A Decreasing Trend of Water Erosion in Wheat-based Croplands of Eastern Washington: WEPP Simulation

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January 9, 2023

Background

- Water erosion a continuous agricultural and environmental problem in the inland Pacific Northwest
- In the inland PNW high erosion rates result from
  - Highly erodible silt loam soil
  - Hilly terrain
  - Rainy winters with frequent freeze-thaw cycles weakening soil
  - Tillage practices leaving soil pulverized and unprotected

Photo courtesy of Dr. DK McCool

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Background

Studies for this region show

- 10–13 t ha^{-1} for 2000s from RUSLE (Kok et al., 2009)
- 27–45 t ha^{-1} from the USLE model (USDA, 1978)
- 53.8 t ha^{-1} for 1940–1982 from field investigation (McCool and Roe, 2005)

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Questions?

- Has the climate changed? If so, how impactful was the change?
- Conservation practices (reduced tillage, crop rotation) have been adopted since 1980s. How impactful are these changes?
- What is the long-term trend of erosion in the inland PNW?

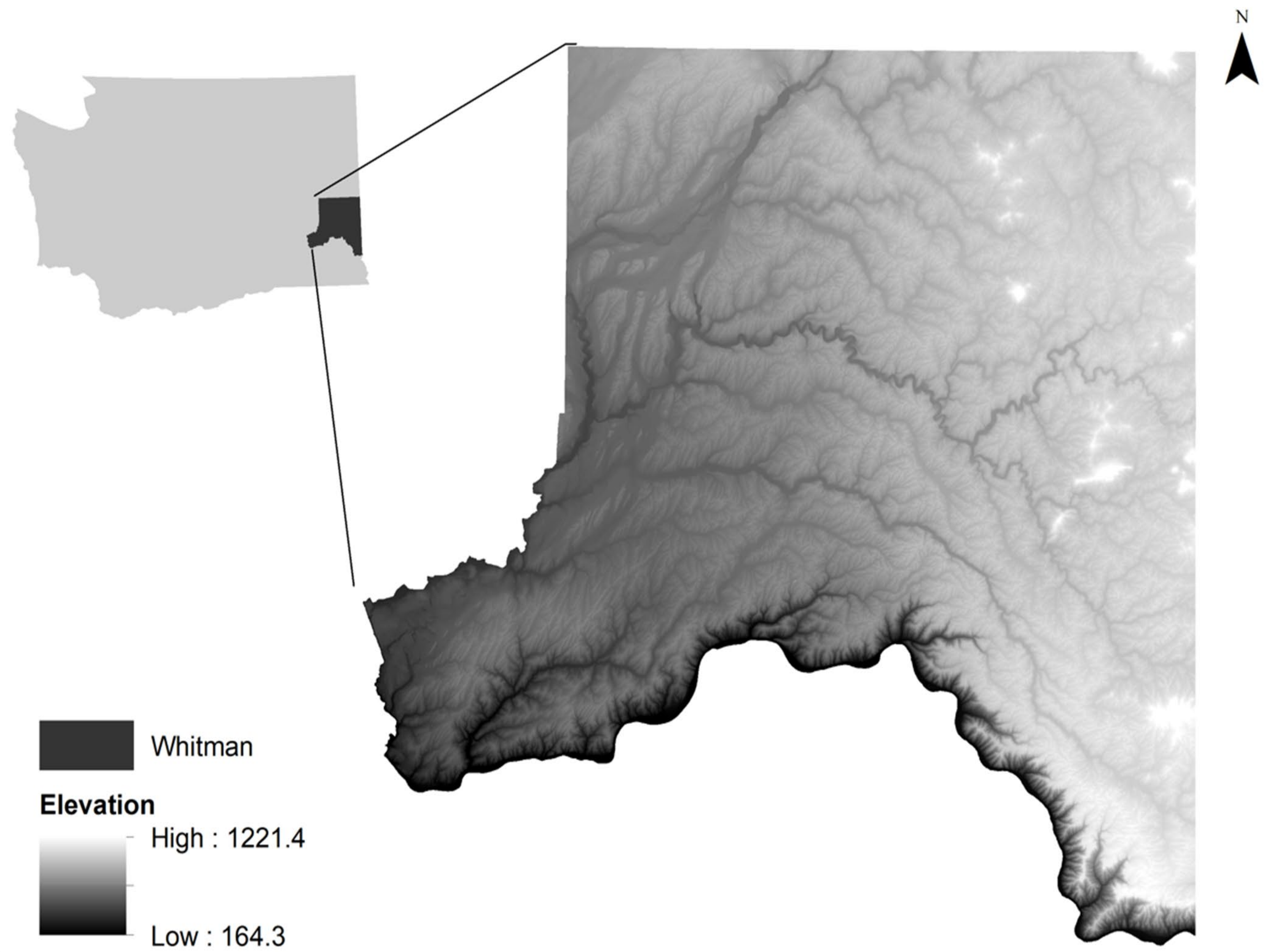
Objectives

1. Evaluate the long-term **(1940–2020)** changes in climate (precipitation, temperature, numbers of extreme events and freeze-thaw cycles)

2. Assess temporal trend in soil erosion as impacted by climatic conditions and management practices based on WEPP simulation

Study Area

- Whitman County: largest cereal-grain production area in eastern WA (3.0×10^5 ha)
- Mediterranean climate with dry summers and wet winters
- Three distinct precipitation zones
  - Low (<380 mm) (Wheat-Fallow = WF)
  - Intermediate (380–460 mm) (Wheat-Barley-Fallow = WBF)
  - High (>460 mm) (Wheat-Barley-Pea = WBP)
- Conservation tillage practices have increased since 1980s



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Climate Analysis

- Climate data divided into two periods
  - Past: **1940–1982**
  - Present: **1983–2020**
- Numbers of
  - extreme precipitation events
  - freeze-thaw cycles
- Statistical analysis
  i. normality (Shapiro-Wilk test)
  ii. means (ann. avg. precipitation, avg. daily T_{max} and T_{min} with t-test or Wilcoxon rank-sum test)
  iii. linear trends (pooled climate data with Mann Kendall test)

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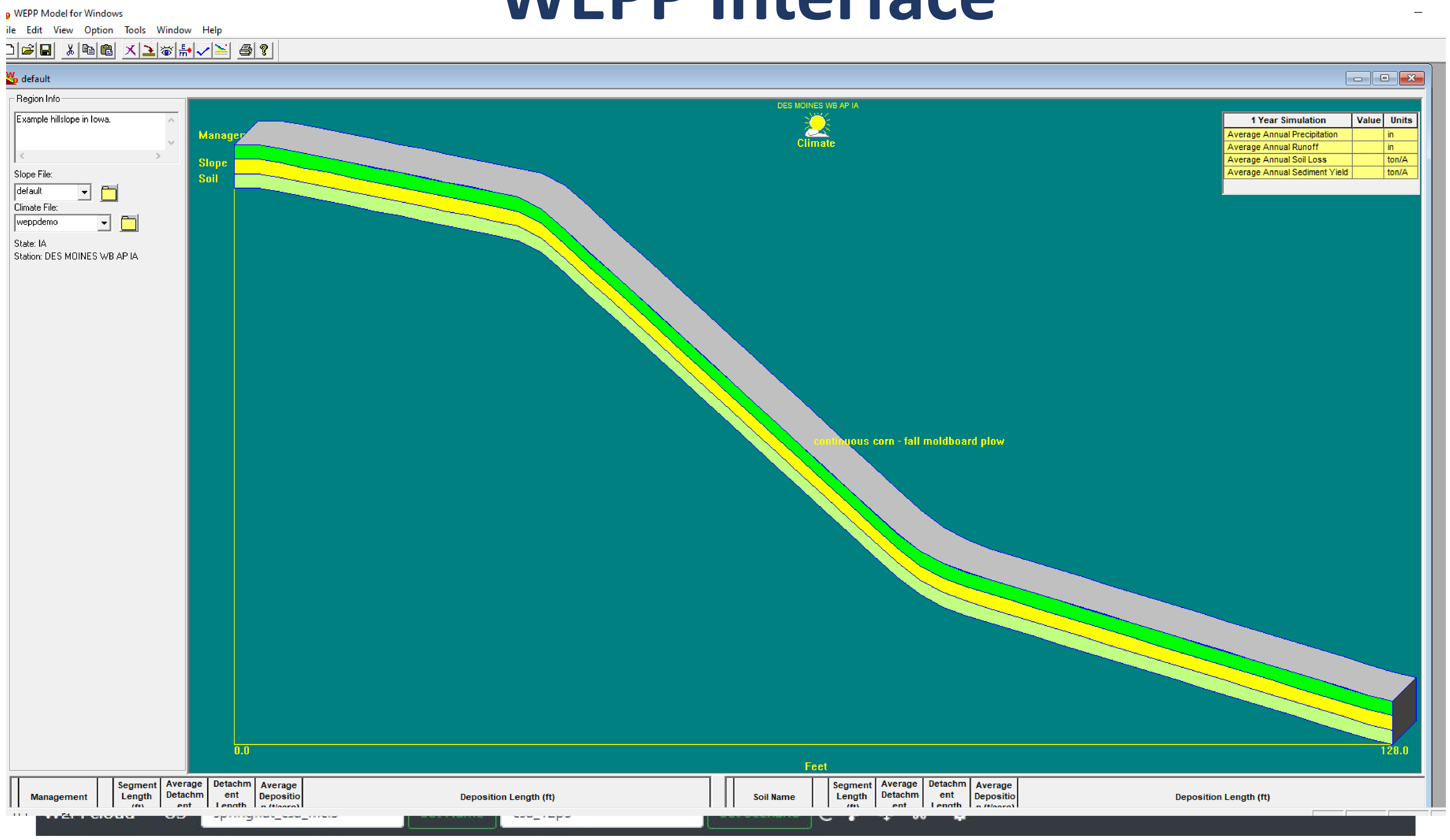
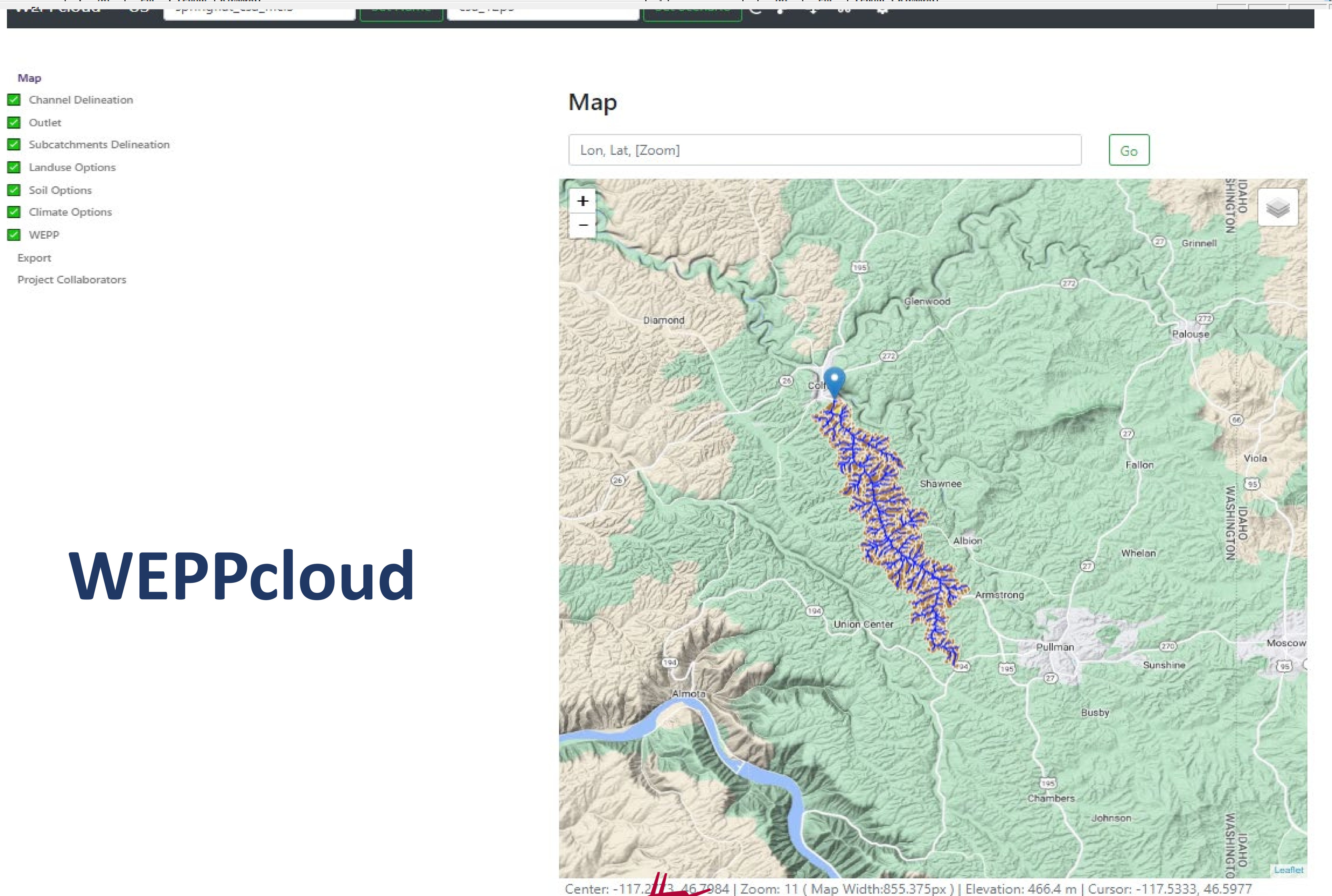
The WEPP Model

- USDA ARS **W**ater **E**rosion **P**rediction **P**roject
- Simulates daily water balance and erosion
- WEPPcloud discretizes watershed into hillslopes and channel segments
- Major inputs: climate, topography, soil, management

WEPP Interface





WEPPcloud

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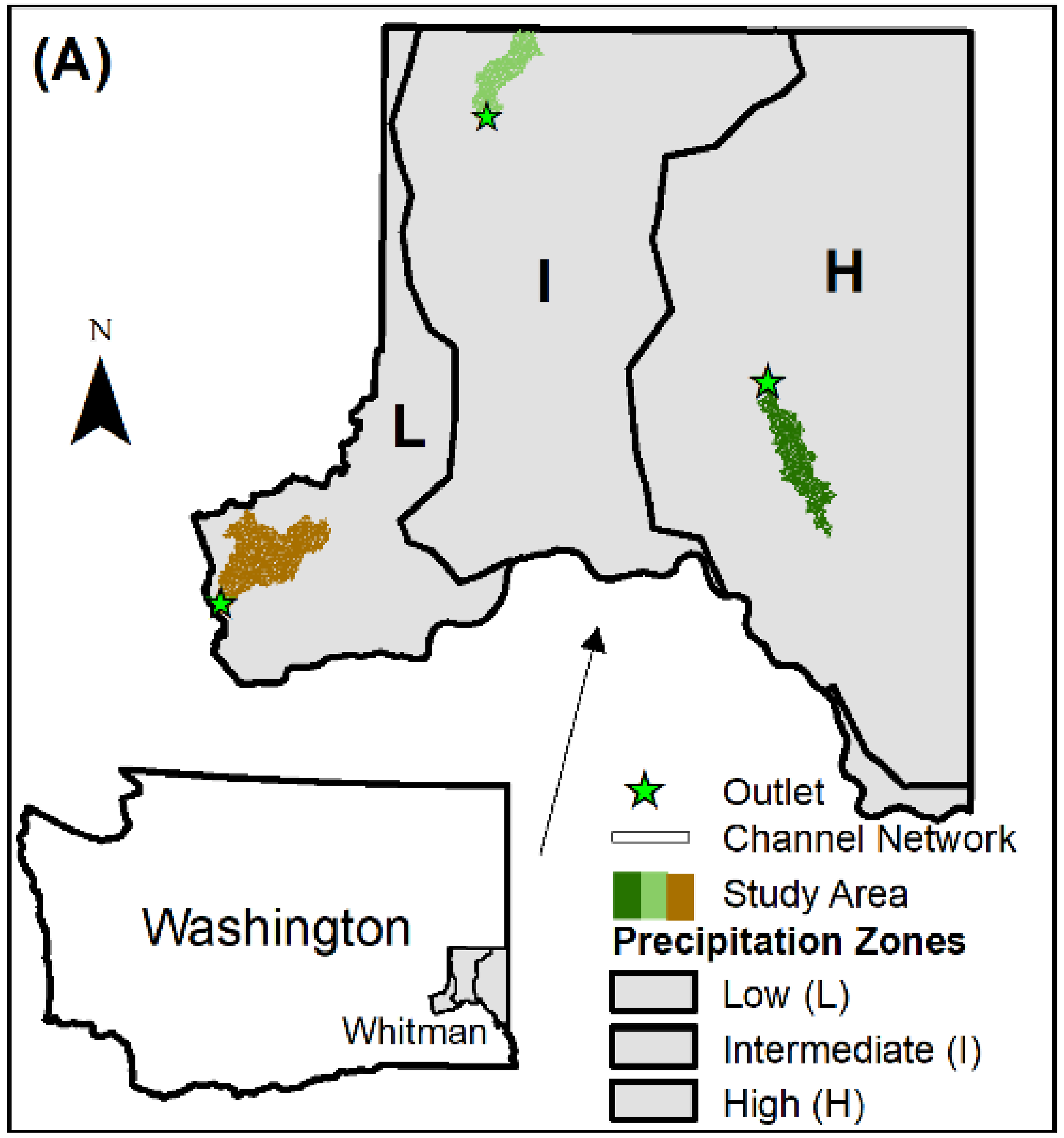
Watersheds Delineation

- **High**: Spring Flat Creek Watershed (SFCW-high)
- **Intermediate**: Upper Imbler Creek Watershed (UICW-intermediate)
- **Low**: Winn Lake Canyon Watershed (WLCW-low)



Watershed	Area (ha)	Hillslopes	Channel Segments
SFCW	5261	1163	507
UICW	3602	801	341
WLCW	8094	1632	721

WEPP Parameterization

1) Climate
   - Temperature and precipitation from nearby stations
2) Topography
   - **rolling hills** predominant in high- and intermediate-precipitation zones
   - **flat areas** more in low-precipitation zone
3) Soil
   - silt loam
4) Management

   a) Tillage: Intense, Reduced, No-till

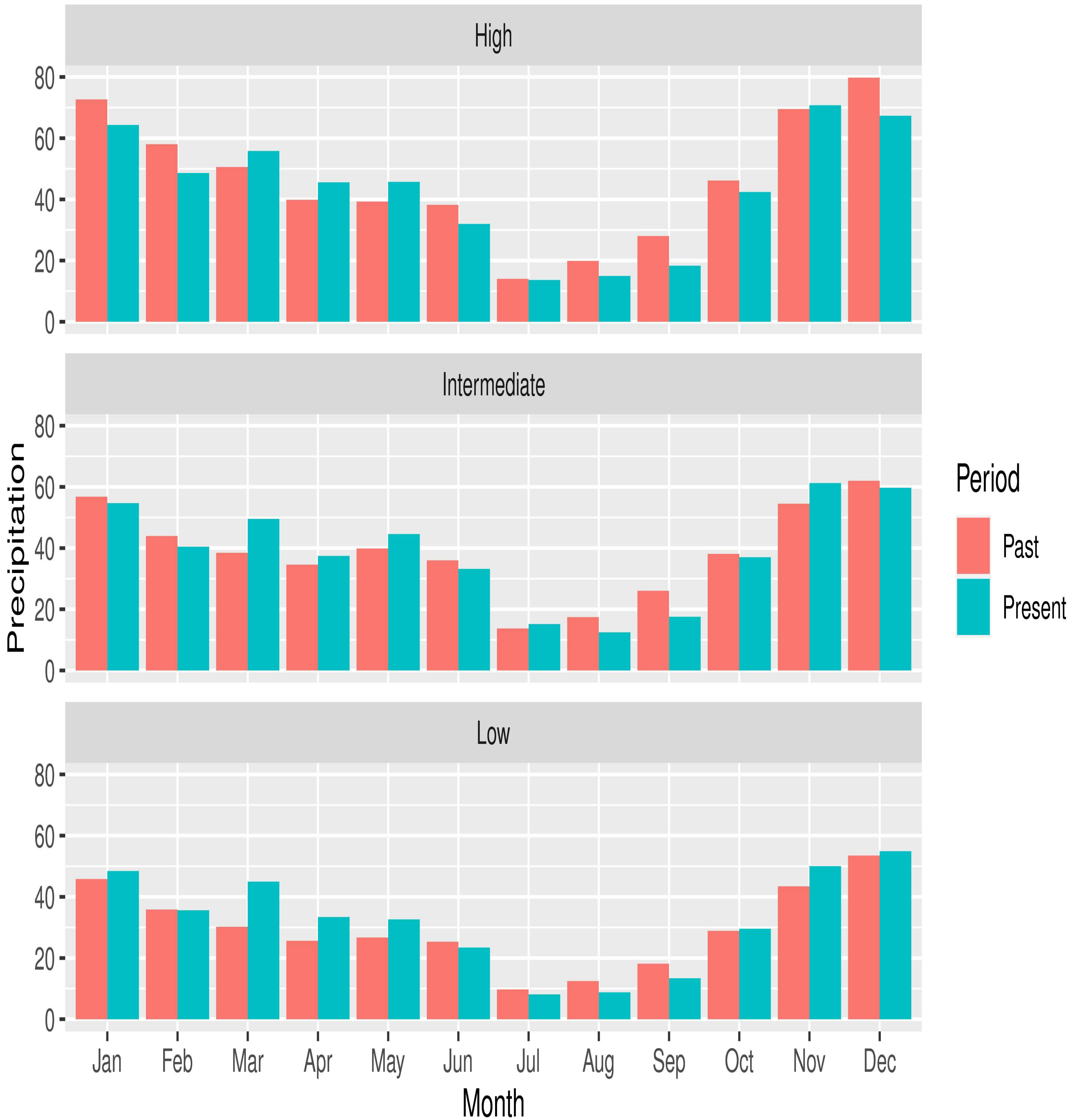
   b) Rotation: **Past** (WF); **Present** (**WF, Low-P**; **WBF, Intermediate-P**; **WBP, High-P**)

RESULTS

Precipitation

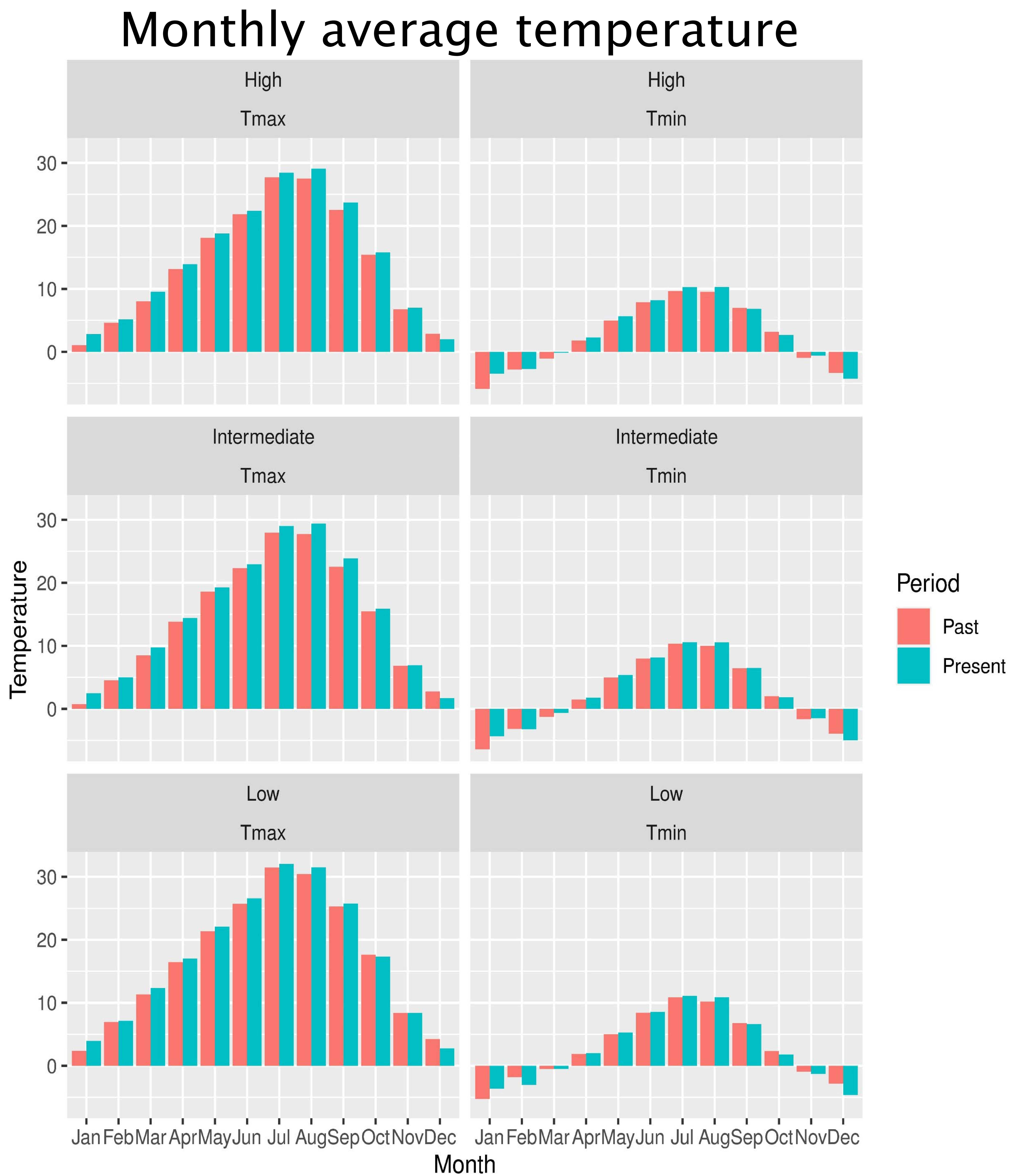
- Average Annual precipitation
  - ➢ High-P: 39 mm ↓
  - ➢ Intermediate-P: 3 mm ↓
  - ➢ Low-P: 24 mm ↑
- High-P: monthly P decreased in winter but increased in spring
- Intermediate-P: similar to high-P
- Low-P: monthly P increased in all but summer season

Average monthly precipitation



Temperature

- T_{max}
  - ➢ High-P: 0.6 °C ⬆
  - ➢ Intermediate-P: 0.5 °C ⬆
  - ➢ Low-P: 0.2 °C ⬆
- T_{min}
  - ➢ High-P: 0.3 °C ⬆
  - ➢ Intermediate-P: 0.2 °C ⬆
  - ➢ Low-P: 0.2 °C ⬇
- General increase in monthly average T_{max} and T_{min} in all three zones

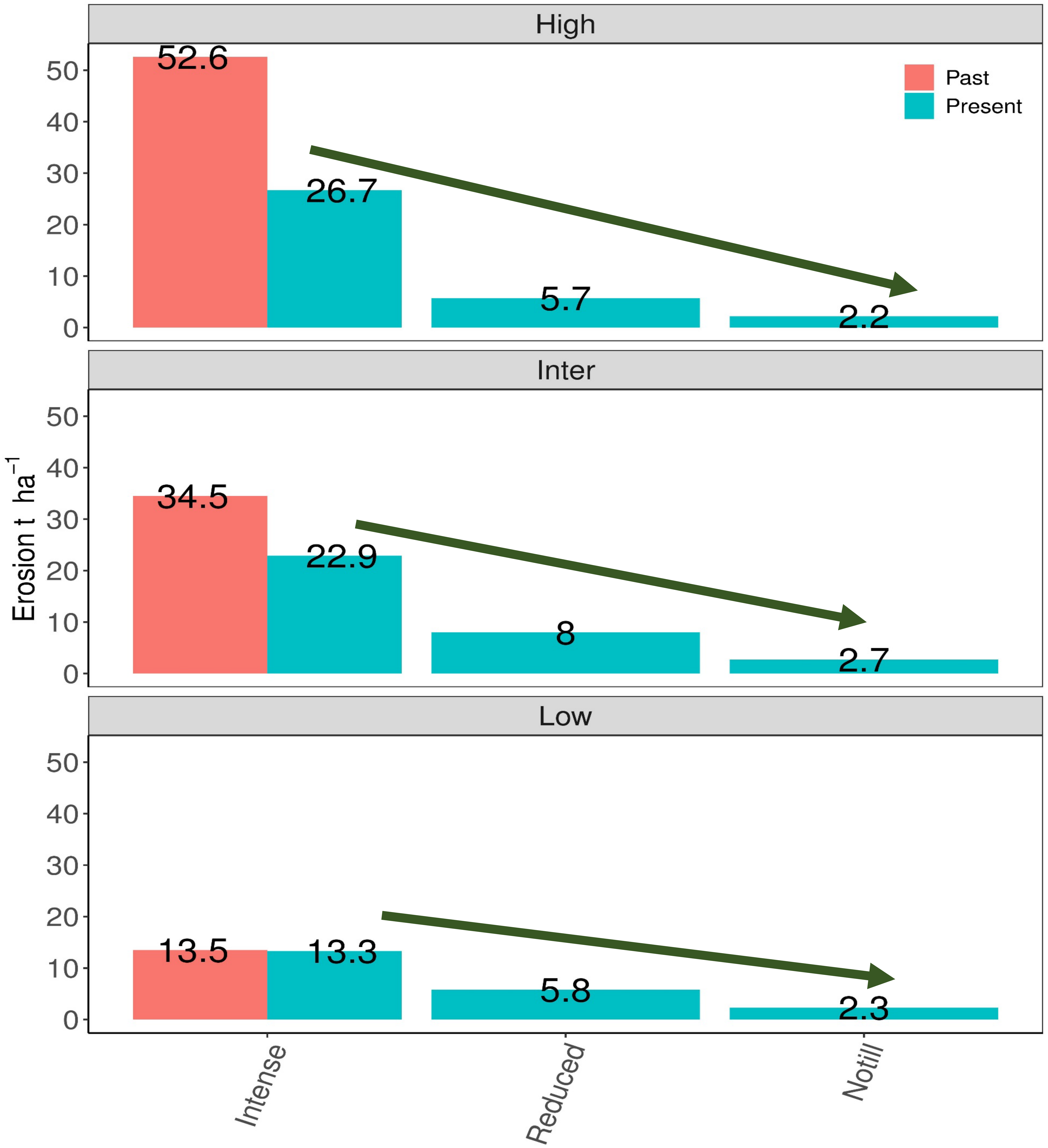


Statistical Analyses ($\alpha = 0.05$)

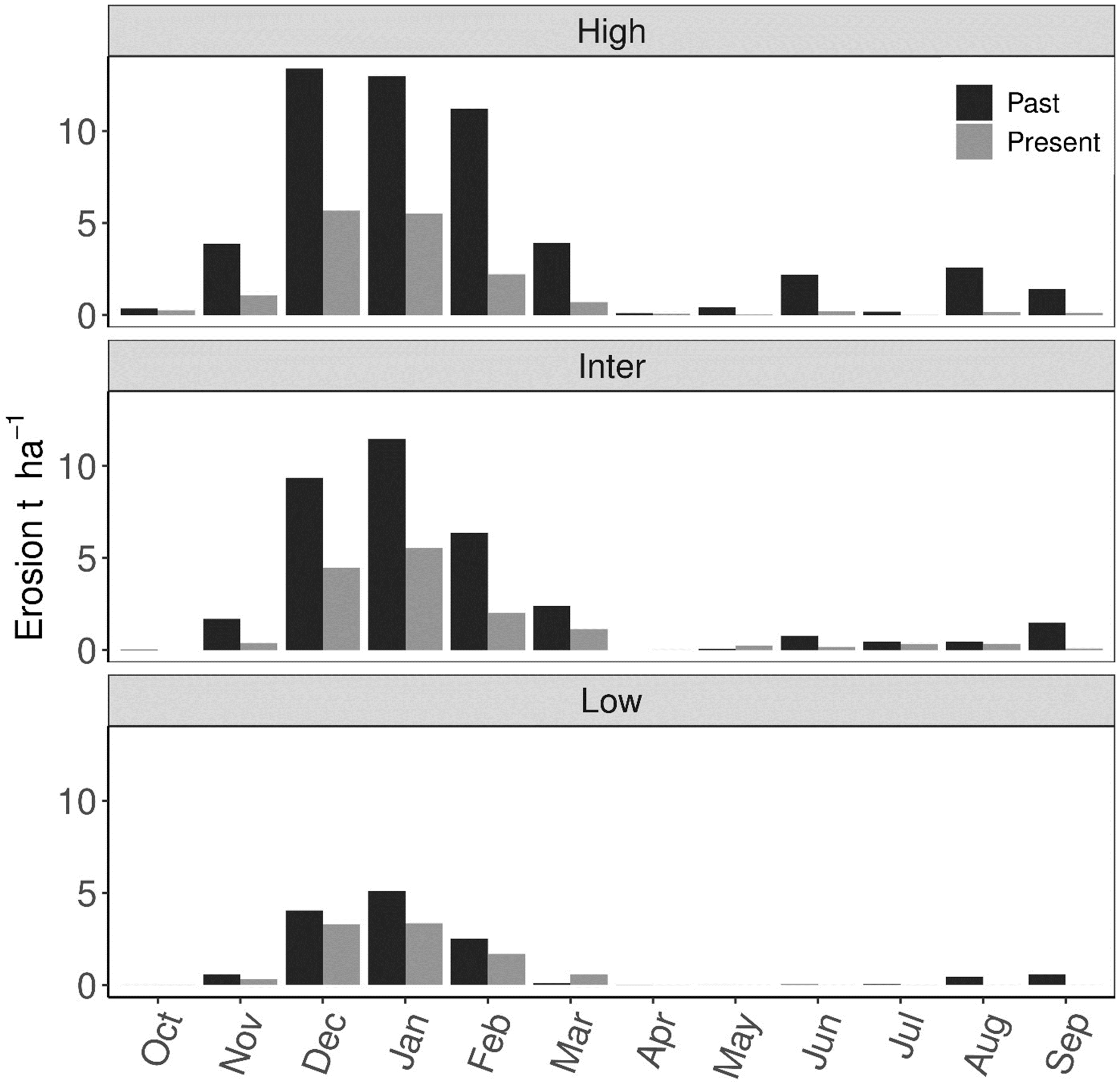
- Changes in precipitation <u>not</u> statistically significant
- T_{max} and T_{min} in the high-precipitation zone significantly <u>increased</u>
- T_{max} in intermediate- and low-precipitation zones significantly <u>increased</u>
- The number of freeze-thaw cycle in the low-precipitation zone significantly <u>decreased,</u> and is <u>not</u> changed for the other two zones

Erosion

- Erosion decreased remarkedly
  - 32%, 57%, and 70% in low-, intermediate-, and high-precipitation zones of Whitman County
- Lower tillage intensity leads to lower erosion
- Erosion primarily occurs in winter

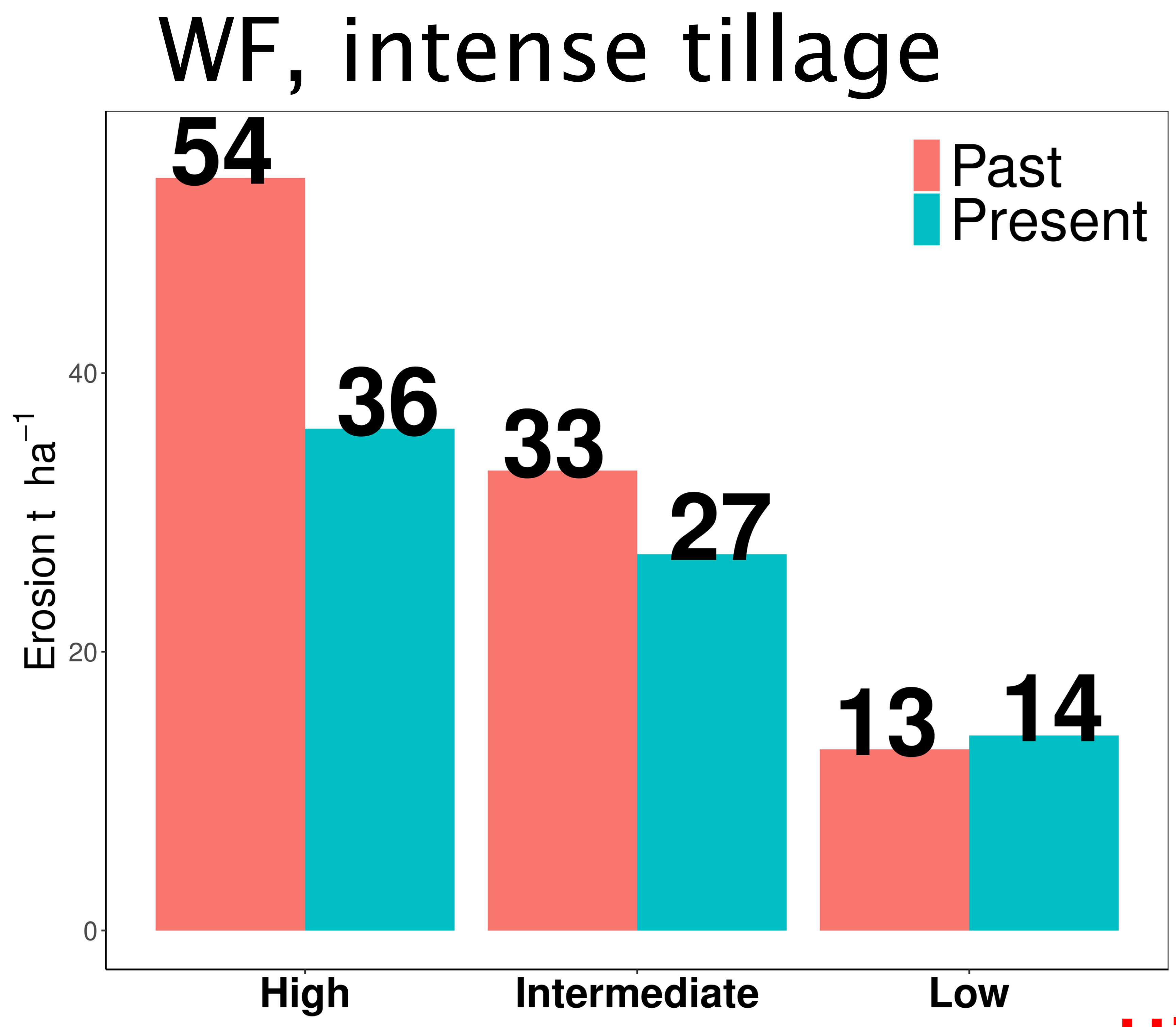


Average monthly erosion



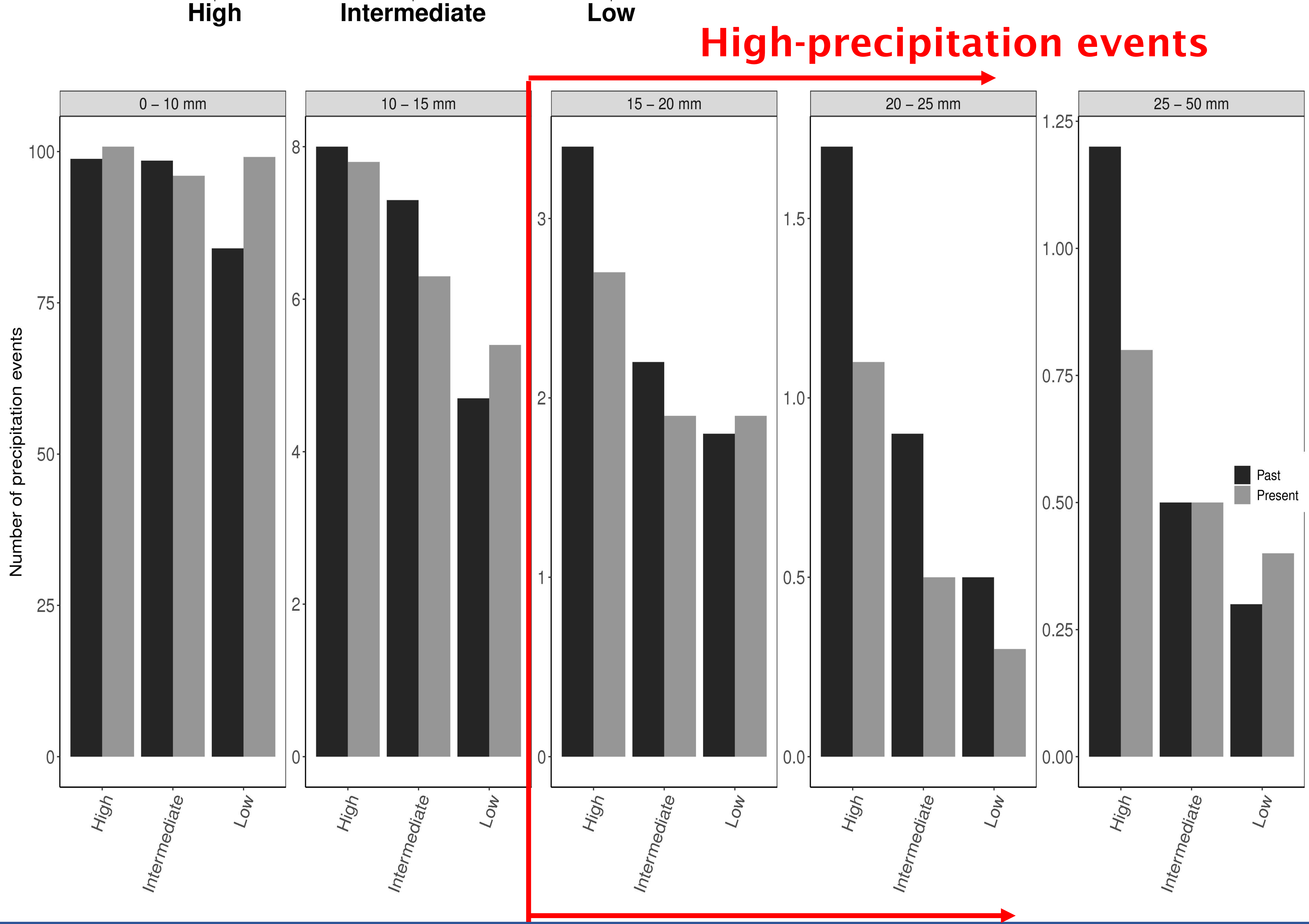
Climate Effects

- Crop rotation and tillage practices being the same, erosion has
  - decreased for high- and intermediate-P zones
  - increased for the low-P zone



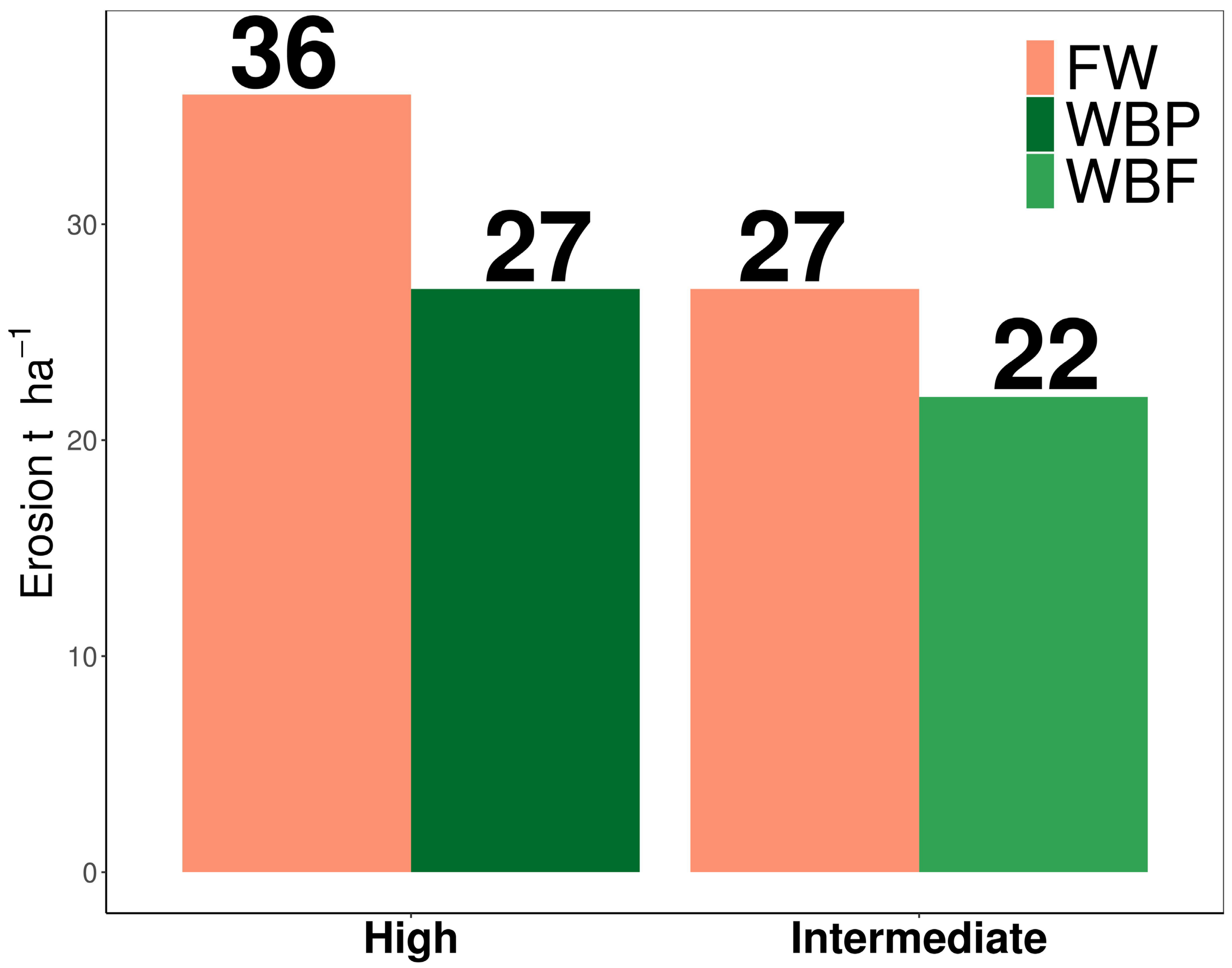
Why?

- Annual precipitation and number of high-precipitation events have
  - decreased in high- and intermediate-P zones
  - increased in the low-P zones



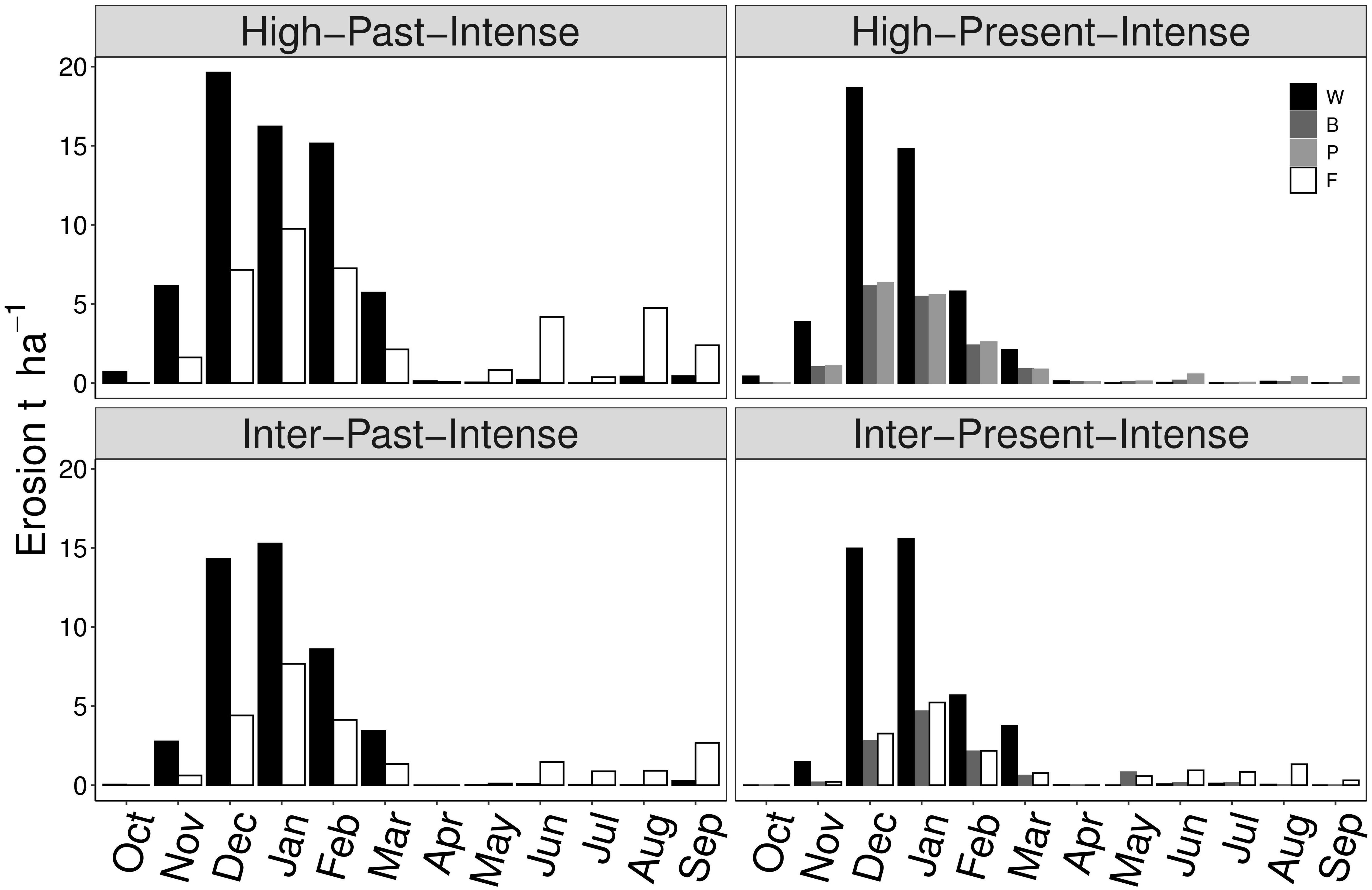
Management Effects

- Climate (present) and tillage (intense) being the same
  - ➢ erosion rate lower in three-year rotations



Why?

- Wheat and fallow years produce higher erosion
  - ➢ Wheat years
    - ○ Larger number of tillage passes
    - ○ Soil surface bare in early winter as crop is not fully grown
  - ➢ Fallow years
    - ○ bare soil provides little resistance to erosion
    - ○ more prone to runoff due to higher soil water saturation without crop consumptive use



CONCLUSIONS

Conclusions

- Climate trend (from past to present)
  - change in annual precipitation **not** significant
  - T_{max} in all three zones, and T_{min} in high-precipitation zone **increased** significantly
  - number of freeze-thaw cycles in low-precipitation zone **decreased** significantly
- Erosion
  - **decreased** from past to present by 32%, 57%, and 70% respectively in low-, intermediate-, and high-precipitation zones of Whitman County
- Decrease in erosion rate was a result of
  - decrease in cold-season precipitation (amount and the number of extreme events)
  - shift from wheat-fallow to three-year rotations (WBP, WBF)
  - adoption of conservation tillage

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Questions?

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- McCool, D.K., & Roe., R.D. (2005). Long-term erosion trends on cropland in the Pacific Northwest. *An American Society of Agricultural Engineering section meeting presentation*. Paper PNW05-1002. St Joseph, MI: American Society of Agricultural Engineers. https://doi.org/10.13031/2013.20047
- United States Department of Agriculture (USDA). 1978. Palouse Cooperative River Basin Study. USDA Soil Conservation Service, Forest Service, and Economics, Statistics, and Cooperative Service.
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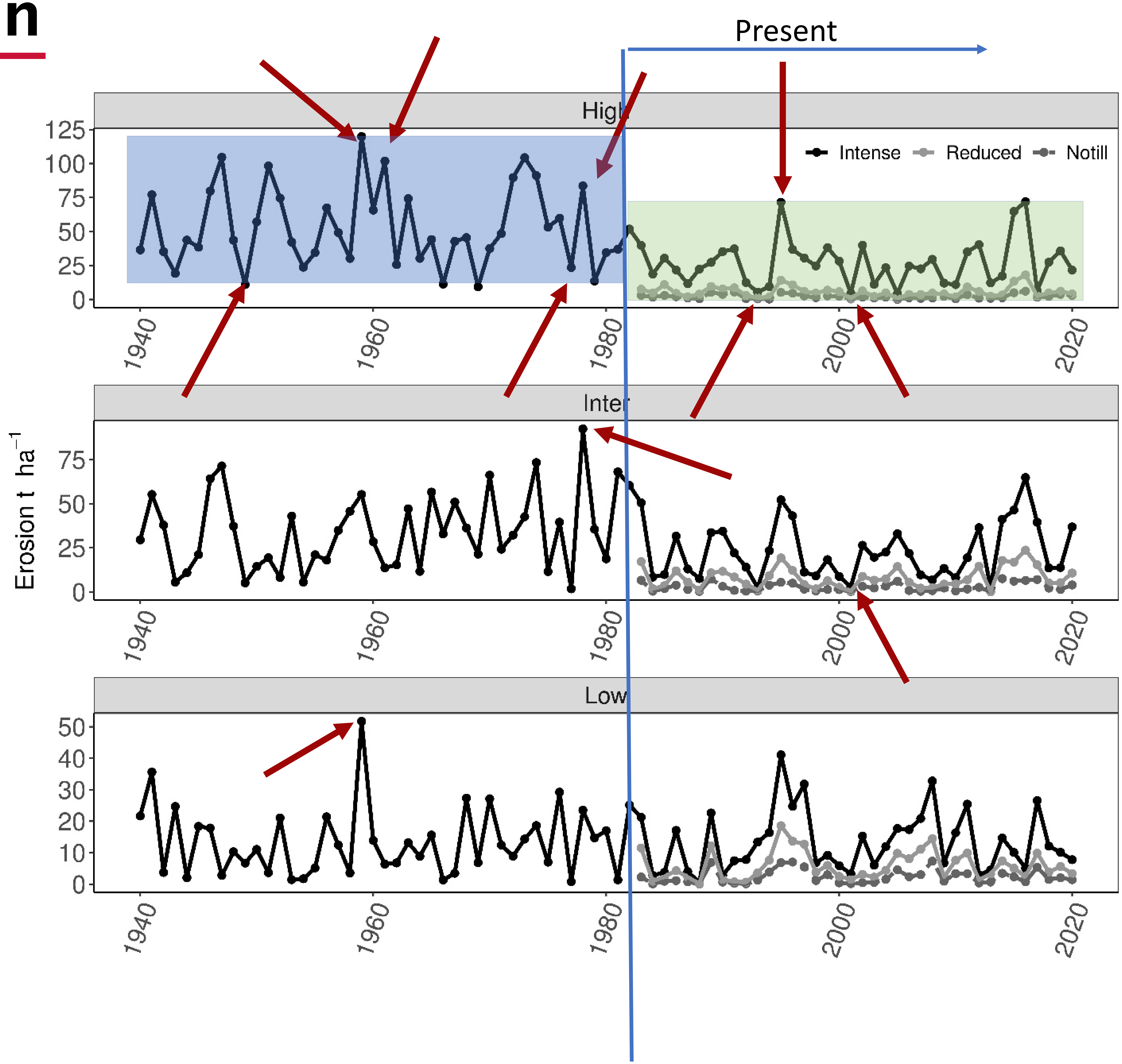
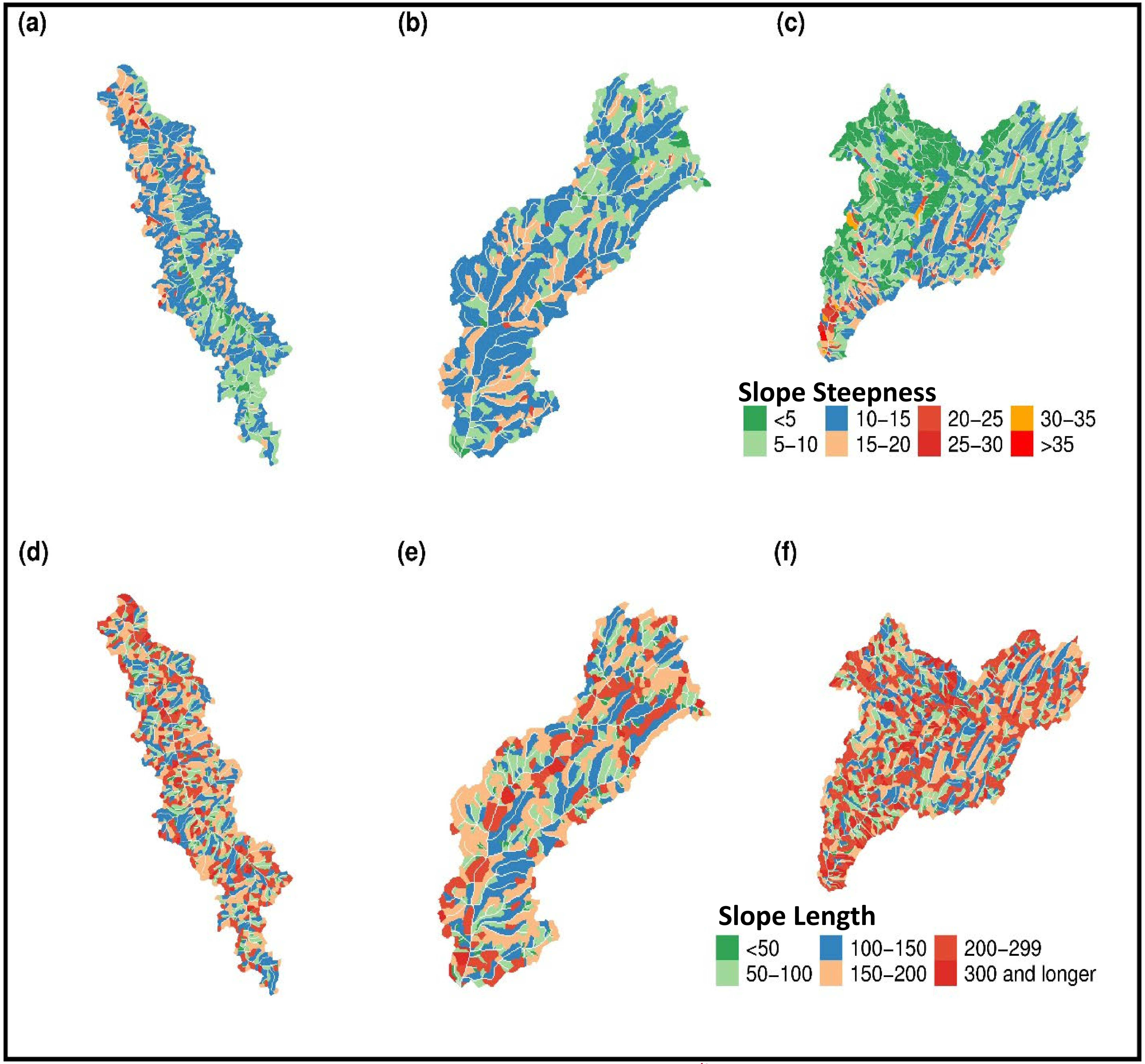
Yearly Variation

- The magnitude of erosion clearly lower in the present
- Large winter precipitation, more extreme events and freeze-thaw cycles produced more erosion and vise versa
  - High erosion years; 1959, 1961, 1978, 1995
  - Low erosion years; 1949, 1979, 1993, 2001



Topography

- Slope steepness
  - **rolling hills** predominating in high and intermediate zones
  - **flat areas** predominating in low zone
- 100-200 m slope length dominant
- Soil depth primarily deep (>1200 mm)



WEPP Scenarios

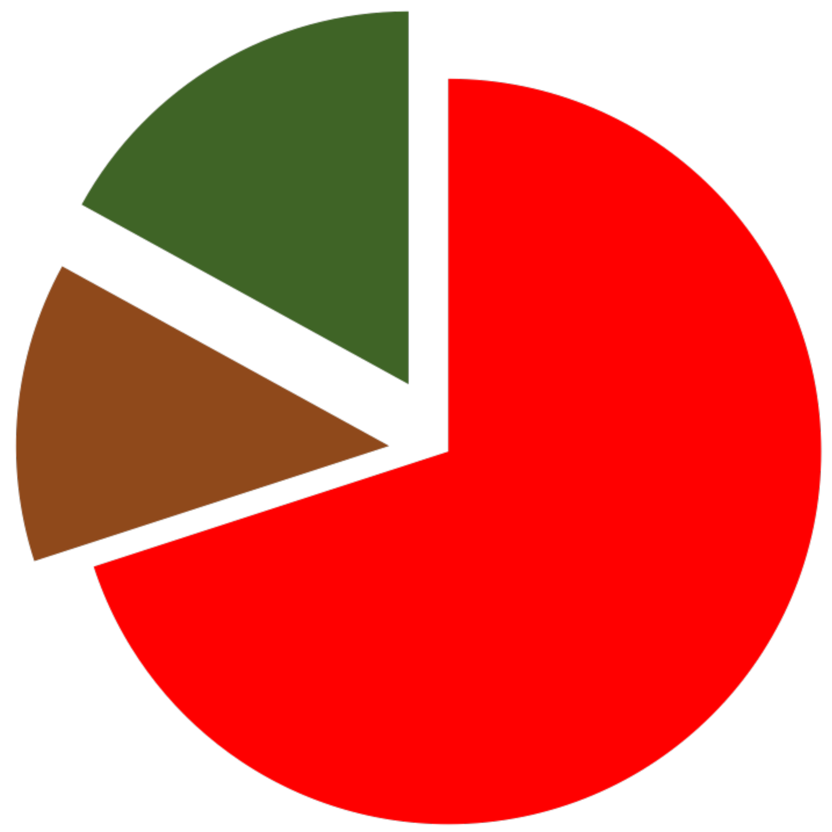
- Three watersheds
- Two time periods
- Three rotations and tillage practices
- Considering different start phase of rotation, e.g. wheat-fallow and fallow-wheat

Spring Flat Creek Watershed (SFCW)				Upper Imbler Creek Watershed (UICW)				Winn Lake Canyon Watershed (WLCW)			
Sce.	Period	Rotation*	Tillage	Sce.	Period	Rotation*	Tillage	Sce.	Period	Rotation*	Tillage
1	Past	WF	Intense	13	Past	WF	Intense	25	Past	WF	Intense
3	Present	WBP	Intense	15	Present	WBF	Intense	27	Present	WF	Intense
4			Reduced	16			Reduced	28			Reduced
5			Notill	17			Notill	29			Notill

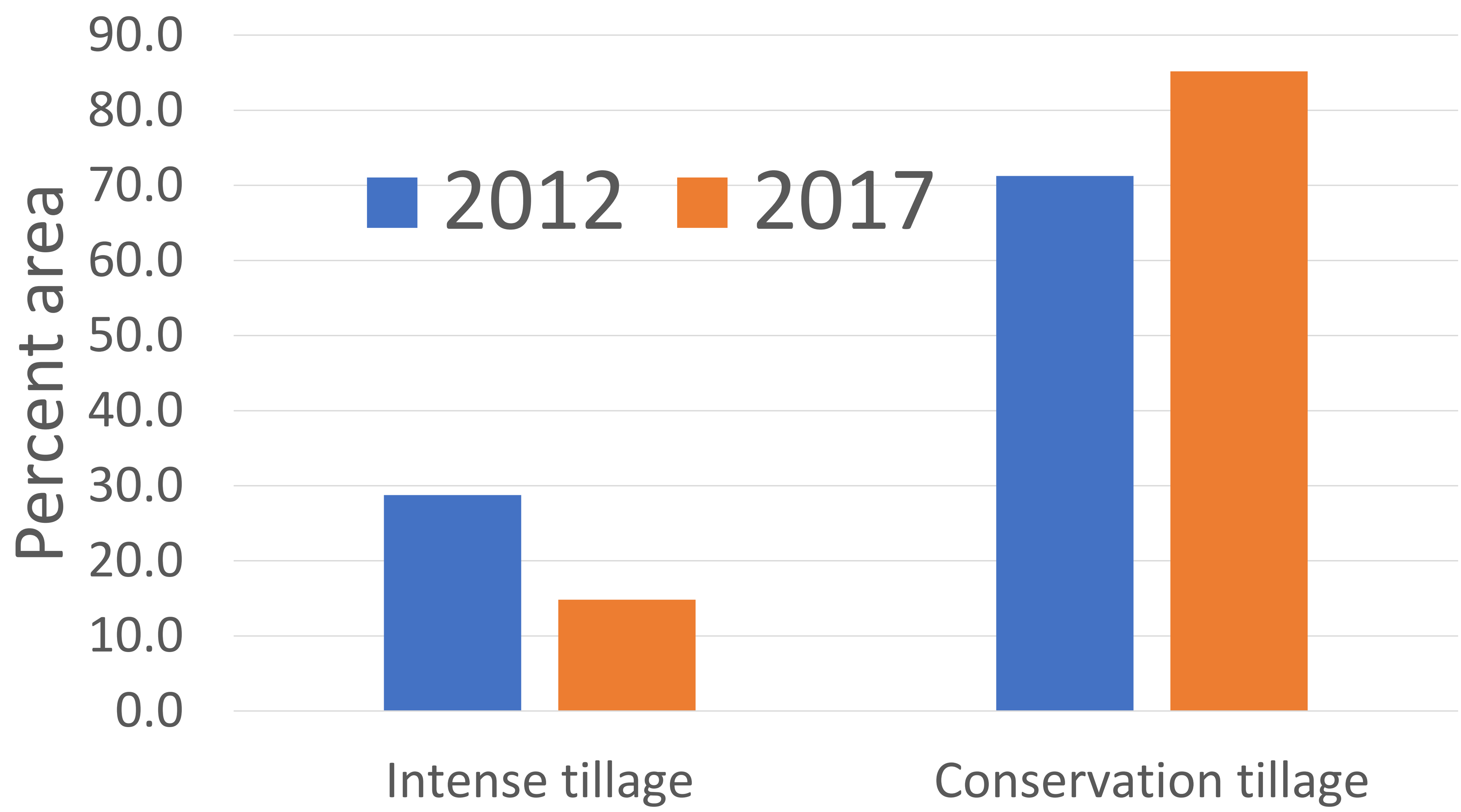
Management

Tillage

1. Intense
2. Reduced
3. No till



Conservation tillage have continuously increased in the study area



Rotation

Past

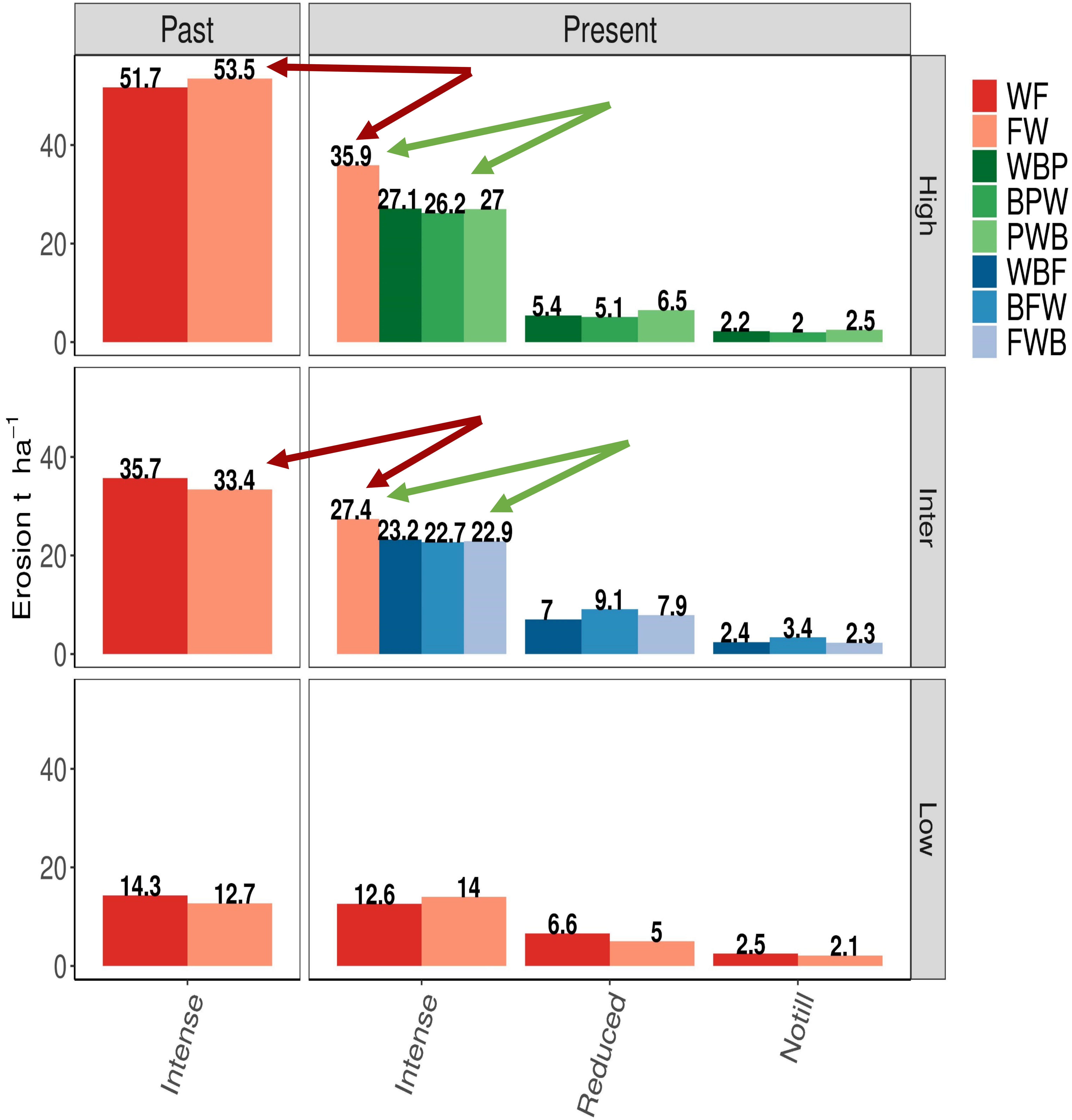
1. Wheat-fallow

Present

1. Wheat-barley-pea
2. Wheat-barley-fallow
3. Wheat-fallow

Climate-Management Interaction

- Effect of climate
  - ➢ Erosion lower in the present though with same rotation as in the past
- Effect of crop rotation
  - ➢ Erosion lower in three-year rotations in the present
- Effect of tillage
  - ➢ Erosion lower with lower tillage intensity



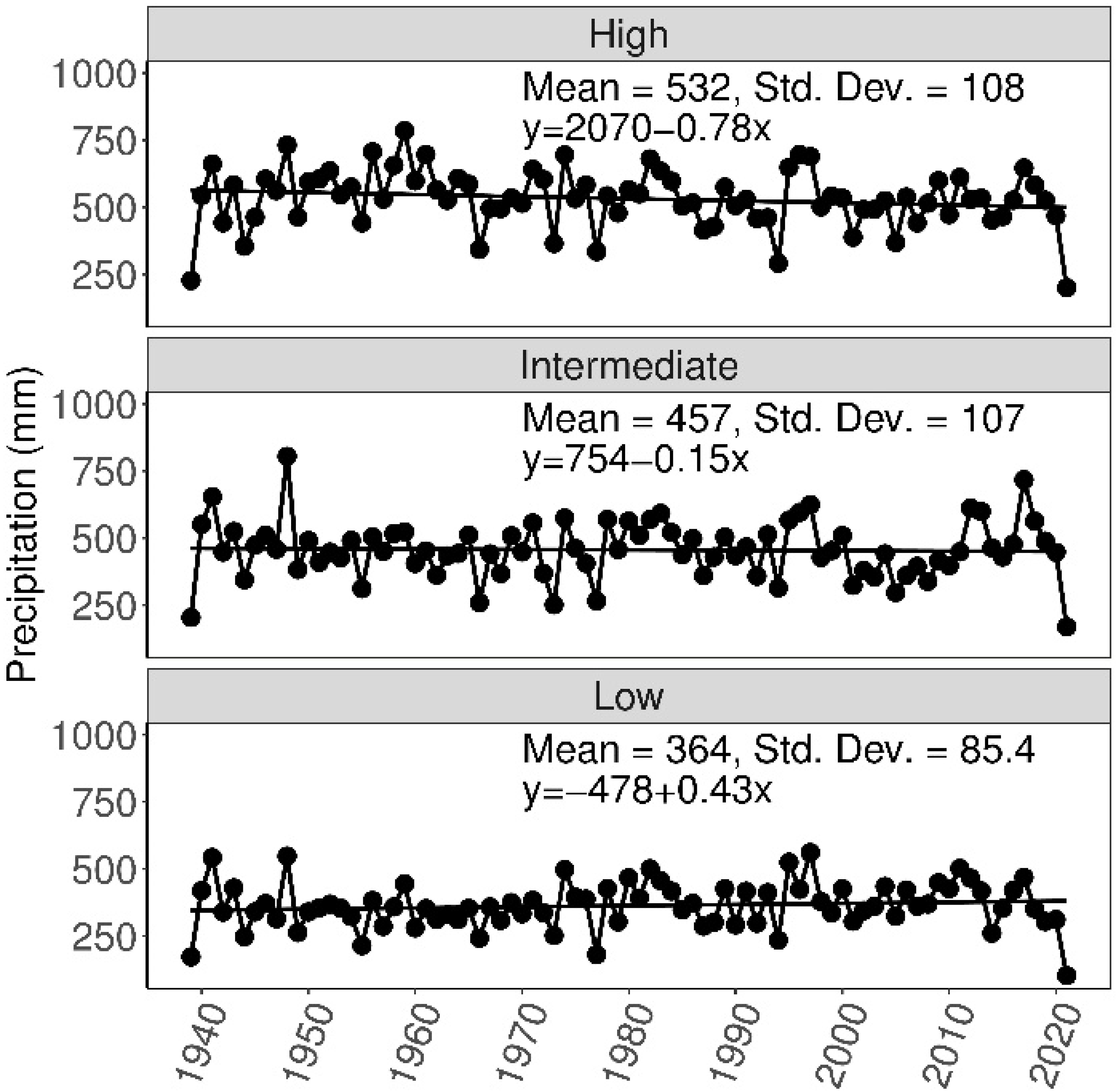
Mean Comparisons

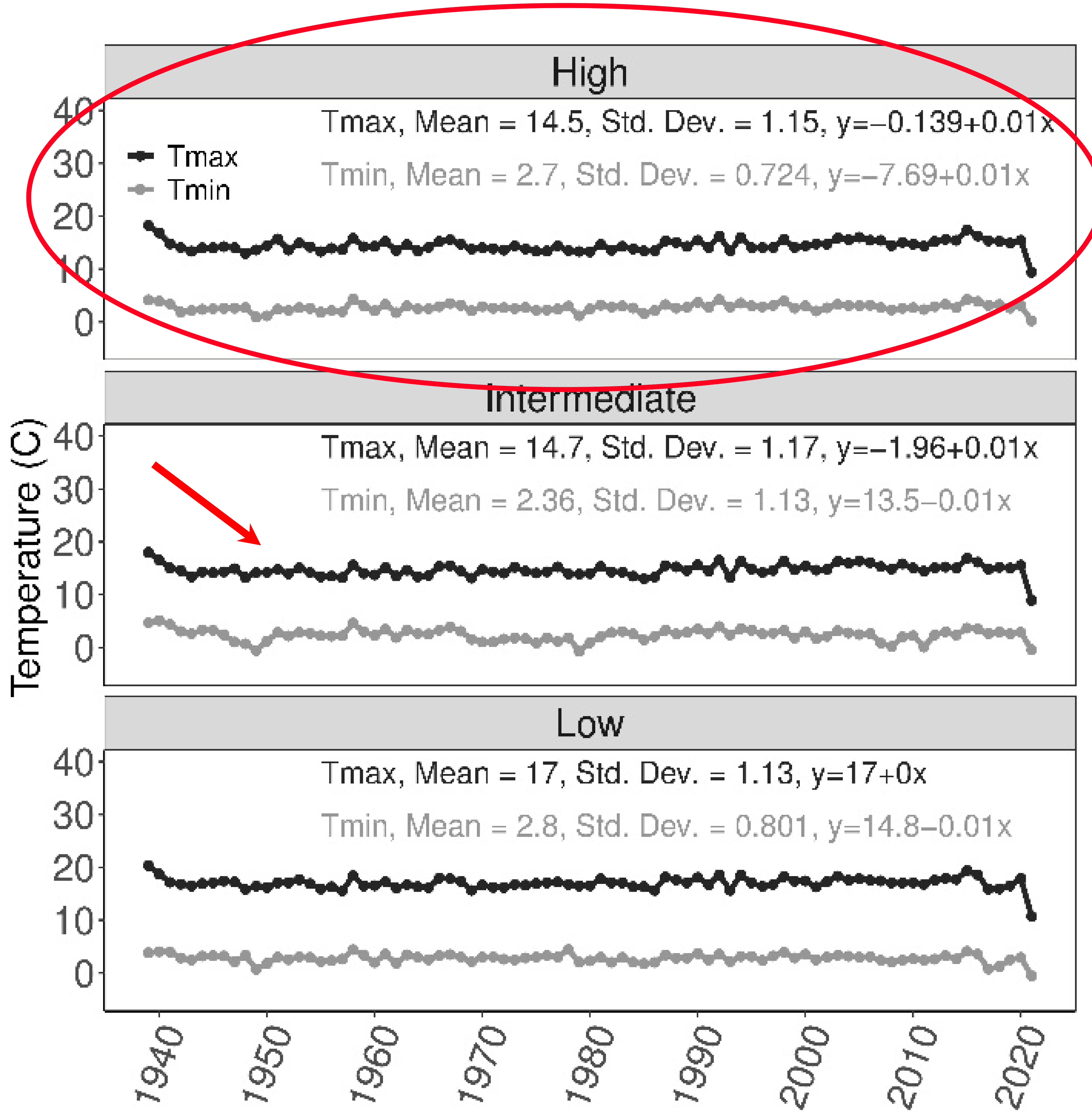
- Change in precipitation **not** statistically significant
- T_{max} and T_{min} in high-precipitation zone significantly **increased**
- T_{max} in intermediate- and low-precipitation zones significantly **increased**
- The number of freeze-thaw cycle in low-precipitation zone significantly **decreased,** and is **not** changed for the other two zones

Precipitation Zone		Amount		Normality test		Student t-test		Wilcox rank sum test	
		Past	Present	W	p	t	p	w	p
High	Precipitation	552.0	511	0.98	0.11	1.75	0.084		
	T_{max}	14.2	14.8	0.91	<0.0001			**474**	**<0.0001**
	T_{min}	2.6	2.9	0.96	0.02			**557**	**0.006**
	Freeze-thaw cycles	22	21	0.96	0.02			975	0.286
Intermediate	Precipitation	458	455	0.98	0.41	0.11	0.911		
	T_{max}	14.4	14.9	0.91	<0.0001			**498**	**0.001**
	T_{min}	2.3	2.5	0.97	0.05			743	0.298
	Freeze-thaw cycles	20	21	0.98	0.17	−0.432	0.667		
Low	Precipitation	353	377	0.99	0.59	−1.28	0.205		
	T_{max}	16.9	17.1	0.85	<0.0001			**638**	**0.045**
	T_{min}	2.9	2.7	0.94	<0.0001			941	0.454
	Freeze-thaw cycles	28	26	0.94	<0.0001			**0.94**	**0.031**

Trend Analysis

- T_{min} and T_{max} increased significantly in high-precipitation zone
- T_{max} in intermediate-precipitation zone increased significantly





Precipitation Events

- Average number of precipitation events greater than 15 mm decreased in general