Innovative No-Till: Using Multi-Species Cover Crops to Improve Soil Health

By Jay Fuhrer, NRCS – Bismarck, North Dakota and Susan Tallman, NCAT

NRCS NCAT

Sponsors

The Burleigh County Soil Conservation District

USDA NRCS

United States Department of Agriculture
Natural Resources Conservation Service

ATTRA **National Sustainable Agriculture Information Service**

a project of the

National Center for Appropriate Technology
NCAT

Speakers

Jay D. Fuhrer
District Conservationist
NRCS – Bismarck, North Dakota
jay.fuhrer@nd.usda.gov

Susan Tallman
Agriculture Specialist
National Center for Appropriate Technology
susant@ncat.org

www.attra.ncat.org

This webinar is being recorded and will be posted to the ATTRA website, **www.attra.ncat.org**

Cover Crops: Designing for what you don't have!

Photo: Jon Stika, NRCS

Resource Concerns:

- Provide crop diversity
- Provide soil surface armor
- Build soil aggregates
- Improve the water cycle
- Integrated Pest Management
- Build soil organic matter

Cover Crops: Designing for what you don't have!

Photo: Jay Fuhrer, NRCS

Resource Concerns (*continued*):

- Promote nutrient cycling
- Enhance pollinators
- Adjust carbon/nitrogen ratios
- Provide wildlife food & shelter
- Integrate livestock

Four Case Studies on Improving Soil Health with Cover Crop Combinations

Brown's Ranch

Photo: Jay Fuhrer, NRCS

Richter Farms

Photo: Jay Fuhrer, NRCS

Black Leg Ranch

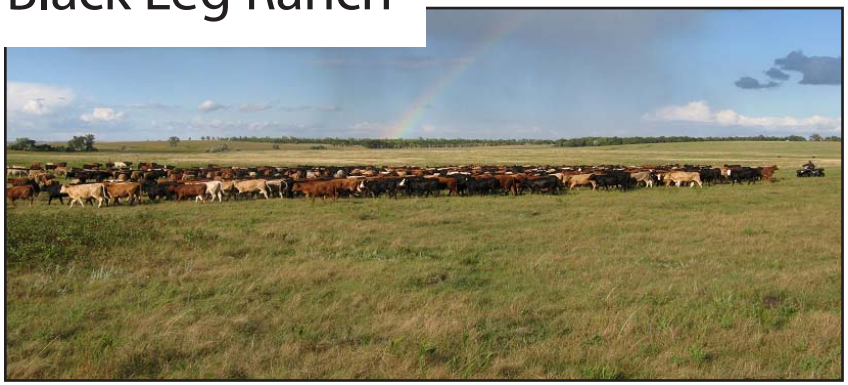


Photo: Joshua Dukart, BCSCD

Menoken Farm

Photo: Jay Fuhrer, NRCS

Case Study 1

Photo: Jay Fuhrer, NRCS

Brown's Ranch -
Gabe and Paul Brown

- Provide crop diversity
- Build soil organic matter
- Promote nutrient cycling
- Adjust C/N ratio
- Integrate livestock

The Answer: Imitate Native Rangeland

Photo: Jay Fuhrer, NRCS

Photo: Jay Fuhrer, NRCS

Photo: Jay Fuhrer, NRCS

Photo: Jay Fuhrer, NRCS

Diversity in the Cropping System

Warm-Season Grass

Photo: Jay Fuhrer, NRCS

Warm-Season Broadleaf

Photo: Jay Fuhrer, NRCS

Diversity in the Cropping System

Cool-Season Grass

Photo: Jay Fuhrer, NRCS

Cool-Season Broadleaf

Photo: Jay Fuhrer, NRCS

Diversity — Crop Types

Warm-Season Broadleaf	Warm-Season Grasses
Alfalfa	Corn
Buckwheat	Proso Millet
Chickpea	Pearl Millet
Amaranth	Sorghum
Cowpea	Sudan
Soybean	
Safflower	
Sunflower	

Diversity — Crop Types (continued)

Cool-Season Broadleafs	Cool-Season Grasses
Canola	Barley
Turnip	Durum Wheat
Crambe	Oats
Pasja	Spring Wheat
Flax	Winter Rye
Pea	Winter Triticale
Lentils	Winter Wheat
Lupin	
Radish	
Mustard	
Forage Canola	
Red Clover	
Sweet Clover	

Brown's Ranch Annual Crops and Cover Crops

Cool-Season Grass

Barley
Wheat
Oats

Cool-Season Broadleaf

Canola
Pea
Turnip
Radish
Lentil
Hairy Vetch
Pasja
Red Clover
Sweet Clover

Warm-Season Grass

Millet
Sorghum
Sudan
Corn

Warm-Season Broadleaf

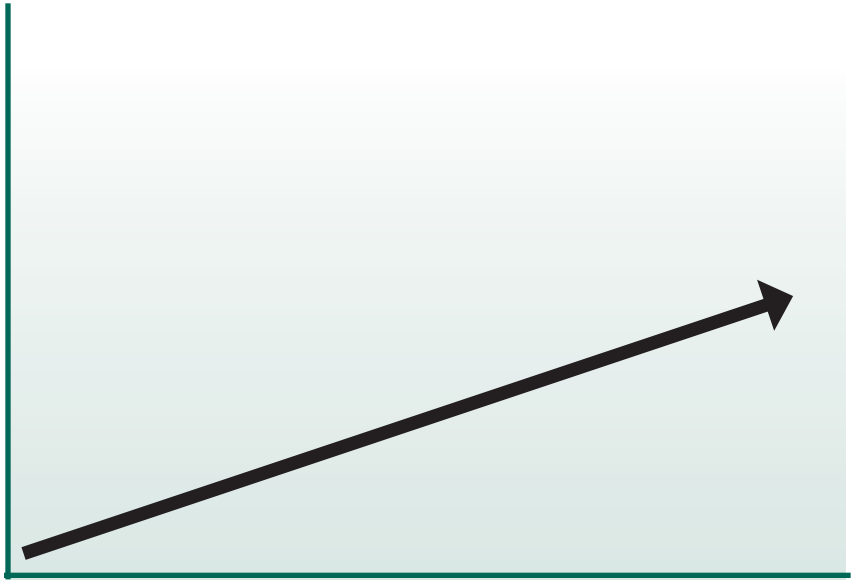
Alfalfa
Sunflower
Sugar Beets
Buckwheat
Cowpea

Soil Organic Matter (SOM)

- Cover Crops provide a continual live root to harvest additional sunlight

Photo: Jay Fuhrer, NRCS

Upward Trend



- 1993..... 1.7 to 2.0%
- Present ..... 3.7 to 4.3%

Nutrient Cycling ~ Carbon/Nitrogen Ratios

Soil Microorganisms, Bacteria *	5/1
SOM, Mollisol Ap horizon *	11/1
Young Alfalfa Hay *	13/1
Rotted barnyard manure *	20/1
Mature Alfalfa Hay *	25/1
Protozoa **	30/1
Corn Stover *	57/1
Wheat Straw *	80/1
Newspaper *	120/1
Deciduous Wood **	300/1

Source:

* *The Nature and Properties of Soils, Fourteenth Edition. Dr. Nyle C. Brady and Dr. Ray R. Weil*

** *Dr. Elaine R. Ingham, Soil Food Web*

Warm-Season Cocktail

Photo: Jon Stika, NRCS

- Cowpea ..... 10 lbs
- Soybean ..... 20 lbs
- Pearl Millet ..... 4 lbs
- Proso Millet ..... 4 lbs
- Radish ..... 2 lbs
- Turnip ..... 1 lb
- Sunflower ..... 10 lbs
- Buckwheat ..... 10 lbs

Cool-Season Cocktail

Photo: Jay Fuhrer, NRCS

Seeded end of April 2009

No commercial fertilizer applied

- Oat ..... 45 lbs
- Forage Pea ..... 30 lbs
- Hairy Vetch ..... 10 lbs
- Turnip ..... 1 lb
- Radish ..... 1 lb
- Red Clover ..... 1 lb

Brown's Ranch

— Same Field —

Photo: Jay Fuhrer, NRCS

July 1, 2009

- Corn planted into last year's cover crop residue

Photo: Jay Fuhrer, NRCS

July 16, 2009

- Rapid residue decomposition

Spring 2008

Photo: Gabe Brown, BCSCD

- Planting into grazed Cowpea/Millet
- Invisible Planting

Livestock Integration

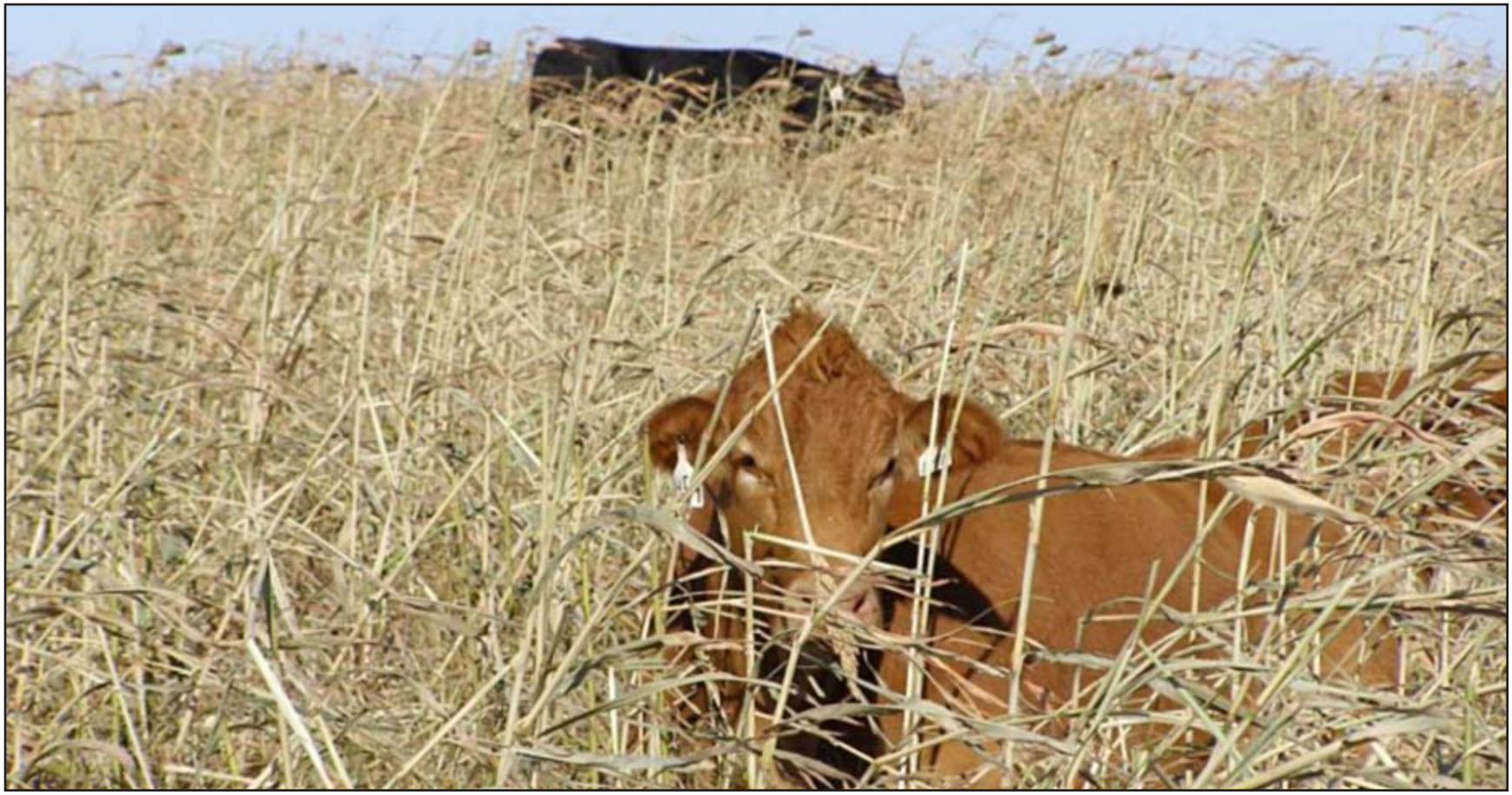


Photo: Joshua Dukart, BCSCD

Mob Grazing on Cropland

Cool-Season Cover Crop Combination

- 2 acres per day
- 6 moves per day
- 327 yearlings

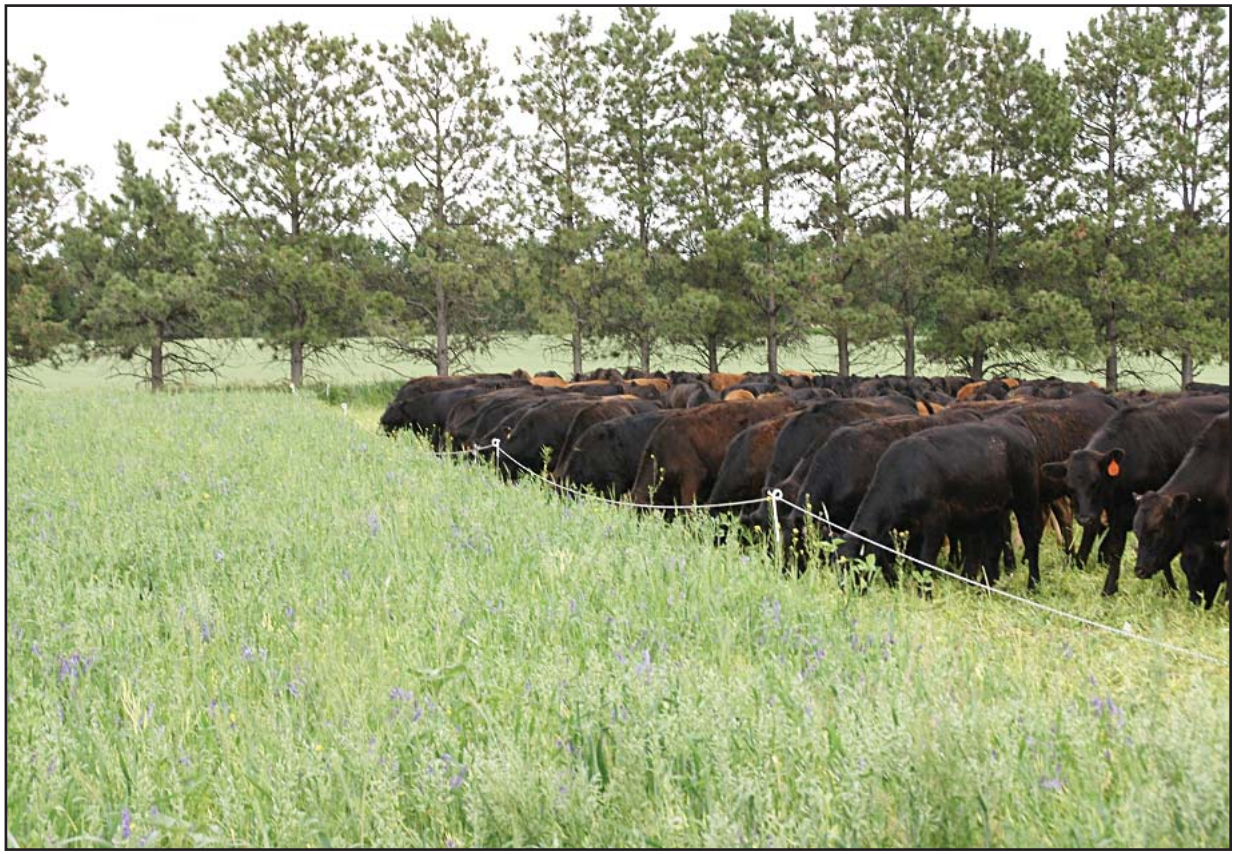


Photo: Gabe Brown, BCSCD

Soil Armor After Mob Grazing

Photo: Jay Fuhrer, NRCS

Case Study 2

Photo: Jay Fuhrer, NRCS

Richter Farms -
Marlyn and Patrick Richter

- Provide soil surface armor
- Build soil aggregates
- Improve the water cycle
- Integrated Pest Management
- Build soil organic matter
- Integrate livestock

Cover Crop Seeded After an Early Harvest

Photo: Jay Fuhrer, NRCS

- Field Pea

Photo: Jay Fuhrer, NRCS

- Winter Triticale

Cover Crop Cocktail

- Millet 8 lbs ..... WS Grass 
- Cowpea 10 lbs ..... WS Broadleaf 
- Soybean 15 lbs ..... WS Broadleaf 
- Turnip ½ lb ..... CS Broadleaf 
- Oilseed Radish 1 lb ..... CS Broadleaf 
- Sunflower 1 lb ..... WS Broadleaf 
- Sweet Clover 1 lb ..... CS Broadleaf 

Ready to Graze 10/1/2007

Photo: Joshua Dukart, BCSCD

141 Pair - Turned In 10/1/07; Turned Out 10/17/07

Photo: Joshua Dukart, BCSCD

Dual Feeding System: Soil Biology and Livestock

Photo: Joshua Dukart, BCSCD

What Do They Weigh?

Bacteria	2,000 - 2,500 lbs/ac
Fungi	1000 - 15,000 lbs/ac
Protozoa	20 - 300 lbs/ac
Nematodes	10 - 300 lbs/ac

Sources:

The Nature and Properties of Soils, Fourteenth Edition.
Dr. Nyle C. Brady and Dr. Ray R. Weil

Soil Biology Primer. Dr. Elaine R. Ingham

52 lbs Average Gain/Calf ~ 3.1 lbs Average Daily Gain/Calf

Photo: Kenneth Miller, BCSCD

Net Profit of Grazing Cover Crops

Gross Income per acre	=	$111.00
Expense per acre	=	$ 45.00
Net Income per acre	=	$66.00

- Value of increased recovery time on Native Rangeland?
- Value of Improved Soil Health?

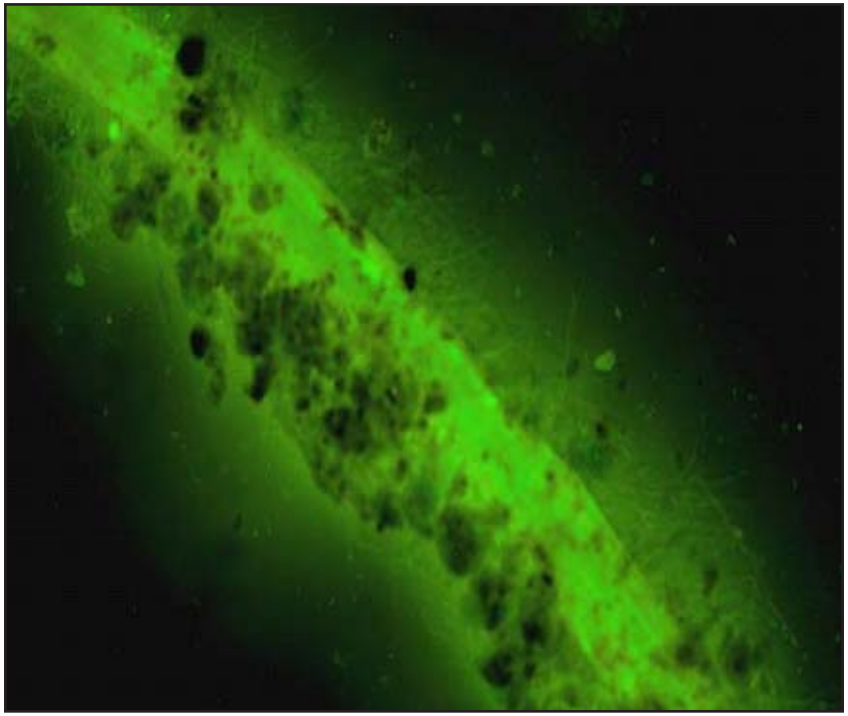
No Wind Erosion on the Cover Crop Field

Photo: Jay Fuhrer, NRCS

Photo: Richard Webb, NRCS

Soil Samples

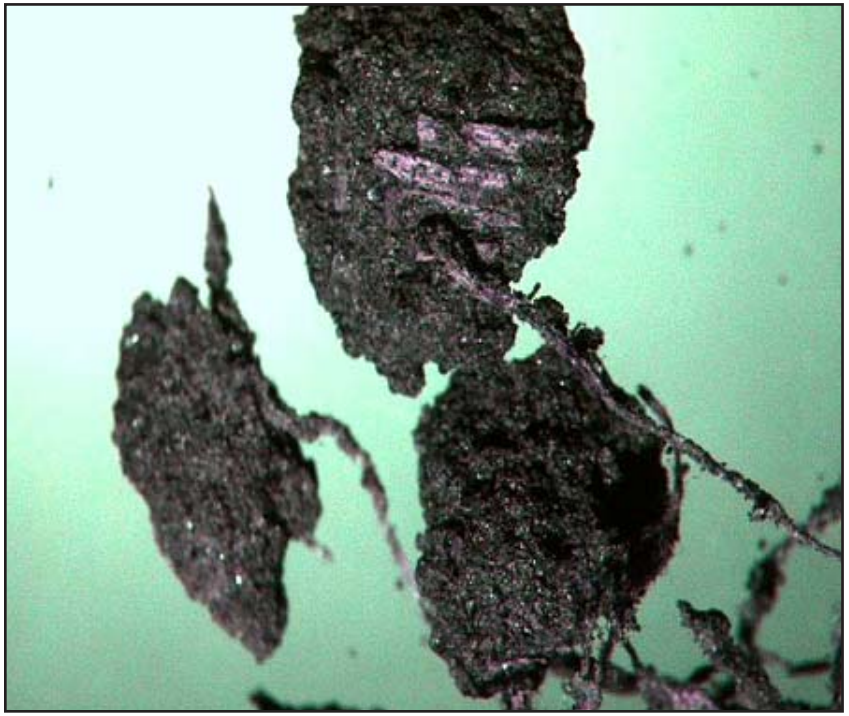
- Soil aggregates on a millet root



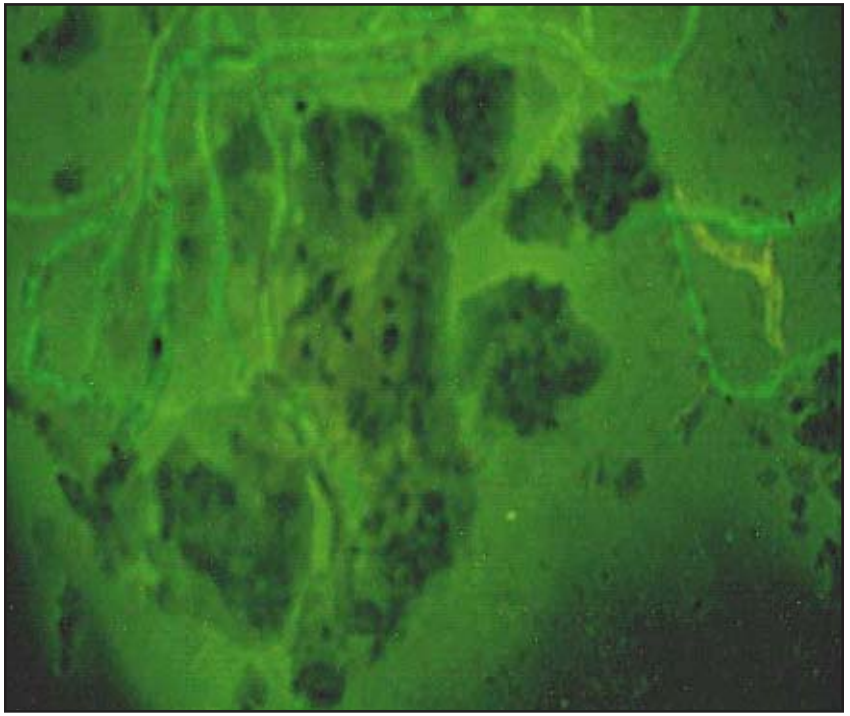
- Glomalin and hyphae show well with a green color in the lab

Dr. Kris Nichols, Microbiologist, ARS, Mandan, ND

Soil Samples



- Enlarged soil aggregates



- Glomalin and hyphae

Dr. Kris Nichols, Microbiologist, ARS, Mandan, ND

NRCS Taking Soil Samples for Available Water Capacity

May 6, 2008

Photo: Joshua Dukart, BCSCD

Estimated Inches of Available Water ~ Sampled 5/6/08

Richter Farms, LLP
Menoken, North Dakota

Inches of Available Water
Parshall Fine Sandy Loam

Depth (inches)	Cover Crop	No Cover Crop	AWC*
0-6	0.44	0.37	0.95
6-12	0.58	0.51	0.95
12-24	0.84	0.89	1.56
24-36	0.74	0.73	1.44
36-48	0.47	0.61	1.20
Total (0-48)	**3.07**	**3.11**	**6.10**

*** AWC - Available Water Capacity (Inches) @ Field Capacity**

Timeline

July 1, 2007	**Harvested Field Peas**
July 7, 2007	**Planted Cover Crop Cocktail Mix**
October 1-17, 2007	**Grazed Cover Crop Cocktail Mix**

Inches of Available Water

Photo: Jay Fuhrer, NRCS

On May 6, 2008
(following the 2007 cover crop)

Summary

- No Cover Crop = 3.11 Inches
- Cover Crop = 3.07 Inches
- Difference = 0.04 Inches

Spring Weed Pressure

Photo: Jay Fuhrer, NRCS

- Cover crop
- No cover crop

2007 Herbicide Expenses

Field	Treatment	Herbicide Applications After Pea Harvest Cost per application = $12.00/ac		
North	Cover Crop No Manure	July 1×	Sept None	$12.00
Middle	No Cover Crop Manure	July 1×	Sept 1×	$24.00
South	No Cover Crop No Manure	July 1×	Sept 1×	$24.00

2008 Corn Herbicide Expense

Field	Treatment	2008 Corn Herbicide Cost per application = $15.95/ac			
North	Cover Crop No Manure	May 1×	June 1×	None	$31.90
Middle	No Cover Crop Manure	May 1×	June 1×	July 1×	$47.85
South	No Cover Crop No Manure	May 1×	June 1×	July 1×	$47.85

Resource Concern ~ Soil Organic Matter

Photo: Ronald Kessel, NRCS

- 2001 SOM Levels Averaged 1.5%
- Present Levels Average 2.5%

Soil Organic Matter and Available Water Capacity

Inches of Water/One Foot of Soil			
Percent SOM	Sand	Silt Loam	Silty Clay Loam
1	1.0	1.9	1.4
2	1.4	2.4	1.8
3	1.7	2.9	2.2
4	2.1	3.5	2.6
5	2.5	4.0	3.0

Berman Hudson
Journal Soil and Water Conservation 49(2) 189-194
March – April 1994
Summarized by:
Dr. Mark Liebig, ARS, Mandan, ND
Hal Weiser, Soil Scientist, NRCS, Bismarck, ND

Soil Organic Matter ~ Nutrient Bank Account

- 1.0% OM = 10,000 lbs Carbon, 1,000 lbs Nitrogen, 100 lbs Phosphorous, and 100 lbs of Sulfur.
- Mineralization Rate = 2-3% from Organic N to Inorganic N.
- Resulting in 20 to 30 lbs of useable N per acre.

Case Study 3

Photo: Joshua Dukart, BCSCD

Black Leg Ranch - Jerry, Jeremy, Jay and Jayce Doan

- Promote nutrient cycling
- Enhance wildlife
- Integrate livestock

Cover Crop Combination

Photo: Jay Fuhrer, NRCS

- Seeded June 14-15
- Designed for nutrient cycling, wildlife and livestock integration
- Sprayed June 17th
- No commercial fertilizer
- Photo taken on June 25

Cover Crop Combination

Photo: Jay Fuhrer, NRCS

- Pearl Millet 1 lb ..... $ .74/lb
- Proso Millet 2 lbs ..... $ .25/lb
- Sudan 4 lbs ..... $ .45/lb
- Soybean 15 lbs ..... $ .53/lb
- Cowpea 10 lbs $1.13/lb
- Sunflower 1 lb $4.00/lb
- Radish 2 lbs $1.53/lb
- Turnip 1 lb $1.53/lb
- Sweet Clover 1 lb $1.40/lb
- Corn 1 lb $1.25/lb

High-Leach-Potential Sands ~ July 20, 2010

Photo: Jay Fuhrer, NRCS

July 20, 2010

Photo: Jay Fuhrer, NRCS

Soil Health Tour at Black Leg Ranch

September 16, 2010

Photo: Kenneth Miller, BCSCD

Soil Health Tour at Black Leg Ranch

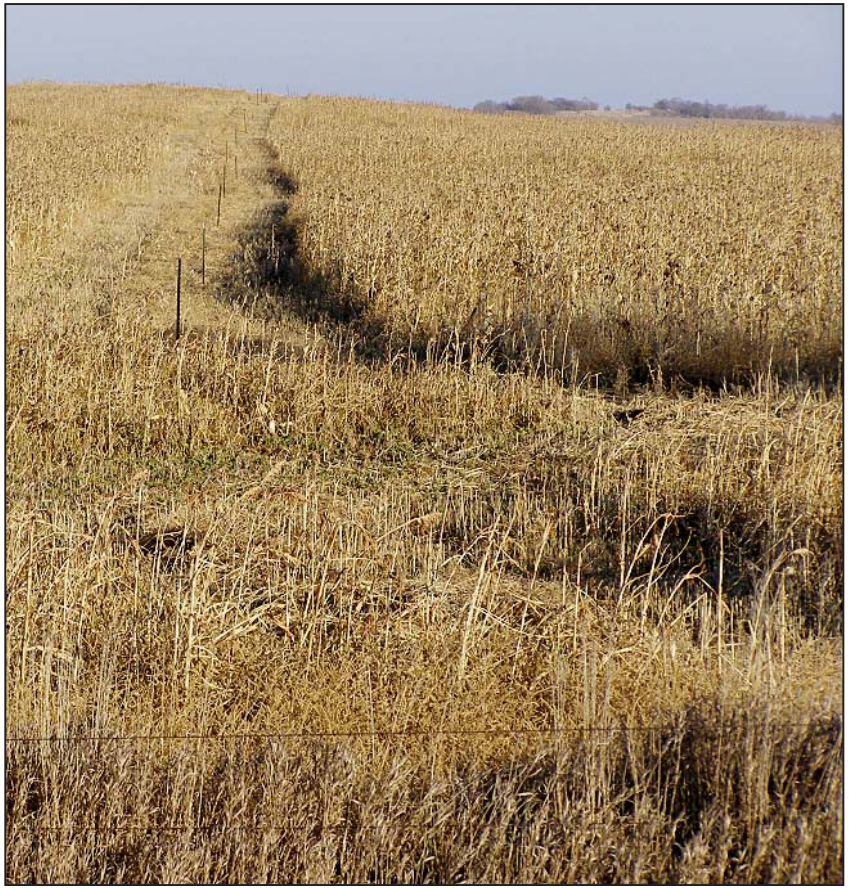


Photo: Jay Fuhrer, NRCS

- Strips were mowed for hunting access
- Steel fence posts were added
- After the hunting season is over the cow herd will be wintered here and strip grazed
- Multiple natural resource benefits: soil health, water quality, herd health, wildlife enhancement, and livestock integration

Case Study 4

Photo: Jay Fuhrer, NRCS

Menoken Farm

- Provide crop diversity
- Promote nutrient cycling
- Enhance pollinators
- Integrate livestock

Menoken Farm ~ Year 1, 2009

Foodweb Analysis
Soil

Report prepared for:
NRCS North Dakota
Hal Weiser
218 2nd Ave SW
Jamestown, ND 58402 USA

hal.weiser@nd.usda.gov

Report Sent: 5/28/2009
Sample#: 01-107264 | Submission:01-019543
Unique ID: 3
Plant: peas
Invoice Number: 3873
Sample Received: 5/19/2009

For interpretation of this report please contact:
Soil Foodweb Oregon
info@oregonfoodweb.com
(541) 752-5066

Consulting fees may apply

Organism Biomass Data	Dry Weight	Active Bacteria (µg/g)	Total Bacteria (µg/g)	Active Fungi (µg/g)	Total Fungi (µg/g)	Hyphal Diameter (µm)
Results	0.860	30.1	1458	14.0	329	2.9
Comments	Above Range	Above range	Above range	In range	Above range	
Expected Range Low	0.45	15	100	10	50	
Expected Range High	0.85	25	300	20	175	

	Protozoa (Numbers/g)			Total	Mycorrhizal Colonization (%)	
	Flagellates	Amoebae	Ciliates	Nematodes #/g	ENDO	ECTO
Results	1607	6674	37	7.99	Not Ordered	Not Ordered
Comments	Low	High	Low	Low		
Expected Range Low	5000	5000	50	20	40%	40%
Expected Range High			100	30	80%	80%

Organism Biomass Ratios	Total Fungi to Tot.Bacteria	Active to Total Fungi	Active to Total Bacteria	Active Fungi to Act.Bacteria	Plant Available N Supply (lbs/ac)	Actino Bacteria (µg/g)
Results	0.23	0.04	0.02	0.46	25-50	3.83
Comments	Low	Low	Low	Low		
Expected Range Low	0.5	0.25	0.25	0.75		
Expected Range High	0.75	0.95	0.95	1.5		

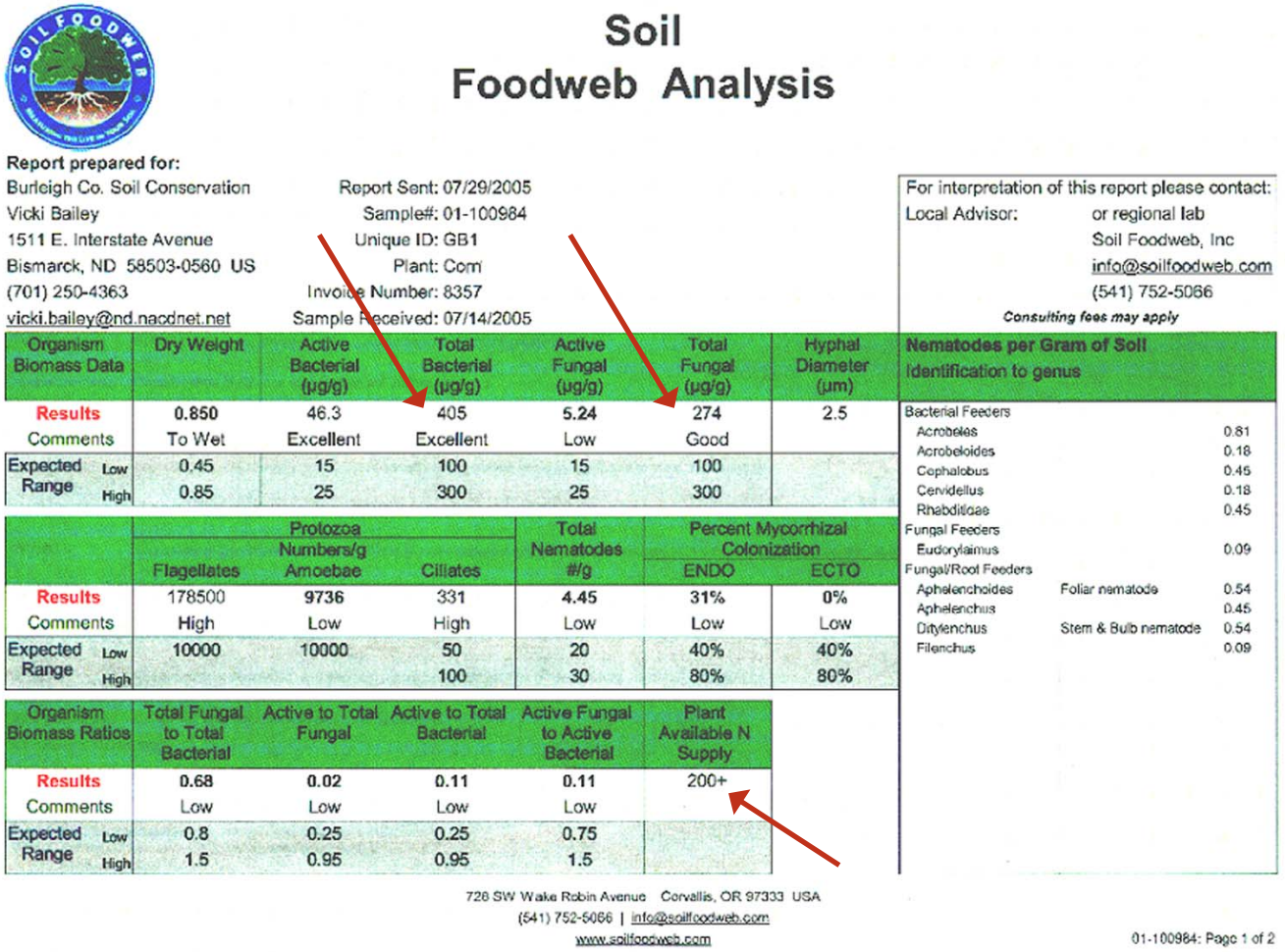
Nematode detail (# per gram or # per mL)
Classified by type and identified to genus.
(If section is blank, no nematodes identified.)

Bacterial Feeders		
Acrobeles		0.86
Acrobeloides		0.34
Cephalobus		1.89
Heterocephalobus		0.17
Metateratocephalus		0.17
Plectus		0.34
Rhabditidae		0.17
Fungal Feeders		
Thonus		0.34
Fungal/Root Feeders		
Aphelenchoides	Foliar nematode	0.17
Aphelenchus		1.38
Ditylenchus	Stem & Bulb nematode	0.69
Filenchus		0.34

1750 SW 3rd St Ste K Corvallis, OR 97333 USA
(541) 752-5066 | info@oregonfoodweb.com
www.oregonfoodweb.com

01-107264: Page 1 of 2

Menoken Farm ~ Year 1, 2009; Long Term No-Till



Soil Foodweb Analysis

Report prepared for:
Burleigh Co. Soil Conservation
Vicki Bailey
1511 E. Interstate Avenue
Bismarck, ND 58503-0560 US
(701) 250-4363
vicki.bailey@nd.nacdnet.net

Report Sent: 07/29/2005
Sample#: 01-100984
Unique ID: GB1
Plant: Corn
Invoice Number: 8357
Sample Received: 07/14/2005

For interpretation of this report please contact:
Local Advisor: or regional lab
Soil Foodweb, Inc
info@soilfoodweb.com
(541) 752-5066
Consulting fees may apply

Organism Biomass Data	Dry Weight	Active Bacterial (µg/g)	Total Bacterial (µg/g)	Active Fungal (µg/g)	Total Fungal (µg/g)	Hyphal Diameter (µm)
Results	0.850	46.3	405	5.24	274	2.5
Comments	To Wet	Excellent	Excellent	Low	Good	
Expected Range Low	0.45	15	100	15	100	
Expected Range High	0.85	25	300	25	300	

	Protozoa Numbers/g			Total Nematodes #/g	Percent Mycorrhizal Colonization	
	Flagellates	Amoebae	Ciliates		ENDO	ECTO
Results	178500	9736	331	4.45	31%	0%
Comments	High	Low	High	Low	Low	Low
Expected Range Low	10000	10000	50	20	40%	40%
Expected Range High			100	30	80%	80%

Organism Biomass Ratios	Total Fungal to Total Bacterial	Active to Total Fungal	Active to Total Bacterial	Active Fungal to Active Bacterial	Plant Available N Supply
Results	0.68	0.02	0.11	0.11	200+
Comments	Low	Low	Low	Low	
Expected Range Low	0.8	0.25	0.25	0.75	
Expected Range High	1.5	0.95	0.95	1.5	

Nematodes per Gram of Soil
Identification to genus

Bacterial Feeders		
Acrobeles		0.81
Acrobeloides		0.18
Cephalobus		0.45
Cervidellus		0.18
Rhabditidae		0.45
Fungal Feeders		
Eudorylaimus		0.09
Fungal/Root Feeders		
Aphelenchoides	Foliar nematode	0.54
Aphelenchus		0.45
Ditylenchus	Stem & Bulb nematode	0.54
Filenchus		0.09

726 SW Wake Robin Avenue Corvallis, OR 97333 USA
(541) 752-5066 | info@soilfoodweb.com
www.soilfoodweb.com

01-100984: Page 1 of 2

Rolling Pea to Provide Armor ~ July 16, 2009

Photo: Jay Fuhrer, NRCS

Eight-way Cover Crop

Photo: Jay Fuhrer, NRCS

- Seeded into rolled pea stubble
- Photo taken on August 18, 2009

No Commercial Fertilizer

September 4, 2010

Photo: Jay Fuhrer, NRCS

- Sunflower ..... 1 lb
- Soybean ..... 15 lbs
- Cowpea ..... 10 lbs
- Turnip ..... 1 lb
- Radish ..... 2 lbs
- Proso Millet ..... 4 lbs
- Pearl Millet ..... 4 lbs

Planting Corn into Last Year's Cover Crop Residue

May 20, 2010

Photo: Emily Bonilla, NRCS

Tissue Analysis Taken on July 7, 2010

Photo: Jay Fuhrer, NRCS

1-2 Tons Compost ~ 2 Tea Aps ~ No Com Fertilizer

Grower:
BCSCD
916 E INTERSTATE AVE

BISMARCK ND
58502

Submitter:
ALLIANCE AG-BISMARCK
1505 YEGEN ROAD SOUTH
BOX 996
BISMARCK ND
58504

Nutrient	Test Level	Rating	Sufficient Range
Total N	3.3 %	S	3.0 To 3.4
P	0.28%	S	0.25 To 0.50
K	2.0 %	S	2.0 To 2.4
S	0.19%	S	0.16 To 0.50
Ca	0.18%	L	0.30 To 0.60
Mg	0.21%	S	0.16 To 0.40
Na	0.01%	S	0.00 To 0.10
Zn	27 ppm	S	20 To 75
Fe	112 ppm	S	50 To 250
Mn	49 ppm	S	18 To 150
Cu	10 ppm	S	5 To 15
B	12 ppm	S	5 To 25

D.R.I.S. FOR CORN:

N	P	K	S	CA	MG	ZN	FE	MN	CU	B
10	-6	8	-8	-39	3	3		5	6	18

Ratings for: CORN 12 in TO TASSLING
VL=Very Low, L=Low, S=Sufficient, H=High, VH=Very High

From: AGVISE LABORATORIES
BOX 510
NORTHWOOD, ND 58267

Date Received: 07-07-10
Date Reported: 07-08-10
Date Sampled: 07-06-10

No Compost ~ No Tea ~ No Com Fertilizer

Grower:
BCSCD
916 E INTERSTATE AVE

BISMARCK ND
58502

Submitter:
ALLIANCE AG-BISMARCK
1505 YEGEN ROAD SOUTH
BOX 996
BISMARCK ND
58504

Nutrient	Test Level	Rating	Sufficient Range
Total N	3.0 %	S	3.0 To 3.4
P	0.30%	S	0.25 To 0.50
K	2.1 %	S	2.0 To 2.4
S	0.20%	S	0.16 To 0.50
Ca	0.21%	L	0.30 To 0.60
Mg	0.23%	S	0.16 To 0.40
Na	0.01%	S	0.00 To 0.10
Zn	28 ppm	S	20 To 75
Fe	107 ppm	S	50 To 250
Mn	54 ppm	S	18 To 150
Cu	10 ppm	S	5 To 15
B	12 ppm	S	5 To 25

D.R.I.S. FOR CORN:

N	P	K	S	CA	MG	ZN	FE	MN	CU	B
4	-5	8	-8	-31	4	3		6	4	16

Ratings for: CORN 12 in TO TASSLING
VL=Very Low, L=Low, S=Sufficient, H=High, VH=Very High

Corn Harvest on November 8, 2010

Photo: Jay Fuhrer, NRCS

The Menoken Farm ~ Power of Crop Diversity

Both sides were planted into last year's cover crop residue.

Photo: Kathy Fuhrer, NRCS

West Side

- No commercial fertilizer
- No compost
- No compost tea
- 122.3 bushels per acre

East Side

- No commercial fertilizer
- 1-2 tons of compost
- 2 Compost tea applications
- 128.8 bushels per acre

Cool-Season Cover Crop ~ Menoken Farm 2010

Photo: Jay Fuhrer, NRCS

Seeded May 12, 2010

14 Species

- Wheat ..... 28 lbs
- Oat ..... 7 lbs
- Forage Pea ..... 30 lbs
- Lentil ..... 5 lbs
- AC Greenfix ..... 4 lbs
- Turnip ..... 1 lb
- Radish ..... 2 lbs
- Sunflower ..... 2 lbs
- Italian Rye Grass ..... 5 lbs
- Hairy Vetch ..... 5 lbs
- Sweet Clover ..... 1 lb
- Phacelia ..... 2 lbs
- Canola ..... 1 lb
- Flax ..... 1 lb

Total lbs/ac = 95

Phacelia and Native Pollinator

Photo: Jay Fuhrer, NRCS

Warm-Season Cover Crop ~ Menoken Farm 2010

Photo: Jay Fuhrer, NRCS

Seeded June 7, 2010

11 Species

- Soybean ..... 15.0 lbs
- Cowpea ..... 10.0 lbs
- Pearl Millet ..... 4.0 lbs
- Proso Millet ..... 4.0 lbs
- Sunn Hemp ..... 5.0 lbs
- Radish ..... 2.0 lbs
- Turnip ..... 1.0 lb
- Sunflower ..... 2.0 lbs
- Sweet Clover ..... 1.0 lb
- Canola ..... 0.5 lbs
- Plains Coreopsis ..... 0.1 lbs

Livestock Integration will Provide:

Photo: Jay Fuhrer, NRCS

- The economics on cover crop years
- Biology to the soil
- A conversion of high-carbon residue to a lower-carbon material
- Additional recovery time for native rangeland

Where Can We Go in the Great Plains Agricultural System?

Photo: Jay Fuhrer, NRCS

Photo: Jay Fuhrer, NRCS

- Supplying the soil biology with food and a home
- Using cropping systems, grazing systems, cover crops, and livestock
- Remember:
  - — Minimize soil disturbance
  - — Provide armor
  - — Continual living roots
  - — Diversity, diversity, diversity

Self Education

- The Nature and Properties of Soils 14th Edition – by Dr. Brady and Dr. Weil
- Buffalo Bird Woman's Garden – by Gilbert Wilson
- Agroecology – by Gliessman
- The One Straw Revolution – by Masanobu Fukuoka
- Managing Cover Crops Profitably 3rd Edition
- Guns, Germs, and Steel – by Jared Diamond
- Soil Biology Primer – by Dr. Elaine Ingham

www.bcscd.com

www.dakotalakes.com

www.sustainableranching.com

www.mandakzerotill.org

www.cedarmeadowfarm.com

Contact Us

The Burleigh County Soil Conservation District

www.bcscd.com

USDA NRCS

United States Department of Agriculture
Natural Resources Conservation Service

www.nrcs.usda.gov

ATTRA

National Sustainable Agriculture Information Service

www.attra.ncat.org • 1-800-346-9140

ATTRA is a project of the

NCAT

National Center for Appropriate Technology

www.ncat.org • 1-800-275-6228 (1-800-ASK-NCAT)