Landscape-scale vegetation recovery trends from Landsat time series analysis

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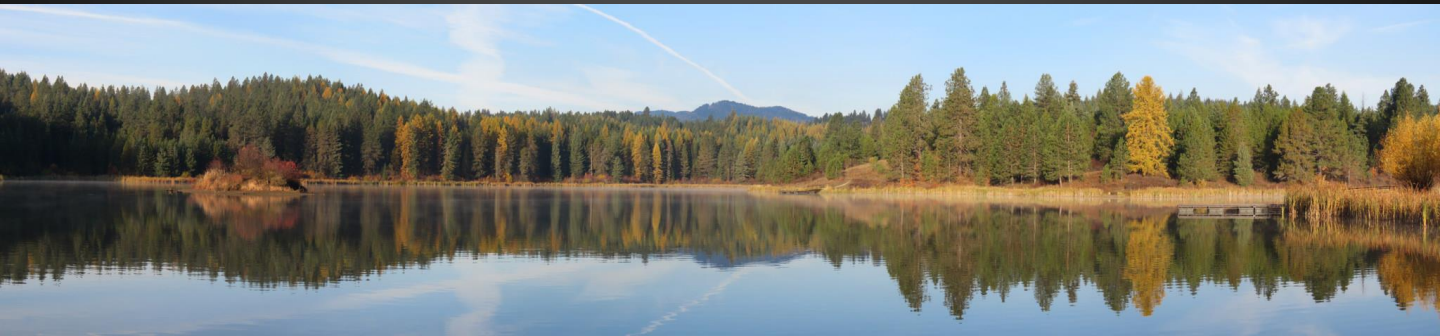
Outline

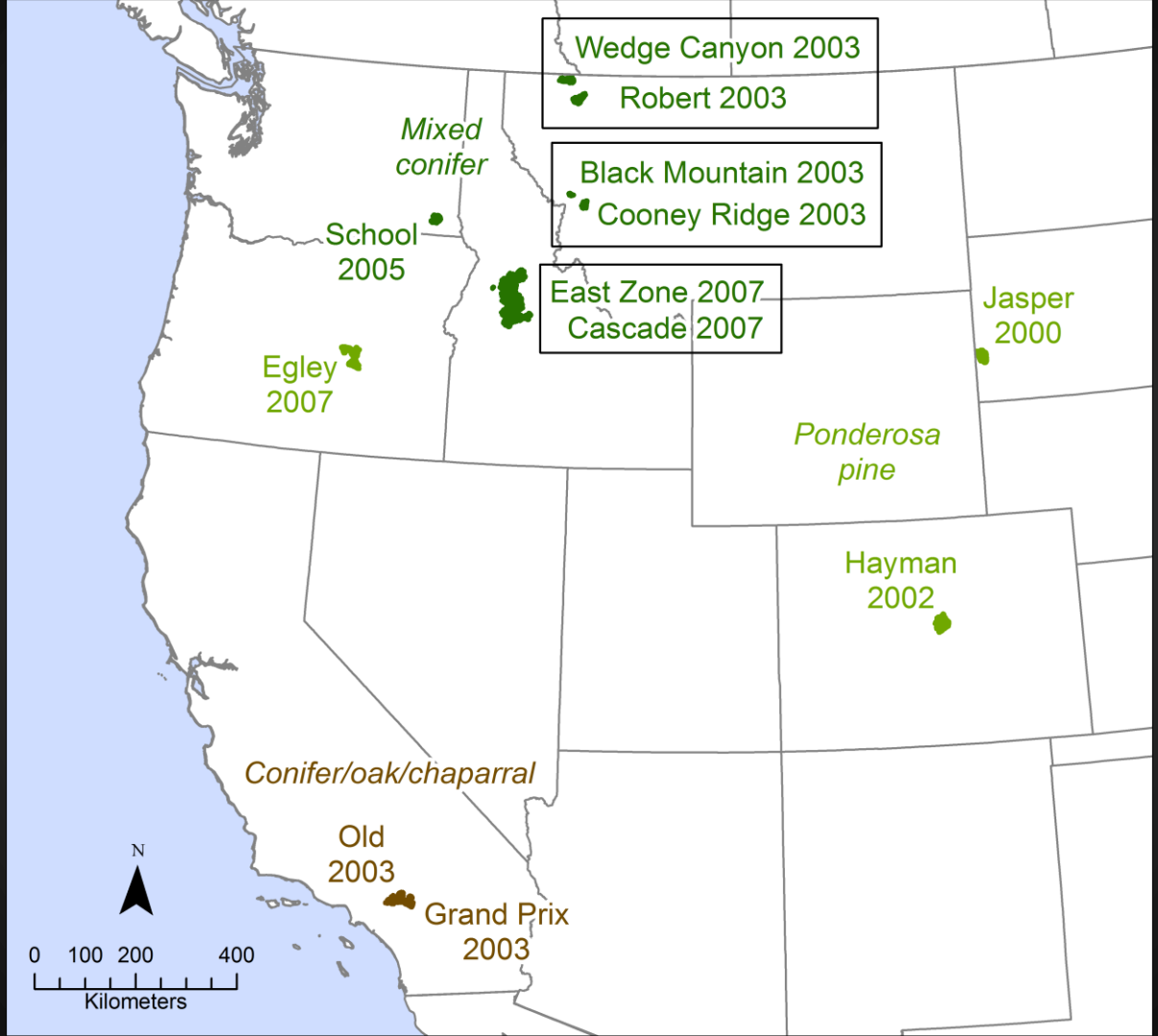
- Research questions
- Methods
  - Study areas
  - Landsat time series analysis
  - Geographic raster data processing
- Results
  - Satellite-derived vegetation recovery following fire
  - Variables that explain variation in long-term post-fire vegetation recovery
- Conclusions

School burn, Washington

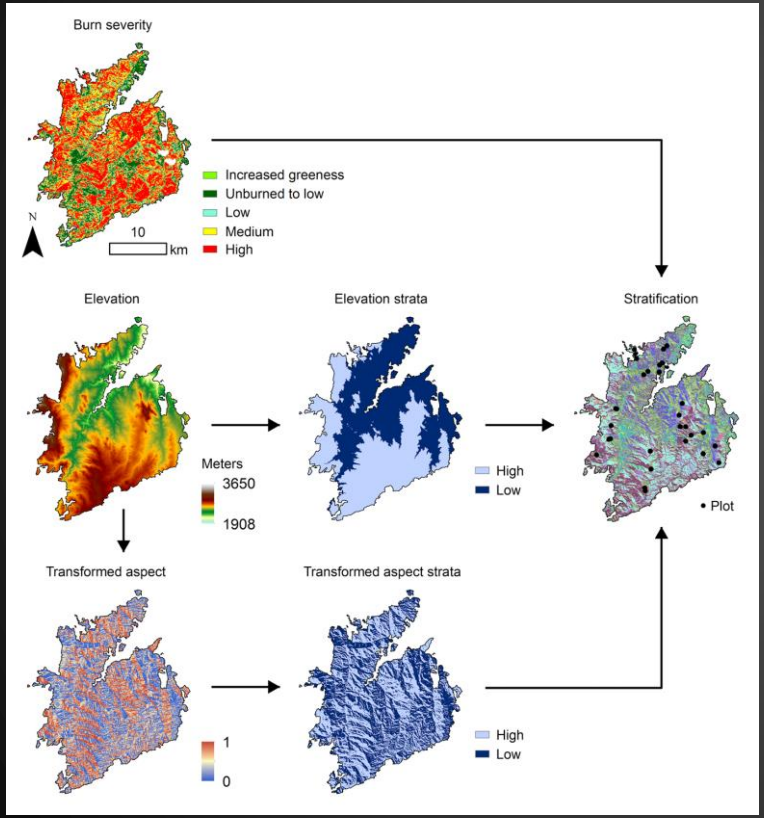
Research questions

- How do rates of vegetation recovery vary over time?
- How quickly do fire patches appear to return to pre-fire spectral conidition?
- How do pre-fire condition, burn severity, and climate affect recovery?




Wedge Canyon 2003
Robert 2003
Mixed conifer
Black Mountain 2003
Cooney Ridge 2003
School 2005
East Zone 2007
Cascade 2007
Jasper 2000
Egley 2007
Ponderosa pine
Hayman 2002
Conifer/oak/chaparral
Old 2003
Grand Prix 2003
N
0 100 200 400
Kilometers

Stratification

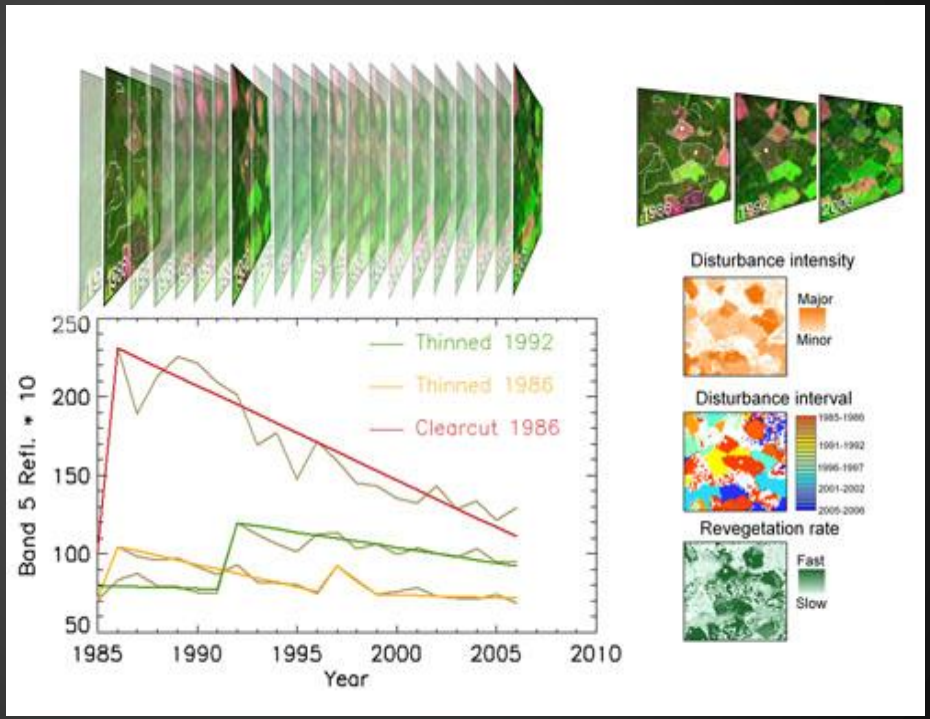


- All study areas are part of a larger project; stratification done to locate field plots
- For this analysis, final stratification rasters were used for patch analysis

Hayman burn, Colorado

Landsat time series data

- LandTrendr - Landsat based detection of trends in disturbance and recovery algorithm (Kennedy et al., 2010)
- Input: Annual Landsat NBR composites from 1984-2016
- Output: Trajectories describing trends for each 30-m pixel
- We used trends fit from Normalized Burn Ratio (NBR) images
- Interested in NBR recovery following fire



http://landtrendr.forestry.oregonstate.edu/content/how-landtrendr-works

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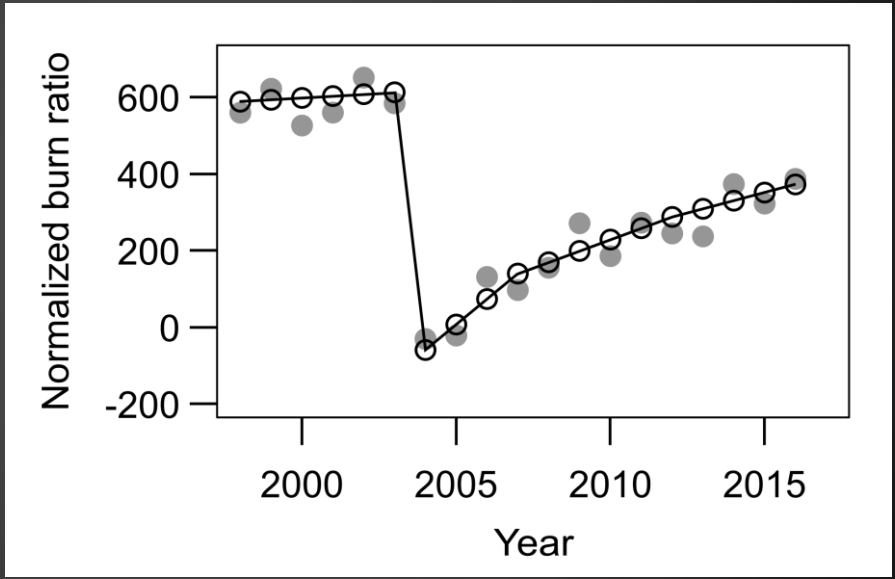
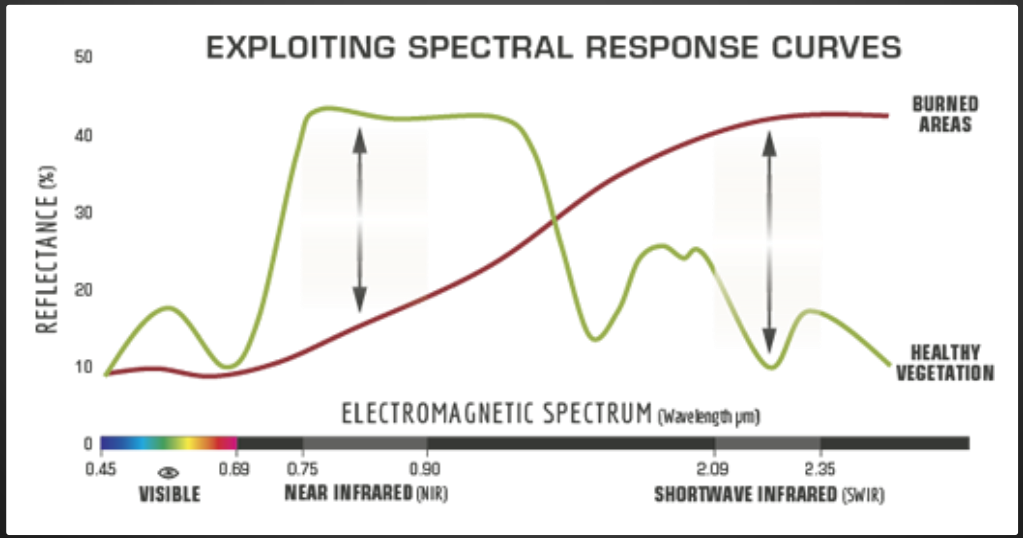


What is NBR?

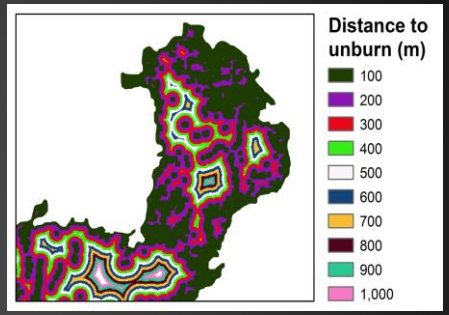
- Normalized Burn Ratio
- (Landsat Band 4 – Landsat Band 7) / (Landsat Band 4 + Landsat Band 7)
- Decrease in NBR indicates disturbance, increase indicates recovery
- Differenced NBR used as an indicator of burn severity



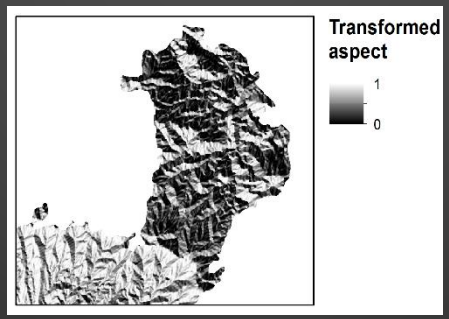
Source: US Forest Service

Climate, topographic, and distance-to-unburn rasters

Fine-scale (30-m) climate variable grids created, post-fire climate anomalies calculated



Distance-to-unburn rasters generated in ArcMap, based on MTBS data



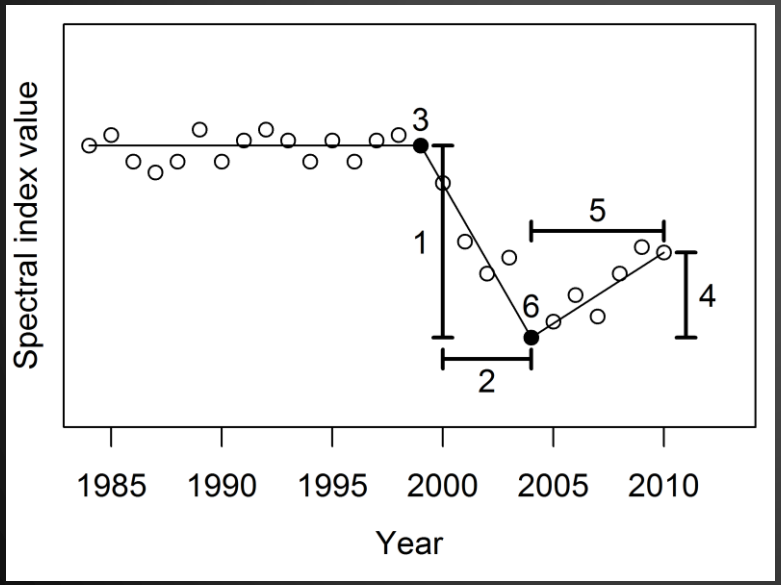
Digital elevation derivatives such as slope generated with ERDAS IMAGINE tool (Ruefenacht)

Raster processing

- For each area, all rasters combined into image stacks with identical projections, origins, and resolutions
- Zonal means calculated for each patch
- Processing done in ArcMap and R (‘raster’ package)
- NBR time series showing vegetation recovery explored
- Random forest modeling used to find variables important to vegetation recovery

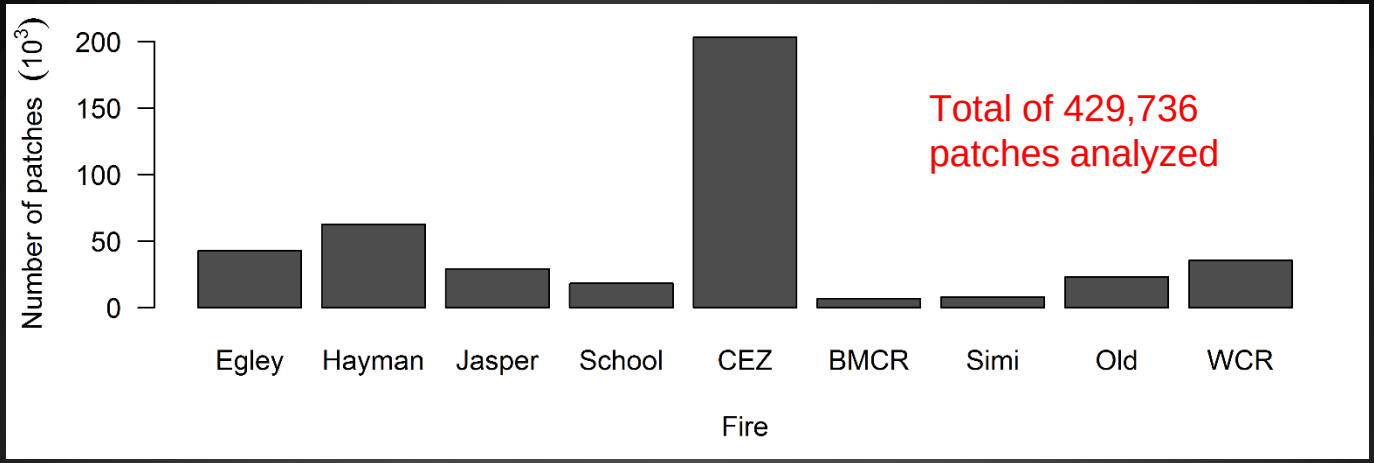
Hayman burn, Colorado

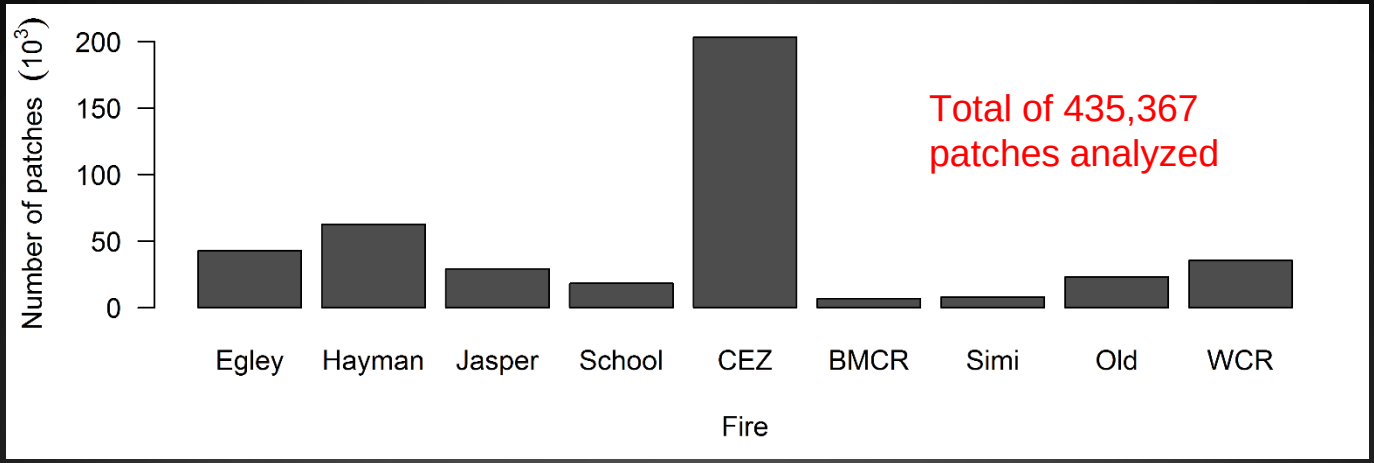
We defined percent recovery as NBR recovery magnitude (4) divided by NBR disturbance magnitude (1) * 100

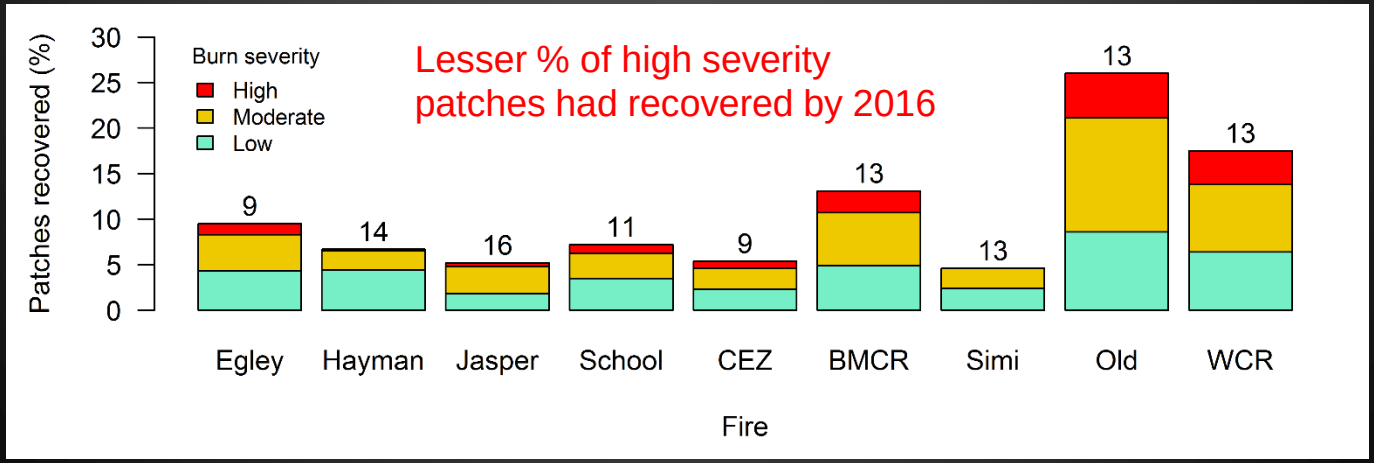


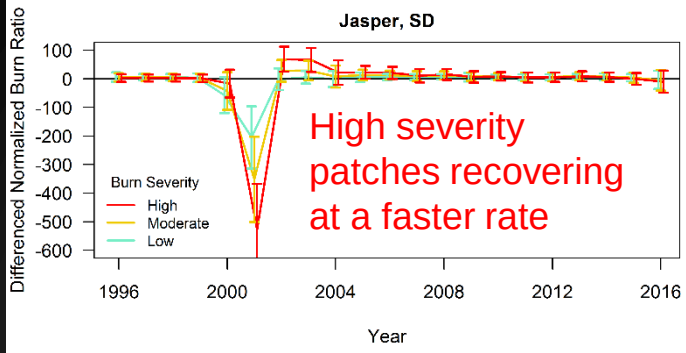
From Bright et al. (2014) IEEE J-STARS

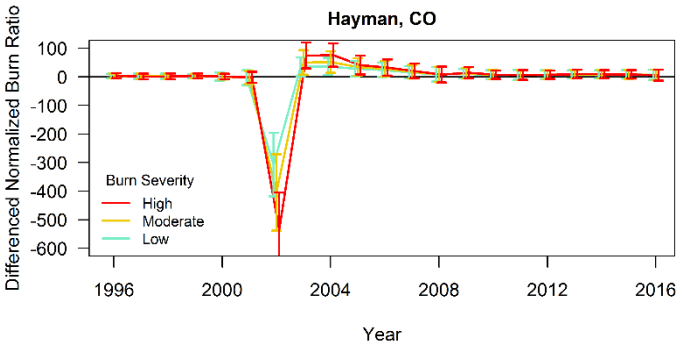
Egley burn, Oregon

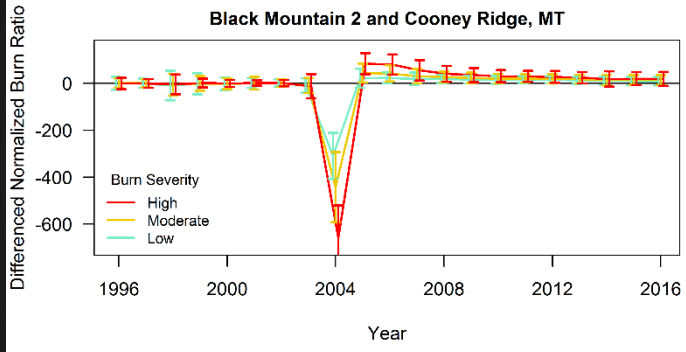

Number of patches (10^3)
200
150
100
50
0
Egley
Hayman
Jasper
School
CEZ
BMCR
Simi
Old
WCR
Fire
Total of 429,736
patches analyzed

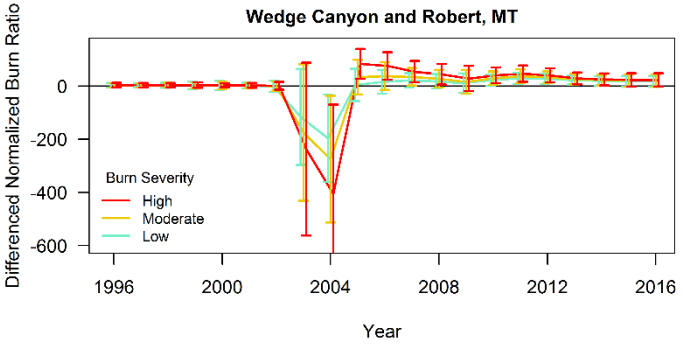

Number of patches (10^3)
200
150
100
50
0
Egley
Hayman
Jasper
School
CEZ
BMCR
Simi
Old
WCR
Fire
Total of 435,367
patches analyzed

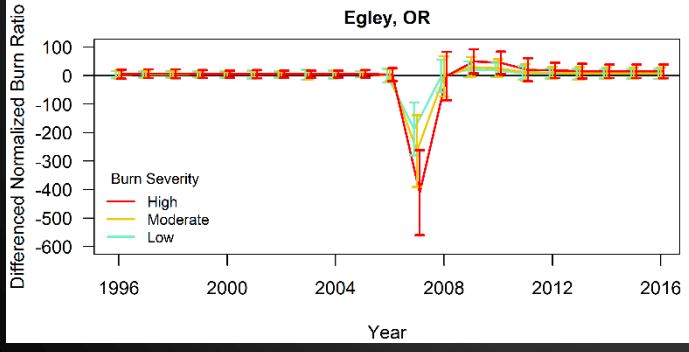

Patches recovered (%)
30
25
20
15
10
5
0
Burn severity
High
Moderate
Low
Lesser % of high severity
patches had recovered by 2016
9
14
16
11
9
13
13
13
13
Egley
Hayman
Jasper
School
CEZ
BMCR
Simi
Old
WCR
Fire

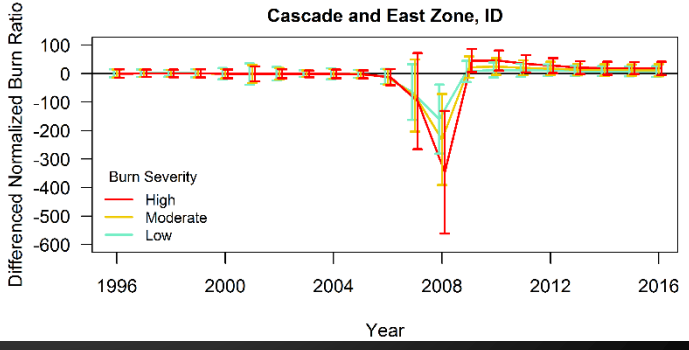

Jasper, SD
Differenced Normalized Burn Ratio
100
0
-100
-200
-300
-400
-500
-600
1996
2000
2004
2008
2012
2016
Year
Burn Severity
High
Moderate
Low
High severity patches recovering at a faster rate

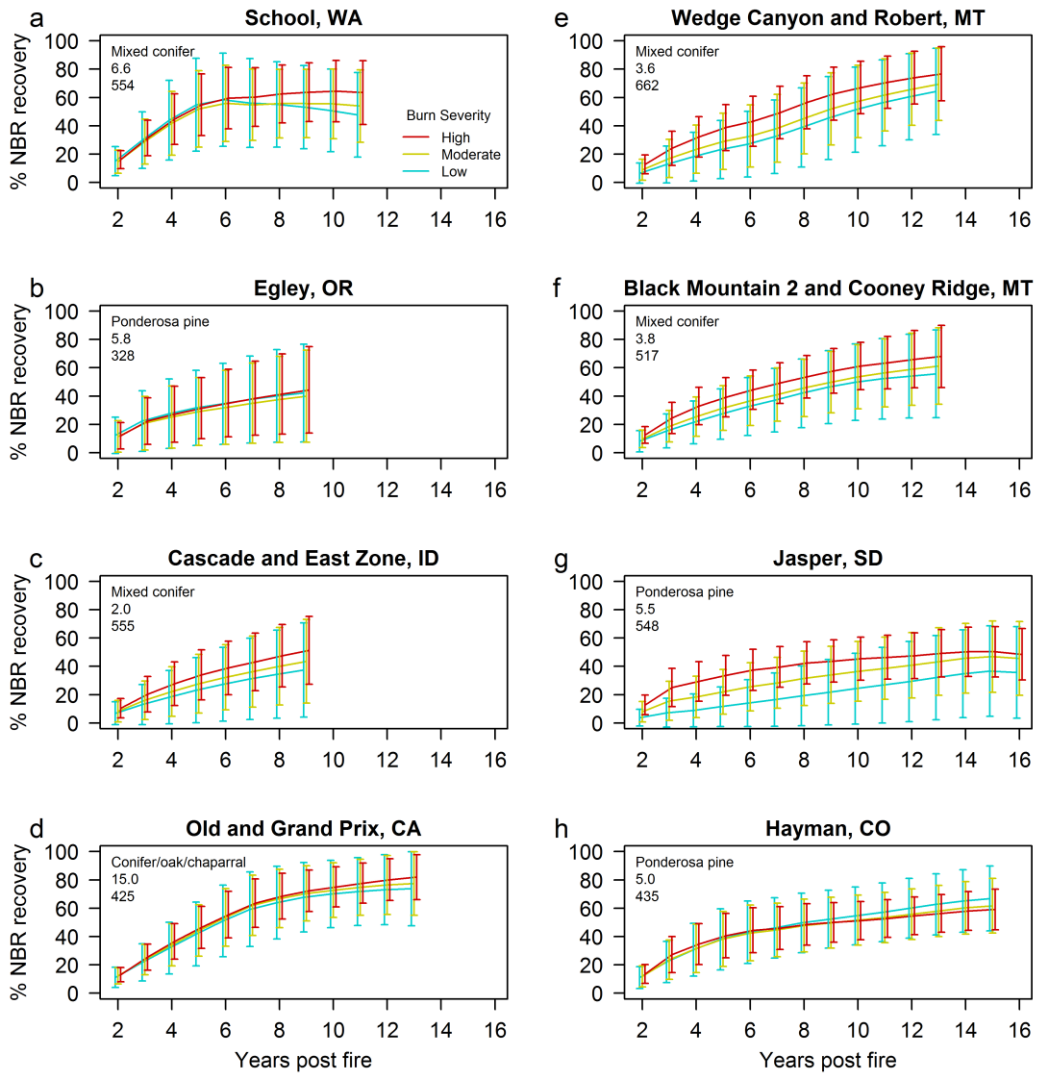

Hayman, CO
Differenced Normalized Burn Ratio
100
0
-100
-200
-300
-400
-500
-600
1996
2000
2004
2008
2012
2016
Year
Burn Severity
High
Moderate
Low


Black Mountain 2 and Cooney Ridge, MT
Differenced Normalized Burn Ratio
0
-200
-400
-600
1996
2000
2004
2008
2012
2016
Year
Burn Severity
High
Moderate
Low

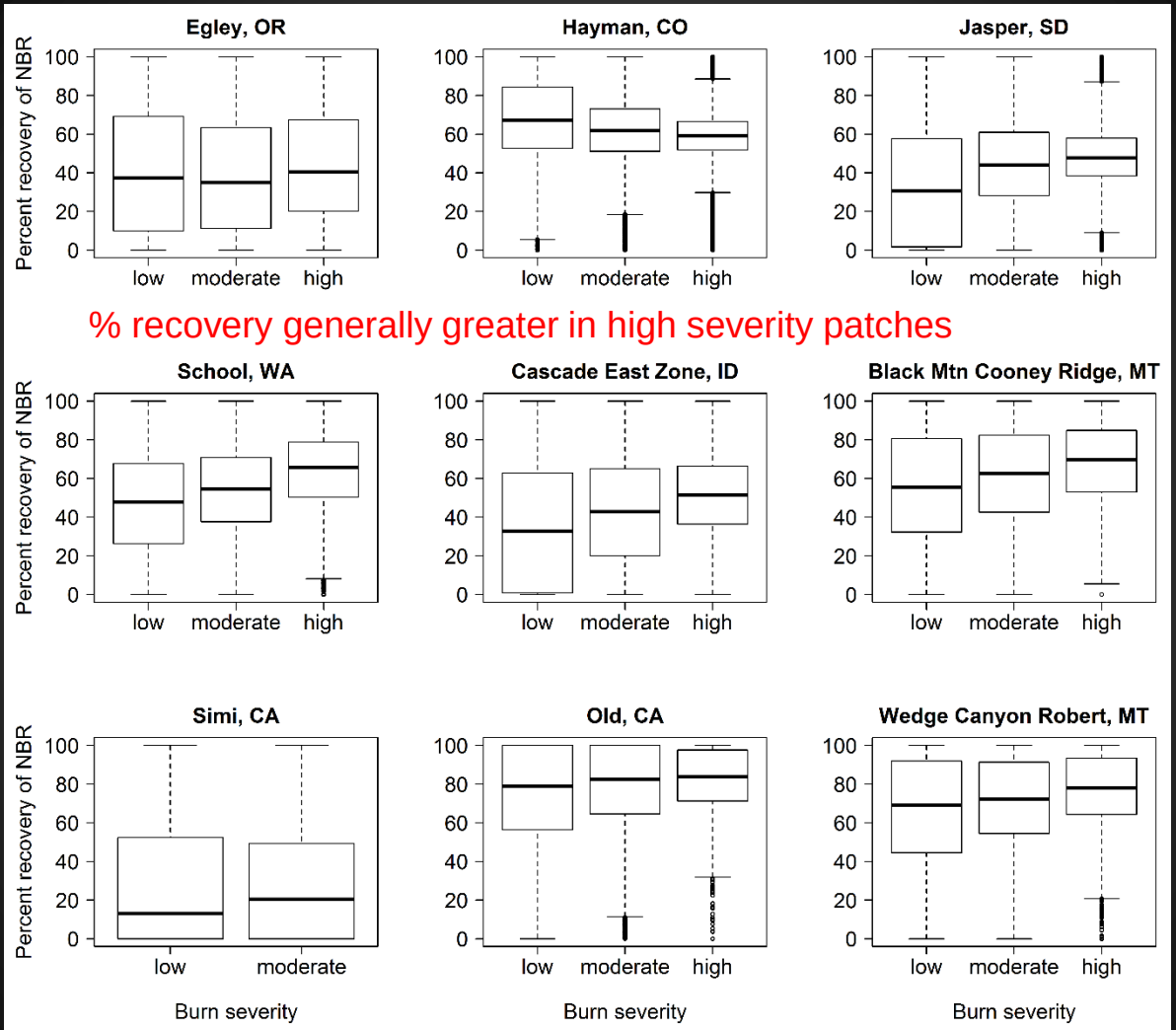

Wedge Canyon and Robert, MT
Differenced Normalized Burn Ratio
0
-200
-400
-600
1996
2000
2004
2008
2012
2016
Year
Burn Severity
High
Moderate
Low

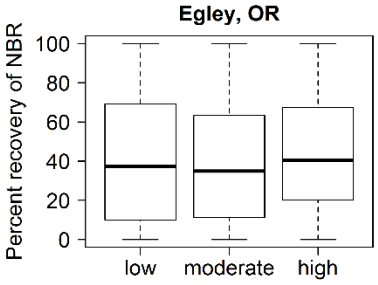

Egley, OR
Differenced Normalized Burn Ratio
100
0
-100
-200
-300
-400
-500
-600
1996
2000
2004
2008
2012
2016
Year
Burn Severity
High
Moderate
Low

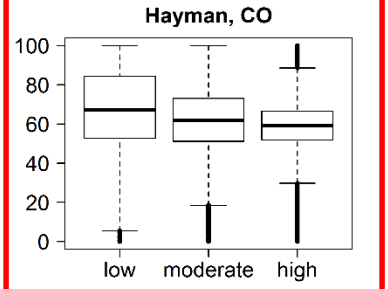

Cascade and East Zone, ID
Differenced Normalized Burn Ratio
100
0
-100
-200
-300
-400
-500
-600
1996
2000
2004
2008
2012
2016
Year
Burn Severity
High
Moderate
Low



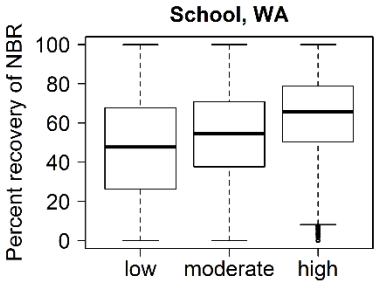
NBR recovery averaged 33-70% nine years post-fire, and averaged 42-77% 13 years post-fire

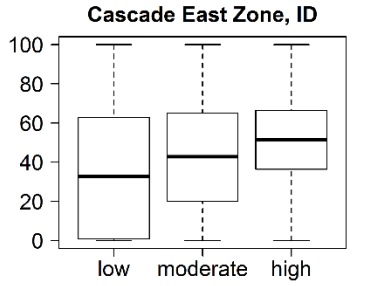

Egley, OR
Hayman, CO
Jasper, SD
Percent recovery of NBR
100
80
60
40
20
0
low
moderate
high
% recovery generally greater in high severity patches
School, WA
Cascade East Zone, ID
Black Mtn Cooney Ridge, MT
Simi, CA
Old, CA
Wedge Canyon Robert, MT
Burn severity

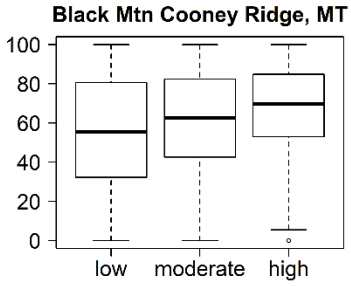


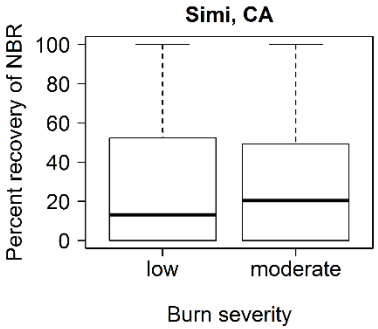


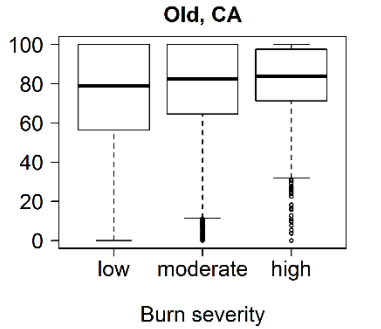
Except for Hayman

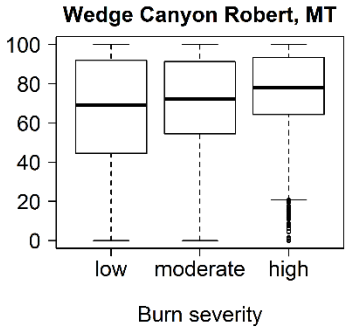


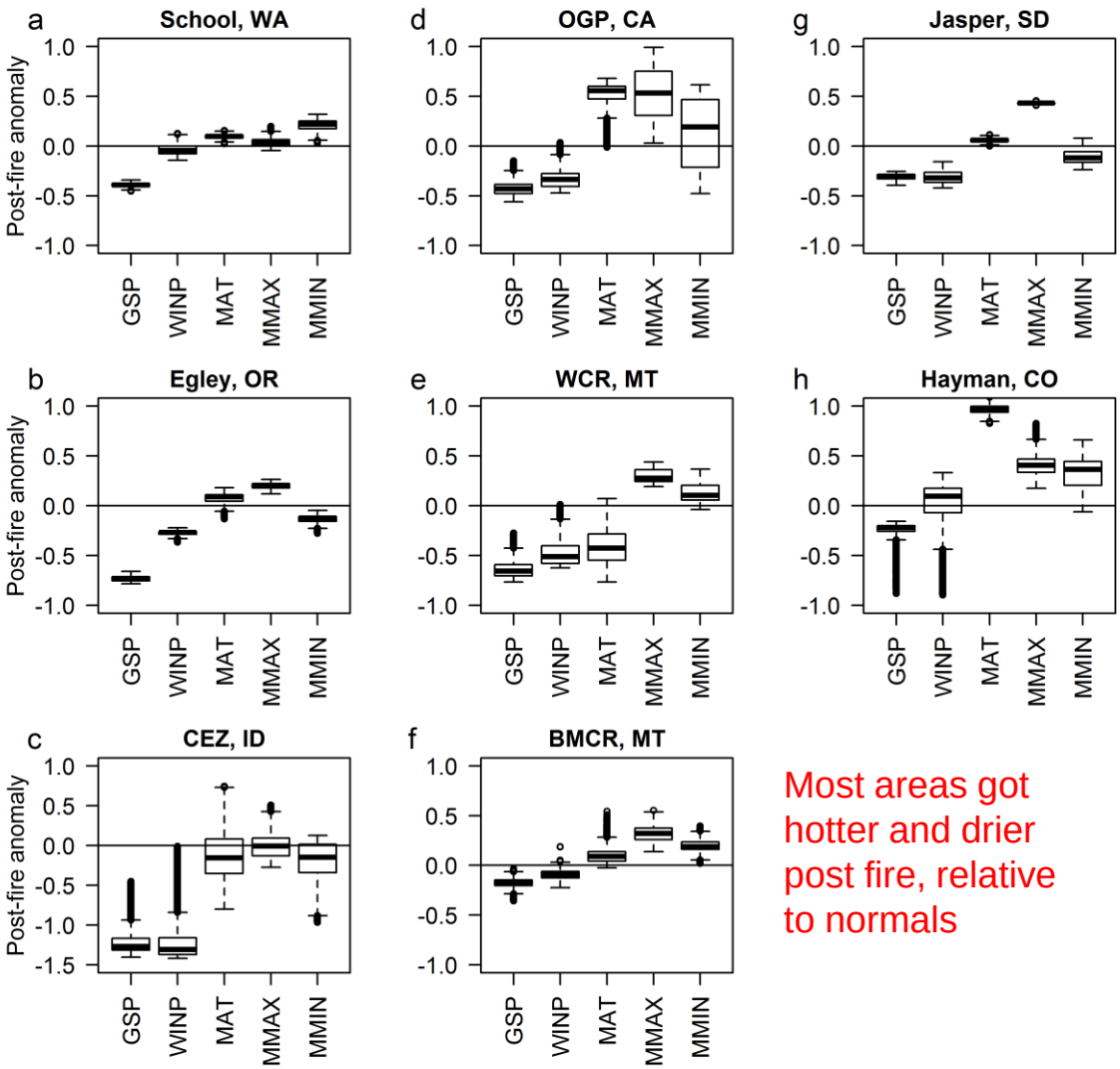












Most areas got hotter and drier post fire, relative to normals

Variables that explain variation in NBR recovery

Burn	Most important variables			Percent variance explained
Egley, Oregon	Pre-fire NBR	Winter min. temp.	Precipitation	49
Hayman, Colorado	Pre-fire NBR	Winter min. temp.	Summer max. temp.	43
Jasper, South Dakota	Pre-fire NBR	Winter min. temp.	Precipitation	45
School, Washington	Pre-fire NBR	Winter min. temp.		62
Cascade, East Zone, Idaho	Precipitation	Mean annual temp.	Summer max. temp.	33
Black Mtn, Cooney Ridge, MT	Pre-fire NBR	Summer precip.	Summer max. temp.	53
Wedge Canyon, Robert, MT	Pre-fire NBR	Winter min. temp.	Precipitation	65
Old, Grand Prix, CA	Pre-fire NBR	Winter min. temp.	Summer max. temp.	38

Pre-fire vegetation condition usually important

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Pre-fire vegetation condition usually important

Winter minimum temperatues important

Summer maximum temperatures important

Precipitation important

Conclusions

- Landsat time series analysis, specifically LandTrendr, can be used to detect and map vegetation recovery trends following wildfire
- More low and moderate severity patches have recovered to pre-fire NBR
- However, high severity patches are generally recovering at a faster rate
- Fire severity important to long-term NBR recovery
- Climate variables explain variation in NBR recovery