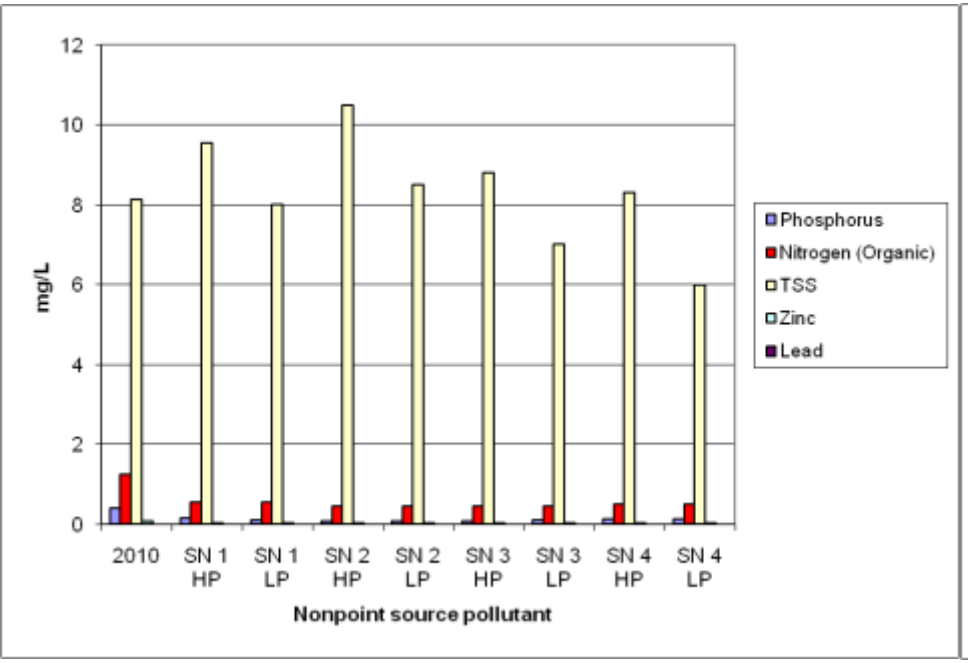
2030

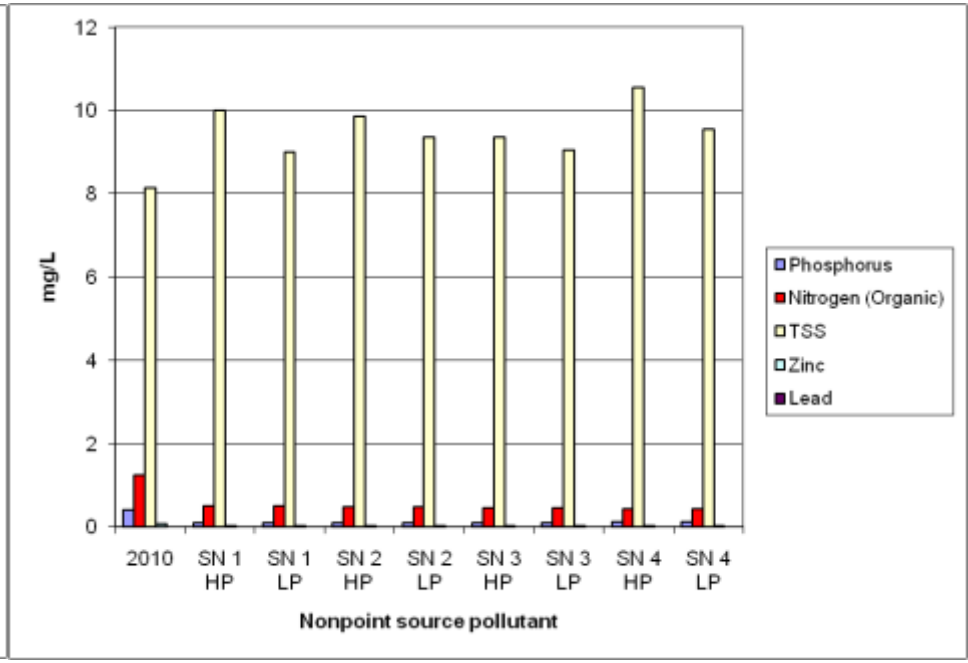
SN = land cover change planning scenario

HP = model prediction of pollutants using downscaled climate variables for B1 low emission climate change scenario.

LP = model prediction of pollutants using downscaled climate variables for A1F1 high emission climate change scenario.

Future nonpoint source pollution concentration for Lake Calumet Watershed





SN = land cover change planning scenario

HP = model prediction of pollutants using downscaled climate variables for B1 low emission climate change scenario.

LP = model prediction of pollutants using downscaled climate variables for A1F1 high emission climate change scenario.

Conclusion

- In Des Plaines River watershed, land cover extent for scenario 4 resulted to the most sustainable water quality by 2020; while by 2030 scenario 2 revealed the most suitable.
- In Lake Calumet Watershed, scenarios 1 and 4 resulted to the lowest concentration of pollutants modeled for 2020, but by 2030 scenario 4 happens to be the most sustainable in terms of water quality.
- The development of low density residential areas at the expense of middle and higher densities will likely contribute to surface water quality impairment in the future within the study watersheds.
- Most suitable land cover configuration for surface water quality varies at micro spatial scales.

Further research

- Increase the types of nonpoint source pollutants modeled.
- Development of tools that can accommodate a wide range of drivers of land use and land cover change in modeling future land cover spatial extents and the impacts of the latter on surface water quality.

Acknowledgement

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Question(s)