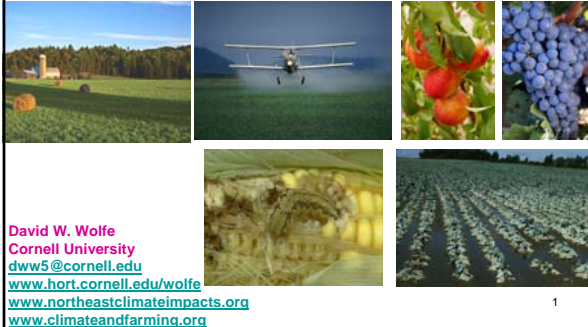


## Climate Change and Northeast Agriculture: Impacts, Adaptation, Mitigation



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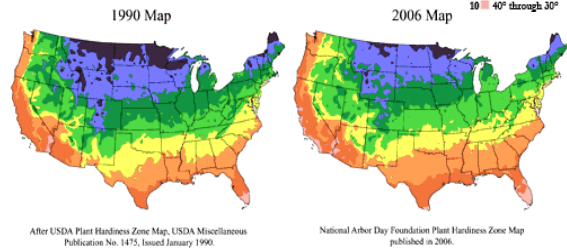
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## The New "Plant Hardiness Zone Map"

Climate change is already here  
(maps based on minimum winter temperatures;  
prior 15 years of weather station record)

Source: [www.arborday.org](http://www.arborday.org)

Zone Arg. Annual Low  
2 -40° through -50°  
3 -30° through -40°  
4 -20° through -30°  
5 -10° through -20°  
6 0° through -10°  
7 10° through 0°  
8 20° through 10°  
9 30° through 20°  
10 40° through 30°



It is not just thermometers telling us the climate is changing. The living world (plants, insects, birds and other animals) are responding to change. For example, in the Northeastern US....



Grapes are blooming 6 days earlier



Apples are blooming 8 days earlier than they were in the 1960s



Lilacs are blooming 4 days earlier

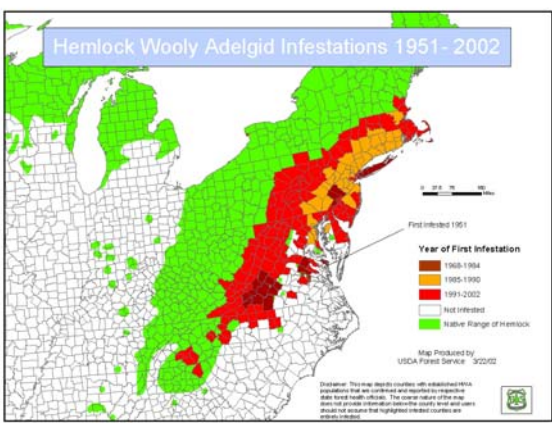
[Source: Wolfe DW et al. 2005. Internat J Biometeor 49:303-309.]

3

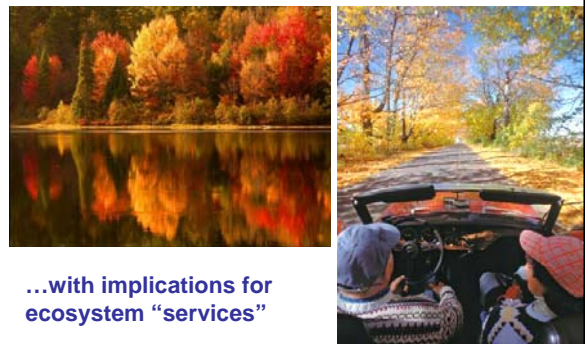
## Biological (Phenological) Responses to Climate Change in the NE

- Lilacs, grapes, apples are blooming 4, 6, 9 days earlier now compared to 1960s in the NE  
(Source: Wolfe et al. 2005. Internat J. Biometeorology 49:303-309)
- Woody plants at Harvard's Arnold Arboretum blooming 8 days earlier from 1980 to 2002 than they did from 1900-1920  
Based on 327 records from 229 living plants representing 37 genera.  
(Source: Primack et al. 2004. Amer. J. Botany 91(8):1260-1264).
- 89 of 100 wildflower species in Wash. D.C. area showing an average 4.5 day advance in spring bloom (1970-99)  
(Source: Abu-Asab et al. 2001. Biodiversity and Conservation 10:597-612).
- Spring arrival dates of 103 migrant birds in NY and MA arriving 4 to 13 days earlier 1951-1993 compared to 1903-1950  
(Butler. 2003. Ibis 145: 484-495)

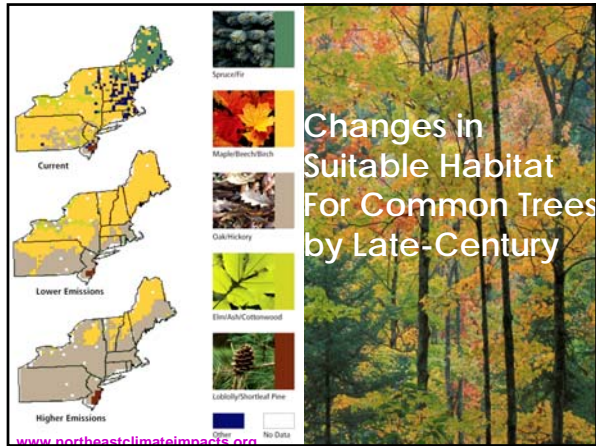
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Climate change will forever alter the fabric of our forests and other natural landscapes...



...with implications for ecosystem "services"



For farmers, gardeners, urban landscapes . . .  
Climate change might allow exploration of new crops and new markets,

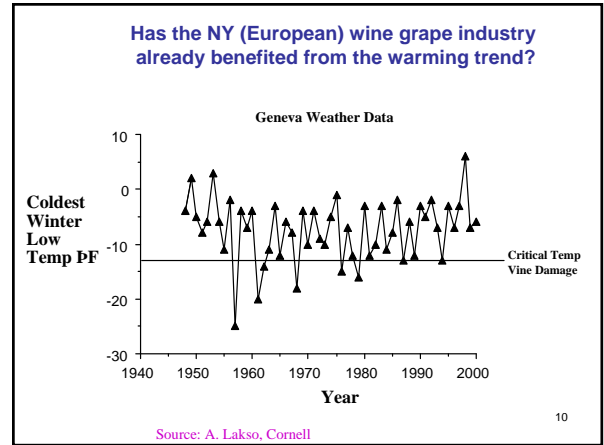
but will also bring with it increased weed, disease, and insect pressure, damaging summer heat stress, and new challenges for water management

In New York, some crops may have already benefited from warmer winters, . . .

while for other crops there is evidence of reduced yields following warmer winters.

(less vine and root damage in European wine grapes with less frequent -12 F winter temps)

(inadequate "winter chill" period (cumulative hours < 45 F), and poor fruit development in apples)

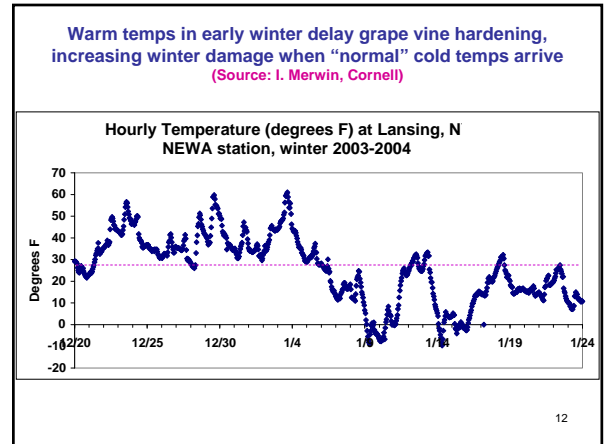


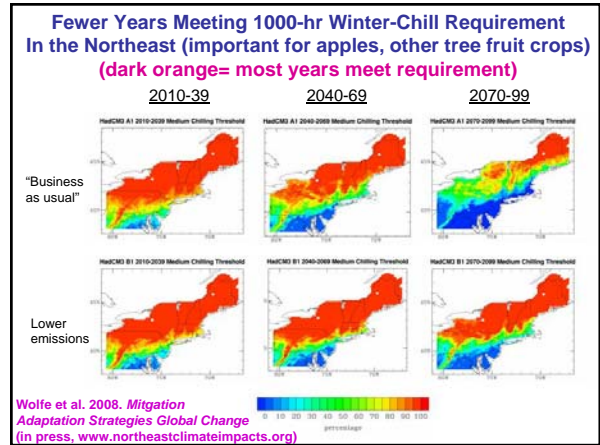
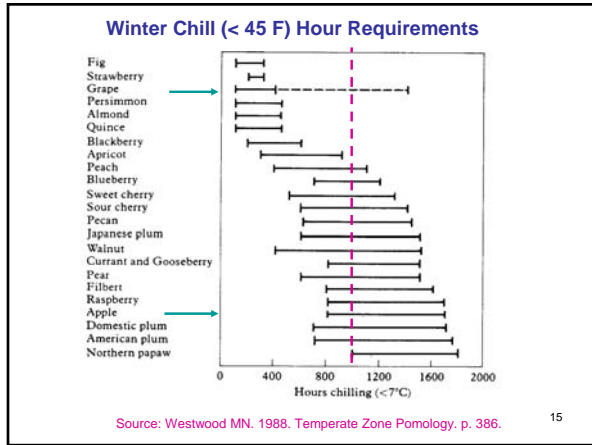
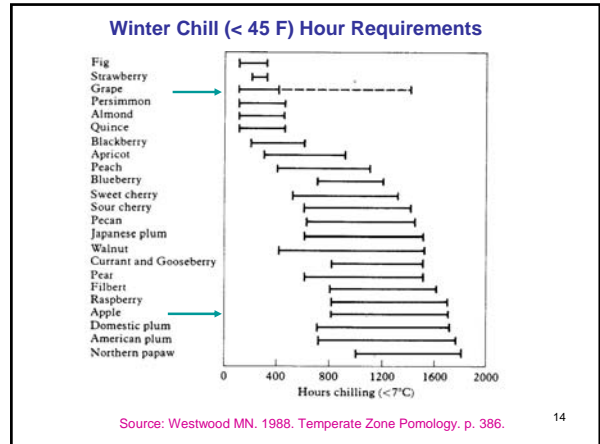
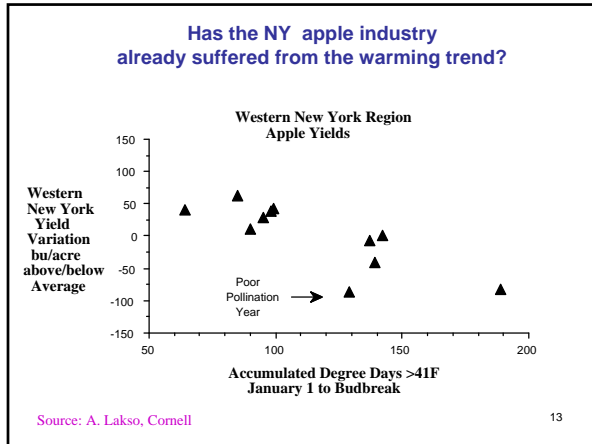
**Expect the Unexpected:  
More Freeze Damage in a Warmer World**

\$\$ millions of freeze damage to NY vineyards in 2003-04 and 2004-05 due to warm Decembers and inadequate winter "hardening" of buds and vines.

Premature mid-winter bloom in agricultural, urban, and natural landscapes.

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### Preparing For Uncertainty and the Unexpected:

Projections indicate more frequent summer droughts

And a continuing trend for more frequent flood events.

### Winter snow cover, soil biological processes, and nitrogen cycling

February 3, 2006      March 3, 2006

### Warmer winters in NE = more pest pressure

Marginally overwintering insects benefit      Invasive weeds benefit



Flea beetle

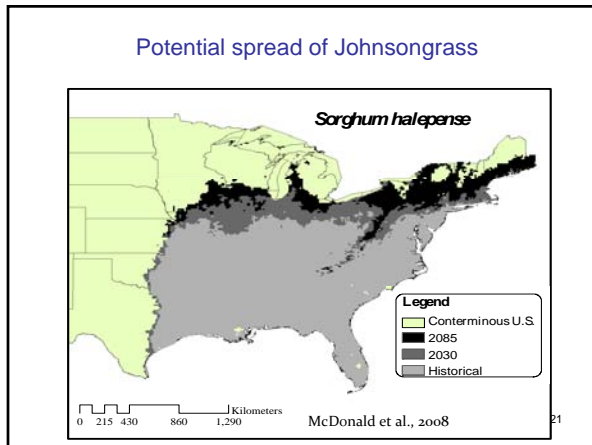
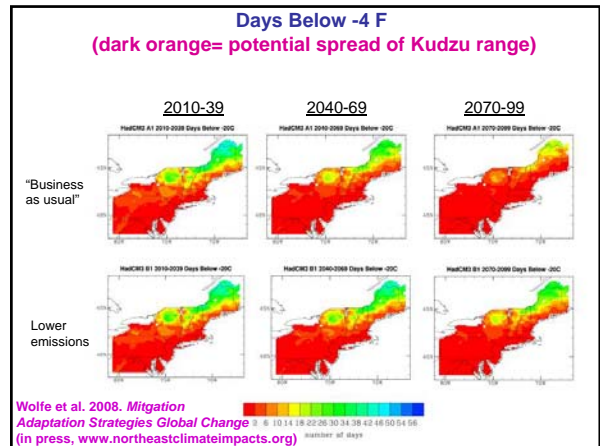


Corn earworm




Kudzu


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### Marginally over-wintering insects will benefit Examples: flea beetle, corn earworm in New York



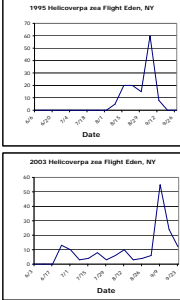
Flea beetle



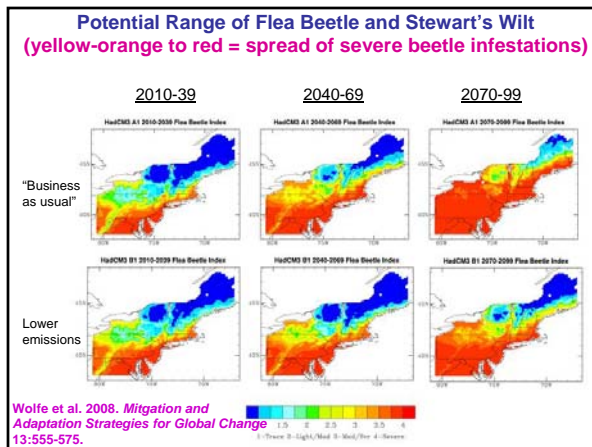
Corn earworm




A vector for Stewart's Wilt




Source: A. Seemann, NY Integrated Pest Management Program; data are from pheromone traps in Eden, NY<sup>22</sup>




### Summer Heat Stress and Fruit Quality




Control (82/71 F) Seeded fruit



Tipburn



Heat stress (90/79 F) undeveloped flowers



Blossom end rot

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## Heat Stress and Livestock

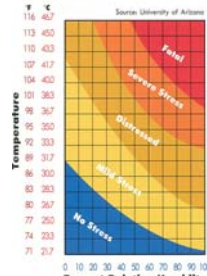


→ Avg annual economic losses of \$24.9 million per year for NY  
 (Source: S. Pierre et al. 2003. J. Dairy Sci 86:E52-77)

→ In hot summer of 2005, NY dairy farmers reported 8-20%  
 reductions in milk production, and increased costs for cooling  
 (Source: L. Chase, Prof. Animal Sci. Cornell Univ.)

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## Dairy Heat Stress Chart



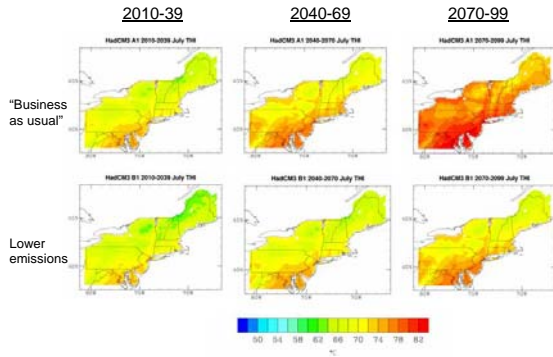
Thermal Heat Index (THI) reaches stress level (THI > 72 and reduced milk production) at:

Temperature °F	Humidity, %
84	15
80	30
77	50
75	65
72	95

Diamond V  
 WEISSBERGER

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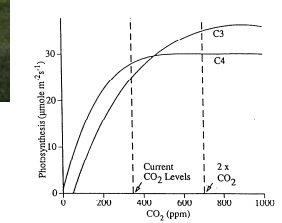
## July Dairy Thermal Heat Index (THI > 72 (yellow-orange to red) = reduced milk production)



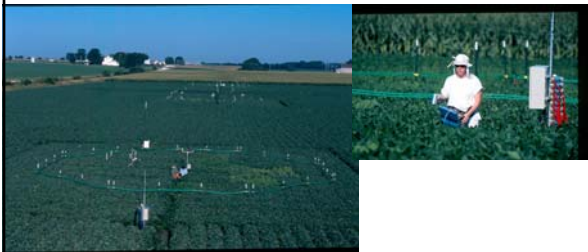
## The Carbon Dioxide (CO<sub>2</sub>) "Fertilization" Effect



Early studies suggested 20 – 30%  
 yield gains possible (under optimum,  
 controlled environment conditions)



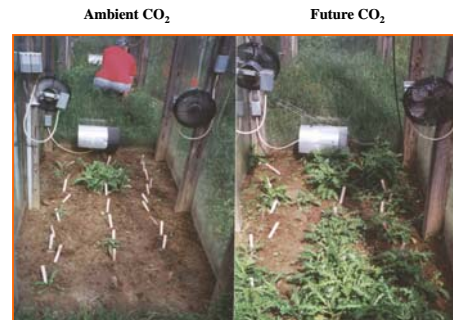
## Under Field Conditions- How Much Can Plants Really Benefit From Increasing CO<sub>2</sub>?



Recent "free air CO<sub>2</sub> enrichment" (FACE) studies suggest that under field conditions yield gains may be about half that typically observed in enclosure experiments.  
 (Long et al. 2006. Science 312:1918-1921)

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## And Many Weeds Benefit More Than Cash Crops From CO<sub>2</sub>: High CO<sub>2</sub> reduces herbicide efficacy



(Source: Ziska et al. 2004 Weed Sci 52:584-588; Ziska et al. 1999. Weed Sci 47:608-615.)

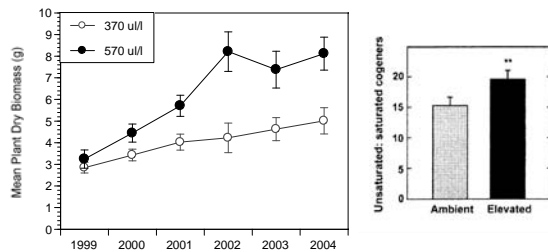
## Duke FACE ("Free Air CO<sub>2</sub> Enrichment") Facility



Poison ivy at Duke Face ring.

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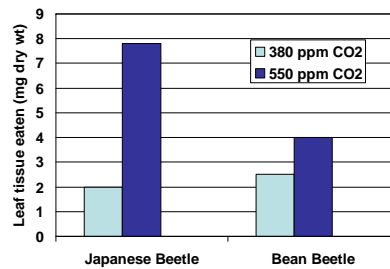
## Poison ivy plants grow faster and are more allergenic at elevated CO<sub>2</sub>



Source: Mohan et al. 2006. Proc. Nat. Acad. Sci. 103(24): 9086-9089.

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## Leaf-feeding insects may do more damage in a high CO<sub>2</sub> world



Data are from soybean FACE field facility (Univ. of Illinois).  
Source: Hamilton et al. 2005 Environ. Entomology 34:479-485

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## Farmers will require new climate-based decision tools for strategic adaptation.



- Do I invest in a new drainage system?...
- Or irrigation system?
- Or both?
- And when?

## Adaptation

(most have costs, risks, and unintended consequences)

- Diversification; new crops and varieties
- Earlier planting dates
- Modifications in pruning
- More intense weed and pest monitoring and control
- Increased irrigation requirements
- Improved drainage
- Improve cooling capacity of livestock facilities

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## Broader Categories of Adaptation

- Information delivery systems
- Managerial
- Diversification (e.g., new crops; new livelihoods and job training)
- Technological
- Design and planning
- Disaster risk management and insurance
- Financial assistance for adaptation investments
- Policy (e.g., coastal zoning, institutional flexibility, regulatory, taxation to spread risk and cover costs)

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## Equity Issues:

Will small family farms have the capital and strategic information to adapt?



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## Mitigation (Becoming Part of the Solution)

- **Recycle and reduce use of disposable products**
- **Reduce fossil fuel use**
- **Renewable energy and biofuel crops**
- **Improve nitrogen fertilizer use efficiency**
- **Increase carbon sequestration**

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## Potential Unintended Consequences of Adaptation and Mitigation

- Undesirable land use change
- Increased food prices and other unintended economic impacts
- Natural resource degradation
- Increased energy use/greenhouse gas emissions
- Increased agricultural (and home-owner) chemical loads to the environment
- Lack of equity in adaptation capacity, with national and regional security implications

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## Concluding Remarks

- Longer growing seasons and shifts in plant hardiness zones will change the fabric of our natural landscapes, and will allow experimentation with new species in the garden and farm. . .
- BUT we may forever lose some favorites
- The insect, disease and weed pest complex will be changing and more challenging to control
- Both irrigation and good drainage will be more essential for gardeners, farmers, urban landscapes
- There are many adaptation and mitigation options for growing healthy and “greener” gardens, farms, and landscapes in the face of climate change
- Some small family farms may lack the capital for strategic adaptations to climate change

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Wishing you a “normal” and peaceful winter

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[www.northeastclimateimpacts.org](http://www.northeastclimateimpacts.org)

