Sustainability Indicators for Mineral Sands Mining in Virginia, USA

W. Lee Daniels
Location of mineral sands ore bodies in Virginia (in red). Similar ore bodies lie approximately 50 miles to south in North Carolina.
Typical prime farmland landscape at Old Hickory with significant enrichment of heavy minerals to a depth of > 8 meters.
Project History and Background

• Mineral sand deposits were discovered along the Upper Coastal Plain of Virginia, USA, in the late 1980's

• Much of the recoverable mineralized area occurs under prime farmlands, and as much as 7,000 Ac. could potentially be disturbed in Virginia and North Carolina
Typical surface expression of mineral in local topsoil.
Old, highly weathered profile west of scarp. This soil is probably 2 to 5 million years old.
The Mining Process

- The deposit is mined with excavators, feeding a mobile mining unit
- At the mining unit, the ore is sized, slurried, and pumped to the concentrator
Reclamation Overview

Reclamation Process – Tailings Management

- Tailings are rotated among several ponds. Generally 4 to 6 ponds are in the rotation at any given time.

- Rotation allows time for settling and dewatering.

- Some ponds are just being “filled” for the first time while others are nearly completely full and receive small amounts of tails to complete filling.
Landowners negotiated as a block and were assured that lands would be returned to prime farmland status and that Virginia Tech research would be implemented in closure protocols via regulatory permit.

Before this research program, the return of mineral sands mines to intensive agricultural use had not been studied, but USA coal mines had been returned to 90 to 95% prime farmland productivity.
110 Mg/ha Yardwaste Compost + Deep Ripping, + 300 kg/ha P, + 8 Mg/ha Lime applied to Tailings/Slimes

25 cm of Topsoil over Ripped/Limed Tailings/Slimes
Winter wheat harvest in June, 1996
Overall crop yields were reduced approximately 20% relative to unmined control plots. Effects of topsoil return vs. compost amendment were not consistent from crop to crop.
60 % Quartz Tailings

40% Fe-Coated Kaolinite

Typical active backfill pit at Old Hickory
Landowner/Company Issues

• In 1989 and 1990, early company officials assured landowners of 100% return to pre-mine row crop productivity.

• Segregation of tailings and slimes within and among pits in early mining (1997 to 2001) led to highly variable post-mine soil conditions.
Pockets of white coarse tailings surrounded by red, high clay slimes. Limited topsoil was available to cover this pit.
Topsoil Issues

• Gross values of minerals in 15 cm of topsoil is at least $15,000 per ha.

• Previous and ongoing work by Virginia Tech has indicated that topsoil substitutes created from tailings/slimes/organic matter are viable.

• Early reclamation in 1997 to 2000 showed very clear benefits from topsoil return, however.
Landowner/Company Issues

- In many instances, topsoil was used to construct dikes before swell factor was fully understood, making it impossible to return topsoil to mine pits.

- Vague regulatory definition of “topsoil” allowed the operator and certain landowners to process topsoil for mineral return.
Final pit dewatering at Old Hickory. Material in foreground is topsoil forming enclosing dike. Overall wet pit surface elevation is 1 to 3 m higher than original ground, but drops with dewatering and final grading.
Landowner/Company Issues

• The local county conditional zoning permit specifically defined topsoil as native A+E horizon materials and the county was asked by several landowners to revoke the mining permit.

• From 2001 to 2003, a number of landowners became increasingly vocal in the local community.
Soil profile from research plots (described later) showing significant buried topsoil and mixing/banding of dissimilar materials in upper profile.

This soil was very compact with almost no rooting below 30 cm or 1 foot.
Iluka’s Efforts to Minimize Tails/Slimes Segregation

- Internal cross-dikes with flashboard risers – implemented originally by Chris Wyatt
- Moving the discharge point periodically
- Reworking slimes pockets with track-hoes
- Final grading to homogenize the surface
Final pit grading; usually done just as soon as dozers can walk the surface, which means it’s wet. This maximizes compactive effort.
Compacted, platy replaced topsoil over highly compacted tails/slimes subsoil.
This is the “appropriate ripper” for these kinds of soil problems! Clint Zimmerman (pictured) was primarily responsible for recognizing the need and implementing routine ripping.
Carraway-Winn
Reclamation Research Farm

Cooperators: Iluka Resources, Virginia Tech, the Carraway-Winn Family, Virginia Health Dept.,
Virginia Division of Mineral Mining, Synagro Technologies Inc., and Clarke Farms, LLC

The agricultural fields behind this sign were mined for heavy minerals (titanium and zirconium oxides) several years ago. Currently, these mined lands are being returned to productive agricultural uses through a Virginia Tech research and demonstration project cooperative with Iluka Resources, the Carraway-Winn family, and others. As can be seen on the map to the left, a portion of the experimental farm is being managed for row-crops while the majority of the land is under intensive forage (hay) management. One of our major objectives is to investigate the effects of organic amendments, topsoil, and conventional lime + fertilizer + tillage treatments on crop productivity. Our second objective is to monitor changes in soil and water quality over time. Please contact us as shown below if you would like more information about this project or if you would like to arrange a tour.

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All other areas will be planted with a cover crop.

All row crop blocks measure:
192 ft X 600 ft

All forage blocks measure:
144 ft X 550 ft

Compaction study area is approximately:
575 ft X 585 ft

Bermudagrass study area is approximately:
420 ft X 1200 ft

Topsoil replacement area is approximately:
100 ft X 780 ft

Conventional reclamation area is approximately:
220 ft X 1250 ft

Rip and biosolids area is approximately:
270 ft X 1000 ft

Pine buffer extends to 400 ft from the middle of the Carraway house
Row crop plots with numbers and treatments

101 (2) biosolids, no-till
102 (3) biosolids, conventional till
103 (1) control
104 (4) topsoil
201 (4) topsoil
202 (2) biosolids, no-till
203 (1) control
204 (3) biosolids, conventional till
301 (2) biosolids, no-till
302 (3) biosolids, conventional till
303 (4) topsoil
304 (1) control

401 (1) control
402 (4) topsoil
403 (3) biosolids, conventional till
404 (2) biosolids, no-till
Topsoil strip after grading and diskimg in April 2005.

75 Mg/ha Biosolids
2005 Corn Yields (kg/ha)

Topsoil/Lime/NPK  4782  c*

Tails + Biosolids:  13,041  a

Tails + Lime + NPK:  10,666  b

Unmined adjacent:  17,561

County Average:  7,683


Adjacent prime farmland – Orangeburg Soil with same management as plot area.

*Yields within experiment followed by different letters were different at p > 0.01
Topsoil yields were reduced by compaction and heavy crusting. Are these “problems” typical of the topsoil replacement process?
2006 Wheat Yields (bu/ac)

Topsoil/Lime/NPK: 4301 b
Tails + Biosolids: 4906 a
Tails + Lime + NPK: 4300 b

Unmined adjacent: 6921
County Average: 3561


Adjacent prime farmland – Orangeburg Soil with same management as plot area.

Winter Wheat on Carraway-Winn Farm in May of 2006
A Rational Standard for Success?

• The current regulatory framework requires that mined lands returned to row crop agriculture must equal long term county averages. We now have three years of data indicating that we can actually exceed county averages and that we can “topsoil substitute”.

• Rather than direct comparison with pre-miner productivity, we are now using 75% of pre-mining as a “voluntary target”.
Harvested (non-topsoiled) mined land in Fall 2005
CONCLUSIONS

The return of post-mining agricultural productivity is considered by multiple stakeholder groups to be one of the most critical aspects of the operations’ long term sustainability.
CONCLUSIONS

Results obtained to date from the cooperative demonstration farm indicate that these lands can be successfully returned to levels of agricultural production equal to or above the local region, but that some loss of productivity from the very best agricultural lands should be expected.
CONCLUSIONS

Perhaps most importantly, this collaborative research/demonstration effort greatly enhances the transparency of the overall mining and reclamation operation with respect to long-term sustainability objectives.
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