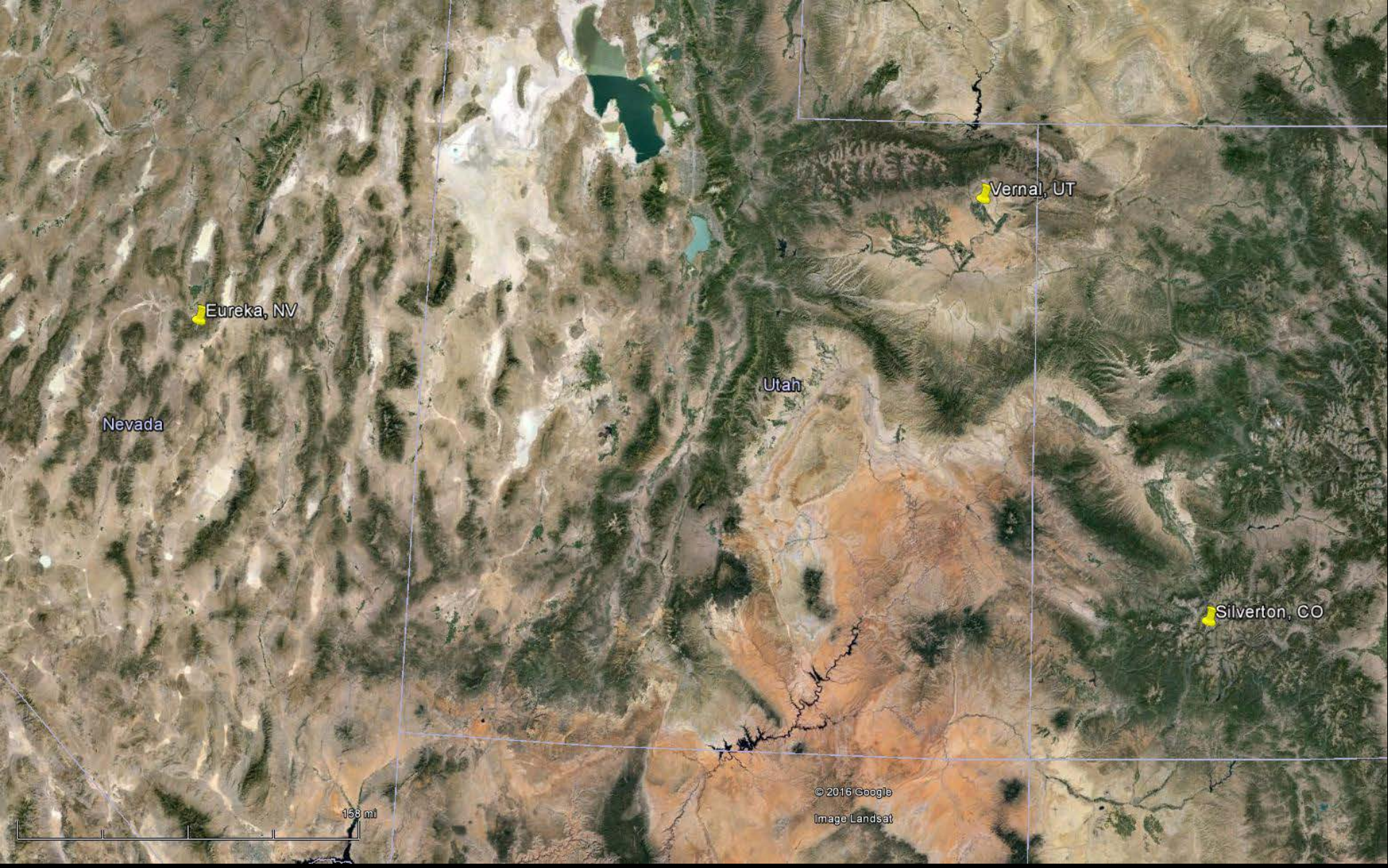
Biochar for Mining Affected Soils

RS RESEARCH SERVICES

Christopher Peltz
Research Services LLC
chris@researchservicesco.com
www.researchservicesco.com



Silverton, CO – Zn, Cu, Pb tailings and waste rock, mineralized soils, acid generating rock

Vernal, UT – Oil and Gas Well Pad, calcareous soils, compaction and crusting

Eureka, NV – Open pit gold mine waste rock pile, calcareous soils, large grain size and low C


Living organisms <5%
Fresh residue <10%
Stabilized organic matter (humus) 33% - 50%
Decomposing organic matter (active fraction) 33% - 50%

What will biochar do?

- Increase soil organic carbon;
- Increase water holding capacity of soils;
- Increase pH and cation-exchange capacity;
- Decrease soil bulk density;
- Increases percentage of 1-2 mm water stable aggregates;
- Increase population and diversity of soil microorganisms;
- Sequester carbon (70-80% fixed C/mass);
- Reduce transport of PAH's in soils
- Reduce the concentrations of As, Cd, Zn, Pb, Cu, Fe, and N, K in soil leachates

Questions

Will applying biochar improve soil conditions and increase plant growth?

- Vegetation growth and vigor
- Soil moisture dynamics
- Soil chemistry

What are the most effective methods of using biochar for mine lands in terms of $, C, and restoration outcomes?

- Application rates and methods
- Determine site or site-type specific restoration methods
- Conduct large scale and paired experiments


Silverton, CO
Cunningham Creek
Cement Creek
Animas River
Mineral Creek

Gold King – August 2015

Image - Geoff Liesik/Deseret News

Photo: Jerry McBride

THE Durango HERALD

Catastrophe on the Animas

Toxic water floods river after EPA disaster at Gold King Mine in Silverton

By Chase Olivarius-Mcallister , Mary Shinn and Shane Benjamin Herald staff writers

Article Last Updated: Thursday, August 06, 2015 11:24pm

Volume 141, issue 6 Thursday, August 13, 2015

Silverton STANDARD & the MINER 50¢

A National Historic Site in Journalism

Weekly Miner established 1875

Silverton Standard established 1889

The Latest

Drinking water in Silverton safe

In light of the recent discharge of concentrated mine tailings into Cement Creek north of Silverton,town Public Works Director John Site issued a statement declaring the town's water supply safe.

"The quality of water in the town distribution system is of the same high quality that our

Disaster declared

- ❑ Gold King blowout sends a toxic plume down the Animas.
- ❑ Spill estimated at 3 million gallons of acid-mine waste.
- ❑ EPA officials: Agency takes full responsibility.
- ❑ No serious impact yet seen on aquatic life, officials say.

The New York Times

U.S.

Environmental Agency Uncorks Its Own Toxic Water Spill at Colorado Mine

By JULIE TURKEWITZ AUG. 10, 2015

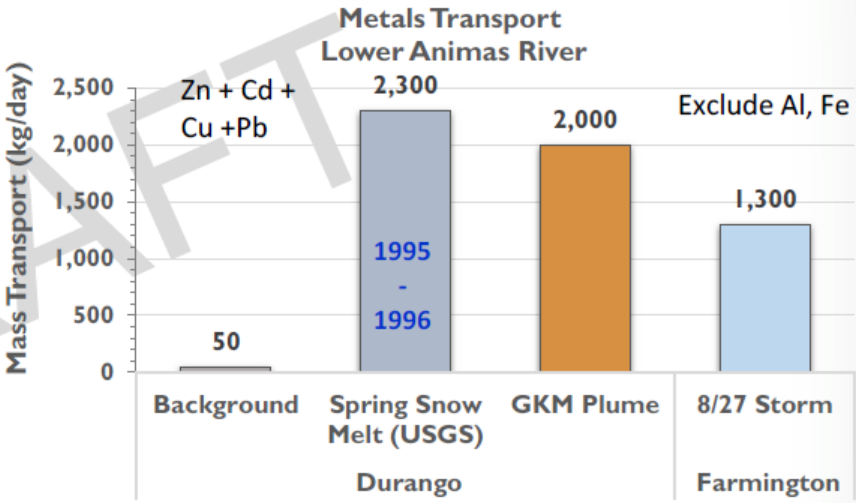

Highland Mary


Henrietta


Red and Bonita

Implications for Monitoring Going Forward

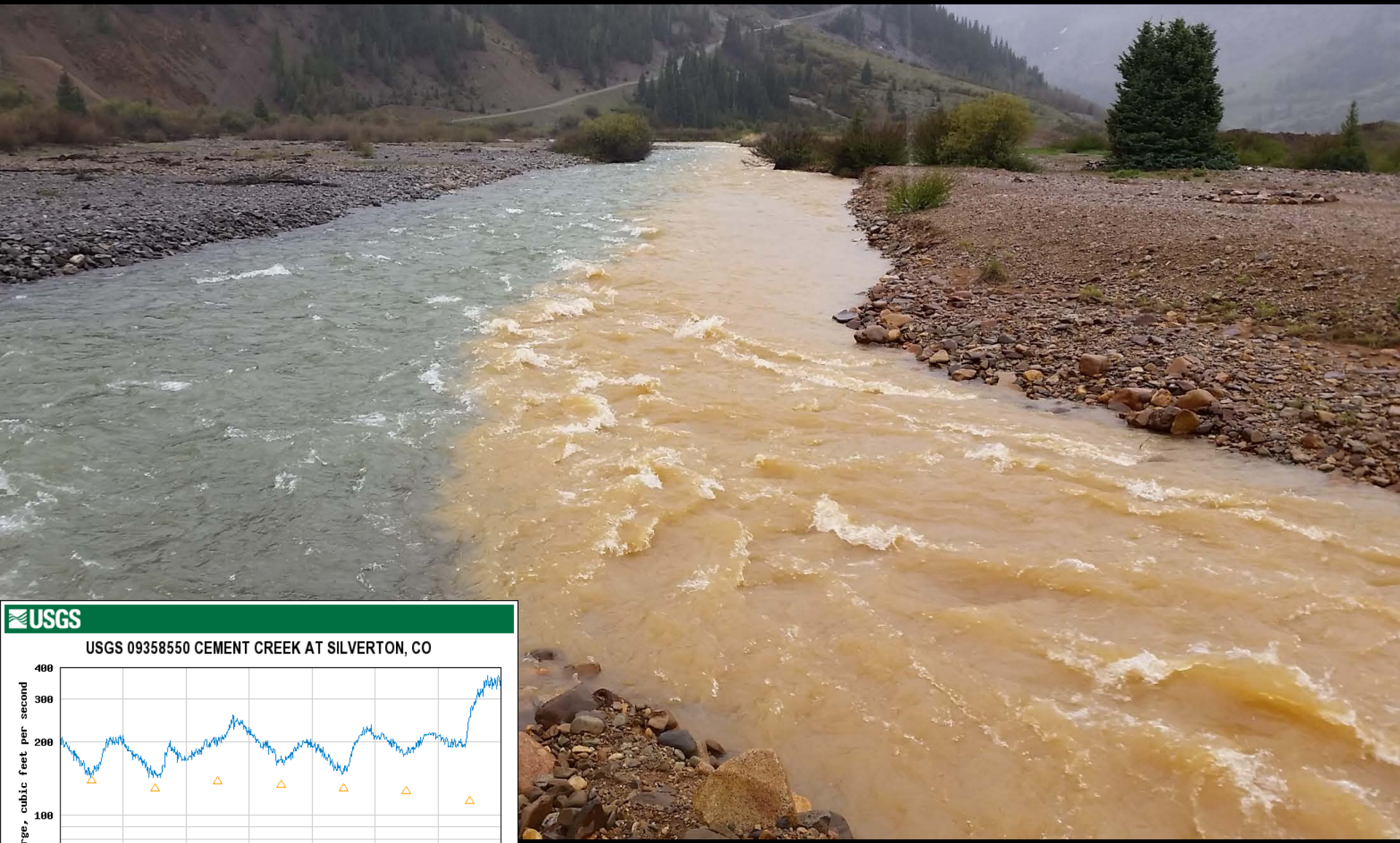
- **USGS sampled metals in the Animas during spring runoff in 1995-96 finding that the Animas River carries large metal loads during high streamflow**
  - Mostly colloidal (85-99%)
  - Some dissolved (1 – 15%)
- **The GKM plume was similar to a day of high spring runoff for combined metals.**
- **Monitoring can expect high metal loads during rain and snowmelt and will need to account for the complexity of contributing sources in the watershed**
- **GKM contaminants may be difficult to isolate during future high runoff from existing and ongoing AMD contamination.**



GKM metal load in the lower Animas was similar to one day of high spring runoff

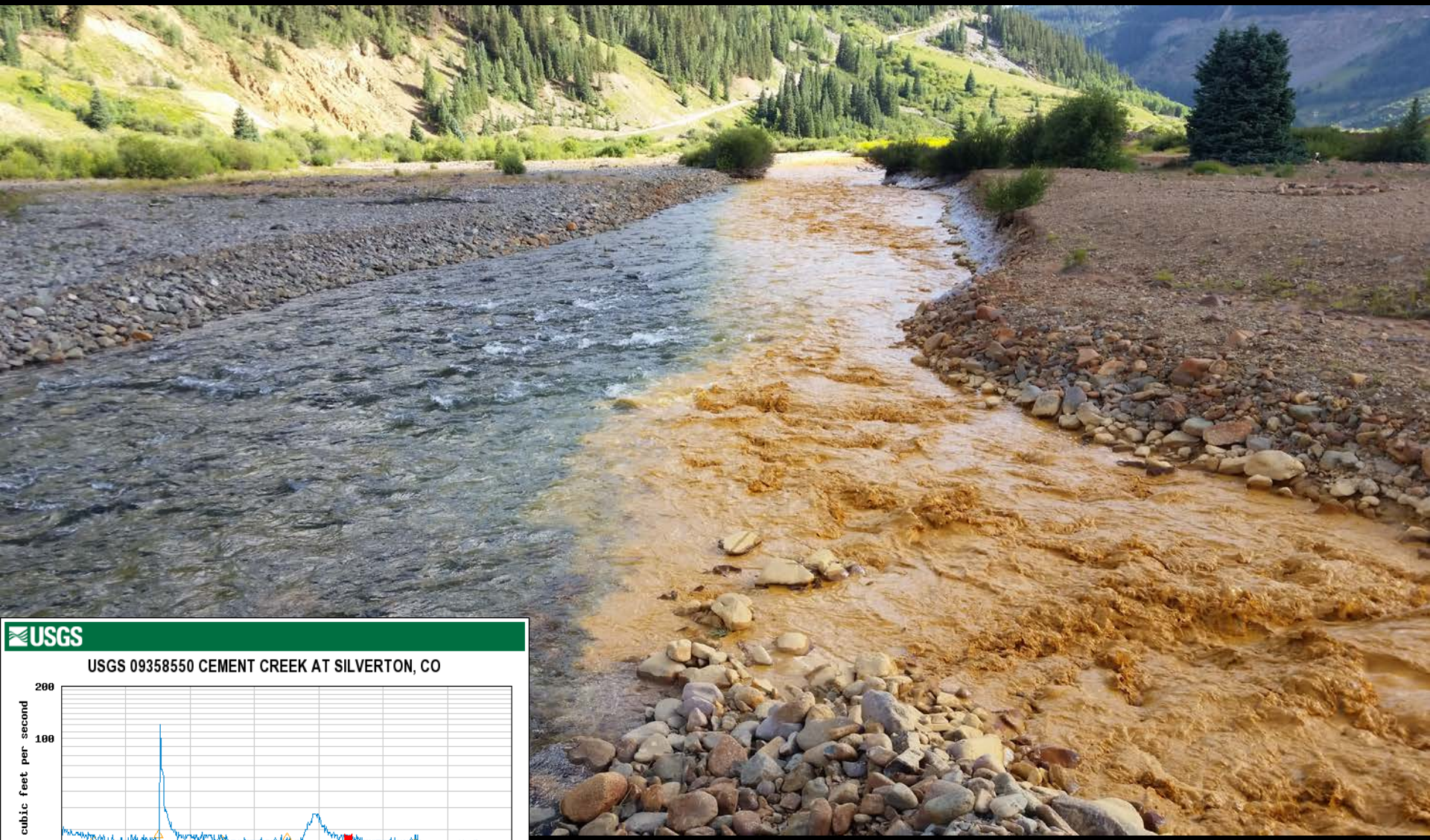
https://www.epa.gov/sites/production/files/201602/documents/analysisfatetransportmetals.pdf

June 6, 2015



USGS
USGS 09358550 CEMENT CREEK AT SILVERTON, CO
Discharge, cubic feet per second
400
300
200
100
50
Jun 04 2015
Jun 05 2015
Jun 06 2015
Jun 07 2015
Jun 08 2015
Jun 09 2015
Jun 10 2015
Median daily statistic (23 years)
Period of approved data
Discharge

August 5, 2015



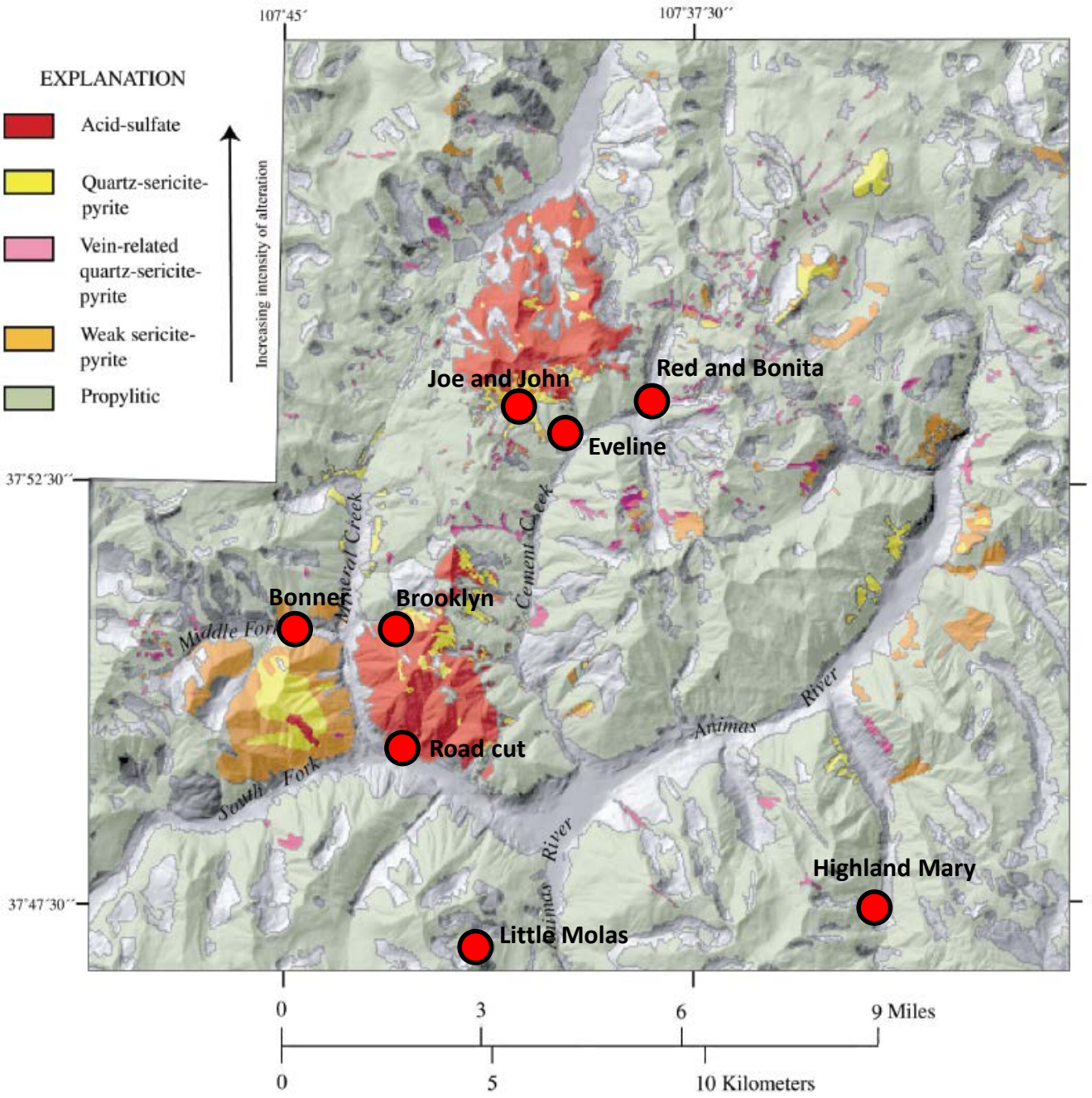
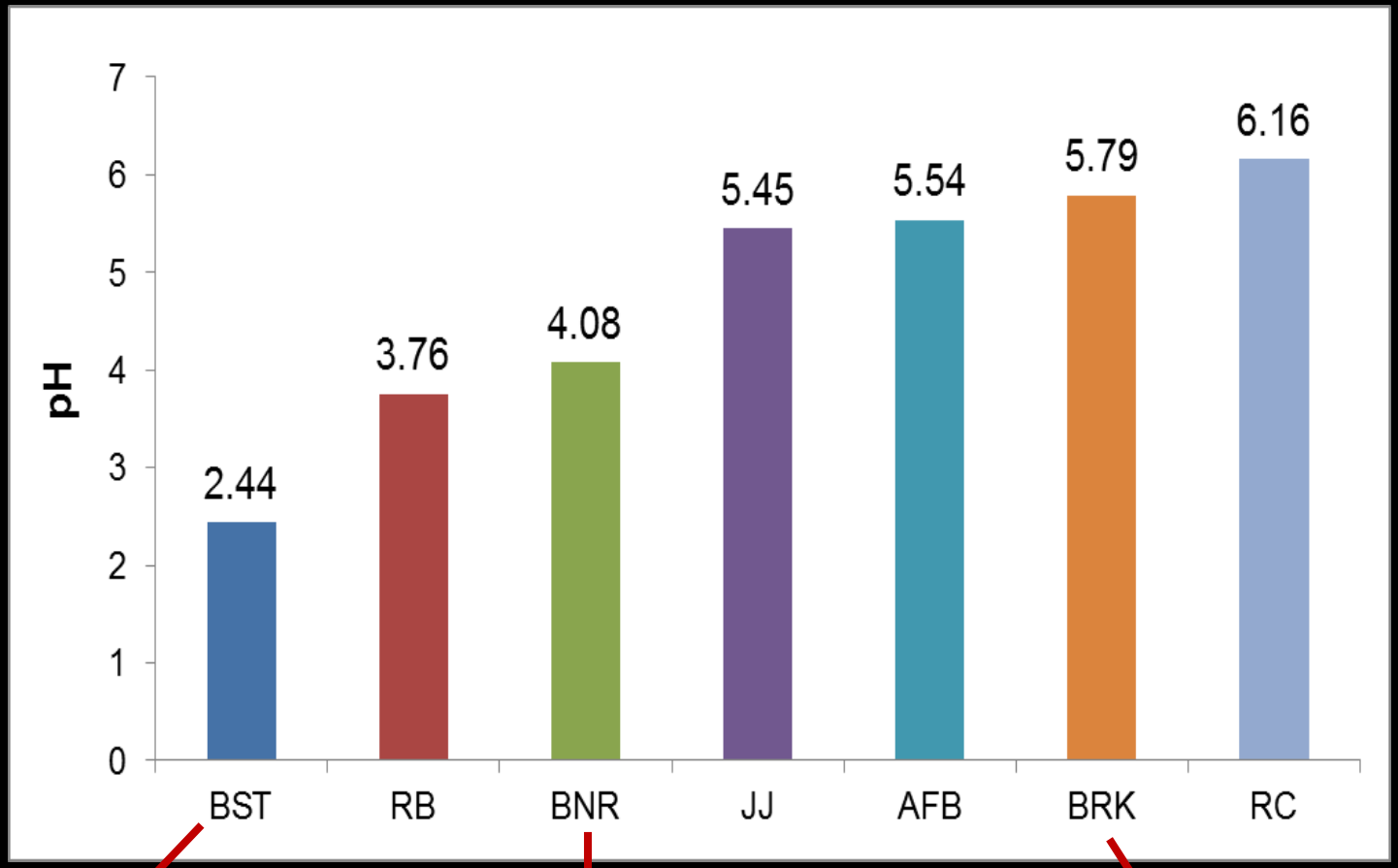
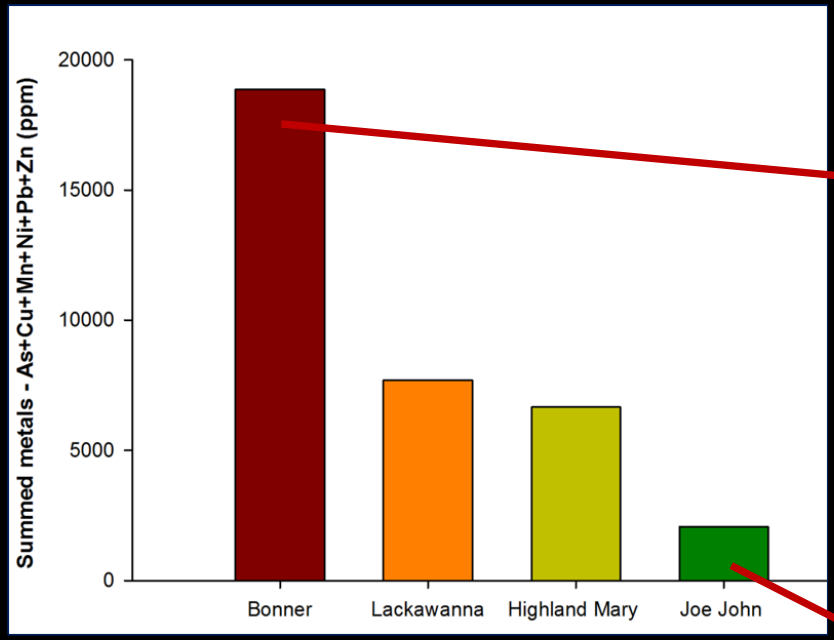
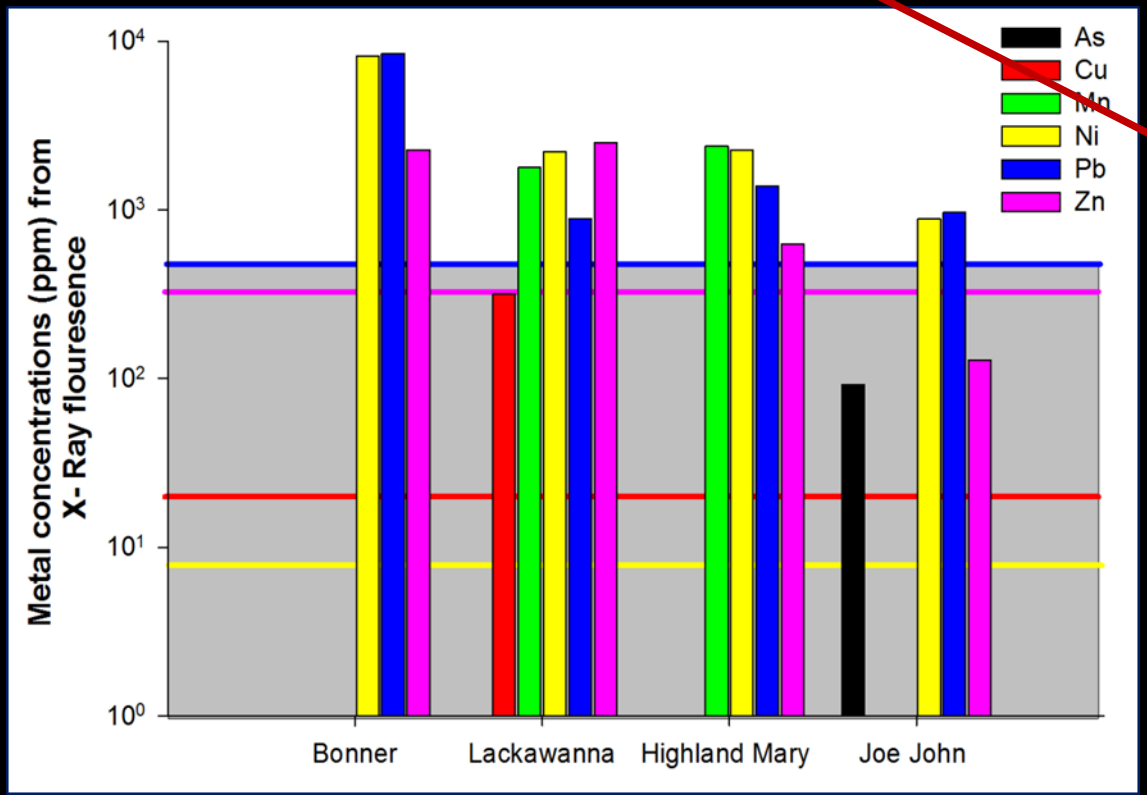
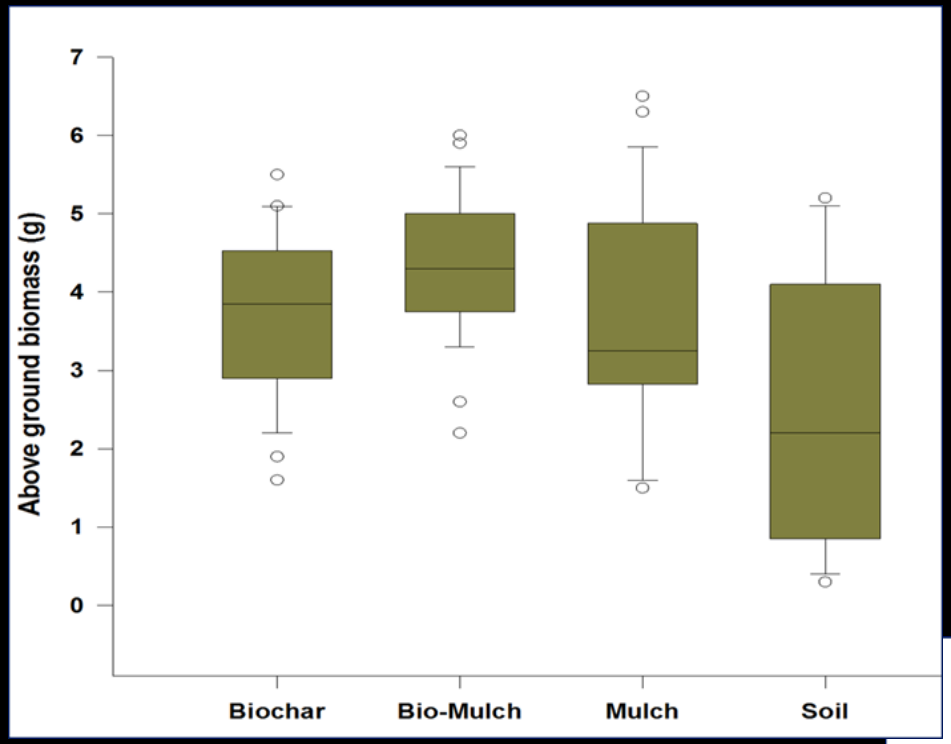


Figure 3. Generalized map of alteration types in the Animas River watershed study area. Data in Bove , Yager and others (2007) and Yager and others (2007).

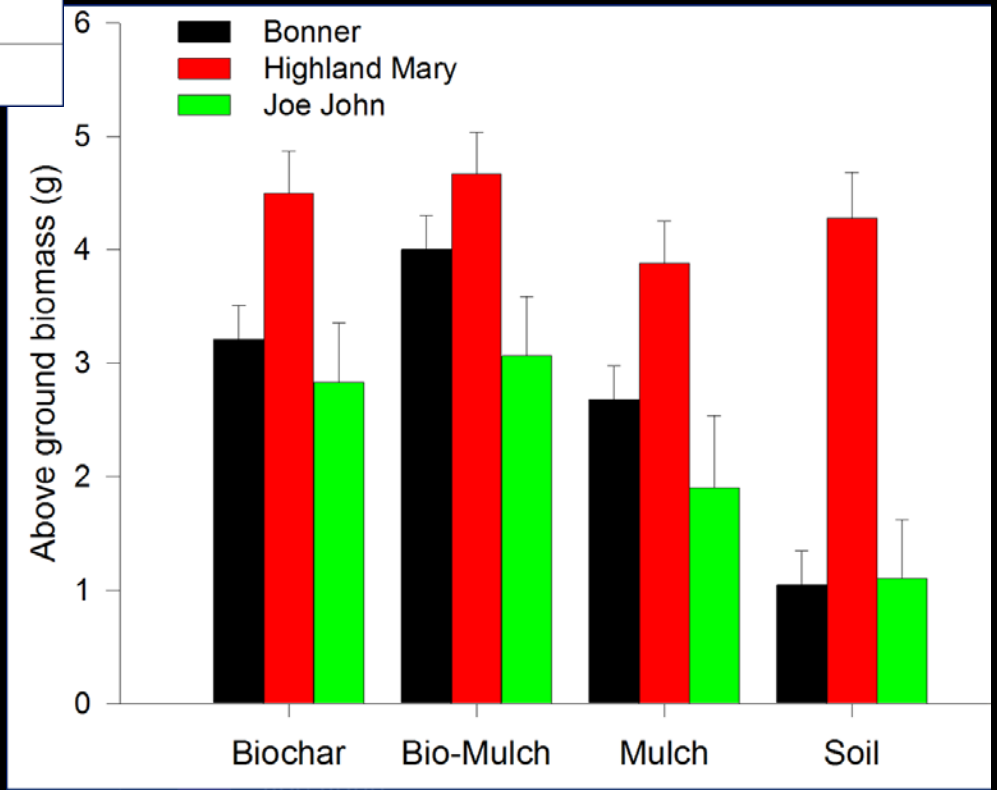

pH
7
6
5
4
3
2
1
0
2.44
3.76
4.08
5.45
5.54
5.79
6.16
BST
RB
BNR
JJ
AFB
BRK
RC


Summed metals - As+Cu+Mn+Ni+Pb+Zn (ppm)
20000
15000
10000
5000
0
Bonner
Lackawanna
Highland Mary
Joe John


Metal concentrations (ppm) from X- Ray flouresence
10^4
10^3
10^2
10^1
10^0
As
Cu
Mn
Ni
Pb
Zn
Bonner
Lackawanna
Highland Mary
Joe John


Above ground biomass (g)
0
1
2
3
4
5
6
7
Biochar
Bio-Mulch
Mulch
Soil

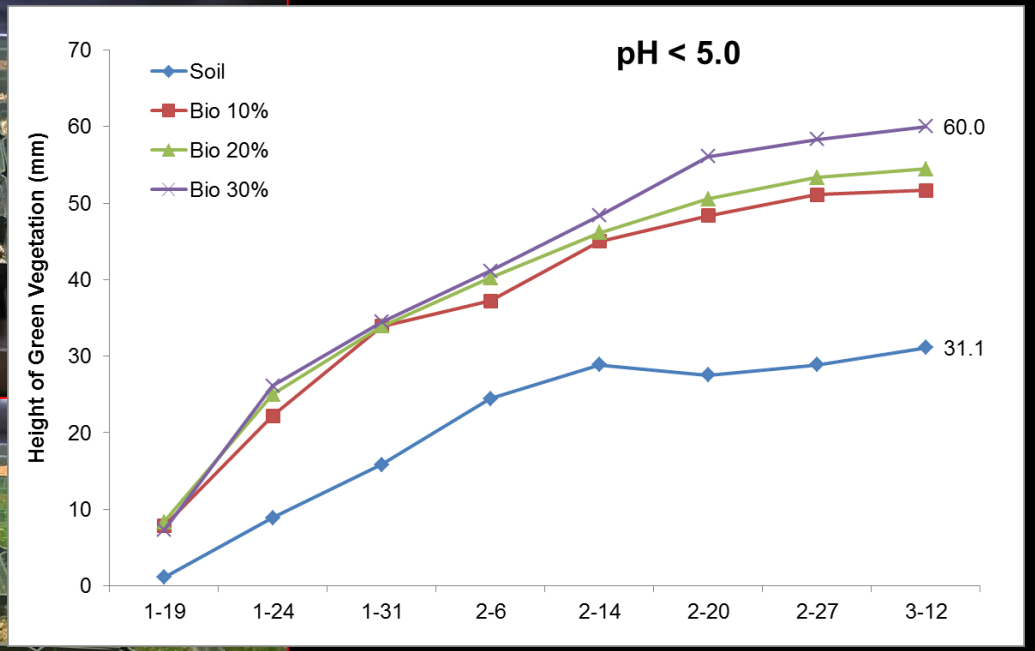

Bonner 2 MULCH
Bonner 2 Biochar + mulch
Bonner 2 SOIL
Bonner 2 Biochar

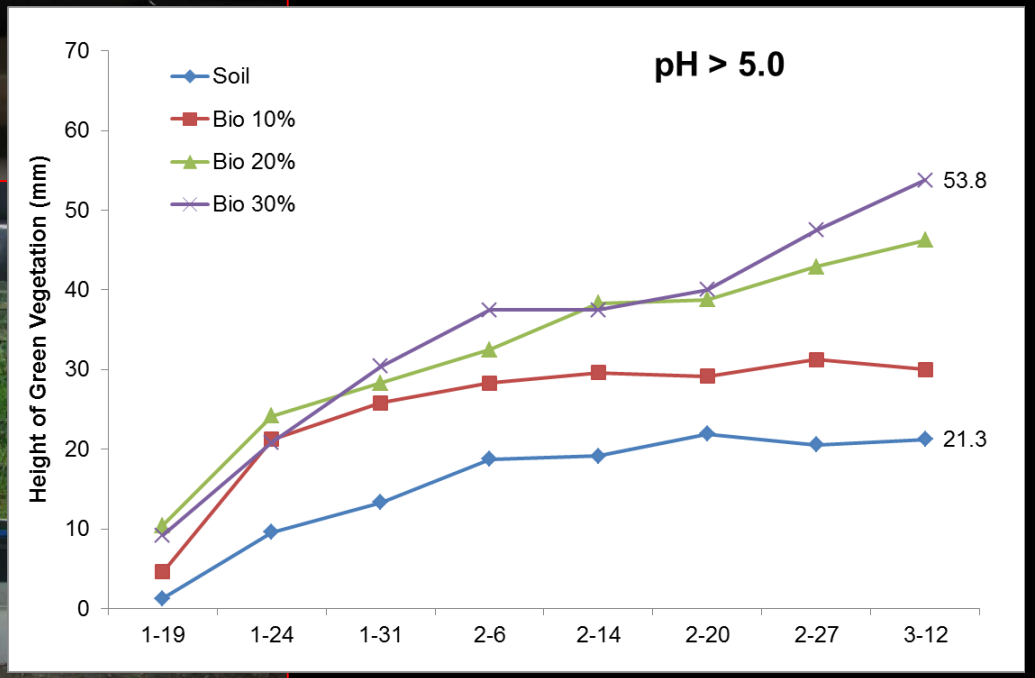

Bonner
Highland Mary
Joe John
Above ground biomass (g)
0
1
2
3
4
5
6
Biochar
Bio-Mulch
Mulch
Soil


1 06


1 31

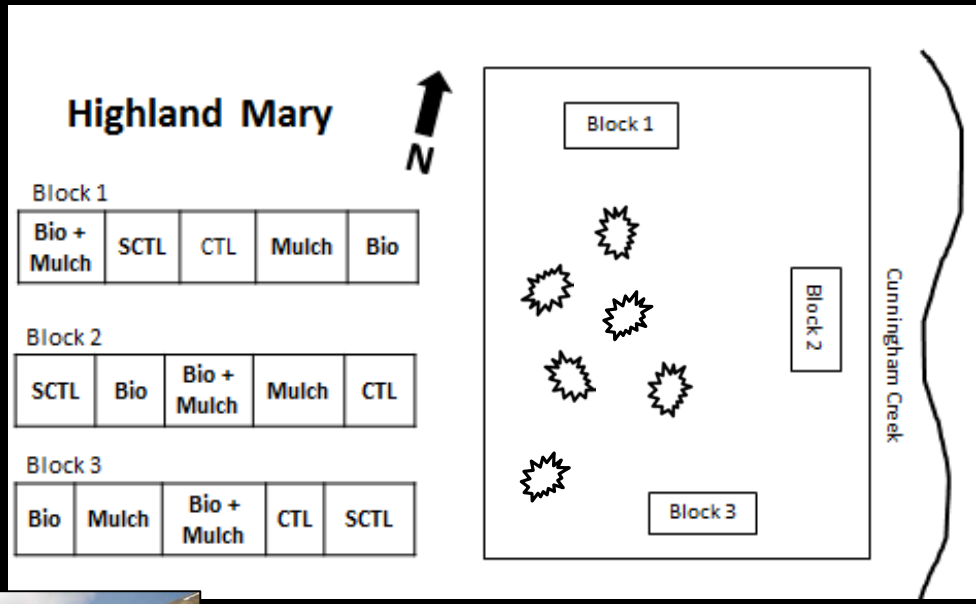

3 13

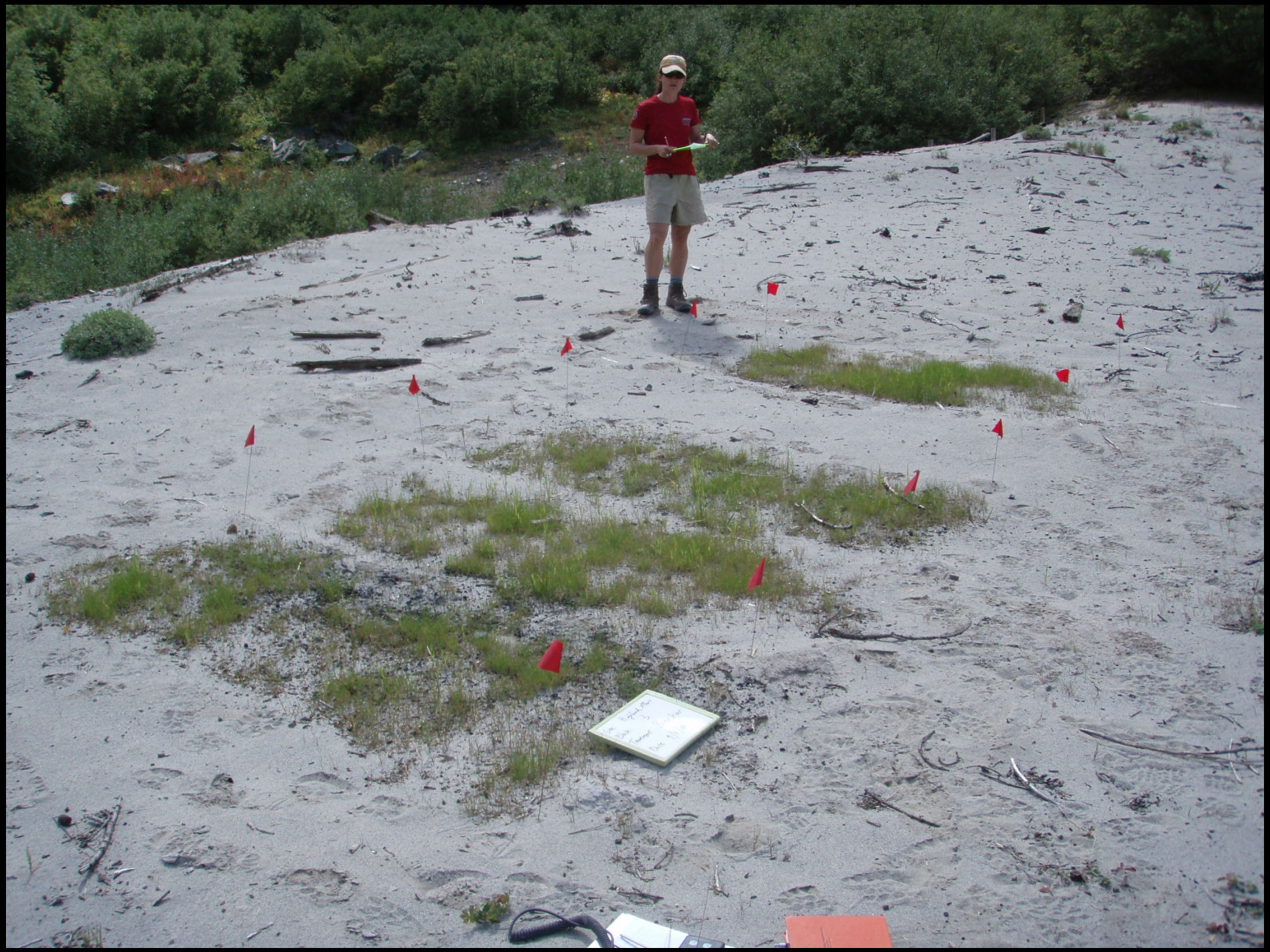

pH < 5.0
Soil
Bio 10%
Bio 20%
Bio 30%
Height of Green Vegetation (mm)
70
60
50
40
30
20
10
0
1-19
1-24
1-31
2-6
2-14
2-20
2-27
3-12
60.0
31.1


pH > 5.0
Soil
Bio 10%
Bio 20%
Bio 30%
Height of Green Vegetation (mm)
70
60
50
40
30
20
10
0
1-19
1-24
1-31
2-6
2-14
2-20
2-27
3-12
53.8
21.3

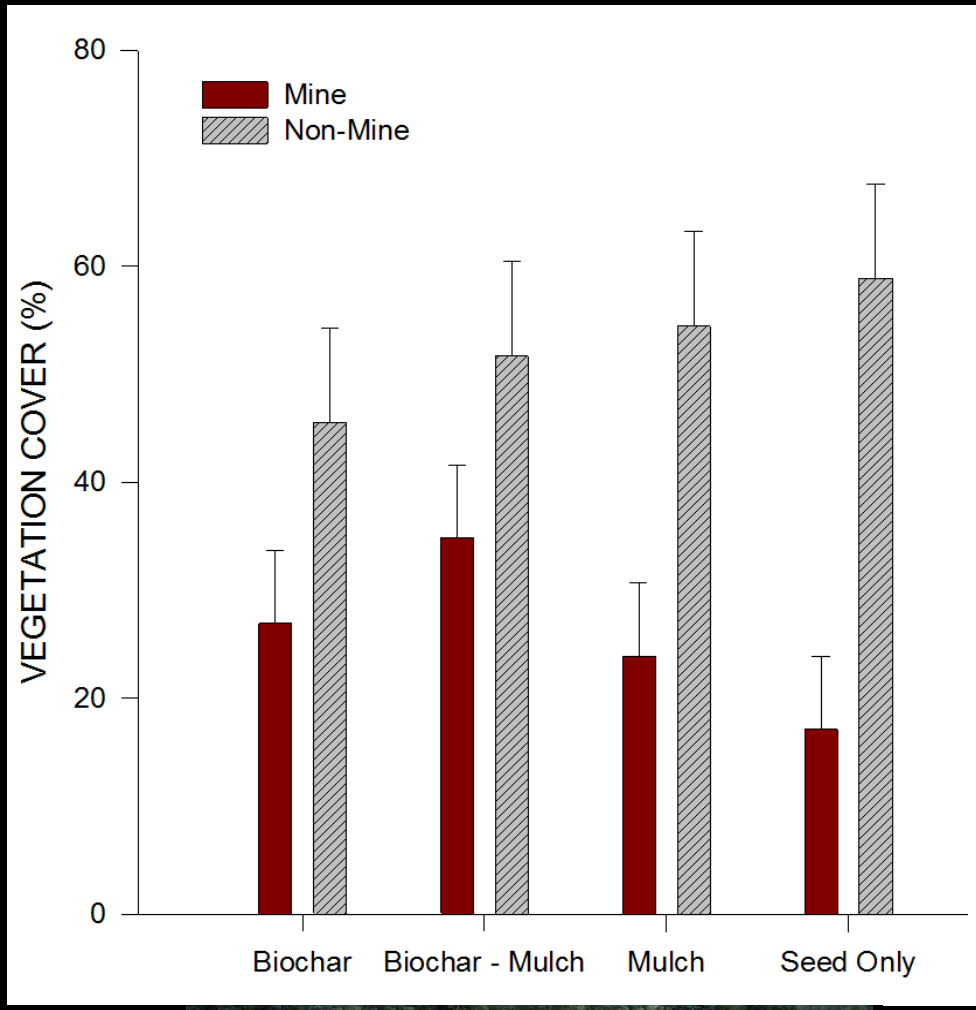
Field

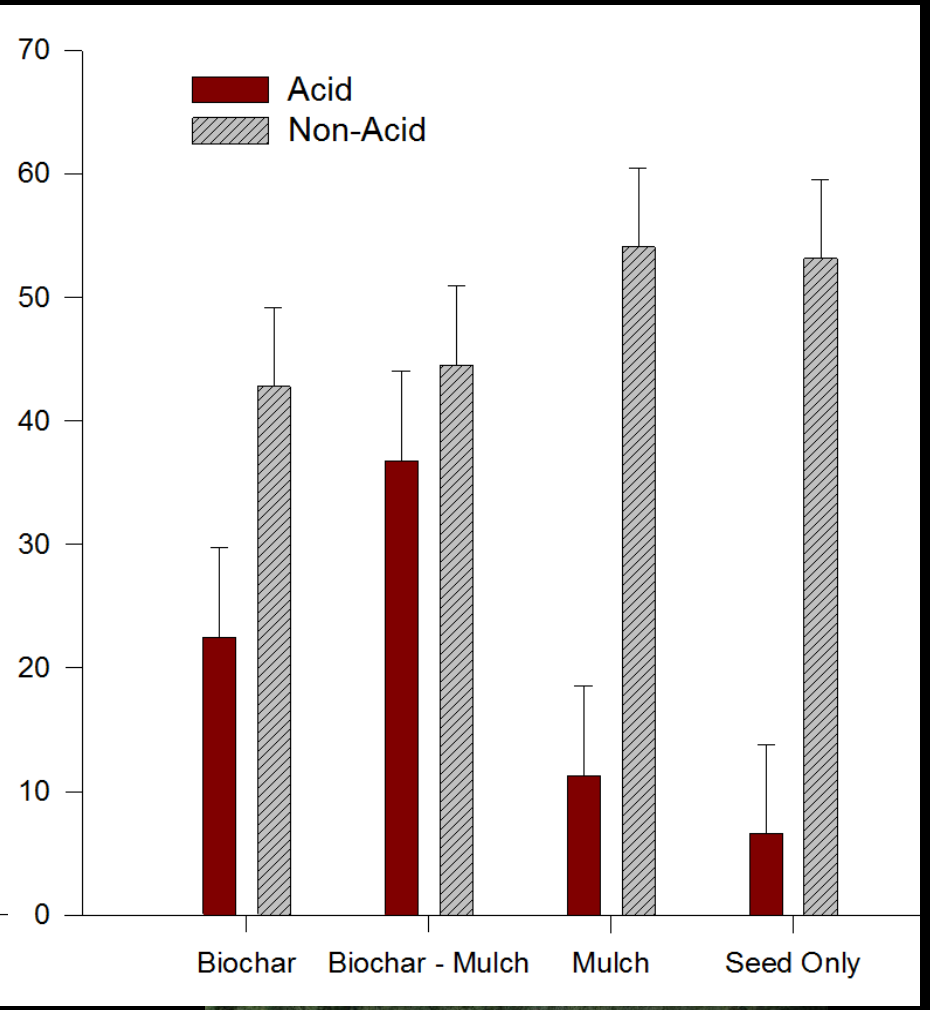
- Randomized block design
- Three treatments (B, B+M, M)
- Alpine mix of grasses (USFS supplied)
- 30% by volume biochar additions
- VWC (%)
- Veg cover (%) estimates ~40 days , 1 year after seeding



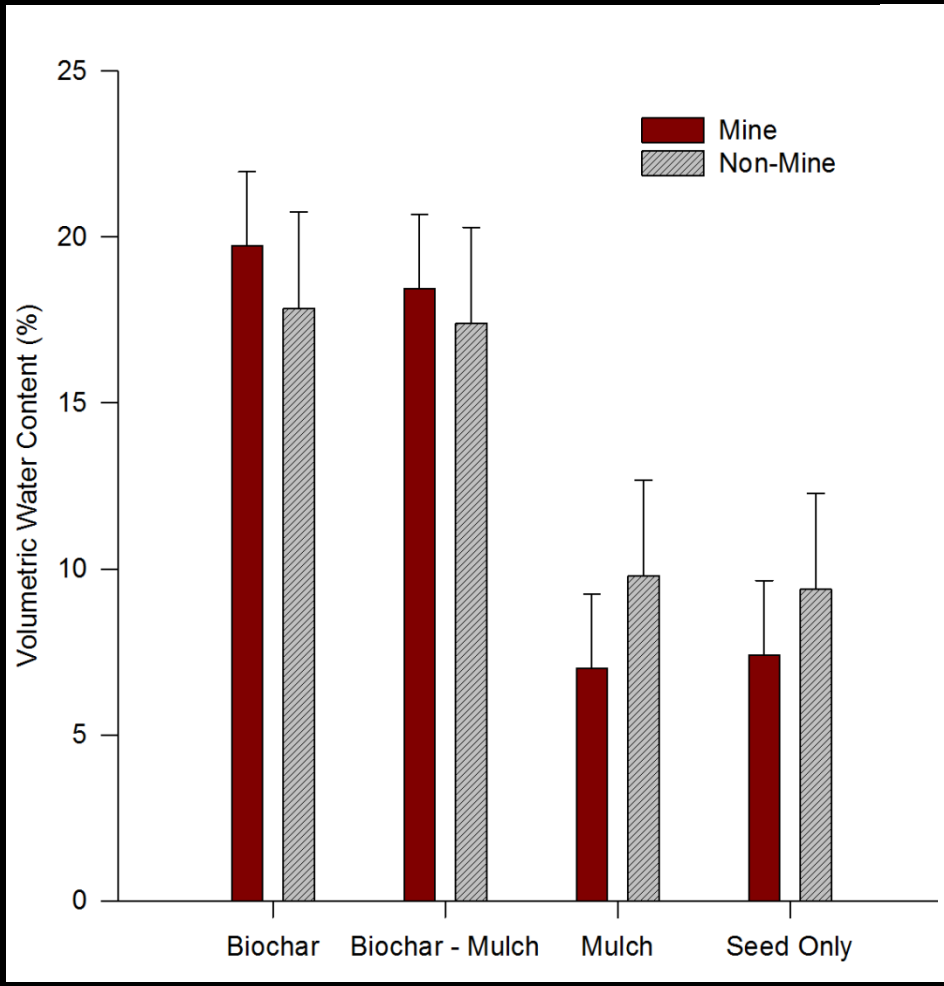


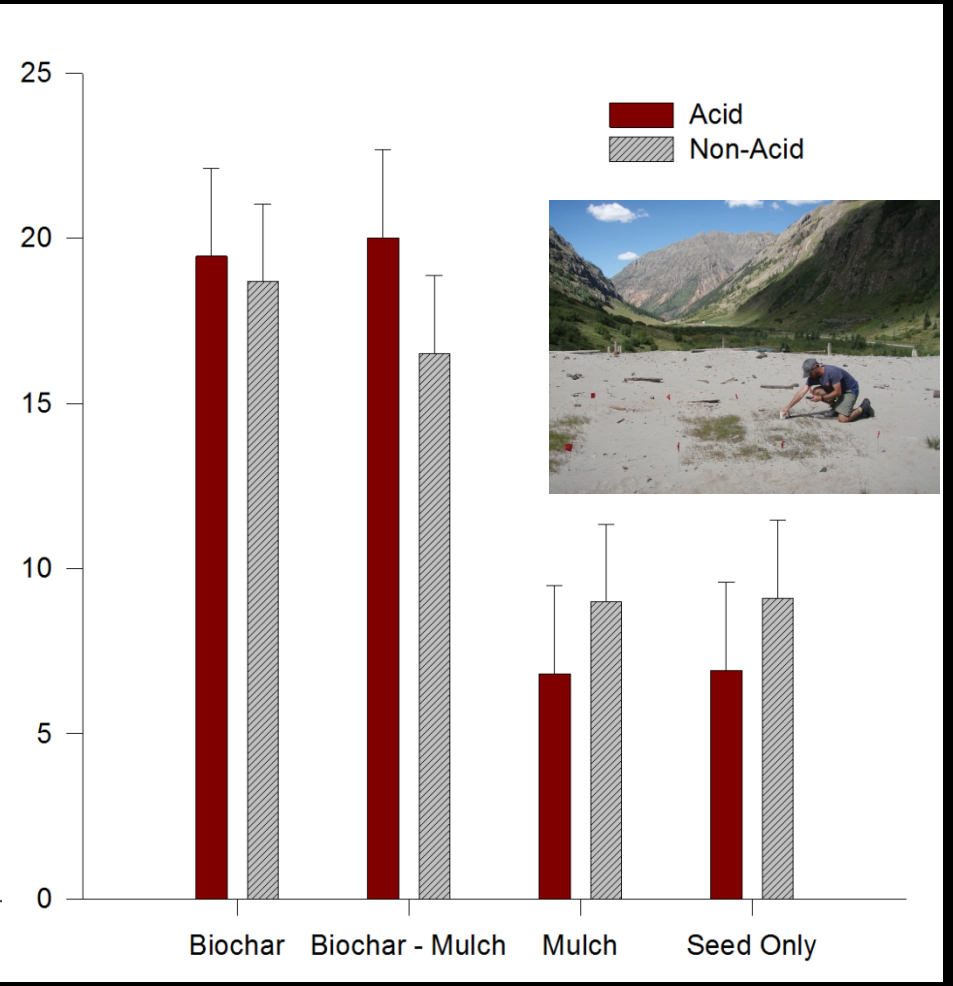
Vegetation Cover





Volumetric Water Content





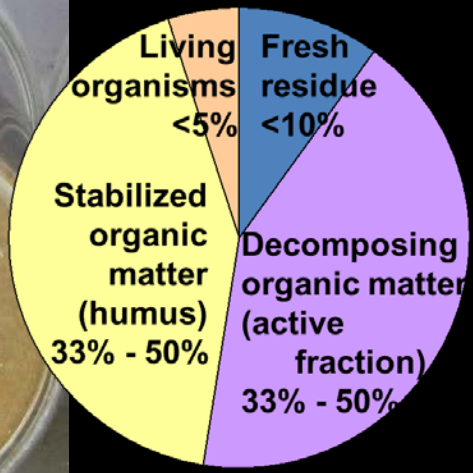
Comparison (mine)	Diff of Means	P
Biochar vs. Mulch	**12.73**	**<0.001**
Biochar vs. Seed Only	**12.32**	**<0.001**
Biochar - Mulch vs. Mulch	**11.44**	**<0.001**
Biochar - Mulch vs. Seed Only	**11.03**	**<0.001**
Biochar vs. Biochar - Mulch	1.29	0.686
Seed Only vs. Mulch	0.41	0.898

Comparison (acid)	Diff of Means	P
Biochar - Mulch vs. Mulch	**13.2**	**<0.001**
Biochar - Mulch vs. Seed Only	**13.1**	**<0.001**
Biochar vs. Mulch	**12.643**	**0.001**
Biochar vs. Seed Only	**12.543**	**0.002**
Biochar - Mulch vs. Biochar	0.557	0.883
Seed Only vs. Mulch	0.1	0.979


Joe and John, 2011
CAT
CAT

Ruby Hill Mine - Eureka, NV


Good reclamation
@ 10 years
Poor reclamation
@ 10 years

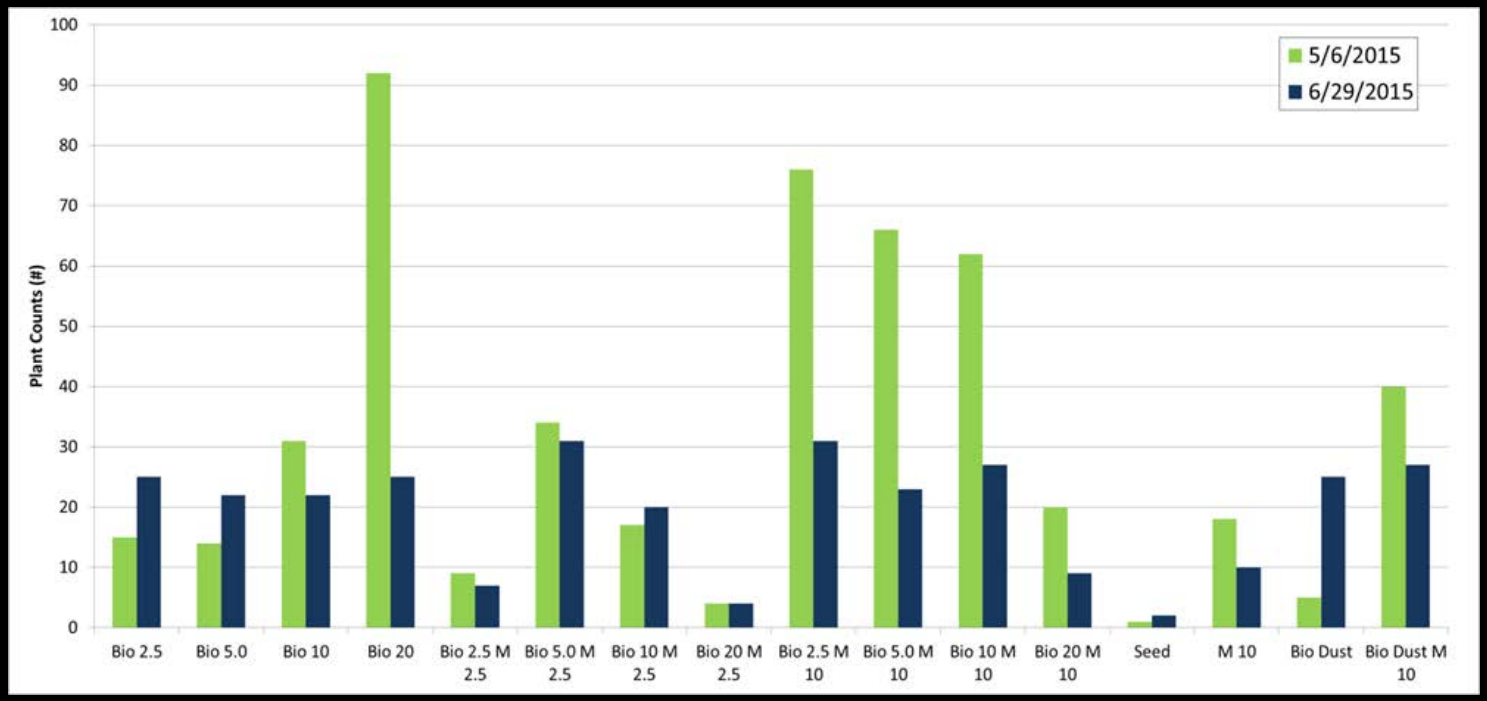


<10 yards/ac ~20 yards/ac >50 yards/ac

Seed Only Control	Manure 10	Biochar Dust	Biochar Dust Manure 10
Biochar 2.5	Biochar 5	Biochar 10	Biochar 20

Biochar 2.5 Manure 10	Biochar 5 Manure 10	Biochar 10 Manure 10	Biochar 20 Manure 10
Biochar 2.5 Manure 2.5	Biochar 5 Manure 2.5	Biochar 10 Manure 2.5	Biochar 20 Manure 2.5


October, 2013
SCD
M 10
BIO DUST
BIO DUST



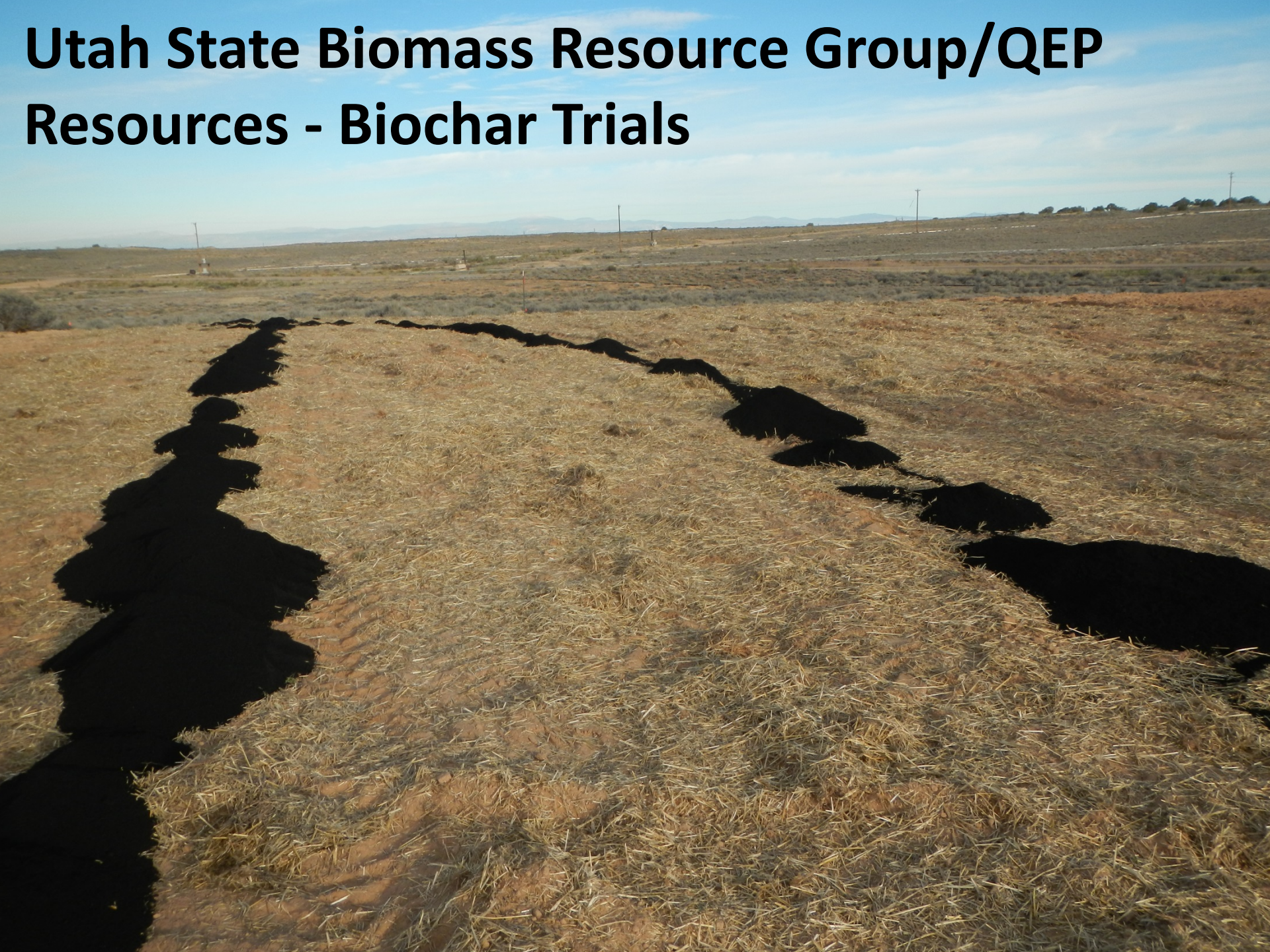
Second summer, # of plant stems

May 6, 2015

Spatial arrangement of vegetation establishment

Animal browse

Utah State Biomass Resource Group/QEP Resources - Biochar Trials



What is the value of adding biochar here?


Topsoil addition
Reduced amount

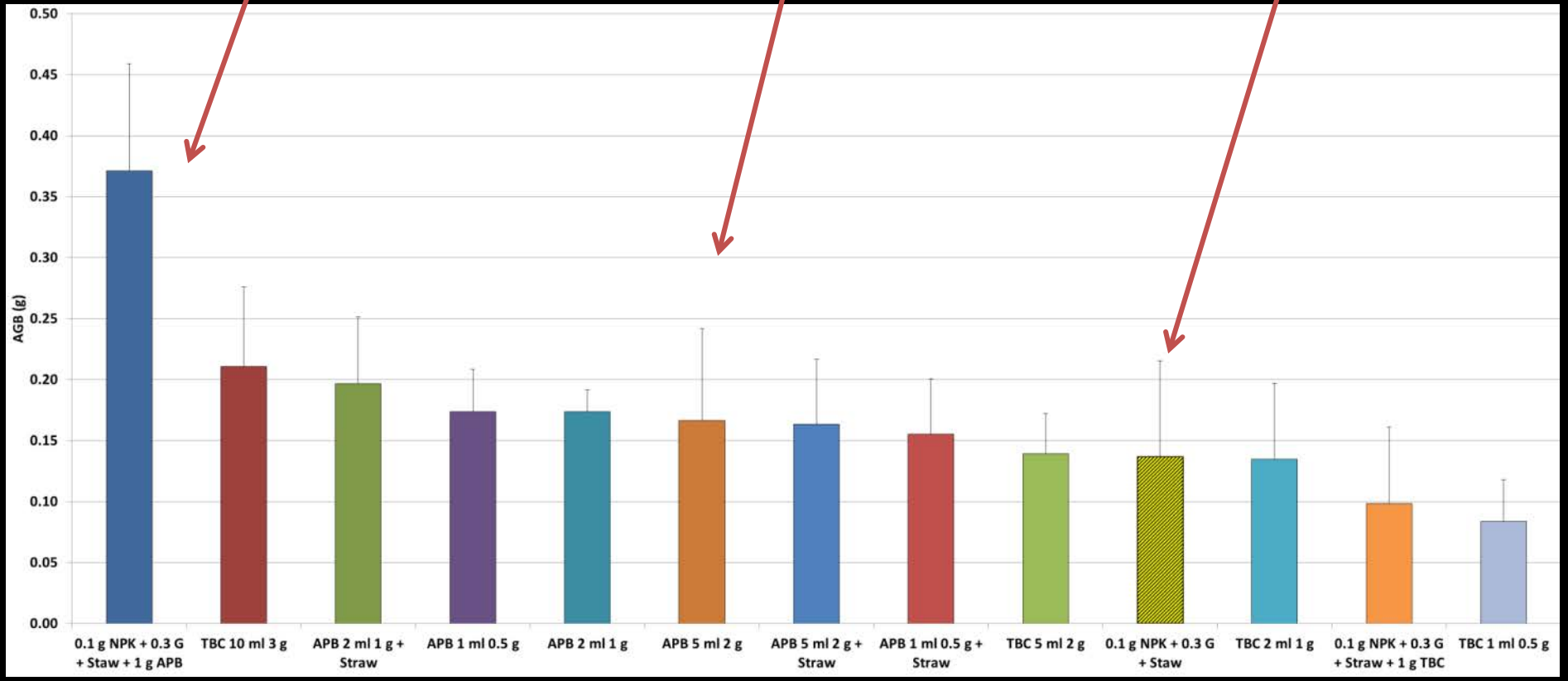

Straw Mulch
Substitute/Combine

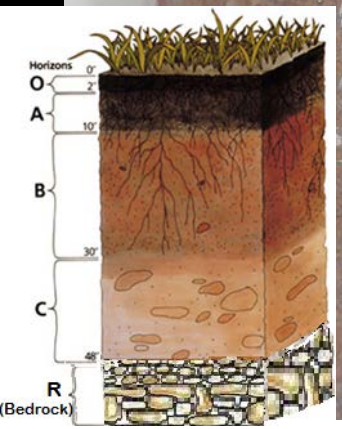

Gypsum/NPK Fertilizer
Substitute/Enhance/Reduce


Imprinting
Substitute/Enhance/Reduce


Soil H20 Management
Enhance

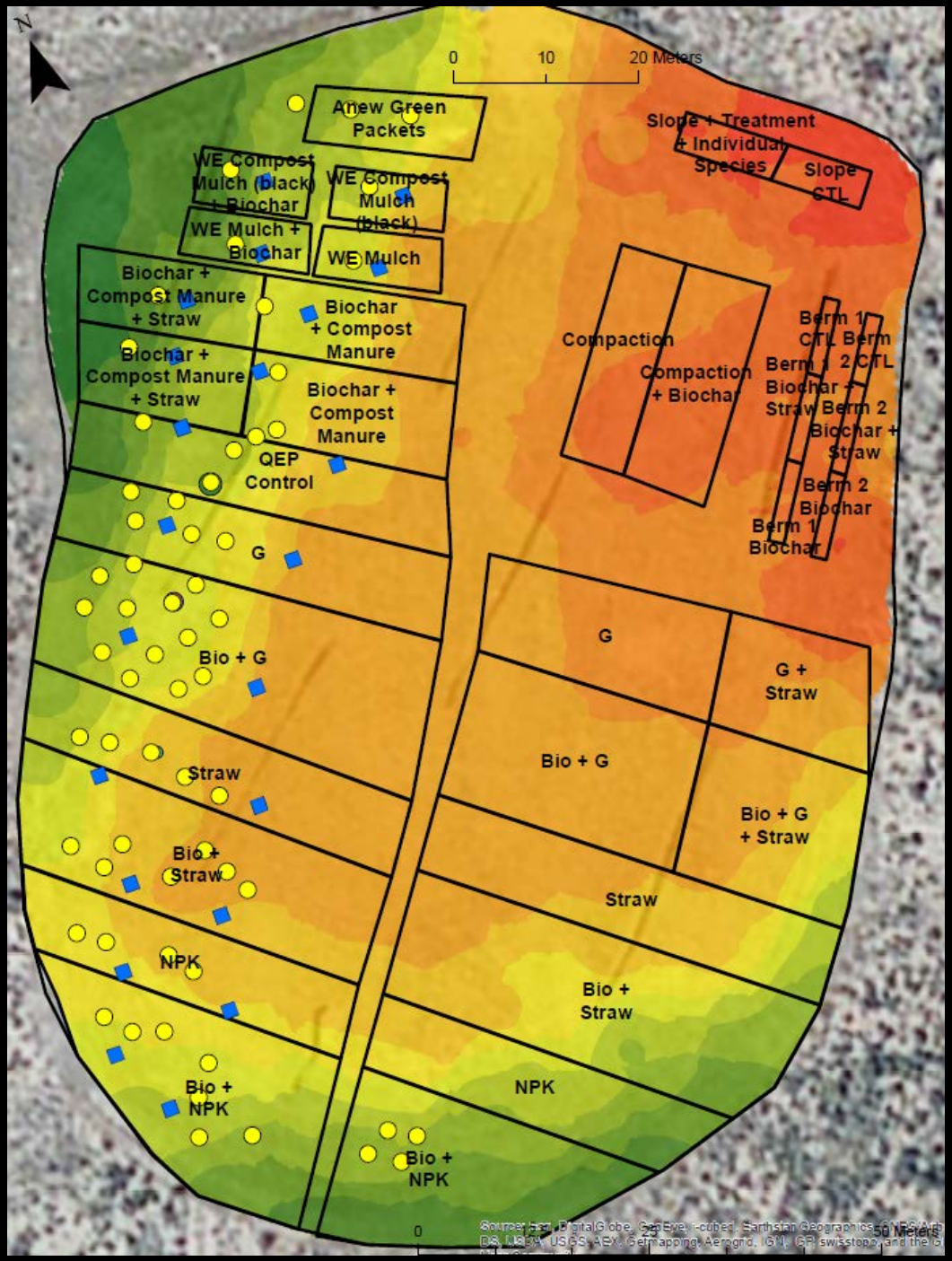

QEP Energy Company
Enhanced Reclamation Program
Presented By:
Stephanie Tomkinson
Senior Biologist
October 14, 2010
Environmentally Friendly Drilling (EFD) Workshop


AGB (g)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.1 g NPK + 0.3 G + Staw + 1 g APB
TBC 10 ml 3 g
APB 2 ml 1 g + Straw
APB 1 ml 0.5 g
APB 2 ml 1 g
APB 5 ml 2 g
APB 5 ml 2 g + Straw
APB 1 ml 0.5 g + Straw
TBC 5 ml 2 g
0.1 g NPK + 0.3 G + Staw
TBC 2 ml 1 g
0.1 g NPK + 0.3 G + Straw + 1 g TBC
TBC 1 ml 0.5 g



The long-term objective of final reclamation is to **set the course for eventual ecosystem restoration**, …… ***and*** **take the steps necessary to ensure that long-term objectives will be reached through natural processes.**

Treatment	Yards of Biochar /Acre
Bio + G + Straw	39
Biochar + Compost Manure + Straw	34
Bio + G	33
Bio + NPK	28
Bio + G	28
WE Mulch + Biochar	26
Biochar + Compost Manure	25
Biochar + Compost Manure + Straw	25
WE Compost Mulch (black) + Biochar	22
Biochar + Compost Manure	22
Bio + Compaction	20
Bio + Straw	19
Bio + NPK	17
Bio + Straw	16
NPK	0
NPK	0
QEP Control	0
G	0
G	0
G + Straw	0
Straw	0
Straw	0
Anew Green Packets	0
WE Compost Mulch (black)	0
WE Mulch	0




Delivered/spread at >10% moisture content to reduce dust.

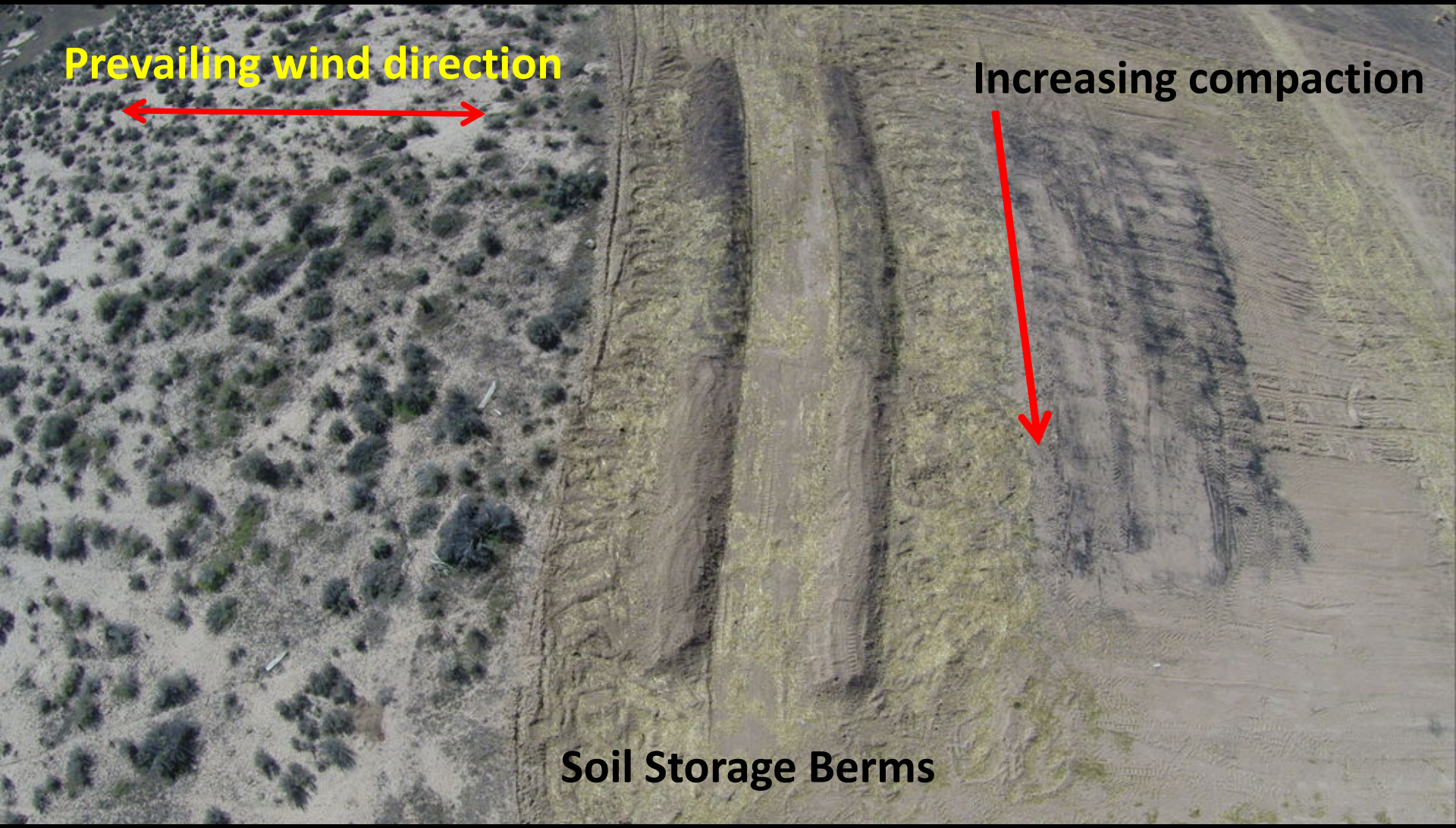
Surface application

Soil storage

Co-application with composted manure

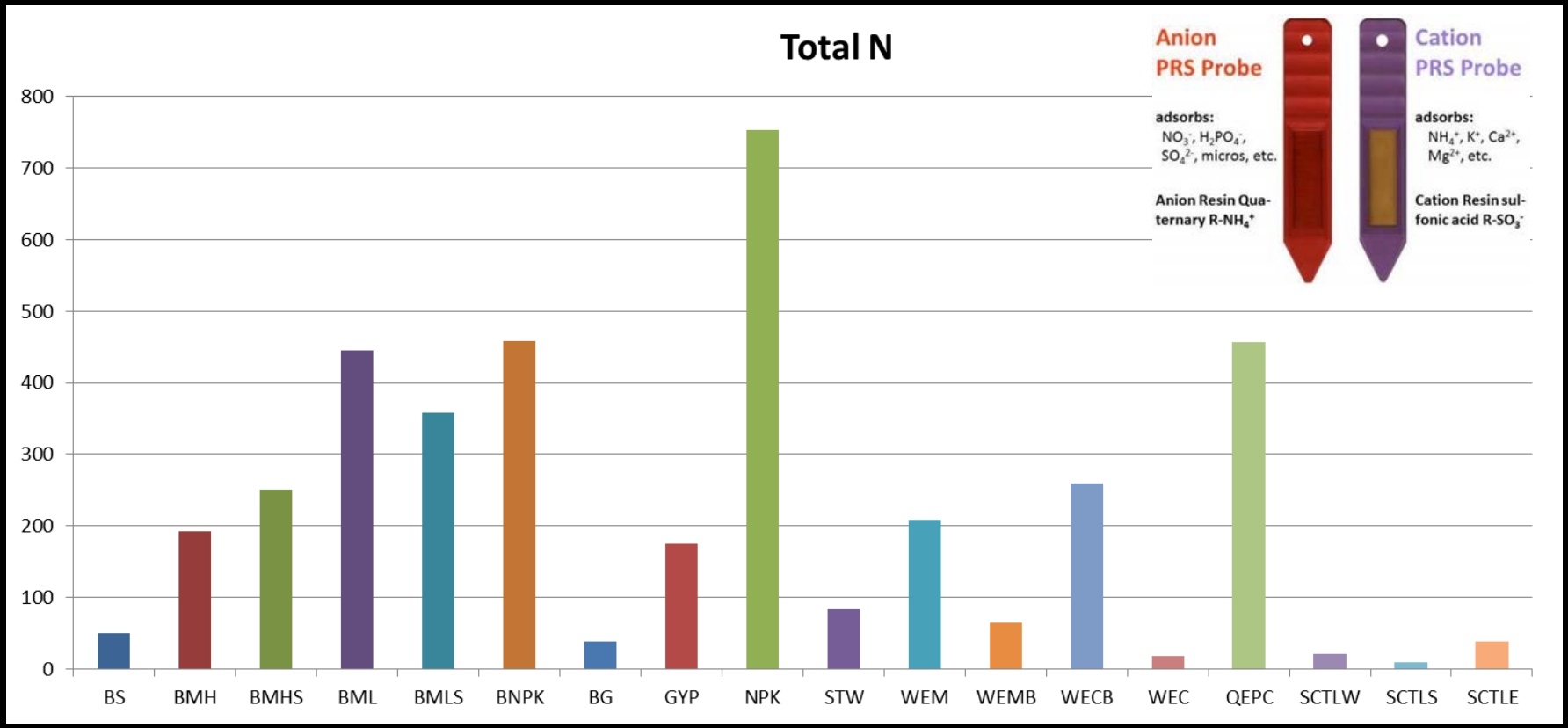

~20 cubic yards/acre

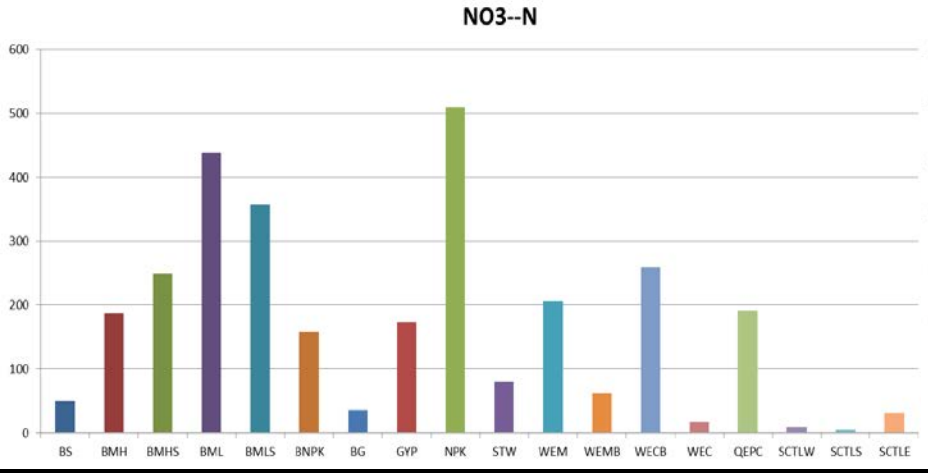
Biochar as part of ongoing soil management and storage

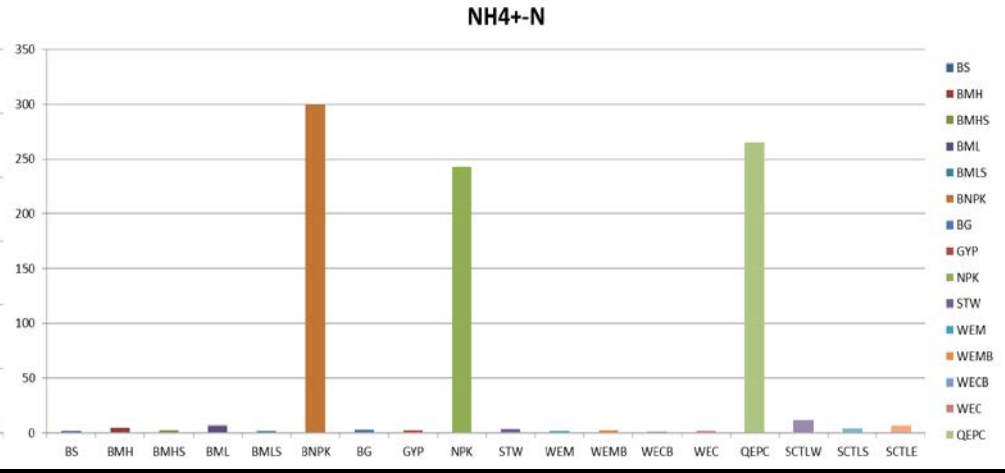


Dennis Hinkamp – Utah State University Extension

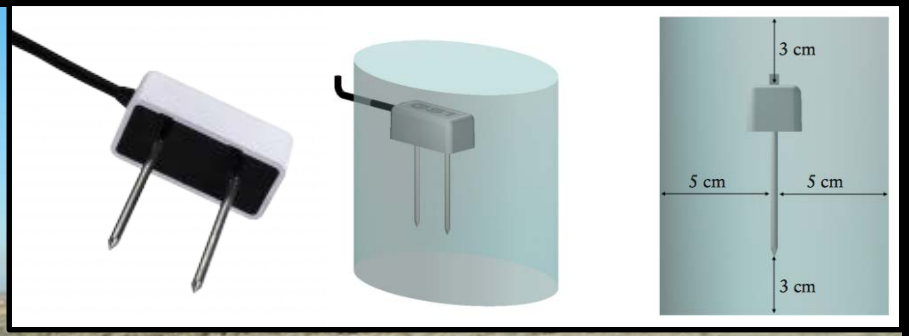
https://www.youtube.com/watch?v=25OR8I-h-pE&feature=youtu.be


Total N
Anion
PRS Probe
adsorbs:
NO_3^-, $H_2PO_4^-$,
SO_4^{2-}, micros, etc.
Anion Resin Quaternary R-NH_4^+
Cation
PRS Probe
adsorbs:
NH_4^+, K^+, Ca^{2+},
Mg^{2+}, etc.
Cation Resin sulfonic acid R-SO_3^-
800
700
600
500
400
300
200
100
0
BS
BMH
BMHS
BML
BMLS
BNPK
BG
GYP
NPK
STW
WEM
WEMB
WECB
WEC
QEPC
SCTLW
SCTLS
SCTLE


NO3--N
600
500
400
300
200
100
0
BS
BMH
BMHS
BML
BMLS
BNPK
BG
GYP
NPK
STW
WEM
WEMB
WECB
WEC
QEPC
SCTLW
SCTLS
SCTLE


NH4+-N
350
300
250
200
150
100
50
0
BS
BMH
BMHS
BML
BMLS
BNPK
BG
GYP
NPK
STW
WEM
WEMB
WECB
WEC
QEPC
SCTLW
SCTLS
SCTLE

Soil Moisture Sensor Network



Open S

UW
2 Ft

DW
2 Ft

DW
6 Ft

Open N

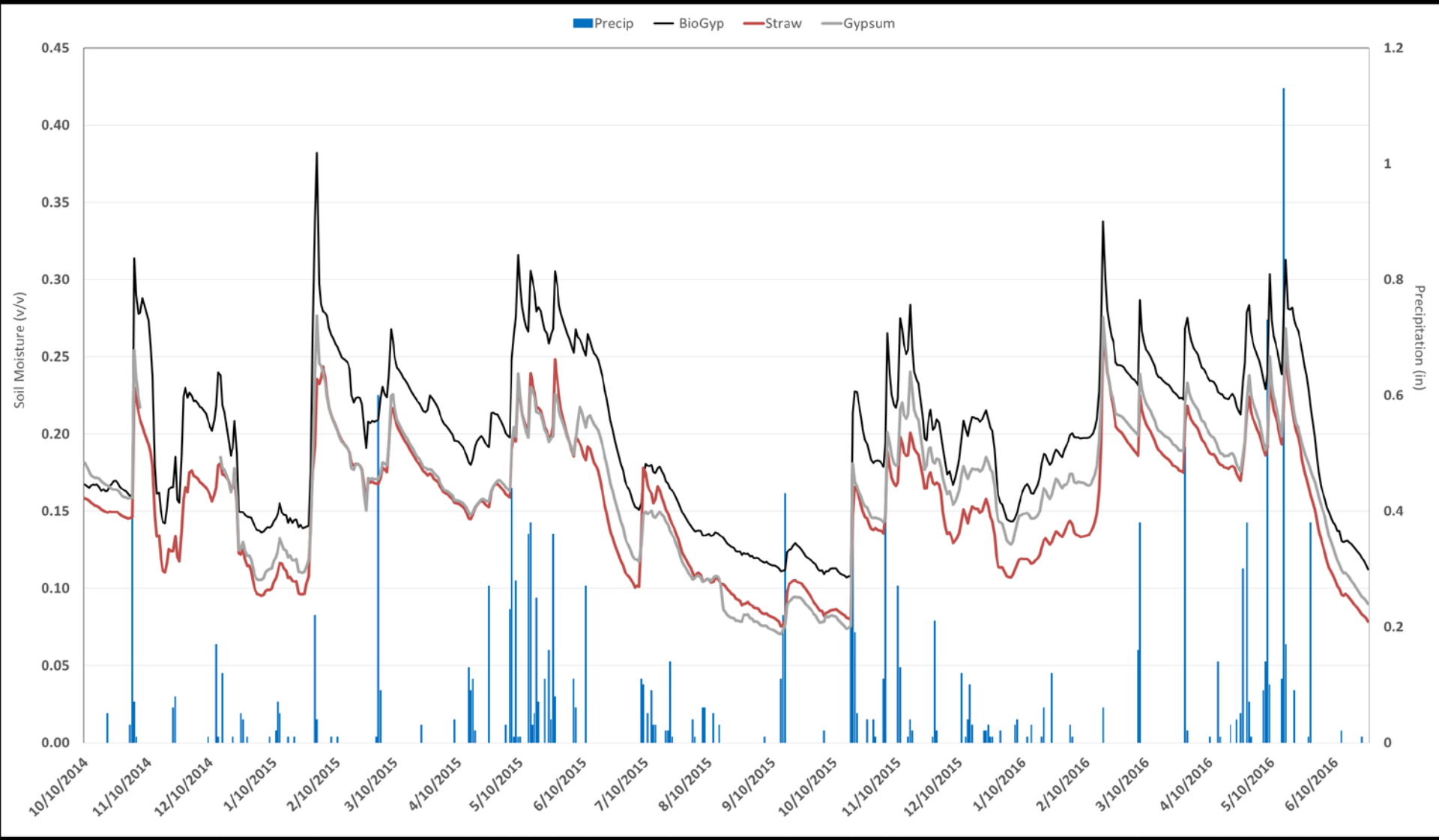

MOULTRIE
20°F
A0000000CAM
04 MAR 2015 09:00 am

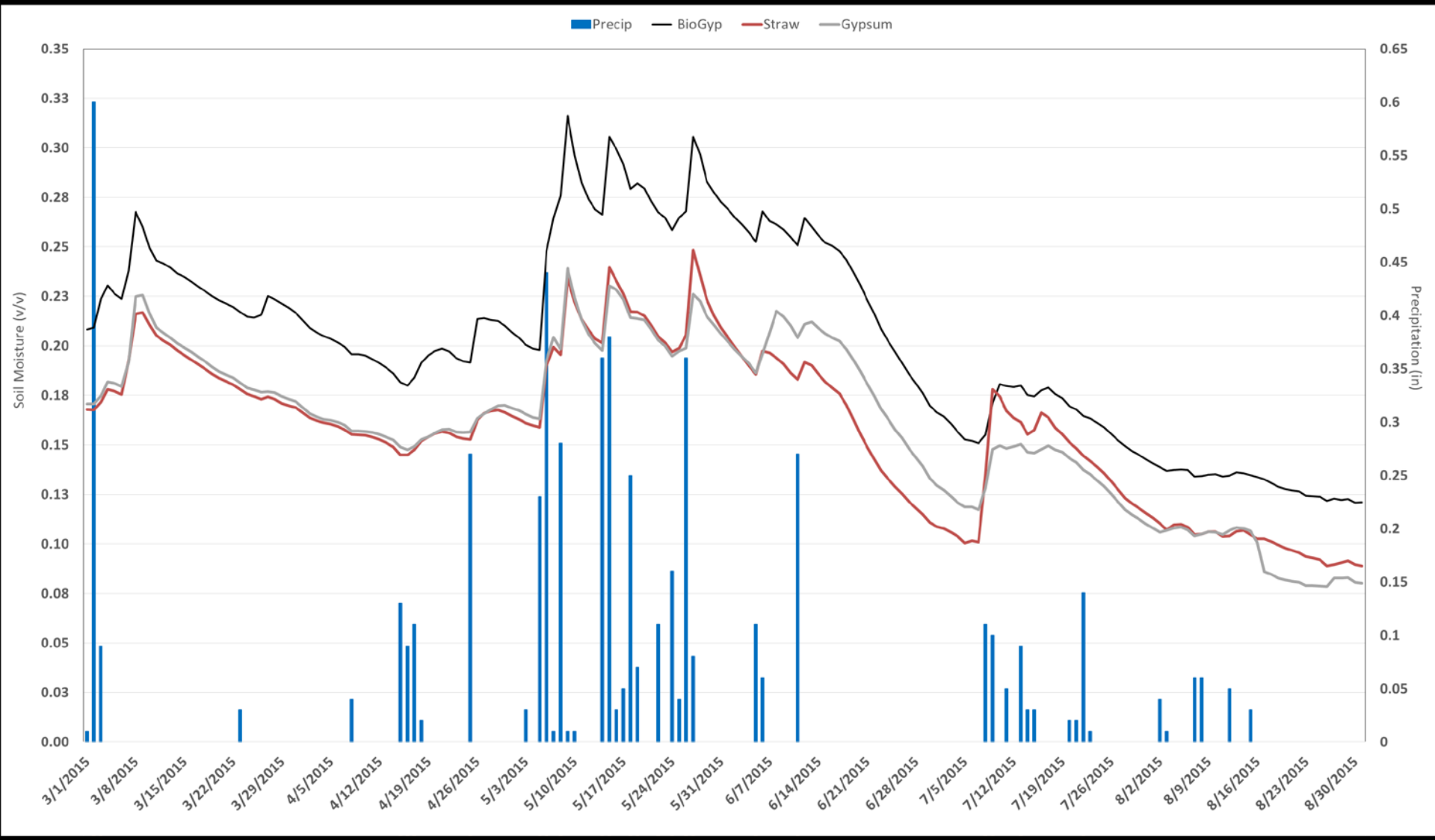

MOULTRIE
35°F
A0000000CAM
07 MAR 2015 09:00 am

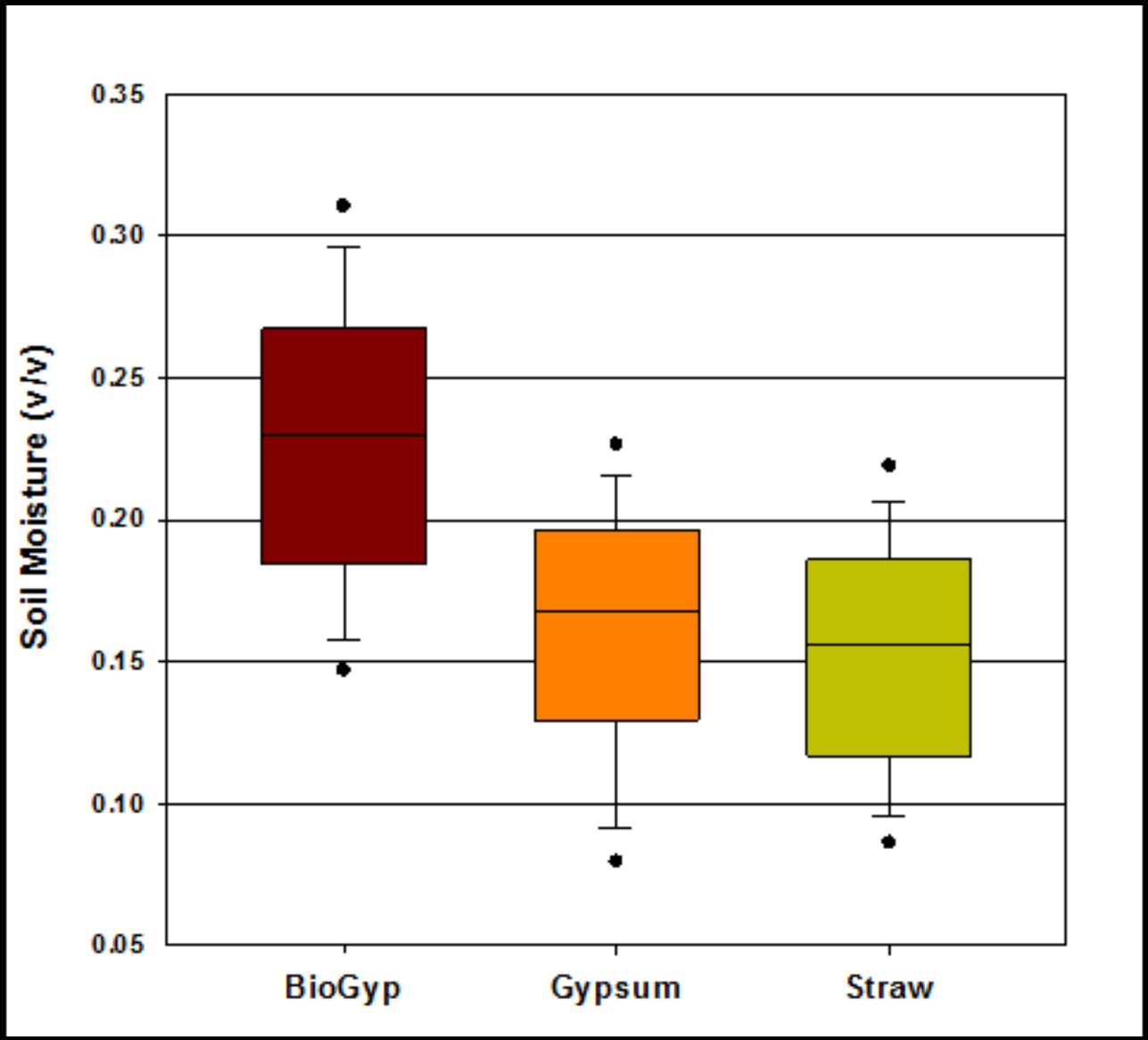

MOULTRIE
37°F
A0000000CAM
08 MAR 2015 09:00 am


MOULTRIE
35°F
A0000000CAM
09 MAR 2015 09:00 am

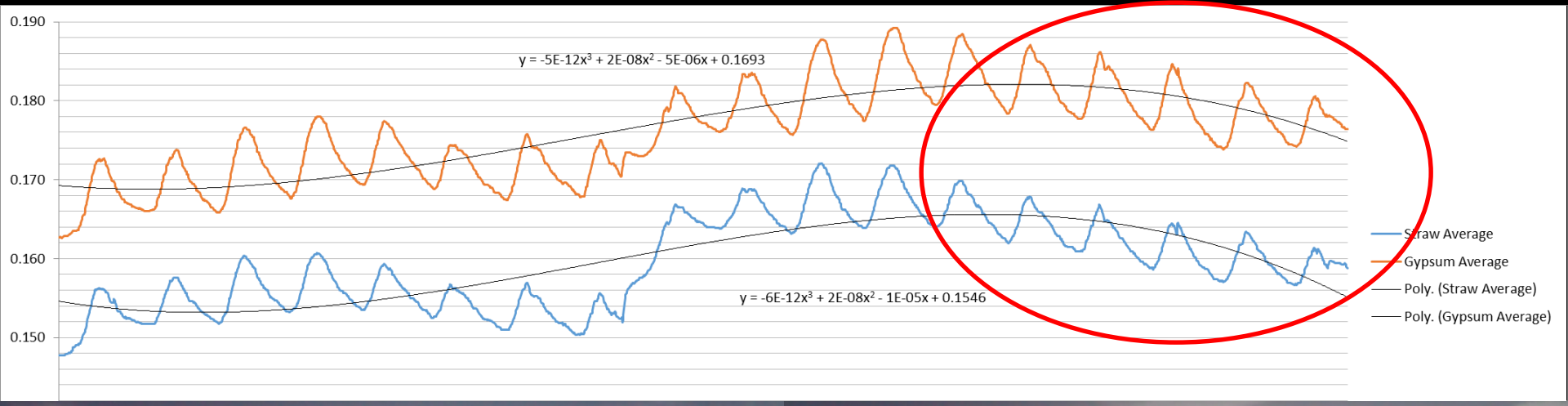
Soil Moisture




Precip
BioGyp
Straw
Gypsum
Soil Moisture (v/v)
Precipitation (in)
0.35
0.33
0.30
0.28
0.25
0.23
0.20
0.18
0.15
0.13
0.10
0.08
0.05
0.03
0.00
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
3/1/2015
3/8/2015
3/15/2015
3/22/2015
3/29/2015
4/5/2015
4/12/2015
4/19/2015
4/26/2015
5/3/2015
5/10/2015
5/17/2015
5/24/2015
5/31/2015
6/7/2015
6/14/2015
6/21/2015
6/28/2015
7/5/2015
7/12/2015
7/19/2015
7/26/2015
8/2/2015
8/9/2015
8/16/2015
8/23/2015
8/30/2015



Group	Median	25%	75%	Comparison	P<0.05
BioGyp	0.230	0.184	0.267	BioGyp vs Straw	Yes
Gypsum	0.168	0.130	0.197	BioGyp vs Gypsum	Yes
Straw	0.156	0.117	0.186	Gypsum vs Straw	Yes


0.190
0.180
0.170
0.160
0.150
y = -5E-12x³ + 2E-08x² - 5E-06x + 0.1693
y = -6E-12x³ + 2E-08x² - 1E-05x + 0.1546
Straw Average
Gypsum Average
Poly. (Straw Average)
Poly. (Gypsum Average)


MOULTRIE
80°F
A0000000CAM
14 APR 2015 03:00 pm


MOULTRIE
80°F
A0000000CAM
14 APR 2015 04:00 pm


MOULTRIE
51°F
MOULTRIECAM
24 JAN 2015 06:00 pm

June 30, 2015

May 19, 2016

High - Zero - Low

> 30 yards/acre - - <10 yards/acre

March 23, 2016

Reduction in soil crusting?
Aeolian transport?


Spatial Reinforcement


Sphere of Influence

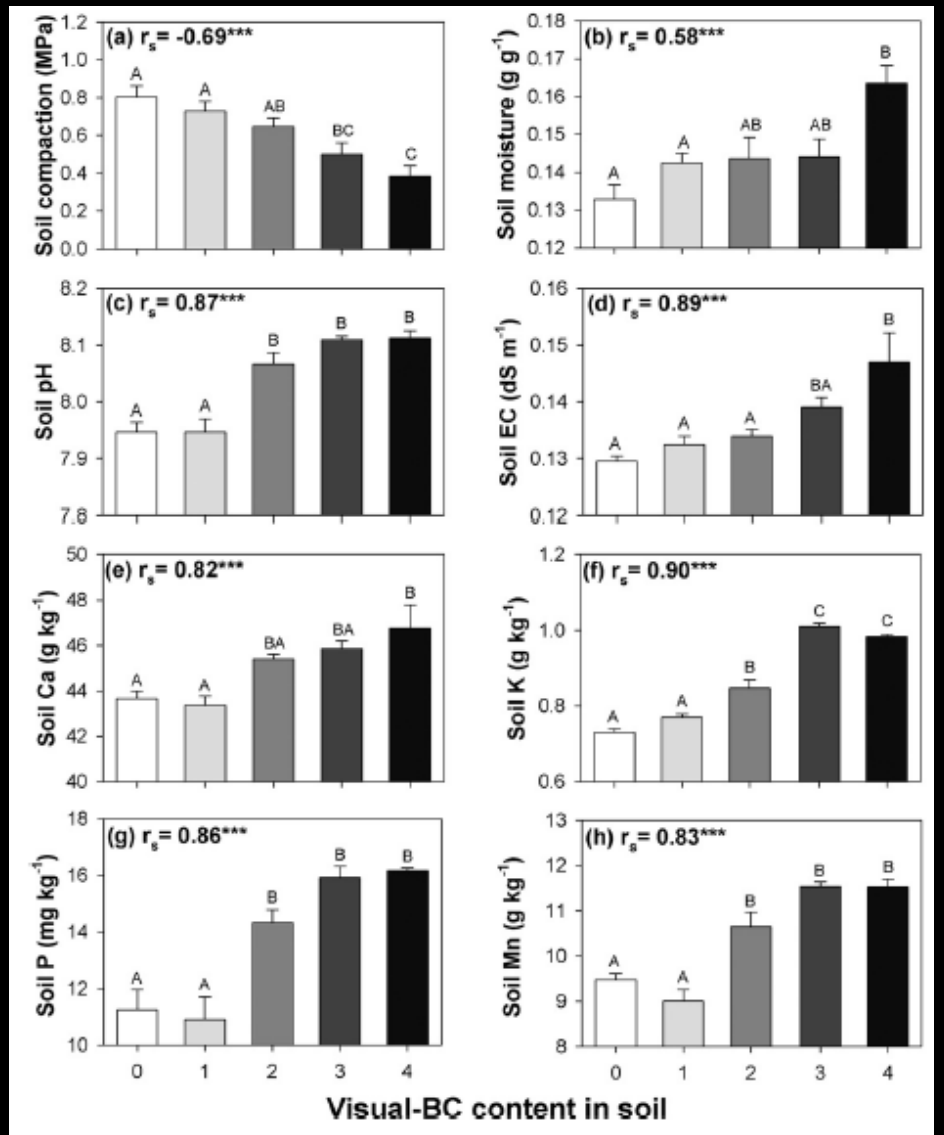
Islands of Establishment

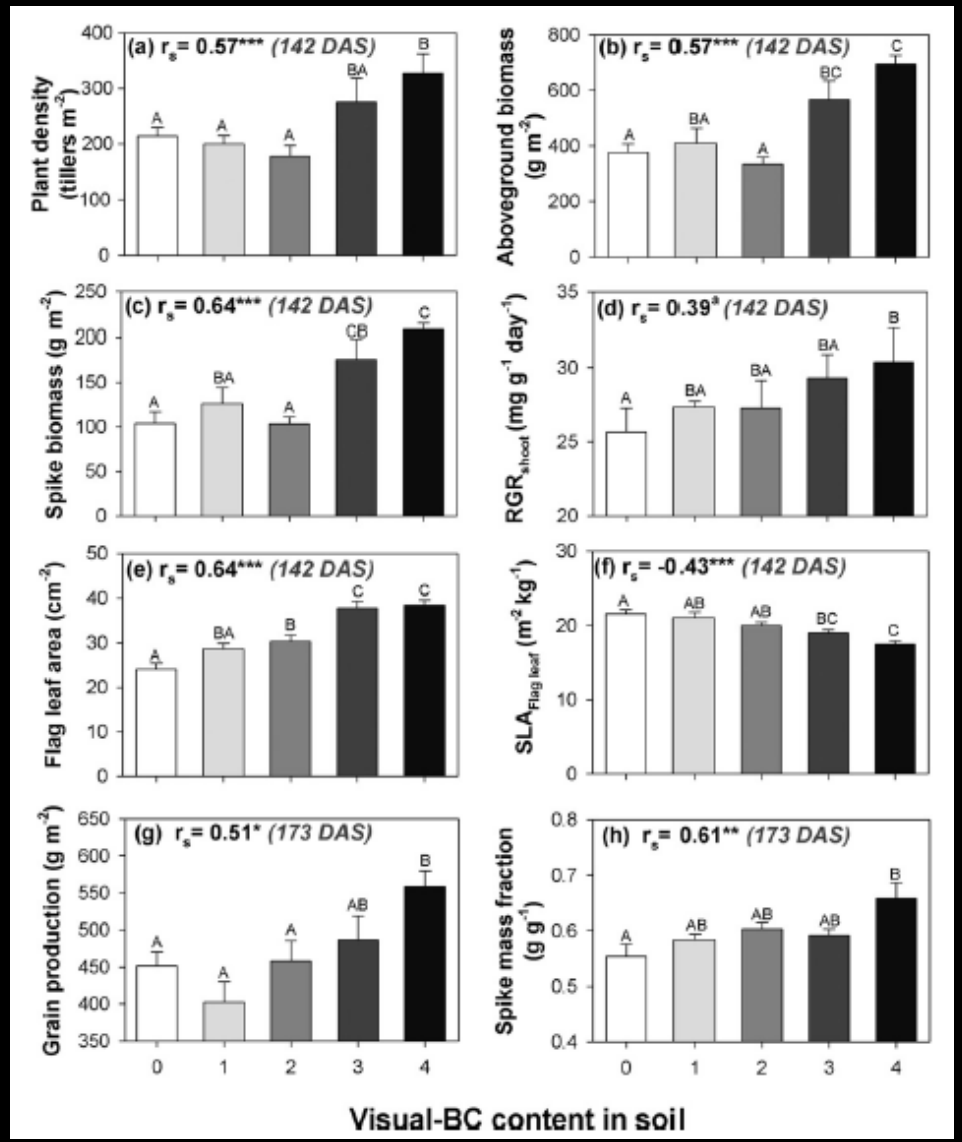
Spatial heterogeneity of soil biochar content affects soil quality and wheat growth and yield

Manuel Olmo [a,*], Ana María Lozano [a], Vidal Barrón [b], Rafael Villar [a]

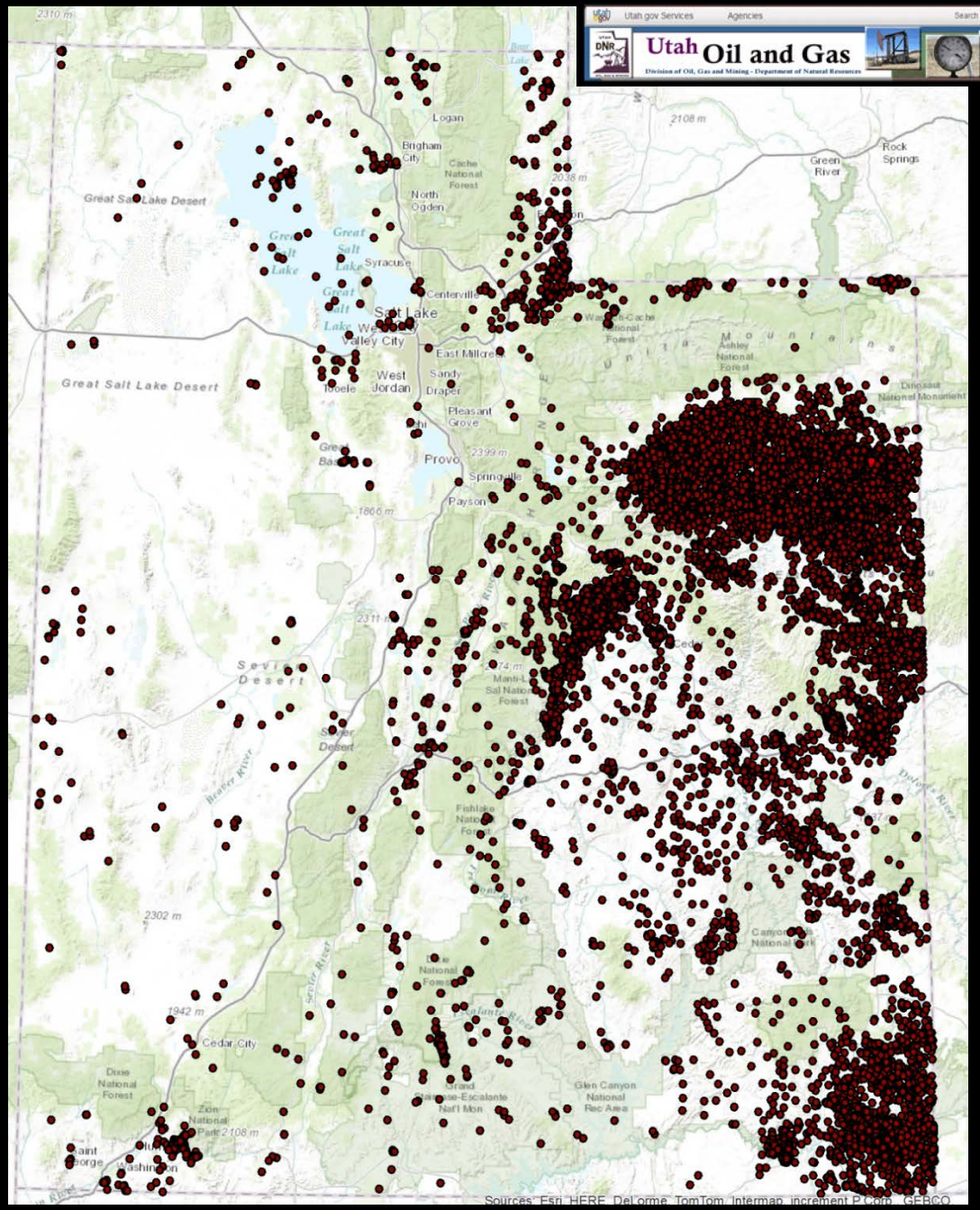
[a] Área de Ecología, Facultad de Ciencias, Universidad de Córdoba, 14071 Córdoba, Spain
[b] Departamento de Agronomía, Universidad de Córdoba, 14071 Córdoba, Spain

Science of the Total Environment 562 (2016) 690–700

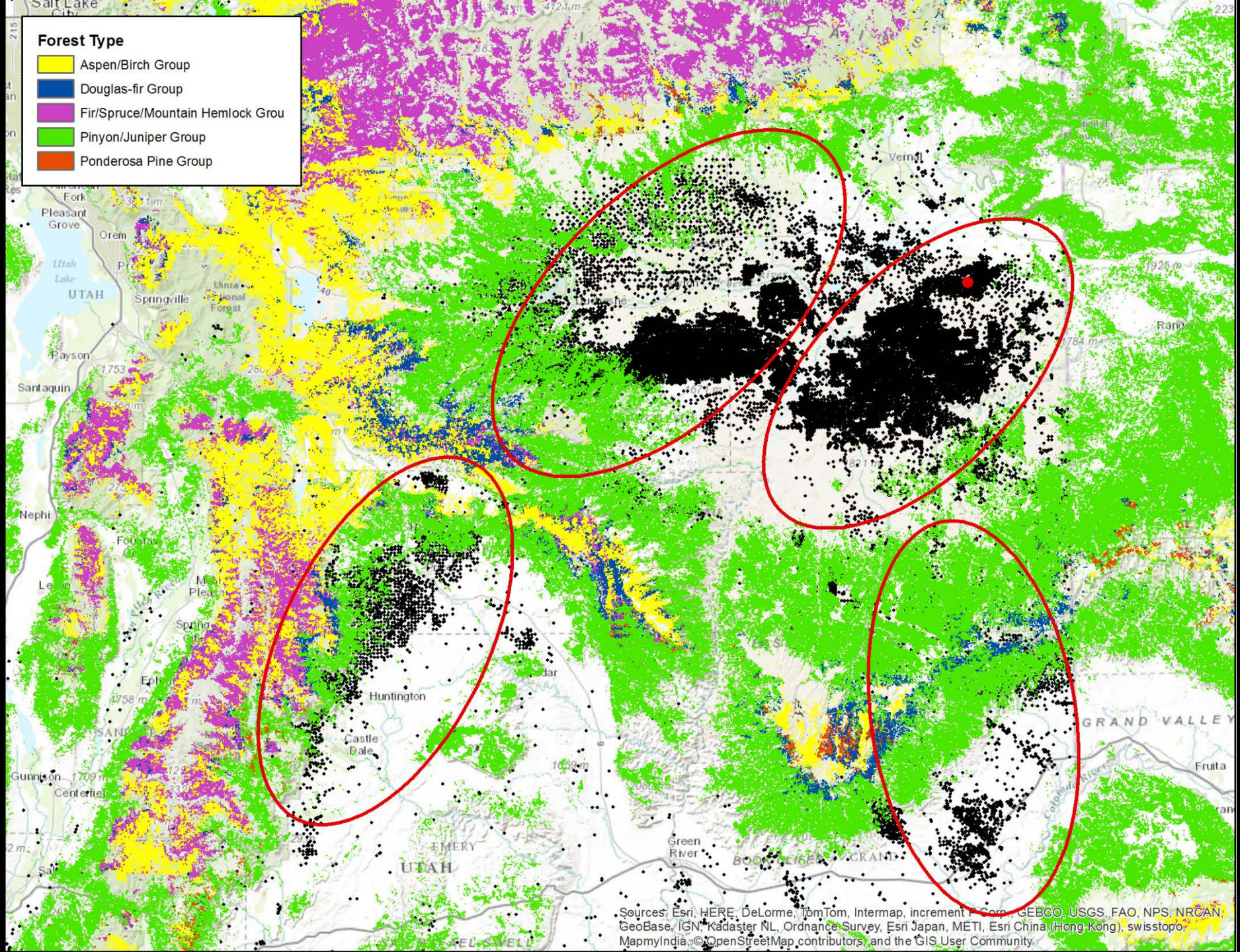




Name	Wells
KERR-MCGEE OIL & GAS ONSHORE, L.P.	4932
NEWFIELD PRODUCTION COMPANY	4512
EOG RESOURCES, INC.	1945
QEP ENERGY COMPANY	**1541**
LINN OPERATING, INC.	1518
XTO ENERGY INC	1174
RESOLUTE NATURAL RESOURCES	819
CRESCENT POINT ENERGY U.S. CORP	744
CONOCOPHILLIPS COMPANY	726
BILL BARRETT CORP	712
ENDURING RESOURCES, LLC	633
EP ENERGY E&P COMPANY, L.P.	609
PETROGLYPH OPERATING CO	568
ENERVEST OPERATING, LLC	525
GASCO PRODUCTION COMPANY	302
ULTRA RESOURCES INC	235
QUESTAR EXPLORATION & PRODUCTION CO	220
ANADARKO E&P ONSHORE, LLC	206
CHEVRON USA INC	194
FINLEY RESOURCES, INC.	194
WESGRA CORPORATION	188
CITATION OIL & GAS CORP	186
GULF OIL CORPORATION	166
QEP UINTA BASIN, INC.	165
AMOCO PRODUCTION COMPANY	156
WEXPRO COMPANY	139
RUNNING FOXES PETROLEUM, INC.	132
LONE MTN PRODUCTION CO	131
SHENANDOAH ENERGY INC	127
SHELL OIL COMPANY	124
FOREST OIL CORPORATION	121
HARKEN SOUTHWEST CORP	121
ROSEWOOD RESOURCES INC	121
COASTAL OIL & GAS CORP	116
LOMAX EXPLORATION COMPANY	114
SUPERIOR OIL COMPANY	111
TEXACO INC	111
WESTPORT OIL & GAS CO LP	110
DOMINION EXPL & PROD INC	107



~34,500 total - ~24,850 (Companies with >100 wells)


Forest Type
Aspen/Birch Group
Douglas-fir Group
Fir/Spruce/Mountain Hemlock Grou
Pinyon/Juniper Group
Ponderosa Pine Group
Pleasant Grove
Orem
Utah Lake
UTAH
Springville
Uinta-Wasatch-Cache National Forest
Payson
Santaquin
Nephi
Huntington
Castle Dale
EMERY
UTAH
Green River
GRAND VALLEY
Fruita
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Biochar Application Studies Key Take Away's:

1. **Regionally appropriate demonstration sites.**
2. **Detailed site characterization accounts for non-linear effects: animals, climatic variability, business environment.**
3. **Combine quantitative and qualitative, discrete and continuous data.**

EPA seeks a home for sludge

Mayflower tailings ponds seen as a possible solution

THE GOLD KING BLOWOUT: ONE YEAR LATER

The Environmental Protection Agency is in discussions with Sunnyside Gold Corp. on the possibility of using the Mayflower tailings ponds to dispose of sludge from the temporary treatment plant at Gladstone.

Rebecca Thomas, manager of the EPA's Superfund project, said the limited space at the Gladstone property is running out, and the lime-based sludge will have to start being removed before winter.

"There's not enough capacity up there for the winter," Thomas said. "We need to find a disposal location by the end of October."

Thomas said the material isn't particularly hazardous and could be deposited in a municipal landfill, but the EPA wants to avoid the high trucking costs and would prefer a repository within the mining district.

Meanwhile Thomas said about 20 people will be involved in a water sampling effort in September in the basin to monitor conditions at low-flow levels.

"We roughly estimate 3,500 cubic yards is currently stored in the drying area (at the Gladstone

See SLUDGE, Page 7

Combination active treatment and filter bag precipitate collection.

1 of 4 major draining adits for ~6 months

Thank You

Debbie Dumrose – USFS
Darren McAvoy – Utah State University
Jonah Levine – Confluence Energy/Biochar Solutions
Dusty Moller – Washington State University
Scott Bell – USFS (Ret.)
Jake Tibbits – Eureka County Natural Resources
Clark Burton – Barrick Gold Corp
Stephanie Tomkinson – QEP Resources
Kyle Hanson – Western Excelsior Corporation
Mike Olson – Road Runner Engineering
Kay Zillich – BLM (Ret.)
Kirstin Brown – CO DRMS
Many others who have helped and supported this work!

Questions?

Chris Peltz
chris@researchservicesco.com
970.691.6351