# Impacts of Changing Land Use, Climate, and Atmospheric Chemistry on Forests of the Chesapeake Bay Watershed

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# Motivation for Assessment

- Chesapeake Bay Watershed is protected by 24 million acres of forests that:
  - Absorb pollutants
  - Sequester atmospheric $CO_2$
  - Maintain air and water quality
- Forest health and services are threatened by:
  - Land use change
  - Climate change
  - Increasing exposure to ground-level ozone and nitrogen deposition

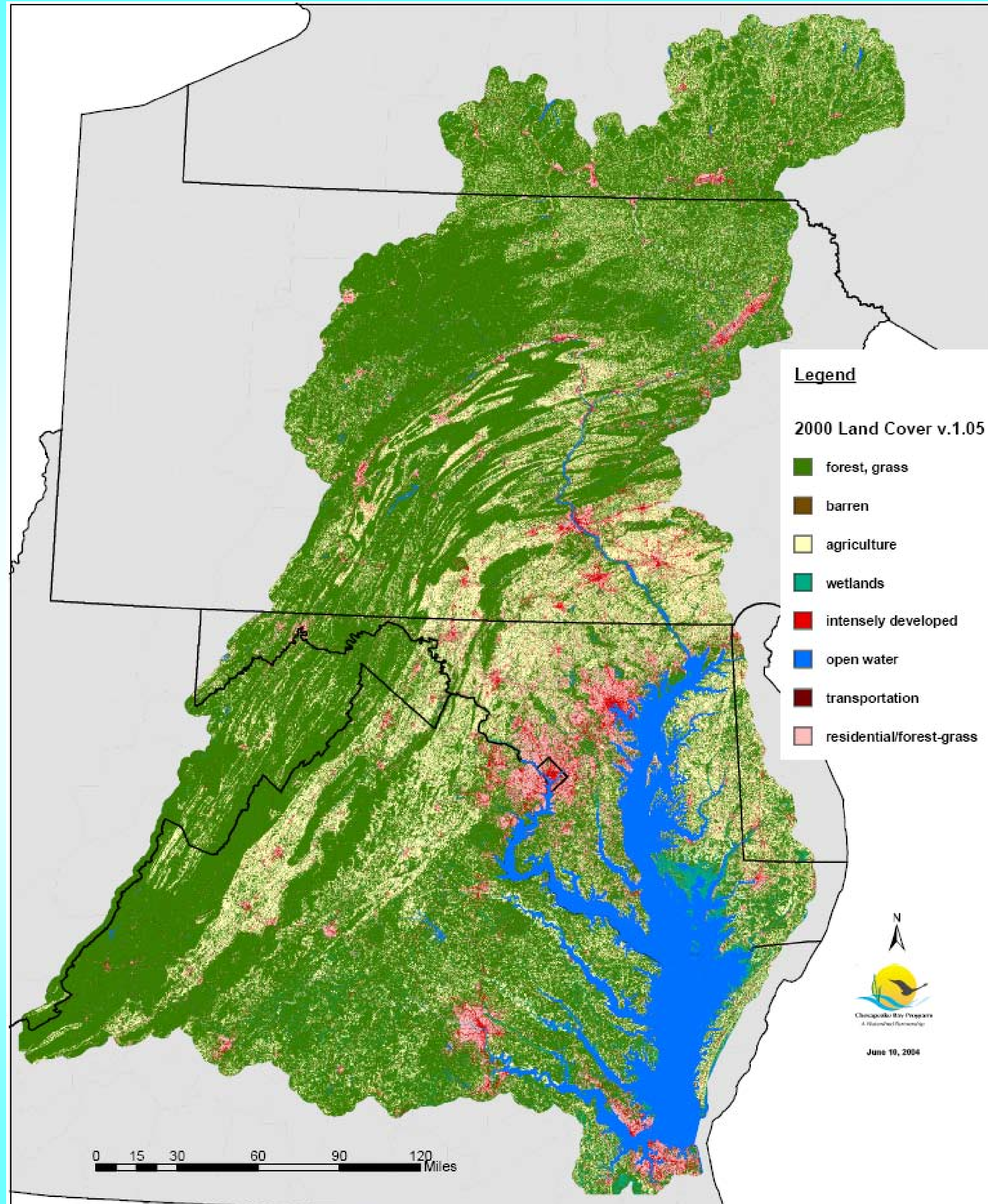
# Science Questions

- To what extent are forests threatened by air pollution and land use change?
- What is the current and future capacity of forests to sequester atmospheric $CO_2$?
- What are current nitrogen (N) loss and retention rates under chronic N deposition?
- Will forest continue to retain N in the future, and which forests will be more sensitive to N loss?

# Overview of Presentation

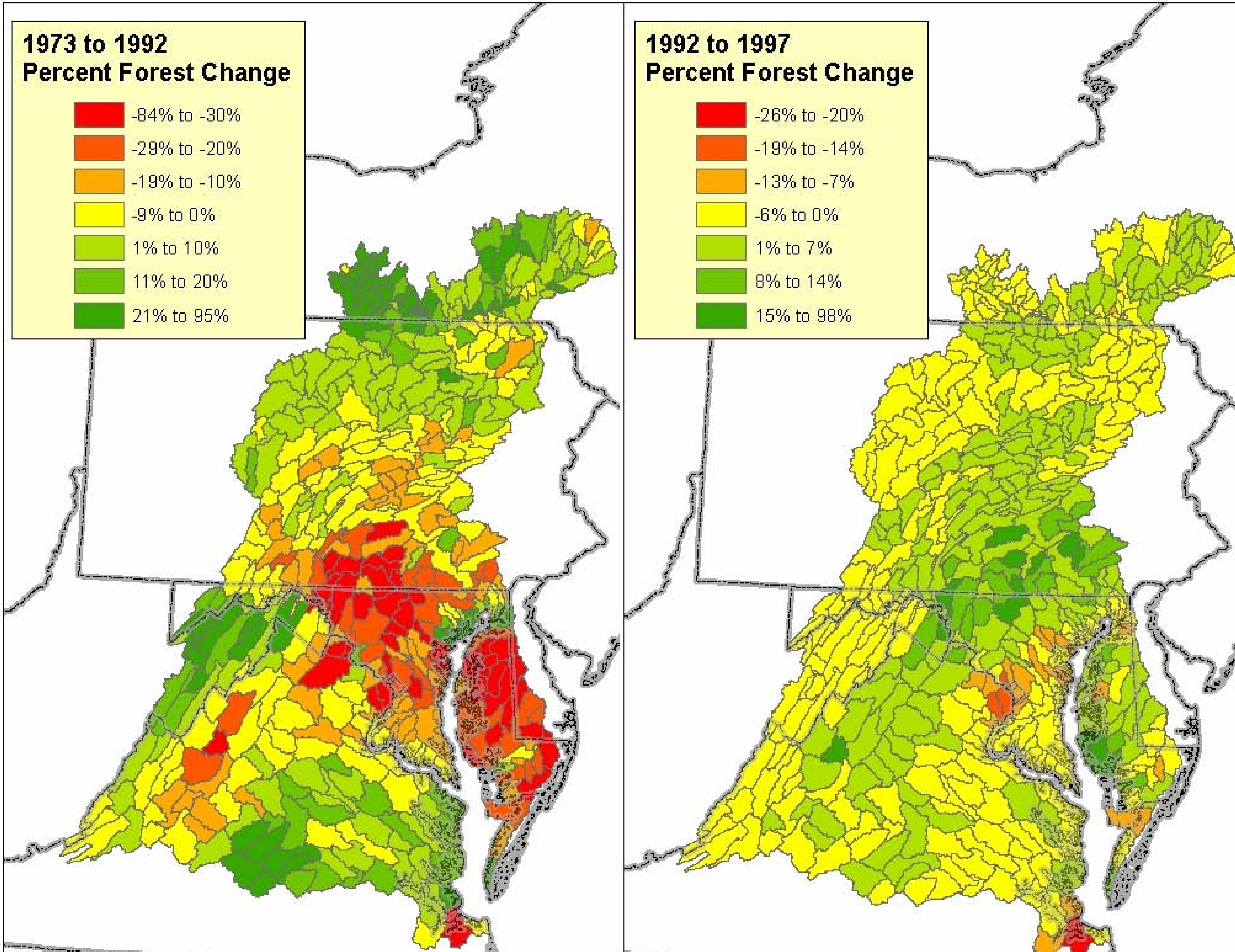
- Analysis of Chesapeake Bay Watershed land cover and forest trends
- Climate trends and air pollution
- Nitrogen deposition, retention by forests, and future scenarios
- Complications of multiple stressors
- Support for decision making

# Land cover of the Chesapeake Bay Watershed




## Percent Cover

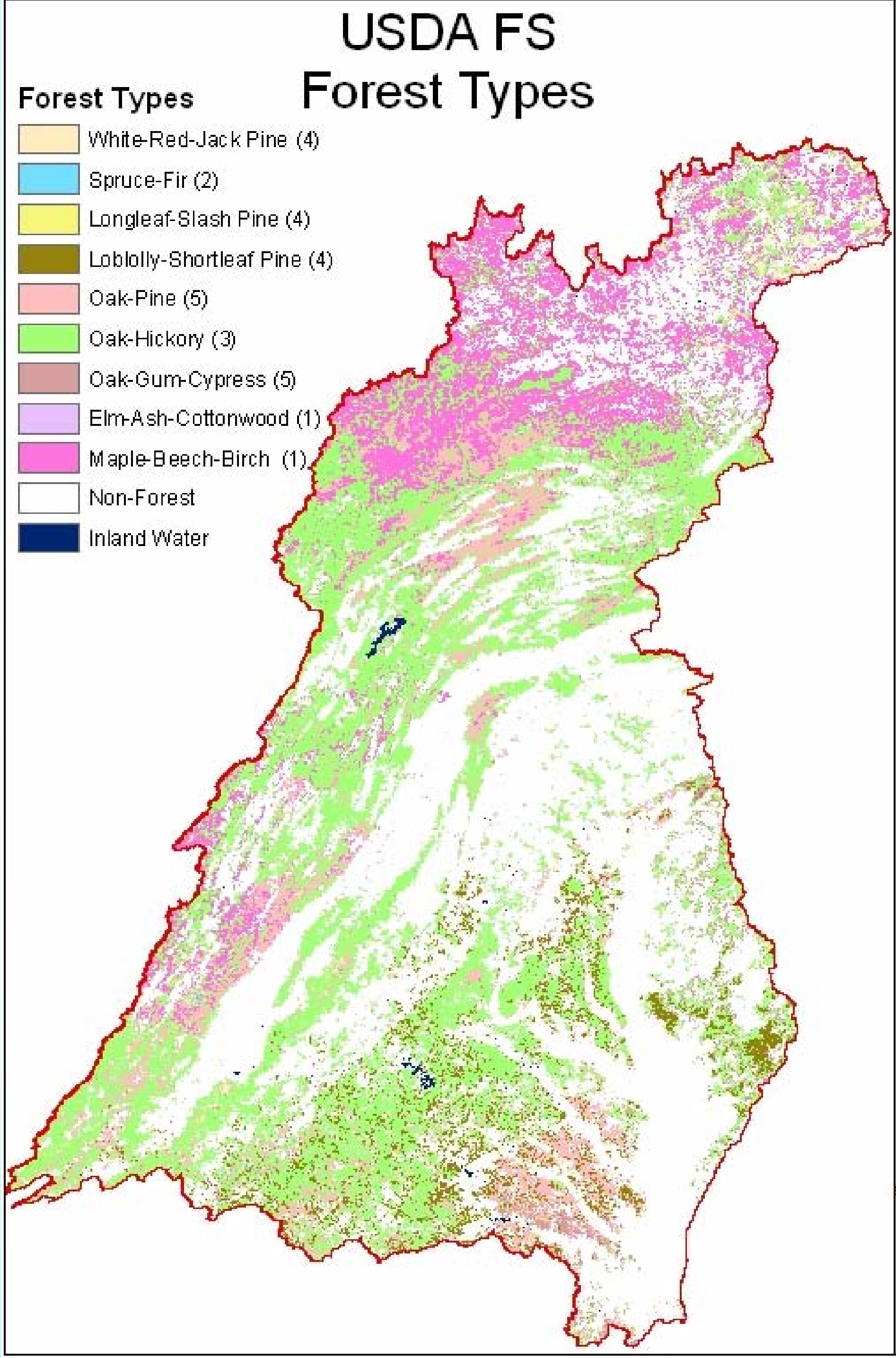
| | |
|---|---|
| **Forest** | **61** |
| **Agriculture** | **29** |
| **Wetland** | **3** |
| **Developed** | **7** |


1973 to 1992
Percent Forest Change
-84% to -30%
-29% to -20%
-19% to -10%
-9% to 0%
1% to 10%
11% to 20%
21% to 95%
1992 to 1997
Percent Forest Change
-26% to -20%
-19% to -14%
-13% to -7%
-6% to 0%
1% to 7%
8% to 14%
15% to 98%

# Forest Types of the Chesapeake Bay Watershed

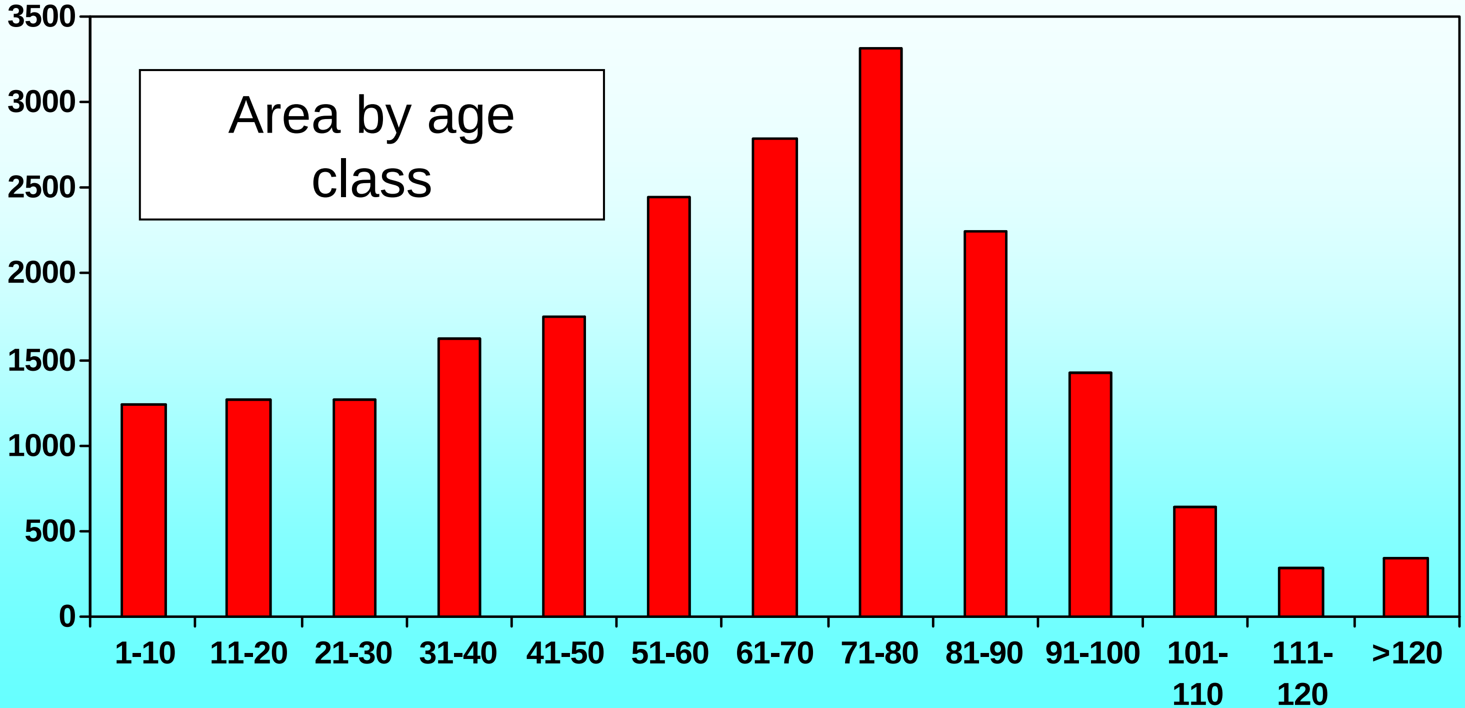
**Percent of total**
**24 million acres**

| | |
|---|---|
| Oak-hickory | 53 |
| Maple-beech-birch | 23 |
| Loblolly pine | 9 |
| Other types | 15 |



# Forest Dynamics

| *Forest Type* | *Area (1000 ac)* | *Change from 1990-2000* |
|---|---|---|
| **Oak-hickory** | **12,461** | **-34** |
| **Maple-beech-birch** | **5,371** | **+779** |
| **Loblolly pine** | **2,081** | **-180** |
| **Other types** | **3,725** | **-553** |
| **Total** | **23,574** | **+13** |

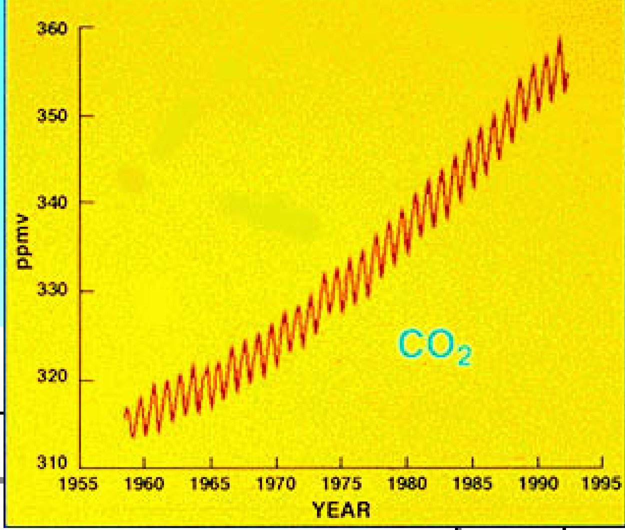


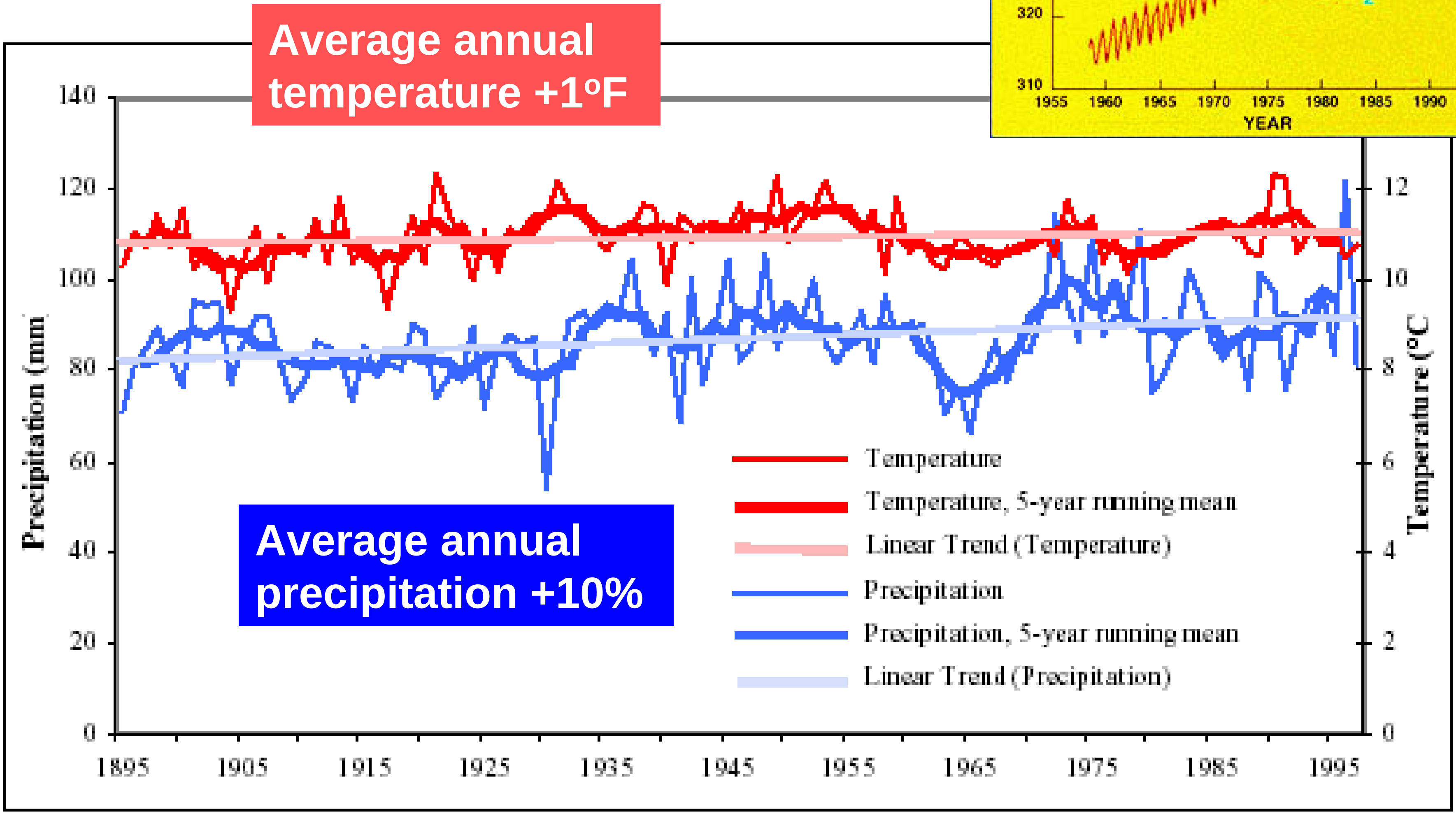
# Forest Carbon Budget, 1990-2000

FORCARB-2 estimators (Heath et al.)

- Chesapeake Bay Watershed forests gained 17 million metric tons C per year
- Forests are highly productive – gains represent 9% of the total for all U.S. forests on just 3% of the land area
- Oak-hickory and maple-beech-birch forests gained the most C
- Land-use change caused loss of 2 million metric tons C per year

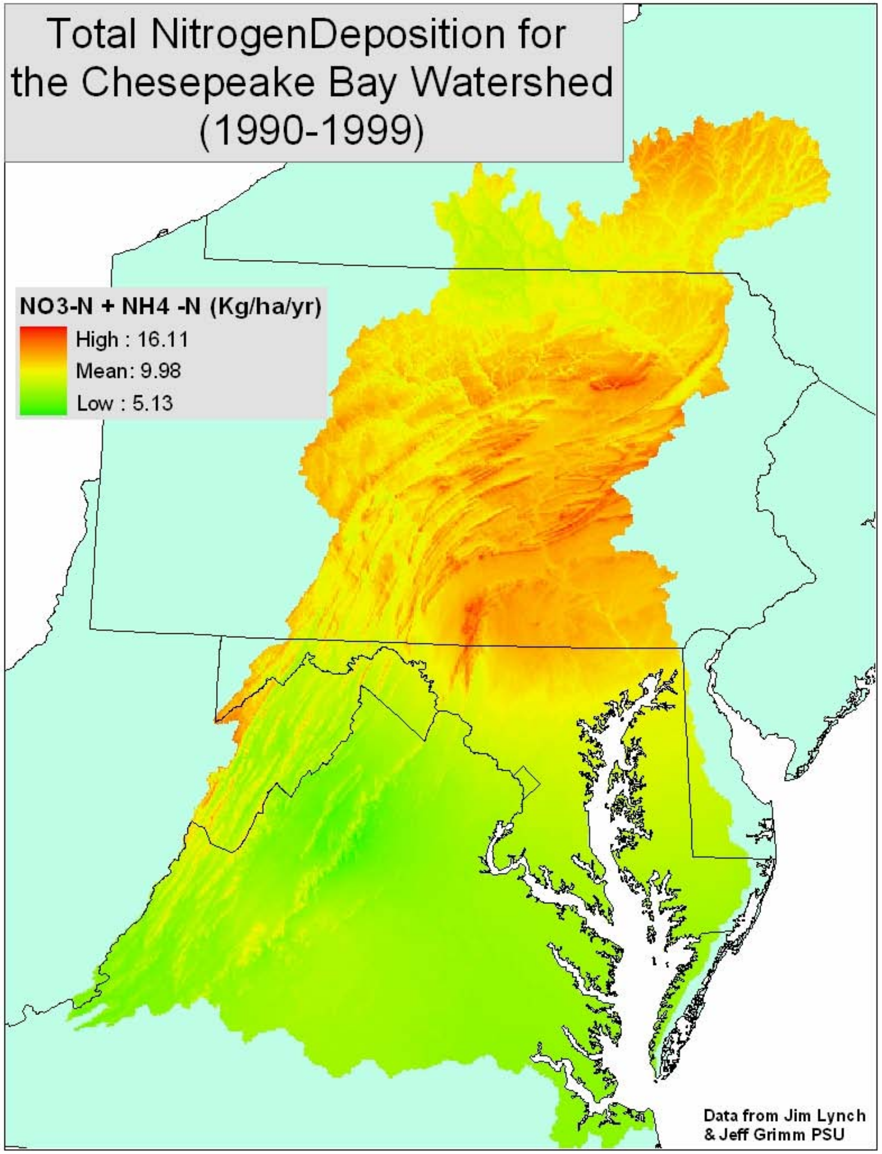
# Climate and $CO_2$ Trends in the Mid-Atlantic Region



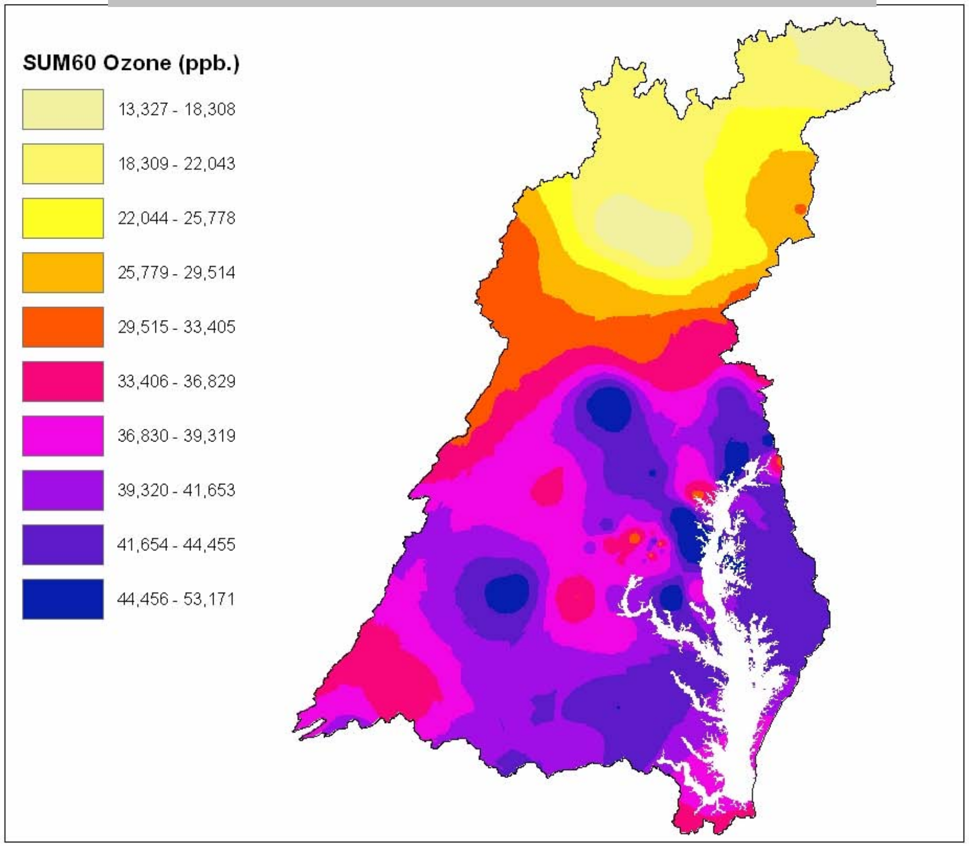




From Mid-Atlantic Regional Assessment

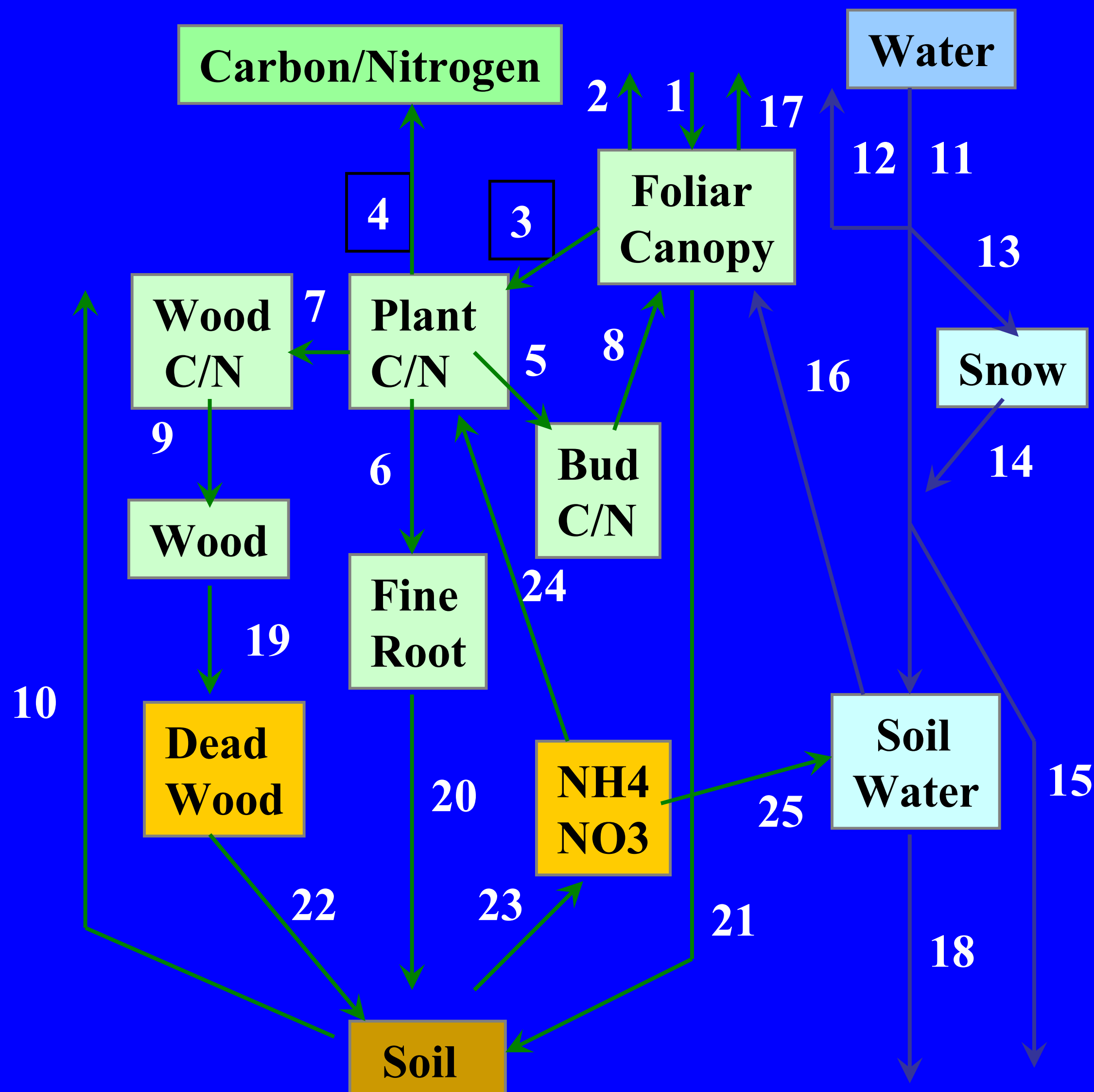
# Nitrogen Deposition and Tropospheric Ozone Exposure, 1990-1999




SUM60 Ozone Exposure During the Growing Season

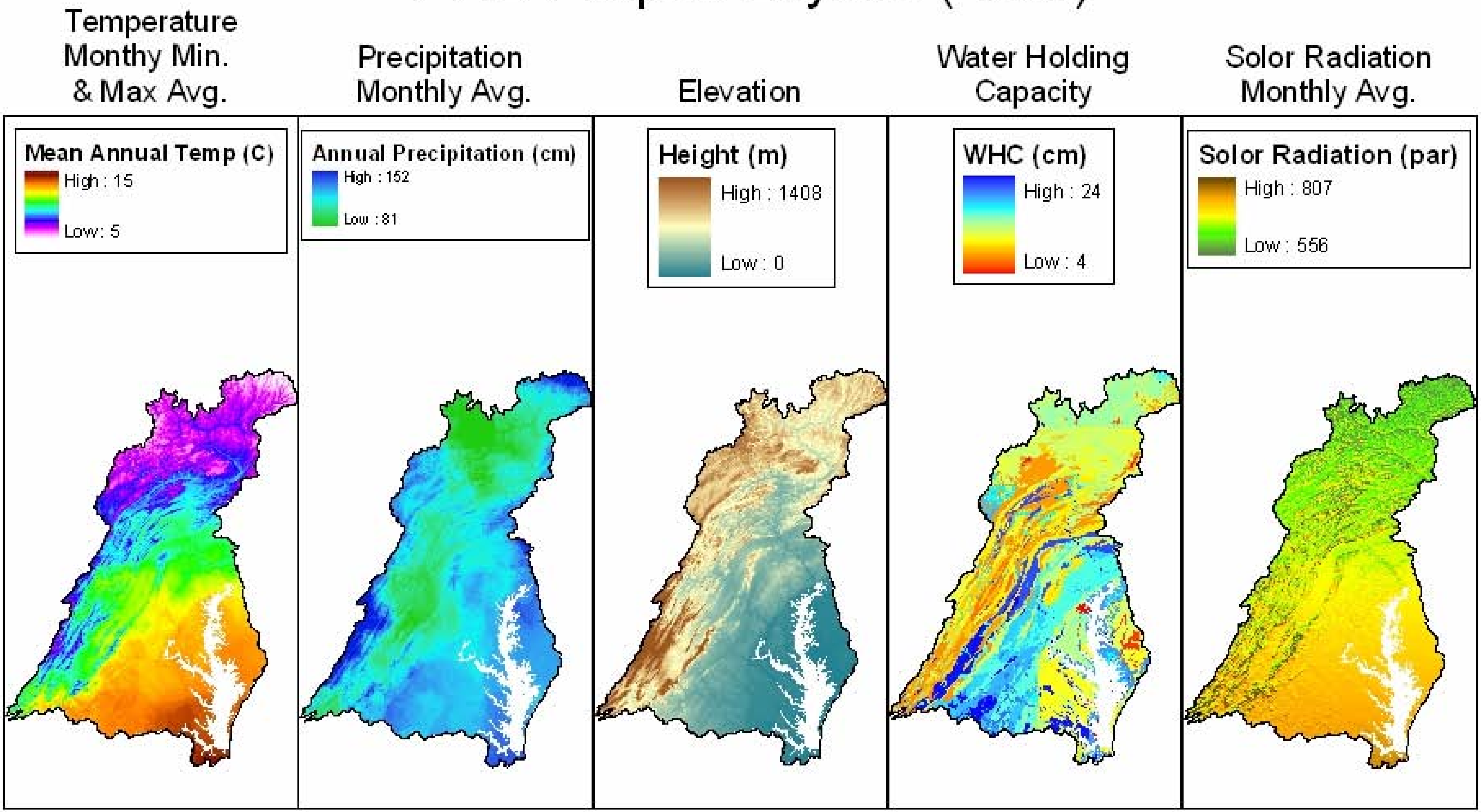


# PnET-CN Model

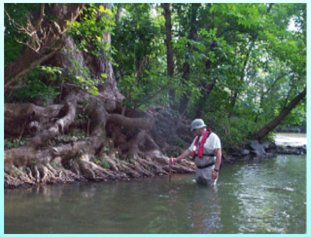



1. Gross photosynthesis
2. Foliar respiration
3. Transfer to mobile C
4. Growth and maintain resp.
5. Allocation to buds
6. Allocation to fine roots
7. Allocation to wood
8. Foliar production
9. Wood production
10. Soil respiration
11. Precipitation
12. Interception
13. Snow-rain partition
14. Snowmelt
15. Fast flow
16. Water uptake
17. Transpiration
18. Drainage
19. Wood litter
20 Root litter
21. Foliar litter
22. Wood decay
23. Mineralization
24. N uptake
25. To soil solution

# PnET Input Layers (1km)



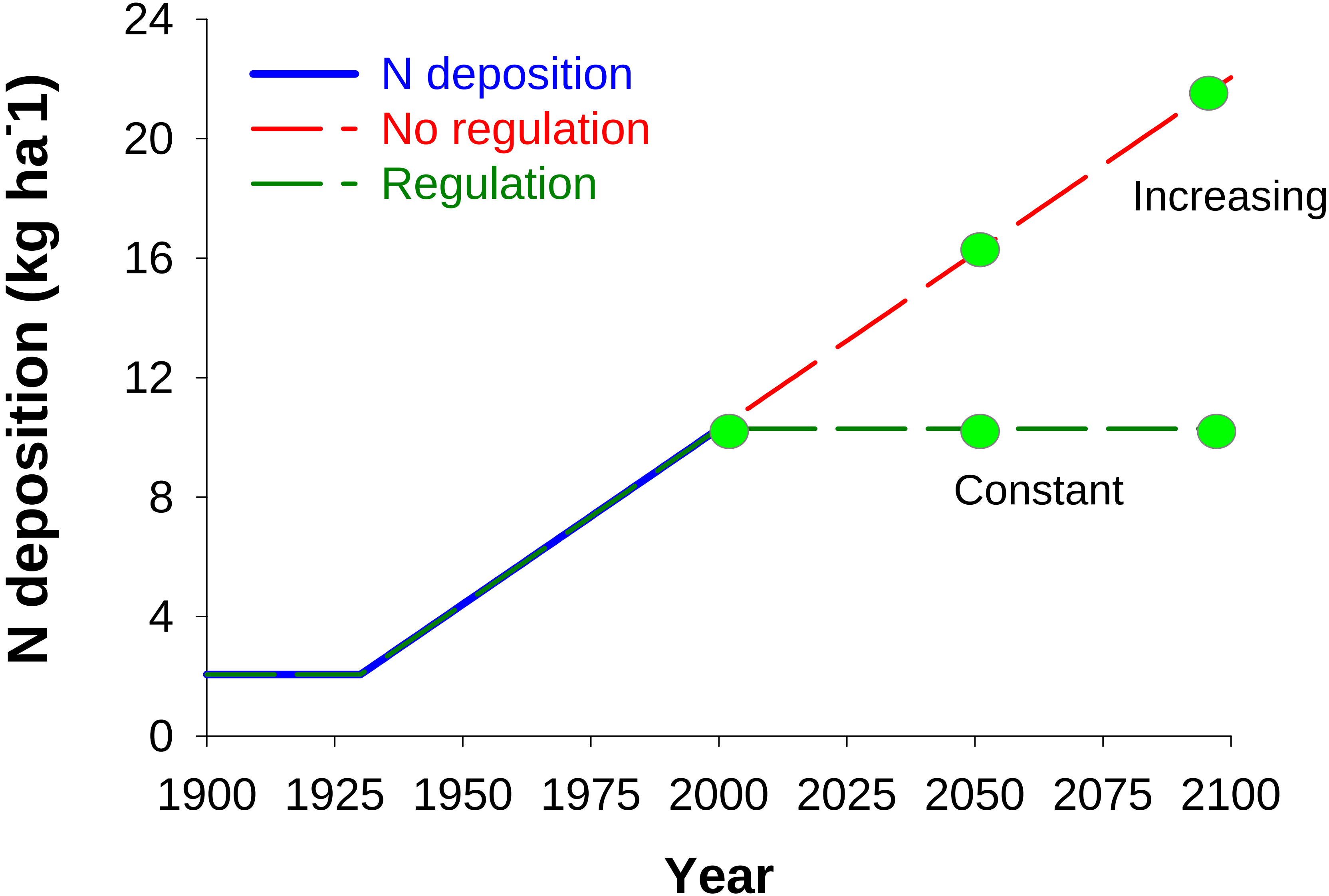
# PnET-C/N Parameters and Validation Data Sets



- Tree growth
- Litterfall
- Foliar chemistry
- Stream samples

- USFS Forest Inventory and Analysis (FIA)
- USGS National Aquatic and Wetlands Assessment (NAWQA)
- Intensive ecosystem observations (e.g. LTER)
- Results of experiments (e.g. FACE)

# Scenarios of Atmopsheric N Deposition



# Forest N export and retention in the Chesapeake Basin watershed.

*Current N Scenario (Mean N deposition = 10.04 kg N $ha^{-1}$ $yr^{-1}$ )*

| *Tree* Groups | Area ($km^2$) | Total N loss (Mg N) | Min | Mean (kg N m2 yr-1) | Max | Retention (%) |
|---|---|---|---|---|---|---|
| N. Hardwood | 20,298 | 3,013.88 | 0.313 | 1.4847 | 2.725 | 86 |
| Spruce-fir | 22 | 4.97 | 0.617 | 2.2580 | 4.444 | 78 |
| Oak-hickory | 52,065 | 5,326.24 | 0.179 | 1.0230 | 2.766 | 90 |
| Pine | 7,404 | 1,023.37 | 0.207 | 1.3822 | 10.590 | 84 |
| Oak-pine | 14,724 | 2,248.66 | 0.224 | 1.5272 | 5.817 | 84 |
| Region | 94,514 | **11,617.00** | 0.179 | 1.2291 | 10.590 | **88** |

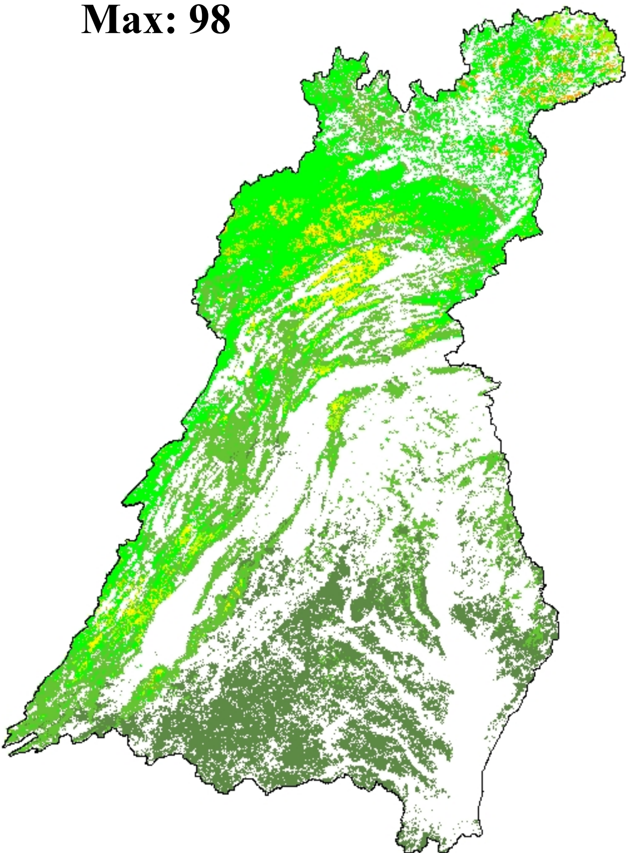
# Retention of N Deposition by Forests Through 2050

**Percentage of Retention for Forest**

0- 50 | 50.1 - 65 | 65.1 - 78 | 78.1 - 83 | 83.1 - 88 | 88.1 - 93 | 93.1 - 98.0

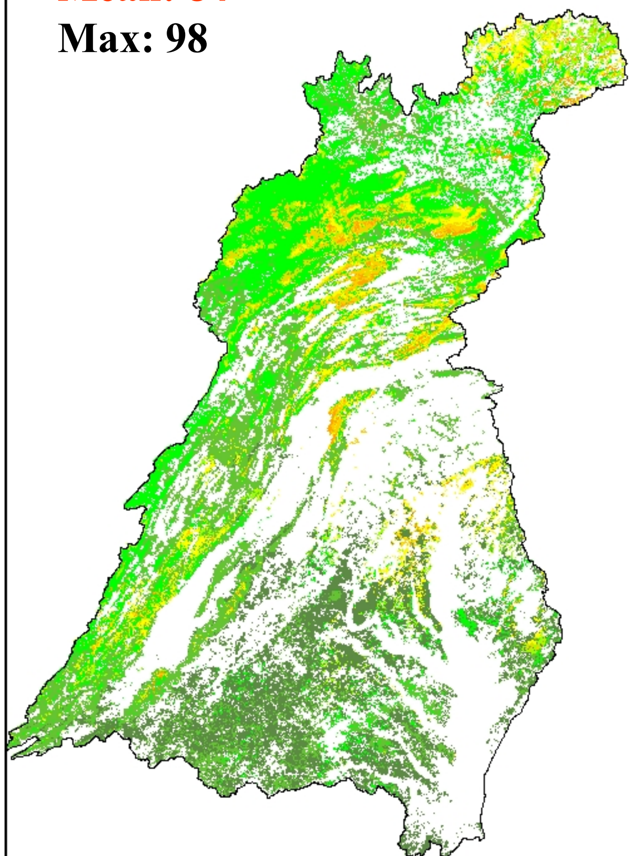
Current

**Min: 18**
**Mean: 88**
**Max: 98**



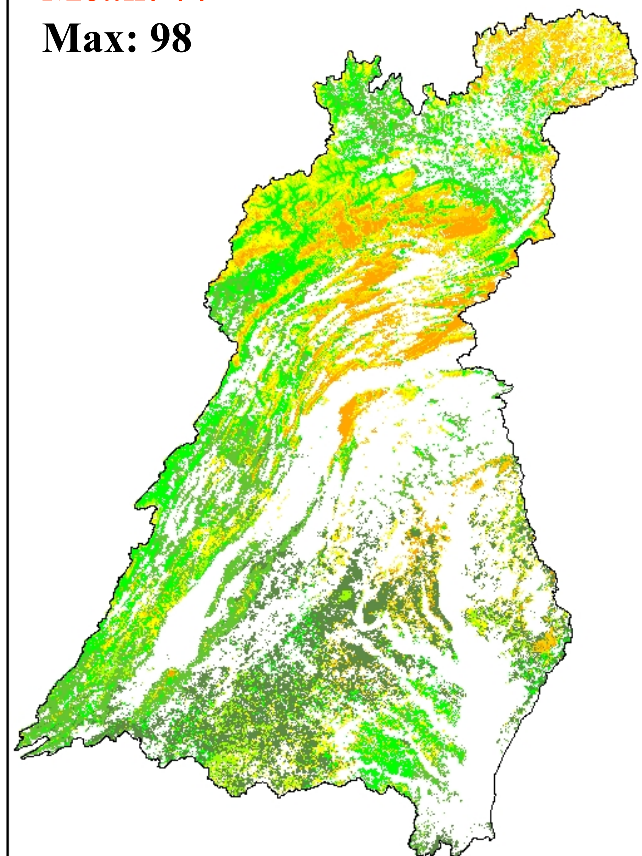
Level off after 2000, Until 2050

**Min: 0**
**Mean: 84**
**Max: 98**

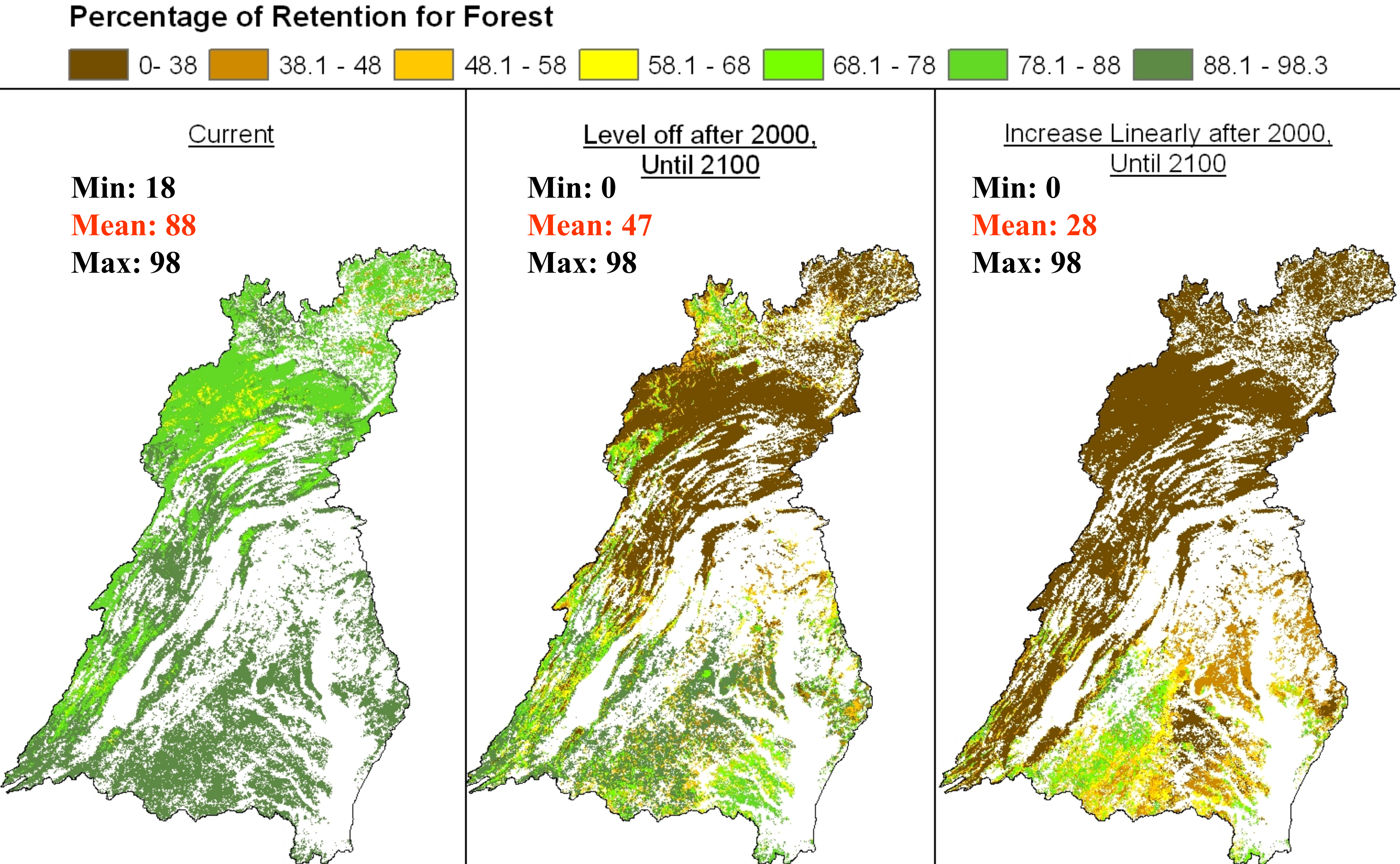


Increase Linearly after 2000, Until 2050

**Min: 1**
**Mean: 77**
**Max: 98**



# Retention of N Deposition by Forests Through 2100



# N-saturation Effect: Non-linear Increase in N loss

| Scenarios | N deposition (kg N /ha/yr) | N loss rate (kg N /ha/yr) | Total N loss (Mg N /yr) | Change (vs. 2000) |
|---|---|---|---|---|
| 2000 N dep. | 10.04 | 1.23 | 11,617 | – |
| 2050 constant | 10.04 | 1.56 | 14,791 | + 27% |
| 2100 constant | 10.04 | 5.30 | 50,087 | + 331% |
| 2050 increasing | 15.77 | 3.62 | 34,250 | + 195% |
| 2100 Increasing | 21.51 | 15.38 | 145,345 | + 1151% |

# Effects of Changing Land Use on N Export

- Current forests export 11,500 Mg/yr
- Loss of 10% of forest cover increases N export by 4,000 Mg/yr (35% increase)
- Gain of 10% forest cover decreases N export by 3,900 Mg/yr (34% decrease)

# Conclusions about N Deposition and Retention by Forests

- The current N retention rate is 88%
- Constant N deposition for 50 years would lower retention to 84% and increase total N export 27%
- Constant N deposition for 100 years would lower retention to 47% and increase total N export by 330%
- Increasing N deposition for 50 years would lower retention to 77% and increase total N export by 195%
- Increasing N deposition for 100 years would lower retention to 28% and increase total N export by 1151%
- Continued N deposition will “saturate” forests causing an increasing inability to retain N
- Increasing N export from forests will dramatically increase the load on N in Chesapeake Bay and it estuaries

# Complications Regarding Effects of Multiple Factors

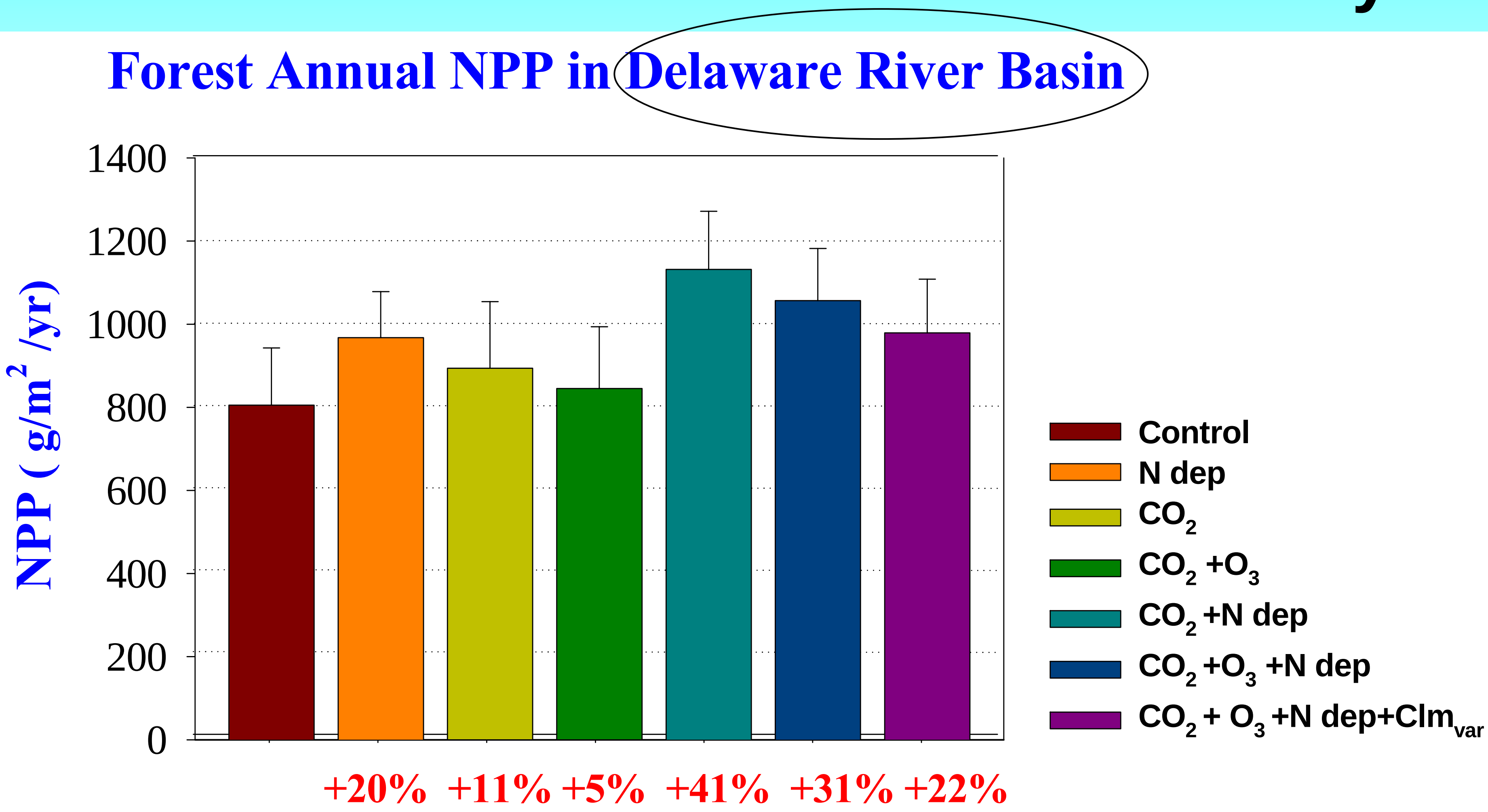
## Factorial Model Experiments

| | $CO_2$ | $O_3$ | N dep. | Clm |
|---|---|---|---|---|
| Run 1: control | ○ | ○ | ○ | ○ |
| Run 2: scenario | ● | ○ | ○ | ○ |
| Run 3: scenario | ○ | ○ | ● | ○ |
| Run 4: scenario | ● | ● | ○ | ○ |
| Run 5: scenario | ● | ○ | ● | ○ |
| Run 6: Scenario | ● | ● | ● | ○ |
| Run 7: Scenario | ● | ● | ● | ● |

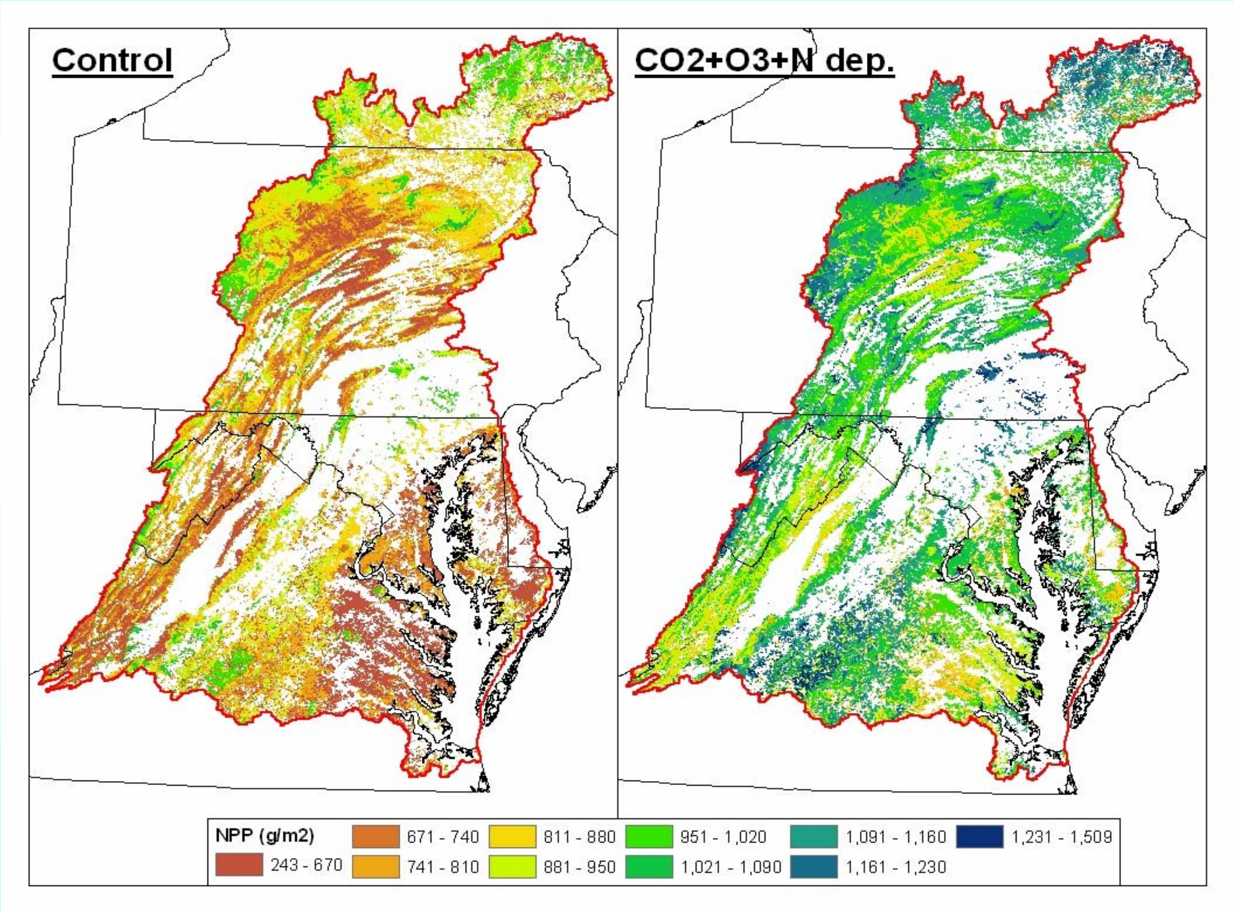
| | | | |
|---|---|---|---|
| ○ ($CO_2$) | Fixed 280 ppmv | ● ($CO_2$) | Ramped up to 366 ppmv |
| ○ ($O_3$) | No ozone input | ● ($O_3$) | Ramped up to current level |
| ○ (N dep.) | No N input | ● (N dep.) | Ramped up to current level |
| ○ (Clm) | Mean climate | ● (Clm) | Historical climate |

**Running years: 1800-2000**

# Effects of Interactions of Climate Change and Air Pollution on Forest Productivity



# The Combined Effects of Increasing $CO_2$, Tropospheric Ozone, and N deposition on Forest Productivity = +20% NPP




The N saturation effect is significantly reduced with increasing $CO_2$

# Comments on Science Questions and Information Needs

- Scientists need to hear what questions are important from the decisionmakers
- Attributing responses of ecosystems to single factors is complicated by interactions with multiple factors
- It is a great challenge to convey the complexity of ecosystem responses in ways that highlight options for decisionmakers
  - Maps
  - Graphs
  - Focused summary statements
  - Simulation tools

# Effective Communication about Complex Issues

- Instill confidence that information is based on sound science
- Increasing use of integrated data-model approaches (results are realistic)
- Good old-fashioned “resource analysis” is essential

# Barriers to Using Climate Information in Decisionmaking

- Our ability to influence climate is rather limited, so there is a tendency to focus on things we can control
- Climate is just one of many factors affecting ecosystems
- The role of climate could be integrated into analyses as….

  …a source of uncertainty

  …an issue of risk management

# How to Maintain Dialogue with Decision Makers

- Seek opportunities to use scientific models as decision-support tools in assessments
- Work with stakeholders to develop decision-support tools for more general applications
- Make available summary data sets, model parameters, and functional relationships