Remote sensing and ground-based methods to assess post-wildfire erosion and debris flow variables in a rangeland environment

Charles Finley

GIS Training and Research Center
Idaho State University

19 September, 2005

Outline

- Background
  - Project overview
  - Wildfire in rangelands
  - Post-wildfire runoff/debris flow discussion
- Objective of research
- Study area
- Methodology
  - Parameters
  - Field assessment
  - Remote sensing assessment
- Results & conclusions
- Implications/future directions

Project Overview

- Masters Thesis, Masters of GIS Science, Idaho State University
- Result of NASA-funded grant:
  - *Impact of Temporal Landcover Changes in Southeastern Idaho Rangelands*
    - *3 yr, $1.4 m project funded July 1, 2004*
    - *Utilize geospatial technologies to assess temporal changes in rangeland environments due to:*
      - *Wildfire*
      - *Management strategies*

Why Rangelands?

- Approximately 700,000 km^2 of rangelands in the Western USA
- Primarily utilized for agriculture (grazing)
- Recreation, natural resources, wildlife habitat, research
- High amounts of post-erosion due to:
  - High summer fire danger
  - Intense rainstorm occurrences
- Lack of research on wildfire in rangeland ecosystems

Debris flow/wildfire relationships

Post-fire conditions that affect and cause debris flow initiation

- Easily erodible sediment due to:
  - Fire-removed litter and organic layers
  - Intense heating, soil drying, decreased cohesiveness

- Decreased infiltration rates
  - Due to formation of water-repellant soil layers under highly erosive soils
  - Increased amount of precipitation-induced runoff

- Removal of Vegetation
  - Decreases raindrop interception and evapotranspiration
  - Increases raindrop impact velocities
  - Controlled by burn severity

Soil water repellency

- Often present to a degree in unburned soils
  - Dry climatic conditions
  - Compaction
  - Organic layers
- Primary factors of formation
  - Organic matter
  - Soil texture
  - Soil-water content
  - Plant-soil relationships
- Recognized when water drops ball up and don’t infiltrate the soil
  - 60 s - <3600 s

Soil water repellency and wildfire

- Combustion of organic matter (vegetation, litter and surface duff)
  - Creates aliphatic hydrocarbons
  - Results in organic surface coating of soil
- Factor of fire behavior, severity and **temperature**
  - <175º C: little change
  - 175º – 200º: high water repellency
  - 280º – 400º: destruction of water repellency

    (DeBano et al., 1998)
- Temperature gradients within soil affect thickness of layer

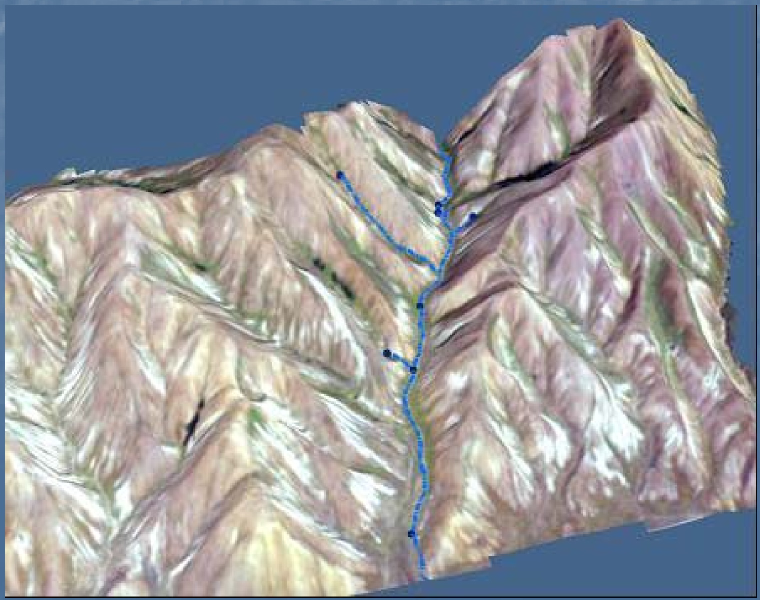
Soil water repellency and debris flows

- Increased water repellency = decreased infiltration
  - Heavy rainfall
    - Increased overland flow of highly penetrable soil layer over water repellent layer
    - Entrenches to rills above water repellent layers
    - Leads to progressive sediment bulking
- Water repellent layer eventually degrades, allowing infiltration

Types of fire-related debris flows

- Progressive bulking of sediments in high-order channels and hillslopes (Cannon, 2001)
- Denuded slopes prevent rainfall interception by vegetation
- Most common type

- Failure of colluvial mass due to root strength decay (Meyer et al., 2001)
- More common 5 years or more after fire



Caddy Canyon Erosion Debris Flow, Pocatello Idaho. Example of progressive sediment bulking on burned hill slopes due to heavy rainfall.

Caddy Canyon debris flow characteristics

Debris flow channel

Debris Flow materials

Objectives of research

- Analyze relationships between burn severity and soil water-repellency
- Assess spatial variability of soil water repellency
- Remote sensing classification of rangeland burn severity and water-repellent soils
- Develop a standardized methodology of remotely assessing soil water repellency and burn severity on rangelands
  - Can be used as input parameters for post-fire susceptibility modeling of sedimentation events such as debris flows and excess overland flow.

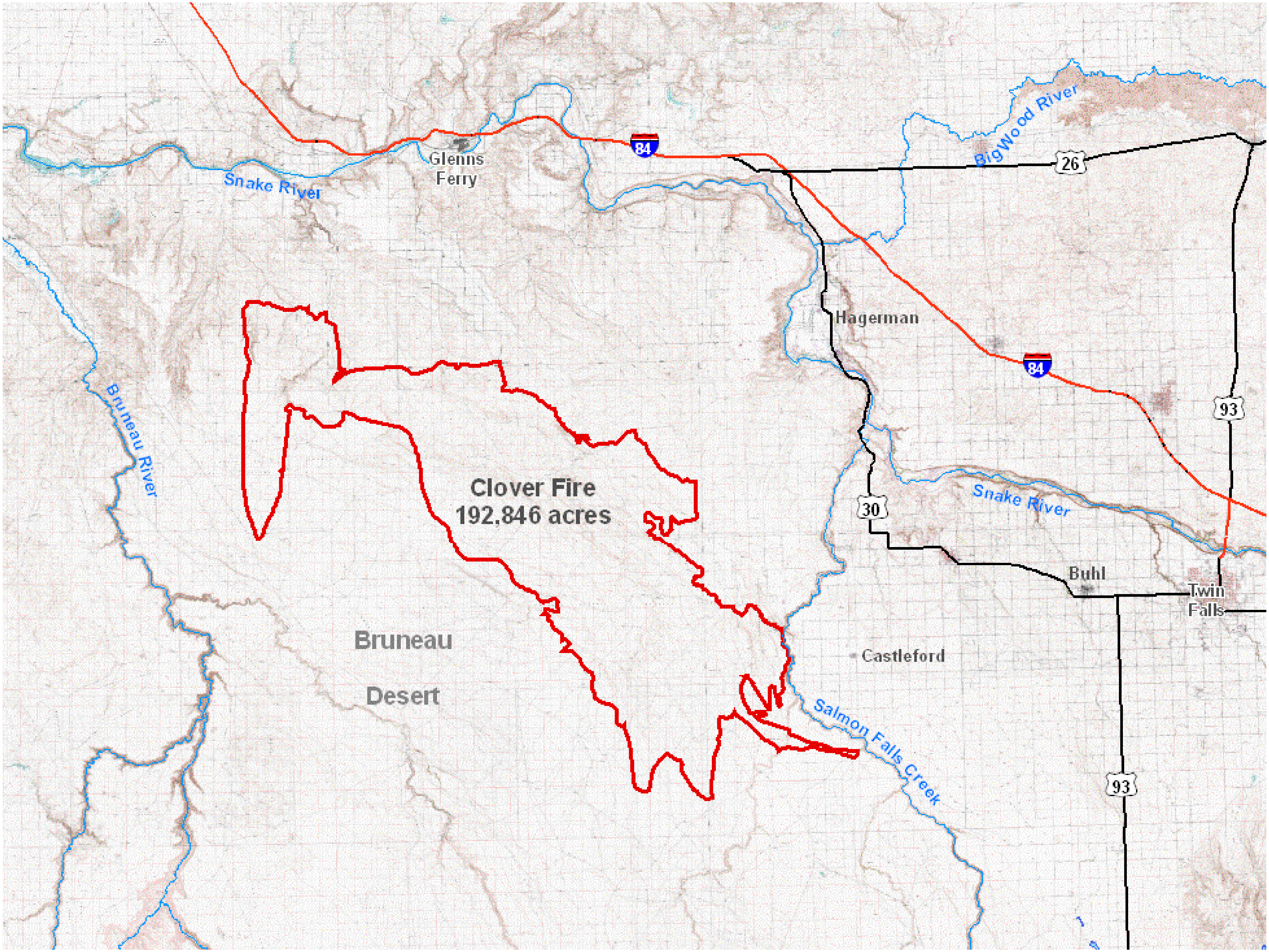
Study area

Criteria:

- Rangeland area, sagebrush-steppe ecosystem
- Recent burn area (summer 2005)
- High-order watersheds
- Large enough for a statistically accurate study
- Varying topography
- Various vegetation and burn severity patches

Clover Fire, Owyhee Co. ID

- 192,846 acres
- Largest wildland fire in Idaho in 2005
- Primarily BLM land
- Flat to rolling topography with steep buttes and gullies
- 1000 to 1345 m elevation
- Sagebrush, perennial grasses with large stands of annual Cheatgrass
- Sandy, silt, deep loam soils


Glenns Ferry
Snake River
84
26
Big Wood River
Hagerman
84
93
Bruneau River
Clover Fire
192,846 acres
30
Snake River
Buhl
Twin Falls
Bruneau
Desert
Castleford
Salmon Falls Creek
93

Methodology

- Parameter assessment
  - Vegetation Burn Severity
  - Soil water repellency
- Field Spectrometry
- Statistical analysis of field data
- Hyperspectral Imagery analysis

Low Burn Severity

- Foliage singed or consumed, branches still intact
- Less than 60% shrub canopy consumed
- Grass stalks/blades may remain, slightly blackened
- Grass may be burned, at least 5 cm unburned stubble remains
- Forbs singed; plant base, some parts remain, recognizable

Moderate Burn Severity

- Foliage, twigs, some branches of shrubs consumed
- Branches up to 1 cm in diameter remain
- 40 to 80 % of canopy consumed
- Unburned grass stubble less than 5 cm tall
- Burns uniform throughout area
- Forb foliage consumed, plant burned near ground

High Burn Severity

- All shrub parts consumed
- Stubs/stumps <1 cm diameter remain
- No unburned grasses above root crown
- All forb parts consumed


Unburned

Testing for water-repellent soils

<u>Water Drop Penetration Test</u>

- 30-60 s: Weak
- 61-180 s: Moderate
- 181-360 s: Strong

<u>Depths</u>

- Surface
- 2,4,6,8,10 cm

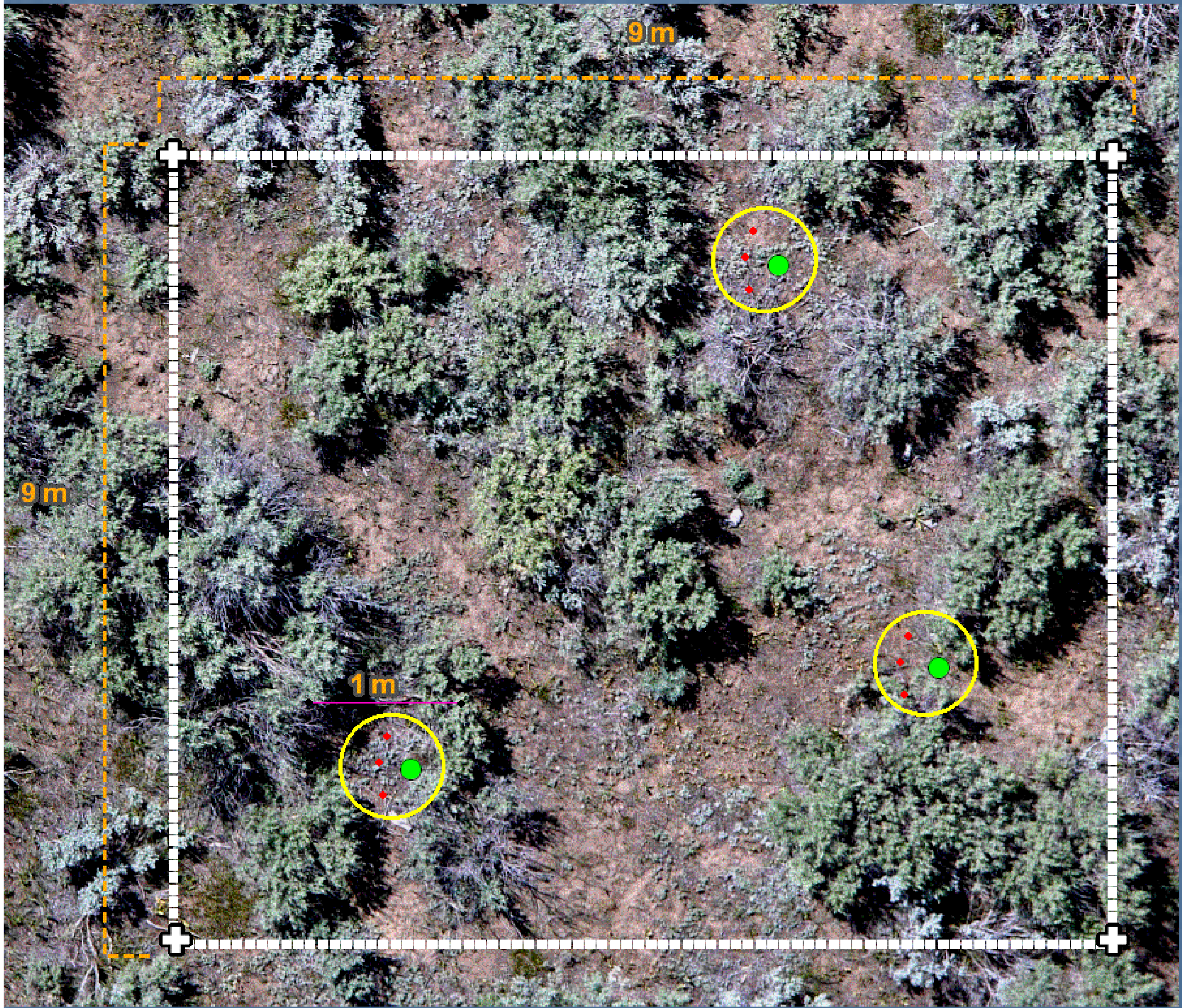
- Most common test
- Time consuming, subjective

Testing for water-repellent soils

Mini-Disc Infiltrometer, Decagon Devices, Inc.

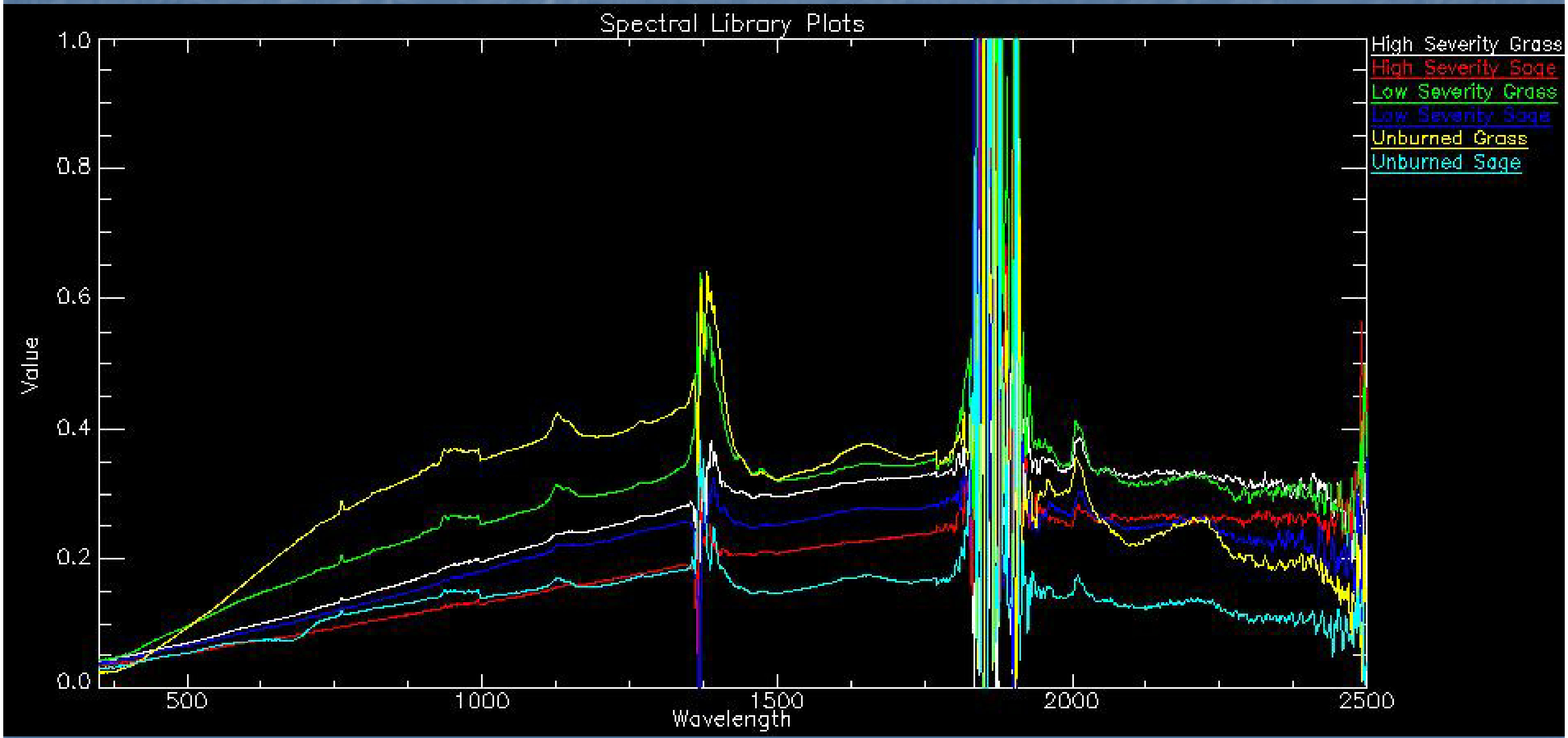
- Constant pressure head cylinder with porous bottom
- Measures:
  - time till infiltration (s)
  - Amount of water infiltrating soil in 1 min. (ml)
- Faster, less subjective

Sampling Scheme



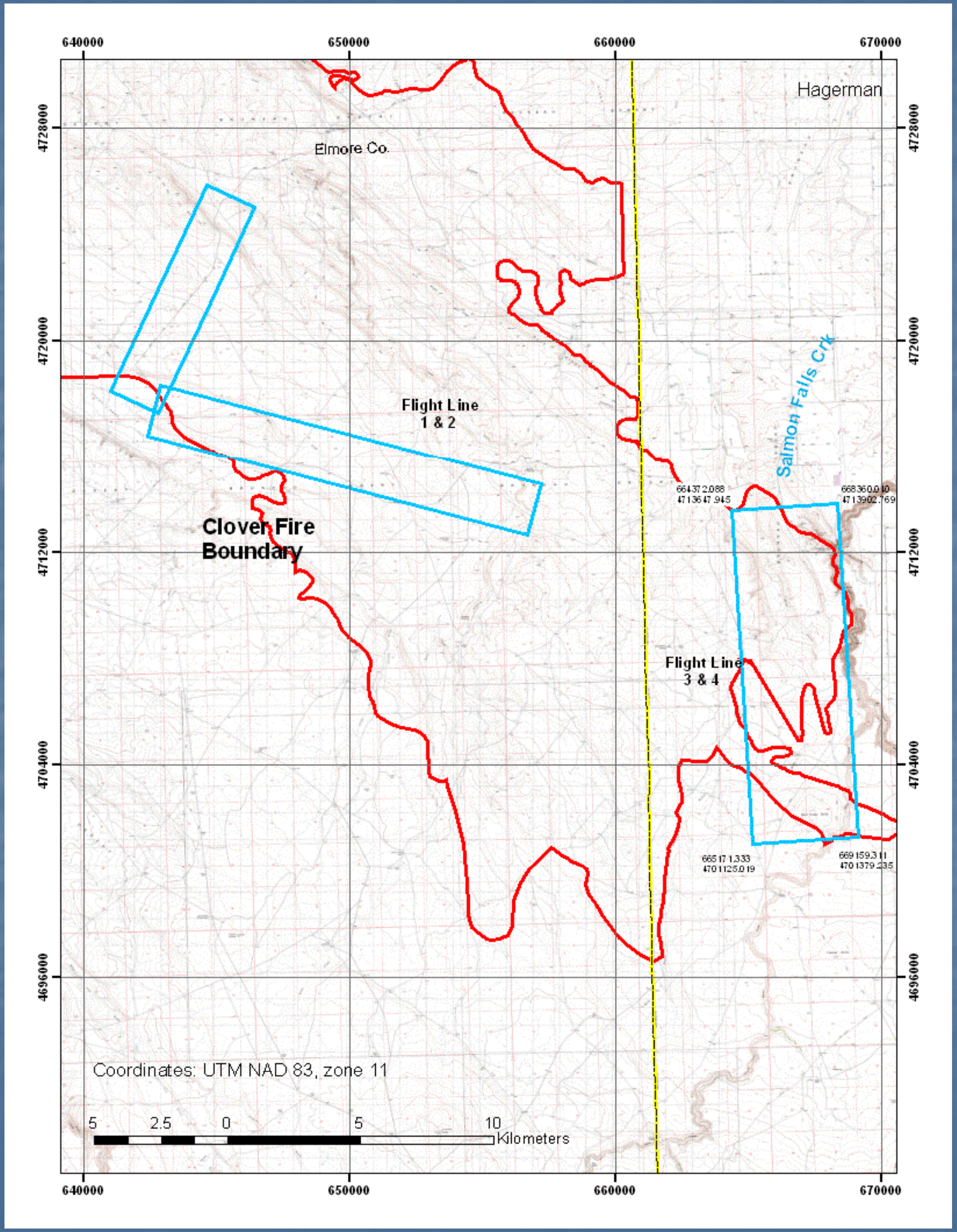
- 9 m x 9 m sample plot
- 1 m diameter pt collection
  - 3 MDI tests
  - 1 WDPT test

Field spectrometry



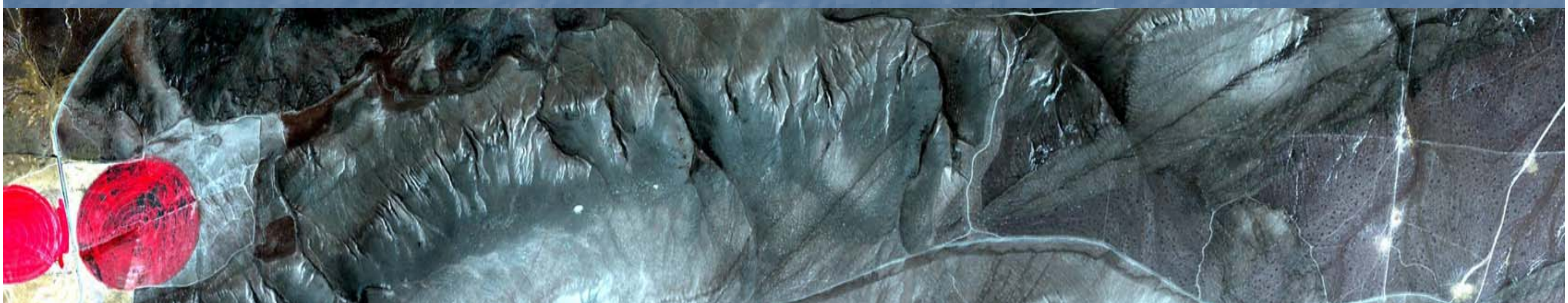
Hymap hyperspectral image acquisition

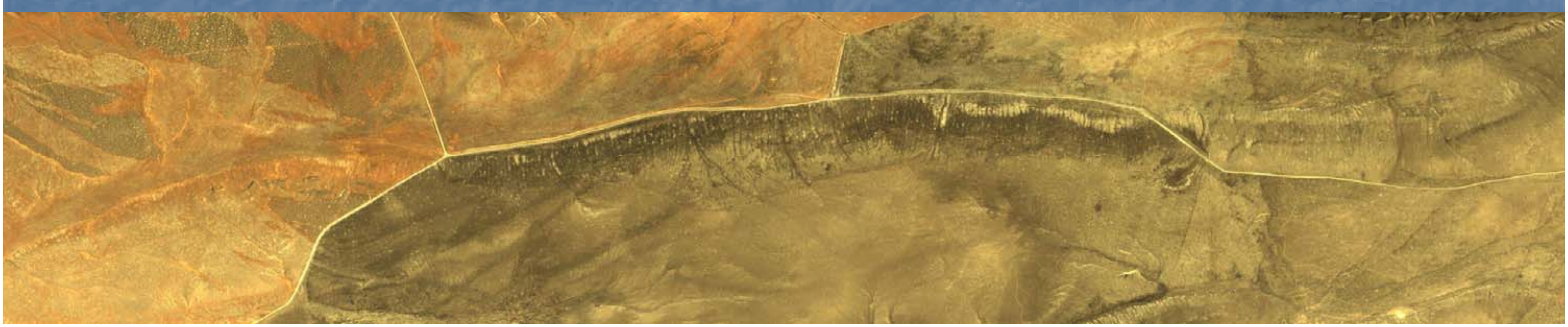
- 3.5 x 3.5 m pixel resolution
- 128 bands
- 0.40 μm and 2.5 μm
- Flight lines flown to cover varying severity, vegetation, slope and aspect classes
- 2 km wide flight lines



Hymap Hyperspectral Imagery

Study site imagery





Remote sensing analysis

- Hyperspectral processing flow

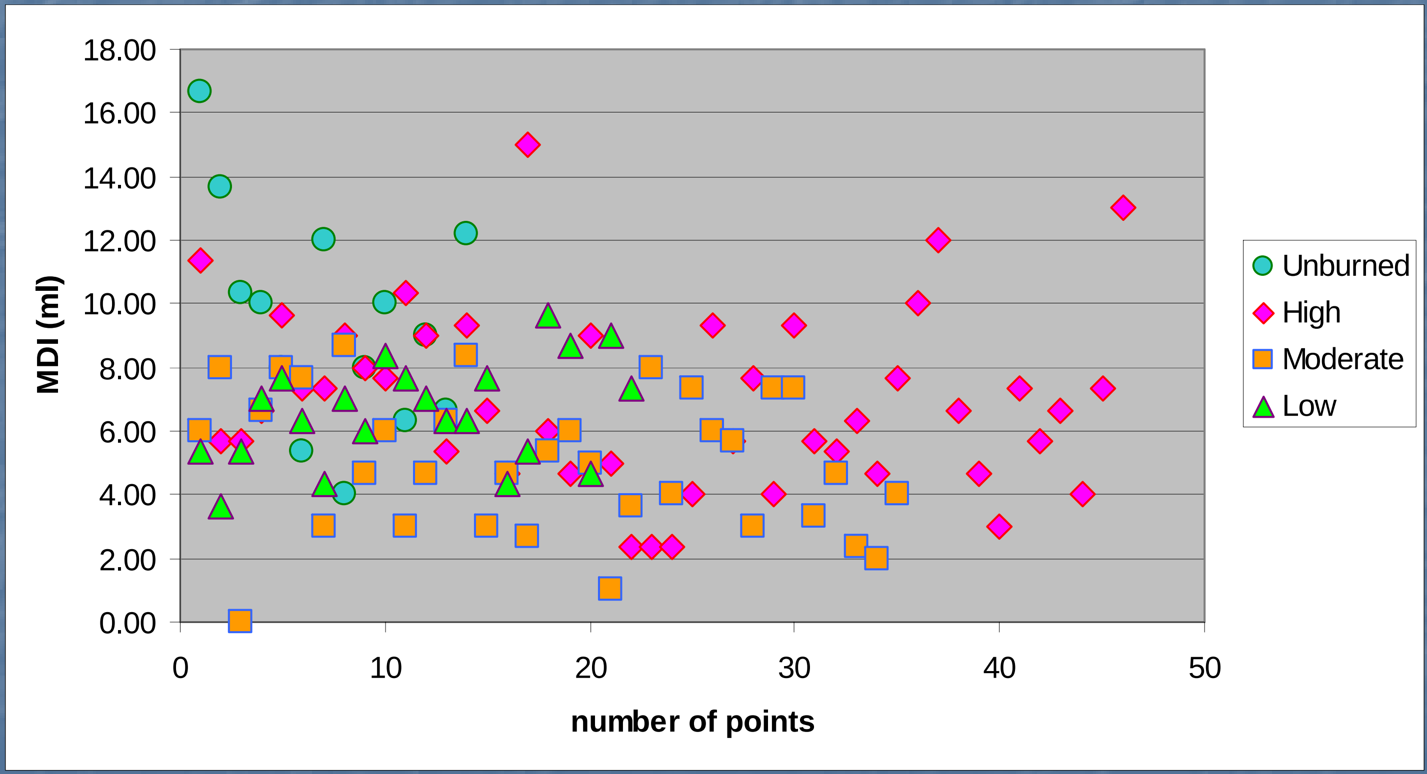
1. Minimal noise fraction (principal component analysis)
2. Endmember assessment
    - Field testing (GPS data collection)
    - Field spectrometer
3. Supervised classification
4. Validation

Expected results

- More water repellent soils are found in areas of moderate burn severity, and less in areas of low and extremely high burn severity
  - Extended residence time of fire in moderate areas
  - Variations in temperature gradients
- Hyperspectral spectroscopy will discern different water repellent soils and burn severity of rangeland wildfire areas

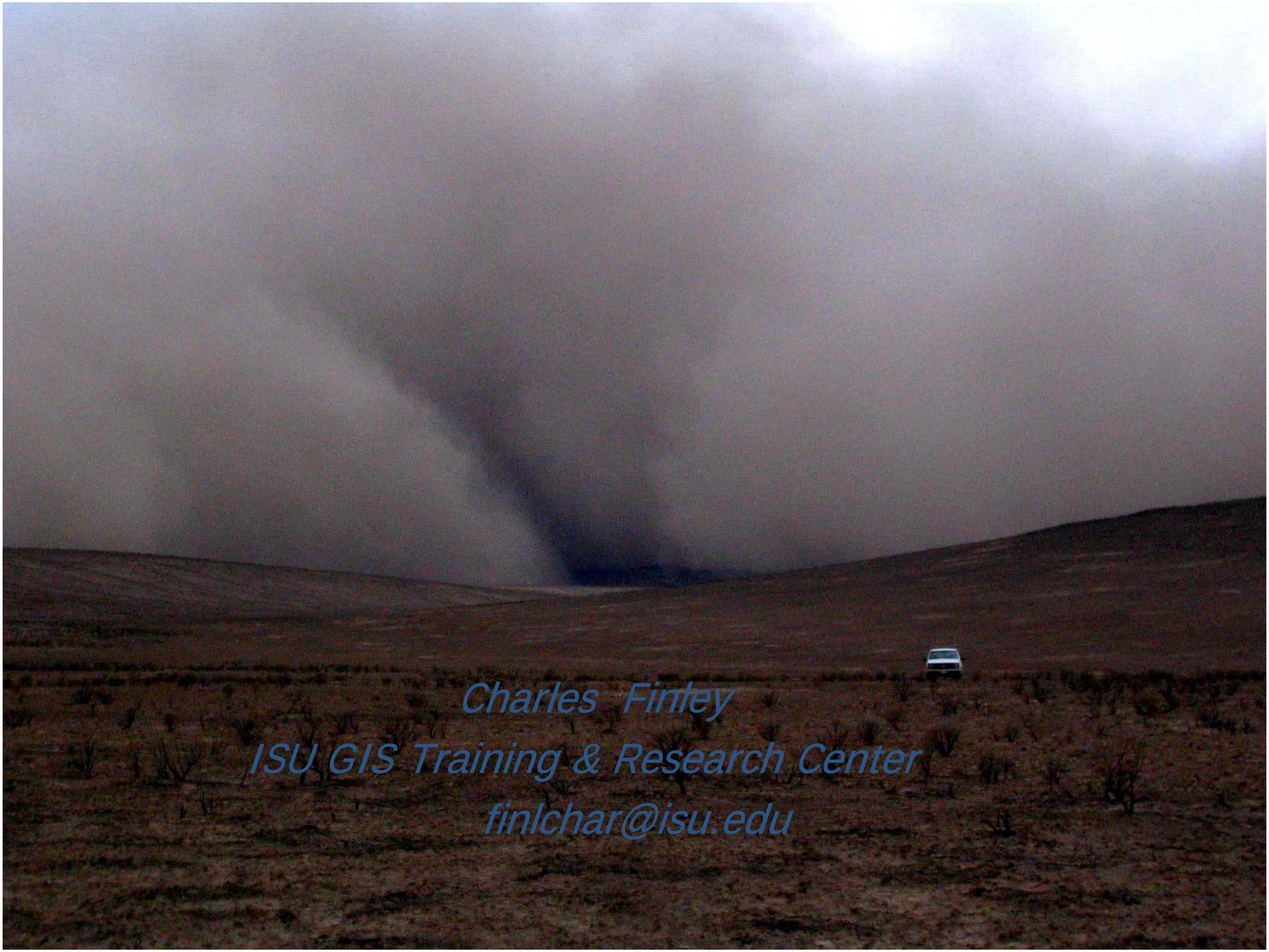
Initial results of field testing

MDI test points



Implications

- Advancements in rangeland remote sensing
- Standardized methodology of assessing debris flow variables of burn severity and soil water-repellency
  - Parameter input to debris flow susceptibility models
  - Efficient method of post-fire burn severity assessment
- Understanding patterns of burn severity and soil water-repellency on a landscape scale
- Watershed modeling
- Aeolian transport modeling


Charles Finley
ISU GIS Training & Research Center
finlchar@isu.edu