Linking Soil and Watershed Health to In-field and Edge-of-Field Water Management

Panel VI: Understanding the Broader Range of Concerns Related to Drainage Water Management

Where do we need water table management?

Using hydrologic connectivity as a screening tool

Genevieve Ali

School of Environmental Sciences, University of Guelph

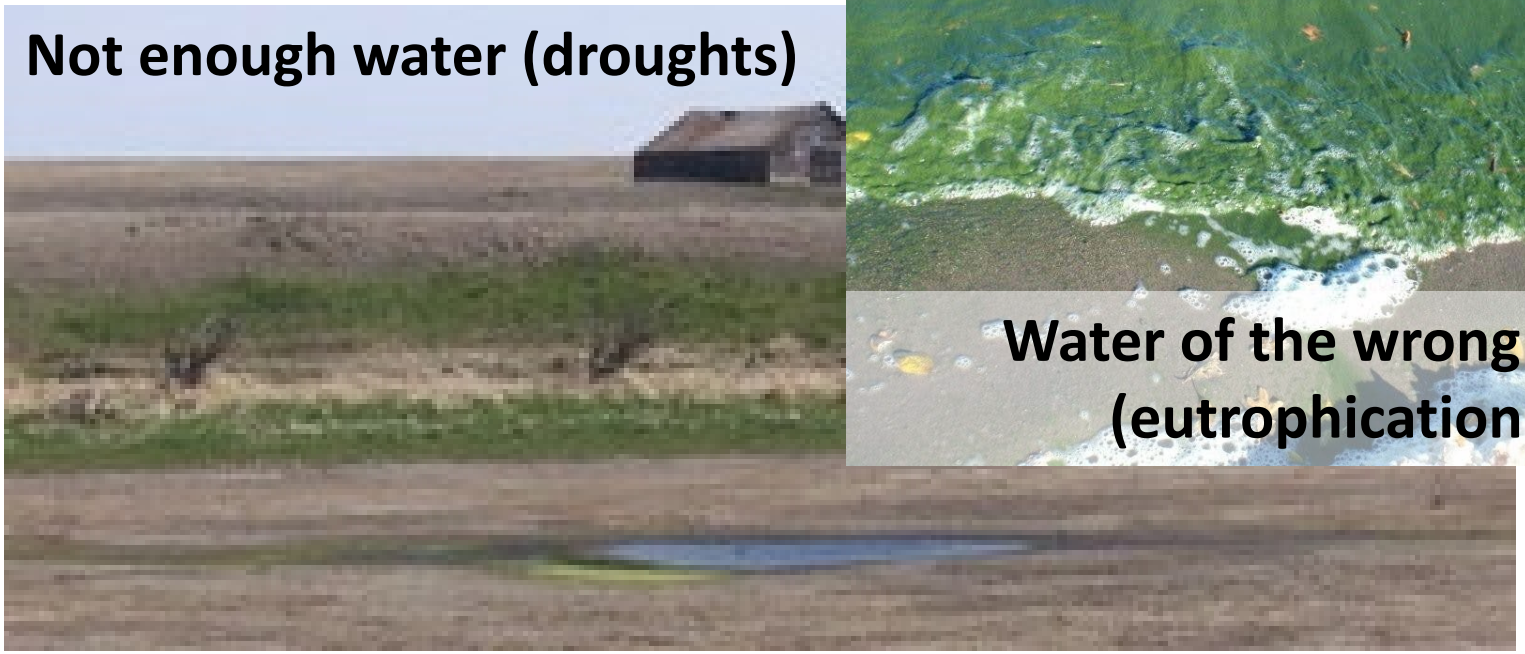
Presentation road map

- Disclaimers

- Hydrologic connectivity: from a scientific concept to a tangible management tool
  - Where is surface water management or water table management needed?
  - Does the answer to that question differ when we target local-scale benefits versus watershed health benefits?

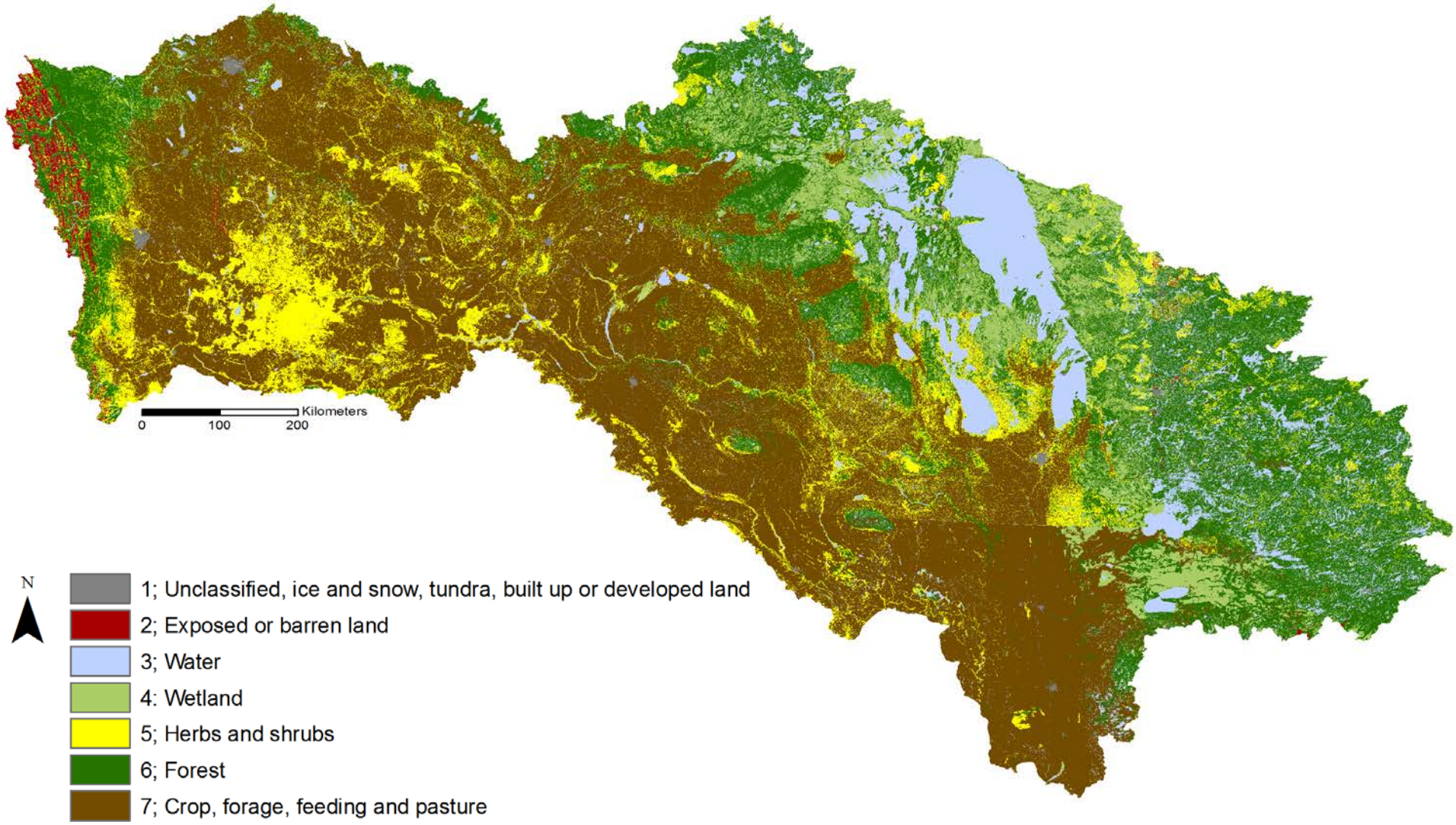
- Case scenario for today: the Canadian portion of the Prairies, specifically the Lake Winnipeg Watershed

Water issues in the Lake Winnipeg Watershed



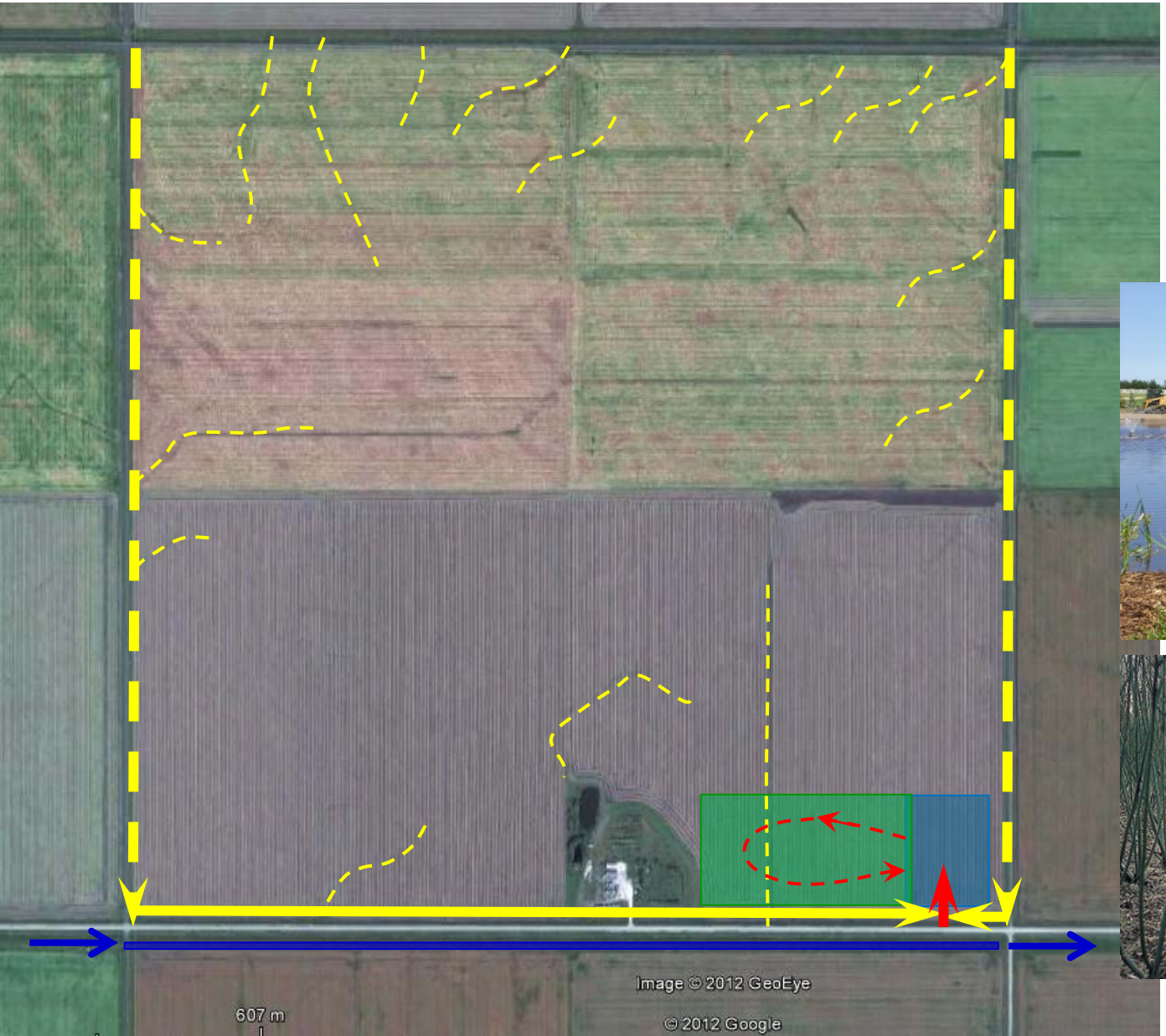
Lake Winnipeg Watershed (LWW)

Land use and land cover



Typical, natural surface drainage on-farm

Slightly enhanced surface drainage on *some* farms



Current situation despite surface drainage improvements

In dry conditions

Photo: Genevieve Ali

Current situation despite surface drainage improvements

In very wet conditions

Photo: Merrin Macrae

One big unknown (for the LWW and beyond)

Are there locations where water management (surface and/or water table) would be especially critical implement in order to:

Avoid persistent local excess moisture issues (goal #1)

AND

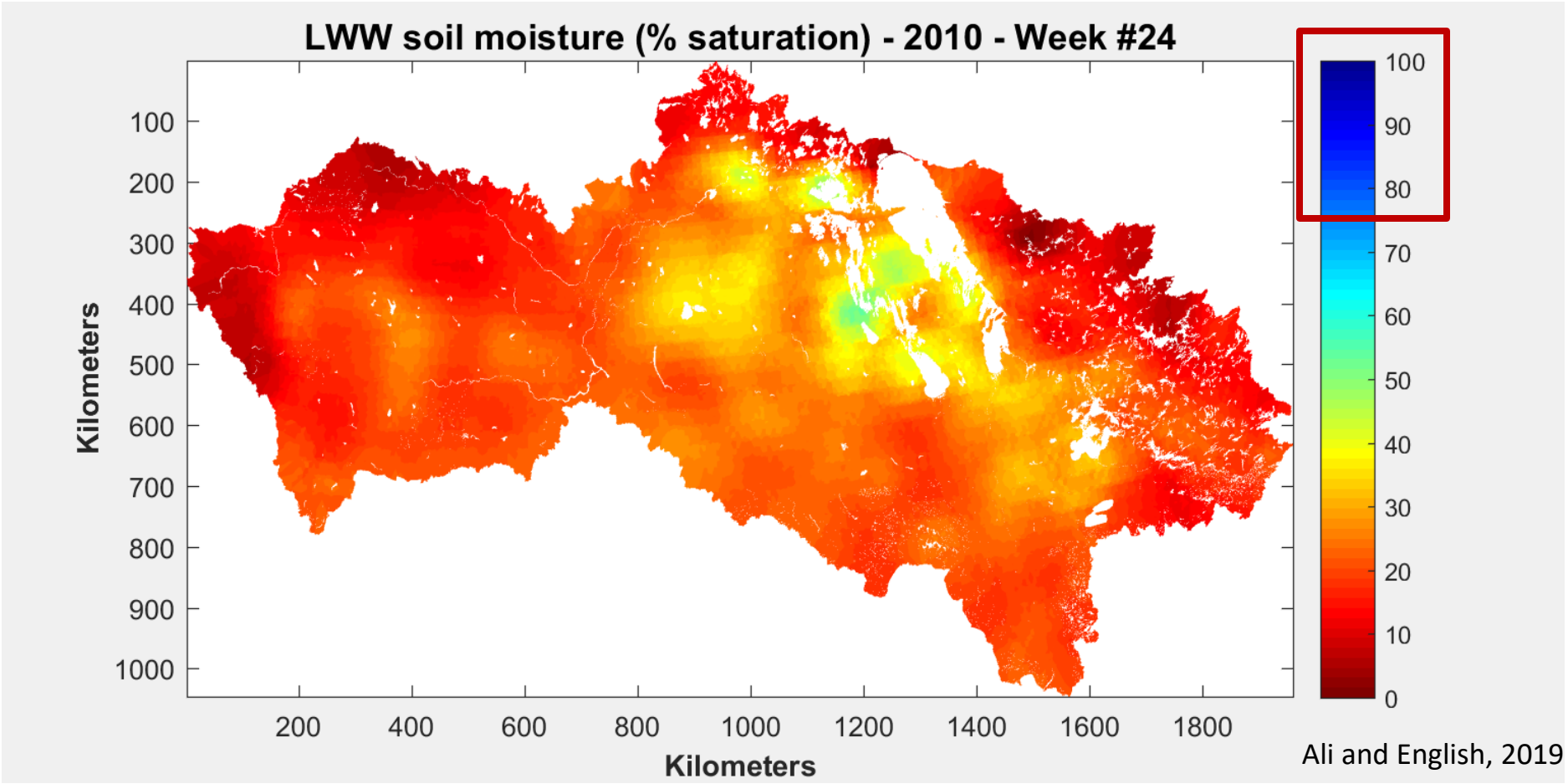
Mitigate downstream flooding and water quality (goal #2)?

Goal #1: address local excess moisture issues

Mapping exercise in the LWW

Comprehensive data lacking at the watershed scale

Satellite-derived soil moisture ≡ proxy for water-logged root zones



Ali and English, 2019

Goal #2: link local water mgmt. to downstream issues

How can connectivity assessments help?

If we were to promote water mgmt. for watershed health benefits, how would we identify critical areas where water mgmt. would be most beneficial?

Connectivity

Probability that a source location "A" is capable of transmitting material (e.g., water, contaminants) to a receptor location "B"

Pringle, 2001; Bracken and Croke, 2007; Bracken et al., 2007

Goal #2: link local water mgmt. to downstream issues

Spatially explicit connectivity framework

Goal #2: link local water mgmt. to downstream issues

Connectivity assessment framework

Spatial framework / Connectivity property	For a single source to outlet	For all sources to outlet
	A→ B	∑i→B
Occurrence	$CW^{occur}_{A\to B,\Delta t} = \begin{cases} 1 \; if \; \frac{d_{travel}}{d_{total}} \geq 1 \\ 0 \; if \; \frac{d_{travel}}{d_{total}} < 1 \end{cases}$	$CW^{contrib}_{Land\ unit,\Delta t} = \frac{\sum_{i=1}^{n} CW^{occur}_{i\to B,\Delta t}}{n}$
Frequency	$CW^{freq}_{A\to B,\Delta T} = \frac{\sum_{\Delta t=1}^{nbts} CW^{occur}_{A\to B,\Delta t}}{\Delta T}$	Probability distribution function of $CW^{freq}_{i\to B,\Delta T}$
Duration	$CW^{dur}_{A\to B,\Delta T} = \int_{\Delta t=1}^{\Delta T} CW^{occur}_{A\to B,\Delta t}\, dt$	Probability distribution function of $CW^{dur}_{i\to B,\Delta T}$
Magnitude	$CW^{mag}_{A\to B,\Delta t} = H_{excess,A,\Delta t} - HA_{A\to B,\Delta t}$	$CW^{mag}_{Land\ unit,\Delta t} = \sum_{i=1}^{n} (H_{excess,i,\Delta t} - HA_{i\to B,\Delta t})$

Ali et al., 2018

Goal #2: link local water mgmt. to downstream issues

Connectivity assessment framework

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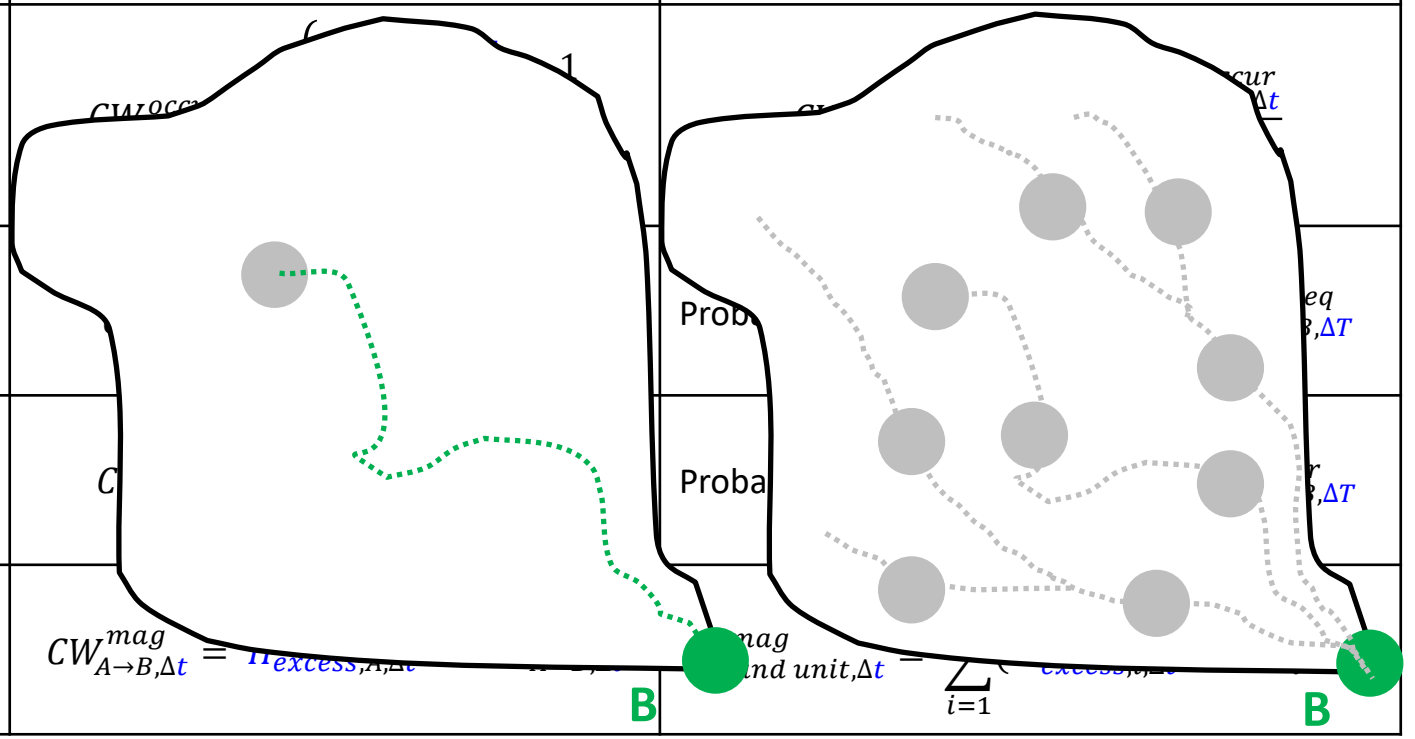
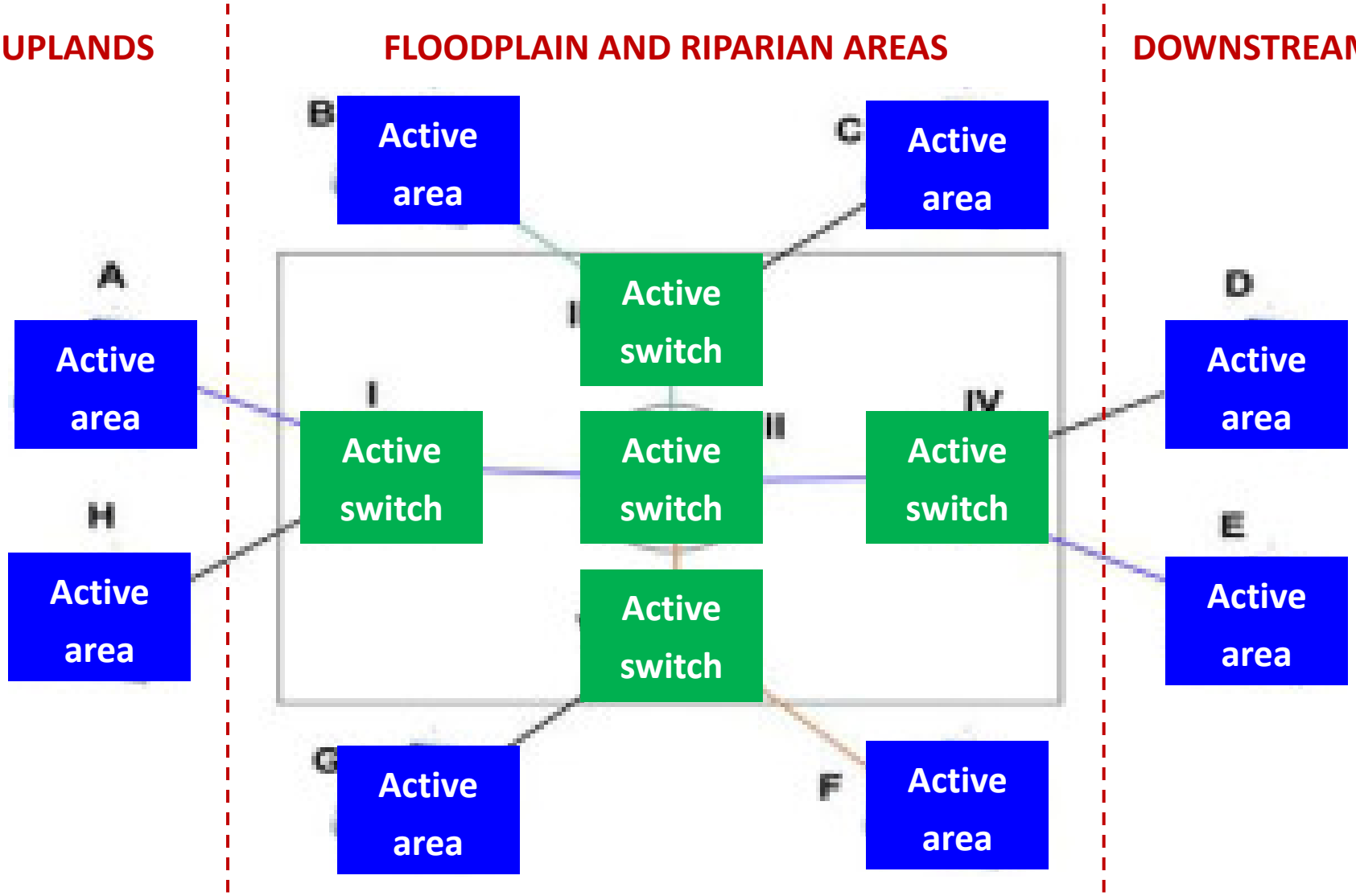
Occurrence		
Frequency		
Duration		
Magnitude		

Ali et al., 2018

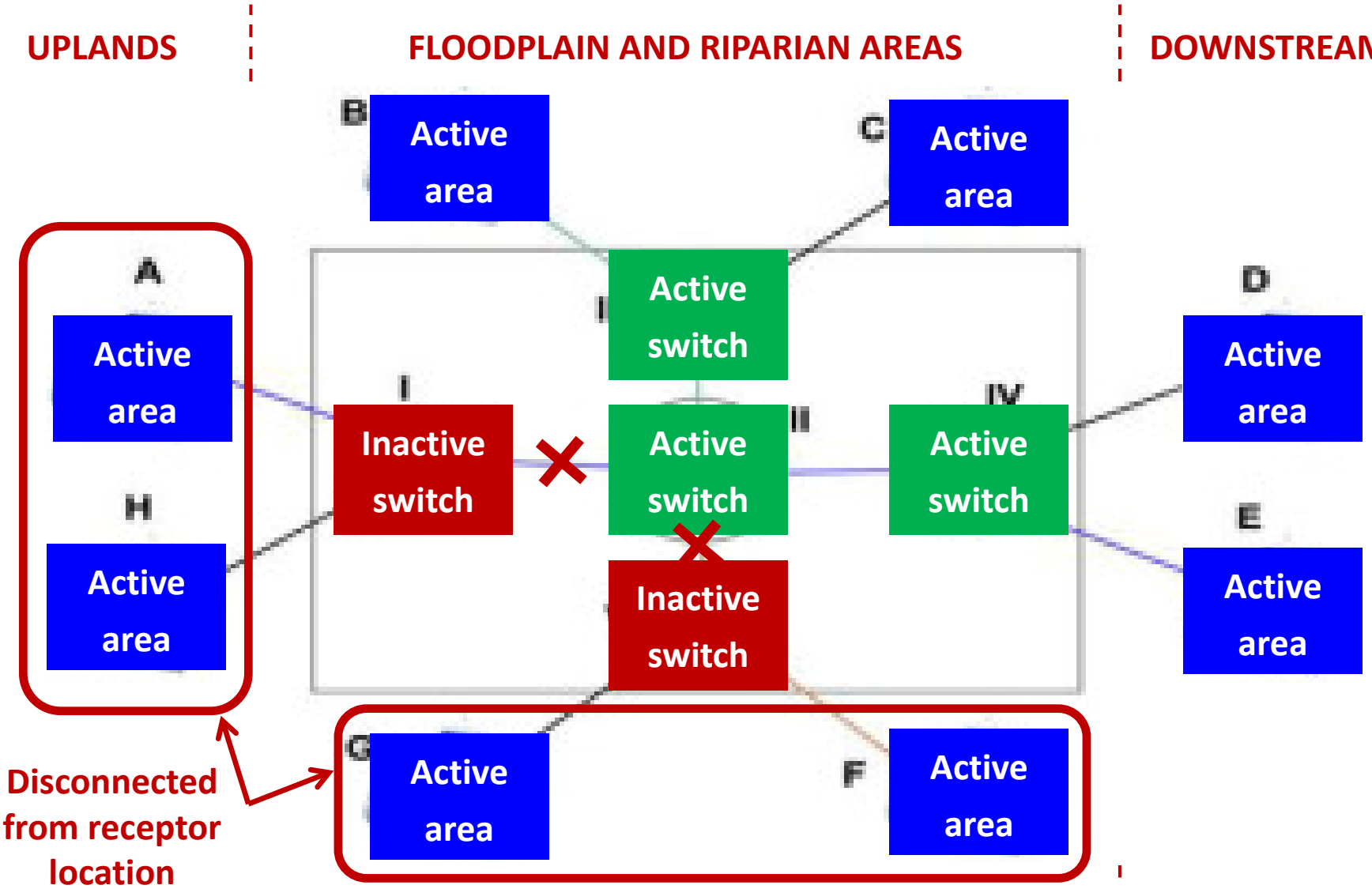
Goal #2: link local water mgmt. to downstream issues

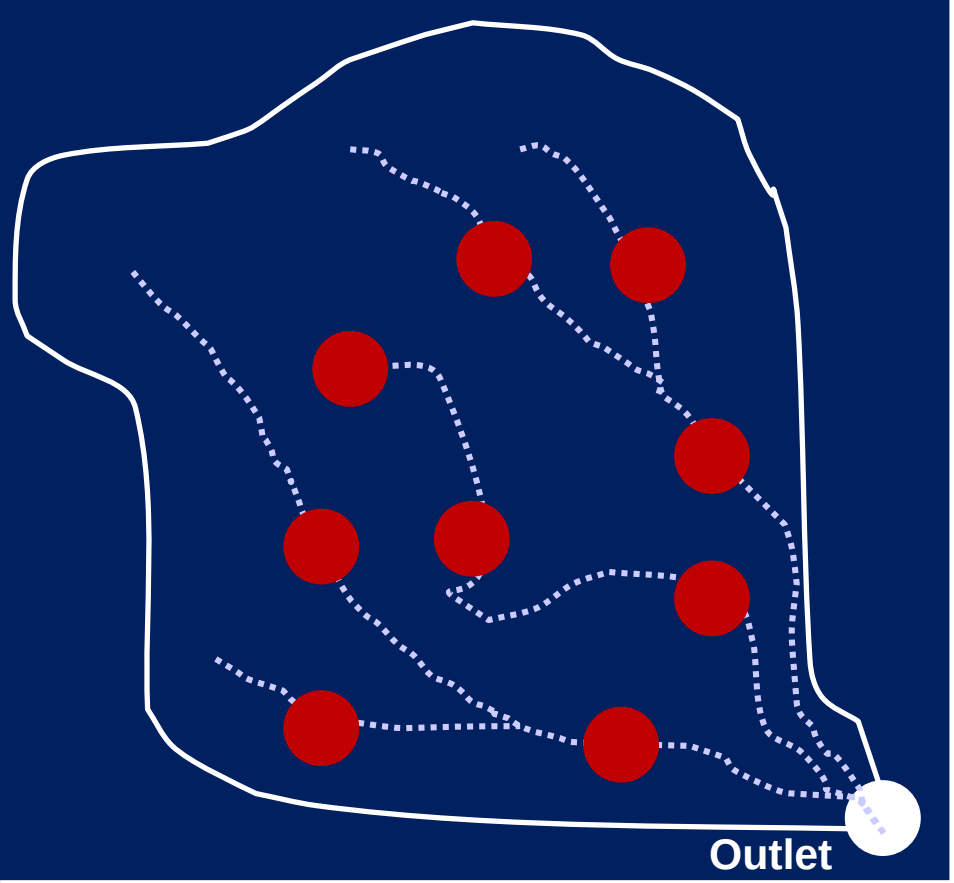
Assessing connectivity using network theory



Goal #2: link local water mgmt. to downstream issues

Promoting disconnectivity via critical nodes





Rationale for spatially-targeted surface runoff management and water table management:

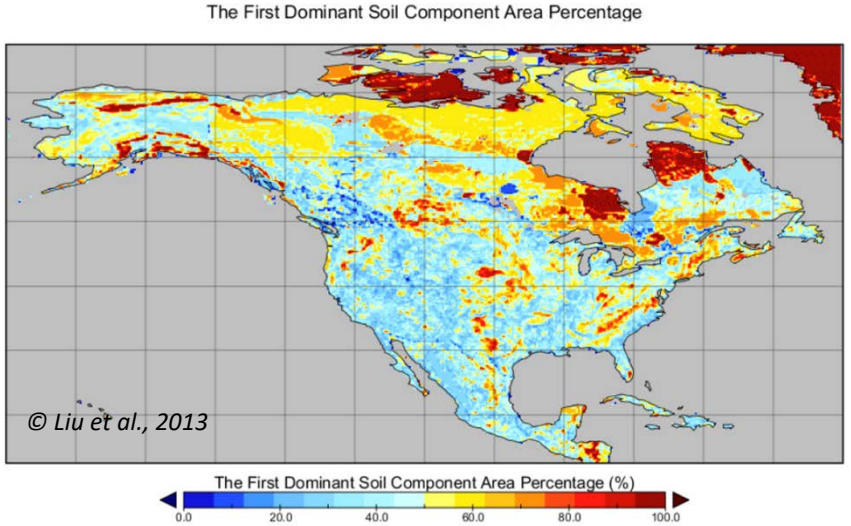
Promoting hydrologic disconnectivity

i.e., "breaking up" natural flowpaths to retain water and associated pollutants on farm

Goal #2: link local water mgmt. to downstream issues

Can we identify priority areas for water mgmt.?

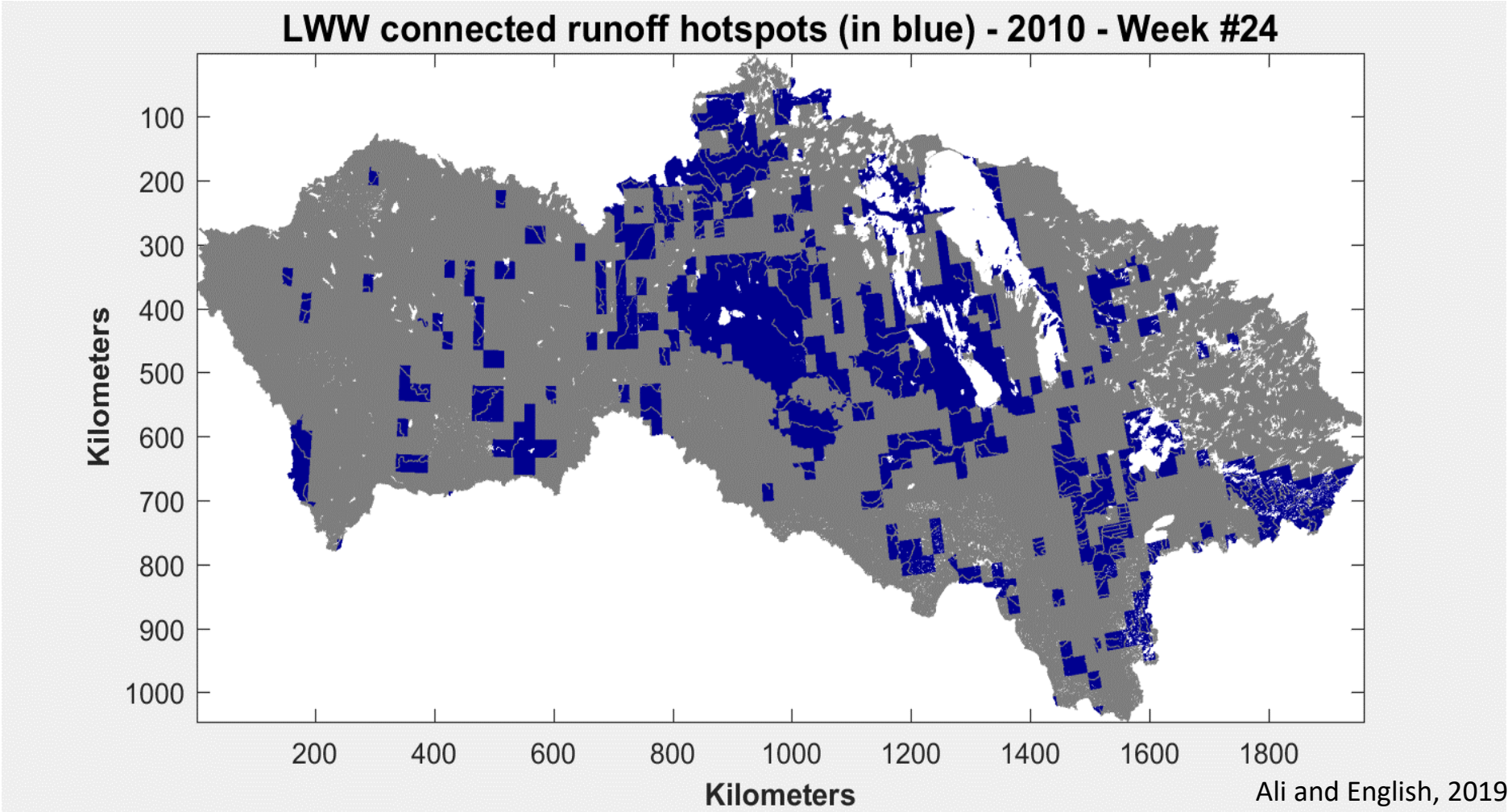
- Connectivity to downstream was inferred for pixels that were:
  - Hydrologically active
  - Adjacent to a 3rd order stream (or higher) or a lake
- Each pixel was classified as:
  - Hydrologically active: root-zone soil moisture ≥ field capacity
  - Inactive: root-zone soil moisture < field capacity
- Field capacity was determined by feeding soil information (Liu et al., 2013) into pedotransfer functions (Saxton and Rawls, 2006)



Goal #2: link local water mgmt. to downstream issues

Can we identify priority areas for water mgmt.?

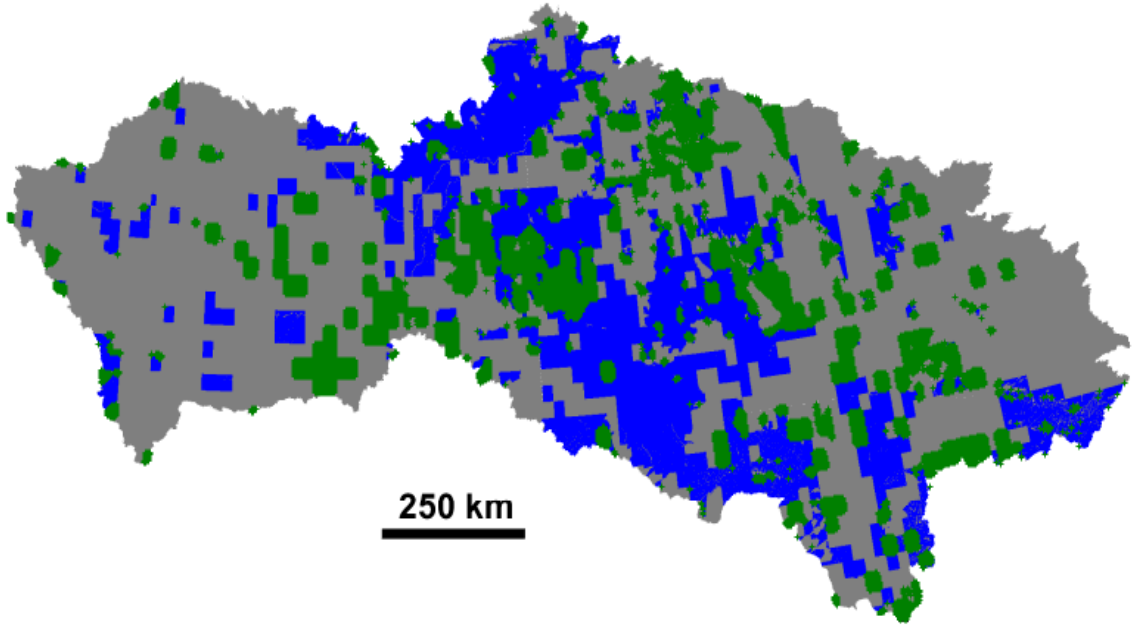
Blue ≡ hydrologically connected areas (ordinary + critical nodes)



Ali and English, 2019

Goal #2: link local water mgmt. to downstream issues

Can we identify priority areas for water mgmt.?



Areas with annual recurrence of hydrologic connectivity to rivers ***not necessarily leading to major algal blooms*** (**ordinary nodes**)

Areas with infrequent or selective hydrologic connectivity to rivers ***leading to major algal blooms*** (**critical nodes**)

Can the connectivity of some specific nodes (within the watershed) be tied to major algal bloom episodes in the Lake? → statistical and network analyses

Goal #2: link local water mgmt. to downstream issues

Can we identify priority areas for water mgmt.?

Critical nodes = priority areas for water management to promote disconnectivity

The methodology for identifying critical nodes is the same regardless of whether we target surface water management or water table management

A similar exercise currently underway across the whole Lake Erie Basin

algal blooms (ordinary nodes) (critical nodes)

Can the connectivity of some specific nodes (within the watershed) be tied to major algal bloom episodes in the Lake? → statistical and network analyses

Rationale for water table management (WTM)

From field-scale concerns to "broader" concerns

- Rationale for WTM at the field scale
  - Improved crop production, reduced erosion, etc.
- Rationale for WTM at the watershed scale
  - Reduced runoff transmission downstream, better water quality downstream

- ***Theoretically speaking***: connectivity assessments can help target priority areas for WTM
- ***The issue***: limited water table data across large spatial scales; soil moisture data may or may not be correlated with water table data; satellite image pixel size is *always* too coarse

Tromp-van Meerveld and McDonnell, 2005; Ali et al., 2018

Speaking of broader concerns…

- In the LWW, is it worth it to identify priority areas for WTM:
  - To mitigate local excess moisture issues? **NO**; limited need across the Lake Winnipeg Watershed
  - To mitigate downstream flooding and water quality? **YES.** Connectivity assessments can help, but they are data-hungry and computationally-hungry. Feasible everywhere?

- Another big unknown, about the timing of WTM:
  - New research shows increased hydrologic connectivity and nutrient export in the non-growing season (NGS) due to climate change (winter thaws, rain on snow)
  - How should we approach WTM in mixed snowmelt- and rainfall-dominated conditions during the NGS? Is it economically/logistically feasible?

Lam et al., 2016; Van Esbroeck et al., 2016; Ali and English, 2019

Thank you!

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