

Climate Change and Assessment of its Impact in Agriculture



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Climate Change

- *“The greatest challenge facing the world at the beginning of the century”*

■

*World Economic Forum
Davos, Switzerland , 2000*

- *“Climate Change is threatening to frustrate poverty eradication efforts and making the prospect of meeting the Millennium Development Goals less certain.*

*(Kofi Annan, at UN Conference on Climate Change,
Nairobi, 2006)*

- *“Climate change is a terrorism multiplier”*

*(Malik Amin Aslam, Former Minister of State,
Government of Pakistan)*

Climate Change: Some Definitions

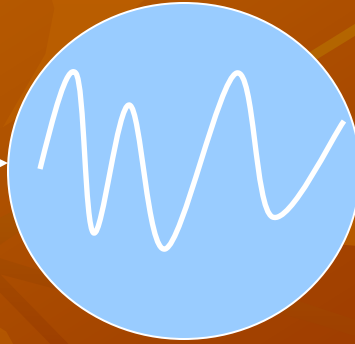
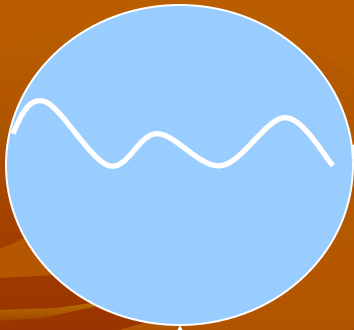
Weather: The state of the atmosphere at a given place, with respect to variables such as temperature, moisture, pressure, etc

Climate: Average weather. Statistical description of mean weather conditions over a period of several years, typically 2-3 decades

Climate Change: Climate change in excess of natural variability, attributable to human activity

Natural Climate
Variability

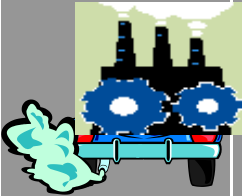
Climate Change
Natural + Anthropogenic



Anthropogenic Influences
since the Industrial revolution



Spiraling
Population



High pace of
Industrialization

Increasing use of
Fossil Fuels in
Industry &
Transport



Deforestation for
Agriculture and
Urbanization

CLIMATE CHANGE

Global Warming

Increased Precipitation & its
uneven Distribution

Melting of Glaciers & Snow

Sea level Rise

Increase in Frequency &
Intensity of Extreme Weather
Events



IMPACTS

Uncertainty in Water Availability

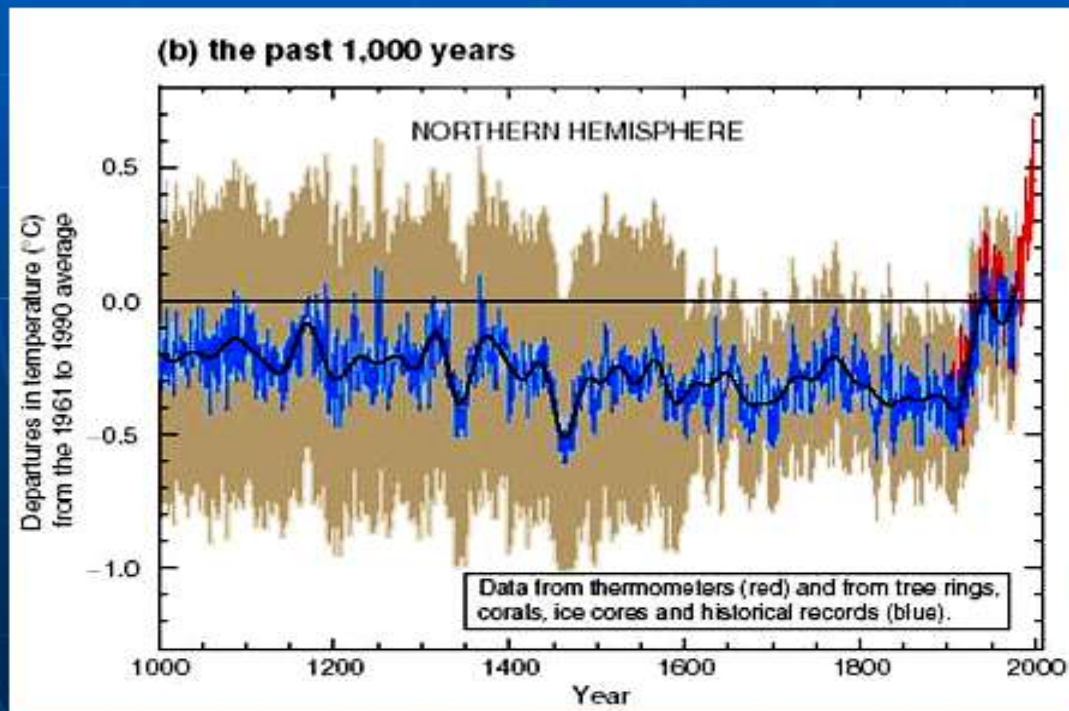
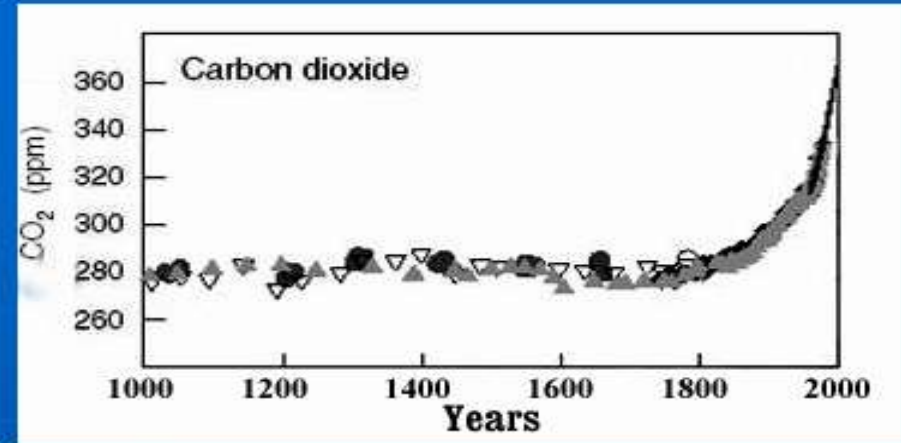
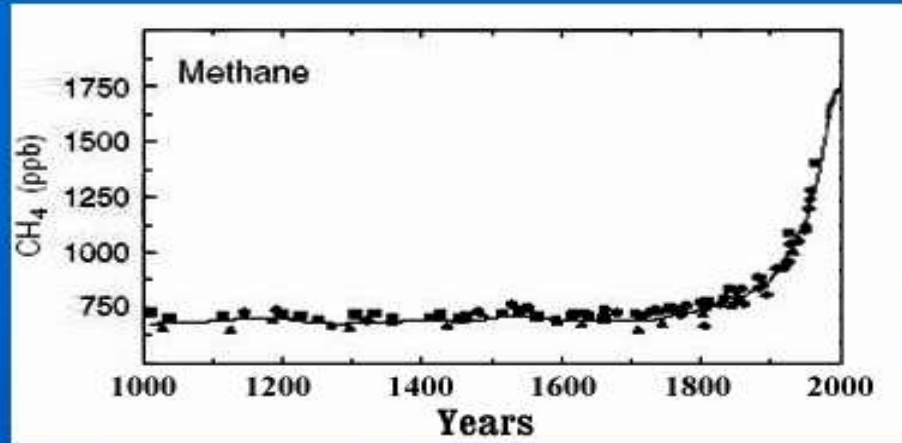
Decrease in Crop Yields

Loss of Biodiversity

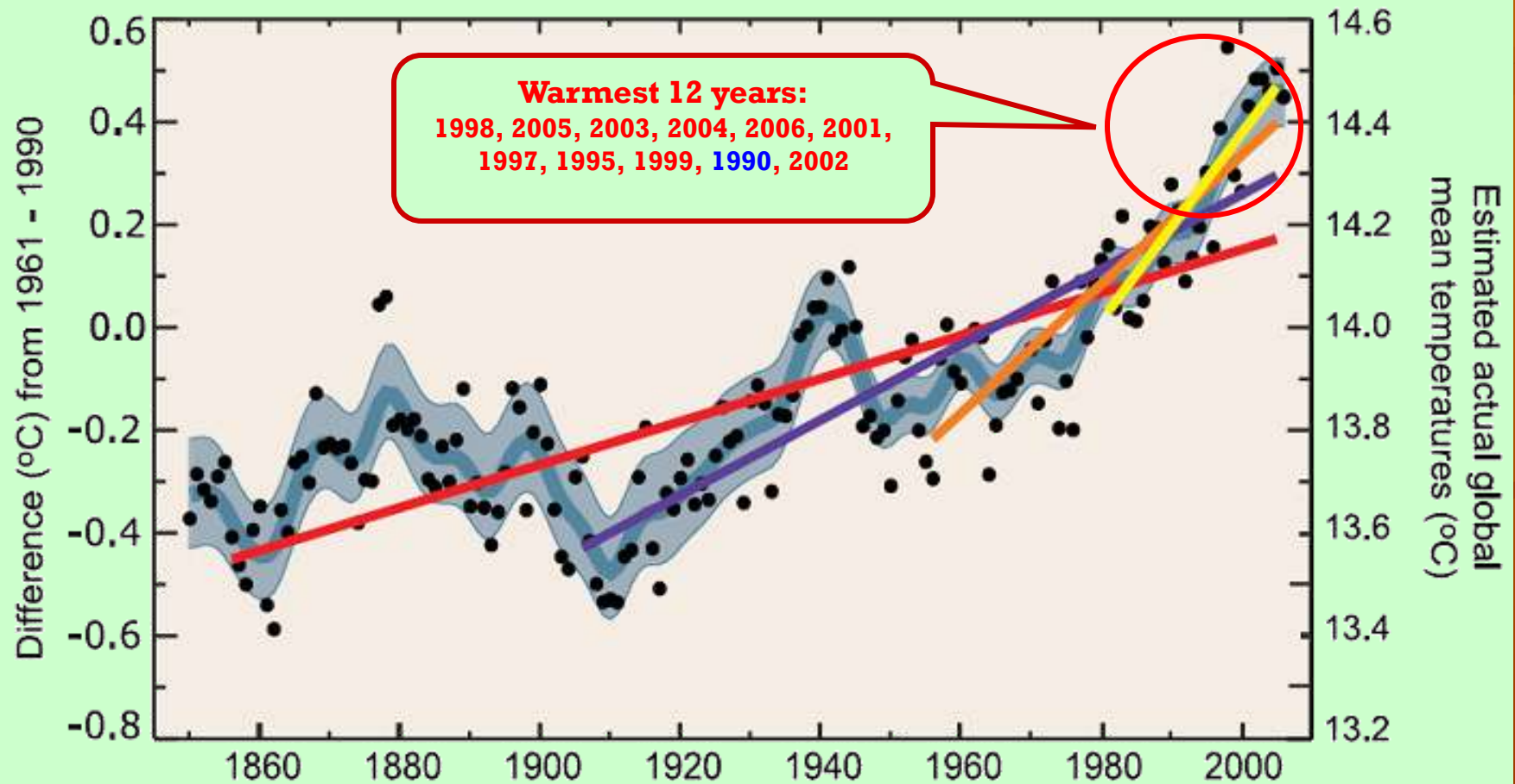
Increased Health Risks

Newer perspective for sources
of energy

Past 1000 Year Changes in Temperature and CO₂ & CH₄ Concentrations



Global Mean Temperature



Rate of Change (°C per decade)

1850 – 2005 (155Years) ——— 0.045

1905 – 2005 (100years) ——— 0.074

1955 – 2005 (50Years) ——— 0.128

Changing Climatic Trends

- Increasing concentration of CO₂ in the atmosphere
 - Pre-industrial revolution (1789) 280 ppm
 - Present (2011) 390 ppm
 - Expected level (2050) 550 ppm
- Rising surface temperatures
 - Global Av. Temp. rise (20th century) 0.6 °C
 - Projections for 2100 1.4 to 5.8 °C
- Changing rainfall patterns
 - Increase in monsoon rainfall in sub-humid and humid areas
 - Decrease in winter and summer rainfall in coastal belt and hyper arid plains

Potential Climate Change Impacts

Climate Changes



Temperature



Precipitation



Sea Level Rise



Water Resources

Changes in water supply
Increased competition for water



Agriculture

Crop yields
Irrigation demands



Health

Weather-related mortality
Air-quality respiratory illness



Forests

Change in forest composition
Shift geographic range of forests
Forest health and productivity



Coastal Areas

Erosion of beaches
Inundation of coastal lands
Costs to protect coastal communities



Species and Natural Areas

Shift in ecological zones
Loss of habitat and species

Global Response

- 1979 UN holds First World Climate Conference.
- 1988 IPCC established.
UN makes environmental issues including Climate Change as part of all its programs.
- 1990 The Second World Climate Conference held.
Resolves climate change as common concern for humanity.
- 1992 Earth Summit held in Rio de Janeiro, Brazil
UNFCCC formed.
- 1997 Kyoto Protocol established to achieve objectives of UNFCCC.
- 2009 The Third World Climate Conference held.
GFCS (Global Framework for Climate Services) formed.

IPCC and UNFCCC

➤ IPCC (Intergovernmental Panel on Climate Change)

- Established in 1988 by UNEP and World Meteorological Organization (WMO); has the support of more than 3,000 leading scientists;
- Published four comprehensive Assessment Reports in 1990, 1995, 2001 and 2007 on Climate Change (each covering Science; Impacts; Mitigation);

➤ UNFCCC (UN Framework Convention on Climate Change)

- Adopted in May 1992; Entered Into Force in 1994; All Parties to the Convention are committed to promote Climate Change research for a better understanding of their vulnerabilities and refining their response strategies;
- KYOTO Protocol adopted in 1997; Calls for reduction of GHG emissions by Developed Countries; New Protocol to be agreed in December 2009.

Climate Change Science Studies in Pakistan

- **2002:** Global Change Impact Studies Centre (GCISC) established by Dr. Ishfaq Ahmad, Special Advisor to the then Chief Executive of Pakistan.
- **2005:** Prime Minister's Committee on Climate Change established; GCISC made its Secretariat and placed under Ministry of Environment.
- **2008:** Task Force on Climate Change established by Planning Commission, with Executive Director GCISC as its Member/Secretary.
- **2010:** Final Report of the Task Force on Climate Change published
Federal Cabinet approves establishment of GCISC as an autonomous body with the then Ministry of Environment , on January 6.
- **2012:** National Climate Change Policy approved by Government.
Preparation of National Plan of Action on Climate Change in progress.

POSSIBLE IMPACTS OF CLIMATE CHANGE

- ✓ Over Most land Areas, warmer days and fewer cold days, warmer and more frequent hot days and nights
- ✓ More frequent warm spells/heat waves over most land areas
- ✓ More frequent heavy precipitation events
- ✓ Area affected by drought increases
- ✓ Intense tropical cyclone activity
- ✓ Increased incidence of extreme high sea level

IMPACTS ON DEVELOPMENT

Without appropriate measures, climate change will likely exacerbate the **poverty** situation and continue to slow down **economic growth**

- Reductions in **agricultural productivity** could especially dampen economic growth

Climate change adds to the list of stressors that challenge our ability to achieve the ecologic, economic and social objectives that define **sustainable development**

Key Vulnerabilities of Agriculture in Pakistan to Climate Change Stresses

- Increasing temperatures; increases higher than the global average increases
- Changes in average rainfall
- Increased variability of Monsoon in timing and intensity
- Changes in availability of irrigation water
- Severe water-stressed conditions in Arid and Semi-arid areas
- Extreme events, such as floods, droughts, heat waves, cold waves, cyclones, etc.

Climate Related Parameters of Agricultural Productivity

- CO₂
- Temperature
- Solar Radiation
- Precipitation
- Others (Wind speed and direction, Soil Moisture, Water vapour, etc.)

Basic understanding of these factors helps manipulate plants to meet human needs of food, fiber and shelter

The parameters also help understand impacts of climate change and devise adaptation/mitigation strategies

Tools for Climate Change Impact Assessment

- Crop Simulation Models (Biophysical or Agronomical models)
- Statistical models
- Micro/Macro-economic models
- Remote Sensing/GIS Techniques
- Land use/Land use changes
- Agro-climatic Indicators, such as Drought Index, Aridity index

Simulation Models Currently Used in Agriculture Section of GCISC

Crop Simulation Models :

DSSAT: Decision Support System for Agro-technolog Transfer (Univ. of Georgia, Griffin, USA) comprising several families of models:

- CERES (for cereals)
- CROPGRO (for grain legumes)
- CROPSIM (for root crops)
- Other Crops (for Tomato, Sunflower, Sugarcane, Pasture)

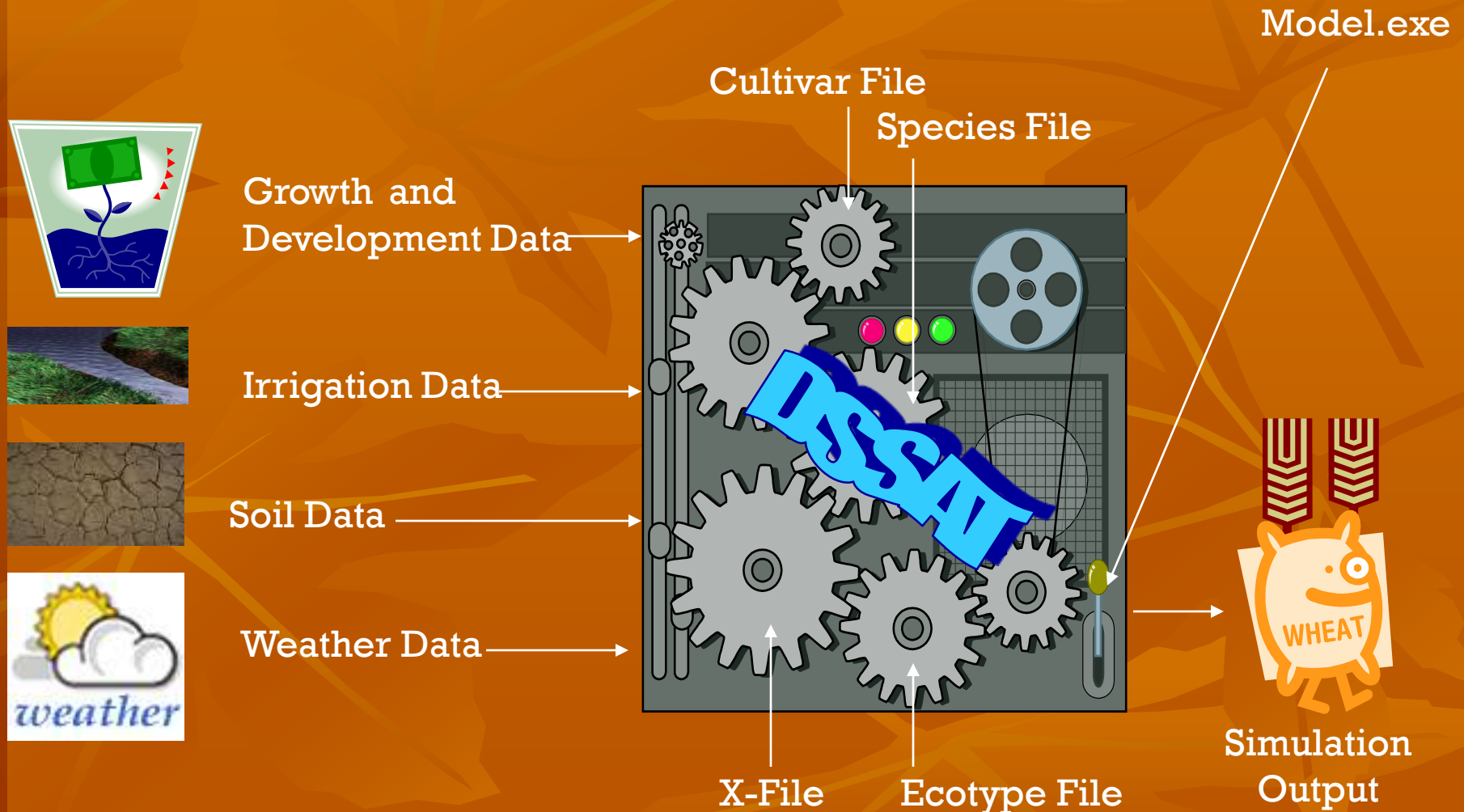
InfoCrop: Indian Council for Agriculture Research

Water Management Models:

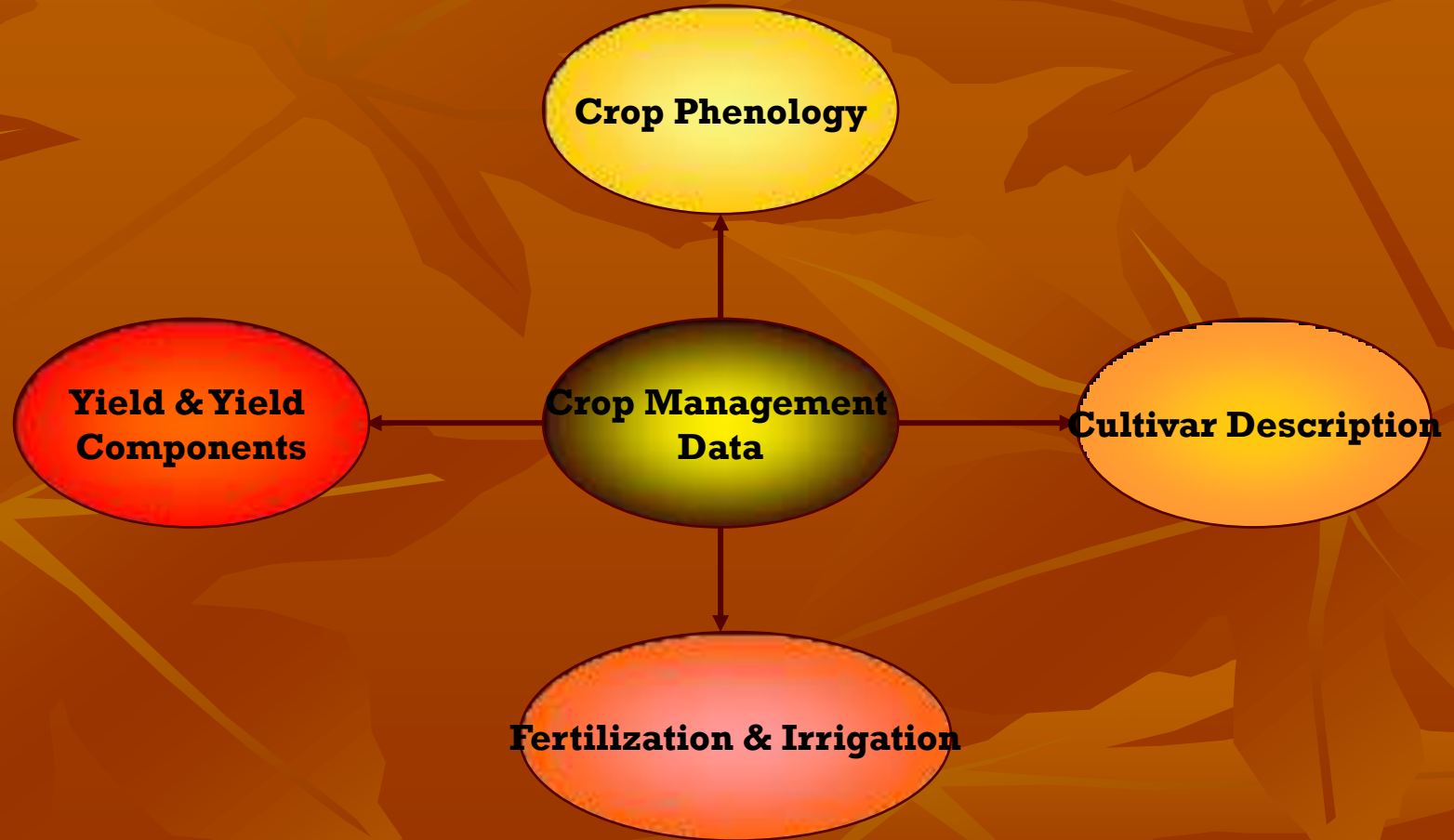
- **PODIUM:** Policy Dialogue Model, International Water Management Institute, Sri Lanka
- **CROPWAT:** FAO

Simulation Process in DSSAT

(Decision Support System for Agro-Technology Transfer,
DSSAT v4.0)

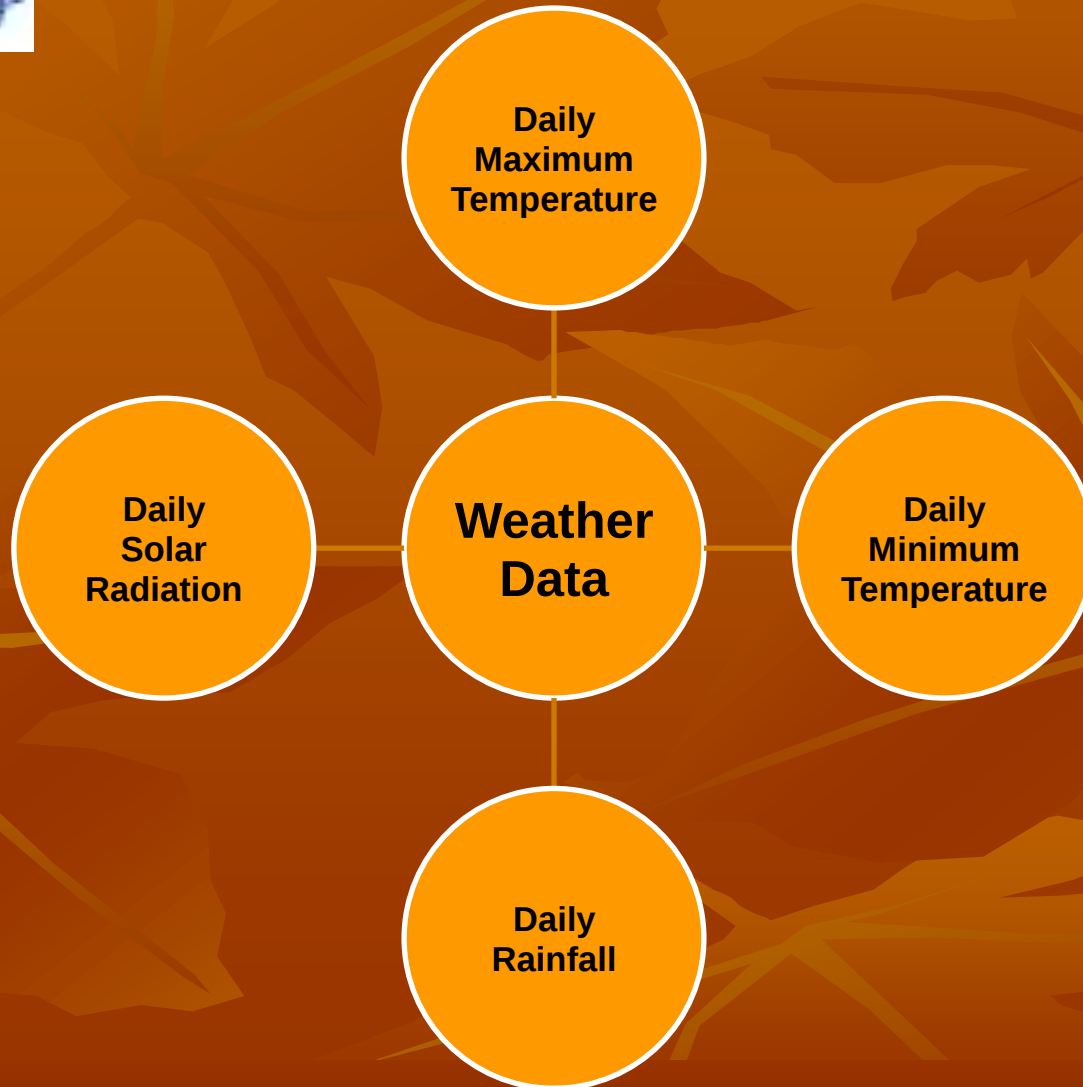


Crop Management Data

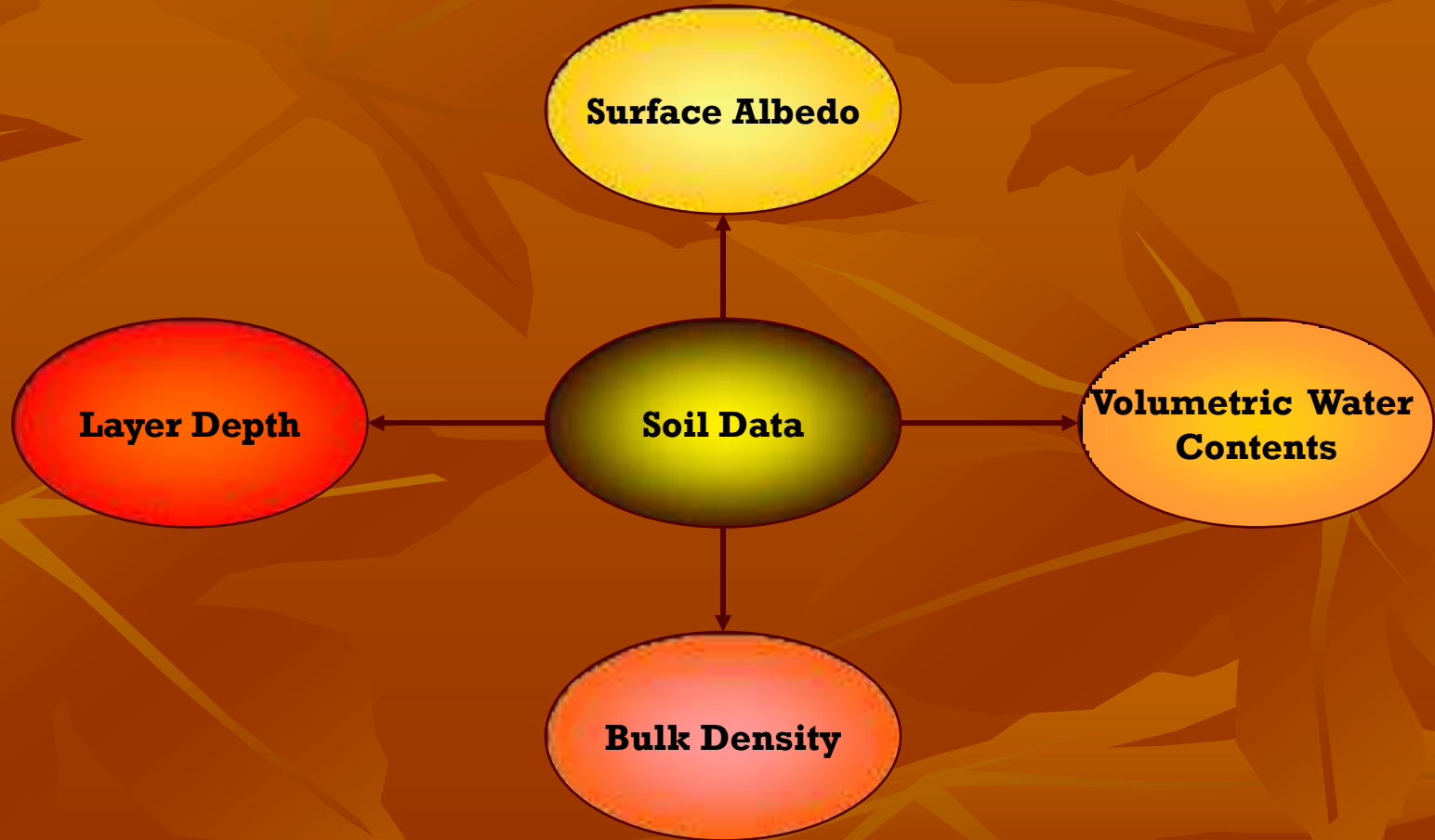




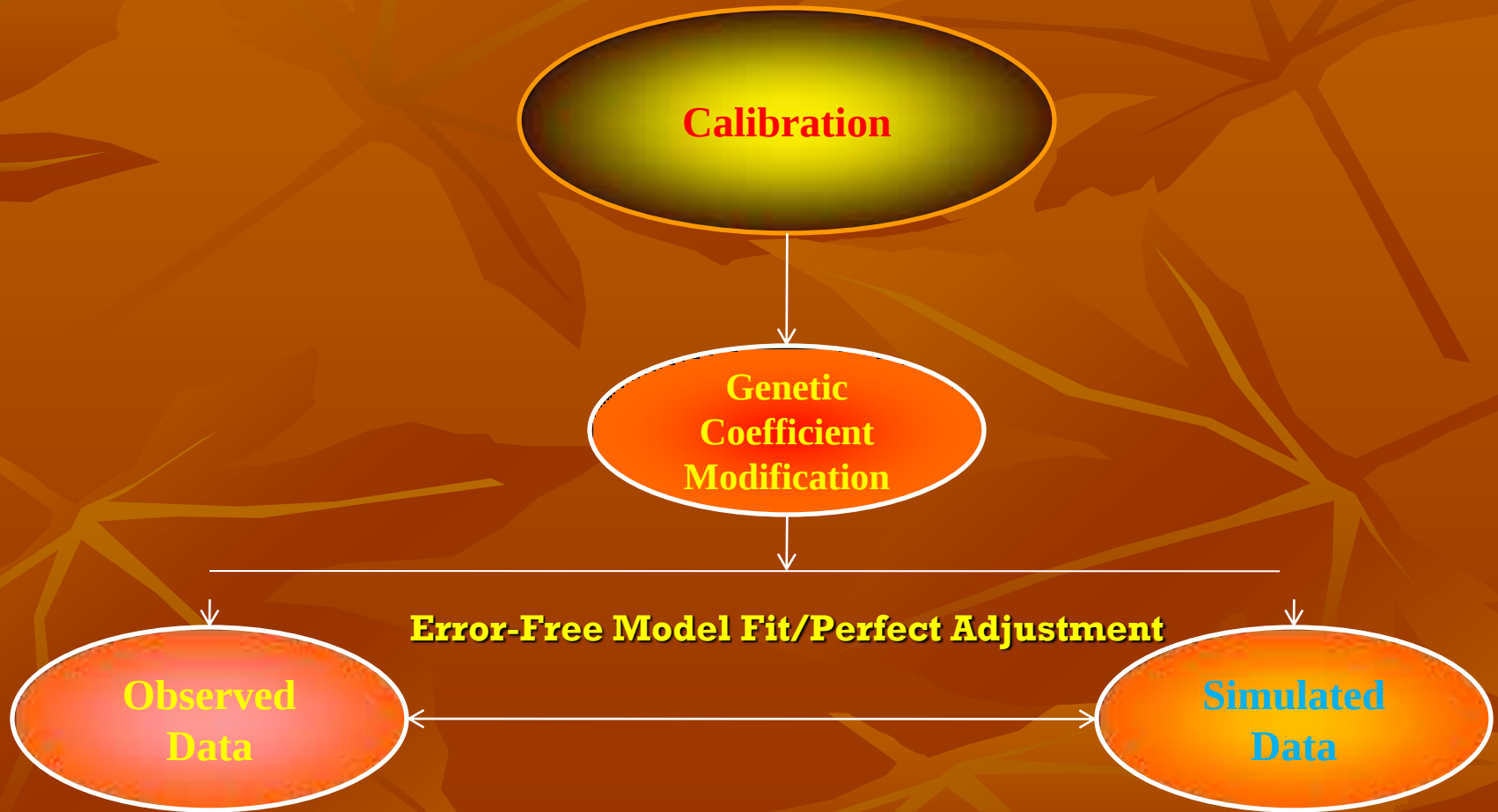
Weather Data



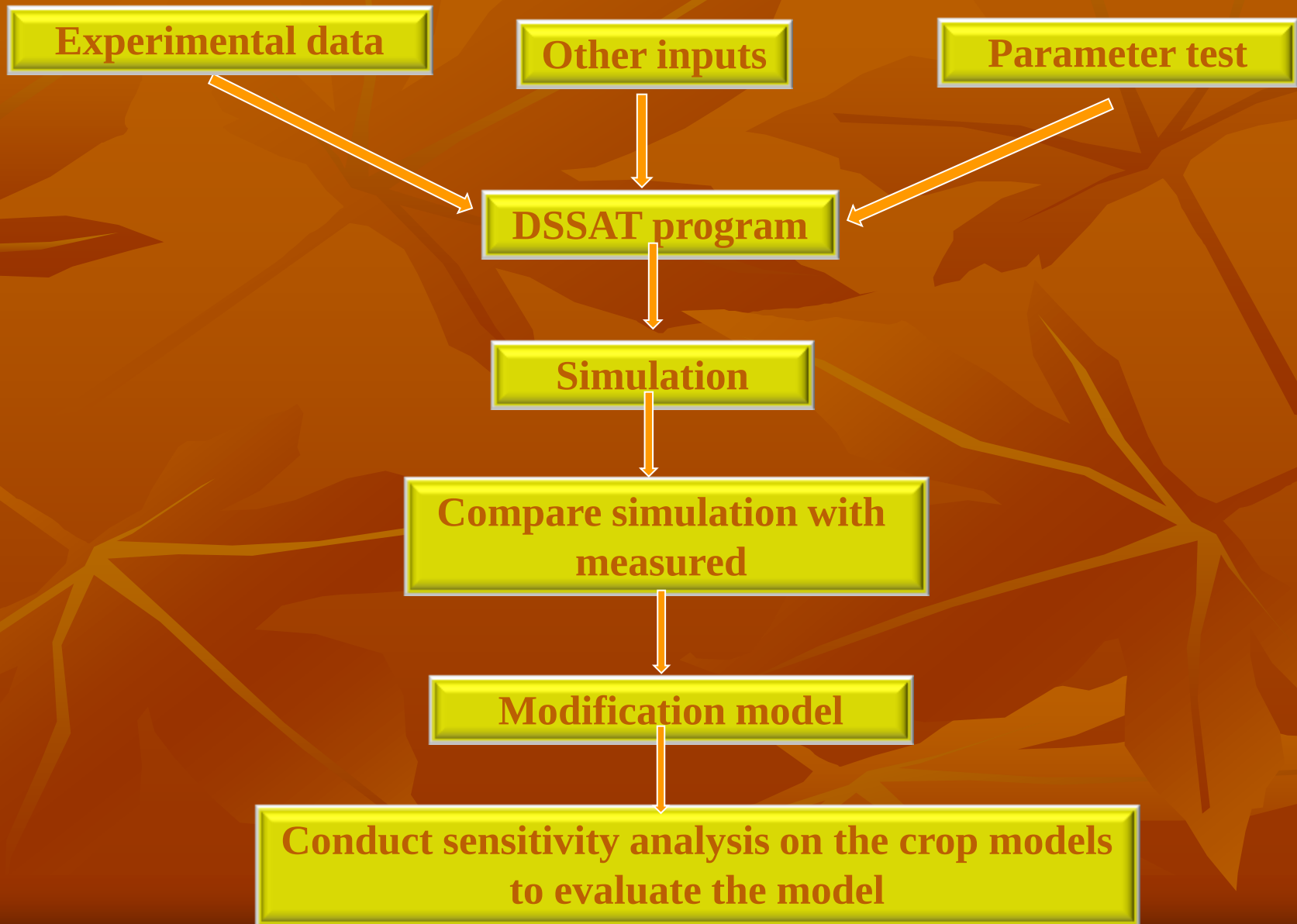
Soil Data



Model Calibration



Model Validation



Climate Change Scenarios

- i) Hypothetical Scenarios**
- ii) IPCC SRES (Special Report on
Emission Scenarios) Scenarios
(A2, B2)**
- iii) New Scenario development**

Hypothetical Climate Change Scenarios

Sr. No.	Scenarios	Parameters
1	Baseline (1960-2004)	Daily observed Temperature, CO ₂ : 375 ppm
2	If only temperature changes	1-5°C above baseline
3	If only CO ₂ level changes	CO ₂ levels:375 ppm and 550 ppm
4	If both CO ₂ and temperature change	CO ₂ levels:375 & 550 ppm; Temperature change:1-5°C

IPCC-SRES (A2 & B2)

- **The A2 storyline and scenario family** describes a :
Heterogeneous world.
Self reliance and preservation of local identities.
Continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.
- **The B2 storyline and scenario family** describes a :
World in which the emphasis is on local solutions to economic, social and environmental sustainability.
It is a world with continuously increasing global population, at a rate lower than A2,
Intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines.
While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

Scenarios of temperature and precipitation change for Northern parts of Pakistan as worked out by GCISC from an ensemble of six GCM outputs

Time Horizon	Global CO ₂ Concentration (ppm)	Northern Pakistan	
		ΔT (°C)	(ΔP/P)%
Scenario A2			
2020	430	1.41 ± 0.14	4.58 ± 2.01
2050	545	3.10 ± 0.30	5.43 ± 3.695
2080	720	5.35 ± 0.56	5.30 ± 5.36
Scenario B2			
2020	415	1.57 ± 0.23	4.27 ± 1.91
2050	485	2.91 ± 0.27	6.03 ± 1.78
2080	565	4.13 ± 0.46	8.83 ±5.21

Development of New Scenarios

- SRES were developed by IPCC in 2000
- A Review Report observed that new scenarios should be developed by the scientific community itself
- Following new scenarios are being developed:
- **RCP** – Representative Concentration Pathways. These are based on radiative forcing and the corresponding CO₂ concentrations
- **SSP** – Shared Socio-economic Pathways. These are based on socioeconomic challenges to development and radiative forcing

Impacts on Crops

- Shortening of growing season length
- Loss/increase in yield
- Heat stress at sensitive growth stages, e.g. flowering, grain initiation stages
- Shift in timing of developmental stages of pests in crop-weed-pest relationships
- Rise in evapo-transpiration rates leading to increased crop requirements
- Shift in spatial crop boundaries – will have enormous socio-economic impacts

Climate Change Impact on Wheat Production in Pakistan by 2085 under A2 and B2 Scenarios

Region	% Share in National Production	Baseline Yield (kg ha ⁻¹)	% Change in yield in 2085	
			A2 Scenario	B2 Scenario
Northern Mountainous	2	2658	+50	+40
Northern Sub-mountainous	9	3933	-11	-11
Southern Semi arid Plains	42	4306	-8	-8
Southern Arid Plains	47	4490	-5	-6
Pakistan	100	4326	-5.7	-6.4

Impacts on Livestock

- ✖ Physiological stress on animal due to high temperature
- ✖ Productivity losses (milk and meat) due to high temperature
- ✖ Stress on conception and reproduction due to high temperature
- ✖ Climate-related disease epidemics
- ✖ Reduced productivity of fodder crops
- ✖ Decreased quality and palatability of forages
- ✖ Increased water requirements of animals and fodder crops

Impacts on Land Degradation

Water-logging:

Rising of water table depth near the soil surface due to high rainfall or impeded drainage, resulting in saturation of the soil profile hindering soil respiration in the root zone.

Salinity:

Deposition of excess soluble salts at the land surface or in the soil profile due to greater evaporation as a result of high temperature, inhibiting germination and growth of plants

Erosion:

Detachment of top soil layer due to the action of water or wind. The process is exacerbated due to high or low rainfall and high wind velocity.

Impacts on Forestry

- Forests in Pakistan cover 4.224 million ha – 5% of total area
- Woody biomass is declining @ 5% per annum (7,000-9,000 ha/year) – the second highest rate of decline in the world

Impacts of Climate Change include:

- Increased CO₂ concentration conducive to more biomass production (being component of photosynthetic process) but the process is limited by availability of water and sunlight.
- Loss of Biodiversity
- Deforestation, leading to soil erosion and landslides
- Shifting of forest areas northwards (to cooler places)

Indus Delta

- 7th largest delta in the world
- Spans over an area of 600,000 ha between Karachi and Desert of Kutch
- Agricultural and fisheries are two important livelihood sources of the region
- Harbors one of the South Asia's largest mangrove forests, fisheries, coastal wetlands and tidal creek system

Impacts on Indus Delta

- Upstream intrusion of sea water upto 80 km
- Over 100,00 ha of agricultural land rendered saline posing risk to agriculture
- Fresh drinking water turned unfit for drinking due to sea water intrusion
- Shrinkage of community livelihood sources due to loss of ecosystem services

Climate Extreme Events

- Their impacts on the Natural Physical Environment: Huge losses to infrastructure, crops and livestock posing threats to food security
- Their impacts on Biological Systems: Human morbidity and mortality due to Diarrhoea, Dengue and Cholera diseases; increased deaths due to heat waves, floods, droughts, storms, and fires.
- Managing risks from the climate extremes at the local, national and international level, and their integration across scales is important for risk reduction

The floods, in Pakistan in 2010, rendered more than 10 million people homeless and affected 20 million

— *According to an assessment by ADB and the World Bank, Pakistan's floods caused an estimated \$9.7 billion in damage to infrastructure, farms and homes.*



The frequency of heavy precipitation events has increased over most land areas

*- Rainfall in Mumbai (India), 2005:
1 million people lost their homes*



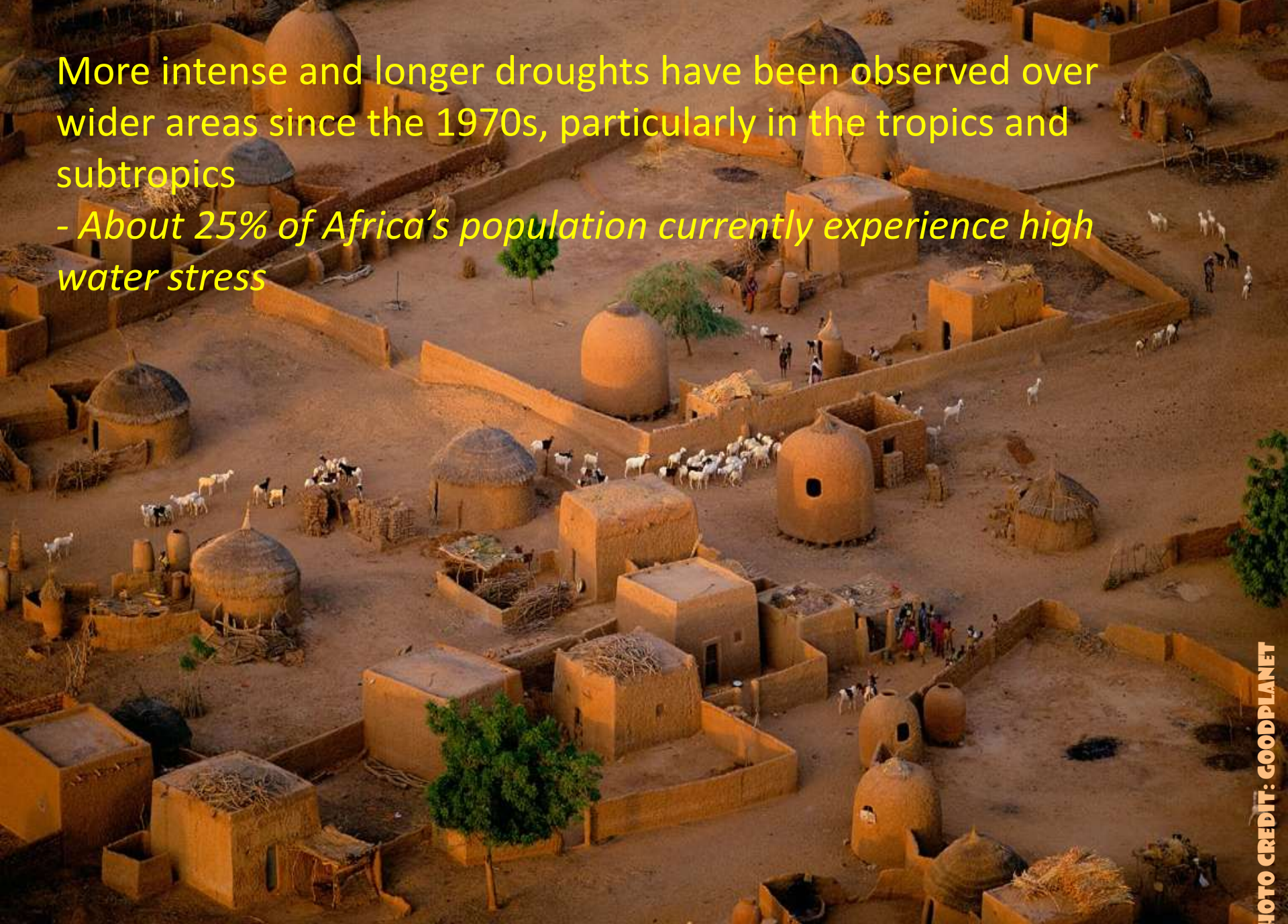


The proportion of high intensity tropical cyclones has increased over the past 3 decades

- *Cyclone Nargis in Myanmar, 2008:*
100 000 estimated deaths

More intense and longer droughts have been observed over wider areas since the 1970s, particularly in the tropics and subtropics

- About 25% of Africa's population currently experience high water stress





Heat waves have become more frequent over most land areas

- *Heat wave in Europe, 2003: 35 000 deaths*

Conclusions

- Climate change is a challenge to researchers, scientists, policymakers and planners alike.
- Pakistan is highly vulnerable to climate change impacts due to its location (South Asia) and weak technological and financial base.
- Pakistan's economy is agrarian which is highly sensitive to changes in rainfall, temperature and monsoon.
- Climate change impacts can be assessed through Simulation modeling, Statistical modeling, RS/GIS techniques, Land use changes and Agro-climatic indicators.
- Impacts of climate change on crops, livestock, forestry, land degradation and Indus delta are described.



Thanks