Measuring erosion rates at plot scales using close-range photogrammetry

Joseph W. Wagenbrenner[1,2]
Peter R. Robichaud[2]
Randy B. Foltz[2]

[1]Washington State University
[2]USDA Forest Service, Rocky Mountain Research Station, Moscow, Idaho

International Symposium on Erosion and Landscape Evolution
19 September 2011

Motivation

- Goal: quantify and develop models to predict hillslope erosion rates from forests
- Data collection is time consuming and expensive
- Objective: determine if close-range photogrammetry can help us better measure erosion rates

Outline

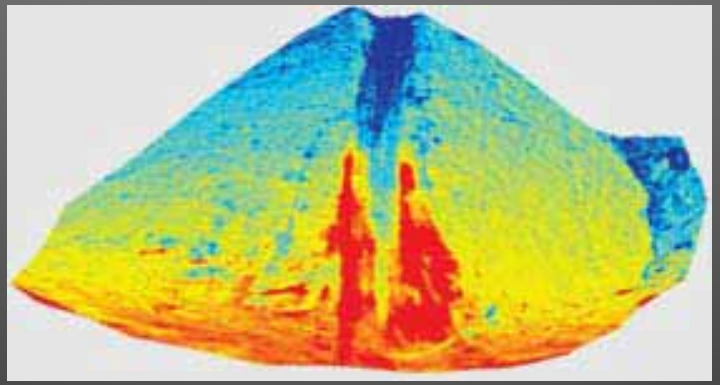
- A brief introduction
- Previous work
- Methods
- Results
- Comments and conclusions

General process

- Camera calibration
  - Adjusts camera internal parameters based on camera and lens settings and distortions
- Photo planning and acquisition
- Match points in stereo pairs
  - Manual and automated
- Exterior adjustment
  - Adjusts pixel coordinates based on relative positions
- Digital Terrain Model (DTM) development
  - Automated triangulation of pixels in stereo pairs

Early applications

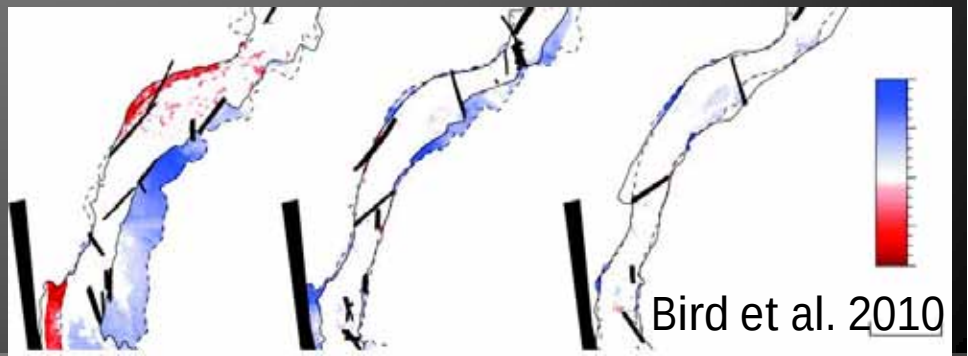
- Mining and excavation
- Accident scene modeling
- City mapping
- Machine vision and manufacturing
- Architectural documentation and monitoring



Matthews, 2008

Erosion studies

- Elliot et al. (1998) WEPP field experiments
  - Boom truck, film camera, manual processing
- Rieke-Zapp and Nearing (2005) laboratory flume experiments
  - Frame mounted, modified digital camera, semi-automatic processing, rill initiation and network development
- Aguilar et al. (2009) roughness measurements in agricultural soils
- Bird et al. (2010) stream channel changes over 15 yr period
  - Digital camera, automated processing, unipod mount
- Gessesse et al. (2010) rill and interrill erosion rates in agricultural plots



Introductory literature

- Matthews (2008) BLM Tech Note 428
- ISPRS recommendations on the use of photogrammetry in Earth sciences
- Several topical publications
  - Photogrammetric Record; Journal of Photogrammetry and Remote Sensing; Photogrammetric Engineering and Remote Sensing; Photogrammetric Journal of Finland...
  - Texts: Mikhail et al. (2001); Kasser and Egels (2002); McGlone et al. (2004)

This study

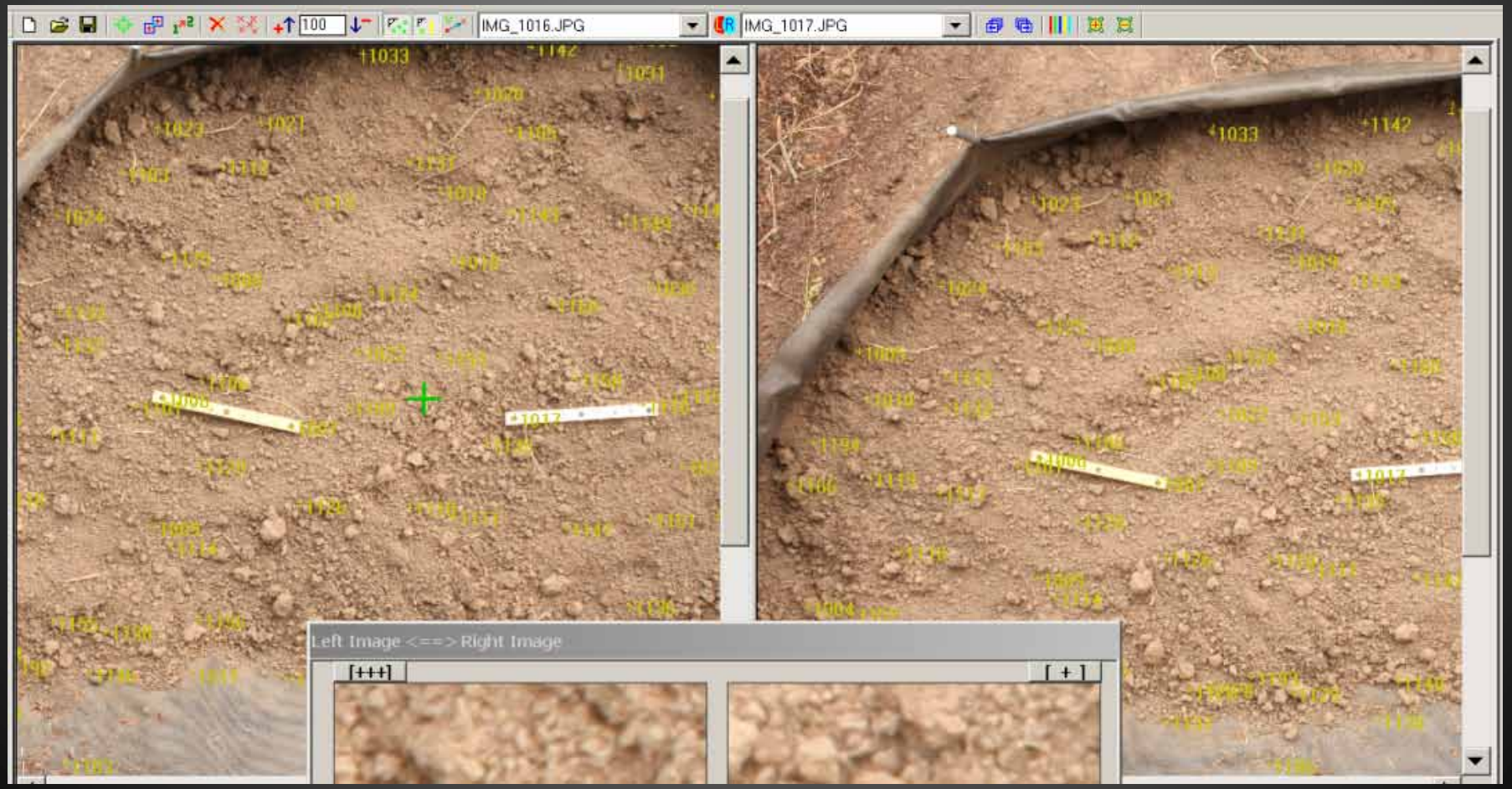
- Objective: Use close-range photogrammetry to measure topography in laboratory or field settings
  - Laboratory flume (volume)
  - Field flume (rill experiment) (volume)
  - Field plot (volume)
  - Two additional analyses:
    - Stream cross-section (morphology)
    - Volume of sediment in silt fence (volume)
- Compare results to more traditional methods

Methods

- Image acquisition
  - Canon EOS Mark II 5D
    - 35 mm sensor
    - 5614 x 3744 pixels, 1 pixel=0.0064 mm (image space)
    - Manual focus (except flumes), natural and artificial lighting
  - Sigma 28-70mm zoom lens
  - Modified tripods
  - Target sticks but no surveyed control points

Post-processing

- Calibration and DTM generation with Adam Technology 3DM software
- DTM analysis in Surfer

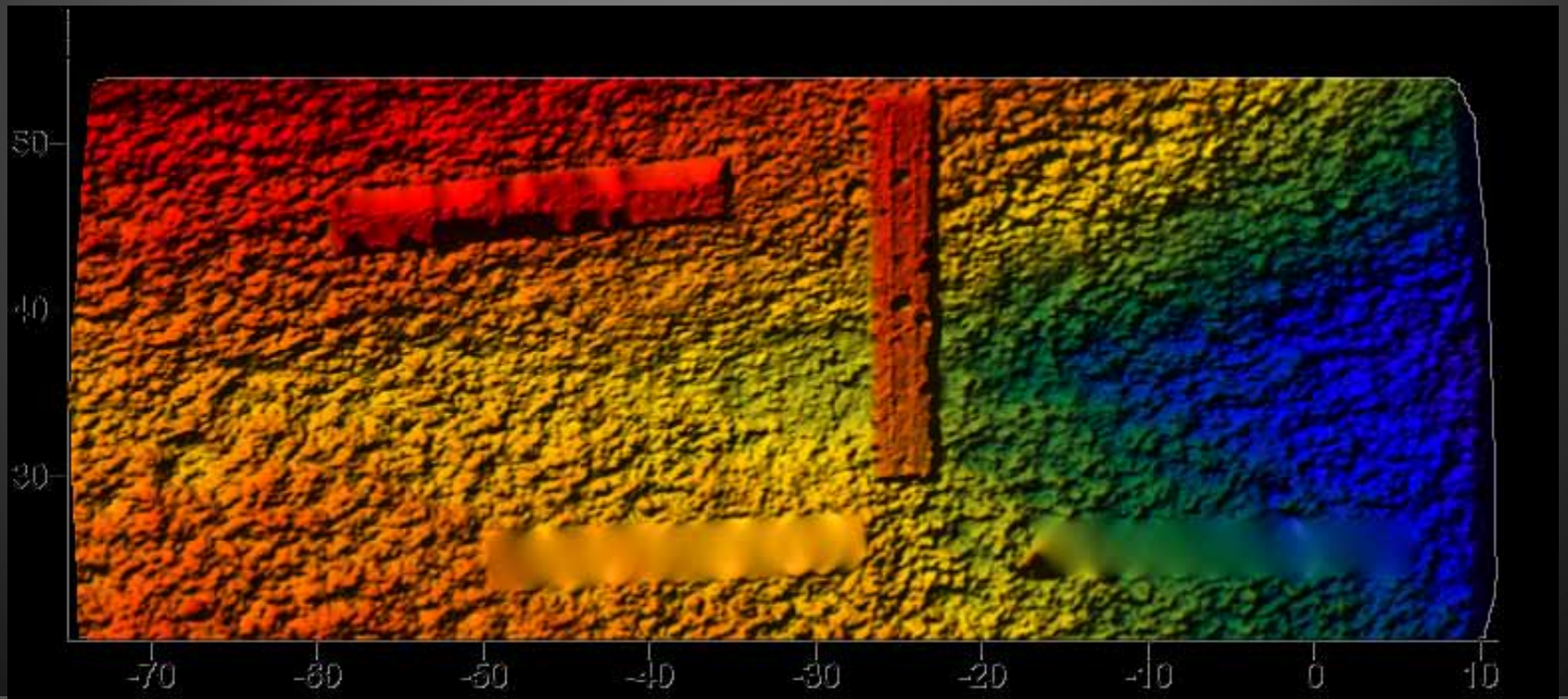


Experimental setup

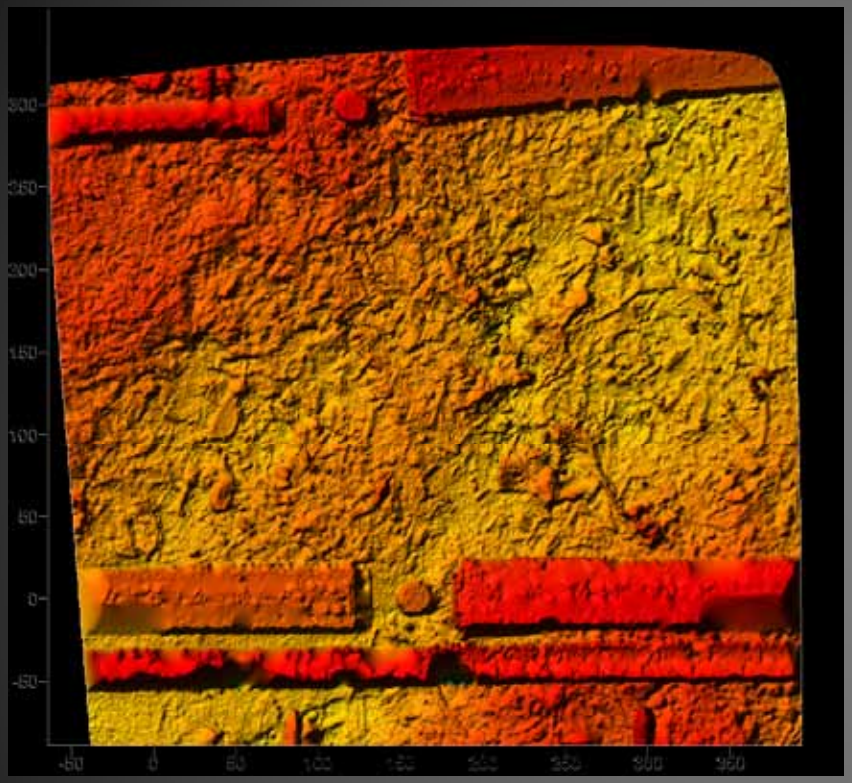
	# photos	Plot size	Comparative method
Lab flume	30	0.4 x 11.4 m	Laser scanner
Field flume	19	1 m x 9 m	Ruler, total sediment yield
Field plot	2	0.5 m x 0.5 m	Rill meter
Stream cross section	10	1 m x 4.8 m	Laser level cross section survey
Silt fence	2	1.5 m x 3 m	Volume measurement

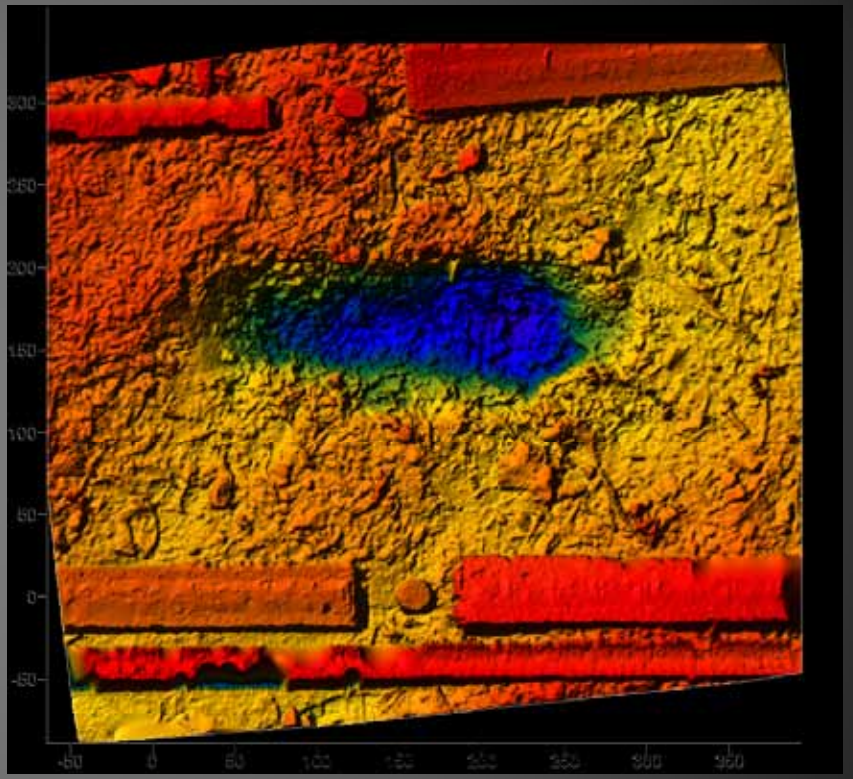
Laboratory (and field) flume settings

- Generated only one DTM from one stereo pair
  - Not enough match points; some photos low quality
- No further analysis conducted



Field plot: surface maps scale



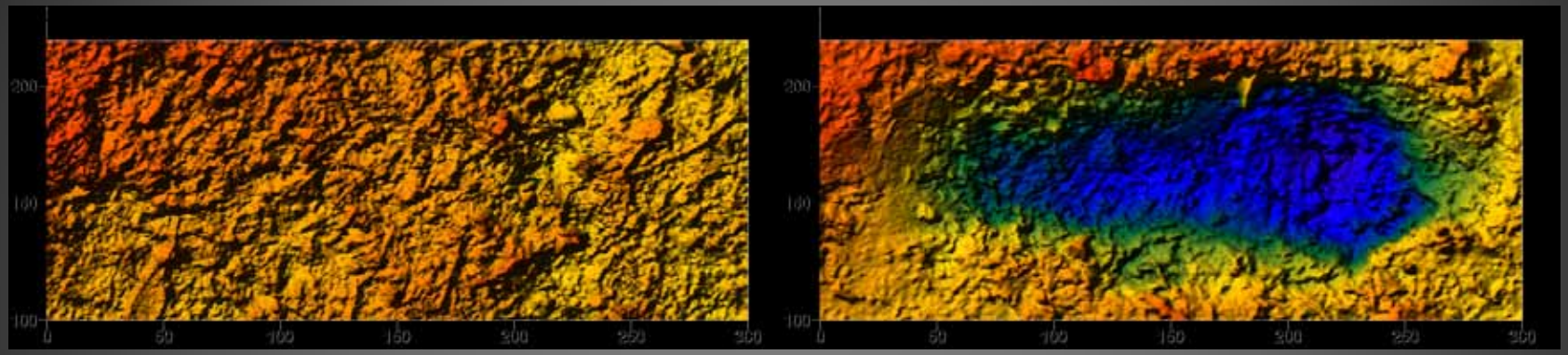


Volume

487 cm^3 (rill meter)

351 cm^3 (photogrammetry) = 28% less volume

Field plot : reduced area surface maps



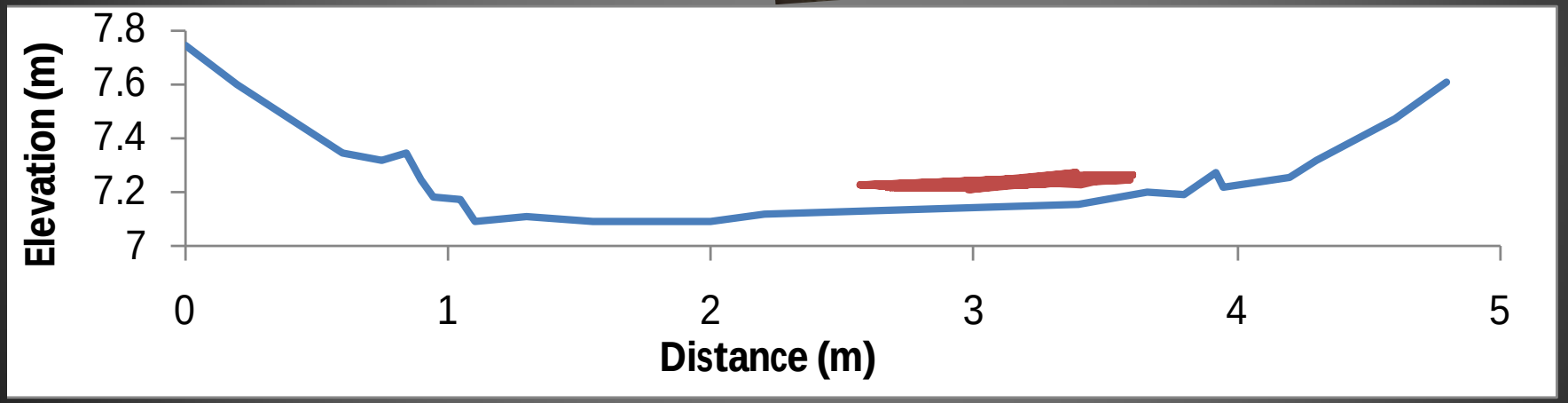
- Reduced area volume change: 346 cm^3
- No real change...

Results—channel cross section

- Paradise Creek, Moscow, Idaho

4.8 m

Results—channel cross section



Systematic error of 8 cm

Results—silt fence

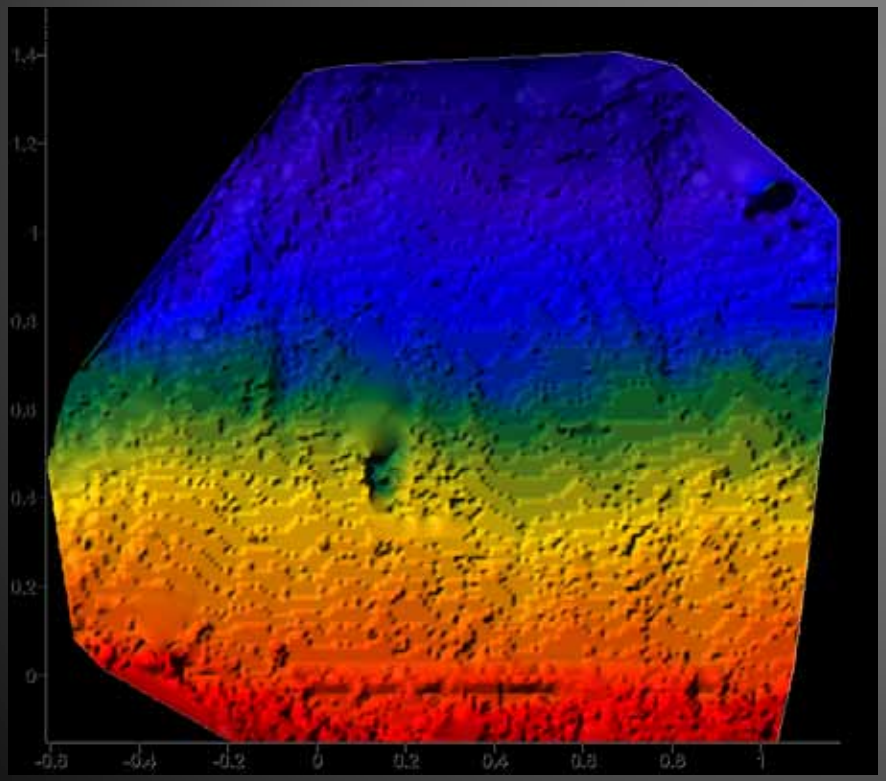
Tripod w/3 m extension

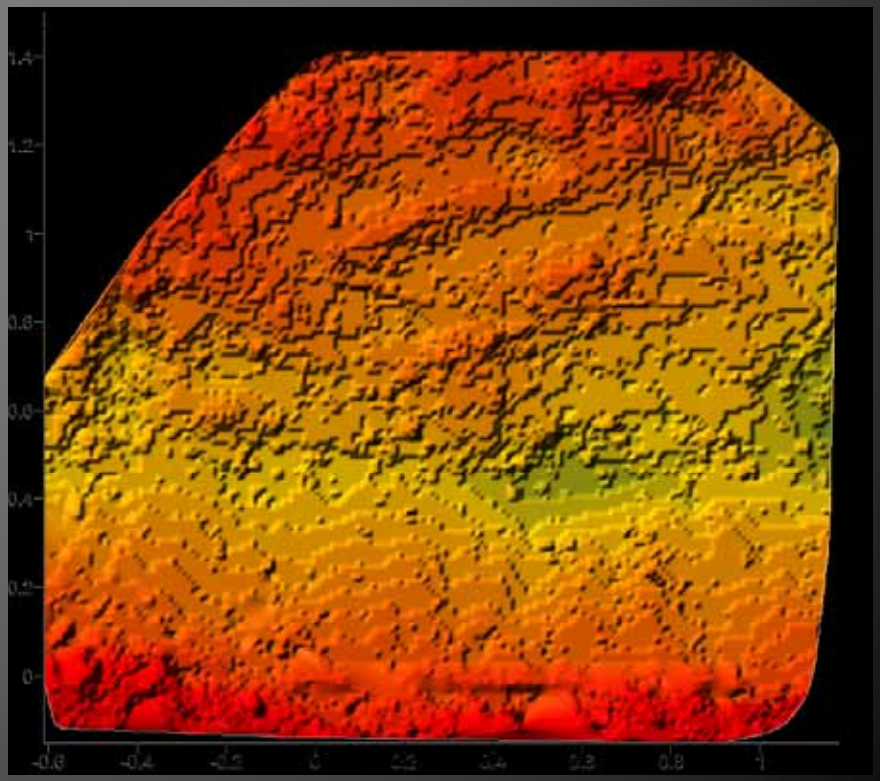
Remote image capture

~12 buckets of silt loam

Results—silt fence scale

- Adjusted added sediment: 0.237 m^3
- Calculated sediment volume: 0.230 m^3
  - 3% less than bucket volume





Discussion—relative errors

Setting	Length (cm)	Error (%)
Micrometer	10.65	
Lab plot	10.63	0.2
Channel cross section	10.24	3.8
Silt fence	10.10	5.2

Discussion—practicalities

- Photos must be acquired without significant site disturbance
  - Moving targets, footprints, etc.
- Maintaining a constant focal distance is difficult at close range in varying topography (e.g., stream banks)
  - Acquire photos from higher elevation
- Vegetation can interfere with model of ground surface
  - As with other remote sensing media
- Software not very intuitive to non-spatially oriented user
- Photo series layout important to getting good overlap and resolution
- Lack of control points prohibited absolute orientations

Possible uses

- Stream channel roughness estimates
- Sediment trap volume measurements
- Road monitoring
  - Culverts, cut slopes, fill slopes, and treads
- Knick point migration
  - See following gully research by Nouwakpo and Huang

Thank you!

- Keenan Storrar, Sierra Larson, and Ben Kopyscianski for their help in image acquisition
- Tom Noble (BLM) for his guidance in initial post-processing