PRIME FARMLAND CROP YIELDS FROM FOUR SOIL RECONSTRUCTION TREATMENTS FOLLOWING MINERAL SANDS MINING: A 9 YEAR SUMMARY

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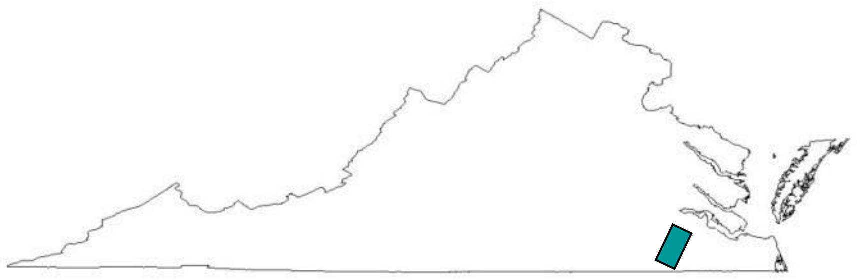
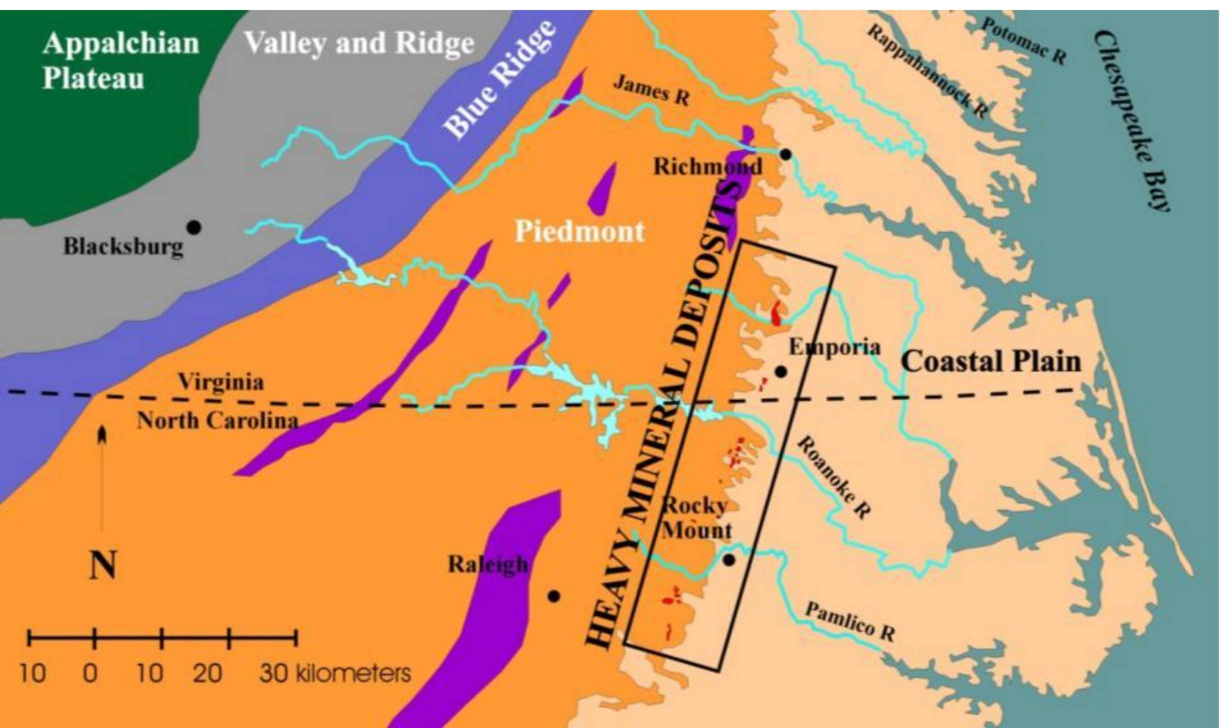
Introduction

Heavy mineral sand deposits (mainly ilmenite, rutile, and zircon) were discovered in Virginia and North Carolina in the late 1980's.

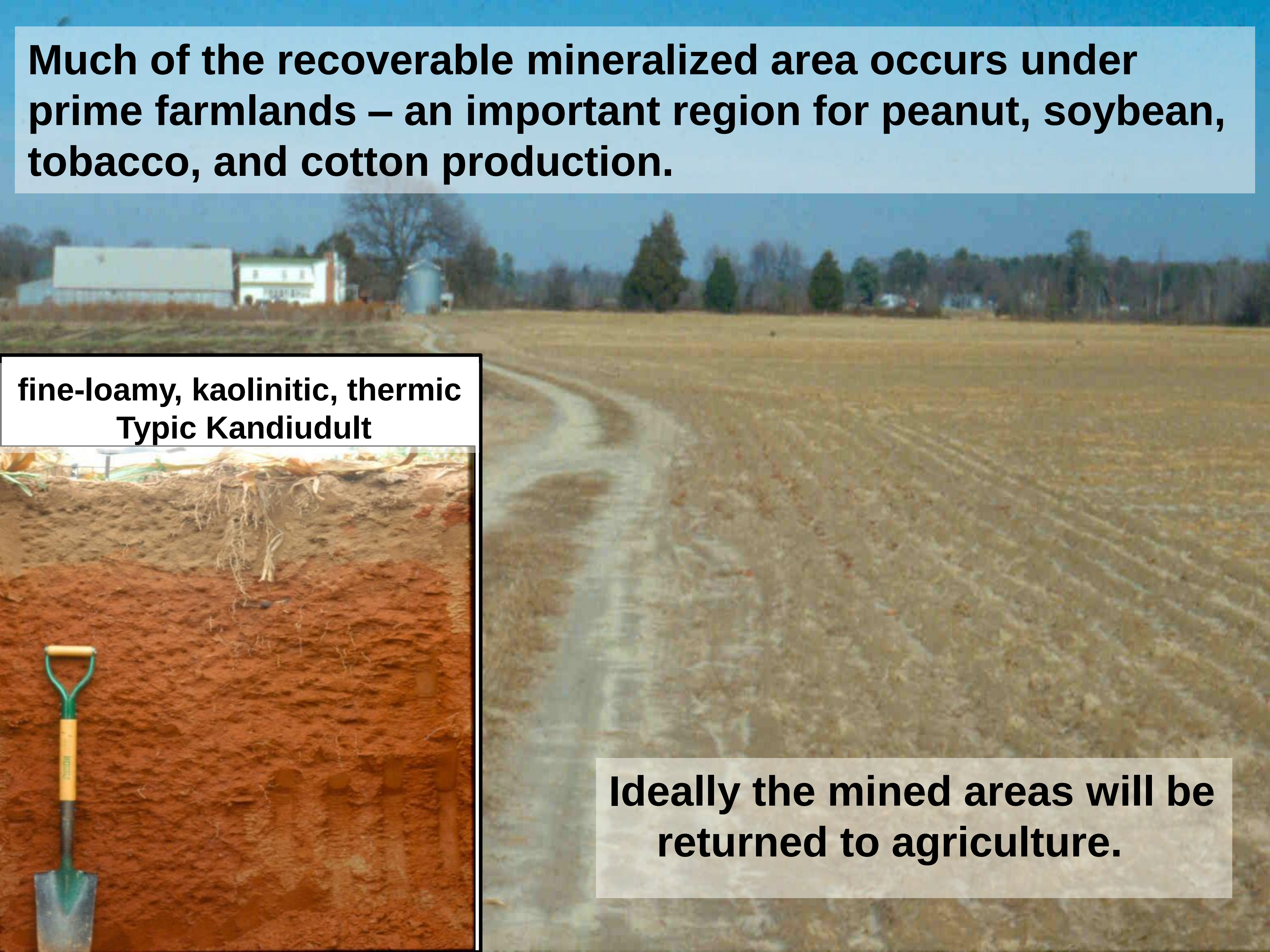


Location of the mineral sands ore bodies are shown below in red.



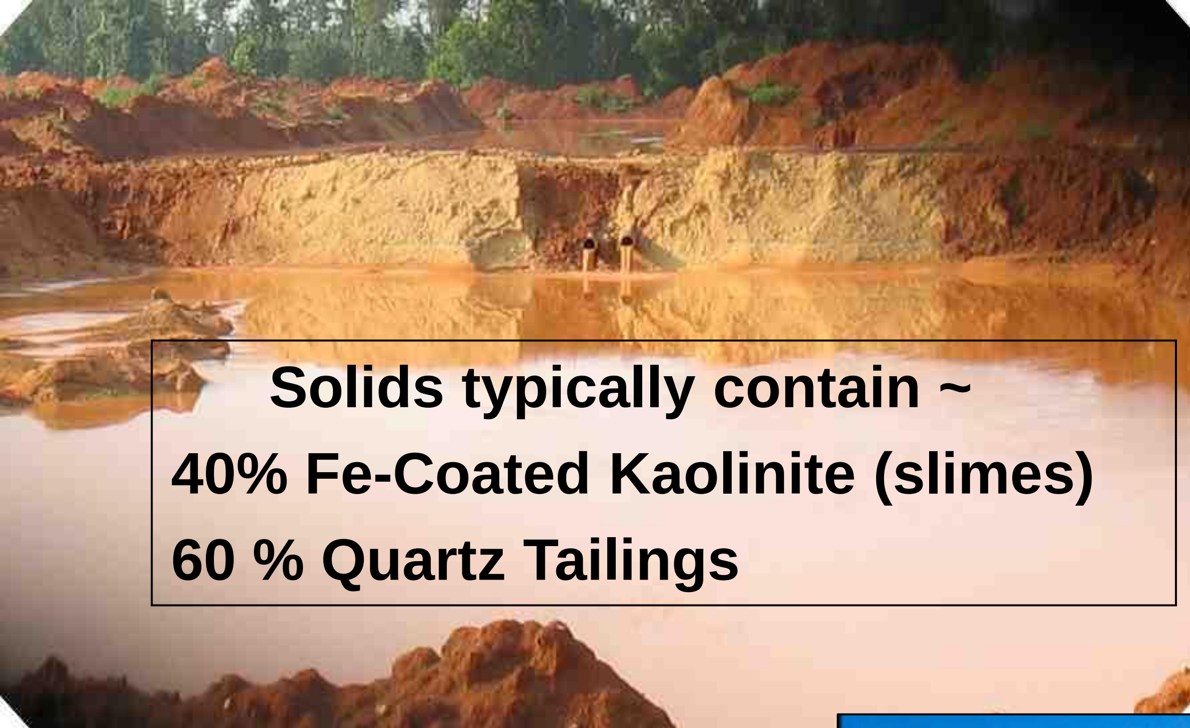
Mining of the Old Hickory deposit (the northern most deposit in VA) began in 1990's.

Up to 7,000 ha potentially could be disturbed.


Much of the recoverable mineralized area occurs under prime farmlands – an important region for peanut, soybean, tobacco, and cotton production.
fine-loamy, kaolinitic, thermic Typic Kandiudult
Ideally the mined areas will be returned to agriculture.

The Mining Process

- The deposit is mined with excavators and fed to a mobile mining unit to be sized, slurried, and pumped to the concentrator.



Solids typically contain ~

40% Fe-Coated Kaolinite (slimes)

60 % Quartz Tailings

After processing, slimes and tails are pumped back to the reclamation pits in a water slurry (35 to 50% solids).

Final pit dewatering at Old Hickory.

Most pits take several months to a year for the surface to dry enough to support machinery.

Regrading and Smoothing

Very soft areas are "dipped and spread" utilizing a long-reach excavator

Dozers are used to spread the slimes to aid in drying

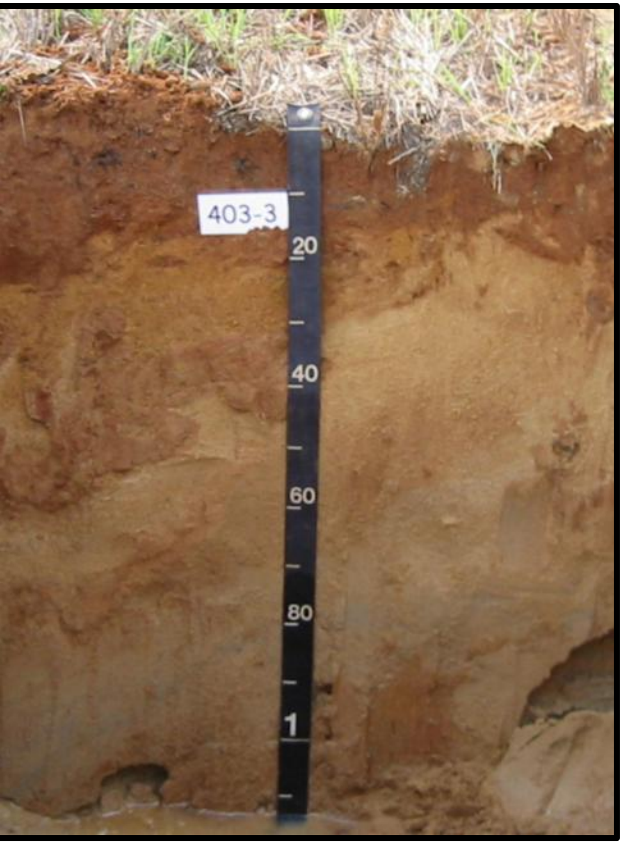
Smoothing gives a rolling uniform appearance, and the resulting grade is easy to work with farm equipment.

Reclamation Challenges

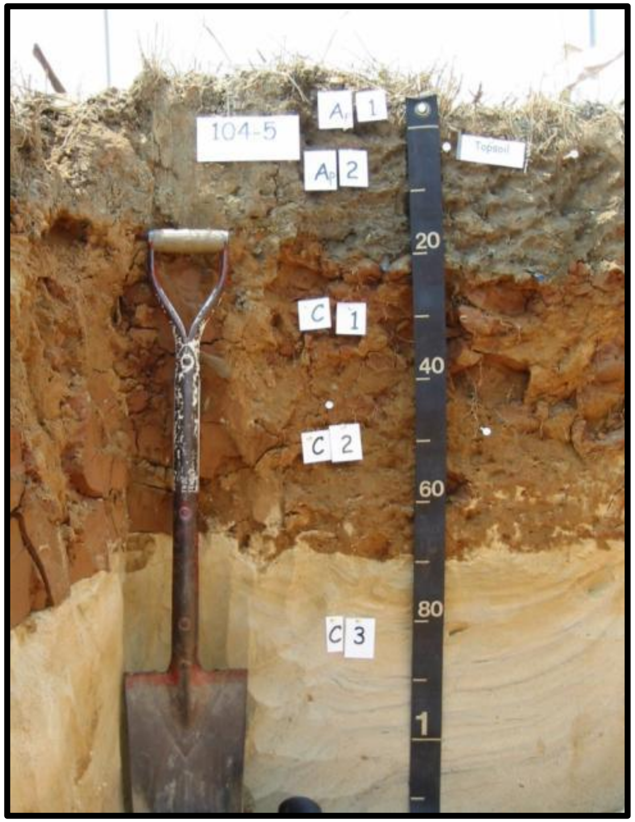
Dewatered tailings/slimes mixtures are highly variable laterally and vertically.

Reclamation Challenges

Soil variability



Biosolids incorporated at surface (20 cm).



Topsoil replacement (20 cm)

Biosolids incorporated at surface (20 cm).

Reclamation Challenges

Topsoil may contain high concentration of mineral sands – some landowners opt to process their topsoil for improved royalty return.

Reclamation Challenges

Physical compaction occurs during final grading.

Densic layers with the following properties have been observed in several soil profiles:

very firm in place

restricted rooting
(typically to < 80 cm)

platy structure

oxidized rhizospheres

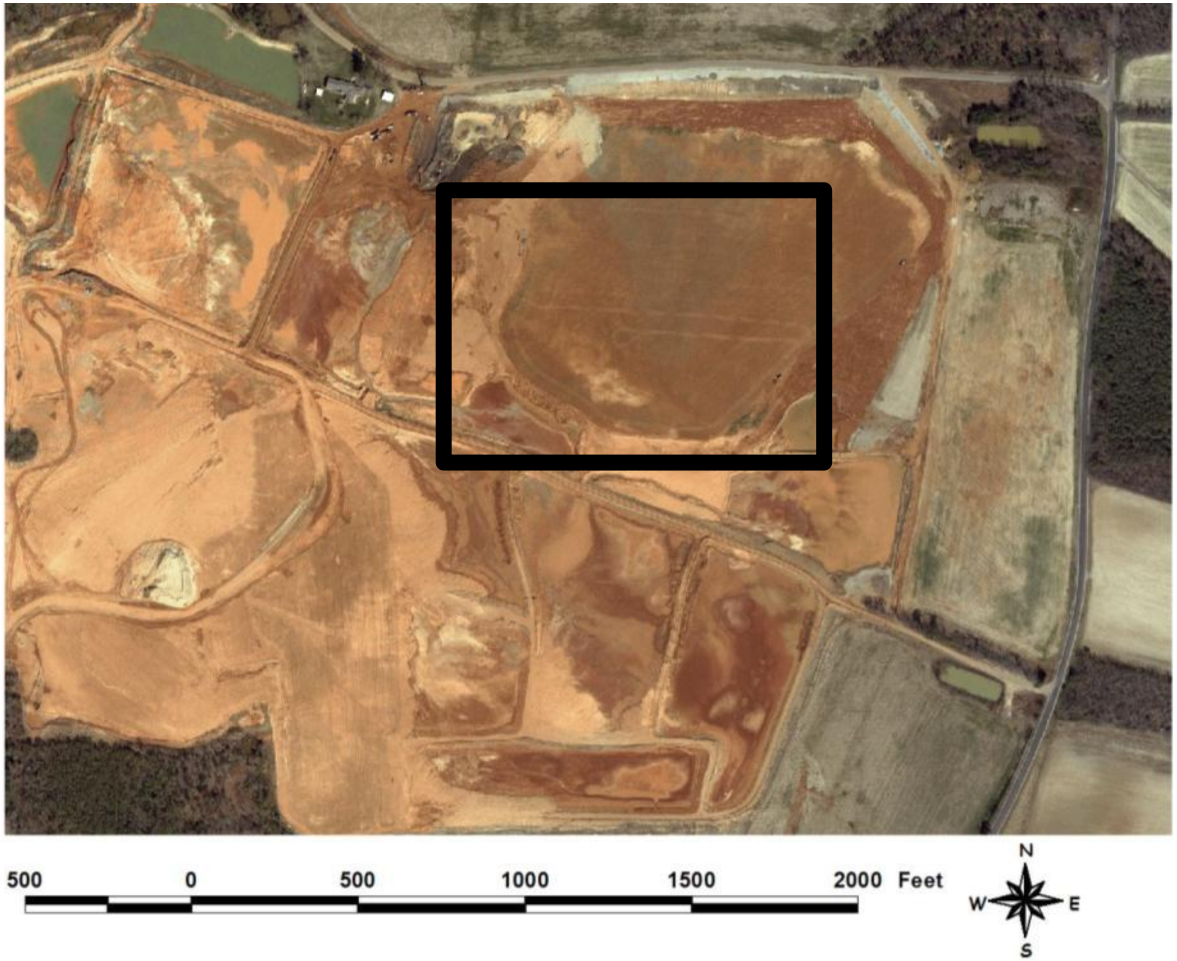
OBJECTIVES

- to evaluate the effects of mine soil reconstruction practices on row crop productivity

- to compare the productivity of the mine soils with nearby undisturbed prime farmland.

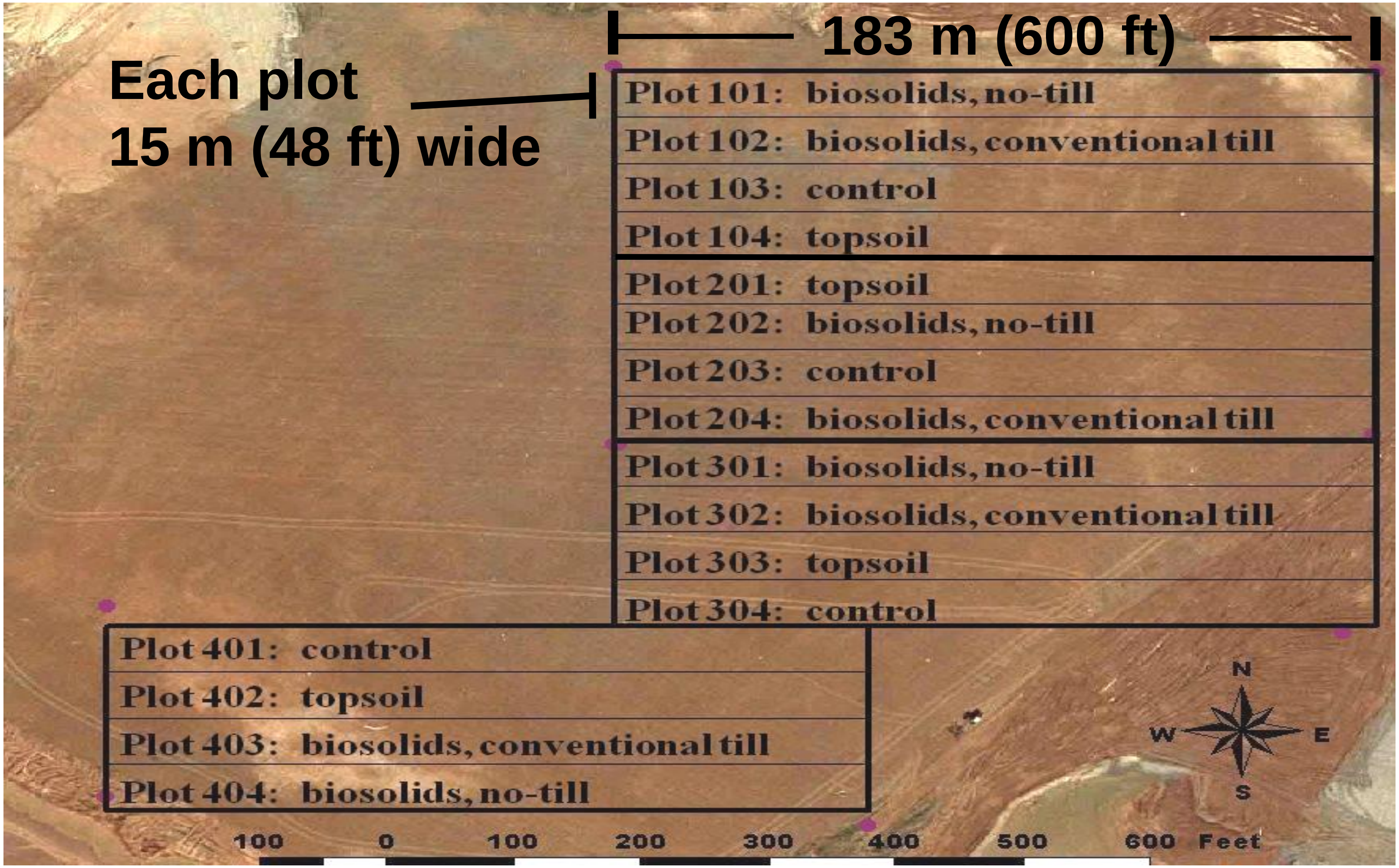
Methods

The research area was mined in 1998 and subsequently received the standard stabilization treatment including 9.96 Mg ha^{-1} lime, 392 kg ha^{-1} P_20_5, and seeding to an herbaceous cover.



Methods

- complete randomized block design (4 blocks)
- 4 treatments (4 plots per block)



Methods

1) **LBS-CT**:
   lime-stabilized biosolids at 78 Mg/ha, conventional tillage.

2) **LBS-NT:**
   lime-stabilized biosolids at 78 Mg/ha, no-till management.

3) **TS**:
   lime and P to subsoil, 15 cm of topsoil added, lime to topsoil

4) **C**:
   lime and P

ALL TREATMENTS WERE DEEP RIPPED AND RECEIVED ROUTINE FERTILIZATION PER SOIL TEST RESULTS

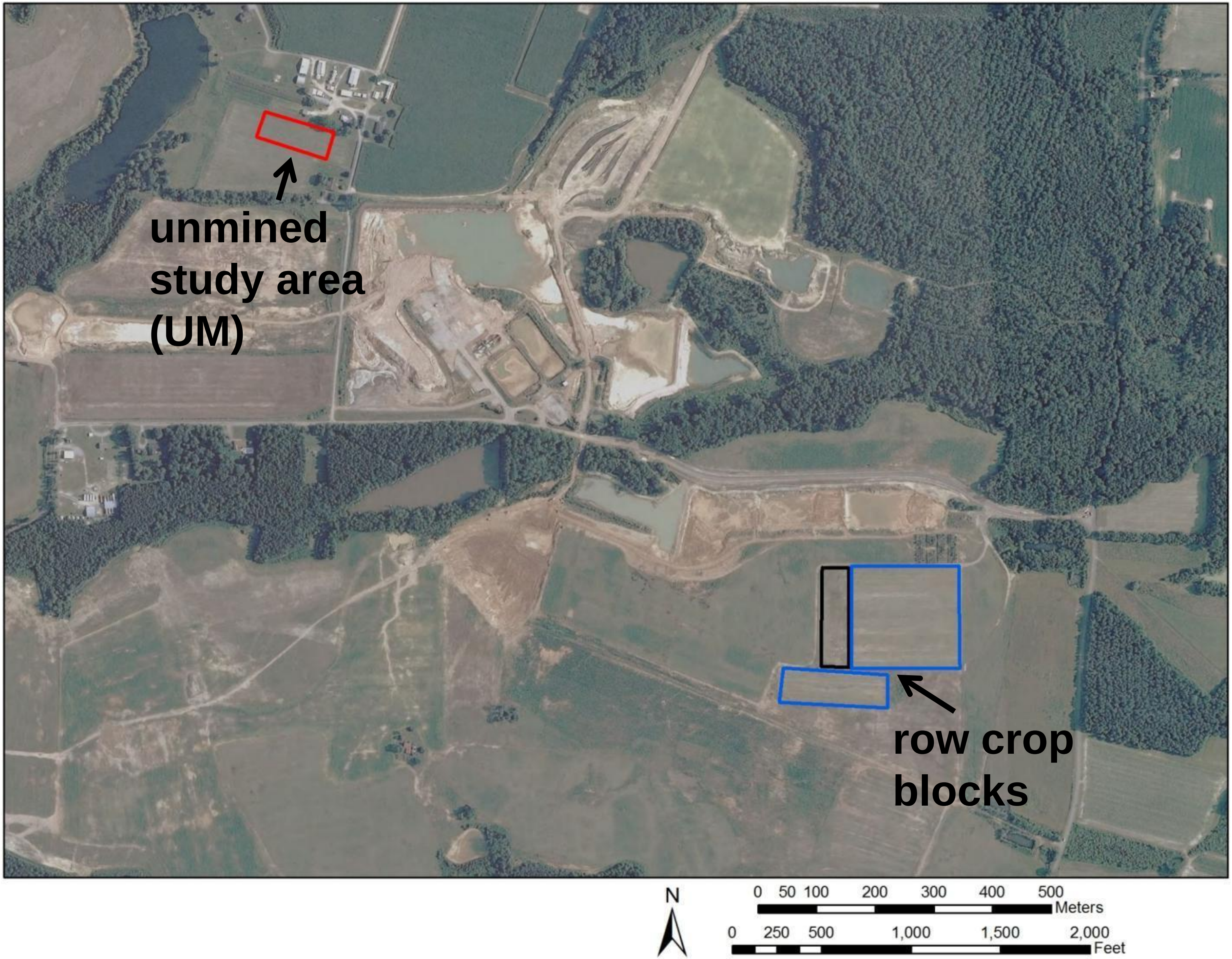
Methods

- Surface soil (to 15 cm) was excavated from the topsoil plots.
- All plots were ripped to 90 cm and chisel plowed to 20 cm.
- Lime (8.96 Mg ha^{-1}) and P (672 kg ha^{-1}) were incorporated to 20 cm on the TS and C plots.
- Topsoil (15 cm) was applied to the TS plots and additional lime (6.72 Mg ha^{-1}) was incorporated to 20 cm.
- Lime stabilized biosolids (78 Mg ha^{-1}) were incorporated to 20 cm on the LBS-NT and LBS-CT plots.
- All plots were smoothed and cleared of debris with a cultivator.


28 7 2004

	Biosolids	Topsoil*
pH	10.43	5.28
	---------------- % ---------------	
Solids	31.7	nd
CCE	15.9	nd
	TOTAL	MEHLICH I
	------------- mg kg^{-1}------------	
Total Kjehldahl nitrogen	32,700	nd
Ammonia-N	4,200	nd
P	15,467	9
K	1,467	76
Ca	109,700	337
Mg	2,500	57
Fe	44,933	123
Mn	318	7.5
Cu	205	2.1
Zn	455	1.5

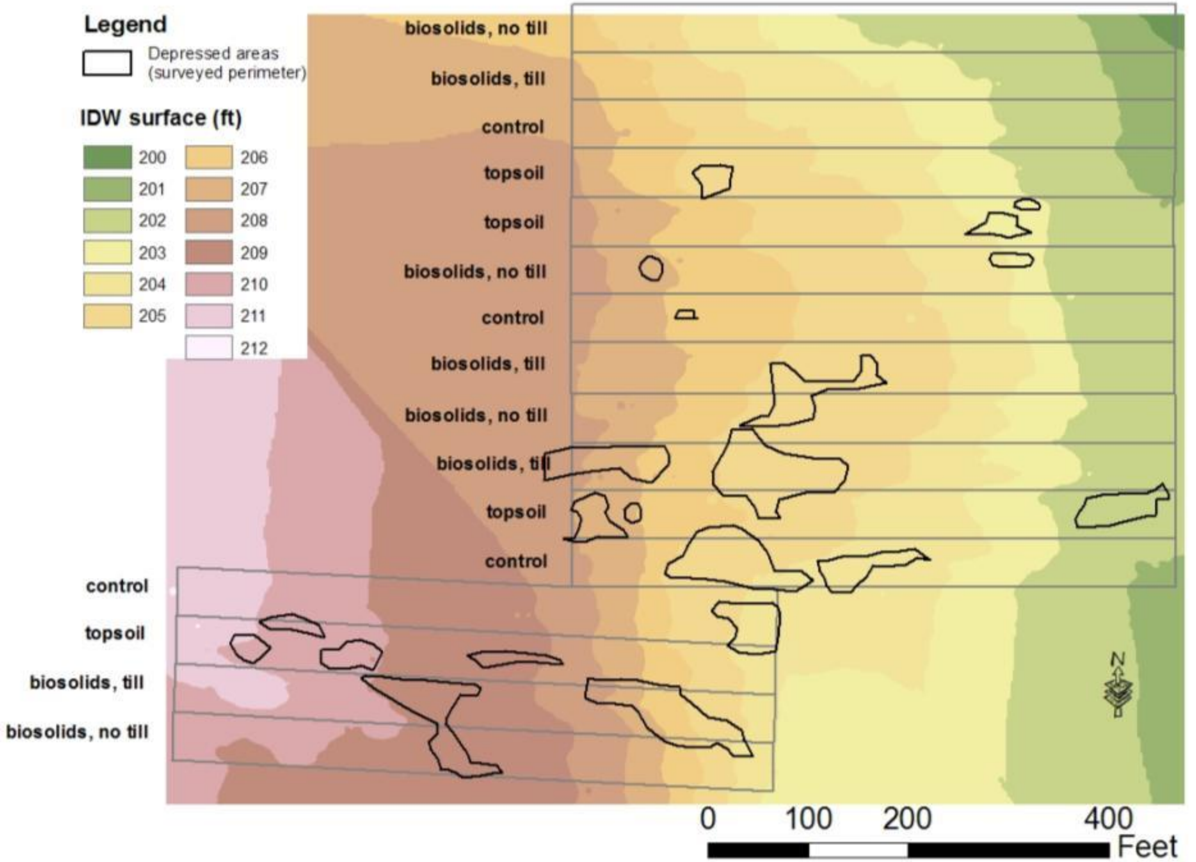
* Topsoil appeared to be of forest soil origin


unmined study area (UM)
row crop blocks
N
0 50 100 200 300 400 500
Meters
0 250 500 1,000 1,500 2,000
Feet

Year	Spring	Summer	NOTES
2005		corn	Corn residue shredded; all plots no-till.
2006	wheat		
		soybeans	Too wet for proper fall harvest; no additional N added to LBS plots.
2007		corn	No additional N added to LBS plots; corn residue left intact.
2008	wheat		
		soybeans	
2009		cotton	
2010	wheat		
		soybeans	Depressions throughout the plots were remediated.
2011		corn	Corn residue left intact.
2012	wheat		
		soybeans	
2013		corn	

- As necessary, all sites were irrigated, no-till ripped, and periodically received herbicides, fungicides and pesticides.
- Fertilizers were applied for optimal nutrient levels per crop based on soil test results and recommendations by the VT Soil Testing Lab.

In 2010, depressions were mapped remediated.



Each area was chisel plowed then filled with the appropriate treatment material using a front-end loader.
Lime and P additions were made to the surface.

Corn yields

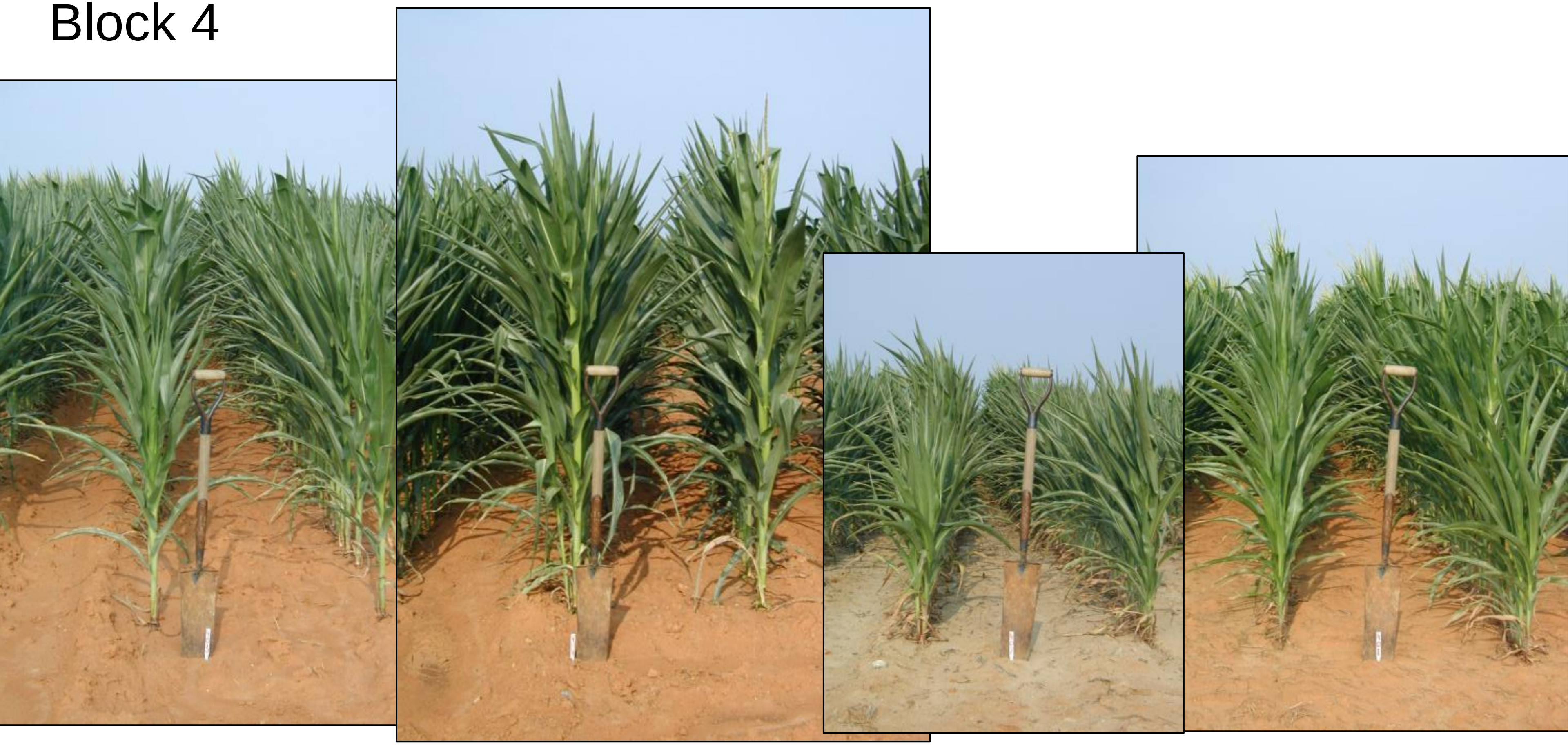
	2005	2007	2011	2013
Treatment	------------ Mg ha^{-1} ------------			
LBS-CT	10.85c†	3.62a	4.77a	13.03a
LBS-NT	10.90c	3.43a	4.75a	12.99a
TS (topsoil)	3.79a	7.23b	4.13a	12.24a
C (control)	8.53b	7.30b	5.30a	11.87a
UM (unmined)	14.30d	9.91c	12.48b	16.01b
Dinwiddie Co.	6.7	3.9	4.8	9.9

†Means in the same column followed by the same letter are not significantly different ($p<0.05$)

- 2005: unexpected low TS yields were due to relatively low pH and P, crusting at surface that inhibited seedling growth, and compaction which occurred during topsoil return.
- 2007: low yields due to very hot, dry conditions AND severe N deficiency in the LBS plots.
- 2011: low yields from mine soils due to excessive moisture and denitrification
- 2011 + 2013: no significant difference among mined treatments; C and TS improved by chiseling and ripping

CORN July, 2005

Block 4



LBS-CT LBS-NT TOPSOIL CONTROL

TOPSOIL plots were chisel plowed in September, 2005 to help alleviate compaction.

Wheat yields

	2006	2008	2010	2012
Treatment	$Mg\ ha^{-1}$			
LBS-CT	5.04b	5.97c	2.74a	3.17a
LBS-NT	5.16b	5.65c	2.76a	3.20a
TS (topsoil)	4.29a	4.89b	2.68a	3.18a
C (control)	4.10a	4.64b	2.51a	3.11a
UM (unmined)	6.90c	3.90a	4.72b	4.45b
Dinwiddie Co.	3.76	4.90	3.27	4.51

†Means in the same column followed by the same letter are not significantly different ($p<0.05$)

- 2008: low UM yield due to interference of bulky corn residue with the planter.
- 2010: yields low due to very dry/hot conditions.

Soybean yields

	2008	2010	2012
Treatment	Mg ha^{-1}		
LBS-CT	2.24ab	0.96a	2.59c
LBS-NT	2.51b	1.11a	2.45c
TS (topsoil)	2.20ab	1.15a	2.51c
C (control)	2.11a	1.10a	2.34b
UM (unmined)	3.20c	1.73b	2.21a
Dinwiddie Co.	1.75	1.01	2.51

†Means in the same column followed by the same letter are not significantly different ($p<0.05$)

- 2010: Low yields due to hot/dry conditions and seeding problems related to recent re-grading of depressions throughout the plots.

Cotton yields

	2009	
Treatment	Mg ha^{-1}	% lint
LBS-CT	1.17a	0.424
LBS-NT	1.18a	0.442
TS (topsoil)	1.18a	0.453
C (control)	1.05a	0.446
UM (unmined)	1.62	0.400

†Means in the same column followed by the same letter are not significantly different ($p<0.05$)

Excellent yields for all treatments

Conclusions

- Biggest challenges: **heavy compaction, lack of structure,** and **low OM** which collectively restrict root growth and reduce water holding capacity.
- Intensive soil reconstruction including ripping, chiseling, and incorporating OM will allow these heavily compacted mine soils to be returned to agricultural use.
- Incorporation of biosolids further improved soil conditions by promoting soil structure and increased water holding capacity.
- No significant differences were observed between no-till and conventional tillage practices.
- Benefits of topsoil replacement initially were overpowered by complicating factors: poor quality topsoil, compaction during application, surface crusting.

Conclusions

- Crop yields from the four reclamation treatments routinely exceeded local county averages; BUT our crops were irrigated while county data was based on irrigated and non-irrigated croplands.
- Under “ideal” conditions, crop yields from the mined plots were reduced by up to 30% as compared to native prime farmland soil.
- With excessive moisture or drought, crop yields from the mined plots may be reduced by 30 – 50%.
- Native prime farmland soils in the mining area are very highly productive; even with reduced productivity, agricultural use of these mine soils is economically viable.

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