Hydrologic Vulnerability of Wooded Shrublands Before and After Tree Removal by Mastication, Cutting, and Burning

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Hydrologic Response as Function of State

Sagebrush-Steppe

Phase I to Phase II

Phase III

Rainsplash

Sheetflow

Concentrated-flow

Site Conditions

Good

Degraded

Rainsplash-Sheetflow

Transition Zone

Concentrated Flow

Phase III

Phase I - II PJ

PJ
1) What are the hydrologic impacts of woodland encroachment?
2) What effects do tree reduction treatments have on hydrologic response?
Approach

Oscillating Arm Simulations, 0.5 m²

Stand Pipe-Type Simulations, 13 – 32.5 m²
Approach
Hydrology Study Sites

- Onaqui – Utah Juniper
- Marking Corral – Pinyon-Juniper
- Castlehead – Western Juniper

- SageSTEP site
- USDA - ARS site

Large Plots/Conc. Flow: 228/292
Small Plots: 292
Resource Conserving vs. Rapidly Eroding

Heterogeneous Cover/Soils

Coarse Structure

Rapidly Eroding

Cumulative Runoff (mm)

0 10 20 30 40 50 60

Sediment Yield (g·m⁻²)

0 50 100 150 200 250 300

Runoff/Erosion Across Spatial Scales

Interspace

Shrub

Tree

Resource Conserving

Rapidly Eroding

Heterogeneous Cover/Soils

Coarse Structure

Rapidly Eroding

Runoff/Erosion Across Spatial Scales

Interspace

Tree

10 20 30 40 50 60

Cumulative Runoff (mm)

0 5 10 15 20 25 30

Sediment Yield (g·m⁻²)

0 50 100 150 200 250 30 150 200 250 300

Interspace

Tree
Woodland Encroachment

Hydrologically Stable – Rainsplash Processes

Hydrologically Unstable

Concentrated Flow
Treatment Method?

Erosion

Rainsplash-Sheetflow

Transition

Concentrated

Sagebrush-Steppe

Site Conditions

Good

Degraded
### Short-term Response to Mastication

<table>
<thead>
<tr>
<th>Vegetation Type</th>
<th>Runoff (mm)</th>
<th>Erosion (g/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shrub Coppice</td>
<td>5</td>
<td>21</td>
</tr>
<tr>
<td>Juniper Coppice</td>
<td>14</td>
<td>49</td>
</tr>
<tr>
<td>Veg. Interspace</td>
<td>23</td>
<td>133</td>
</tr>
<tr>
<td>Bare Interspace</td>
<td>52</td>
<td>313</td>
</tr>
<tr>
<td>Interspace-Residue</td>
<td>11</td>
<td>39</td>
</tr>
<tr>
<td>Interspace-Tracked</td>
<td>53</td>
<td>403</td>
</tr>
</tbody>
</table>
Short-term Response to Cutting

**Interspace**
- Runoff: 43 mm
- Erosion: 272 g/m²

**Juniper Coppice**
- Runoff: 13 mm
- Erosion: 49 g/m²

**Cut - Interspace**
- Runoff: 47 mm
- Erosion: 270 g/m²
Long-term Effects: Cutting

1) Juniper woodland 145 g erosion
2) 10 years post-cutting 45 g erosion
3) 20 years post cutting 20 g erosion
Short-term Response to Burning

**Juniper Coppice**
- Bare Soil: 18%
- Runoff: 13 mm
- Erosion: 49 g/m²

**Burned Juniper**
- Bare Soil: 73%
- Runoff: 50 mm
- Erosion: 1083 g/m²

**Interspace**
- Bare Soil: 89%
- Runoff: 43 mm
- Erosion: 272 g/m²

**Burned Interspace**
- Bare Soil: 89%
- Runoff: 43 mm
- Erosion: 572 g/m²
Short-term Response to Burning

![Image of burned area]

![Graph showing erosion vs. runoff]
Short-term Response to Burning – Sagebrush Steppe

**Runoff (mm h⁻¹) vs. Time (min)**

- **Year 1 - Burned**
- **Year 2 - Burned**
- **Unburned**
- **Year 3 - Burned**

**Large Plot Sediment:Runoff Ratio / Rainfall (g m⁻² mm⁻¹ mm⁻¹)**

- $Y = 0.023 \times \exp(0.051 \times X)$
- $r^2 = 0.77$  $n = 26$

**Percent Bare Ground vs. Large Plot Sediment:Runoff Ratio / Rainfall (g m⁻² mm⁻¹ mm⁻¹)**
Summary and Conclusions

• Effects of encroachment related to development of extensive bare interspace and site specific erodibility.

• Runoff and erosion increase exponentially where bare ground > 60%.

• Mastication may reduce erosion from interspace areas – long-term results unknown.
Summary and Conclusions

• Short-term effects of tree cutting are minimal.

• Cutting does reduce erosion significantly over long-term (8-fold at Steens Mtn.).

• Burning increases runoff and erosion from tree coppices (4 and 22 fold in this study) in immediate post-fire period.

• Burning has minimal effect on interspace runoff, but erosion can increase 2 fold following fire.
Summary and Conclusions

• Effects of burning generally longer lasting for erosion than runoff:
  – Runoff generally returns to pre-fire levels within 1 growing season
  – Erosion increases typically much greater and relative rates return to pre-fire levels after 2-3 growing seasons.
  – Recovery rates here based on commonly occurring storm.
  – Recovery against extreme storms may take much longer.

• SageSTEP has greatly advanced our understanding of woodlands hydrology and erosion and has facilitated development of predictive technologies (RHEM, ERMiT).
Rangeland Hydrology and Erosion Model

User's Input

Storm  
Slope  
Soil  

Hydrology & erosion parameters

Ke  Fe  Fr  
Kss  Kc  t_c

Model Core

Hydrology (Infiltration)  
(Overland flow generation)

Erosion processes  
(Splash and sheet erosion)  
(Concentrated flow erosion)

Model Output

Hydrograph  
Sediment yield  
Soil loss uncertainty

RETURN PERIOD GRAPHS

P=Rain

Q=Runoff

Sediment Yield

Soil Loss

2 YEAR RETURN PERIOD RESULTS

<table>
<thead>
<tr>
<th>MARK1</th>
<th>MARK2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rain (mm)</td>
<td>21.80</td>
</tr>
<tr>
<td>Runoff (mm)</td>
<td>2.31</td>
</tr>
<tr>
<td>Sediment Yield (ton/ha)</td>
<td>0.02</td>
</tr>
<tr>
<td>Soil Loss (ton/ha)</td>
<td>0.02</td>
</tr>
</tbody>
</table>

10 YEAR RETURN PERIOD RESULTS

http://dss.tucson.ars.ag.gov/rhem/

USDA Agricultural Research Service

NRCS Natural Resources Conservation Service