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COPING WITH CLIMATE CHANGE IN THE SEMI-ARID TROPICS

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ABSTRACT

Most climate change models suggest rise in temperatures, sea levels, and extreme weather events leading to unprecedented changes in various sectors, including agricultural production in the future years. Both developed and developing countries are affected, but developing countries with little adaptive capacity and limited resources are more vulnerable to climate change effects. Desertification, fresh water shortages, soil erosion, increased salinity, changed pest and disease scenario, biodiversity loss, reduction in length of growing period are some of the consequences that adversely affect the agricultural productivity straining the national economies. Detailed implications of climate change effects, resilience of populations and coping mechanisms are not fully understood in most countries in semi-arid tropics (SAT) of Asia and Africa [1, 2]. ICRISAT, with the help of partners, is working to better understand the global, national and regional impacts of climate change on agricultural production and resource management and developing mechanisms to better cope up with the climate change effects in the semi-arid tropics (SAT) of Africa and Asia[1].

ICRISAT has developed an operational research strategy (ORS) (2008–2015) entitled "Adaptation to and mitigation of climate change in the semi-arid tropics". This strategy addresses key climate change adaptation challenges, through two major strategic initiatives designed for short-to-medium term and medium-to-longer term[2].

- Short-to-medium term: Helping farmers and their support agents to cope better with *current* rainfall variability as a prerequisite to adapting to *future* climate change.
- Medium-to-longer term: Adapting our mandate crops (sorghum, pearl millet, pigeonpea, chickpea and groundnut) to grow in a warmer world.

Productivity uncertainty associated with between and within season rainfall variability remains a fundamental constraint in SAT areas. Climate change is likely to make matters worse with increases in rainfall variability being predicted for the SAT region. ICRISAT believes that the ability of agricultural communities and agricultural stakeholders should first be enhanced to enable them to cope better with the constraints and opportunities of current climate variability if they are to be in a position to adapt to the predicted future increases in climate variability. Developing better forecasting methods, improved management practices and capacity enhancement of stakeholders is given priority in the short- to medium-term.

ICRISAT has identified medium term priority strategies that will result in crop varieties and cropping systems that are adapted to a changed environment. Key factors considered in ICRISAT's Integrated Genetic and Natural Resources Management (IGNRM) strategies are[2]:

- Higher temperature tolerance.
- Increased root stress due to drought, soil salinity, acidity, nutrient availability and flooding.
- Changed severity and distribution of pests and diseases.
- The migration of our mandate crops into geographical areas already marginal for crops currently being grown there.

The IPCC climate model projections suggest an increase in global average surface temperature of between 1.4 and 5.8°C from 2001 to 2100, the range depending largely on the scale of fossil-fuel burning between now and then and on the different models used. However, broad trends will be overshadowed by local differences, as the impacts of climate change are likely to be highly spatially variable[3] (Table 1).

Table 1. Future changes in temperature and rainfall in the SAT.
(Based on regional predictions for A1B scenario for the end of the 21st Century)

Region	**Season**	**Temperature response (°C)**	**Precipitation response (%)**
East Africa	Oct-Dec	3.1	11
	Mar-May	3.2	6
Southern Africa	Oct-Mar	3.1	-10
West Africa	Jul-Oct	3.2	2
South Asia	Jun-Feb	3.3	11

How to cope with climate change effects?

There is no silver bullet to address the impacts of climate change effects. Adaptation is important, but it alone cannot help coping with climate change effects. Adaptation and mitigation should go hand-in-hand. A blend of adapted cultivars, improvement natural resource management technologies, better forecasting methods, knowledge sharing and market intelligence help overcoming the climate change effects in agricultural production. On-farm testing of technologies and village level studies on coping mechanisms give valuable information for shaping research programs and capacity enhancement. Climate policy is critical in shaping the coping mechanisms. However, climate outcomes will be influenced not only by climate-specific policies but also by the development path chosen[4]. Asia and Africa, which are already experiencing the adverse impacts of climate change, cannot afford to "wait and see" or follow the historic, unsustainable, carbon-intensive development path of industrialized countries. Climate change mitigation and adaptation policies need to be integrated with sustainable development policies.

The road map for future

As indicted earlier, there is no 'silver bullet' for all climate change problems. A combination of adapted cultivars, improved management practices, better forecasting methods, policy initiatives and knowledge sharing mechanisms contribute to better coping with climate change effects. IARCs and ARIs need to prioritize the efforts in this direction taking the NARS and other stakeholders on board. Falling agricultural yields would block the development and heighten poverty, thereby increasing the risk of conflicts across the globe. ICRISAT, with the climate resilience of its mandate crops; past work and on-going efforts with the new operational research strategy internalized along with the policy research is well positioned to support the smallholder farmers in SAT regions of Africa and Asia.

KEYWORDS
Climate change, Semi-Arid Tropics, Crop modeling, Crop adaptation, Mitigation

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Coping with Climate change in the Semi-Arid Tropics

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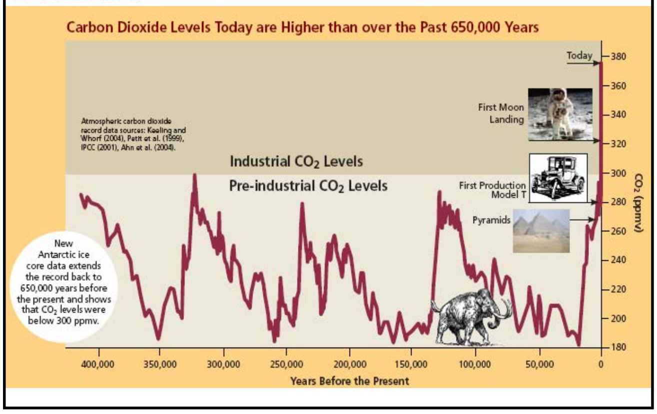
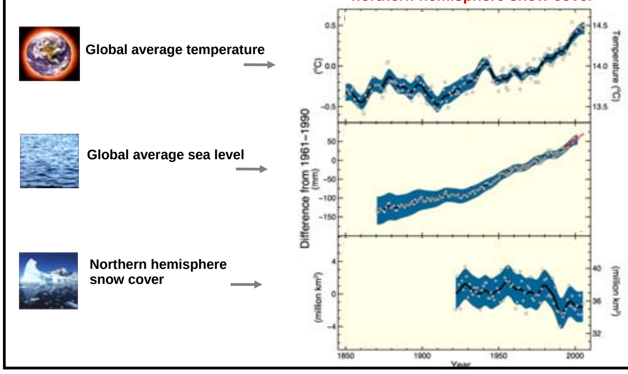
APAARI/JIRCAS Climate Change Symposium,
21-22 October 2008,
Tsukuba, Japan

Carbon di-oxide levels



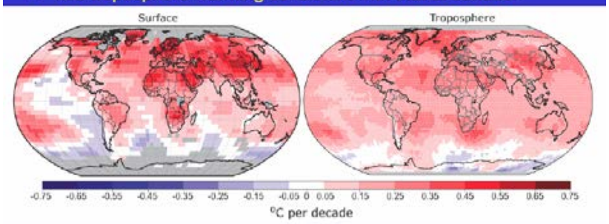
Direct observations of recent climate change



Warming is truly global

Warming trends since 1979 (when satellite measurements started) show:

- Warming everywhere at surface except in eastern Pacific, Southern Ocean and parts of Antarctica;
- Land warming significantly faster than ocean over last 20 years;
- Mid-troposphere warming consistent with that at surface.



Heavier precipitation, more intense and longer droughts....

Key vulnerabilities to climate change

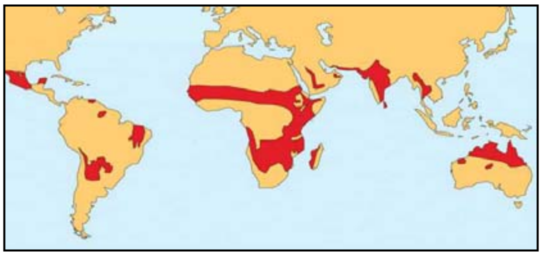
- **Some regions will be more affected than others:**
  - The Arctic (ice sheet loss, ecosystem changes)
  - Sub-Saharan Africa (water stress, reduced crops)
  - Small islands (coastal erosion, inundation)
  - Asian mega-deltas (flooding from sea and rivers)
- **Some ecosystems are highly vulnerable:**
  - Coral reefs, marine shell organisms
  - Coral Tundra, boreal forests, mountain and Mediterranean regions
  - 20-30% of plant and animal species at risk of extinction

Beyond adaptation

- **Adaptation is key to combat climate change while mitigation is the long term and most sustainable solution**
- **A successful adaptation strategy require**
  - **Plan early – time to act is now**
  - **Systematic and strategic**
  - **Use the best information**
  - **Flexible and dynamic**
  - **Team work and sharing information**
- **However:**
  - **Adaptation alone cannot cope with all the projected impacts of climate change**
  - **The costs of adaptation and impacts will increase as global temperatures increase**

ICRISAT's focus

SAT of Sub-Saharan Africa and Asia



- **One-sixth of the world's population**
- **> 500 million of the world's poorest people**
- **Marginal environment: climate, soils, infrastructure**

Global warming and changes in rainfall patterns are predicted to make rainfed agriculture even more risk prone. But in many regions the nature of change is *still uncertain* across 21 GCM's and different 'carbon emission storylines'. (IPCC 2007)

Region	Annual Temp. Response					Annual Precipitation Response (%)				
	Min.	25	50	75	Max.	Min.	25	50	75	Max.
West Africa	1.8	2.7	3.3	3.6	4.7	-9	-2	2	7	13
East Africa	1.8	2.5	3.2	3.4	4.3	-3	2	7	11	25
Southern Africa	1.9	2.9	3.4	3.7	4.8	-12	-9	-4	2	6
East Asia	2.3	2.8	3.3	4.1	4.9	2	4	9	14	20
Southern Asia	2.0	2.7	3.3	3.6	4.7	-15	4	11	15	20

However, farmers and their support agents will need to adapt to those changes as they emerge.

ICRISAT—
Operational Research Strategy (ORS)

"Adaptation to and mitigation of climate change in the SAT"

To enable investors in rainfed farming to better understand and manage both the risks posed and the opportunities offered by climate variability and change

ICRISAT—
Operational Research Strategy (contd...)

- **Managing current climate uncertainty and adapting to future climate change**
- **Short- and medium-term: Helping farmers to cope up with current rainfall variability for adapting to future climate change (2008-15)**
- **Medium to longer-term: Adapting our mandate crops to grow in a warmer world (2008 to future)**

Six factors that shape ICRISAT's ORS

Factor 1: Rainfed farming in SSA and Asia is vital for current and future food security

Factor 2: Investment is constrained by seasonally variable rainfall and reflected in uncertain production. Farmers and support agents are risk-averse and overestimate the negative impacts. They are reluctant to invest and exploit the opportunities

Factor 3: Global warming and changes in rainfall patterns are predicted to make rainfed agriculture even more risk-prone

Six factors that shape ICRISAT's ORS (contd…)

Factor 4: Because of the current vulnerability of the rural poor in the SAT and the uncertain nature of future climate change, need to build adaptive capacity

Factor 5: Climate driven tools are available that enable the development of risk management frameworks that span across different time and space scales

Factor 6: Adapting our crops to current and future vagaries of climate

Improve livelihood resilience and adaptive capacity of farmers to cope better with current climate

If they are to have any hope of *adapting to future climate change*

Mapping out development pathways for the poor - VLS

- Track development pathways
- Influence policy-making
- Guides research priority setting
- Monitors technology gaps

ICRISAT mandate crops

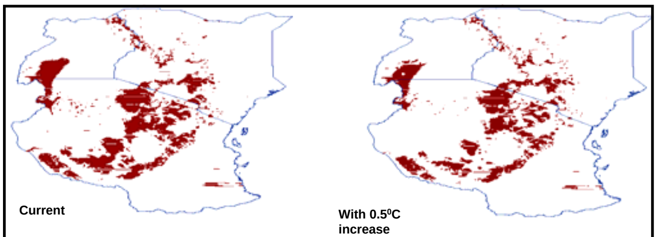
- Evolutionary advantage of mandate crops
- Sorghum and pearl millet pigeonpea are grown in harsh environments
- Sorghum and pearl millet have good salinity tolerance
- Vast data on crop simulation studies, G × E interaction of crops
- CACC draw strength from current research products

ICRISAT— ORS

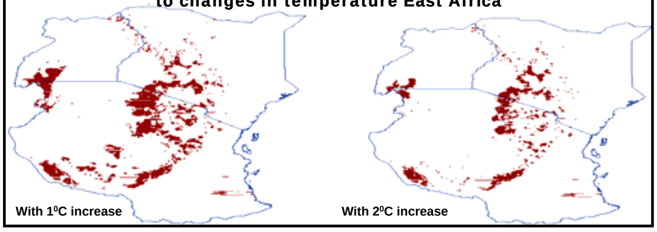
Adapting our mandate crops to current and future vagaries of climate

Key factors:

- High temperature tolerance
- Increased moisture stress
- Changed distribution and severity of pests and diseases
  - Botrytis Grey Mold
  - *Helicoverpa*
- The 'migration' of our mandate crops to new geographical areas
- Increased CO_2 levels



Scenarios of changes in long duration pigeonpea growing areas due to changes in temperature East Africa



Current status and future strategies

Crop	What is at hand	Breeding strategies for 2035
Sorghum 	Improved Varieties &Hybrid Parents with phenological diversity	Selection for improving varieties for germination and growth under high temperature and moisture stresses
	Ability to grow in temperatures up to 42ºC and tolerance to soil salinity and acidity	Breeding for soil salinity and acidity
	Genotypes with moderate levels of tolerance to water-stress in early, medium and terminal-season	Breeding for industrial uses
	Know-how on photoperiod flowering responses	Development of heterotic gene-pools for tolerance to high temperatures, moisture stress
	Time tested and efficient breeding tools for abiotic stress and end uses	Identification of genes for minimized rates of dark respiration and their incorporation in breeding lines
	Range of genomic regions (QTLs) identified for non-senescence (stay-green)	

Current status and future strategies

Crop	What is at hand	Breeding strategies for 2035
Pearl millet 	Populations and breeding lines with seedling survival at soil temperature >60°C	Development of parental lines for high temperature tolerance during reproductive growth
	Hybrids with flowering and good seed-set at 44ºC	Phenotyping of WCA landraces for drought tolerance
	Material for salinity tolerance	Developing broad-based *Striga* resistant genepool
	Knowledge on the photoperiod-sensitive flowering through modeling	Dynamic *in situ* population/ genepool management to allow adaptation and develop mass reservoir of adaptation
	Phenotypic section criteria for terminal drought tolerance	
	QTL for grain filling ability under terminal drought	

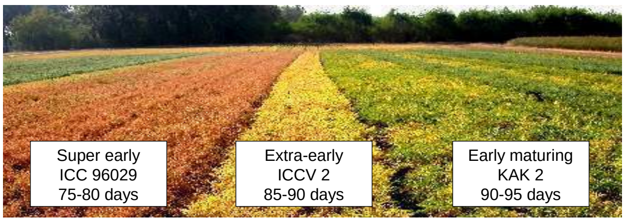
Current status and future strategies

Crop	What is at hand	Breeding strategies for 2035
Groundnut 	Knowledge on mechanism surrogate traits and screening methodology for drought tolerance	Understanding physiological mechanism underlying heat tolerance
	Genetic variation for transpiration efficiency harvest index and water use efficiency	Screening techniques for heat tolerance
	Information on genotypic variation for sensitivity to heat tolerance	Identification of QTLs for drought tolerance
		Development of varieties better adapted to drought

Current status and future strategies

Crop	What is at hand	Breeding strategies for 2035
Pigeonpea 	Extra short and medium duration lines to avoid drought	Cost effective screening techniques for heat tolerance
	Hybrids with 30% extra root mass to better cope up with drought	Identification of germplasm for maintaining transpiration efficiency and partitioning under increased temperature
Chickpea 	Cultivars with heat stress tolerance during reproductive stage	Development of effective screening techniques for screening of germplasm to heat stress
	Desi and kabuli types with FW resistance well adapted to short growing seasons	Selection for early phenology
	Lines with high root mass, prolific and deeper root systems for drought tolerance and fewer leaflets for reduced transpiration	Identification of germplasm for high transpiration efficiency and partitioning under increased temperature
		Identification of QTLs for root traits

Get ahead of climate change - Ready adapted products: Development of early, extra-early and super-early chickpea cultivars at ICRISAT



ICRISAT is ahead of the game with its breeding program – need to develop core modeling capacity to ensure this is maintained in all aspects of our work

Climate risk management projects

A total of eleven projects either in operation or approved by various donors over the last two years months, e.g.,

- Building adaptive capacity to cope with increasing vulnerability to climate change
  Donor: IDRC/DFID CCAA
  Partners: CIAT, NARES in Zambia and Zimbabwe
- Vulnerability to climate change: Adaptation strategies and layers of resilience
  Donor: Asian Development Bank
  Partner: NARES Bangladesh, China, India, Pakistan, Sri-Lanka
- Community management of crop diversity and resilience, yield stability and income generation in changing West African Climate"
  Donor: BMZ
  Partners: University of Hohenheim, NARES Burkina Faso, Ghana, Mali, Niger

Conclusions-1

- Effects of climate change will be severe in Semi-Arid Tropics (SAT)
- ICRISAT's ORS geared to help farmers to adapt and mitigate effects of CC
- Short-term goal is to help farmers to cope with current rainfall and climate variability
- Medium to long-term goal is to adapt our mandate crops to grow in warmer climates
- Mapping out development pathways to help the poor in the SAT

Conclusions-2

- ICRISAT crops have evolutionary advantage for harsher climates
- We already have varieties that are adapted to warmer and drought conditions
- Eleven projects in operation/starting to address adaptation to climate change
- Public-private partnerships essential to address strategies for adaptation and mitigation of climate change