# Climate Change and Food Security.

Food security is necessary for civilization.  Food security, in turn, depends on cereals.

Green Re
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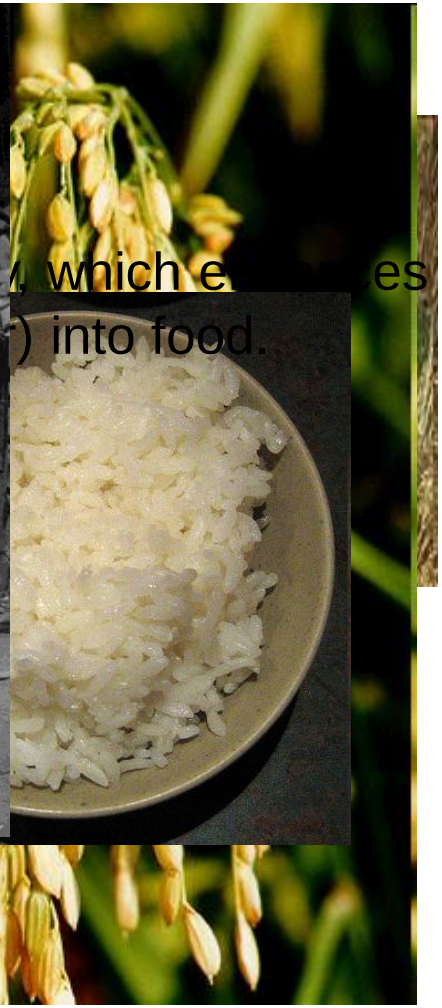


. which e es
) into food.

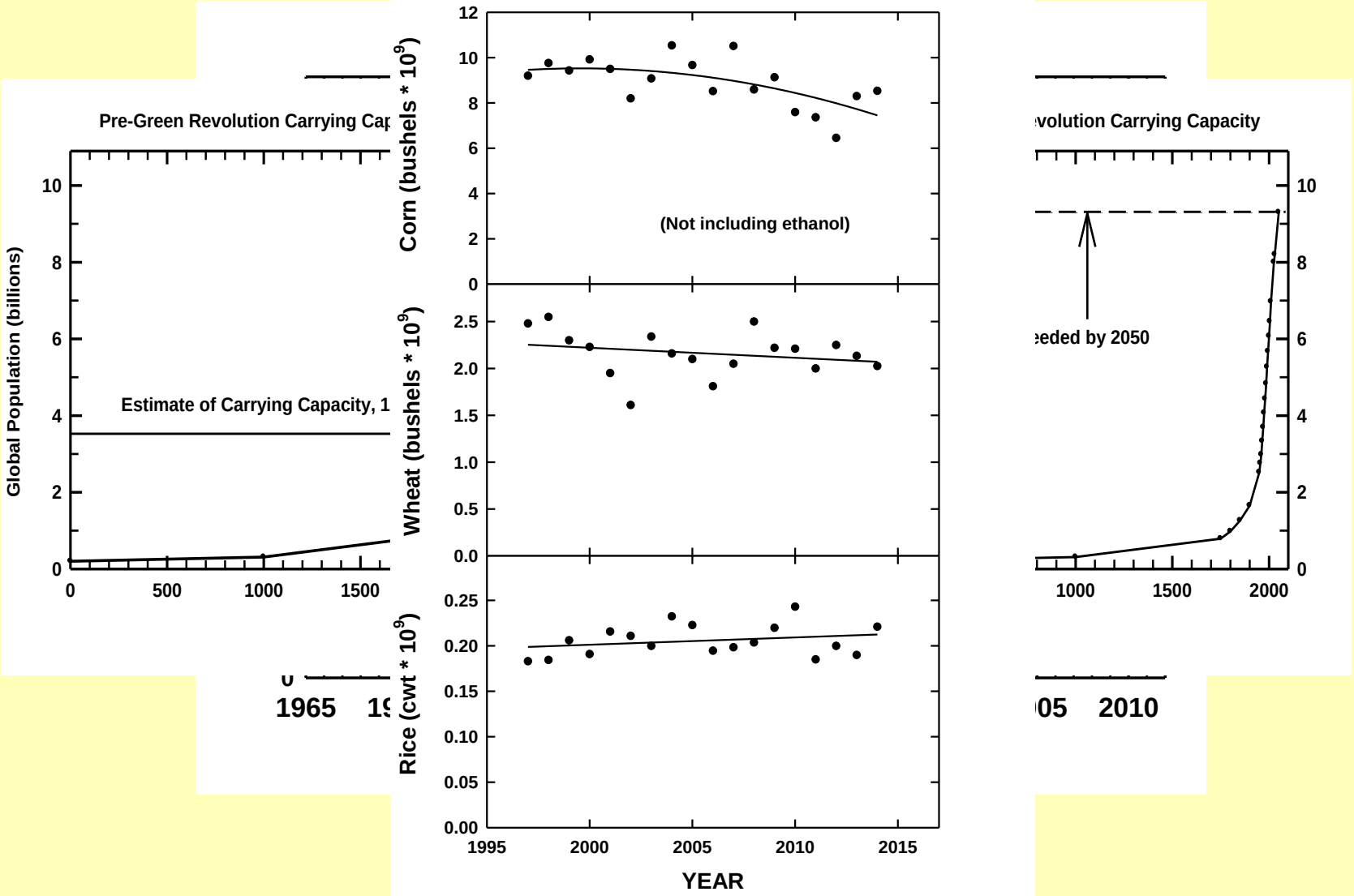
# For the 21st century we are asking the green revolution to do more, including:

Food for the additional one billion people every 15 years. Over nine billion by 2040?

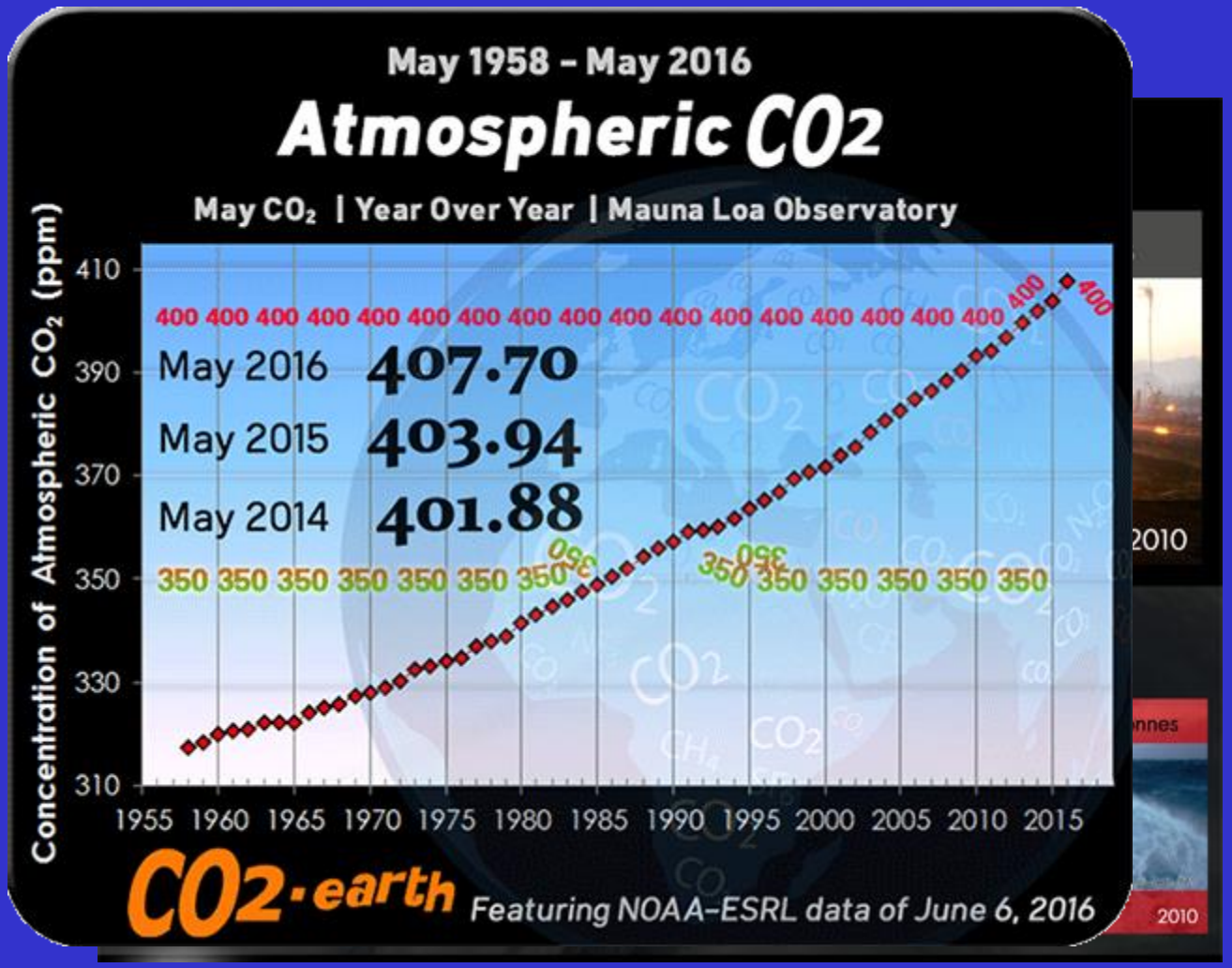
Feed for animals: protein for an emerging middle class.

Fuel for more bio-energy.

# Can the green revolution meet future cereal demand?



# Atmospheric CO2

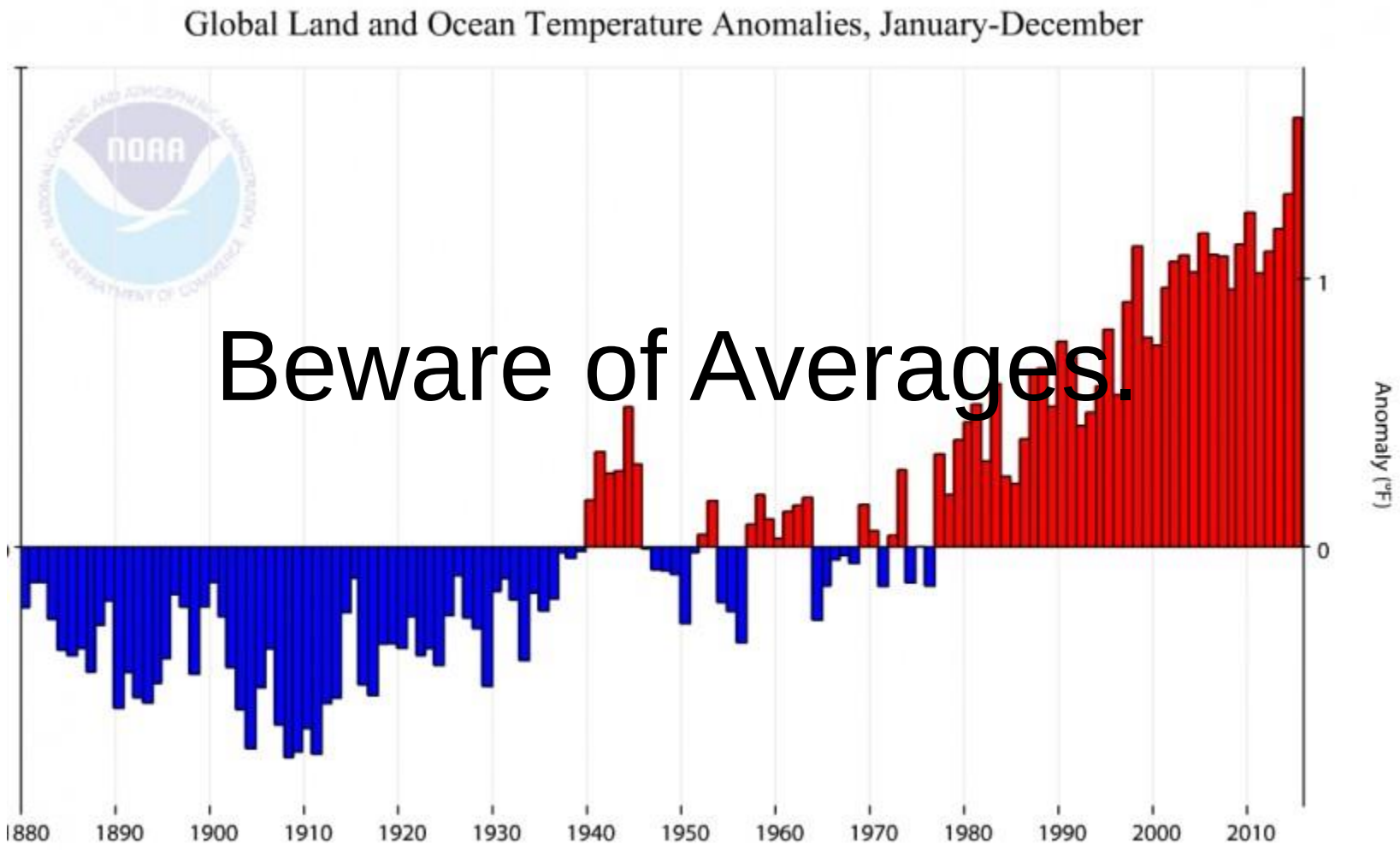


# I. An indirect effect of rising carbon dioxide: warmer temperatures.

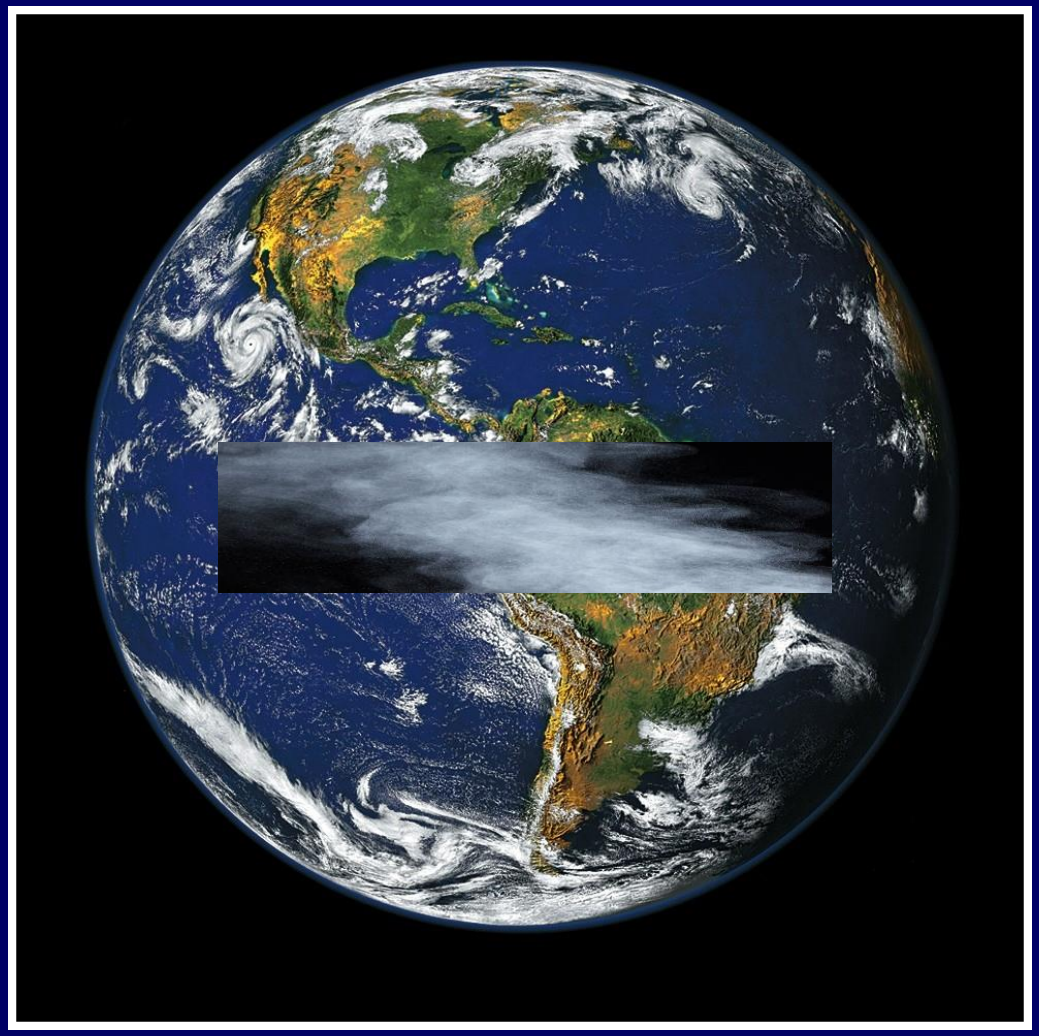
| Gas | % |
|---|---|
| Nitrogen ($N_2$) | 78.1 |
| Oxygen ($O_2$) | 20.1 |
| Argon (Ar) | 0.93 |
| Carbon Dioxide ($CO_2$) | 0.04 up to 0.100 |
| Water ($H_2O$) | 0.05 to 1.00 |

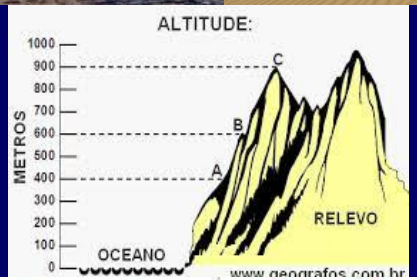
No $H_2O$ and $CO_2$? Surface temperature would be –18°C. With H2O and CO2? Surface temperature is 15°C.

# Physical Consequences: Temperature



# $H_2O$ vs. $CO_2$

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VS
Winter Olympics
Summer Olympics

# Physical Consequences

- Less temperature increases where water vapor is high, more precipitation.
- Greater temperature increases with latitude or altitude; winter vs. summer.
- Increased desertification, increased drought.
- Rising sea levels from increased polar and glacial melt.

# Plants are essential to life.

# Plant Biology Consequences

- $CO_2$ is a fundamental resource for plant growth.
- Not all plants are beneficial to human society.
- Not all plants respond the same way to a resource.
- Differential plant response will affect plant-to-plant interactions, competitive outcomes.

# Climate, Water and Food

Beer = 20-40 gallons

Potato = 20-30 gallons

Slice of bread = 20-30 gallons

Salad= 40-900 gallons

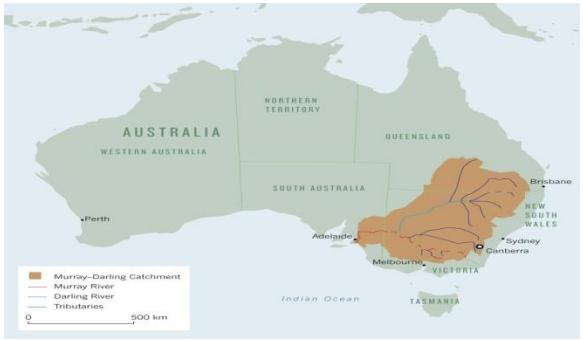
Steak= 2500-5000 gallons

75% of fresh water is used in agriculture.

# Irrigation: The Colorado River


# Other rivers that no longer flow to the sea.

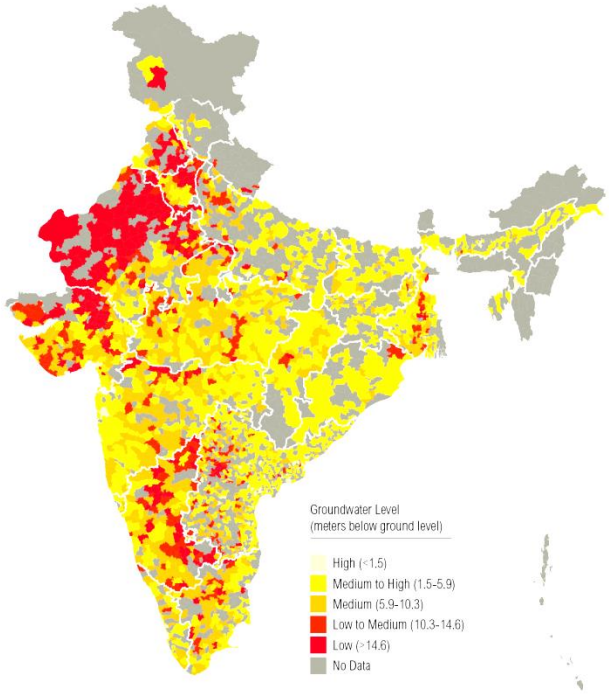

Because of diminished snow and ice, river flows will diminish over time, even as rising Temperatures necessitate more water for agriculture.

# Where else does agriculture get its water?
# Aquifers

**54%**
of India's Ground-water Wells Are Decreasing

# of Permits




www.indiawatertool.in

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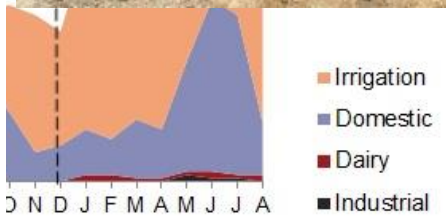
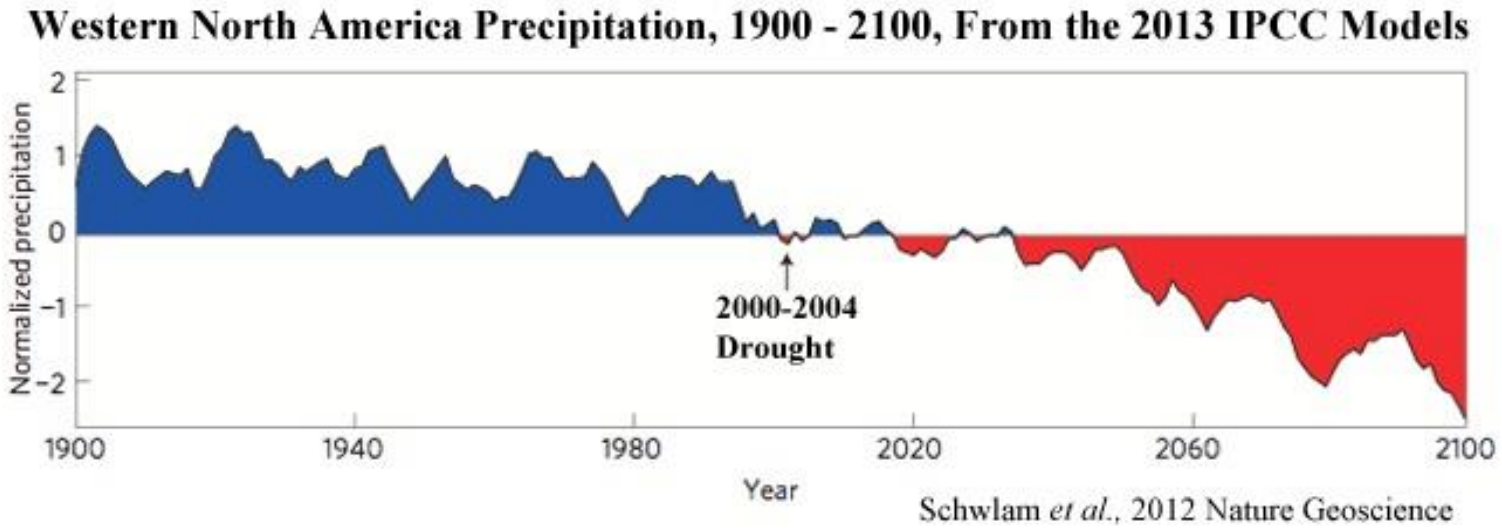



Globally, all countries are using ground water at a faster rate than it is being replenished. This rate is expected to increase with warming.

# Where does agriculture get its water?
# Rainfall: Too Little.



# Production: Water, climate and cereals.

Global Rice and Water Use

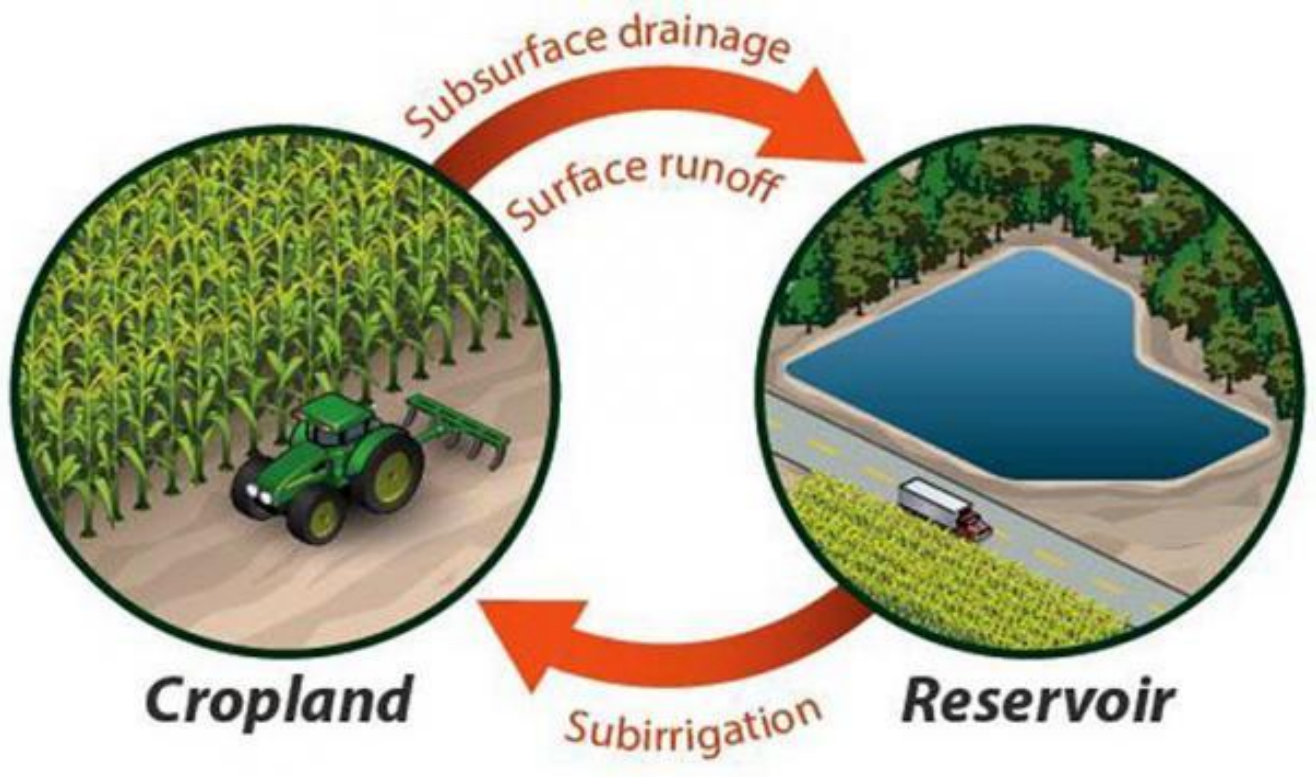
- 100
- 80
- 60
- 40
- 20
- 0

Rice production

# G.E.M.----G x E

“old” vs. “new”
Wheat vs. Sorghum?

# G.E.M.----E x M



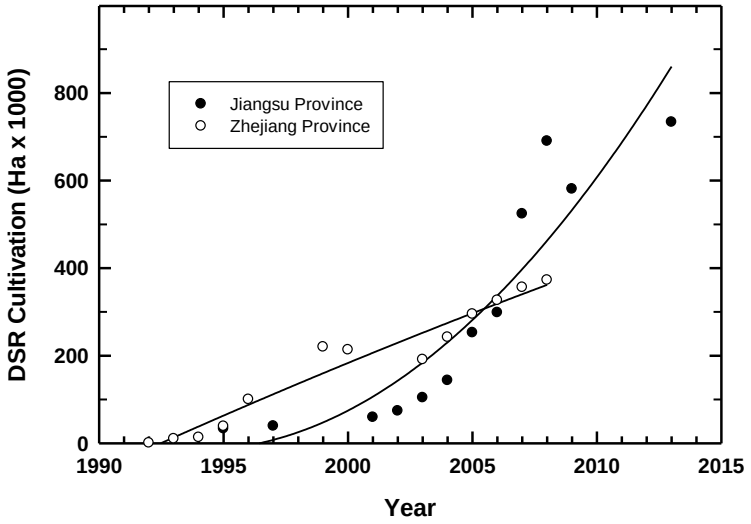

Capture and Use:  Increase resiliency.

# E x M for rice: Water and Irrigation.

Flooding reduces weed competition, but requires large inputs of water And labor. In addition, flooding can exacerbate methane emissions.

Rice can be seeded directly, then irrigated, using different techniques such as AWD.

Adoption of DSR in China

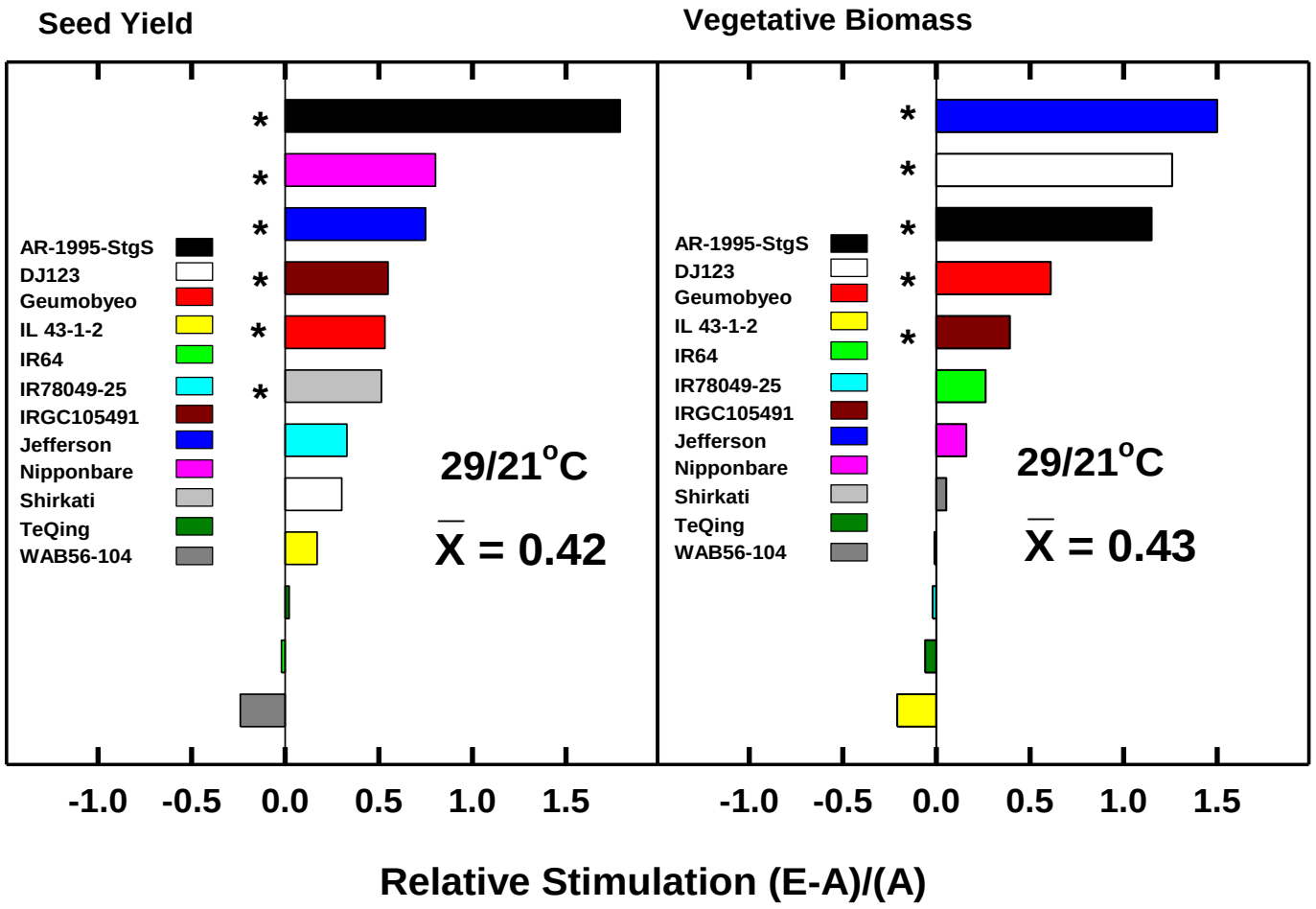


# CLIMATE AND FOOD SECURITY

- Water is indispensable for agriculture.  Yet, it is clear that climate change will significantly impact water availability. Such availability will impact rice production, but the long-term consequences are not clear.
- G x E x M as one opportunity.

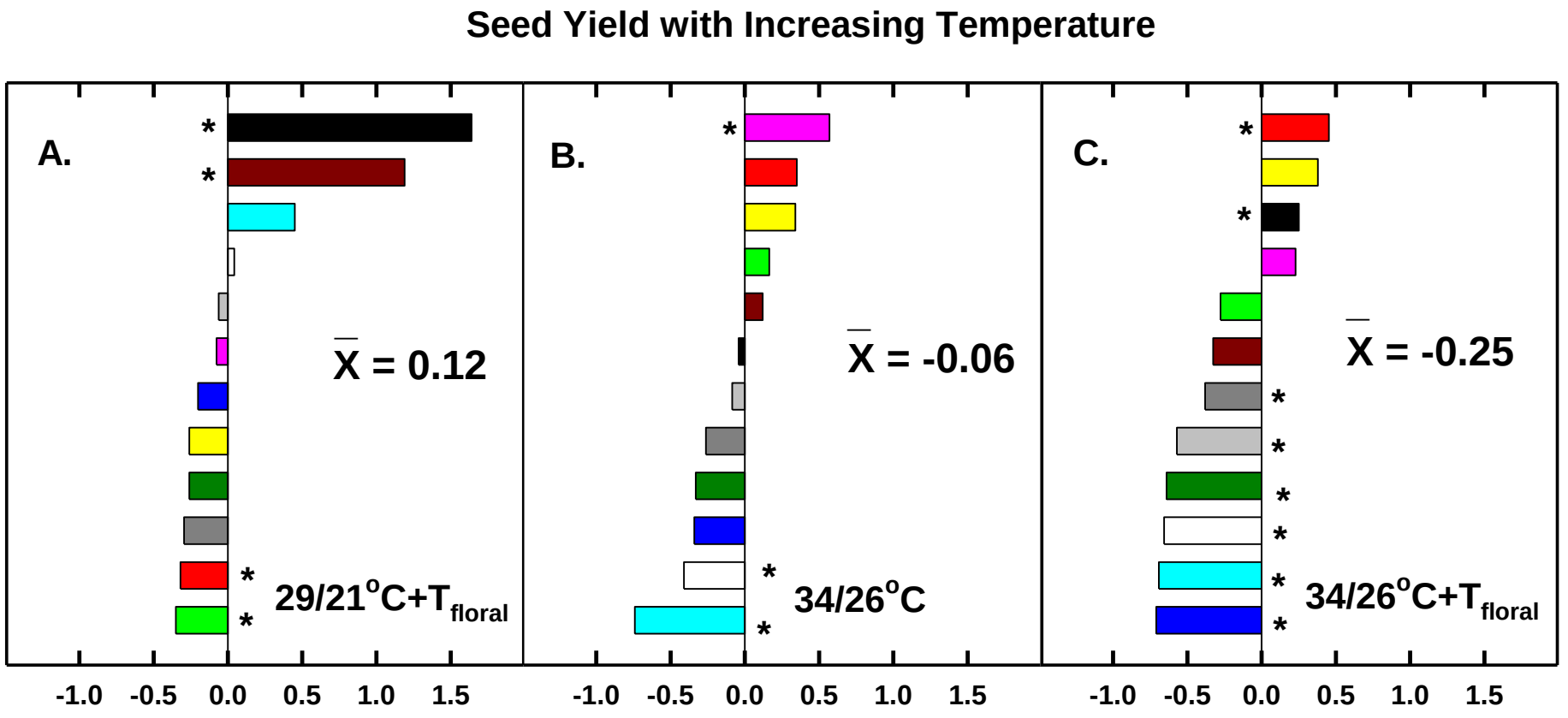
What about Carbon Dioxide?

# Can we select for $CO_2$ responsiveness?




Wang et al. 2016, Global Change Biology, 22:2260

# $CO_2$ and temperature and yield: Making things worse?




(E-A)/A

Matsui et al. 1997, Field Crops Research 51:213

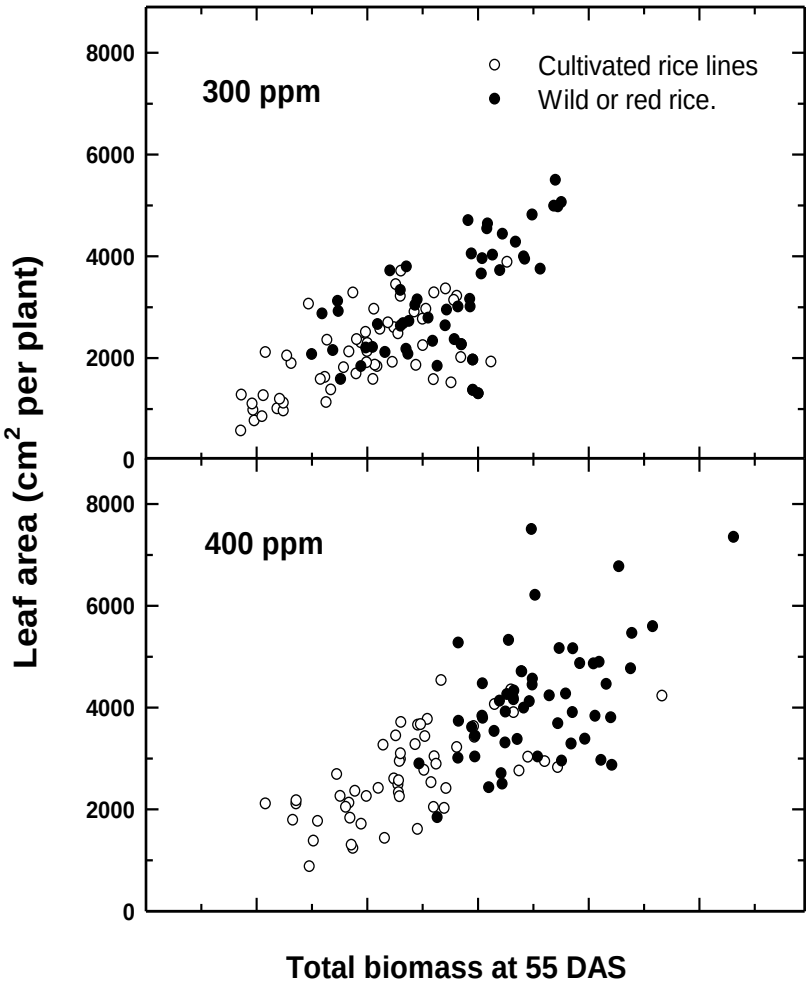
# Don’t weeds respond to $CO_2$?

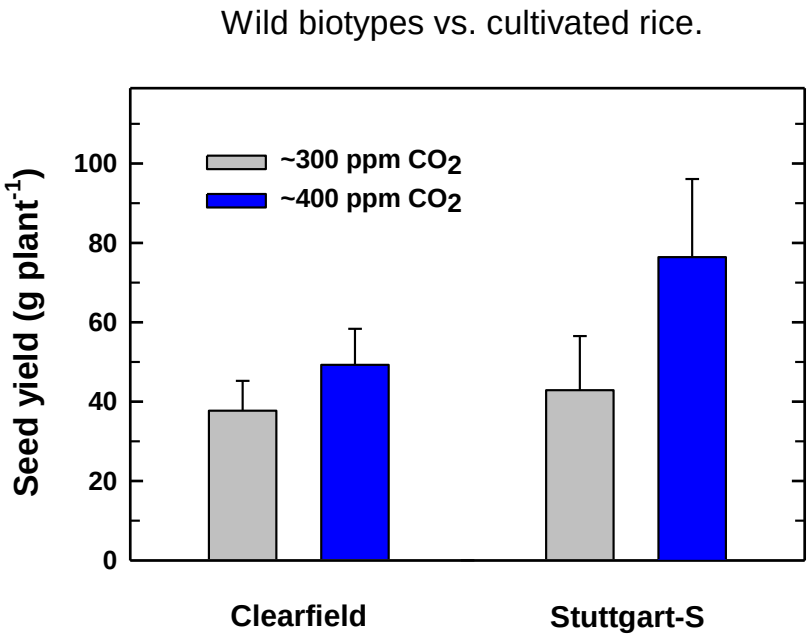
Wild vs. cultivated rice


Biological Consequence:  As carbon dioxide increases, red or weedy rice responds more. Consequently cultivated rice yields decline.

# Differential Response to a Resource.

**A comparison of wild and cultivated rice lines.**

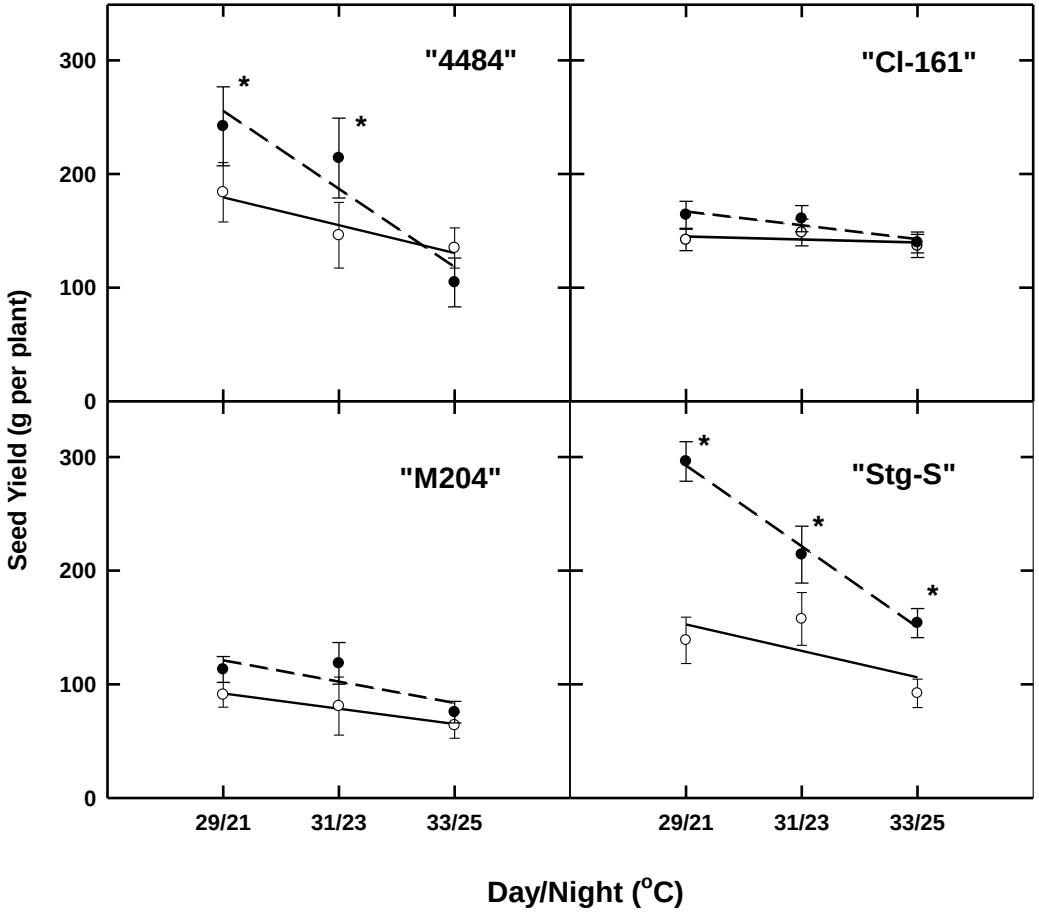



**Two different selection forces.**

**What can weedy rice teach us about adaptation to climate change?**

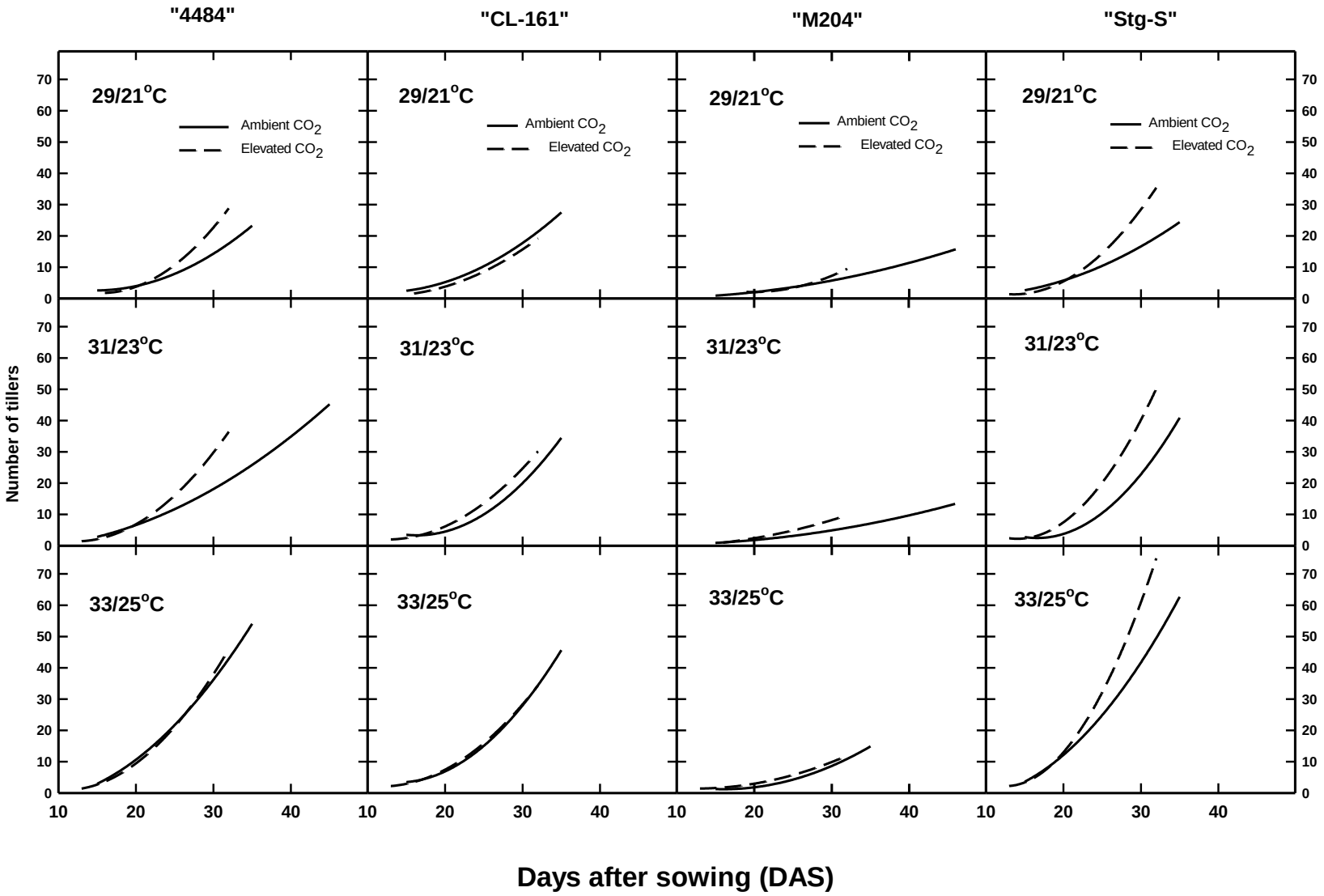
# Using genetic diversity to adapt to climate change



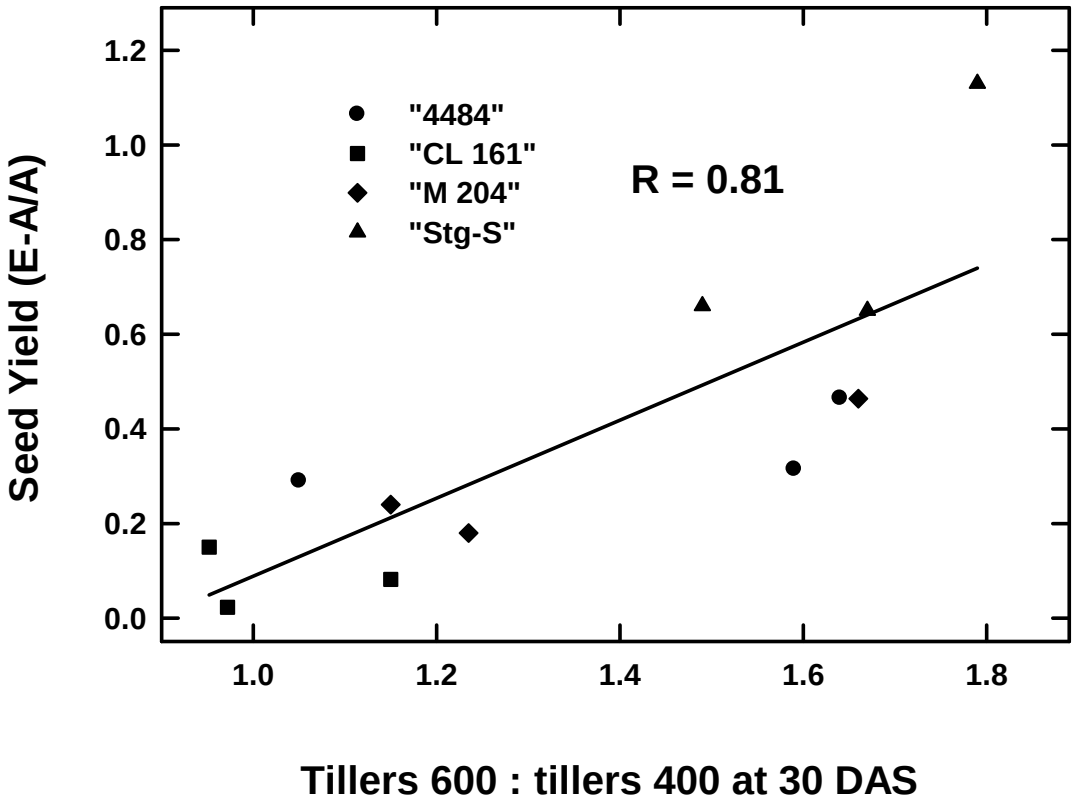

Ziska et al. 2014 Functional Plant Biology 41:236.

**Can our "worst" weeds be our best hope for adapting to climate change?**

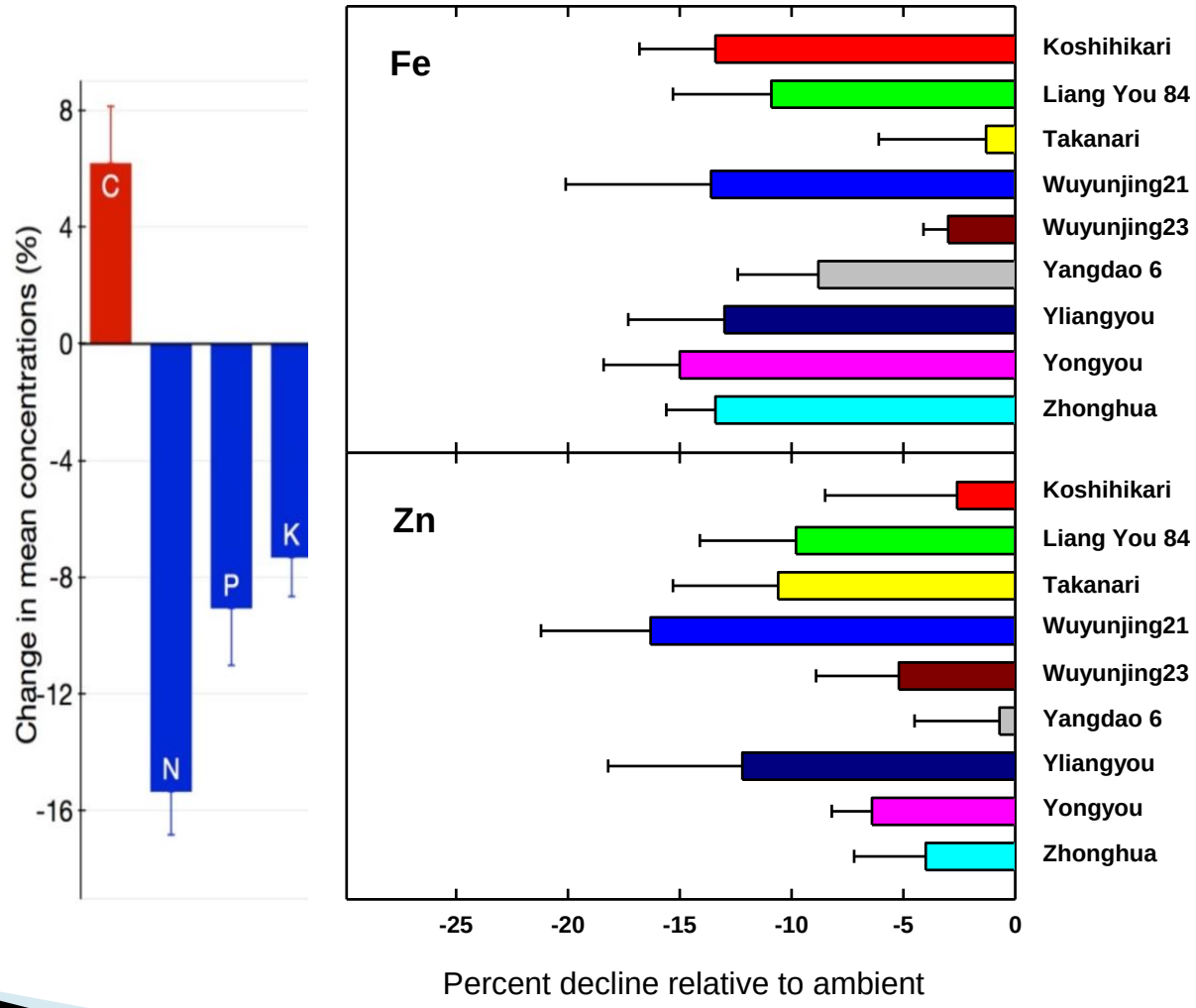
# How are weeds adapting?



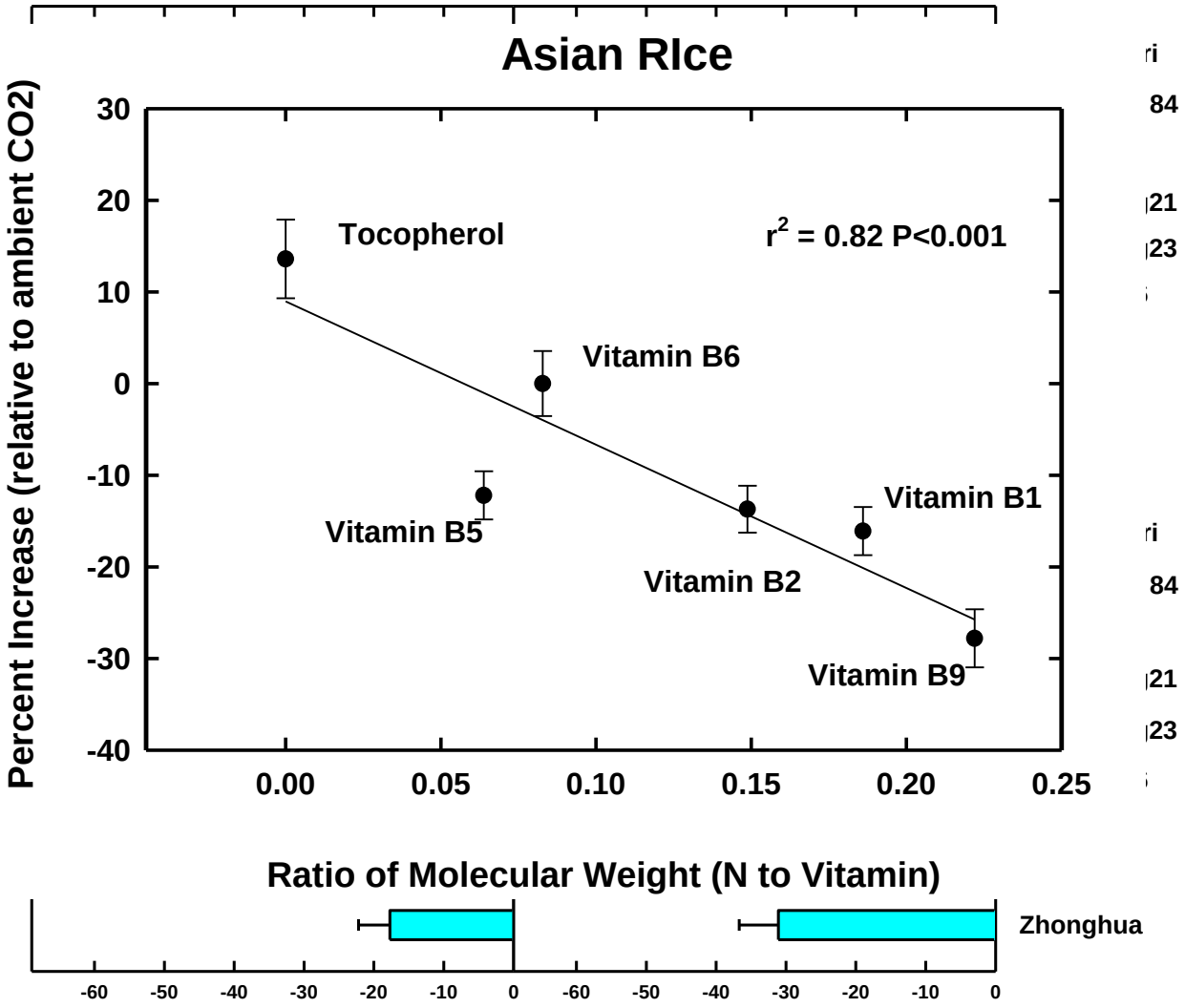
# Adapting Yield to CO2 and Climate: Next Steps.



# Wait! What about quality?



# Change in vitamin content.




Percent decline relative to ambient.

# Biological Consequences

1. The increase in $CO_2$, of an by itself, will also significantly impact crop yields. It cannot be assumed that such an impact is positive.

2. Because increasing $CO_2$ affects transpirational cooling, higher temperatures may result in greater canopy temperatures and increased sterility.

3. Weedy rice overall may provide a unique set of germplasm that could be used to adapt cultivated rice to climate change through selection.

4. There is substantial evidence that $CO_2$ per se, will significantly affect cereal quality, including vitamin deficiencies in rice. Such impacts appear to have little intraspecific variation.

# Overall.

1. The green revolution has ended; but agricultural demands have not.

2. The green revolution could be reversed because the basis for the increase, i.e. water, consistent climate, cheap energy, etc. will be impacted by climatic change.

3. Do not assume that the increase in CO2 will negate any climate impacts. However, as with any rapid increase in a resource, there could be opportunities for selection.

4. There are also management opportunities, that can help conserve resources, e.g., AWD in rice.

5. AND???????????