Dynamic Analysis of Reclamation: Overview

Dr. Roger Coupal, Agricultural and Applied Economics (AGEC),

Dr. Kristina Hufford, Ecosystem Science and Mgt. (ESM)

Dr. Fabian Nippgen, Ecosystem Science and Mgt. (ESM)

Carolyn Johnson, MS Graduate Student AGEC

Maria Oreshkina, PhD Graduate Student ESM

University of Wyoming

Interdisciplinary Research Team

I. Dr. Kristina Hufford, Ecosystem Science and Mgt., Ecology
II. Dr. Fabian Nippgen, Ecosystem Science and Mgt., Hydrology
III. Dr. Roger Coupal, Ag. and Applied Economics, Economic Analysis
IV. Dr. Noriaki Ohara, Civil and Architectural Engineering, Snow Hydrology

with:

Maria Oreshkina, PhD Graduate Student ESM
Carolyn Johnson, MS Graduate Student AGEC

Research Framework

This study investigates the goal directed nature of reclamation and ecological restoration techniques.

- ***The issue is more than what variables can or should be used to measure success over the time period.***
- ***The science needs to understand how agencies and operators define a successful effort so that we can more closely interpret our results to inform their use of the measures, or modify our interpretations based on the science.***

Goals

1. What is a successful reclamation? general ecological structure based on some types versus others?
2. What are the biological goals? – general ecological structure, area obligate focused, shrub and forb development, et al
3. What are the hydrological goals? – less gully formation, soil depth, soil water levels

Dynamic Analysis justification

- Reclamation is goal oriented so understanding where you want to end up and when is as important as what you measure.
- "If you don't know where you want to go, any road will get you there".
- Communicating goal details to stakeholders allows them to understand where those lands and land use will settle

Central Spoils Pre-Law Reclamation Slope Prior to Reclamation

Central Spoils following regrading. View of native ridge was previously obscured from the road by spoils as shown in photo above. Note varied reclamation topography seen left center following revegetation.

Operation location and Plan of work:

I**. Location: Gas Hills**

Scale: Site-based analysis

Time-scale: 20 years

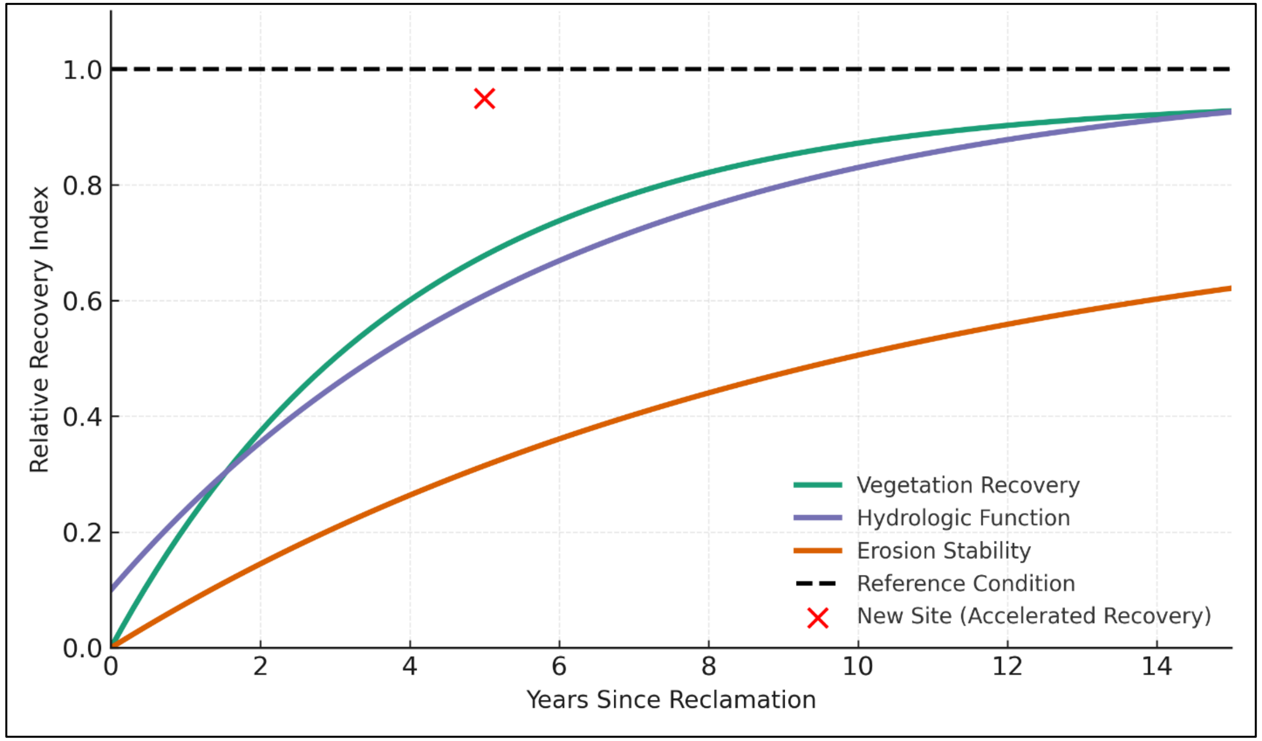
II. **Data and information collection**

1. Cost Data from BRS – *Thank you Harold Hutson!*
2. On-ground transects
3. Hydrological data
4. UAV Remote sensing – Advanced liDAR, MSI, and RGB

III. Modeling framework

IV. Agency and stakeholder information and feedback

Recovery trajectories over time



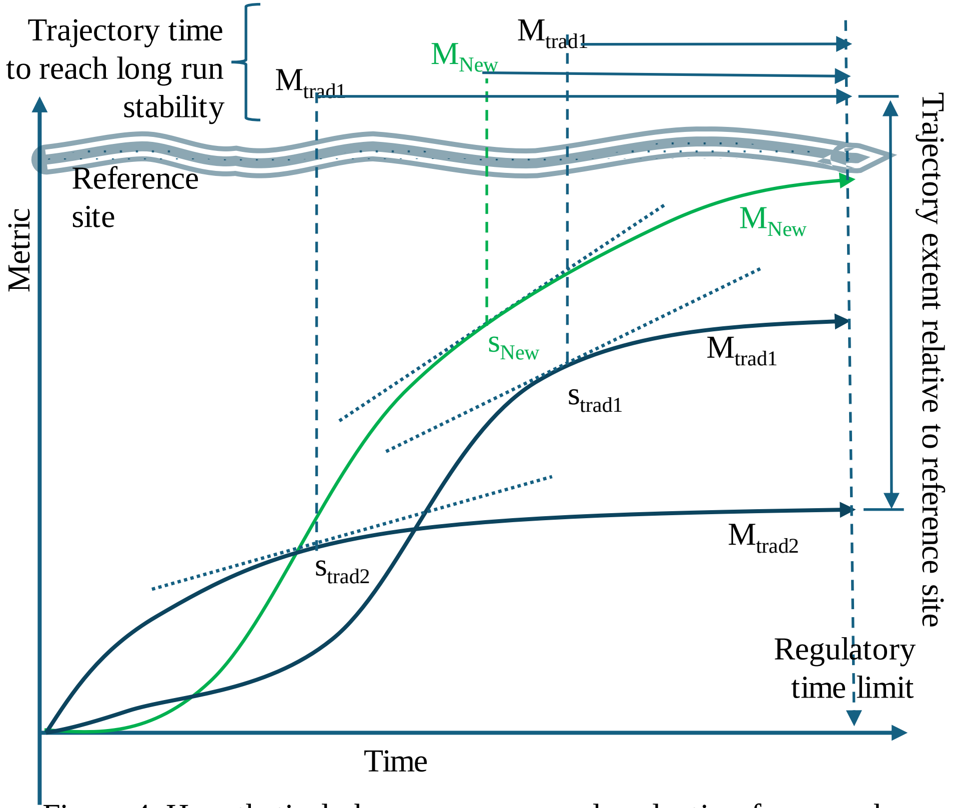
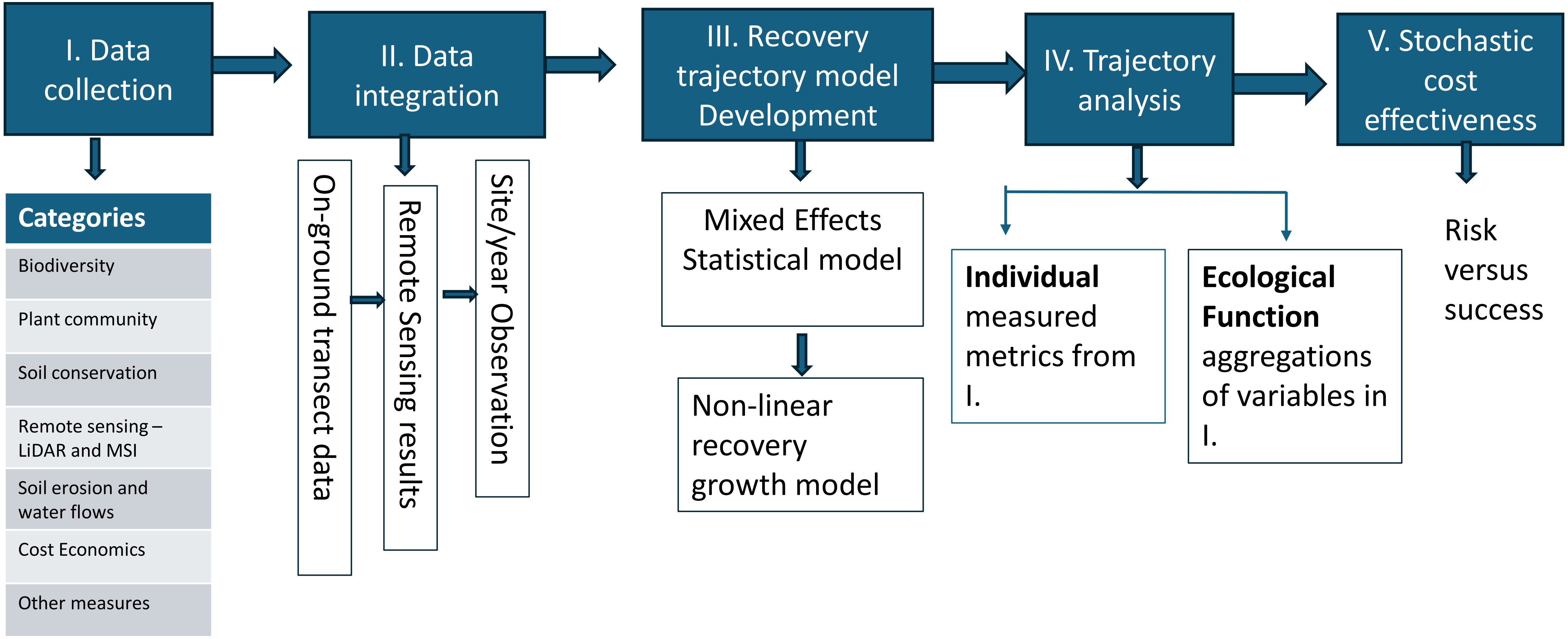


Figure 4. Hypothetical chronosequence and evaluation framework

Analytical process on evaluating reclamation



What are we measuring?

Range of Potential measurements

Table 1: Potential Recovery Trajectory indicators	
Category	Possible variables
Biodiversity	Shannon-Weaver; Simpson
Plant Community	Plant coverage; shrub height and coverage; native and non-native composition; pct Forb count; Ecological Patch development; root diameter, et al.
Remote Sensing	Advanced LiDAR surface changes, Multi-spectral imaging: NDVI, shrub coverage; et al
Soil conservation	Soil loss rates; soil collection and ecological patch development
Soil quality and water holding level	Organic C ; native soil organisms; water content or holding capacity.
Economics	Cost Effectiveness; Risk analysis;.

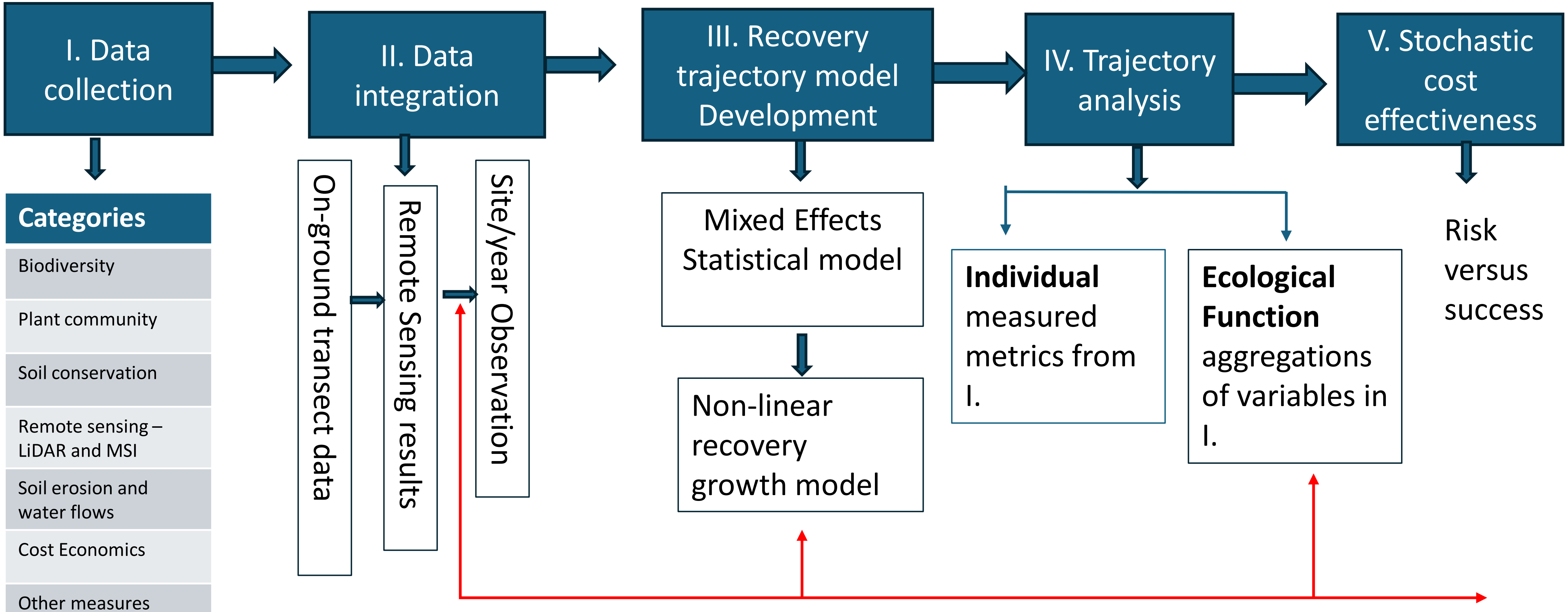
Reference Details (for Discussion):

[a]Extent is defined as a measure of how close to the reference areas is the reclaimed area.

[b]Stability is defined as the whether change in growth is increasing at a decreasing rate.

	[b]Stability and [a]Extent			
Index	Ground level Ecological results	Hydrological results	Remote sensing imputed estimates	Economic benefit Cost effectiveness comparison
Shannon-Weaver and/or Simpson Biodiversity	Stability and Extent	Stability and Extent	Imputed stability and extent	Stochastic Cost / Risk comparison at both stability and extent
Non-indigenous plants	Stability and Extent			
Shrub height and coverage	Stability and Extent		Imputed stability and extent	Stochastic Cost / Risk comparison at both stability and extent
Native plants	Stability and Extent	Stability and Extent	Imputed stability and extent	Stochastic Cost / Risk comparison at both stability and extent
Erosion rates	Stability and Extent	Stability and Extent	Imputed stability and extent	Stochastic Cost / Risk comparison at both stability and extent
Soil moisture	Stability and Extent	Stability and Extent	Imputed stability and extent	Stochastic Cost / Risk comparison at both stability and extent
Economics				Cost Effectiveness.

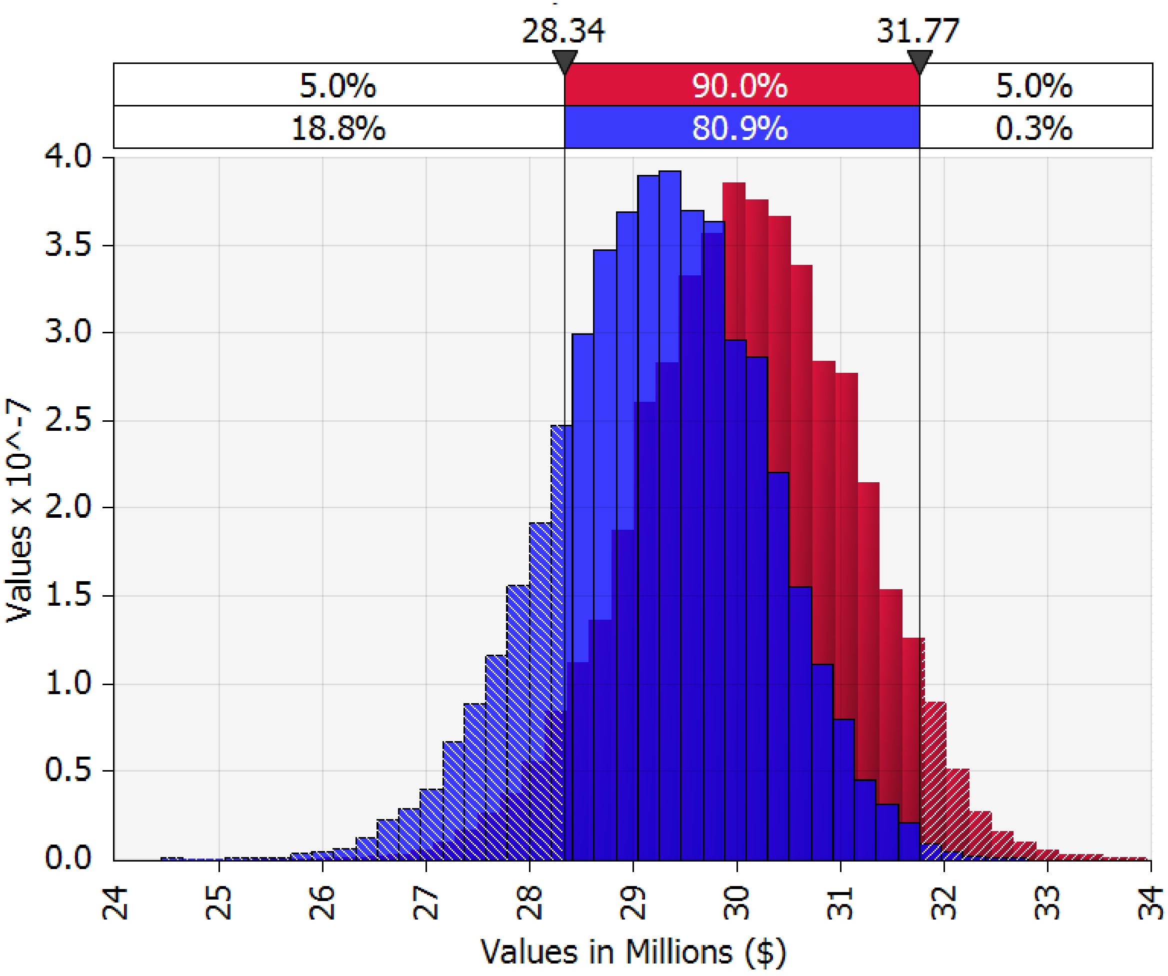
Analytical process on geomorphic reclamation



Areas of work where the team will be analyzing and testing new approaches to modeling

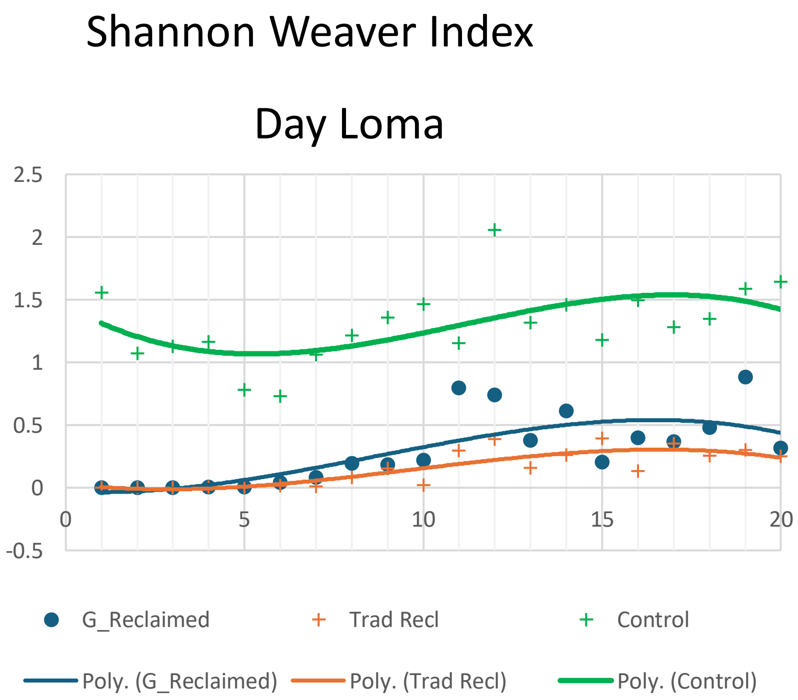
Previous work on the Gas Hills risk modeling:

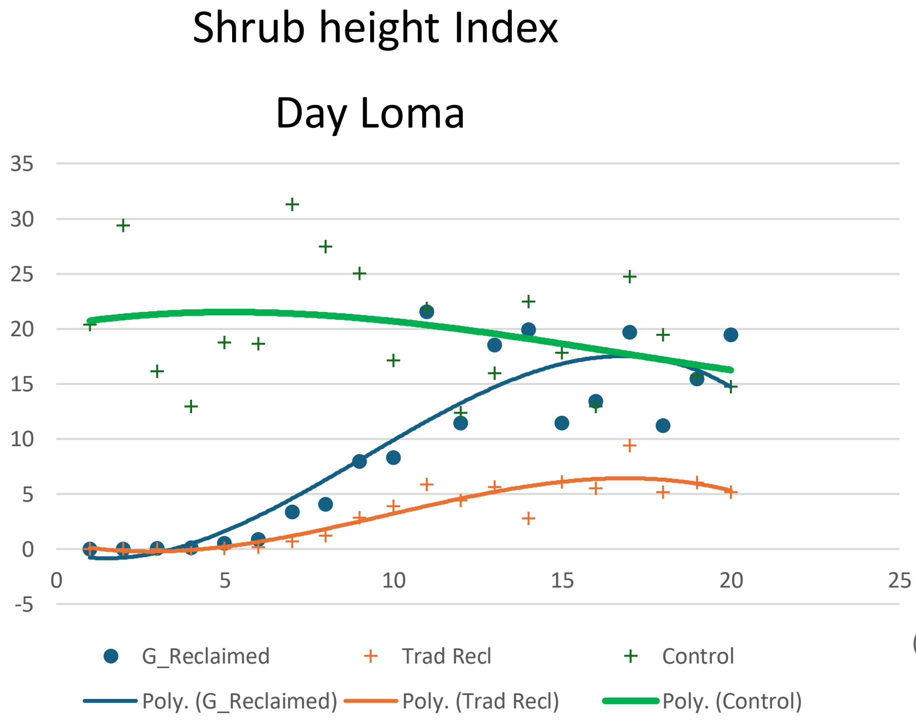
NPV of costs over 20 years going forward, Geomorphic versus Traditional

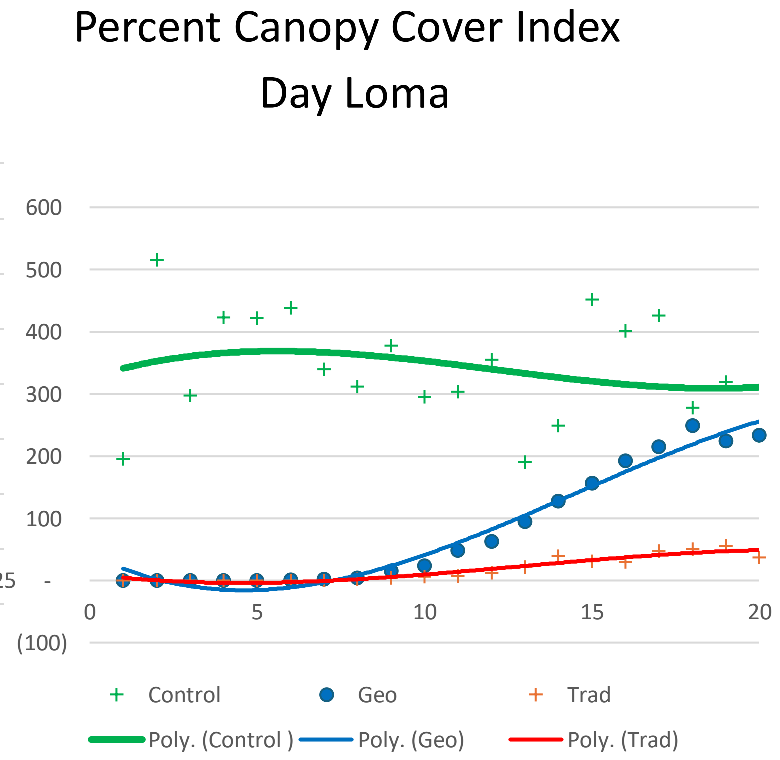


	NPV / Traditional	npv / Geomorphic
Cell	Enterprise Bu..	Enterprise Bu..
Minimum	$25,341,691.9..	$24,434,853.8..
Maximum	$33,976,355.1..	$32,810,054.6..
Mean	$30,092,668.8..	$29,223,849.5..
90% CI	± $17,101.99	± $16,627.23
Mode	$30,012,345.8..	$29,549,596.8..
Median	$30,102,784.4..	$29,249,547.4..
Std Dev	$1,039,630.57	$1,010,770.16
Skewness	-0.1146	-0.1818
Kurtosis	3.0185	3.0490
Values	10000	10000
Errors	0	0
Filtered	0	0
Left X	$28,341,841.0..	$28,341,841.0..
Left P	5.0%	18.8%
Right X	$31,766,958.3..	$31,766,958.3..

Previous work in Biometric simulation Day Loma

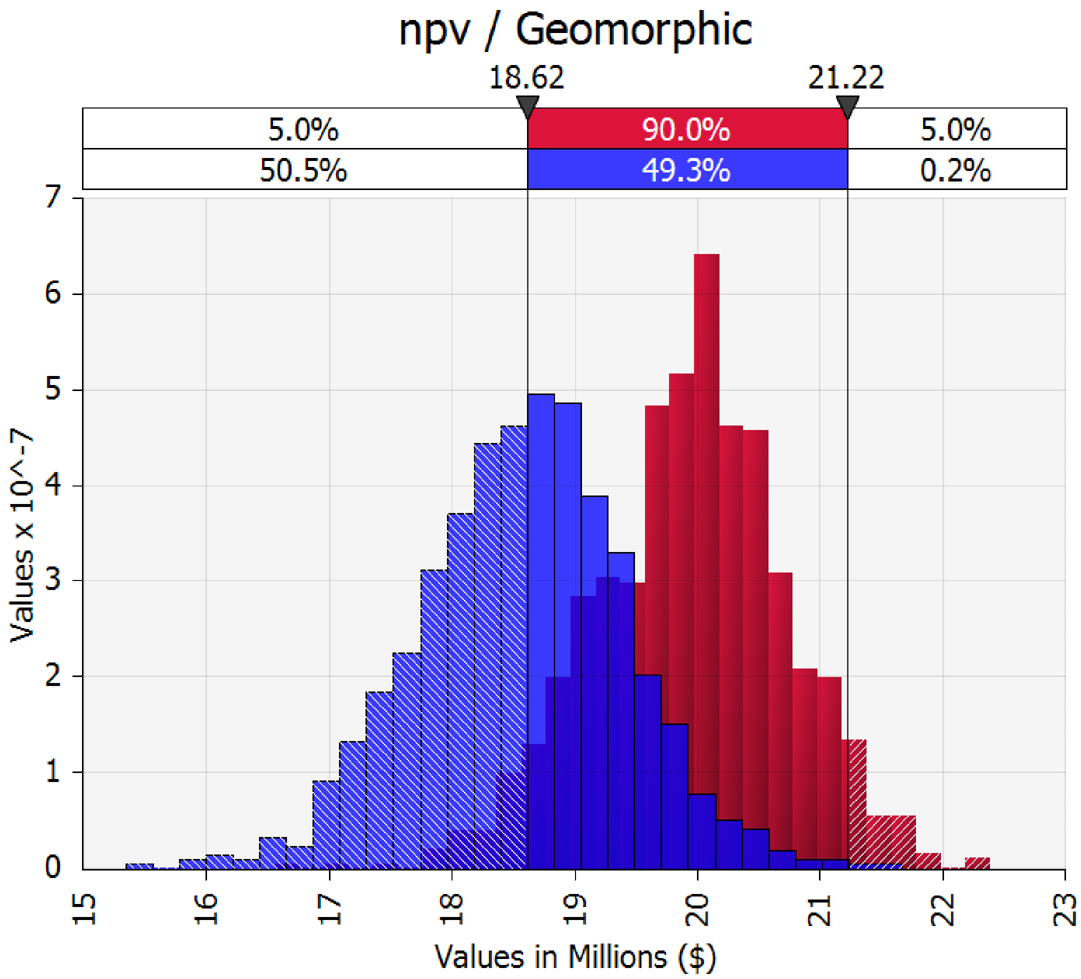






Adjusted Acres on a 488 acre site: Average over final 10 years

- Constructed a logistic growth function for progression over the planning time frame.
- Assumed Truncated Normal Distribution:
  - Min value truncation = 0
  - Max value truncation = Control average Shannon
- Calculated the difference between the terminal value of the Shannon index – Control site Shannon for each
- monte carlo simulation
- ----------------------
- Ultimate difference in the two simulations provide a beginning for the cost effectiveness analysis.



	npv / Geomorphic	NPV / Traditional
Cell	Enterprise Bu..	Enterprise Bu..
Minimum	$16,557,832.6..	$15,338,520.1..
Maximum	$22,392,592.3..	$21,674,622.1..
Mean	$19,953,487.5..	$18,578,452.8..
90% CI	± $40,552.88	± $44,029.76
Mode	$20,160,217.7..	$18,732,900.2..
Median	$19,990,234.0..	$18,607,349.3..
Std Dev	$778,918.33	$845,700.40
Skewness	-0.2173	-0.0567
Kurtosis	3.2828	3.4600
Values	1000	1000
Errors	0	0
Filtered	0	0
Left X	$18,616,633.8..	$18,616,633.8..
Left P	5.0%	50.5%
Right X	$21,221,930.2..	$21,221,930.2..

Data to Modeling to Information and Feedback and reverse

I. Reclamation Roundtable – Operators, nonprofits, and agencies discuss goals and techniques.
   1. Annual Roundtable discussions – 1st held early December 2025
   2. Wyoming Association of Conservation Districts 2026 (Potentially)
   3. Analysis and results presentation December 2027

II. Rates of change from both measures level and aggregation to simulate ecological functions:
   1. Methodological variations in types of individual measures.
   2. Regulatory agency and stakeholder preferences of measures
   3. Aggregations of plant community measures plus hydrological measures that might approach approximations to overall ecological function performance

III. Hopefully the Roundtables will continue after the NSF project is finished as an UW/Extension / DEQ collaboration with operators, consultants and community representatives

Questions? Thanks for the opportunity.

Contact information:
Roger Coupal (Agricultural and Applied Economics): coupal@uwyo.edu, +(307)766-5539
Kristina Hufford (Ecosystem Science and Management): khufford@uwyo.edu
Fabian Nippgen (Ecosystem Science and Management): fnippgen@uwyo.edu

References

1. Avirmed, O., Lauenroth, W. K., Burke, I. C., & Mobley, M. L. (2015). Sagebrush steppe recovery on 30–90-year-old abandoned oil and gas wells. *Ecosphere*, *6*(7), 1-10.