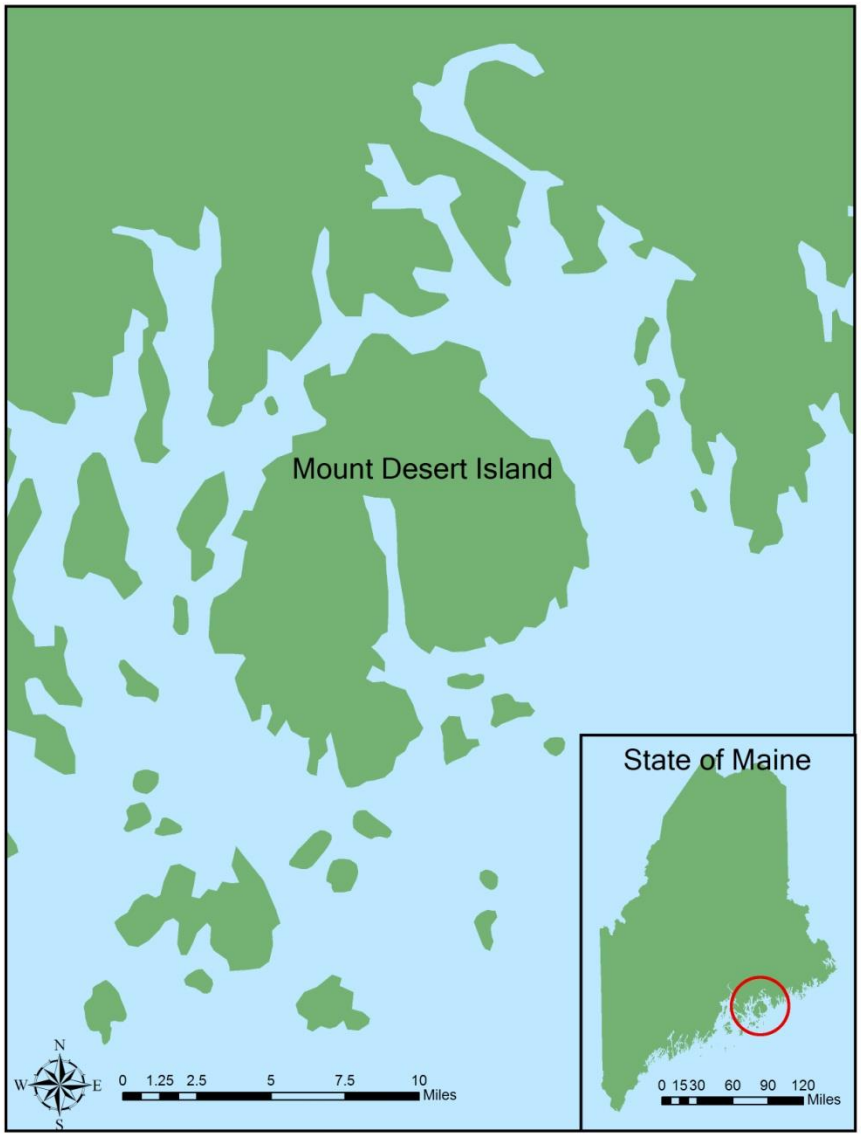
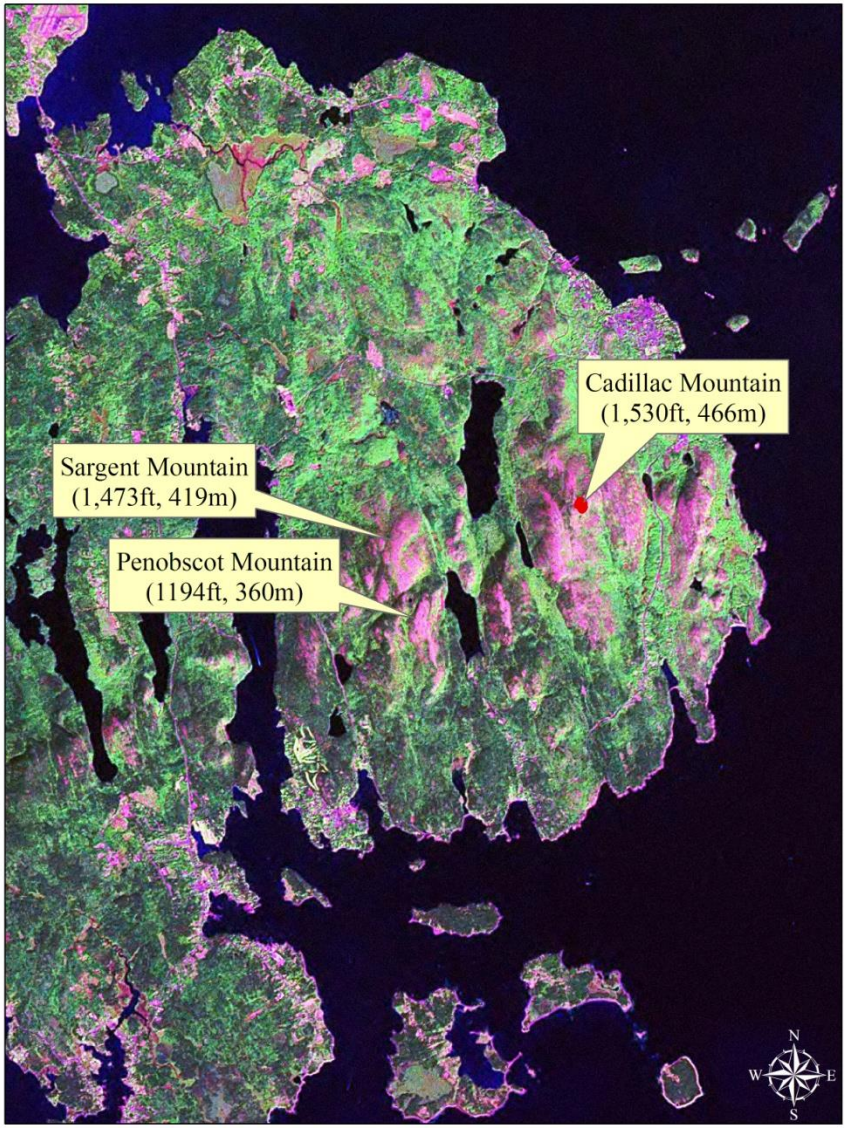
Enhancing Recreation Resource Management through Remote Sensing: Insights from Acadia National Park

Min Kook Kim, Ph.D., Stockton University
John Daigle, Ph.D., University of Maine

Study Site: Cadillac Mountain, ANP





Study Site: Cadillac Mountain, ANP

- The only mountain in ANP with an automobile road **(accessibility).**

- Approximately 75% of total ANP visitors visit Cadillac Mountain: Icon/must-see attraction (**estimated 1.5 - 2.0 million/year**).

- Extremely high visitor use in a small and sensitive area during summer **(from June to August).**

- Micro sites having vegetation damage and soil erosion are easily discovered along the summit loop trail by natural disturbance or human recreational use.

- Indirect management actions (based on **physical barriers** & **Leave No Trace Signs**) have been implemented since 2000 in the vicinity of the summit loop trail.

- A more active style of management, **ecological restoration projects** were implemented in 2015.

- **Vehicle reservation system,** a direct management action, has been adopted in 2021 to limit visitor use.

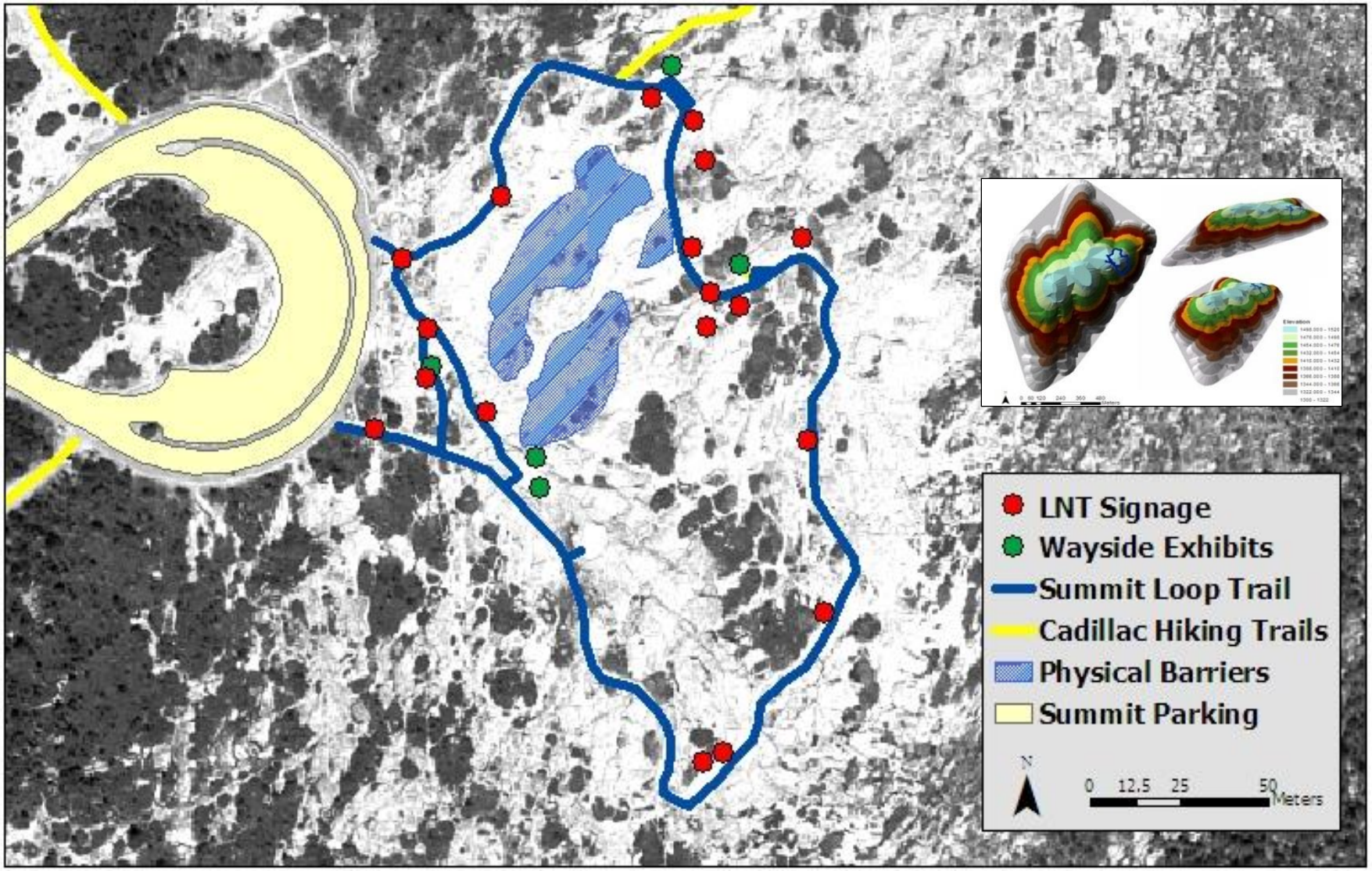
Study Site: Cadillac Mountain, ANP

- Buckboard Road: 1860s-1870s
- Three Hotels in the vicinity of summit loop trail: 1860s-1897
- Cog Railroad: 1880s
- Acadia (Lafayette) National Park: 1919
- Current Automobile Road: 1929-1932
- Current Pavement of Summit Loop Trail: 1933 (often re-paved afterward)
- U.S. Navy Radar Station: During WWII
- Acadia National Park Fire (major natural disturbance): 1947

Study Site: Cadillac Mountain, ANP

2000-2020

Study Site: Management



Study Site: Management

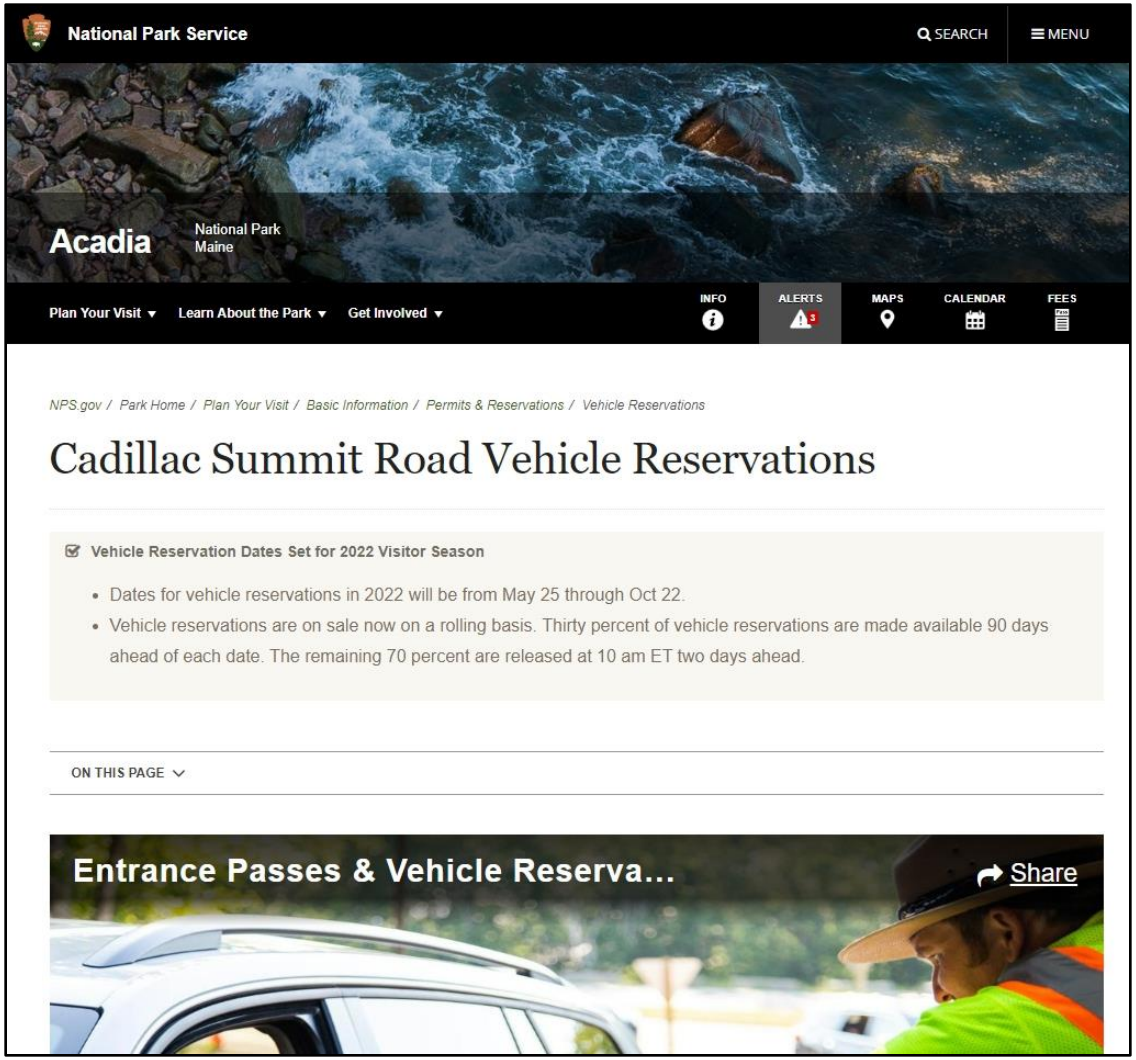
LNT Messages (since 2000)

Barriers (since 2000)

Low-impact educational messages based on LNT (above) and physical barriers (below) were implemented in 2000. Physical barriers were updated with lines of ropes later.

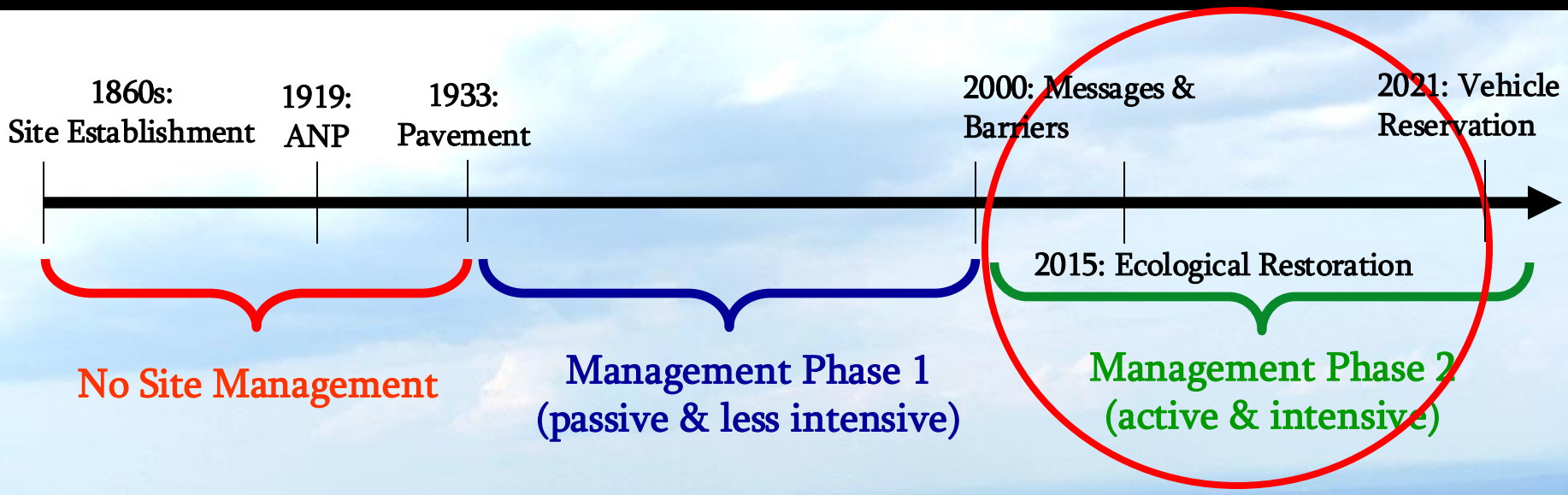
Study Site: Management

Ecological Restoration (since 2015)



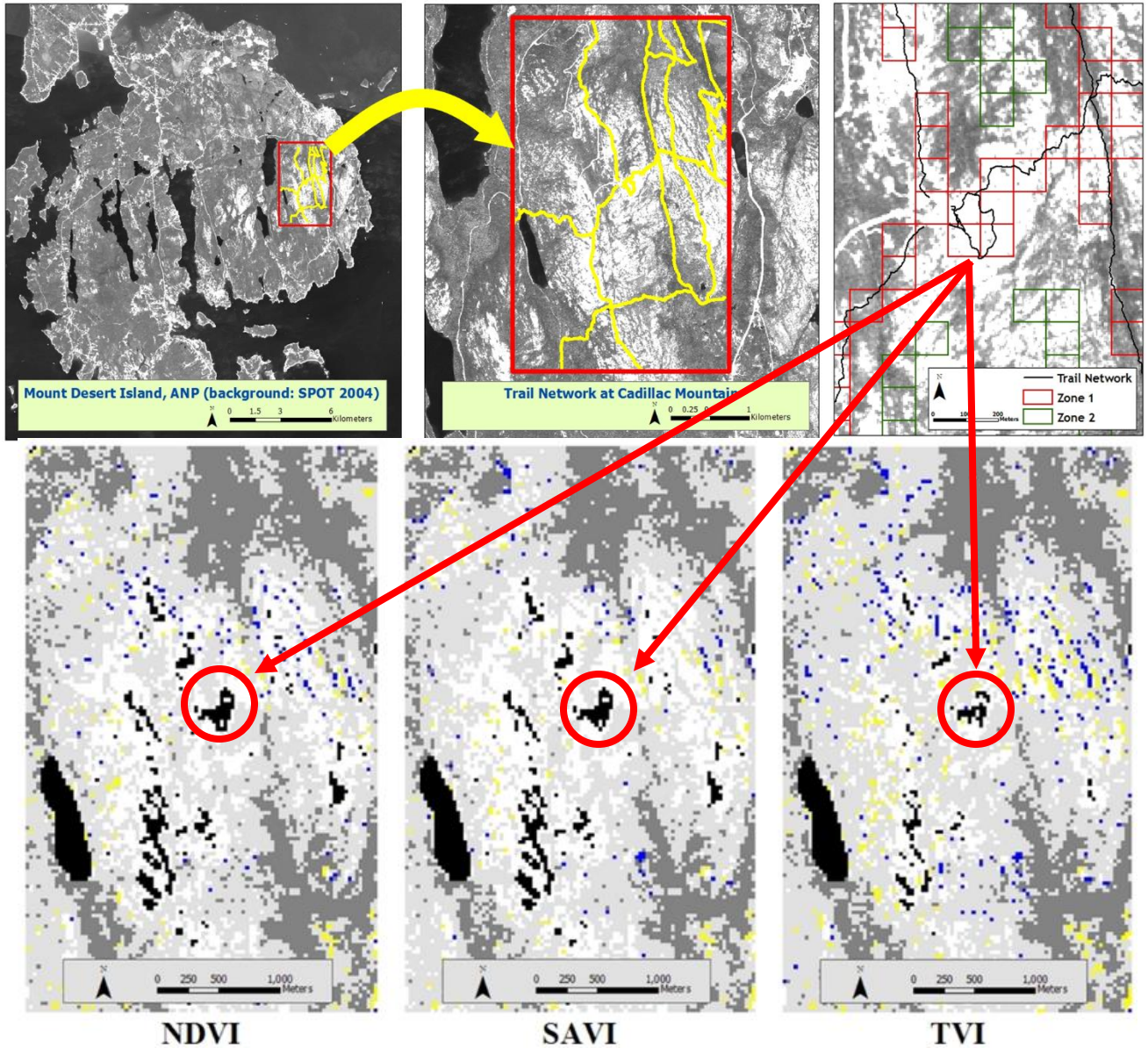
Vehicle Reservation System (since 2021)

Study Site: Objective



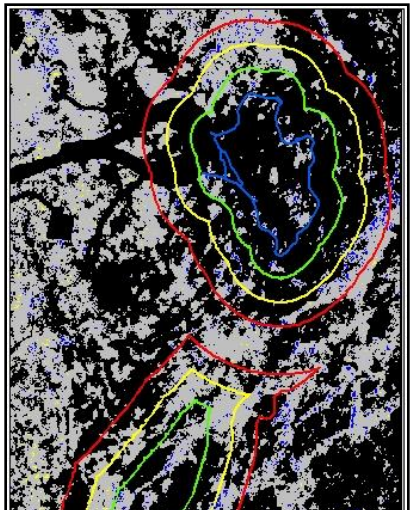
1. Examine the effect of the management strategies to reduce impact and enhance recovery (amount of vegetation cover) at this high-use destination, using remote sensing dataset analysis (2010-2018, 2001-2021).
2. Identify the utilities of "remote sensing": whether it could be used effectively as a monitoring tool for vegetation conditions in a mountain summit environment.

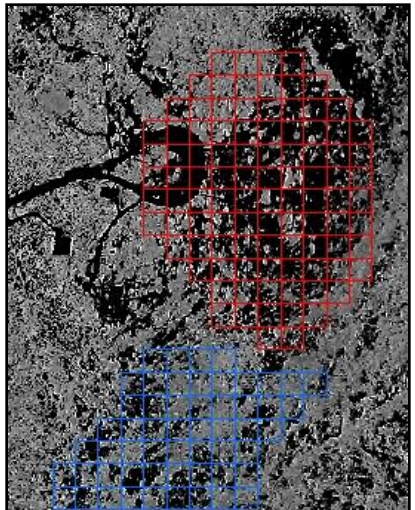
Methodology: Monitoring at large spatial scale

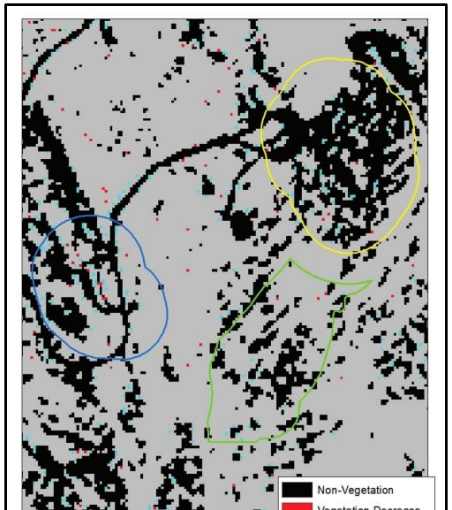


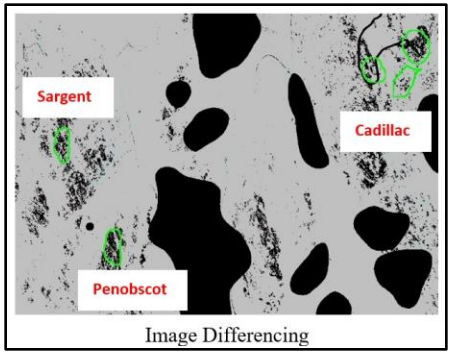
Methodology

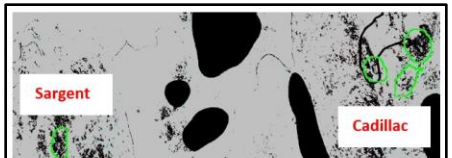
Study 1 (completed)	Study 2 (on-going)	Study 3 (completed)	Study 4 (on-going)
1. IKONOS (August 18, 2001): 1m (Pan), 4m (multi), B, G, R, and NIR 2. Airborne (June 25, 2007): 0.96m (Pan & Multi), B, G, R and NIR	1. IKONOS (August 18, 2001): 1m (Pan), 4m (multi), B, G, R, and NIR 2. Planet Data: PlanetScope (August 28, 2018): 3m (multi), B, G, R, and NIR	1. Planet Data: RapidEye (August 30, 2010): 5m, B, G, R, RE and NIR 2. Planet Data: RapidEye (August 31, 2018): 5m, B, G, R, RE and NIR	1. IKONOS (August 18, 2001): 1m (Pan), 4m (multi), B, G, R, and NIR. 2. Planet Data: PlanetScope (August 15, 2021): 3m (multi), B, G, R, and NIR
Fractional vegetation cover change detection analysis based on pre-classification (*NDVI*) = 2 classes (vegetation. vs. non-vegetation)	Vegetation diversity change analysis based on vegetation indices (*NDVI, SAVI, TVI*) and # of different classes (*20, 50, and 100 classes*)	Fractional vegetation cover change detection analysis based on pre-classification (*NDVI*) = 2 classes (vegetation. vs. non-vegetation)	Fractional vegetation cover change detection analysis based on pre-classification (*NDVI, ARVI*) = 2 classes (vegetation. vs. non-vegetation)





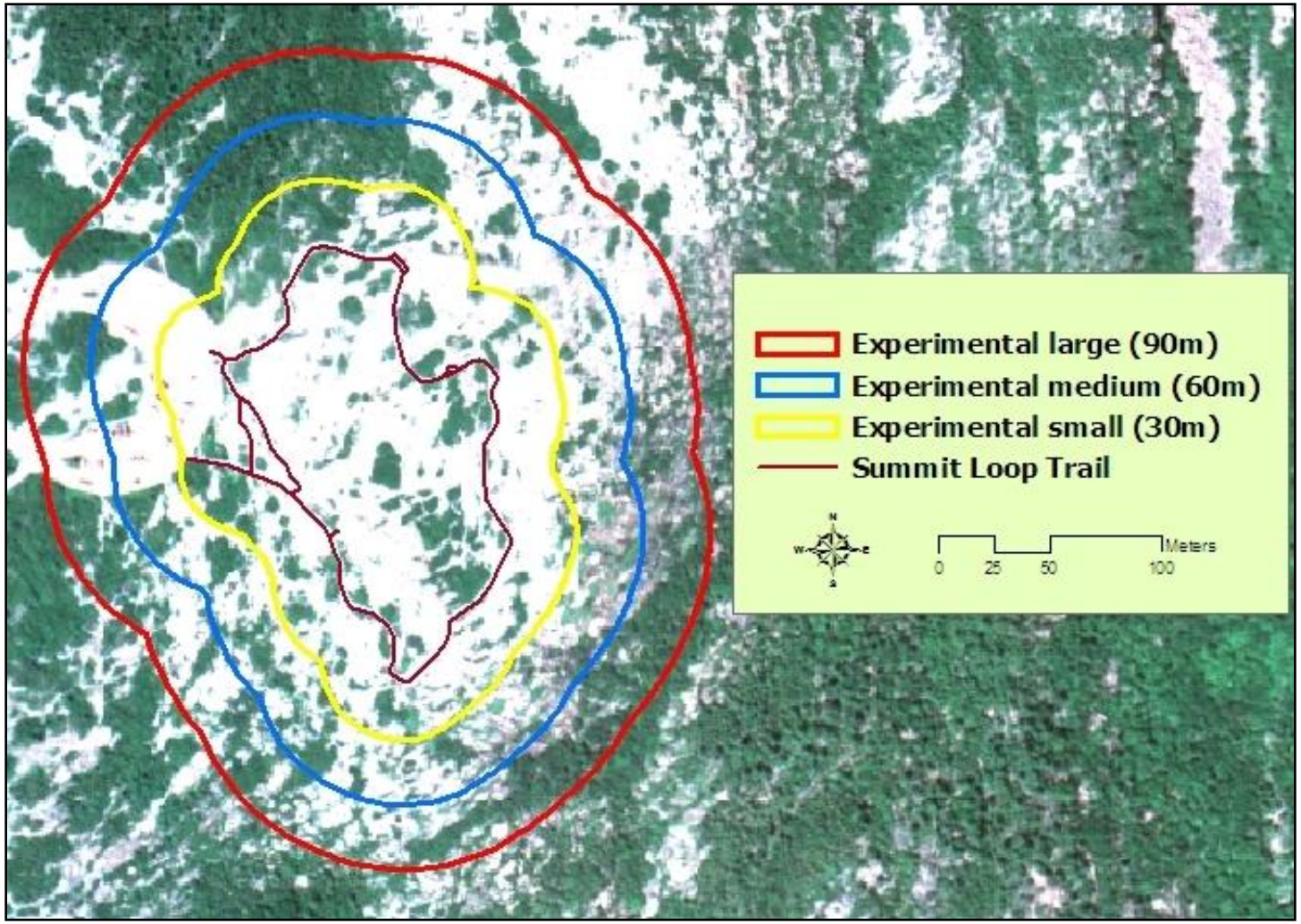






Methodology

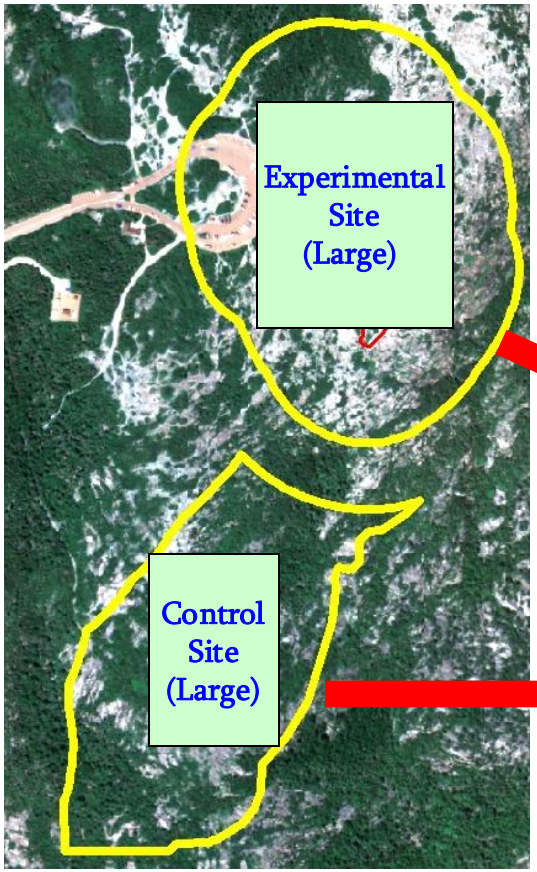
1. Multi-Spatial Scales Approach

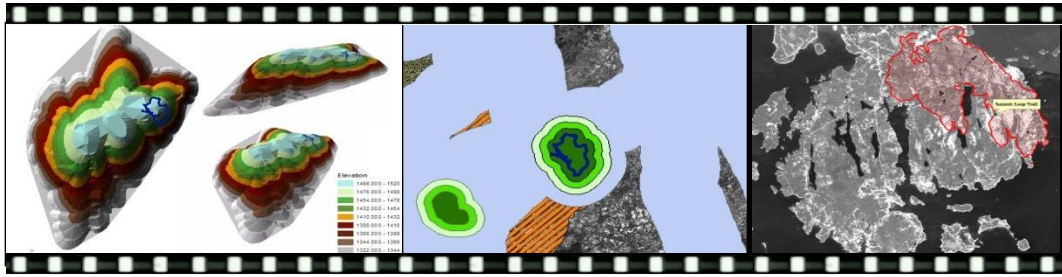


Methodology

2. Control Site Selection

1) **Natural Factors**: Temperature, Precipitation, **Elevation**, Vegetation Homogeneity
2) **Human Disturbance Factors**: Existing Trails, Automobile Road, Concession Area
3) **Natural Disturbance Factors**: **Fire**, Wind, Ice, Storm





Experimental Site

1. Visitor Impacts
2. Site Management Strategies (LNT, barriers, ecological restoration)

Control Site

1. No/little Visitor Impacts
2. No Site Management Strategies

Methodology

2. Control Site Selection (Study 3: 2010 - 2018)

Experimental Site

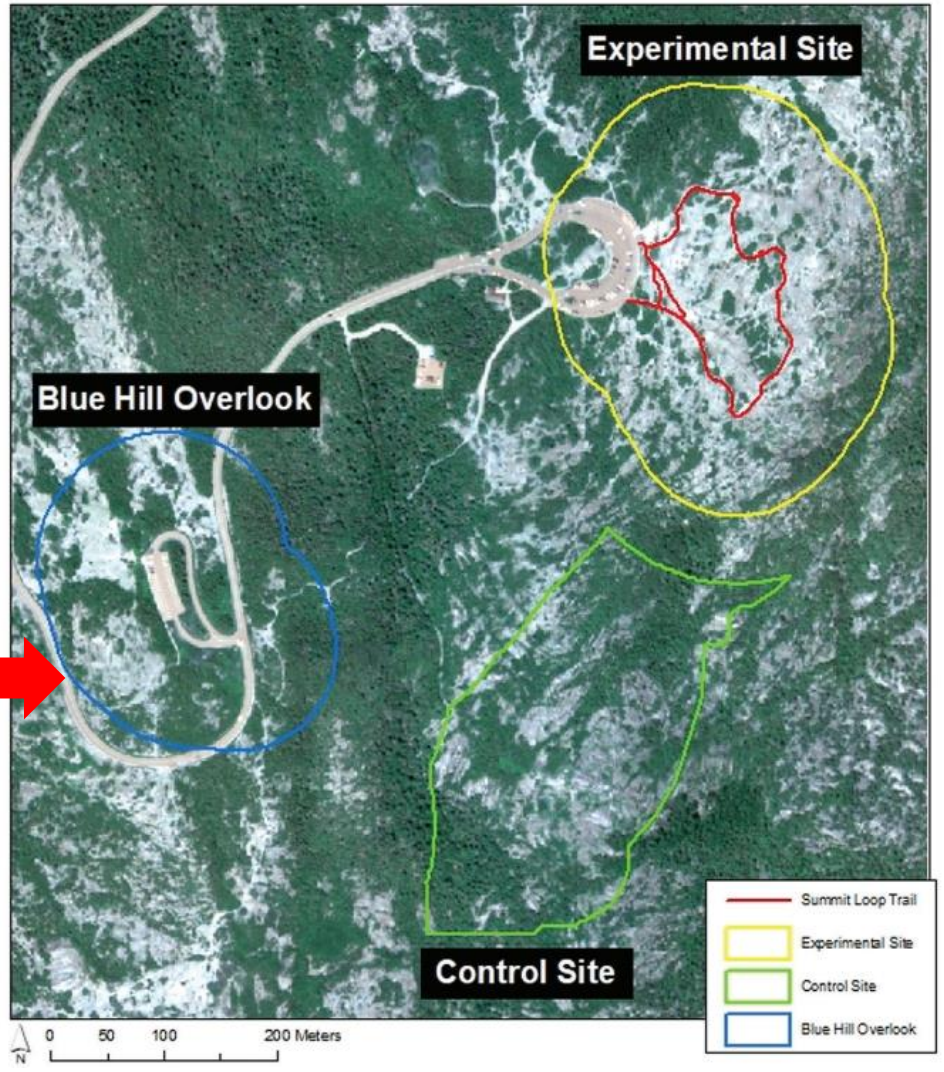
1. Visitor Impacts
2. Intensive Management Strategies (LNT, barriers, ecological restoration)

Control Site

1. No/little Visitor Impacts
2. No Site Management Strategies

Blue Hill Overlook

1. Visitor Impacts
2. No Intensive Management Strategies



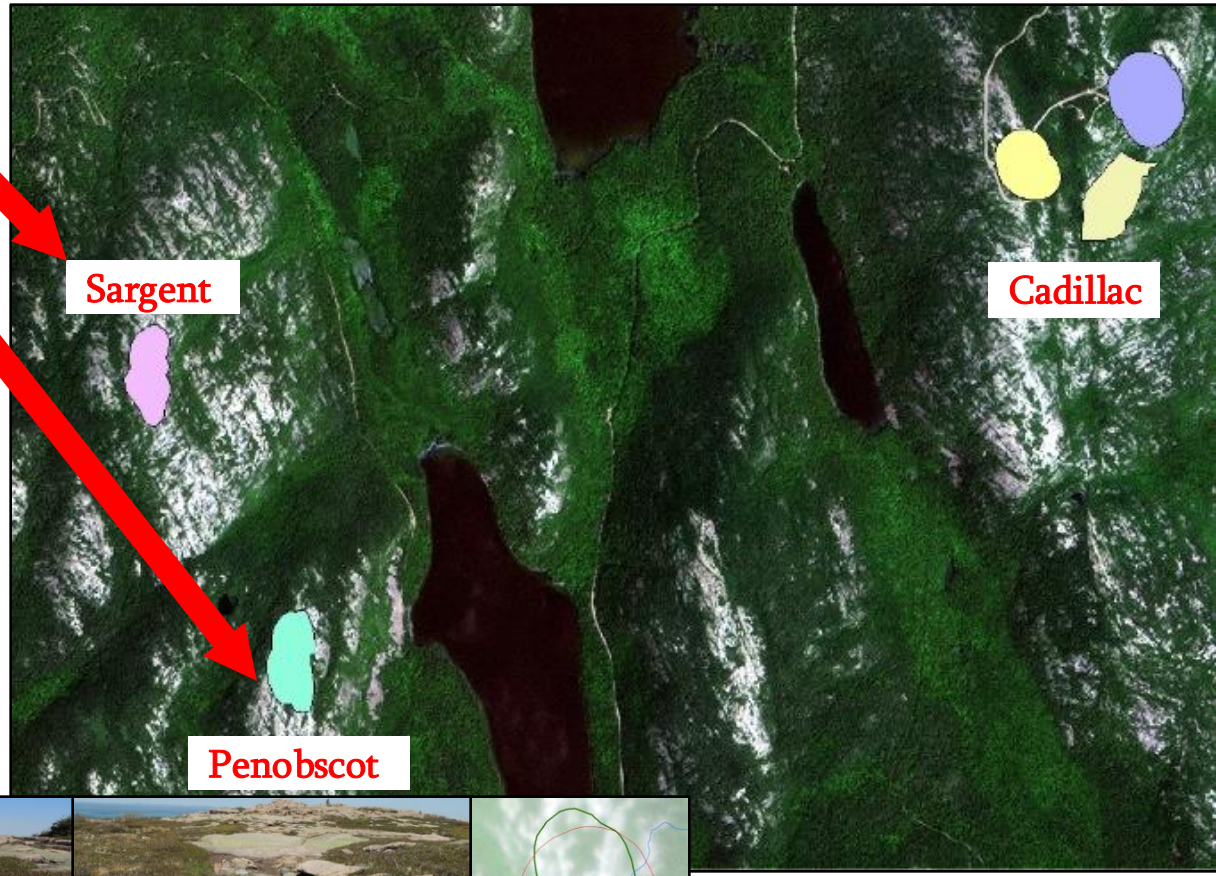
Methodology

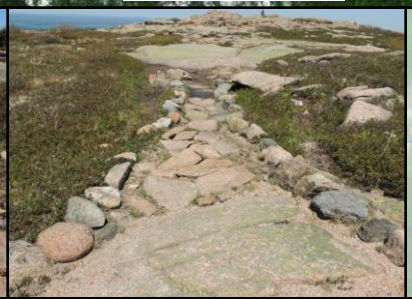
2. Control Site Selection (Study 4: 2001 – 2021)

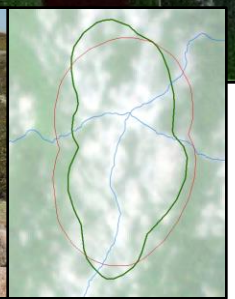
Sargent (1340 ft)

Penobscot (1120 ft)

1. Visitor Impacts (but no automobile road)
2. No Intensive Management Strategies (e.g., cairn, pavement)



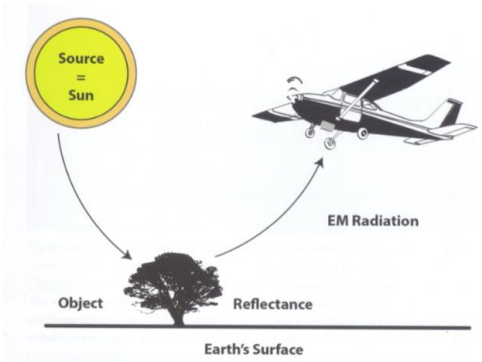


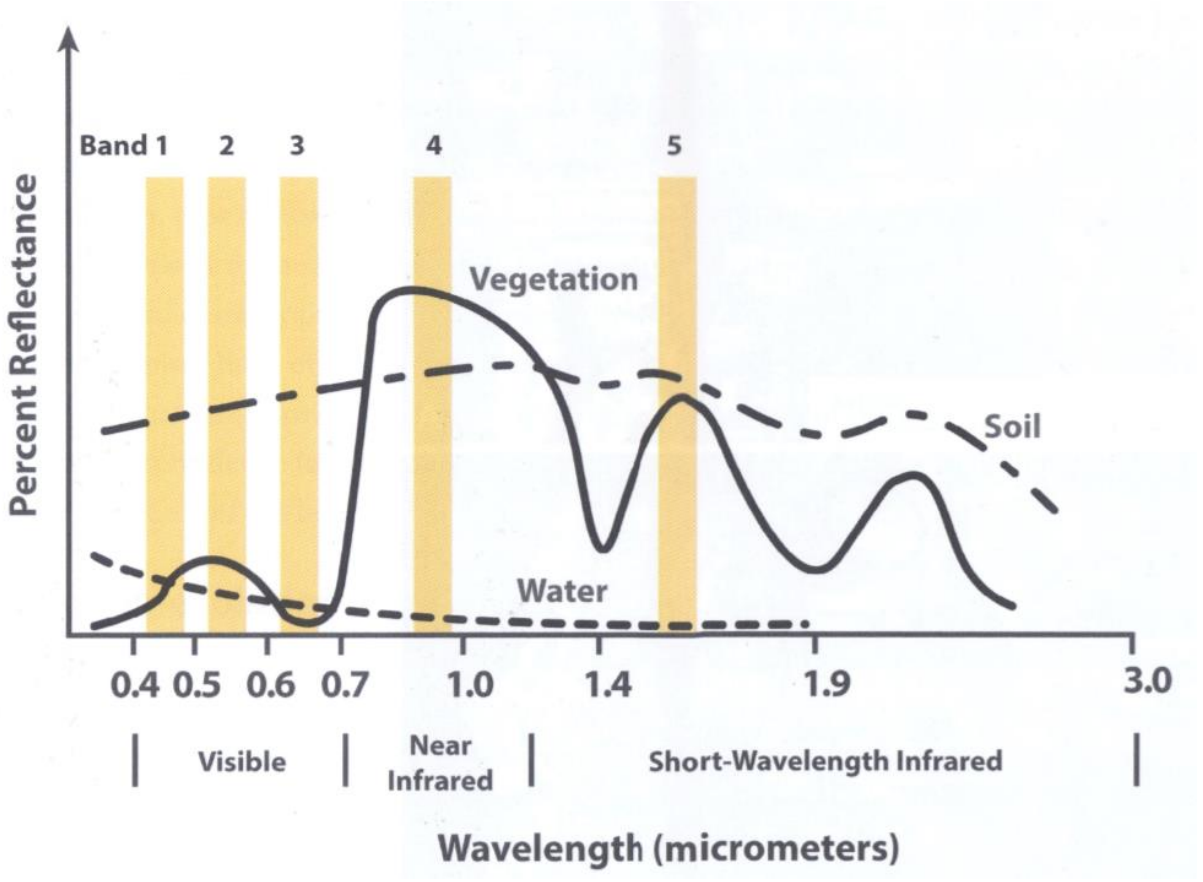


Methodology

3. Change Detection: NDVI = (Band4 – Band3)/(Band4 + Band3)

ARVI = (Band4 – RB)/(Band4 + RB)

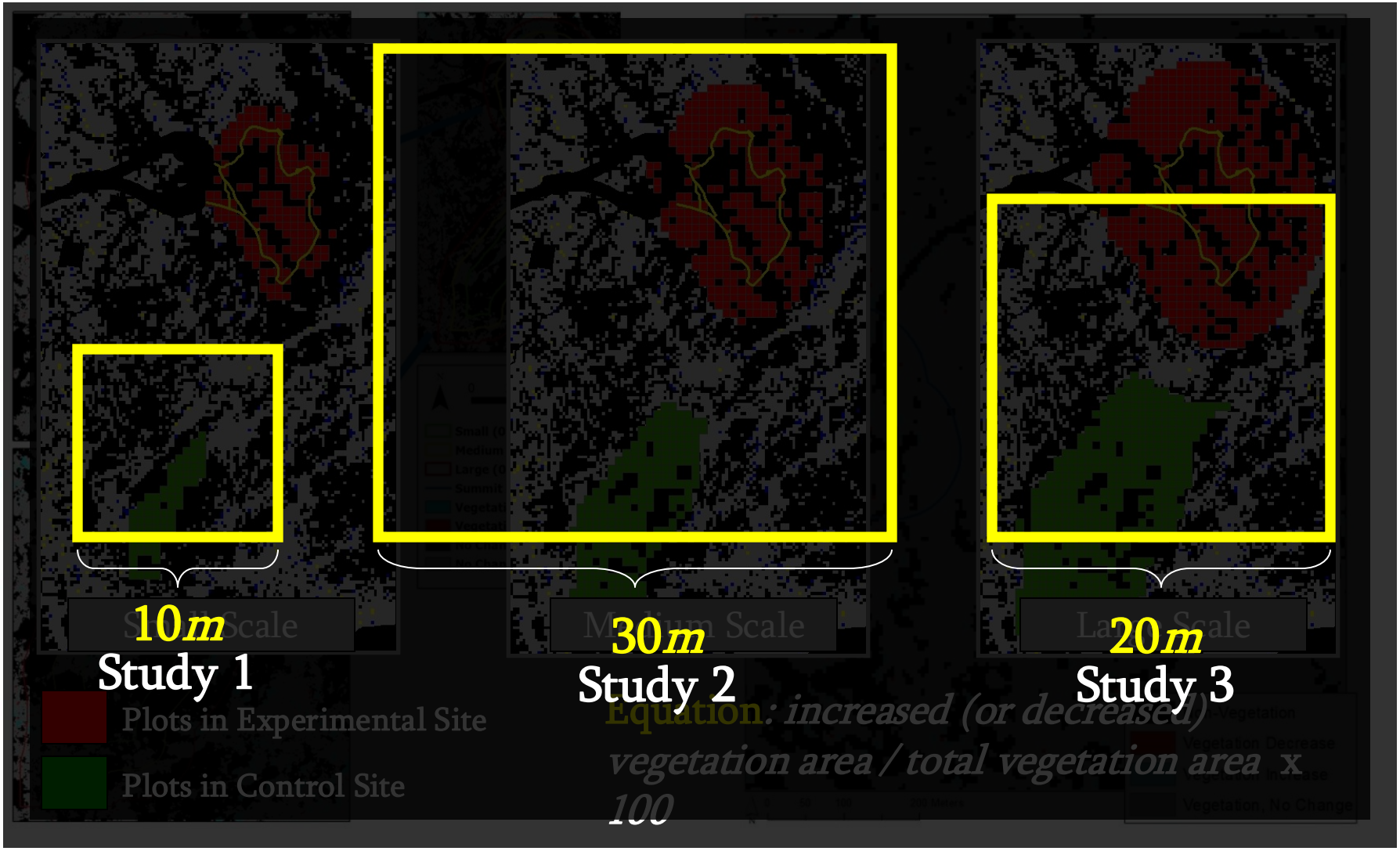




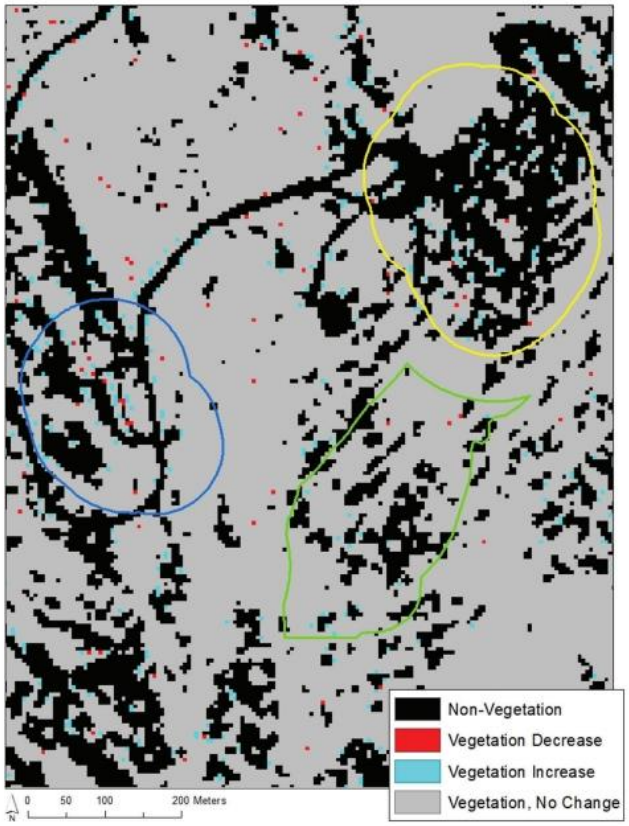
Sources: Images courtesy of ESRI

Methodology

4. Statistical Analysis: systematic sampling, T-test



Results: Vegetation Cover Changes



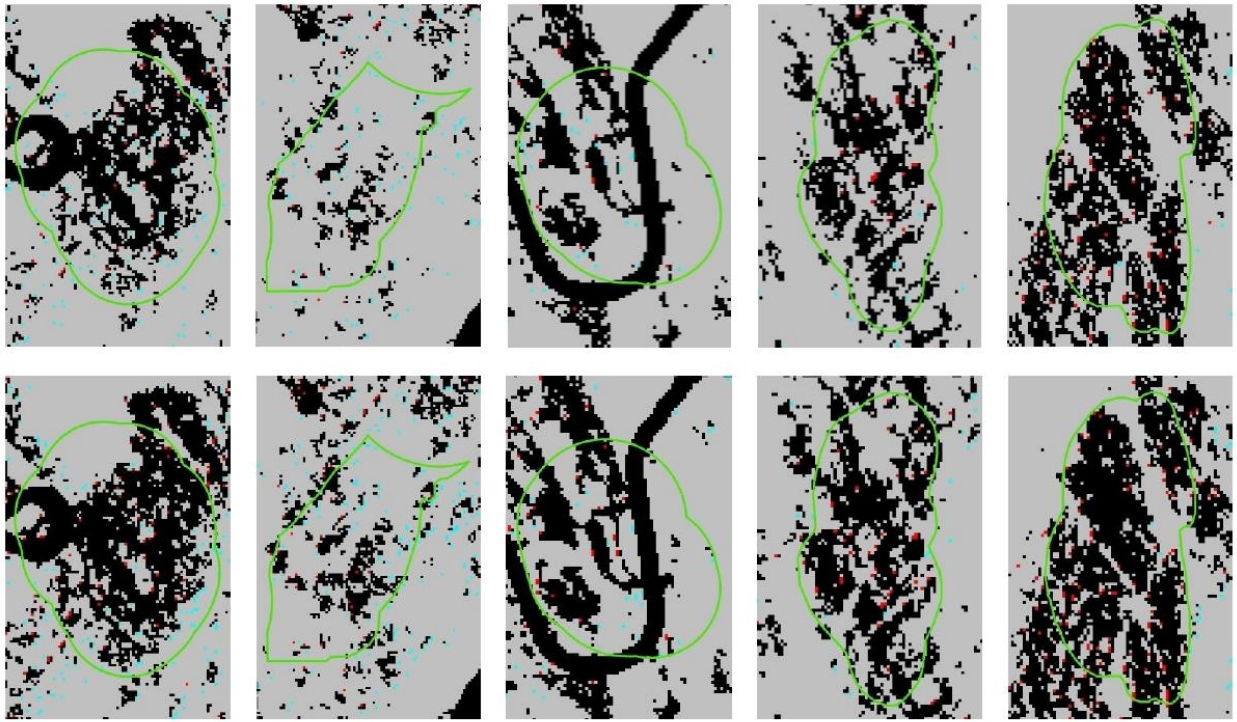


Figure 24. NDVI Change Detection Analysis (from the TOAR data)
Top: Image Differencing, **Bottom**: RGB-NDVI Color Composites

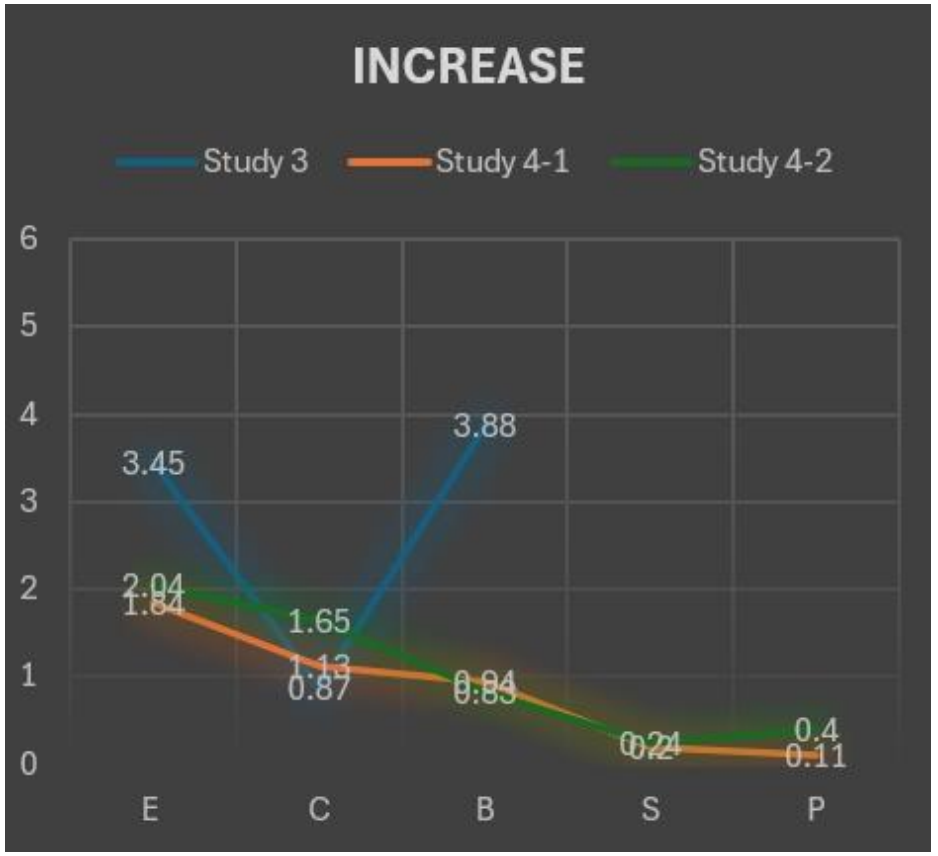
	Study 3 (296 reference points)	Study 4-1 Image Differencing (161 reference points)	Study 4-2 RGB-NDVI, Machine Learning (161 reference points)
Overall Accuracy	74.15%	85.09%	86.34%

Results: Vegetation Cover Changes

2010 – 2018	Experimental Site (0 – 90 meters)		Control Site (0 – 90 meters)		Blue Hill Overlook (0 – 90 meters)	
	Unit (m^2)	%	Unit (m^2)	%	Unit (m^2)	%
Vegetation Decrease	150	0.36	75	0.16	325	0.87
Vegetation Increase	1,425	3.45	400	0.87	1,450	3.88
Vegetation, No-change	39,675	96.18	45,500	98.97	35,625	95.25

2001 - 2021	Decrease (m^2, %)	Increase (m^2, %)	Vegetation (Non-Change) (m^2, %)
Image Differencing: Experimental	352 (0.72)	896 (1.84)	47,376 (97.43)
Image Differencing: Control	160 (0.30)	608 (1.13)	53,056 (98.57)
Image Differencing: Blue Hill Overlook	144 (0.39)	352 (0.94)	36,816 (98.67)
Image Differencing: Sargent	384 (1.22)	64 (0.20)	30,944 (98.57)
Image Differencing: Penobscot	1,108 (3.84)	32 (0.11)	27,232 (96.05)
RGB-NDVI: Experimental	688 (1.69)	832 (2.04)	39,200 (96.27)
RGB-NDVI: Control	336 (0.68)	816 (1.65)	48,240 (97.67)
RGB-NDVI: Blue Hill Overlook	320 (0.93)	288 (0.83)	33,888 (98.24)
RGB-NDVI: Sargent	624 (2.38)	64 (0.24)	25,584 (97.38)
RGB-NDVI: Penobscot	1,264 (5.46)	32 (0.14)	21,856 (94.40)

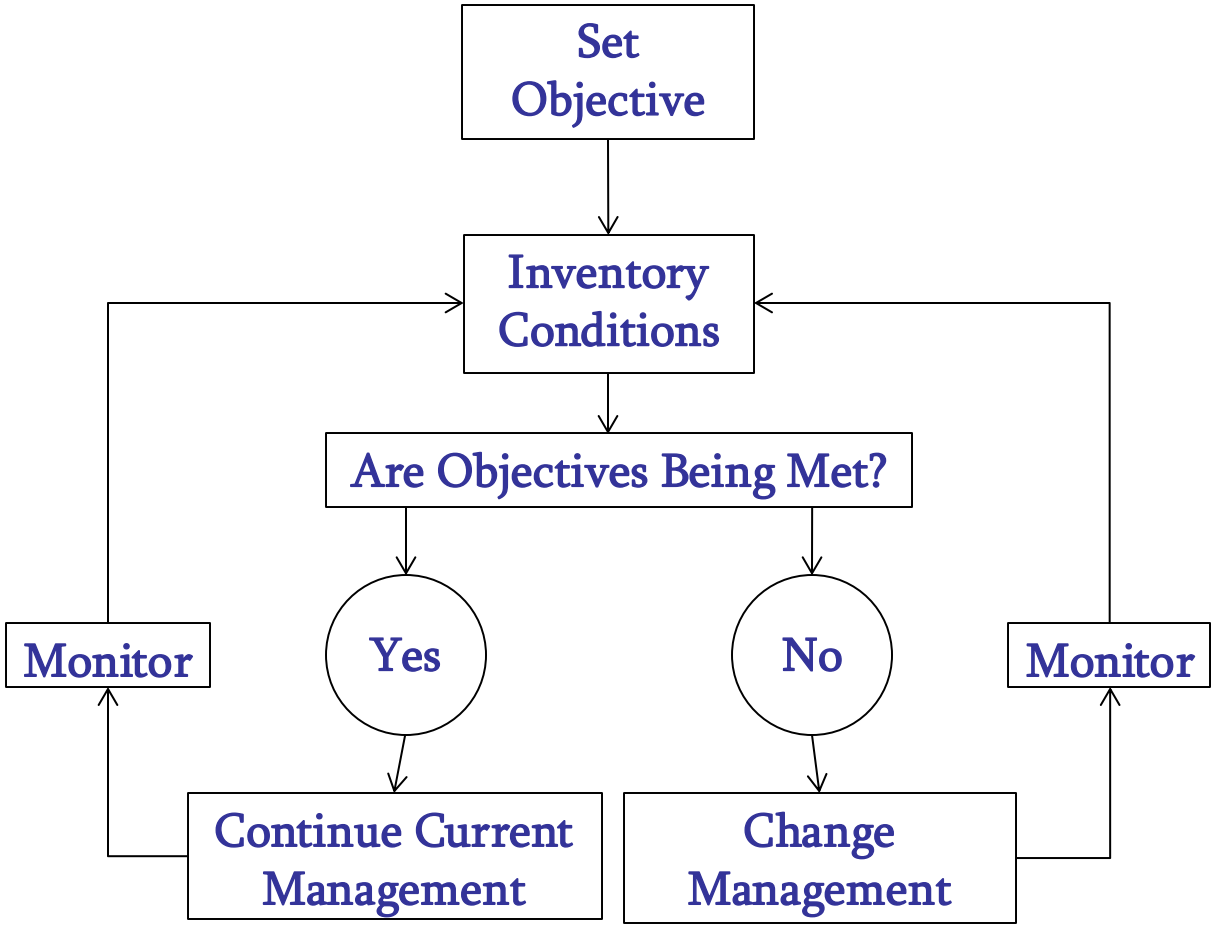
Results: Vegetation Cover Changes



Between 2010 and 2018 (Study 3), both experimental and control sites exhibited a **greater increase in vegetation** compared to a decrease in vegetation. The magnitude of both increase and decrease was found to be higher in the experimental site than in the control site.

Between 2001 and 2021 (Study 4), Cadillac Mountain Summit (Experimental, Control, and Blue Hill Overlook) showed **more increase** and **less decrease**, whereas Sargent and Penobscot showed **more decrease** and **less increase**. Specifically, the decrease in vegetation at Penobscot was higher than at Sargent, while their levels of increase were minimal.

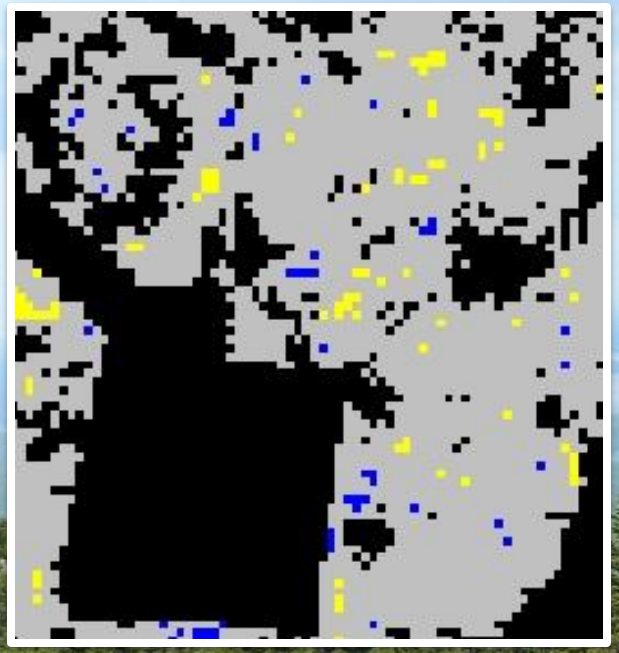
Discussion: Utility of Remote Sensing

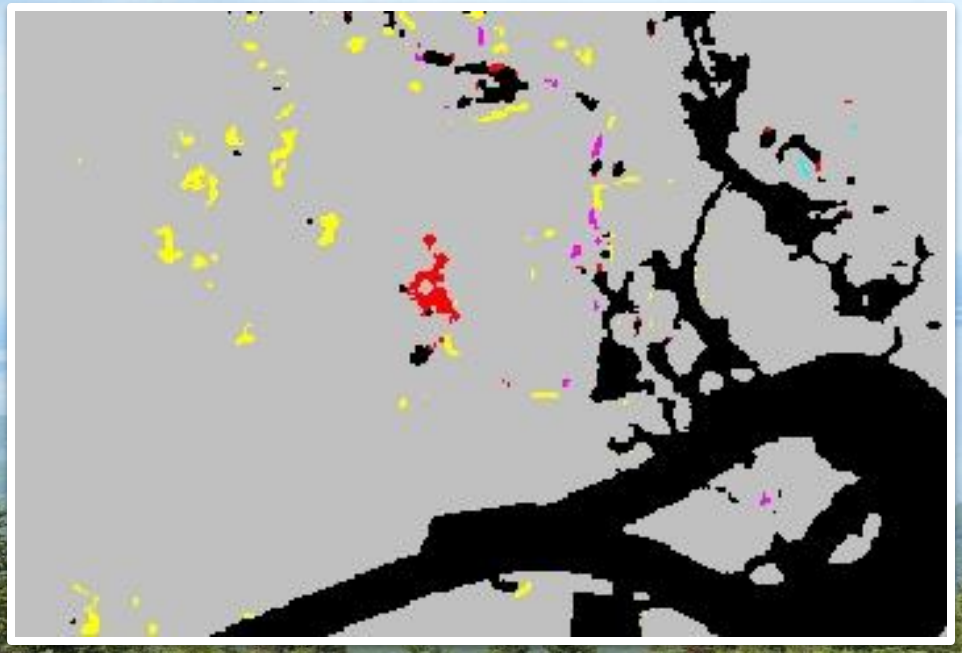


Source: Hammitt et al., 2015

Discussion: Utility of Remote Sensing

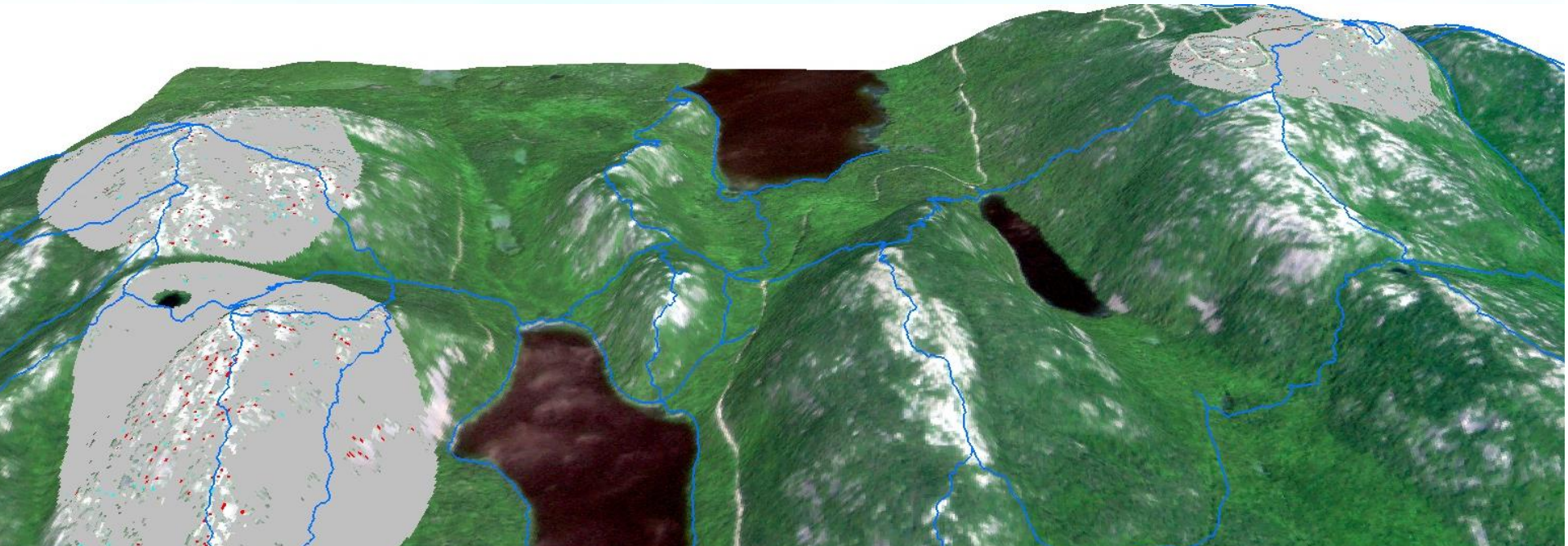
Need to map informal trail and heavily impact area outside of the summit loop trail





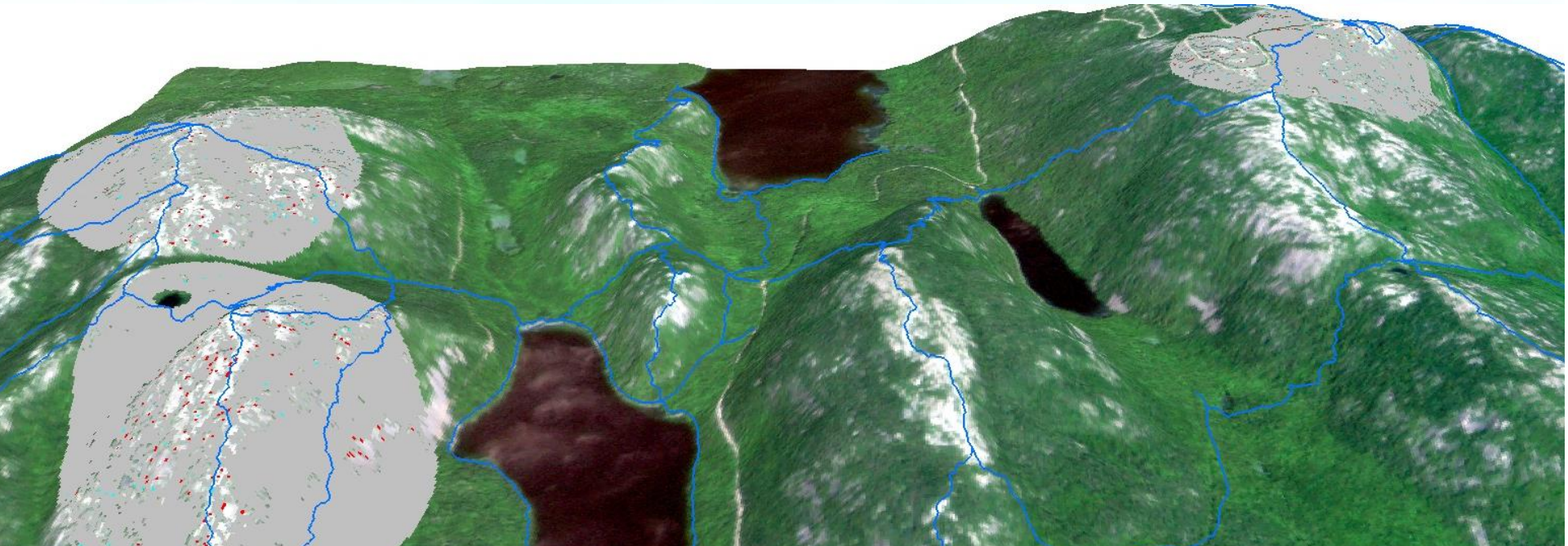
Discussion: Utility of GIS/RS

1. Supporting general management purposes (e.g., mapping, classification…)
2. Inventorying natural resource conditions (e.g., soil, vegetation, water, wildlife…)
3. Monitoring changes in resource conditions

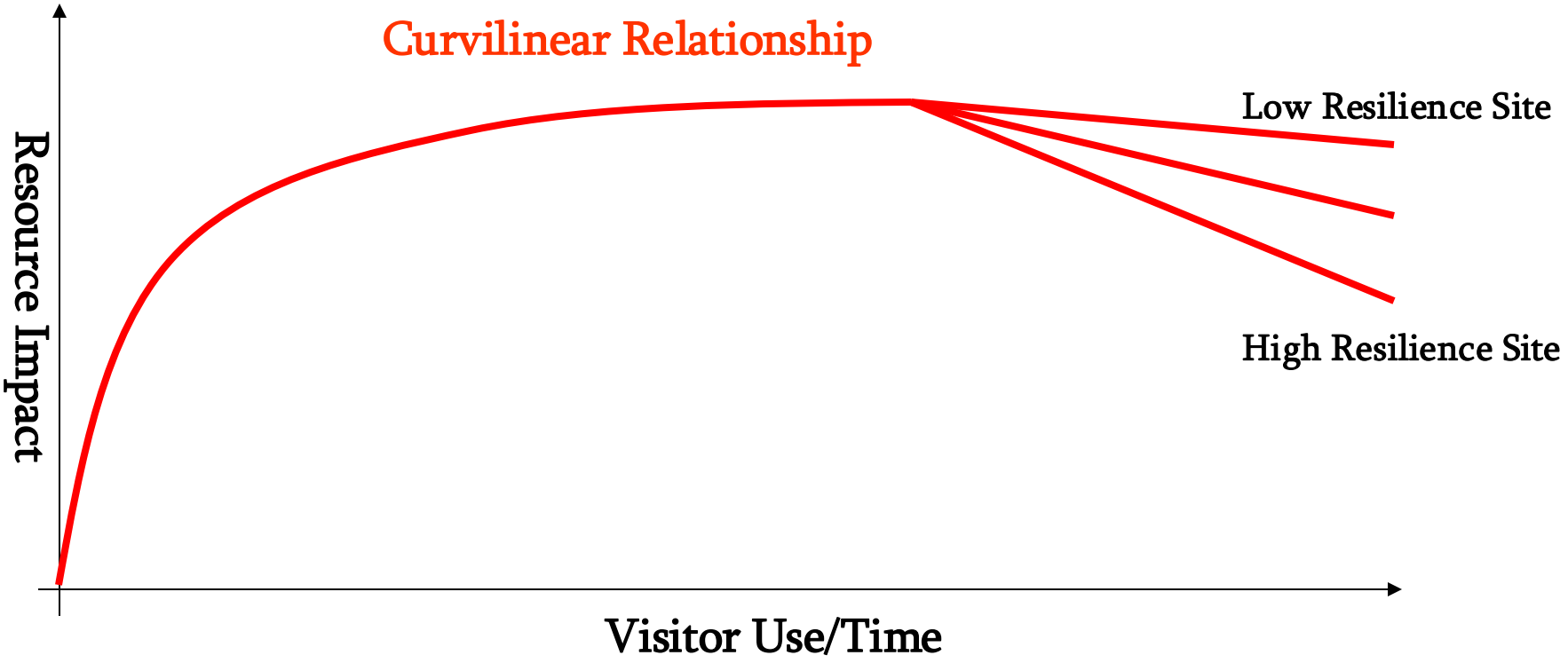


Discussion: Utility of GIS/RS

4. Facilitating data-informed decision-making by providing baseline/trend information (e.g., the boundary of the site, management objective…)

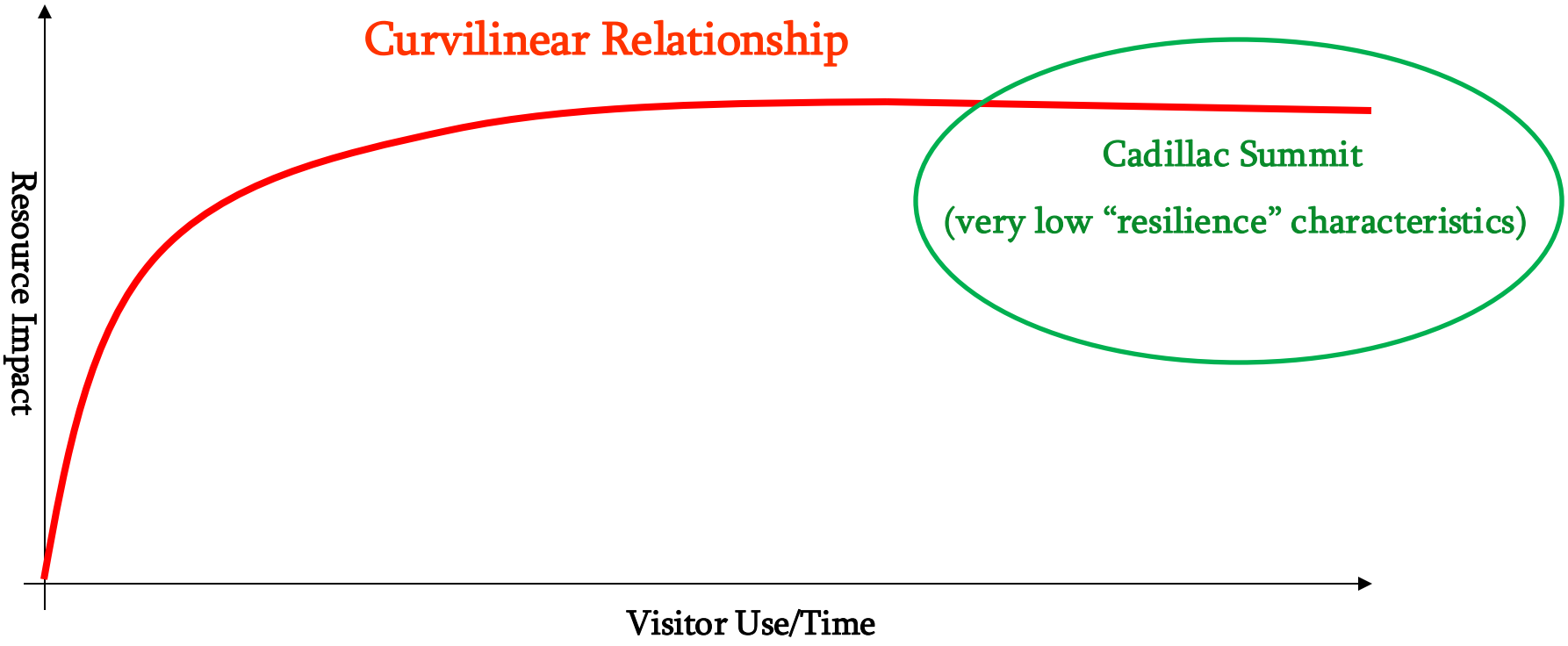


Conclusion



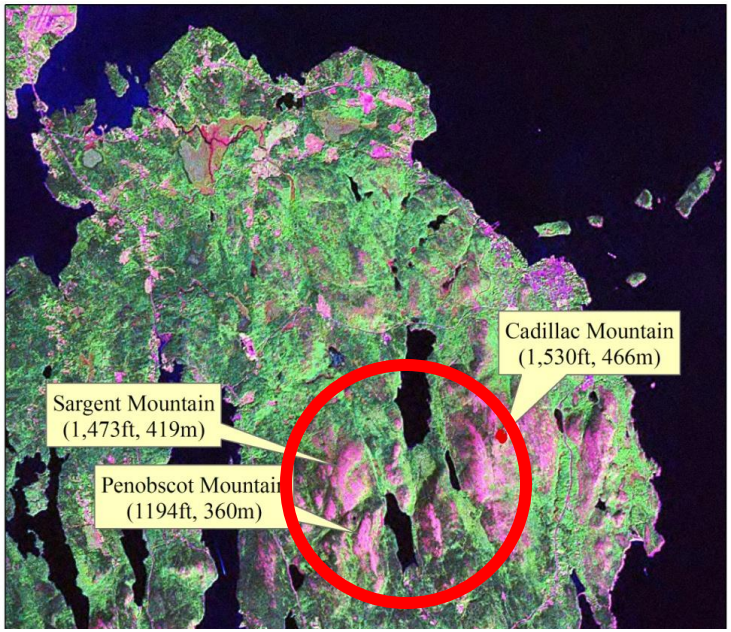
After resource impact, the level of recovery would vary by **environmental condition** (e.g., amount of rainfall and length of growing season), **site characteristics** (e.g., resilience and resistance, topographic factors), **use level/type**, and **appropriate site/visitor management actions**.

Conclusion



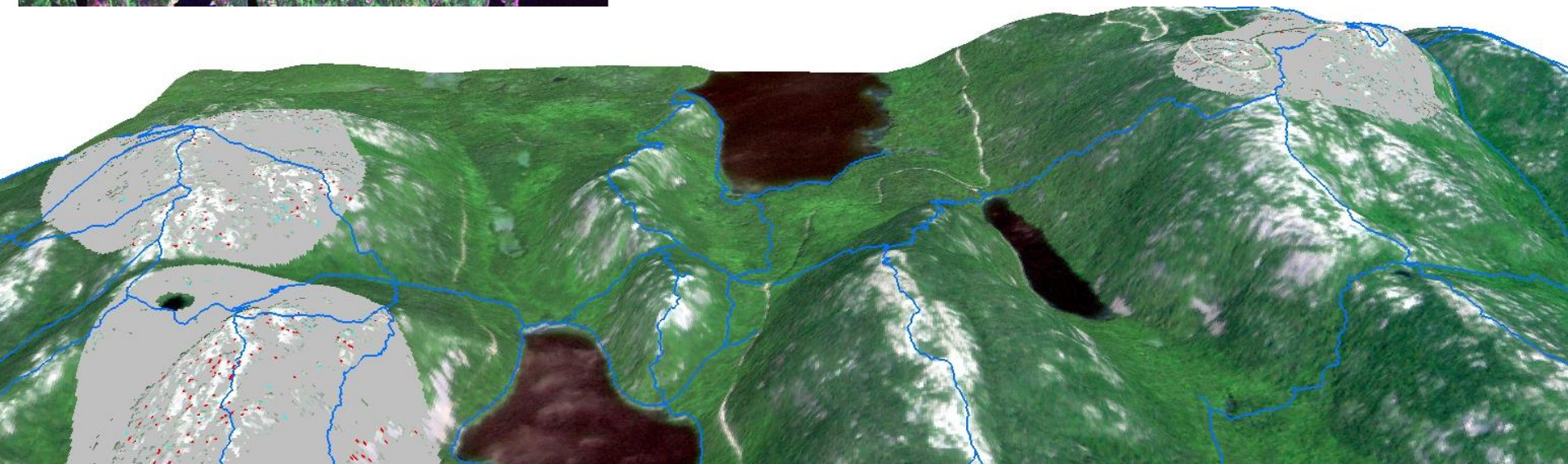
1. Tough and difficult place for vegetation recovery (e.g., short growing season, thin/sandy soil, shortage of available water, constant/intensive visitor use).
2. Utility of remote sensing at Cadillac Summit.

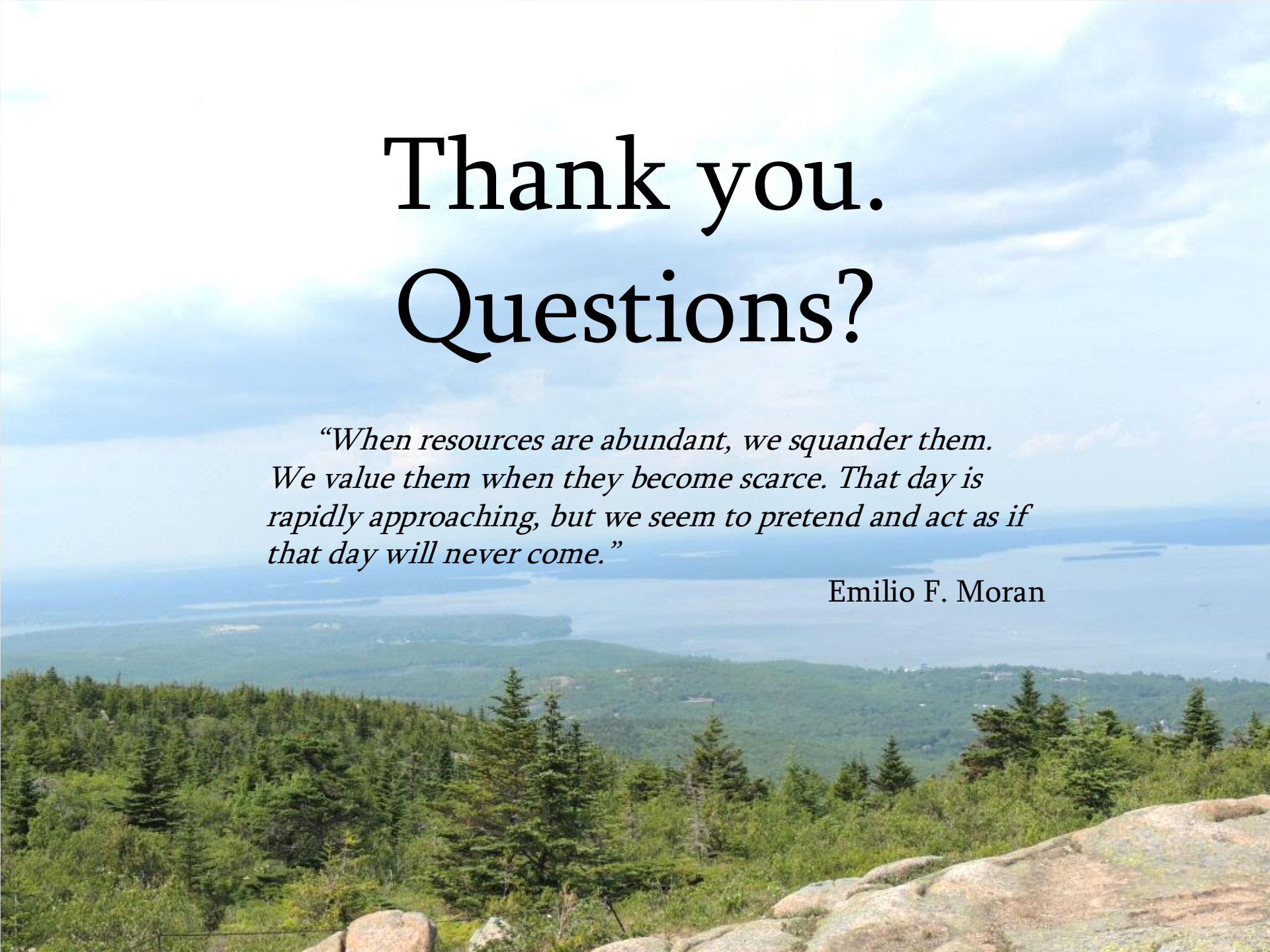
What's Next: Save Our Summits Project



SOS Project (NPS, UMaine, UNLV, Native Plant Trust, Schoodic Institute)

1. Ecological Restoration
2. Spatial Extents of Sargent/Penobscot
3. Accuracy Assessment
4. Integration of Social Science Research Outcomes





Thank you.
Questions?

"When resources are abundant, we squander them. We value them when they become scarce. That day is rapidly approaching, but we seem to pretend and act as if that day will never come."

Emilio F. Moran