Impacts on Soils From Mechanized Steep Slope Operations

…learnings from widespread implementation of winch-assist CTL equipment

MILLER CUT-TO-LENGTH

Preston Green[1], Chuck Rhoades[2], Maddie Roberts[2], Hunter Harrill[3], Karolyn Fagundes[3], Dzhamal Amishev[4]

1 = Miller Timber Services, presenter; 2 = USFS Rocky Mountain Research Station; 3 = Cal Poly Humboldt; 4 = Lakehead University

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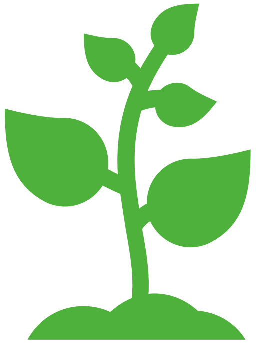
California Coast

California Objectives

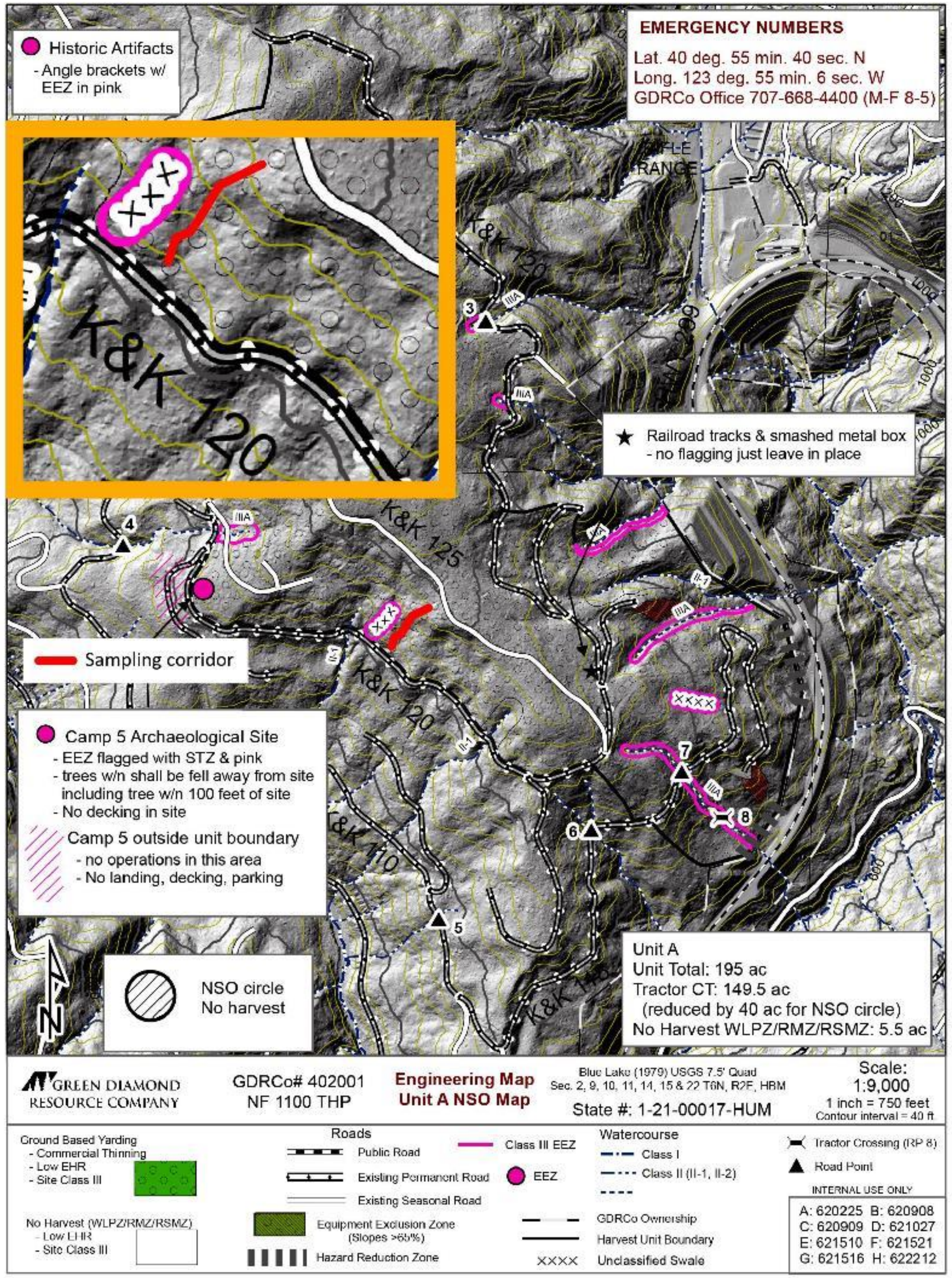


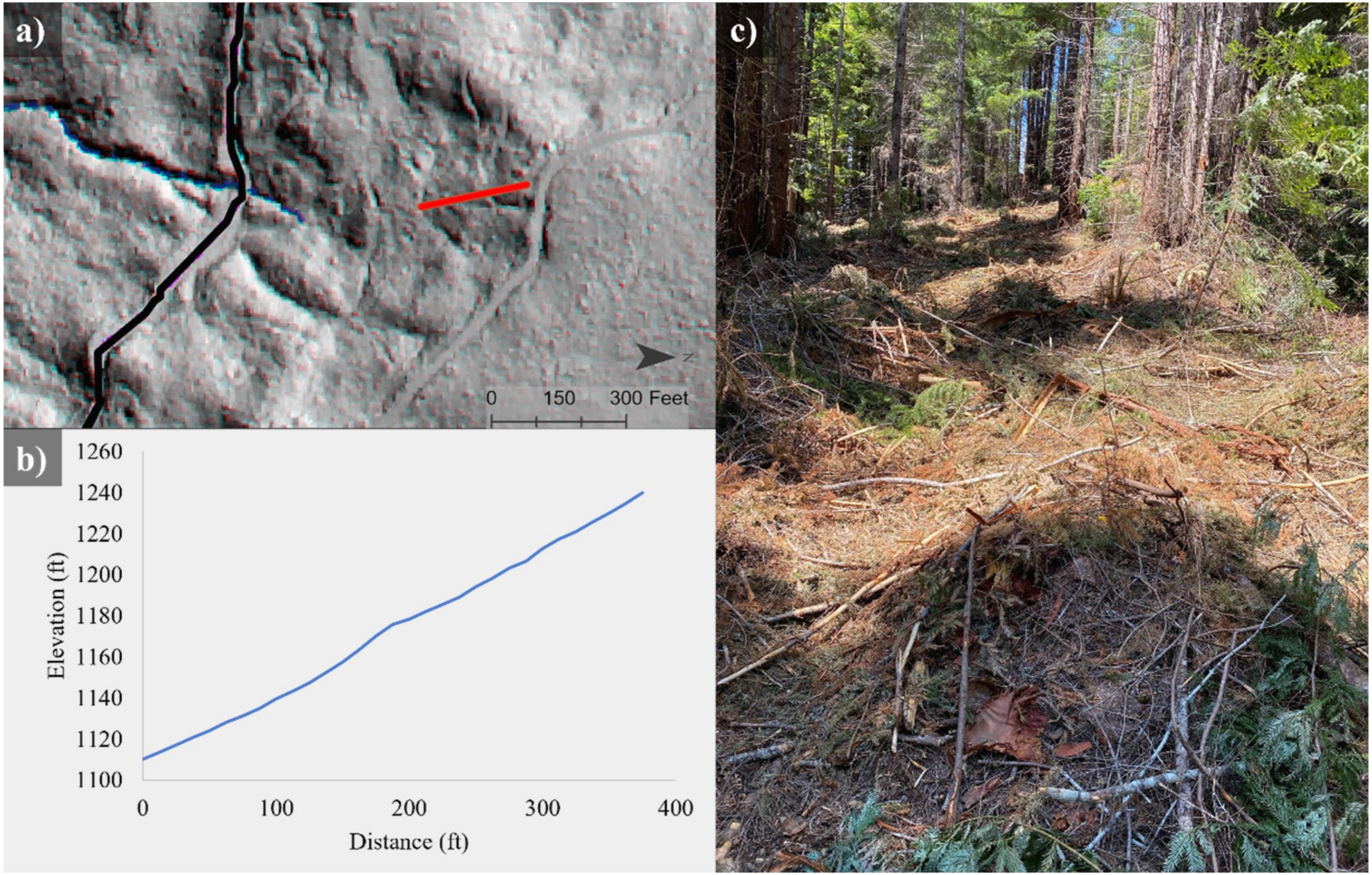
What is the extent of visual soil disturbance caused by tethered harvesting?

What is the severity of the soil disturbance caused by tethered harvesting?

California Coastal Operations

- Industrial ground
- High slash content
- Harv./Forw. CTL harvest system
- History of tethered CTL
- Avg. 40% slope
- 79% redwood, 16% Douglas fir, 5% other conifer





a)
N
0 150 300 Feet
b)
Elevation (ft)
Distance (ft)
1100
1120
1140
1160
1180
1200
1220
1240
1260
0
100
200
300
400
c)

DATA COLLECTION: EXTENT OF SOIL DISTURBANCE

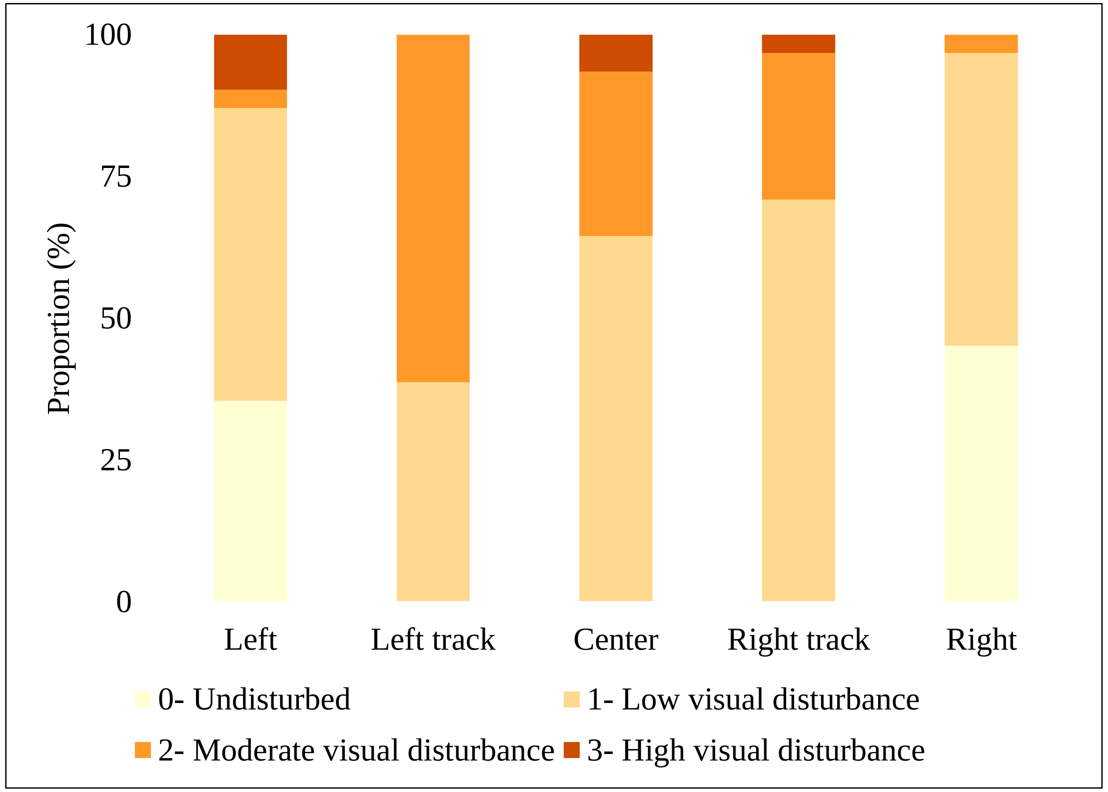
Class 0

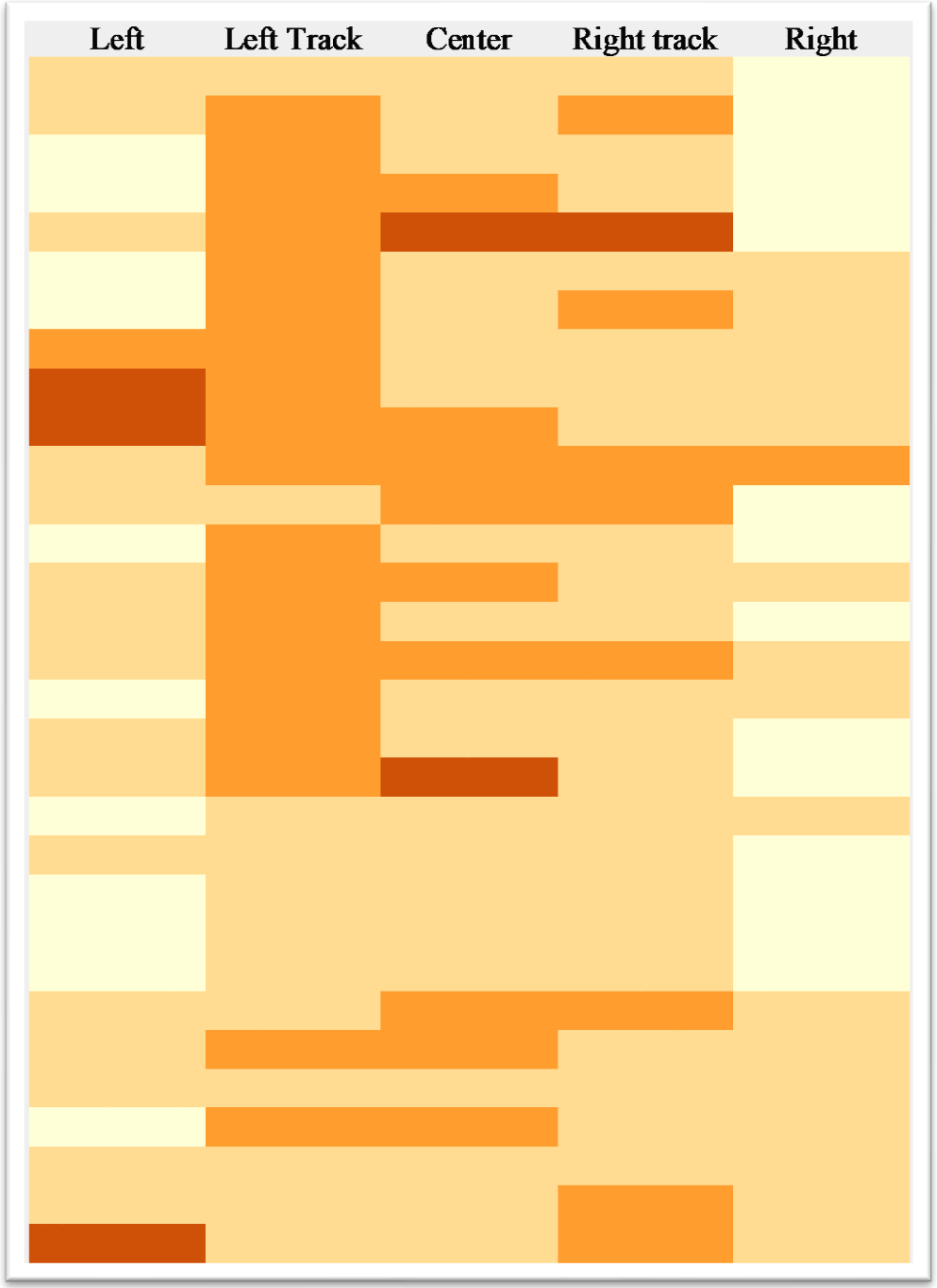
Class 1

Class 2

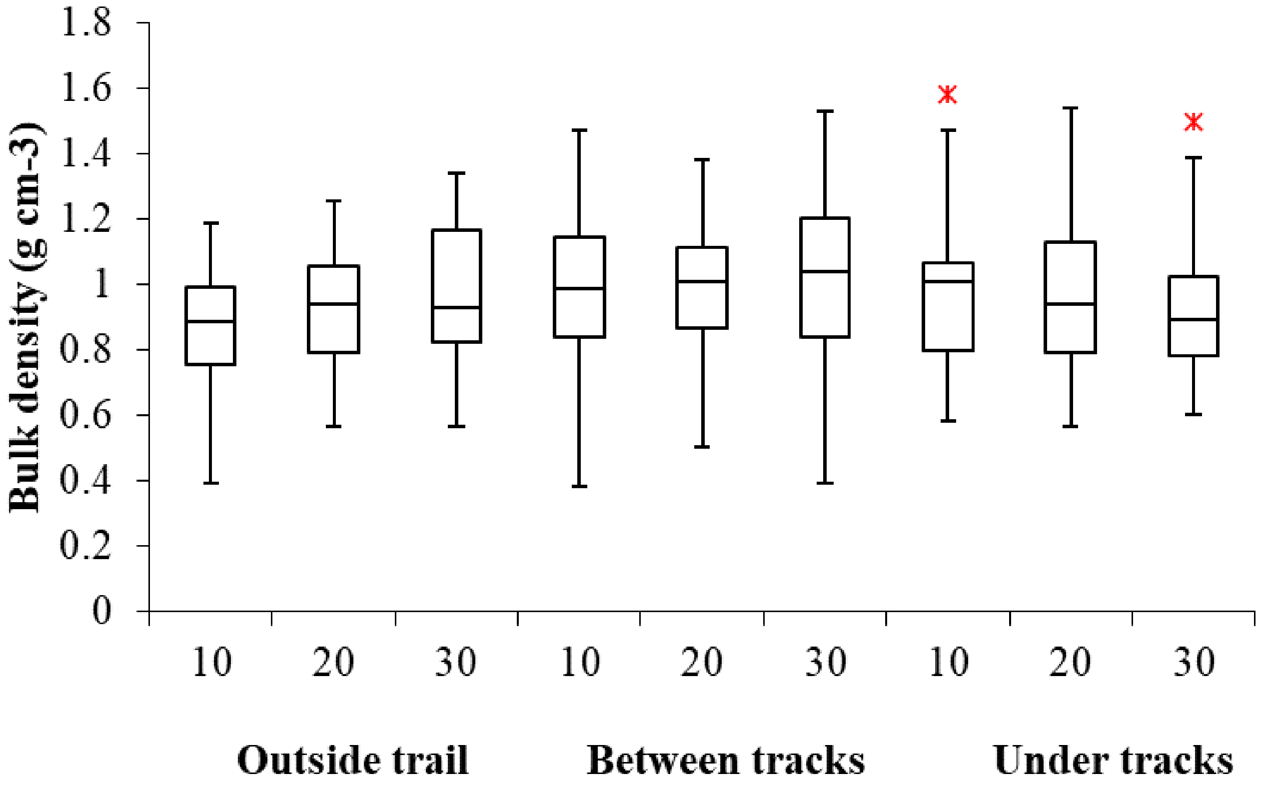
Class 3

California Results: Extent of Visual Disturbance





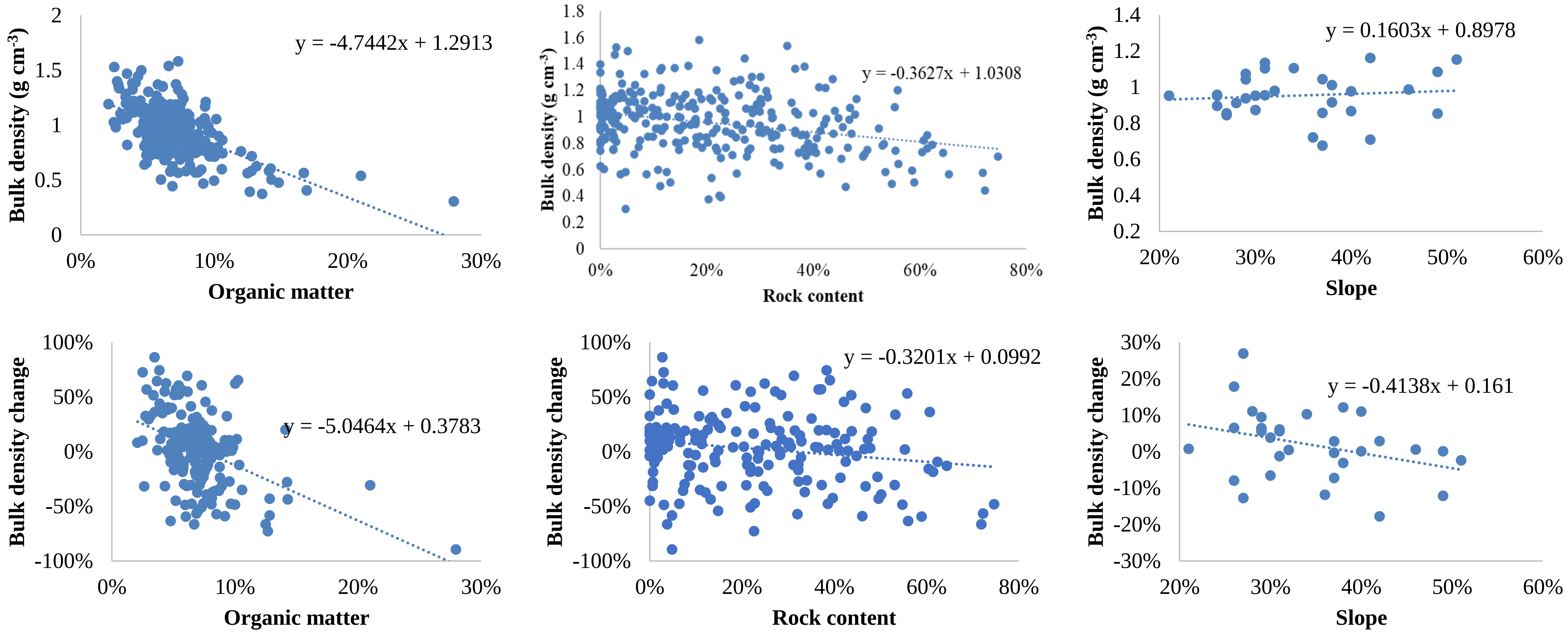
California Results: Bulk Density



California Results: Severity of Disturbance

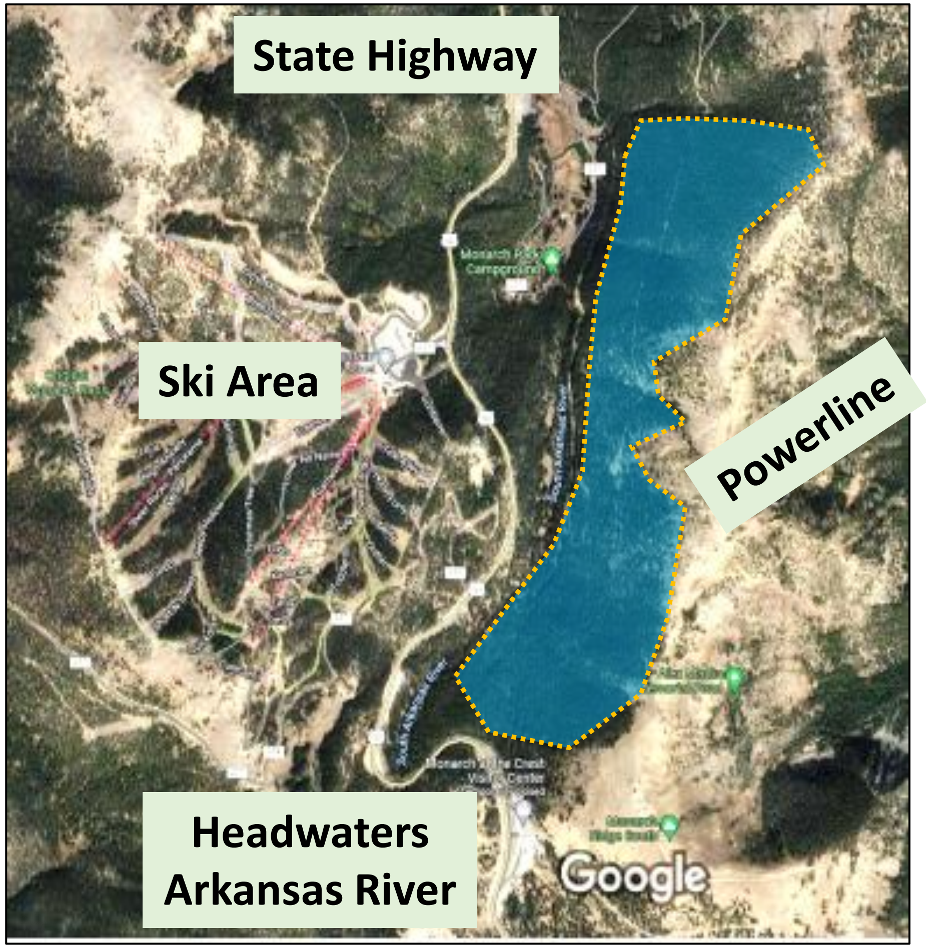
Variable	Sample position	Depth (cm)	Mean	Standard deviation	Minimum	Maximum
Bulk density change	Between tracks	10	-4%	36%	-90%	86%
		20	1%	34%	-67%	74%
		30	5%	36%	-73%	72%
	Under tracks	10	13%	29%	-48%	65%
		20	4%	33%	-66%	69%
		30	-2%	29%	-54%	55%

California Results:
Factors Influencing Bulk Density and Change in Bulk Density



Colorado (Continental Divide)

Headwaters Salvage Project - Motivations



Forest Health: Severe beetle infestation (spruce, fir, pine)

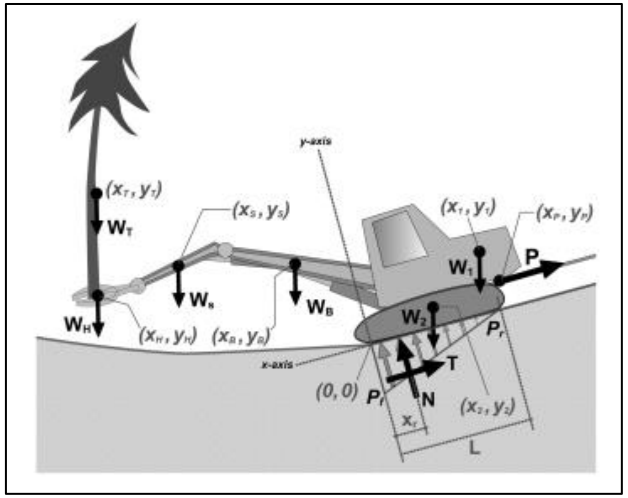
Values at Risk:

- Transport: Major E-W hwy over Continental Divide
- Recreation: Monarch Pass Ski area
- Water: Headwaters of Arkansas River, supply for Salida, Pueblo, Canyon City
- Energy: Powerline corridor

Local Interest: Water providers financial support, watershed collaborative helping admin the project

"Making a Difference at Monarch Pass: Project thins beetle-kill trees on steep slopes to mitigate wildfire risk, protect water resources." J. Stone, Heart of the Rockies Radio, 9/21

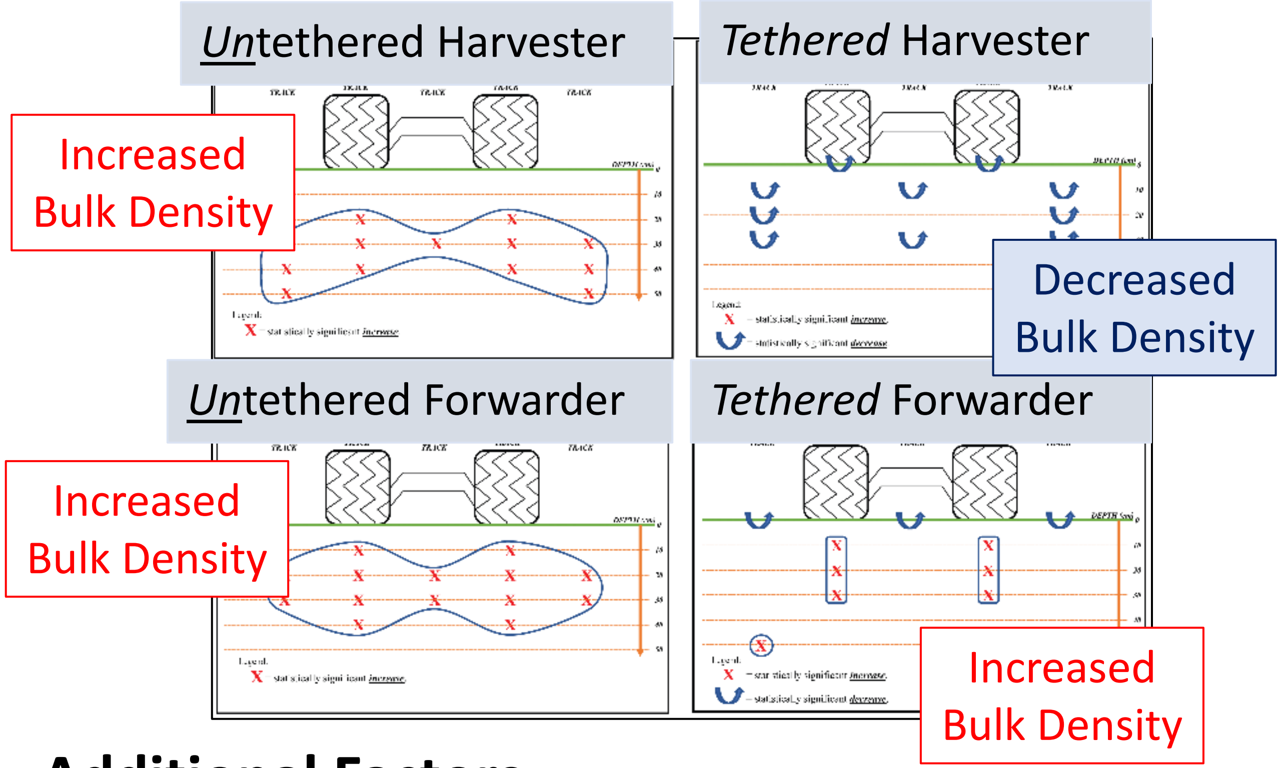
"Monarch Pass could serve as a new model for wildfire mitigation in treacherous areas." J. Blevins, Colorado Sun, 10/21



TETHERED LOGGING - *Observed Benefits*

Challenges of Steep Slope Operations

Machine stability, traction, safety ; Increased soil disturbance



Traction, Stability, Gradeability Enhancing Factors:
Deeper grousers, higher cable tensions, wider tracks, ground pressure (Sessions et al. 2017; Belart et al. 2018).

Soil Impacts:
Tracked bogies reduce slippage, compaction, rutting
Less blading of temp roads: top, bottom of units only
CTL units require fewer landings.

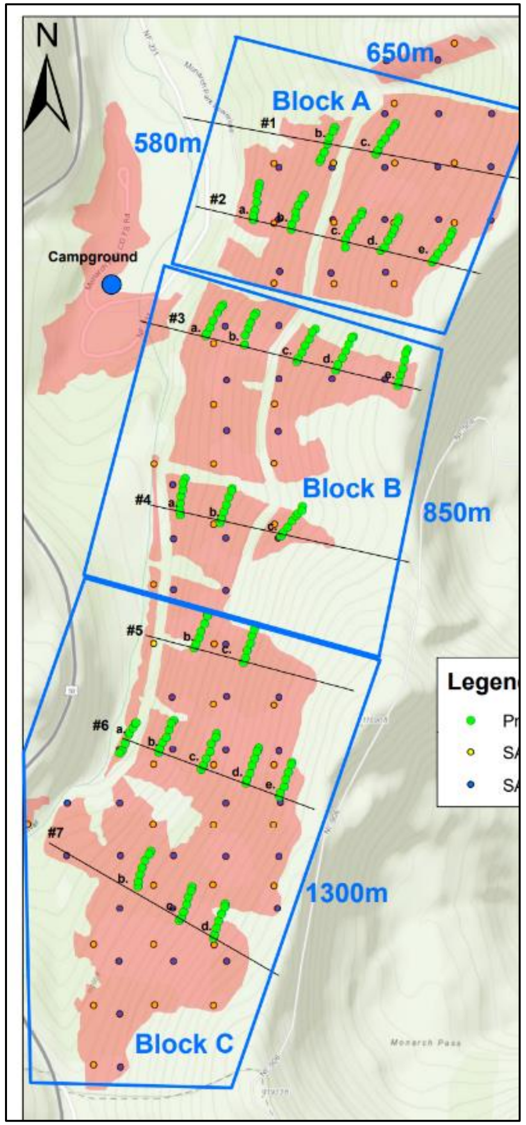
Case Study - OSU Research Forest (Green et al. 2019)
Fine-textured, gravelly, cobbly soil (27-50% clay)
Reduced shear resistance, peak ground pressure
Tethered vs Untethered: compacts soil to lesser extent
Less increase in penetration resistance, varies with initial density
Preharvest soil density, moisture more important than number of passes, slope %

Additional Factors:

Decreased wander, lower track footprint & extent of soil disturbance

Harvest Area Layout

- 2020 and 2021, 132 ha. of tether logging (cut 0.8-1.0 ha/day)
- Equipment anchored at ridge, mid-slope road
- Tether roads 15-18 m apart; ~305 long
- Machines intended to operate over slash mats
- Decking and hauling along mid- and lower-slope roads



Post-Harvest Data Collection

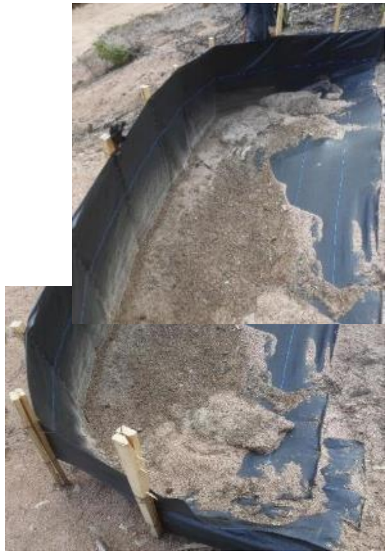
Erosion

- Sediment fences
- Rill surveys

Stream water quality

Fuel redistribution & fire behavior

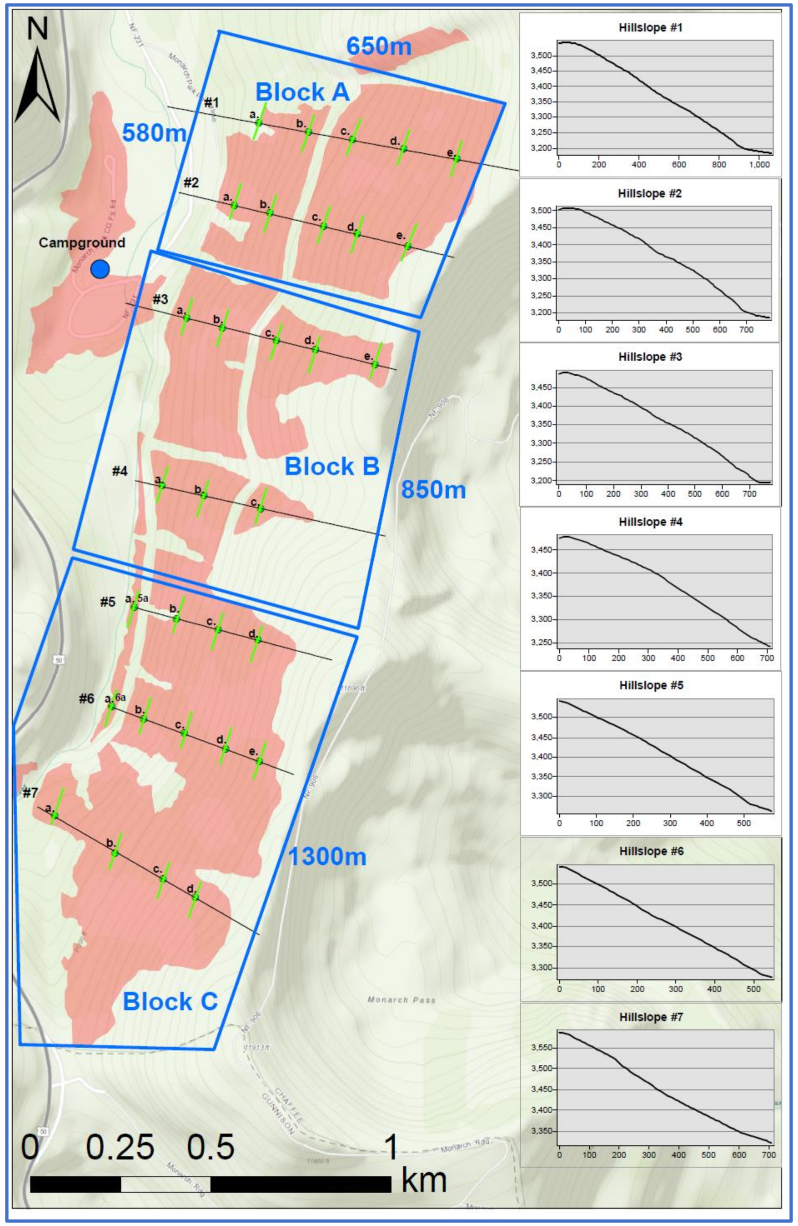
Regeneration & understory response



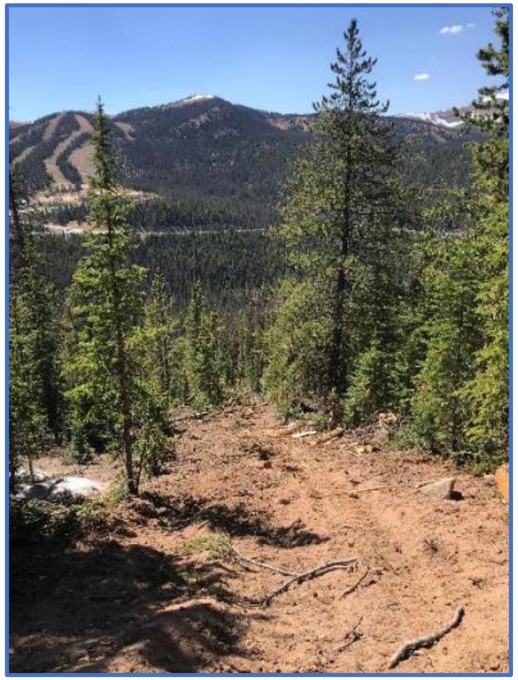
Slopes

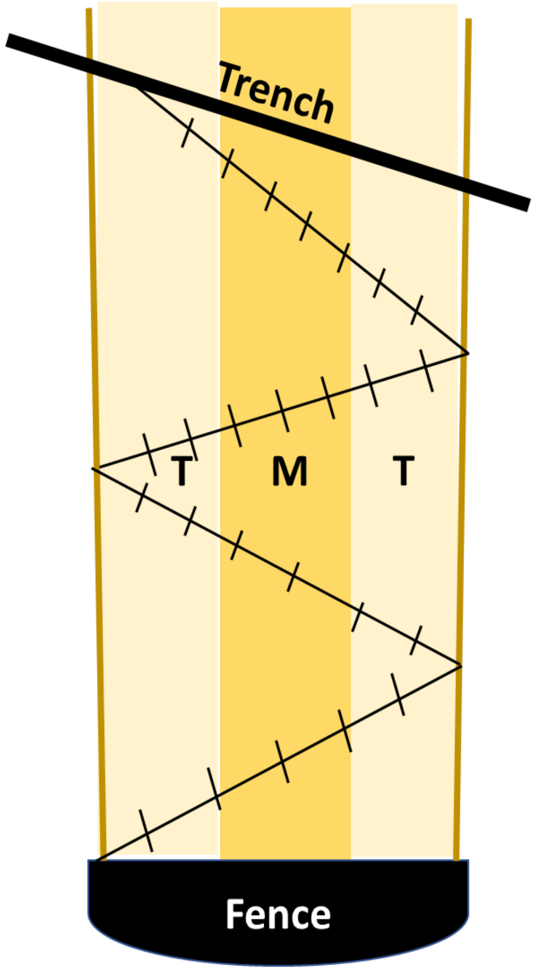
Average: 49 -60%

Max: 80-100%



HILLSLOPE EROSION SAMPLING





Fence Installation - June 2021, 2022

Base of ~ 30 x 3 m hillslope sections

(~0.01 ha contributing areas)

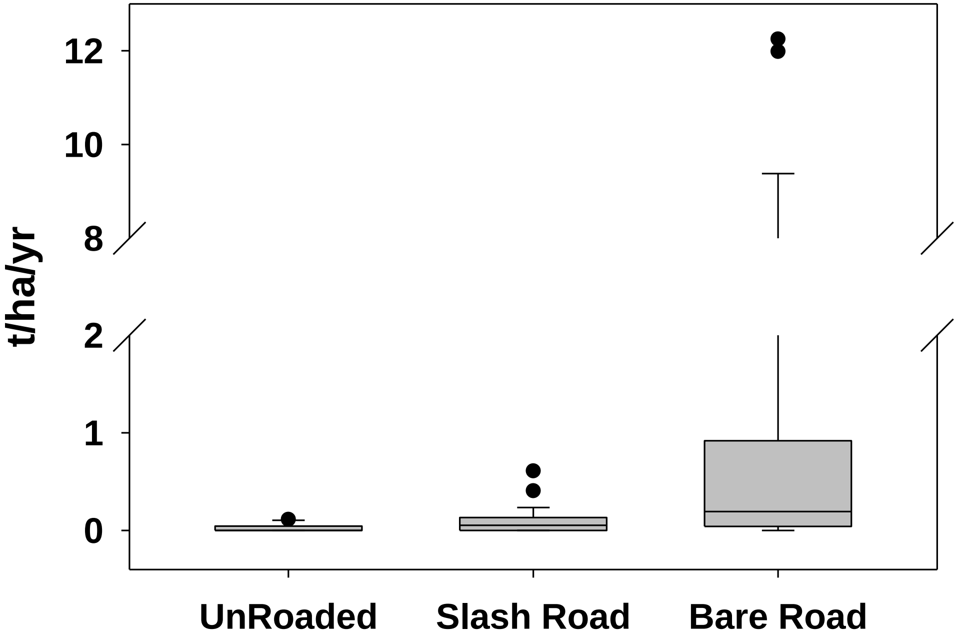
Trenched to eliminate additional inputs

16 Bare tether roads

16 Slash-covered roads

10 Un-roaded, cuts

HILLSLOPE EROSION



	Control	Slash	Bare
	----------	t/ha/yr	----------
Mean	0.0	0.1	1.9
Median	0.0	0.1	0.2
Max	0.1	0.6	12.2

Annual erosion rates on tether roads with slash mats was low and erosion was infrequent.

Erosion highest on bare roads ($p = 0.003$); similar pattern in Yrs 1&2

Bare Tether Roads

	Yr1	Yr2
	----- t/ha/yr	-----
Mean	1.6	2.1
Median	0.6	0.1
Max	8.3	12.2

SEDIMENT PRODUCING EVENTS

		8/9/21	6/16/22	6/30/22	7/7/22	7/13/22	8/15/22	**Date**
		1	**2**	**3**	**4**	**5**	**6**	**Event**
Bare Road	**Fences w/ > 0 t/ha**	100%	10%	25%	31%	44%	13%	
	" w/ >0.1 t/ha	100%	10%	6%	19%	13%	6%	
Slash Road	**Fences w/ > 0 t/ha**	100%	0%	6%	31%	13%	0%	
	" w/ >0.1 t/ha	50%	0%	0%	13%	0%	0%	
Unroaded Cut	**Fences w/ > 0 t/ha**	100%	0%	0%	6%	6%	0%	
	" w/ >0.1 t/ha	0%	0%	0%	0%	0%	0%	
	Max Storm Intensity - I_{15} (in/hr)	1.5	NA	0.7	0.6	0.6	1.8	
	Largest Storm Total (in)	1.4	NA	0.7	0.3	0.3	0.8	

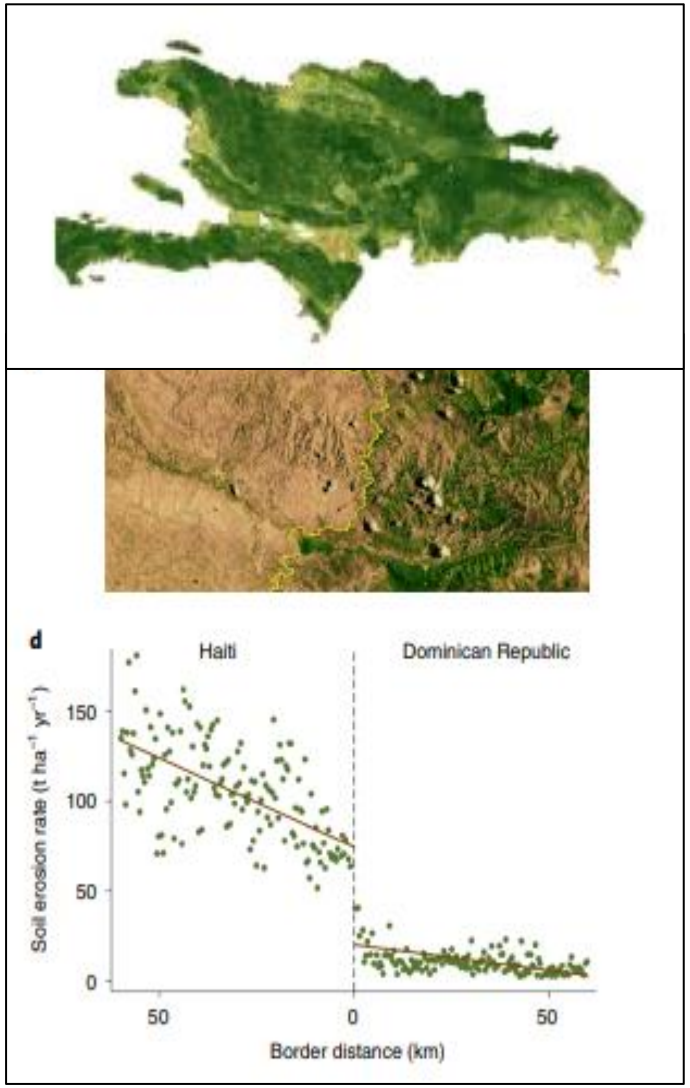
6 significant erosion producing events: (0.1 t/ha; 0.04 US t/Ac threshold)

Hillslope erosion occurred during storms with rainfall intensities of ***i15*** > 0.5 in/hr. (3.81 cm/hr.).

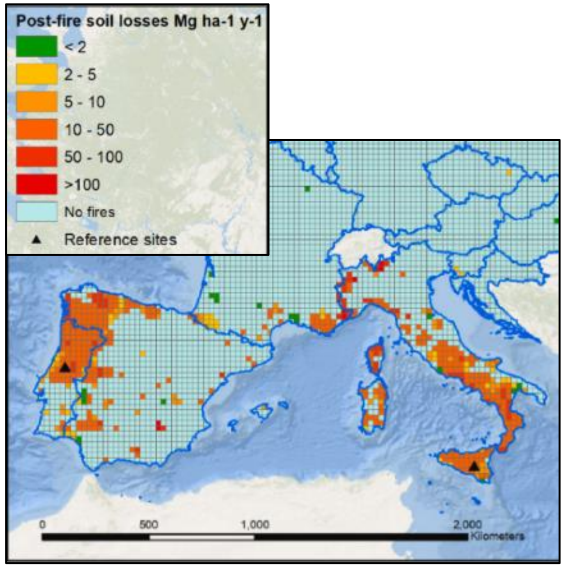
The largest storm (***i15*** > 1.5 in/hr. [3.81 cm/hr.]) triggered sediment most broadly.

Lower intensity storms (***i15*** 0.1-0.2 in/hr.) generated no sediment.

How Big are Our Erosion Numbers?



	t/ha/yr	
Bare Land	50 - 150	Global Estimate
Crop Land	10 – 150	“
Forest Land	0.1 - 10	“
Post-Fire	5 - >100	
Unpaved Roads	50 - >100	
Bladed skid trails	39-138	US
	t/ha/yr	**t/ha/yr**
Tether Roads	**Brazil***	**Monarch**
Bare	30 (max 89)	2 (max 12)
Slash	4.3 (max 10)	0.1 (max 0.6)
Unroaded	0.4	0.0 (max 0.1)
	Garren et al. ’19 *modelled rates	This study

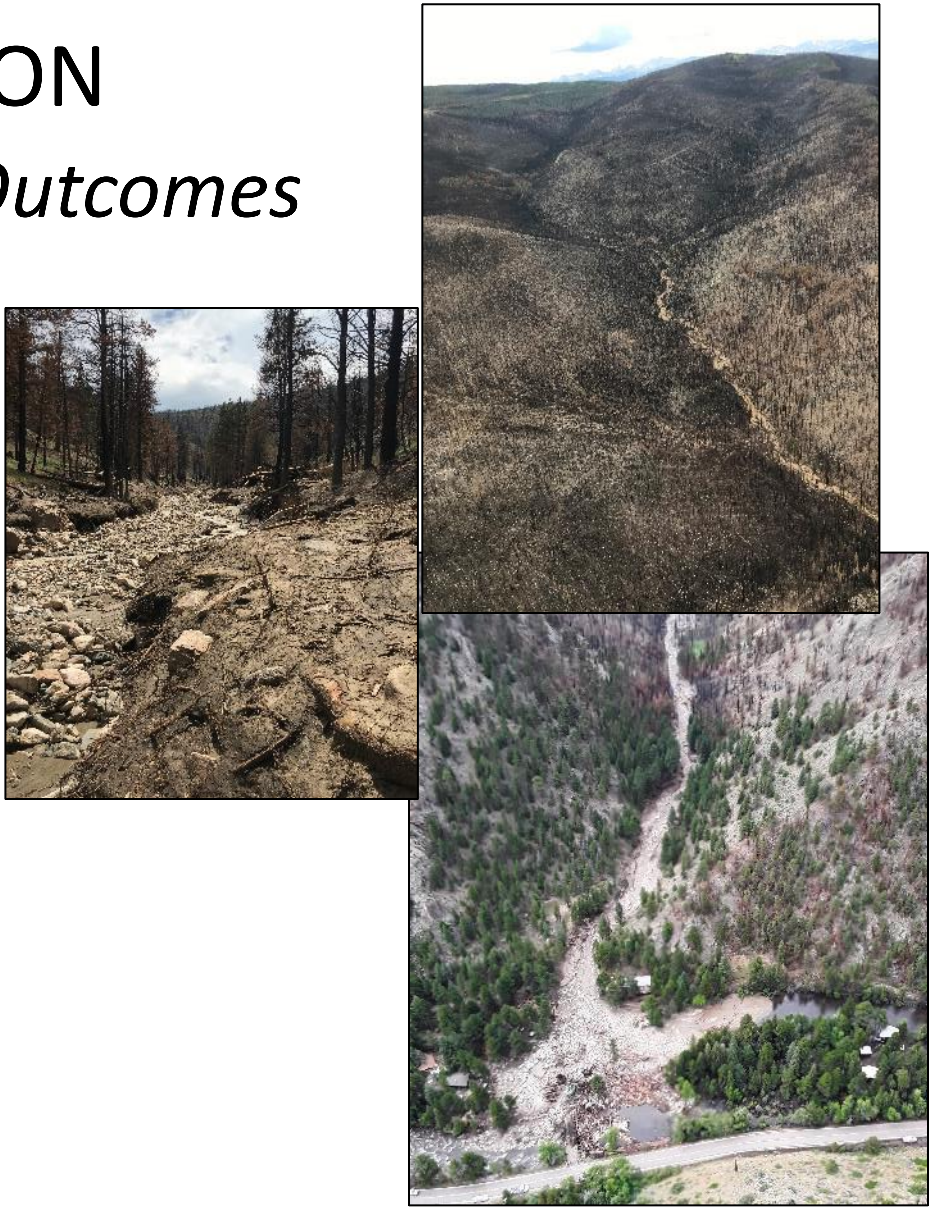


Garren et al. 2019 Forests
Ramo-Sharron & MacDonald 2007 Catena
Vieira et al. 2023 Sci Tot Env
Wade et al. 2012 S. J. Appl For
Wenger et al. 2018 Env Res Lett
Worrell et al. 2011 S. J. Appl For
Wuepper et al. 2020 Nature Sustainability
Xiong et al. 2019 Geoderma

Land Cover Impacts on Erosion

Similar Rainfall - Very Different Outcomes

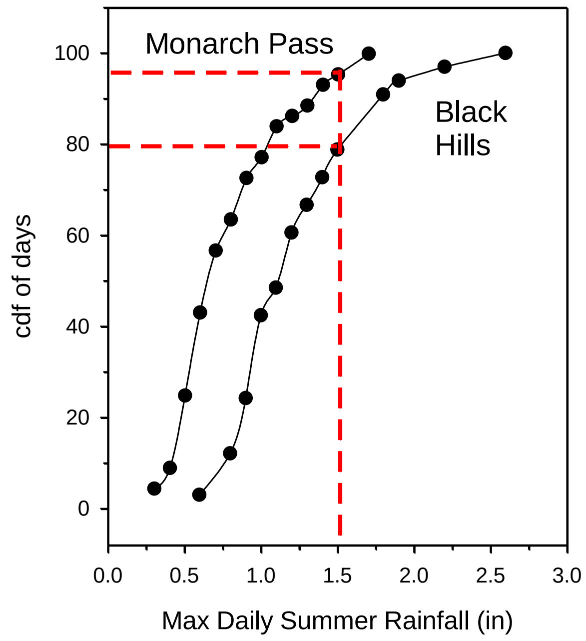
Monarch Pass – Tethered Logging Project
Pike San Isabel NF; 0.52”/15 min (2.1”/hr)

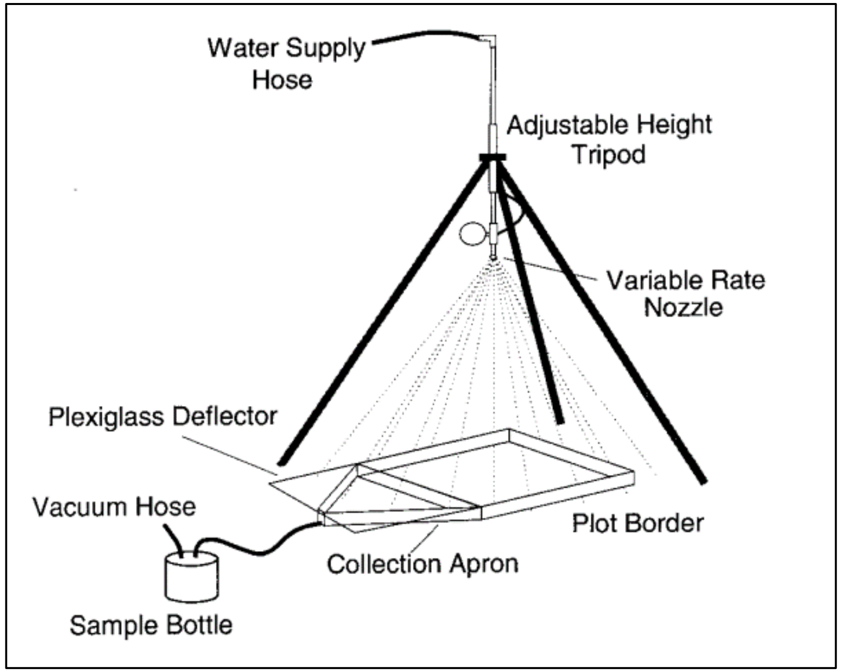


Black Hollow Debris Flow - **Cameron Pk Fire**
0.6“ in 14 minutes

NEXT STEPS
Expand Range of Inference

- Rainfall simulation: Determine what storm intensities triggers surface erosion for various soil/slash covers.
- n > 1 …. measure erosion for multiple soil, slope, precipitation, forest cover, harvest equipment/layout combinations.
- Model erosion across the range of conditions.
- Identify optimal conditions and limitations of the approach.





Key Take Aways

Sediment Production & Rill Formation

- Slash-covered trails have near zero erosion
- Bare trails more susceptible, though rates were reasonable
- Mixture of bare and mulch limits off-site transport
- Sediment production rainfall intensity (0.5”/hr) exceeded 4-5 times/yr

Pre-harvest Soil & Stand Conditions matter

- Soil type, forest cover determine susceptibility to post-harvest erosion
- Most erosion from isolated highly erosive sites, prior disturbance
- Sparse stand structure, dead trees limit slash to cover roads
- Pre-harvest site survey is critical

Thank you!

Preston Green
Miller Timber Services
(541) 929-2840
www.millertimber.com

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