Variability of Precipitation and Precipitation Effectiveness in India

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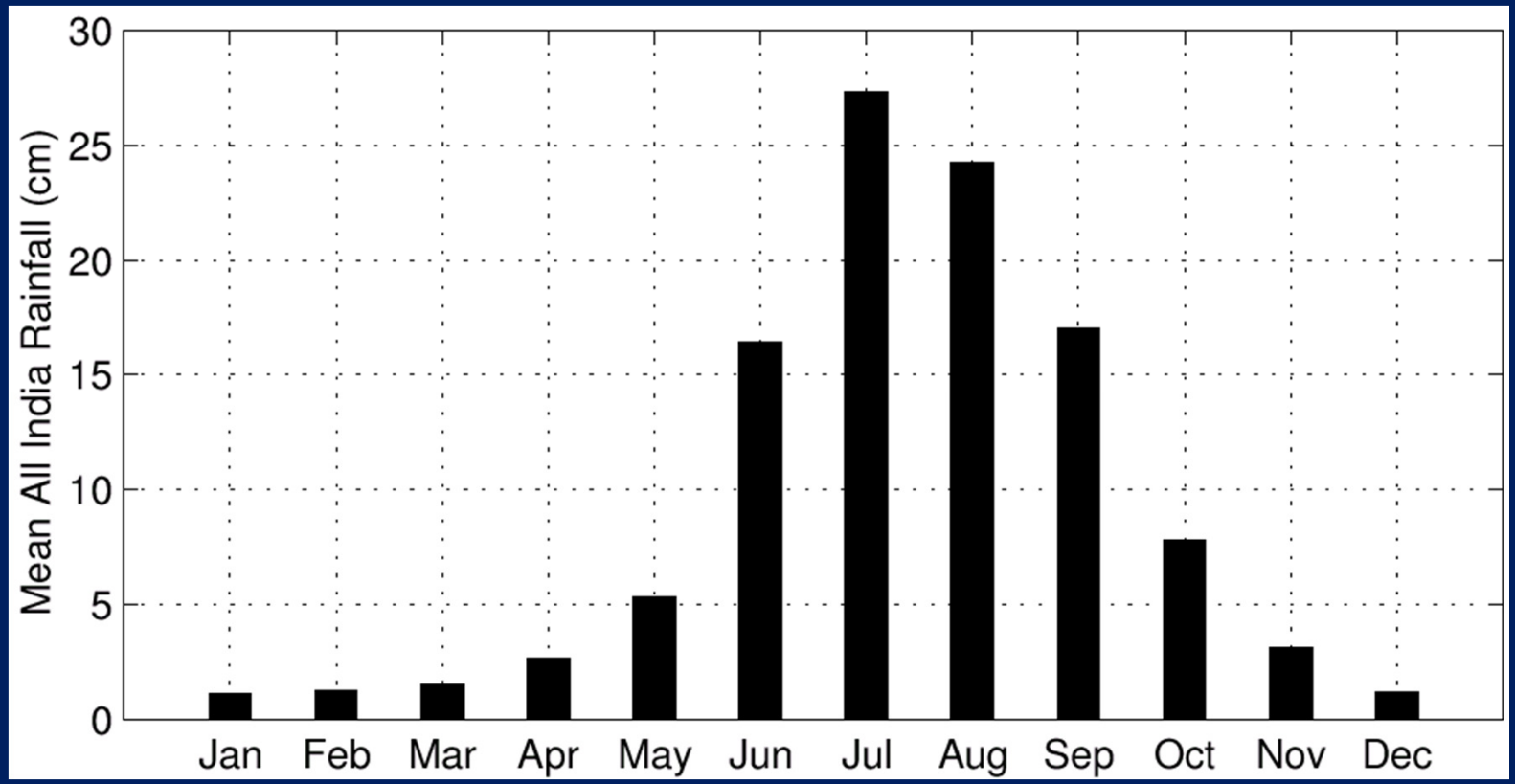
Outline

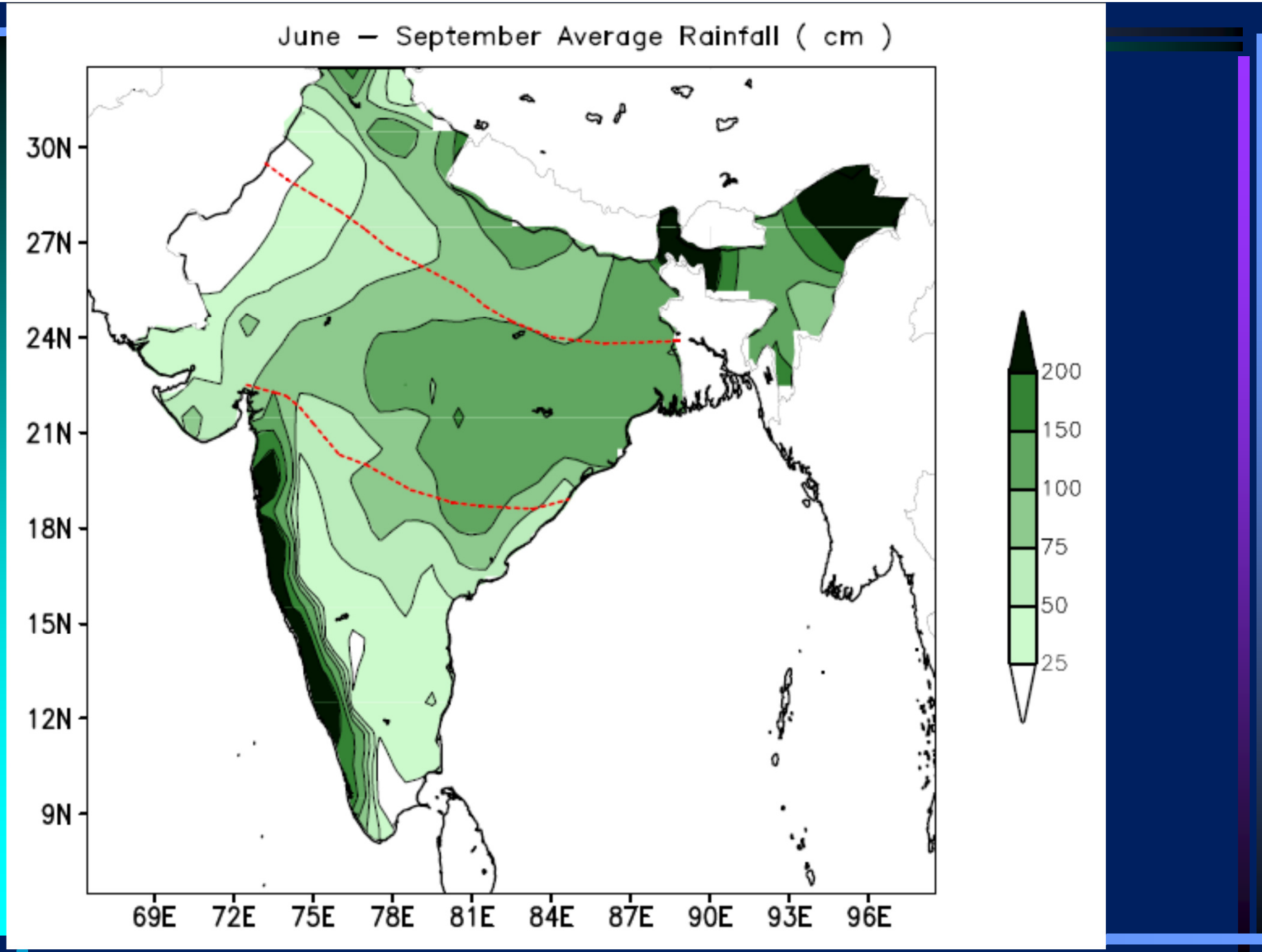
- Introduction: Climate change and the Indian monsoon
- Impact of the year to year variability of the Indian summer monsoon rainfall on food-grain production and GDP
- Precipitation effectiveness
- Importance of extremes-links to El Nino, La Nina and the Equatorial Indian Ocean Oscillation (EQUINOO)

Basic features of rainfall over India:

Mean monthly all-India rainfall



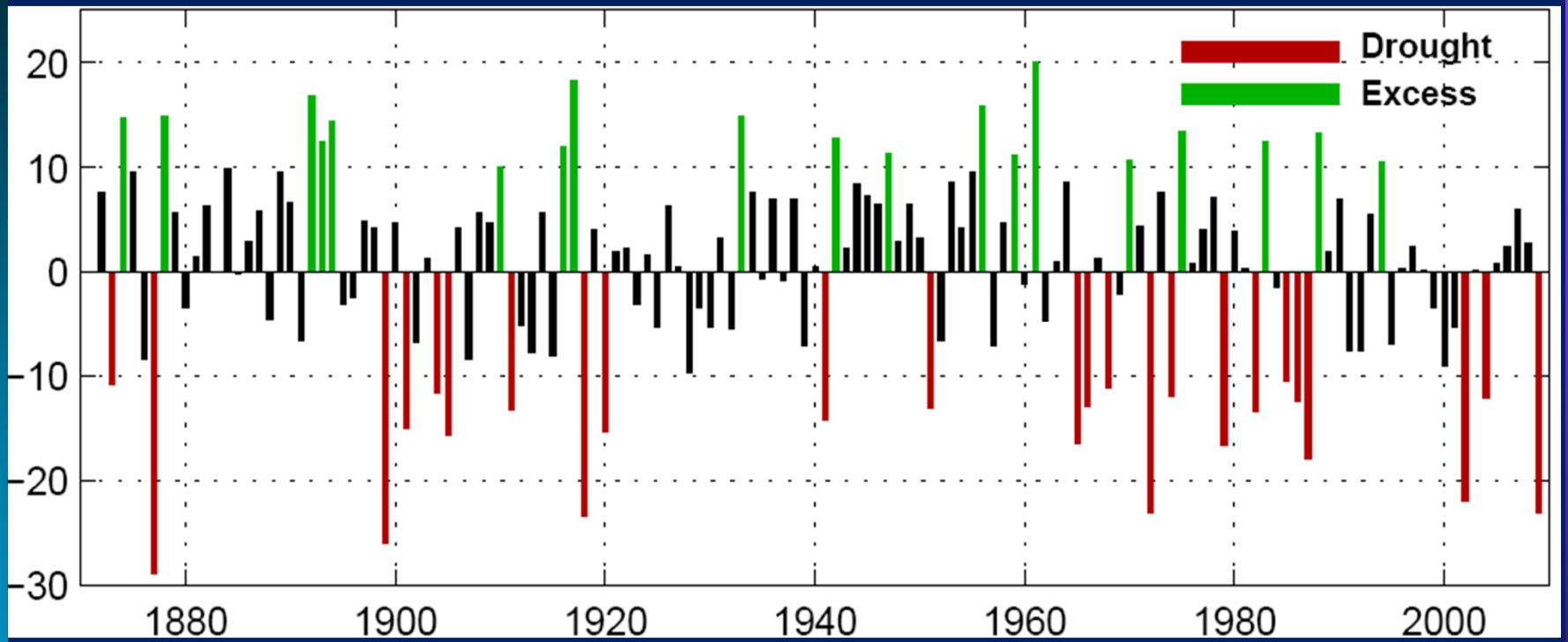
Most of the rainfall occurs during June-September-summer monsoon season; the focus of most studies is the summer monsoon. (However, over some parts such as the peninsula, the rainy season is different.)


June – September Average Rainfall (cm)
30N
27N
24N
21N
18N
15N
12N
9N
69E
72E
75E
78E
81E
84E
87E
90E
93E
96E
200
150
100
75
50
25

- **The average rainfall over the Indian region during the summer monsoon in any year, is denoted by ISMR.**
- **The ISMR anomaly of a given year is defined as the ISMR of that year minus the average ISMR.**

Interannual Variation of the anomaly of ISMR

(as % of the mean); (std dev is about 10% of mean)



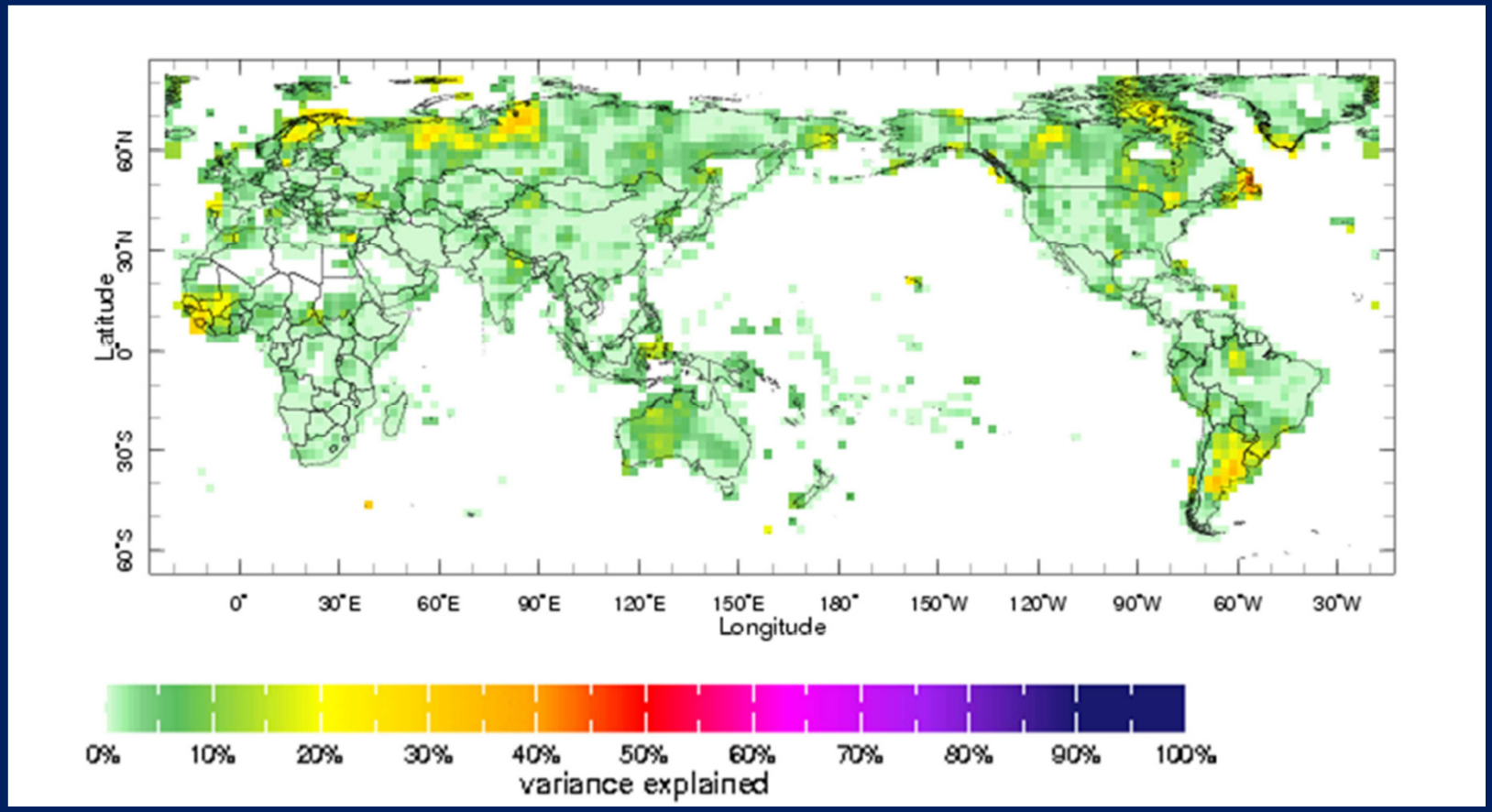
Drought: ISMR anomaly <-10% of the mean

Excess rainfall seasons: ISMR anomaly >10% of the mean

Climate change and implications for water resources & nutrition security

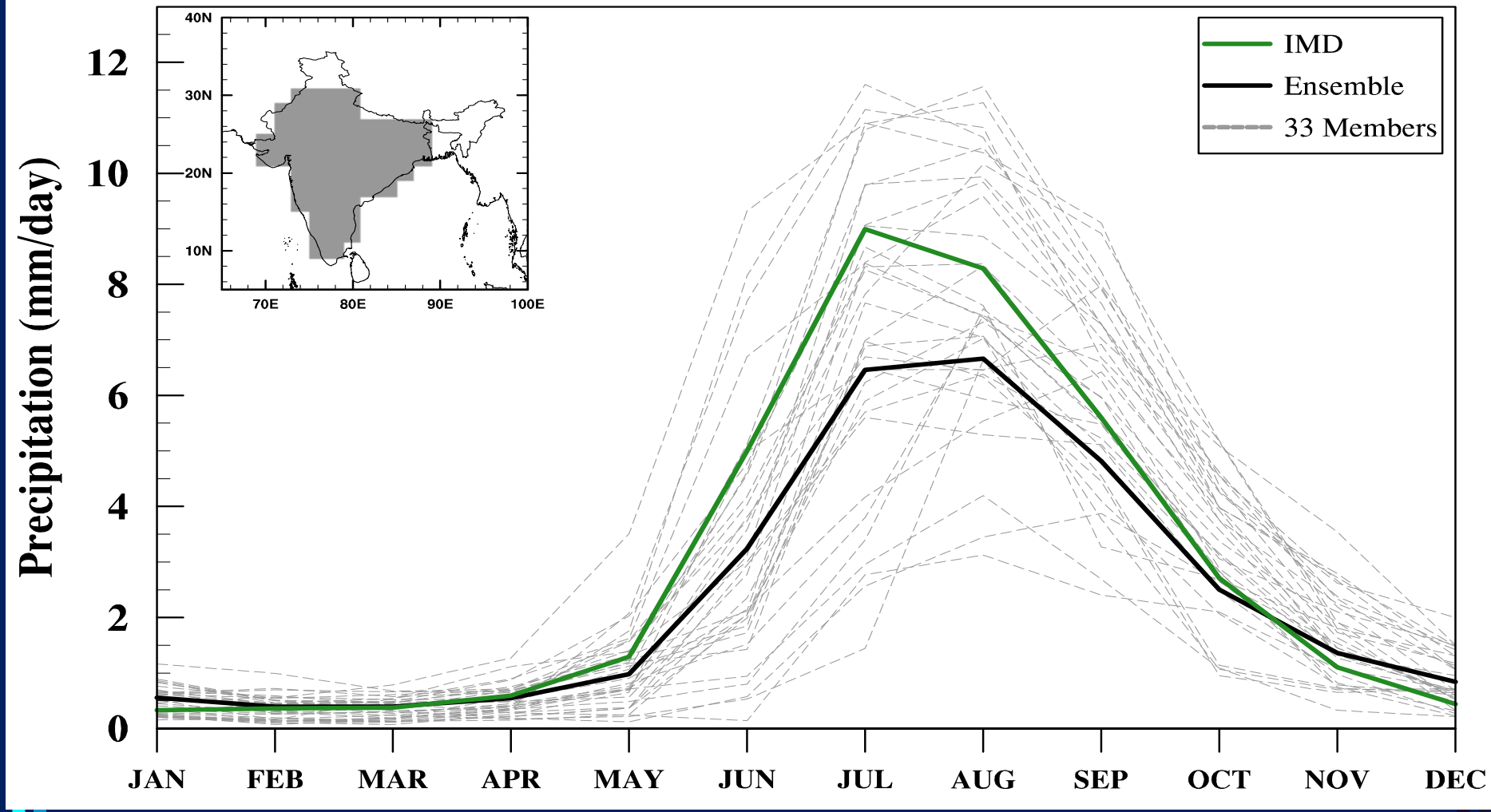
- Climate change-focus is on the change due to anthropogenic factors such as enhancement of GHGs, land use, land surface changes etc. The existence of global warming is now well established and can be attributed to such factors.
- The impact of the climate change bandwagon on the community has been so large, that in some circles, ‘climate’ has become synonymous with ‘anthropogenic climate change.’ However, for many parts of the world, and especially in the case of precipitation, climate change is a relatively small part of the climate we have experienced to date.

Estimated percent of ‘variance’ of 20th century observed precipitation, annual mean, ascribed to non-linear trend.



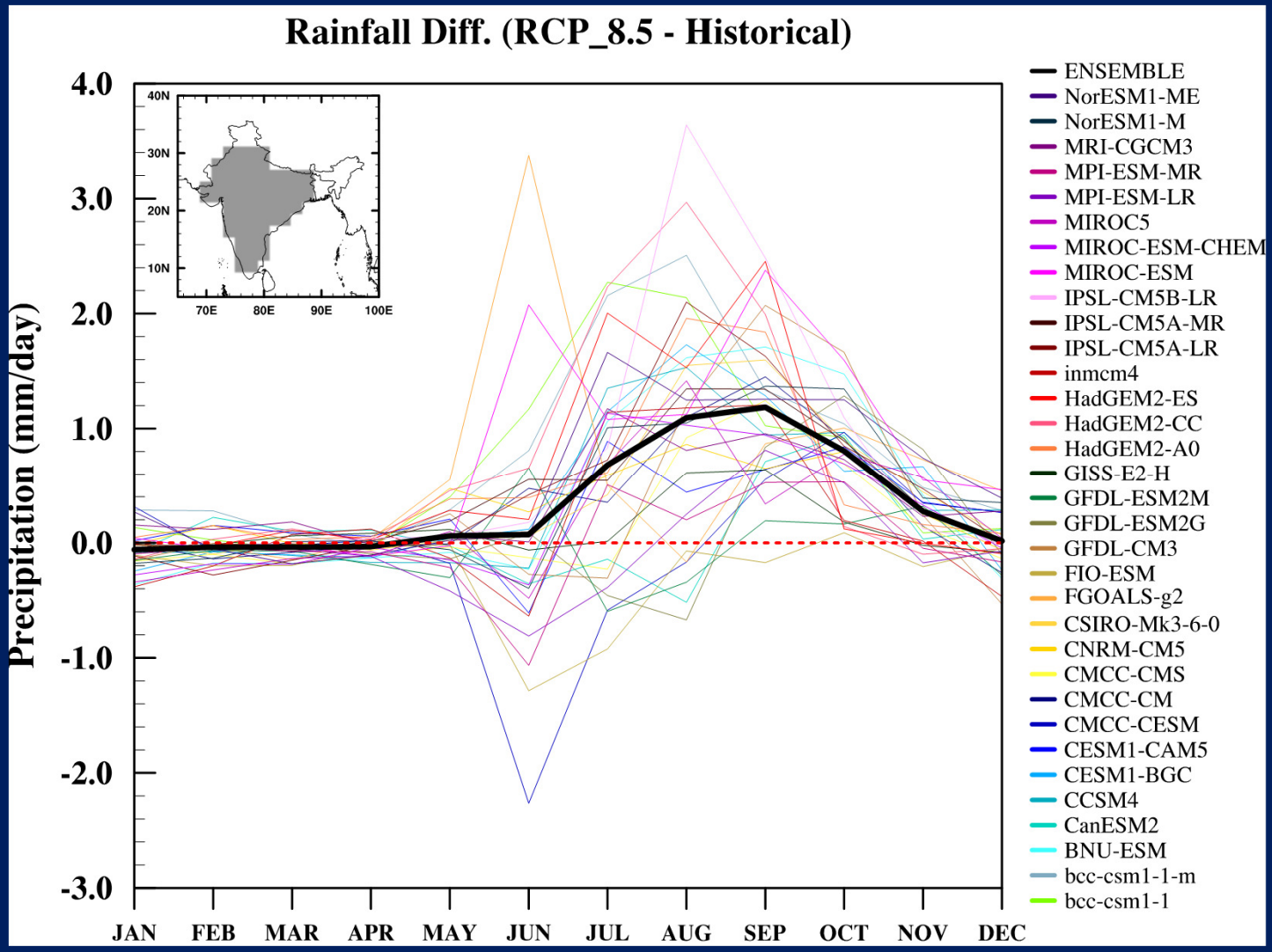
- **The climate change due to anthropogenic factors is predicted using climate models. For the Indian monsoon, the skill of these models in simulating present day climate variability is rather poor; the predictions for climate change vary considerably from model to model.**

Present-day Annual Cycle: CMIP 5



1950-1999

Sajani 2013



2070-2099 minus present

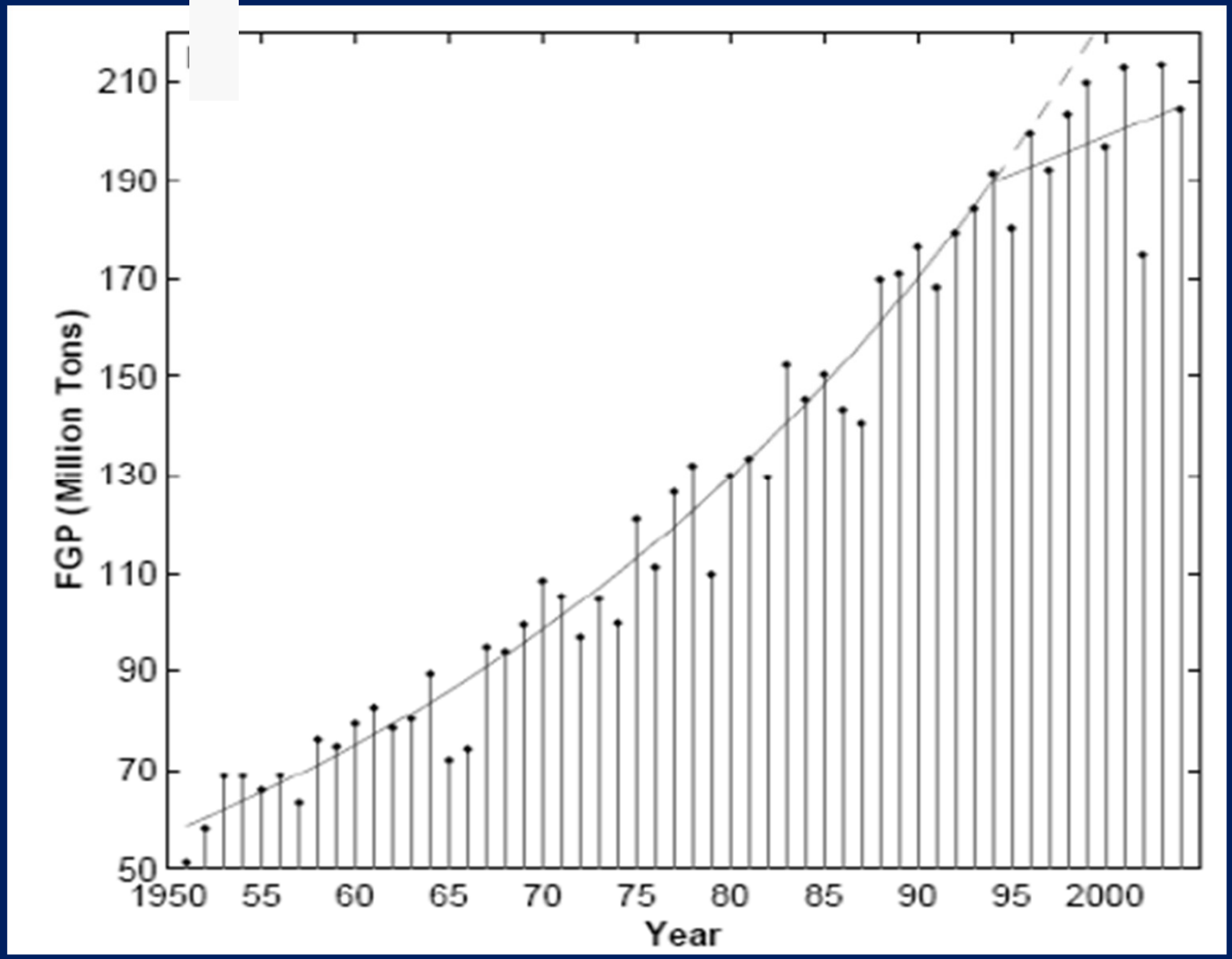
Sajani 2013

Climate variability and climate change

- The major robust conclusion of the climate change modelling studies of IPCC AR4 and AR5 is that the frequency of the extremes (droughts, excess rainfall seasons) will increase.
- Hence if the aim is to manage water resources , food and nutrition security, in the face of climate change, it is critical we adapt to the present climate variability, particularly the extremes.
- As far as the Indian monsoon is concerned it is clear that if we manage climate variability, climate change will take care of itself.

How has agricultural production fared in the face of monsoon variability over the past six decades?

Food grain Production (FGP)

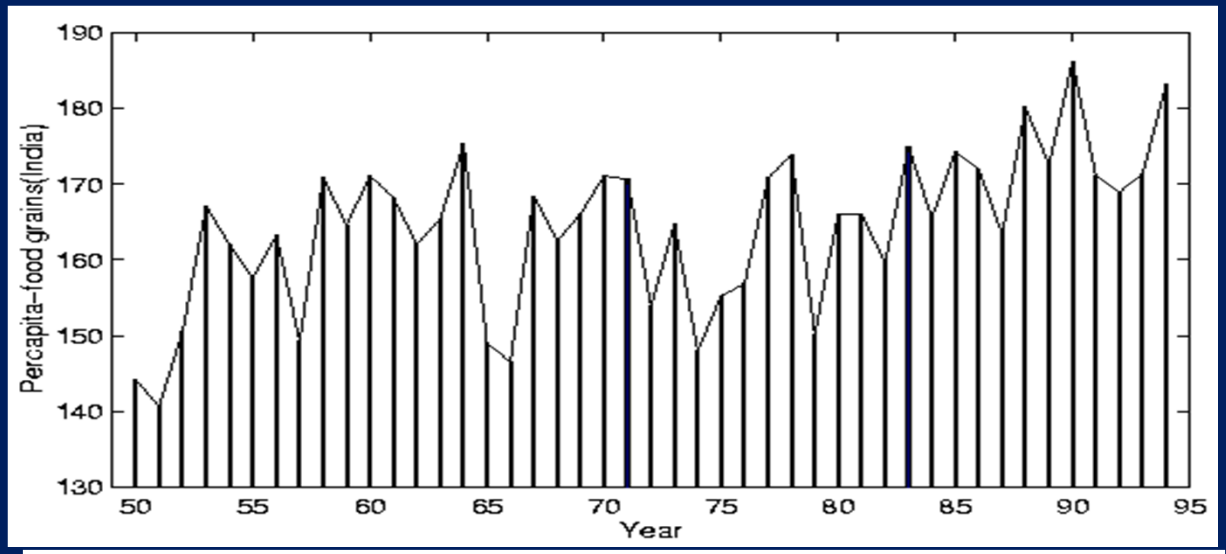


Note that the overall food grain production, started increasing with the end of the colonial rule, because of the large investments in irrigation since the 50s ; and in association with the green revolution since the 70s.

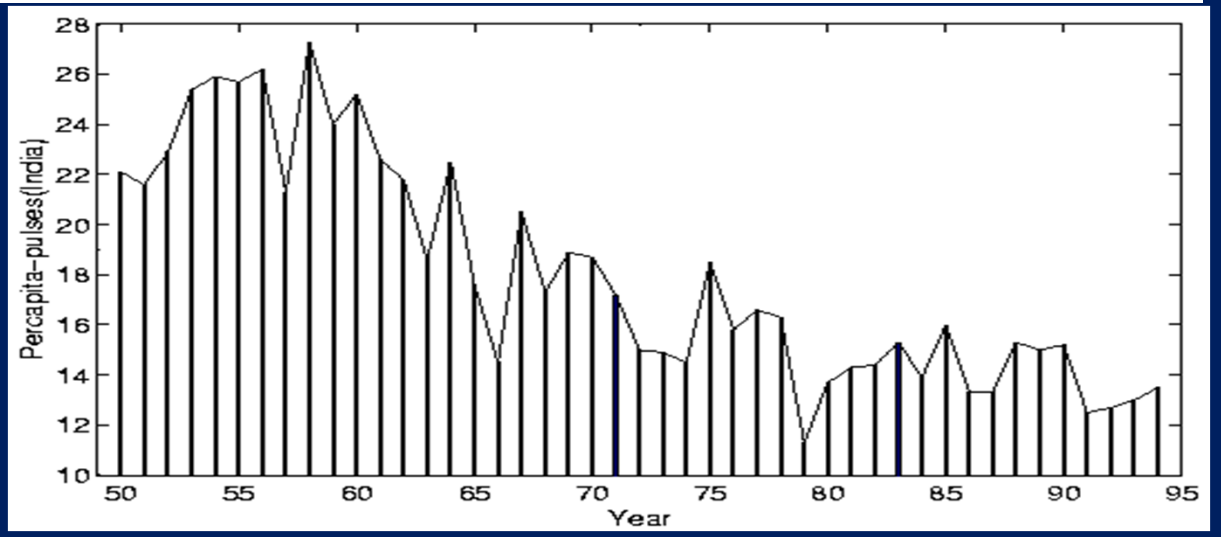
- Hence the per capita availability of food grains has remained stable since the mid-50s despite the growing population.
- However, the production of rainfed crops such as pulses, which is critical for nutrition security, hardly increased over this period and the per capita availability has been reduced to almost 50% of what it was[1].

Food security, nutrition security

Percapita Foodgrains



Percapita Pulses



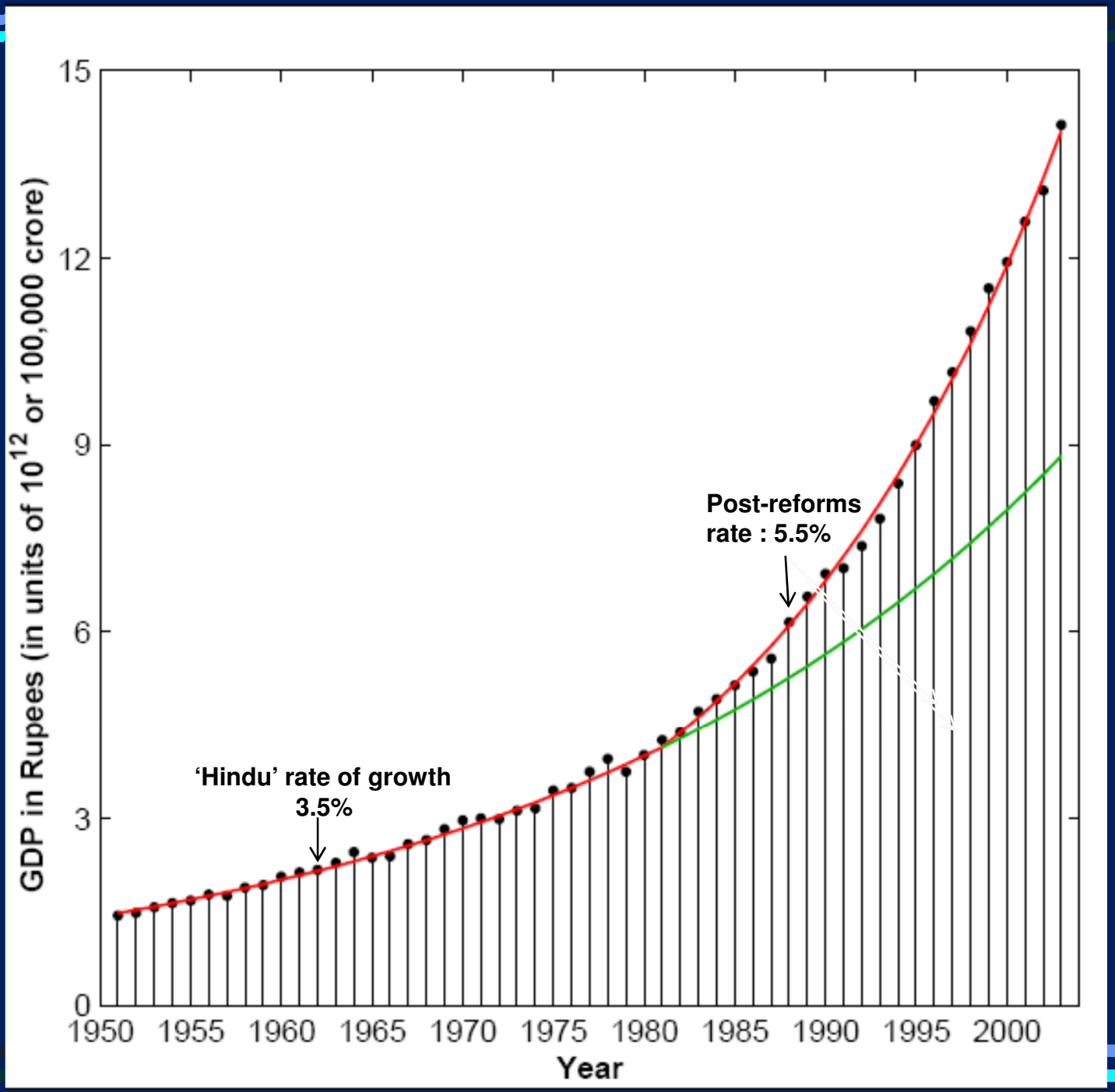
The impact of the green revolution has been primarily on irrigated lands

- **The first step in adaptation to climate-monsoon variability is a quantitative assessment of the impact on critical resources such as food-grain production and the overall economy i.e. the GDP.**

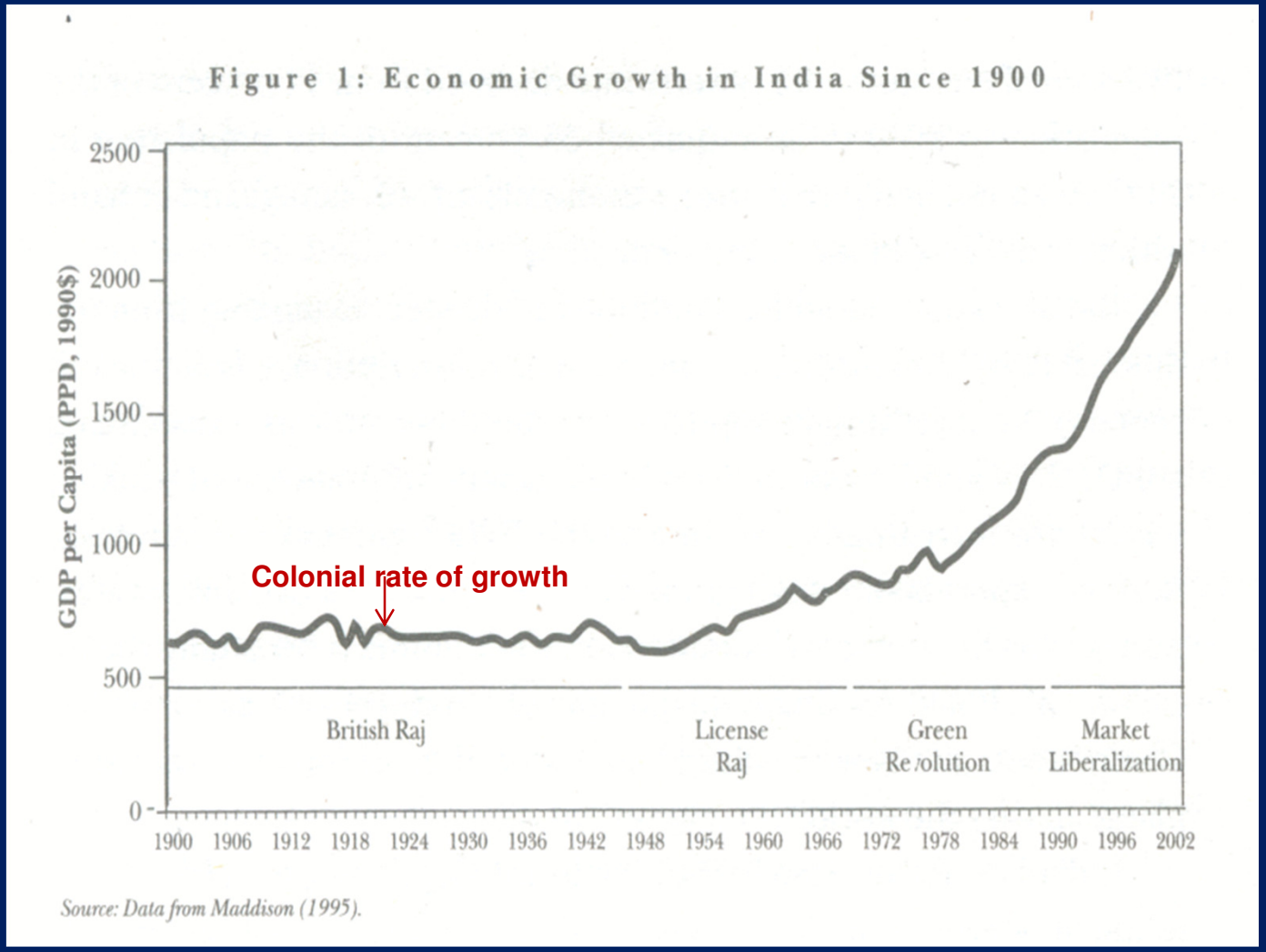
Impact of the monsoon : all-India scale

- Variation of the food-grain production (FGP)
- Variation of GDP
- Quantitative assessment of the impact of events of each year (e.g. the monsoon) on FGP, GDP

The Indian Monsoon, GDP and Agriculture, Gadgil, Sulochana and Siddhartha Gadgil, 2006, Economic and Political Weekly, XLI, 4887-4895

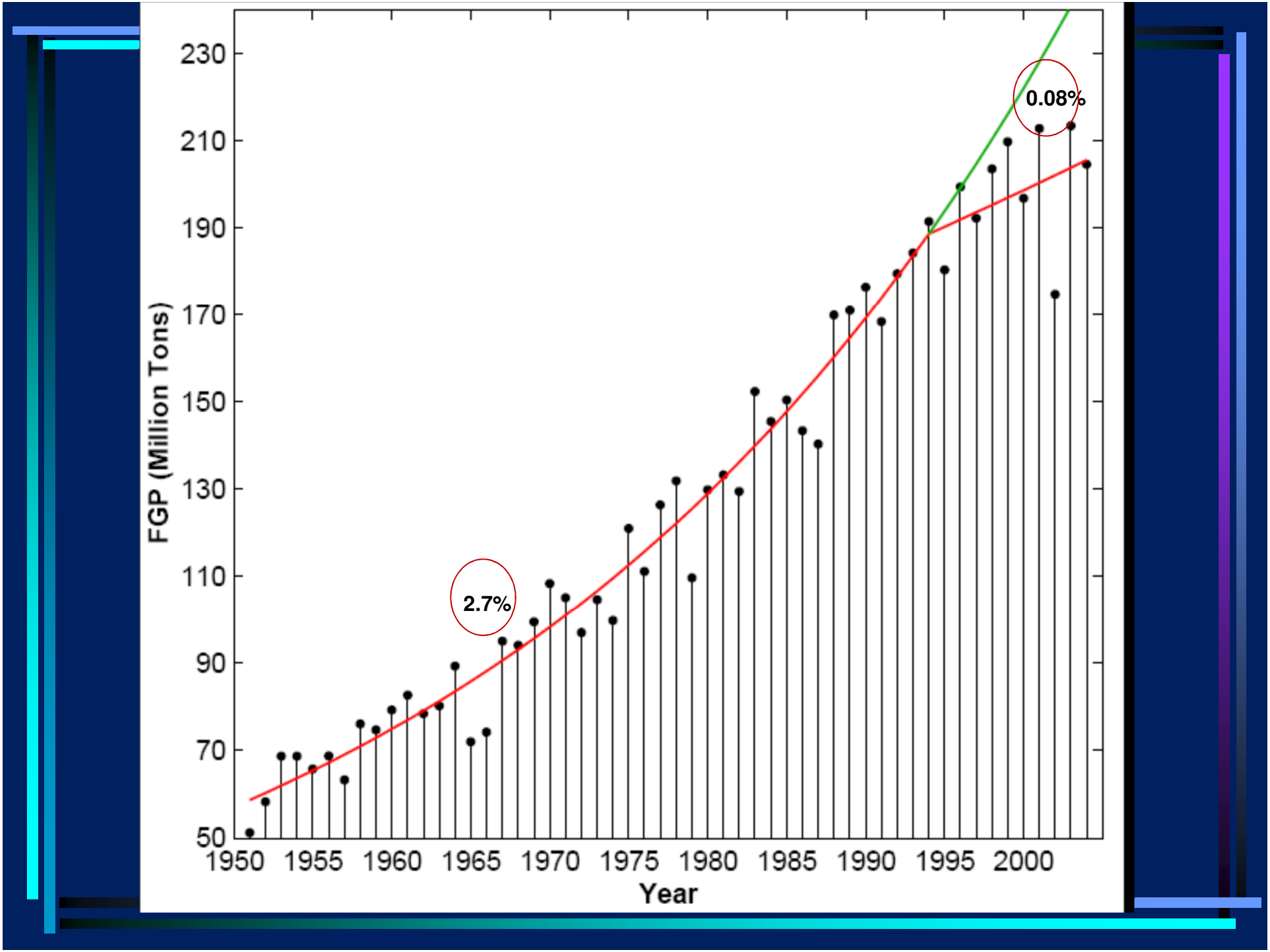

15
12
9
6
3
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Year
GDP in Rupees (in units of 10^{12} or 100,000 crore)
'Hindu' rate of growth
3.5%
Post-reforms
rate : 5.5%

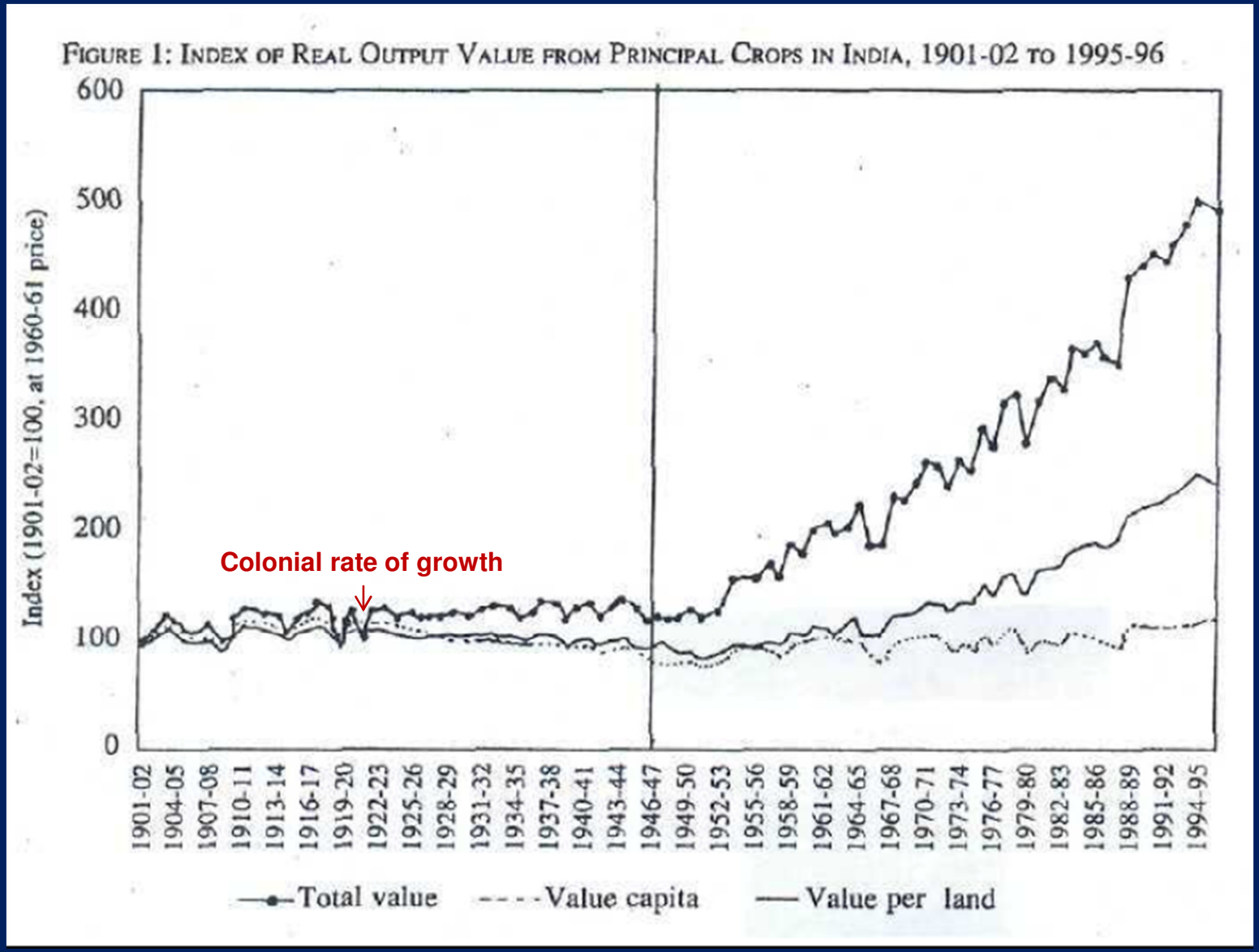
GDP per Capita



British Raj:1900-47, License Raj:1947-70, Green revolution :1970-91; Economic reforms : 1991-present

From ‘End of Poverty” Sachs 2005, p181


FGP (Million Tons)
230
210
190
170
150
130
110
90
70
50
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Year
2.7%
0.08%

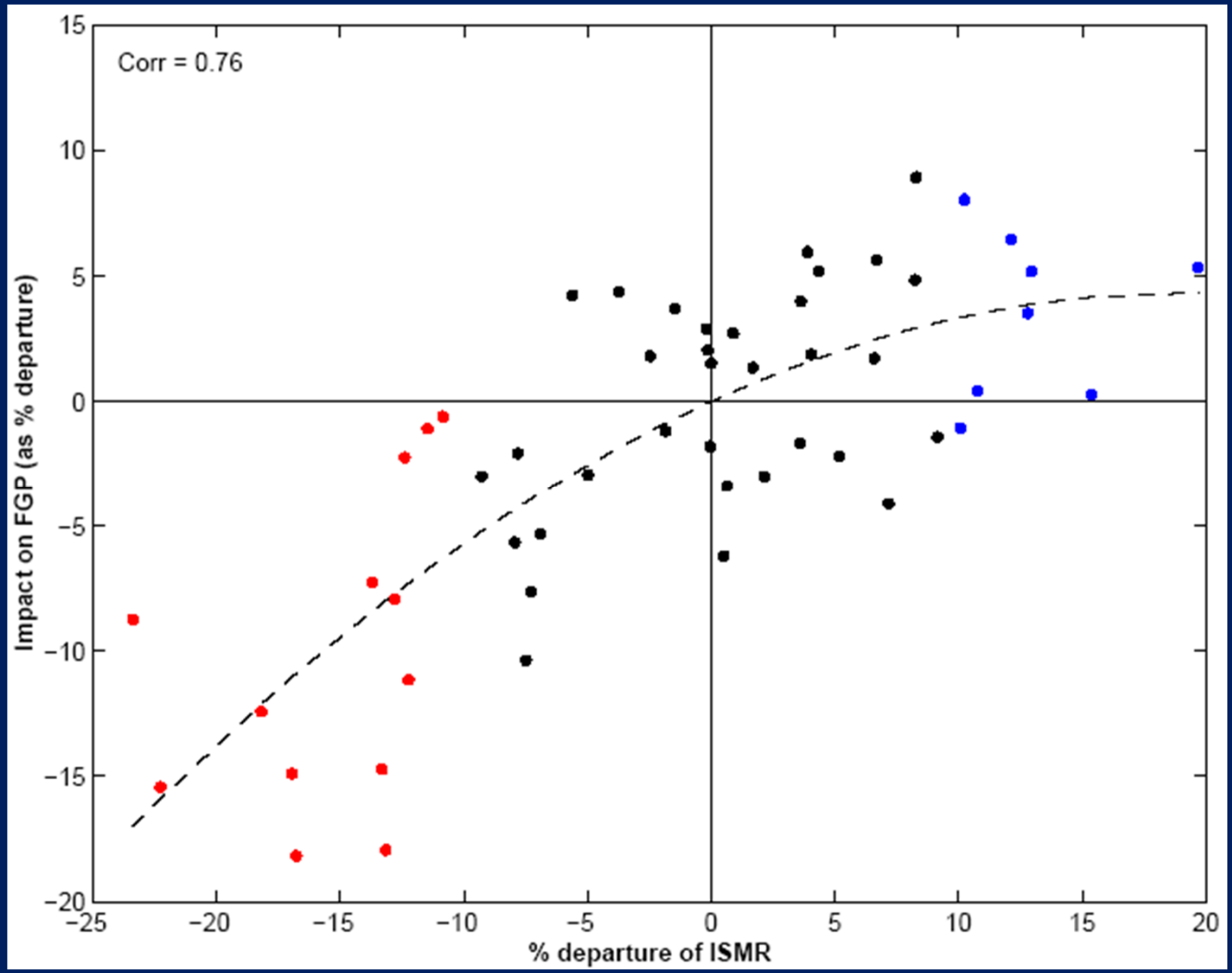


after Kurosaki T, EPW 25 Dec.1999

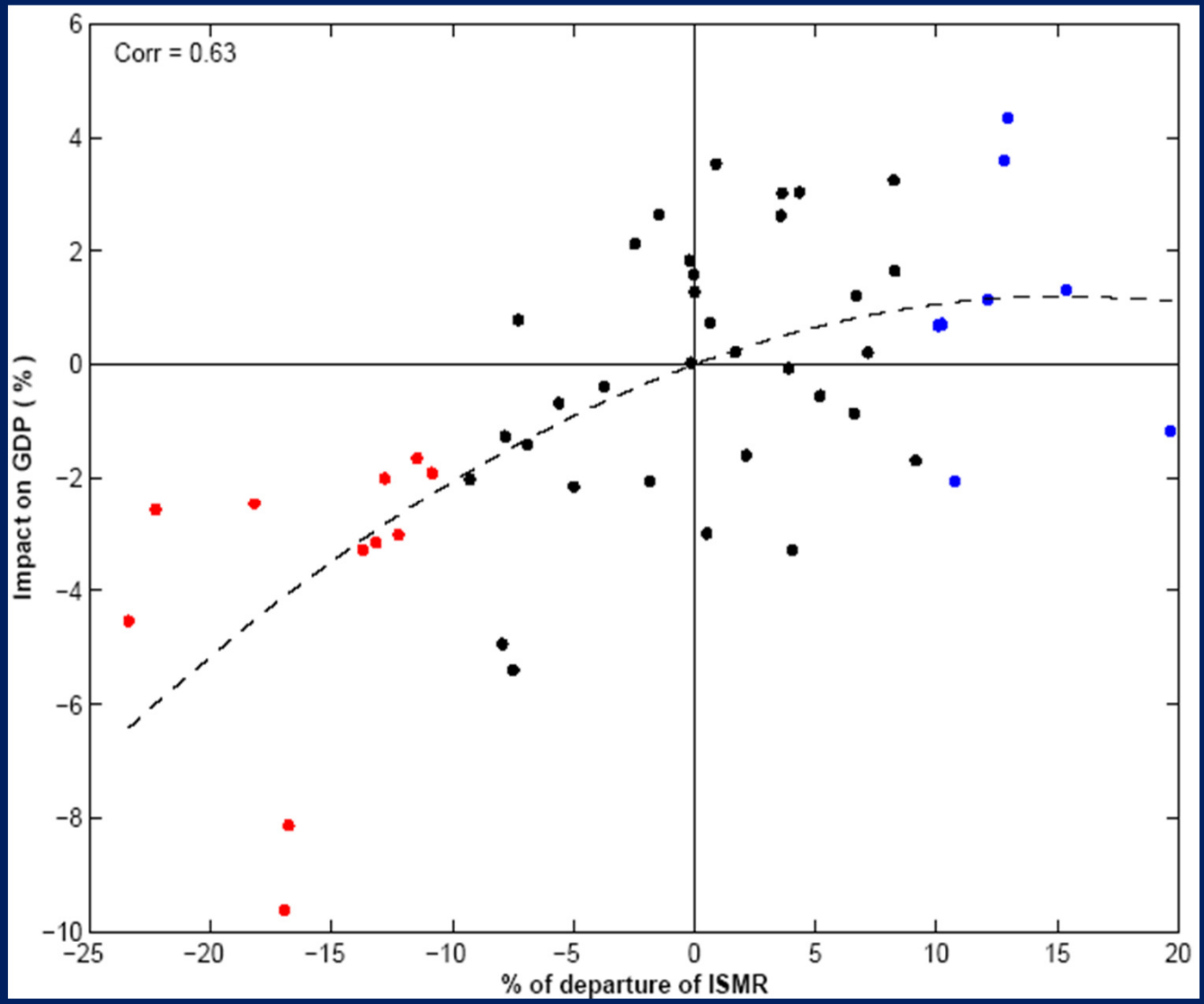
Calculation of the impact of the monsoon

- We expect the observed deviations of GDP and FGP for a specific year (i.e. DevGDP (year) and DevFGP (year) to be related to the important events in that year and particularly to the ISMR anomaly of that year.
- However, the deviation of the GDP from the fitted curve depends not only on the events of that year (such as a deficit monsoon), but also on the deviation of the previous year. This is taken care of in the calculation of the impact of the events in a specific year.

Asymmetry in response to droughts vis a vis surpluses



Asymmetry in response to droughts vis a vis surpluses

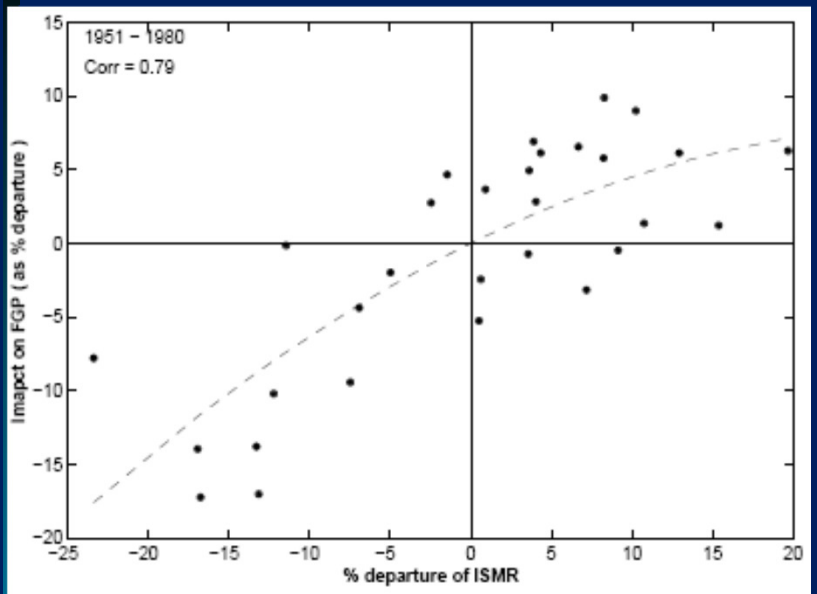


ISMR anomaly= departure of the monsoon rainfall from the mean

Precipitation Effectiveness

- The impact of the monsoon on FGP and GDP is highly nonlinear, with the magnitude of the impact of a negative ISMR anomaly being larger than that of a positive ISMR anomaly of the same magnitude.
- Thus while deficits in the monsoon rainfall have a large negative impact, the precipitation effectiveness of normal or surplus monsoon is not commensurate with the magnitude of the rainfall anomaly.

- **Furthermore, this asymmetry in the impact of the monsoon on FGP increased sharply in the last three decades.**
- **Whereas in the earlier era, the magnitude of the impacts of a drought and a surplus on FGP were comparable in magnitude; while after 1980 the impact of surpluses has become almost negligible.**



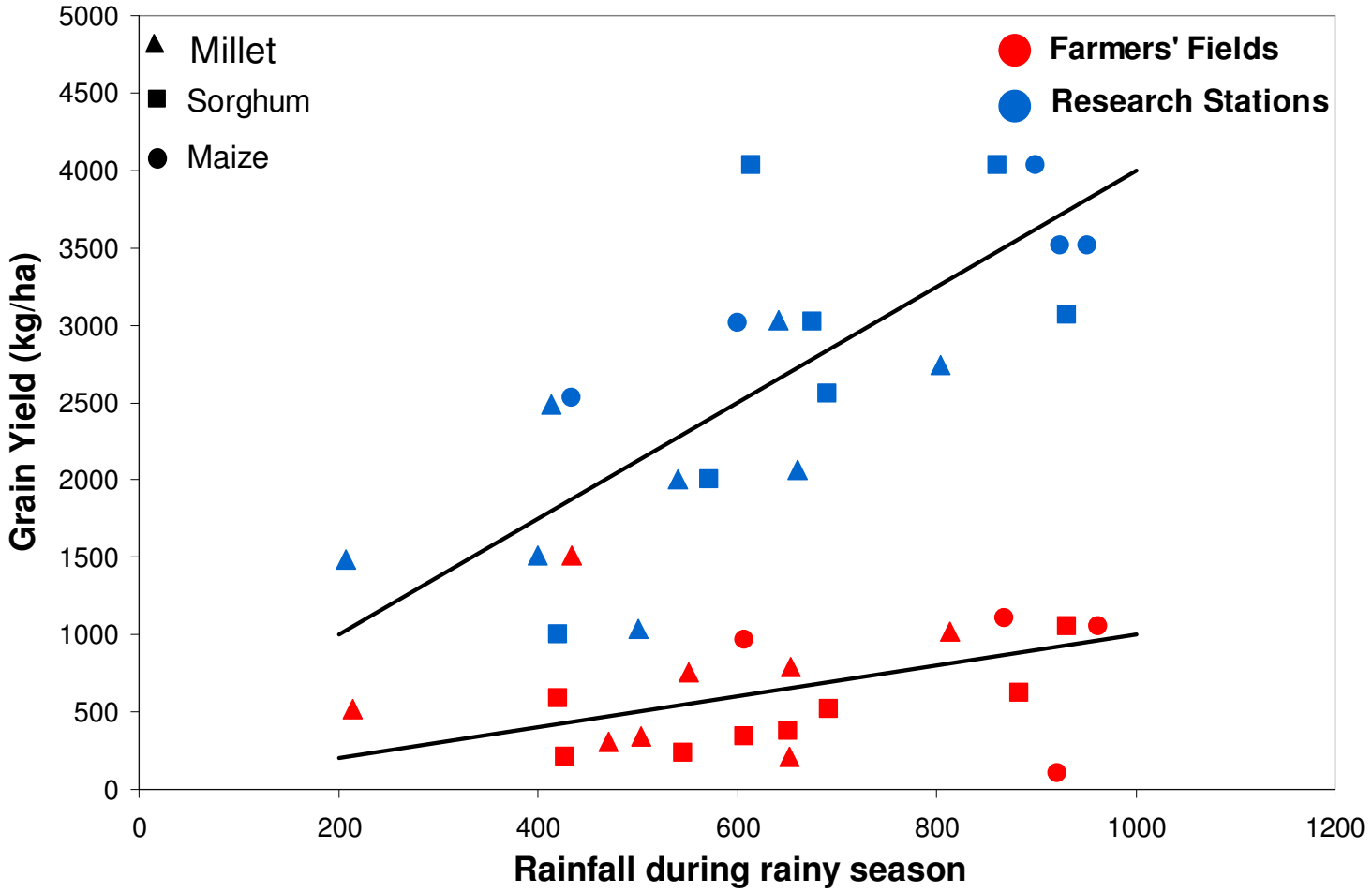
Period	1951 - 80	1981 - 04
ISMR	FGP	FGP
-25	-19.13	-18.81
-20	-14.41	-13.29
-15	-10.13	-8.65
-10	-6.30	-4.89
-5	-2.93	-2.00
0	0.00	0.00
5	2.48	1.12
10	4.50	1.37
15	6.08	0.73
20	7.21	-0.79

- This implies that even if there is no long period trend in the monsoon rainfall, the FGP will decrease over time because the impact of deficits will not be made up.

- We have suggested a factor that can lead to the marked asymmetry since the 80s.

The major changes since the 80s

- Change in cropping systems,
- Non sustainable agriculture:
- intensive agriculture leading to loss in fertility of the soils,
- mono-cropping over large areas leading to several pests becoming endemic and facilitating spread of diseases
- So it is not possible to get good yield even in good rainfall years without application of fertilizers and pesticides in this era.



Relationship between rainfall during the rainy season and yield of maize , sorghum and millet at 15 dryland locations in India (after Shivakumar et al. 1983)

ICRISAT

Yield gap is large only for above average rainfall years

Similar result for groundnut, soyabean, pigeonpea and chikpea

Why does the yield gap increase with seasonal rainfall?

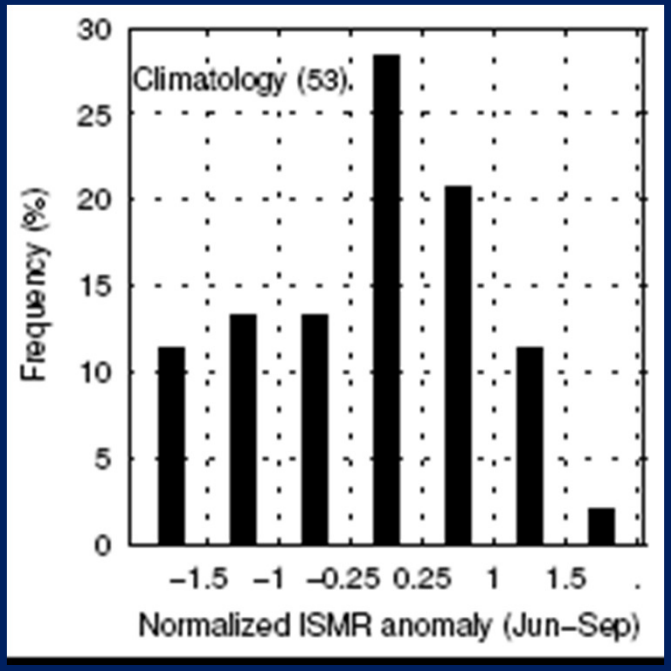
- Major difference in the management at agricultural stations and farms: application of fertilizers and pesticides.
- These do not enhance yields in poor rainfall years.
- In the absence of a reliable forecast of no drought, farmers do not consider them cost-effective and hence do not invest in them (although they have the know-how and do apply them over irrigated patches).

- However, at agricultural stations farm economics is irrelevant and liberal doses of fertilizers and pesticides can be applied.
- Even then, the yields are not very much better than the farmers' yields in poor rainfall years (which is why the farmers do not apply them) .
- However, in normal or good monsoon years the yield enhancement due to this application is very large. Hence the yield gap increases with seasonal rainfall.

Mitigation

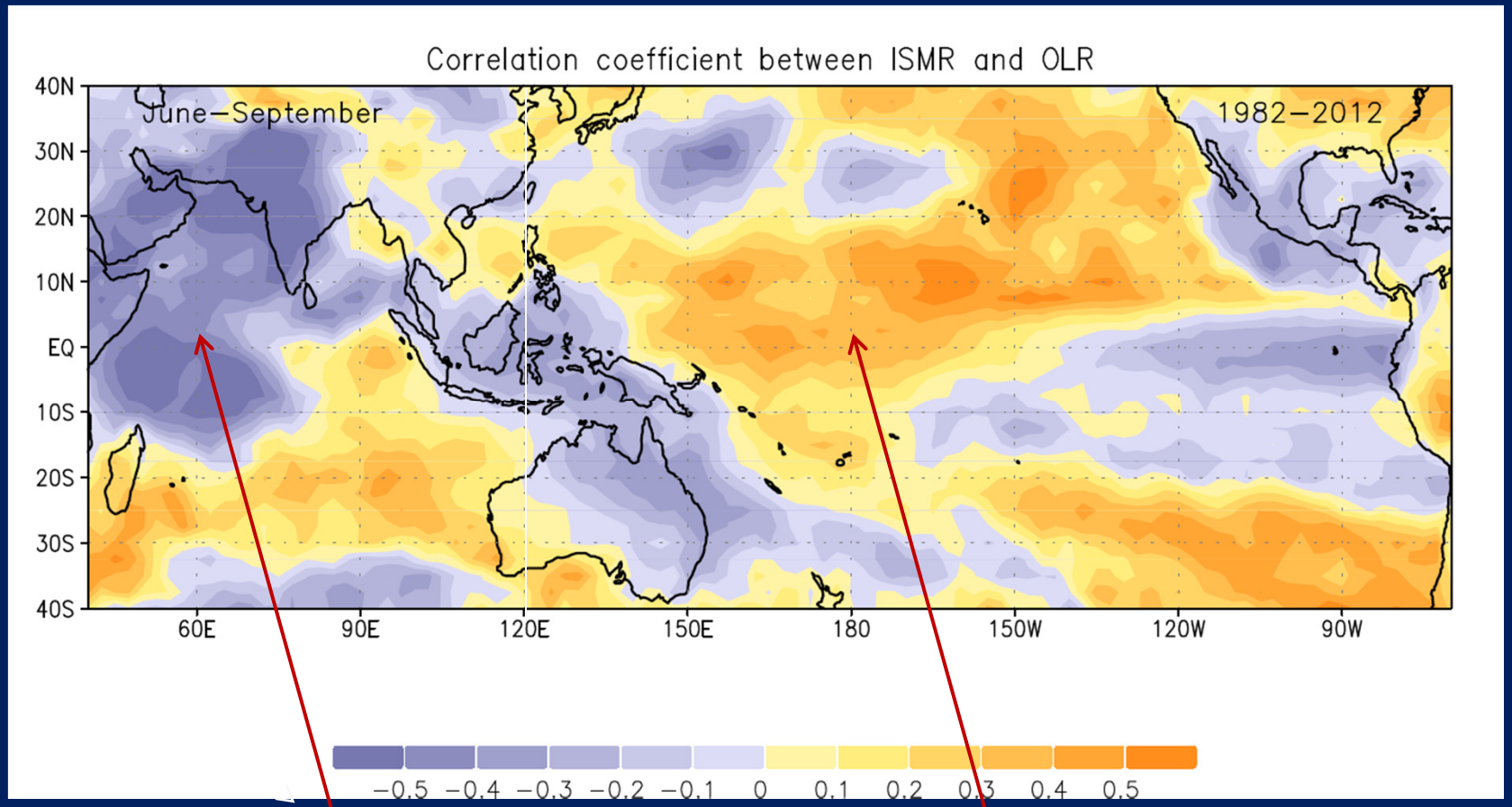
- To increase the effectiveness of rainfall in the absence of droughts, it is necessary to adopt farming strategies using the predicted frequency of occurrence /nonoccurance of droughts.
- Thus prediction of extremes of monsoon rainfall is most important.

A reliable forecast of the non occurrence of droughts can enhance production in seasons of normal or good rainfall (i.e. 75% of the monsoon seasons).



ISMR	Climatology (n=53)
ISMR <= -1.0	24.5
-1 < ISMR <= -0.25	13.2
-0.25< ISMR < 0.25	24.5
0.25 <= ISMR < 1	22.7
ISMR >=1.0	15.1

Teleconnections of the monsoon

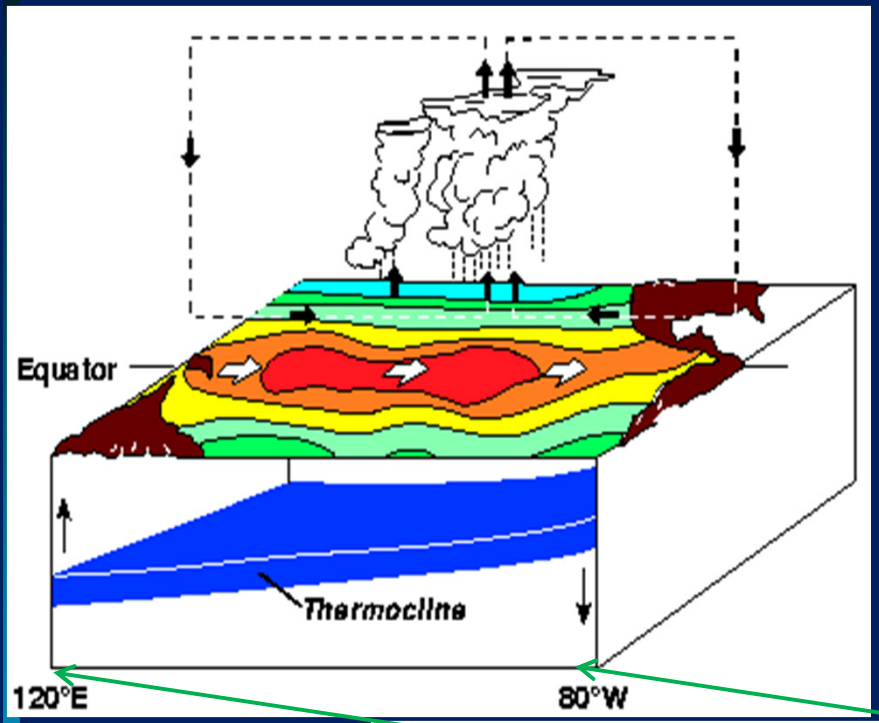


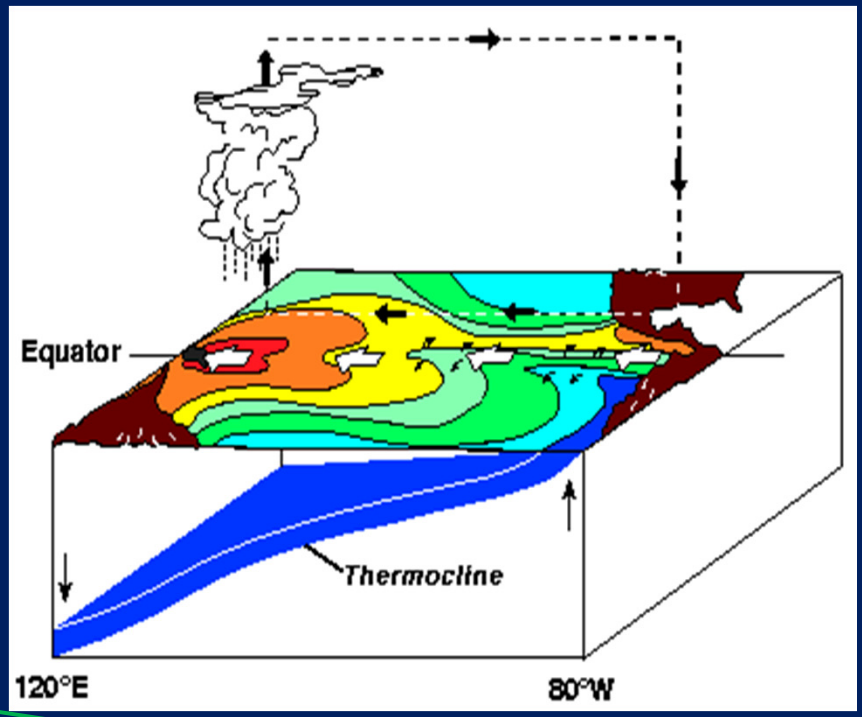
Equatorial Indian Ocean Oscillation (EQUINOO)

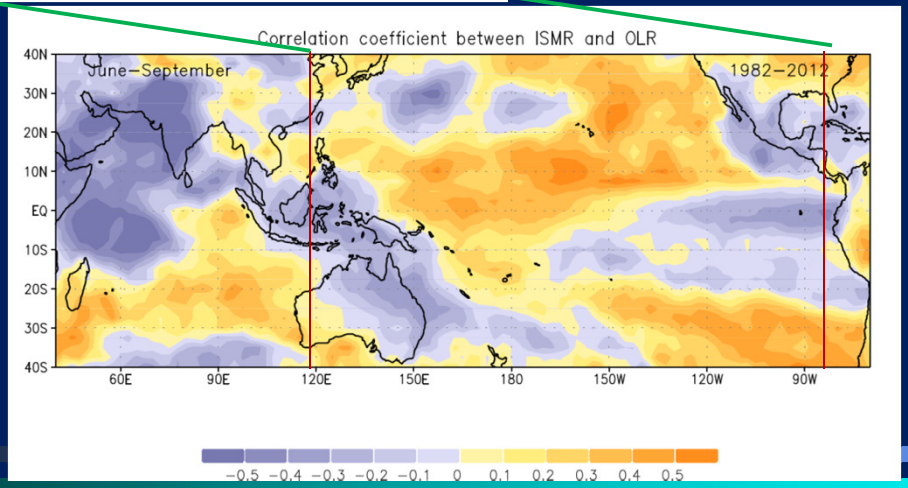
El Nino, La Nina and the Southern Oscillation (ENSO)

El Nino

La Nina

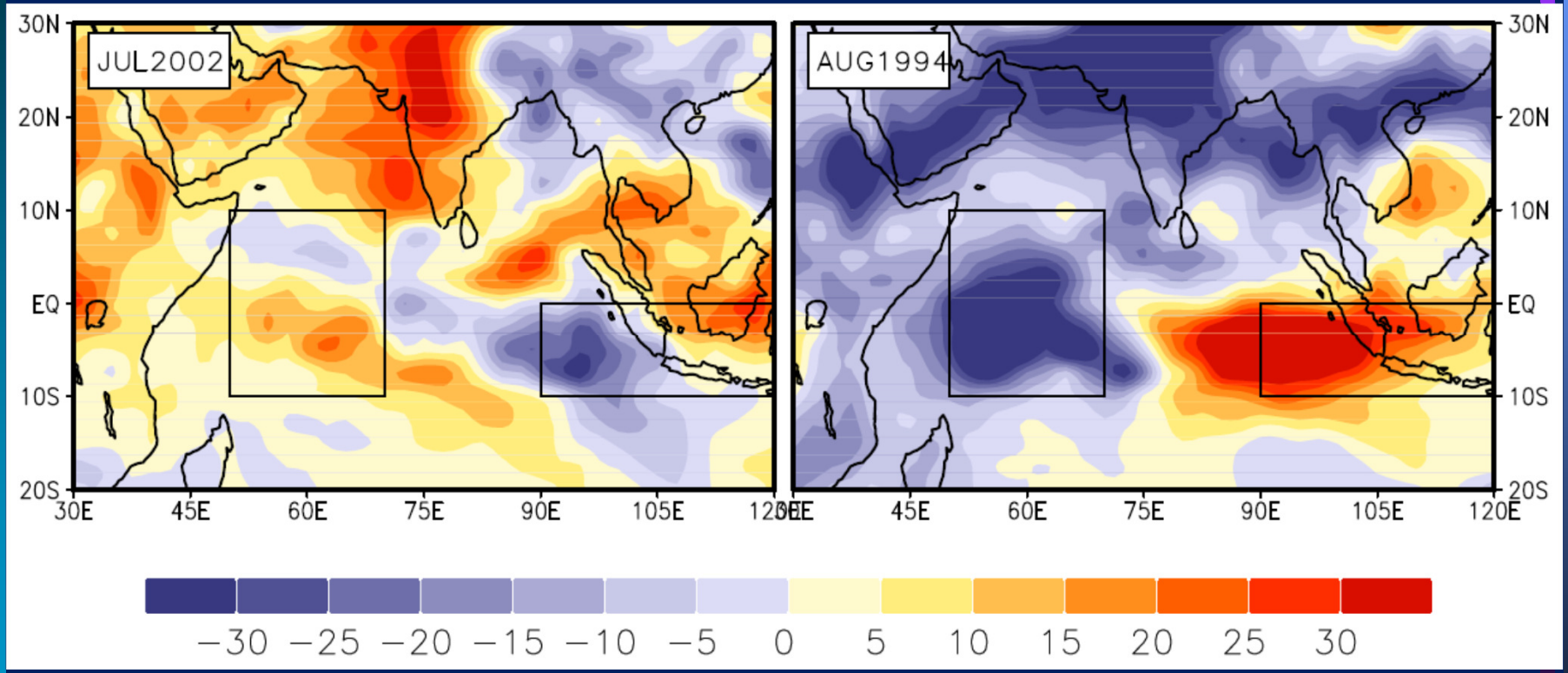






Equatorial Indian Ocean Oscillation (EQUINOO)

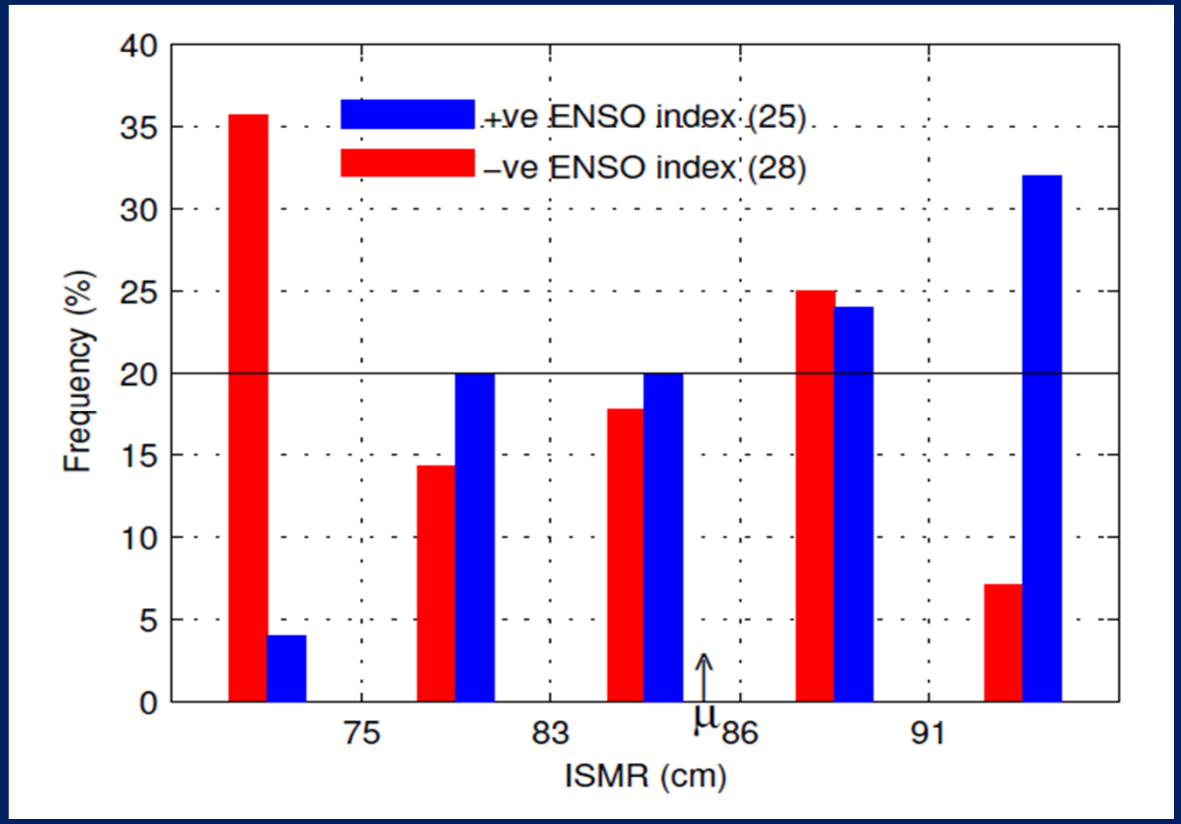
OLR anomalies



July 2002

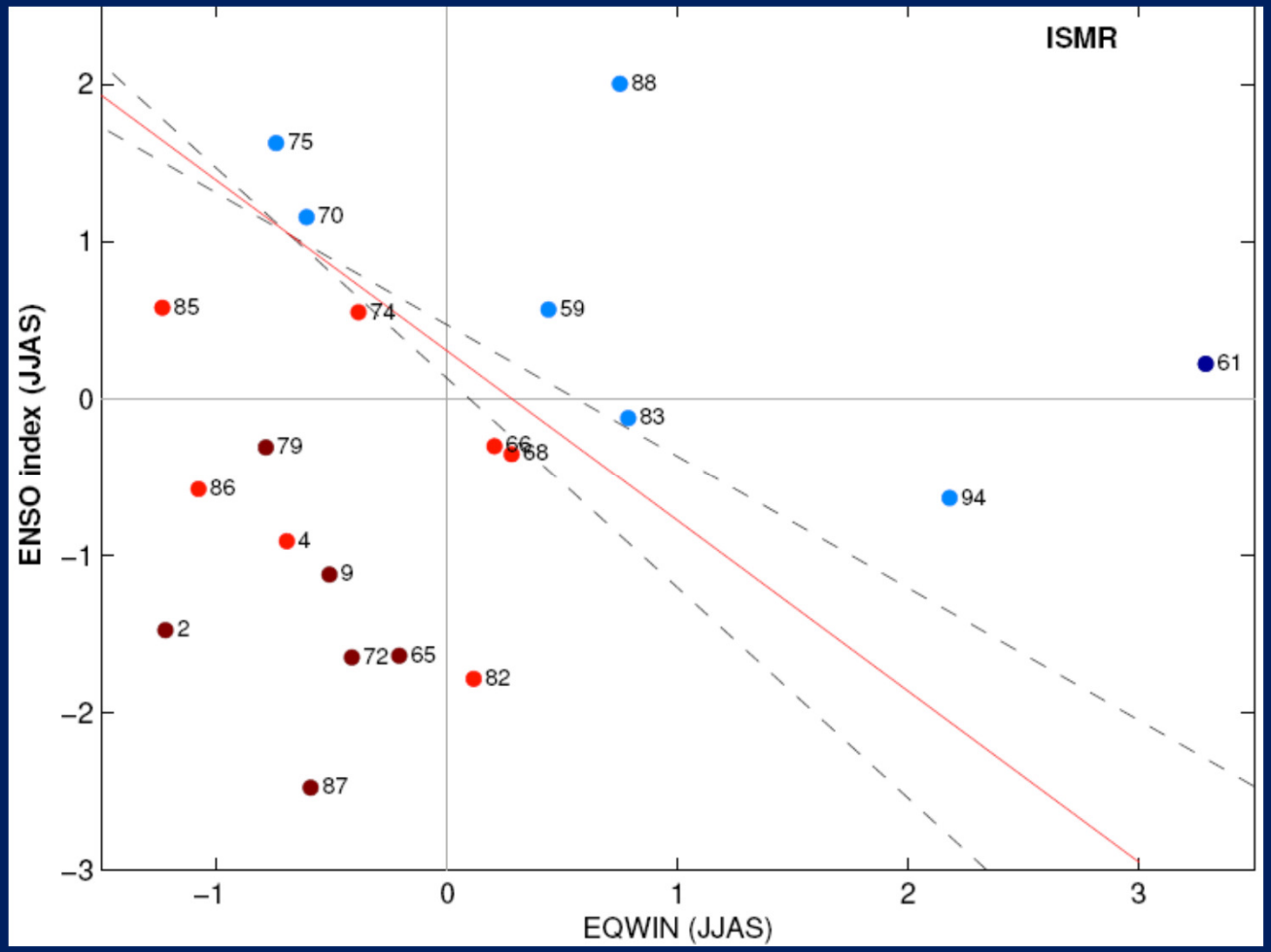
August 1994

ENSO has a large impact primarily on the probability of occurrence of extremes

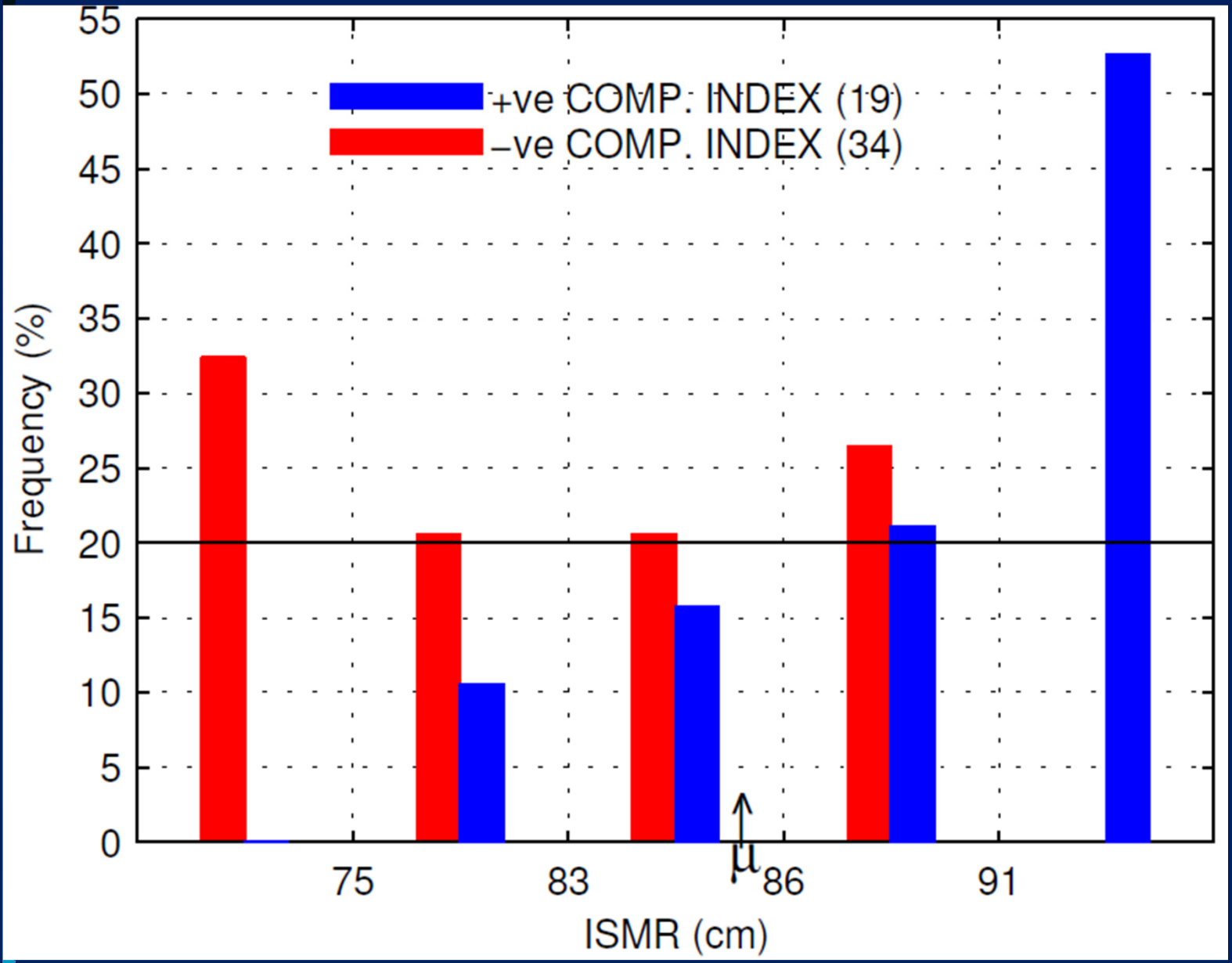


ISMR categories chosen so that climatological prob. of each is 20%

ENSO and EQUINOO ‘explain’ all the extremes of the Indian monsoon rainfall observed so far



Gadgil et. al 2004

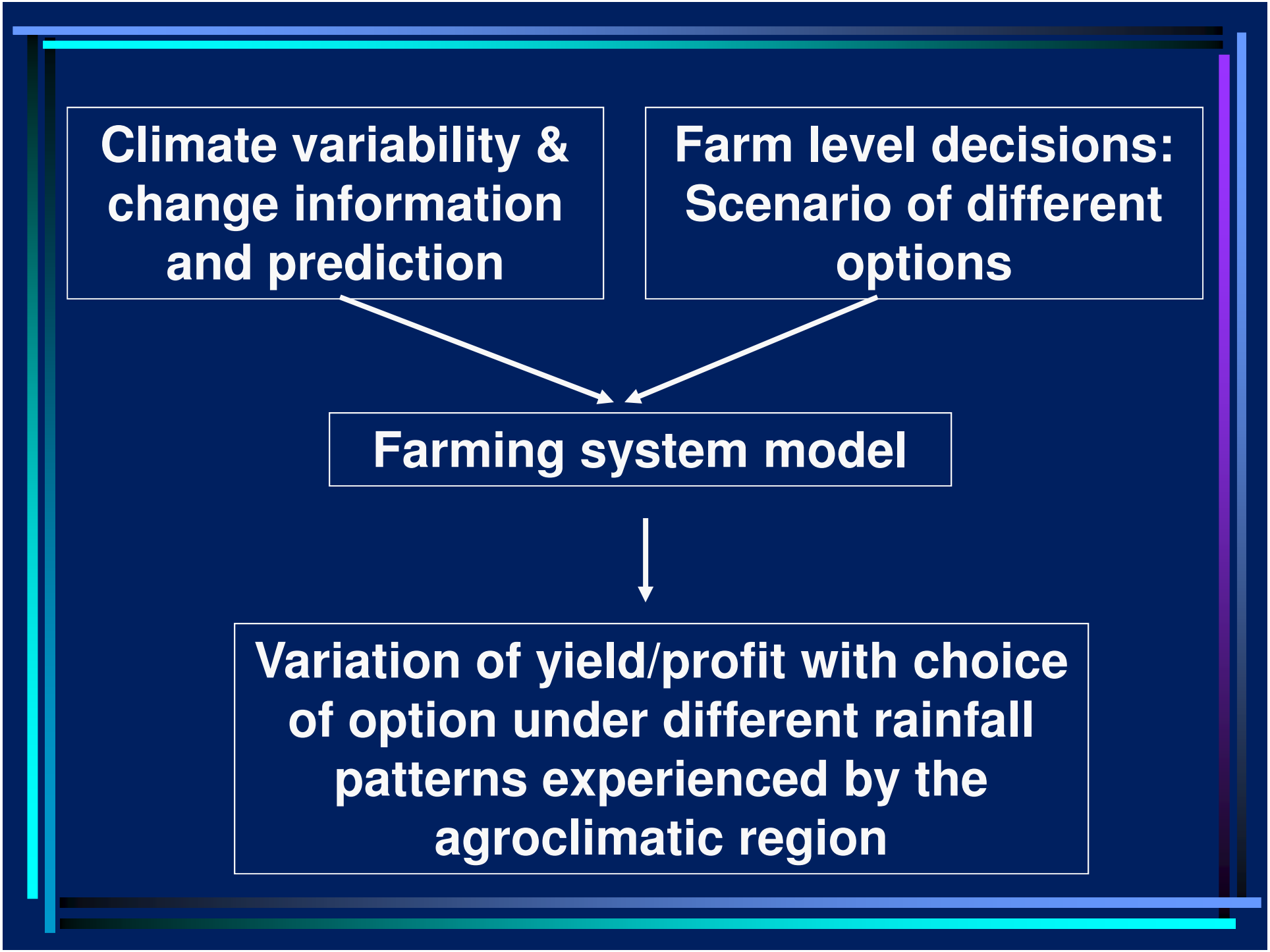


Large Impact on extremes

- **There has been a phenomenal progress in prediction of ENSO since the 90s. If such progress occurs in the prediction of EQUINOO with improvement of climate models, reliable predictions for climate variability and change for the Indian monsoon can be generated and strategies for adaptation and mitigation worked out.**

To identify the farming strategies which can ensure food and nutrition security in the face of climate variability and change, advances in atmospheric and agricultural sciences have to be harnessed in a genuinely interdisciplinary* approach involving farmers as well.

transdisciplinarity enabled


Climate variability & change information and prediction
Farm level decisions: Scenario of different options
Farming system model
Variation of yield/profit with choice of option under different rainfall patterns experienced by the agroclimatic region

Thank you