THE OHIO STATE UNIVERSITY
COLLEGE OF FOOD, AGRICULTURAL, AND ENVIRONMENTAL SCIENCES

Managing for a delicious ecosystem service under a changing climate: can sugar maple (Acer saccharum) syrup provision be maintained in a warming climate?

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The Sugar Maple tree (*Acer saccharum*)

Native Americans taught the colonists about making maple syrup

Collecting Sugar Maple Sap
late winter-early spring for about 4-6 weeks

Historical – small scale

Modern – large scale

Creating Maple Syrup
40:1 ratio – evaporate!

Historical – small scale

Modern – large scale

What makes for a good sap flow?

Sap flow is primary temperature dependent, with some influence of conditions of prior growing season (influence carbohydrate storage)

1. Cold nights (< 0C) followed by warm days (~3-7C) creates positive differential.

2. Repeating cold-warm temperature cycles necessary to sustain flow and economic production of syrup.

3. When temperatures are consistently too warm (>10C) and bud break begins, the traditional sap season is over.

4. **New technology can extend and make for more productive seasons but these conditions also still show strong latitudinal gradients!**

What makes for a good sap flow?

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1. Cold nights (< 0C) followed by warm days (~3-7C) creates positive differential.

2. Repeating cold-warm temperature cycles necessary to sustain flow and economic production of syrup. **More sustained in Northern locations and slower thaw best for production**

3. When temperatures are consistently too warm (>10C) and bud break begins, the traditional sap season is over. **Happens quicker in south**

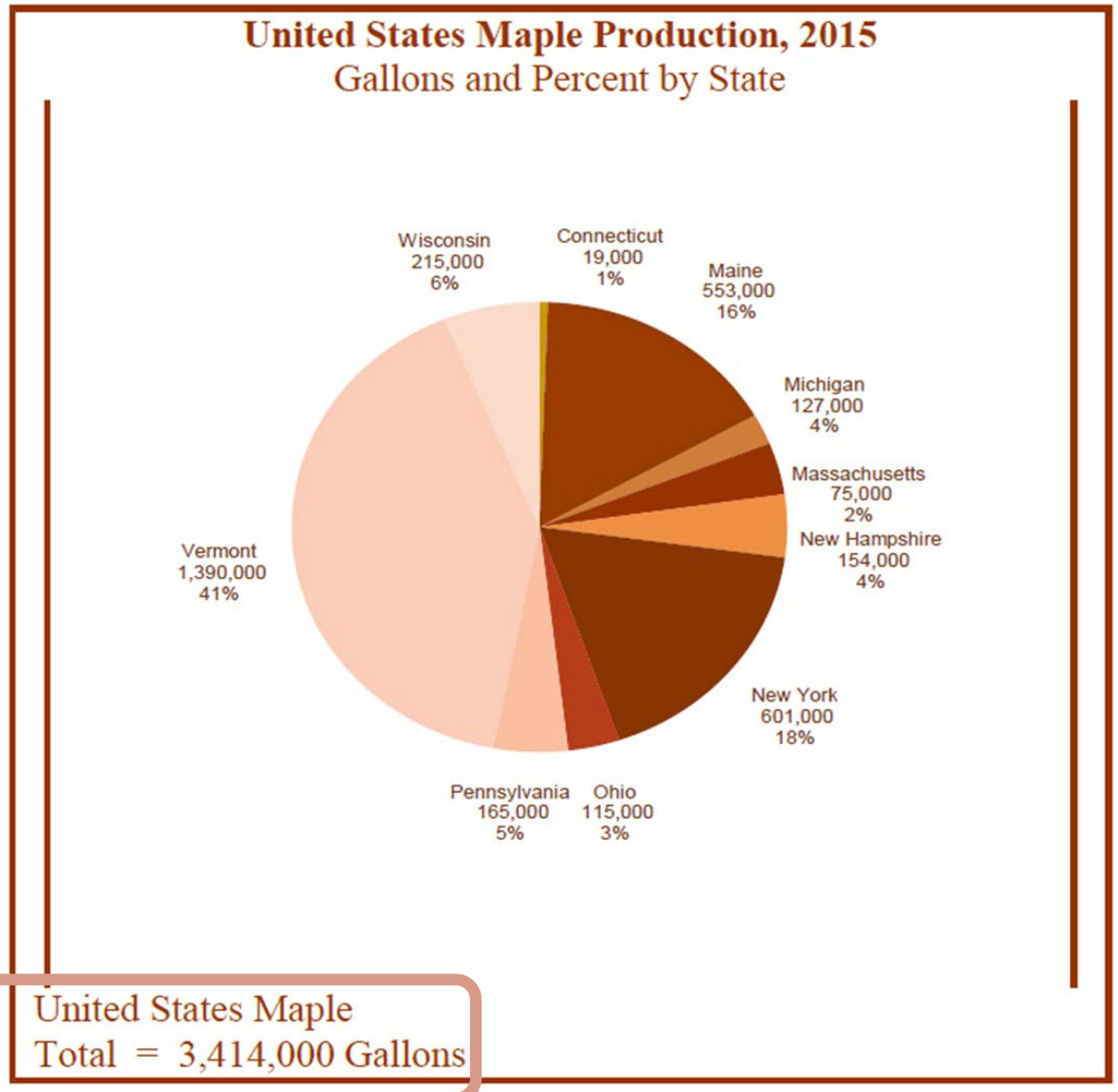
4. **New technology can extend and make for more productive seasons but these conditions also still show strong latitudinal gradients!**

Objectives

- What are spatial patterns of sugar maple trees, taps, and production of syrup now?
- What might be the impact of a changing climate on these patterns?

Maple Syrup is North American
73% in Canada, 27% in US

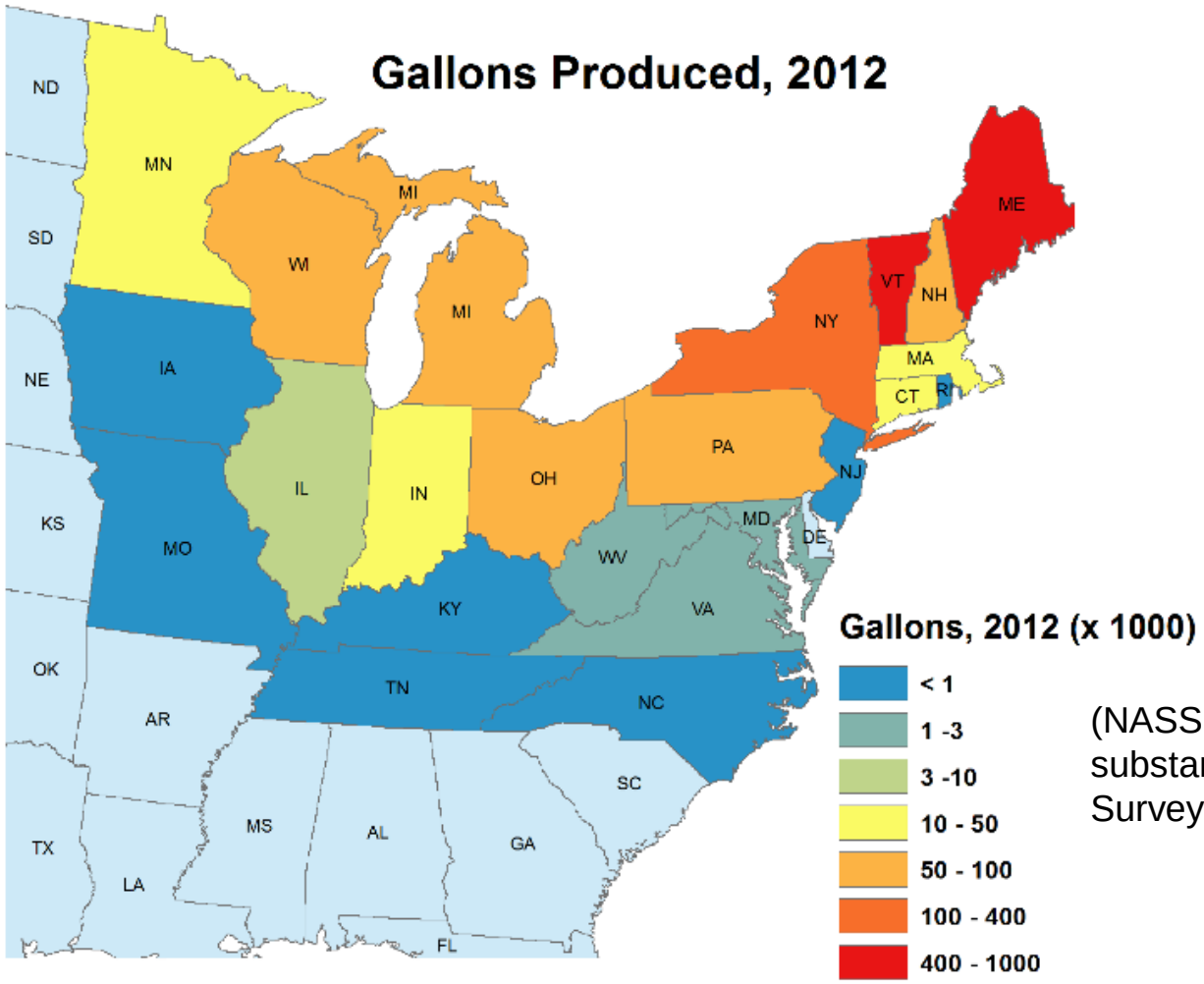
41% of US syrup from Vermont
18% from New York
16% from Maine
Rest of states < 6%



Gallons of syrup (*3.79 for liters)

Calculates to ~$136 million value of syrup in US, and about 3x that in Canada.

Gallons Produced by State, 2012



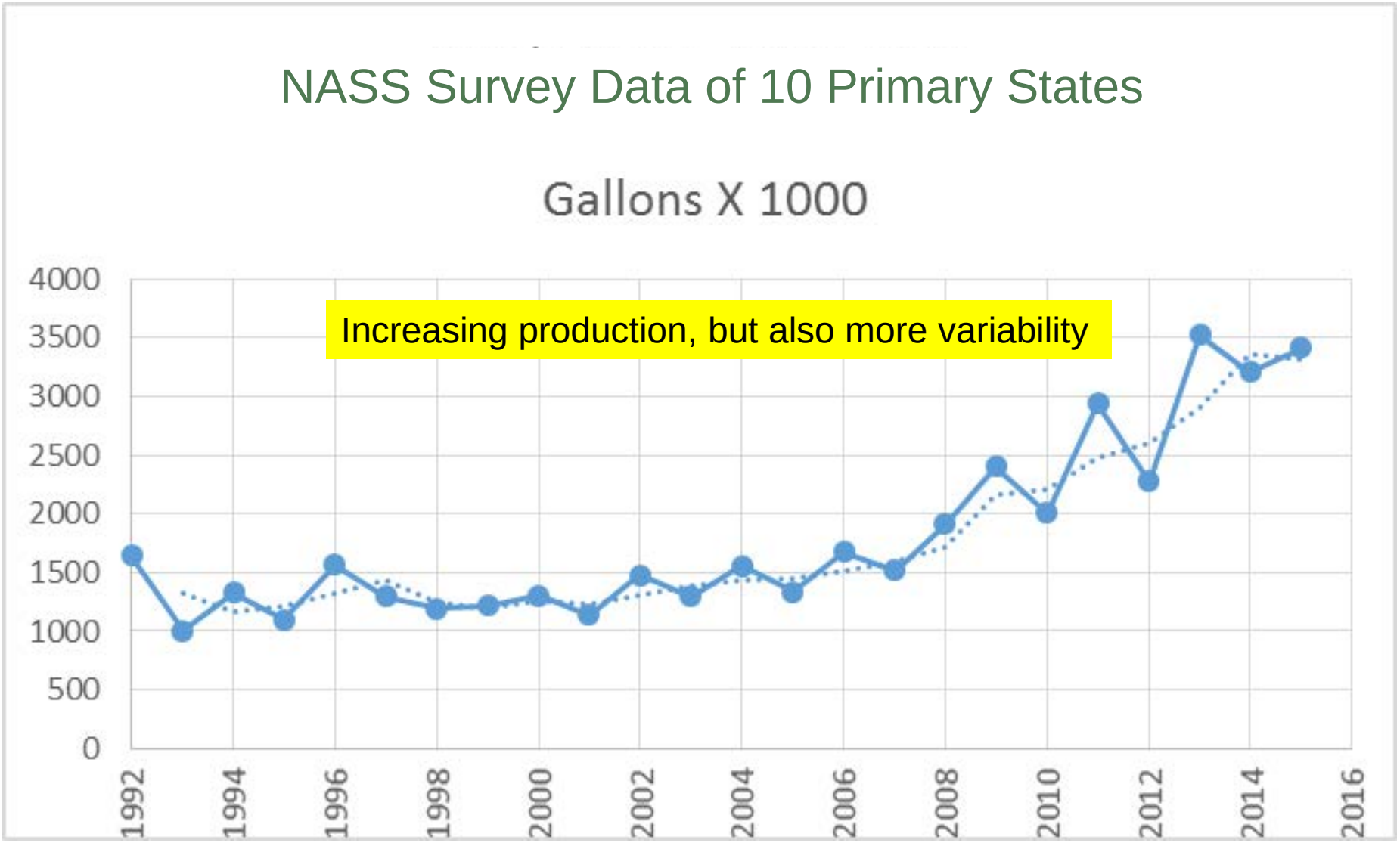
Total via NASS: 2.3 million

1.0 m from VT

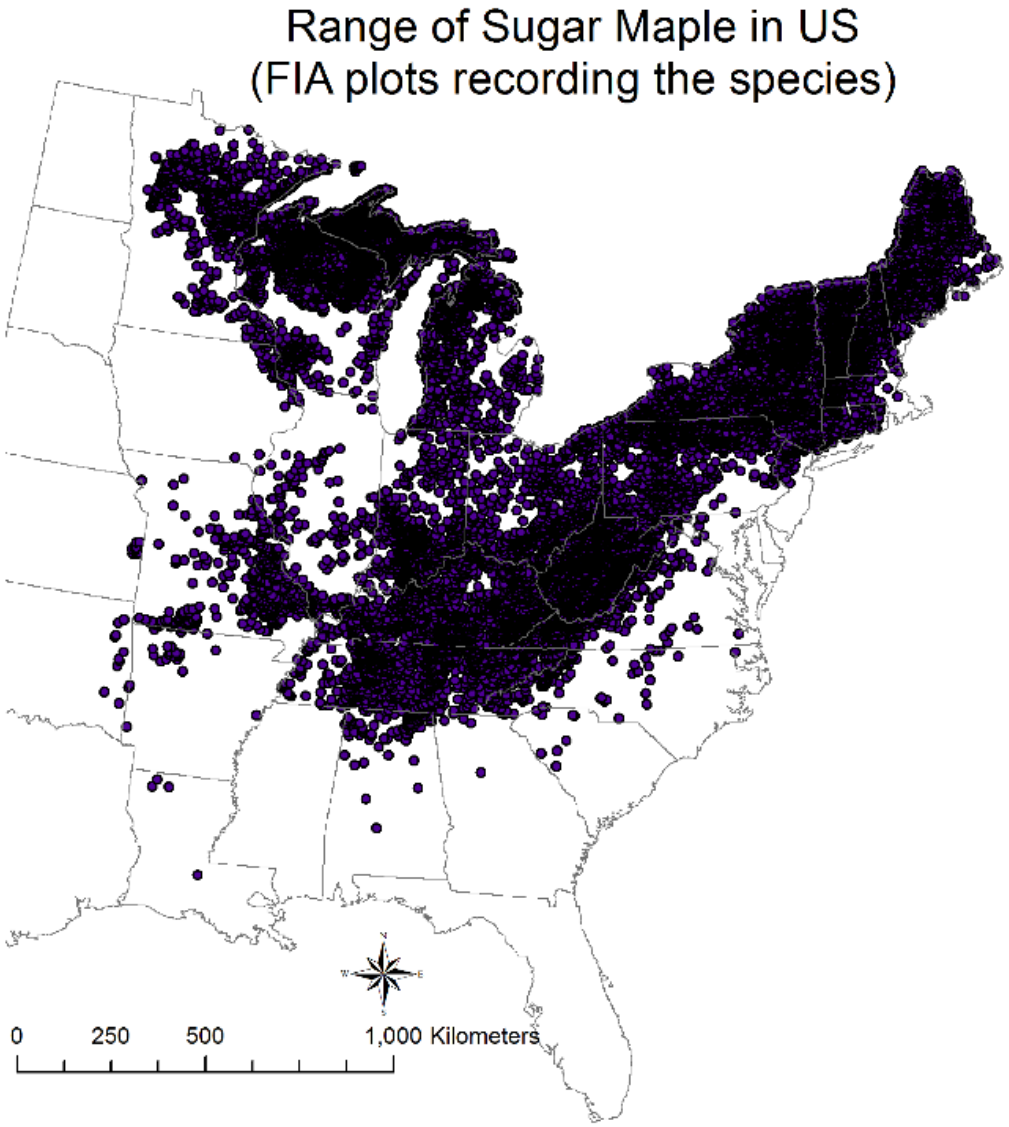
(NASS Census data are substantially smaller than Survey data)

National Agricultural Statistics, Census

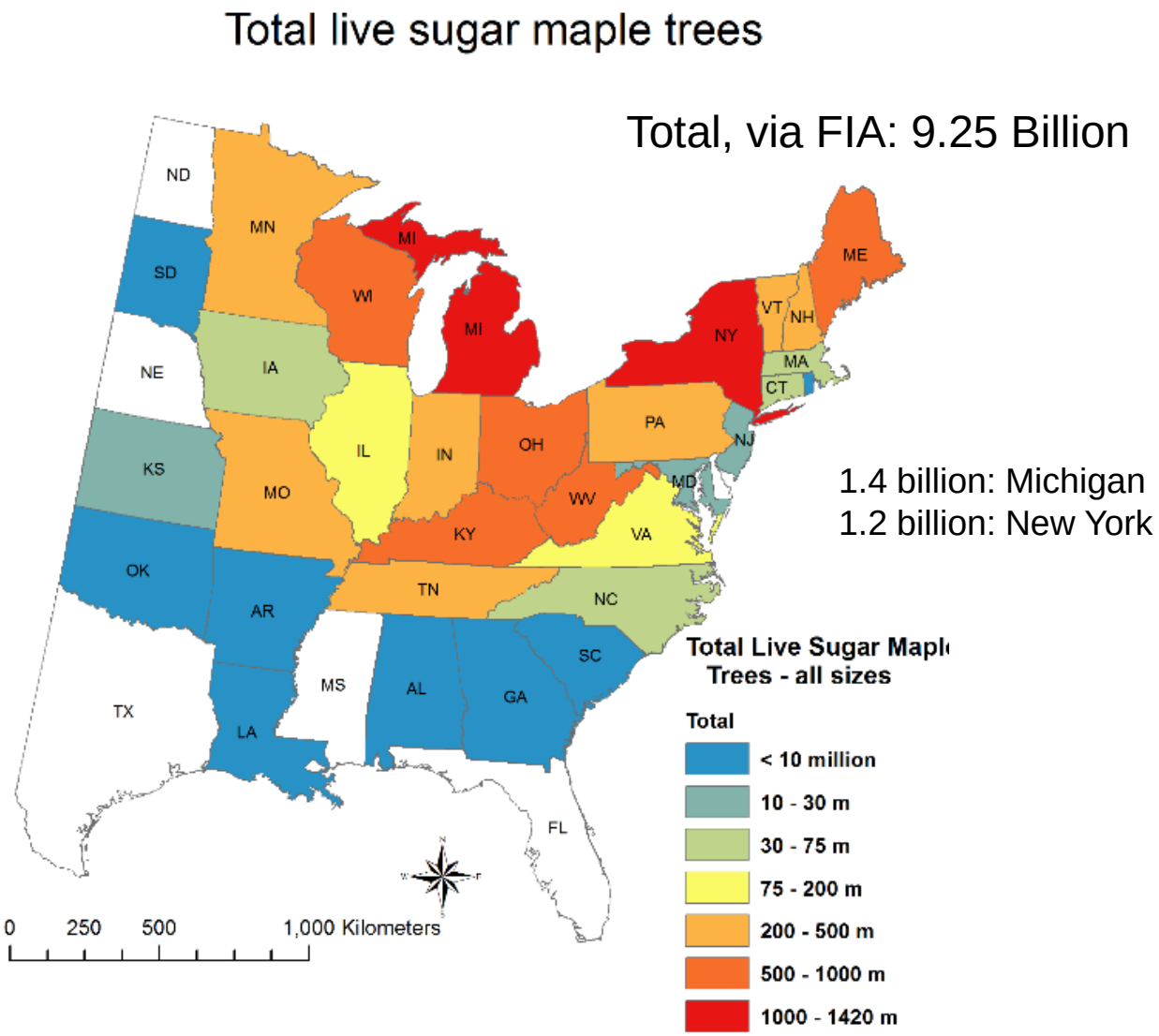
Maple Syrup, 1992-2015



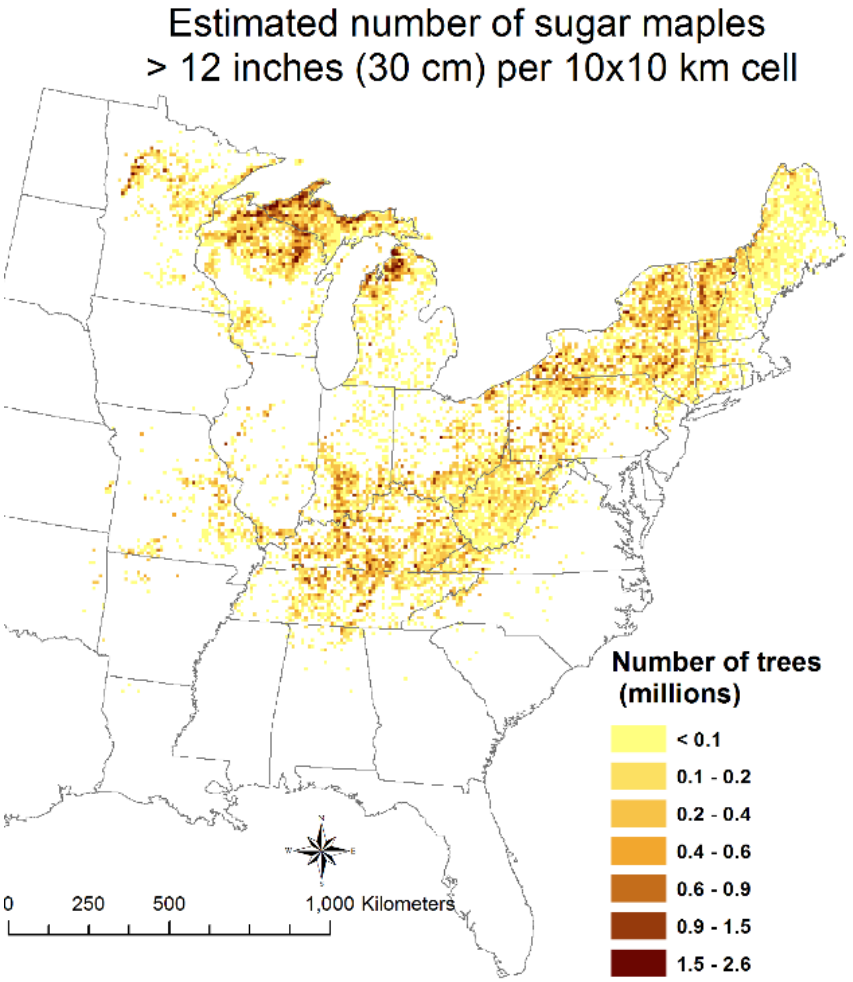
Where is Sugar Maple in US?



Total number of live sugar maples

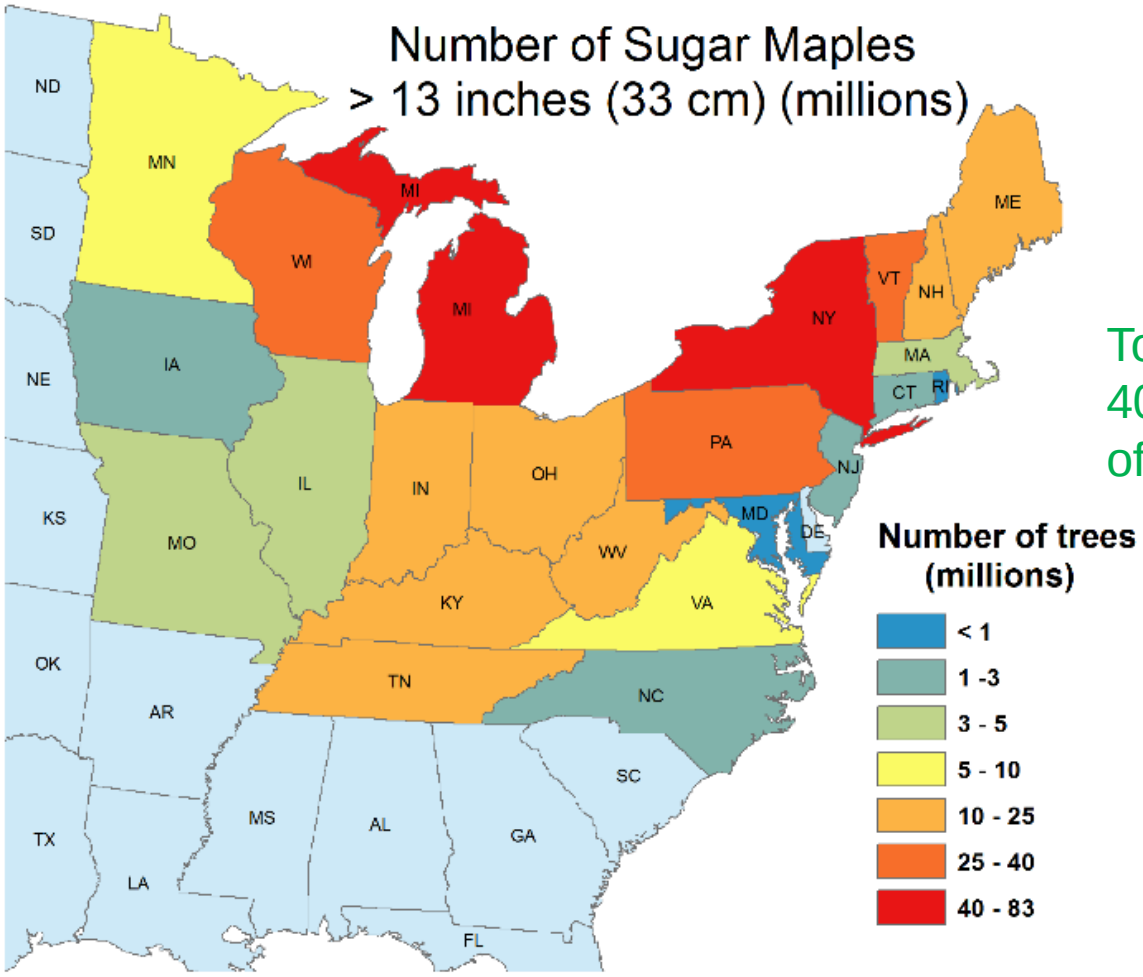


Number of live sugar maples, by 10x10 km



Based on FIA plots and estimates of forestland per cell

Number of large sugar maple trees



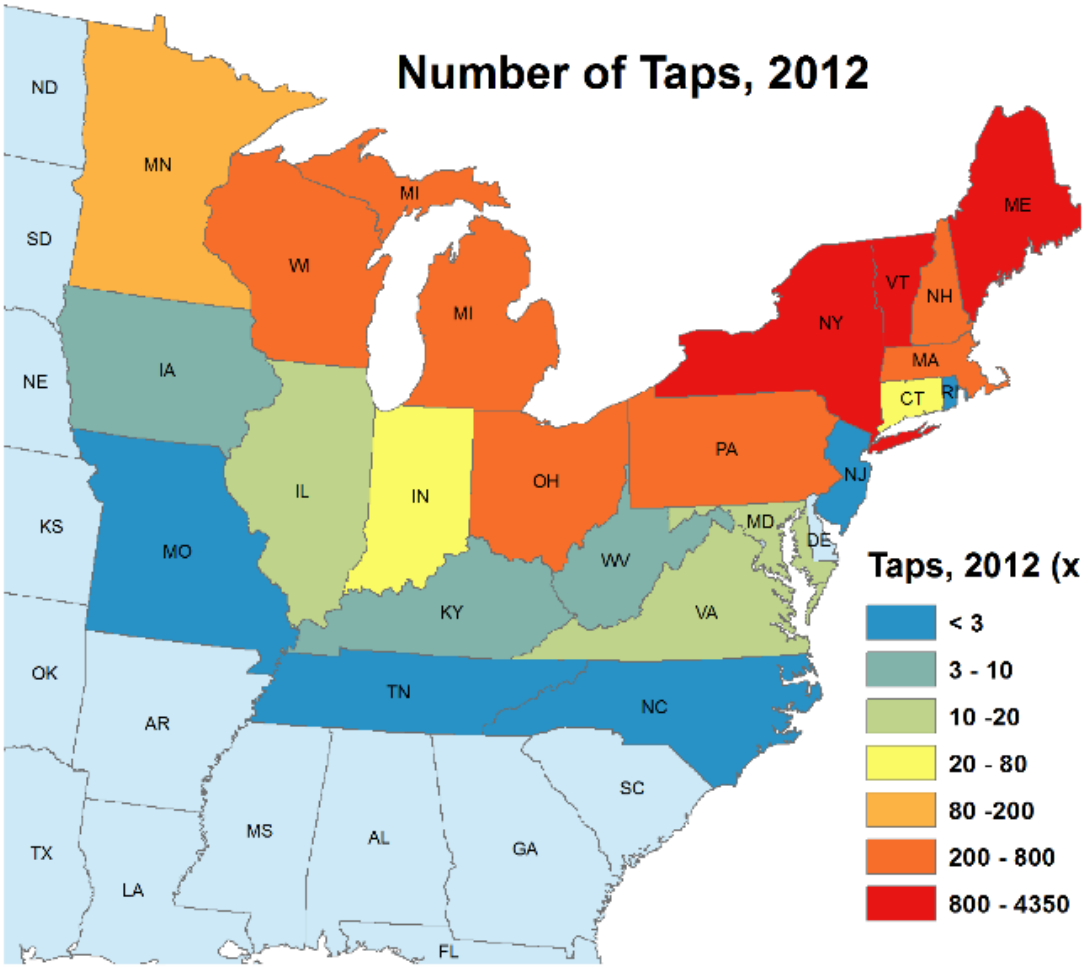
Total number, via FIA: 406 million, only 4.4% of total maple trees

FIA data

Calculating Potential Taps and Percentage Tappable

- Conservative approach to calculating taps:
  - Only sugar maple (not red or other maples)
  - One tap for trees 13-21 inches (33 – 53 cm)
  - Two taps for trees > 21 inches (> 53 cm)
- Ratio of taps (NASS) to potential (FIA) = Pct Tapped or Potentially Tappable

Number of maple syrup taps, by state

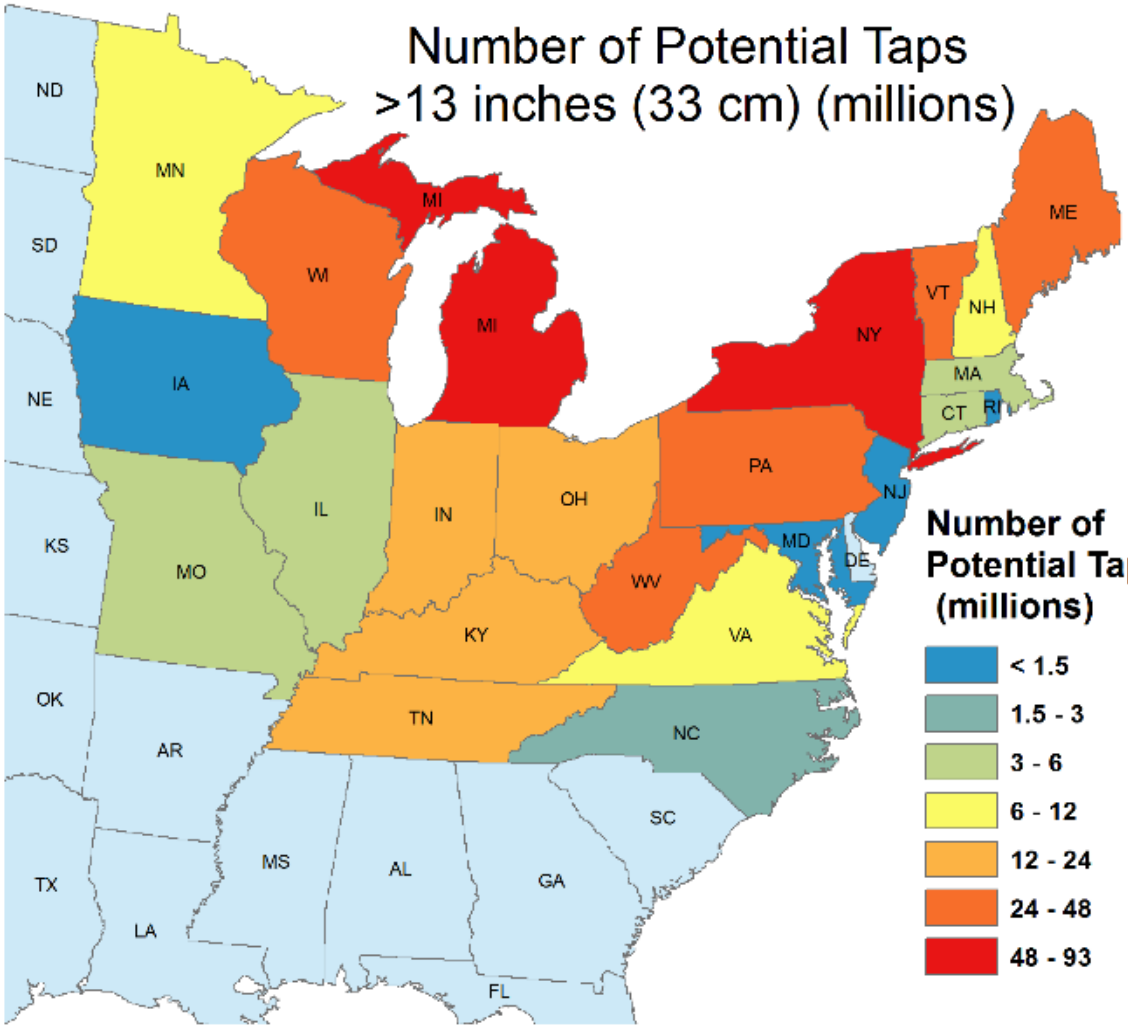


Total, via NASS:
11.4 million

4.3 m in VT
2.1 m in NY
1.9 m in ME

National Agricultural Statistics, Census

Number of potential taps, by state

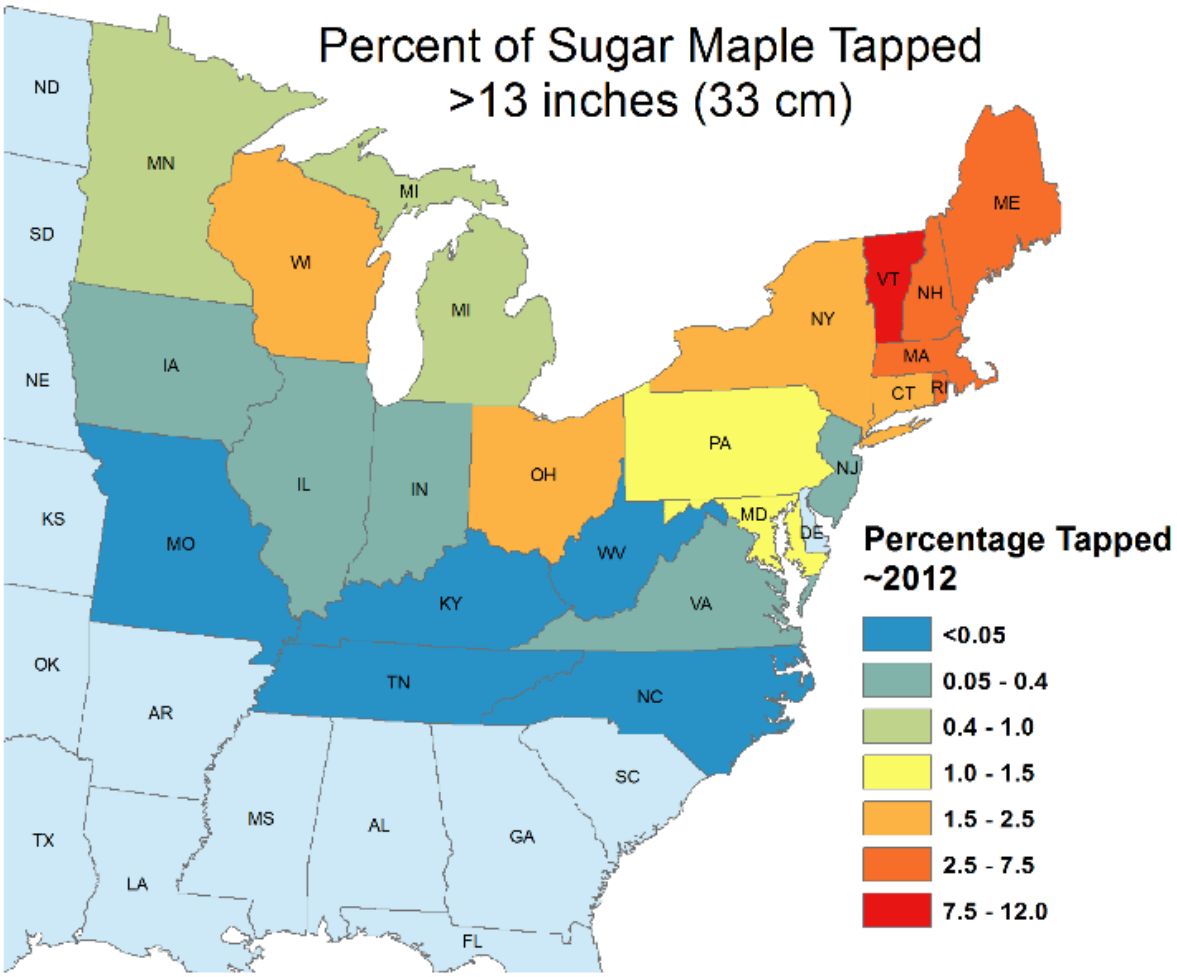


Total, via FIA:
448 million

93 m in NY
70 m in MI
41 m in PA
36 m in VT
…
2.6 m in NC

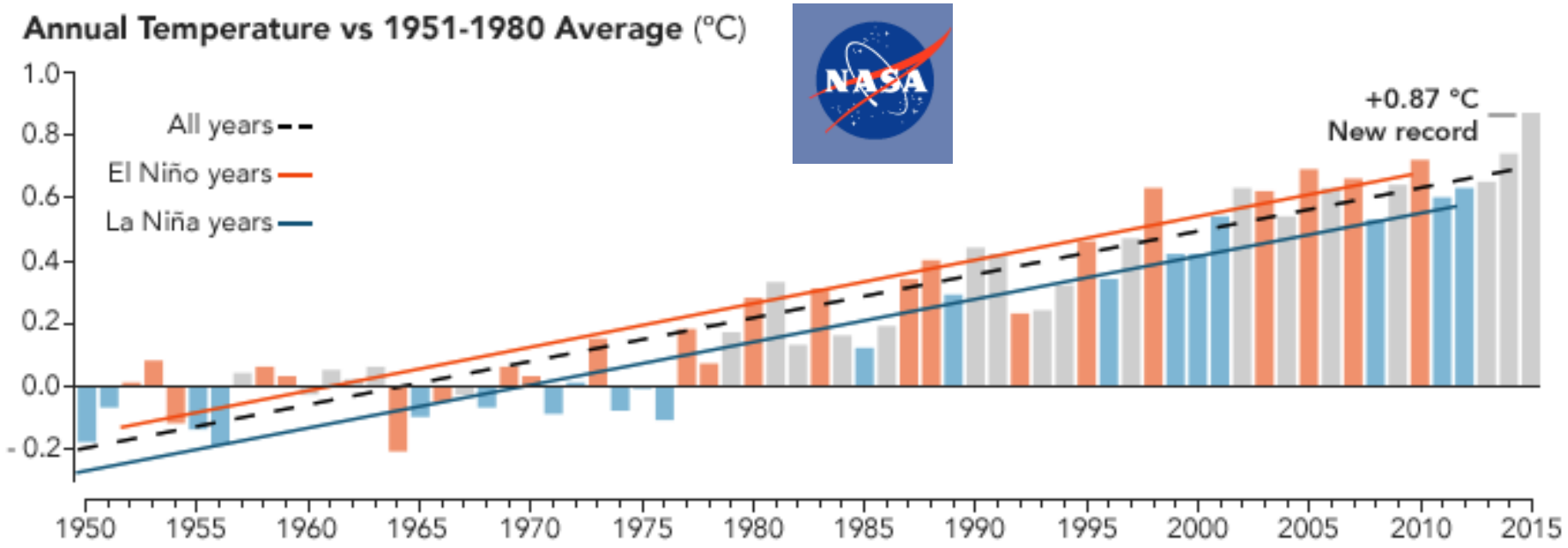
Assuming 1 tap for 13-21 inch trees, 2 taps for >21 inch trees, FIA data

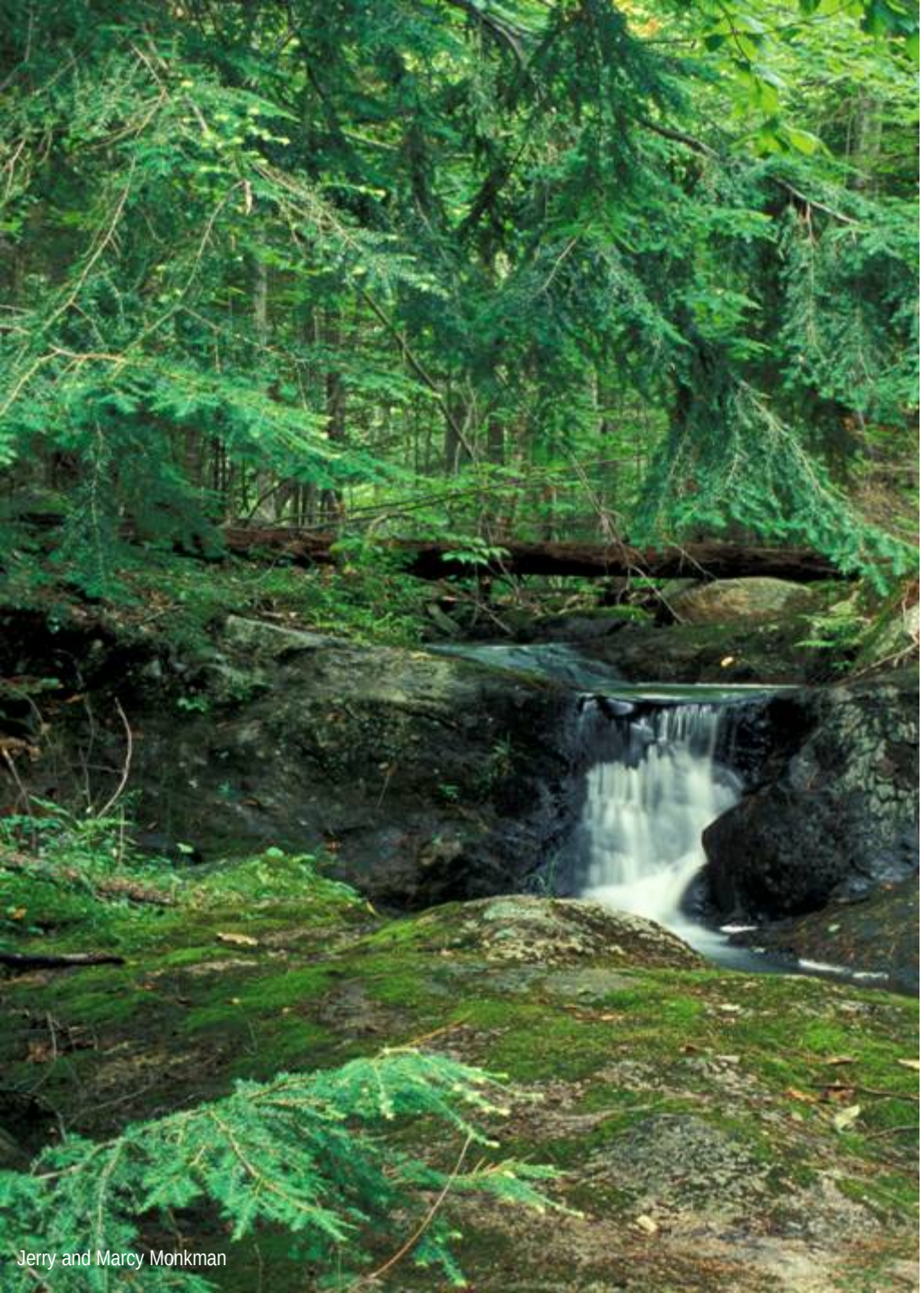
Percentage of potential taps tapped



Ratio of taps (NASS) to potential taps (FIA)

What impact might a changing climate have on sugar maple, and the syrup industry?





Jerry and Marcy Monkman

Modeling Impacts on Suitable Habitats for Tree (and Bird) Species in the Eastern US – An Atlas

sugar maple (*Acer saccharum*)

Model Reliability: High

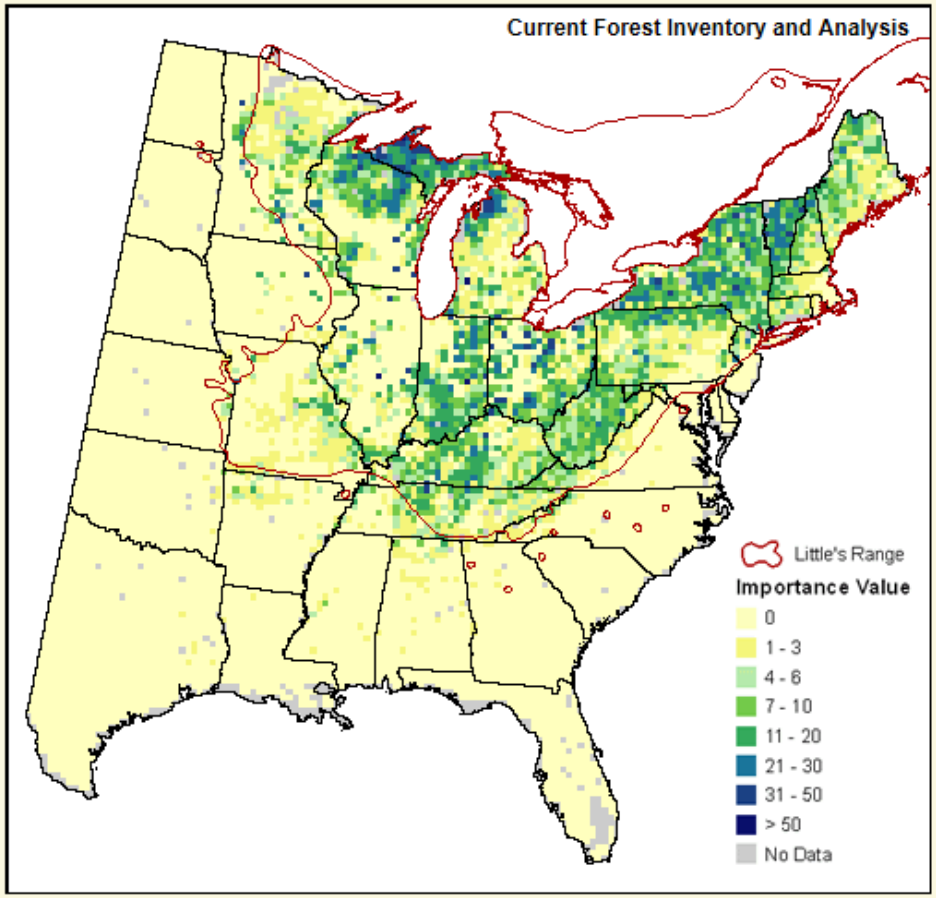
Current Distribution | Projected Future Habitat | Predictor Maps

Current Distribution Maps for sugar maple

Help »

Current Forest Inventory and Analysis

Compare Two Species



Potential Changes in Abundance and Range (Future)

GCM SCENARIO	% Area Occ	Ave IV	Sum IV	Future/Current IV
Actual FIA	31.8	8.6	26,735	NA

Cautions & Model Info

Notice:

This is an updated version of the Climate Change Tree Atlas. You can view the previous sugar maple page, or browse the previous Tree Atlas.

About sugar maple

Family: Aceraceae
Guild: persistent, slow-growing understory tolerant
Functional Lifeform: large deciduous tree

- Life History and Disturbance Response
- Silvics Manual
- Photos of sugar maple in USDA Plants Database
- View current and modeled sugar maple distributions in Google Earth (219 KB)

Download Google Earth for free

Climate Change Adaptability

Summary of Predicted Changes

Range and Niche Maps

Predictor Analysis

Search for Trees & Birds:

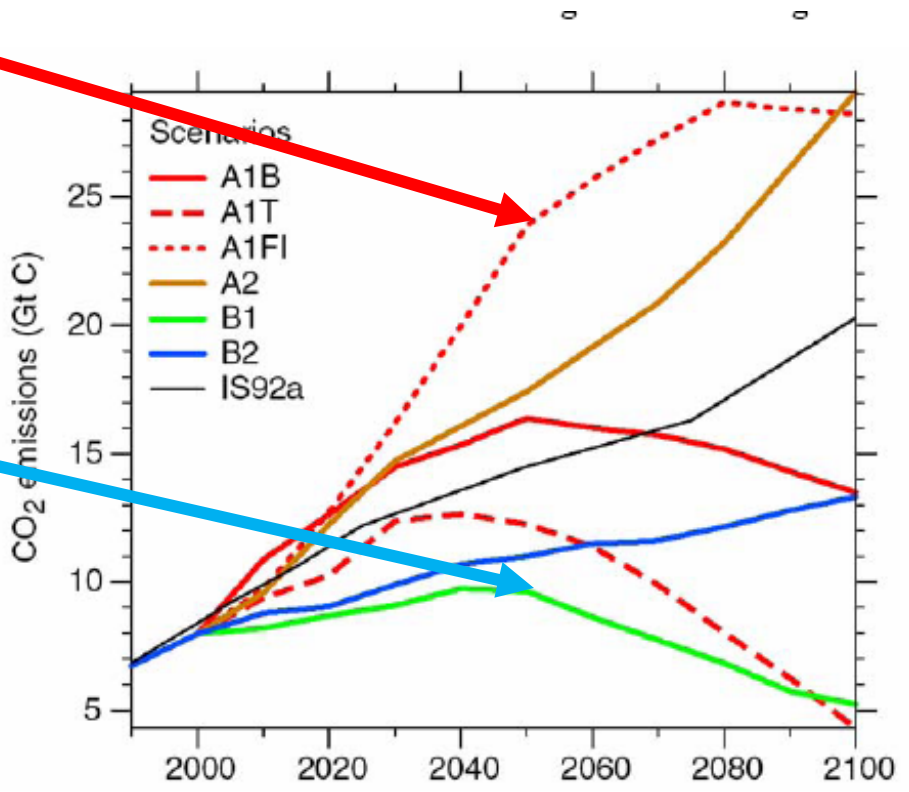
Enter a common or scientific name

http://www.nrs.fs.fed.us/atlas

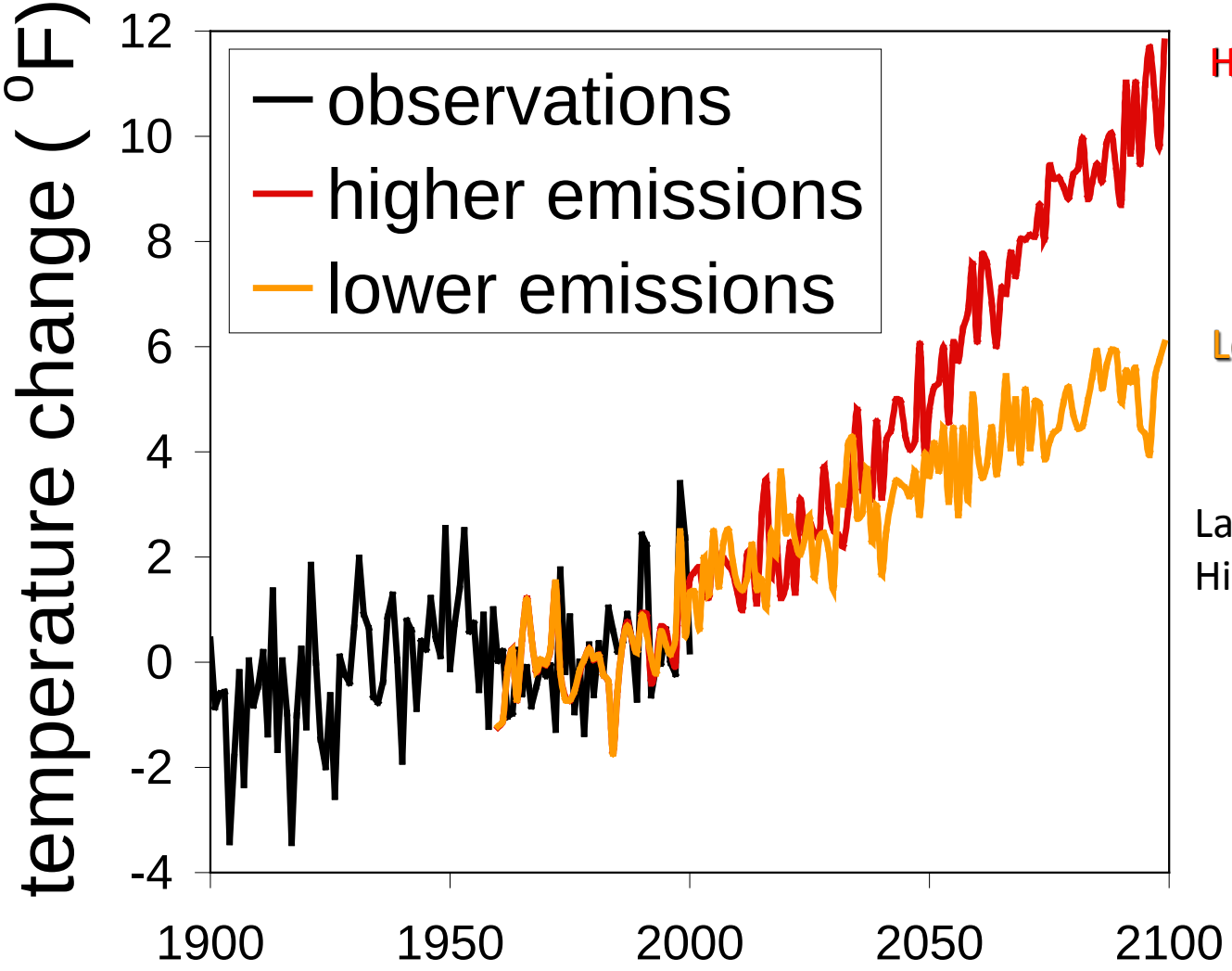
The Future Climate

Emissions of CO2 – range of scenarios over next 100 years

- A1fi (high)-fossil fuel intensive until later century
- B1 (low)-shift to resource efficient technology



Rising Temperatures in Eastern US



Higher: 3.6 – 7.0 °C

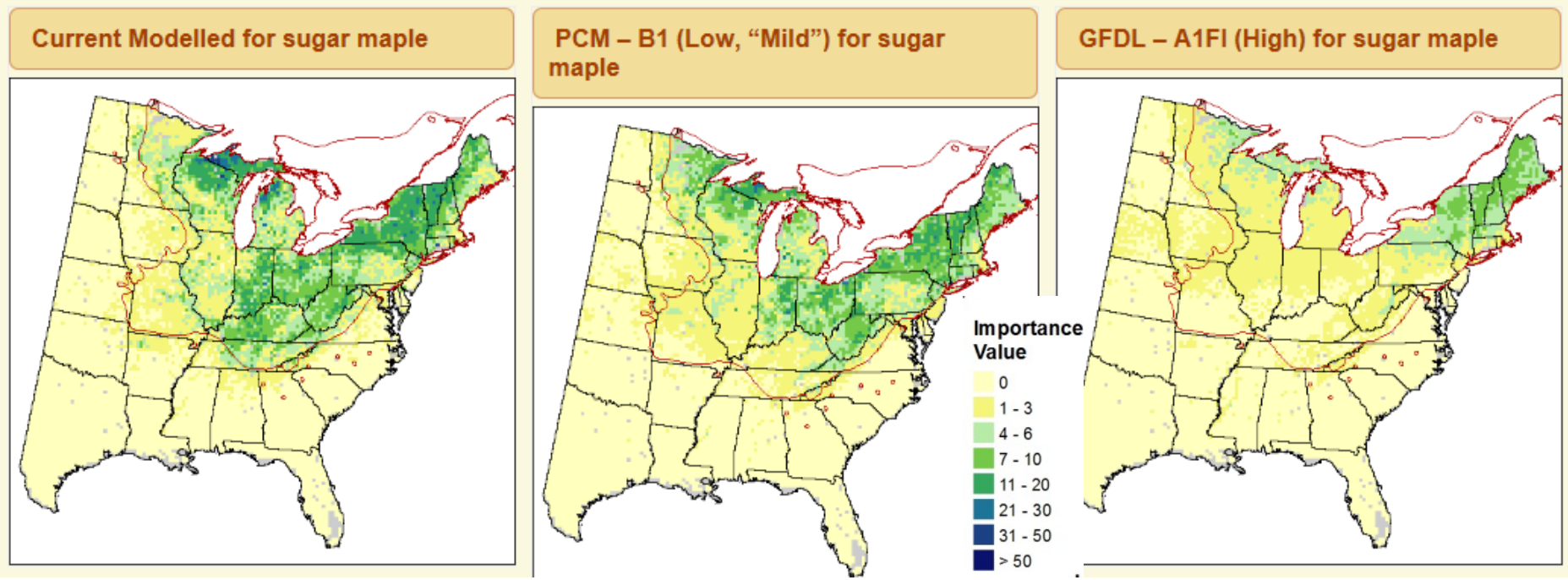
Hadley A1Fi

Lower:2.0 – 3.6°C

PCM B1

Large difference between High and Low emissions!

Modeled Fate of Sugar Maple Habitat by 2100

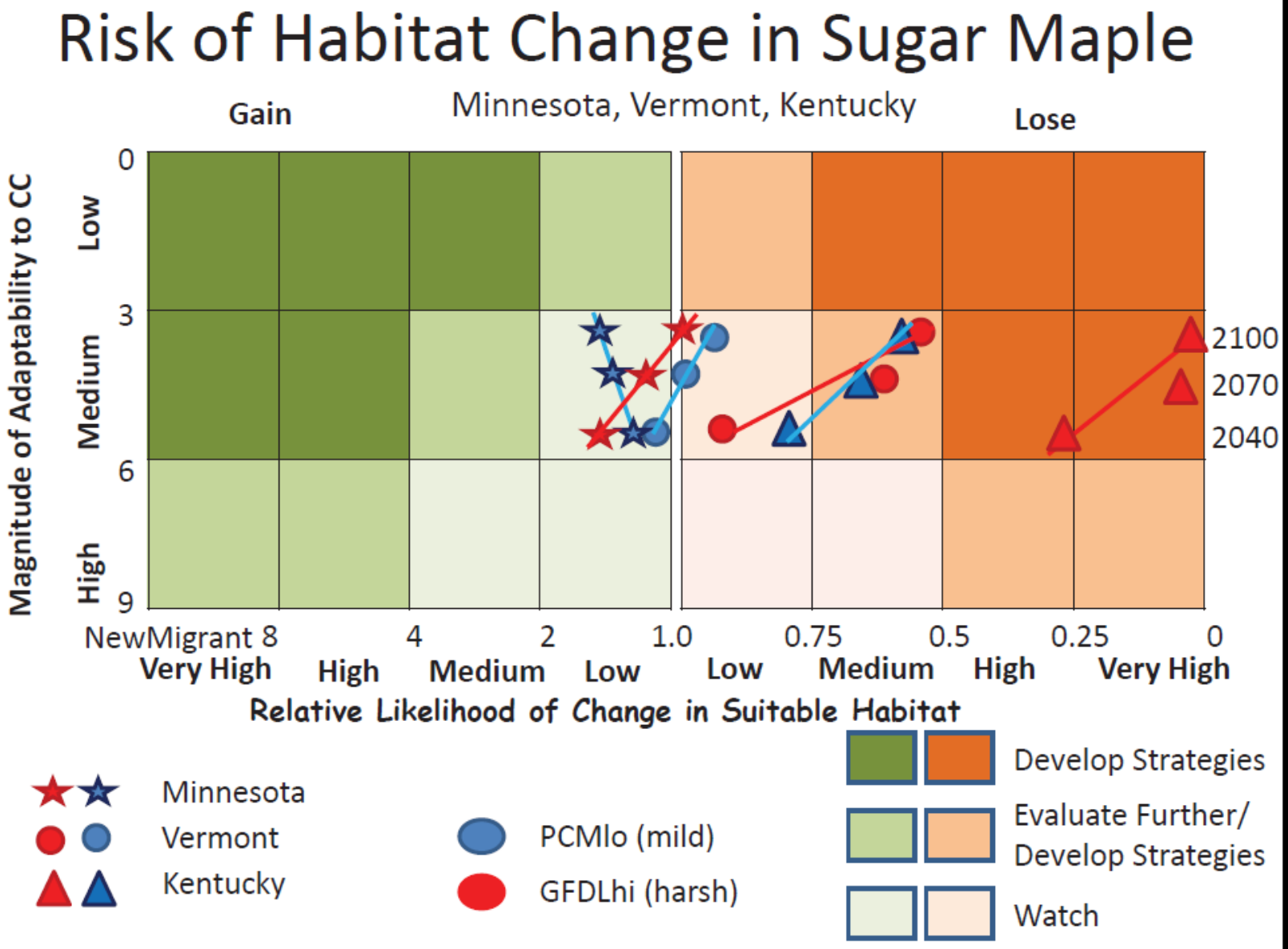


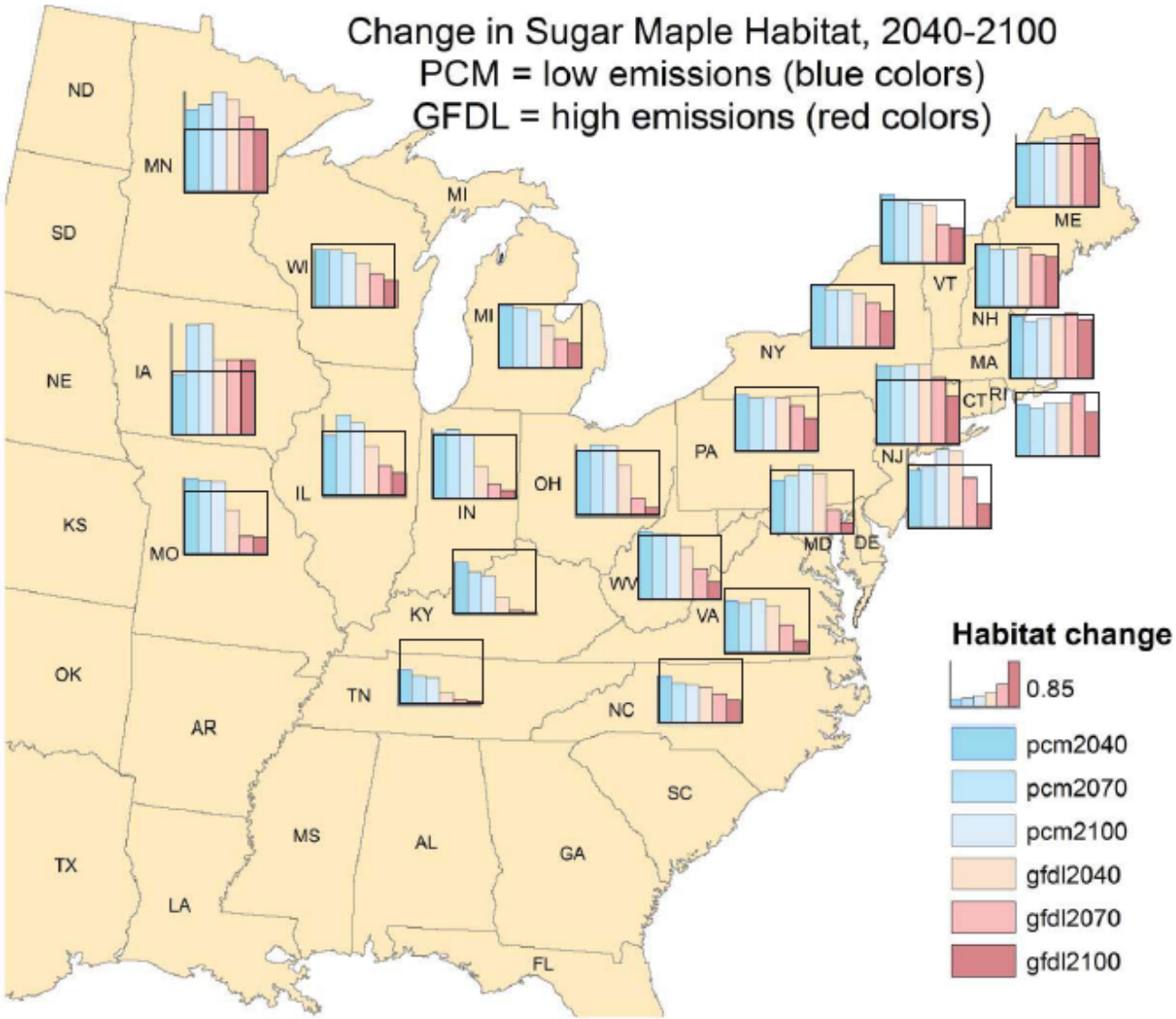
0.78

0.35

Habitat suitability = Ratio of Future: Current
< 1 = loss of habitat; >1 = gain in habitat

Sugar Maple Habitat – change through time and consider other life history traits

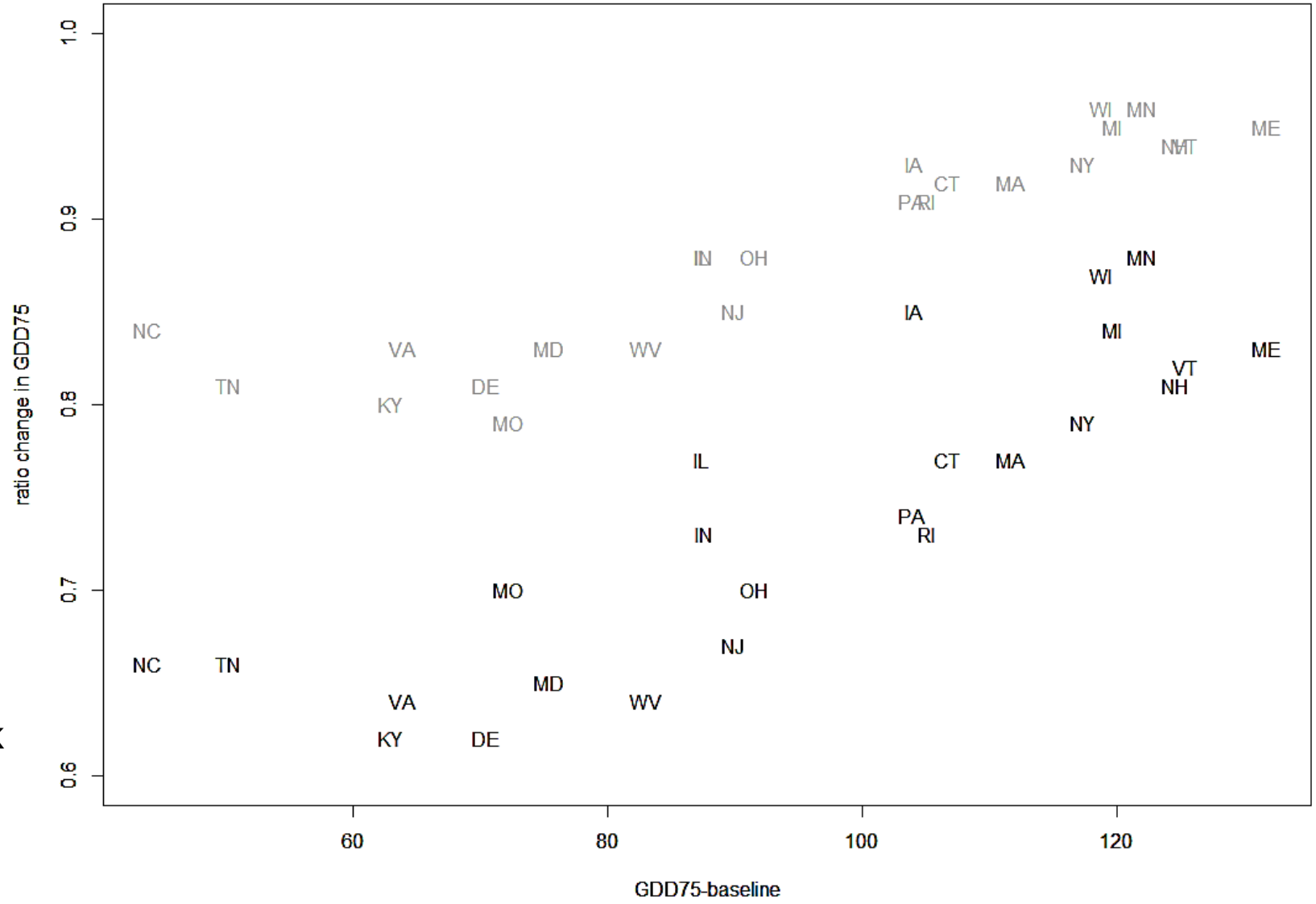



Change in Sugar Maple Habitat, 2040-2100
PCM = low emissions (blue colors)
GFDL = high emissions (red colors)
ND
MN
SD
WI
MI
NE
IA
IL
IN
OH
KS
MO
KY
WV
VA
OK
TN
NC
AR
SC
MS
AL
GA
TX
LA
FL
NY
PA
MD
DE
NJ
CT
RI
MA
VT
NH
ME
Habitat change
0.85
pcm2040
pcm2070
pcm2100
gfdl2040
gfdl2070
gfdl2100

Changes in Maple Syrup Ecosystem Service for Sugar Maple with Climate Change

- Assumes loss of suitable habitat ~ loss of capability to produce syrup:
  - Shorter season of sap flow
  - Less suitable growing conditions overall
  - Less syrup per tap per season

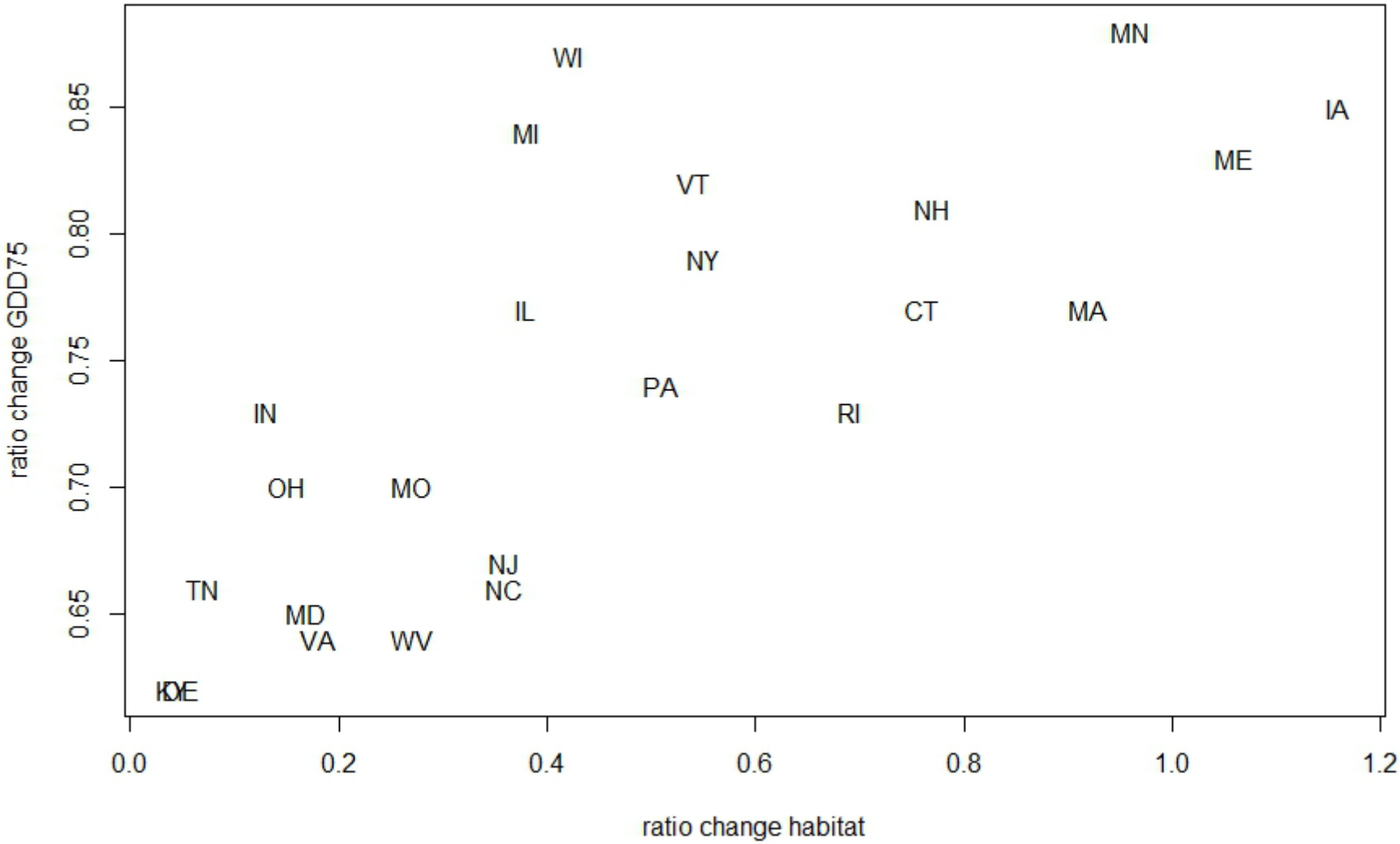
- loss of suitable habitat ~ change in length of season
- # of day to Growing Degree Days 75



Emissions scenarios
B1-gray
A1Fi-black

- loss of suitable habitat ~ change in length of season

At state level projected change in GDD to 75 strongly associated (r=0.75) with projected change in habitat



Calculating additional taps needed to reach 2012 production levels, under varying scenarios of climate change

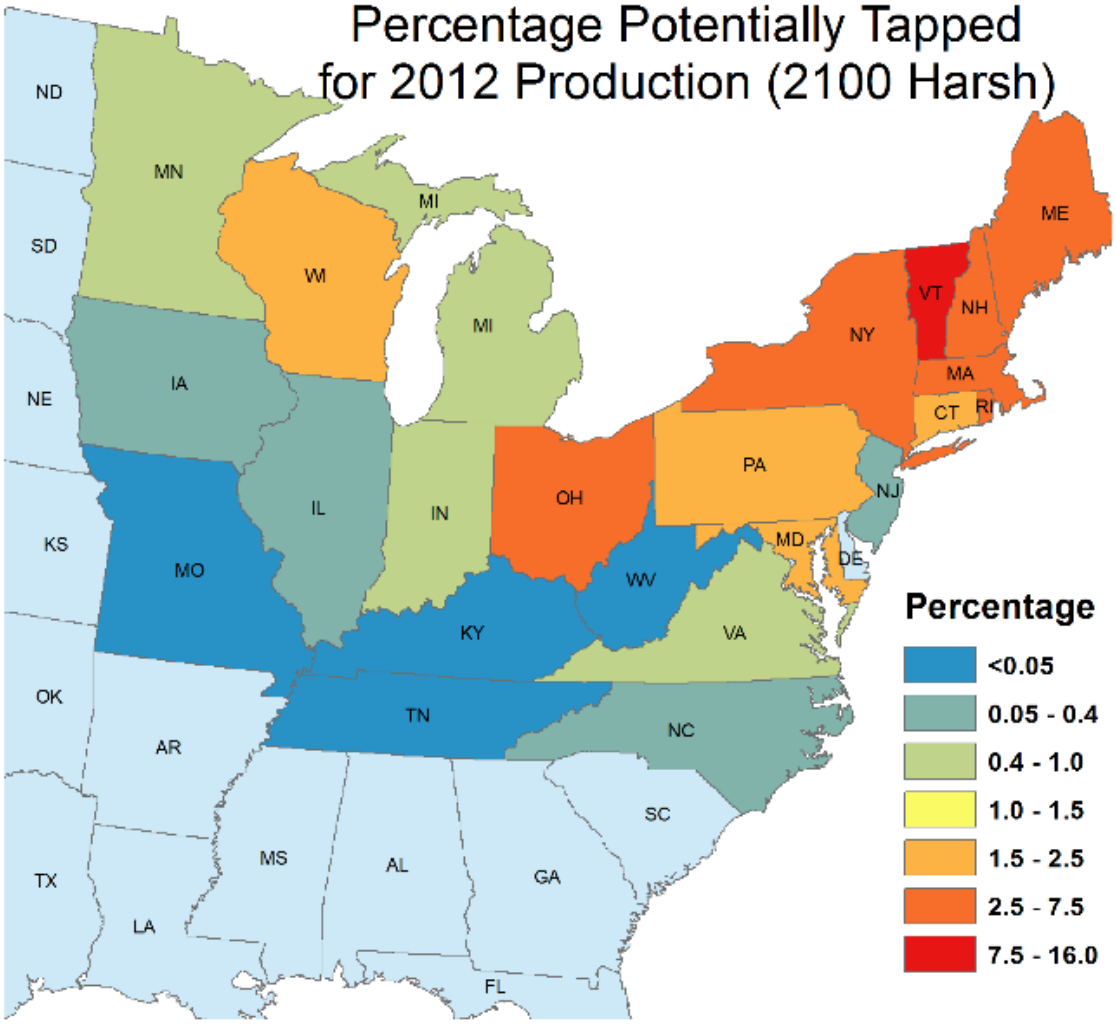
- Habitat ratios for each of 3 times (2040, 2070, 2100) and 2 GCM scenarios (PCM B1=mild and GFDL A1FI=harsh) multiplied by gallons produced in 2012 = shortfall requiring additional taps
- Calculate percent increase needed in taps per state to maintain 2012 production
- Calculate Pct Tappable trees after adding new tap requirements
- Add smaller trees of 9-13 inches (23 – 33 cm) and calculate Pct Tappable again

Estimated Impacts under Climate Change

	Gallons	Change	New Taps	
	(all values x1000)			
2012	2,296			
pcm2040	2,298	2	17	
pcm2070	2,210	-86	313	
pcm2100	2,181	-116	407	
gfdl2040	2,067	-229	2,340	
gfdl2070	1,621	-675	2,957	
gfdl2100	1,450	-846	4,896	

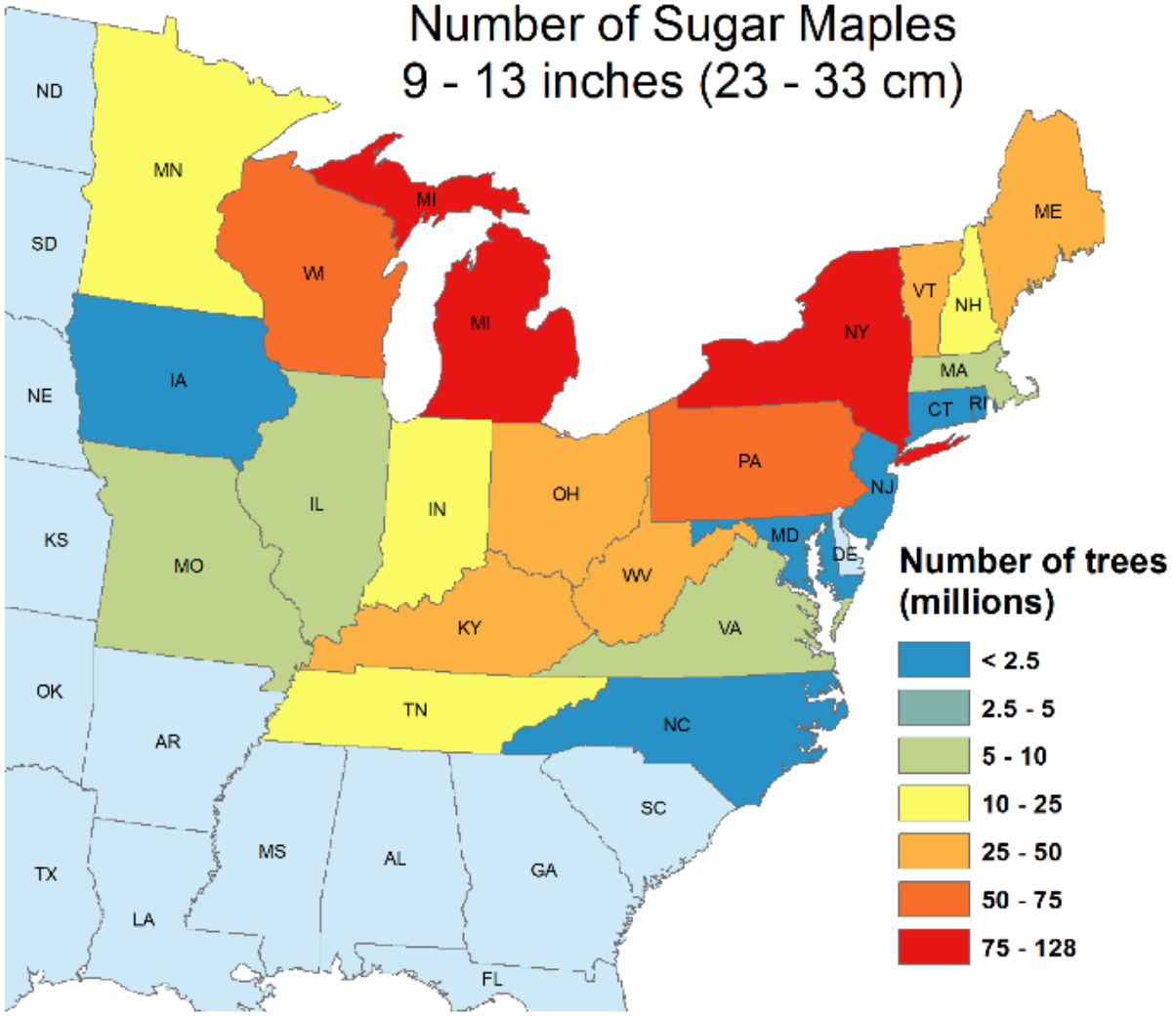
St	Taps 2012 (x1000)	Taps Needed GFDL-A1Fi 2100 (x1000)	% Tapped 2100 under GFDL-A1Fi	Sugar Maple size class 22-33cm (x1000)	% Tapped by 2100 of 22-33cm cohort
VT	4348.2	1483	16.01	46.3	7.05
NY	2064.9	620.7	2.9	122.1	1.25
ME	1884.5	-88.9	6.71	41.4	2.63
WI	682.3	135.5	2.39	73.3	0.76
PA	506.2	177.3	1.63	53.1	0.72
NH	495.6	69.1	4.88	20.2	1.78
OH	439.6	306.6	3.47	27.8	1.52
MI	433.5	158.5	0.85	127.1	0.3
MA	229	13.9	5.19	5.3	2.44
MN	83.1	1.6	0.89	19.3	0.29
CT	64	11.2	2.31	2.5	1.3
IN	49.5	40.3	0.52	19.3	0.24
VA	19.8	5.5	0.42	7.9	0.18
MD	16	7.5	2.13	1.5	0.9
IL	10.2	7.7	0.39	5.2	0.18
WV	8.8	3.6	0.05	41.1	0.02
IA	5.5	-0.5	0.34	1.6	0.16
KT	4.8	1.9	0.04	33.9	0.01
NJ	2.7	1	0.32	1.9	0.12
RI	2.6	0.3	5.51	0.1	2.14
NC	1.1	0.5	0.06	2.5	0.03
MO	1	0.4	0.04	9.1	0.01
TN	0.1	0.1	0.00	18.3	0
	11,353	2,957	--	680.3	--

Potentially tapped under harsh climate change



Vermont would need to tap up to 16% of trees > 13 inches (33 cm)

Many smaller Sugar Maples coming up!

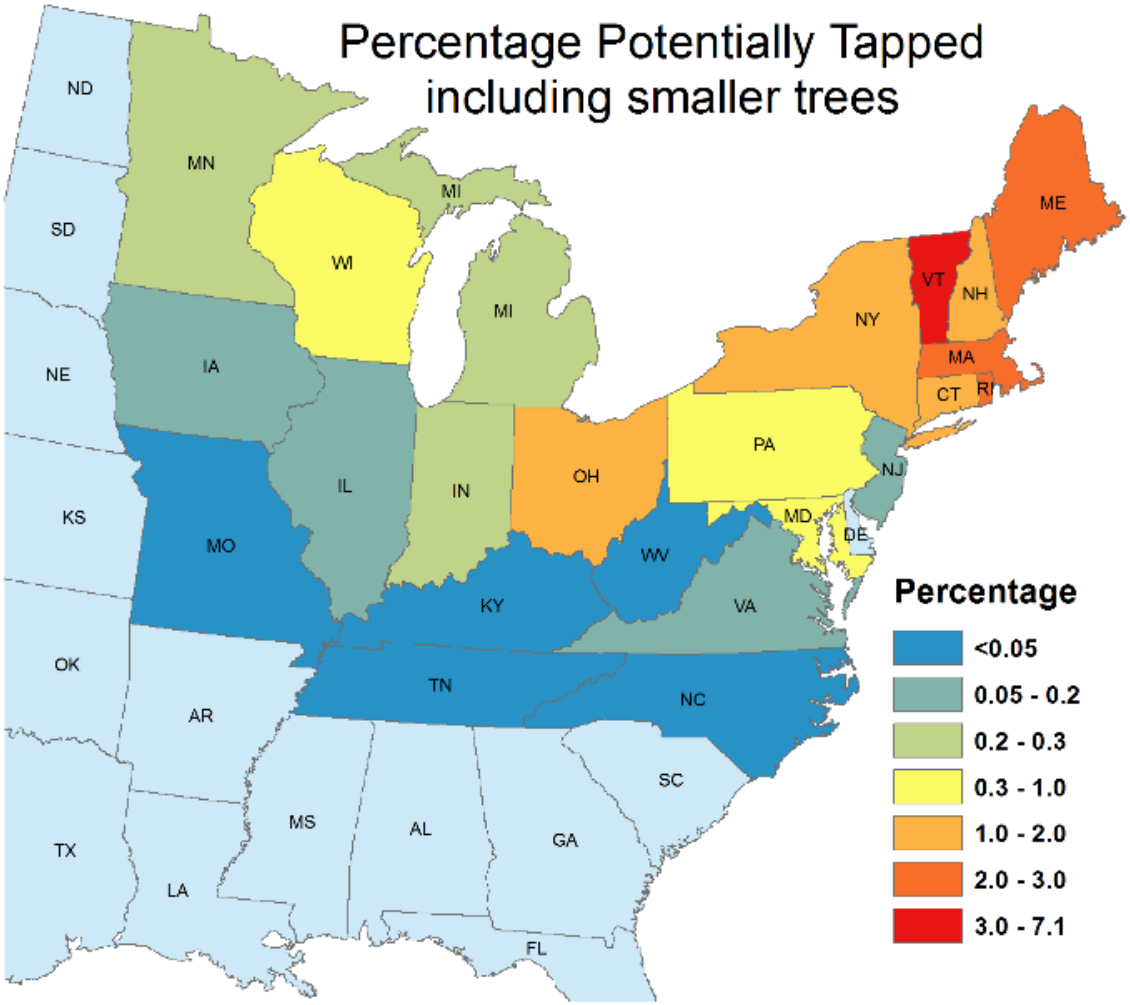


FIA data

Total, via FIA:
681 million

127m MI
122m NY
…
2.5m NC

Percentage Potentially Tapped using all SM Trees > 9 inches (23 cm)



Quick Conclusion

- Original question: Can this 'delicious' ecosystem service be maintained in a changing climate?
- Quick answer: Yes, but it will cost more, and range-edge locations will suffer more.

- But a lot more work needs to be done
  - How much of new stock can be accessed?
  - How will red maple compare?
  - What are physiological limits along these gradients?

More Drawn-Out Conclusions

- Maple syrup provides a delicious ecosystem service, and it is currently increasing in volume and value.
- This ES for sugar maple is likely to be reduced, or at least shifted north, in coming decades due to climate change.
- Many southern states may see greater impacts. Maine and Minnesota, however, may see new opportunities.
- Potential trees for tapping are now plentiful, but millions of additional taps may be required to sustain production (consumers pay more!)

Thank you!

- US Forest Service Northern Research Station
  - A. Prasad, M. Peters
  - Rich McCullough, FIA
- National Climate Assessment
- Northern Institute of Applied Climate Science

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Climate Change Atlas: http://www.nrs.fs.fed.us/atlas