

Hydrologic and Erosional Impacts of Altered Fire Regimes and Plant Invasions

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Problem: Change in Hydrologic Function and Stability



Stable rangelands effectively capture and store soil and water resources, safely release water, resist alteration of these functions, and recover these capacities post-disturbance (Pellant et al., 2005).



Hydrologic function is maintained by site specific structural and spatial soil and vegetation arrangements that elicit hydrologic processes favoring soil and water retention.

Fire and related plant invasions are altering the vegetative structure and function of desert rangelands across the western United States.



Vegetation/Hydrology Interactions



Vegetation

Canopy cover

Ground cover

Litter accumulation

Soil organic matter

Bulk density

Faunal activity

Soil/Site Characteristics

Slope/topography

Soil texture

Surface rock

Hydrology/Erosion

Rainfall interception

Surface water storage

Higher infiltration

Lower soil erodibility

Vegetation: Protection Against Water/Wind Erosion



Hillslope -
Catchment
Scales

Site protection

Canopy cover

Ground cover

Bare soil

Hydrologic connectivity

Hydrology

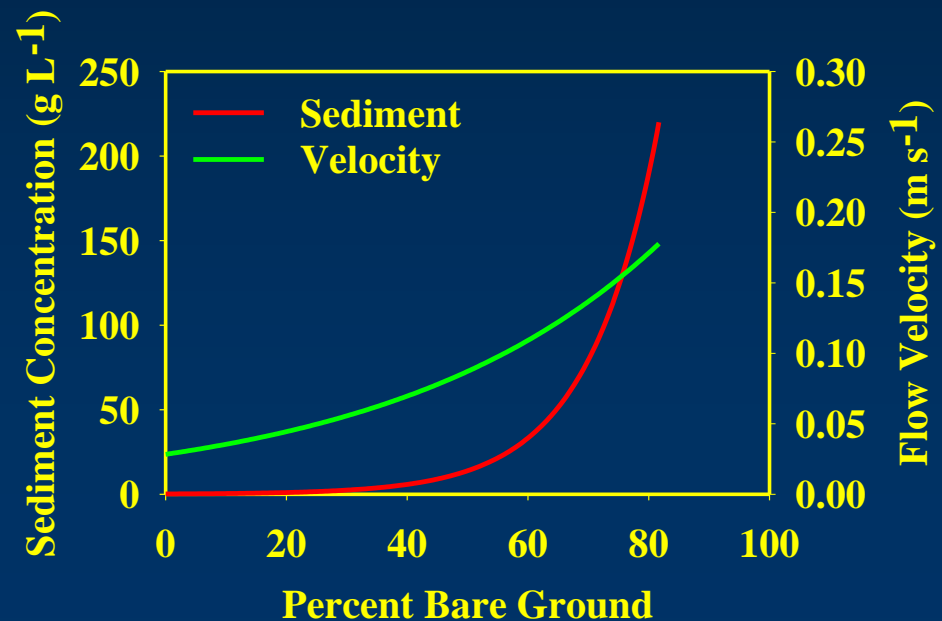
Sediment detachment

Sediment transport

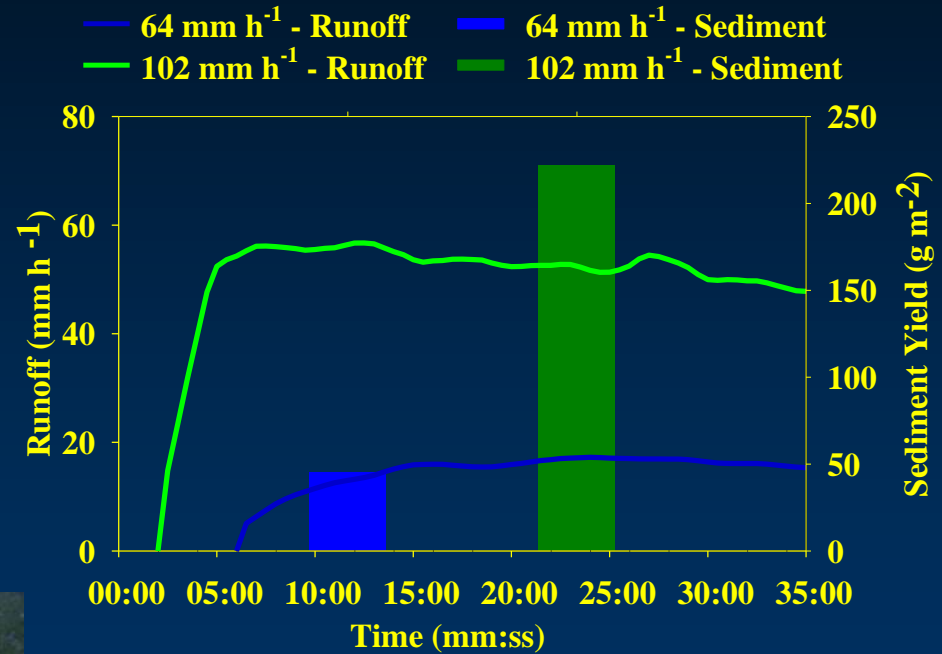
Concentrated flow

Flow velocity

Flow depth



Climate: Driver for Disturbance



Precipitation and Climate

Snowfall vs. Rainfall

Frontal vs. Convective storms

Climate change?

Hydrologic Response to Disturbance



Soil/site
properties

+

Vegetation
protection

X

Climate
drivers

=

Hydrologic
response

Plot Scale: Hydrologic Impacts of Fire



Shrub Coppice

Unburned:
Runoff = 21 mm
Sediment = 7 g m⁻²
(strongly water repellent)

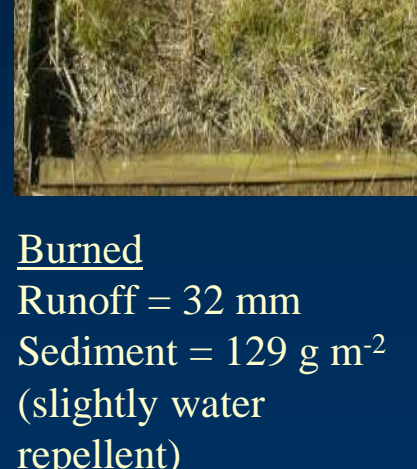


Interspace

Unburned:
Runoff = 41 mm
Sediment = 10 g m⁻²
(slightly water repellent)



Burned
Runoff = 25 mm
Sediment = 77 g m⁻²
(strongly water repellent)

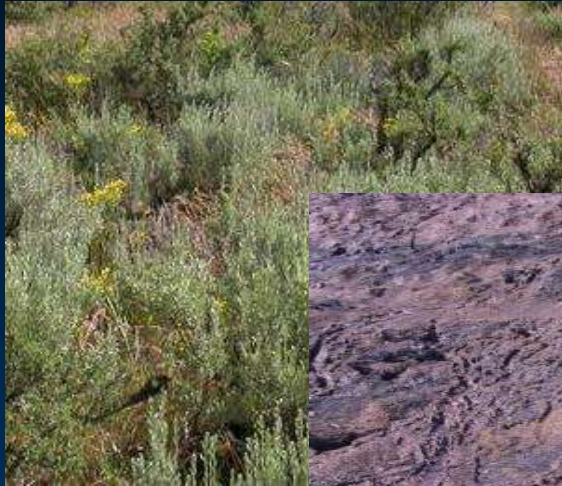


Burned
Runoff = 32 mm
Sediment = 129 g m⁻²
(slightly water repellent)



Reduced surface protection: Decreased rainfall interception and surface water storage resulting in elevated rainsplash and sheetwash.

Hillslope Scale: Hydrologic Impacts of Fire

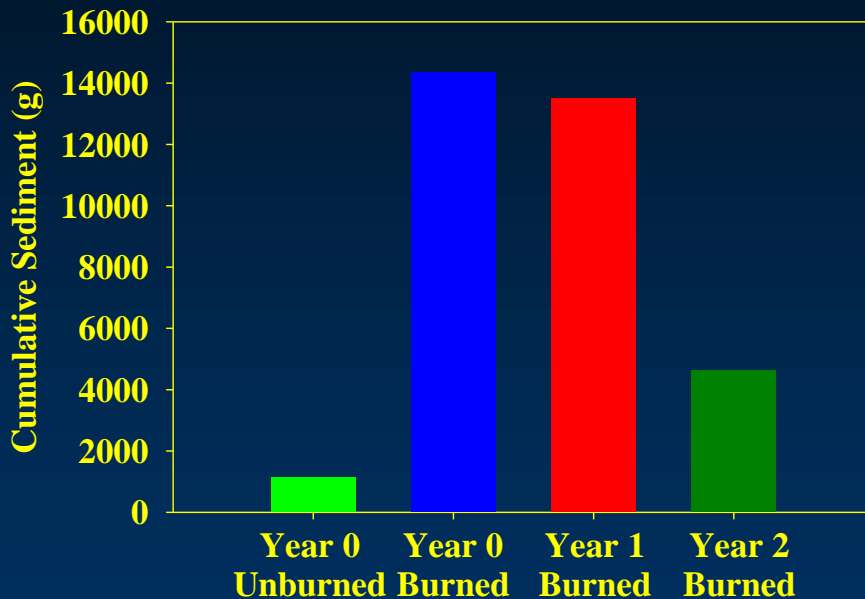


Decreased surface water storage and resistance to overland flow.

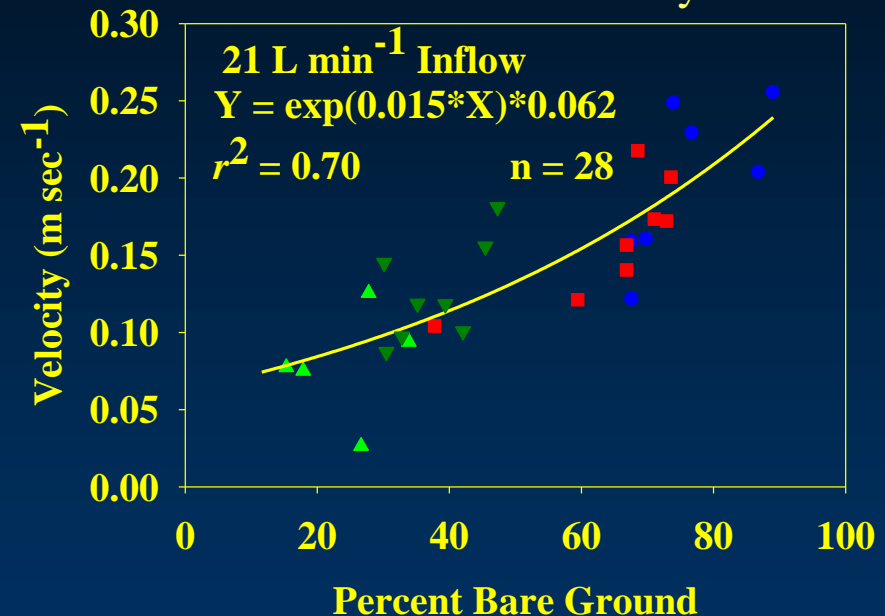
Increased spatial continuity of concentrated overland flow.

Hillslope Scale: Hydrologic Impacts of Fire

Rill Erosion



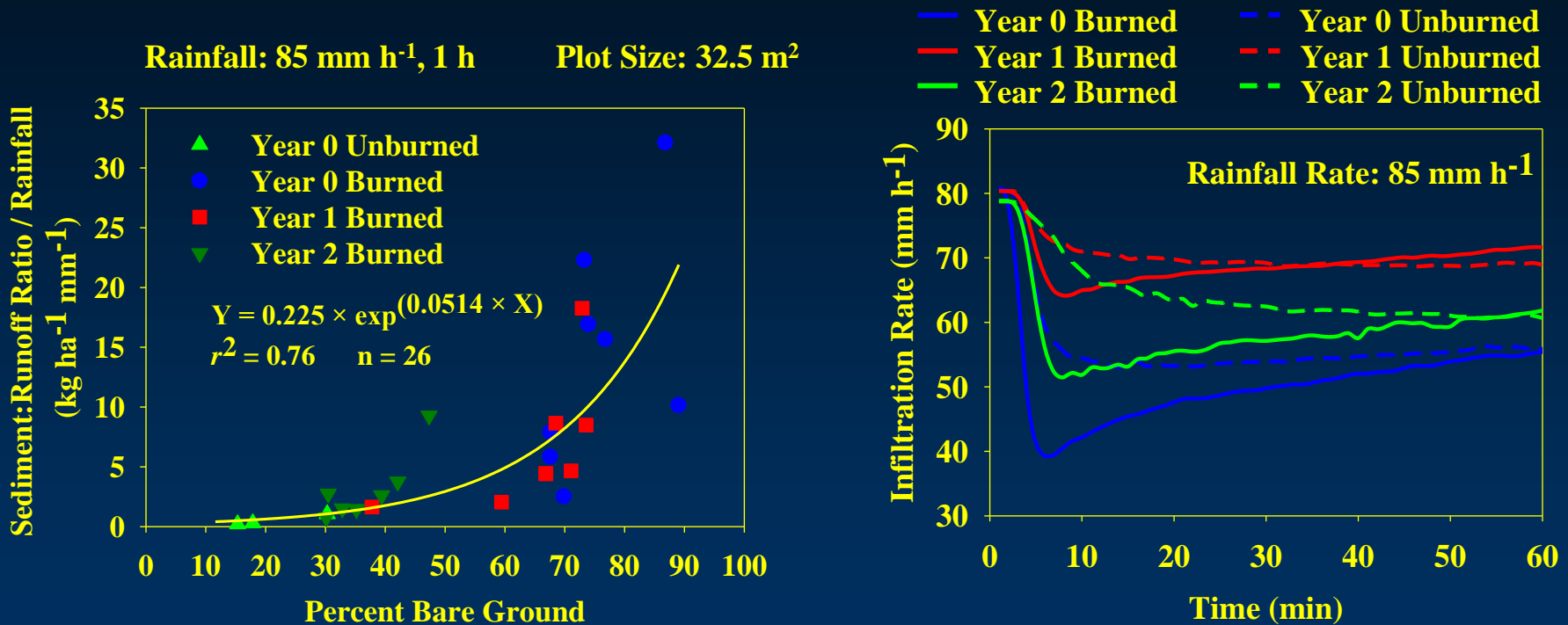
Rill Flow Velocity



Increased concentrated flow velocity – greater erosive energy and transport capacity.

Fire effects typically greater and more persistent for sediment yield than runoff.

Hillslope Scale: Hydrologic Impacts of Fire



Hydrologic recovery depends on time required to achieve pre-fire structural and functional plant community (surface protection).

Temporal variability may confound recovery assessments.

Plant Invasions: Annual Grasses

Sagebrush-Steppe

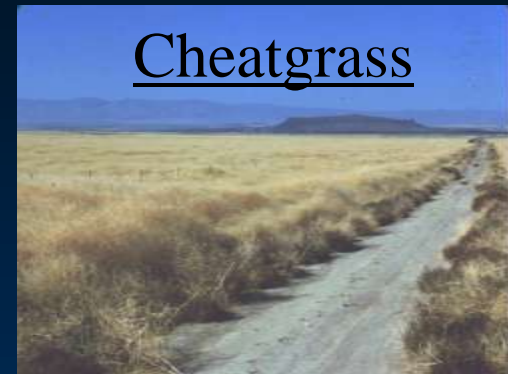


Soil/site
properties



Vegetation
protection

Cheatgrass



Rapid and uniform protection:

- Canopy cover
- Ground cover
- Litter accumulation
- Bare soil coverage
- Hydrologic connectivity

Long-term changes?

- Extreme events
- Wind erosion
- Bulk density
- Soil organic matter
- Root structure/biomass
- Soil water repellency
- Faunal Activity

Altered Fire Regimes: Annual Grasses



Alteration of fuel structure and density with grass invasions increases the **expanse, uniformity, and frequency** of wildfires.

Larger more frequent fires increase bare soil exposure over time and space creating greater **risk of large-scale flooding and soil loss** from water and wind erosion events.

Altered Fire Regimes: Woody Plant Invasions

Sagebrush-Steppe

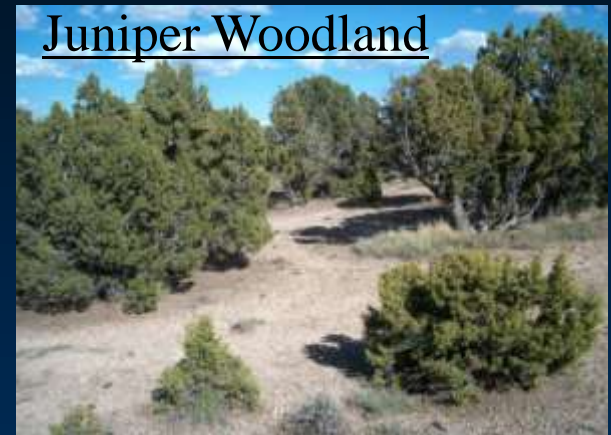


Soil/site
properties

Vegetation
protection



Juniper Woodland



Gradual long-term decreases:

- Understory canopy cover
- Ground cover between trees
- Surface litter accumulation
- Bulk density
- Soil organic matter

Gradual long-term increases:

- Bare soil coverage
- Hydrologic connectivity
- Runoff amount and frequency
- Surface soil loss

Woody Plants: Altered Site Stability

Vegetation protection **X** Climate drivers

Storm: duration-depth-frequency

Rainfall = 53.3 mm h⁻¹



Storm Return Period (years)	Runoff (mm)		Erosion (kg ha ⁻¹)	
	Juniper Woodland	Juniper Removed	Juniper Woodland	Juniper Removed
2	0.1	0	7	0
4	0.5	0	34	0
10	1.1	0	70	0
50	4.1	0	269	0
100+	13.5	1.0	1053	11

Increased bare soil exposure facilitates hydrologic connectivity of runoff areas and amplifies loss of soil and water.

Woody Plants: Altered Hydrologic Function



Hydrologic functions:

- Plant water use
- Timing and amount of stream flow
- Interception losses
- Precipitation distribution
- Soil protection – wind erosion



Scaling: Spatial and Temporal

1. Questions are asked at field, watershed, and basin scales.
2. Current understanding of hydrologic function/stability is largely limited to the plot and hillslope scales.
3. Generally assume greater off-site impacts with increased size and frequency of disturbance.
4. Long-term impacts of fire and vegetation changes on landscape development are unclear.



Future: Research Needs

1. Scaling plot and hillslope level information to watershed scales.
2. Long-term experimentation and analyses.
3. Probability-based analyses and predictions.
4. Hydrologic implications for plant invasions across biomes.
5. Understanding of wind erosion is very limited.

Future: Managing Increased Risk

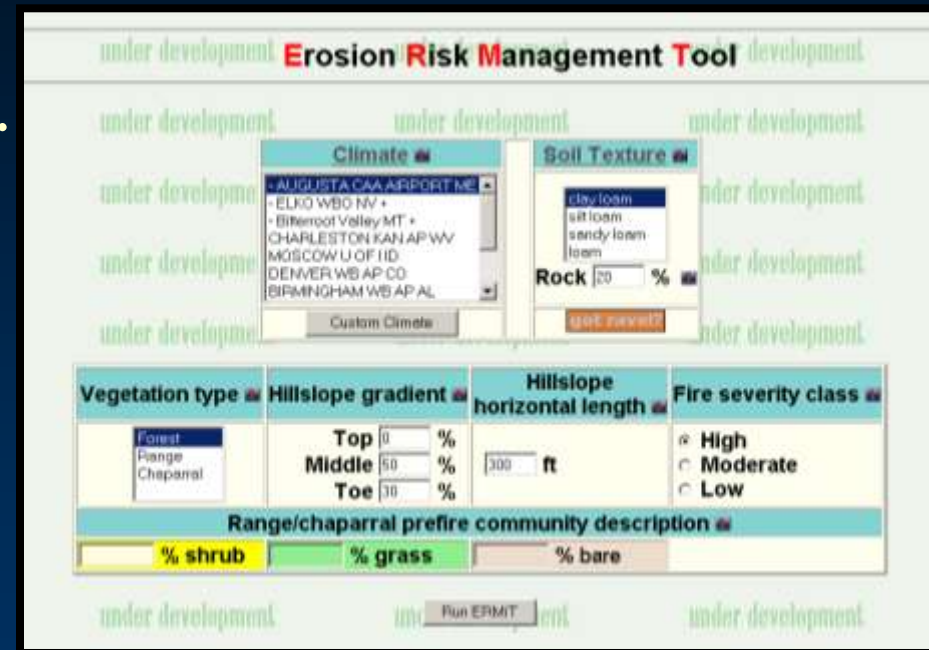


Increased probability of occurrence of damaging hydrologic events:

- Disturbances occurring more frequently
- Disturbances occurring over larger areas
- Potential for increased frequency of higher intensity storms

Challenge: Tools for Managers

- Simple and easy to use tools.
- Robust across variable landscapes.
- Address multiple scales.



Need: Tools based on sound science with supporting databases for management application.