Assessment of Biodiversity and Ecological Uplift Potential to Leverage Natural Capital

MONTROSE ENVIRONMENTAL

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Content

Our Vision for Ecosystem Valuation

Natural capital valuation places a monetary value on economic services provided by a given ecosystem

We take an economic view of ecosystem valuation and biodiversity using an **"ecosystem-based approach"** to address challenges

Six key elements of a successful ecosystem-based approach:

1. Consideration of geographic areas defined by ecological boundaries
2. Recognition of complexities of natural processes and social systems
3. Explicit definition of biological, economic, and social goals
4. Emphasis on science-based and informed decision-making to achieve specific goals
5. Comparison to similar ecological reference area(s)
6. Recognition that nature is unpredictable and adaptive management is necessary to adjust strategy over time

Cinclus mexicanus – American water dipper
Photo – R. Mandel

Our Vision for Realizing Ecological Benefits

Realizing ecological benefits requires two-step strategy:

1. Understanding **current balance sheet** of a property - ecological and human use assets and management expenses
2. Using balance sheet to **identify investments and actions** that maximize asset values while optimizing management expenses

Which benefit(s) to focus on depends on client's specific vision, goals, and objectives for a property

Ecological Benefits of Well-Managed Natural Areas

Carbon sequestration
Conservation/Enhancement of biodiversity
Contribution to climate regulation
Control of invasive species
Ecosystem protection
Maintenance of harvestable resources
Nutrient cycling
Prevention of soil erosion
Provision of clean water
Provision of clean air
Preservation of medicinal and genetic resources
Recreation
Soil regeneration
Watershed protection

Content

Definition of Biodiversity

- The **variety of life on earth** at all levels, from genes to ecosystems
  - Encompasses the evolutionary, ecological, and cultural processes that sustain life
  - Considers interactions between **species and their environment**

- Represents **living genetic history** of our planet
  - Our survival as organisms and as a living planet is dependent upon depth, diversity, and resiliency of our gene pool

- Increased biodiversity allows an ecosystem to more effectively resist climate change and more successfully provide ecosystem services

Hanging wetland Photo – R. Mandel

Why is Biodiversity Important?

Ecosystem Health

- Balanced & Functional Ecosystems
- Sustainable Food Chains
- Provision of Ecosystem Services (e.g., Clean Water & Biodiversity)
- Resilience to Natural Disasters (e.g., fire, storms, flooding, tornados)
- Genetic Resiliency & Integrity
- Climate Regulation

Human Health

- Natural Medicine & Pharmacology
- Mental & Physical Wellness
- Education & Spirituality
- Open Space
- Rejuvenation / Relaxation
- Sustainable Food Provision

Economic Health

- Job Creation & Sustainability
- Circular Economies
- Natural Capital
- Sustainable Provision of Raw Materials
- Resilient Societies & Communities
- Recreation & Tourism

The What and Why of Carbon Sequestration

- The process of **capturing and storing atmospheric carbon**
  - Essential for offsetting carbon emissions that contribute to greenhouse gasses (GHG)
  - Stabilizes carbon to prevent it from entering Earth's atmosphere
- 3 Main Types
  1. **Biological – naturally occurring process of storing carbon in vegetation**
  2. Geological – carbon stored in underground geologic formations or rocks
  3. Technological – carbon capture through anthropogenic processes

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- Natural carbon sinks are reduced by habitat loss, while global carbon emissions continue to increase
- Habitat enhancement requires consideration of many factors in selection process
  - Real-estate cost and tenure agreements
  - Existing ecosystem function
  - Habitat health and viability
  - Natural hazard vulnerability
  - Community support

Content

Biodiversity: Three Levels of Assessment

On-Site Assessment

Habitat evaluations

On-Site & Remote Assessment

Site orthomosaic drone image

On-Site, Remote Assessment & AI

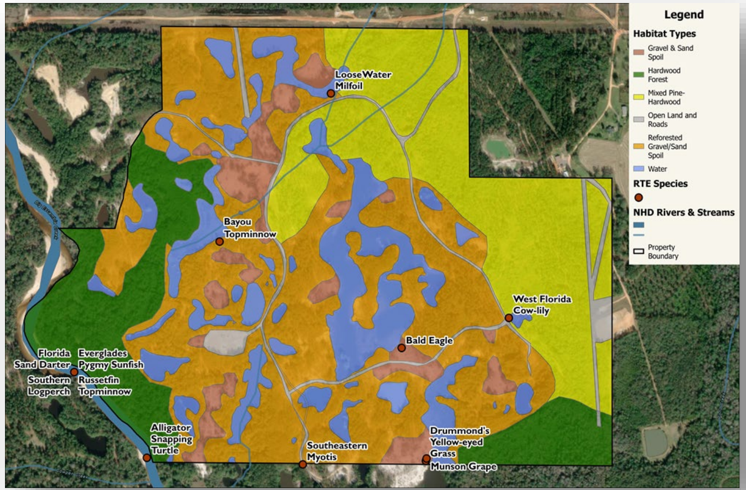


Image based on LiDAR and on-site monitoring

Typical Approach to Biodiversity On-Site Assessment

On-Site & Reference Community Data Review

On-site and publicly available data reviewed to determine:

- Site history
- Reference conditions
- Climax/steady state communities
- T&E survey
- Wetland conditions
- Reference communities identified to determine the defining attributes for different habitat and community

On-Site Surveys

Verify current conditions such as:

- Habitat type
- Site stressors (erosion, noxious species, etc.)
- Canopy cover & height
- Hydrology
- Species richness, distribution, and dominance
- Wetland delineation
- Soil type
- Sediment transport and other variables

Comparative Analysis

On-site and reference conditions compared to determine biodiversity status and trajectory

Biodiversity "Scorecard"

Gap analysis used to determine the status of on-site ecological resources relative to reference communities

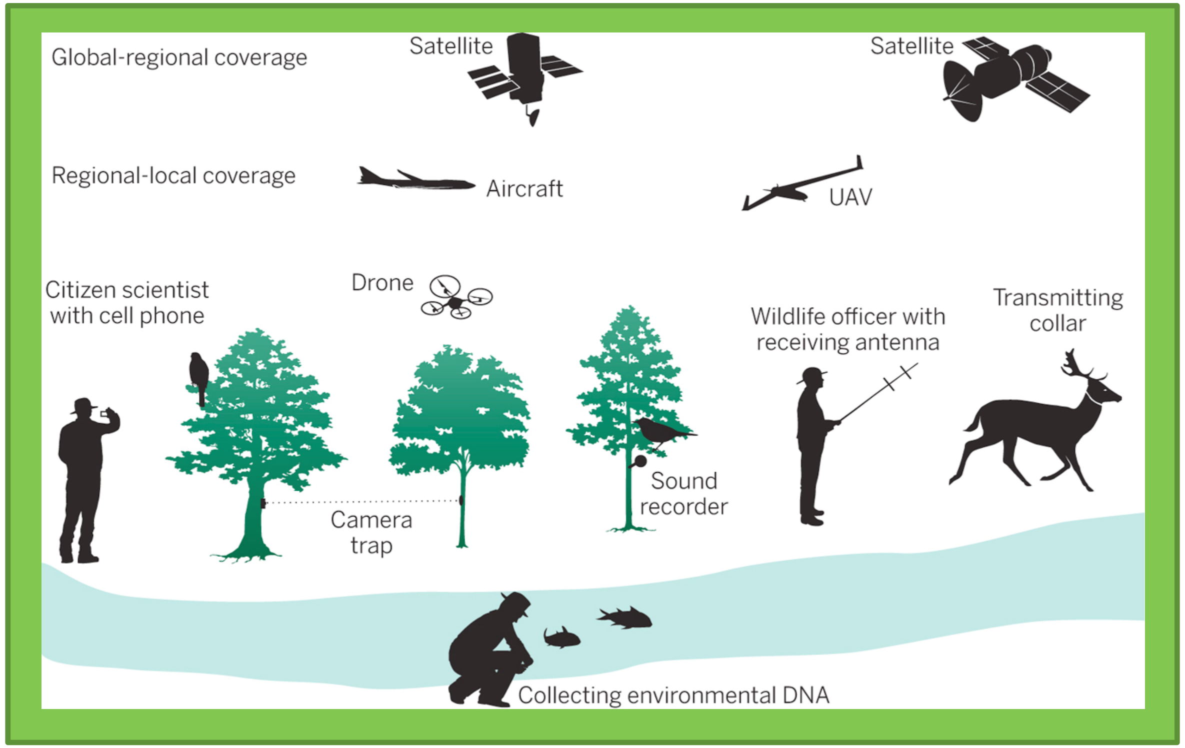
A "scorecard" is created to determine uplift potential and guide the identification of costs, priorities, and resource management drivers

Incorporating Remote Sensing in Biodiversity Assessment

- **Provides a data-rich visualization component to biodiversity assessment**

- Remote sensing tools
  - Satellite imagery
  - Radar
  - IR & NIR
  - LiDAR
  - Drones
  - Algorithms for Optimization

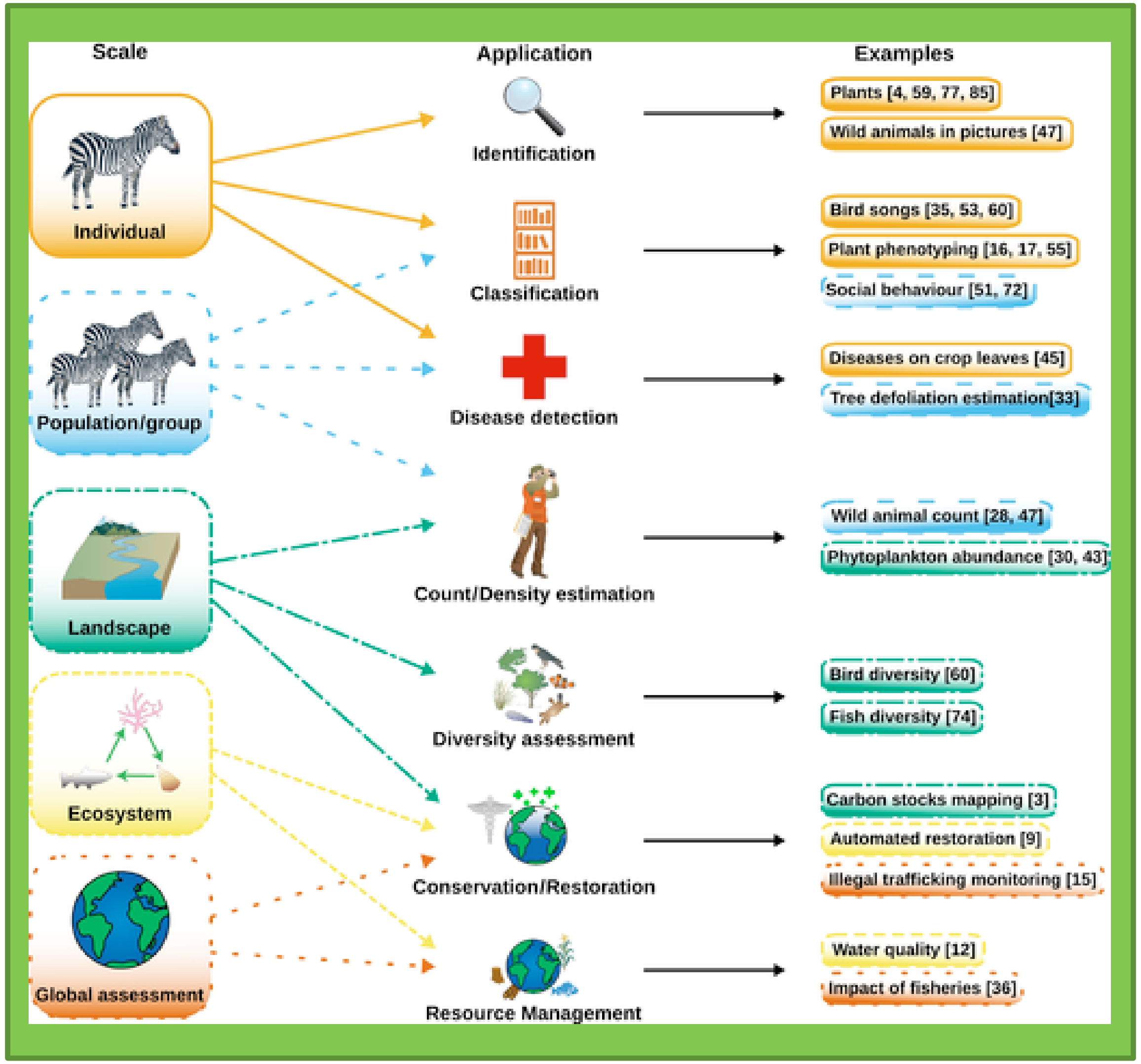
- **Expanded data quality, availability, spatial and temporal resolution as well as technologies to utilize remote sensing data**



Turner, 2014. Sensing Biodiversity. Science. 346(6207:301-302. DOI: 10.1126/science.1256014

Using Deep Learning to Inform Biodiversity Assessment

- Monitoring information + predictive modeling → patterns in large and heterogeneous datasets
- Reference community data + comparative analysis → models that classify habitat conditions and predict **changes across time and space**
- Works over **large land areas** in **safe, time-efficient, and cost-effective manner**
- Elucidates relationships between climate change, species adaptation/biodiversity, and resiliency



Christin et al. 2019. Applications for Deep Learning in Ecology. Methods in Ecology and Evolution. 10(10):1632-1644. DOI: 10.1111/2041-210X.13256.

Our Expanded Approach to Biodiversity Assessment

On-Site & Reference Community Data Review

On-site and publicly available data reviewed to determine:

- Site history
- Reference conditions
- Climax/steady state communities
- T&E survey
- Wetland conditions
- Reference communities identified to determine the defining attributes for different habitat and community

Remote Sensing

Remote analysis of site performed using satellite imagery, LiDAR, and/or drone survey to determine conditions such as:

- Habitat type and extent
- Site-stressors
- Canopy cover & canopy height
- Hydrology
- Species richness, distribution, and other variables.

On-Site Surveys

Verify current conditions such as:

- Habitat type
- Site stressors (erosion, noxious species, etc.)
- Canopy cover & height
- Hydrology
- Species richness, distribution, and dominance
- Wetland delineation
- Soil type
- Sediment transport and other variables

Comparative Analysis

On-site and reference conditions compared to determine biodiversity status and trajectory

Predictive Modeling

Baseline information and comparative analysis used to create predictive model through integration of training data by habitat type.

This data is then embedded through algorithms as deep learning to further classify habitats over larger areas in a safe, time-efficient, and cost-effective manner.

Biodiversity "Scorecard"

Gap analysis used to determine the status of on-site ecological resources relative to reference communities

A "scorecard" is created to determine uplift potential and guide the identification of costs, priorities, and resource management drivers

Carbon Assessment

- Sequestration traditionally measured in terms of above ground carbon, normally through standing woody biomass
- Our team is leveraging the ***combined above, below ground, and blue carbon*** sequestered in given site, therefore providing a ***more accurate assessment and understanding***
- Our methodology for estimation includes the combination of:
  - Ecosystem biomass calculations
  - Met-towers with above and below ground probes to measure gas exchange
  - Calculations of carbon sequestration potential
  - Sequestration potential based on habitat type and condition
  - Application of advanced algorithms and informatics

Content

Using LiDAR for Habitat Identification and Vegetation Analysis

- LiDAR detects above-ground biomass and vegetative attributes such as canopy height and diameter, species richness and distribution, undergrowth characteristics, and noxious species invasion

- Provides detailed bare-earth topography normally obscured by vegetation and difficult to measure using aerial photogrammetry

- Through comparison with reference area information, can determine health, trajectory, stressors, etc. by habitat type to form predictive modeling that can be coupled with natural capital analysis to inform land management decisions

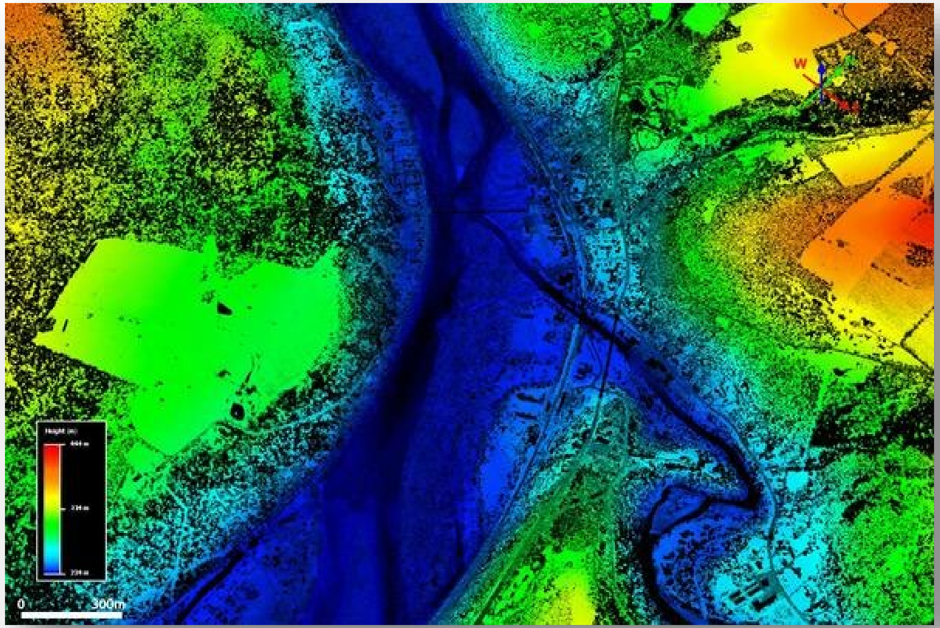


Image from USGS. https://www.usgs.gov/centers/eesc/science/mapping-riverine-habitats-delaware-river-using-bathymetric-lidar

Geographic Information Systems (GIS)

- GIS **provides geospatial view of biophysical and habitat data** through time and over land area. It provides physical assessment and overall trajectory for ecological systems

- GIS commonly used to **create maps to understand biodiversity in a given area** at different spatial scales

- Geoinformatics helps assess **spatial biodiversity for conservation assessment and planning**. Coupled with advanced remote sensors and deep learning tools, GIS enables better understanding of ecological systems for decision making

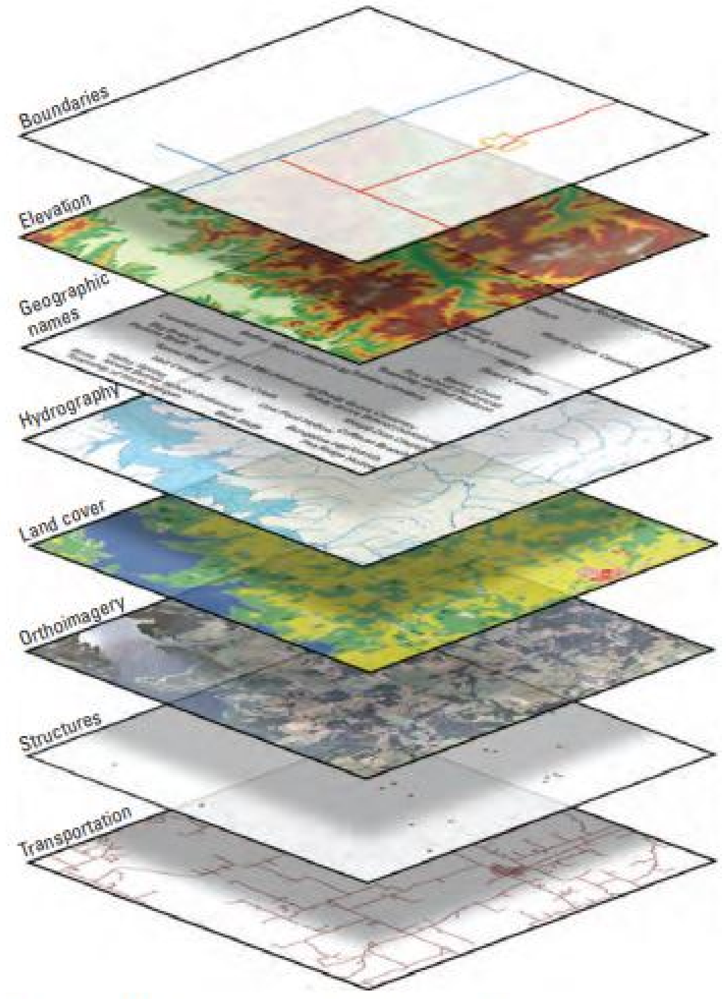


Figure 1. Eight base layers of *The National Map*.

Image from USGS (https://www.usgs.gov/media/images/8-base-layers-national-map)

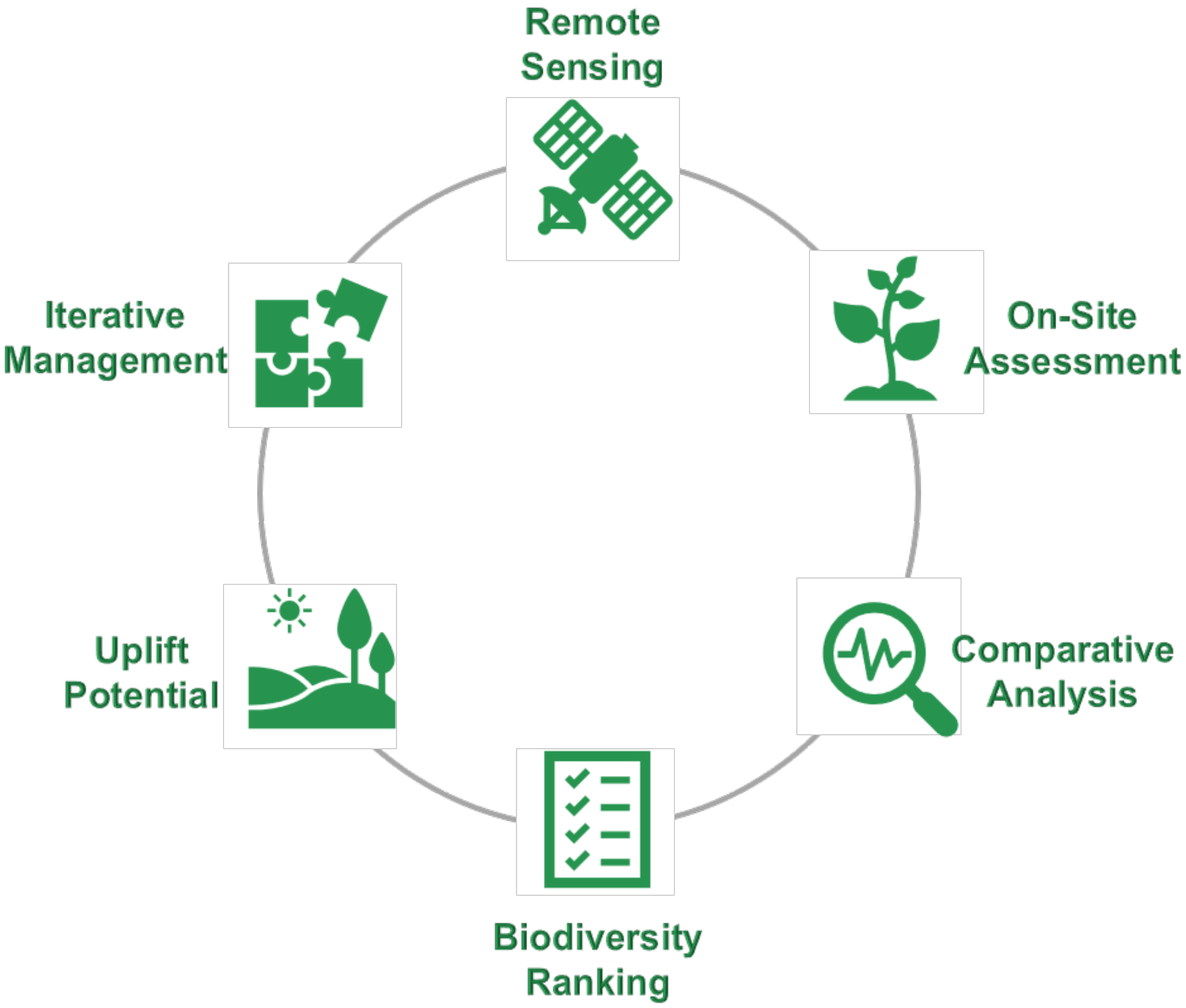
Comparative Assessment Methodology

- Combination of **on-the-ground assessment** coupled with **remote assessment** ensures the most accurate understanding of environments and uplift potential
- Habitats are compared with **adjacent reference areas** comprised of similar community types
- Habitat assessment is based on:
  - Type (distinguished by hydrology, soils, climate, and expected vegetative)
  - Extent (e.g., area)
  - Distinctiveness (e.g., uniqueness)
  - Condition (relative to reference site)
  - Stressors
  - Uplift Potential
- Assessment results in a **habitat score** to note current condition and track change over time

Pedicularis groenlendica – elephanthead
photo– R. Mandel

Calculating Ecological Uplift Potential

- **Uplift Potential:** weighted product of area, distinctiveness, score, condition, strategic significance, stressors, and other factors
- Reproducible methodology enables tracking of habitat change over time
- Accounts for both gains and losses:
  - Gains – implement adaptive management, achieve uplift
  - Losses – development removes habitat or through degradation
- Remote/on-site monitoring tracks trajectory over time
- Combine with Environmental Economics assessment, including outlay, return, and natural capital considerations



Content

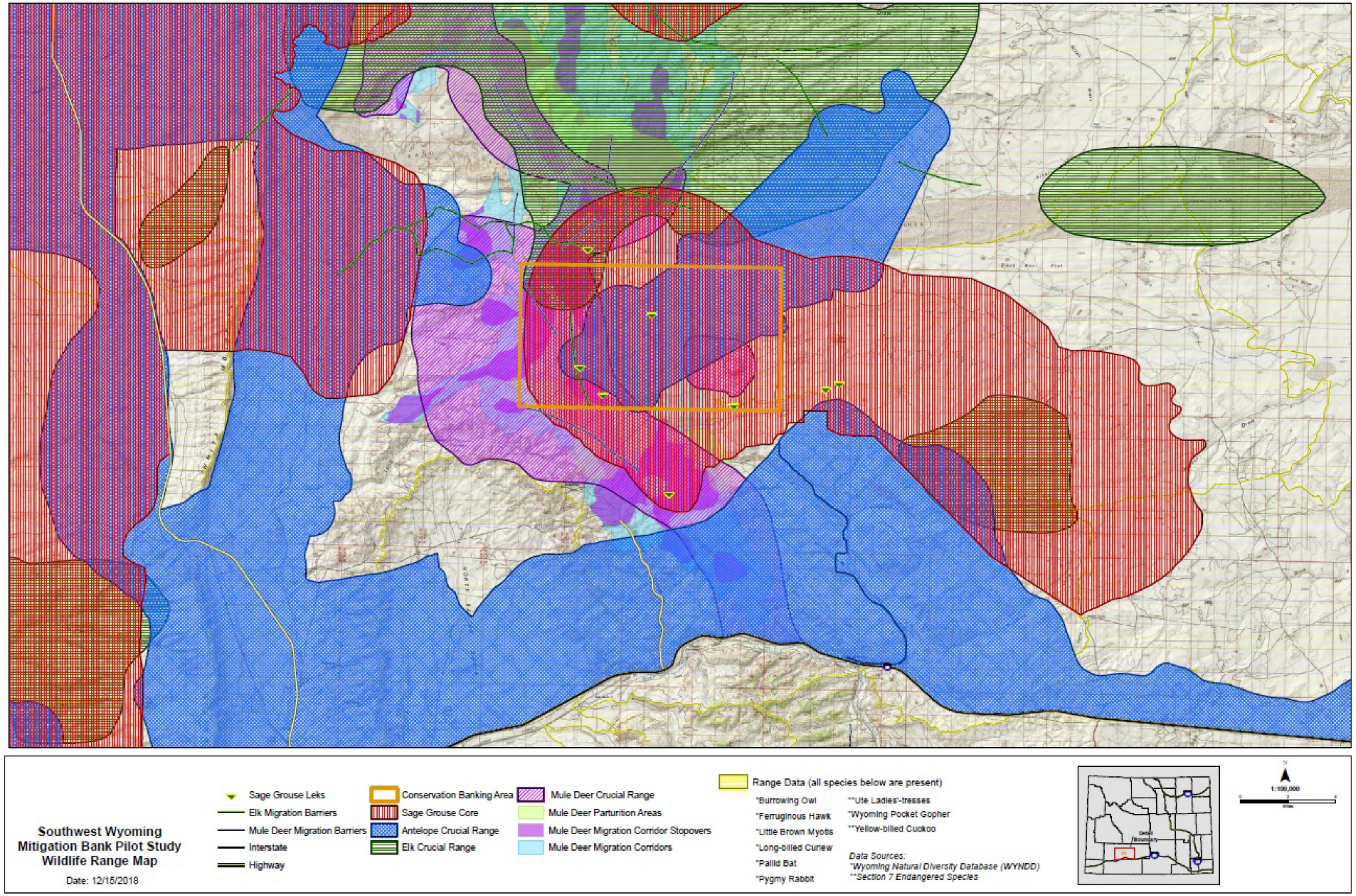
Example – Wyoming Land Assessment

Sublette County, WY Field Assessment
photo - R. Mandel

Centrocercus urophasianus – Greater sage-grouse

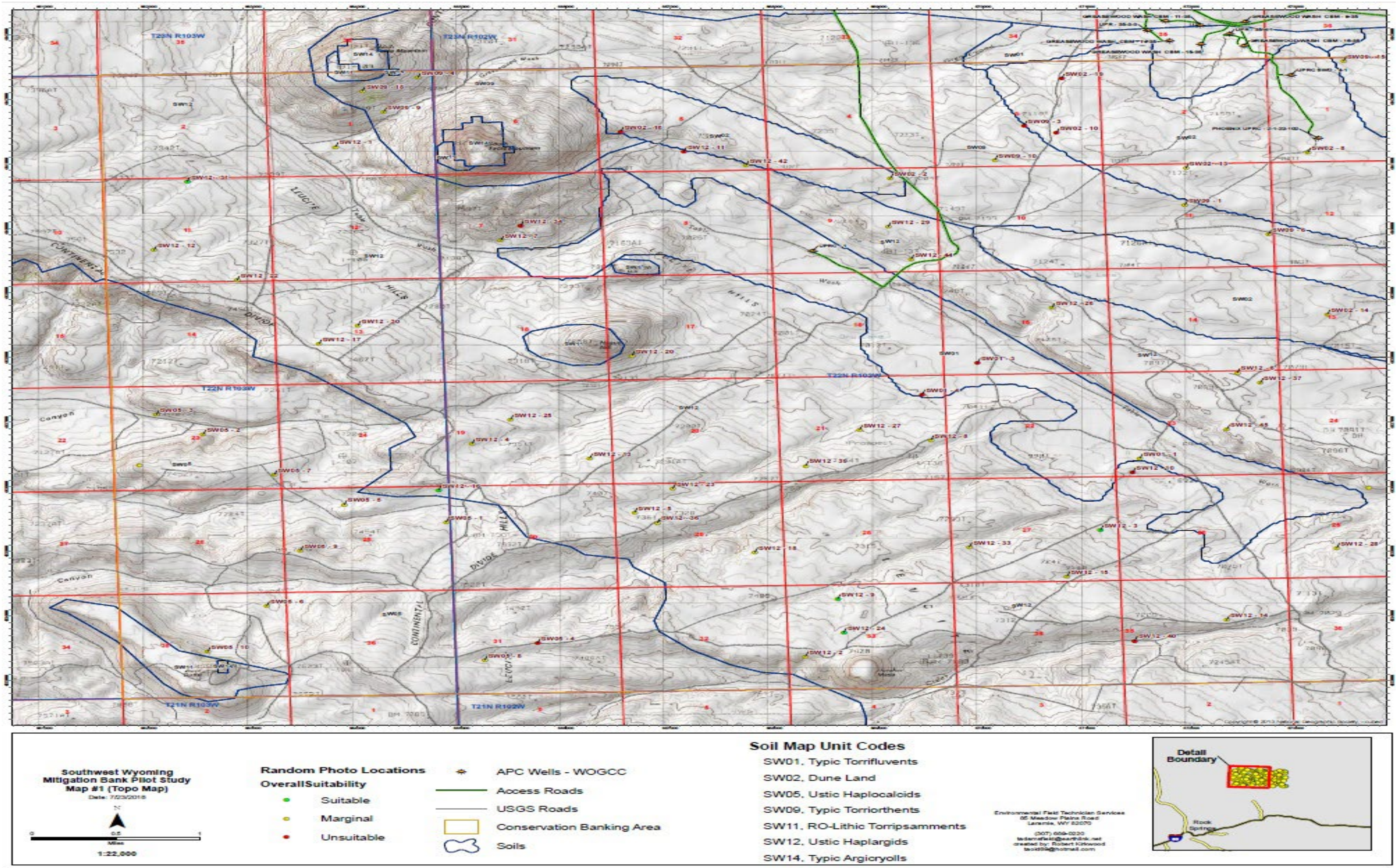
Calochortus gunnisonii - Gunnison mariposa lily
photo R. Mandel

Example - Wyoming Habitat Assessment



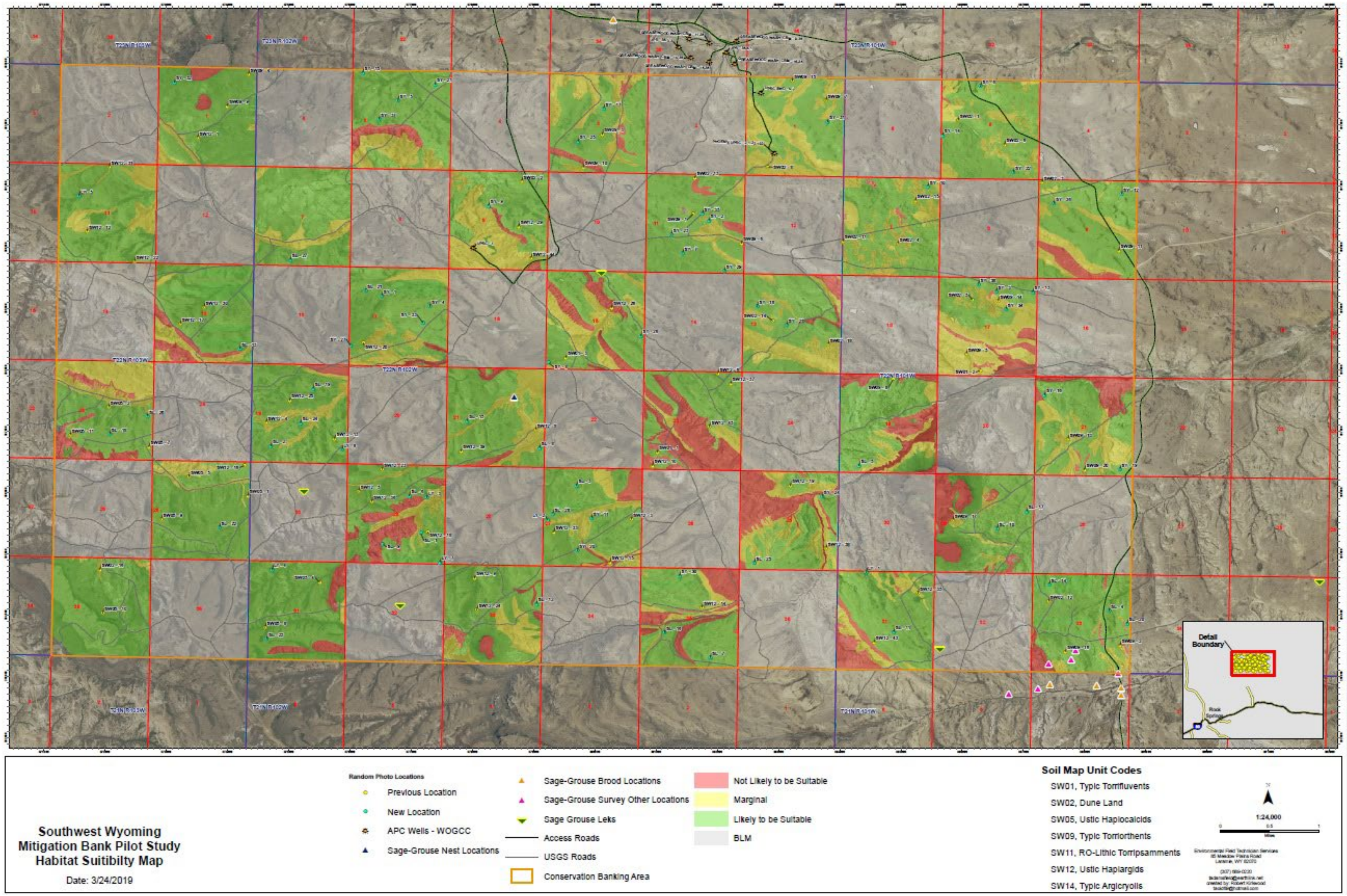
- **Step1:** review of existing site data (pilot studies, LiDAR, photologs, past monitoring, etc.)
- **Step 2:** review of desktop resources (National Wetlands Inventories, NRCS Technical Guides, Soil Maps, Ecological Site Descriptions; USFWS, USACE, NGO, and State Agency Data; etc.)
- **Step 3:** Determination of habitat type, coverage, and distribution for site analysis
- **Step 4:** Identification of habitat and distribution for spp. of concern essential for habitat analysis

Example – Wyoming Habitat Assessment



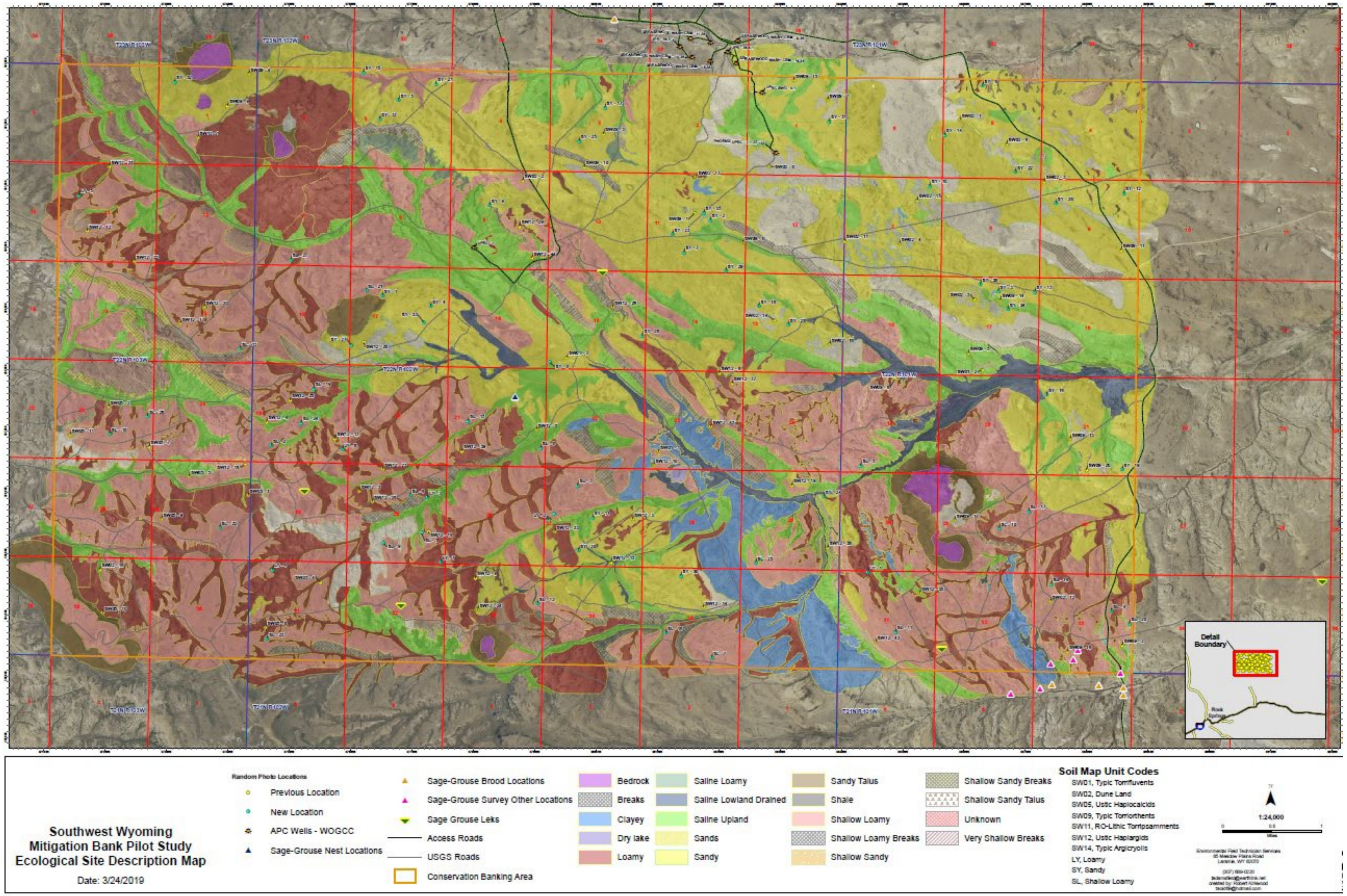
- Habitat and spp. data used for development of prioritization matrix to inform remote and on-site monitoring
- Prioritization matrix superimposed upon site maps to determine sampling locations
- Sampling locations determined through **Balanced Acceptance Sampling (BAS)** design
- BAS locations used to determine ecological typology and accessibility to remove impractical locations

Example – Wyoming Habitat Assessment



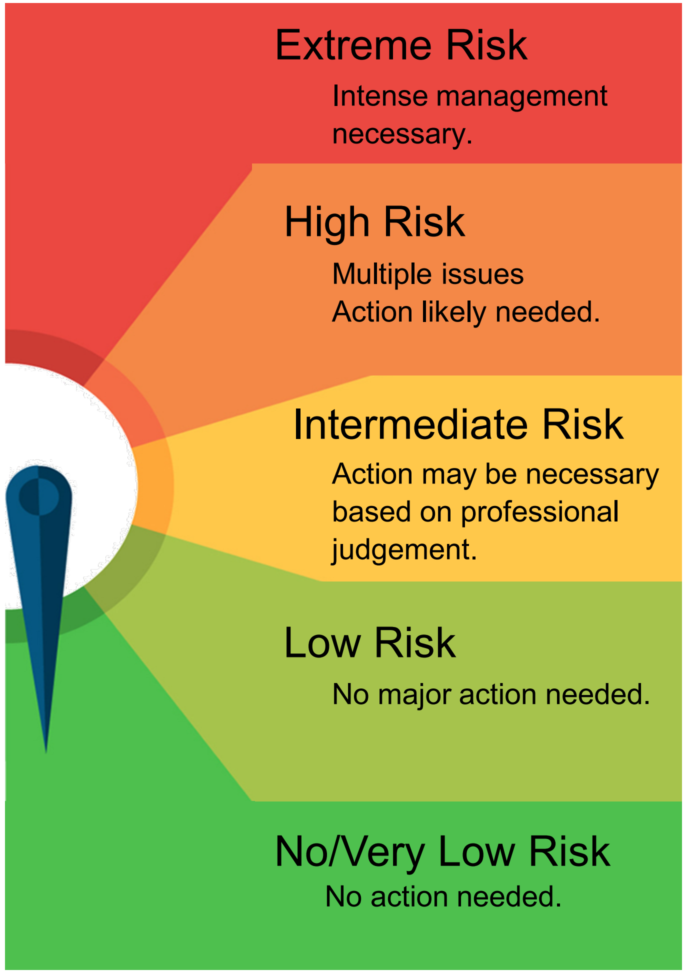
- Use of site selection important for example because of occurrence within WY “Checkerboard Lands”
- Ensures that sampling sites are spread across study area; allows for collection of estimates in efficient manner
- Allows for removal of lands outside of study area without impacting statistical robustness

Example – Wyoming Habitat Assessment



- Finalized site locations superimposed with critical spp. habitat, typology, land ownership, and accessibility. Yields detailed map refinable through integration of additional information (e.g., soil type)
- Combined attributes can be prioritized into schema reflecting management decisions (e.g., regulatory criteria and/or corrective actions)
- Developed prior to initial monitoring, then refined through further data/ management input

Example – Wyoming Habitat Assessment

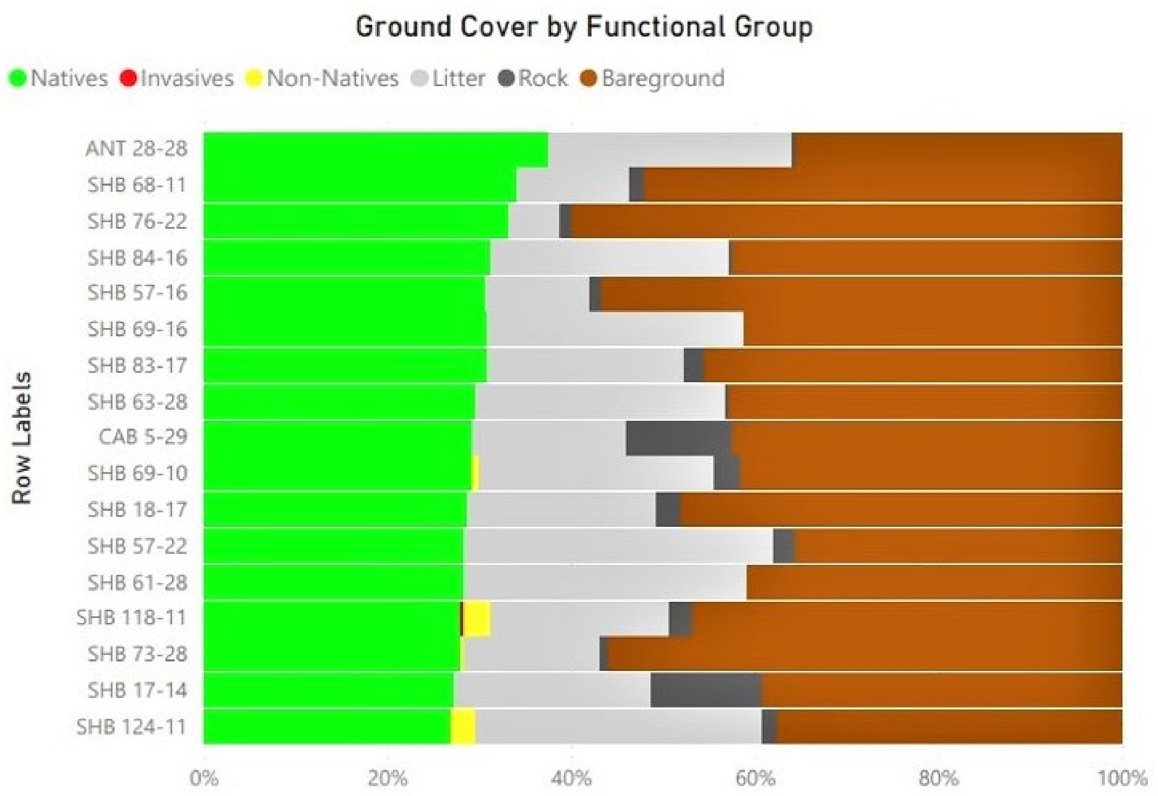


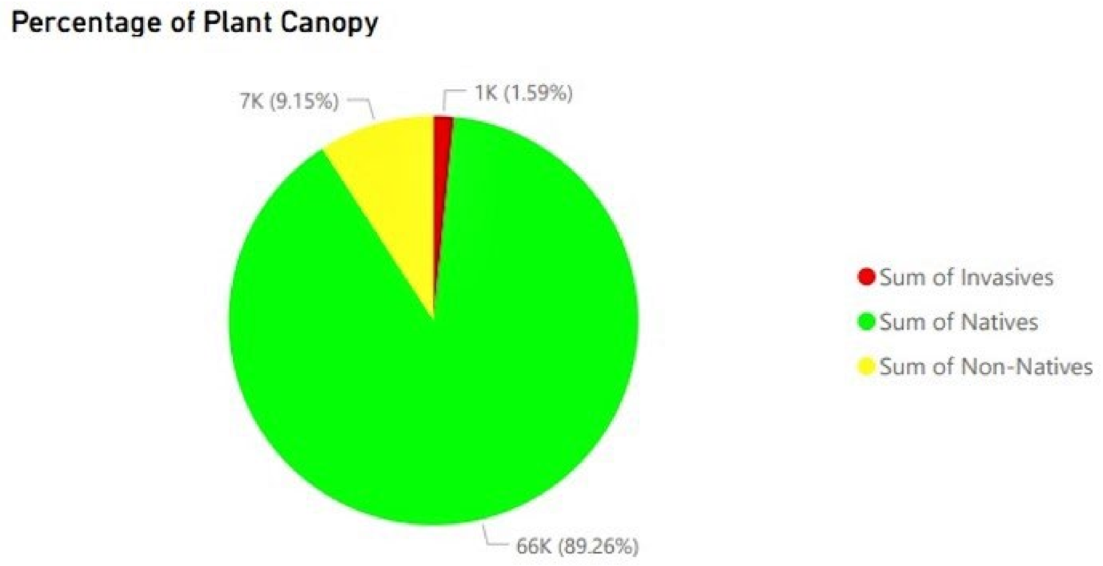
- Remote and on-the-ground monitoring data are assembled into a **matrix** and weighted by priority and attribute
- Data is summed by habitat type to yield a **weighted score**
- Weighted score then assembled into **"stoplight" dashboard** to show risk and inform management
- Allows for time- and cost-efficient summary to show what areas and actions will have greatest impact
- Indicates which sites should be deprioritized because they're unlikely to benefit from remedial action
- **Systematic and repeatable** process. Resulting scores based on science, are transparent, and statistically robust
- Allows for **informed decision-making** guided by current conditions and overall trajectory

Example – Wyoming Habitat Assessment

Summary of 2022 Site Scores		Cottonwood Creek Bentonite	Crows Nest NW #20	Dave Johnston	Day Loma Overall	Day Loma 2012	Day Loma 2014	Deep Creek North #35 & South #26
Ranking Factor	Category	Wt. Score	Wt. Score	Wt. Score	Wt. Score	Wt. Score	Wt. Score	Wt. Score
Land Surface Reclamation for young sites (0-2 years) (5x weight)	Erosion Features	15	5	0	0	0	0	5
	Undesirable Species	10	5	0	0	0	0	5
	Desirable species establishment	10	5	0	0	0	0	5
Land Surface Reclamation for sites 2+ years (5x weight)	Erosion Features	0	0	10	15	10	15	0
	Undesirable Species	0	0	10	15	15	15	0
	Desirable Species Establishment	0	0	10	15	15	15	0
Ecological Setting (3x Weight)	Reference Community	9	6	9	9	9	9	9
	Proximity to lek	9	6	9	9	9	9	9
Time since last monitoring (3x weight)	Time since last monitored	9	9	3	3	3	3	9
Site Ownership (3x Weight)	Ownership	3	6	9	6	6	6	3
Size of Site (1x Weight)	Reclamation Area	2	2	3	3	3	3	2
Priority Assessment								
Weighted Score (Sum) =		67.0	44.0	63.0	75.0	70.0	75.0	47.0
Weighted Score (Average) =		8.4	5.5	7.9	9.4	8.8	9.4	5.9

Example – Wyoming Habitat Assessment





- Dashboard data can be re-assembled into a **priority chart** by property or other criteria
- Clarity, transparency, and defensibility of process and dashboard allows accelerated management response times and concise reports, allowing for time and budget efficiencies