Mapping biological soil crust distribution in the Muddy Mountains Wilderness Area, Nevada

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ABSTRACT:

Biological soil crusts (BSCs) are critical features in arid landscapes. Often dominating plant interspaces in arid regions, BSCs influence erosional processes, soil water movement, soil fertility, and seed germination. Soil lichen, mosses, and cyanobacteria fuse around soil particles creating a delicate desert skin that is highly susceptible to disturbance. Management of these crusts is often difficult, as the component organisms are easily overlooked and difficult to identify. In this research, we created a field-based map of BSCs within a portion of the Muddy Mountain Wilderness Area, NV. This map was compared with two remotely sensed maps, created by applying two established BSC indexes (Karnielli, 1997; Chen et al., 2005). These indexes were first tested using Landsat ETM (30 m resolution), while we tested these indexes using Quickbird® multispectral satellite imagery (2.44 m resolution). Both indexes were able to differentiate between crusts dominated by cyanobacteria and those crusts dominated by lichen and moss pinnacles. Additionally, the indexes were able to moderately differentiate between high moss/lichen cover and intermediate moss/lichen cover. From these initial results, it appears that the Karnielli (1997) index yields more consistent values for a 3-category mapping system. While index values may potentially yield BSC organism density results, field based mapping allows for the
differentiation of crust surface morphology. Future work includes the following: (1) Quantifying actual BSC organism densities and comparing them with the BSC index maps; (2) Collection of transect data to determine the factors influencing BSC distribution; (3) Comparing a geomorphic surface map to the field-based BSC map. This research has the potential to influence the management of BSCs in the Mojave Desert, where little is known about the factors influencing BSC distribution or how to efficiently map their occurrence in the landscape.

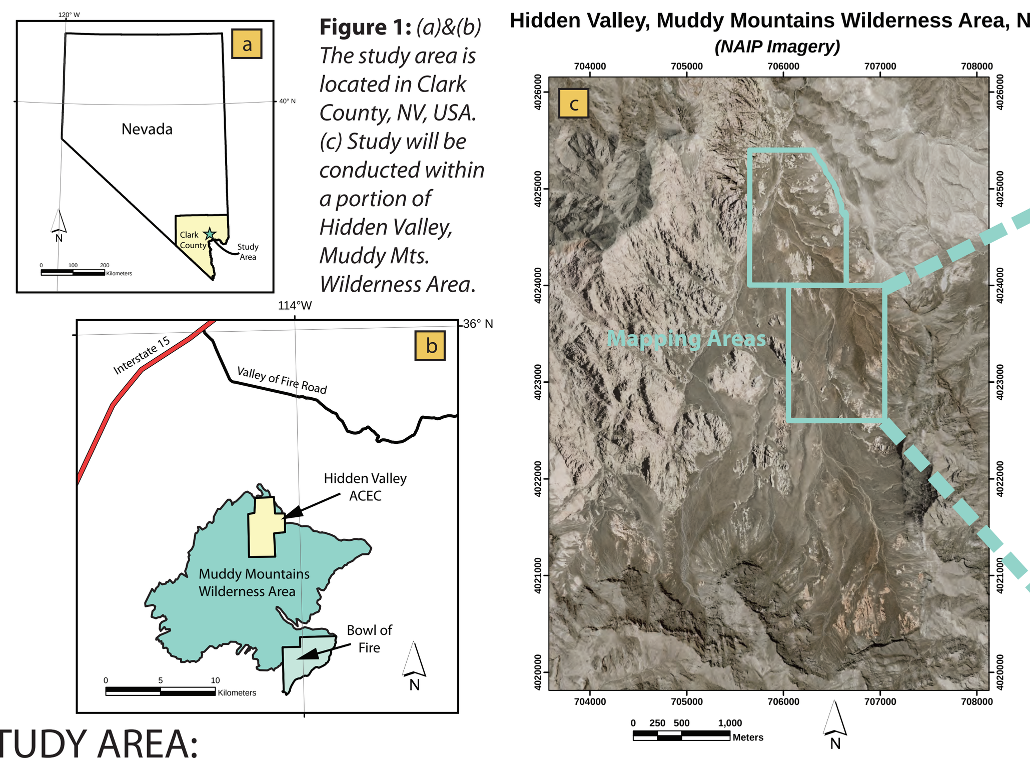


Figure 1: *(a)&(b) The study area is located in Clark County, NV, USA. (c) Study will be conducted within a portion of Hidden Valley, Muddy Mts. Wilderness Area.*

STUDY AREA:

- Mapping and research will occur in two subregions of Hidden Valley, within the Muddy Mountains Wilderness Area, in Clark County Nevada, USA. (Fig. 1)
- The valley is a pristine area with well-developed BSCs.
- Limestone and sandstone are soil parent materials that form 10 distinct geomorphic surfaces.

BACKGROUND:

- Biological Soils Crust (BSCs)
  - Matrices of mosses, lichen, cyanobacteria, fungi, bacteria, and algae (Friedmann and Galun, 1974). (Fig. 2)
  - Organisms fuse around soil particles to form a "DESERT SKIN" that prevents soil loss (Belnap, 1995).
  - BSCs fill plant interspace, covering up to 70% of the landscape in arid regions (Belnap, 1994). (Fig 2a, Fig. 3a)
  - BSCs prevent erosion (maintain native fertility), fix C and N, manage soil moisture, decrease annual weeds establishment (Eldridge and Green, 1994).
- Land Management Considerations: ***BSCS are...***
  - Extremely fragile (impacted by foot traffic, grazing, off-road vehicles)(Fig. 5),
  - Very Old; Late succession crusts develop over 10s to 1000s of years (Reviewed in Belnap et al., 2001).

QUESTIONS:

- What environmental factors correlate with the BSC distribution, density, morphology, and species composition within this site? (Factors to be investigated include surface clast morphology, soil texture, vascular vegetation, aspect/topography, solar radiation, soil EC.)(Fig. 4)
- Does geomorphic surface age control BSC distribution, density, morphology, and species composition within the study site?
- How accurately do the Karnielli (1997) spectral crust index and Chen et al. (2005) biological soil crust index reflect actual biological soil crust density within the study area? Can these techniques be used in place of field-based mapping? (Fig. 7c, 7d)
- Is the Chen et al. (2005) index a more reliable technique than the Karnielli (1997) technique for mapping the distribution of BSCs?

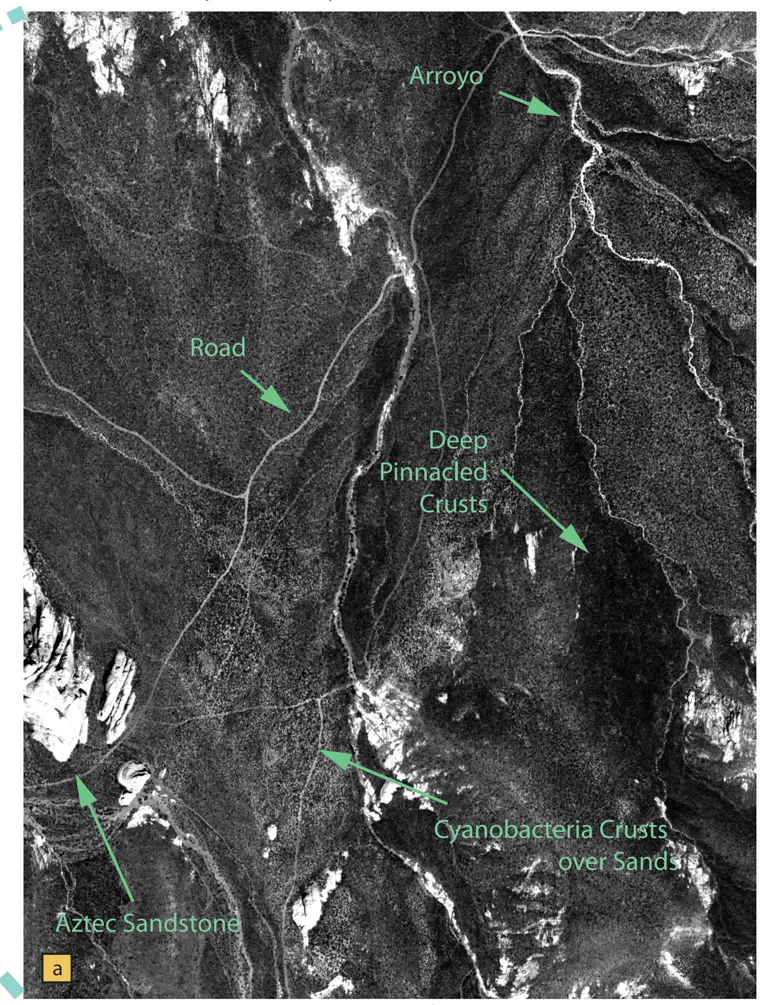


Figure 7(a): *Quickbird® panchromatic images served as base imagery for the field-based BSC mapping. Note the high spatial resolution (0.6 meter), and surface tone changes associated with pinnacled crusts.*

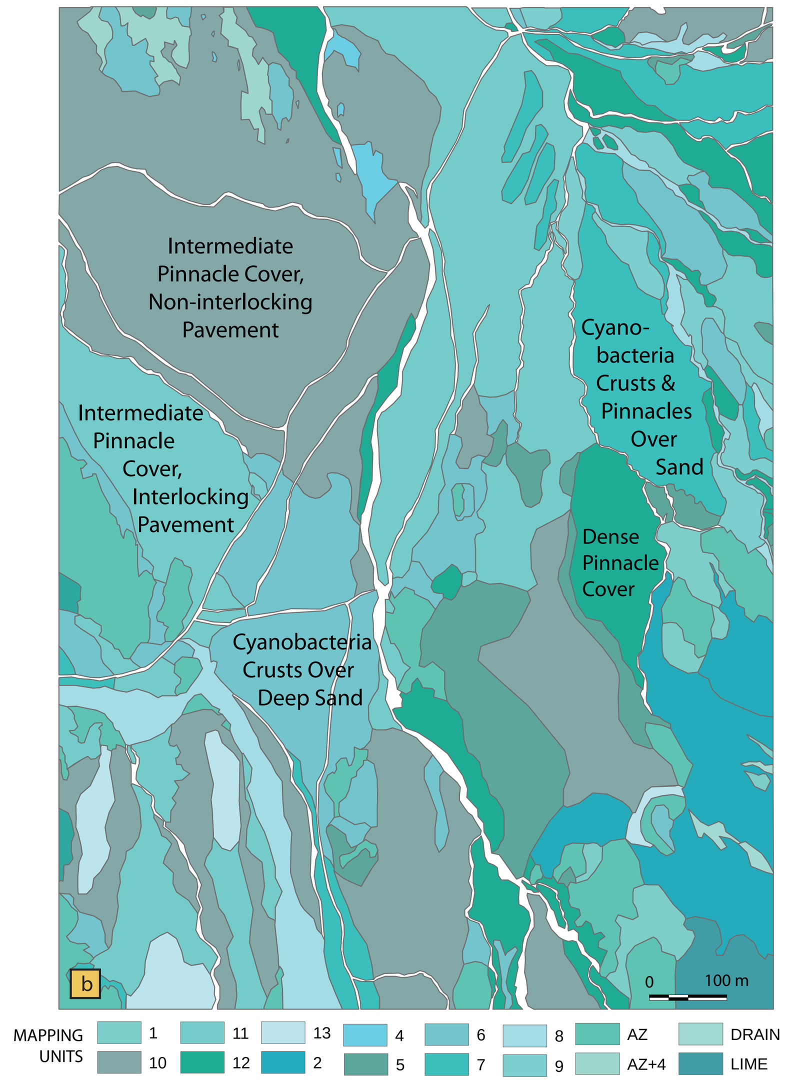


Figure 7(b): *The field-based map delineates unique BSC units, based on changes in crust density, distribution, morphology, and species composition. All map units and polygons were field verified. This BSC map contains 12 unique categories.*

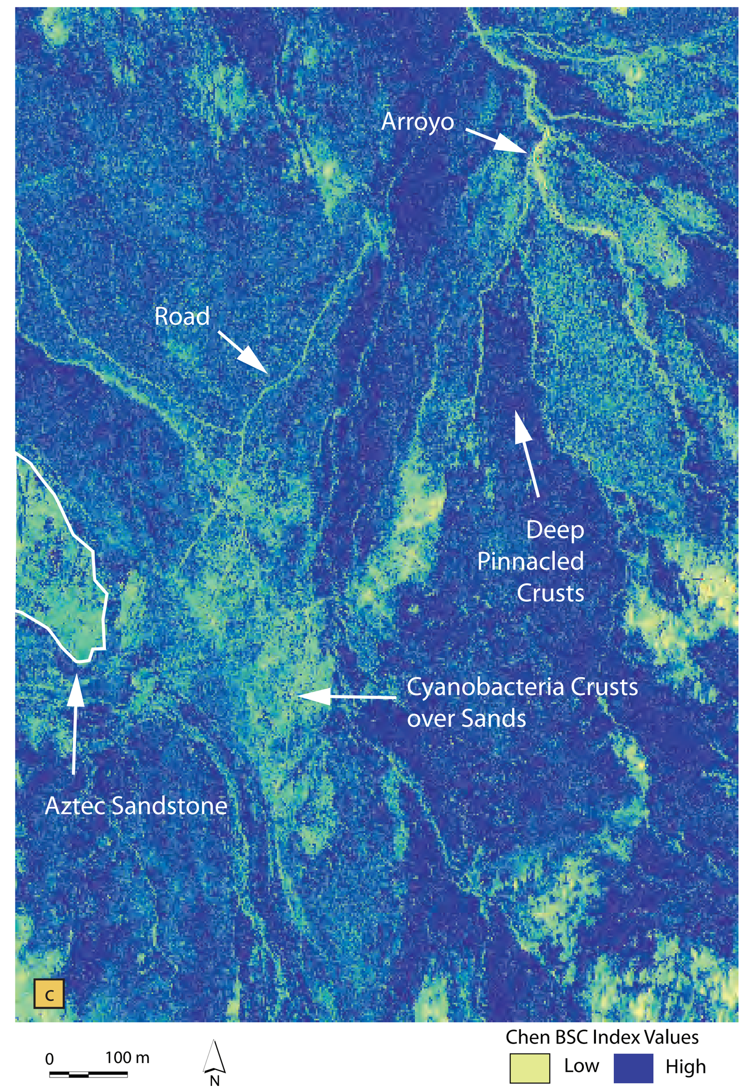


Figure 7(c): *The biological soil crust index was developed by Chen et al. (2005). This image was produced with Quickbird® multispectral imagery (2.44 m resolution), in contrast to the work by Chen et al. (2005) that applied Landsat ETM imagery (30 m resolution). This index was based on the unique spectral signature of pinnacled crusts.*

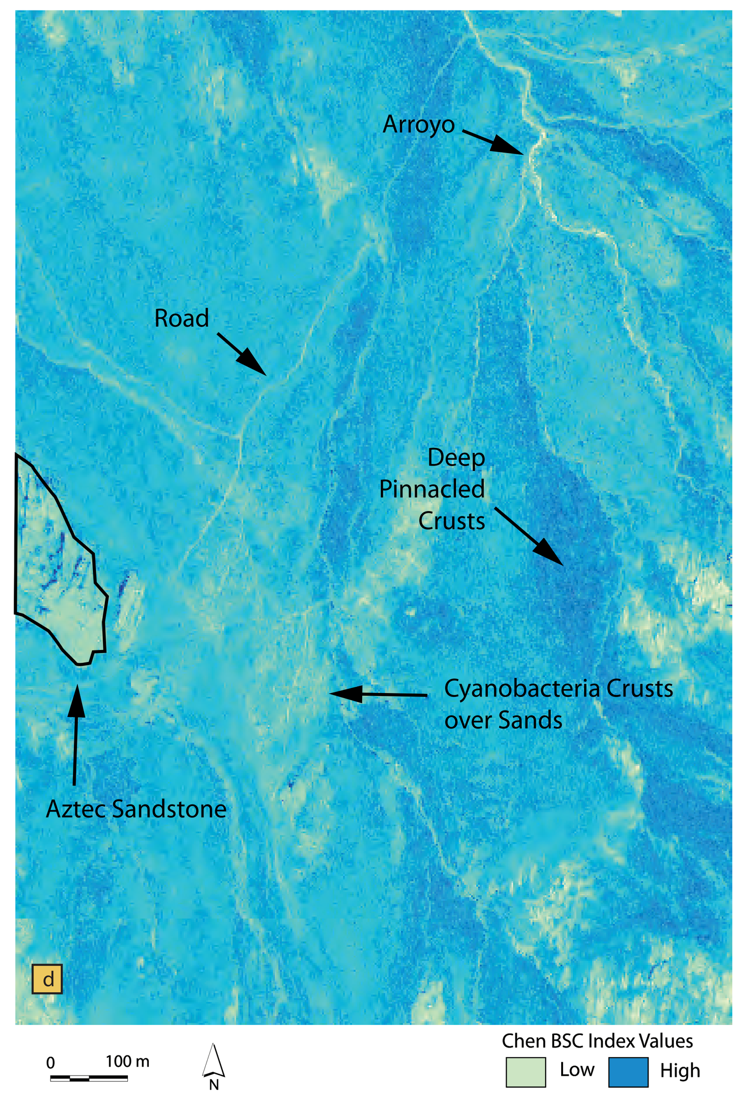
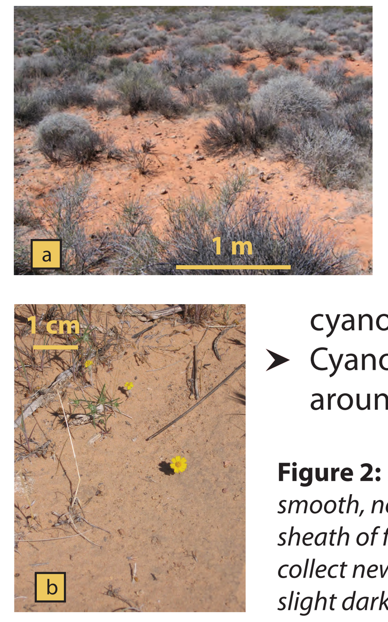


Figure 7(d): *The spectral crust index was developed by Karnielli (1997). This image was produced with Quickbird® multispectral imagery (2.44 m resolution, in contrast to the work by Karnielli (1997) that applied Landsat ETM imagery (30 m resolution). This index was based on the unique spectral signature of cyanobacteria crusts.*

TWO Morphologies of BSCs in the Mojave Desert:



1. Cyanobacteria Crusts:
   - 1st crusts to form, stabilizing the soil surface;
   - Primarily composed of filamentous cyanobacteria (Microcoleus sp.)
   - Cyanobacteria "move" to fuse around sediments.

Figure 2: *(a) Cyanobacteria form smooth, nearly invisible crusts. (b) Sticky sheath of filamentous cyanbacteria collect newly deposited sediments. (Note slight darkening of surface.)*

2. Pinnacled Crusts:
   - 2nd crusts to form, on stabilized surface;
   - Primarily composed of mosses, lichens, and existing cyanobacteria
   - Mosses and lichens are less mobile;
   - Density and surface morphology can be highly variable .

Figure 3: *(a)&(b) Pinnacled crusts form a dark, roughened surface in plant interspaces.*

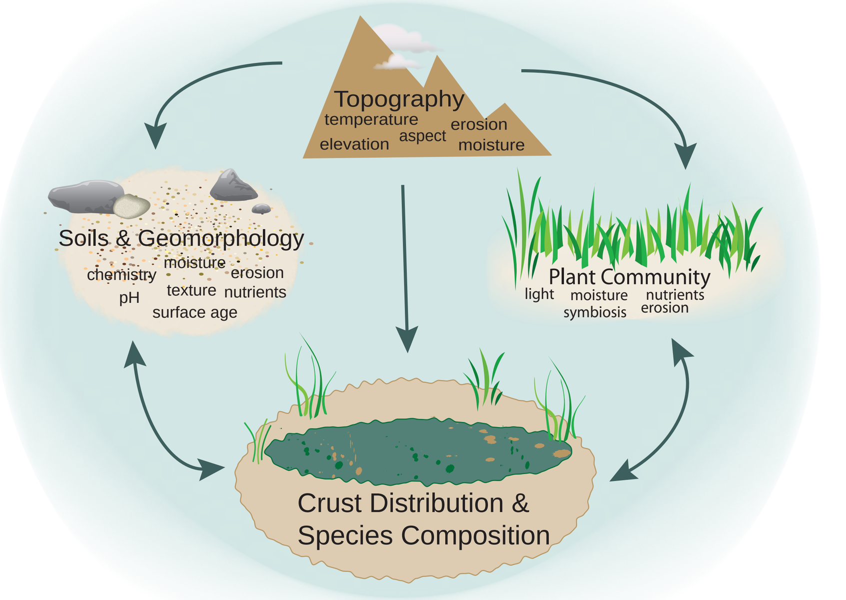


Figure 4: *Potential factors influencing biological soil crust distribution and species composition.*

Figure 5: *Tracks left by motorized vehicles scar the landscape within Hidden Valley, Muddy Mts. Wilderness Area, NV.*

Figure 6: *A dynamic alluvial history preserved: Hidden Valley contains 10 distinct geomorphic surfaces.*

METHODS & PROGRESS:

- Field-based BSC Map - *completed* (Fig. 7a, 7b)
- Field-based Geomorphic Map – *initial lines drawn*
- Transect Data Collection – *some transects collected*
- Soil Chemical Analyses – *to be completed*
- Crust Index Maps using Quickbird® Multispectral Data (2.5m resolution) – *completed* (Karnieli, 1997; Chen et al., 2005)(Fig. 7c, 7d)

INITIAL RESULTS:

- Environmental Factors:
  - Field-based BSC map represents crust species distribution, density, morphology, species composition. (Fig. 7b)
  - Field based map stratifies the landscape for transect data collection into 12 unique BSC mapping units.
  - Additional work includes transect Data concerning BSC characteristics, vegetation, surface cover, surface clast morphology, BSC species density, topography, and soil sampling for chemical analyses (pH, texture, EC).
- Geomorphology:
  - Study area contains 10 distinct geomorphic surfaces.
  - Finalized maps and transect data needed to verify correlation of geomorphic surfaces with BSC distribution, density, morphology, and species composition.
- Remote Sensing:
  - Both indexes (Karnieli, 1997; Chen et al. 2005) separate pinnacled and cyanobacteria crusts. (Fig. 2, 3, 7c, 7d)
  - Some delineation of crust density is visible. (Fig. 7c, 7d)
  - Indexes will likely yield 3 distinct mapping units.
  - Index reliability is greatly increased with the use of Quickbird® multispectral imagery (2.5m resolution) versus the Landsat ETM (30m resolution) used in previous studies.
  - Increased spatial resolution is key to effective crust index mapping, because BSCs usually occur in patches that are 1 to 4 meters in diameter. (Fig. 8)

INITIAL CONCLUSIONS:

- Quickbird® multispectral imagery (2.5m resolution) creates BSC index maps that are more accurate and reliable than maps created with Landsat ETM (30m resolution).
- Both remote sensing indexes show good potential for mapping BSCs into 3 categories that do not reflect surface morphology or stability.
- Field-based crust mapping reflects BSC distribution, density, morphology, and species composition in 12 mapping categories.
- Initial field surveys show there may be some correlation between geomorphic surfaces and BSC distribution.
- These crust indexes could potentially be used throughout Clark County, NV, as Quickbird® imagery is available to several government agencies.

Figure 8: *(a) BSCs often grow in patches 1 to 4 m in diameter, protecting interspaces from erosion. (b) BSCs grow around interlocking desert pavement clasts.*

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