

Climate, CO₂ and Invasive Weeds: Meeting the Challenge



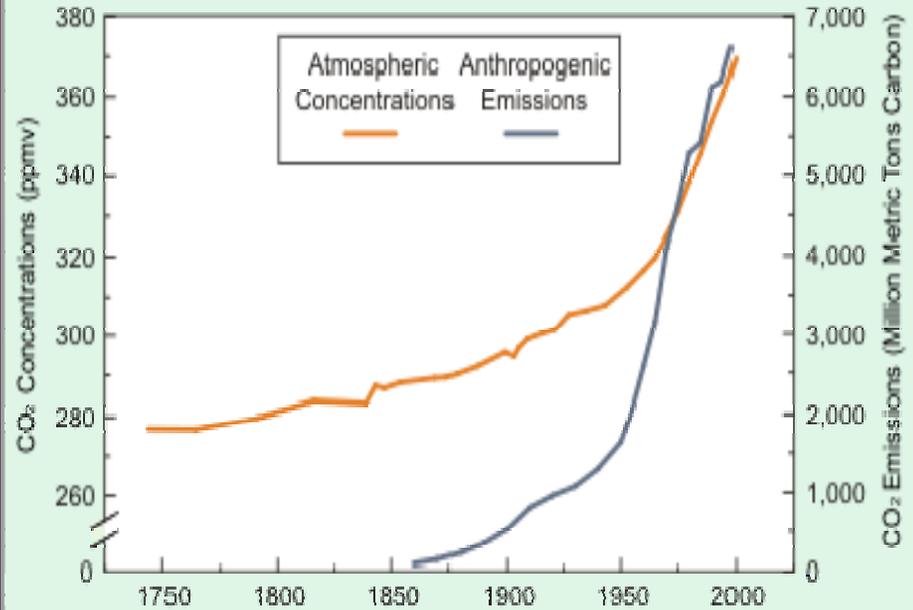
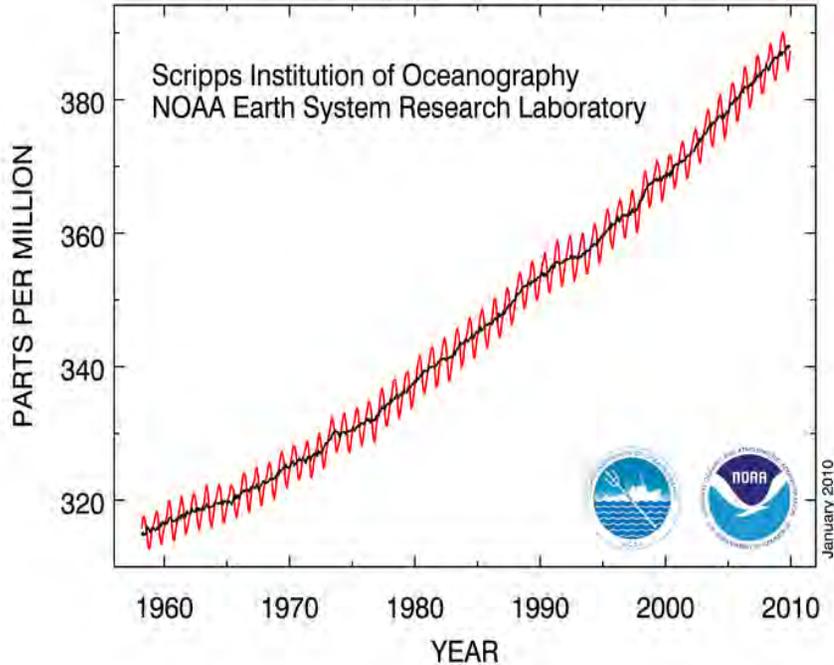
Lewis H. Ziska, USDA-ARS, Crop Systems and Global Change Lab.



AgMasters Conference, University of Illinois, December 2, 2010

Atmospheric CO₂

Atmospheric CO₂ at Mauna Loa Observatory

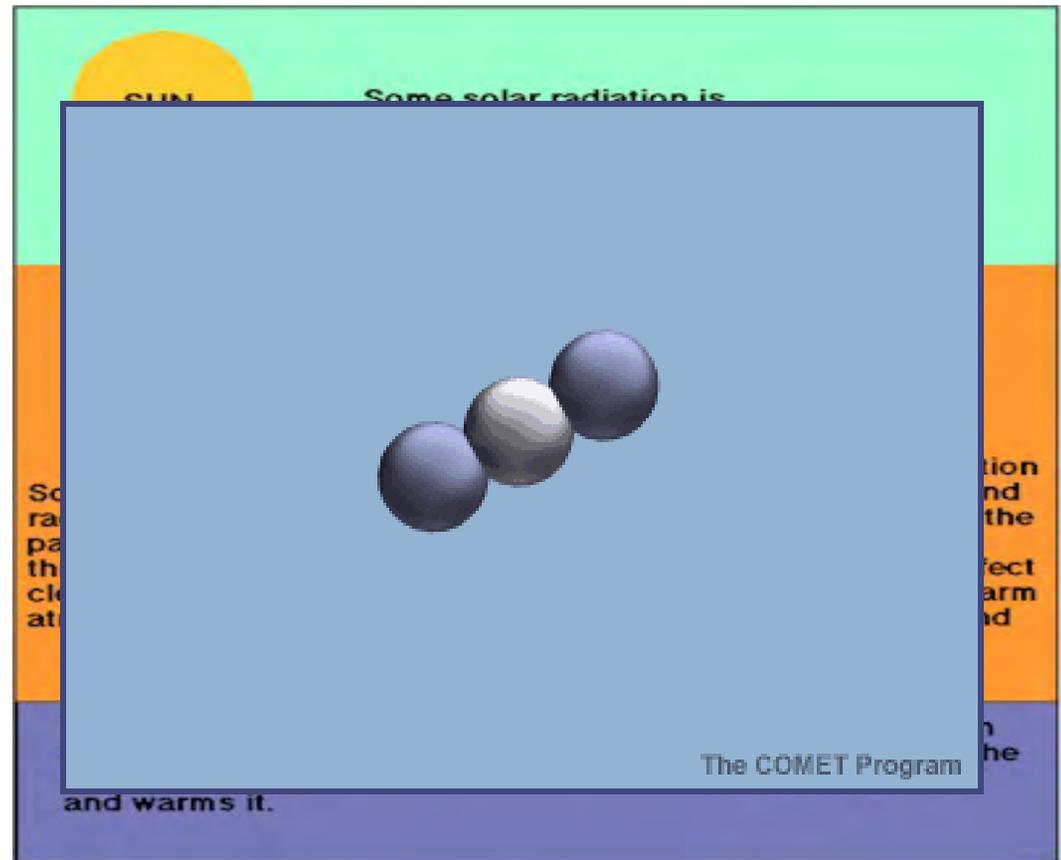


Source: Oak Ridge National Laboratory, Carbon Dioxide Information Analysis Center, <http://cdiac.esd.ornl.gov/>.

So what if CO₂ goes up?

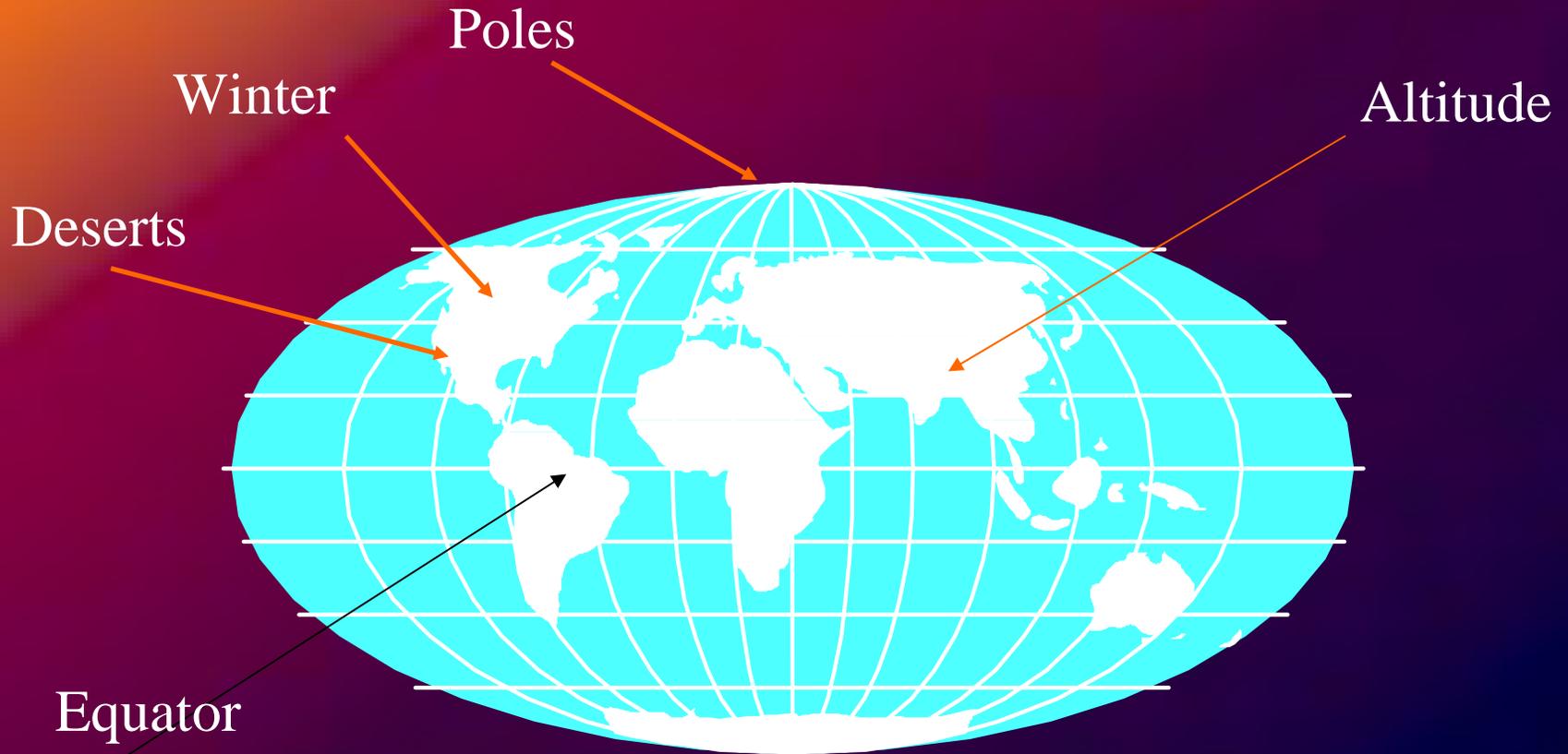
I. An indirect effect of rising carbon dioxide: warmer temperatures.

Gas	%
Nitrogen (N ₂)	78.1
Oxygen (O ₂)	20.1
Argon (Ar)	0.93
Carbon Dioxide (CO ₂)	0.04 up to 0.100
Water (H ₂ O)	0.05 to 1.00



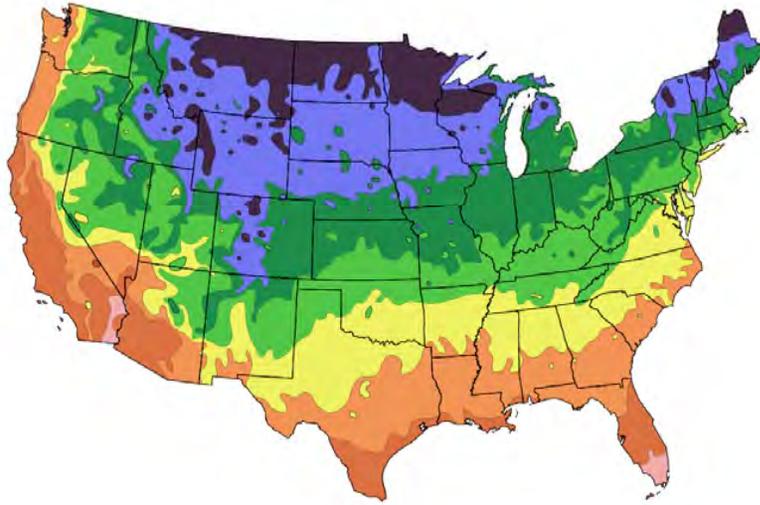
No H₂O and CO₂? Surface temperature would be -18°C . With H₂O and CO₂? Surface temperature is 15°C .

H₂O vs. CO₂



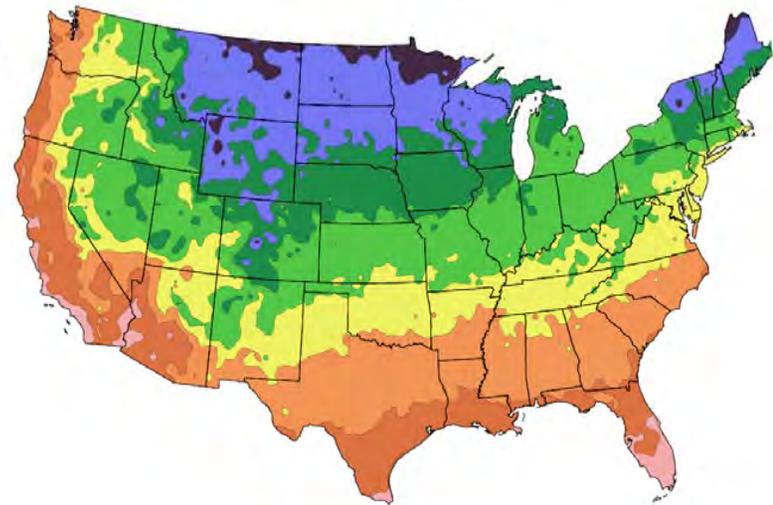
**If water vapor is high, it will be the dominant warming gas....little effect of CO₂
If water vapor is low, adding CO₂ will increase the surface temperature.**

1990 Map



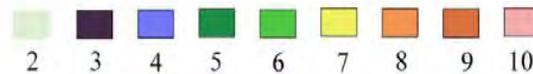
After USDA Plant Hardiness Zone Map, USDA Miscellaneous
Publication No. 1475, Issued January 1990

2006 Map



National Arbor Day Foundation Plant Hardiness Zone Map
published in 2006.

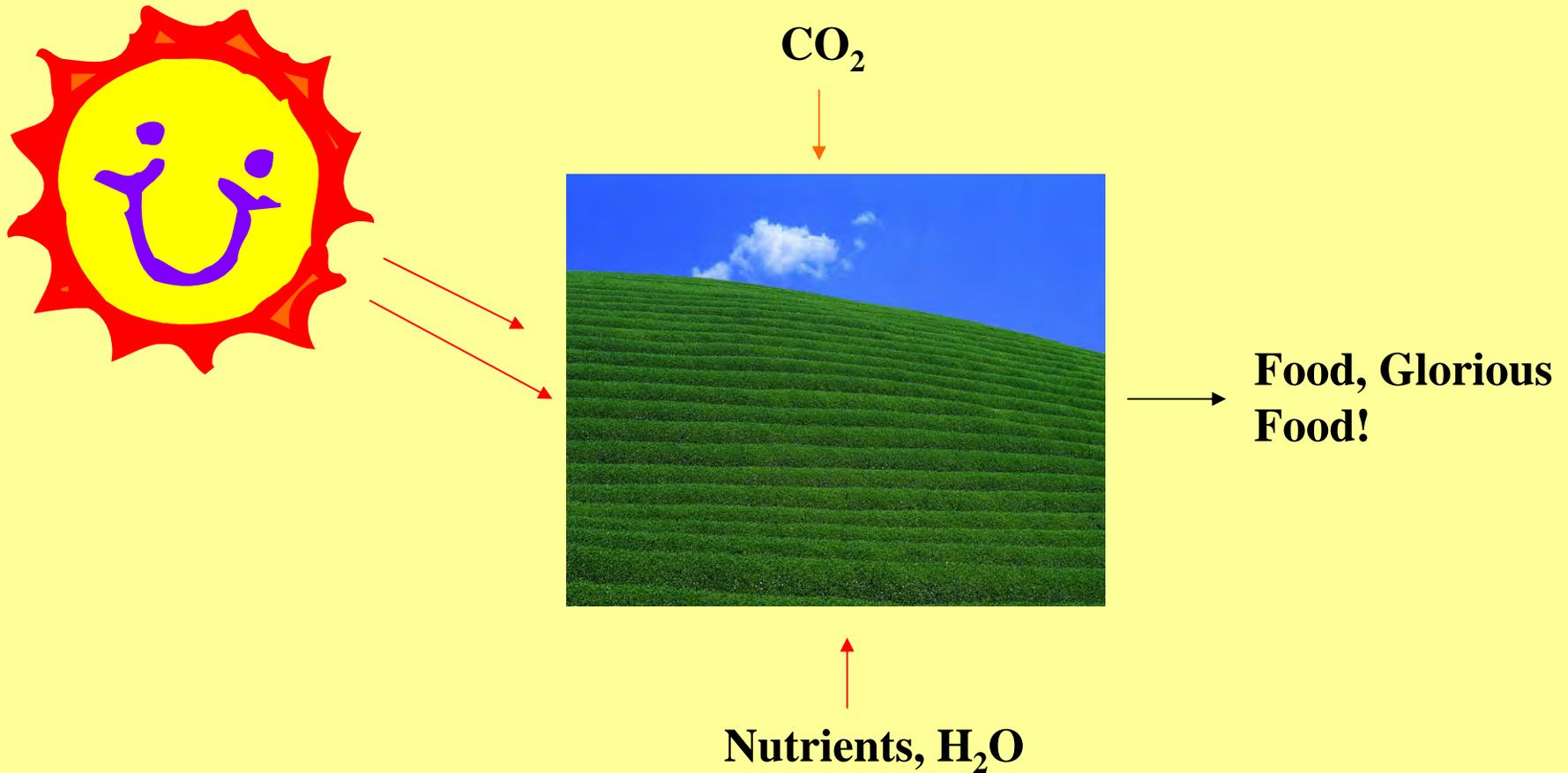
Zone



© 2006 by The National Arbor Day Foundation®

So, indirect effect of temperature on biological distribution.

II. A direct effect of rising CO₂: Stimulation of plant growth.



Any change in light, water, nutrients or carbon dioxide will alter plant growth.

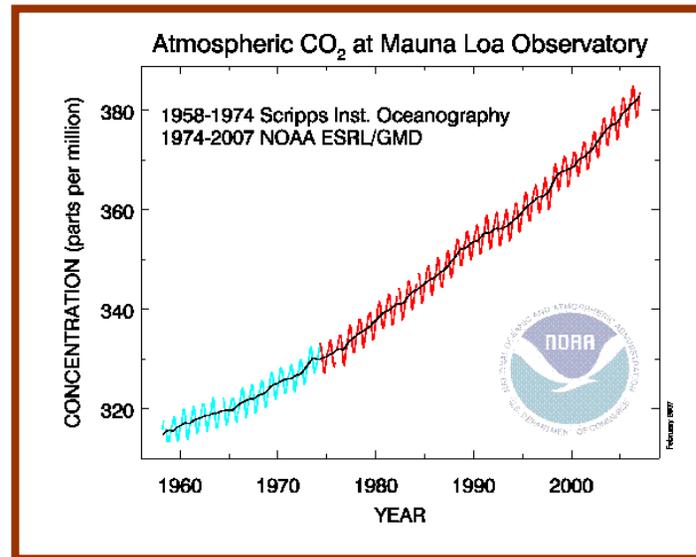
Plants are Important.

Plants are necessary for the flow of energy and carbon through ecosystems. 90% of all living matter consists of plant life.

With the exception of a few subterranean organisms, if plants did not exist, life would not exist.

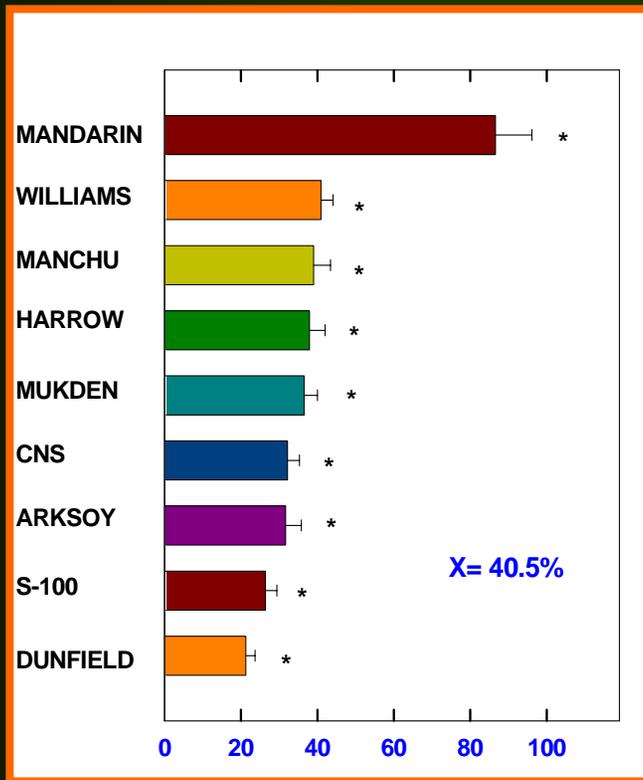
Plant growth however is dependent on four physical inputs.

Any perturbation in these inputs will alter all living systems.



But isn't more plant growth, "good"?

Genetic variability in soybean with increasing CO₂



Evaluation of yield response of 9 soybean cultivars to 710 ppm CO₂.

Greenhouse study, USDA
Crop Science 41:385-391

CO₂ is a VERY smart molecule.



Green is not always good.

CO₂, climate change and plant biology

Food Security

Crop/weed competition

***Invasive plant species**

Weeds and public health.

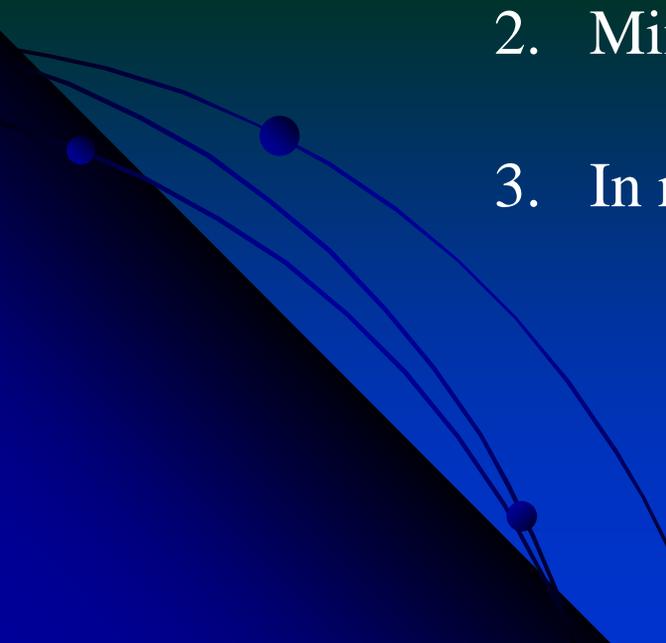
Invasive weeds

A weedy species, usually non-native for a given region, whose introduction results in wide-spread environmental or species degradation.

- **Financial Cost:** In the billions.
- **Environmental Cost:** loss of genetic diversity



How will temperature and/or CO₂ alter the potential success of invasive weeds?

1. Canada thistle, nitrogen and CO₂
 2. Minimal temperatures and Kudzu migration
 3. In real time.
- 

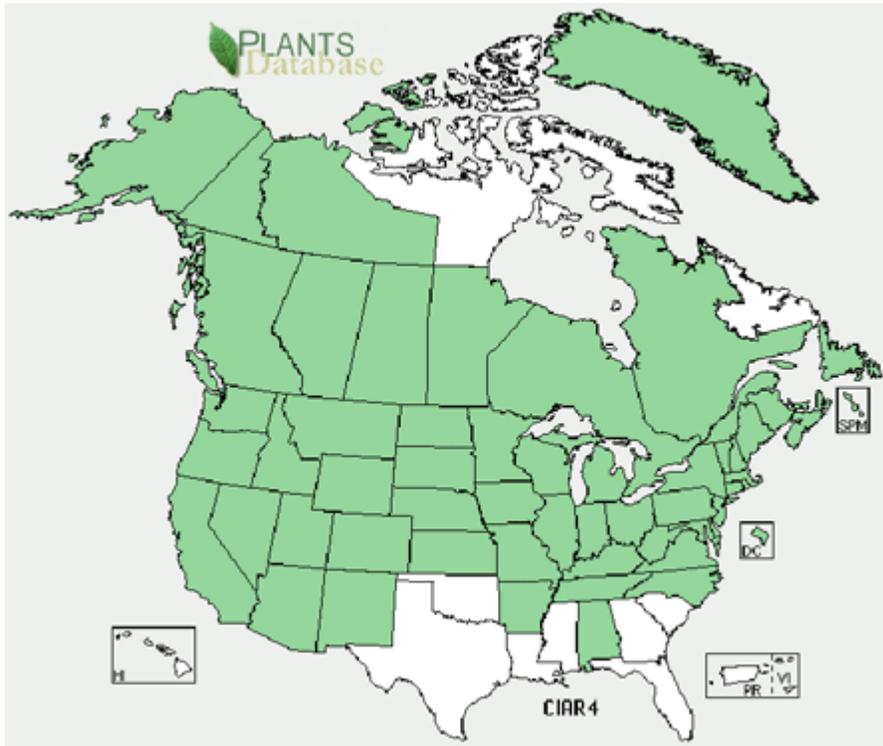
CO₂ and Canada thistle

Some Noxious Weeds: The best of the worst.

Skinner et al. Weed Science, 48:640



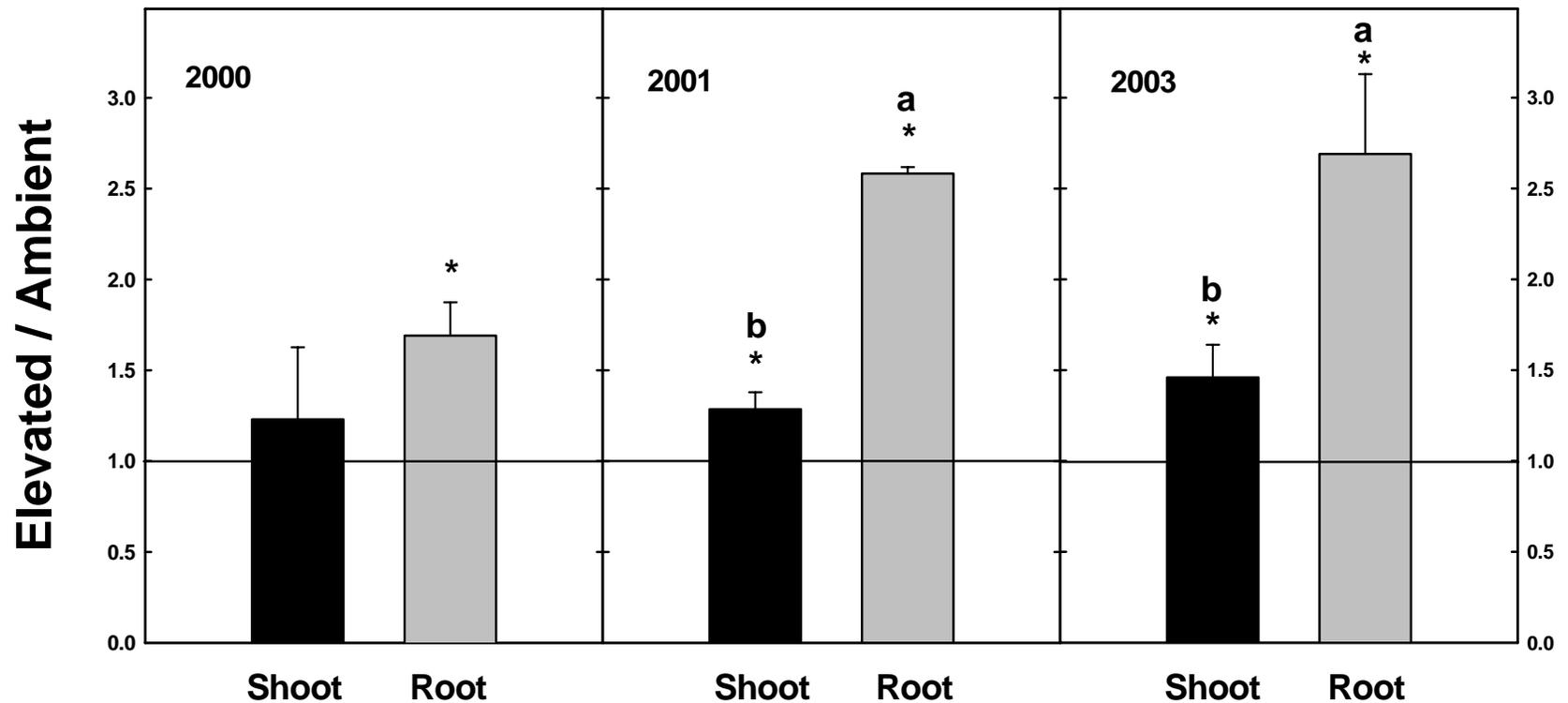
1. *Cirsium arvense*, Canada thistle 33 lists
2. *Carduus nutans*, musk thistle 24 lists
3. *Lythrum* spp., loosestrife 24 lists
4. *Convolvulus arvensis*, field bindweed 23 lists
5. *Euphorbia esula*, leafy spurge 22 lists
6. *Acroptilon repens*, Russian knapweed 20 lists
7. *Sorghum* spp., sorghum 20 lists
8. *Cardaria* spp., whitetop 17 lists
9. *Centaurea maculosa*, spotted knapweed 17 lists
10. *Sonchus arvensis*, perennial sowthistle 17 lists
11. *Centaurea diffusa*, diffuse knapweed 16 lists
12. *Elytrigia repens*, quackgrass 16 lists
13. *Cuscuta* spp., dodder 12 lists
14. *Linaria dalmatica*, Dalmation toadflax 12 lists
15. *Centaurea solstitialis*, yellow starthistle 11 lists



Canada thistle

Canada thistle: Best of the worst.

Canada Thistle



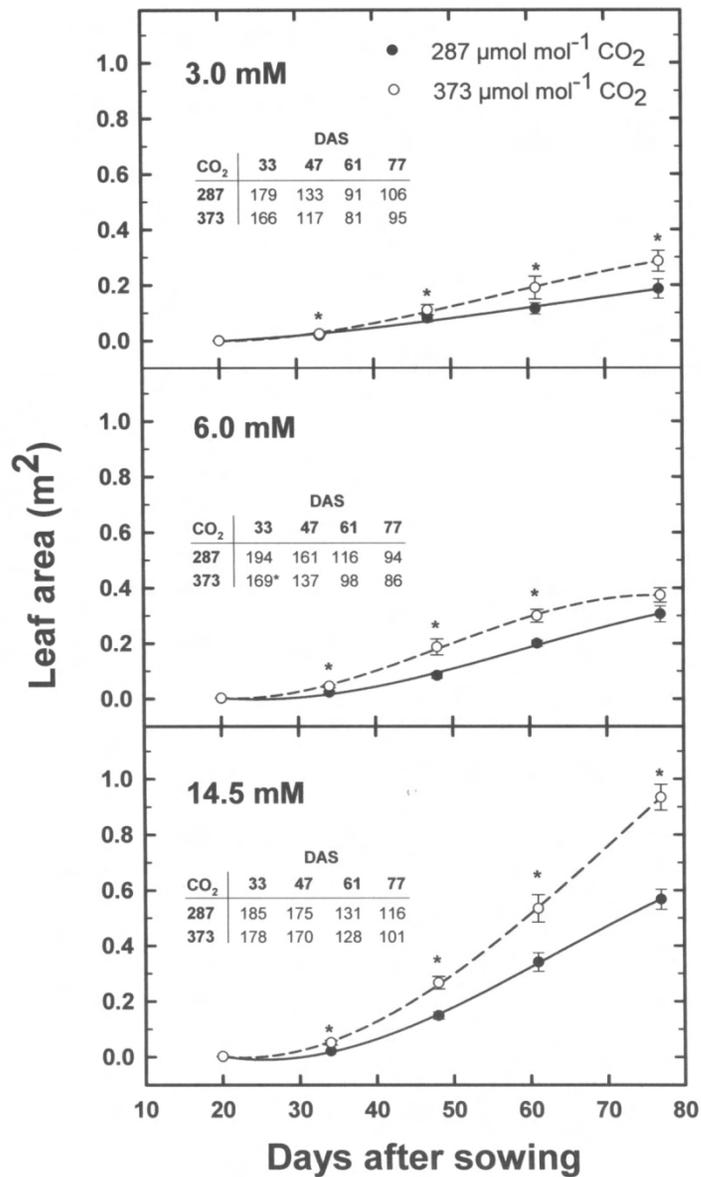
3 years of field trials at +250 ppm above ambient.

Canada thistle, CO₂ and N

One of the assumptions regarding rising CO₂, is that it will have no effect because any stimulation will be limited by other resources (e.g. nutrients).

Examined response of Canada thistle from 287 to 373 μppm CO₂ at N levels of 3, 6 and 14.5 mM during vegetative stage of growth.

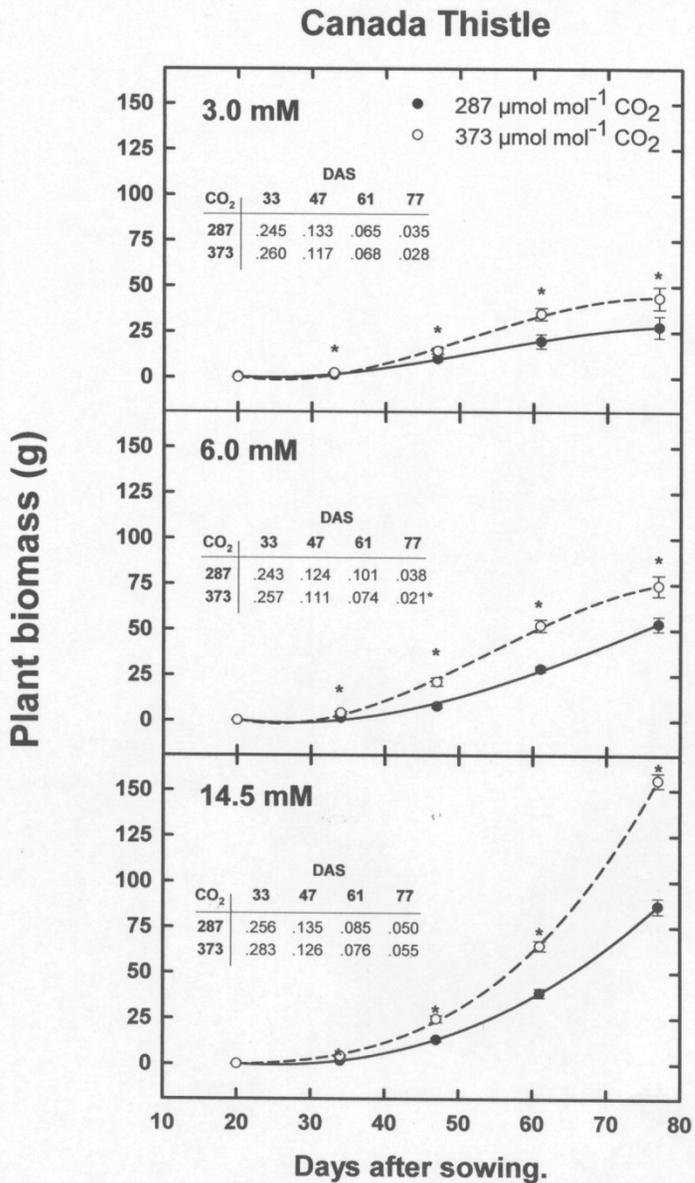
Canada Thistle



Canada thistle, CO₂ x N

No change in relative stimulation of leaf area.

Canada thistle, CO₂ x N

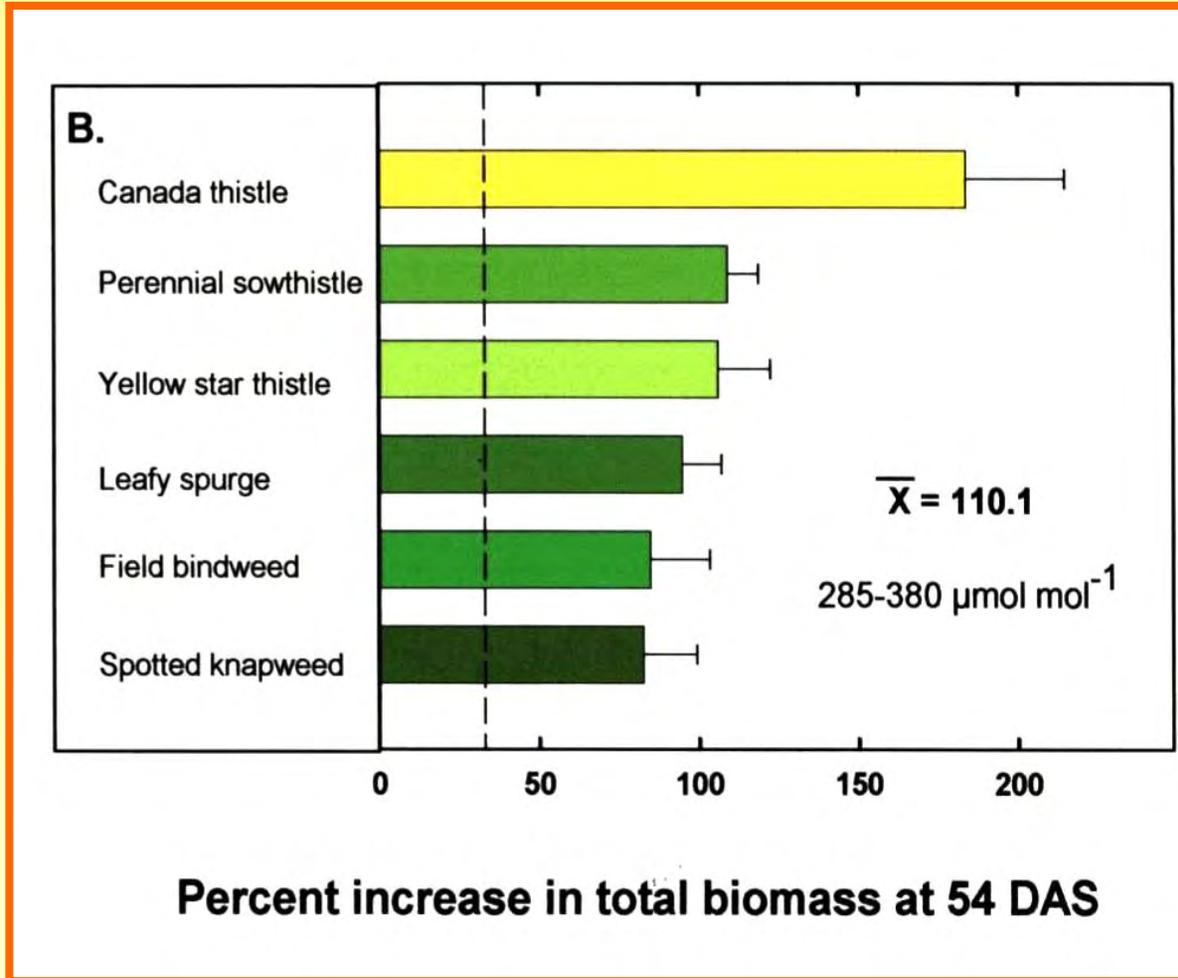


No change in relative stimulation of plant biomass.

Overall for Canada thistle.

- Strong response to rising carbon dioxide with differential response of root >> shoot.
- The response to recent changes in carbon dioxide appears independent of N concentration.

Present vs. Past



So far only examined individual plant response.

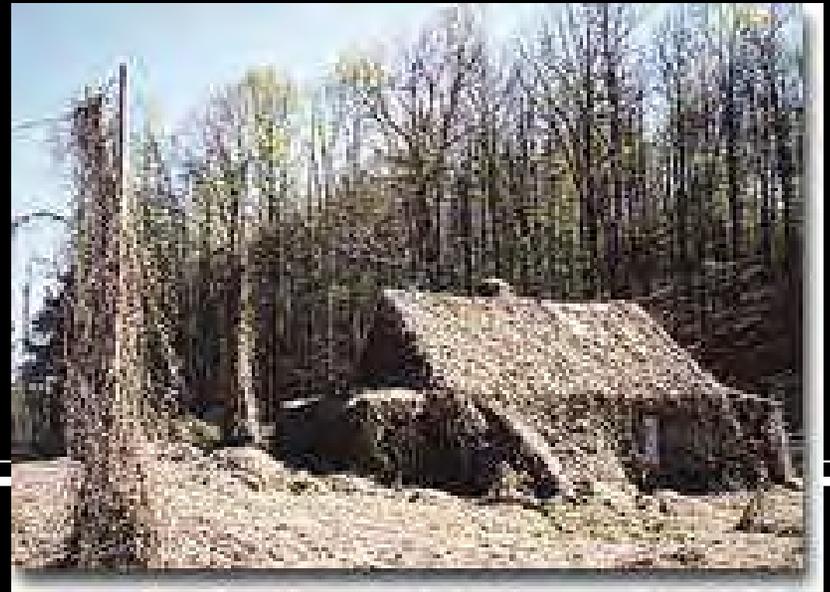
Does CO₂ preferentially select for invasive species within communities?

Species	Community	Favored?	Reference
Yellow star thistle	California grassland	No.	Dukes, 2002
Honey mesquite	Texas prairie	Yes.	Polley et al. 1994
Japanese honeysuckle	Forest under-story	Yes.	Belote et al. 2003
Cherry laurel	Forest under-story	Yes.	Hattenschwiler & Korner 2003
Red Brome	Desert	Yes.	Smith et al. 2000

Out of over 600+ Invasives in N. America alone.

Kudzu migration and temperature:

Ah, you may have watched the blacksnake run
To the shaded hole from the blistering sun,
And you may have seen the swallow's flight
And the shooting star in the deep, dark night;
But until you have watched the kudzu grow
You never have seen the fastest show.



What is the thermal limit for kudzu? Does it vary depending on population?

Examined 8 populations throughout the U.S., over a 1300 km N-S transect. Vegetative stems (asexual reproduction at N limit).

RC	Tissue Temp. (°C)
0.10	-7.0+0.9°
0.25	-10.8+0.9°
0.50	-16.1+0.8°
0.75	-21.7+1.0°
 0.95	-28.6+1.1°

Where was kudzu
growing in 1971?

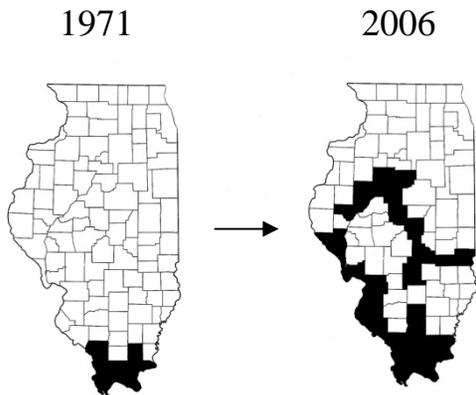
Data are from Clyde Reed,
a USDA scientist. Published
in “Common Weeds of the
United States.

Focus on mid-western
populations, away from
urban centers or mountains.

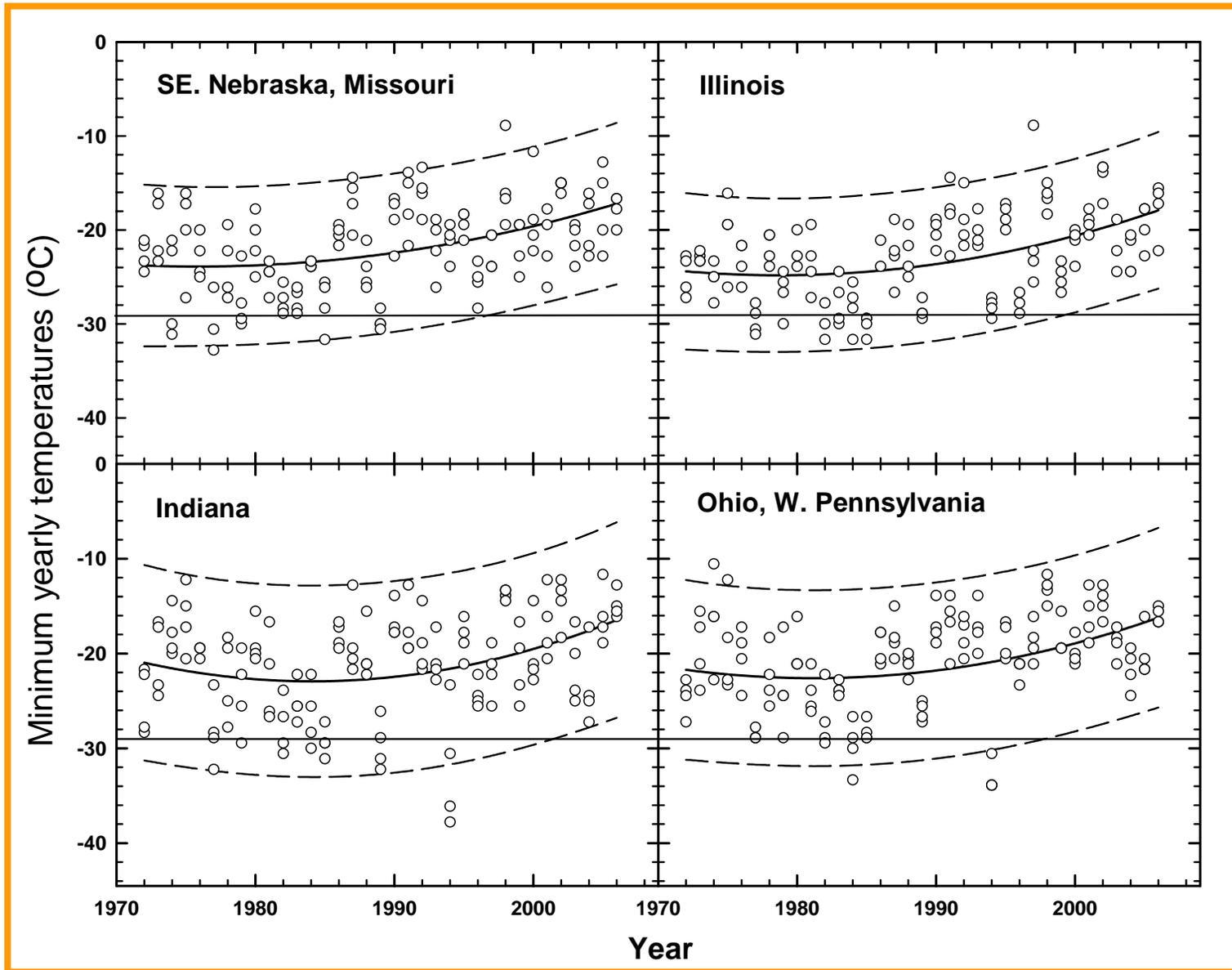


Where is it growing now?

Current estimates of kudzu distribution for Nebraska, Missouri, Illinois, Indiana, Ohio and Pennsylvania were evaluated using three separate sources: a) National Resource Conservation Service (NRCS), database of invasive U.S. Species (plants.usda.gov/java/profile?symbol=PUMO) b) the National Agricultural Pest Information Service (NAPIS) in cooperative agreement between the Animal Plant Health Information Service (APHIS) and Purdue University as part of their Cooperative Agricultural Pest Survey (CAPS) program (ceris.purdue.edu/napis/pests/weeds/imap/kudzu.html), and c) the Department of Natural Resources (DNR) for the states of Pennsylvania, Ohio, Indiana, Illinois, and Missouri, including the publication of “The Green Plague Moves North” by the Illinois DNR.



Has the minimum temperature threshold changed?



Some implications.

1. **Data suggest that the link between global warming and the spread of an invasive species may be real, not hypothetical. What about spring temperatures?**
2. **Why else should you care if kudzu moves northward?**

Asian soybean rust....



Soybean



Kudzu

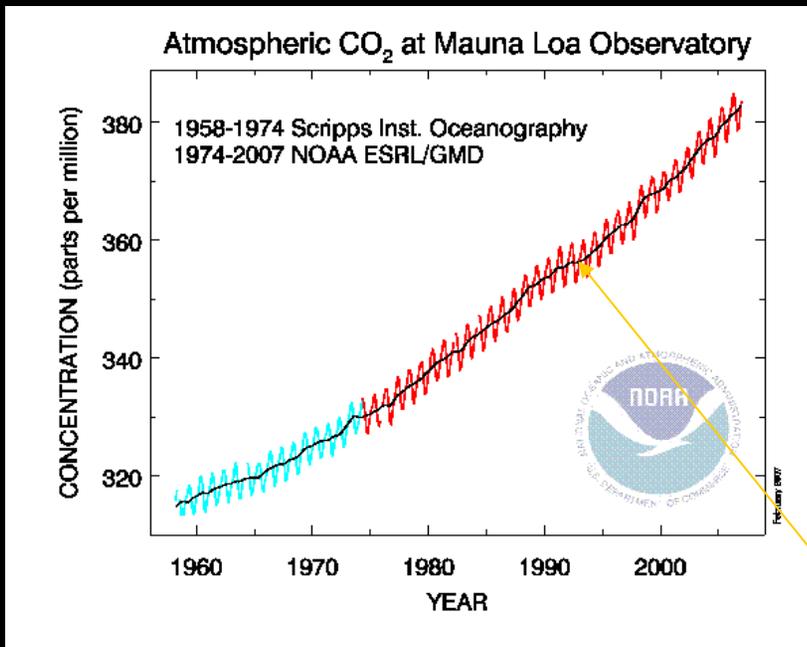
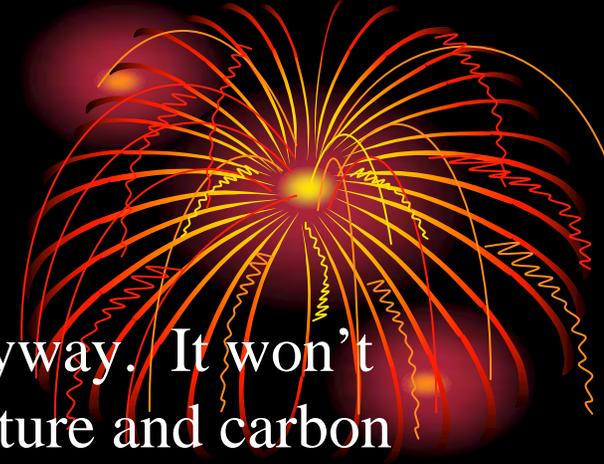
Kudzu can serve as an alternative host for the pathogen. If warmer winters allow kudzu to move northward, what will the impact be on the spread of the disease?

Summary: Invasive weeds and CO₂ / temperature

- Initial evidence indicates that increasing minimum winter temperatures associated with climatic change may be a factor in the northward spread of kudzu.
- Canada thistle, the “worst” invasive, shows a strong response to CO₂, but greater below ground, relative to above ground growth. Response to CO₂ is nitrogen independent.
- Suggestion that CO₂ may select for invasives within assemblages of plants.

In real time?

All this is “blue-sky” hypothetical & *^\$%# anyway. It won't happen in real-life, and even if it does, temperature and carbon dioxide effects are a long ways away.



Mauna Loa, “Official” CO₂ data.

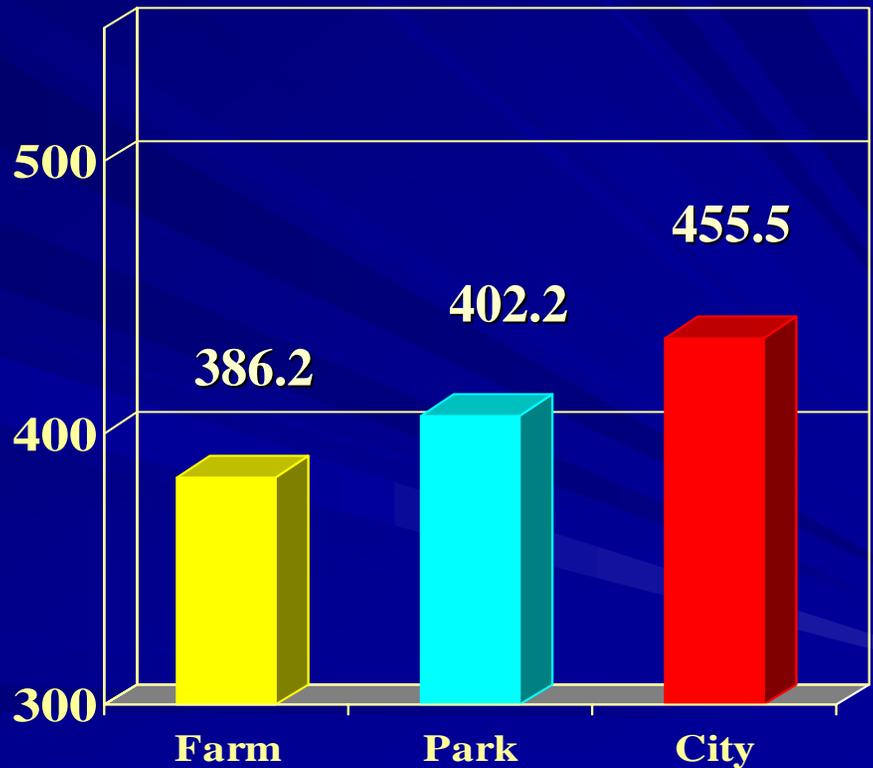
Crazy
Liberals!



10,000 feet on a mountaintop in Hawaii.

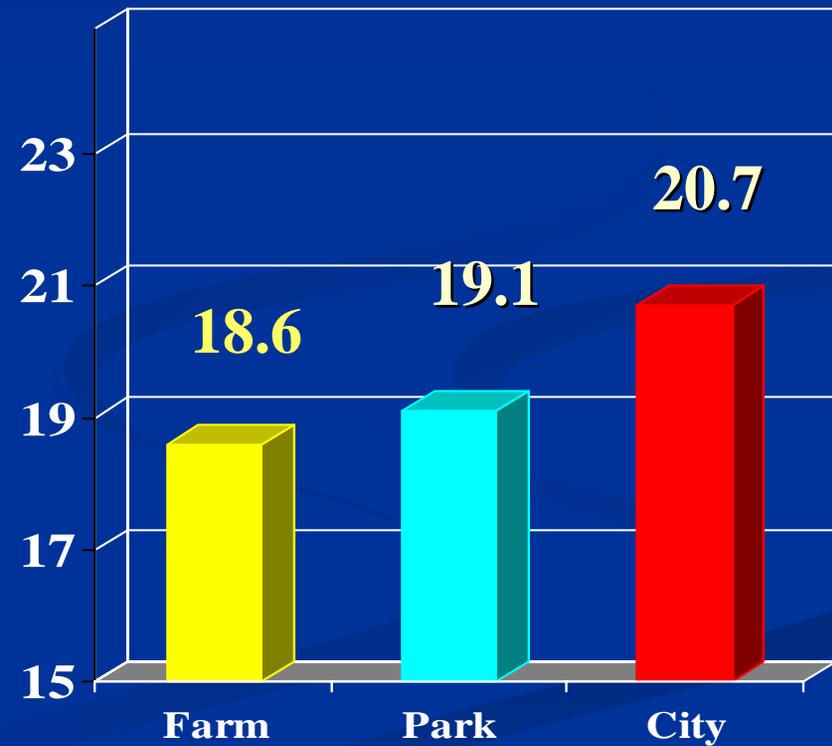
Is the rise in CO₂ the same everywhere?

- Change in average day-time CO₂ concentration (ppm) from downtown Baltimore to an organic (rural) farm.



Is the increase in temperature the same?

- Change in average daily temperature (°C) from downtown Baltimore to an organic (rural) farm (2002).



And if it isn't...Can we study the effects of climate
change NOW?



**Placing four 2x2 m² plots
Near downtown Baltimore.
Use same soil and seed bank
in suburban and rural locations.**

“Necessity may be the mother of invention,
poverty is the father....”

Technical skills....



Back-filling to maintain uniform bulk density

Took mixed fallow topsoil (top 20 cm. 99% of seed bank), and placed it at each site.

Watered at each site to match ET

First year response, rural farm, 2002



First year re-growth of fallow soil, +90% lambsquarters, 6-8 feet in height.

(About as big as it gets)

First year response, urban Baltimore, 2002



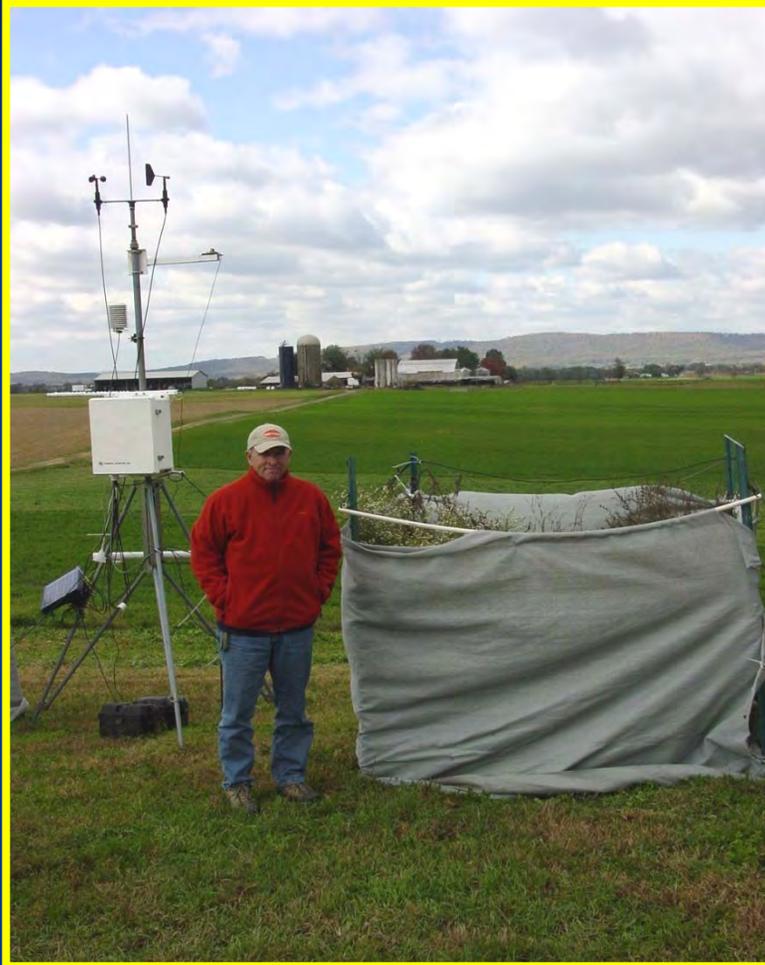
First year re-growth, 80% lambsquarters, 10-12 feet in height. More annual weeds present.

No other meteorological factors (wind speed, ozone, etc.) varied along the transect.

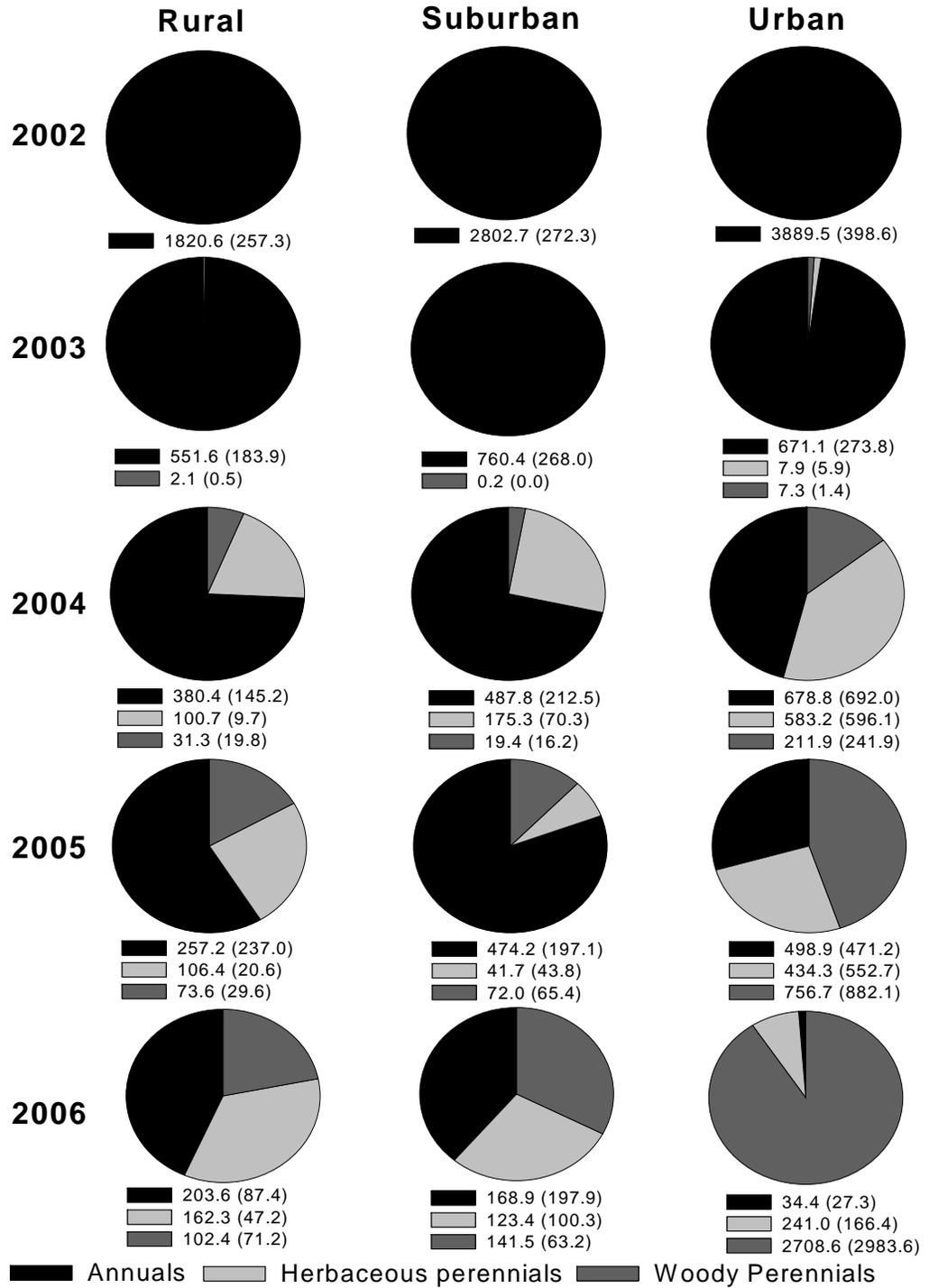
Ziska et al. *Oecologia*, 139:454-458, 2004

George et al. *Atmos. Env.* 41:7654-7665, 2007

And after 5 years.....



Why is succession faster in urban areas?



Litter deposition and seed germination.



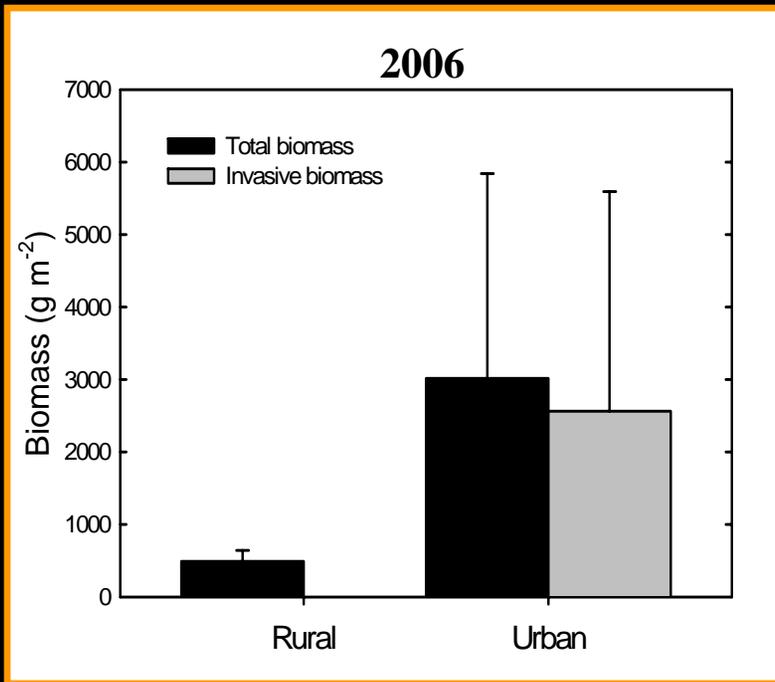
Rural location

Greater litter deposition from the urban site (high carbon dioxide, temperature) prevents germination of small seeded annuals (e.g. ragweed), while promoting larger seeded (usually perennial) species.



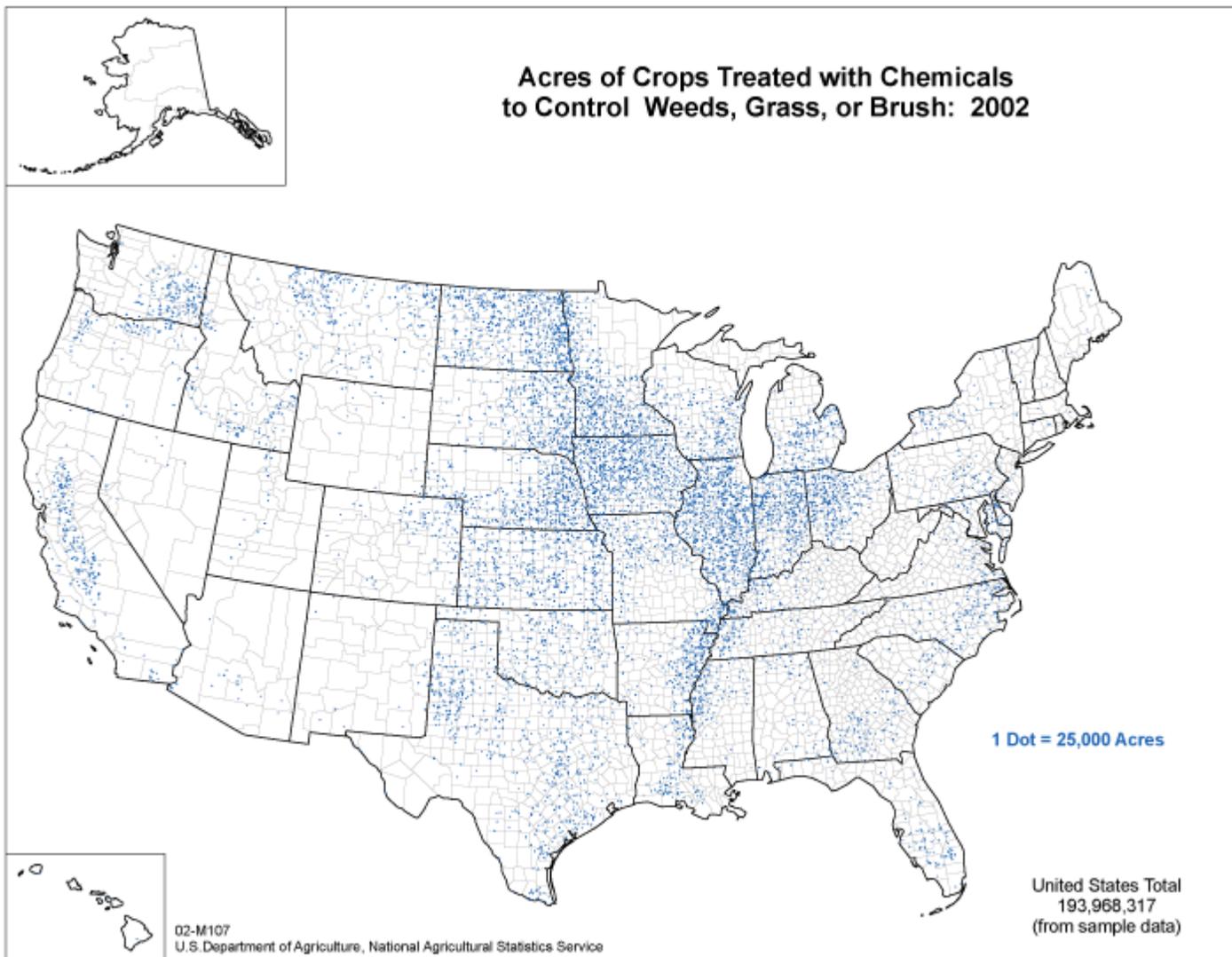
Urban location

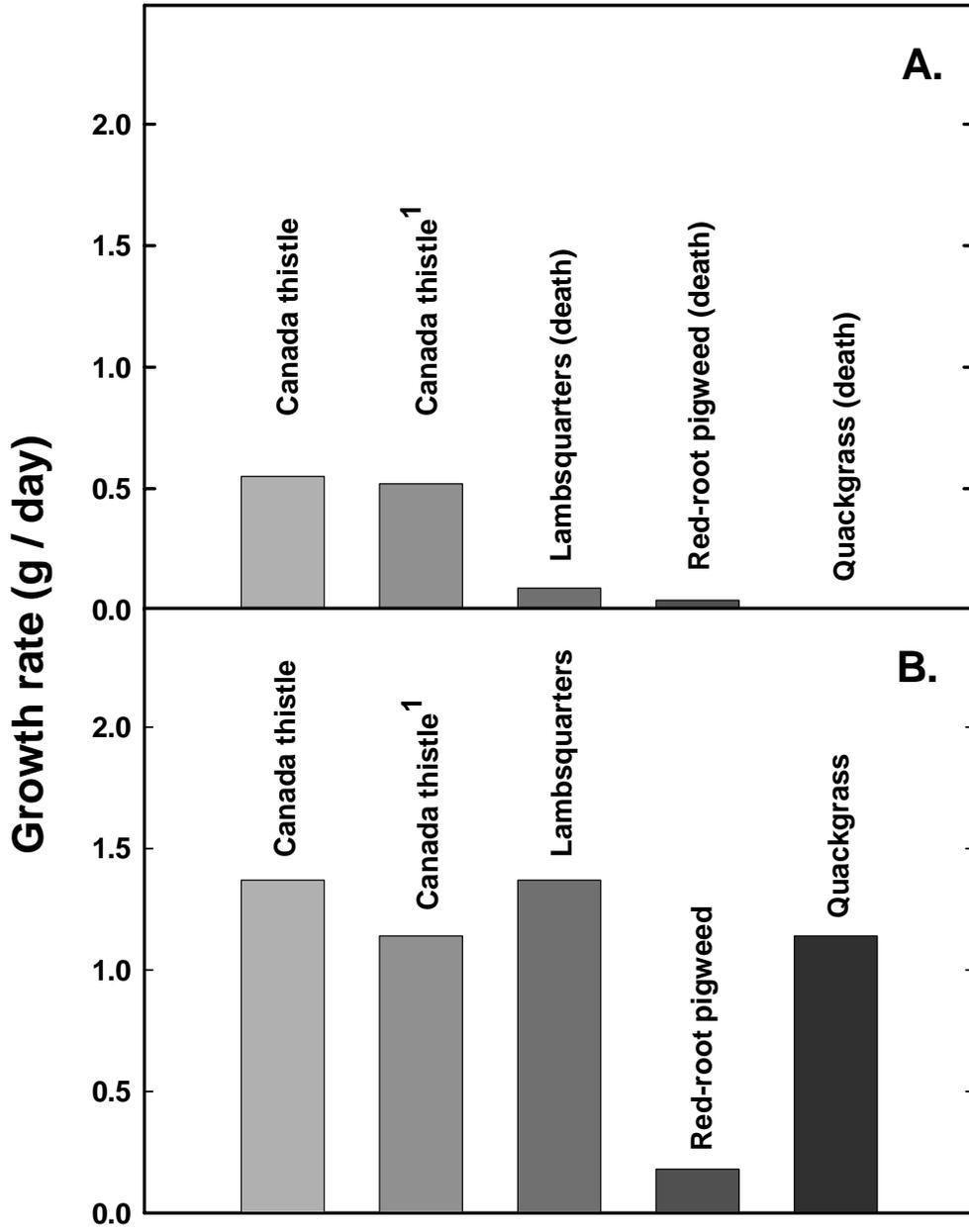
Weeds and Climate Change: Real Time: After 5 years



Are cities “reservoirs” of invasive species?

Climate change/CO₂, implications for weed management.





Change in herbicide efficacy as a function of increased carbon dioxide.

Ambient CO₂

Future CO₂ (+300 ppm)



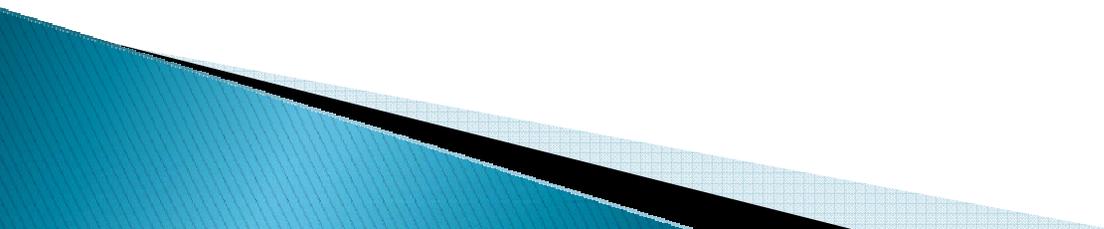
Increasing CO₂ reduces herbicide efficacy.

e.g. Ziska et al. *Weed Science* 2004

Summary: Weed Management

Chemical control of weeds is very much dependent on climate. Climate is likely to change in ways that will be difficult to predict but changes in weed distribution are almost certain.

Biological? Cultural? Physical? Unknown.



Where do we go from here?



Invasive plants are invasive, in part, because they lack predators to keep populations in check. Climate therefore, will be a major factor in limiting population establishment and spread of invasive species. Differential response to CO₂ may also favor invasive species.

As climate and carbon dioxide change, invasive weed populations will change.

Which ones are more likely to increase their range? Why?

How will climate and CO₂ alter competition between native and invasive plants?

How can we manage invasive species in the future?

WHAT ELSE? WHAT DO YOU THINK?

