# Improved Methods for Assessing Plant Species Diversity on Four-Standard Western U.S. Mine Reclamation Sites

## A 10-year Update

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SMCRA 1977:  return a "*diverse*, effective and permanent vegetative cover….

The prospects of establishing species diversity seemed high as rules and regulations were formulated. [if only because the expectations were almost certainly very modest]

- Gardening had long been successful in growing a great many species including many natives
- The belief that "if you plant them they will grow" seemed entirely reasonable

As time went on --- some practical constraints of reality began to become apparent  -- and at the same time expectations for diversity rose

# How to Express a Standard for Species Diversity

# Shannon – Weiner Index

Mathematical Expression:

$$H = -SUM[(pi) * \ln(pi)]$$
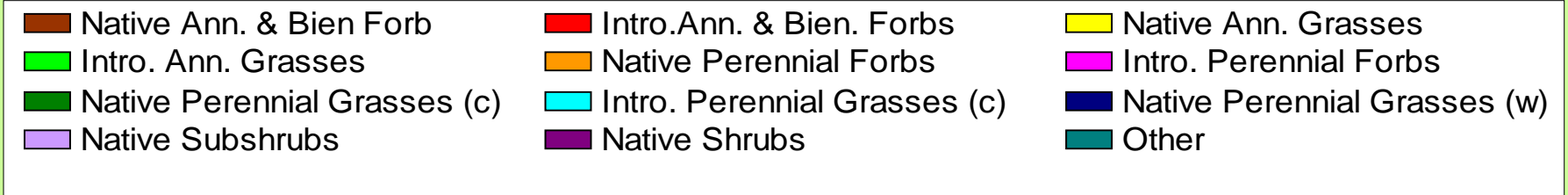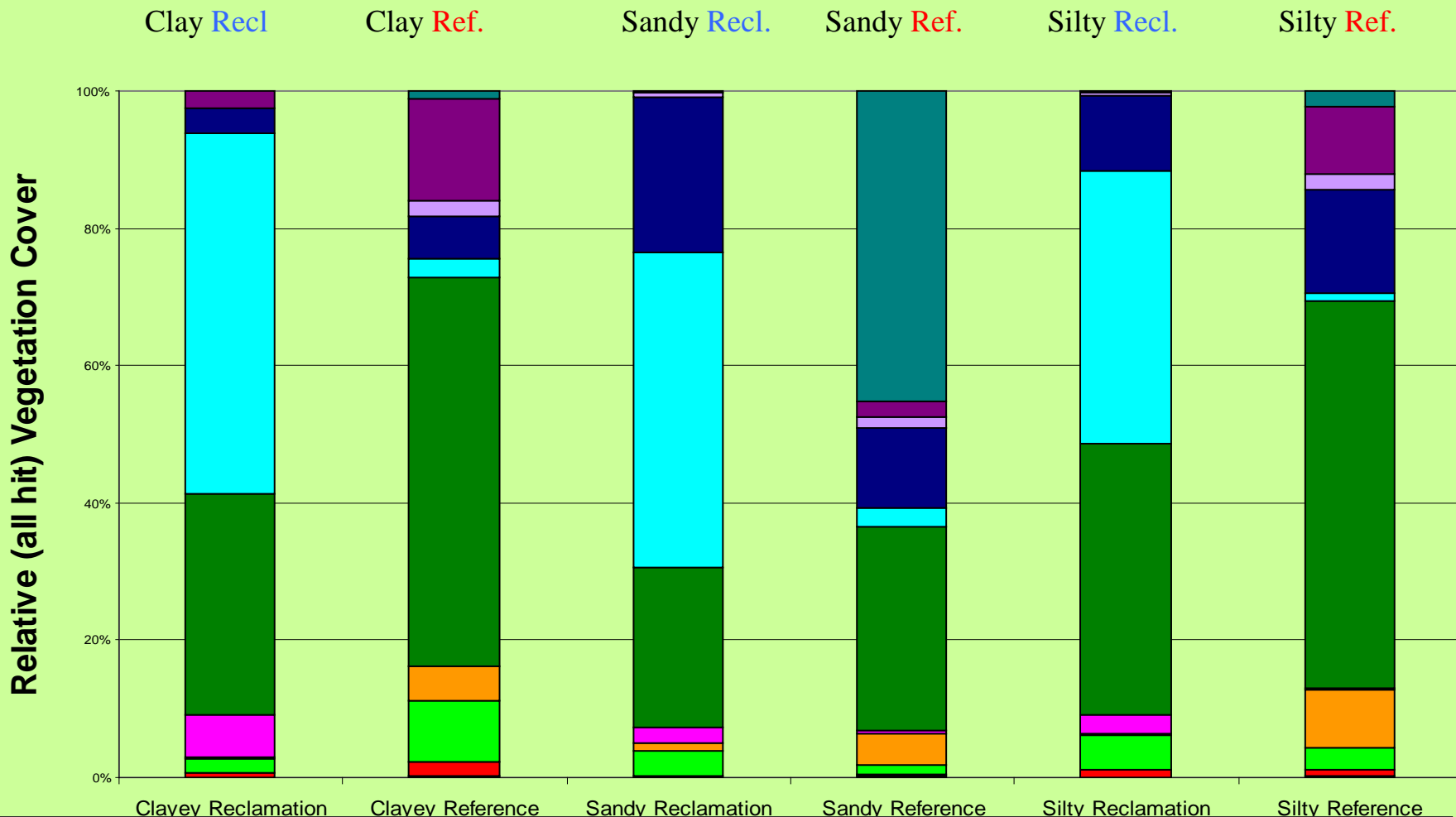
# "Recipe" Approach

- X cool season grasses with (at least) C percent relative cover

- Y native perennial forbs with (at least ) D percent relative cover

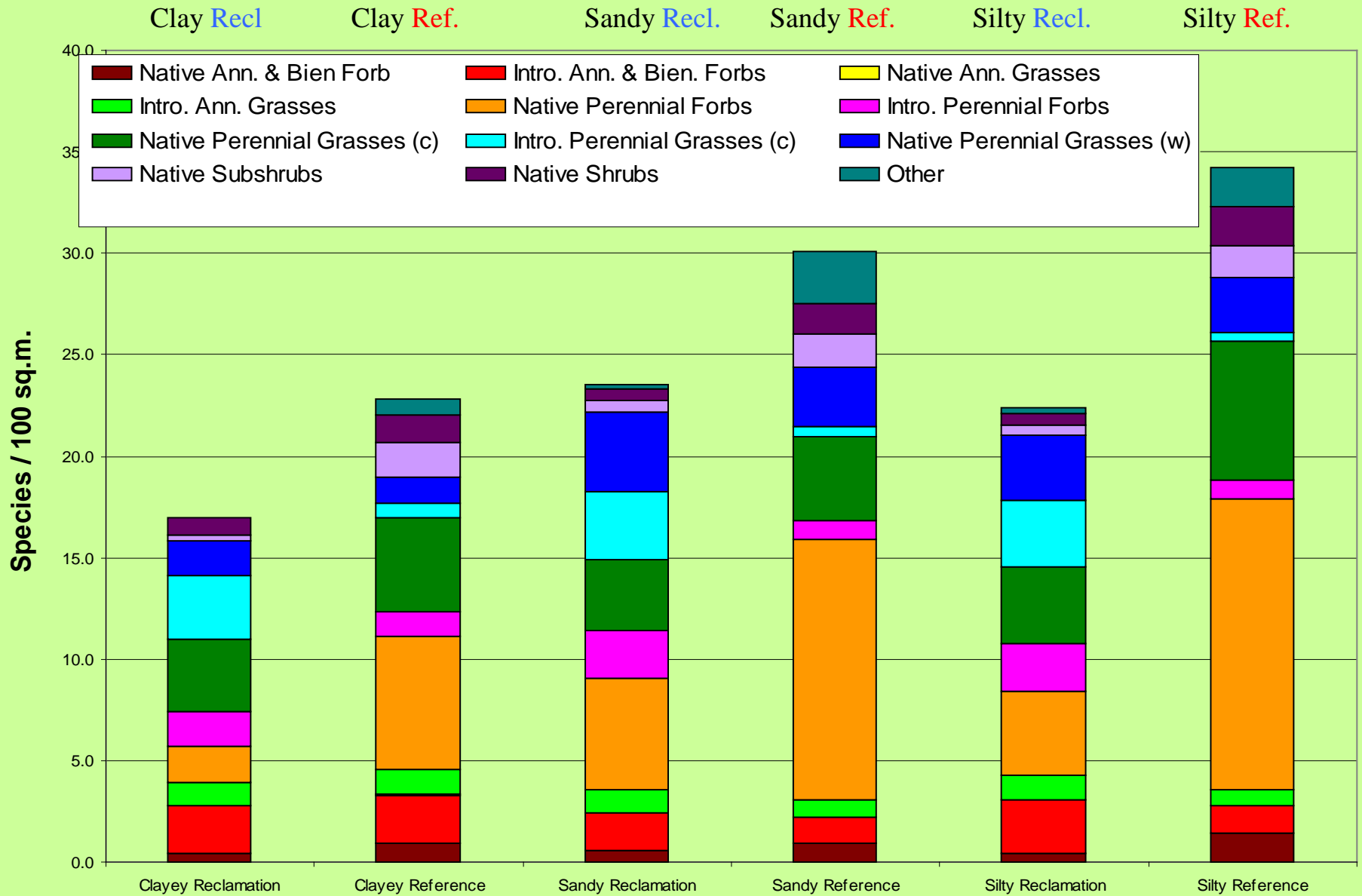- Z shrubs with (at least) E percent relative cover

# Practical Constraints of Establishing High Diversity on 4-standard Reclaimed Lands

- Required physical configurations of reclamation sites (deep suitable soil, moderate to low slope) worked to support very strong growth of grasses

- The perfection of this world for grasses was further enhanced by low soil bulk density and rapid mineralization of soil organics after topsoil replacement.

- Very effective competitive exclusion of forbs and shrubs as the reestablished vegetation matured became repeatedly apparent.

# Efforts to Counteract this Competitive Exclusion of forbs and shrubs have been made.

* Reduction of most competitive grass species

* Reduced overall seeding rates of grasses

* Split seeding - temporal or spatial [to separate forbs and shrubs from high-competition grasses

* Altered growth media - more rocky or thinner [ to discourage pervasive competition from grass roots]

Relative (all hit) Vegetation Cover

Clay Recl | Clay Ref. | Sandy Recl. | Sandy Ref. | Silty Recl. | Silty Ref.

Clayey Reclamation | Clayey Reference | Sandy Reclamation | Sandy Reference | Silty Reclamation | Silty Reference

Legend:
- Native Ann. & Bien Forb
- Intro. Ann. & Bien. Forbs
- Native Ann. Grasses
- Intro. Ann. Grasses
- Native Perennial Forbs
- Intro. Perennial Forbs
- Native Perennial Grasses (c)
- Intro. Perennial Grasses (c)
- Native Perennial Grasses (w)
- Native Subshrubs
- Native Shrubs
- Other

Clay Recl    Clay Ref.    Sandy Recl.    Sandy Ref.    Silty Recl.    Silty Ref.

**Species / 100 sq.m.**

Legend:
- Native Ann. & Bien Forb
- Intro. Ann. & Bien. Forbs
- Native Ann. Grasses
- Intro. Ann. Grasses
- Native Perennial Forbs
- Intro. Perennial Forbs
- Native Perennial Grasses (c)
- Intro. Perennial Grasses (c)
- Native Perennial Grasses (w)
- Native Subshrubs
- Native Shrubs
- Other

Clayey Reclamation    Clayey Reference    Sandy Reclamation    Sandy Reference    Silty Reclamation    Silty Reference

Long-term observations have shown that as episodes of stress occur, incremental small increases in species presence are observable.

Gardening as a metaphor

*versus*

Re-establishment of a Naturally Functioning Community subject to Ecological Response through time

If you view reclamation as a garden that has either succeeded or failed, then an inevitably arbitrary test for adequate species diversity is unavoidable.

But if instead of believing this process to be an exercise in gardening, you choose to believe that the goal is to have re-established a viable, dynamic and resilient plant community that is

subject to the same sorts of formative influences in response to variation in environment that natural communities are over long periods of time.

# Alternative Approaches to Evaluation of Species Diversity

Test A. Total Species Density

Test B. Similarity by Lifeform

Test C.  Scaled Native Species Density

These are all tests intended to project forward to a time when the vegetation has matured – perhaps 30, 50 or 100 years hence.

Remember that although the SMCRA liability period is 10 years (Western USA), 10-year old plant communities are still juvenile.

Unless we want to wait for natural maturation of these juveniles, well beyond the legally mandated 10 years, we need tests to peer forward as best we can.

# Alternative Test A: Total Species Density

- Compare total species density [number of species per 100 sq.m.] that is observed in the reclaimed area to the observed 90% probability range of variation of species density in the reference area.

# Alternative Test B: Similarity by Lifeform

- Use Motkya Index ( 2c / a + b) to assess similarity of contributions of cover or species density by lifeform.  Compare value to 90% of the internal similarity of the reference area.

# Test C.  Scaled Native Species Density

- Compare cumulative number of native species occurring in the set of samples taken for cover (often twenty or so) to the average native species density of the reference area.

Test C compares native species content of perhaps 2000 sq. m. of reclamation (20 samples x 100 sq.m.) to the average number per 100 sq.m. of the reference area. As such it checks to see whether the "ecological shelves" are reasonably stocked to allow the "fill-in" of new species toward eventual match of un-mined areas in terms of species per 100 sq.m.

# Summary

In the context of dynamic ecology, development of greater species diversity in 4- standard reclaimed areas can be viewed ecologically as a sign of aging - the slow accumulation of scars on what would otherwise be a nearly perfect "skin" of grasses.

# Summary (continued)

- Progress towards accumulation of original (pre-mining) levels of species density lurches forward during periods of stress to grasses (e.g. droughts or overgrazing)

# Summary (continued)

Methods can be constructed to peer into the future towards what present evidence suggests may happen based on the presence (though quantitatively small) of diverse plant species.

# Summary (continued)

- Given ecological and temporal realities, these methods are needed to proceed with evaluation of species diversity during bond release testing.

# 10-year Update

- These tests have been used in successful Phase 3 bond release testing at coal surface mines in Colorado, Wyoming and Montana over the period of 2006 to 2015.