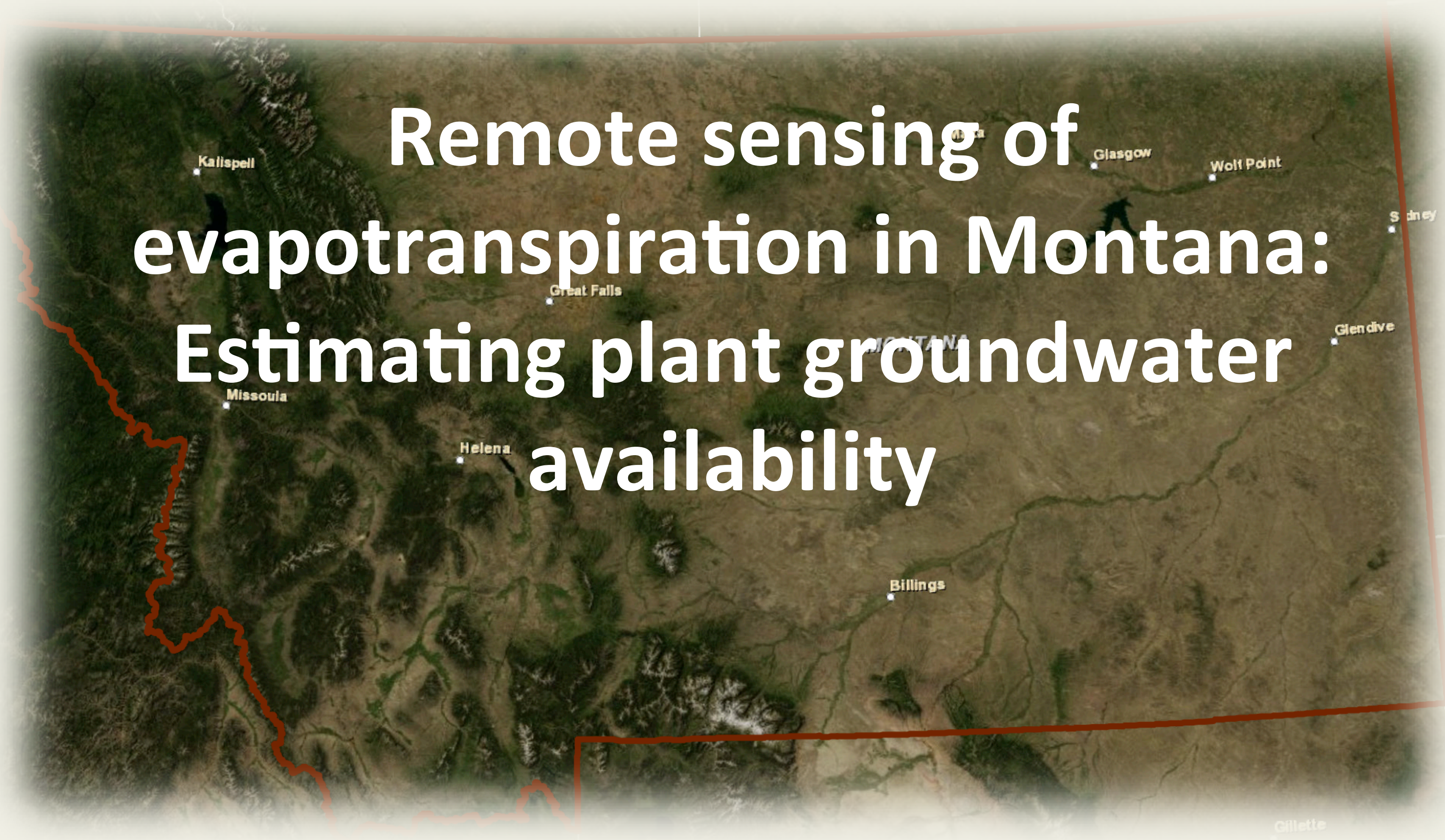
Remote sensing of evapotranspiration in Montana: Estimating plant groundwater availability



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Judith River Watershed

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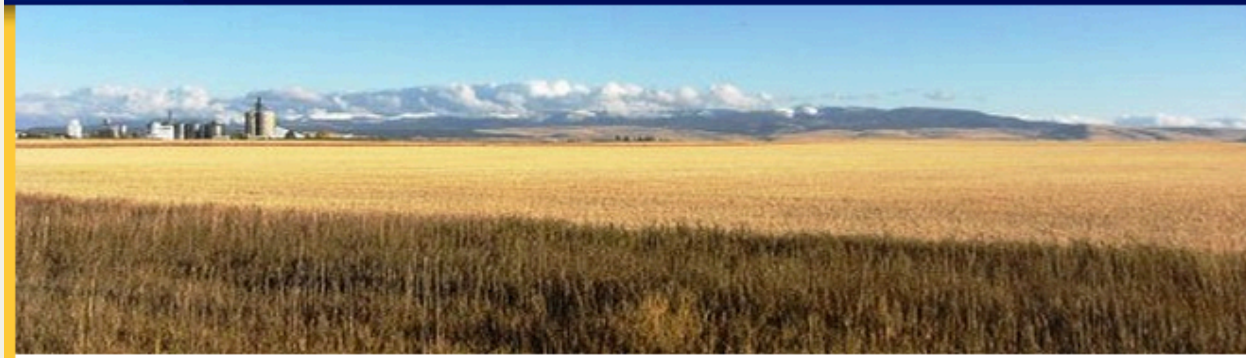


Judith Basin Nitrogen Project (JBNP)

The Judith Basin Nitrogen Project is a research project funded by the USDA National Institute of Food and Agriculture (NIFA) to explore sources of nitrogen in ground and surface water in the Judith Basin of central Montana. Concentrations of nitrate greater than 10 mg/L are considered to pose health risks and have been detected in many private drinking water wells in Judith Basin and Fergus counties. In addition to health risks, elevated nitrogen and other nutrients can cause nuisance algae growth and impacts to fish in surface water. In addition to potential health and environmental concerns, nitrogen lost from cropping systems represents lost fertilizer and/or yields which is an added expense to the farm operation.

Starting in the fall of 2011, researchers from Montana State University and Utah State University will work with the local community in the Judith Basin to design a research project to address the following three goals:

- To better understand the sources of nitrate in ground and surface water.
- To evaluate which practices are likely to be effective to reduce nitrate leaching and are also likely to be adopted and maintained.
- To engage the local community to ensure that the research is relevant and useful.

The project is scheduled to last three years and will involve surveys of agricultural producers, soil nitrogen testing, installing monitoring wells and water sampling. See the links below for information about the researchers, the local advisory teams, background information, and project updates.

Dr. Stephanie Ewing
Adam Sigler
Dr. Clain Jones

Soil Moisture

- Thin soils on a perched water table
- Land use

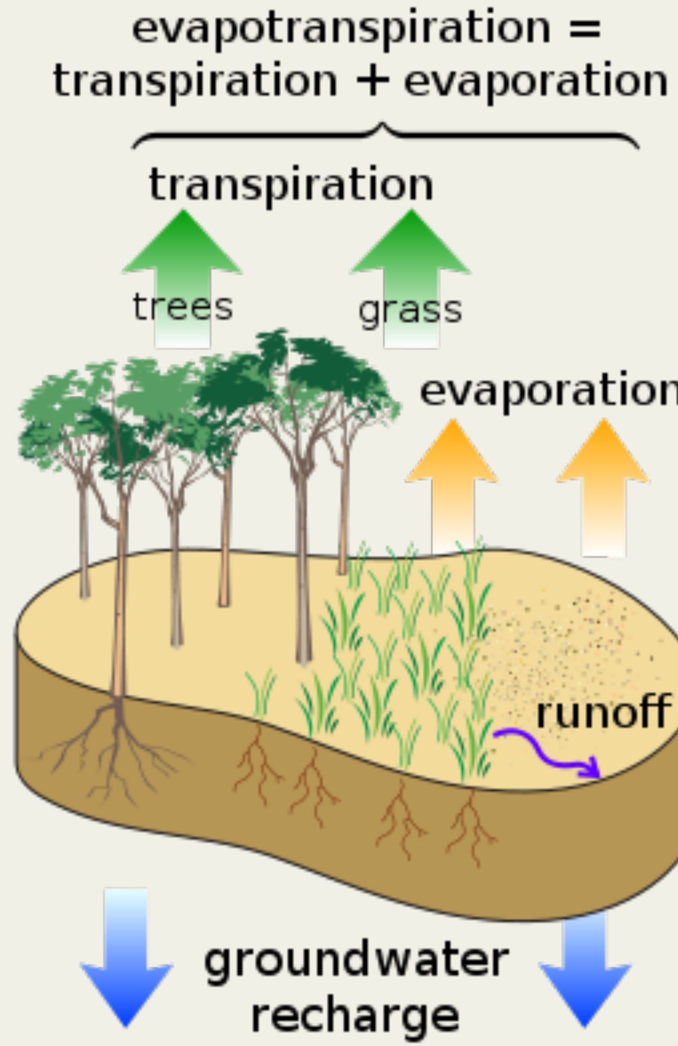
$\downarrow$

Vegetation/Fallow

$\downarrow$

Evapotranspiration

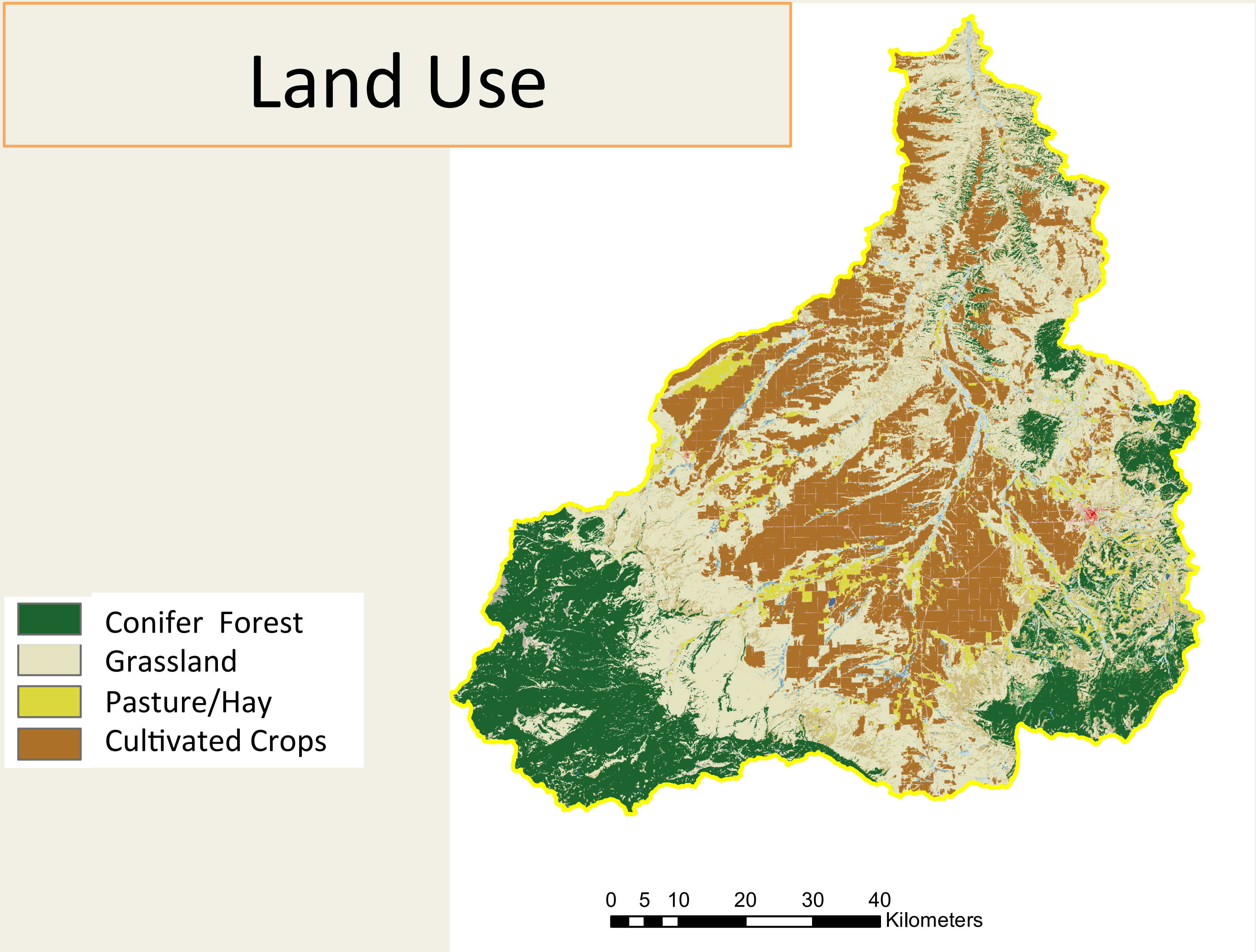
- Precipitation



Soil Moisture

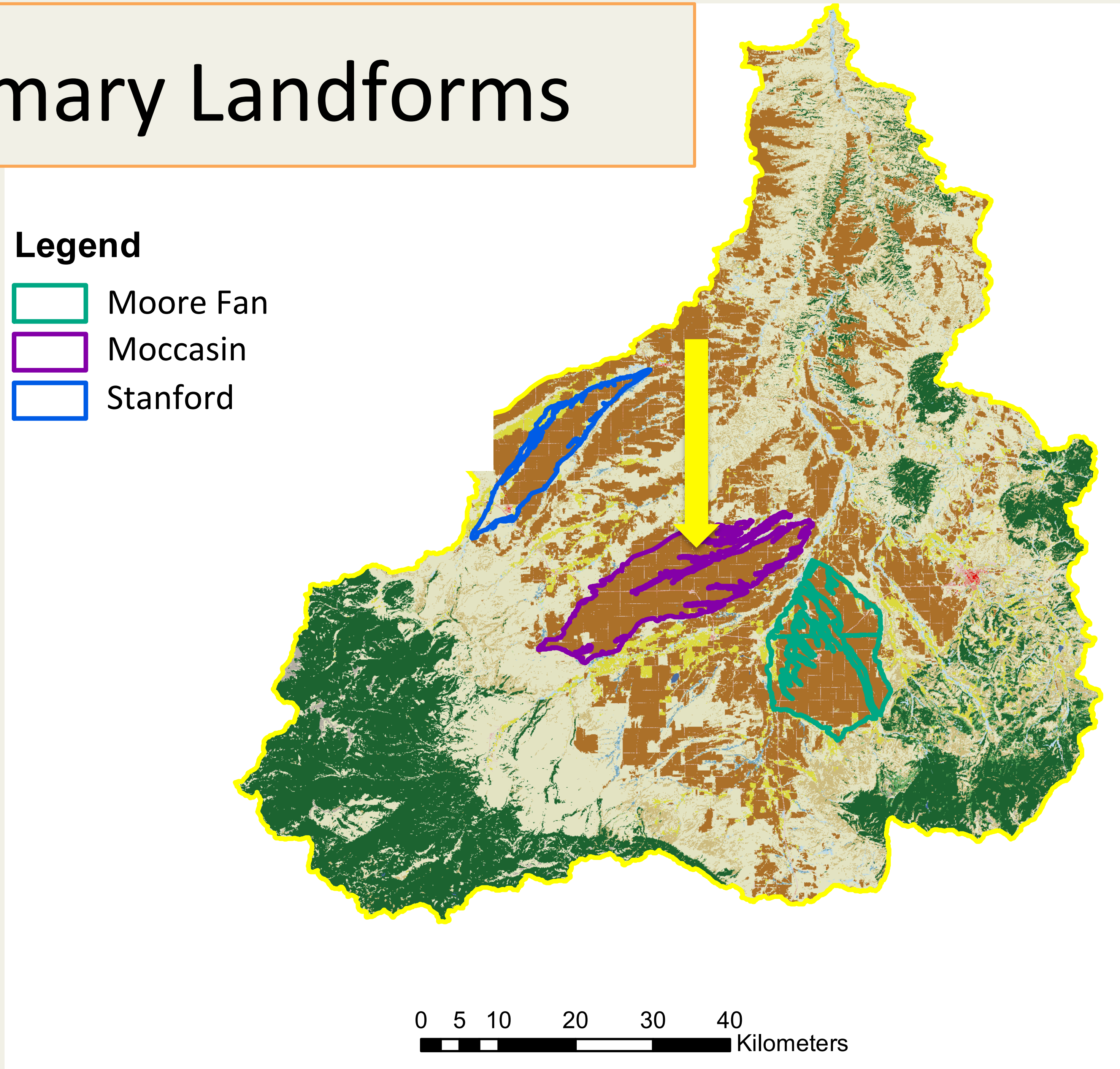
- Thin soils on a perched water table
- Land use (vegetation types)
- Precipitation regime

Land Use

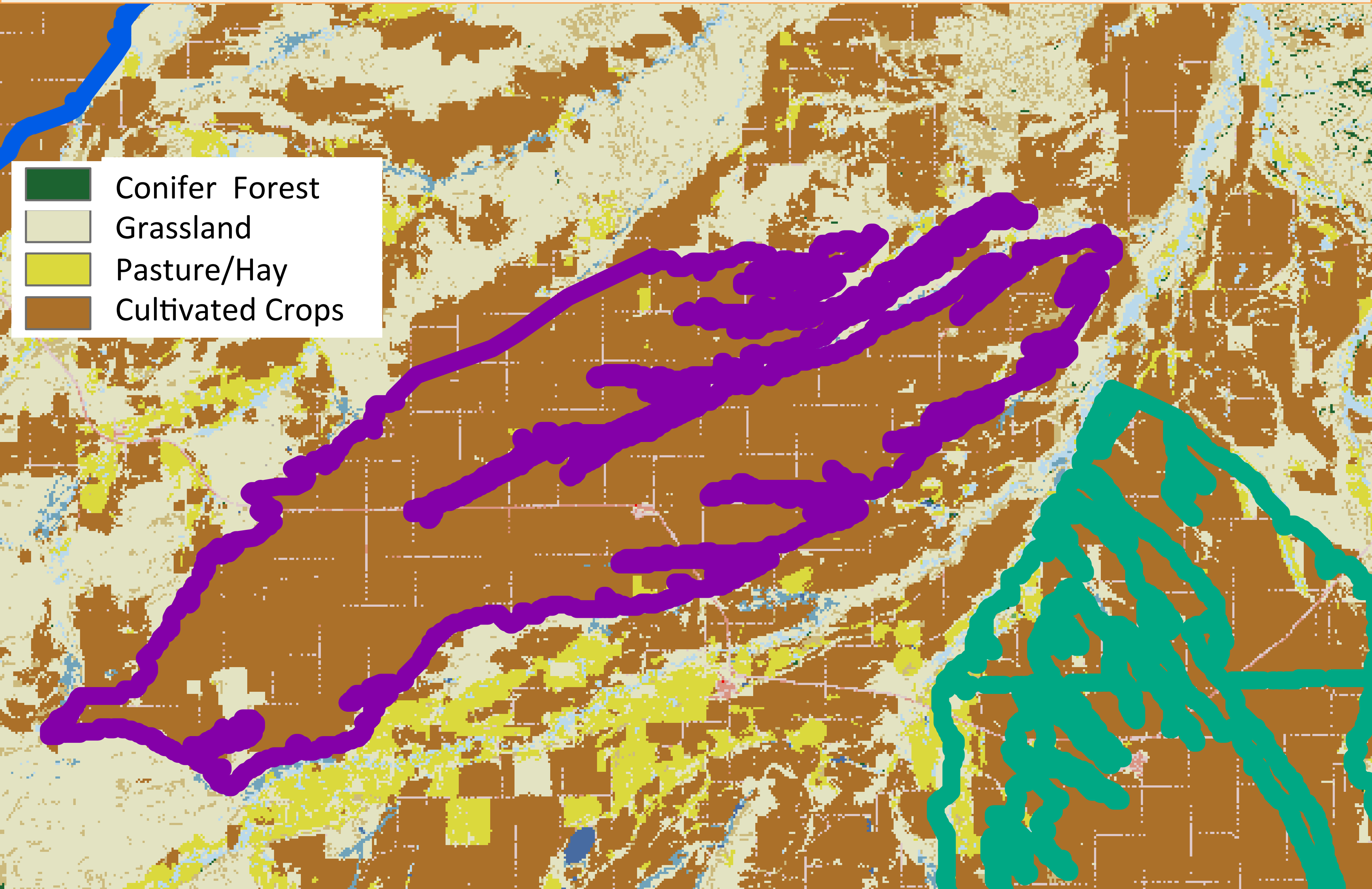


Conifer Forest
Grassland
Pasture/Hay
Cultivated Crops
0 5 10 20 30 40
Kilometers

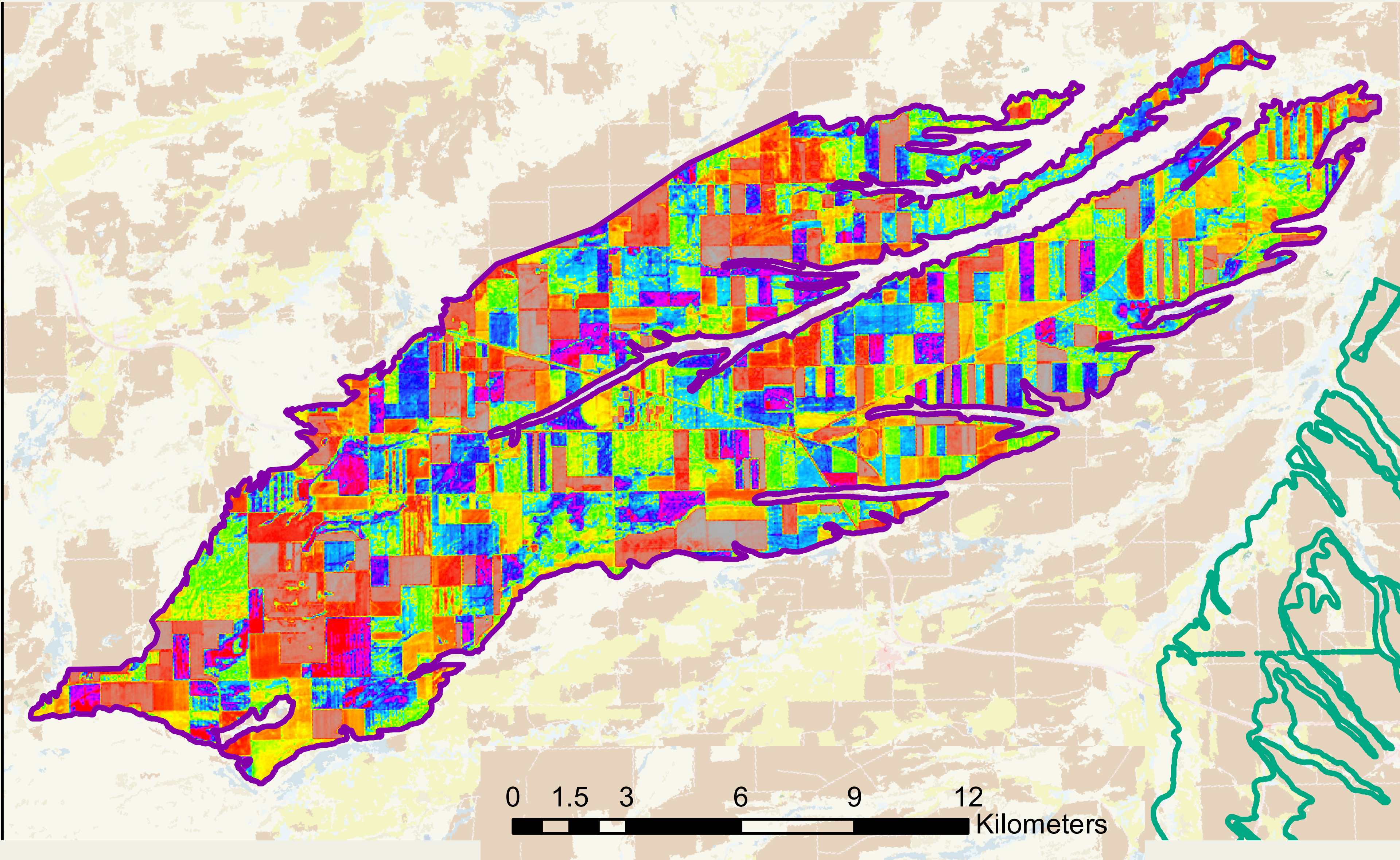
Primary Landforms



Moccasin Terrace – Land Use



Moccasin Terrace – Land Use

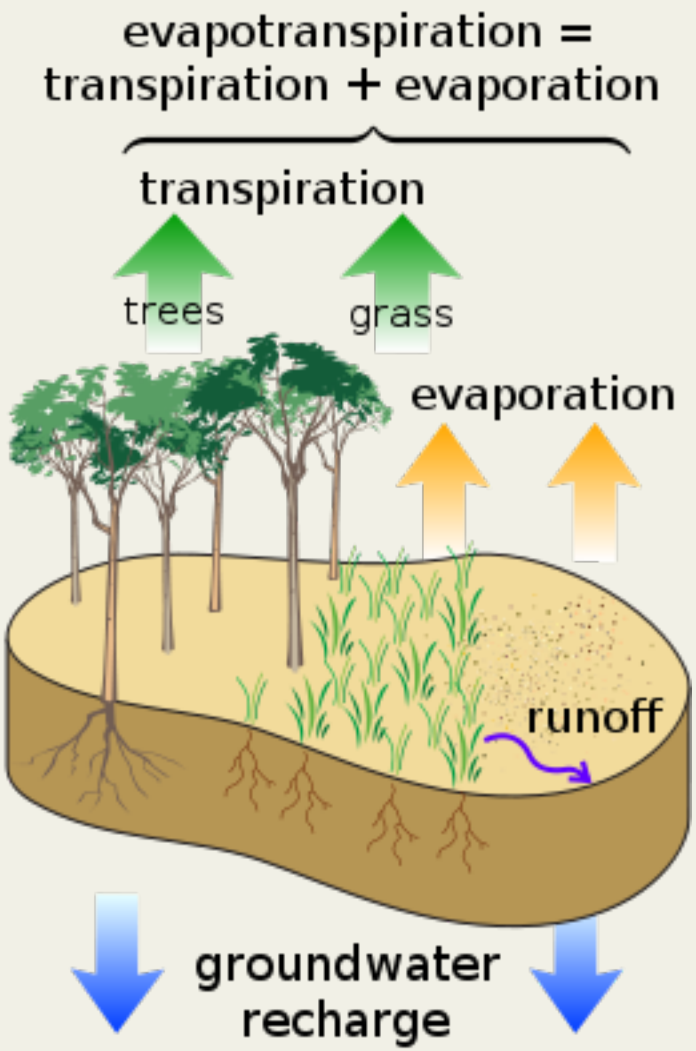


Soil Moisture

- Thin soils on a perched water table
- Land use

↓
Vegetation/Fallow
↓
Evapotranspiration

- Precipitation



Evapotranspiration (ET): An energy balance approach

$$R_n = LE + H + G \rightarrow LE = R_n - H - G$$

Net radiation (R_n) SW in – SW out + LW in – LW out

Sensible heat flux (H)

+ Photosynthesis - Ecosystem respiration = NEE

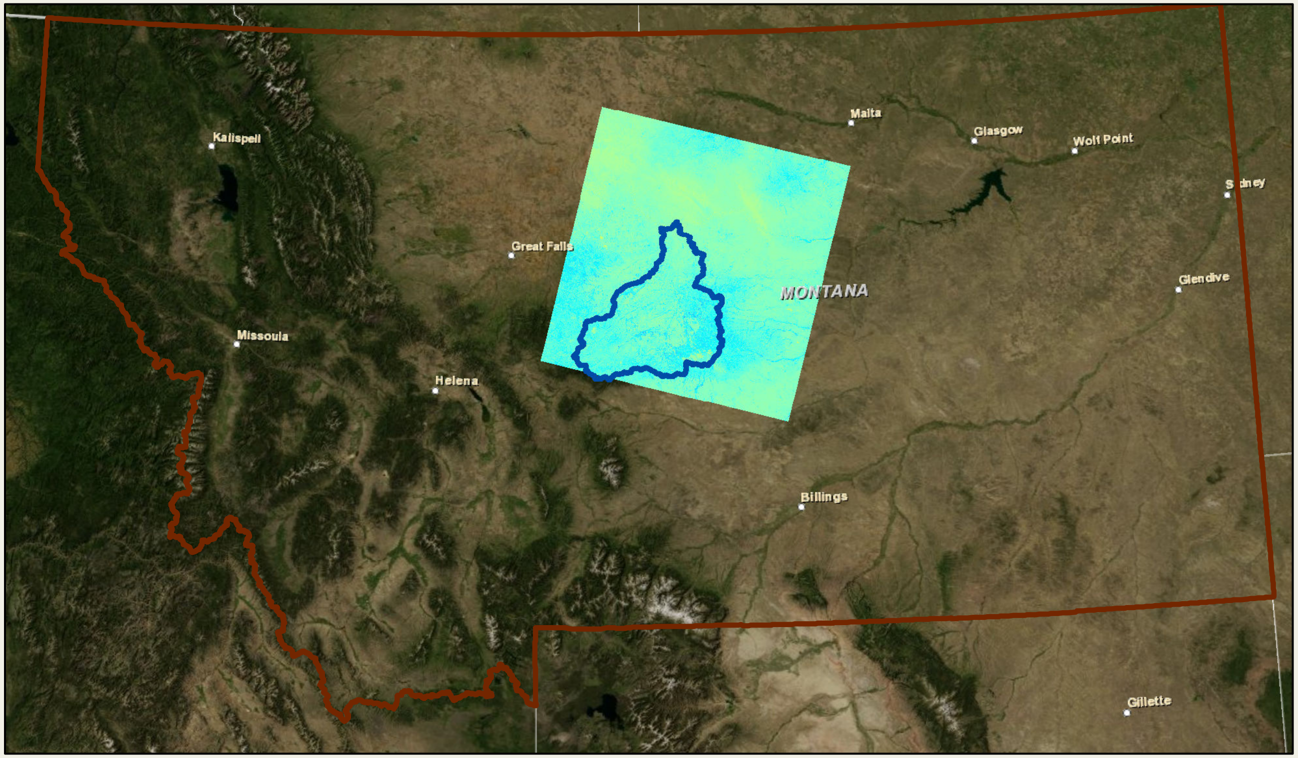
Soil Heat Flux(G)

+

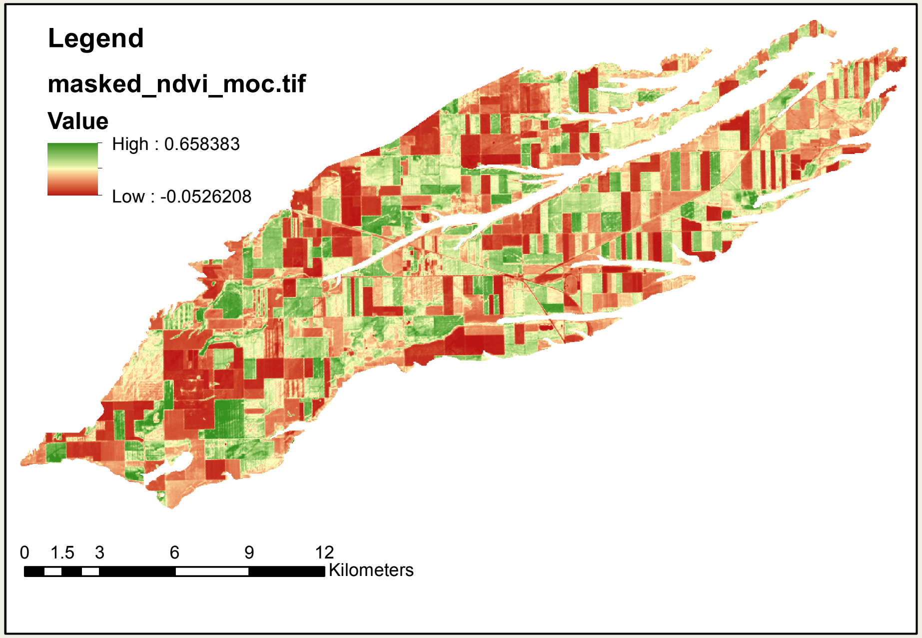
Evapotranspiration (LE) + Runoff + Storage + Drainage = Water balance

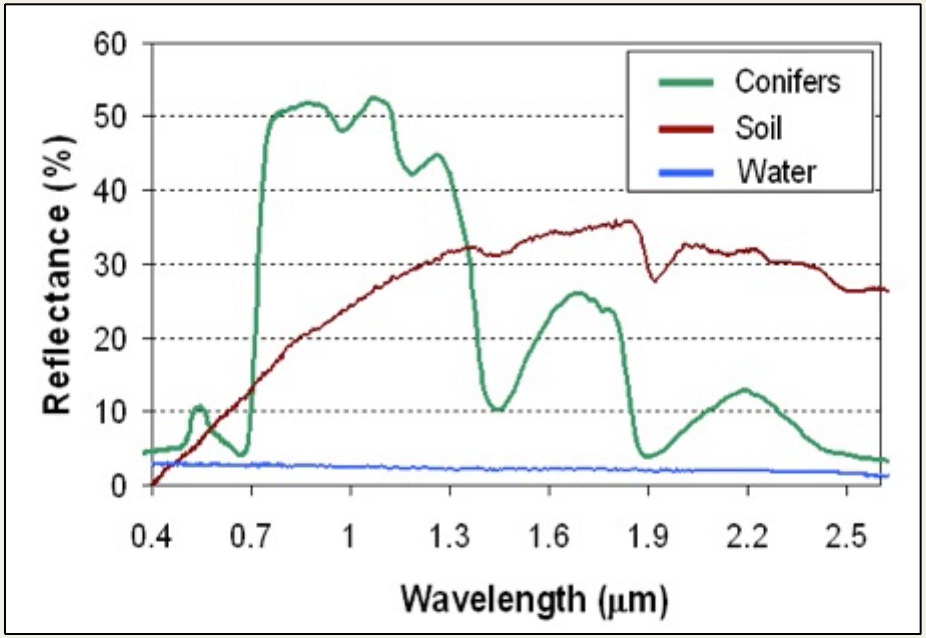
Landsat Satellite Data

- 30 m spatial resolution (~180 km^2 extent)
- 16 day repeat cycle
- Available from 1980's
- Data bands: Visible, NIR, MID IR, Thermal



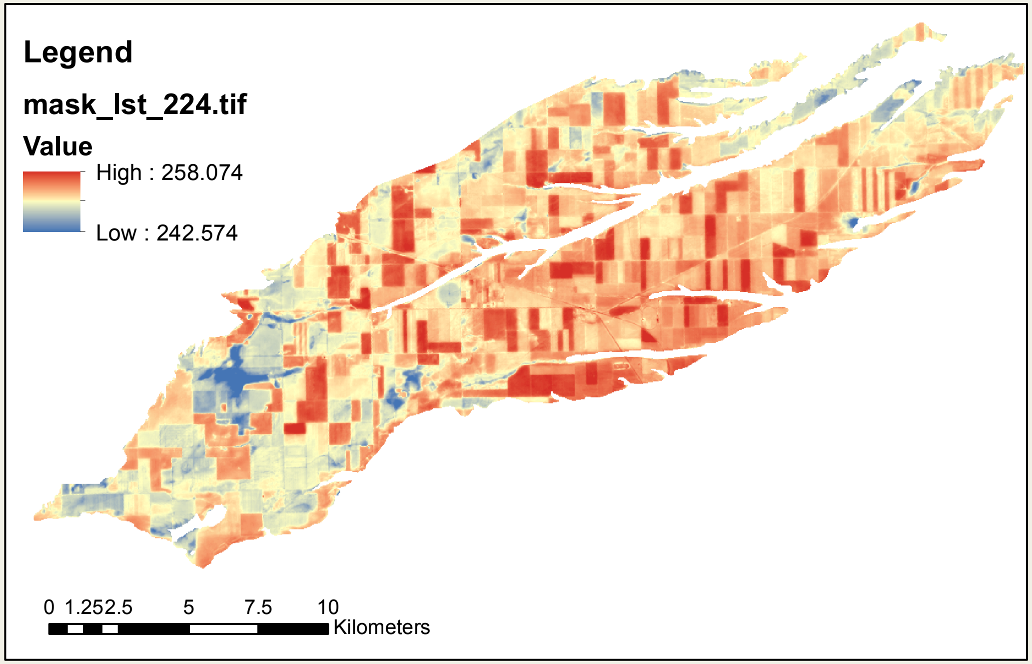
Normalized Difference Vegetation Index (NDVI)





"Greenness index" NDVI = NIR-RED/NIR + RED

Land Surface Temperature (LST) in K

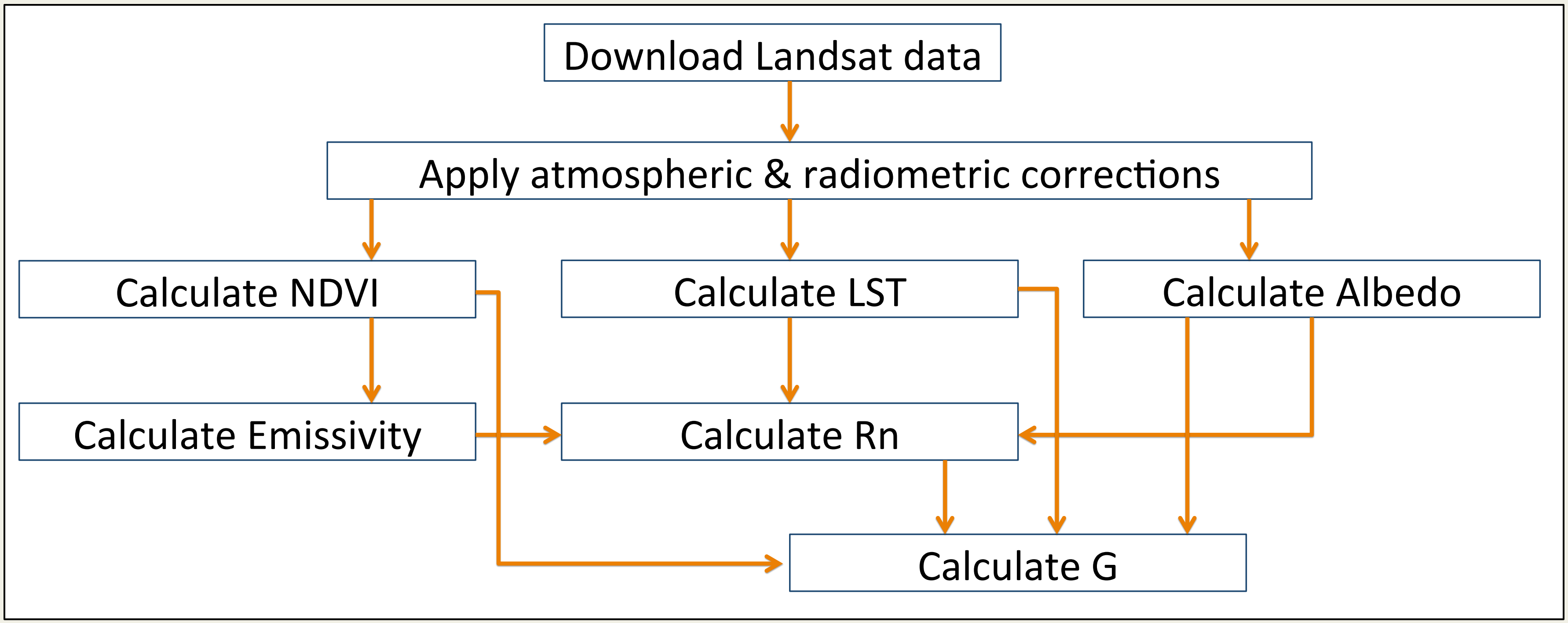


$$T = \frac{K2}{ln\left(\frac{K1}{L_\lambda} + 1\right)}$$

K1 = Calibration constant 1 (666.09 watt/m2 * ster * µm)
K2 = Calibration constant 2 (1282.71 K)
L_λ= At-sensor radiance calculated from prior pre-processing

ET Model & Landsat data

$$R_n = LE + H + G \rightarrow LE = R_n - H - G$$



Pulling it all together

Model of evapotranspiration

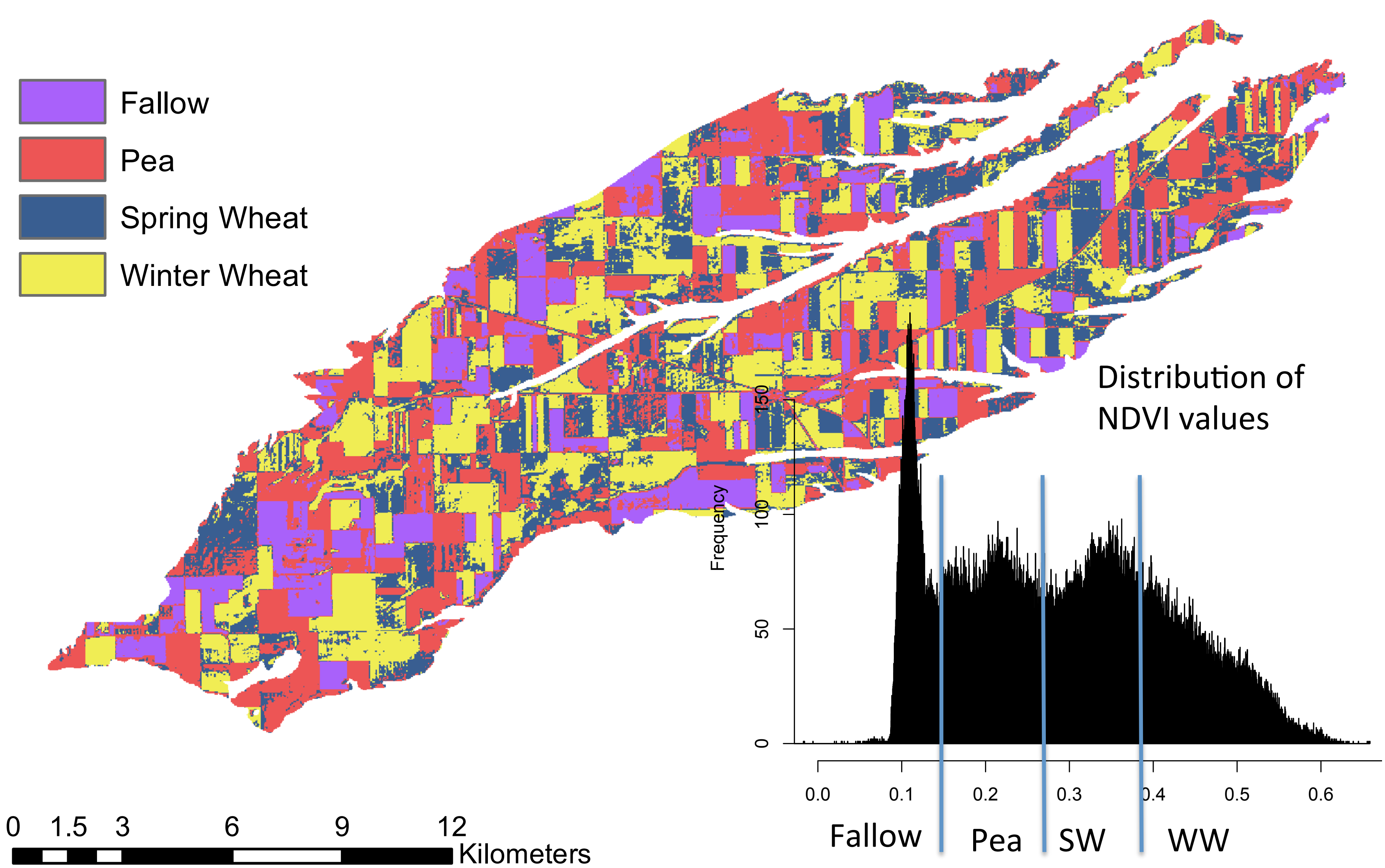
Different land uses

NDVI (high)

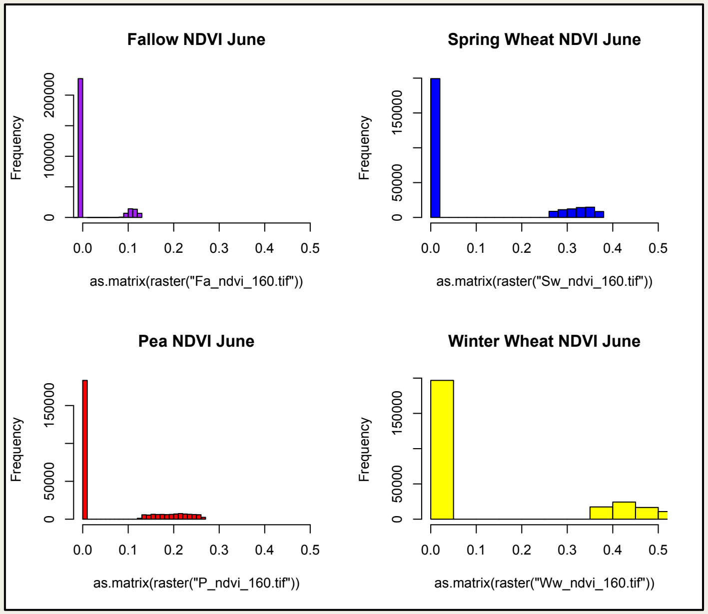
Land surface temperature (cool)

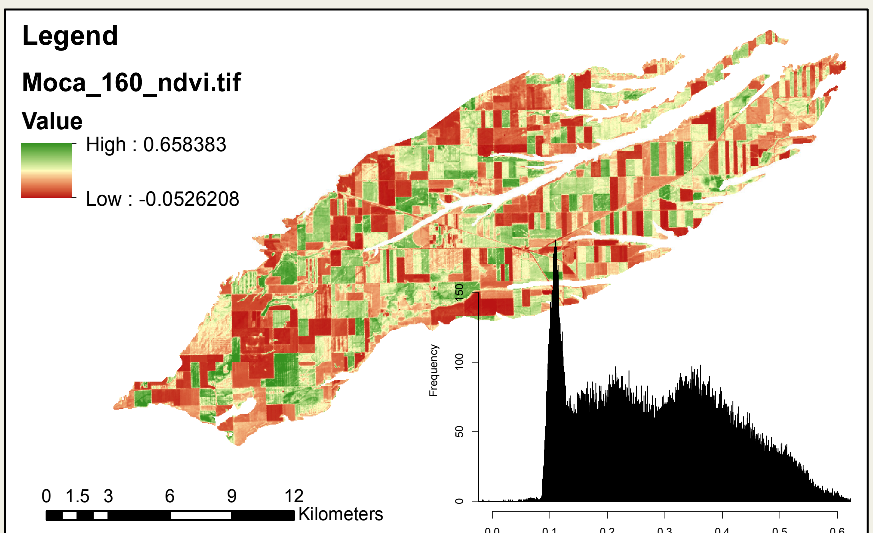
Plant groundwater availability

Land Use Classes

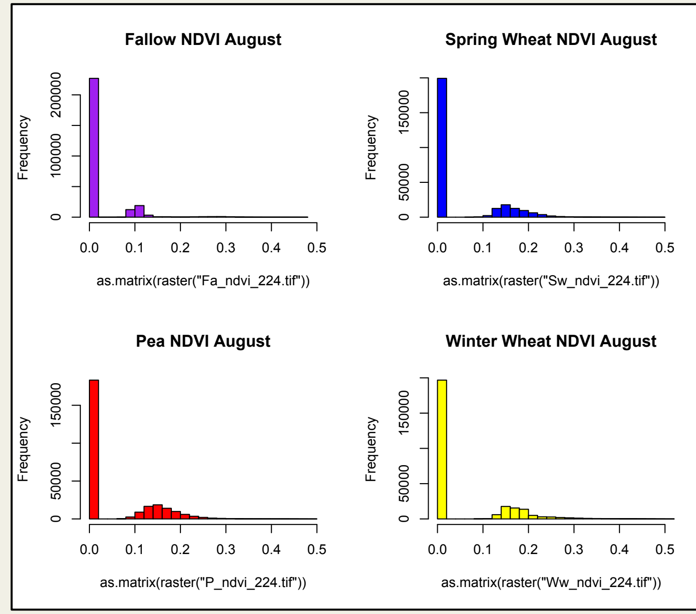


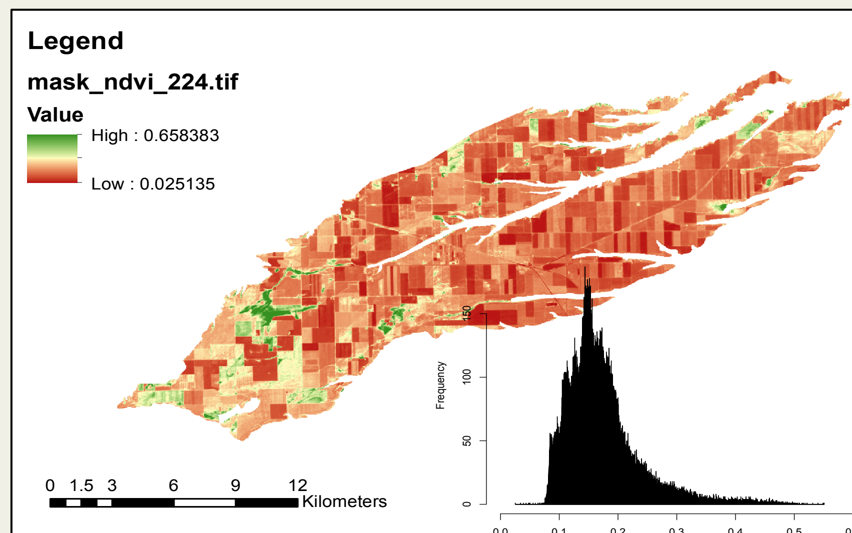
NDVI June



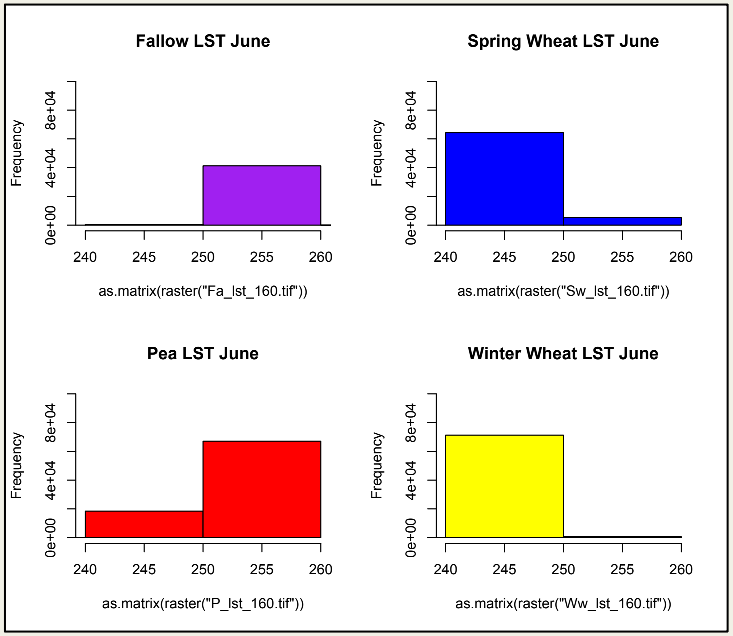


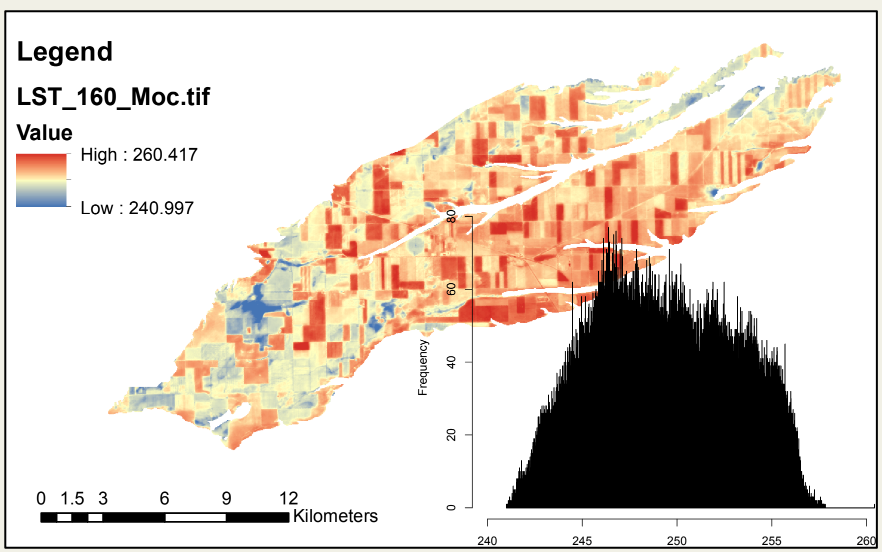
NDVI August



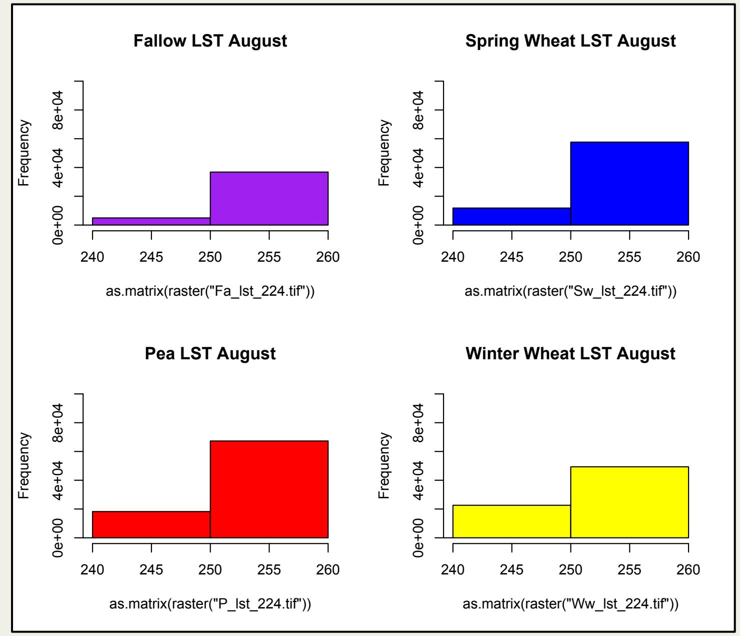


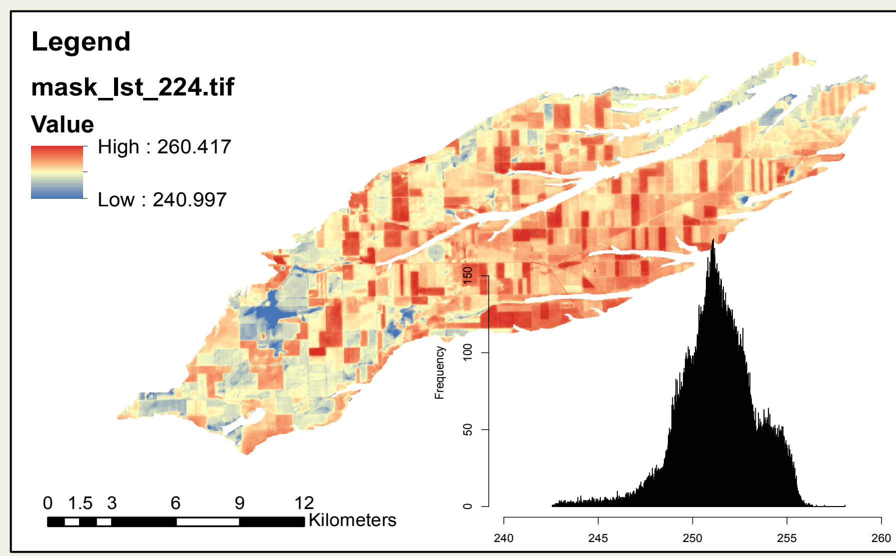
LST June





LST August





Results

- NDVI
  - Late in the season, NDVI values are too similar to relate them to ground water availability
- LST
  - SW and WW are the sources of increase in LST late in the season.
  - The range of LST late in the season is narrower relative to earlier in the season.
- Due to NDVI decreases locating areas of high plant ET, with low surface temperatures is not feasible in August.

Directions for Future Research

- Apply these methods to early season data in lower than average water year
  - NDVI (high) & LST (cool)

- Complete Landsat ET estimates and compare to results presented here
  - Is ET highly correlated w/NDVI and/or LST?

- Consider other biophysical attributes
  - Ability to indicate ground water access by plants

Acknowledgements

- Montana Institute on Ecosystems
- Adam Sigler
- Dr. Paul Stoy
- Dr. Stephanie Ewing
- Dr. Scott Powell
- Dr. Mark Greenwood

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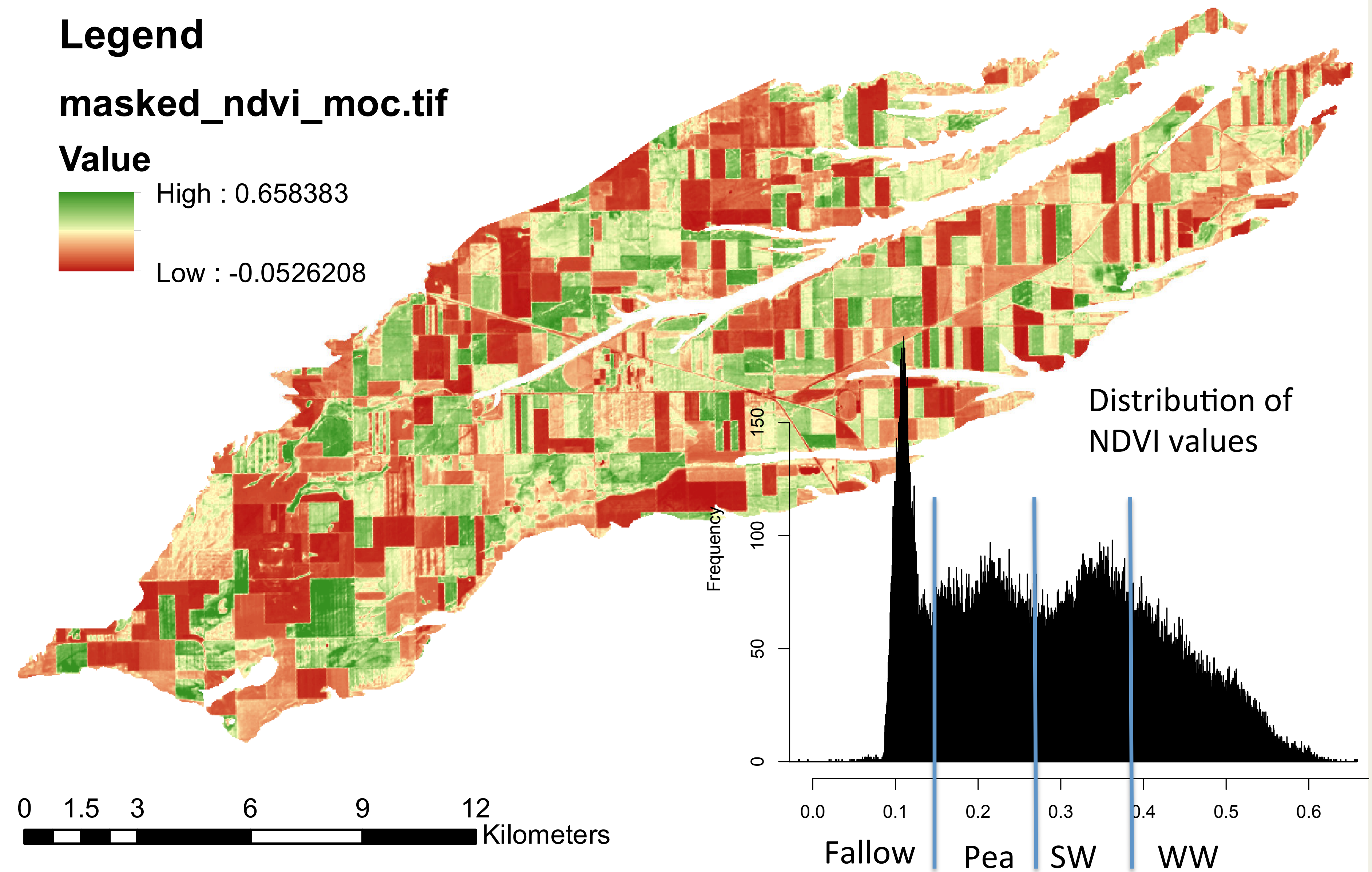
NDVI


Legend
masked_ndvi_moc.tif
Value
High : 0.658383
Low : -0.0526208
0
1.5
3
6
9
12
Kilometers
Distribution of NDVI values
Frequency
0
50
100
150
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Fallow
Pea
SW
WW

Evapotranspiration (ET): An energy balance approach

$$R_n = LE + H + G \rightarrow LE = R_n - H - G$$

Water Balance

Precipitation

=

Radiation Balance

Carbon Balance

Evapotranspiration **+**	**Sensible Heat Flux + Soil Heat Flux +**	**Photosynthesis**	**=**	**Net Radiation =**

Water balance = ET + Runoff + Storage + Drainage

+ Runoff

+ Drainage

+ Storage

via canopy conductance

= NEE

- Ecosystem Respiration

Shortwave in +

Shortwave out -

Longwave in -

Longwave out

R_n = Total Incoming Radiation

LE = Latent Heat of Vaporization(ET)

H = Sensible Heat

G = Soil Heat Flux

Estimating Evapotranspiration

Penman-Monteith Equation

$$LE=(Rn-G)+pC_p(T_a-T_{s)}\ /rH$$

Evapotranspiration (ET); An Energy balance Approach

$$Rn = LE + H + G$$

Rn = Total Incoming Radiation, LE = Latent Heat (ET), H = Sensible Heat, G = Soil Heat Flux