Modeling Erosion at Archaeological Sites with Image-based Modeling and GIS

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Objectives

- To develop a method for modeling erosion at archaeological sites
- To estimate the effects of erosion on specific sites
  - Khirbat Nuqayb al-Asaymir
- To improve the archaeological survey toolkit
  - Allowing for hypothesizing of effects of natural formation processes on archaeological sites
Khirbat Nuqayb al-Asaymir (KNA)

- Middle Islamic IIa
  - (13th century CE)
- Southern Jordan
  - Wadi Arabah
  - Southeast of the Dead Sea
- Copper-production site
  - 15 primary buildings
  - Slag mounds
  - 1,000 tons of slag
Methods

- Low-altitude aerial photography
- Photogrammetric Image-based Modeling
- Ethnographic analogy via ethnoarchaeology
- GIS-based spatial analysis
  - Soil Science
Low-altitude Aerial Photography

- Balloon-based recording
  - Sites
  - Excavation units
- Canon 50D DSLR
  - 18 mm focal length
  - Intervalometers
    - 10 seconds
- Transects across sites
  - Ideal 75%+ overlap between images
- 600+ photos/site
Structure from Motion

- Digital Photogrammetry
  - 3D models from photography using Agisoft Photoscan
  - Point cloud -> Geometry -> Texture
  - 3D models can be georeferenced, allowing for export of GIS outputs
Agisoft Photoscan
- Point Cloud, Dense Cloud, Mesh, Texture
  - High specifications
- Georeferencing:
  - Based on spray-painted markers at site
  - GCPs recorded with Leica TS02 total station
  - Model Accuracy: 19 cm accuracy
    - Not ideal but substantially better than alternative datasets
In order to spatially quantify cultural transformation processes

*Primary vs Secondary Refuse*

- From Schiffer 1972
- Primary: deposition in associated activity area
- Secondary: deposition elsewhere
  - Provisional discard
  - Household maintenance
  - Dumping
  - Loss
Ethnoarchaeology

- Primary discard
  - Within buildings or areas
- Provisional discard
  - Usually associated with edges of buildings
- Household cleaning
  - Often swept or thrown out entrances
    - Highest density within 5 meters
    - No uphill deposition
- Based on Syrian villages and semi-nomadic Bedouin camps in Jordan (Kamp 2000; Simms 1988)
Simulating Deposition

- Primary and provisional deposition:
  - Within structures
  - Immediately outside

- High-density secondary deposition
  - Within 5 meters of areas
  - Not uphill
  - Not pit disposal
Quantifying Erosion

Revised Universal Soil Loss Equation (RUSLE)

From soil science
Calculated soil loss/ha/year from variables:
- **R**: rainfall erosivity factor
- **K**: soil erodability factor
- **LS**: Slope length and gradient factor
- **C**: Cropping management factor
- **P**: Conservation practices factor
RUSLE factors

- **R**: Rainfall Erosivity Factor
  - Calculated for site from annual rainfall data in Faynan
- **K**: Soil Erodability Factor
  - Estimated for site using soil survey information from agricultural fields near Khirbat Faynan
- **LS**: Slope Length and Gradient Factor
  - Calculated within GIS using SfM-produced DEM
- **C and P**: Cropping Management and Conservation Practices Factors
  - No cropping or conservation practices at KNA
- **RUSLE**: Soil loss/ha/year
Risk Categories from Farhan et al 2013
Simulating Erosion Paths

- Prepare DEM for analysis
  - Sink removal
- Least cost path downhill from each area of simulated erosion
- Convert raster paths to polylines
- Buffer polyline
Erosional Deposition

- Mixed Deposition
- Darker color values represent deposition areas, lighter values represent erosion areas
Results

- Simulated erosion paths allow for the possibility of (loosely) associating eroded artifacts with original proveniences
  - Erosion paths linked to hypothetical deposition areas
- May provide explanation for concentrations of artifacts found away from structures
- Provides consideration of one type of n-transform’s effects on the site at KNA
Evaluation of Technique

- Calculating Erosion Risk
  - Highly dependent on available data
- Simulating Erosion Paths
  - ca. 1.5 hours of field recording
  - ca. 8 hours of processing models
  - Depending on available hardware
  - ca. 2-3 hours of GIS analysis
- Cost-effective
  - Equipment can be scaled down substantially without significant loss of quality
- Survey tool
Potential to associate artifacts from surface survey (Jones et al 2012, in BASOR) with erosion models
Possibility of measuring erosion through time
   By comparison of DEMs recorded years apart
   Empirically test erosion model
Provides basis for an *a priori* understanding of effects of erosion on future sites
Questions?
Balloon Specifications

- 1-ply Kingfisher Aerostat K14U-SC balloon
- Dimensions: ca. 3.6 m x 3.0 m
- Volume: ca. 21.0 m³
- Lift: ca. 13.6 kg
- Custom triangular frame with two 15.1 megapixel Canon EOS 50D DSLRs
  - 18mm lenses
- 800 lb. SPECTRA line tether