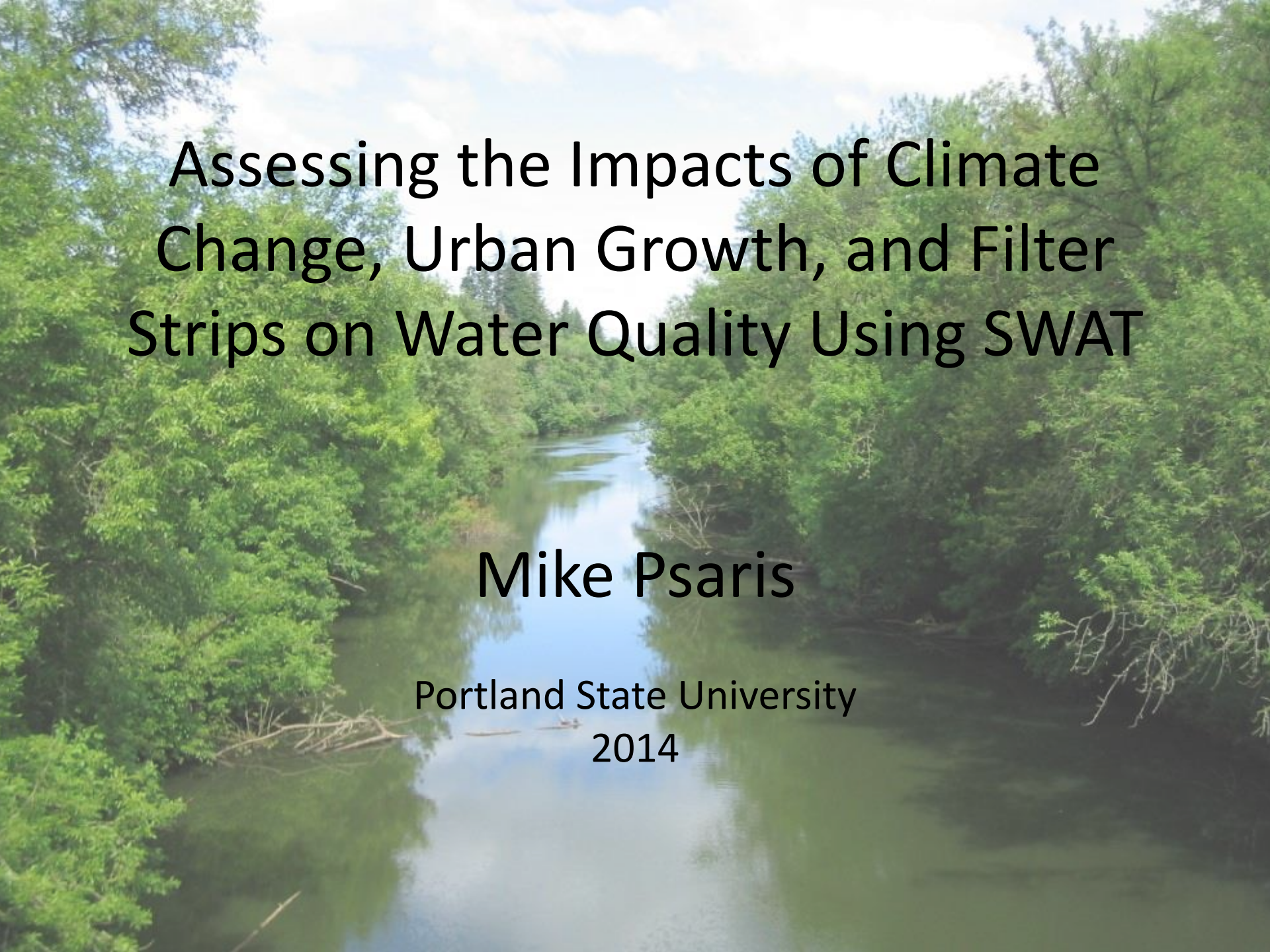


Assessing the Impacts of Climate Change, Urban Growth, and Filter Strips on Water Quality Using SWAT

Mike Psaris

Portland State University

2014

Forward

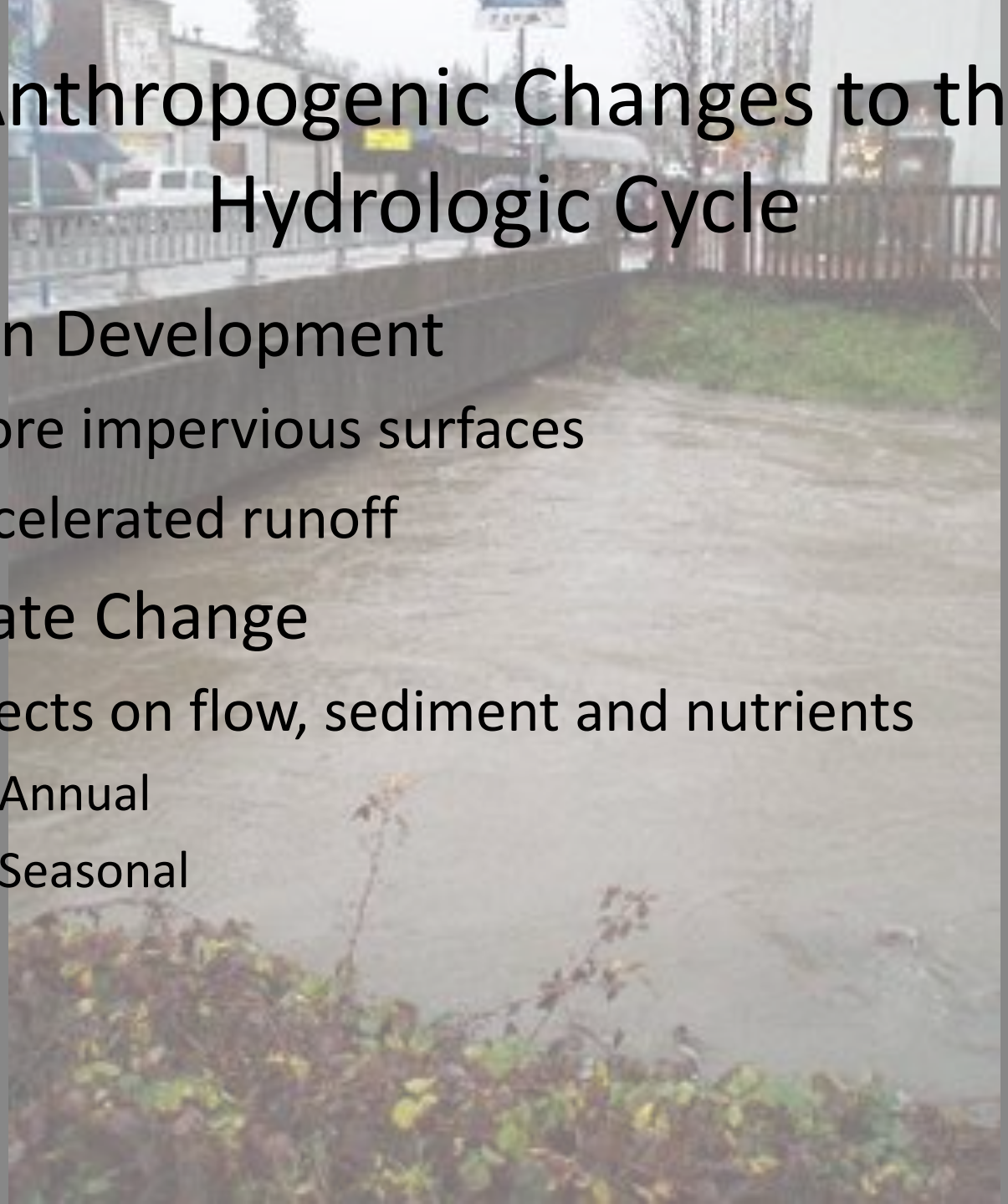
- Research done for the NSF funded SESAME Project.
  - PI (and my thesis adviser): Dr. Heejun Chang
  - Ecosystem Services in the Tualatin and Yamhill basins.

Contents

- Background
- Research Questions
- Study Site
- Data/Methods
- Results
  - Model Calibration
  - Scenario Runs
    - Climate/Land Use
    - Filter strips
- Discussion
- Conclusions
- Question/Comments


BACKGROUND

Anthropogenic Changes to the Hydrologic Cycle



- Urban Development
  - More impervious surfaces
  - Accelerated runoff
- Climate Change
  - Effects on flow, sediment and nutrients
    - Annual
    - Seasonal

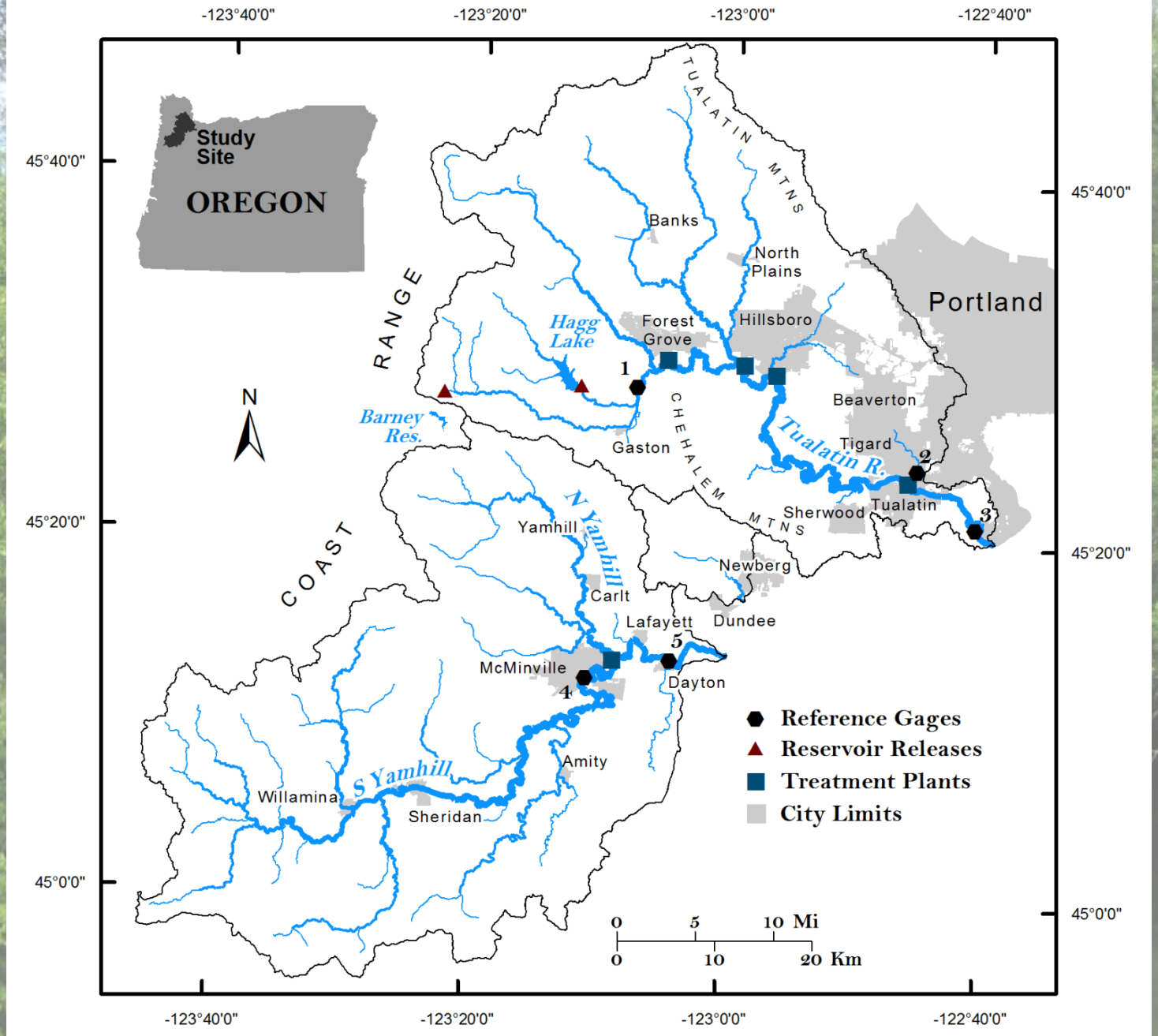
How We Respond

- Use models to
  - Better understand current and future conditions
    - Locate critical source areas (CSAs) of pollutants (Niraula et al 2013)
    - Project future changes
  - Explore management options
    - Vegetated Filter Strips (VFS) (Arnold et al 2012)

Research Questions

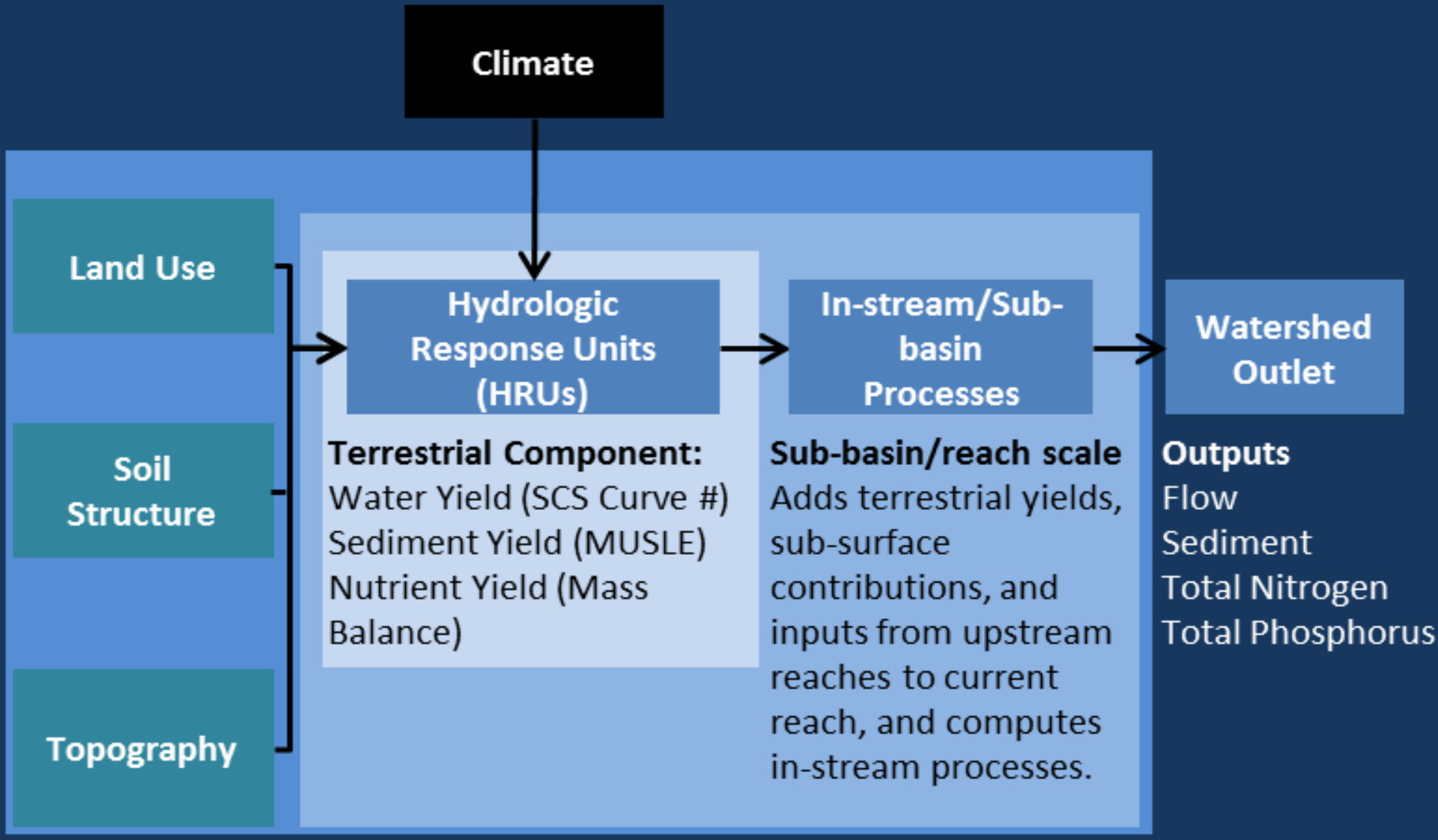
- How do water, sediment and nutrient yields change annually and seasonally under climate change and urban growth?
- What are the locations of CSAs, and will these locations shift in the future?
- What effect does the implementation of vegetated filter strips have on sediment and nutrient yields?


STUDY SITE


-123°40'0"
-123°20'0"
-123°0'0"
-122°40'0"
45°40'0"
45°20'0"
45°0'0"
Study Site
OREGON
N
TUALATIN MTNS
RANGE
COAST
CHEHALEM MTNS
Banks
North Plains
Portland
Hillsboro
Forest Grove
Hagg Lake
Barney Res.
Gaston
Beaverton
Tigard
Tualatin R.
Tualatin
Sherwood
Yamhill
N Yamhill
Carlt
Newberg
Lafayett
Dundee
McMinville
Dayton
Amity
Willamina
S Yamhill
Sheridan
1
2
3
4
5
Reference Gages
Reservoir Releases
Treatment Plants
City Limits
0 5 10 Mi
0 10 20 Km

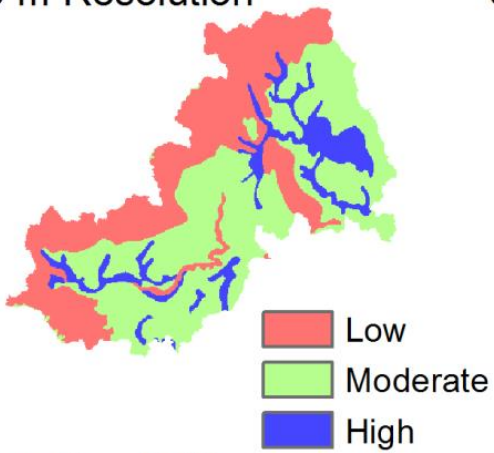
DATA AND METHODS

Soil and Water Assessment Tool (SWAT)

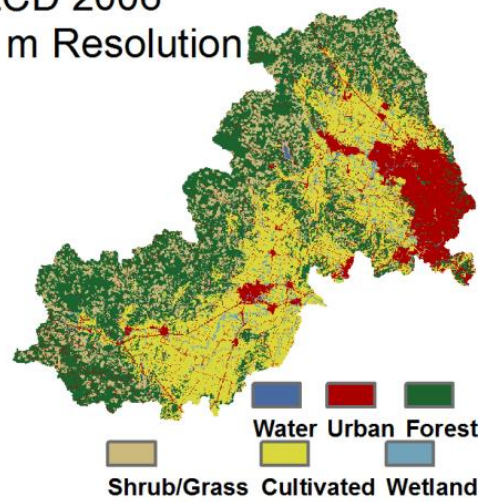


Data Inputs

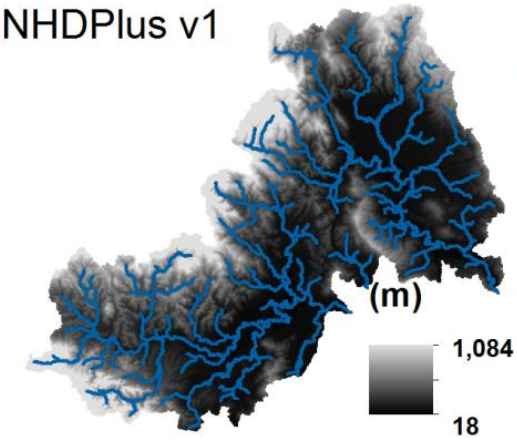
STATSGO Soils
30 m Resolution



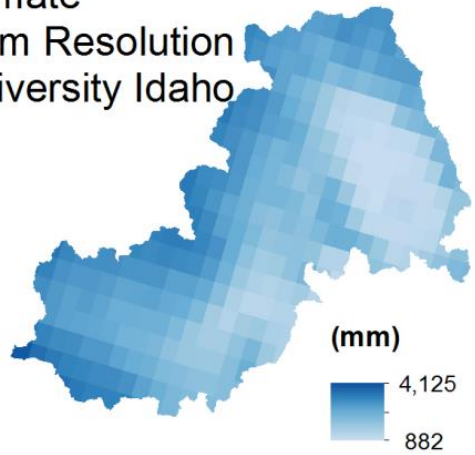
NLCD 2006
30 m Resolution



Elevation & Streams
NHDPlus v1



Climate
4 km Resolution
University Idaho

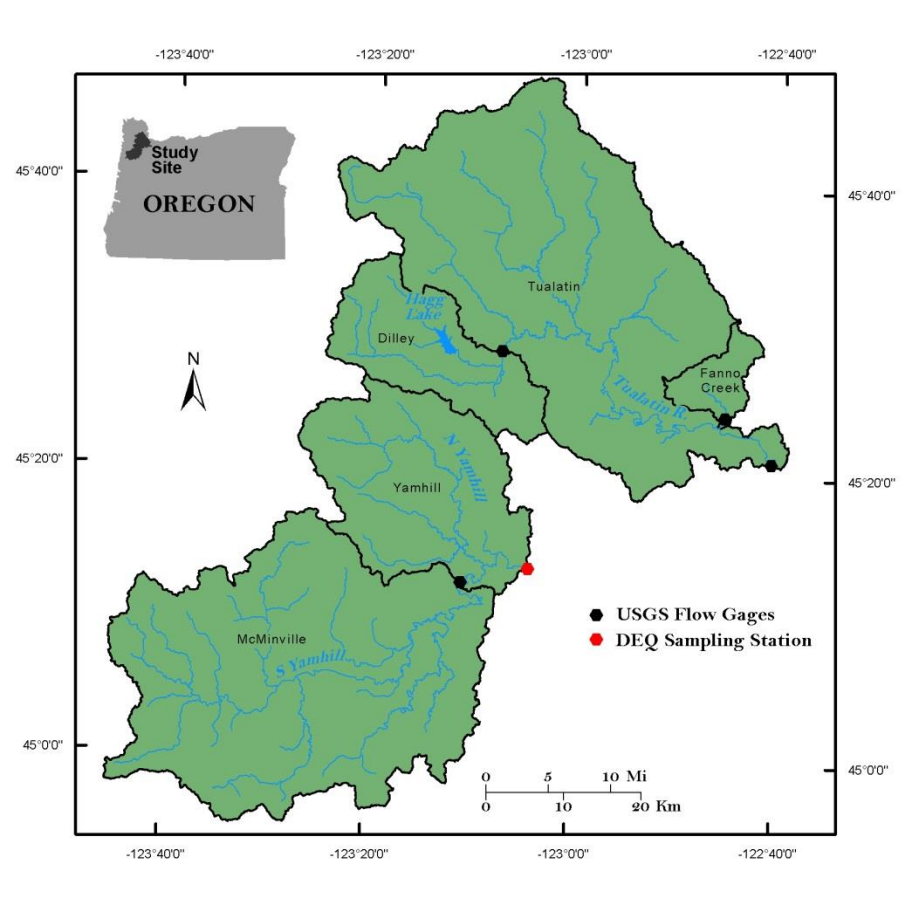


Model Construction

- Reservoir Characteristics
  - Bureau of Reclamation
  - USGS
- Waste Water Treatment Plant Effluent & flow augmentation
  - Clean Water Services
  - No nutrient data

Sediment and Nutrient Load Estimates

- USGS LOADEST software
- USGS and DEQ grab samples paired with USGS daily flow measurements
- Aggregated to monthly loads for calibration



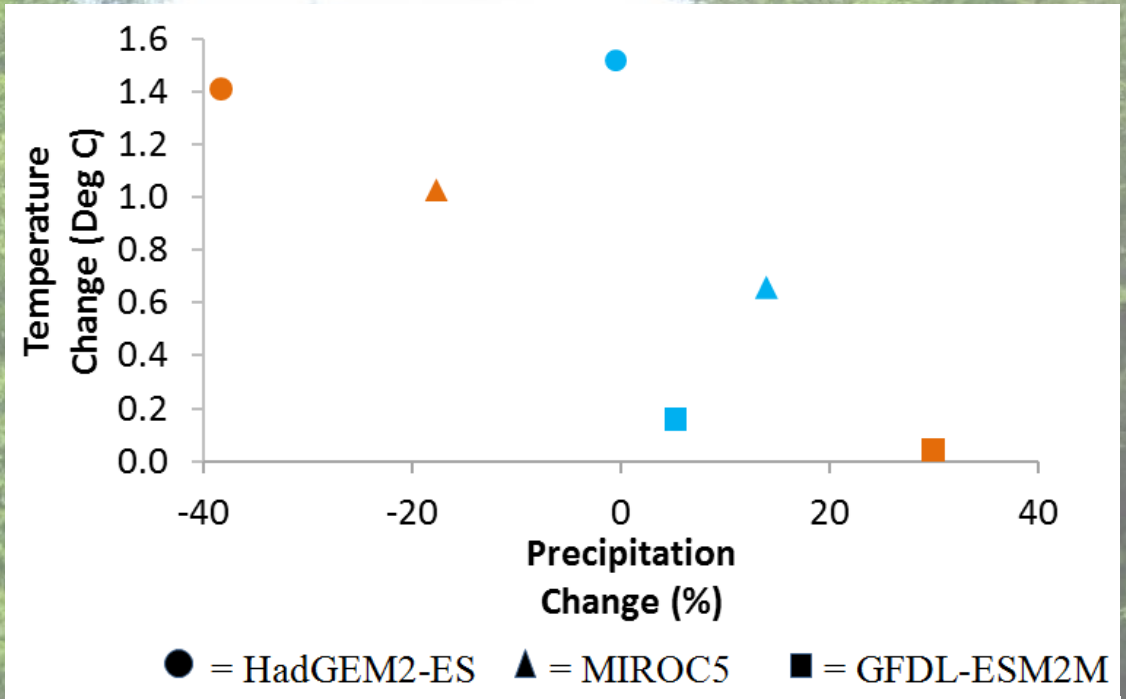
Model Calibration & Validation

- Manual Calibration (1981-2005)
  - Monthly
- Validation (2006-2010)
- Metrics
  - Nash-Sutcliffe Efficiency (NSE)
  - Percent Bias
  - RSR

Calculating Changes

3 Climate scenarios
2 Urbanization scenarios

Climate Scenarios



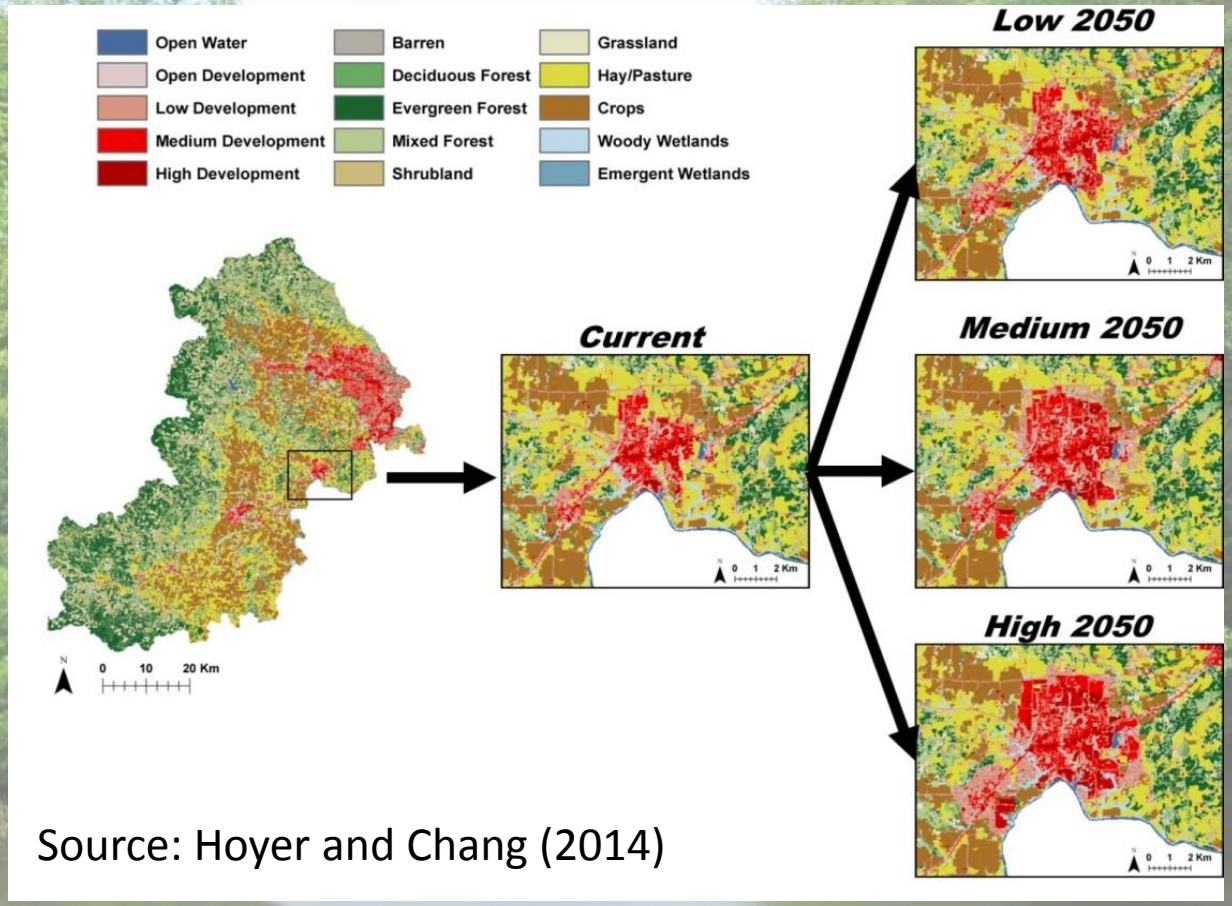
Baseline: 1981-2010

Future: 2036-2065

Winter=DJF

Summer=JJA

Urbanization Scenarios



Source: Hoyer and Chang (2014)

Critical Source Areas

$$INDEX = 0.5S + 0.25N + 0.25P$$

Sediment

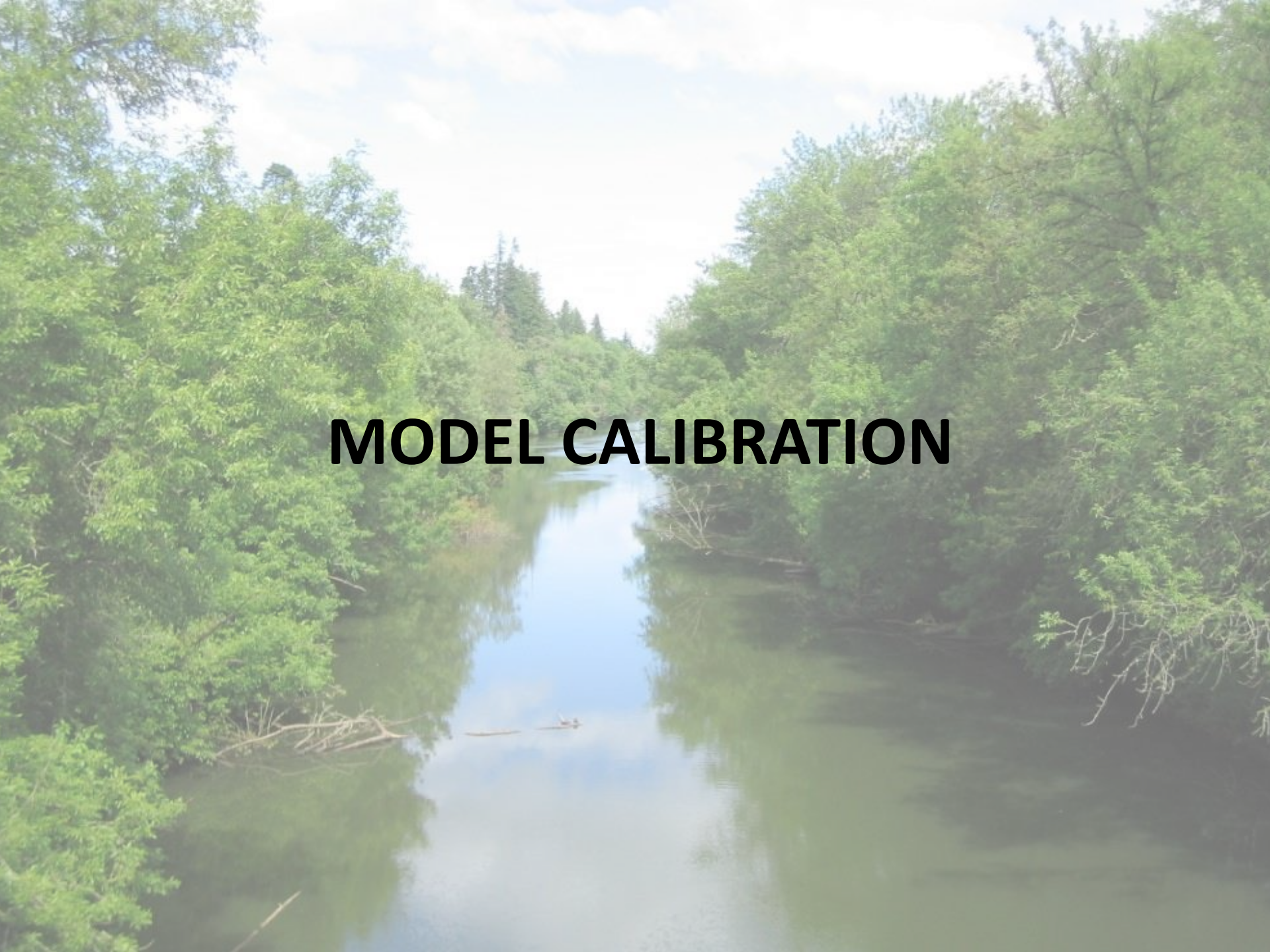
Total Nitrogen

Total Phosphorus

Vegetated Filter Strip (VFS) Model

- Sub-basins with indices in the top 5% in Yamhill
- Two representative years: Water Year: 1994-95

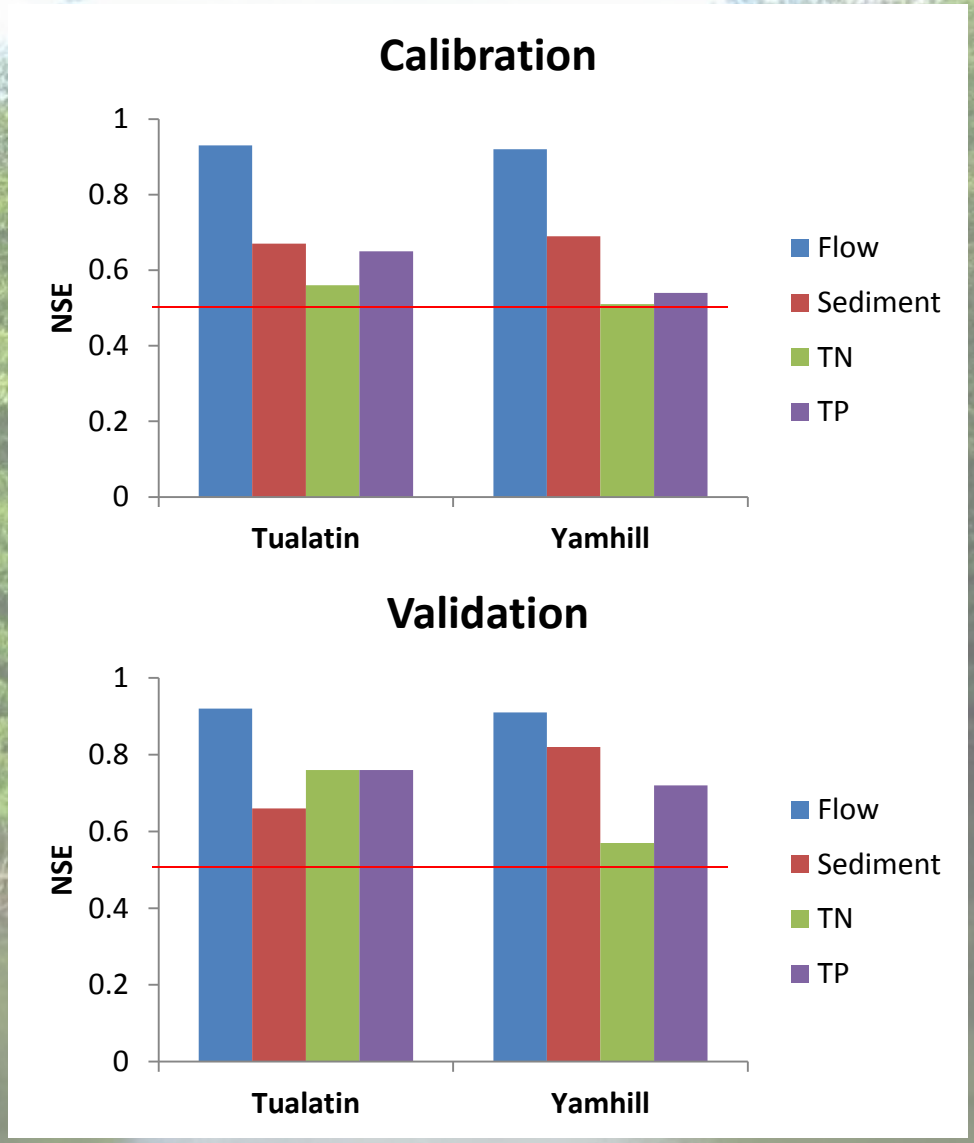

RESULTS


MODEL CALIBRATION

NSE

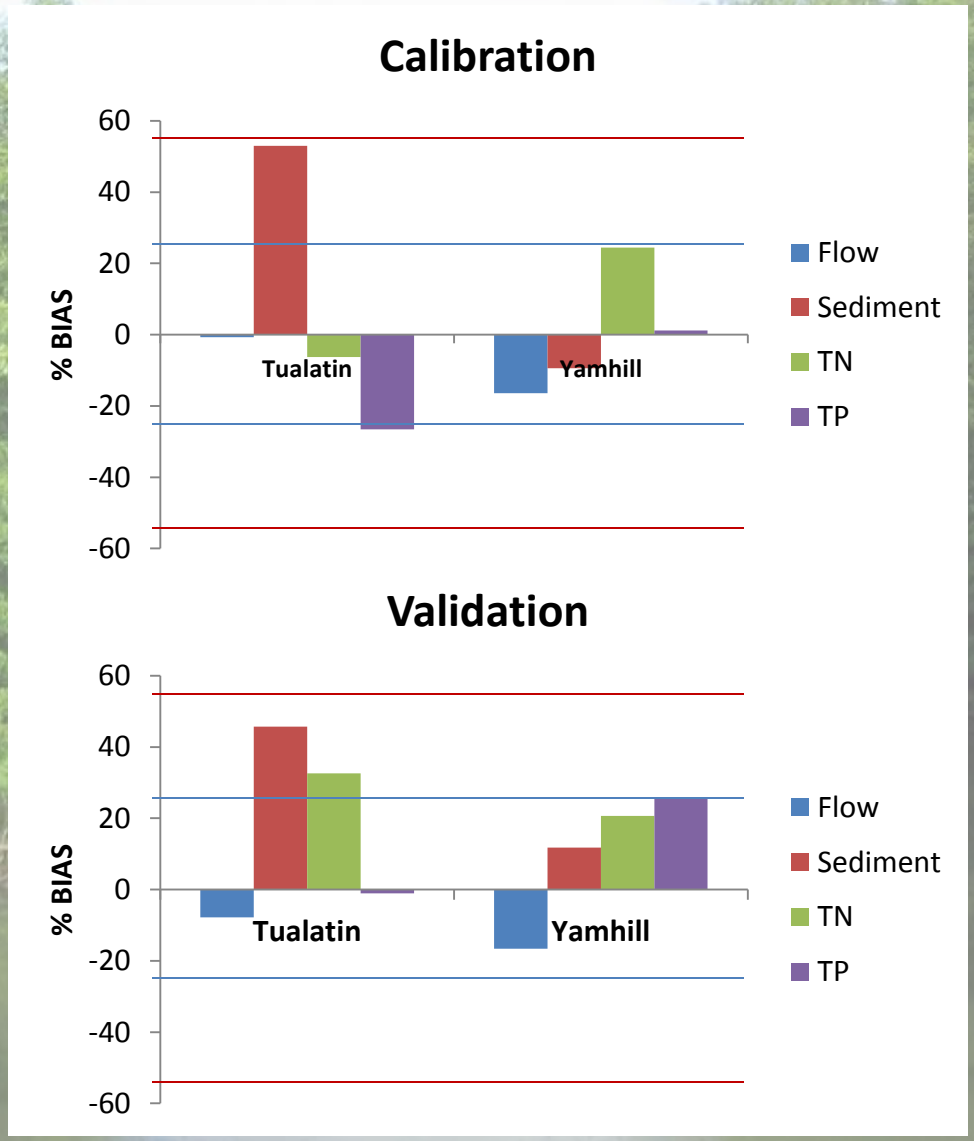
Goal

NSE > 0.5



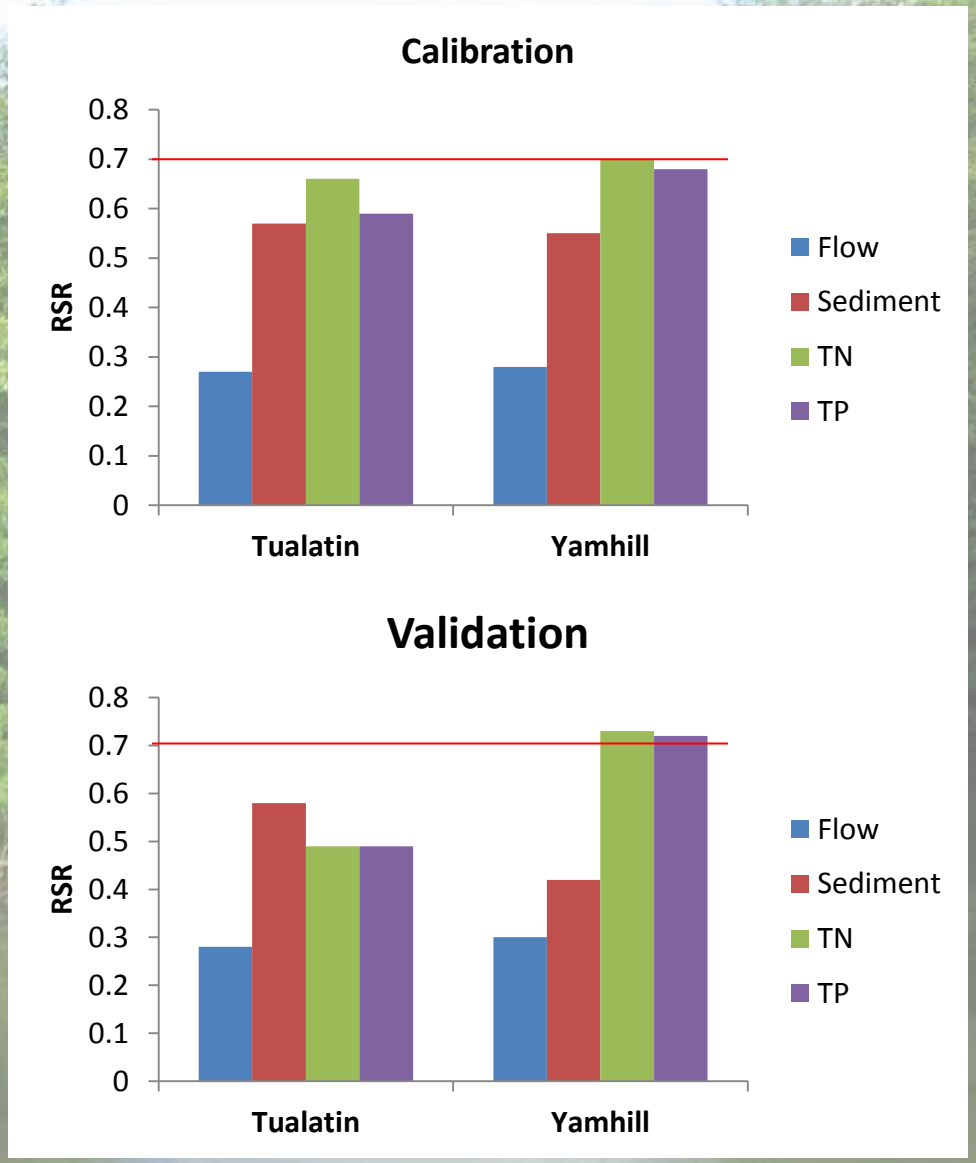
%BIAS

<u>Goal</u>
Flow: %BIAS < 25%
Sediment: %BIAS < 55%
Nutrients: %BIAS < 70%

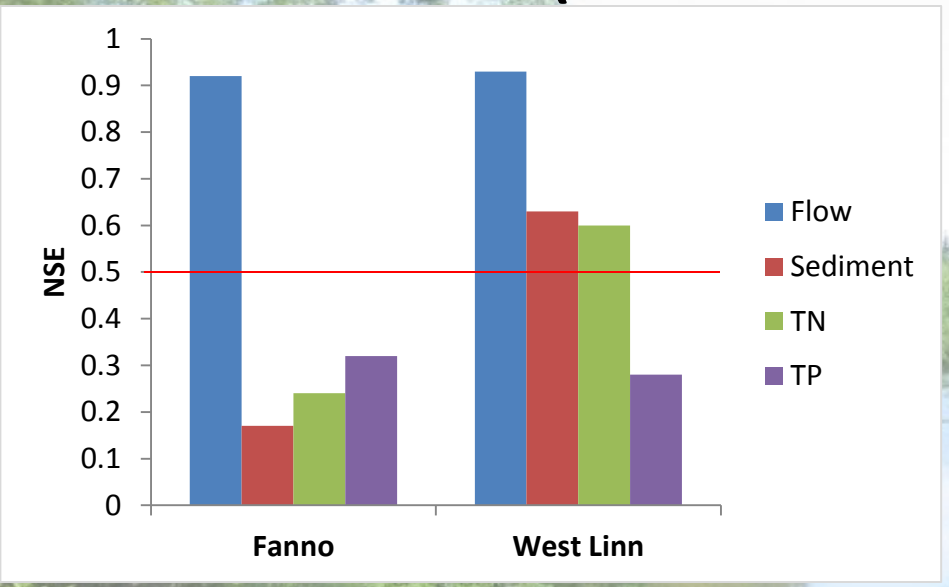


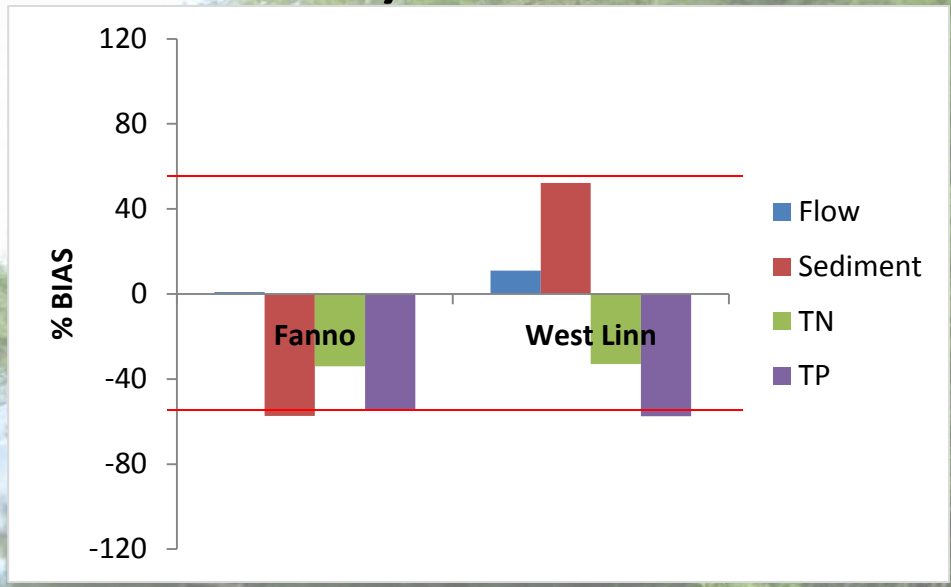
RSR

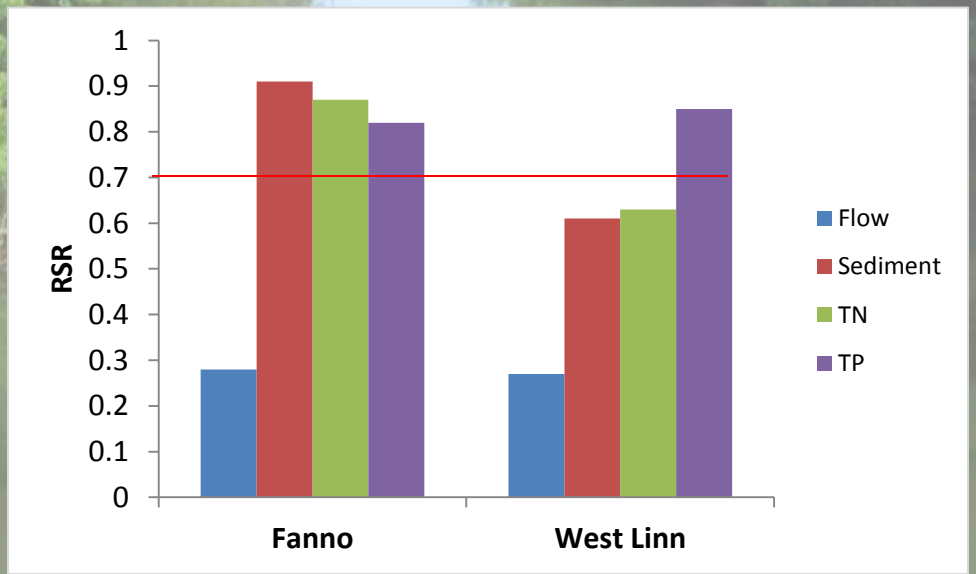
Goal
RSR <= 0.7



Fanno Creek and West Linn (Calibration Period)

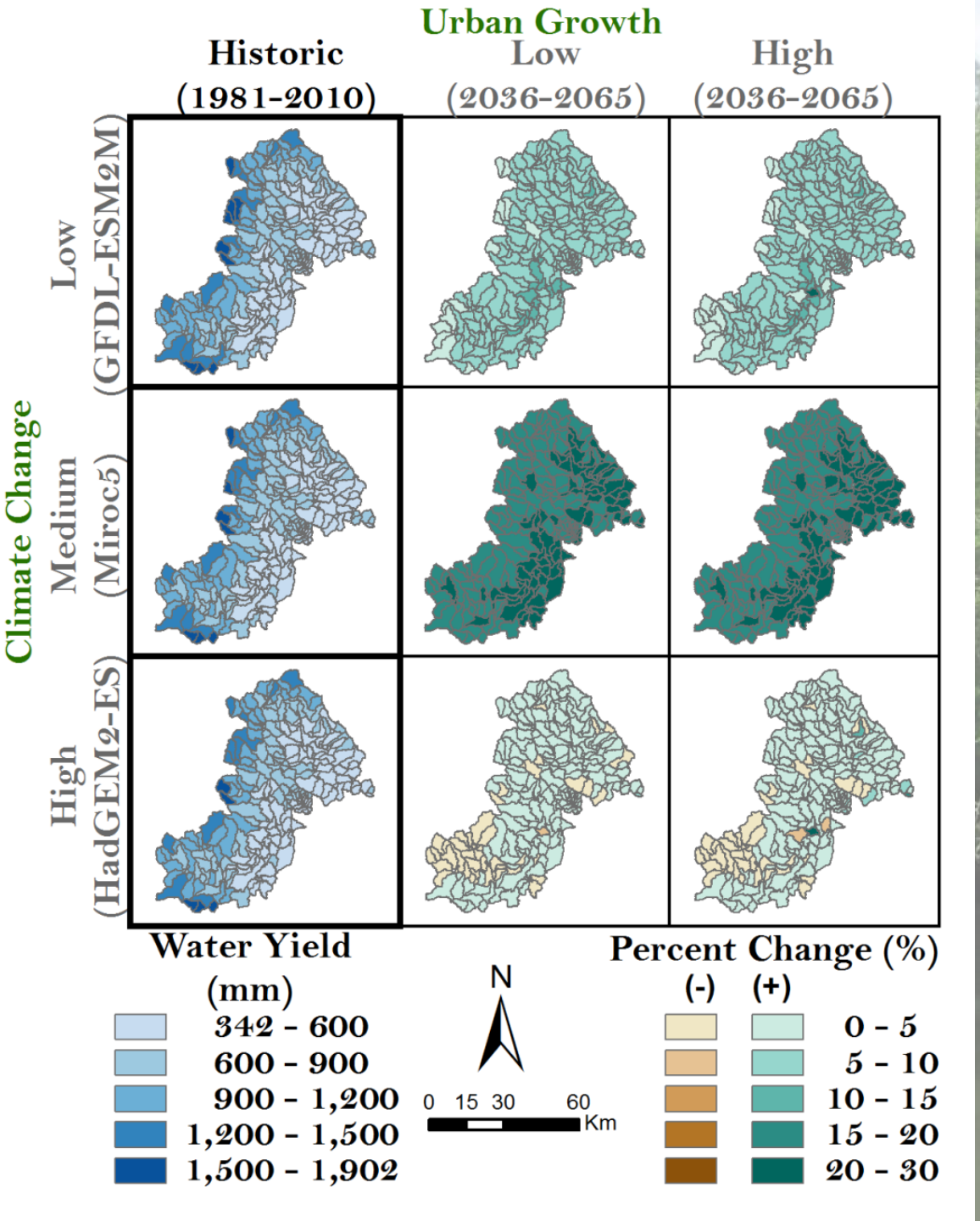




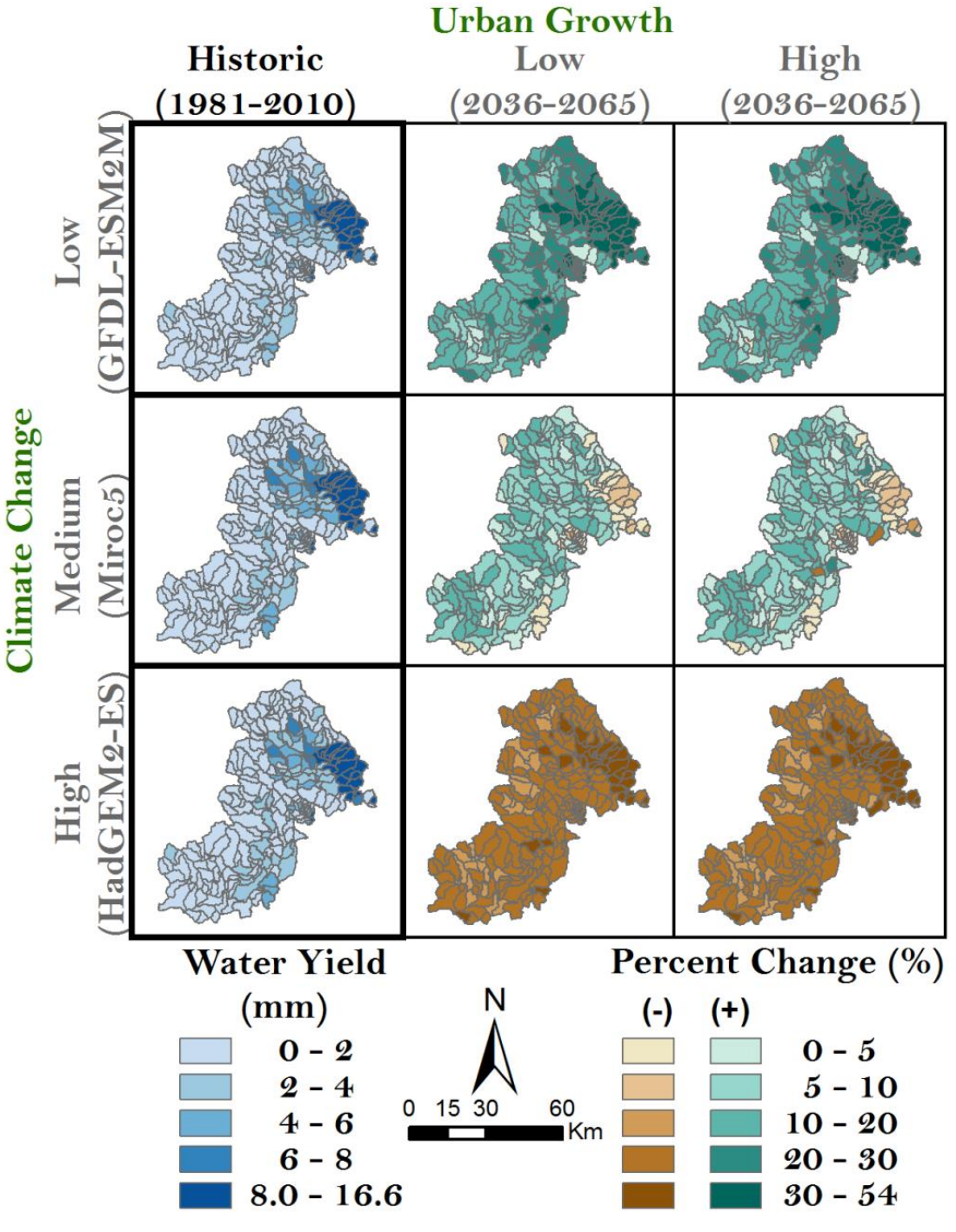


SCENARIO RESULTS

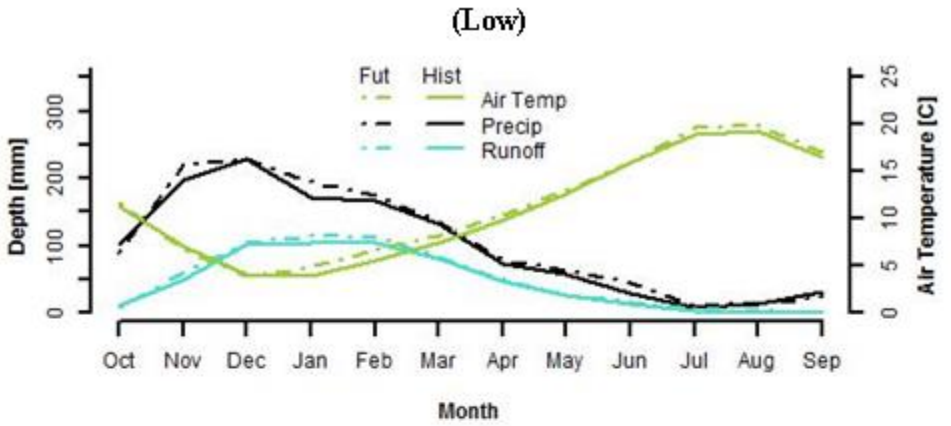
Annual Flow

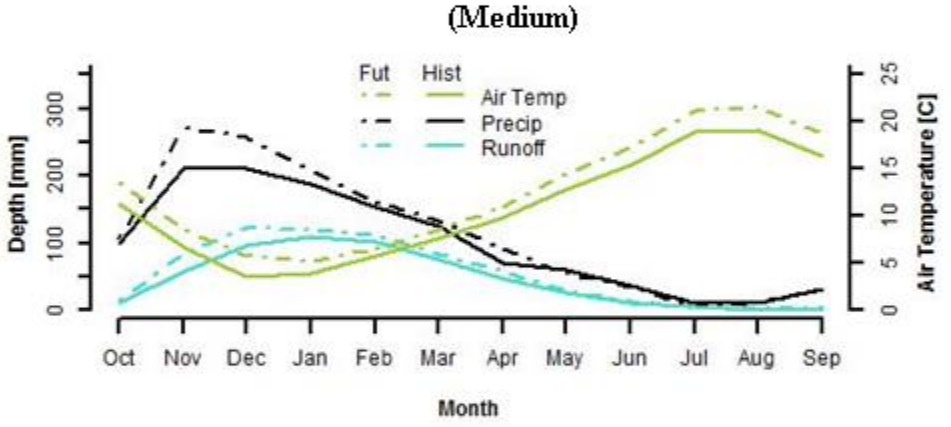

Urban Growth
Historic (1981-2010)
Low (2036-2065)
High (2036-2065)
Climate Change
Low (GFDL-ESM2M)
Medium (Miroc5)
High (HadGEM2-ES)
Water Yield (mm)
342 - 600
600 - 900
900 - 1,200
1,200 - 1,500
1,500 - 1,902
N
0 15 30 60
Km
Percent Change (%)
(-) (+)
0 - 5
5 - 10
10 - 15
15 - 20
20 - 30

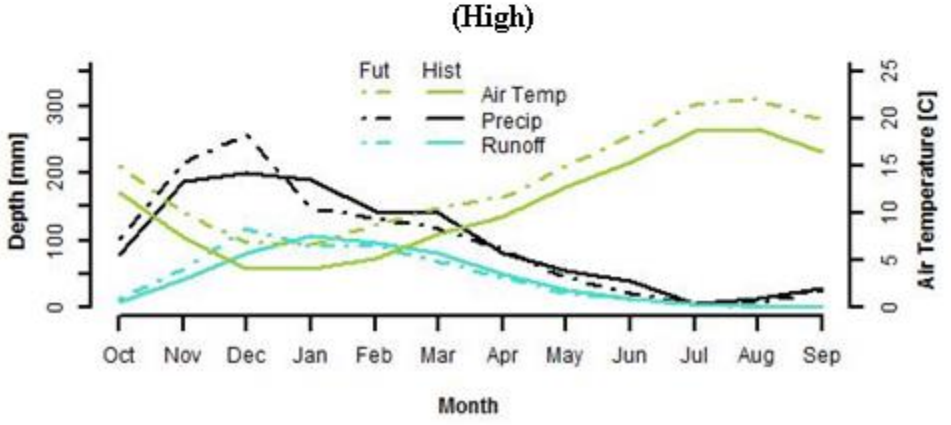
Summer Flow


Urban Growth
Historic (1981-2010)
Low (2036-2065)
High (2036-2065)
Climate Change
Low (GFDL-ESM2M)
Medium (Miroc5)
High (HadGEM2-ES)
Water Yield (mm)
0 - 2
2 - 4
4 - 6
6 - 8
8.0 - 16.6
N
0 15 30 60
Km
Percent Change (%)
(-)
(+)
0 - 5
5 - 10
10 - 20
20 - 30
30 - 54

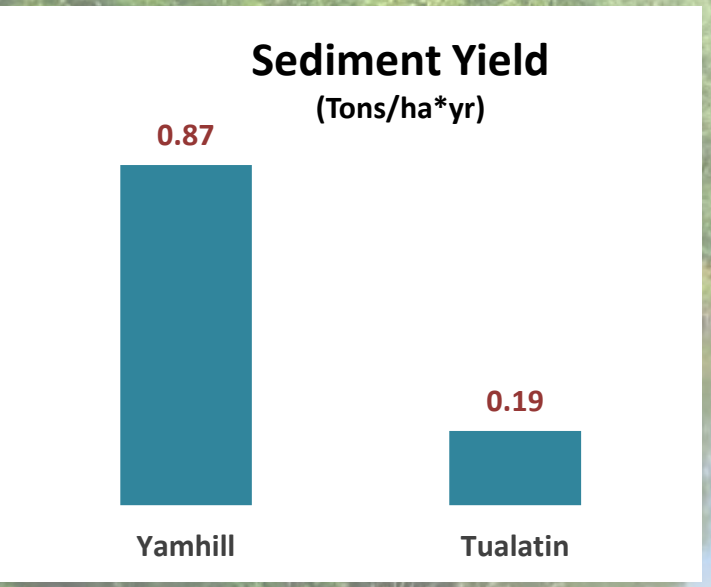
Changes in Tualatin's Climate and Hydrography



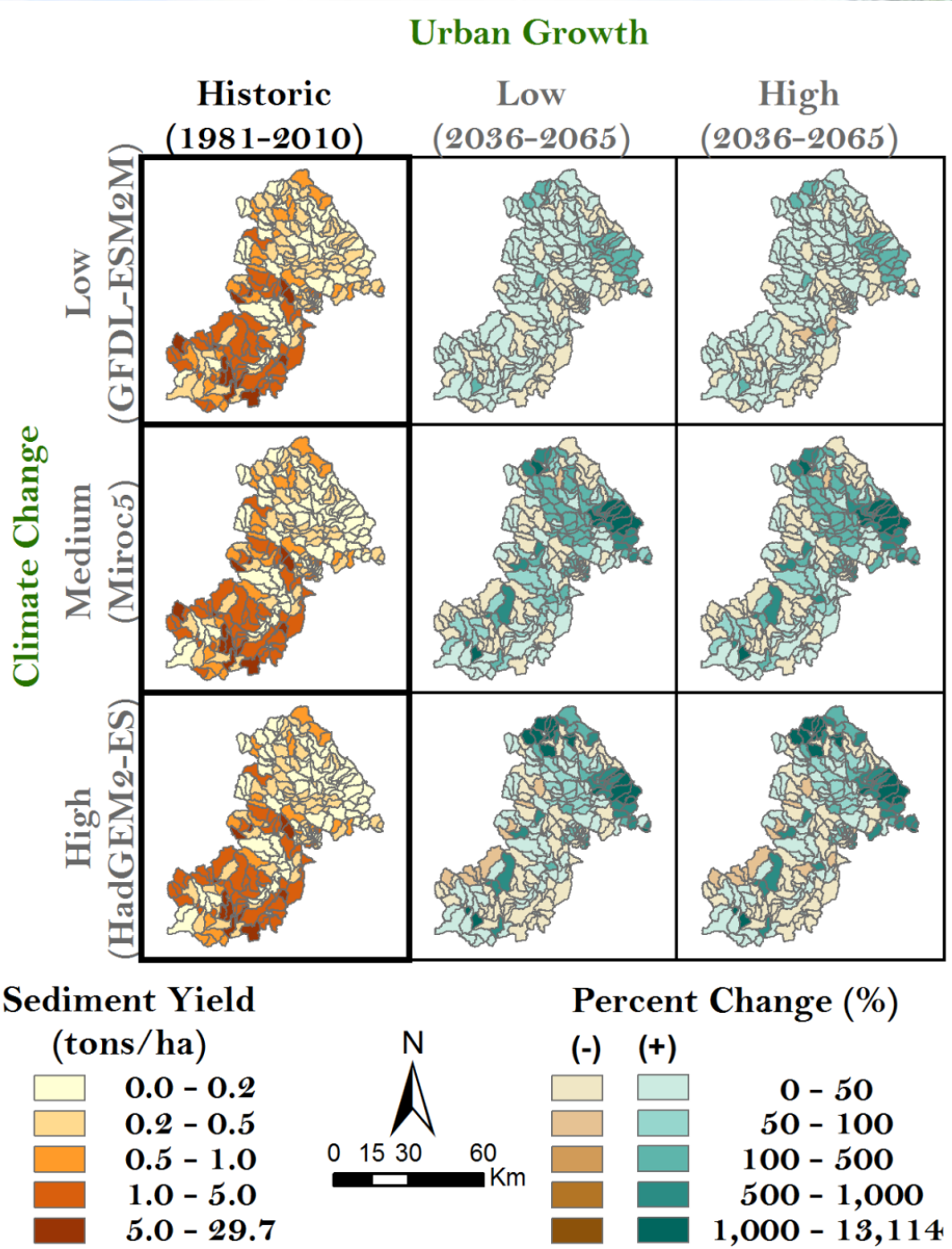




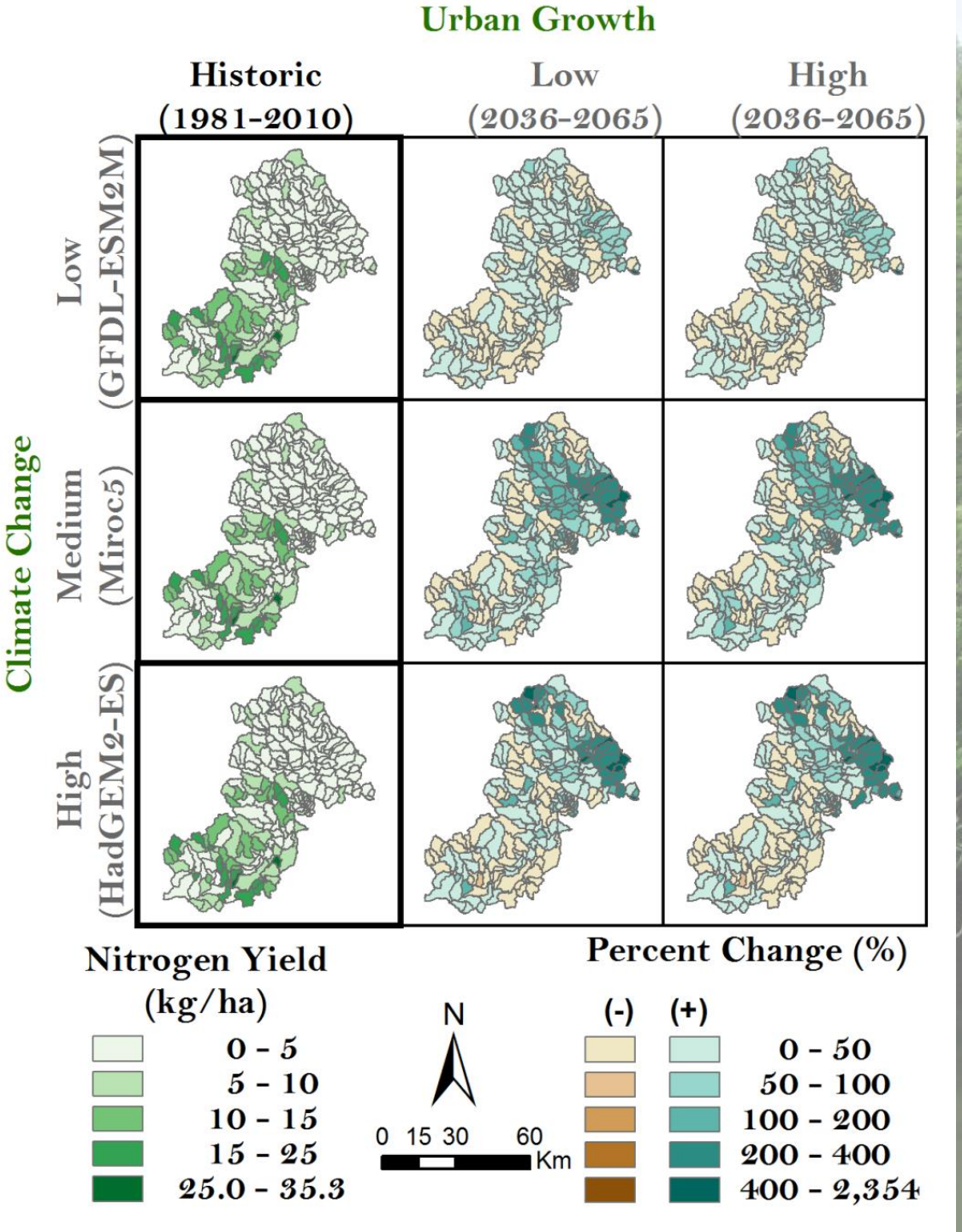
Sediment



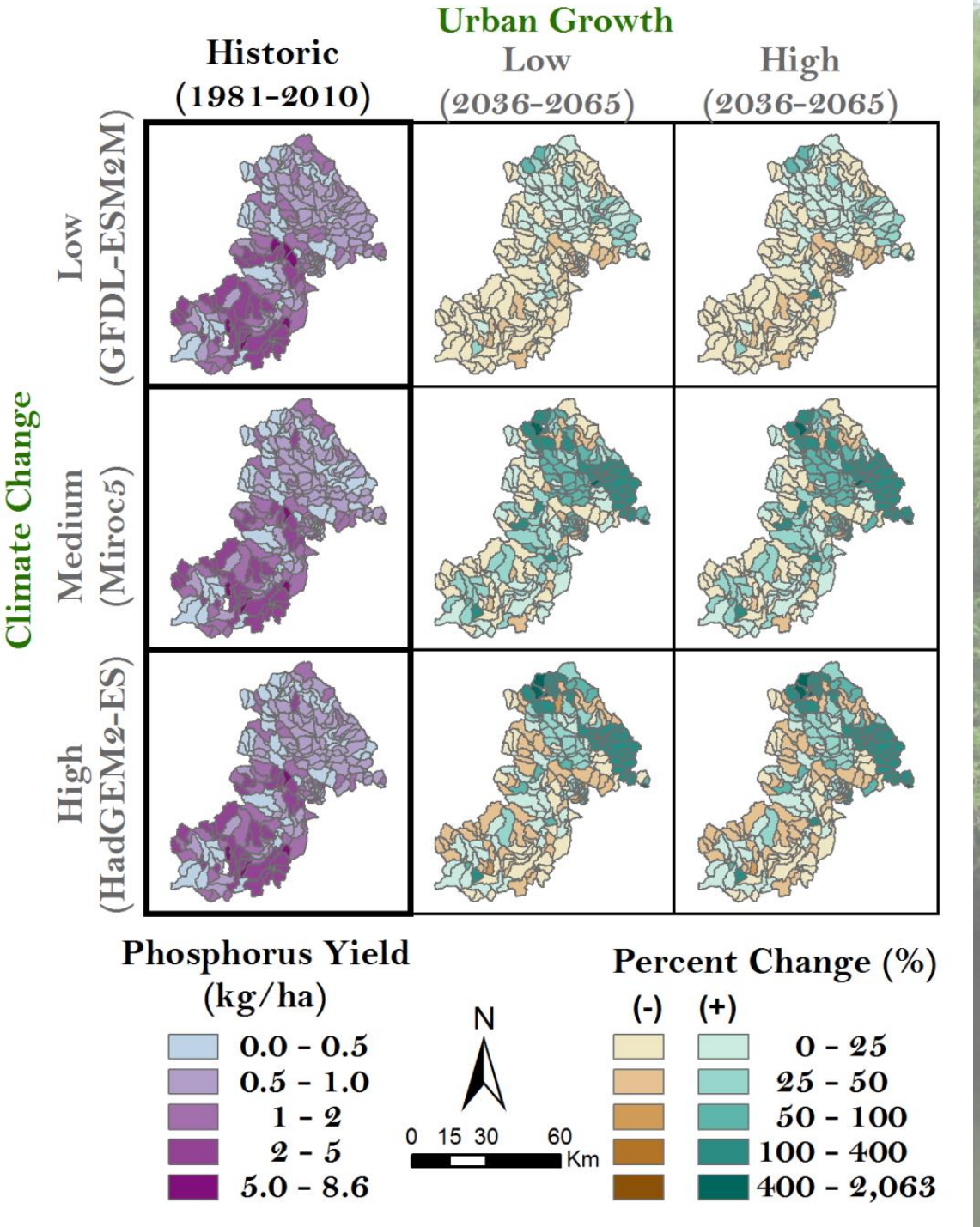
- No in-stream processes calibrated



Nitrogen

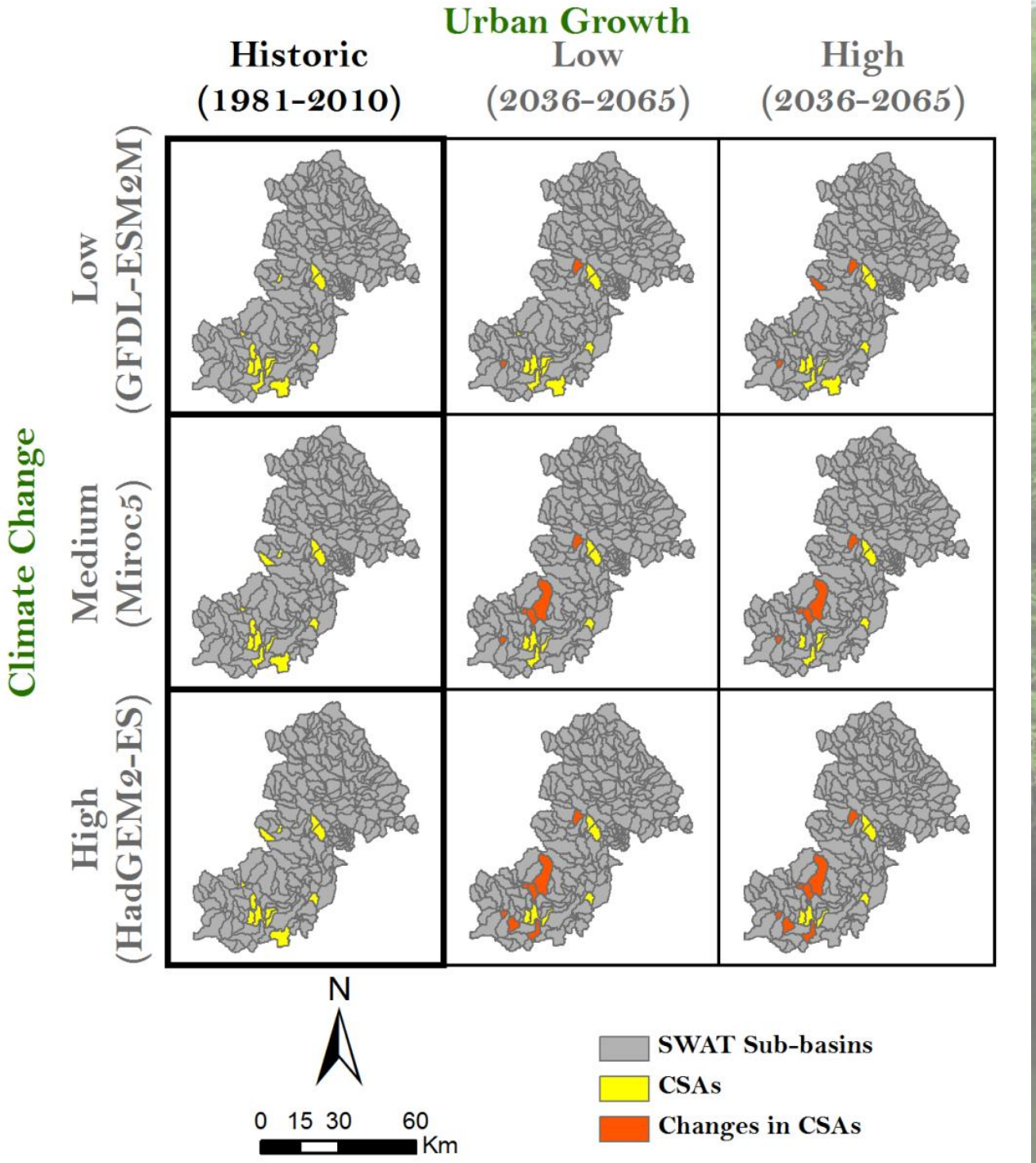

Urban Growth
Historic (1981-2010)
Low (2036-2065)
High (2036-2065)
Climate Change
Low (GFDL-ESM2M)
Medium (Miroc5)
High (HadGEM2-ES)
Nitrogen Yield (kg/ha)
0 - 5
5 - 10
10 - 15
15 - 25
25.0 - 35.3
N
0 15 30 60
Km
Percent Change (%)
(-)
(+)
0 - 50
50 - 100
100 - 200
200 - 400
400 - 2,354

Phosphorus

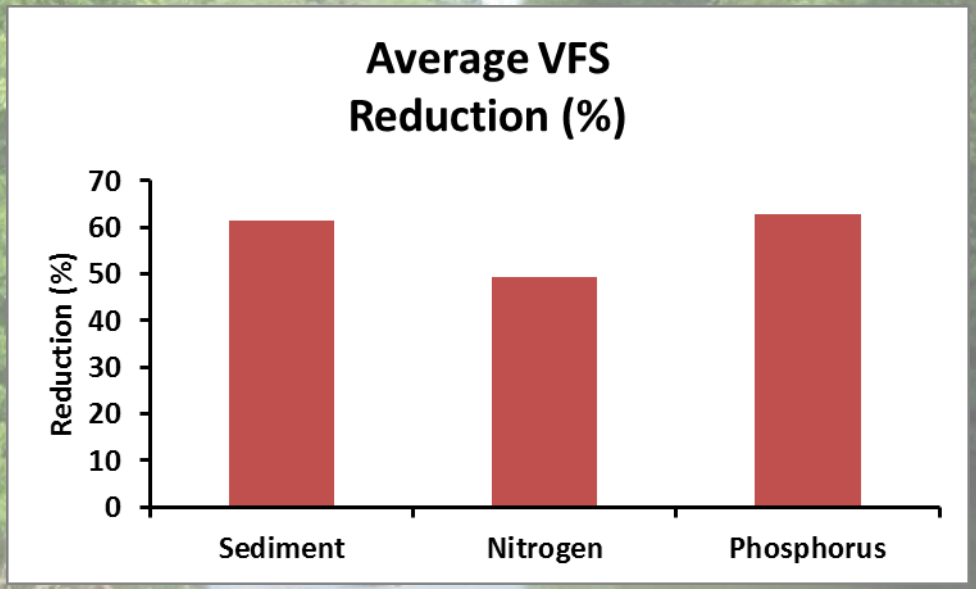

Urban Growth
Historic (1981-2010)
Low (2036-2065)
High (2036-2065)
Climate Change
Low (GFDL-ESM2M)
Medium (Miroc5)
High (HadGEM2-ES)
Phosphorus Yield (kg/ha)
0.0 - 0.5
0.5 - 1.0
1 - 2
2 - 5
5.0 - 8.6
N
0 15 30 60
Km
Percent Change (%)
(-) (+)
0 - 25
25 - 50
50 - 100
100 - 400
400 - 2,063

CSAs

Indices in top 5%



Vegetative Filter Strips



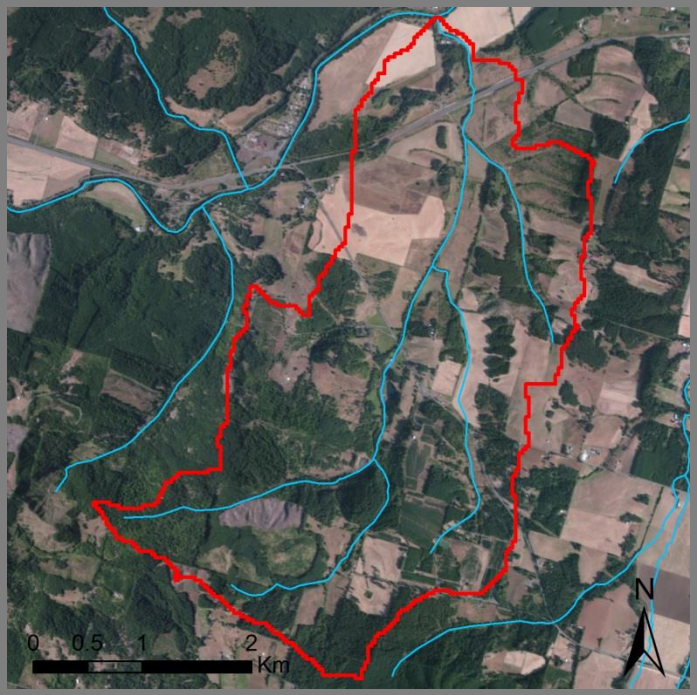
Effects on CSAs

Dominant Land Use: Hay

Dominant Soil: Moderate hydraulic conductivity

Dominant Slope: >12%

Rank	
No management	VFS
1	**1**
2	16
3	19
4	25
6	33



Discussion

- Uncertainty
  - GCM Structure
  - Sediment calibrations
    - In-stream sources and sinks of sediment
    - “Second-storm” effect
- Land cover thresholds
  - Clearly outline project goals
- Validation of CSA Identification
  - Field studies verifying SWAT accuracy

Conclusions

1. Basin wide effects are more sensitive to climate change than urbanization
2. Flows exhibit some seasonal lag in non-urban areas
3. Urban areas respond more immediately to precipitation patterns due to increased impervious surfaces
4. The largest increases in sediment and nutrients occur in urban and high sloping agricultural areas
5. CSAs show moderate changes in response to climate change and urban growth
6. VFS reduce sediment and nutrient yields by 58%, suggesting they are an effective method of pollutant reduction

References

- Arnold, J.G., Moriasi, D.N., Gassman, P.W., Abbaspour, K.C., White, M.J., Srinivasan, R., Santhi, C., Harmel, R.D., van Griensven, A., Van Liew, M.W., Kannan, N., Jha, M.K. 2012. SWAT: Model use, calibration and validaiton. Transactions of the ASABE 55(4): 1491-1508
- Hoyer, W, and Chang, H. 2014. Development of Future Land Cover Change Scenarios in the Metropolitan Fringe, Oregon, U.S.A. with Stakeholder Involvement, Land *3*(1): 322-341.
- Niraula, R., Kalin, L, Srivastava, P., and Anderson, C.J. 2013. Identifying critical source areas of nonpoint source pollution with SWAT and GWLF. Ecological Modelling: 123-133.


Questions/Comments?
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