Sulfur Deficiencies in Crop Production

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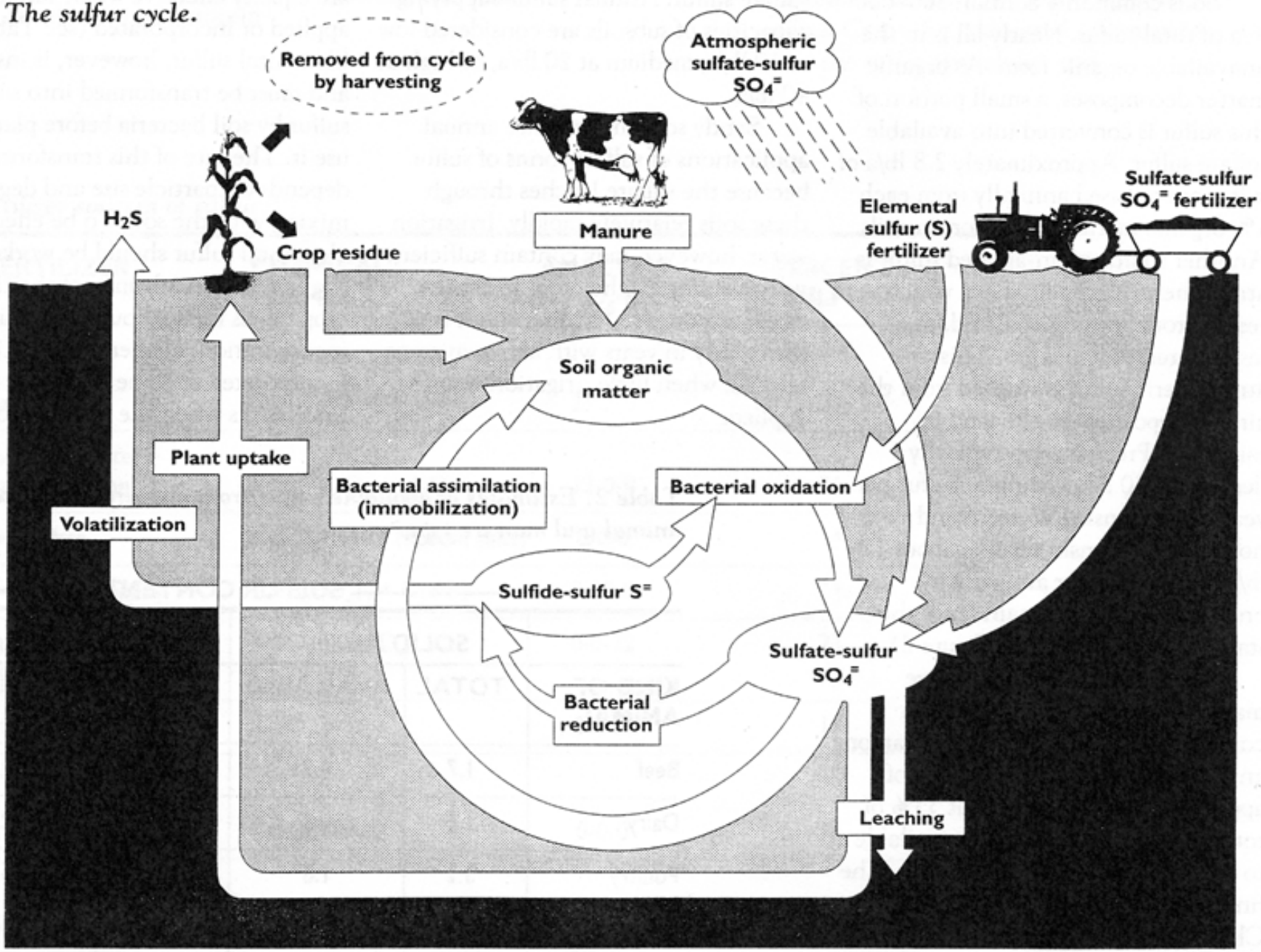
SULFUR (S)

- Role of S in plants
  - Component of amino acids
  - Essential for nitrate reductase enzyme
    - Nitrate ⟶ organic-N
- Deficiency symptoms not localized

Figure 1. The sulfur cycle.



Sulfur Removed by Crops

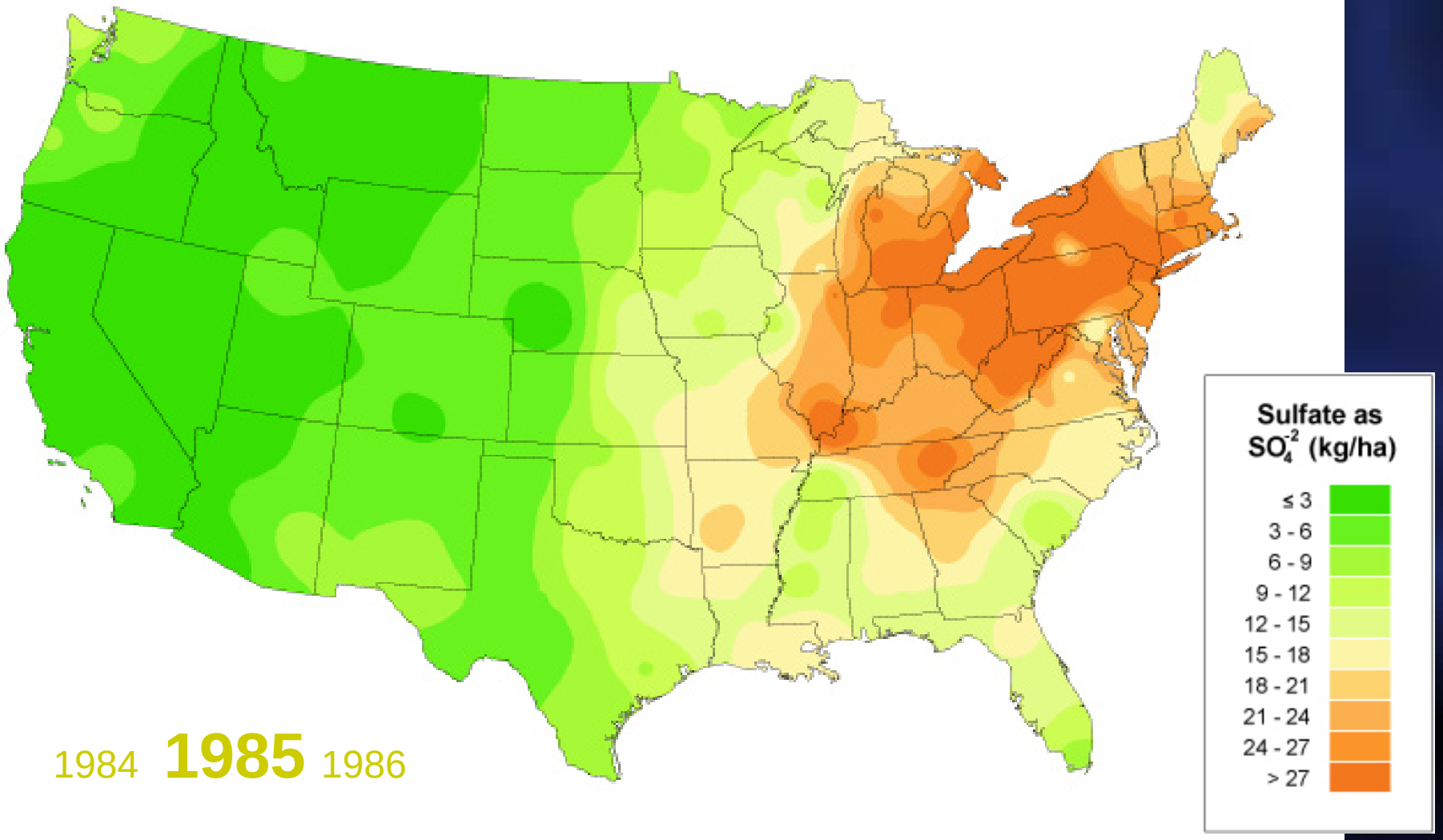
Crop	Portion harvested	Yield/acre	Sulfur removed
			-- lb/acre --
Alfalfa	hay	4 tons	23
Corn	grain	150 bu	10
	silage	15 tons	25
Oat	Grain	80 bu	5
	straw	2 tons	9
Potato	tubers	400 cwt.	10


SULPHUR
DEFICIENT
NORMAL

POTENTIAL SULFUR DEFICIENCIES

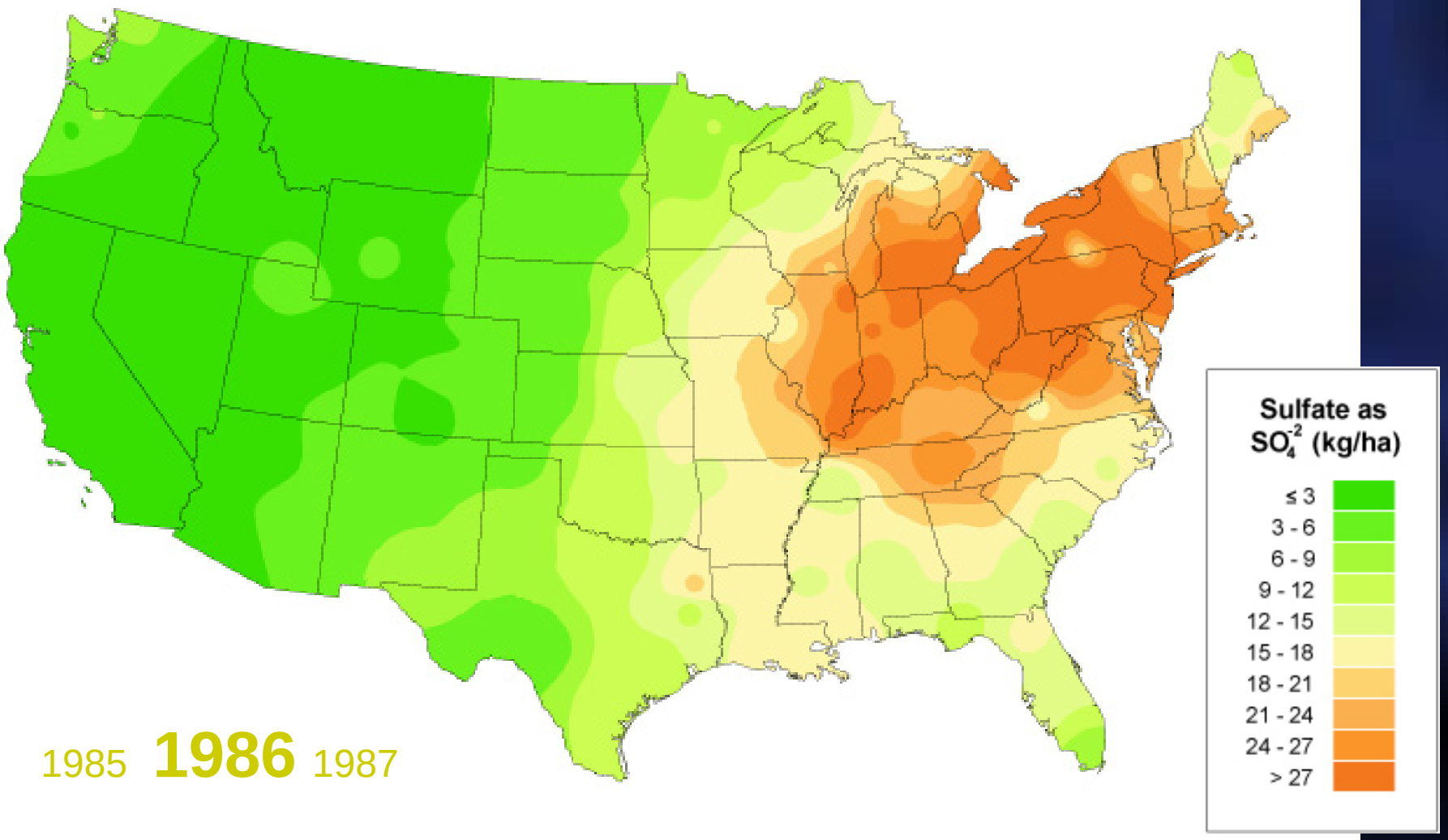
- Low organic matter soils
- No recent manure history
- Low subsoil sulfur
- Low sulfur in precipitation

Sulfate Ion Wet Deposition 1985-2005



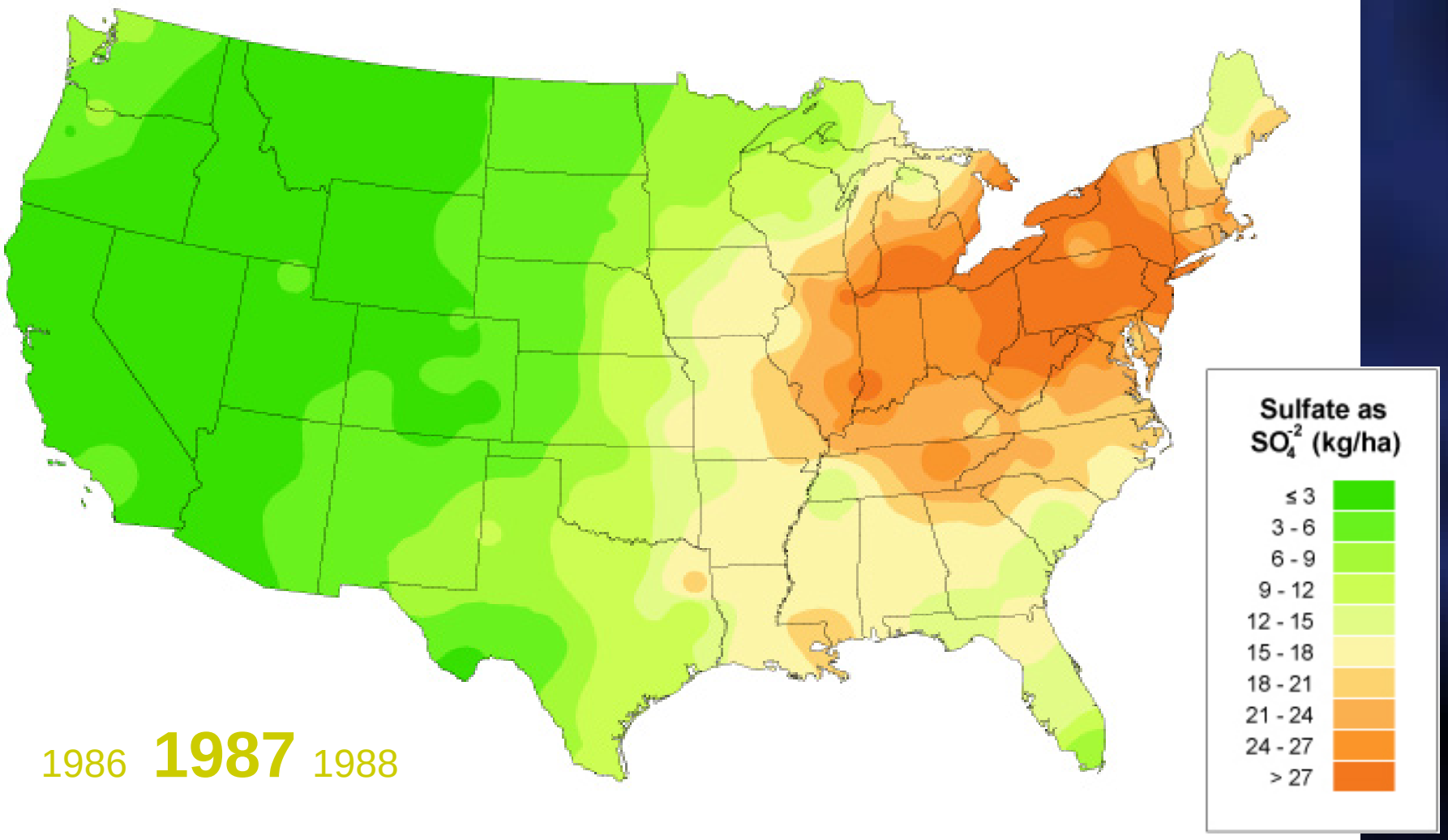
1984 **1985** 1986

Sulfate Ion Wet Deposition 1985-2005



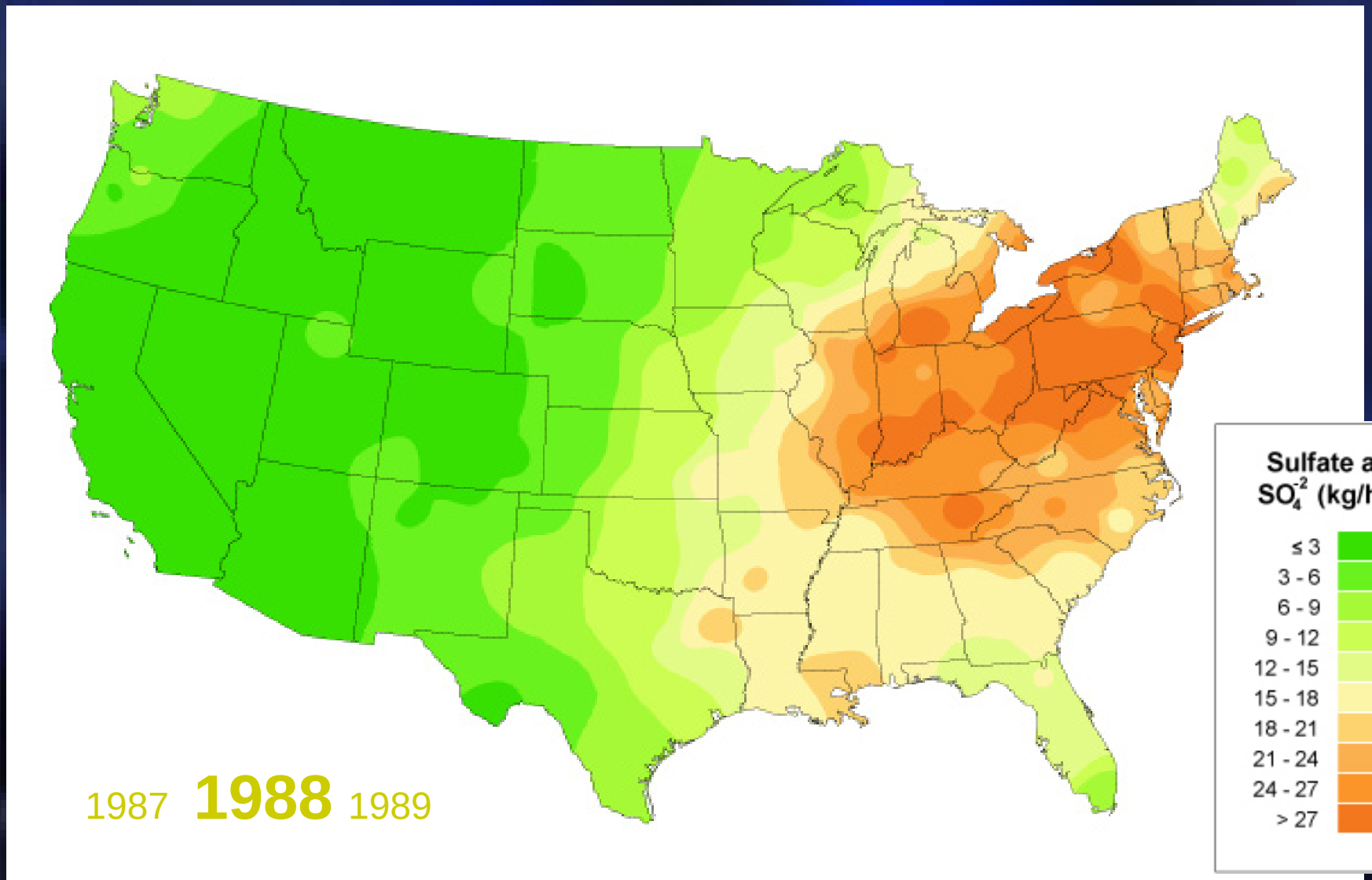
1985 **1986** 1987

Sulfate Ion Wet Deposition 1985-2005



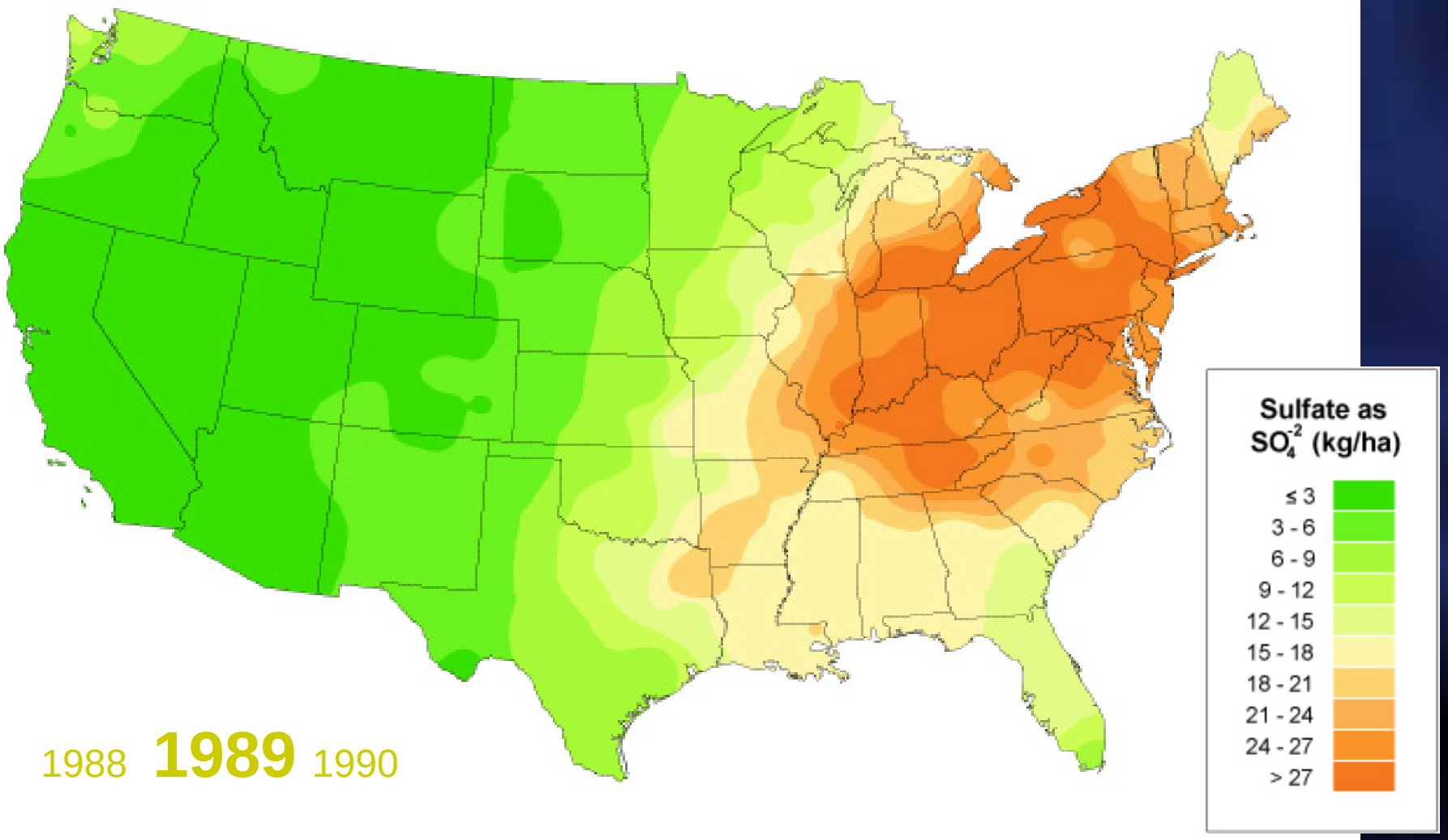
1986 **1987** 1988

Sulfate Ion Wet Deposition 1985-2005



1987 **1988** 1989

Sulfate Ion Wet Deposition 1985-2005



1988 **1989** 1990

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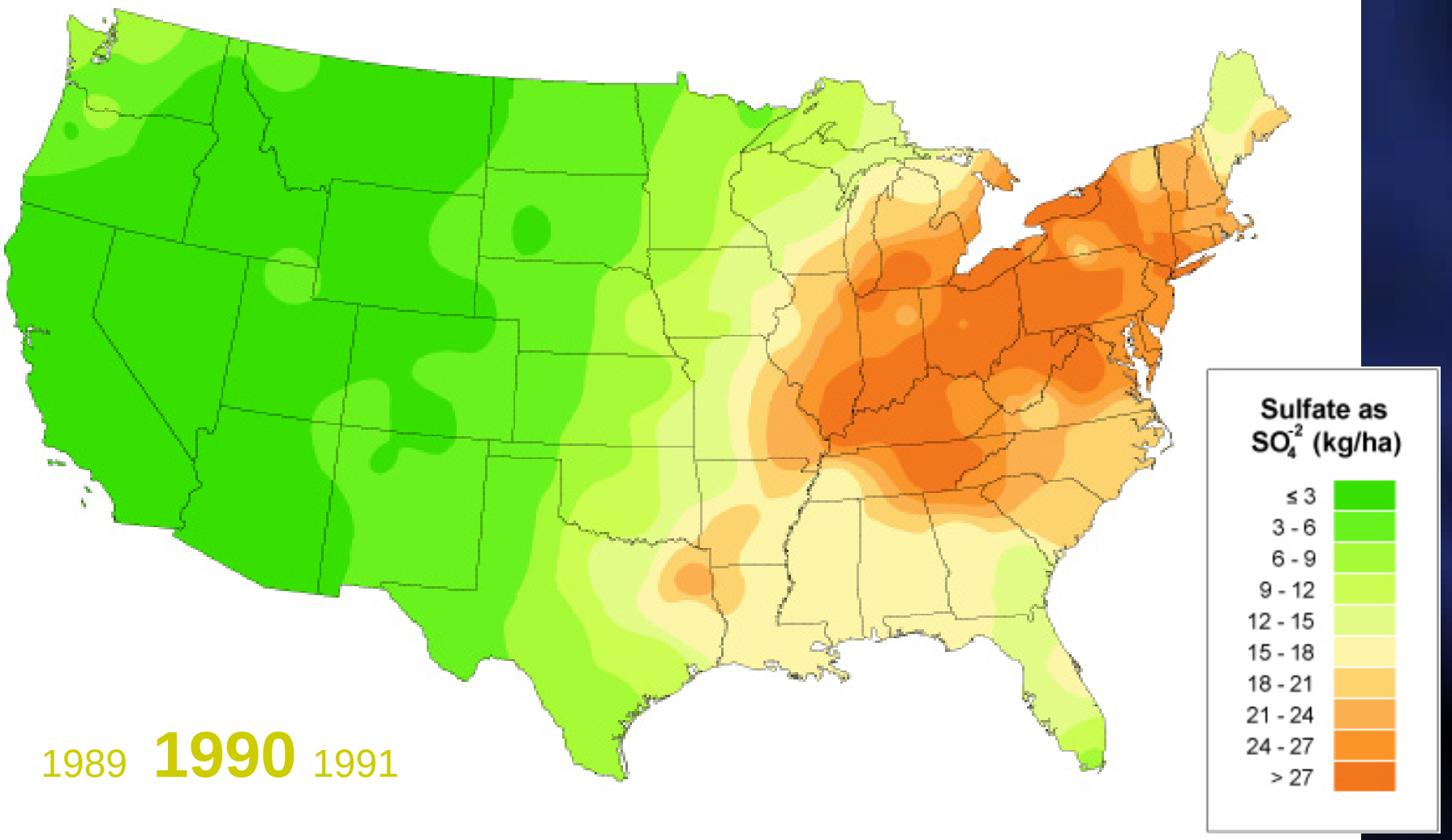

1989 **1990** 1991

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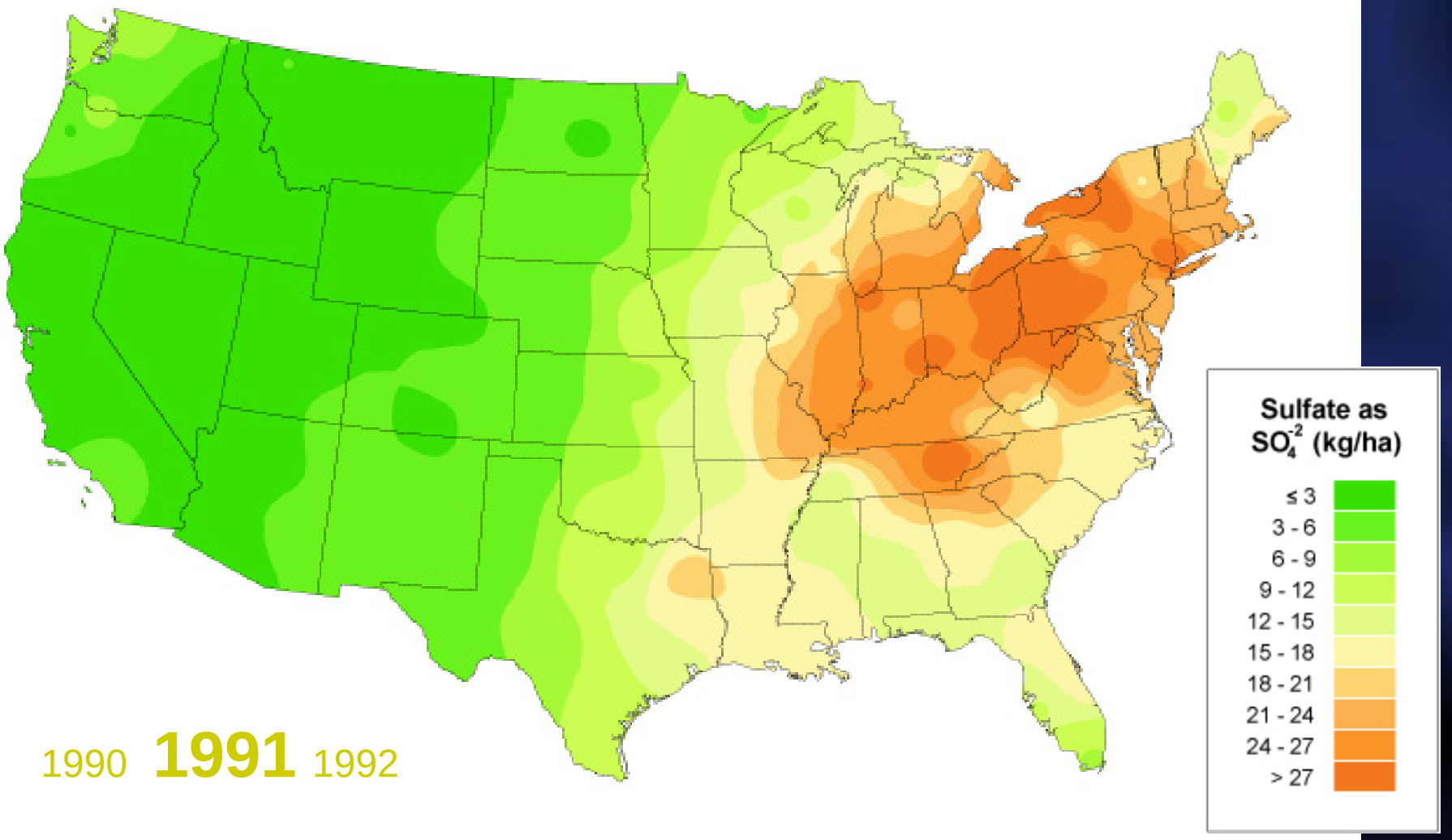

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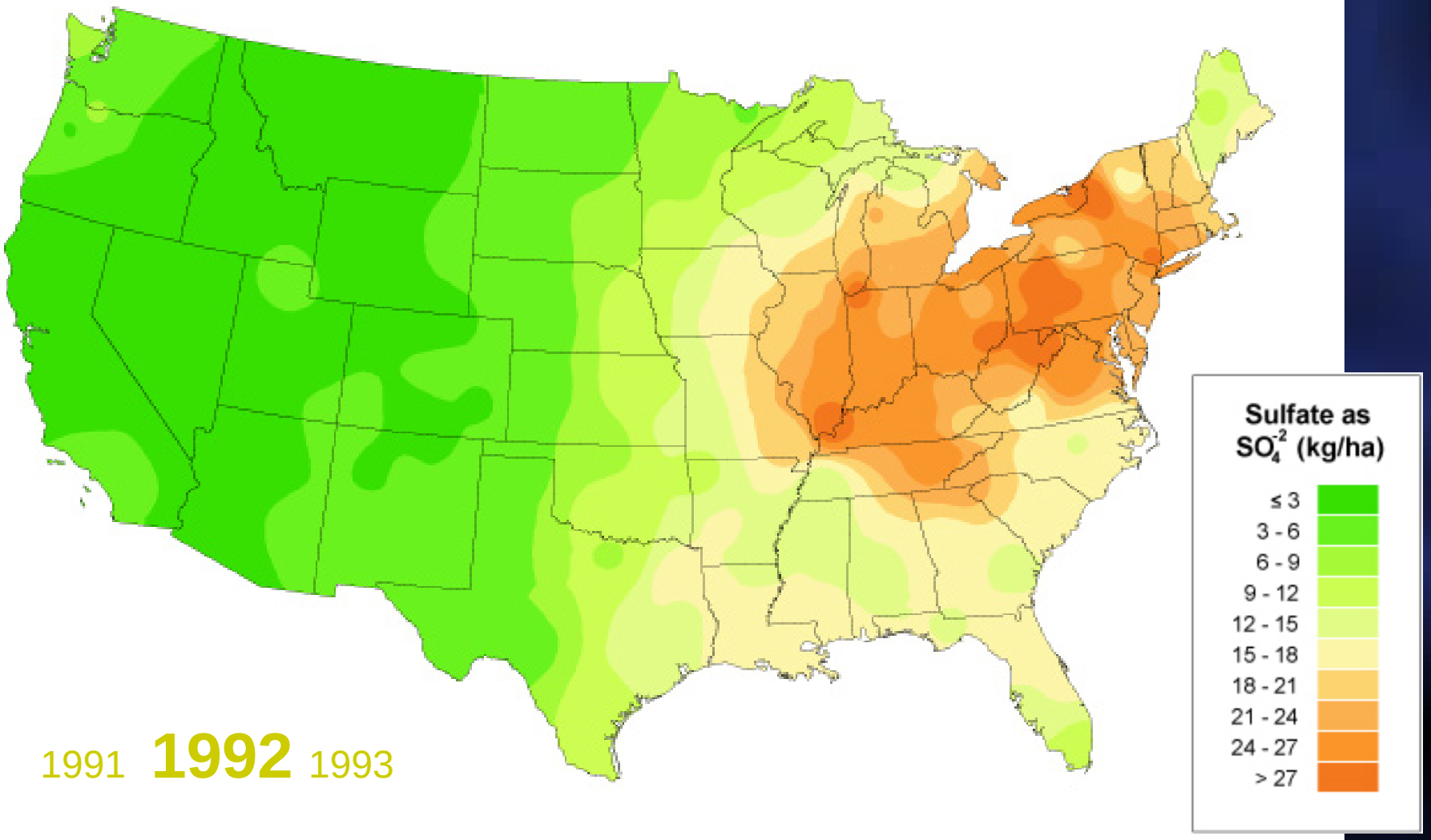

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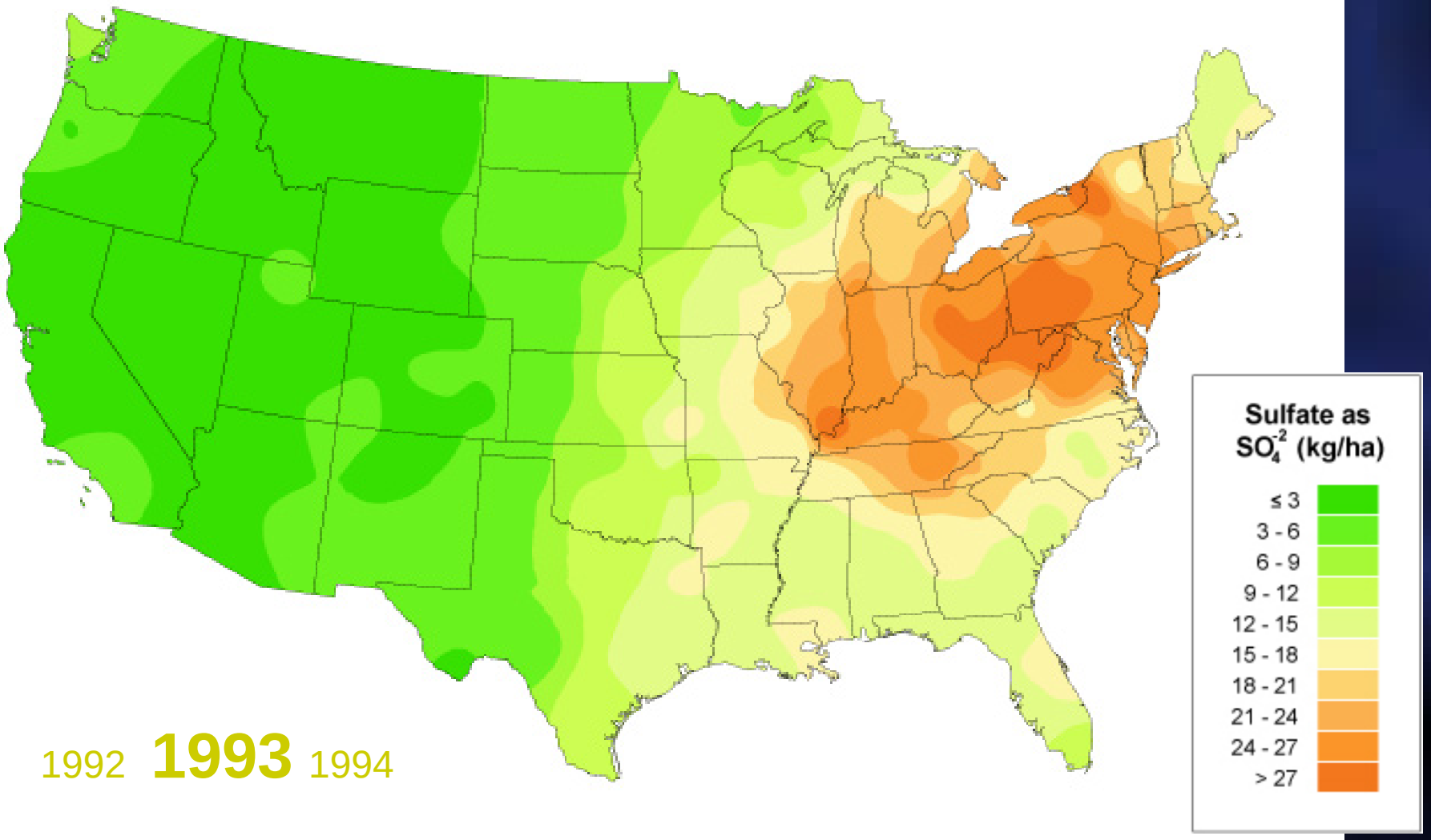

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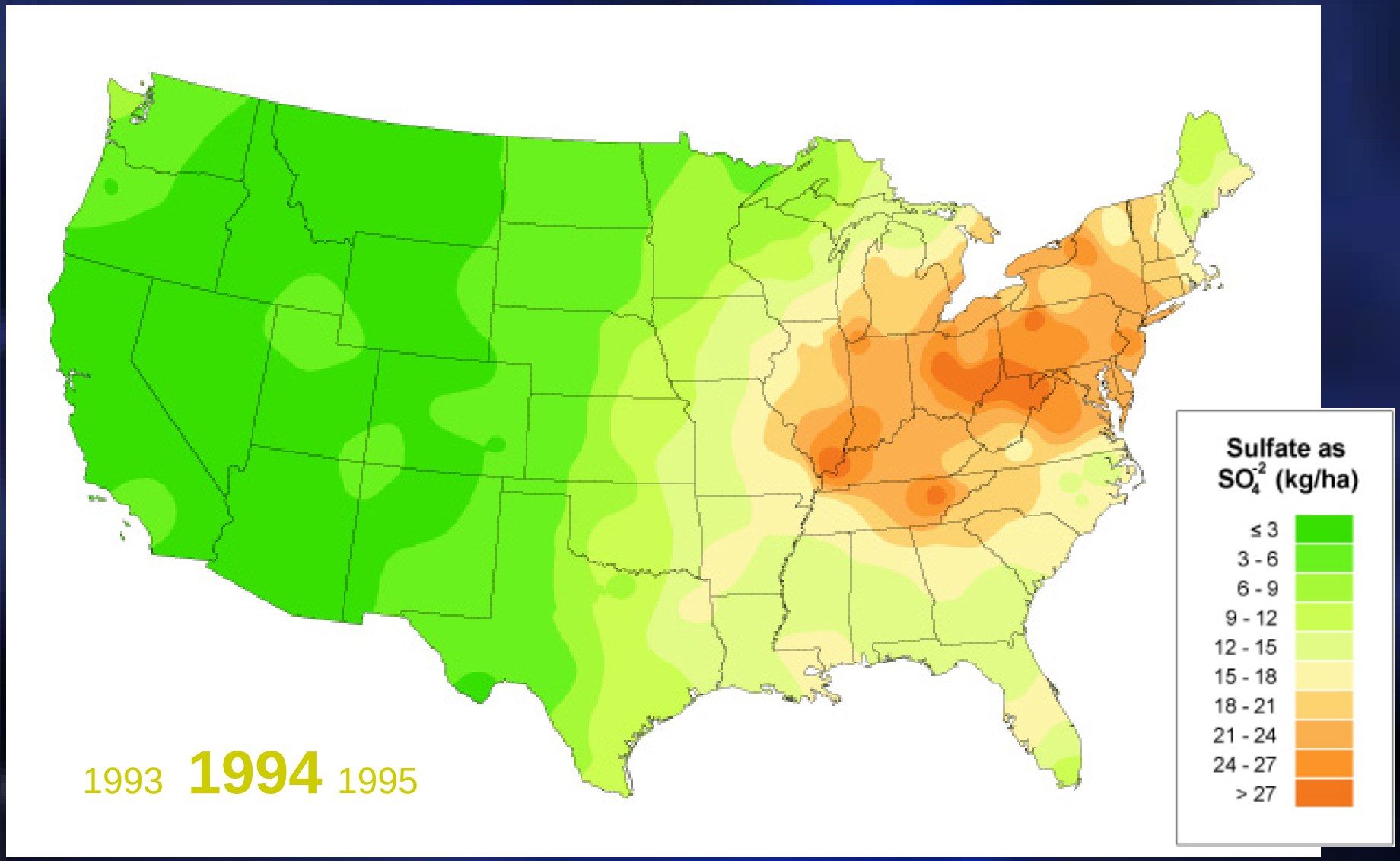

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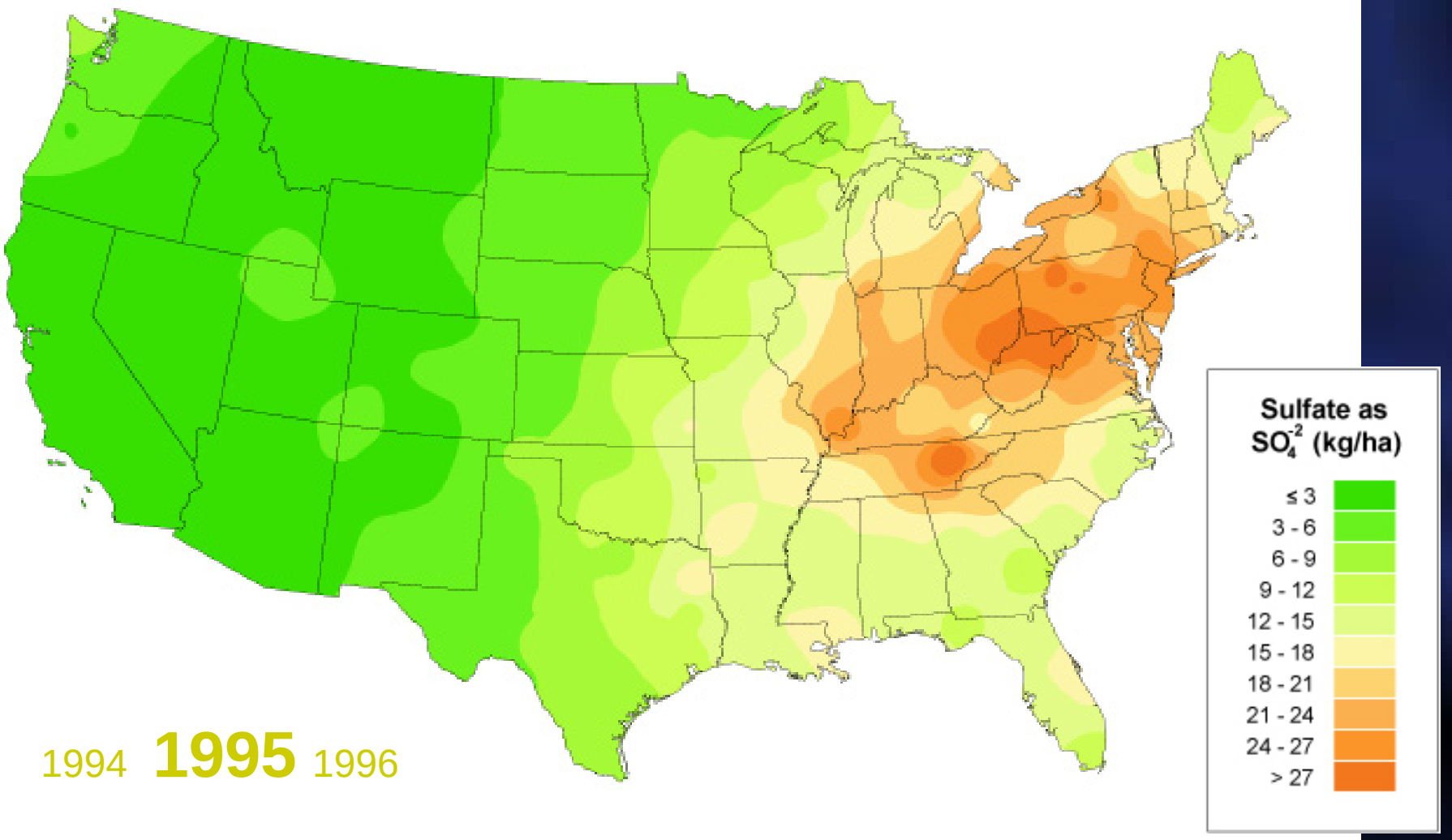

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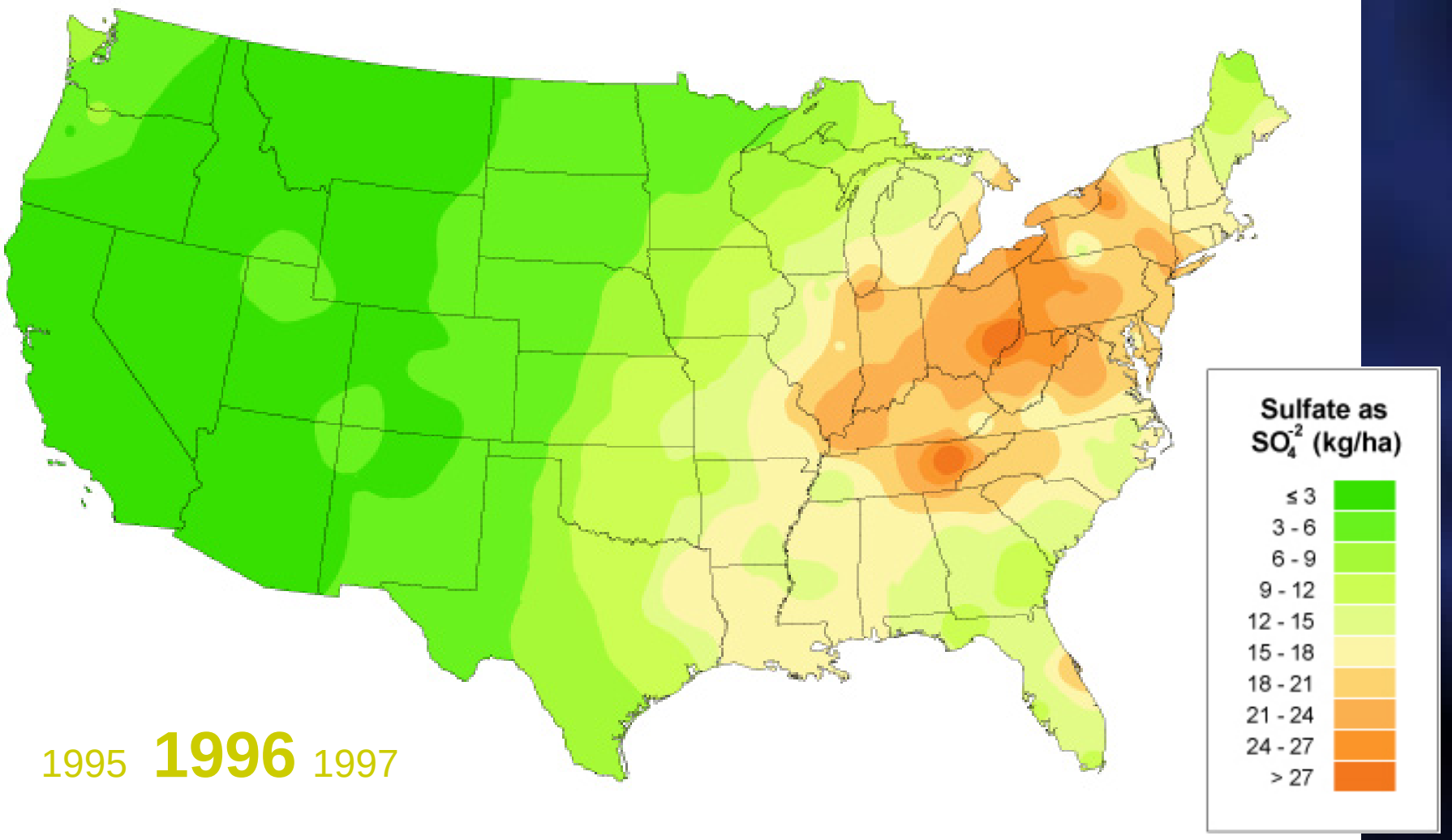

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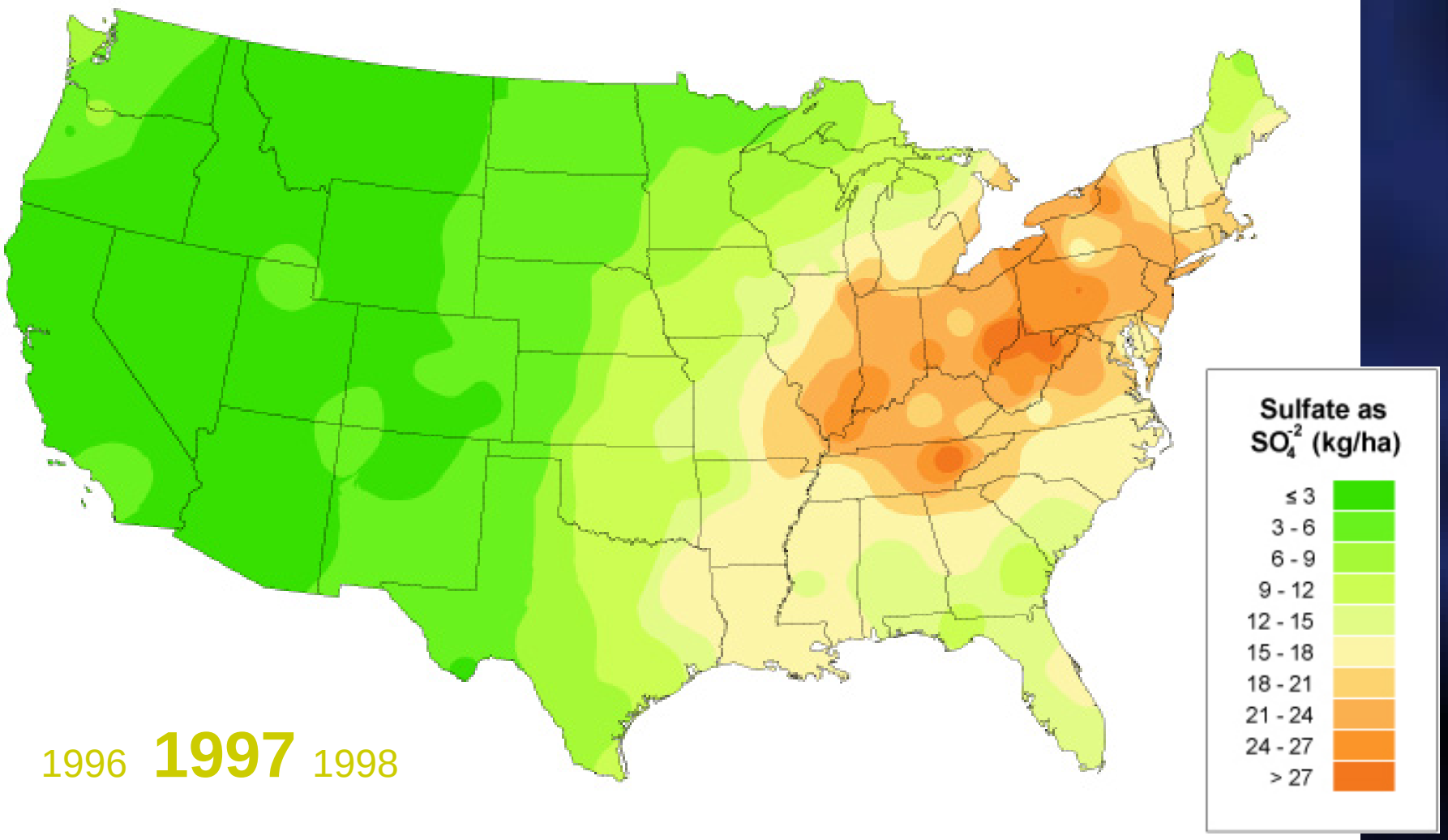

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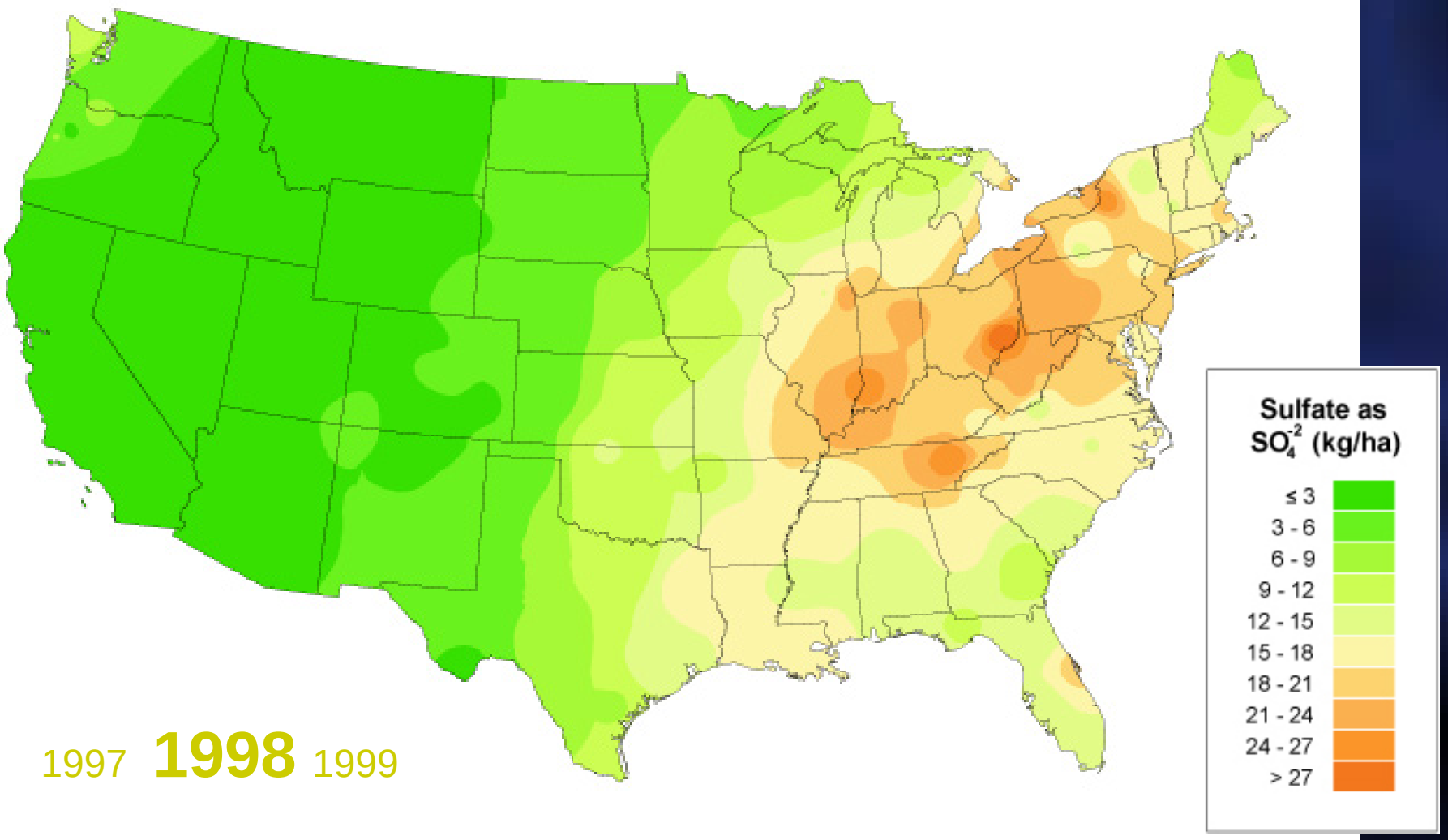

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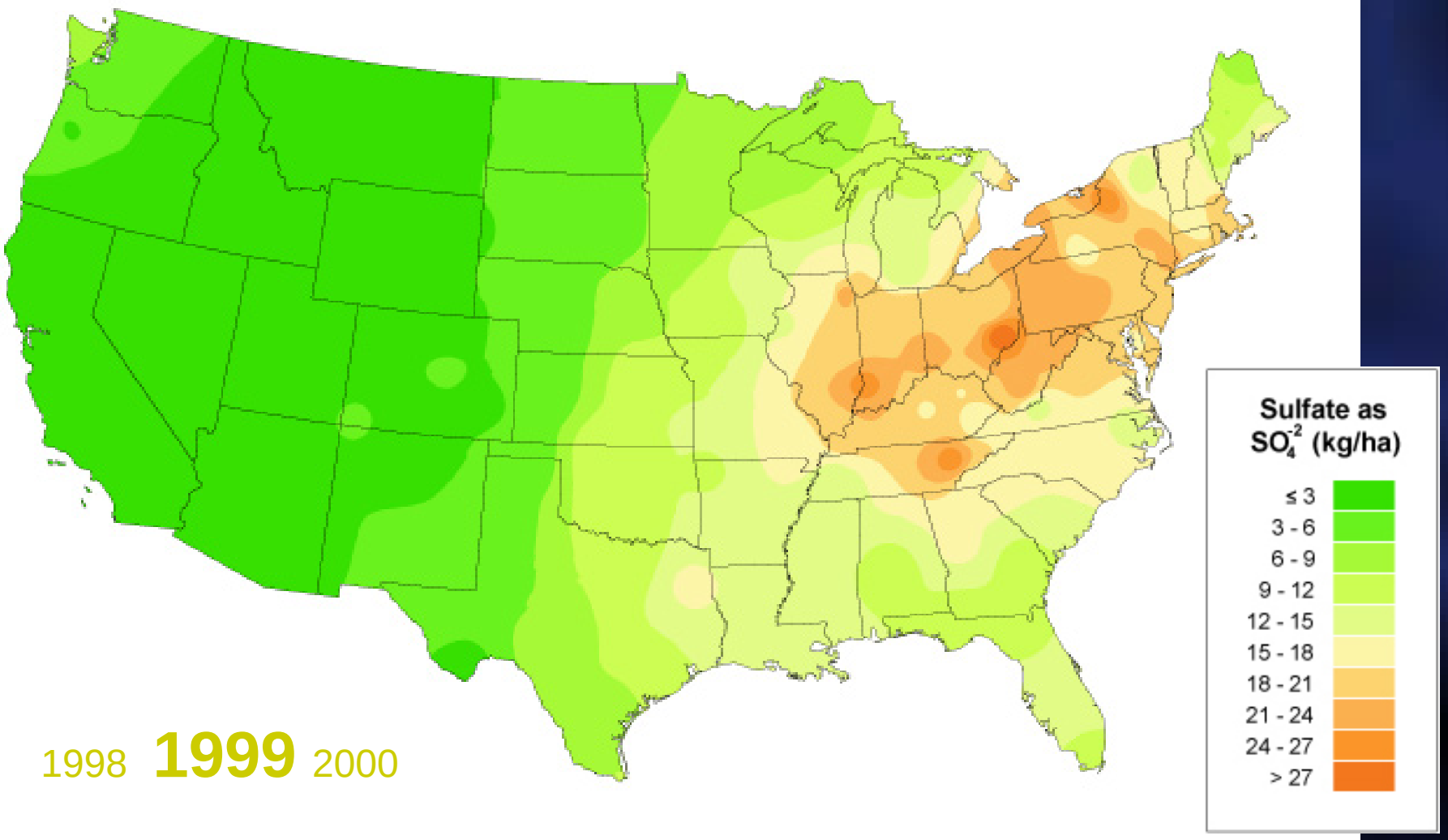

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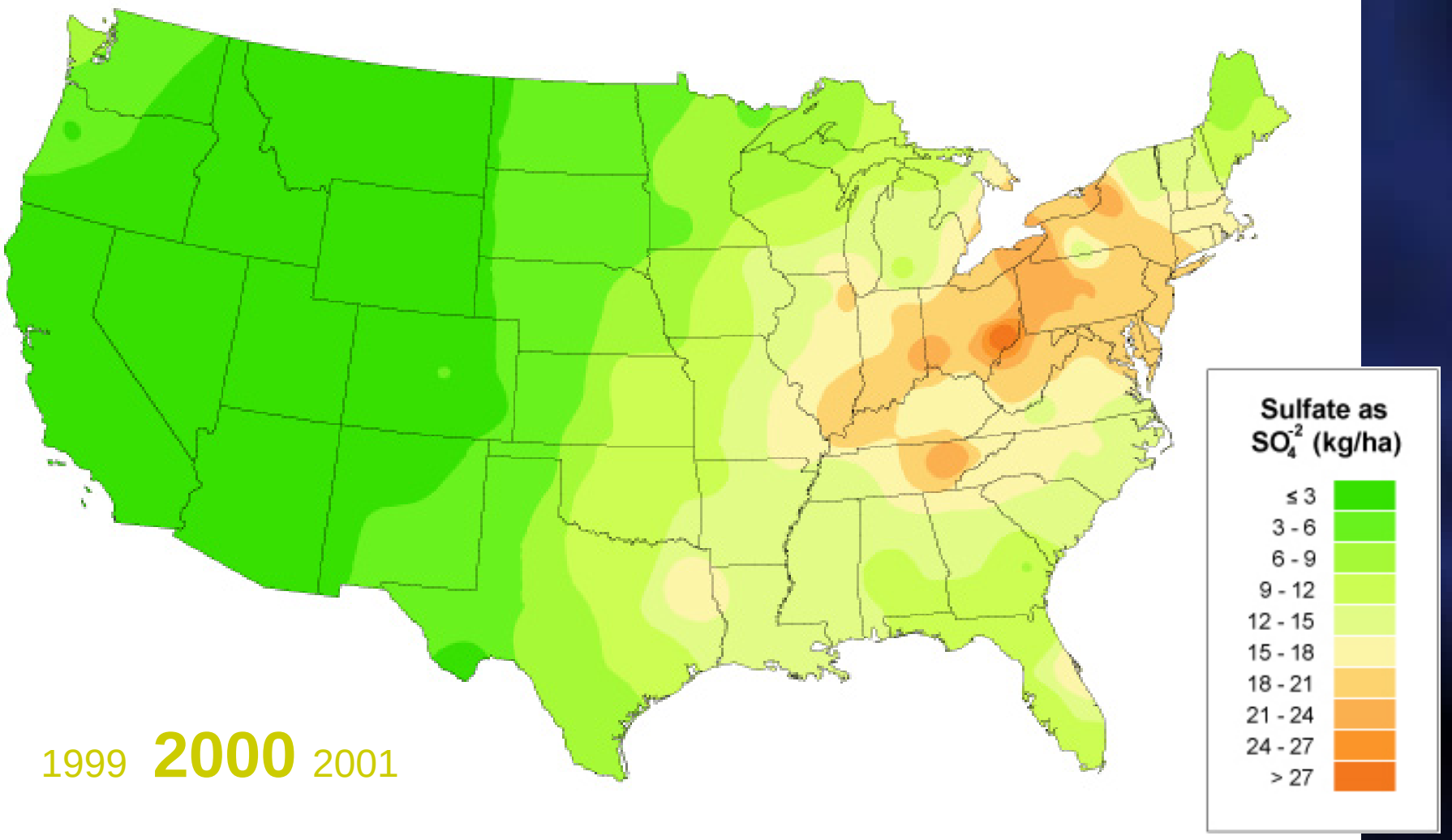

1999 **2000** 2001

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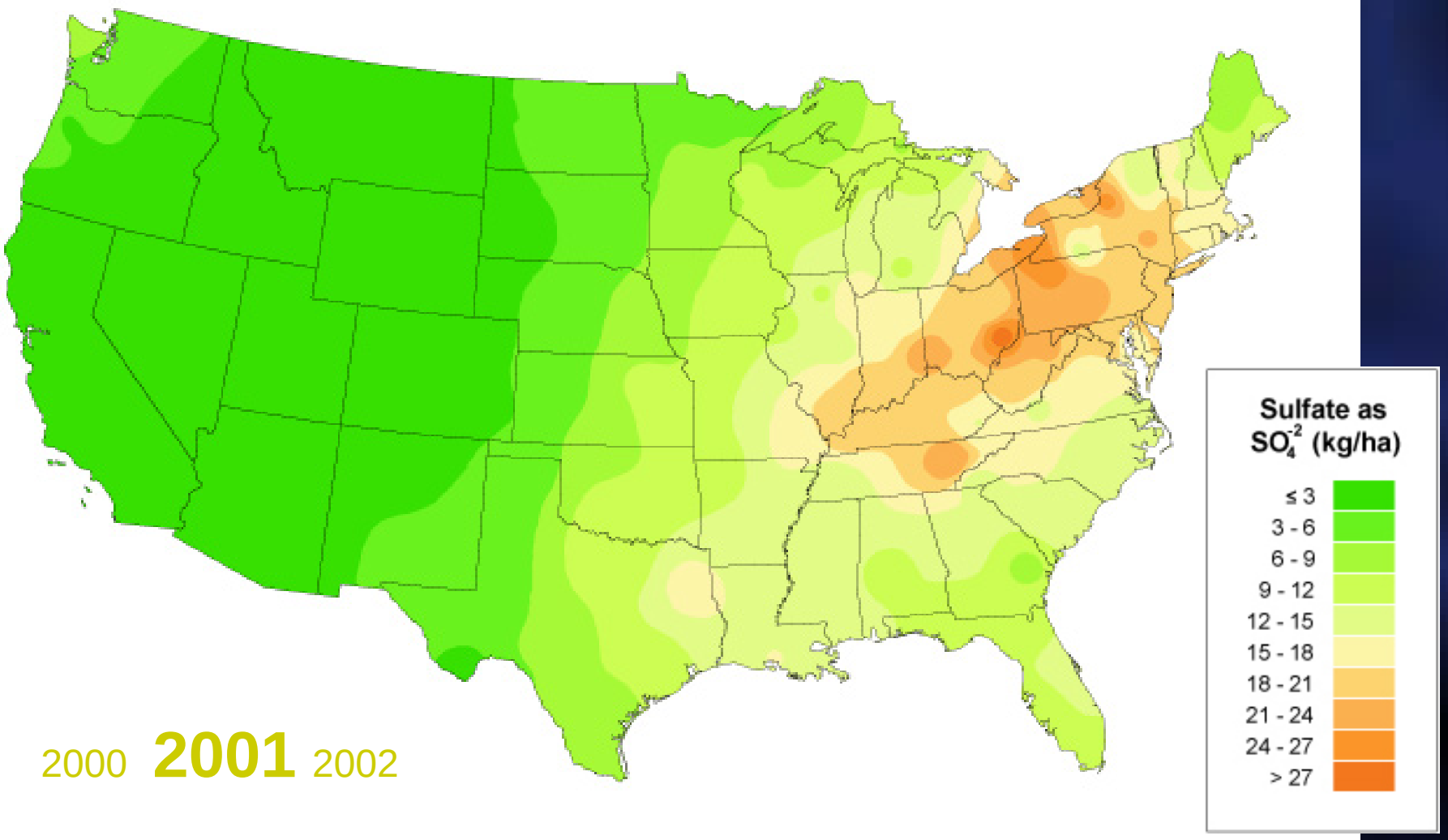
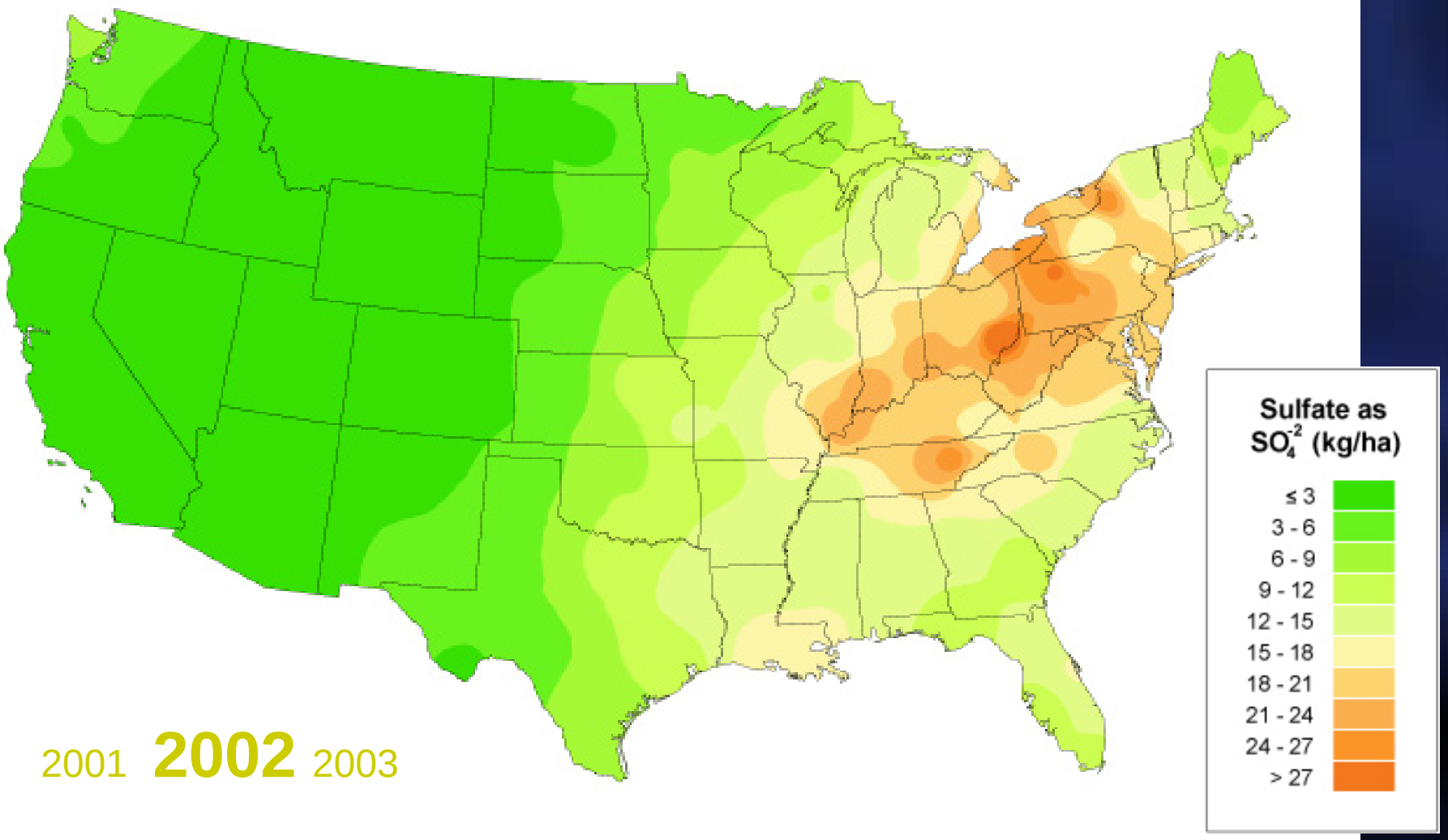


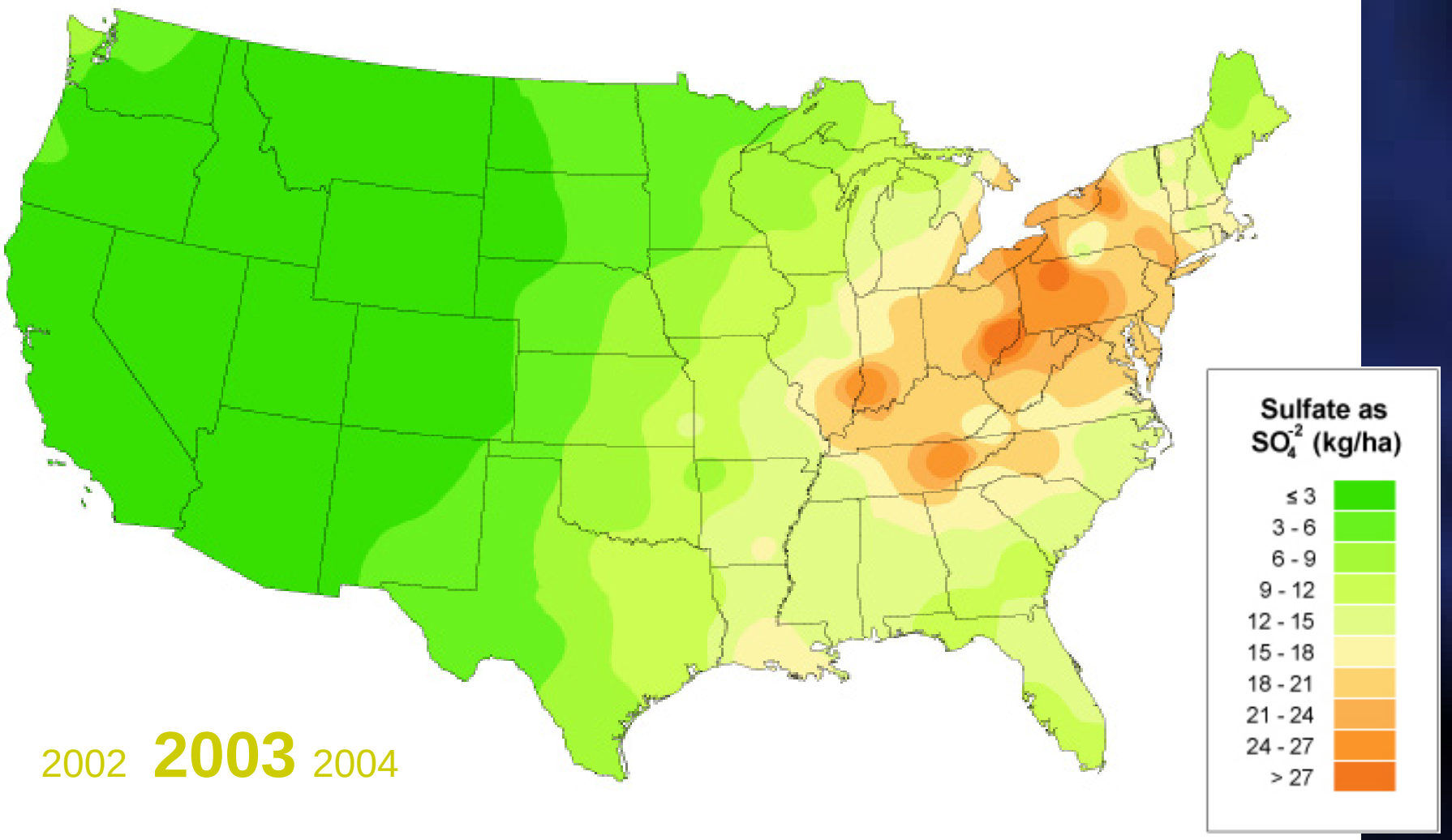
2000 **2001** 2002

Sulfate Ion Wet Deposition 1985-2005



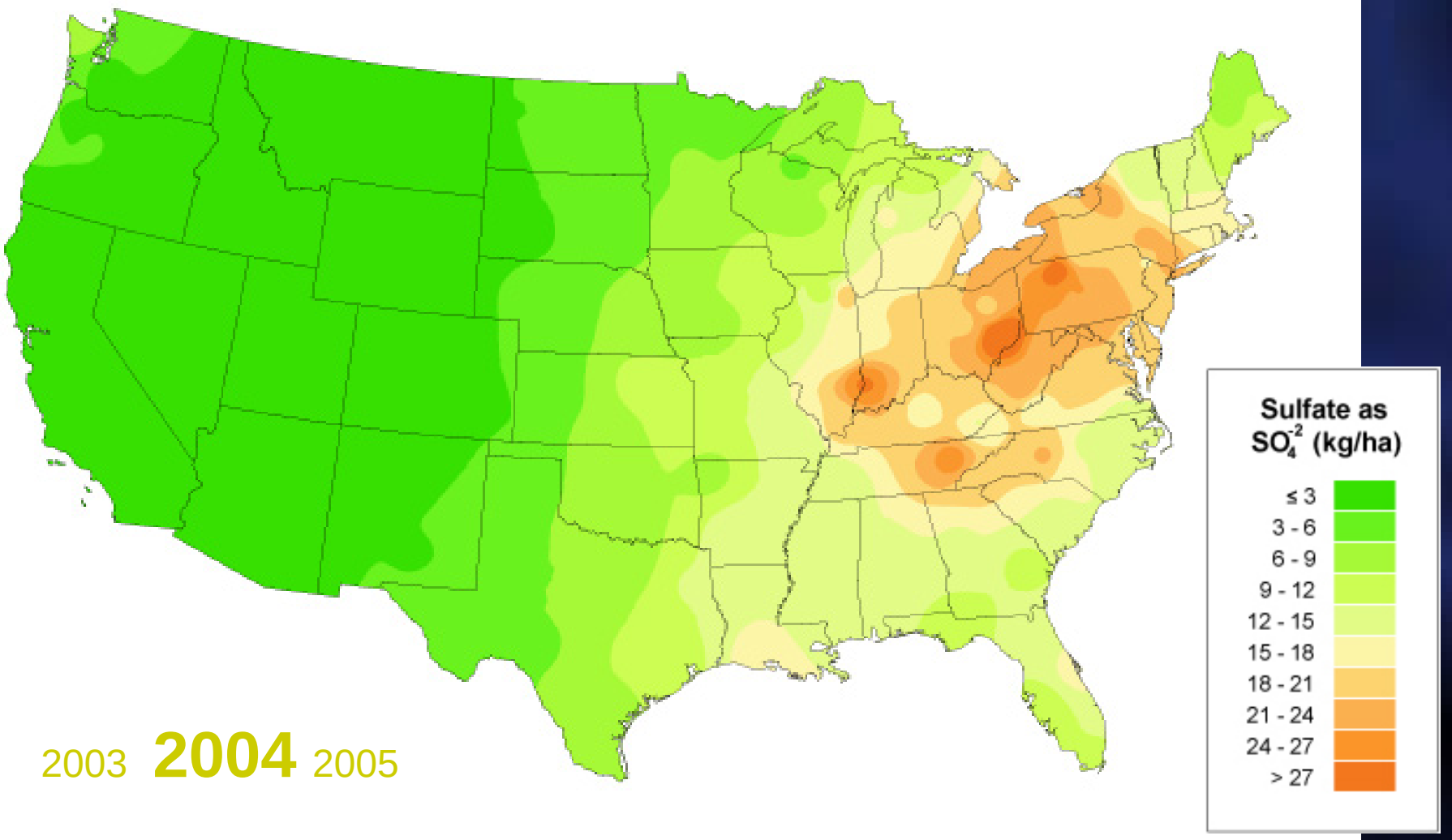
2001 **2002** 2003

Sulfate Ion Wet Deposition 1985-2005



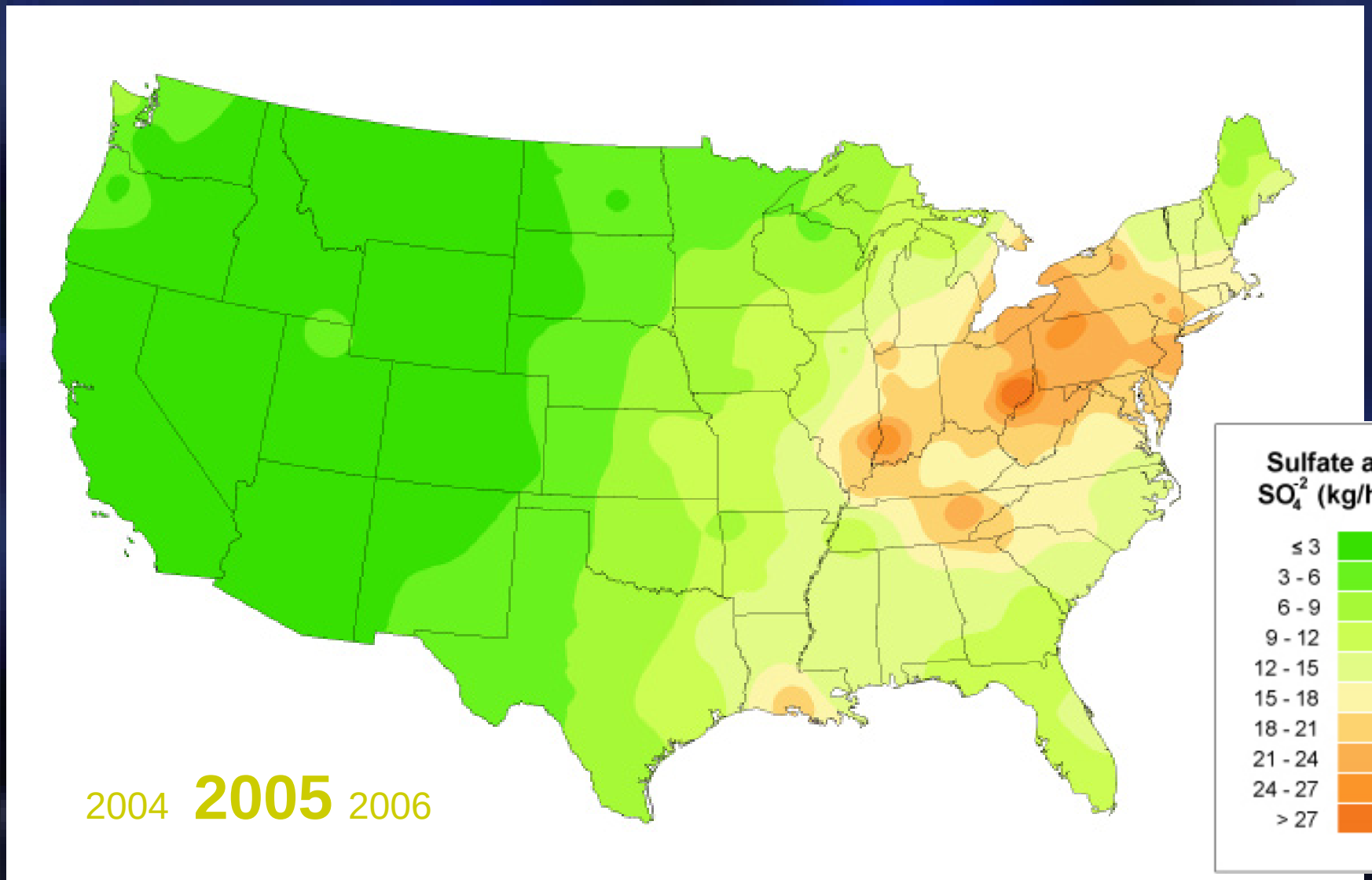
2002 **2003** 2004

Sulfate Ion Wet Deposition 1985-2005



2003 **2004** 2005

Sulfate Ion Wet Deposition 1985-2005



2004 **2005** 2006

North Central Region S Testing Status

- Most prevalent in the more northerly and westerly areas of the region
- Areas with less concentrated industry
- S soil test has traditionally been thought of as not being reliable or repeatable

States Offering a S Soil Test

- Kansas
- Minnesota
- Missouri
- North Dakota
- South Dakota
- Wisconsin
- Others …
- All use monocalcium phosphate (NCR-13 method)

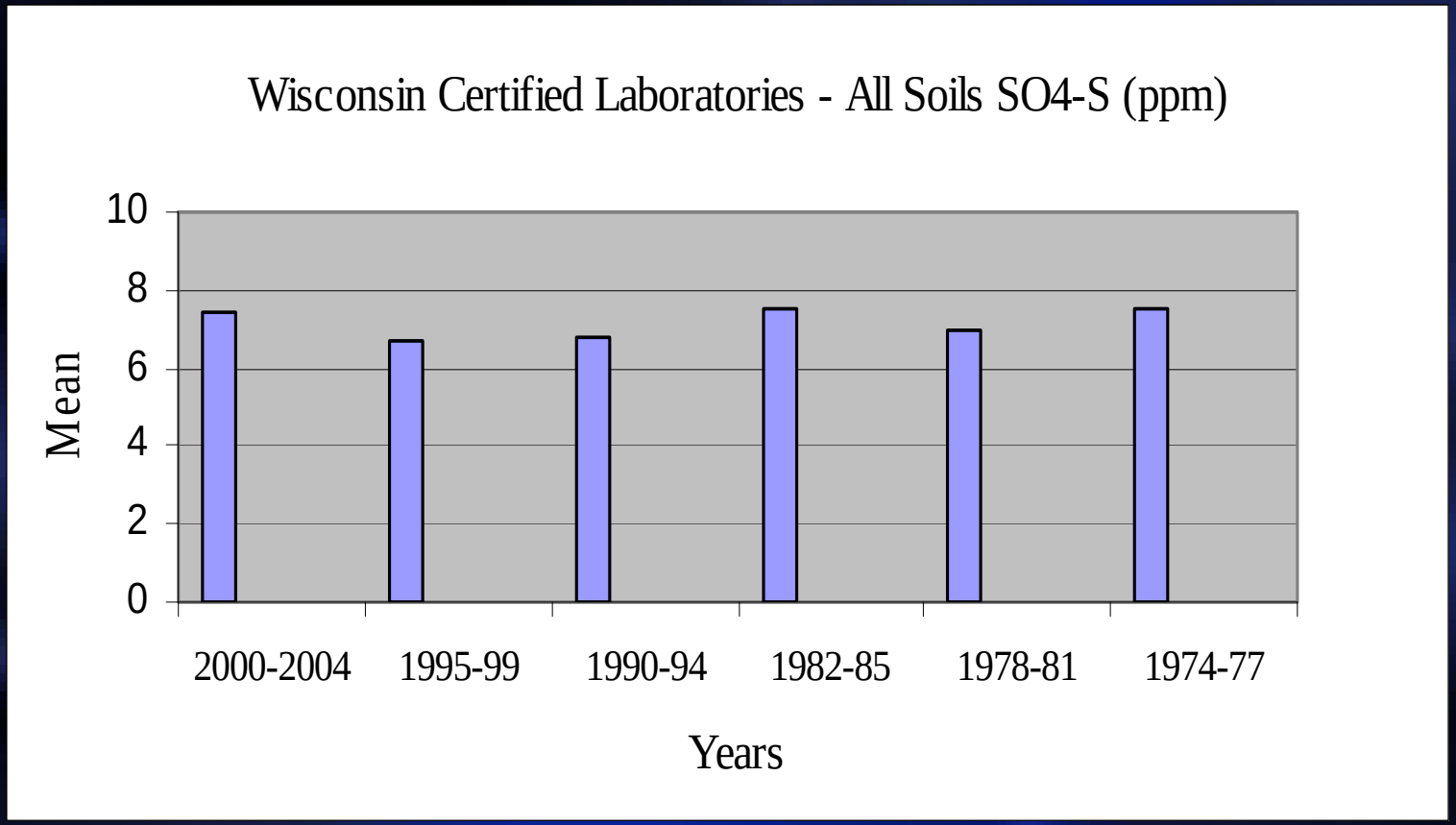
Experiences with the Sulfur Soil Test

- Not as precise as test for P or K
- Measures SO_4-S
- Ignored S from other sources
- Tells when adequate; may not help when results are marginal or low
- Plant analysis encouraged

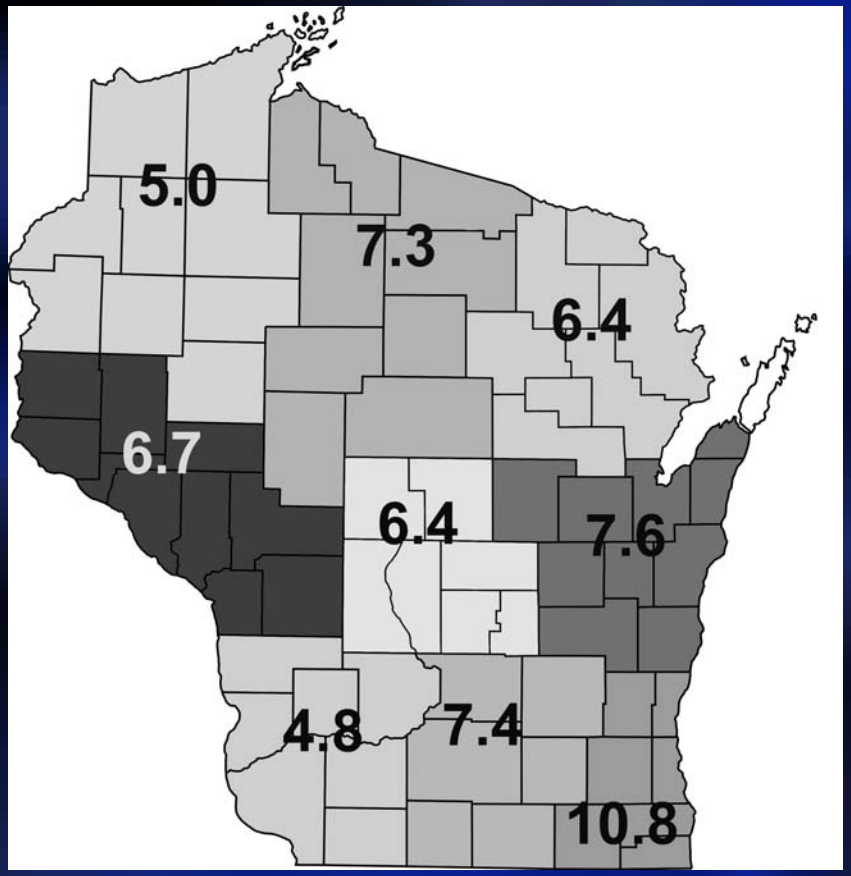
Percent of samples in various sulfur soil test ranges in Wisconsin

Period	Test Range (ppm) 0-5 (VL)	5-10 (L)	10-15 (M)	>15 (H)
	---------- % of samples ----------			
1974-77	49	29	12	10
1977-81	46	36	11	7
1982-85	41	38	13	8
1995-99	53	32	8	7
2000-04	54	32	5	8

Sulfate-S in Plow Layer Samples

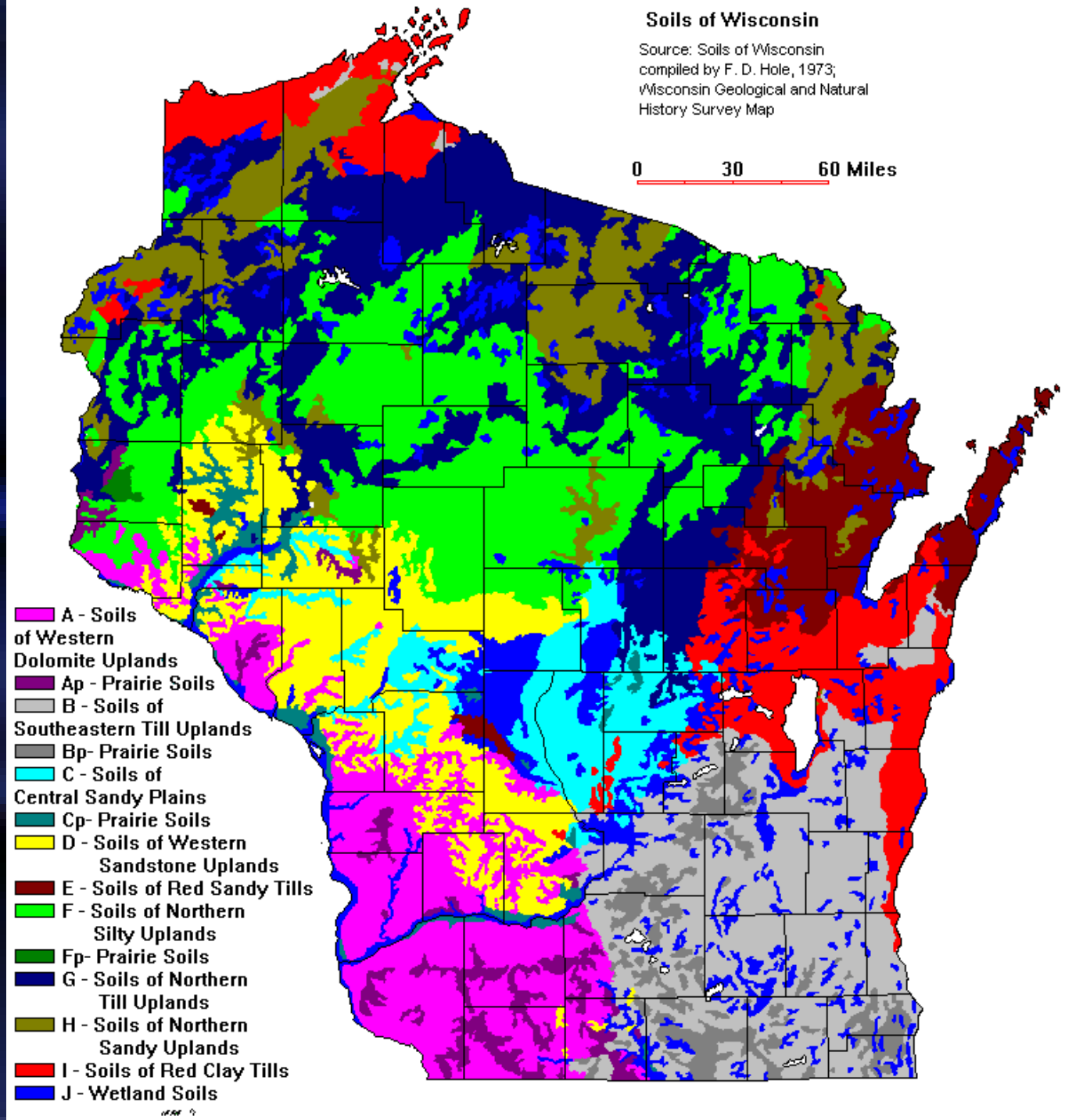


Average SO_4-S soil test levels, by region (2000-04)

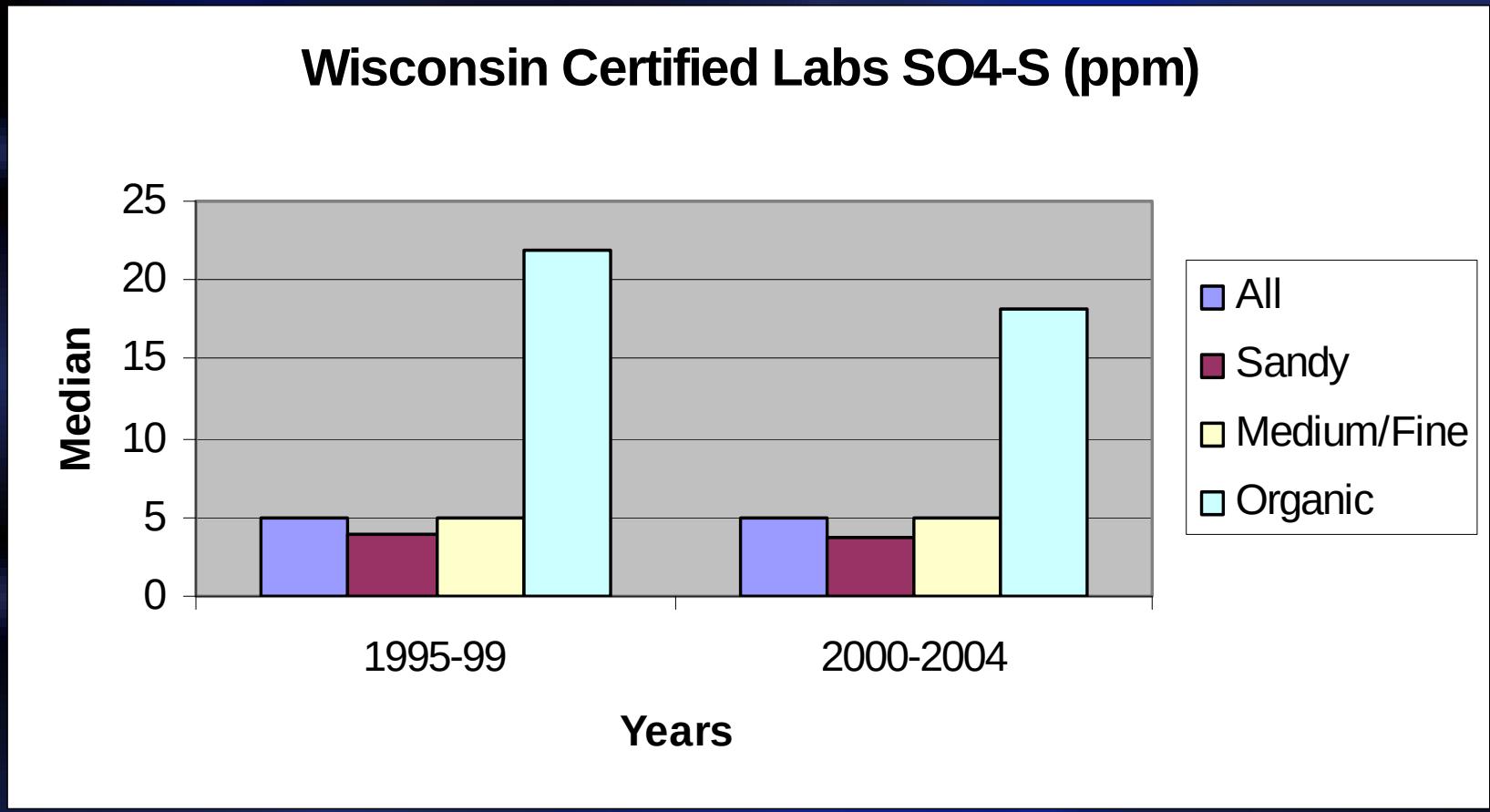


The Wisconsin Approach:

1. Sulfur need in northern and western Wisconsin identified in late 1960's
   - Sandy, low organic matter, no manure
2. Soil test tells half the story; plant analysis encouraged


Soils of Wisconsin
Source: Soils of Wisconsin compiled by F. D. Hole, 1973; Wisconsin Geological and Natural History Survey Map
0 30 60 Miles
A - Soils of Western Dolomite Uplands
Ap - Prairie Soils
B - Soils of Southeastern Till Uplands
Bp- Prairie Soils
C - Soils of Central Sandy Plains
Cp- Prairie Soils
D - Soils of Western Sandstone Uplands
E - Soils of Red Sandy Tills
F - Soils of Northern Silty Uplands
Fp- Prairie Soils
G - Soils of Northern Till Uplands
H - Soils of Northern Sandy Uplands
I - Soils of Red Clay Tills
J - Wetland Soils

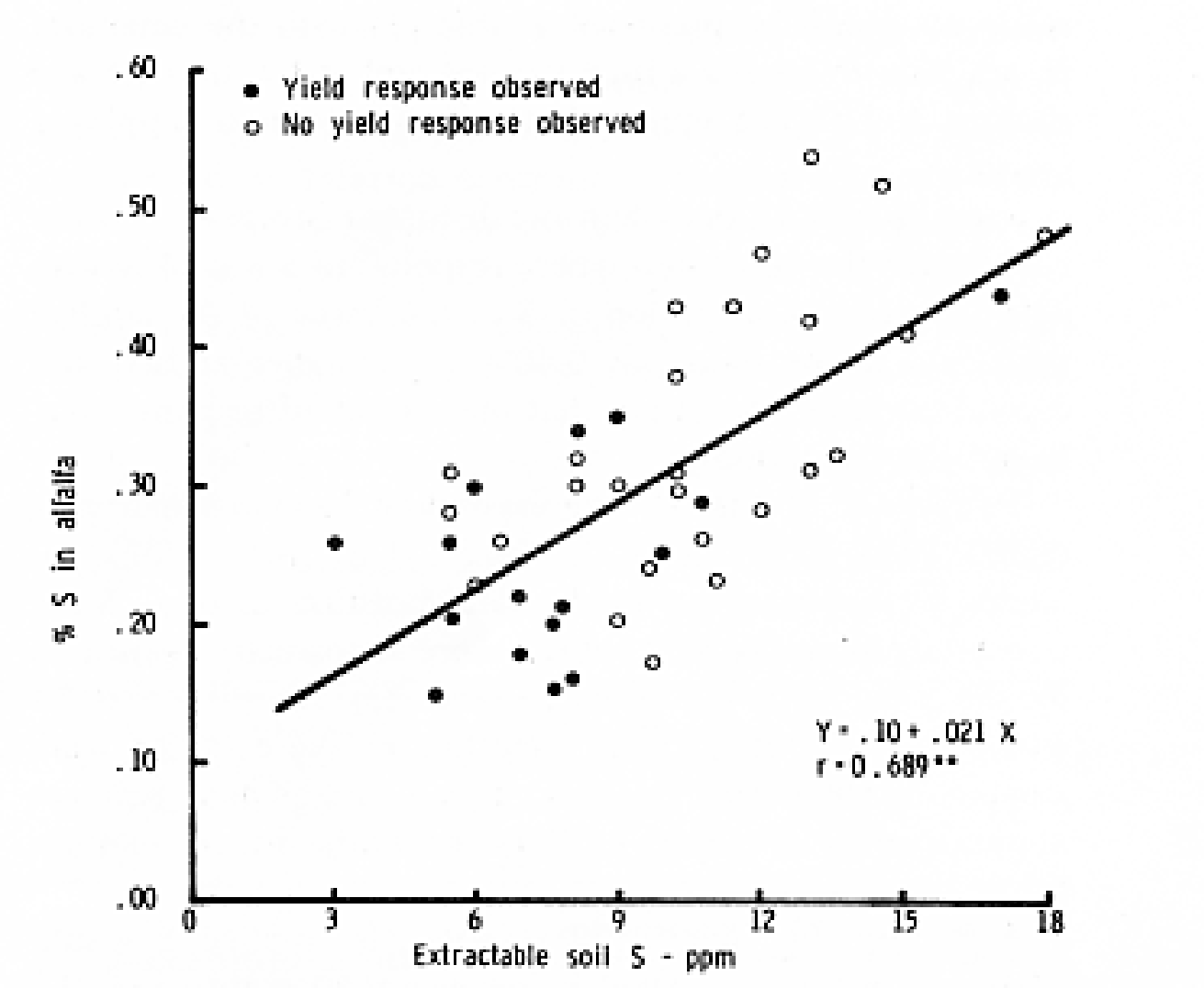
Sulfate-S in Plow Layer of Various Texture Soils



Situation Changing in WI:

- Reports of deficiency in southern and eastern Wisconsin on older stands
- Measured responses at Arlington (high organic matter, southern soil) in 1996 and 1997
- Less S in precipitation

Relationship between soil test S and alfalfa tissue S

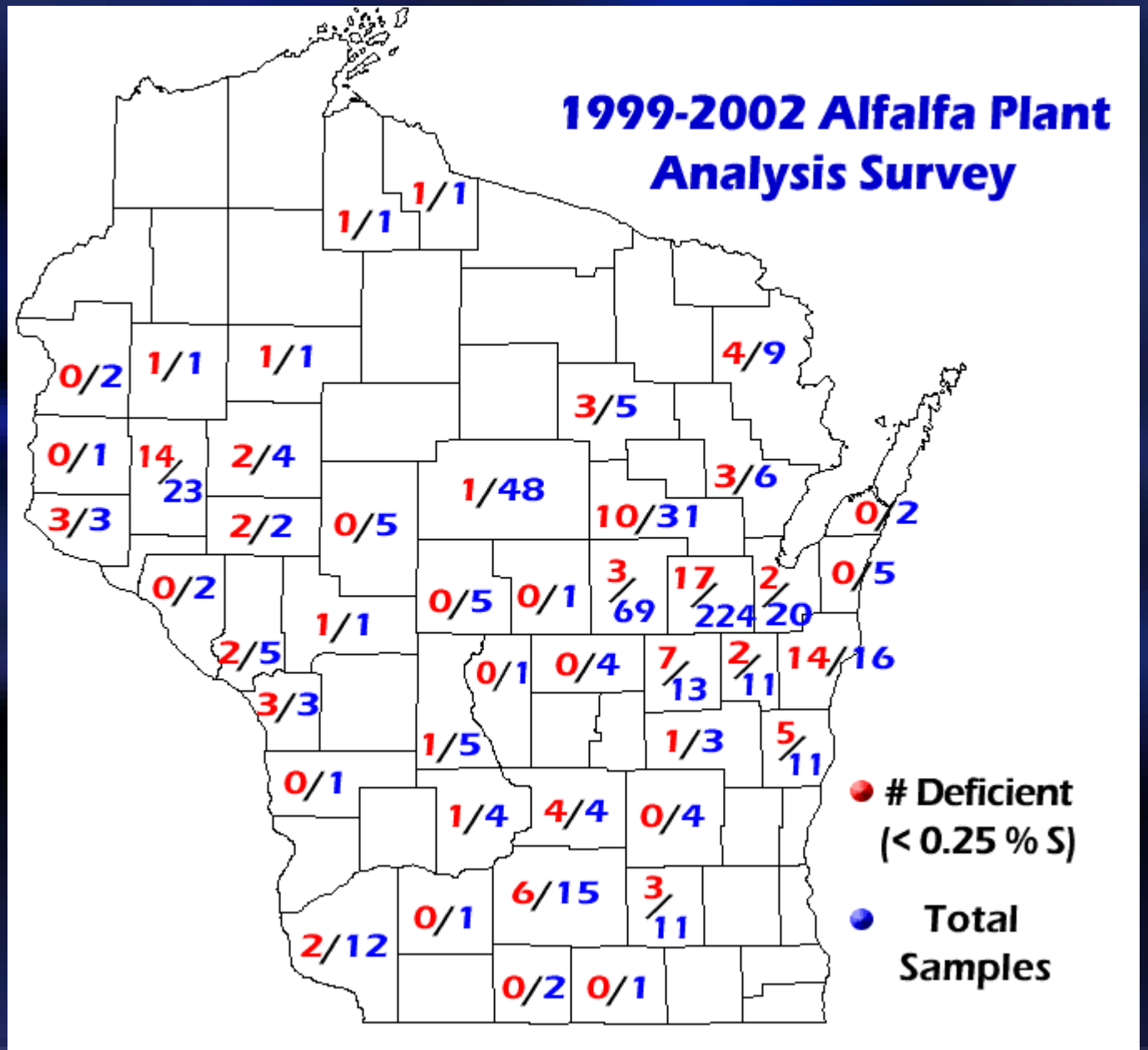


Adapted from Hoeft el al., 1973

Wisconsin Alfalfa Sulfur Survey:

- Sample numbers:
  - 53 in 2000
  - 72 in 2001
  - 5 in 2002
- Obtained routine alfalfa results from WI labs
  - 462 samples 1999-2002
- 44 counties represented
- Tissue S data:
  - 0.09 to 0.58%
  - 55 of 140 samples < 0.25% S
  - 40 of 462 samples < 0.25% S

Sulfur Deficiency More Common



Results of this survey:

- Sulfur deficiency possible in southern Wisconsin on medium-textured soils
- Precipitation S over-weighted

SULFUR AVAILABILITY INDEX (SAI)

- A tool to predict the need for sulfur fertilization
- Estimates the amounts of sulfate-S provided from various sources:
  - Soil
  - Organic Matter
  - Subsoil
  - Precipitation
  - Manure

SULFUR AVAILABILITY INDEX (SAI)

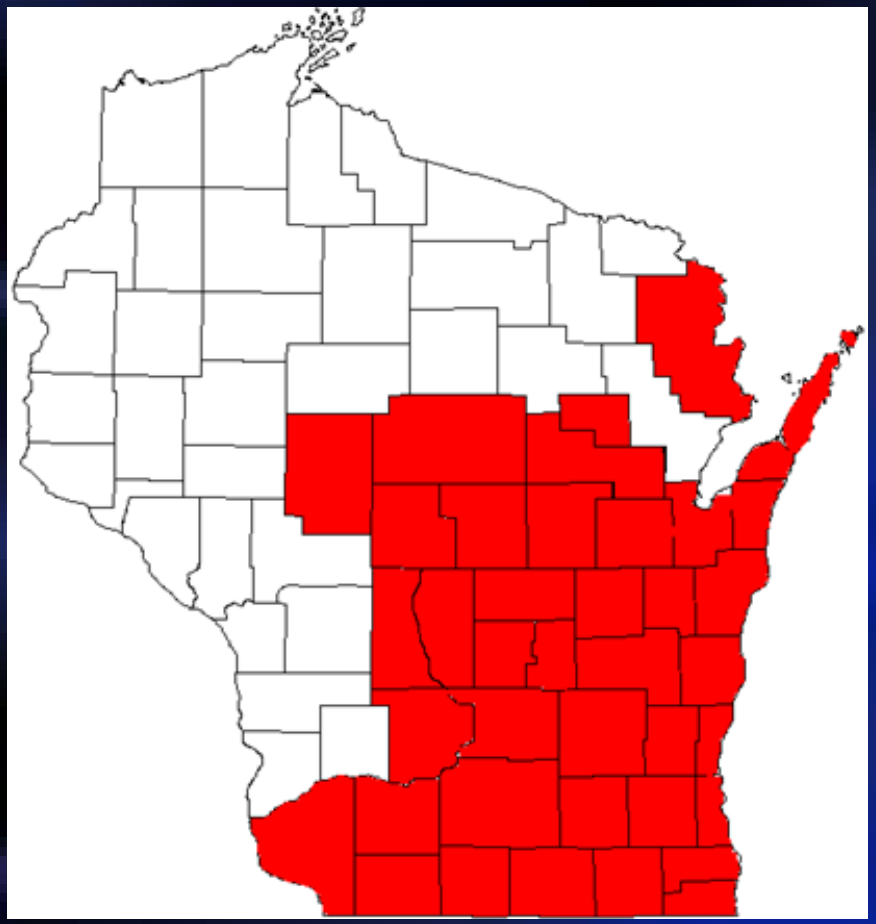
= Sum of available S inputs:

- Organic matter – 2.8 lb S/a for 1% OM
- S in rain & snow – 5, 10, or 15 lb S/a
- S in subsoil 5, 10, or 20 lb S/a
- S in manure – depends on rate, kind
- Soil sulfate-S test (x 4)

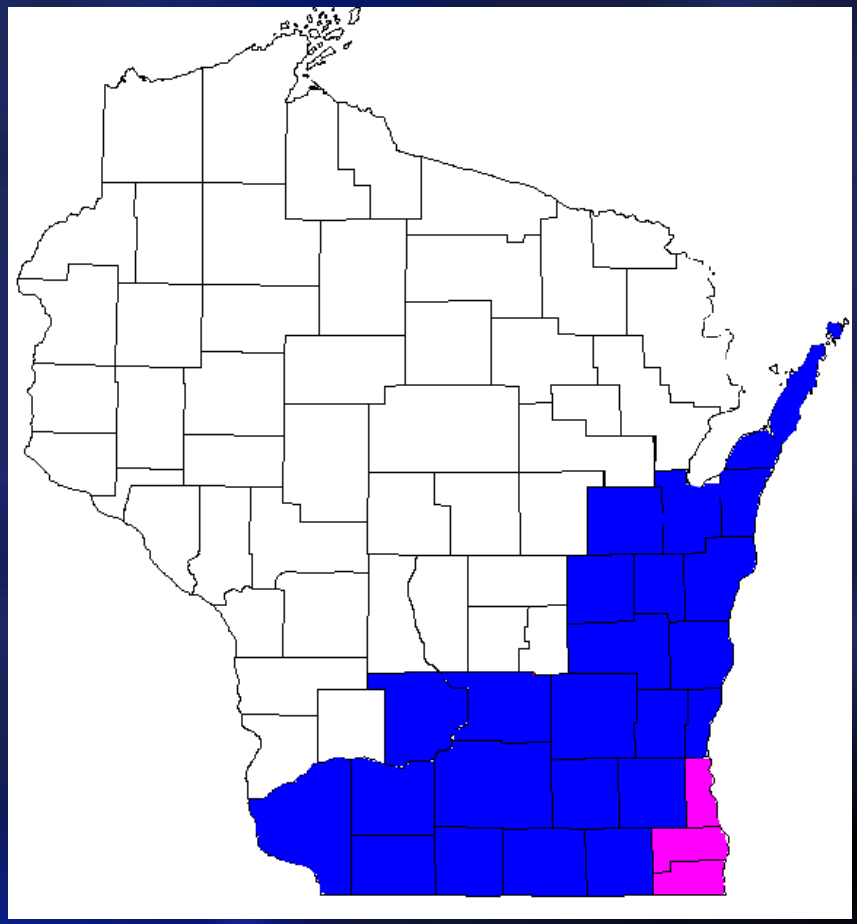
Sulfur deposition at selected Wisconsin locations

Location	1969-71	1985-87
	---------- lb S/a/yr ----------	
Arlington	36	21
Lancaster	50	20
Marshfield	46	20
Spooner	12	9

Changed precipitation S



20 lb/a 10 lb/a



10 lb/a 5 lb/a

15 lb/a

Changed subsoil S

Subsoil group	Old	New
	--------- lb S/a ----------	
A	5-10	5-10
B	10	10
C	10	5
D	5-20	5-10
E	5-10	5
O	20	20

Available sulfur from several types of manure

Animal type	Sulfur content			
	Solid (lb S/ton)		Liquid (lb S/1000 gal)	
	Total	Avail.	Total	Avail.
Beef	1.6	1	4.7	3
Dairy	1.5	1	4.2	2
Poultry	3.9	2	9.1	5
Swine	2.7	1	2.4	1

SAI Interpretation:

- < 30 = Apply S to S-demanding crops
- 30-40 = Confirm S need by plant analysis
- > 40 = No additional S needed

Crops most likely to respond to S additions
Email survey of NCR-13 representatives, Jan. 2007

State	Crop response	Conditions favoring crop response
Iowa	alfalfa in NE Iowa	
Indiana	wheat, alfalfa	low OM, cool soils
Kansas	corn	check S level in irrigation water
Michigan	alfalfa, canola, wheat>corn>soybean	sandy, low OM soils
Minnesota	corn, barley, wheat, forages, corn	recs. Based on OM, not soil test
Missouri	row crops, small grains, alfalfa	sandy, low OM soils with sulfate-S < 7.5 ppm
North Dakota	canola	always recommend, regardless of the soil test level
Ontario	canola	responses rare
South Dakota	corn>wheat>soybeans	no-till, and low OM fields
Wisconsin	alfalfa, corn, small grain, vegetable and fruit crops	low OM, far from urbanized areas

Most frequently tested crops using plant analysis (2003 – 2007)

Crop	Type	Avg	Critical Level
		----------% S ----------	
Alfalfa	Top 6”	0.31	0.25
Apple	Fully developed leaf at midpoint of new shoots	0.15	0.14
Cranberry	Growth above berries	0.13	0.08
Field Corn	Ear Leaf	0.20	0.16
Field Corn	Whole Plant	0.21	0.15
Soybean	Newest fully developed leaf	0.27	0.38

Samples Analyzed By:
UW Soil & Plant Analysis Lab
8452 Mineral Point Rd
Verona, WI 53593
(608) 262-4364

PLANT ANALYSIS REPORT

COOPERATIVE EXTENSION
University of Wisconsin-Extension
University of Wisconsin-Madison
Department of Soil Science, Madison, WI

Client:
Soil & Forage Analysis Lab
8396 Yellowstone Dr.
Marshfield, WI 54449

Send to:
Soil & Forage Analysis Lab
8396 Yellowstone Dr.
Marshfield WI, 54449

Account: 555901

Lab Information

Lab Number:	12345
Date received:	7/22/2002
Date processed:	1/2/2007
County:	Dane

Sample Information

Sample ID:	1
Field:	1
Crop:	Field corn
Growth Stage:	Tassel to silk
Plant Part:	Ear leaf
Appearance:	Normal
Soil Submitted:	Yes

SUFFICIENCY RANGES

Plant Results

Element		Low	Sufficient	High
N	(%)	1.00		
P	(%)	0.10		
K	(%)		1.90	
Ca	(%)	0.15		
Mg	(%)	0.10		
S	(%)	0.12		
Zn	(ppm)		32.00	
B	(ppm)		8.00	
Mn	(ppm)		31.00	
Fe	(ppm)			232.00
Cu	(ppm)		4.00	

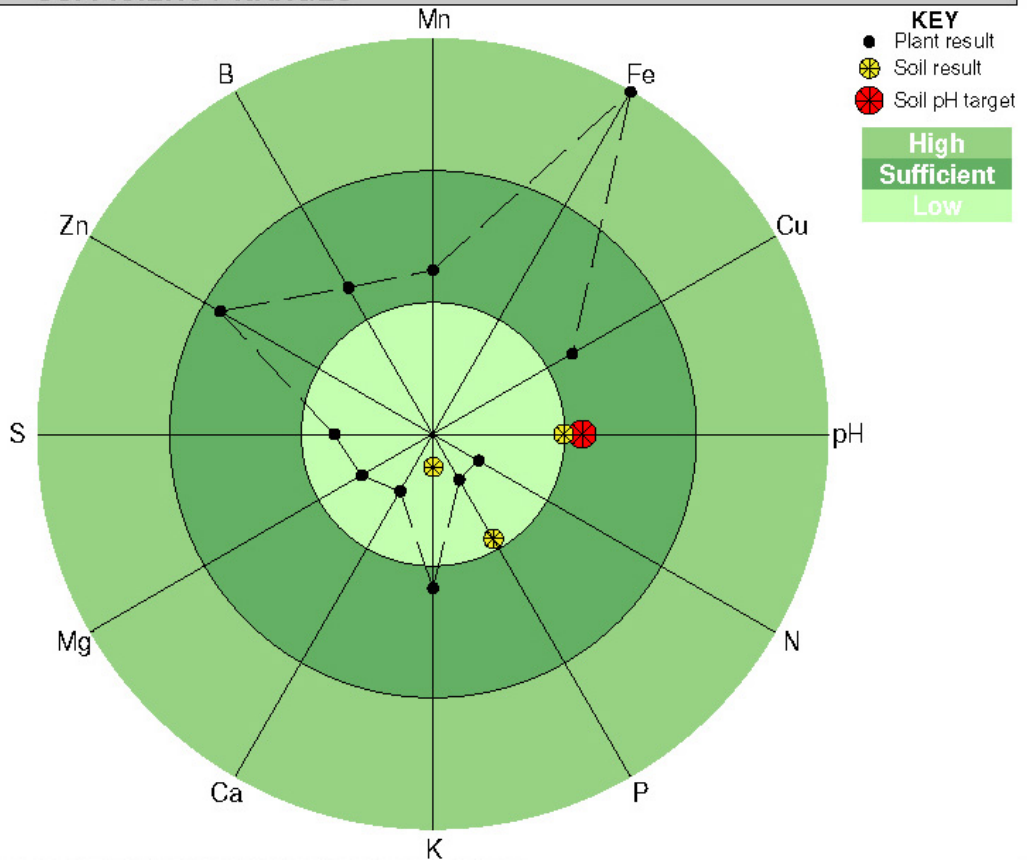
Al	(ppm)	450.00
Na	(ppm)	151.00

Soil Results

pH: 5.8, target pH = 6.0
OM: 3.0%

Element			Optimum	
P	(ppm)	10 L		
K	(ppm)	30 VL		

Note: L = Low, VL = Very Low, H = High, VH = Very High, E = Excessive



Sources of sulfur fertilizer

Name of fertilizer	Chemical formula	Fertilizer analysis (%) $N\text{-}P_2O_5\text{-}K_2O$	Sulfur Content (%)
Very soluble:			
Ammonium sulfate	$(NH_4)_2SO_4$	21-0-0	24
Potassium sulfate	K_2SO_4	0-0-50	18
Potassium-magnesium sulfate	$K_2SO_4 \cdot 2MgSO_4$	0-0-22	23
Ammonium thiosulfate	$(NH_4)_2S_2O_3$	12-0-0	26
Magnesium sulfate	$MgSO_4 \cdot 7H_2O$	0-0-0	14

Sources of sulfur fertilizer

Name of fertilizer	Chemical formula	Fertilizer analysis (%) $N\text{-}P_2O_5\text{-}K_2O$	Sulfur Content (%)
Slightly soluble:			
Calcium sulfate (gypsum)	$CaSO_4 \cdot 2H_2O$	0-0-0	17
Insoluble:			
Elemental sulfur	S	0-0-0	88-98

Suggested treatments for sulfur deficiencies

Crop	Sulfur needed
	-- lb S/acre --
Forage legumes:	
Incorporated at seeding	25 - 50
Topdressed on established stand	15 - 25
Corn, small grains, vegetables & fruits	10 - 25

Summary

- Is there a greater potential for crop response to S applications in Wisconsin now than in the past?
- In addition to soil testing is there a need for additional tools to aid in making sound S nutrient application decisions?
- Consider – crop to be grown, soil texture, soil OM, atmospheric S, subsoil S, S in irrigation water, recent manure applications


Any questions?