“Exploring New Frontiers in Ecological Resources: Integration, Delivery, and Partnerships”

WESTERN REGIONAL COOPERATIVE SOIL SURVEY CONFERENCE

Telluride, Colorado

July 7-12, 2002

Western Regional Cooperative Soil Survey Committee Reports

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Western Regional Cooperative Soil Survey Conference 2002

"Exploring New Frontiers in Ecological Resources; Integration, Delivery, and Partnerships"

July 7-12, 2002
Big Billie Conference Room, Wyndham Peaks Resort, Telluride, Colorado

Sunday July 7, 2002

7:30am-12:30pm	Geomorphic Tour-San Juan Mountains	Rob Blair, Ft. Lewis College
2:00pm-4:00 pm	Registration	Foyer, Big Billie Room

Monday July 8, 2002

Moderator: Tim Sullivan

7:00am-9:00am	Registration	Foyer, Big Billie Room
9:00am-9:15am	Introductory Remarks	Bill Ypsilantis, BLM
9:15-9:30am	Welcome	Ann Morgan, BLM Colorado State Director
Agency Reports		
9:30am-9:45am	Agricultural Experiment Station	Bob Graham, University of California, Riverside
9:45am-10:00am	Bureau of Indian Affairs	Bob Hetzler, BIA
10:00am-10:30am	BREAK	
10:30am-10:45am	Bureau of Land Management	Bill Ypsilantis, BLM
10:45am-11:00am	National Park Service	Pete Biggam, NPS
11:00am-11:15am	Natural Resources Conservation Service	Berman Hudson, NRCS
11:15am-11:30am	Forest Service	Randy Davis, FS
11:30am-1:00pm	LUNCH	
Cooperator Reports		
1:00pm-1:15pm	Colorado Association of Soil Conservation Districts	Bob Zebroski, CASCD
1:15pm-1:30pm	National Society of Consulting Soil Scientists	Barry Dutton, Land and Water Inc.
1:30pm-1:45pm	Tribal Liaison Update	Marcy Arrowchis, NRCS
1:45pm-2:15pm	Geology of the San Juan Mountains	Rob Blair, Ft. Lewis College
2:15pm-2:45pm	BREAK	
2:45pm-3:15pm	Shoshone NF Terrestrial Ecosystem Unit Inventory	Kent Houston, FS
3:15pm-3:45pm	Update of Ecological Site Descriptions	Curtis Talbot, NRCS
3:45pm-4:15pm	Soil Quality Indicators in Rangeland	Arlene Tugel, NRCS
4:15pm-4:45pm	Soil Crust Taskforce Report	Janice Boettinger, Utah State

		University
5:00pm	Evening Reception/No Host Bar	Legends Room

Tuesday July 9, 2002

Moderator: Cameron Loerch

8:00am-8:30am	Soil Data Warehouse	Ken Harward, NRCS
8:30am-9:00am	Terrestrial Ecological Unit Inventory - Geospatial Toolkit	Haans Fisk, FS
9:00am-9:30am	Demonstration of TERRA/NRIS	Mike McArthur, FS
9:30am-10:00am	Development of GIS-based Soil Mapping Techniques in the Pacific Northwest	Alan Busacca, Washington State University
10:00am-10:30am	BREAK	
10:30am-11:00am	Interagency Applications of the Soil Data Viewer	Ken Harward, NRCS
11:00am-11:30am	Role of Biological Soil Crusts in Rangeland Health	Jayne Belnap, USGS
11:30am-1:00pm	LUNCH	
1:00pm-3:00pm	Committee Breakout Sessions	Group
3:00pm-3:30pm	BREAK	
3:30pm-3:45pm	Soils Field Tour Orientation	Bill Ypsilantis, BLM
3:45pm-5:00pm	Poster Session/Demo's	Big Billie Conference Room

Wednesday, July 10, 2002

8:00am-4:30pm	Soil Field Tour	

Thursday, July 11, 2002

Moderator: Craig Ditzler

Committee Reports		
8:00am-8:20am	New Technology Committee Report	Pete Biggam, NPS
8:20am-8:40am	Research Needs Committee Report	Gene Kelley, Colorado State University
8:40am-9:00am	Soil Survey Standards Committee Report	Duane Lammers, FS
9:00am-9:20am	Opportunities/Cooperative Agreements Committee Report	Cameron Loerch, NRCS
9:20am-9:30am	Group Discussion of Committee Reports	
9:30am-10:00am	BREAK	
10:00am-10:45am	Colorado River Salinity/Selenium Issues	Win Wright, USGS Karla Brown, Colorado State University
10:45am-11:15am	Rangeland Restoration Initiatives and Issues	Mike Pellant, BLM
11:15am-11:30am	National Soil Survey and Rangeland Ecosystem Classification Strategy	Bill Ypsilantis, BLM
11:30am-1:00pm	Luncheon, Alpenglow Room	Guest Speaker-Marilyn Colyer, Mesa Verde National Park

1:00pm-1:30pm	National Soil Survey Laboratory Update	Dewayne Mays, NRCS
1:30pm-2:15pm	Soil Survey: Becoming Relevant in a Changing World	David Hammer, University of Missouri
2:15pm-2:45pm	Tephra Workshop Overview	Duane Lammers, FS
2:45pm-3:00pm	BREAK	
3:00pm-4:00pm	Agency Breakout Sessions	Group
4:00pm-4:30pm	West Regional NCSS Business Meeting	Group
4:30pm-5:00pm	Meeting Wrap-up and Friday Field Tour Logistics	Bill Ypsilantis, BLM Pete Biggam, NPS

Friday, July 12, 2002

7:30am-5:00pm	Field Tour-Mesa Verde National Park	Pete Biggam, NPS Doug Ramsey, NPS Arlene Tugel, NRCS

Western Regional Cooperative Soil Survey
Standing Committee on New Technology

Report to the Western Regional Cooperative Soil Survey Conference
Telluride, Colorado
July 8-12, 2002

Pete Biggam, Chair, NPS, Lakewood, CO
Bill Ypsilantis, Vice-Chair, BLM, Lakewood, CO

Committee Members In Attendance

Janis Boettinger, Utah State University
Alan Busacca, Washington State University
Ed Bulloch, BIA
Jan Cipra, Colorado State University
Hayes Dye, NRCS
Haans Fisk, FS
Chuck Gordon, NRCS
Charles Hibner, NRCS
David Hoover, NRCS
Janelle Jersey, BIA
Earl Lockridge, NRCS
Tommie Parham, NRCS
Alan Price, NRCS
Doug Ramsey, NRCS
Tom Reedy, NRCS
Ken Scheffe, NRCS
Peter Scull, UC Santa Barbara
Dave Smith, NRCS

Background

This is a new Committee for the Western Region Cooperative Soil Survey, however, at the national level, there is a Standing Committee on New Technology currently active. This is the first time that this Committee has met, so it has no previous charges to react to, other than that of the "national charge" in regards to New Technology.

Initial Charges of West Region Standing Committee on New Technology

"To develop and document procedures, processes, and standards that will be used to integrate GIS, remote sensing, landscape modeling, and other similar technologies into the mainstream of the soil mapping and landscape inventory program"

Activities

1. Determined what/how issues regarding New Technologies can be adopted or included in the Western Region

a) Reviewed the 2001 report of the NCSS New Technology Standing Committee and determined which recommendations we might implement in the Western Region.

b) Also identified "new charges" which the group felt were needed to pursue for the initial stages of this committee's development.

2. Approved "New Charges" for the Committee to Pursue

a) ***Develop interest-oriented work groups charged with identifying new technologies that can be used to facilitate soil resource inventory, interpretation, information delivery, and agency implementation strategies*** **(Potential for 4 work groups)**

b) ***Each interest-oriented work group will also be tasked with identifying specific needs in soil resource inventory, interpretation, information delivery, and agency implementation strategies.***

c) Compile, regularly update, and communicate to committee members a list of conferences, training sessions, workshops, etc. on development and implementation of emerging new technology.

d) Develop and implement methods for interagency technology transfer in NCSS and report to the National Standing New Technologies Committee.

e) Charge all task forces/work groups in recruiting members, specifying objectives, and developing realistic time lines for meeting objectives

f) Evaluate progress of work groups and redefine charges as needed, at minimum of every two years at WRCSS conferences.

g) Committee Chair will recruit/appoint/solicit members from NCSS to participate in appropriate work groups as needed.

h) Committee Chair will develop a comprehensive report and provide a presentation at each Western Regional Cooperative Soil Survey Conference

Recommendations

This committee needs to aggressively pursue the recommended “new charges” in a timely manner, to “strike while interests are still high”

Communicate to the Standing Committee on New Technology with what the Western Region is pursuing, and coordinate with other Regional Cooperative Soil Surveys in regards to what they are doing regarding new technology.

Western Regional Cooperative Soil Survey
Conference Committee on Research Needs

"We need to recognize that as our understanding of the soil changes so must the soil survey. The "survey"is not static and is a product of an evolving scientific platform."

Examples of Relict Concepts

•Soil Depth

•Biologically Active Zone

•Biological Zero

What are the research needs of NCSS cooperators ?

•Research that will increase our understanding of the soil system & increase the utility of Soil Surveys

•Promote the "research continuum" understanding that Basic as well as Applied research is needed.

Try to highlight the interdisciplinary nature of Pedology

Major Issues

•Soil Survey and Environmental Needs.

•Carbon Sequestration

•Terrain Analysis and Soil Mapping

•Sub-aqueous Soils

•Deep Regolith

•Dynamic Soil Properties

•Model Development

Soil Survey and Environmental Needs (examples)

•Determine additional characterization needs.

•Retro-fit Soil Surveys (augmentation)

•Include remediation information

•Needs to be included in updates

Carbon Sequestration

1) Management Systems/Soil Types
2) Spatial extrapolation of C data
3) Develop C based conservation programs
4) Inorganic C inventory (updates)
5) define the limitations of current data and utility under "current regime".

Terrain Analysis and Soil Mapping

•Don't let this slip away

•Assist in Developing Protocols for mapping

•Utilize cooperators

•Push for new soil surveys and updates

•Essential for updates

- Attribute maps

Sub-aqueous Soils

1) need to develop prootcols
2) standards for characterization
3) environmental importance

Deep Regolith

1) how to investigate
2) need to develop standard methods for characterization and sampling
3) Retro- old soil surveys

Dynamic Soil Properties

1) test state transition model
2) ID key properties that reflect "ecosystem status" (e.g. Crust, agg stability)
3) 3)Investigate Microbial Populations (e.g. PLFA)
4) Fire influences
5) Develop "common vocabulary" (function is vague)

Model Development

1) develop models for characterization lab to assist in screening soils data
2) Physically based models to assist in mapping and interpretations

Recommendations

- NCSS needs to set priorities and commit to supporting Soil survey related research.
- Develop projects that allow NCSS to train future employees
- Make WRCC-93 permanent research committee by changing by-laws.
- Need to develop real funding opportunities

Western Regional Cooperative Soil Survey
Standing Committee for Standards

Report to the Western Regional Cooperative Soil Survey Conference
Telluride, Colorado
July 8-12, 2002

<u>2002 – Telluride, CO</u>

Steering committee appointed a Standing Committee for Standards (NSSH, SSM, ST).

Membership appointed by the Steering Committee

Duane Lammers, FS, Chair
Steve Park, NRCS, Vice Chair
Pete Biggam, NPS
Randy Southard, UC Davis

Membership appointed by the Committee Chair
Chad McGrath, NRCS
Tom Hahn, NRCS
Bill Johnson, NRCS
Neil Peterson, NRCS
Mike McArthur, FS

Table 1. Membership on the subcommittees

<u>Subcommittee on Soil Taxonomy</u>	<u>Subcommittee on SSM and NSSH</u>
Duane Lammers	Steve Park
Chad McGrath	Bill Johnson
Randy Southard	Neil Peterson
Tom Hahn	Mike McArthur
	Pete Biggam

Tasks given to the committee by the Conference Steering Committee

1. What roles and function should this committee have in the West Region?
2. Does the West Region Conference Bylaws specifically address this committee and its membership?
3. Review and discuss findings and recommendations of Soil Crust Task Force.
4. Review and discuss current proposals to amend Soil Taxonomy and make recommendations.
5. Prepare committee report.

Standards Committee Report on Tasks Assigned by the Steering Committee of the West Region NCSS Conference, 2002

Committee members participating in the Standards Committee meeting

Duane Lammers, FS, Chair
Randy Southard, UC Davis
Chad McGrath, NRCS
Tom Hahn, NRCS
Bill Johnson, NRCS
Neil Peterson, NRCS
Mike McArthur, FS

1. What roles and function should this committee have in the West Region?

a) The West Regional Standards Committee serves as a technical advisory committee to the National Leader for Standards. Committee tasks are assigned by the Conference Steering Committee for the West Region.
b) The Committee represents West Region interests on proposed changes to standards.
c) The Committee reviews proposals on changes to NCSS standards including Soil Taxonomy, National Soil Survey Handbook, Soil Survey Manual and makes a recommendation on approval.
d) The Committee serves as a forum for new issues and recommends action to address these issues.
e) Two members of the Committee represent the West Region on a National Standards Committee.

The committee recognizes the need for review of proposed changes to NCSS standards, but also acknowledges the challenge to members of finding time to read and evaluate proposals. By accepting an appointment to this committee, members have accepted responsibility to review proposals. Because this is an additional workload, the effort needed to adequately address proposed changes should be kept to a minimum.

To facilitate review by committee members, it is recommended that staff at the NSSC conduct the following tasks for change management of NCSS standards:

1) Assist in drafting proposals, to ensure they are technically correct, within principles and guidelines for NCSS standards and consistent across all published standards (e.g. SSM and NSSH);
2) Write a narrative that discusses rationale, identifies potential concerns (e.g. departure from principles, inconsistency in terminology) and lists impacts of the proposed change (e.g. number of series, regions impacted, interpretations, NASIS data dictionary, guide for describing soils);
3) Post proposals to a web page and distribute a memorandum to cooperators that lists proposed changes, web address and reply due date;
4) Compile and review comments on the proposals and writes a reconciliation statement that addresses the comments on each proposal;
5) Distribute compiled comments and reconciliation statements to Standards Committees in all four Regions for review and recommendation for approval

6) Facilitate communication among Standards Committees in the four regions, and resolution of recommendation for approval or disapproval of proposed standards
7) Coordinate implementation of the final version into all appropriate documents, databases, etc.

2. Does the West Region Conference Bylaws specifically address this committee and its membership?

Not specifically! The Bylaws say that the Conference Steering Committee determines the standing committees and appoints a Chairperson. The Chair in-turn selects committee members. It is probably not necessary for the Bylaws to specifically address this committee and its membership.

This Standards Committee recommends that:

1. membership on the committee be for a period of six years and rotate with two or three new members added each year and a like number retired from the committee.
2. Standards committee members be assigned to one of two subcommittees: (1) a Soil Taxonomy subcommittee, and (2) subcommittee to review proposed changes NSSH and SSM.
3. proposals for changes to standards will be received for review in April and November of each year; and about three months be allowed for each review process.

The following text documents how the Bylaws of the Western Region address standing committees:

Bylaws, revised in 2000, with reference to establishment of permanent standing committees to bylaws of the National Conference:

> *Permanent standing committees are established by the By-laws of the National Cooperative Soil Survey Conference as contained in the NSSH Part 602.00 and Exhibit 602-1.*

Bylaws of the National Conference do not establish specific standing committees; it directs how they are established and how committees conduct business.

> Article VIII. Committees
>
> *Section 1.0 -- The committees of the Conference shall be determined by the Steering Committee. Permanent or standing committees, ad hoc committees, and task force groups are considered to be committees of the Conference. The Steering Committee shall select committee chairs.*
>
> *Section 2.0 -- Committee members shall be selected by the committee chairs. Committee members shall be selected after considering Steering Committee recommendations, Regional Conference recommendations, individual interests, technical proficiency, and continuity of the work. They are not limited to members of the National Cooperative Soil Survey.*
>
> *Section 3.0 -- Each committee commonly conducts its work by correspondence among committee members. Committee chairs shall provide their committee members with the charges as assigned by the Steering Committee and procedure for committee operation.*
>
> *Section 4.0 -- Each committee chair shall send copies of a draft committee report to the Steering Committee prior to the Conference*

Section 5.0 -- Each committee shall report at the Conference

3. Review and discuss findings and recommendations of Soil Crust Task Force.

The Soil Crust Task Force Report was presented to the Standards Committee, by Arlene Tugel, during the two-hour committee break-out session at the conference.

In the limited time for discussion, several issues surfaced concerning description of biological soil crusts.

- Are biological soil crusts plants, soil or combination of both?
- Is it appropriate to think of these crusts as plant communities with potentials, state and transition?
- Should aerial extent be monitored to determine disturbance from footprints or tire tracks?
- How would biological crusts be described in map units, if they have been obliterated in one area and undisturbed in another area of the same polygon or map unit?
- Can we afford the additional cost of describing biological soil crusts in standard soil surveys?

The Standards Committee recognizes that a standard protocol for identification and description of biological crusts is needed and recommend that this protocol be proposed as a change to the Soil Survey Manual. The Committee also supports incorporating field methods with those for other surface features. These methods may be appropriate as an appendix to the Manual or as a section on field methods for surface features. Methods for monitoring soil compaction, soil displacement, or other soil disturbance are similar to monitoring for soil crusts. Data elements will need to be added to the Field Guide for Describing Soils and data fields added to NASIS.

The Standards Committee does not unanimously agree that collection of biological soil crust information is a soil survey activity. Biological crusts are susceptible to disturbance. The present condition (kind and occurrence) could be monitored like is done with present vegetation and soil disturbance.

The Committee recommended that description of biological crusts be attempted on a few progressive soil surveys to evaluate the utility of collecting these data.

The concept of a potential biological crust with state and transition needs evaluation. A potential crust could be correlated to map unit components of soil survey.

Extent of biological crust degradation as an indicator of a threshold to ecosystem integrity is worthy of further development.

Although text has been written for the Soil Survey Manual, there is no indication of where this fits or how it affects other text in the Manual. The Manual makes reference to transect methods to determine surface features, and also to determine map unit composition. Clarification is needed. Can the two be combined into one field effort? Rock outcrop and badland are miscellaneous areas (i.e. map unit components); bedrock is listed as a species code for a soil surface feature. Not a good idea. Roughness is being used to refer to crust micro-topography. Roughness is already defined in the Manual. The ocular method for collecting crust information was not included in the report.

The Committee recommends the Soil Biological Crust Task Force work closely with Soil Survey Standards staff to clarify terms and to incorporate soil crust methodology in the SSM.

4. Review and discuss current proposals to amend Soil Taxonomy and make recommendations.

Proposals for changes to Soil Taxonomy have been distributed and reviewed by committee members. Steve Park compiled concerns and recommendations. The committee will deliver recommendations to the National Leader for Taxonomy and Standards by August 9.

5. Prepare committee report.

So Done.

Western Regional Cooperative Soil Survey
Conference Committee on Partnering Opportunities

Report to the Western Regional Cooperative Soil Survey Conference
Telluride, Colorado
July 8-12, 2002

Cameron Loerch, Chair, NRCS, Lakewood, CO

Committee participants:

Phil Camp, NRCS, AZ
Clarence Chavez, NRCS, NM
Don Fallon, USFS, UT
Bob Hetzler, BIA, AZ
Bill Puckett, NRCS, AL
Jim Ware, NRCS, NHQ
Darrell Schroeder, NRCS, WY
Mike Pellant, BLM, ID

Charge: Compile success stories concerning new opportunities for funding and cooperative agreements within the NCSS.

Discussion centered around the following issues:

- Are there new and better ways of doing business?
- Soil Survey Production (inventory activities, data collection, correlation)
- Expanding use of technology tools.

We made an attempt to identify barriers that currently exist or are percieved:

- Related to meeting NCSS Standards
  - Database requirements such as data populated in NASIS
    - The National Soil Survey Handbook is being revised to indicate that NASIS is the official NCSS database for soils.
  - Private lands – there are mandatory needs for USDA programs, CST
  - Public lands - may need some flexibility in interpreting correlation requirements
    - What is enough data to correlate and interpret.

    (Some MO's have now prepared minimum documentation requirements in NASIS related to correlation of surveys, private and public.)
- There are parallel efforts going on with database development
  - NASIS and TERRA
  - We need to continue to find ways to work together at the field level to meet the needs of agencies working with in the NCSS.

The definition of a "standard soil survey" was agreed to as meeting NCSS standards and being correlated to those standards.

- Issue: there is some inconsistency in applying the standards

For proceedings: Capture success stories from balance of conference members:

Identify what accomplished
What process
Examples of product
Contracts, Agreements
Budgets
What to avoid

Committee Recommendations:

- Keep partnering as a committee.
- Continue to have presentations on Partner successes.
- Identify Barriers and come up with strategies to Address them.
- Advertise to line officers our cooperative successes.
    - Direct information to RO/STC/STD/Dept. Head
- Expand the partners:
    - Extend invites to Nature conservancy, ARS, Military, Tribes, City, County, SCD, etc.
- Work to fill holes in database with:
    - Reimbursable's, Private Sector,
- Develop or design a listing of Interagency Govt service contractors that are approved by the agencies.
- Develop a Certification Process for Mapping Soil Scientists:
    - Consider NSCSS as a certifying body.
- Shared Correlator Position's between Forest Service/NRCS and others.
- Treat this session as a beginning.
- Continue committee efforts as a means of information transfer.
- Tools out there, People are there, now lets use them.

Report and Recommendations of the Soil Crust Task Force

West Regional Soil Survey Conference
6-28-02 Presented July 8, 2002
Telluride, CO

Chair: Arlene J. Tugel
atugel@nmsu.edu

Co-Chairs: Janis Boettinger, Tom Reedy

Task Force Members

Dr. Jayne Belnap, Research Ecologist, USGS, Moab, UT
Pete Biggam, Soil Scientist, NPS, Denver, CO
Dr. Janis Boettinger, USU, Logan, UT
Bill Broderson, State Soil Scientist, NRCS, Salt Lake City, UT
Bill Johnson, Soil Scientist, MO8, NRCS, Phoenix, AZ
Mike Natharius, Soil Scientist, USFS, Silver City, NM
Steve Park, Soil Data Quality Specialist, MO6, NRCS, Lakewood, CO
Vic Parslow, Soil Scientist, NRCS, Richfield, UT
Doug Ramsey, Project Leader, NRCS, Cortez, CO
Tom Reedy, Soil Scientist, National Soil Survey Center, NRCS, Lincoln, NE
Pat Shaver, Range Mgt. Spec., Grazing Lands Technology Institute, NRCS, Ft Worth, TX
Arlene Tugel, Soil Scientist, Soil Quality Institute, NRCS, Las Cruces, NM
Bill Ypsilantes, Soil Scientist, BLM, Denver, CO

Charges

1. Identify agencies' needs and potential uses for biological soil crust information.
2. Locate areas to test soil crust identification and definition criteria in the field.
3. Develop and test the process to describe soil crusts.
4. Prepare recommendations and report to be presented to the West Region Cooperative Soil Survey Standards committee.

Part I Executive Summary and Recommendations

The Soil Crust Task Force was established in response to a proposal from the West Regional Cooperative Soil Survey Conference, Coeur d'Alene, ID, 1998 and the rangeland health/soil quality indicator needs on rangelands. The Task Force conducted the initial field test of methods to be used to describe biological soil crusts for soil survey activities in Moab, Utah, May 6-9, 2002. Cover methods were developed by biological soil crust expert, Dr. Jayne Belnap, Research Ecologist, USGS, Moab, UT, Arlene Tugel, NRCS Soil Quality Institute, Las Cruces, NM and Dr. Jeff Herrick, ARS Jornada Experimental Range, Las Cruces, NM. Dr. Belnap provided training and technical guidance during the week and led a tour of the variety of soil crust types and associated soil parent materials typical of the Colorado Plateau. Arlene Tugel led the field test of four methods for measuring soil surface cover of biological crusts. Task Force members developed examples of soil profile descriptions that characterize biological crusts. Pat Shaver, Grazing Lands Technology Institute, NRCS made a presentation on State and Transition Models, a decision aid for land managers that explains vegetation dynamics and recognizes that disturbances can affect dynamic soil properties as well as the plant community. The Bureau of Land Management, National Park Service, Forest Service, US Geological Survey, and Natural Resources Conservation Service representatives described agency needs for soil crust information.

There was 100% agreement among the Task Force Members that biological soil crusts are important and their identification and description should be included in soil survey. Crusts perform valuable functions in soil stability, nutrient cycling and the hydrologic cycle and information is needed in agency programs. The Task Force suggested and agreed that information on all surface features important for soil surface resistance to erosion, raindrop interception and runoff, not just biological crusts, should be gathered in soil survey work.

Recommendations made by the Task Force are listed below. Part II fully discusses the Task Force response to each charge. Part III summarizes research needs, action items and additional charges that need to be addressed. Part IV lists resources for additional information. Part V, Appendices, includes the list of agency needs, a Soil Survey Manual draft, the surface cover methods, soil descriptions and photos.

Recommendations

1. **Biological crusts are important and their identification and description should be included in soil survey.**
   The attributes of crusts that the task force identified as important to measure are, at minimum: percent cover by morphological group (moss, lichen, cyanobacteria – light vs. dark) and surface roughness/surface relief (organism neutral). Other important features are the location of crusts in relation to canopy cover and color of crust organisms.
2. **Alternative approaches to incorporating crust morphology (vertical and horizontal) into a soil description must be developed and evaluated.**
   Suggested alternatives are 1) an A horizon with biological crust or 2) a surface feature that is a part of the profile description. See Appendix 4 for example profile descriptions.
3. **All surface features (e.g., biological, physical and chemical crusts, bare ground, rock fragments, litter and plant bases) should be included in soil surface cover methods. Protocols are needed for soil survey.**
   By including all surface features that relate to soil surface stability, runoff and infiltration in one transect, the surface feature method: 1) collects data valuable for functional interpretation, 2) increases efficiency of data collection, and 3) facilitates the development of a nationally applicable transect spreadsheet in which statistical analyses can be performed. "Guidelines for describing soil surface features" (ver. 2.0) were modified after the test in Moab and incorporate this recommendation (Appendix 3). Additional criteria for physical and chemical crusts must be included.
4. **Appropriate surface cover methods should be identified in the standards and specifications for each soil survey based on considerations of workloads and interpretation needs. The methods (Appendix 3) and their suggested uses are:**
   a) **Ocular estimates (Method 5) of total biological crust cover (0, 1-5, 6-25, >25%) and presence or absence of dark cyanobacteria, lichen, or moss will be recorded in field notes;**
   b) **Line-point transects (Method 4) will be used to measure surface features at typical pedons and for map unit component documentation. Transects will be georeferenced.**
   c) **Photographic documentation of surface features will be taken at pedons and georeferenced.**
   d) **Quadrats (Methods 2 and 3) have value for training and calibration and can be ideal methods in ecosystems other than those tested in Moab.**
5. **New crust data elements developed must be added to soil survey databases (National Soil Survey Information System, NASIS).**
6. **Soil surface cover and soil description methods must be tested on other types of biological crusts in other physiographic/ecological regions, including the Chihuahuan Desert, Sonoran Desert, Mojave Desert, Great Basin and short grass prairie.**

7. **Biological crust training for agency personnel is needed. Multi-agency support for this training is encouraged.**

Part II. Report on Charges

CHARGE 1. Identify agencies' needs and potential uses for biological soil crust information.

1. Needs and uses. A full list of needs and potential uses presented by agency representatives is in Appendix 1. Agencies either currently use or plan to use biological soil crust information in a variety of activities including NEPA documentation, soil survey, ecological site descriptions, state and transition models, information and education programs, inventory and monitoring (National Resources Inventory, biological inventories), rangeland health and soil quality assessments of ecosystem processes, and possibly as vital signs or threshold indicators for ecosystem processes.

Task Force Participants also identified needs for information and research. Information about where and when crusts are a management consideration is needed. We know that biological crusts help stabilize soil and protect it from both wind and water erosion. Crust organisms fix carbon and some crust organisms fix nitrogen for plant growth. They also provide sites for trapping seeds and can effect infiltration in a variety of ways, depending on soil texture and surface roughness. Crusts may not be as important in some ecosystems as in others. Inventory data showing where different types of crusts occur is needed. Research conducted in a variety of ecosystems will add valuable information to our current knowledge of the importance of biological crusts in different ecosystems. Research topics include 1) the role of biological crusts in soil surface stability, mineral cycling, and water cycling, 2) the use biological crusts as a threshold indicator, and 3) the effects of management on biological crusts and the functions they perform.

Specific needs include protocols to describe crusts, a simplified photographic field guide of crusts, a simplified guide for NEPA documentation such as a checklist or flow chart and training available to field personnel of all agencies. Multi-agency support ($$$) is needed for training. A database that links biological crust information to soil properties, site characteristics and location is needed.

2. How can soil survey address biological soil crusts (BSCs)? All task force participants agreed that BSCs were important for understanding soil function in an ecological context, and agreed that a minimum set of data on BSCs should be included in standard soil survey methods. In the next phase of the National Resources Inventory (NRI), NRCS intends to gather line-point intercept data to monitor a variety of properties, including biological soil crusts, that reflect ecosystem functions. This data will be tied to soil map units. If BSC occurrence and characteristics can be linked to soils data, we have the potential to develop and test predictive models.

However, many participants were concerned with the increasing amount and diversity of data required for soil and site descriptions. Depending on the difficulty of excavation and soil depth and complexity, one whole day could be spent on pedon morphology without addressing BSCs. Therefore, we must 1) identify which BSC attributes are most important for understanding ecological function, and 2) determine the most efficient methods for collecting a standard data set characterizing these attributes. The most important BSC attributes and their priority are listed in Table 1. Brief explanations of why the attribute is important are provided for each.

- **Surface roughness.** Surface roughness has implications for infiltration and surface runoff. For example, a high degree of surface roughness can slow runoff and increase infiltration.

- **Cover by morphological groups of organisms.** Moss, lichen and cyanobacteria (light and dark) are three different morphological groups. Morphological group cover has implications for soil stability and nutrient cycling. Crusts containing mosses and lichens are more stable than crusts dominated by cyanobacteria. Cyanobacteria crusts stabilize soil better than bare soil. Mosses and lichens fix more carbon than cyanobacterial crusts. Some lichens and cyanobacteria fix nitrogen. The terms morphological and functional are often used interchangeably. Morphological group is preferred for our purposes. The term functional, if applied to crust organism groups, can be confusing in relation to N fixation. Some species of cyanobacteria and some types of lichen (gelatinous) fix N, but not all species. So, not all lichens function the same way in regards to N-fixation, but both cyanobacteria and gelatinous lichen do.

- **Spatial distribution in relationship to plants.** Spatial distribution provides information about soil-plant relationships and can be used to infer disturbance effects on soil stability and resistance to erosion (e.g., BSC concentrated under shrubs indicates that soil under plants is more resistant to surface erosion than soil in the interspace between plants). Although spatial distribution can be very site-specific and related to land management practices or intensity of use (e.g. heavy use by wildlife, livestock or humans), it is a dynamic soil property that is important for state and transition models, assessments and monitoring programs. Spatial distribution of total crust cover can be documented qualitatively with photo-documentation, and provides a good historical record, but photo resolution may not be high enough to distinguish morphological groups. Quantifiable methods such as transects provide information for each morphological group in relation to canopy.

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Table 1. Biological Crust Attributes and Their Importance.

Priority	Attribute	Function or Importance
1 – high	Surface roughness	Runoff and infiltration
2 – high	Cover by kind (CYN, LIC, MOS) and total cover	Soil stability, nutrient cycling, infiltration
3 – medium	Location of crust in relation to canopy cover	Disturbance impacts, soil stability
low	Color of biological crust organisms	Genus or species present, N-fixation potential

3. Properties related to crust occurrence and function. We also discussed specific soil properties that research indicates are related to biological crust occurrence and function. Some of these are also important for interpreting the resistance and resilience of biological crusts to disturbance. Important properties are:

- **Texture:** It is unlikely that lichens and moss will occur in the interspace on extremely sandy soil because the shifting sands may not provide a stable enough substrate for organism colonization and growth. However, cyanobacteria will generally occurs on sandy soil. Biological crusts can also facilitate trapping of fine particles, evidenced by finer texture in the upper few mm of soil. Texture can determine whether a biological crust increases or decreases infiltration.
- **Major cations:** An abundance of cations (ie. Ca, K) in soil may facilitate BSC colonization and morphological composition. Because BSCs play an important role

in nutrient cycling, the presence and morphological composition may also influence the vertical distribution of major cations in soil.

- **Carbonates and gypsum:** It is likely that soil chemical constituents influence BSC morphological composition. For example, we observed the most developed and morphologically diverse BSC community on gypsiferous soils.
- **pH:** Soil reaction likely influences BSC morphological composition. Dr. Belnap has observed cyanobacterial crusts occurring at pH 7.0 to 10.5. At pH less than 7, green alga crust occur. BSC can also influence the vertical distribution of soil pH; Dr. Belnap observed a pH of 10.5 in the upper 0.5 mm of soil with a biological crust.
- **Physical and biological crust relationships.** Biological crusts often form on physical crusts. The effect of biological crusts on infiltration can be confused with the effect of the underlying physical crust on infiltration. The role of biological crusts in the breakdown of physical crusts in not known.

CHARGE 2. Locate areas to test soil crust identification and definition criteria in the field.

1. Locations. Six regions where biological crusts are dominant features on the landscape are the Colorado Plateau, Chihuahuan Desert, Sonoran Desert, Mojave Desert, Great Basin, and short grass prairie. Biocrust organisms (moss, liverworts) also occur in more humid environments but their ecological importance in these systems is unknown. The dominant morphological group varies among the six regions. This initial field test was conducted in the Colorado Plateau where pinnacled crusts (Appendix 5, photo) of cyanobacteria and lichen are prevalent. Additional tests are needed in other regions where crust composition and morphology are different.

2. Terminology and fundamental information. A draft Soil Survey Manual document "Biological Soil Crusts" (Belnap and Tugel) was prepared to provide fundamental information and terminology for biological crusts in soil survey (Appendix 2). The occurrence of crusts in arid regions and their composition are described. The importance and types of biological crusts, their relation to physical crusts and their distribution are also discussed.

CHARGE 3. Develop and test the process to describe soil crusts.

Methods for measuring soil surface coverage of biological crusts (total and by morphological group) and cover stratified by canopy were tested on the Colorado Plateau. Soil scientists also prepared descriptions of the pinnacled crusts at this site to illustrate the variety of ways that pinnacled crusts can be described. The results of these activities are discussed below.

1. Cover. The Task Force tested four methods (Appendix 3) in Moab, UT where pinnacled crusts of dark cyanobacteria and lichens are the dominant crust type. The step-point, ocular estimate with quadrats/transect, line-point quadrat methods were used to estimate or measure biological crust cover. The line-point intercept method from the Montioring Manual for Grassland, Shrubland and Savanna Ecosystems (Herrick et al., in press) will be a part of NRI and was slightly modified for this test for soil survey purposes. It can be used to measure biological crust cover stratified by canopy. Results of the test are reflected in the recommendations. The following are comments by task force members on the four test methods for evaluating cover:

Step-point (Method 1)

- Destroyed what you were trying to look at
- Repeatability limited because of destruction from steps

- Hard to maintain a straight line around vegetation. The tendency would be to walk around and avoid dense or thorny plants, thus biasing the results.
- Had to bend down and look at tiny crust features, didn't look as closely as for other methods
- Fast
- Easy to get randomness and lots of points in areas with low vegetation cover

Ocular estimate with quadrats (Method 2)

- Need to get calibrated each field season before using with confidence. FS uses a modification of this method now.
- Fast
- Has training and calibration value

Line-point quadrat (Method 3)

- Rapid
- Easy
- Seems fairly accurate
- Has value in teaching crust organisms and for calibration

Stratified line-point intercept (Method 4)

- Method is used in monitoring (part of NRI protocols)
- Seemed less appropriate for determining morphological composition of biological crusts than quadrat methods in this ecsosystem
- If one goes to trouble to set up line, take as much info as possible (i.e., rock fragment cover, etc.)
- Once line is set up, fairly rapid
- Need to emphasize that you have to get down and look closely at the organisms.
- Can obtain information on spatial patterns (i.e., crusts associated with canopy/no canopy or with plant species).
- May be most appropriate for determining soil surface cover for typical pedons, not day to day mapping

We then asked the question, which methods, if any, would you use in day-to-day soil mapping activities? Those task force members who work primarily in the field stated they would probably use an ocular estimate method, unless required to do otherwise by superiors. All recognized the importance of using a more reliable method. But, they admitted that time was limited and there was already an abundance of data to collect in pedon and site descriptions. In order to insure that inaccruate values of crust cover by morphological group were not made by ocular estimate, the group agreed to the need for a fifth method. Ocular estimates (Method 5) of total biological crust cover will use four cover classes (0, 1-5, 6-25, >25%) and simply indicate the presence or absence of dark cyanobacteria, lichen, or moss. The stratified line-point method was the preferred method for data collection at pedons and for ecological sites.

Because of workload considerations, some members of the Task Force suggested that ocular estimates of total biological crust cover be recorded in field notes and line-point transects be used to measure all surface cover features at typical pedons for initial surveys. For update soil survey operations, use line-point transects of all soil surface cover features for all map units and their components and georeference and photograph the profile and surface features.

Because of ease of use and the variable nature of the distribution of crusts, some methods are better suited than others to specific situations. Dr. Belnap suggested that the line-point method is best suited where there is >25% shrub or tall grass cover, OR where patches of biological crusts are widely scattered. The quadrat/transect method (framepoint) is best suited to the Colorado Front range, bunchgrasses, OR where shrub cover is < 25%.

2. Soil descriptions. A significant amount of our discussion focused on how best to accurately and efficiently describe biological crusts in the context of a pedon and site description. Some argued in favor of describing the BSC as a horizon feature. Others argued that BSC should be described solely as a surface feature. Most acknowledged that it may be possible to describe BSCs as both surface and horizon features.

The task force broke into groups and each was charged with describing a soil that had a well developed, pinnacled biological crust. The descriptions are in Appendix 4. The first group treated the biological soil crust primarily as a horizon feature. Because the BSC was very highly pinnacled, soil depth to hard bedrock was 8 cm measuring from the valleys between pinnacles and13 cm measuring from pinnacle tops. Therefore, they described the crust as an A horizon from 0 to 3 cm, ranging in thickness from 1 to 5 cm, and used the mid-point of the crust as the effective soil surface. They noted “pinnacled” in the “accessory property” column of the soil description form (R3-FS-2500-6). They noted the average width of and distance between pinnacles, and the morphological groups of organisms present.

The second group also focused on the biological crust as a horizon, describing “pinnacled” vs. “non-pinnacled” areas. Measuring up from the lithic contact, they described two A horizons separated by a broken boundary. The A1 was the pinnacle itself, which had a high concentration of biological crust material, and the A2 was the thin crust between pinnacle, with a high concentration on undifferentiated material (physical crust and light cyanobacteria crust). They suggested describing biological crusts similarly to ped and void surface features (page 2-24 of <u>Field Book for Describing and Sampling Soils</u>). Filaments and sheaths of crust organisms would be described similarly to roots in the soil matrix.

The third group focused on the biological soil crusts as a soil surface feature. They first identified the type as “pinnacled. The measured the vertical (height of pinnacles) and horizontal (length and width) dimensions. They suggested describing size classes, similar to classes of blocky or prismatic soil structure. Cover by morphological group, average color for pinnacle and inter-pinnacle space, location on the soil surface, thickness of the “rind” (crust), and surface roughness could be described. This group identified the soil surface (0 cm) at the valley (lowest part) between the pinnacles.

The last group acknowledged that there was merit in describing the biological crust as both a horizon and a soil surface feature. Because some important information may be lost if the crust is lumped with underlying soil, a 1-cm crust was split out and the pinnacle height was included in the range of horizon thickness. They suggested that the surface of the soil (0 cm) could possibly start at the base of the “rind” (crust), but most others did not agree. The crust could be identified with a special suffix in the horizon designation (“u” for cr<u>u</u>st, for example). Soil surface spatial features should also be described; a table for all types of soil crusts is probably needed in NASIS.

3. Conclusions on cover methods and profile descriptions. Following these independent group observations and the test of cover methods, the task force revisited the specifics of describing biological crusts in soil survey. Everyone agreed that BSCs should be described as soil surface features. There was general consensus that BSCs should be included in surface cover characterization and that we should develop protocols for describing all types of soil crusts as well as all surface features:

- Physical crusts

- Chemical crusts (e.g., salt crusts)
- Biological crusts
- Biologic components at the surface, e.g., periphyton
- Rock fragments
- Plant bases
- Bare soil and non-crusted soil
- Litter

Modifications to methods 1-4 and a new Method 5 based on the recommendations of this test are in "Guidelines for describing soil surface features (ver 2.0)." The methods were modified to include all surface features important for soil surface resistance to erosion, raindrop interception, and runoff.

The attributes of crusts that the task force identified as important to measure were, at minimum:

1. % cover by morphological group (moss, lichen, cyanobacteria – light vs. dark)
2. Surface roughness/Surface relief (organism neutral). Ideas on how to describe this included:
   - Shape, height, width, and length of units
     - Structural units? For example, establish three size classes for three structural unit shapes
   - Distance or area between units
   - total surface area/ total 2D area of observation

Color may also be an important property to describe, however Dr. Belnap considers it less important than cover, roughness and spatial distribution. Lichens occur in many colors including black, brown, white, pink, yellow and green. Old, stable lichen crusts commonly have a grater diversity of species and hence more colors than young crusts.

There was less agreement on whether to describe biological crusts as horizons and, if so, how. However, there was some consensus that we needed more information, and the following recommendations were made:

- Evaluate alternate approaches to describe crust morphology (vertical and horizontal) as a part of a soil description, e.g., A horizon or a surface feature;
- Examine crusts in other areas of the country;
- Explore options for sampling soil crusts for laboratory characterization.
- Consider use of "u" subscript to indicate the surface has some kind of crust.

Part III Research Needs, Action Items, Additional Charges

1. Research Needs. Continued research is needed to answer questions about the role and occurrence of crusts in various ecosystems. This information will help with the interpretation of biological crust information and prediction of the effects of land use and disturbances on biological crusts. Priority needs are:

1) Document occurrence of biological soil crusts in different ecosystems (Research and Inventory):
   - Document location and current condition of crusts (Inventory and Assessment);
   - Develop predictive model of potential crust distribution (Research).
2) Determine relative importance of biological soil crust function in different ecosystems.

3) Develop models of resistance and resilience of biological soil crusts to disturbances at various levels:
   - Landscape (e.g., soil-landscape-vegetation transects);
   - Soil mapping unit – Soil surveys can provide info on resistance and resilience based on soil-biological crust relationships;
   - Ecological site.
4) Biological soil crusts as indicators of ecological thresholds.

2. Action items.

1. Develop issue paper on accurately, consistently, and efficiently capturing biological soil crust information in soil descriptions, addressing the options of treating biological crusts as horizon vs. surface features.

   Who: Park and Ramsey When: Dec 2002
   Status:

2. Summarize methods available for measuring surface roughness and evaluate their potential for documenting biological soil crust morphology.
   Who: Boettinger, Reedy, Parslow When: Dec 2002
   Status:

3. Develop written guidelines for the ocular method for estimating biological soil crust cover to be used for field notes.
   Who: A. Tugel, J. Belnap When: July 2002
   Status: Completed. See Appendix 3.

4. Make revisions to the surface cover methods based on the field test in the Colorado Plateau. Incorporate all surface features and guidelines for transect length and number of points per transect that are needed for soil components smaller than 50 meters across.
   Who: A. Tugel, J. Belnap When: July 2002
   Status: Completed. See Appendix 3.

3. Additional charges that need to be addressed.

1. Provide illustrations of how biological crust information can impact or improve resource assessment, land management and soil interpretations.
2. Review the draft manuscript "Biological Soil Crusts" for inclusion on the Soil Survey Manual.
3. Guidance on when and where to measure this dynamic soil property is needed. Alternatives include an area that represents the site potential, a plant community likely to shift to a different state or a plant community in a "stable" functional state. Selecting the site will require a well trained range conservationist and soil scientist working together.

Part IV Resources for Additional Information

The items below are readily available. They contain information about biological soil crusts and their importance.

Belnap, J., J.H. Kaltenecker, R. Rosentreter, J. Williams, S. Leonard and D. Eldridge. 2001. Biological soil crusts: ecology and management. TR-1730-2, USDI, BLM, Denver, CO. Web site http://www.blm.gov/nstc/library/techref.htm

Herrick, J.E., J.W. Van Zee, K.M. Havstad and W.G. Whitford. in prep. Monitoring manual for grassland, shrubland and savanna ecosystems. USDA-ARS Jornada Experimental Range. Island Press, Washington, D.C. contact jherrick@nmsu.edu

NRCS. 1997. Introduction to microbiotic crusts. USDA-NRCS, Soil Quality Institute and Grazing Lands Technology Institute, Ft Worth, TX. Web site http://www.statlab.iastate.edu/survey/SQI/

NRCS. 2001. Rangeland Soil Quality Information Sheets - 10 titles including Soil Biota; Soil Crusts-Physical and Biological. USDA-NRCS, Soil Quality Institute and Grazing Lands Technology Institute, USDA-ARS Jornada Experimental Range, USDI Bureau of Land Management. Web site http://www.statlab.iastate.edu/survey/SQI/

Pellant, M. et.al., 2000. Interpreting Indicators of Rangeland Health, ver 3. Technical Reference 1734-6. USDI-BLM, Denver, CO. Web site http://www.blm.gov/nstc/library/techref.htm

Stringham, T.K., W.C. Krueger, and P.L. Shaver. 2001. States, transitions, and thresholds: Further refinement for rangeland applications. Ag Exp. Sta. Special Report 1024, Oregon State University. (Order copies from: Dept. of Rangeland Resources, Oregon State University, 202 Strand Hall Corvallis, OR 97331-2218), or download pdf at http://www.ftw.nrcs.usda.gov/glti/pubs.html

Websites

BLM. Soil Biological Communities. http://www.blm.gov/nstc/soil/index.html

BLM, USGS, USPS. Biological Soil Crusts http://www.soilcrust.org/

NRCS-Soil Quality Institute Website. Soil Biology Information Resources http://www.statlab.iastate.edu/survey/SQI/SBinfo.htm

Part V Appendices

Appendix 1. Agency needs

Appendix 2. Soil Survey Manual manuscript, draft,

Belnap, Jayne and Arlene J. Tugel. 6-19-02 draft. Biological Soil Crusts.

Appendix 3. Methods and data sheets

Belnap, Jayne, Arlene J. Tugel and Jeffrey E. Herrick. 6-26-02 draft. Guidelines for describing soil surface features (ver 2.0) and data sheets used in the Moab test.

Appendix 4. Soil descriptions

Appendix 5. Photos

Appendix 1. Agency Needs

BLM

1. Where is crust a management consideration and where not?
2. Must address biological soil crusts in NEPA documentation.
3. Need a simplified field guide such as a check list or flow chart of factors related to biological crusts that should be included in NEPA documentation.
4. Need a simplified field guide (with photos) for assessing crusts related to inventory and monitoring protocol.
5. Need information on how to minimize impacts to biological crusts.
6. Need training for the field personnel in federal agencies.
7. Need a database clearing house (NASIS?) for collected data and photo records.
8. Need a module in soil data viewer related to crusts.
9. The Ecological Site Description is a good tool to pull together soil and ecological resource information.
10. We encourage other states to follow the BLM partnership model in New Mexico for Ecological Site development.

NPS

1. See BLM, ditto for Park Service.
2. NPS must shift from managing visitors to managing resources.
3. Need to identify crusts in the soil survey program.
4. Would use biological crusts in information and education programs on ecological significance of crusts across landscapes.
5. Would use crust information in Park Service to help identify concepts of impairment of the resource.
6. Need a monitoring network.
7. Would use crust information in biological inventory, possibly as vital signs or indicators for ecosystem processes.
8. Would look at the State and Transition Models as a tool.
9. We encourage the use of Ecological Site Descriptions in monitoring and inventory.
10. All federal agencies (e.g., BLM, NPS) should share model sites illustrating ecological condition.

FS, Reg. 3.

1. Region 3 is already documenting the occurrence of biological soil crusts using an ocular method in their Terrestrial Ecosystem Surveys.
2. Need to describe and record crusts in soil survey.
3. Need protocols to describe crusts.
4. Biological soil crusts must be included in NEPA documentation as more information is needed for appeals, etc.
5. The BLM Crust training course needs to be continued for all agencies.
6. Welcome distribution of USGS fact sheets on biological soil crusts to FS personnel.

USGS

1. Need multi-agency support (money) for training and mapping.
2. Because of limited resources and knowledgeable personnel, need to “train the trainers”.

Appendix 2

Biological Soil Crusts

For the Soil Survey Manual
Jayne Belnap, USGS, Moab, UT and Arlene J. Tugel, NRCS-SQI, Las Cruces, NM
3-26-02 (rev 6-28-02)

Biological soil crusts are a living community of cyanobacteria, mosses and lichens that occur in most arid and semi-arid regions. They are a part of, and can heavily influence, the morphology of the near-surface zone of soils in these regions. They affect local hydrologic patterns by either increasing or decreasing infiltration (depending on their morphology and site characteristics) and by retarding evaporation of soil moisture. The polysaccharide material extruded by these organisms binds soil particles together, providing protection from raindrop-induced erosion and physical crusting and creating soil aggregates. These soil aggregates provide sequestration sites for nutrients and carbon and activity sites for decomposition. They also increase the water-holding capacity of the upper few millimeters to centimeters of the soil. Biological soil crusts fix both carbon and nitrogen, making them an important source of soil nutrients.

Biological soil crusts occur in all regions where plant cover is sparse, especially semi-arid and arid regions. Biological soil crusts also occur in temperate zones where soils are infertile (e.g., pine barrens) or where vegetation removal (e.g., treefall or agricultural activities such as herbicide treatment of orchard rows) has left soil exposed and available for crust colonization. In our definition, biological soil crusts do not include thick vegetative moss mats where most of the biomass is above-ground (e.g., spike moss; club moss mats in northern latitudes).

Relationship to Mineral Crusts

Non-biotic soil surface crusts, or physical crusts, are also a major structural feature in many arid regions. Chemical crusts are dominated by macro- or microcrystalline evaporites. Physical crusts are soil-surface layers generally formed by raindrop impact, disruption of soil aggregates followed by in-filling of pore spaces, deposition of sediments from short-range runoff, or puddling resulting from freeze-thaw processes on bare ground (no biological soil crust present). They range in thickness from less than one millimeter to a few centimeters. The presence of a physical crust often aids biological soil crust establishment, as the physical crust provides a stable surface for colonization. Like biotic crusts, physical crusts reduce soil loss via wind erosion. However, because physical crusts often disperse when wet and biotic crusts do not, biotic crusts are more effective at reducing soil loss from water erosion. Well-developed biological crusts resist both wind and water erosion. Biotic crusts also create stable soil aggregates, unlike physical crusts.

Types of Biological Soil Crusts

There are 4 main types of biological soil crusts (Belnap 2001), distinguished by the soil surface microtopography that they create (Figure 1). The microtopography is reflected in the height of the “peaks” and the width of the spaces between the “peaks”.

Smooth crusts and *rugose* crusts occur in hyper-arid and arid hot deserts where high air temperatures and low rainfall result in very high potential evaporation (PET) and soils never freeze. In contrast, *pinnacled crusts* and *rolling crusts* occur in semi-arid cool and cold deserts, where soils freeze during cold winters and PET is lower than hot deserts. These crust classifications are based on late successional stages of crusts; in frequently disturbed areas, smooth or rugose crusts can be seen in any geographic region.

Smooth crusts: Smooth crusts are dominated by cyanobacteria, and lack lichens and mosses. Soil surfaces are mostly mineral particles. They are extremely flat, as the binding action of cyanobacteria create an even smoother soil surface than bare ground. Smooth crusts occur in hyperarid and arid regions, where precipitation is very low, temperatures are very high, and soils never freeze (e.g., central Sahara desert, Negev desert in Israel). There are few crusts of this type in the western US, except in areas where soils are frequently disturbed.

***Rugose crusts*:** Rugose crusts occur in arid and semi-arid regions where soils never or seldom freeze, but that have lower PET than areas with smooth crust. Like smooth crusts, rugose crusts are dominated by cyanobacteria, but they also contain sparse patches of lichens and mosses growing on the more-or-less even soil surface. This type of crust occurs in the Sonoran, Chihuahuan, and Mojave deserts. Rugose crusts can also occur as a successional stage in areas where soils are recovering from disturbance.

Pinnacled crusts: Pinnacled crusts occur in areas where soils freeze during winter. They are dominated by cyanobacteria, but support up to 40% lichen and moss cover. These crusts are characterized by strikingly pedicelled mounds that are formed as the frost-heaved soils are differentially eroded by downward-cutting water. These castle-like mounds can be up to 10 cm high and have delicate tips that are less than 4 mm across. Lichens, mosses, small rocks, or concentrations of cyanobacteria often act as a cap for these tips, offering greater resistance to erosion than adjacent soil. Pinnacled crusts occur in mid-latitude cool deserts such as the Colorado Plateau and the southern Great Basin. This crust type is the most vulnerable to soil surface disturbance, as the frost-heaved surface is easily broken and churned, often burying crustal organisms.

Rolling crusts: Rolling crusts occur in colder regions where soils freeze in winter and where PET is low (e.g., northern Great Basin, Columbia Plateau and the Arctic tundra). Rolling crusts are heavily dominated by lichens, mosses, and/or thick dark mats of cyanobacteria. The upward frost-heaving of the soil is counteracted by the cohesive, thickly-encrusted mats of lichens, mosses, and surface roots of vascular plants; thus, rather than pinnacled surfaces, this combination creates a rough, rolling surface. When disturbed, these types of crusts are sometimes easily detached from the soil surface, as they can adhere more to themselves than the soil. This makes them vulnerable to soil surface disturbances.

Major Components of Soil Crusts: Cyanobacteria, Lichens, and Mosses

Biological soil crusts include bacteria, microfungi, cyanobacteria, green algae, mosses, liverworts and lichens (Belnap et al. 2001). Various characteristics that do not require identification to the species level can be used to differentiate the three major components (broad morphological groups) of soil crusts in the field.

Cyanobacteria ("blue-green algae") are primitive filamentous or single-celled bacteria that come in a variety of sizes and shapes. These organisms fix both carbon and nitrogen. Only the filamentous species can be seen without a microscope. They look like fine threads that dangle and twirl when chunks of the soil surface are held aloft (unlike roots, which are often too stiff to blow as freely). These threads often have small soil particles attached. Cyanobacterial crusts with low biomass and diversity are generally the color of the substrate (most often light). Cyanobacterial crusts with high biomass and diversity are dark (brown-black), due both to increased biomass and the production of UV-protective pigments by the organisms. *Lichens* are fungi that capture and cultivate photosynthetic algae or cyanobacteria as partners. There are two main types of lichens, gelatinous and non-gelatinous. Gelatinous lichens are black, swell when moistened, and are capable of nitrogen fixation. Non-gelatinous (crustose, squamulose, foliose, and fructicose) lichens come in all colors, do not swell when moistened, and generally do not fix nitrogen. In deserts of the western US, soil lichens are generally a mixture of gelatinous, crustose and squamulose lichens.

Mosses are photosynthetic plants with small leaves that unfurl when moistened (thus the moss appears to swell). When dry, mosses are dark and dull-colored; when moistened, the color changes markedly to a bright, light green to brown. This makes them easy to distinguish from lichens.

Morphological groups (Table 1) group organisms that are similar in shape, appearance, and function. Minor and difficult-to-observe components can be included with the three major biological crust groups (cyanobacteria, lichen, moss). Green algae, single-celled photosynthetic organisms, are included with cyanobacteria because they are difficult to observe in the field without high magnification but sometimes give the moist soil surface a green tint. Liverworts are minor in arid environments and can be included with lichen. For special studies, such as monitoring the abundance of N-fixing lichens, specific morphological groups, or even species, can be measured.

Table 1. Morphological groups for biological crust components and their N-fixing characteristics. **(Belnap et al. 2001)**

Broad morphological group	**Morphological group**	**Representative taxa**	**N-fixing**
Cyanobacteria	Green algal crusts	Coccoids	No
	Cyanobacterial crusts	*Microcoleus vaginatus, Nostoc spp*	Most species
Lichen	Crustose lichen	*Fulgensia desertorum*	No
	Gelatinous lichen	*Collema coccophorum*	Yes
	Squamulose lichen	*Psora decipiens*	A few species
	Foliose lichen	*Peltigera occidentalis*	No
	Fruiticose lichen	*Aspicilia hispida*	No
	Liverworts	*Riccia spp*	No
Moss	Short moss (< 10mm)	*Bryum* spp.	No
	Tall moss (> 10mm)	*Tortula* ruralis	No

Soil Surface Roughness/Crust Age

The roughness of the soil surface is important in runoff, the retention of water and litter, and can provide an indication of crust age. For example, in Colorado Plateau and southern Great Basin pinnacled crusts, the height of the pinnacles relates to the number of frost-heaving events that have occurred once disturbance has ceased Thus, the age of pinnacled crusts can be estimated via soil surface roughness. In an undisturbed crust, pinnacles "grow" about 1 cm a year for about 5 years, and so surface roughness is estimated in 1 cm increments up to 5 cm. After reaching 5 cm, the height of the pinnacle is determined by soil texture and the species composition of the biological crust. The exception is areas where water pools; here, the crust micro-topography is often limited to 1 cm or less.

Lichens and moss generally take at least 10 years to colonize; thus soils with lichen/moss cover have generally been undisturbed for at least this long. For smooth, rugose, and rolling crusts, height cannot be used to age the soil crust. The only visible indicator of development is lichen and moss cover. These components recover more quickly on fine-textured soils and with increasing effective precipitation. Therefore, before using lichen and moss cover as an indicator of soil crust age, these site-specific factors must be taken into account.

Distribution of Crusts

The percent cover and the components of the crust can vary across short distances. For example, the percent cover and abundance of morphological groups in interspaces can be quite different than those under shrub canopies. Closed plant canopies or thick litter layers limit the development of crust organisms. Where soil-disturbing activities are present, soil crusts are likely to be most developed in areas protected from trampling such as under shrubs, or adjacent to obstacles such as fallen trees and rocks (Rosentreter et al. 2001). Recording information about the distribution of crusts in relation to the plant canopy species or type (herbaceous, shrub, tree, none) will aid in the interpretation of the function of biological crusts on the site.

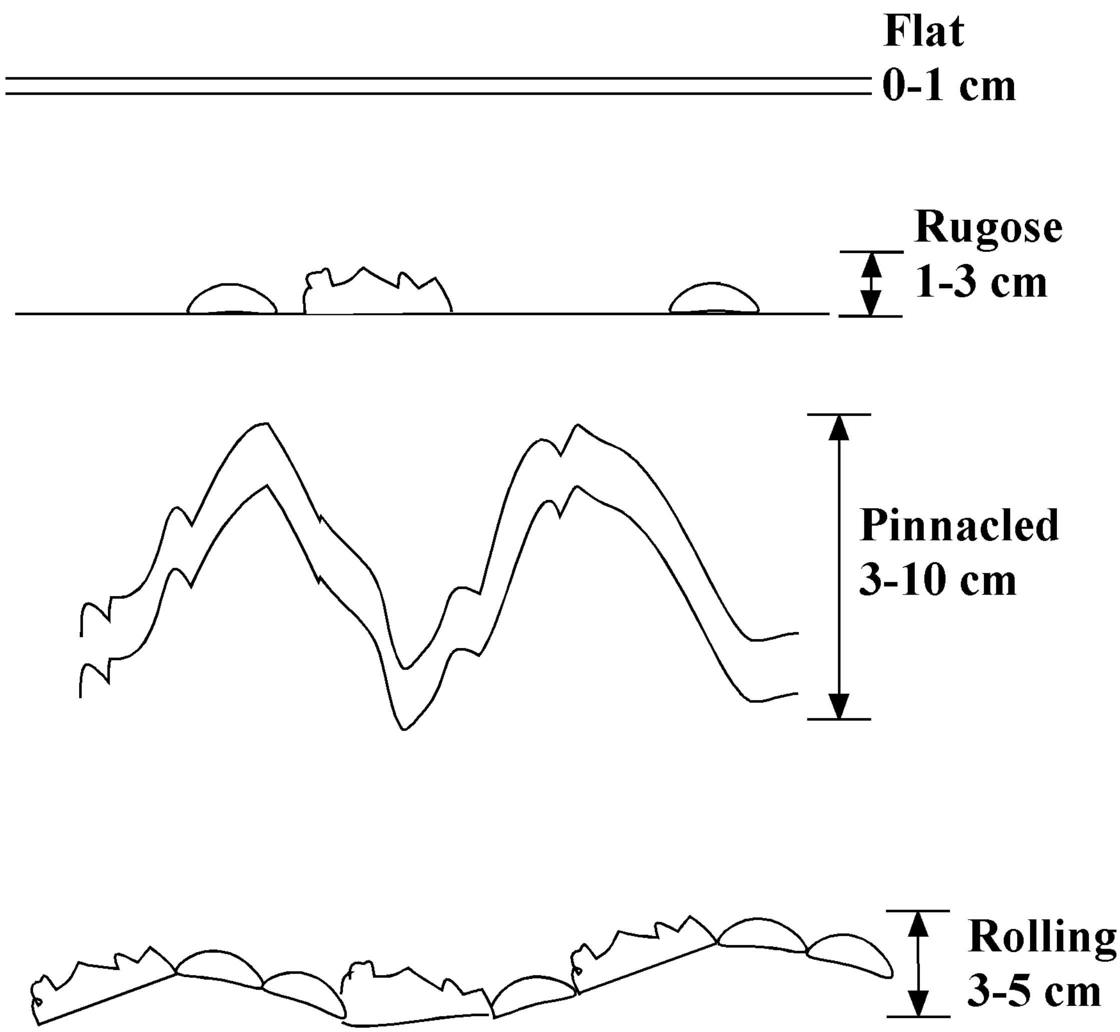
References

Belnap, J. 2001. Comparative structure of physical and biological soil crusts. *In:* J. Belnap and O.L. Lange, eds . Biological soil crusts: structure, function, and management. Ecological studies, v. 150. Springer-Verlag, Berlin.

Belnap, J., J.H. Kaltenecker, R. Rosentreter, J. Williams, S. Leonard and D. Eldridge. 2001. Biological soil crusts: ecology and management. TR-1730-2, USDI, BLM Denver, CO.

Rosentreter, R. D.J. Eldridge, and J.H. Kaltencker. 2001. Monitoring and management of biological crusts. *In:* J. Belnap and O.L. Lange, eds . Biological soil crusts: structure, function, and management. Ecological studies, v. 150. Springer-Verlag, Berlin.

Figure 1. Biological soil crust types. Flat crusts contain only cyanobacteria, and are not frost-heaved. Rugose crusts are similar to flat crusts, except they contain occasional lichen/moss patches. Pinnacled crusts are cyanobacterially-dominated, and can have up to 40 percent cover of lichen/moss. Their distinctive characteristic is great surface roughness due to frost-heaving. Rolling crusts are also frost-heaved, but their high lichen/moss cover prevents the heightened surface roughness of pinnacled crusts; instead, they exhibit a rolling surface.



Additional information: Not for inclusion in the Soil Survey Manual

Rationale for measuring cover for morphological groups as well as total cover.

Measures of cover and abundance of morphological groups can be obtained more rapidly and simply than measuring individual species. Rosentreter et al. 2001 p 460

"Given the variable responses of species, the presence and abundance of individual species or morphological groups of species may be better indicators of range condition and soil stability than total crust cover." Warren and Eldridge, 2001" p 407 in Belnap and Lange, 2001

The edits and additions in Version 2.0 are based on the initial field test of these methods in Moab, UT, May 6-9, 2002. This document is a part of the report of the Biological Crust Task Force, West Regional Soil Survey Conference, Telluride, CO, July 8-12, 2002.

Guidelines for describing soil surface features

Version 2.0

6-26-02

J. Belnap, A. J. Tugel, J. E Herrick

Soil surface features include 1) physical, biological and chemical crusts and structural aggregates that affect the resistance of the soil surface to erosion and 2) rocks, woody debris, litter, and plant bases that intercept raindrops or slow runoff.

Record total coverage of each surface feature (Surface Features table), surface roughness (needs to be developed), and (optional) distribution of surface features in relation to plant canopy.

1. **Surface features**

   a. **Biological Crust** *(also called microbiotic, microphytic or cryptogamic crust): a thin, biologically dominated surface layer comprised most commonly of cyanobacteria (blue-green algae), green and brown algae, mosses, liverworts and/or lichens (NRCS, 1997, Belnap, 2001).* **–** identify biological crust components based on broad morphological groups (cyanobacteria, lichen and moss). Groups consist of organisms that are similar in shape and appearance. *Note: Biological crusts often establish on top of a physical crust. Guidelines for describing such combination crusts have not been proposed, but need to be discussed.*

   b. **Physical and chemical crusts** – identify type of crust (not yet developed for rangelands)
   c. **Plant bases –** identify plant bases by species or plant functional group (perennial grass, shrub, tree, etc.)

   d. **Rock and litter** – identify bedrock inclusions, rock fragments by size class, woody debris and litter on the soil surface.

   e. **Structural aggregates** – identify other surface features including structural aggregates or bare soil

Surface features

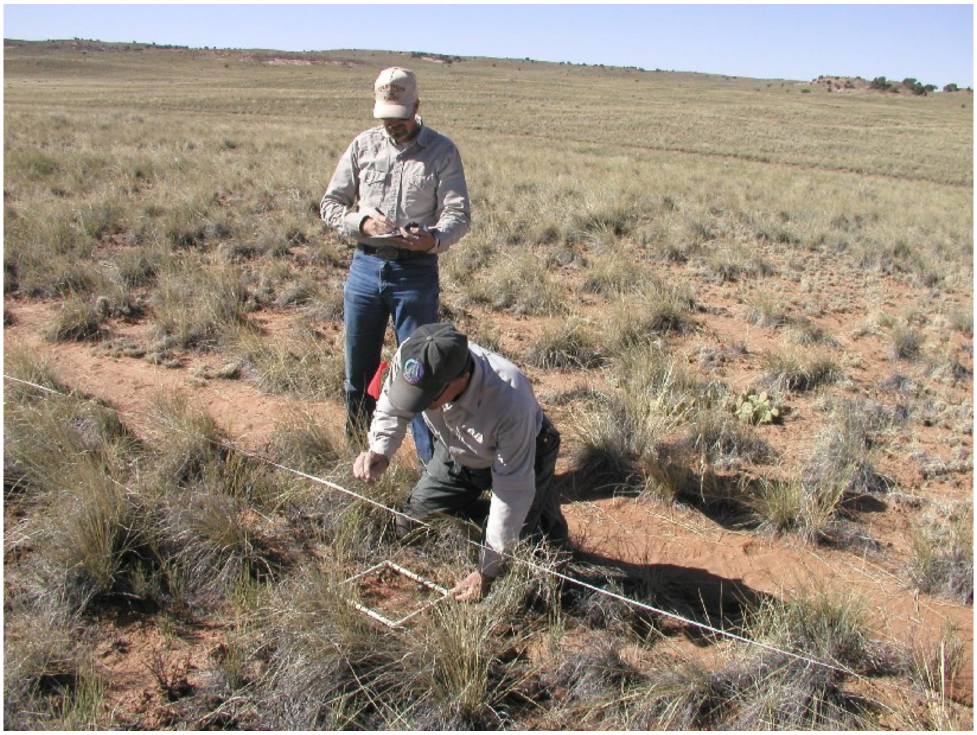
Appendix 5. Photos

Lichens and mosses on gypsiferous soil

Smooth dark cyanobacterial crust

Pinnacled cyanobacteria and lichen crust

Pinyon and juniper landscape with pinnacled biological soil crust and rock outcrop (white-colored slick rock).


Mehod 3. Line-point quadrat


Quadrat frame (25cm square, 20-hit frame)

Method 4. Stratified line-point intercept

Soil surface stability test kit.

Biological Soil Crust Task Force, May 6-9, 2002, Moab Utah