Climate Change Impacts on Indian Agriculture

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INDIA AND AGRICULTURE

CONTEXT

- Population : 1 billion +
- GDP from Agriculture : 34 % (1994), 42 % (1980)
- Area under Agriculture : 50 % (160 mha)
- Population dependent on Agriculture: 70%
- Average farm size: : 1 to5 ha
- Landless dependent on others

	T. Area (mha)	Irrigated (mha)	Prod (mt).	Earnings (Rs.)	% of GDP
Rice	42	20	73	365	22
Wheat	24	21	57	208	12.6

Impact of Climate Change

- FCCC: ensure that food production is not threatened
- Rosenzweig and Parry: significant adverse impact on developing countries
- Parikh J and KaviKumar: a detailed analysis of Indian Agriculture

d t	2.5^0C	to	4.9^0C
Rice Yield	- 15%	to	-4.9%
Wheat Yield	-25%	to	-42%

(without carbon fertilization effect)

With carbon fertilization effect: Smaller but similar impact

With Adaptation

$\Delta T + 2^0C + 7\%$ precipitation $\Rightarrow GDP_{Agri} \downarrow 7\%$

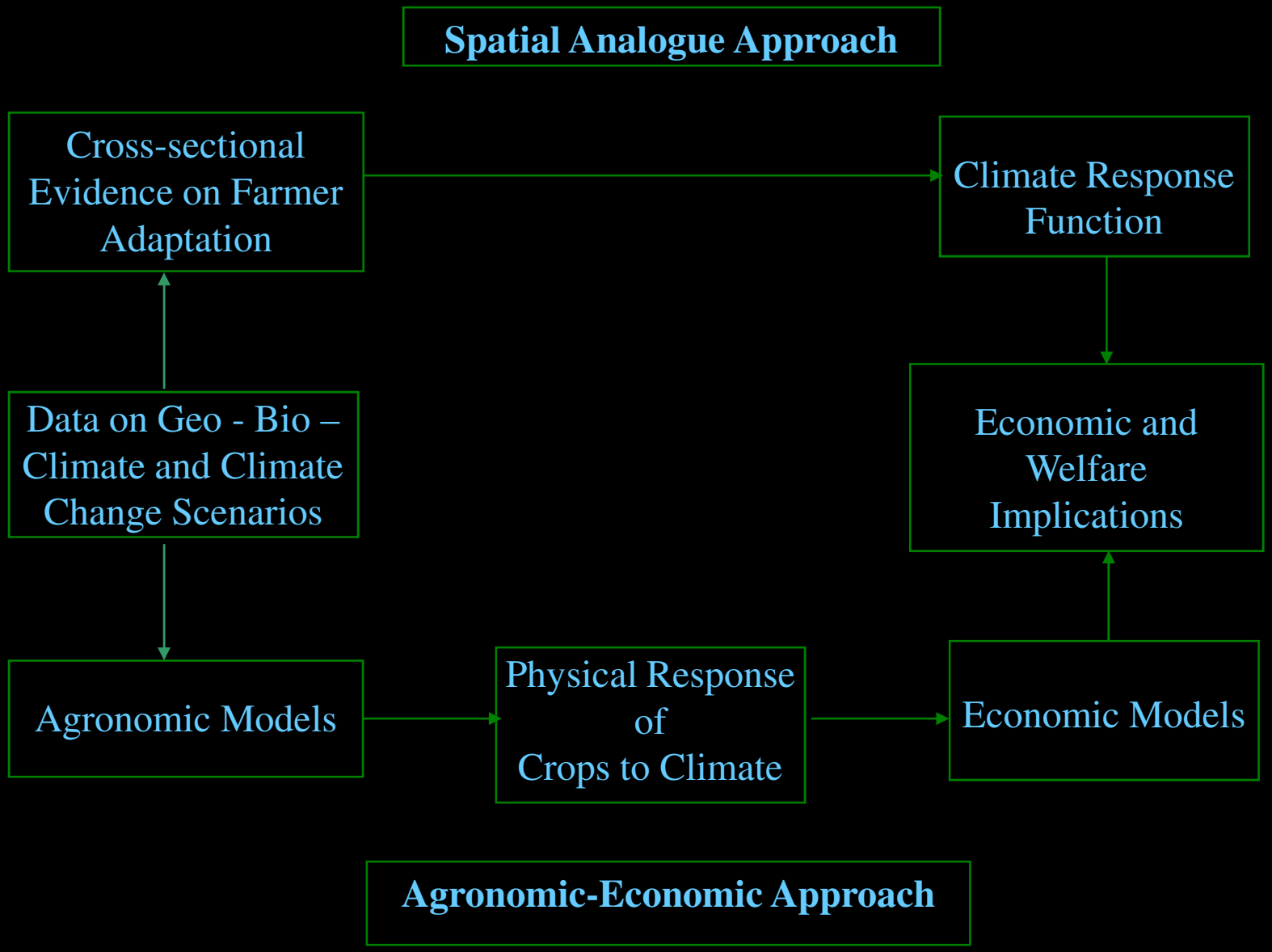
$\Delta T + 3.5^0C + 15\%$ precipitation $\Rightarrow GDP_{Agri} \downarrow 25\%$

$\Rightarrow$ Poverty $\uparrow$ $\Rightarrow$ Hunger $\uparrow$

Indian Agriculture – Strengths and Challenges

- Strong strides made in increasing the production in the past 50 years, mainly due to adoption of HYVs and other technological developments
- Subsistence agriculture with small land holdings and skewed distribution of land
- Wide variation in regional productivities
- Majority still depend on rainfed agriculture
- Frequently affected by extreme weather events such as droughts and cyclones
- Significant proportion of population still reels under poverty, mal-nutrition and chronic hunger
- Emerging economic challenges – WTO, economic liberalization etc.

Vulnerability Assessment Framework



Socio-economic Impact Assessment Methodologies

Agronomic-Economic Approach

- Agronomic models are used first to predict climate change impacts on crop yields and the estimated yield changes are then introduced into economic models to predict output and price changes.

$$Y_i \leq F_1(X_{i1}, X_{i2}, \ldots X_{ik}) * F_2(E_1, E_2, \ldots E_j)$$

- Feasible to model CO_2 fertilization effects.
- Relatively difficult to include *all* possible farm level adaptation options.

Adams et al. (1990, 1999), Rosenzweig and Paryy (1994), Kumar and Parikh (2001b)

Agroecological Zone Approach

- Assigns crops to agroecological zones and estimates potential crop yields. As climate changes, the extent of agroecological zones and the potential yields of crops assigned to those zones changes. These acreage and yield changes are then included in economic models to assess socio-economic impacts.

Darwin et al. (1995, 2000), Kumar (1998), IIASA (2002)

Ricardian Approach

- Similar to Hedonic pricing approach of environmental valuation. The approach is based on the argument that, 'by examining two agricultural areas that are similar in all respects except that one has a climate on average (say) 3^{o}C warmer than the other, one would be able to infer the *willingness to pay* in agriculture to avoid a 3^{o}C temperature rise'.
- Uses statistical analysis of data across geographic areas to separate climate from other factors (such as soil quality) that explain production differences across regions and uses the estimated statistical relationships to assess impacts of climate change.
- Main advantage of this method is that it incorporates *all* private adaptation measures.
- Assumes that relative prices do not change and hence biases the results.
- Not feasible to incorporate CO_2 fertilization effects.

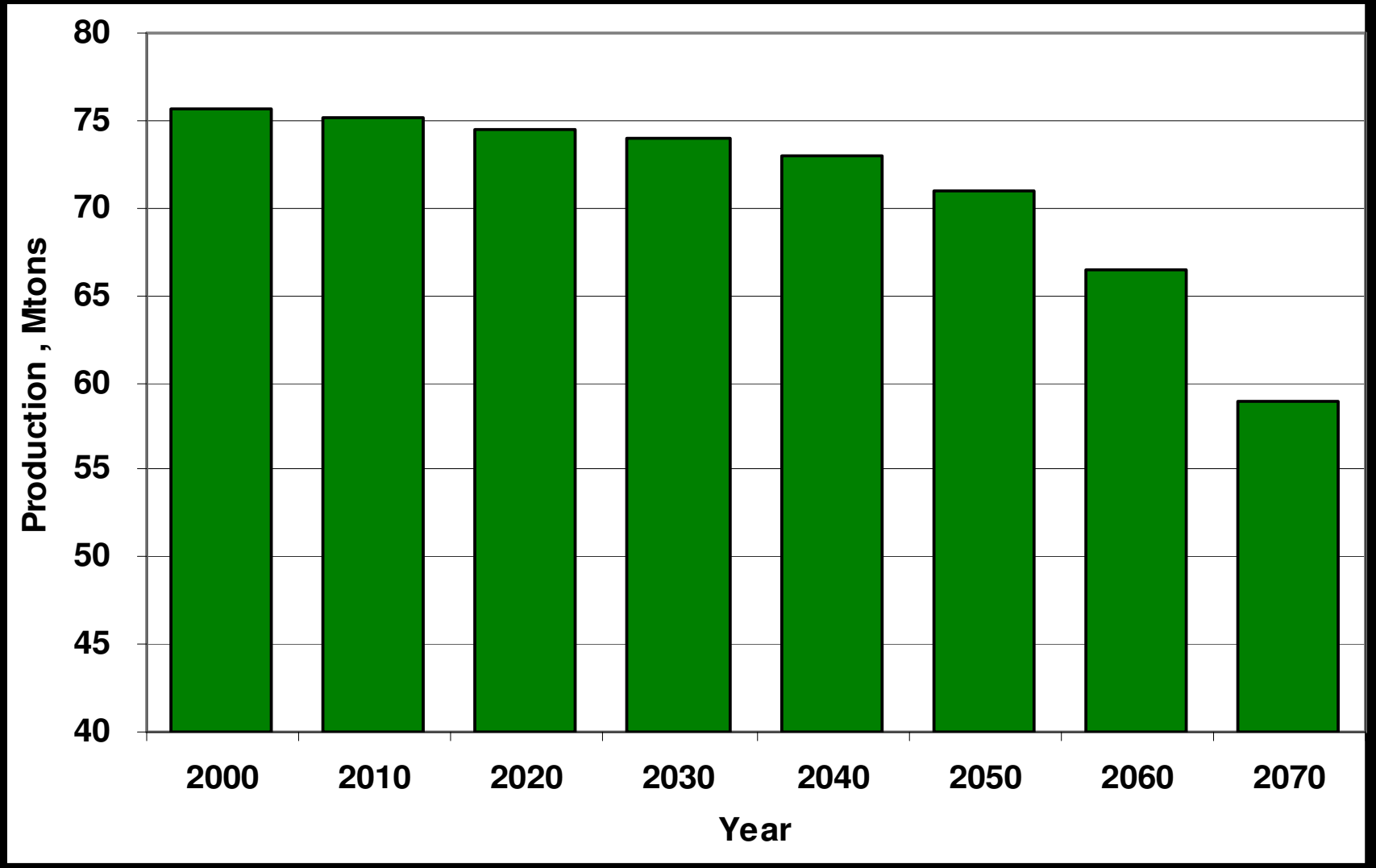
Mendelsohn et al. (1994), Dinar et al. (1998), Kumar and Parikh (2001a)

Impacts on Indian Agriculture – Literature

- Sinha and Swaminathan (1991) – showed that an increase of 2°C in temperature could decrease the rice yield by about 0.75 ton/ha in the high yield areas; and a 0.5°C increase in winter temperature would reduce wheat yield by 0.45 ton/ha.
- Rao and Sinha (1994) – showed that wheat yields could decrease between 28 to 68% without considering the CO_2 fertilization effects; and would range between +4 to -34% after considering CO_2 fertilization effects.
- Aggarwal and Sinha (1993) – using WTGROWS model showed that a 2°C temperature rise would decrease wheat yields in most places.
- Lat et al. (1996) – concluded that carbon fertilization effects would not be able to offset the negative impacts of high temperature on rice yields.
- Saseendran et al. (2000) – showed that for every one degree rise in temperature the decline in rice yield would be about 6%.
- Aggarwal et al. (2002) – using WTGROWS and recent climate change scenarios estimated impacts on wheat and other cereal crops.

All these studies focused only on agronomic impacts of climate change.

Potential Impact of Climate Change on Wheat Production in India



Source: Aggarwal et al. (2002)

Socio-economic Impacts of Climate Change and Climate Variability

Some recent estimates for India

Results Based on Agronomic-Economic Approach

These results are obtained by incorporating crop yield changes associated with various equilibrium climate change scenarios into an applied general equilibrium model, and the reported figures correspond to the terminal period of the simulation.

Variable	GFDL	GISS	UKMO
GDP (%)	-1.8	-2.5	-3.4
Cal per cap (%)	-18.2	-19.5	-21.6
Pop. prop. in bottom two expenditure classes - rural (base 0.183)	0.283	0.294	0.311
Pop. prop. in bottom three expenditure classes – urban (base 0.145)	0.208	0.214	0.226

Socio-economic Impacts of Climate Change and Climate Variability

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Results Based on Ricardian Approach

These results are based on climate response function estimated using district level time-series observations on farm management and crop output. Reported figures indicate percentage change in total net-revenue and the 95 percent confidence interval are given in brackets.

ΔT \ ΔP	0%	+7%	+14%
+1.0°C	-3.1 (-2.3 to –3.9)	-1.3 (-0.5 to –2.2)	+0.5 (+1.5 to –0.4)
+2.0°C	-9.6 (-8.5 to –10.7)	-7.8 (-6.7 to –8.9)	-6.0 (-4.7 to –7.2)
+3.5°C	-27.5 (-25.5 to –28.8)	-25.7 (-23.6 to –27.0)	-23.7 (-21.6 to –25.2)

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Ricardian Estimates with Climate Variation

$$R = f(T, P, DVarT, YVarT, K)$$

ΔT/ΔP	Impacts as percentage of Net Revenue		
	Without Variation Terms	With Variation Terms	With Variation Terms and 5% Higher Variation
2°C/7%	-7.8	- 6.8	-9.5
3.5°C/14%	-24.0	- 17.8	-28.1

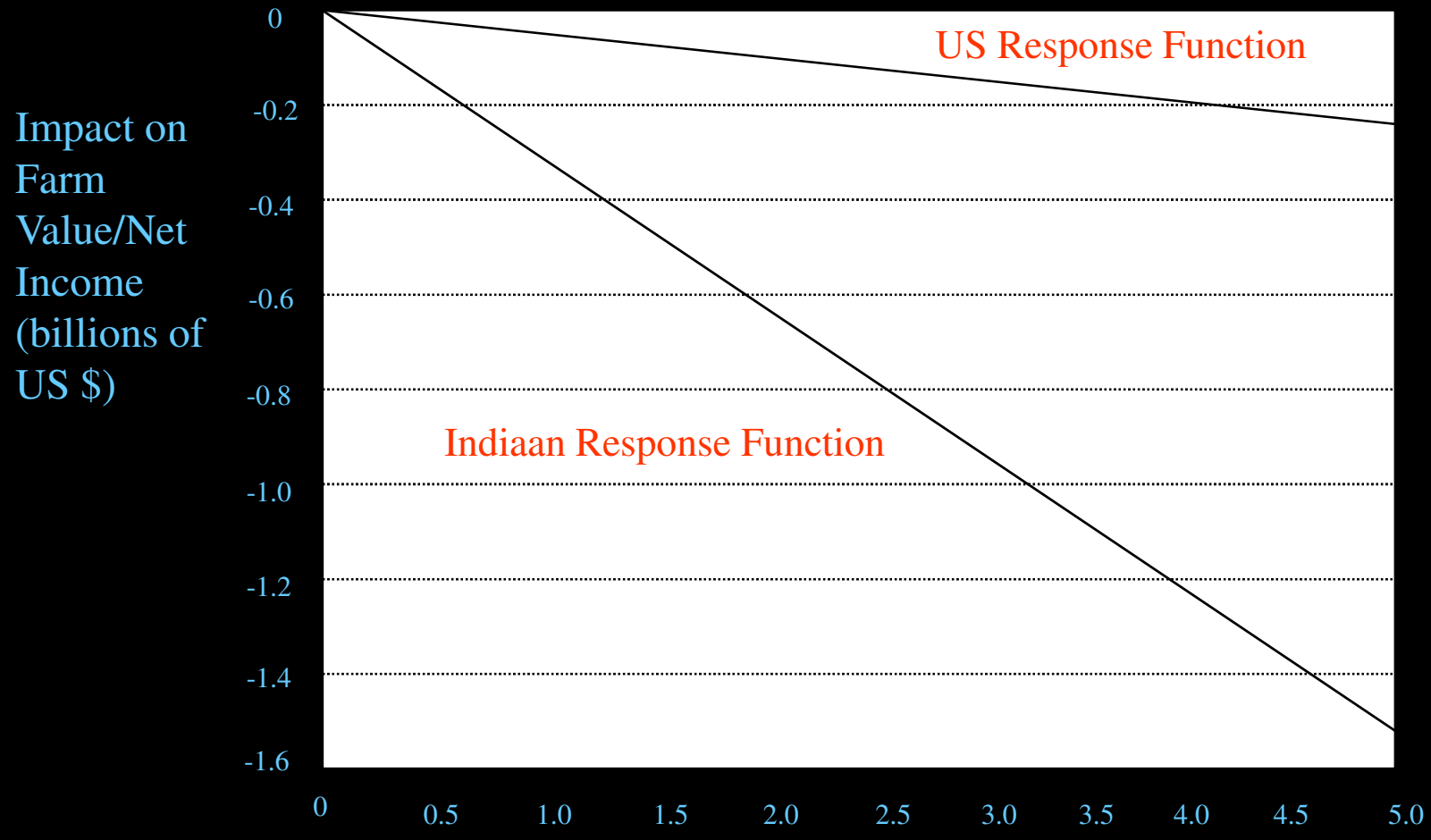
Limitations of current estimates

- The impacts estimated using agronomic-economic approach are likely to be upwardly biased (compared to the Ricardian estimates) as they do not account for adaptation.
- On the other hand the Ricardian estimates by not capturing the carbon fertilization effects tend to over estimate the impacts.
- The use of cross-section variation to predict time series behavior requires many assumptions to be satisfied: (a) that variations over time and space are equivalent, (b) only one steady state occurs per set of exogenous conditions, and (c) that a few climatic variables (say, average temperature and precipitation and perhaps a simple measure of variability) capture all the relevant information about climate change and its impacts on agriculture.

Excluded from the estimates

- Present estimates do not account for impacts due to extreme weather events, whose frequency and intensity is likely to get altered with climate change.
- A number of agronomic links – such as impact of climate change on behavior of pests and diseases - are still not very clearly understood and hence their economic implications are also not incorporated in the current estimates.

Climate Sensitivity Functions of the US and India – Applied to India



Source: Mendelsohn and Dinar (2000)

Adaptation Options

- Possible at various levels - farmer, economic agent, macro
- Potential and costs of adaptation - possibly through historic analysis of technology penetration
- For example, Reilly and Schimmelpfenng (1999) show the relative speed of adoption of various measures:

Adaptation Measure	Adjustment Time (years)
Variety Adoption	3-14
Dams and Irrigation	50-100
Variety Development	8-15
Tillage Systems	10-12
Opening New Lands	3-10
Irrigation Equipment	20-25
Fertilizer Adoption	10

Jodha (1989) using observations of adoption and technological response in post-independent Indian agriculture estimated response time of 5-15 years for items such as productive life of farm assets, crop rotation cycles, and recovery from major disasters.

Broad categories of responses - ***some of which could be beneficial regardless of how or whether climate changes*** - include:

- Improved training and general education of populations dependent on agriculture.
- Identification of the present vulnerabilities of agricultural systems.
- Agricultural research to develop new crop varieties.
- Food programs and other social security programs to provide insurance against supply changes.
- Transportation, distribution, and market integration to provide the infrastructure to supply food during crop shortfalls.
- Removal of subsidies, which can, by limiting changes in prices, mask the climate change signal in the marketplace.

Thank You