Implications of limited data on sediment yield predictions in a tile drain dominated landscape

Le Sueur River Basin (south central Minnesota)

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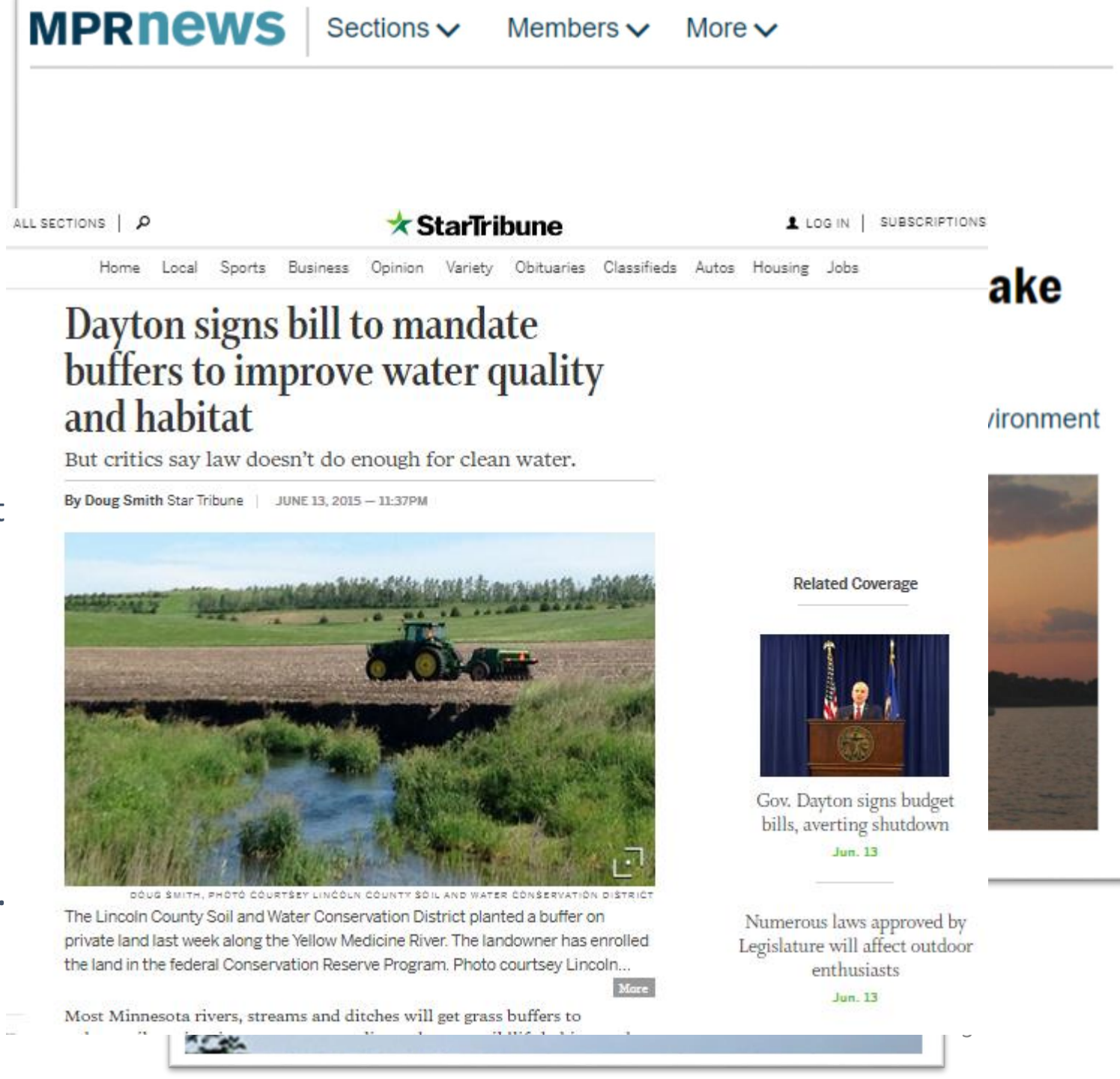
Study area

- Located in south central Minnesota
- Size: 711, 838 acres.
- An extensive ditch and tile system facilitates movement of water throughout the watershed.
- Pre Euro-American settlement
  - Covered with hardwood forests and long-grass prairies.
- Now
  - 35% - corn% and 32% - soybeans.
  - Lakes and wetlands currently comprise 8% of the watershed.

Background

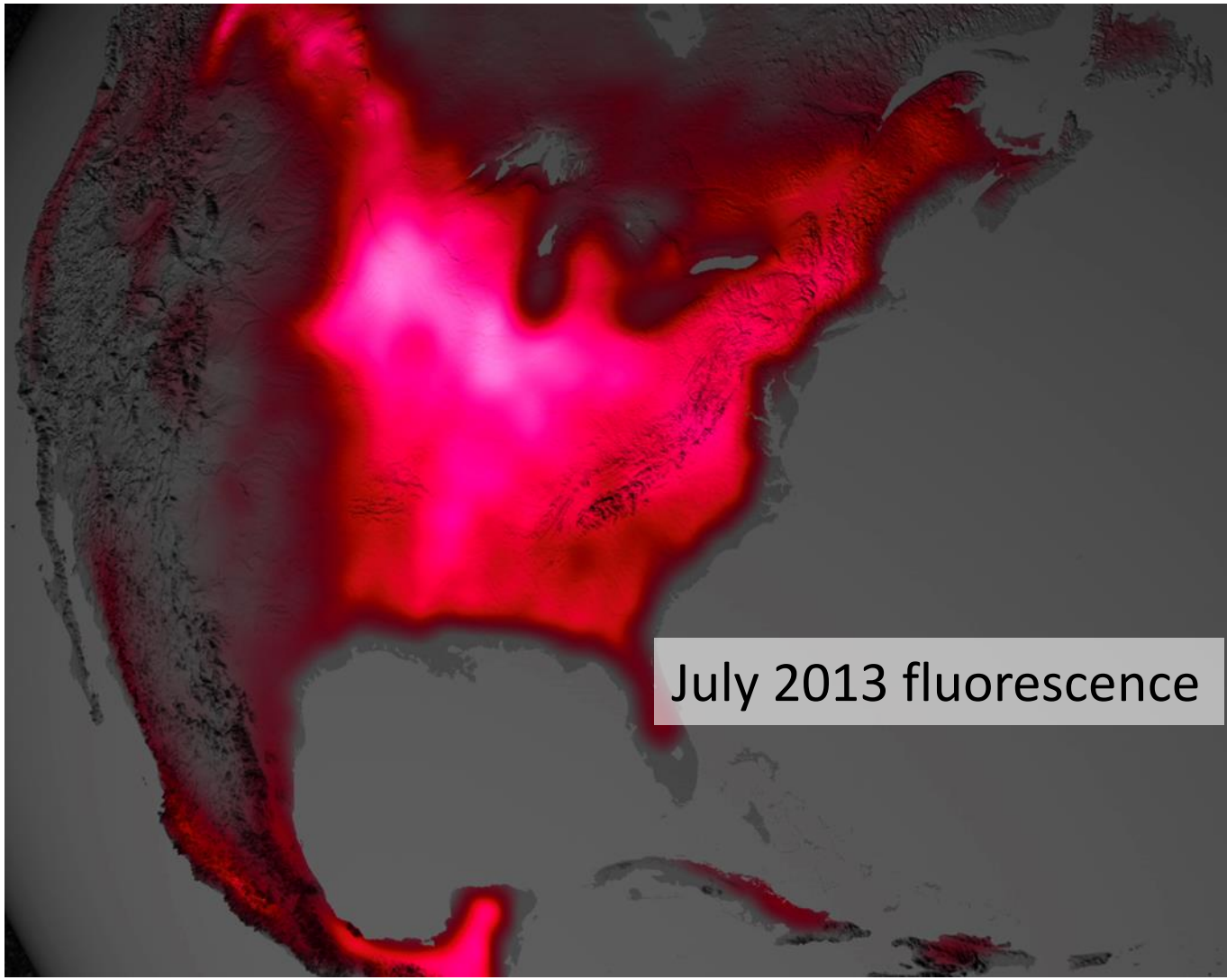
- There is a sediment problem
  - Where is it coming from?
- Environmental implications
  - Fish will lose their spawning habitat
  - Mussels will disappear.
- Economic implications
  - Land loss
  - Loss of recreational and land values.
  - Attracting water thirsty industries?
- Regulations are being put in place..
  - Does it really address the problem?



Modern land and water management

The up-sides of drainage

- Crop productivity is way up!
- More rainfall infiltrates into the soil, less runs off the surface

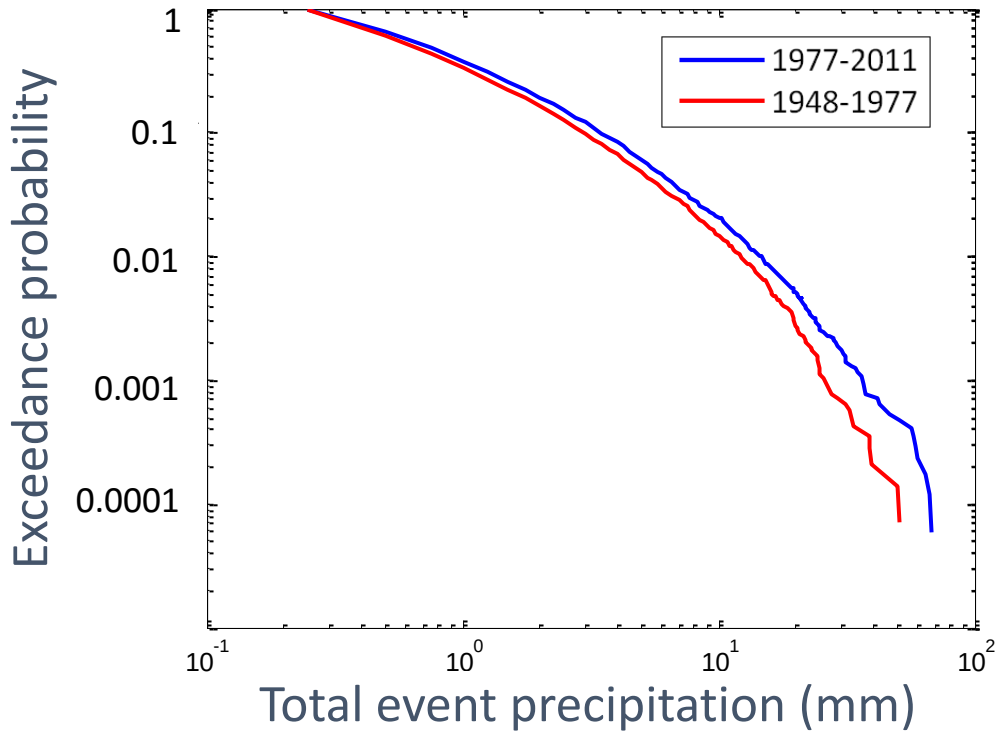


The down-sides of drainage

- Concentrating flow in some sensitive areas
- Increasing the amount and rate of water delivered to the river

And we're getting more rain

- Precipitation has increased!
- Big events are getting bigger



Zeinab Takbiri

Bluff failure

Quick recap and objective

Recap…

- Landscape is currently heavily tiled.
- Tile location, spacing and connectivity unknown.
- More water gets to the river.
- And there is more rain.
- Resulting in increased turbidity and land loss.
- Pivotal to the sediment question is the tile.

Objective…

- Use SWAT mainly to quantify flows.
- Understand the role tiles and precipitation in a large watershed.
- Predict local terrestrial erosion rates.
- Use additional sources of information to quantify channel and near channel sources.

Model performance

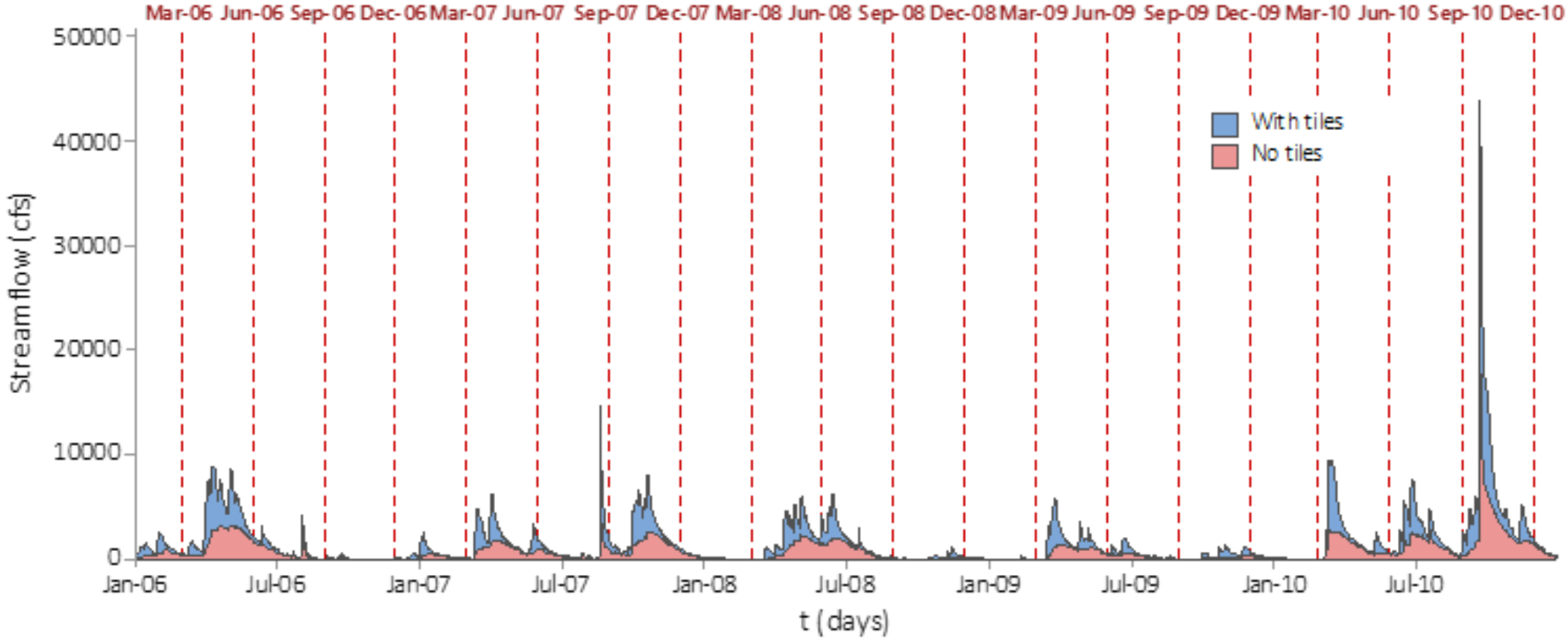
- Peak flow (so, NSE)
- Daily time step NSE values
- e.g. seasonal NSE value

Stream gage	Fall 2007 NS	Overall NS
Le Sueur River at St. Clair, CSAH28	0.65	0.65
Le Sueur River nr Rapidan, CR8	0.80	0.57
Le Sueur River nr Rapidan, MN66	0.89	0.72
Little Beauford Ditch nr Beauford, MN22	0.60	0.68
Little Cobb River nr Beauford, MN	0.75	0.63
Big Cobb River nr Beauford, CR16	0.70	0.48
Maple River nr Sterling Center, CR18	0.82	0.76
Maple River nr Rapidan, CR35	0.65	0.68

Change in the hydrograph due to tiles

At mouth of the watershed

- Higher peak flows.
- Steep rising and falling limbs.

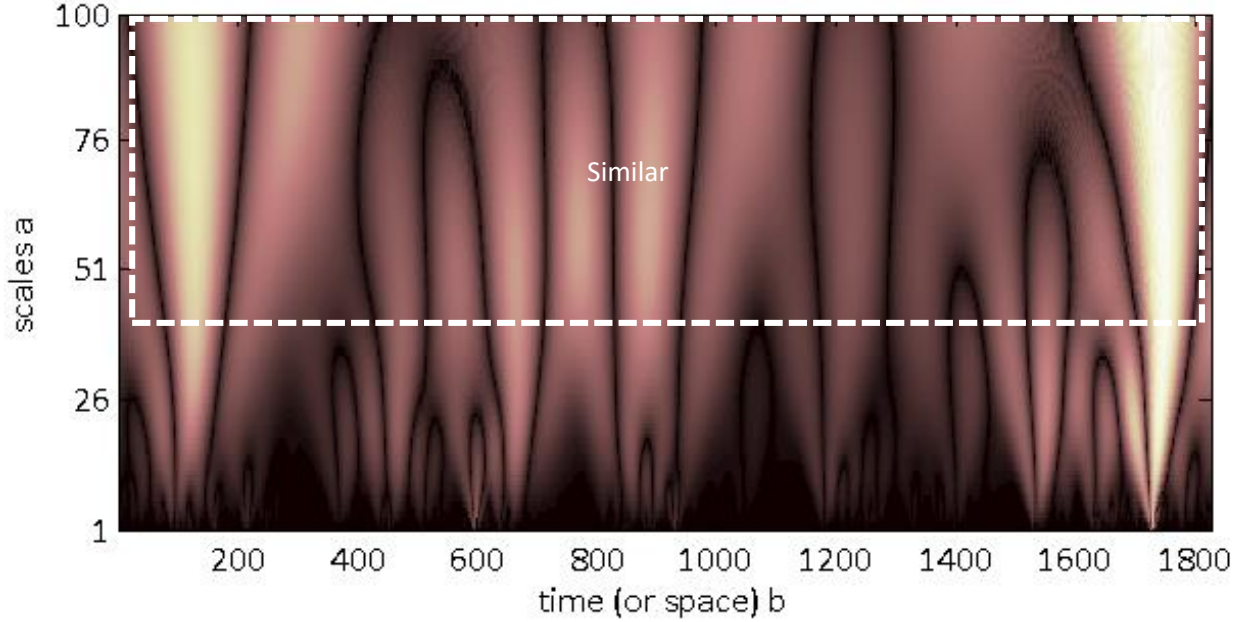


Another way to look at the hydrograph
frequency domain analysis

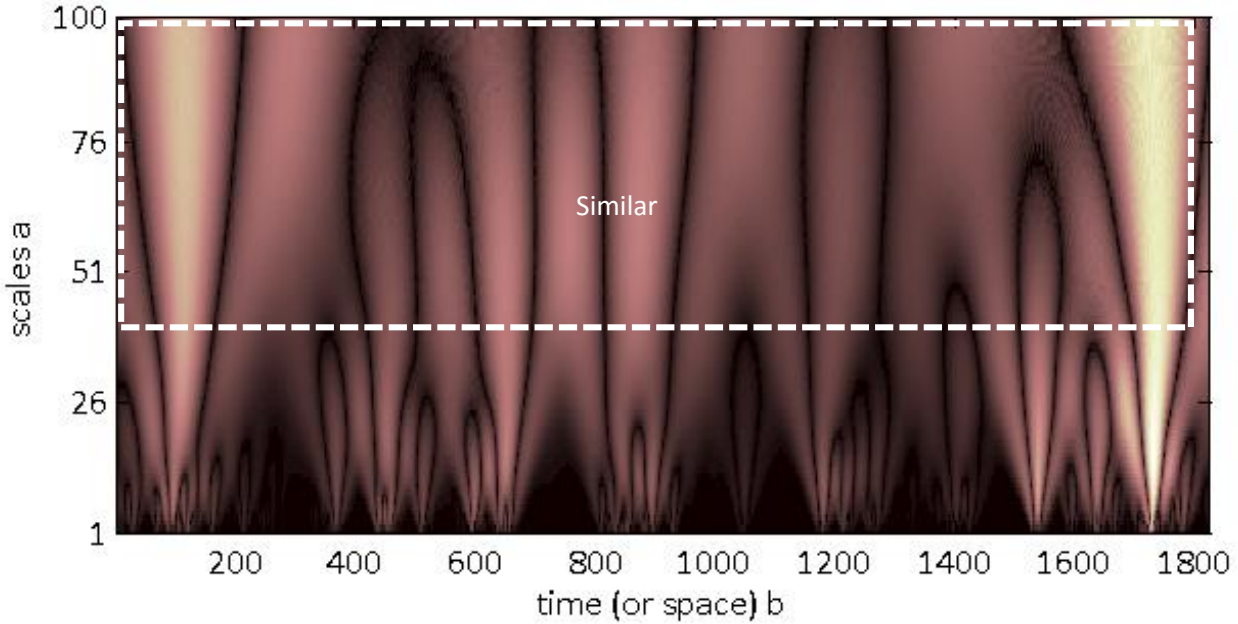
- Streamflow vs. time as a 1-D signal
- Feature extraction
- Wavelet transform
  - non-periodic and transient
  - analyze the signal in the frequency domain

What has changed?

- Longer term flow patterns remain unchanged
- Change occurring at lower scales (significant variability at daily flows).



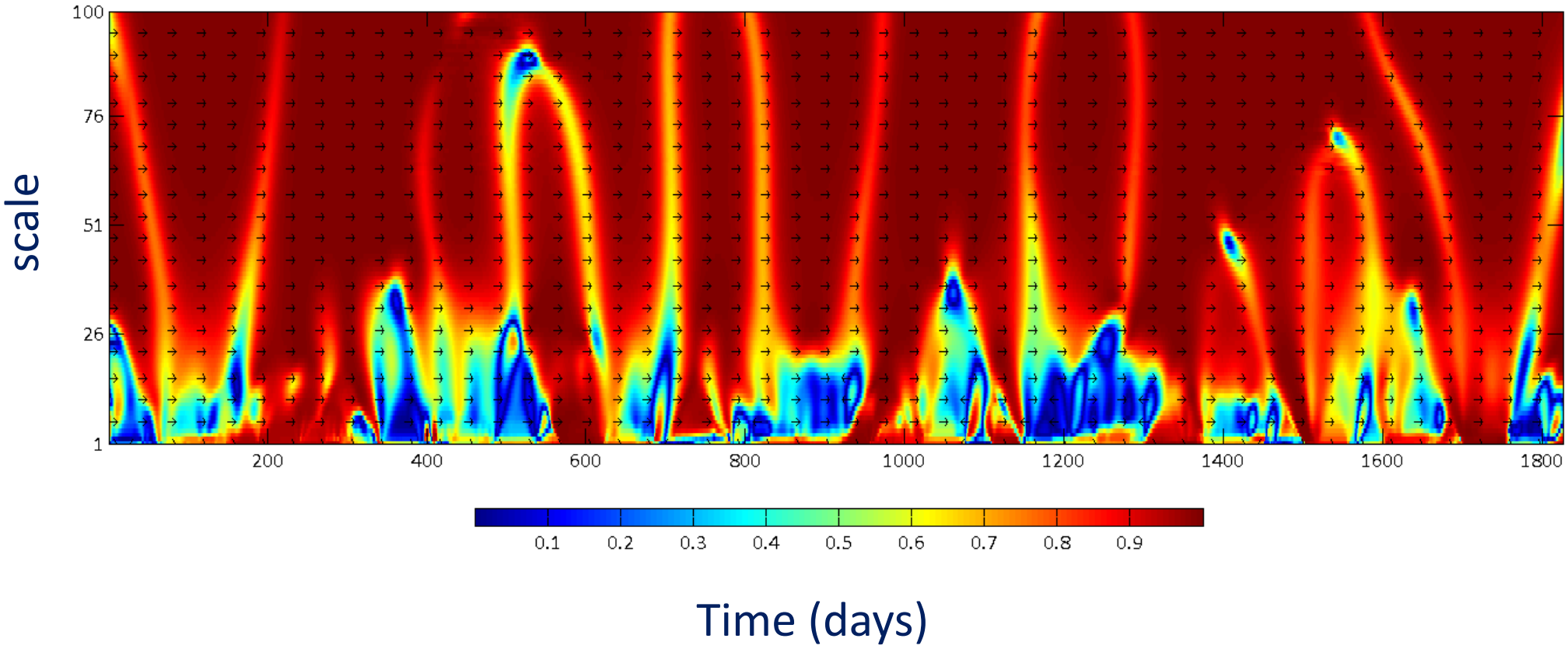
No tiles



With tiles

What has changed?

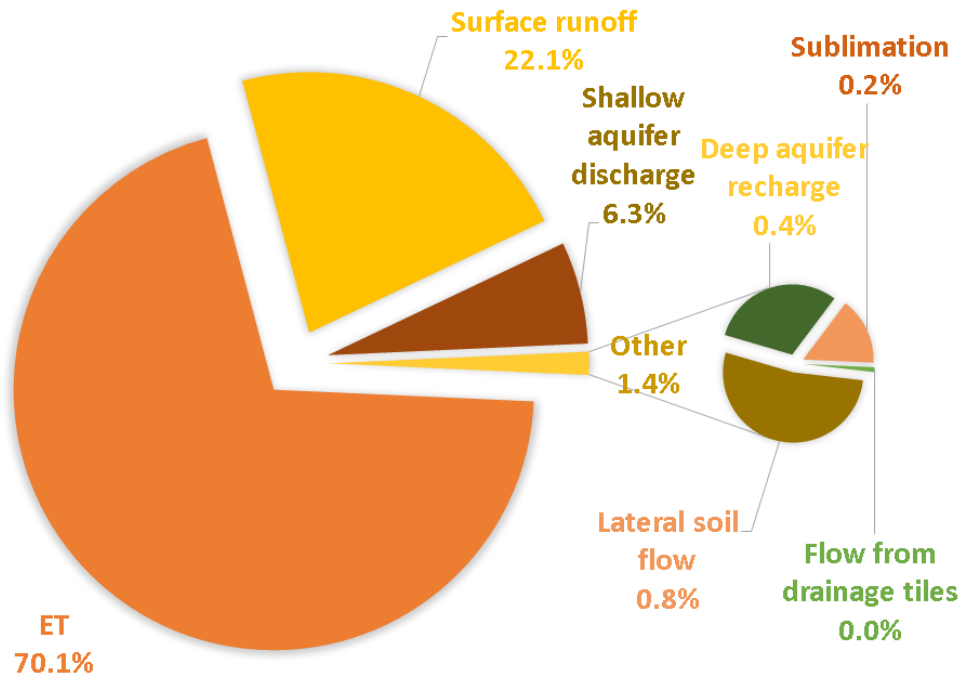
Another direct way to identify the change



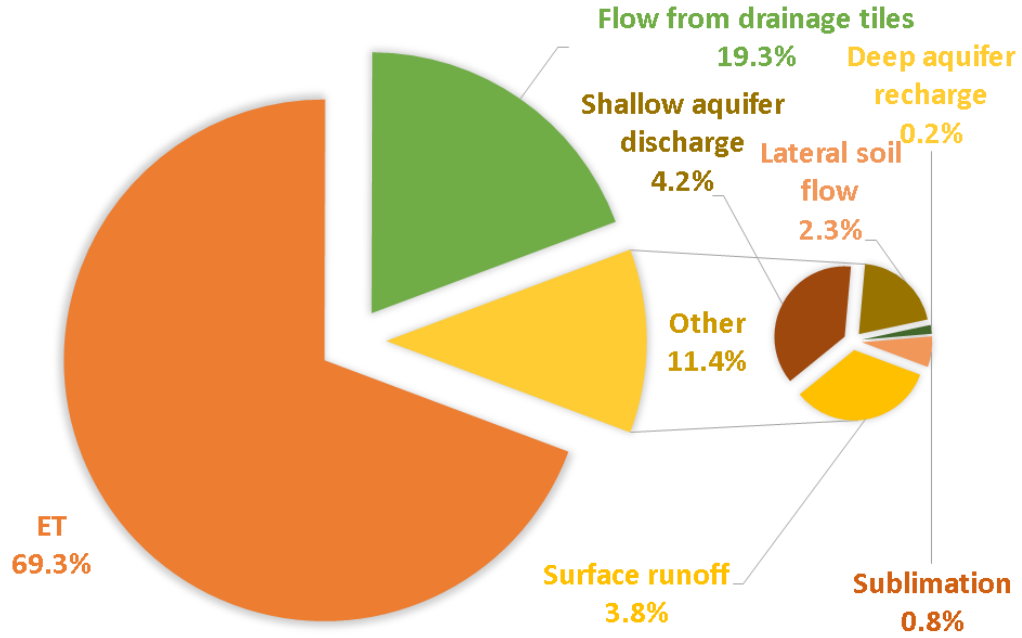
Influence of tiles

Annually averaged water balance - watershed scale

No tile



Tile



Scenarios

Role of tile, precipitation and scale

Tile spacing (e.g., 15m, 20m)

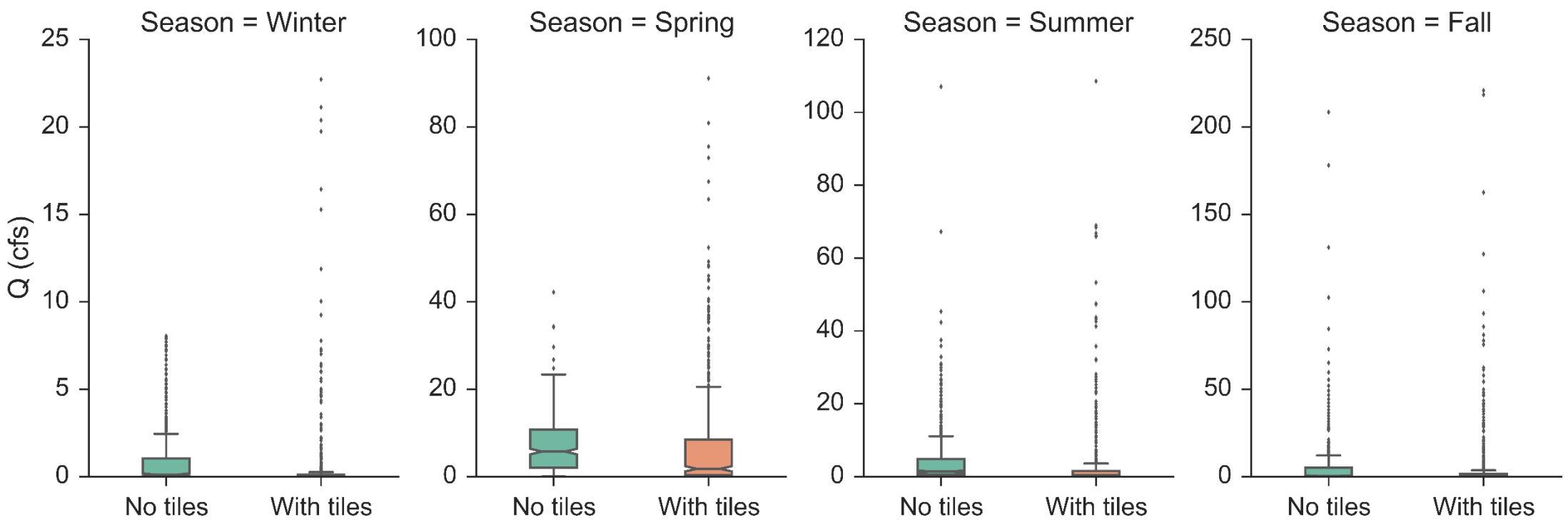
Precipitation (vary intensity, duration and frequency)

Seasonal character

Scale (Field vs. Watershed)

Seasonal character of tiles on hydrology

Field scale



(χ^2 = 64.93 and P = <0.05)

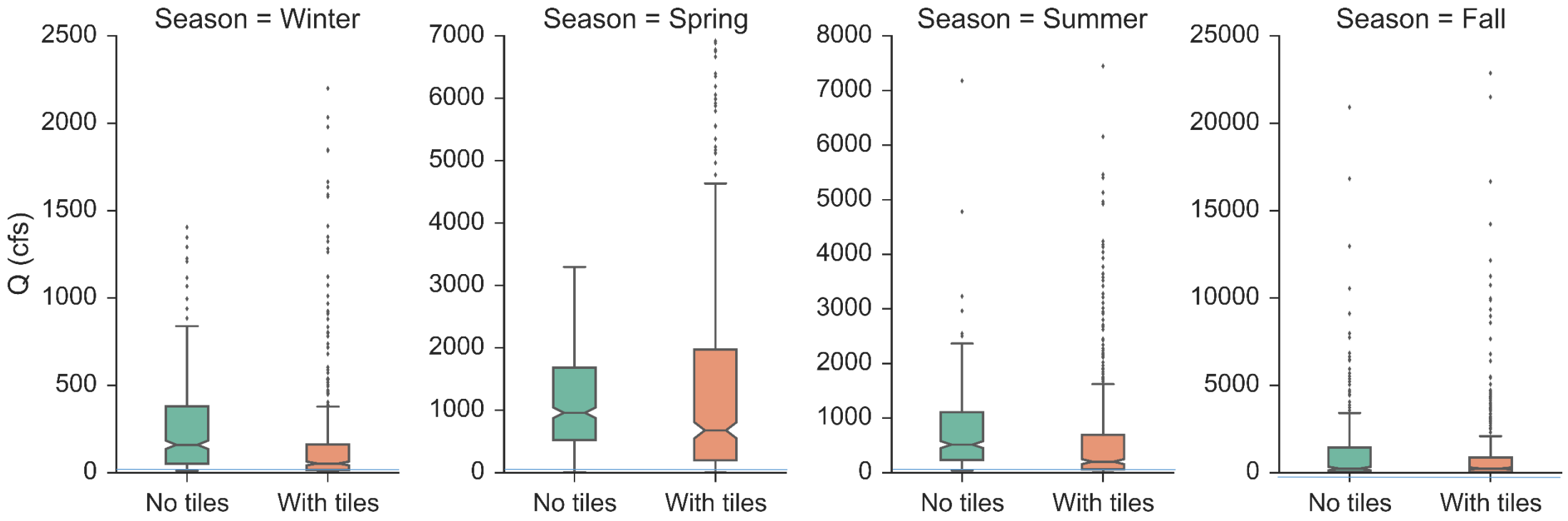
(χ^2 = 41.76 and P = <0.05)

(χ^2 = 78.07 and P = <0.05)

(χ^2 = 4.22 and P = 0.040)

Seasonal character of tiles on hydrology

watershed scale



(χ^2 = 56.63 and P = <0.05)

(χ^2 = 11.76 and P = 0.001)

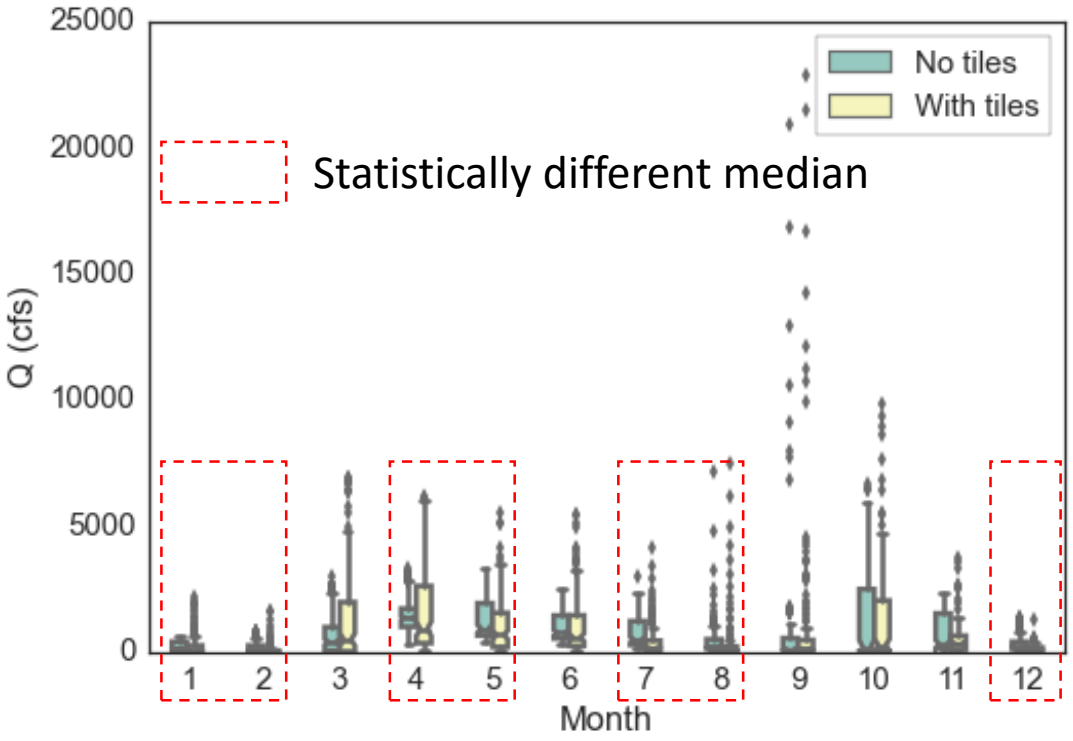
(χ^2 = 71.23 and P = <0.05)

(χ^2 = 0.00 and P = 0.947)

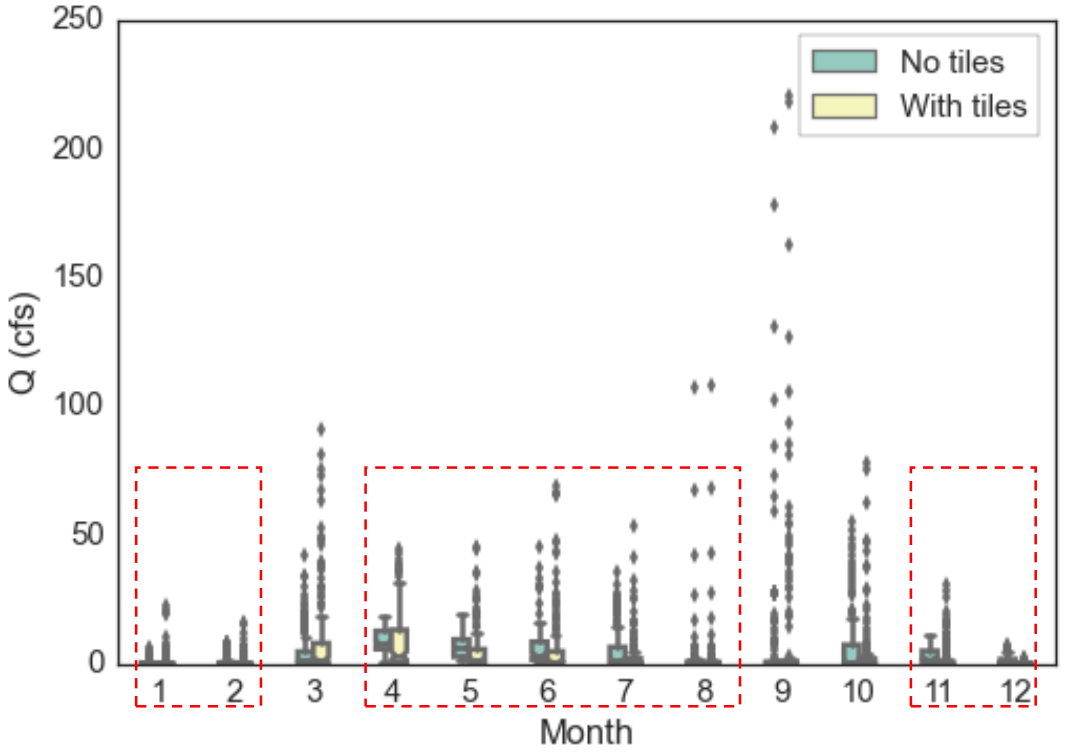
Monthly variability between tile vs. no tile cases

actual precipitation

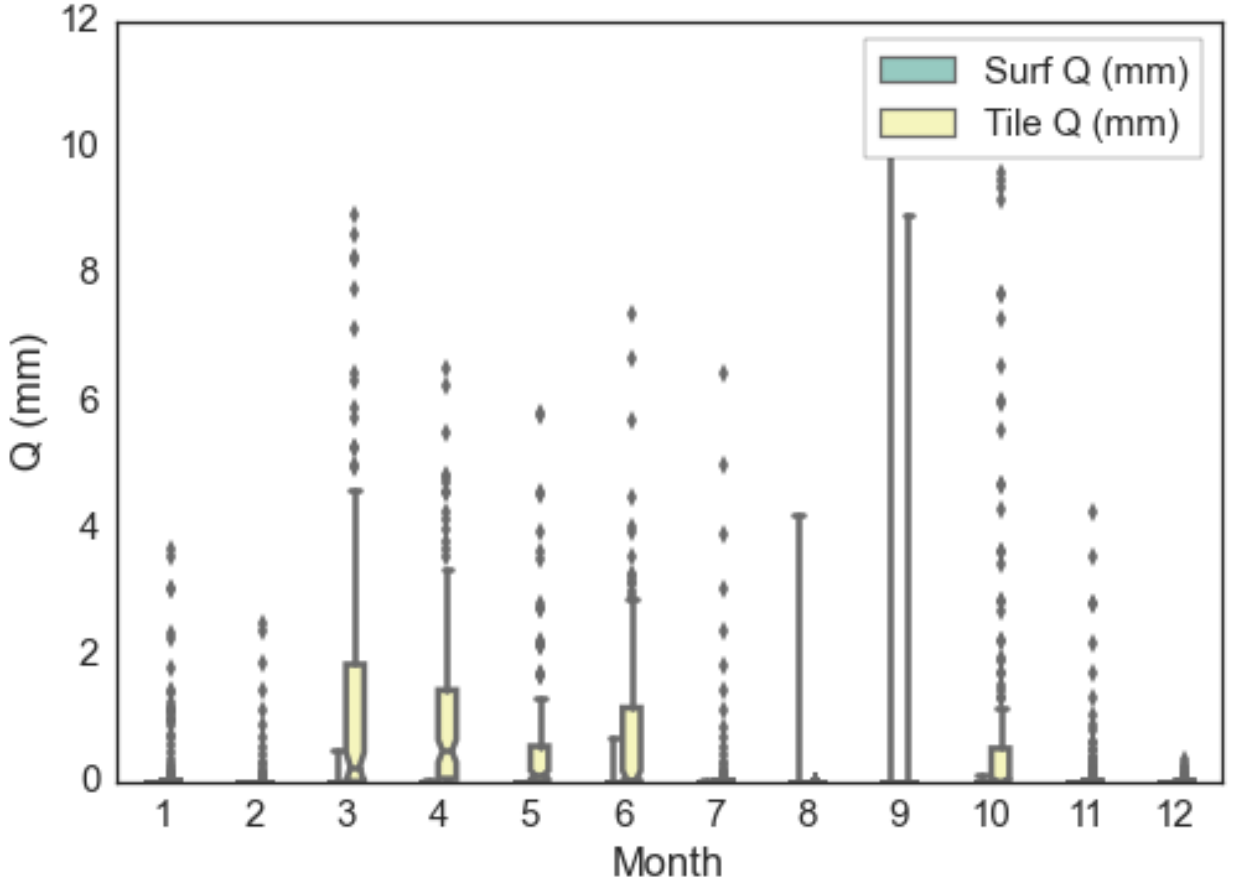
Watershed scale



Field scale



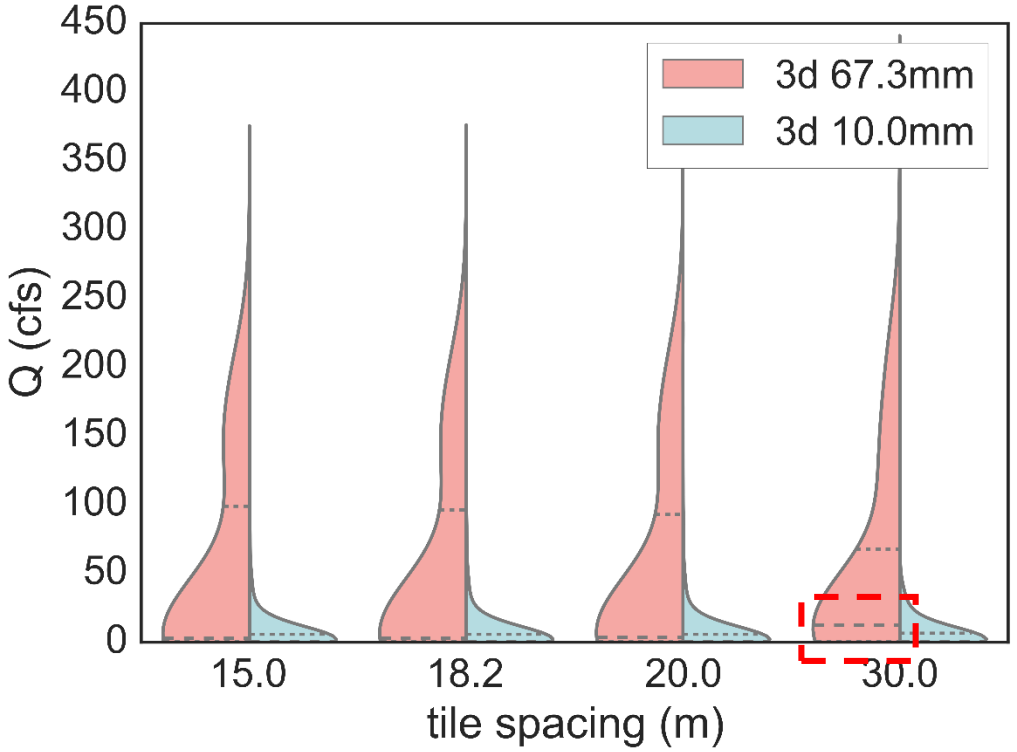
Surface runoff vs. tile flow



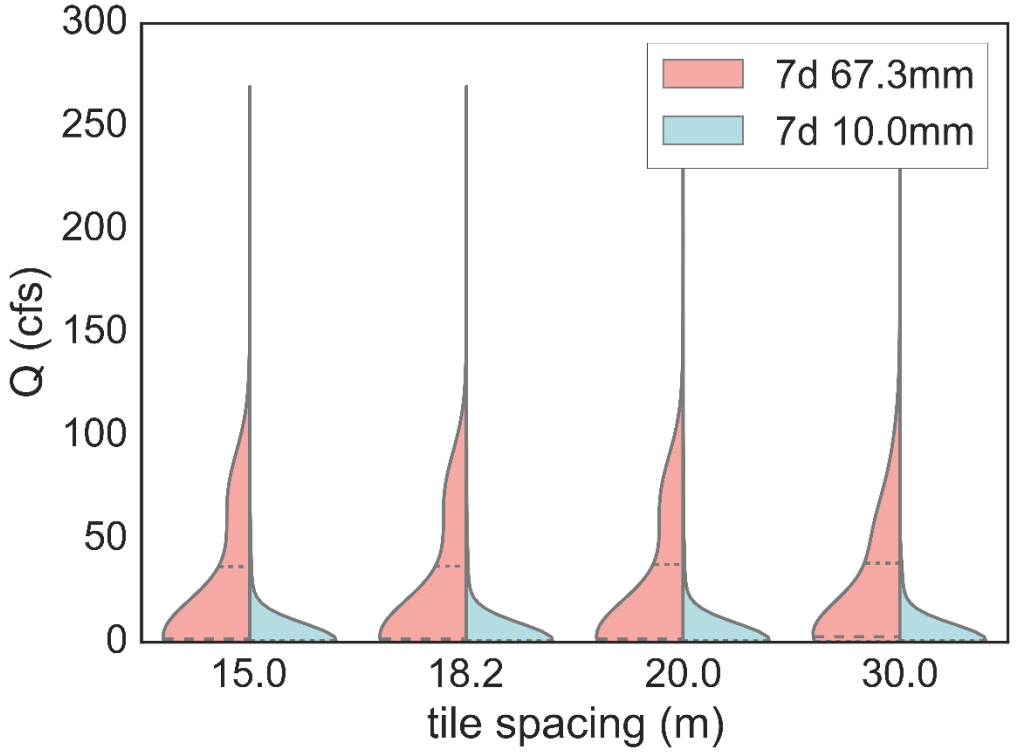
Rainfall intensity vs. tile spacing

Field scale

Rainfall more often (every 3 days)



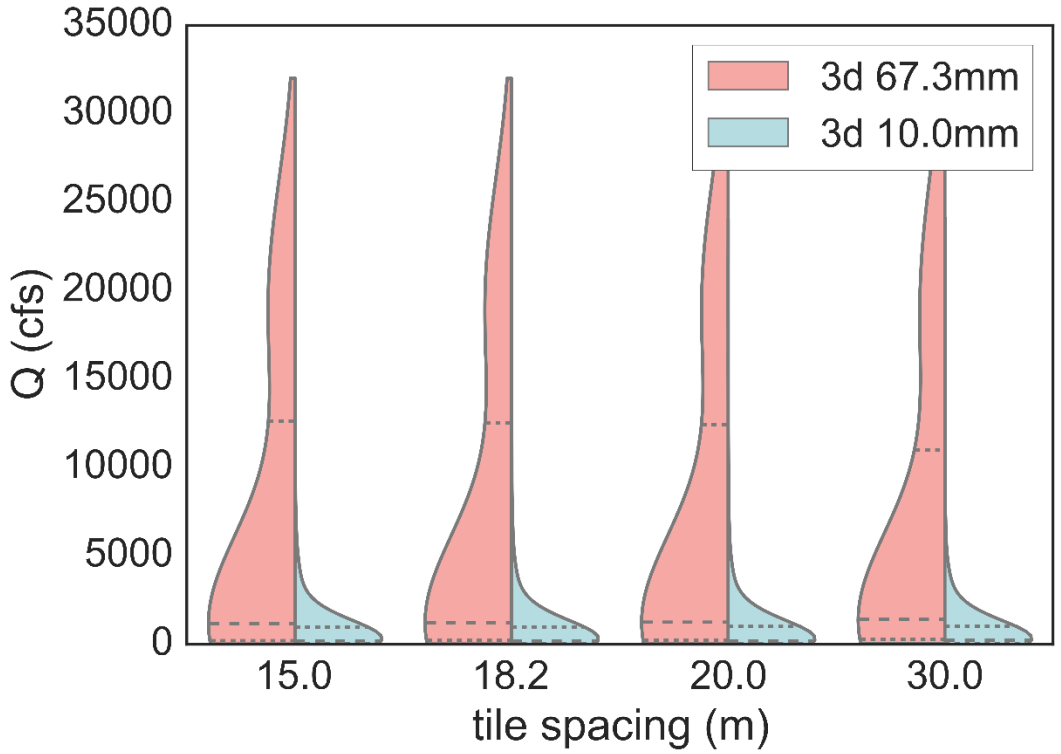
Rainfall less often (every 7 days)



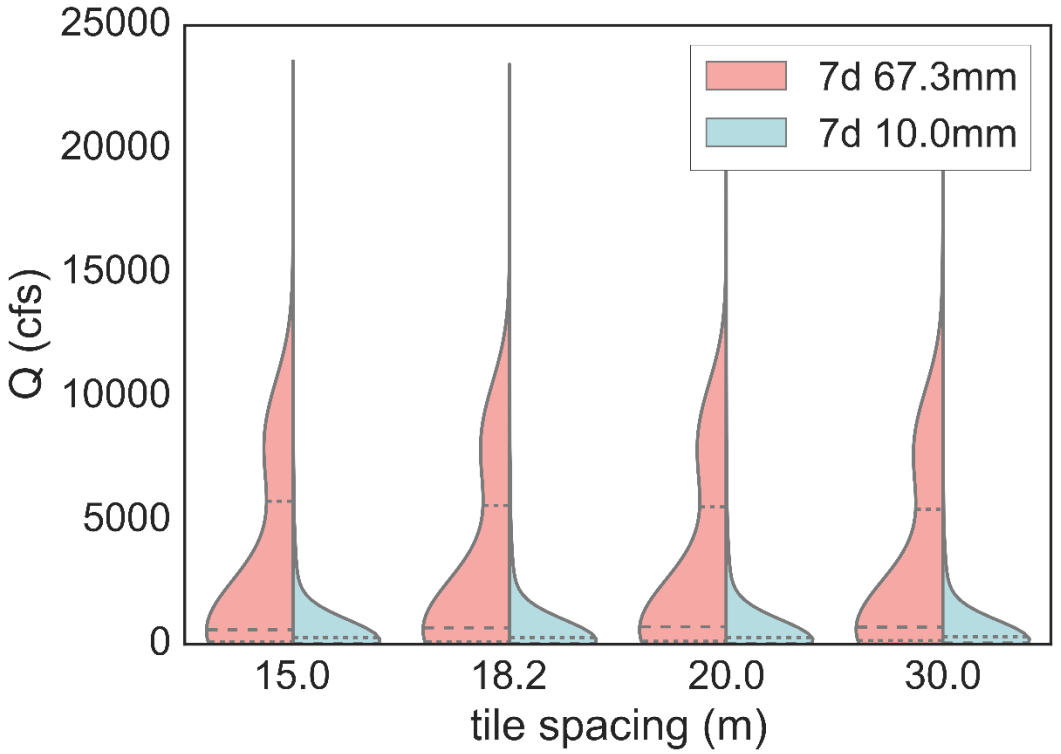
Rainfall amount vs. tile density

Watershed scale

Rainfall more often (every 3 days)

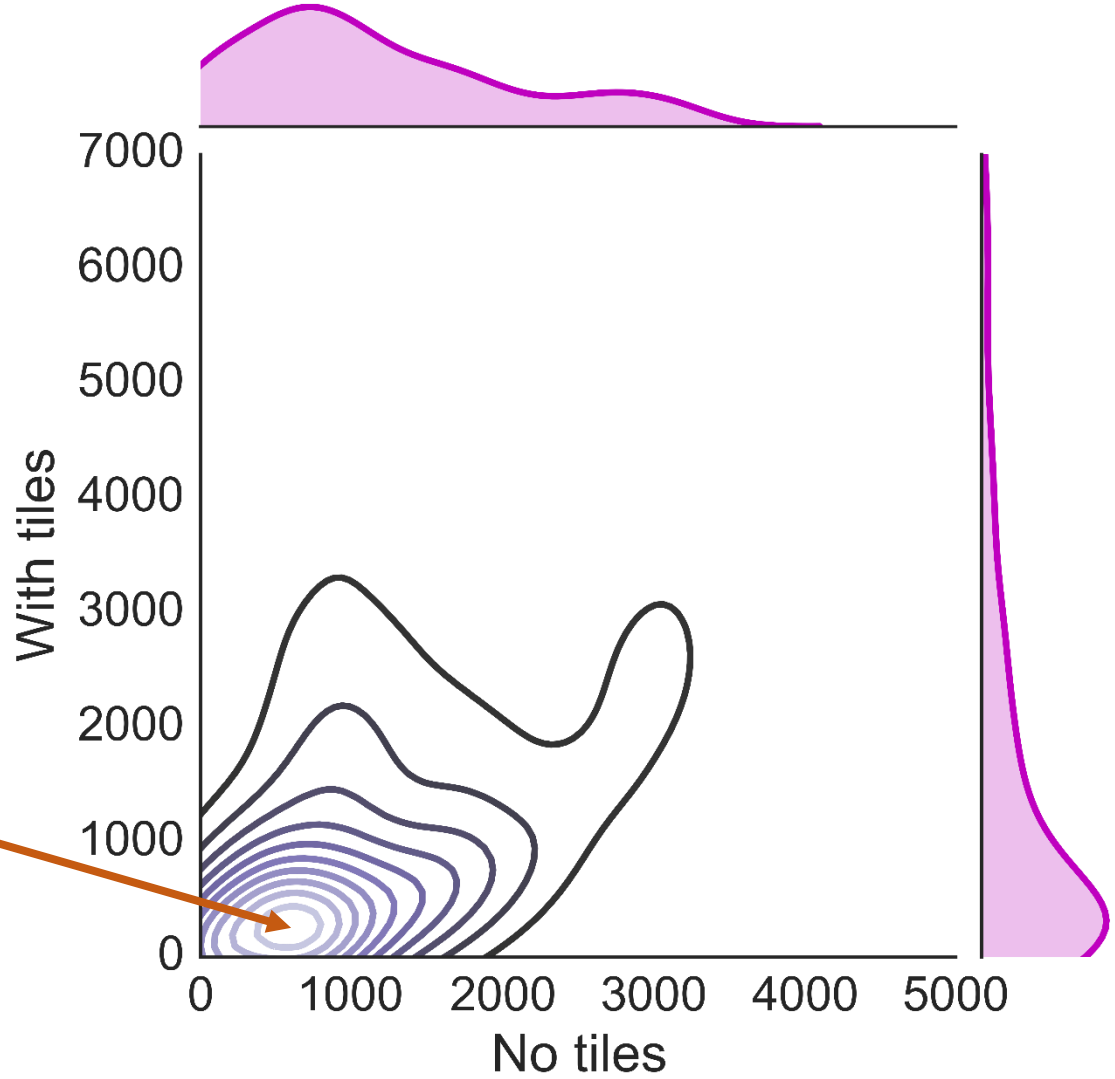


Rainfall less often (every 7 days)



Likely flow with or without tiles

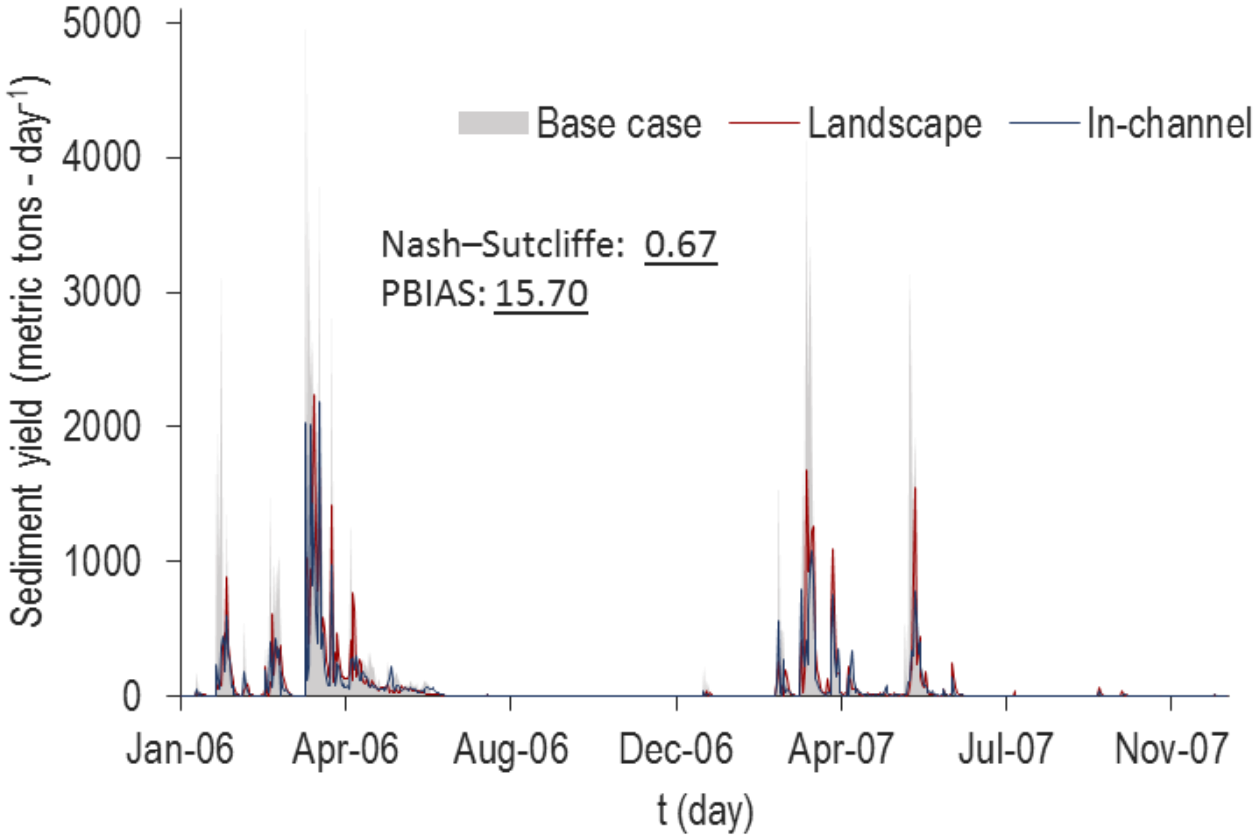
What scale?

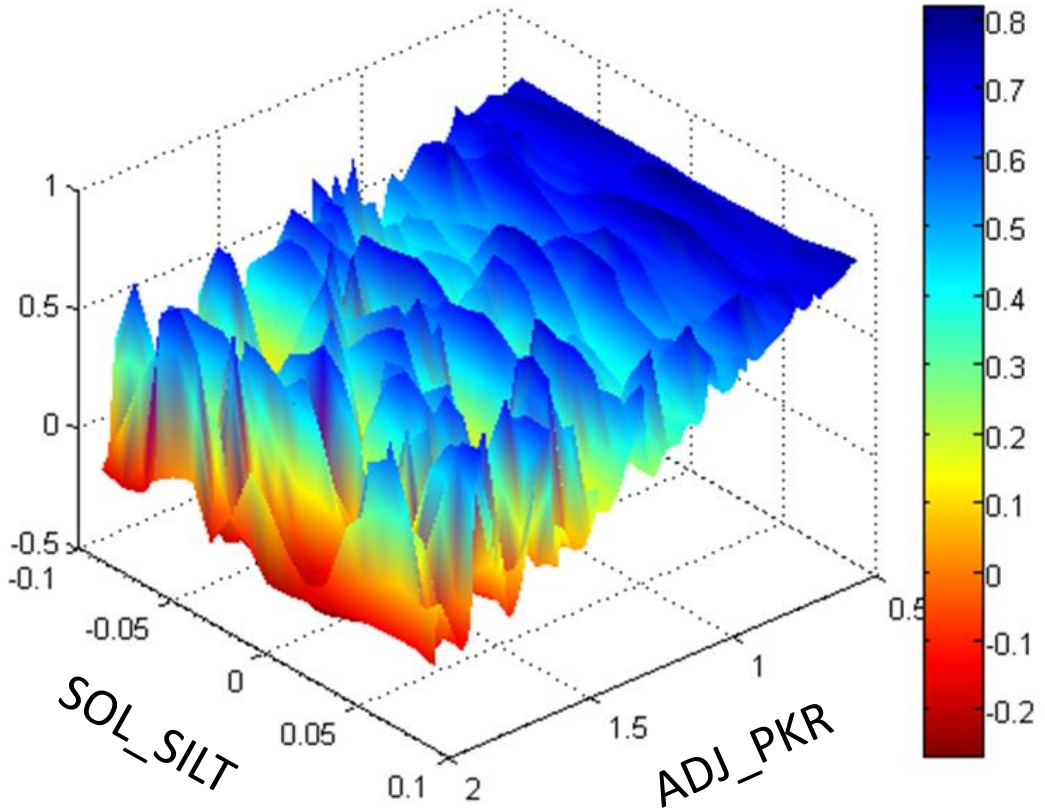


Most likely flows

Where is the sediment coming from?

Challenge with SWAT





Other lines of evidence

- Air photo analysis
- Bluff photogrammetry analysis
- Sediment fingerprinting

Conclusions

- Equifinality still a challenge, however, can be constrained to some extent.
- Peak flow:
  - Watershed scale: tiles increases peak flow.
  - Field scale: tiles attenuates peak flow.
- Time resolution critically important for understanding the role tiles play in LSRB.
- Increases in intensity, duration, and frequency of precipitation has a pronounced effect on flow compared to tile spacing at both scales.
- Tile spacing does not play a major role at watershed scale.
- On the other hand at field scale tile spacing is critical.

Acknowledgements

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