CRITICAL LOADS OF ATMOSPHERIC N DEPOSITION

PROTECTING PLANT BIODIVERSITY IN THE WESTERN UNITED STATES IN THE CONTEXT OF OIL AND GAS DEVELOPMENT AND A CHANGING CLIMATE

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Critical Loads Overview

- Annual rate of deposition *below which* significant harm to ecosystems is avoided
- Deposition stressors
  - S
  - N
  - Hg
- CL largely depends on the resource to be protected
  - Aquatic: fish, insects, diatoms
  - Terrestrial: ground vegetation, trees, lichens

Focus for today

	Aquatic	Terrestrial
Acidification		
N Enrichment		X
Biodiversity		X
Biogeochemistry		
Bioaccumulation and Toxicity		

Approaches to Critical and Target Loads

- Empirical (observation)
  - Experiments
  - Gradient studies
  - Observed ambient conditions
- Steady state modeling
- Dynamic modeling

Empirical CL: Pardo et al. 2011

Tabulated empirical CL from studies within each level 1 ecoregion

Empirical critical loads of nutrient N for North American Desert ecoregion. Reliability rating: # fairly reliable; (#) expert judgment

Ecosystem Component	Critical load for N deposition (kg N ha^{-1} yr^{-1})	Reliability	Response	Study
Lichens	3	(#)	Lichen community shifts, increase in thallus N concentration	Geiser et al. 2008 Porter 2007
Shrubland, woodland, and desert grassland	3-8.4	#	Vegetation response, community change. Increased biomass of invasive grasses; decrease of native forbs	Allen et al. 2009 Inouye 2006 Rao et al. 2010

Dynamic CL Modeling

- Are often called “target loads” (TL)
  - Specific time is specified to attain desired conditions

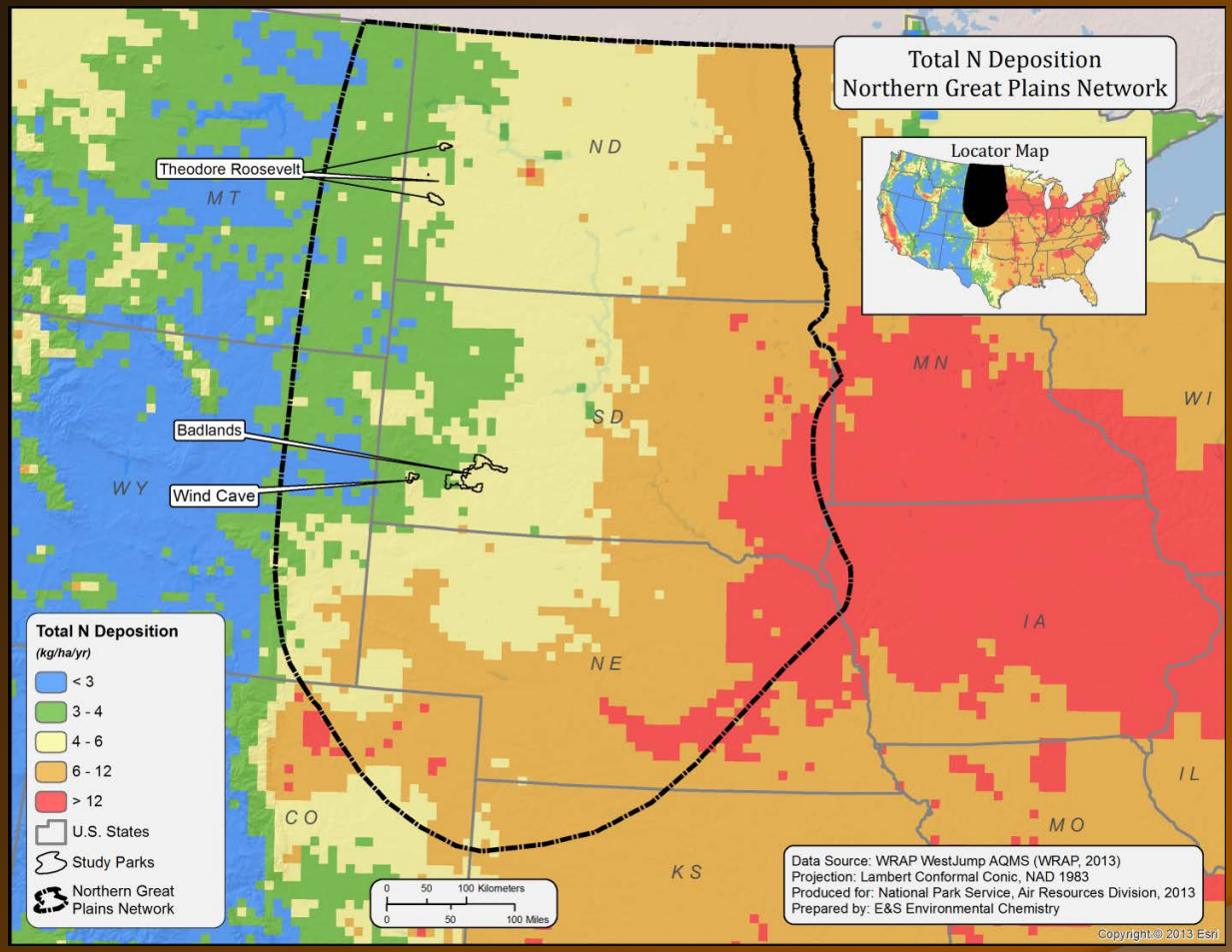
- Process Models
  - MAGIC
  - PnET-BGC
  - ForSAFE-VEG

Exceedance:

Ambient deposition higher than CL or TL

Empirical CL Application to NPS Vegetation Data

Voyageurs NP
Theodore Roosevelt NP
Great Lakes Network
Northern Great Plains Network
Wind Cave NP
Badlands NP
Dinosaur NM
Northern Colorado Plateau Network
Mojave Desert Network
Arches NP
Colorado NM
Canyonlands NP
Black Canyon of the Gunnison NP
Mesa Verde NP
Grand Canyon NP
Joshua Tree NP
Southern Colorado Plateau Network
Sonoran Desert Network
Saguaro NP
Source: US National Park Service


Total N Deposition
Northern Great Plains Network
Locator Map
Theodore Roosevelt
Badlands
Wind Cave
MT
ND
SD
WY
NE
CO
KS
MN
WI
IA
IL
MO
Total N Deposition
(kg/ha/yr)
< 3
3 - 4
4 - 6
6 - 12
> 12
U.S. States
Study Parks
Northern Great Plains Network
0 50 100 Kilometers
0 50 100 Miles
Data Source: WRAP WestJump AQMS (WRAP, 2013)
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2013
Prepared by: E&S Environmental Chemistry
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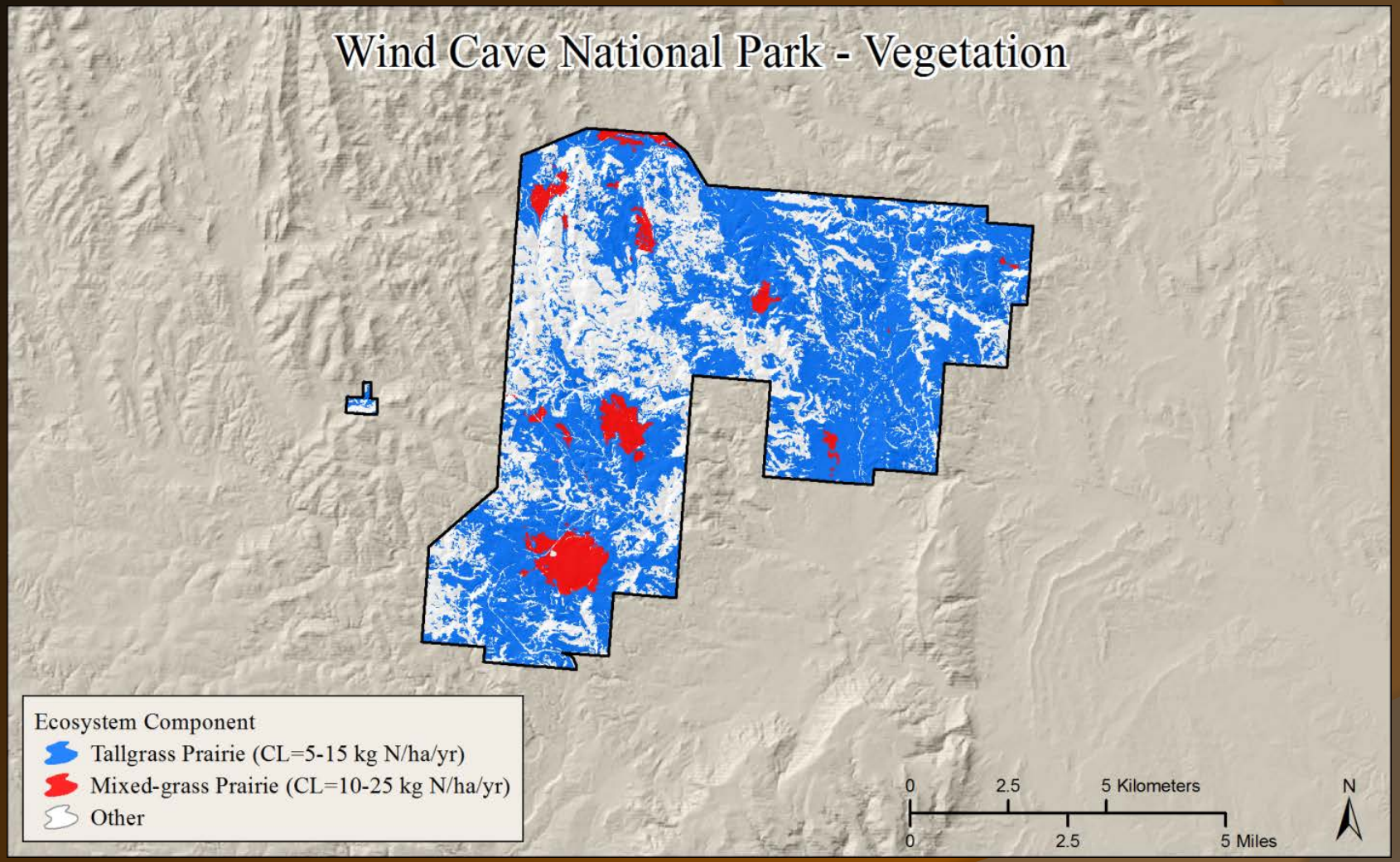
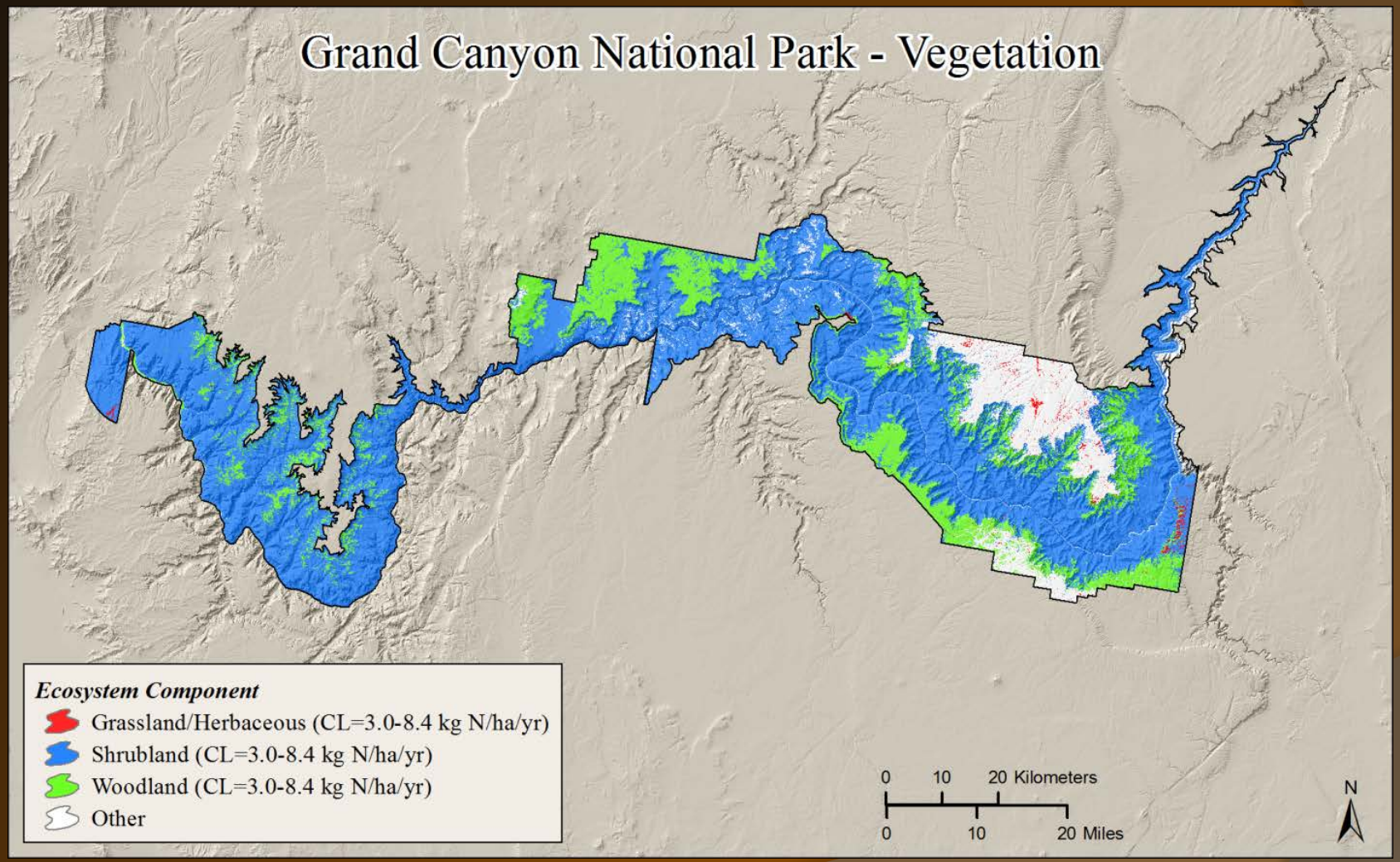
N-Sensitive Vegetation


Wind Cave National Park - Vegetation
Ecosystem Component
Tallgrass Prairie (CL=5-15 kg N/ha/yr)
Mixed-grass Prairie (CL=10-25 kg N/ha/yr)
Other
0
2.5
5 Kilometers
0
2.5
5 Miles
N

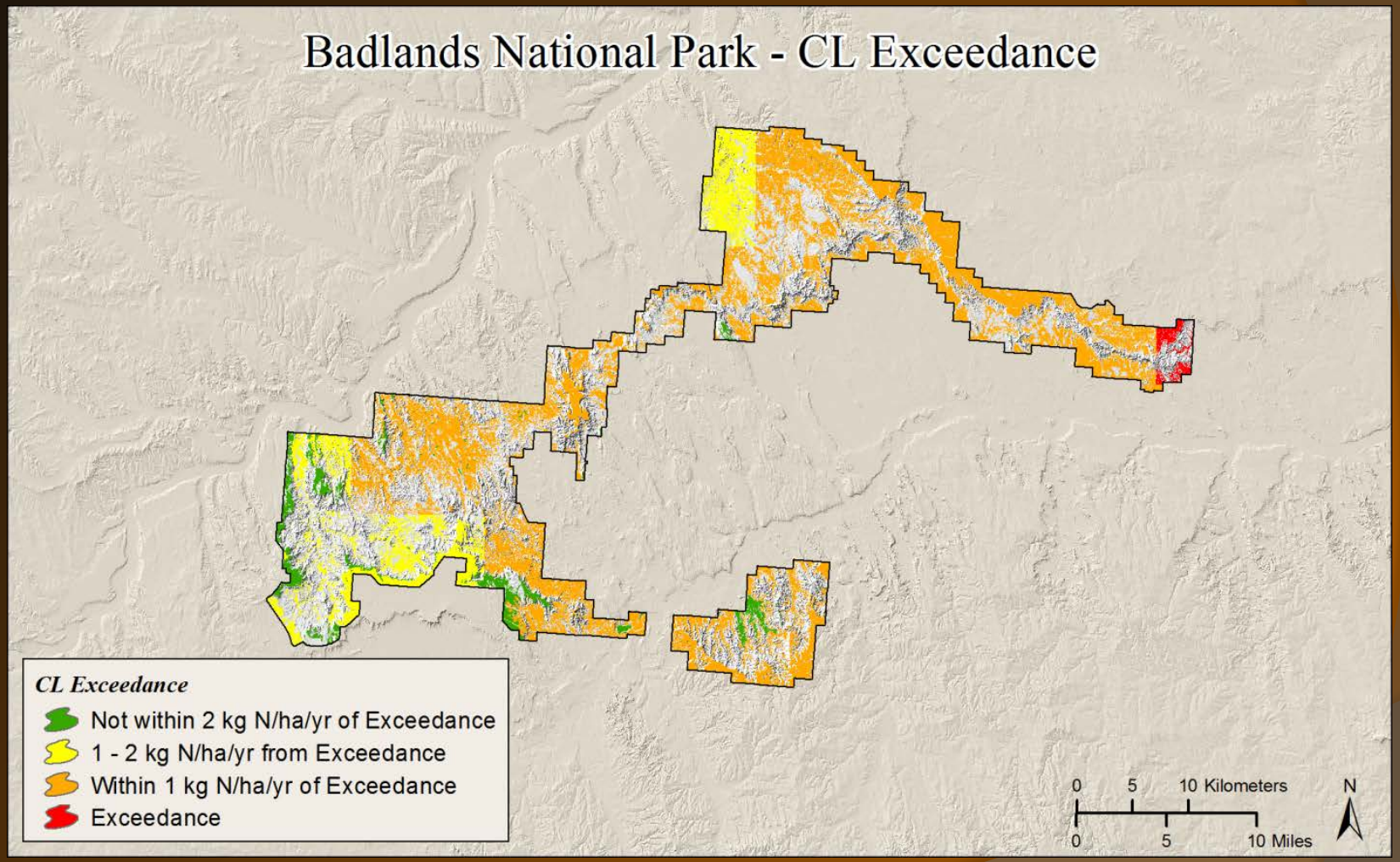

Grand Canyon National Park - Vegetation
Ecosystem Component
Grassland/Herbaceous (CL=3.0-8.4 kg N/ha/yr)
Shrubland (CL=3.0-8.4 kg N/ha/yr)
Woodland (CL=3.0-8.4 kg N/ha/yr)
Other
0 10 20 Kilometers
0 10 20 Miles
N

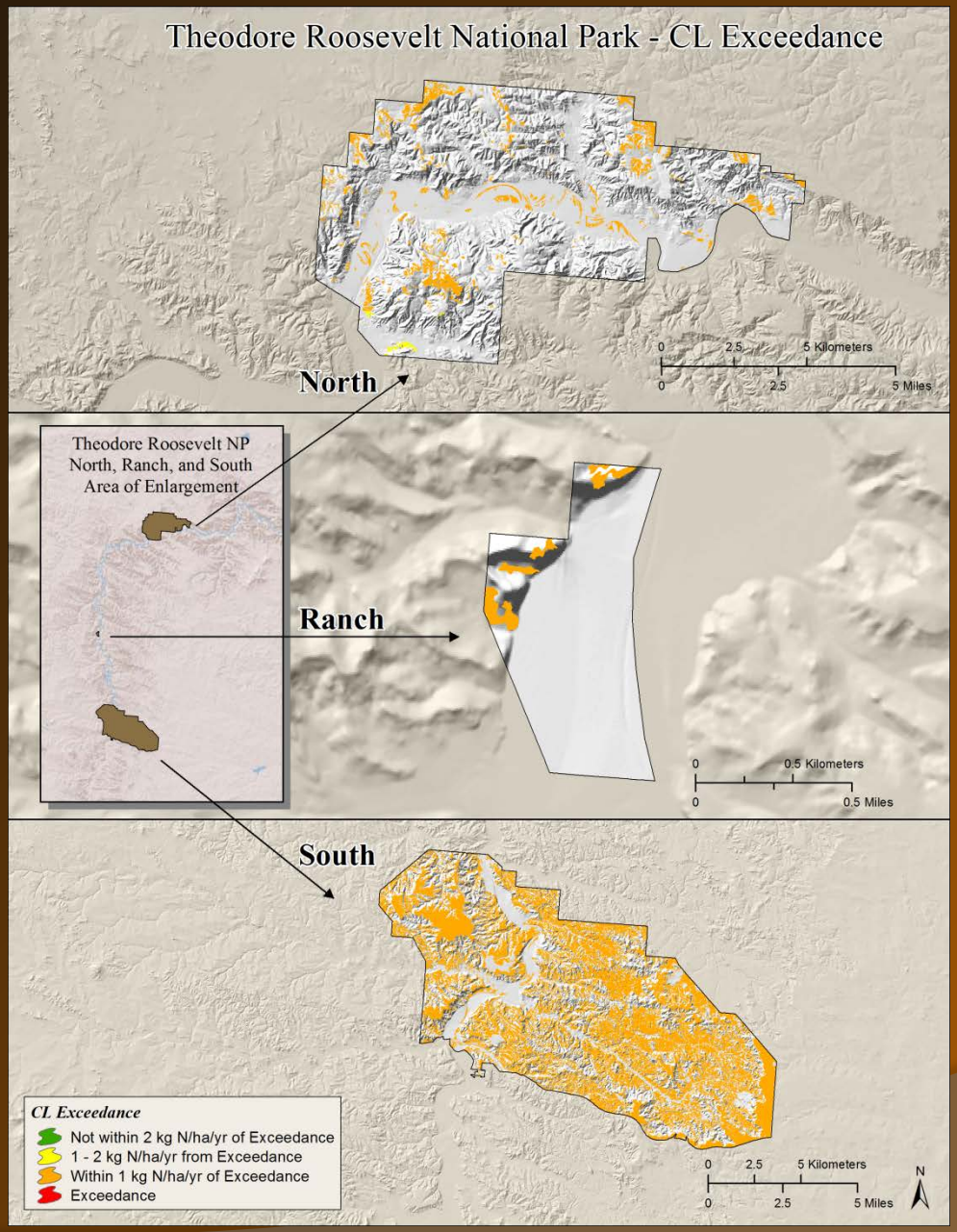
Exceedance Maps

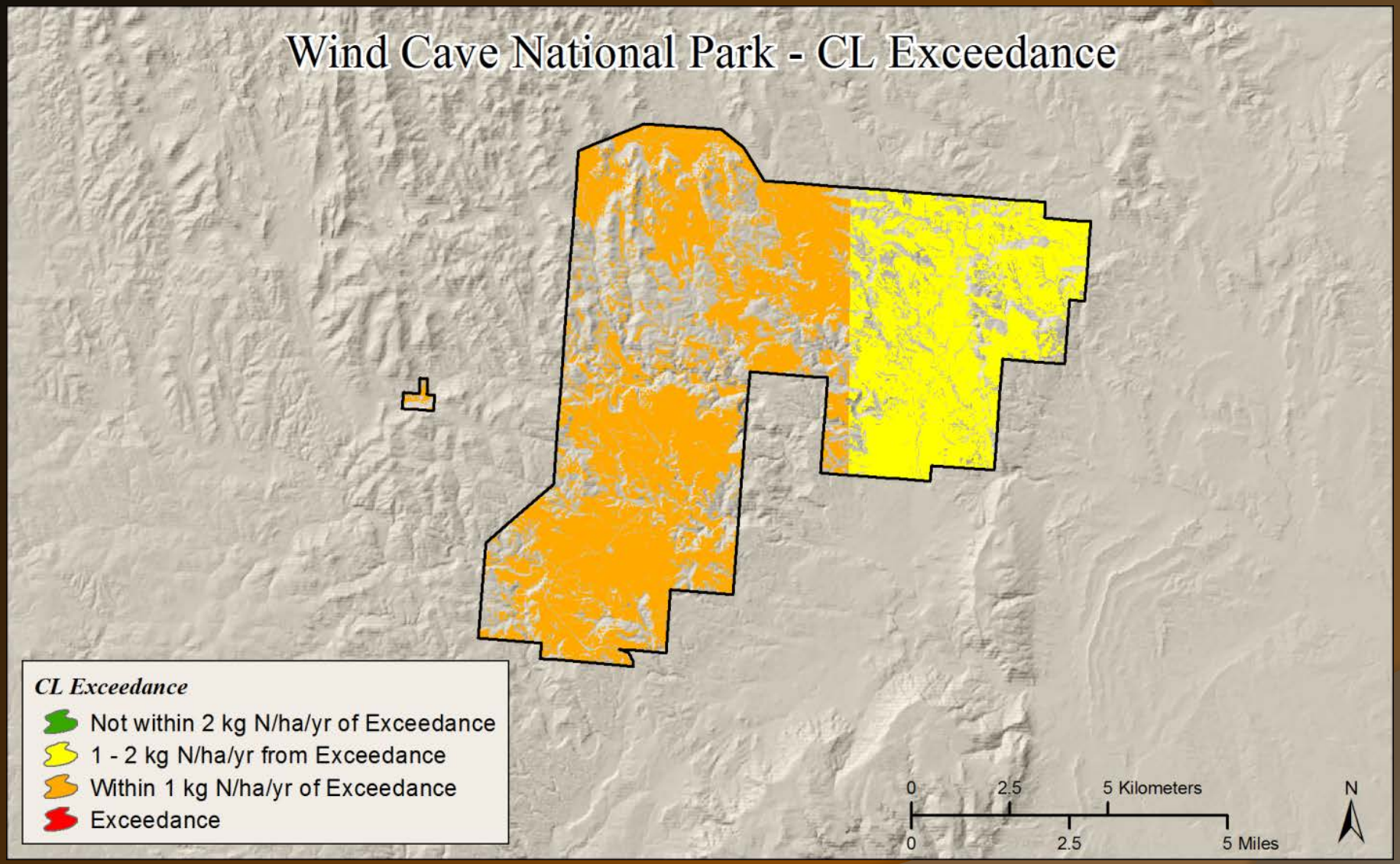
Red – exceedance

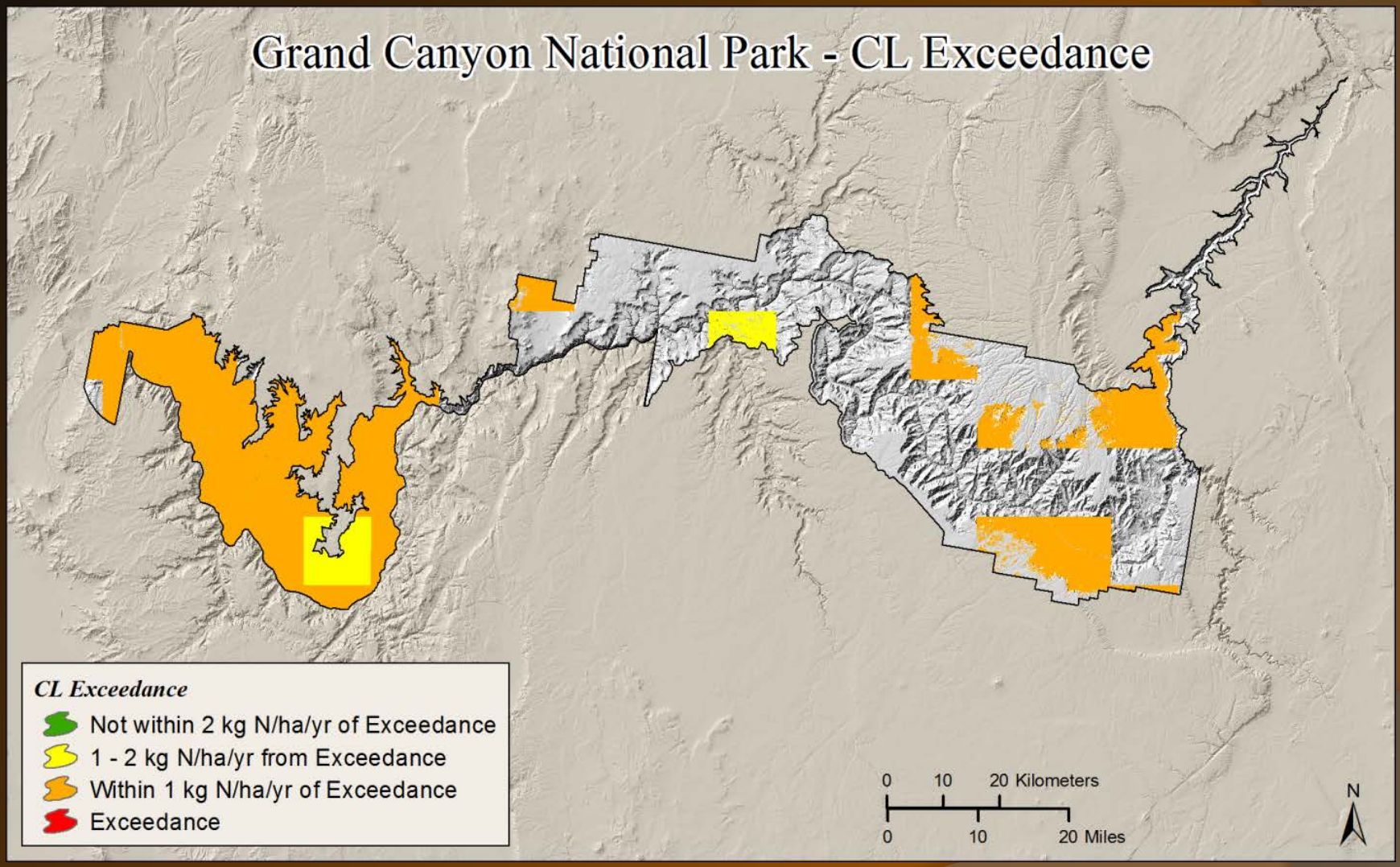
Orange – very close

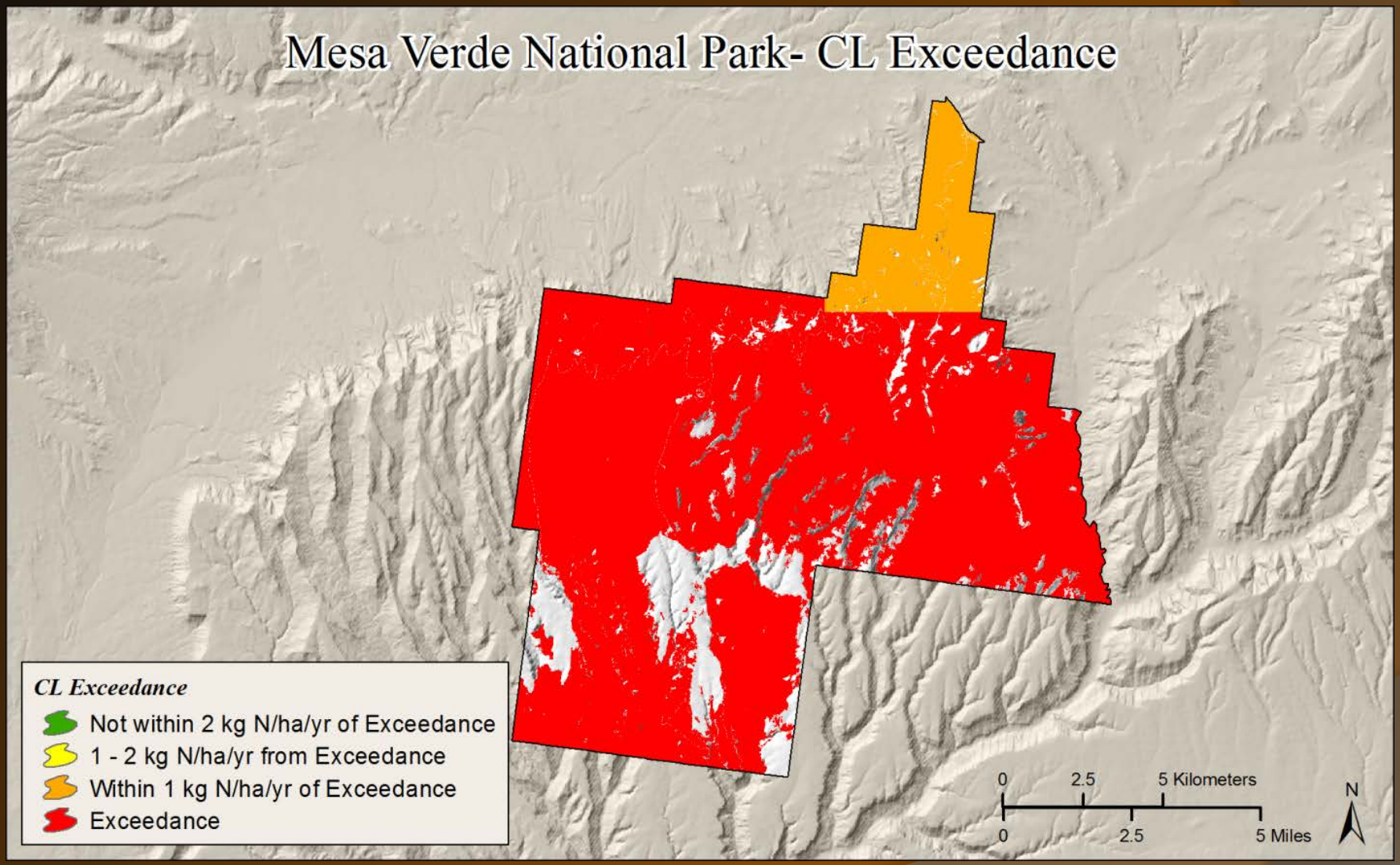
Yellow – close

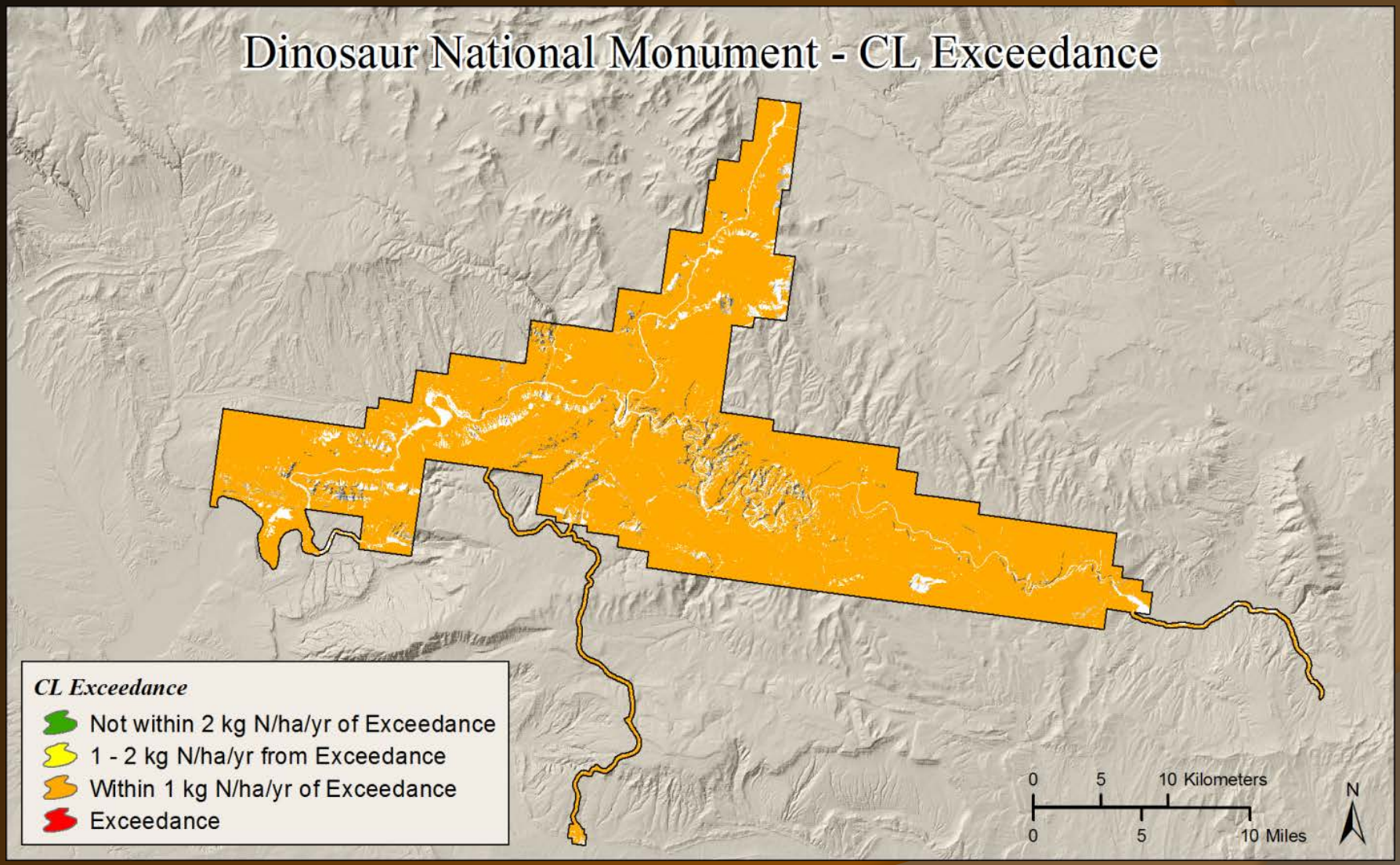

Badlands National Park - CL Exceedance
CL Exceedance
Not within 2 kg N/ha/yr of Exceedance
1 - 2 kg N/ha/yr from Exceedance
Within 1 kg N/ha/yr of Exceedance
Exceedance
0 5 10 Kilometers
0 5 10 Miles
N

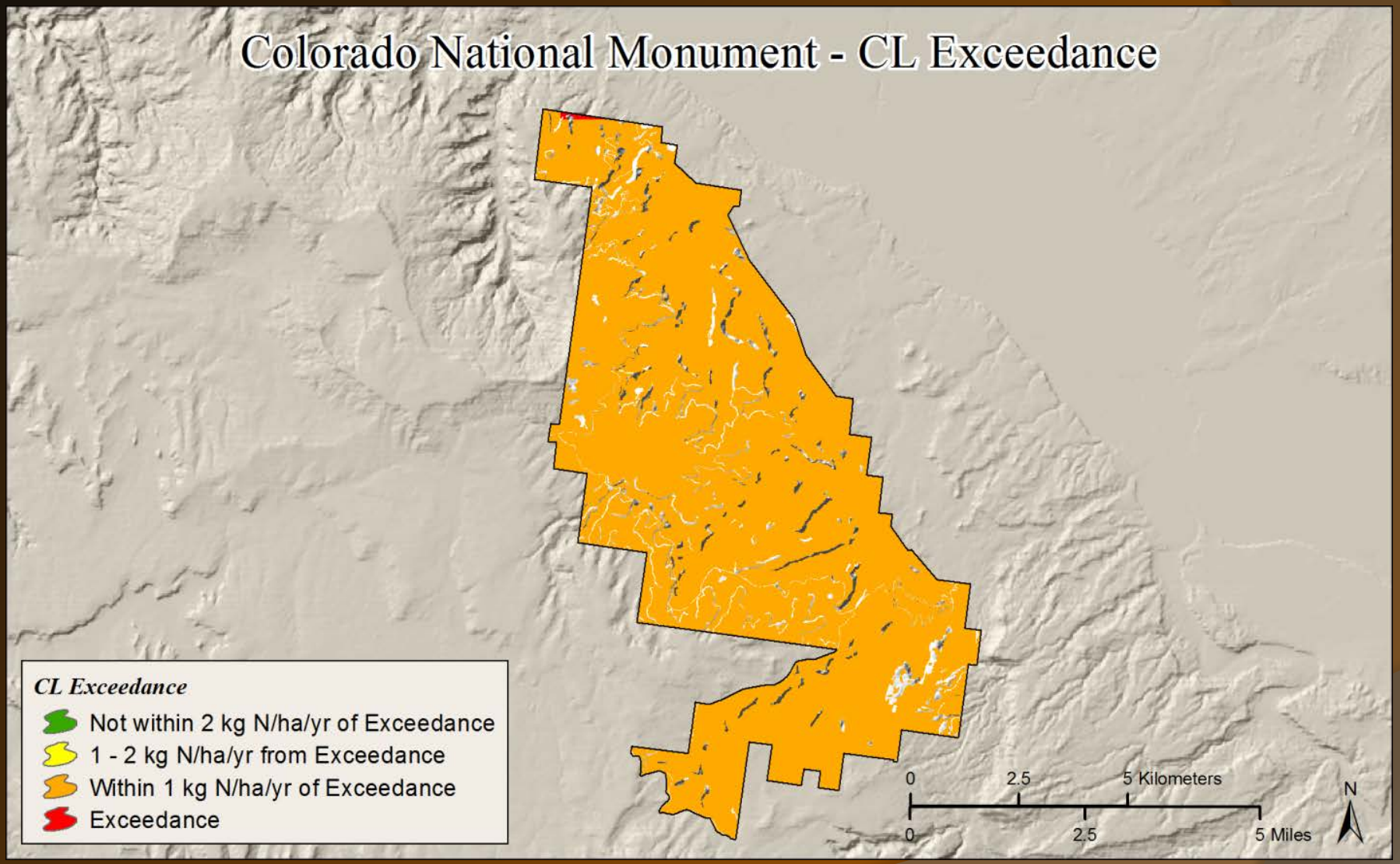

Theodore Roosevelt National Park - CL Exceedance
North
Theodore Roosevelt NP
North, Ranch, and South
Area of Enlargement
Ranch
South
0 2.5 5 Kilometers
0 2.5 5 Miles
0 0.5 Kilometers
0 0.5 Miles
CL Exceedance
Not within 2 kg N/ha/yr of Exceedance
1 - 2 kg N/ha/yr from Exceedance
Within 1 kg N/ha/yr of Exceedance
Exceedance
N

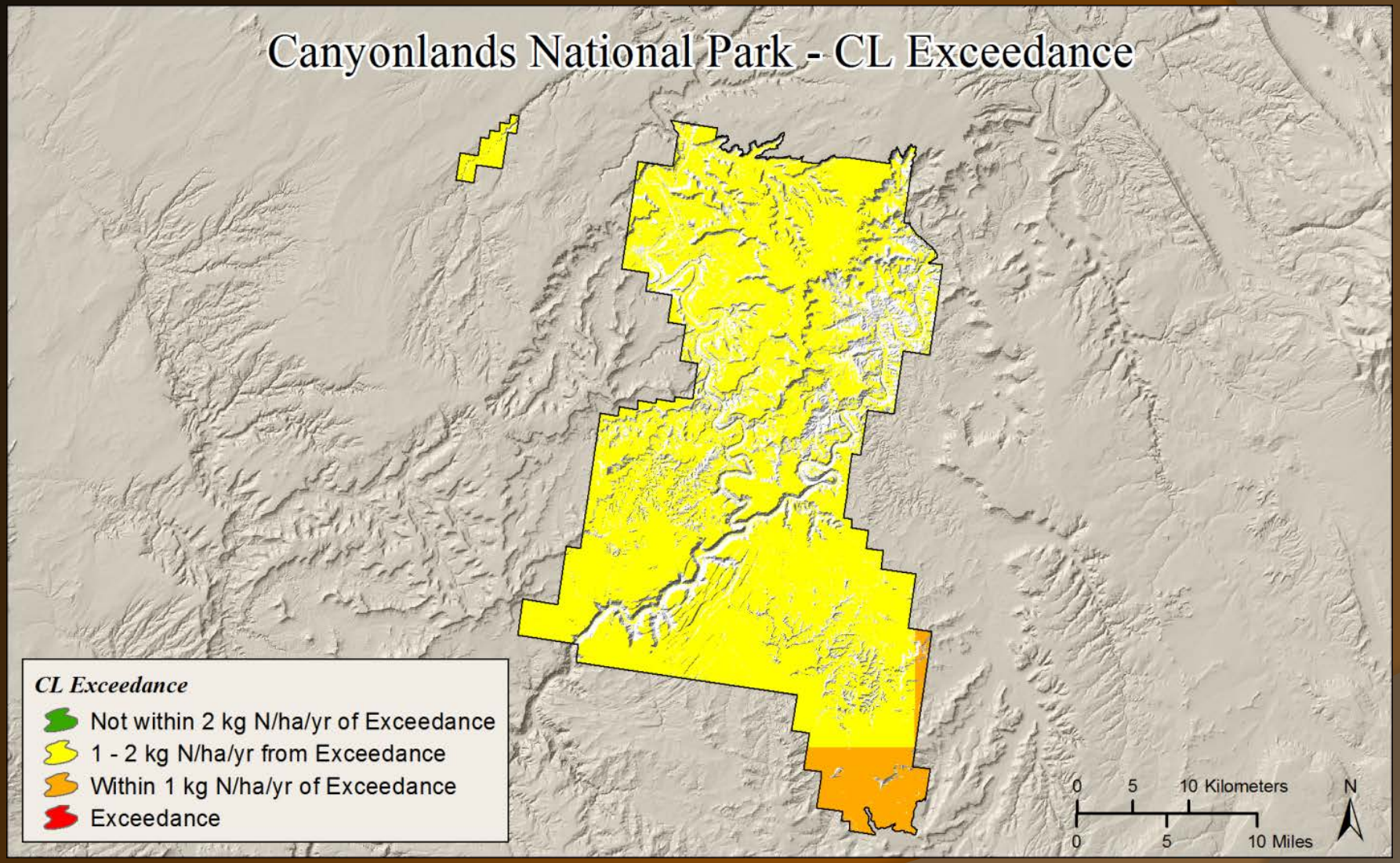

Wind Cave National Park - CL Exceedance
CL Exceedance
Not within 2 kg N/ha/yr of Exceedance
1 - 2 kg N/ha/yr from Exceedance
Within 1 kg N/ha/yr of Exceedance
Exceedance
0
2.5
5 Kilometers
0
2.5
5 Miles
N

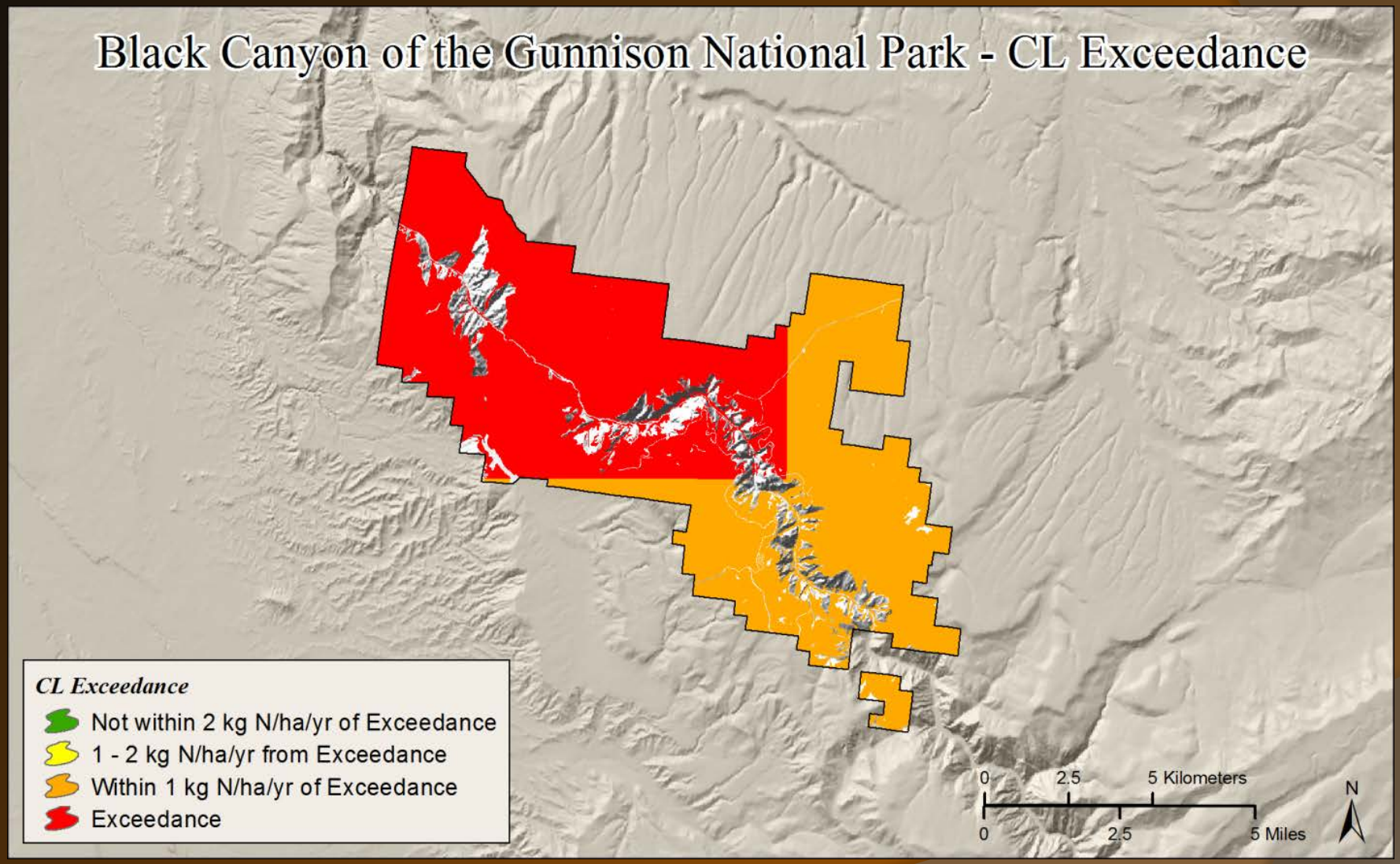

Grand Canyon National Park - CL Exceedance
CL Exceedance
Not within 2 kg N/ha/yr of Exceedance
1 - 2 kg N/ha/yr from Exceedance
Within 1 kg N/ha/yr of Exceedance
Exceedance
0 10 20 Kilometers
0 10 20 Miles
N

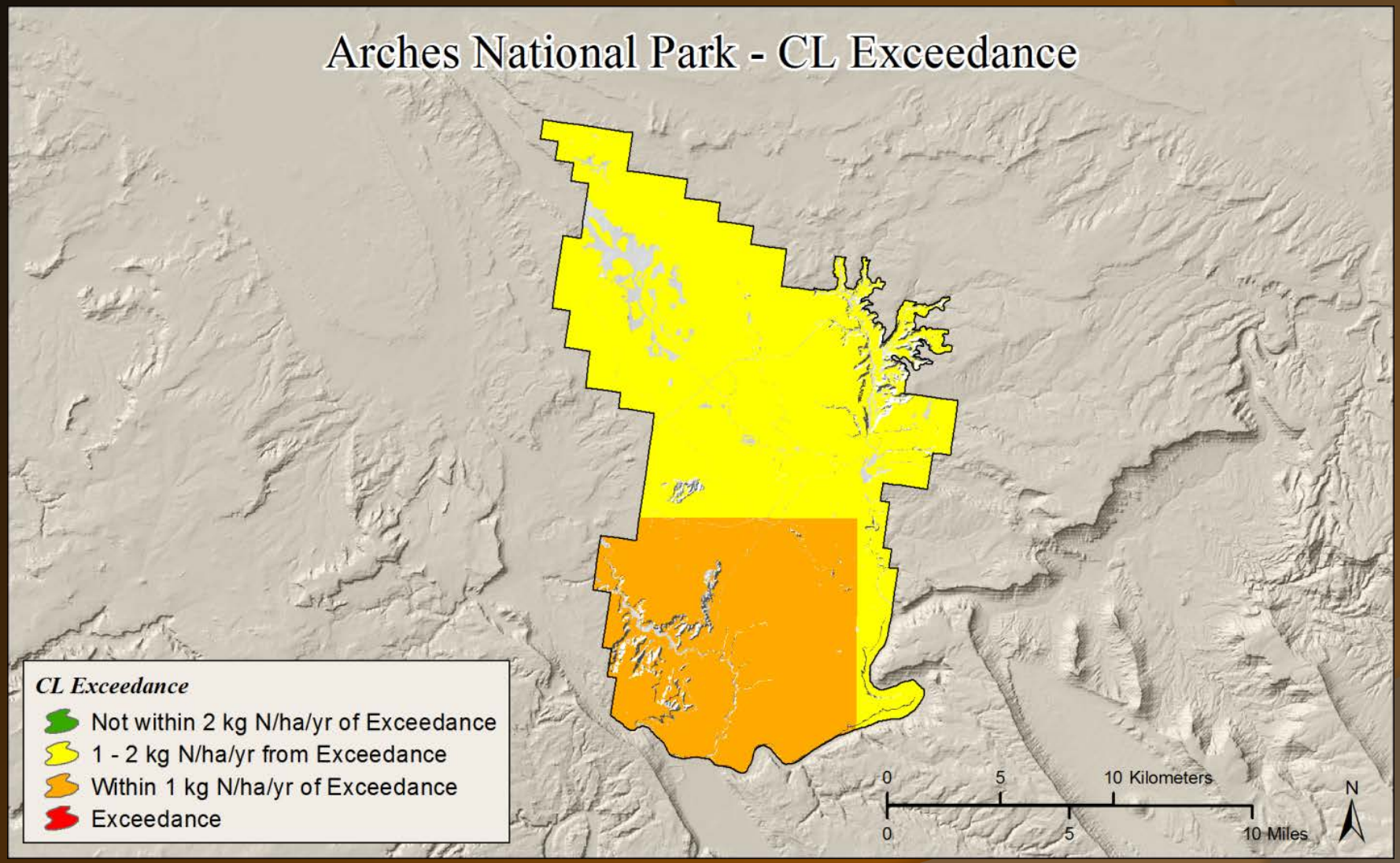

Mesa Verde National Park- CL Exceedance
CL Exceedance
Not within 2 kg N/ha/yr of Exceedance
1 - 2 kg N/ha/yr from Exceedance
Within 1 kg N/ha/yr of Exceedance
Exceedance
0
2.5
5 Kilometers
0
2.5
5 Miles
N

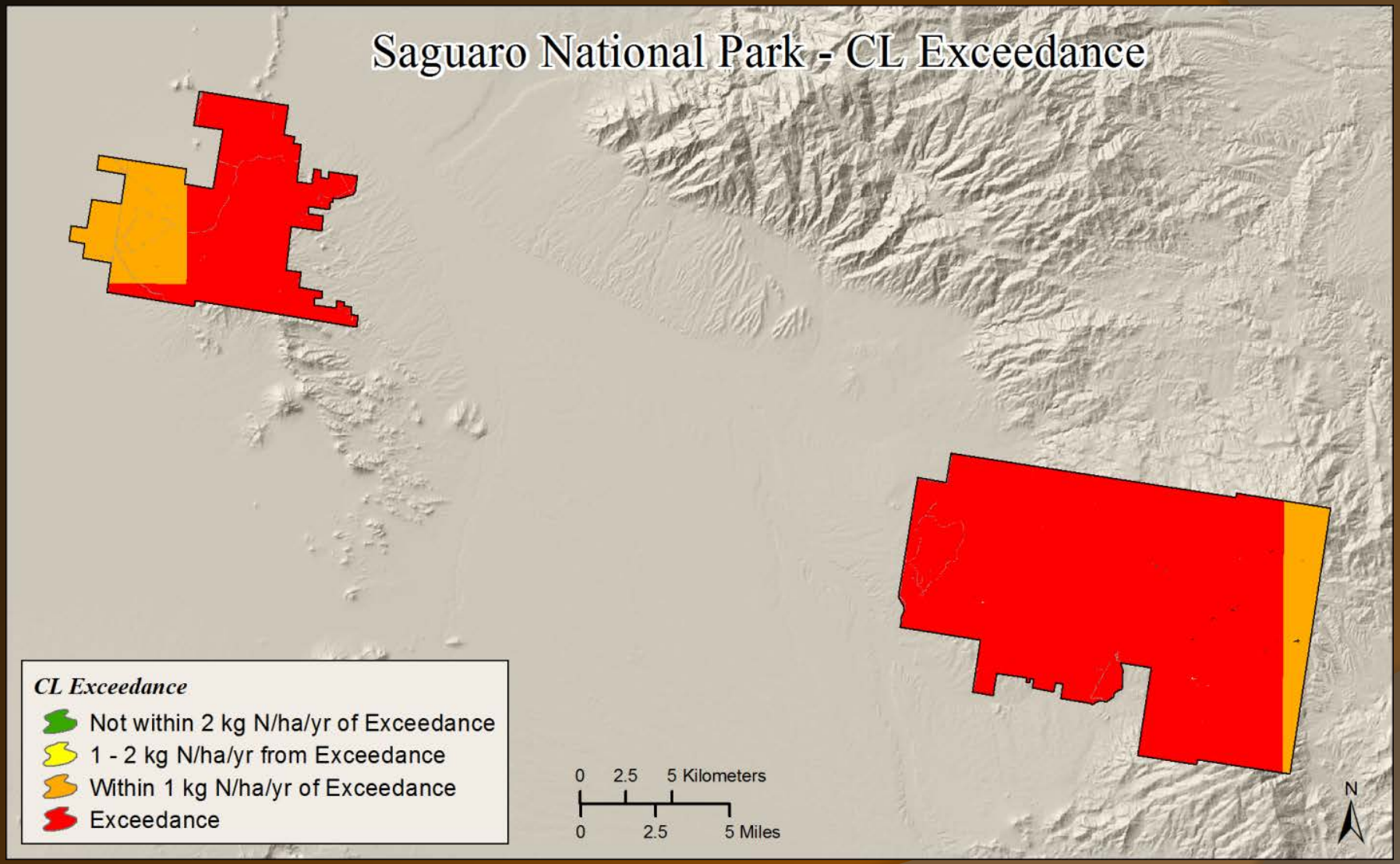

Dinosaur National Monument - CL Exceedance
CL Exceedance
Not within 2 kg N/ha/yr of Exceedance
1 - 2 kg N/ha/yr from Exceedance
Within 1 kg N/ha/yr of Exceedance
Exceedance
0
5
10 Kilometers
0
5
10 Miles
N


Colorado National Monument - CL Exceedance
CL Exceedance
Not within 2 kg N/ha/yr of Exceedance
1 - 2 kg N/ha/yr from Exceedance
Within 1 kg N/ha/yr of Exceedance
Exceedance
0
2.5
5 Kilometers
0
2.5
5 Miles
N


Canyonlands National Park - CL Exceedance
CL Exceedance
Not within 2 kg N/ha/yr of Exceedance
1 - 2 kg N/ha/yr from Exceedance
Within 1 kg N/ha/yr of Exceedance
Exceedance
0
5
10 Kilometers
0
5
10 Miles
N

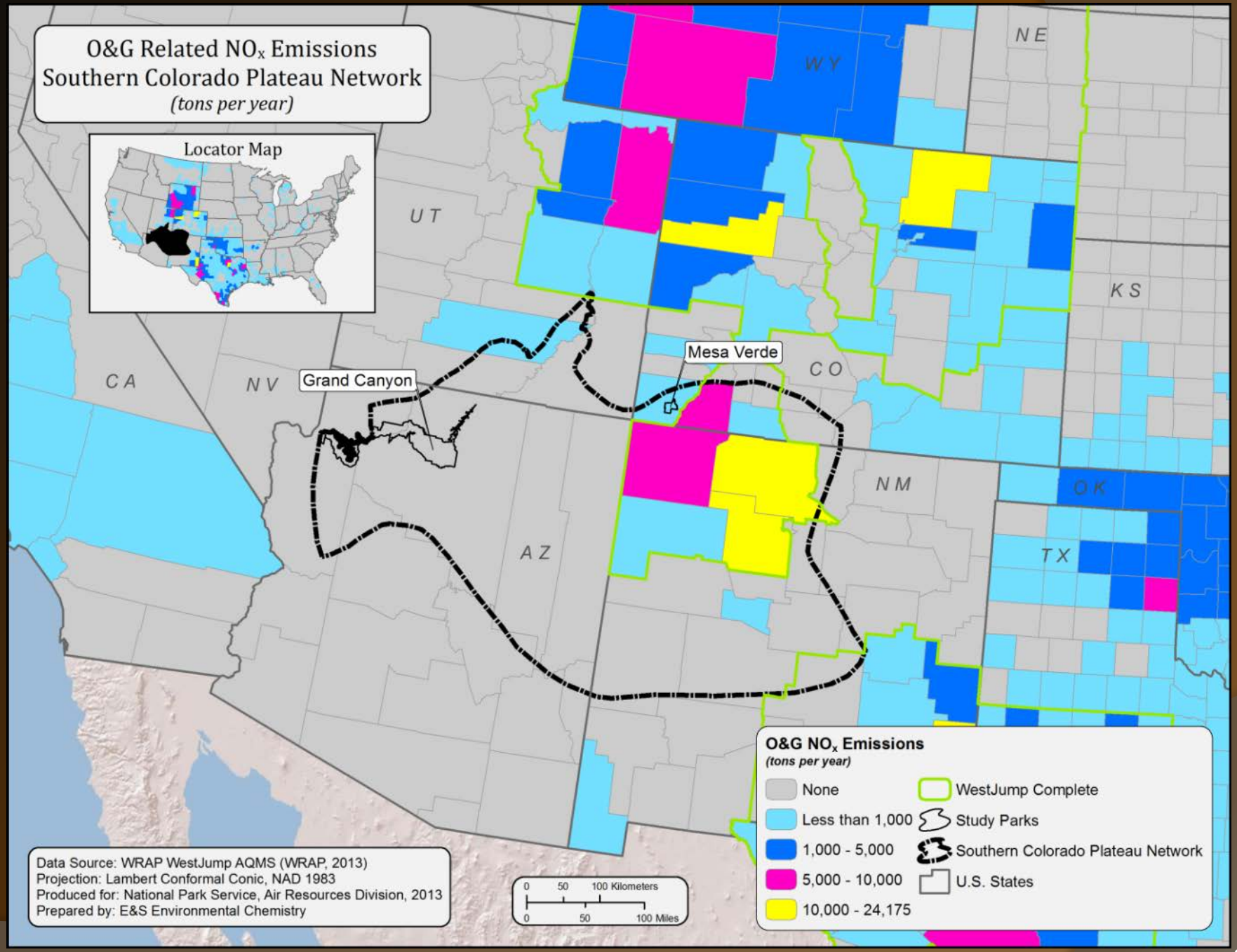

Black Canyon of the Gunnison National Park - CL Exceedance
CL Exceedance
Not within 2 kg N/ha/yr of Exceedance
1 - 2 kg N/ha/yr from Exceedance
Within 1 kg N/ha/yr of Exceedance
Exceedance
0
2.5
5 Kilometers
0
2.5
5 Miles
N


Arches National Park - CL Exceedance
CL Exceedance
Not within 2 kg N/ha/yr of Exceedance
1 - 2 kg N/ha/yr from Exceedance
Within 1 kg N/ha/yr of Exceedance
Exceedance
0
5
10 Kilometers
0
5
10 Miles
N

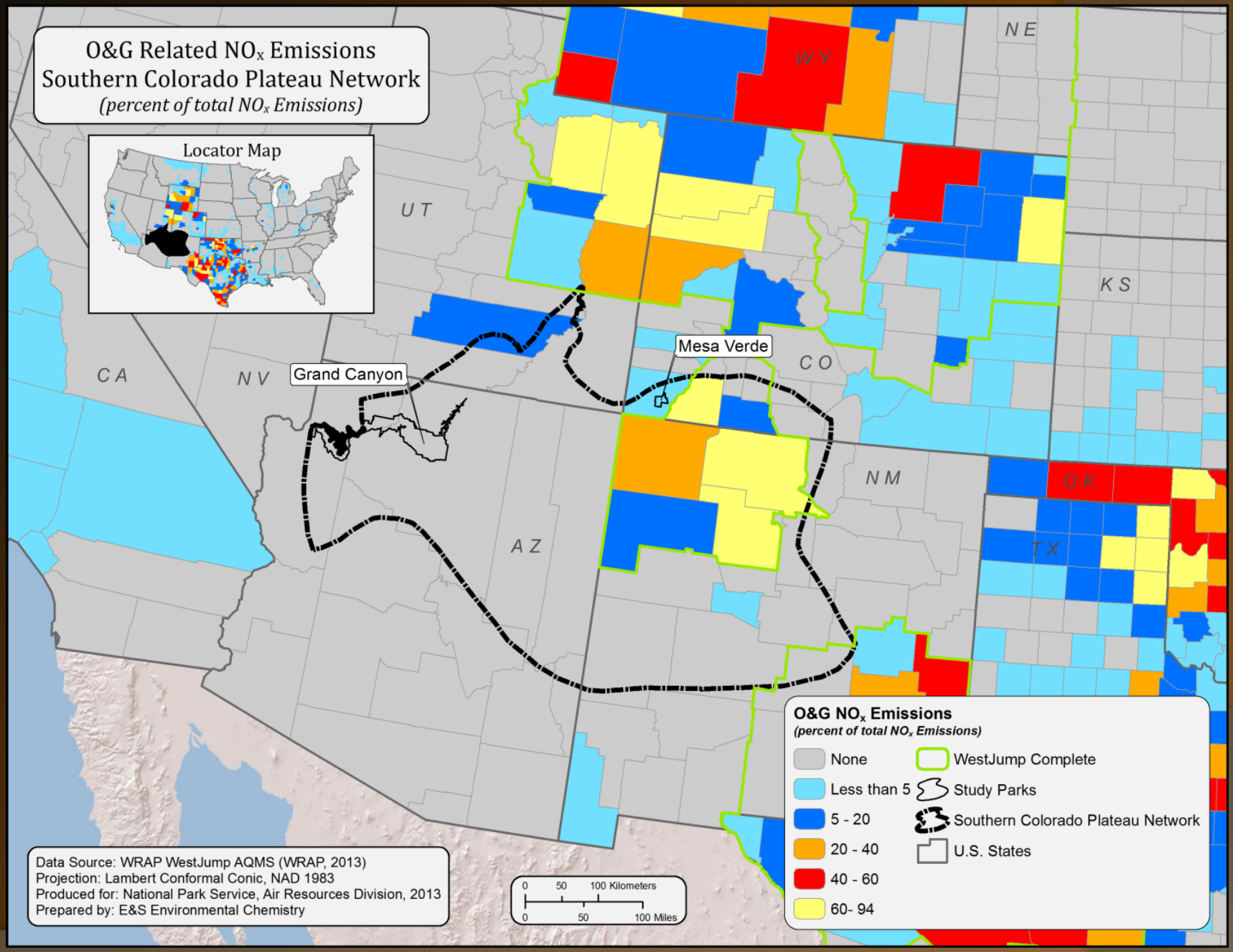

Saguaro National Park - CL Exceedance
CL Exceedance
Not within 2 kg N/ha/yr of Exceedance
1 - 2 kg N/ha/yr from Exceedance
Within 1 kg N/ha/yr of Exceedance
Exceedance
0 2.5 5 Kilometers
0 2.5 5 Miles
N

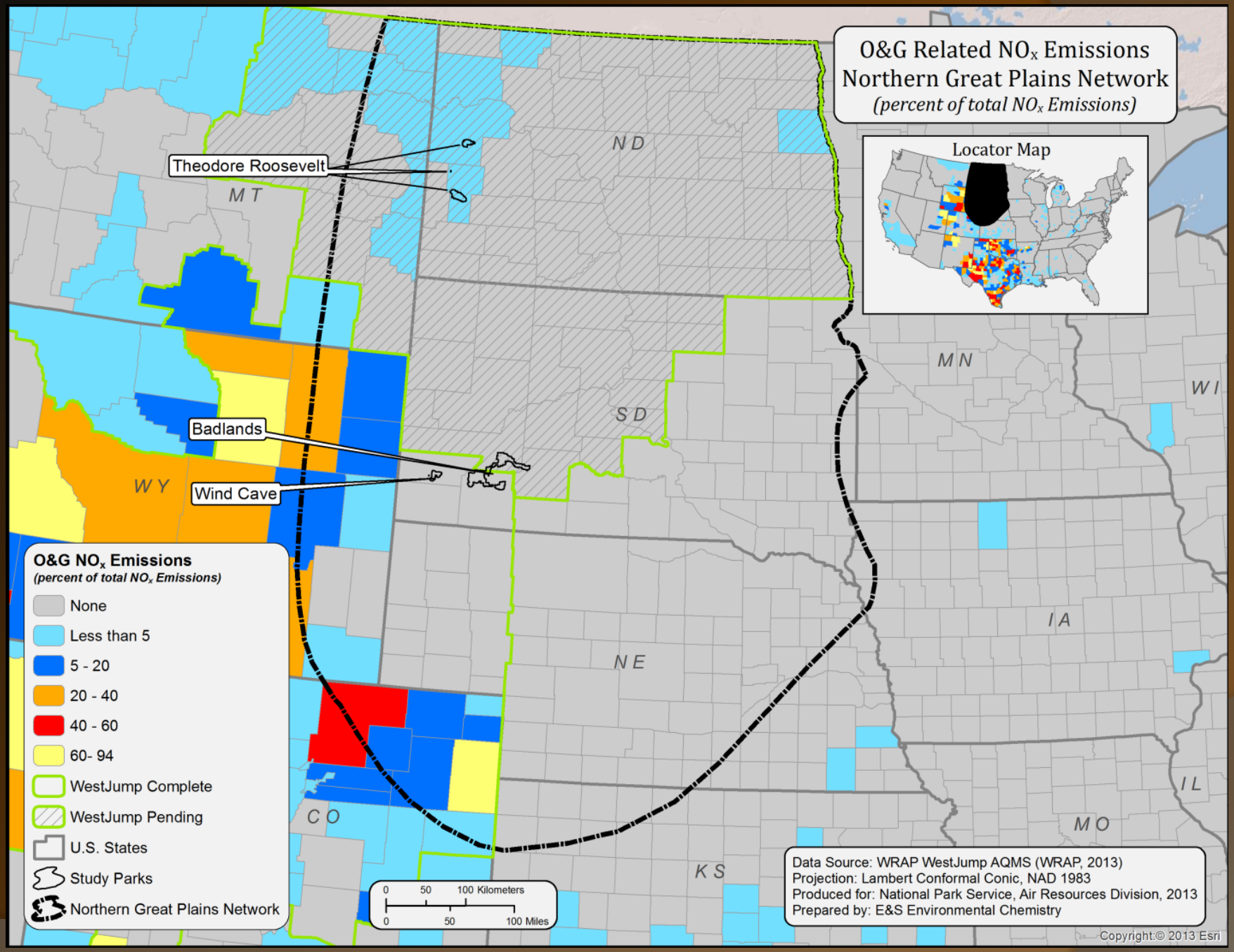
O & G Emissions

Western Regional Air Partnership (Environ)


O&G Related NOx Emissions
Southern Colorado Plateau Network
(tons per year)
Locator Map
UT
WY
NE
KS
CO
NM
OK
TX
AZ
NV
CA
Grand Canyon
Mesa Verde
O&G NOx Emissions
(tons per year)
None
Less than 1,000
1,000 - 5,000
5,000 - 10,000
10,000 - 24,175
WestJump Complete
Study Parks
Southern Colorado Plateau Network
U.S. States
Data Source: WRAP WestJump AQMS (WRAP, 2013)
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2013
Prepared by: E&S Environmental Chemistry
0 50 100 Kilometers
0 50 100 Miles

O & G Emissions
(as % of Total)


O&G Related NOx Emissions
Southern Colorado Plateau Network
(percent of total NOx Emissions)
Locator Map
UT
WY
NE
KS
CO
NM
OK
TX
AZ
NV
CA
Grand Canyon
Mesa Verde
O&G NOx Emissions
(percent of total NOx Emissions)
None
Less than 5
5 - 20
20 - 40
40 - 60
60- 94
WestJump Complete
Study Parks
Southern Colorado Plateau Network
U.S. States
Data Source: WRAP WestJump AQMS (WRAP, 2013)
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2013
Prepared by: E&S Environmental Chemistry
0 50 100 Kilometers
0 50 100 Miles


O&G Related NOx Emissions
Northern Great Plains Network
(percent of total NOx Emissions)
Locator Map
Theodore Roosevelt
Badlands
Wind Cave
ND
MT
SD
WY
MN
WI
IA
NE
IL
MO
CO
KS
O&G NOx Emissions
(percent of total NOx Emissions)
None
Less than 5
5 - 20
20 - 40
40 - 60
60- 94
WestJump Complete
WestJump Pending
U.S. States
Study Parks
Northern Great Plains Network
0 50 100 Kilometers
0 50 100 Miles
Data Source: WRAP WestJump AQMS (WRAP, 2013)
Projection: Lambert Conformal Conic, NAD 1983
Produced for: National Park Service, Air Resources Division, 2013
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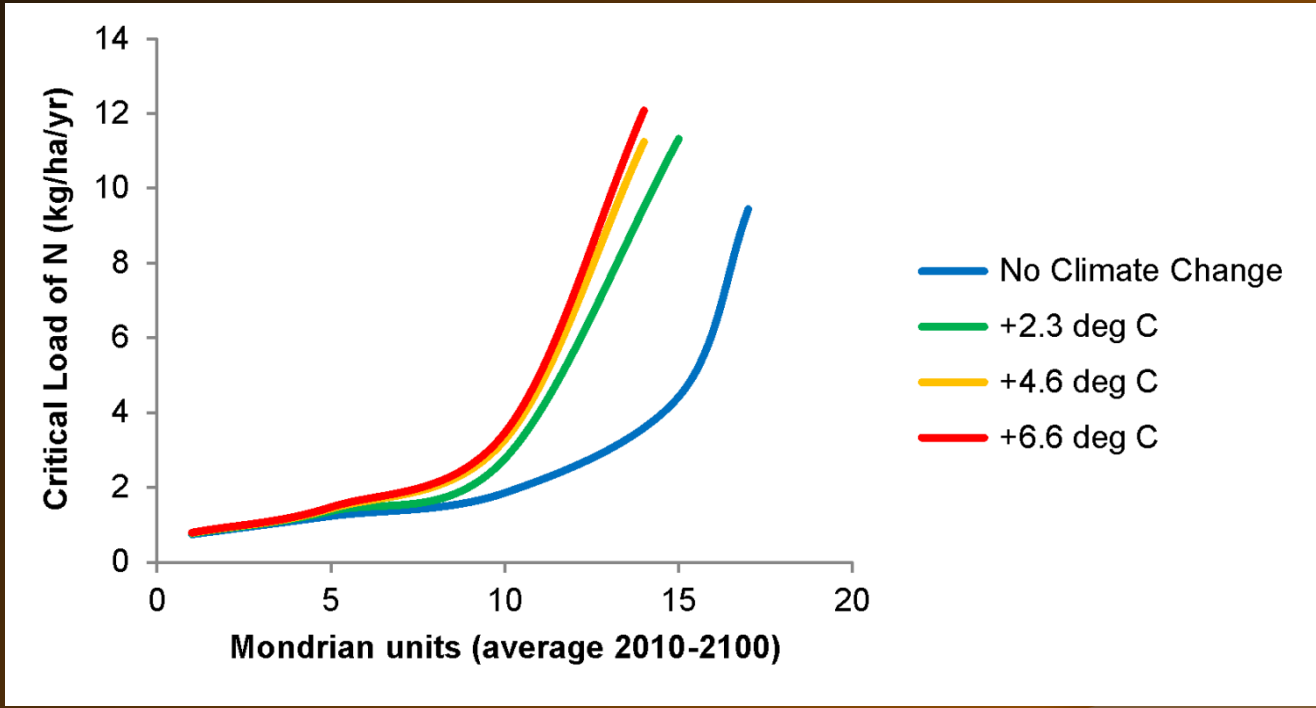
ForSAFE-Veg: Rocky Mountain NP

Loch Vale LTER site

ForSAFE-Veg: Rocky Mountain NP

Critical Load (target load) of N Deposition



Mondian unit = % change in the vegetation community

CONCLUSIONS

- Many ways to estimate CL
- Empirical data for intermountain West suggest
  - Some NPs exhibit extensive exceedance of empirical CL of N
  - Much of NP landscape in study region close to exceedance for N
- Dynamic modeling (ForSAFE-VEG) at Rocky Mt. NP supports empirical data
- New and/or increased emissions sources must be considered

- O&G appears to be substantial emissions source near some parks
- Will be important to track new and/or increased emissions sources (O&G, agri.) moving forward