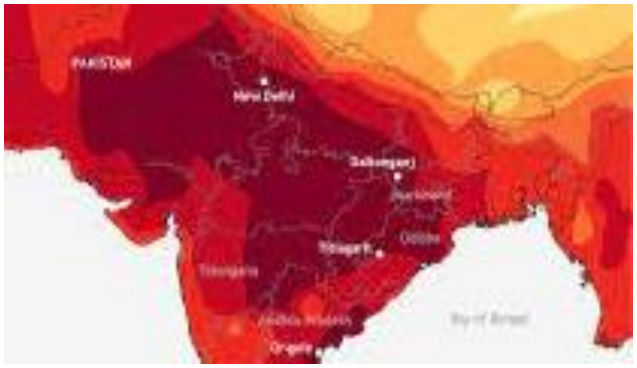
Indian Agricultural Research Institute
भारतीय कृषि अनुसंधान संस्थान
(An ISO 9001:2008 Certified Institute)

National Workshop on Heatwave 2024



Impact and Risk Mitigation of Extreme Heat on Agricultural Crops

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Borlaug Institute for South Asia
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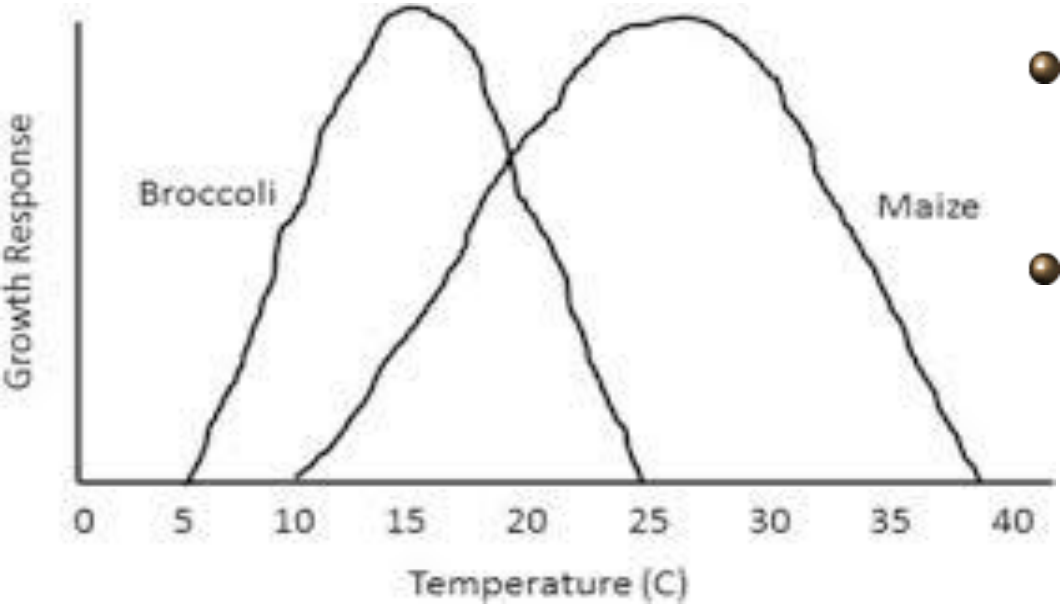
Extreme Temperature & Heat Wave Criteria

- **IMD Criteria:**
  - **Tmax > 40 °C (for Plains) and Tmax > 30 °C (For hills)**
  - following criteria should be met at least in **2 stations** in a meteorological sub-division for **at least two consecutive days**
  - **Tmax <= 40 °C**
    - Heat wave: Tmax Departure from normal is 5°C to 6°C
    - Severe heat wave: Tmax Departure from normal is 7°C or more
  - **Tmax > 40 °C**
    - Heat wave: Tmax Departure from normal is 4°C to 5°C
    - Severe heat wave: Tmax Departure from normal is 6°C or more
  - **Tmax > 45 °C**
    - irrespective of normal maximum temperature, heat waves should be declared
- IMD definition is more from the point of Human Health impacts
- WMO has not adopted yet a standard and mathematically rigorous definition for heat waves

Cardinal Temperatures of Crops

Crops	Minimum	Optimum	Maximum
Oat	4 - 5	25	30
Maize	8 - 10	32 - 35	40 - 44
sorghum	8 - 10	32 - 35	40
Pearl millet	8 - 10	30 - 32	40
Berseem	3 - 4.0	25 - 27	32
Wheat	3 - 4.5	25	30
Rice	10 - 12	30 - 32	36 - 38

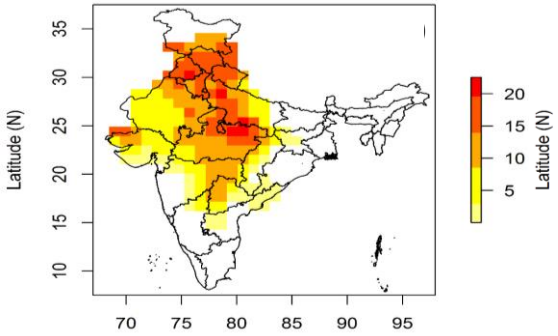


- Criteria could be based on **percentile** deviation from base line period
- **HWMId**: sequence of 3 or more days in which the daily maximum temperature is above the 90th percentile of daily maximum temperature for a 31-day running window

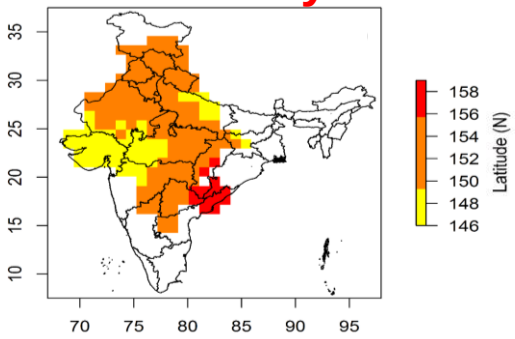
Heat Wave Calculation: Heat Wave Magnitude Index daily (HWMId) and its validation

Reported- 30 may–10 Jun,1995 **1995**

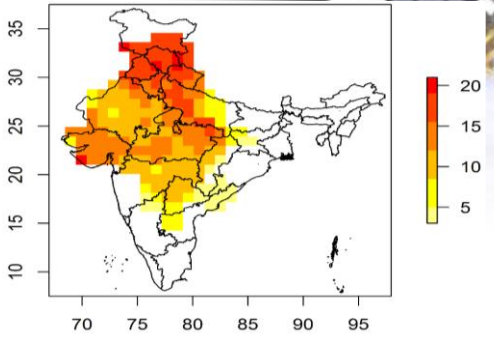
HWMId



Start Day

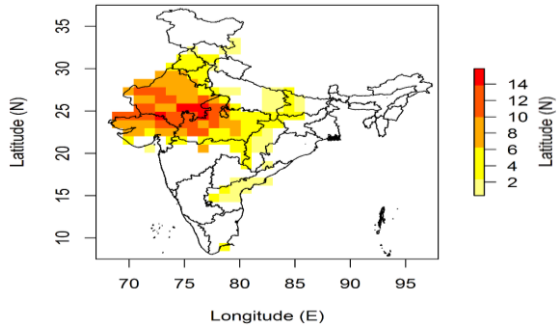


Duration

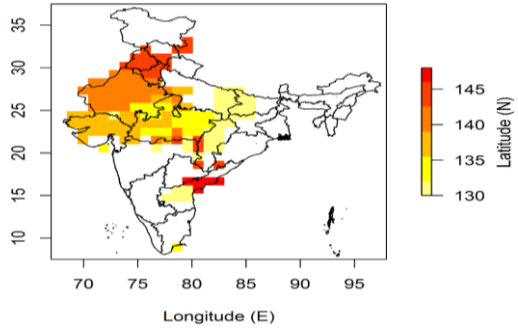


Reported- 18–27 Mar 2010 **2010**

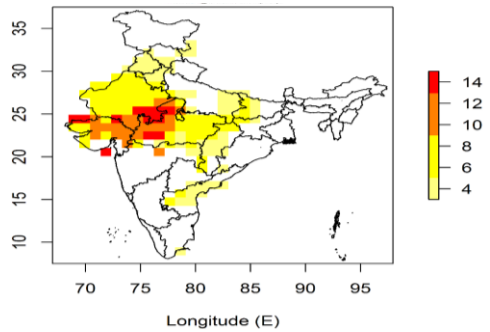
HWMId



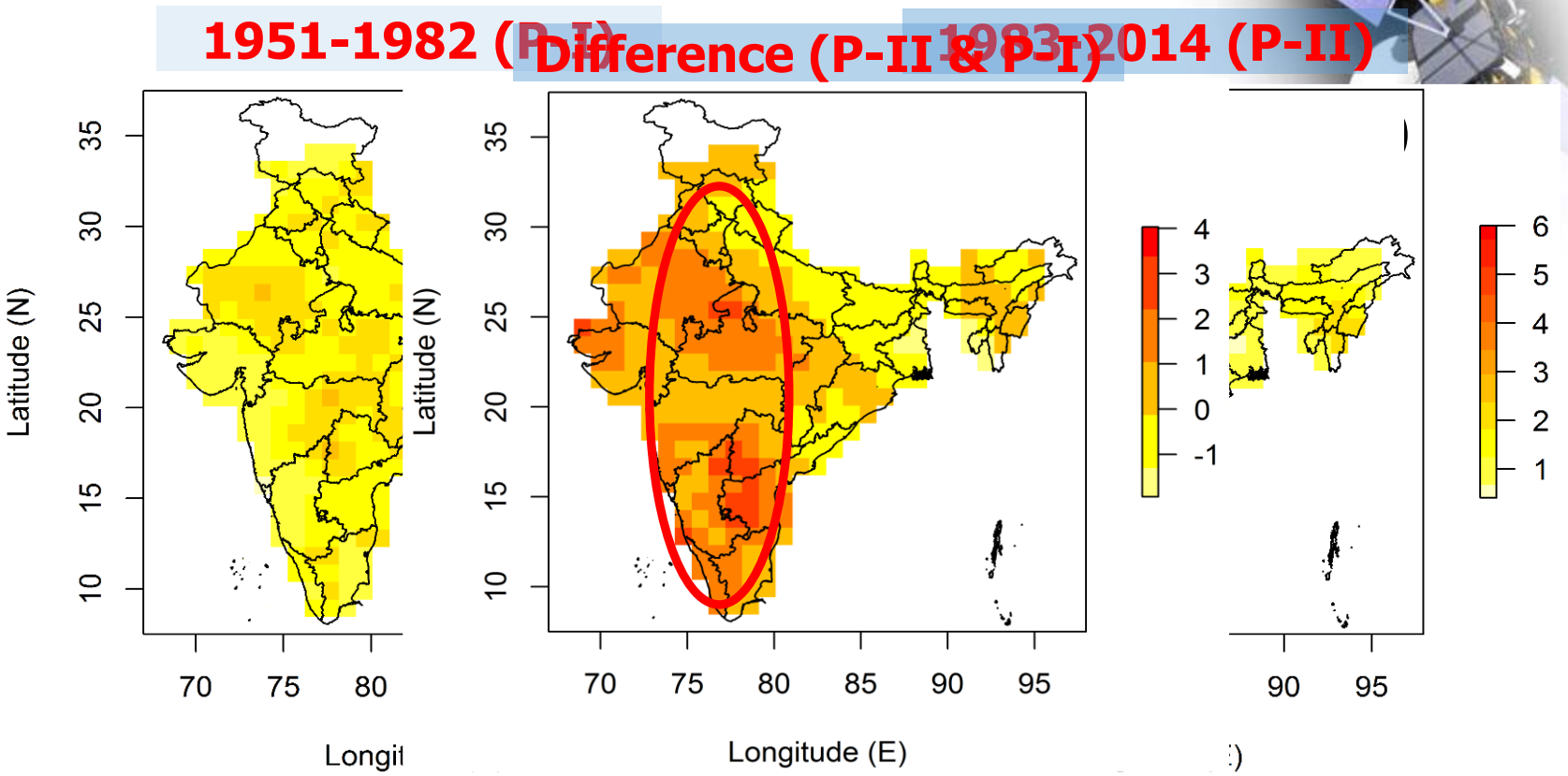
Start Day



Duration



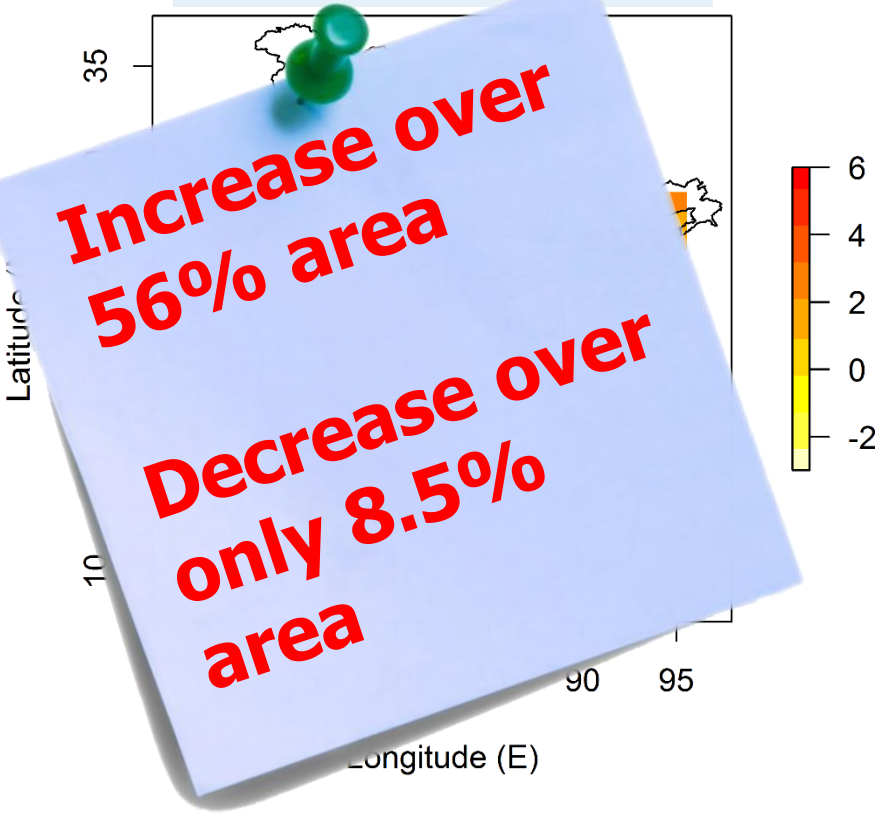
HWMId climatology and their difference



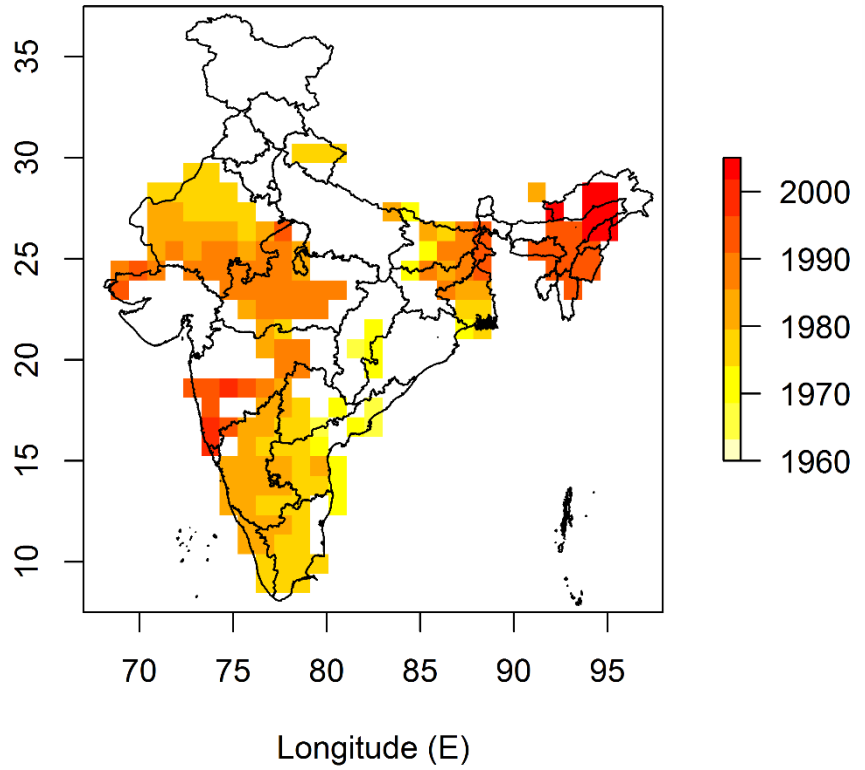



Trend and abrupt shifts in time series of HWMId during 1951-2014

Trend

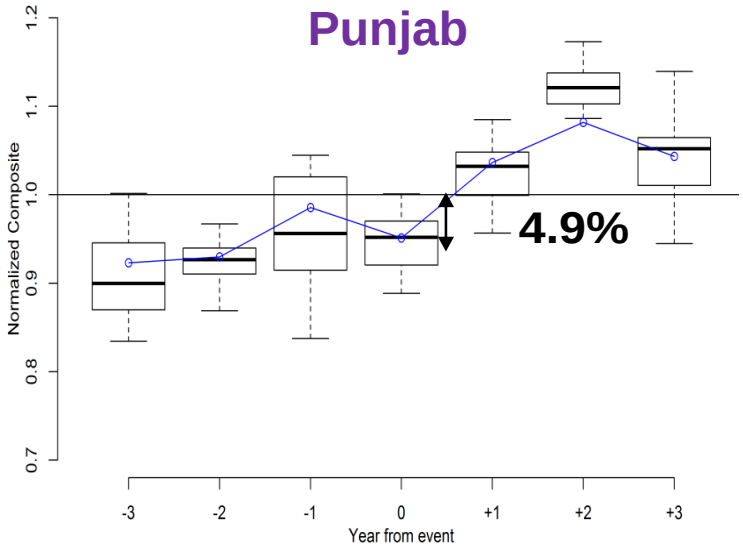


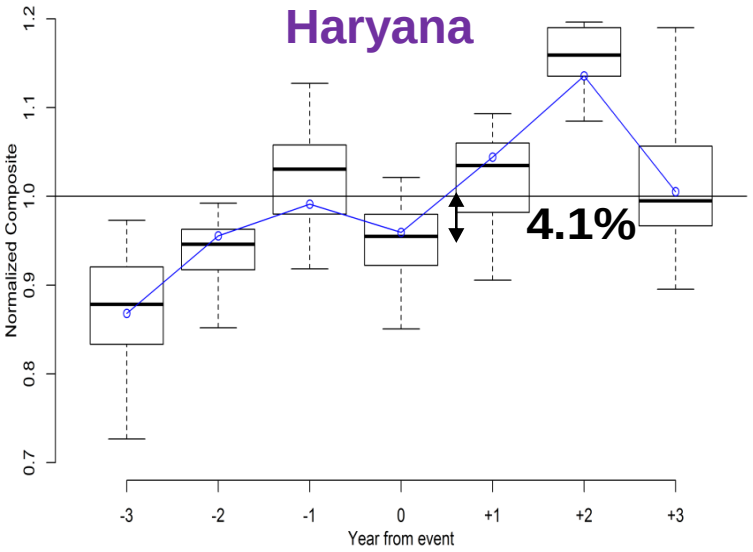
Change Point

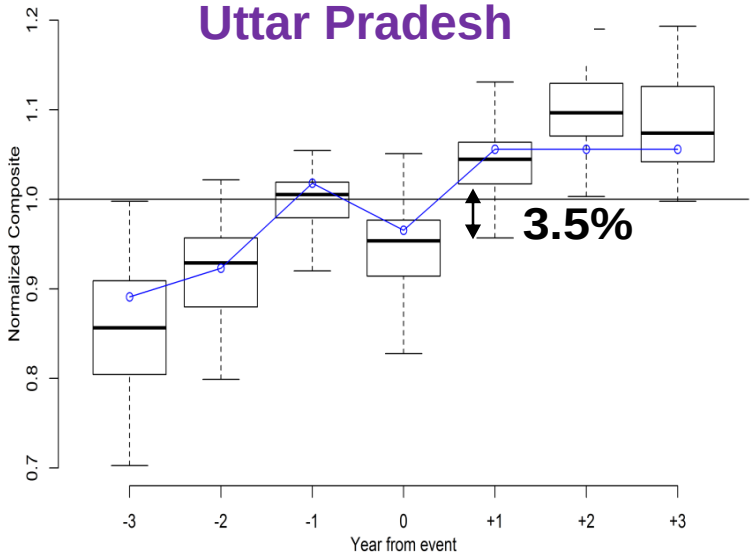





March 2010 Heat Wave : analysis of wheat yield loss due to using Copula



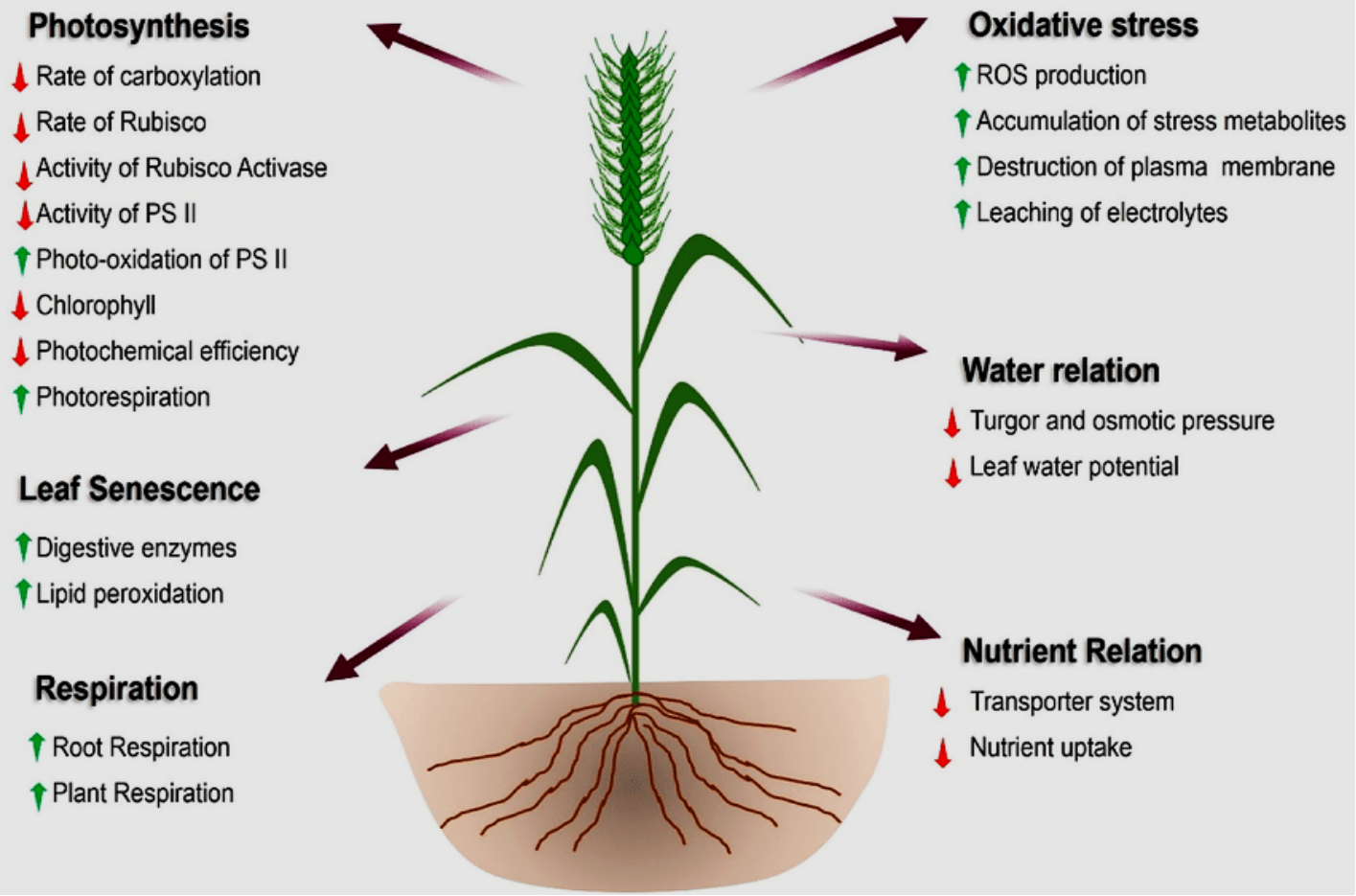




Broader Impacts of ExT H/W on Agriculture

- **Soil:** Drier, low C, less microbial activity, salt buildup, reduced productivity
- **Water:** Increased demand, reduced supply, increased use of poor quality water, increased competition
- **Pests:** Increased ranges and populations, more pesticides
- **Production:** Wilting, Die, Reduced crop yield
- **Quality:** shriveled grains, scalded fruits
- **Livestock:** reduced milk production, lower fertility, death, higher cost of shelter
- **Economic impact:** Reduced agricultural output
- **Positive impact:** Increased temperature in cold area – introduce crops in higher altitude, control of soil borne diseases and pests
- **Winter crops more sensitive than summer crops**

Effect of heat stress on the wheat



The upward arrow means increase, and
the downward arrow means decrease

Source: Mishra et al., 2023

Effect of heat stress on the wheat

Heat Stress in grain number and weight
- Reduce spikelet and grains per spike
- Reduce fertility of ovule
- Extreme effects on grain numbers during floral initiation

Heat Stress in reproductive stages
- Alter spikelet production
- Insufficient assimilated supply
- Reduce sink size
- Floret abortion
- Pollen sterility
- Reduce starch content in the grain

Heat Stress in the Vegetative Stage
- Harm photosynthetic machinery
- Reduce tillering
- Advanced flowering
- Reduce shoot and root
- Affect spikelet formation at double ridge stage

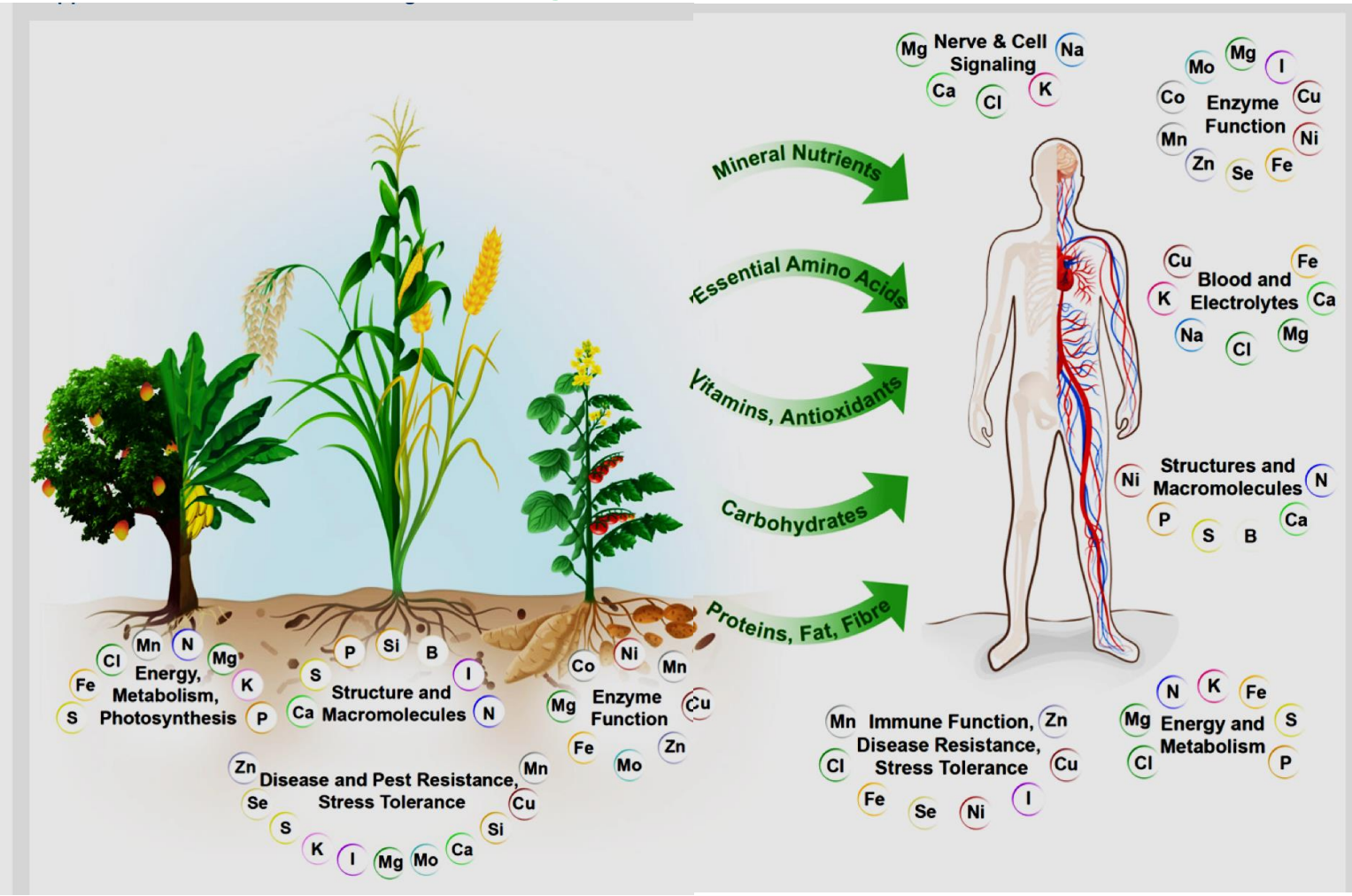
Heat Stress in grain filling and grain filling rate
- Speed up the grain filling rate
- Decrease grain filling time
- Change in proteomics
- Rapid apoptosis
- Early harvest maturity
- Decrease grain weight
- Reduce the number of endosperm cells in grain

Heat Stress in grain quality
- Slowing down the starch deposition process
- Increase in protein concentration
- Reduce glutenin synthesis
- Reduction in essential amino acids
- Rends to decrease flour consistency
- Decreases the swelling strength of wheat flour noodles
- Increases the broken grain

Source: Farhad et al., 2023

Linkage to Human Health

The nutrition of humankind depends on providing nutrients to plants



Source: SPRPN.ORG

Morphological Symptoms of ExT H/W

- **Scorching of leaves and twigs**
- **Sunburn on leaves, branches and stems**
- **Leaf senescence and abscission**
- **Shoot and root growth inhibition**
- **Fruit discolouration, Fruit drop and damage and reduced yield**
- **Reduction in the internodal length**
- **Rapid death of plant parts or whole plant**

Some Examples

Rajasthan

Impacts of 2022 Heat Wave

Northern and **central India**

Scroll.in

The heatwaves roasting North India...

The Times of India

Wheat export ban: India's extreme heat ...

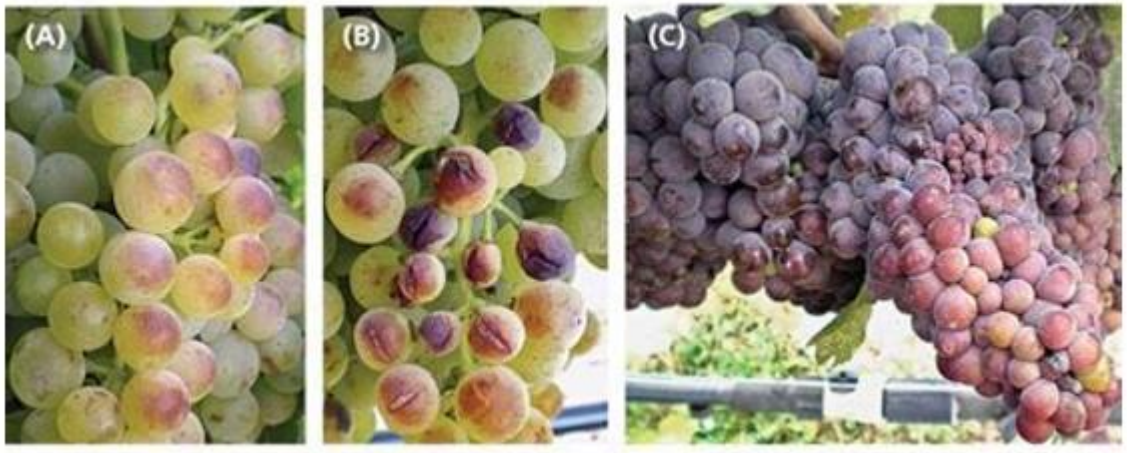
Some Examples

1. Necrosis: Fruit tissue dies on the sun exposed side of the fruit.

- **For cucumbers fruit skin temperature threshold for sunburn necrosis is 38-40^{0}C.**

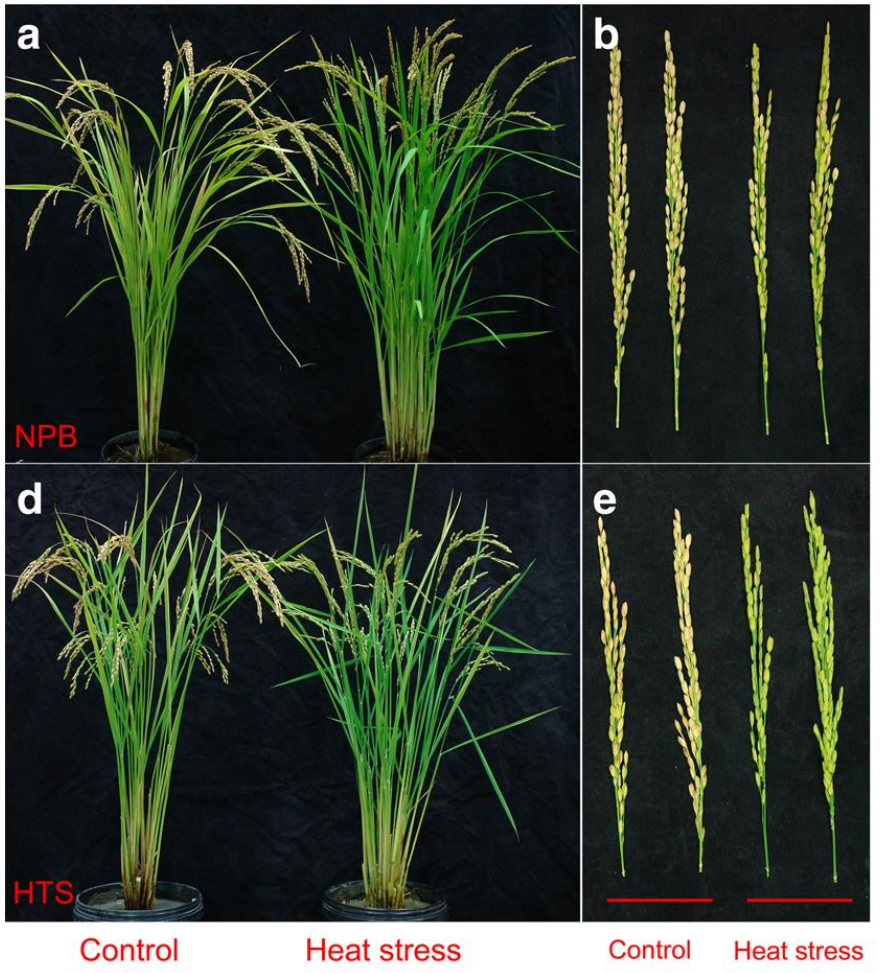
2. Browning: cause loss of pigmentation resulting in a yellow, bronze, or brown spot on the sun exposed side of the fruit.

Pigments such as chlorophyll, carotenes, and xanthophylls are denatured or destroyed.



Some Examples: Rice

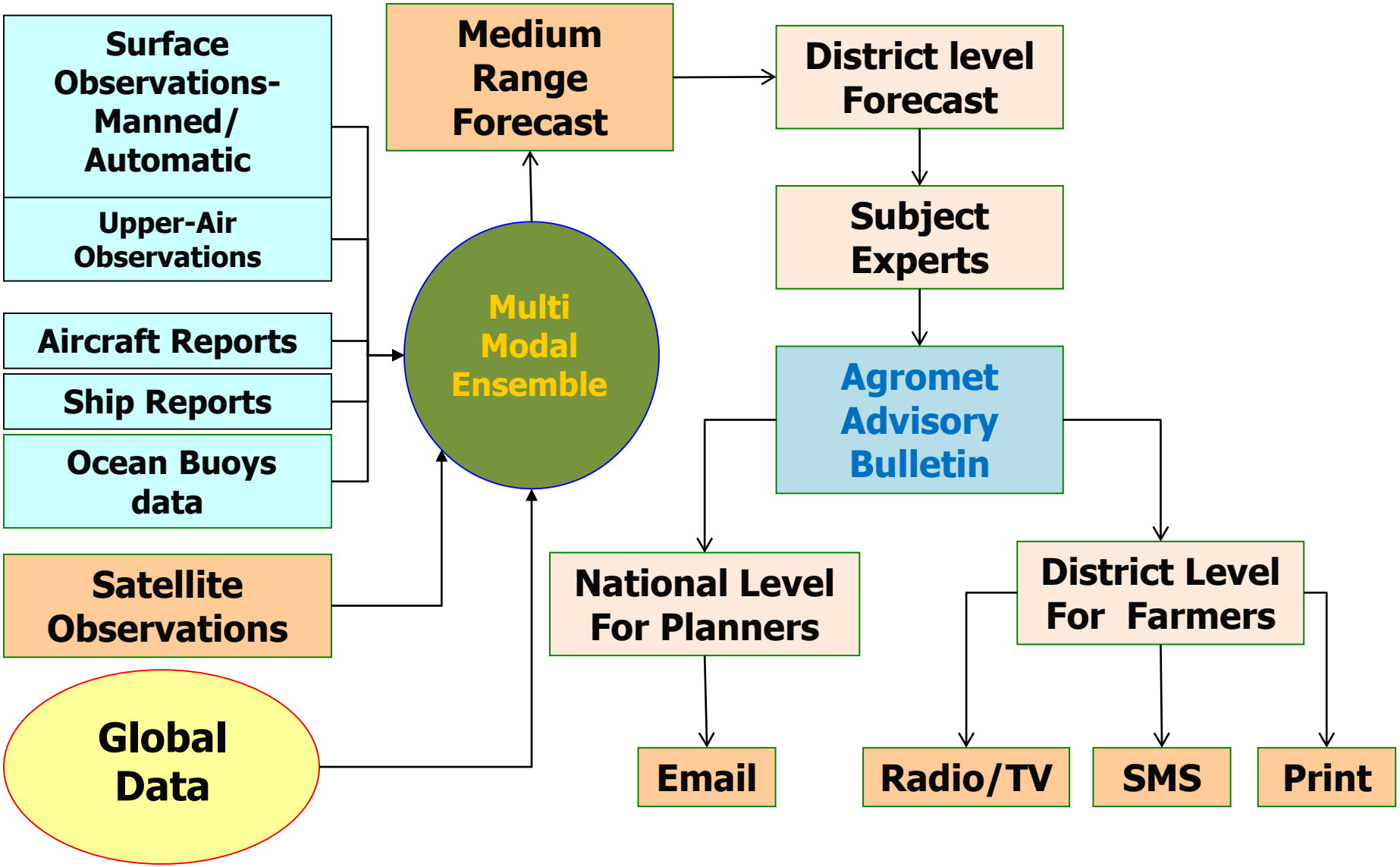
- **The impact of high temperatures at night is more devastating than day-time or mean daily temperatures.**
- **Booting and flowering are the stages most sensitive to high temperature, which may sometimes lead to complete sterility.**



Adaptation Measures

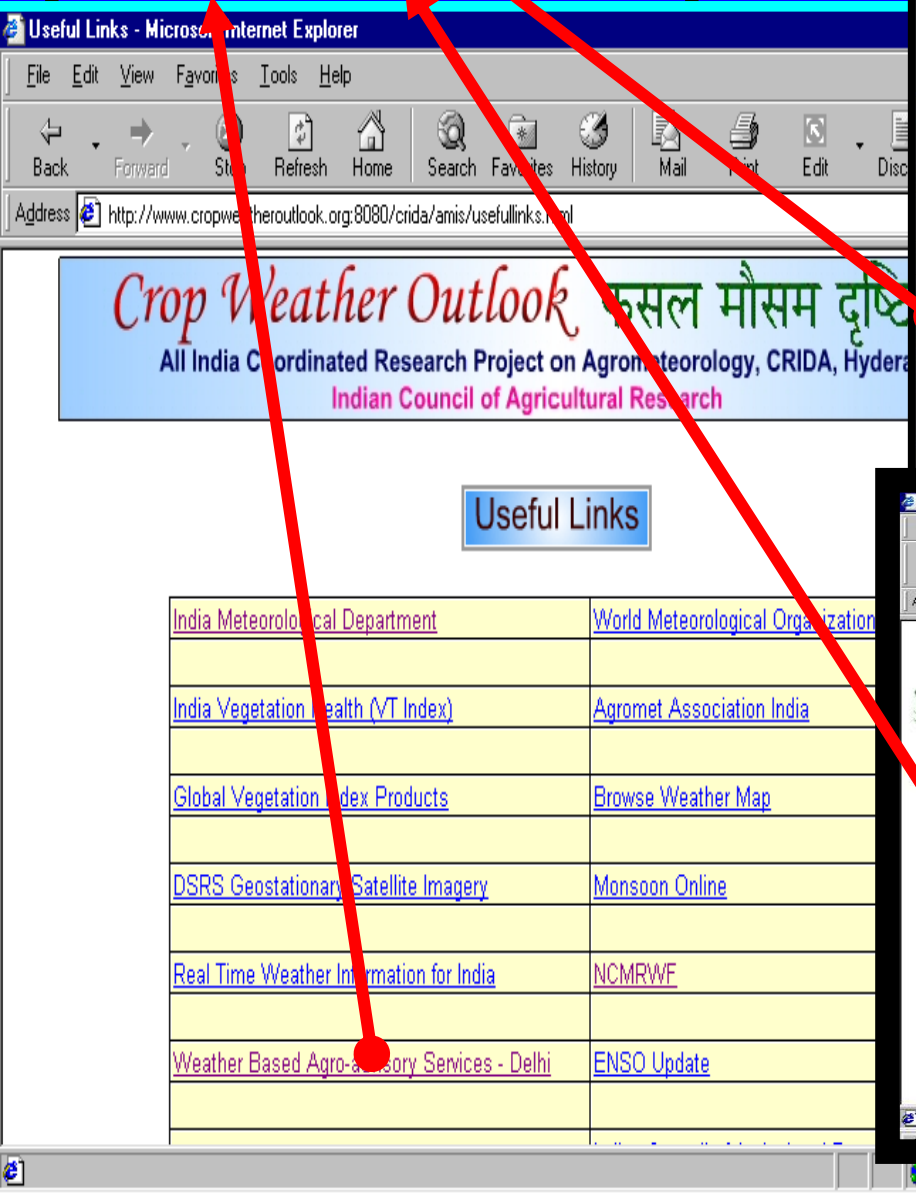
- **Monitoring and Early Warning**
- **Crop contingency plans,**
- **Replacement of heat-sensitive cultivars with heat-tolerant ones,**
- **Choice of crops/varieties with a growth duration allowing avoidance of peak stress periods, and**
- **Crop insurance**

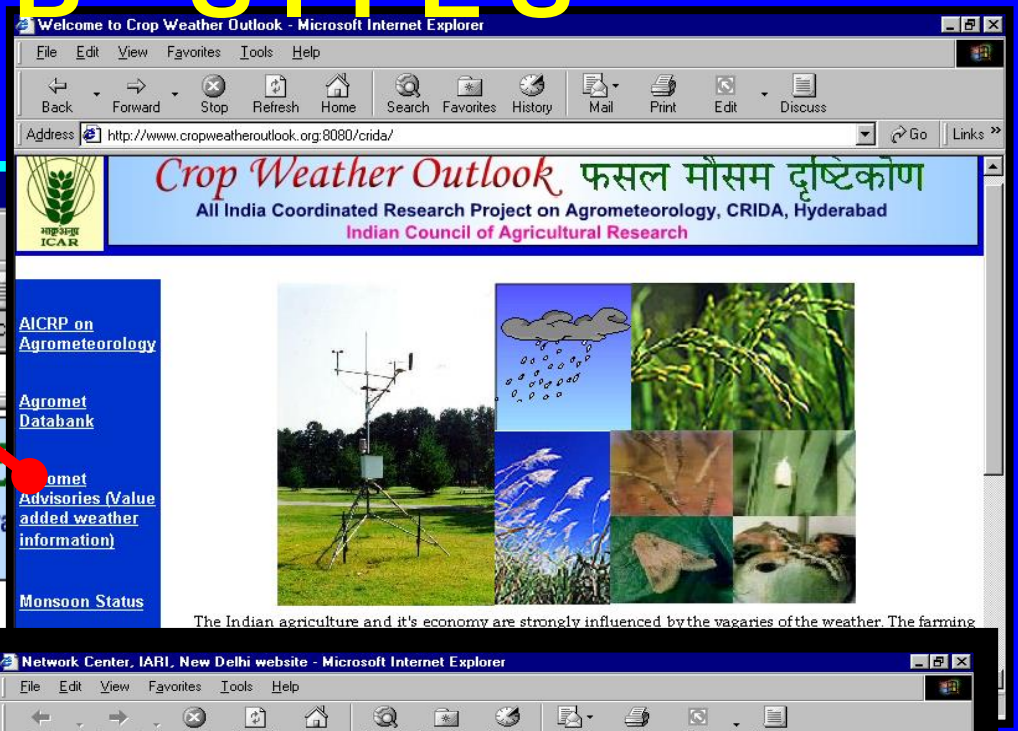
Medium Range Weather Forecast Based Agro-Advisory System: IMD - ICAR

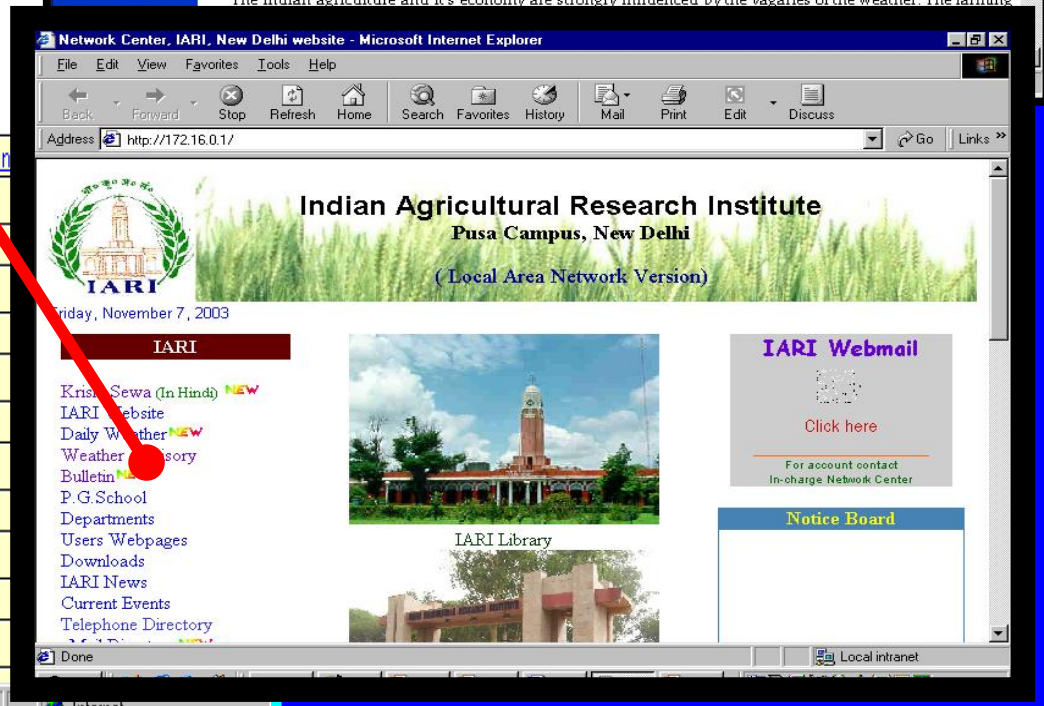


WEB–SITES

WAAS-DELHI LINKAGES

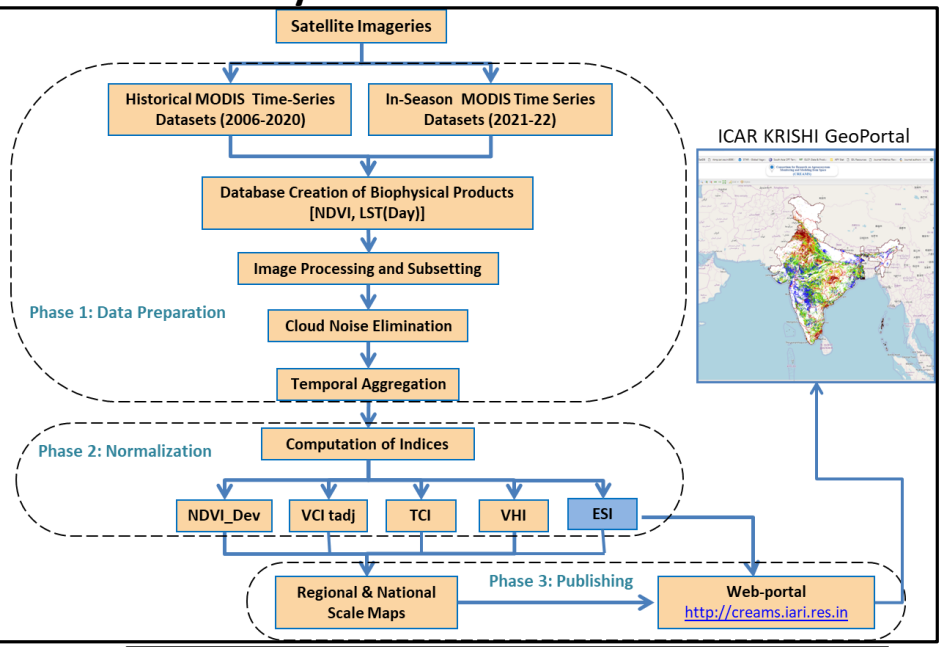




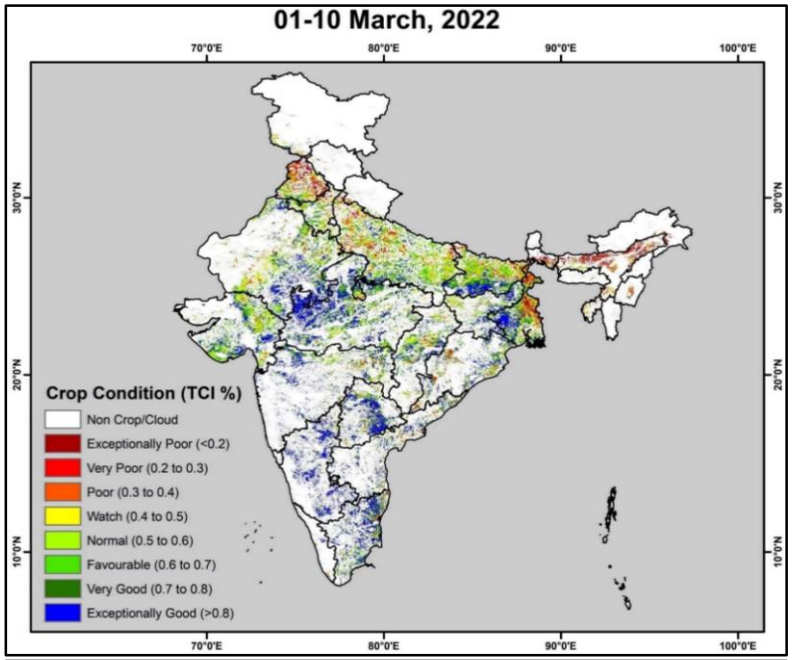


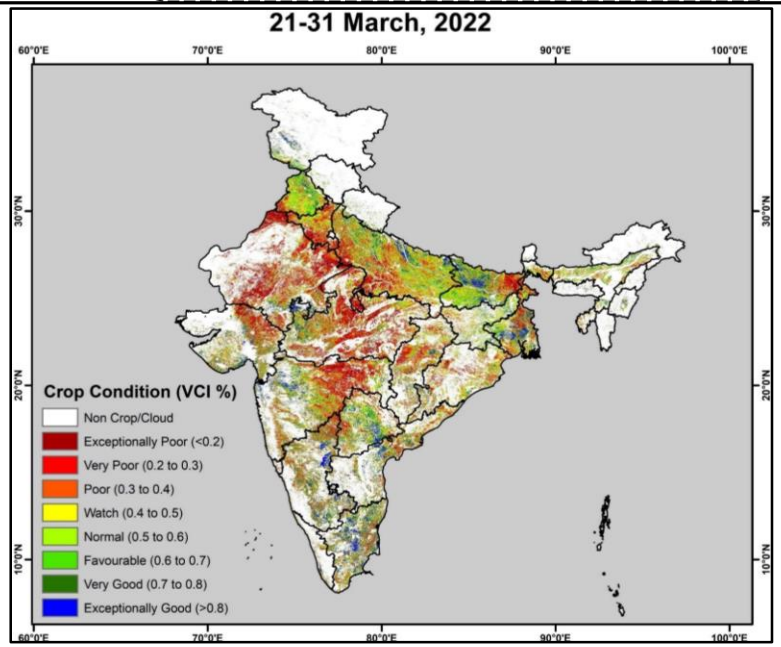
Crop health monitoring by Satellites for Improved Agroadvisory

System Overview

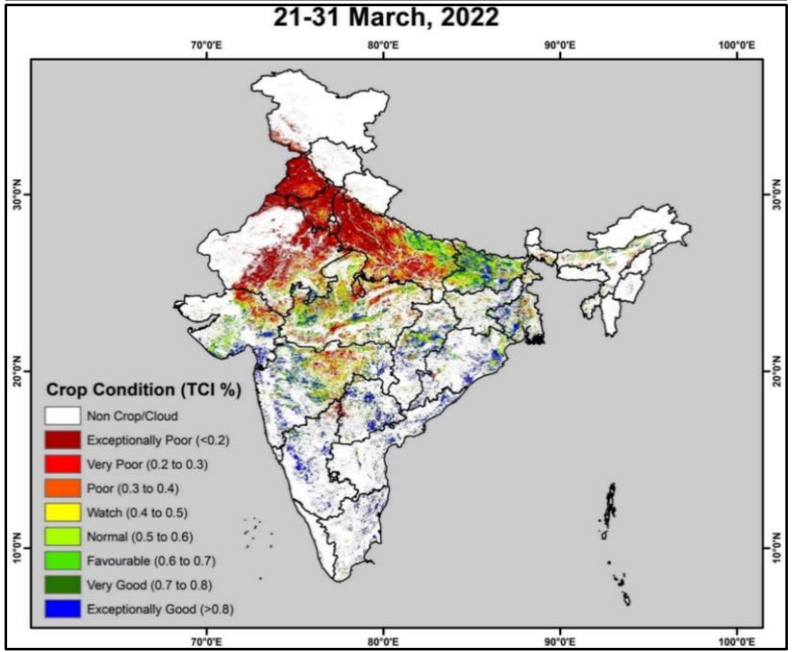


Temperature Condition Index

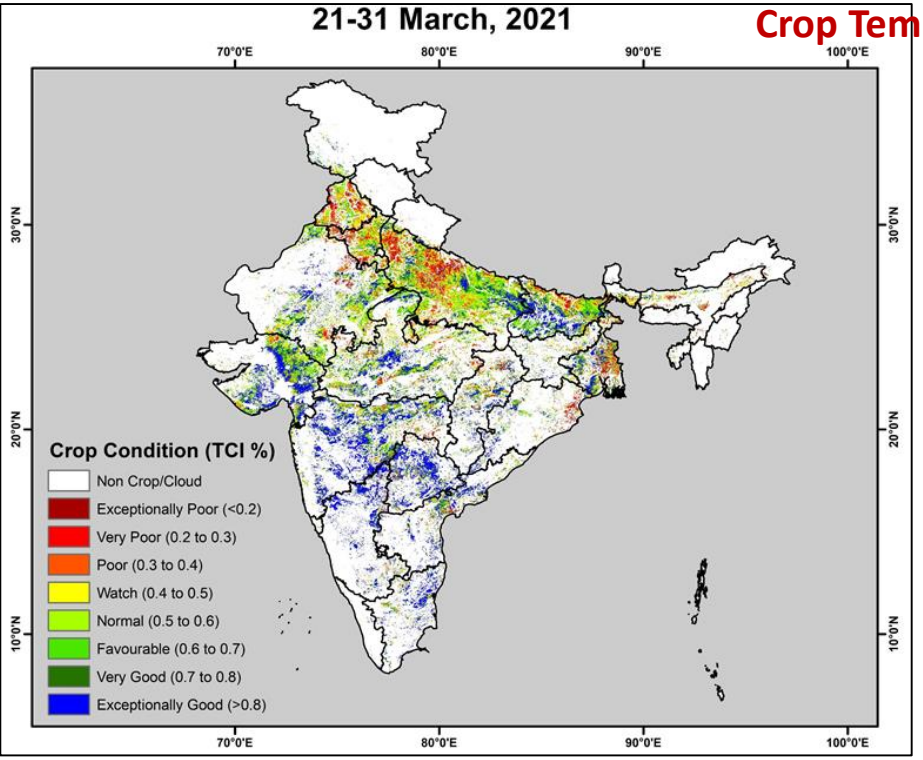




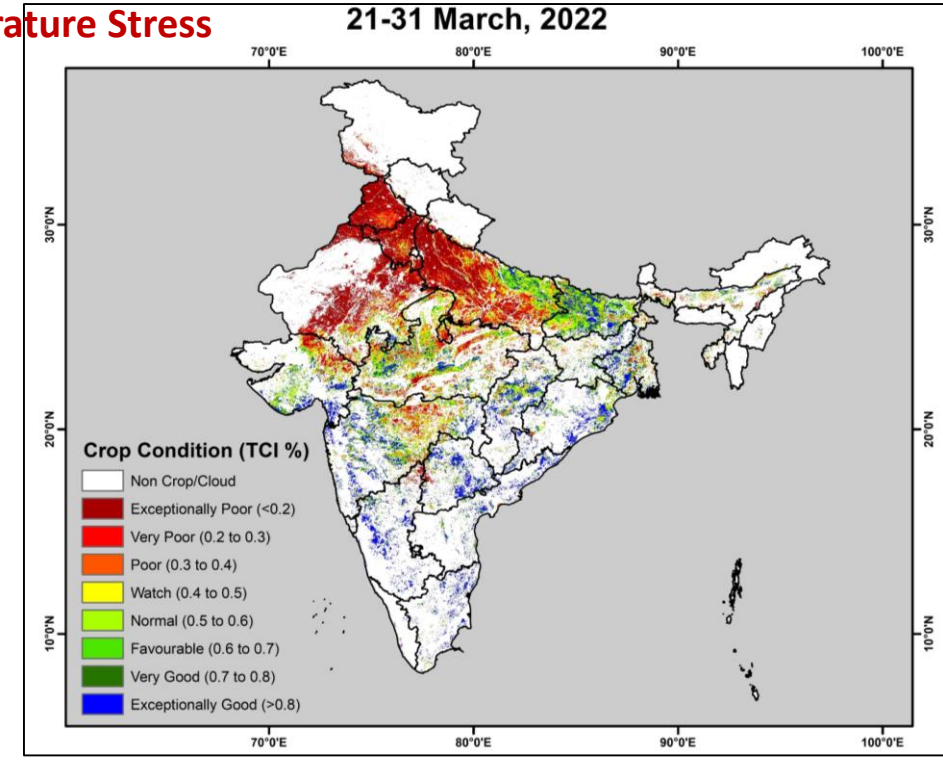
Vegetation Condition Index

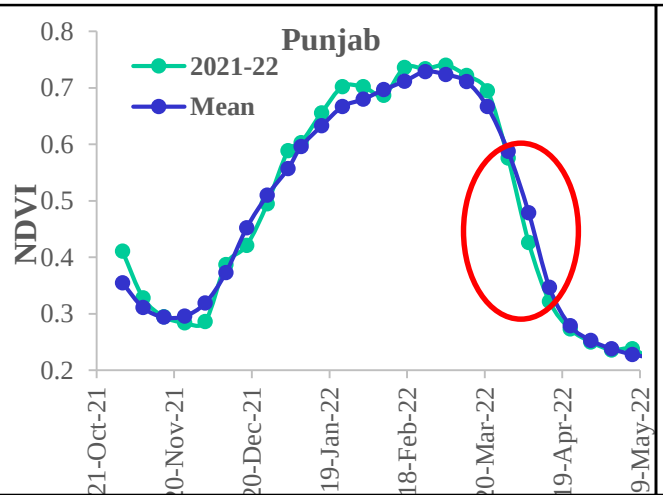


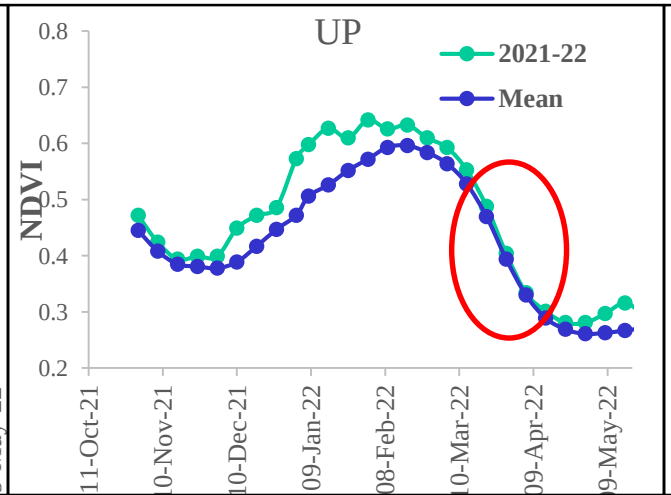
Temperature Condition Index

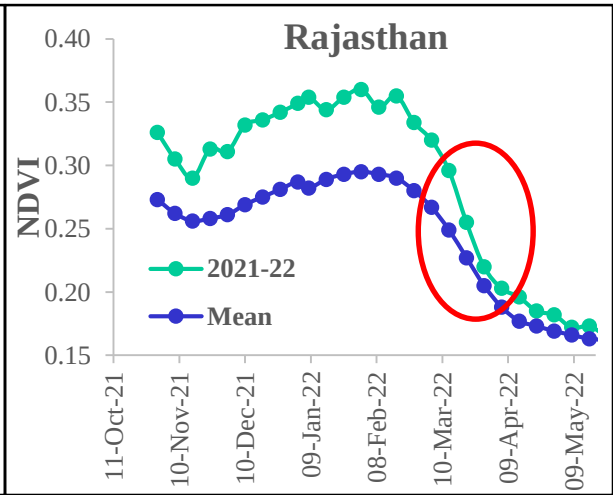


Crop Temperature Stress

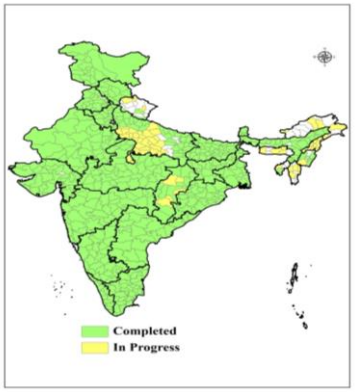








District Level Contingency Plans (DLCPs) for Weather Aberrations in India



Prepared 640 district level contingency plans to meet weather aberrations in crop, livestock, poultry and fisheries sectors

The Plans cover:

- Delay in monsoon onset
- Breaks in monsoon leading to early, mid and late-season droughts
- Delayed or limited release of water for irrigation
- Floods
- Unseasonal rains
- Extreme weather events: **heat wave,** cold wave, frost, hailstorm and cyclone

Approach:

Bottom-up involving district level scientists of Agricultural Research Stations and KVKs of SAUs

Organizations involved:

- CRIDA - Nodal Institute
- 46 State Agricultural Universities (SAUs)
- 7 ICAR –NRM institutes (NBSS& LUP, CAZRI, PDFSR, CSWCRTI, DWM, ICAR RCER, ICAR RC-NEH)

DLCPs - Outcomes

- Pilot implementation of plans by Department of Agriculture (DAC), Ministry of Agriculture, GoI; to be implemented in three states during XII Plan
- Extract of plans developed as a web enabled "Contingency Crop Planning tool" by CRIDA
- Real time implementation of DLCP's taken up at 23 locations across India by AICRP on Dryland Agriculture (AICRPDA)
- On-farm demonstration of climate resilient technologies taken up under the National Initiative on Climate Resilient Agriculture (NICRA) in 100 districts through KVK's
- Plans adopted by the State Departments of Agriculture on real time basis during delayed monsoon and deficit rainfall situations

Access to District level Contingency Plans in Farmers' portal
(http://farmer.gov.in)

Web based Contingency Crop Planning tool for Monsoon Aberrations

Source: CRIDA

Climate-smart Crop Varieties

Varieties tolerant to:

- Submergence
- Drought
- Salinity
- Heat stress

NRRI (2017) IARI-NICRA (2016)

Climate-smart Crop Varieties

Pusa Basmati 1509 | Pusa Basmati 1121

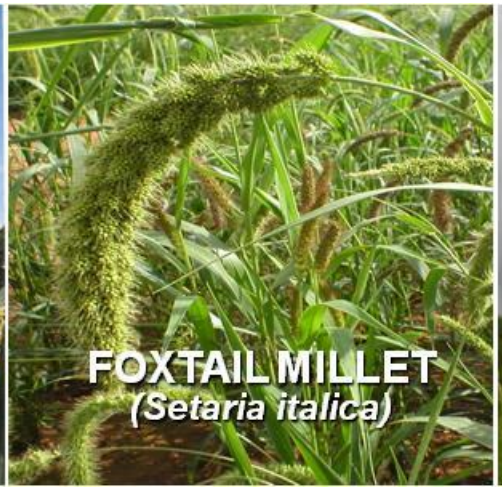
Wheat variety HPW 368 in Kullu district

Wheat variety JW-3288 in Satna district

Wheat variety PBW-725 in Faridkot district

SMALL MILLETS: Climate Savior Crops

- **Small millets, consisting of six species, known to have superior chemical profile in protein, amino acids, fiber, minerals such as calcium, iron, and magnesium and vitamins**
- **Their low gycemic index is an important nutraceutical value in managing diabetes.**



Agronomic Measures

- **Adjustment of sowing time / cropping sequence**
- **Efficient irrigation (drip, sprinkler), sensor based**
- **Appropriate canopy management**
- **Cover crop or intercropping**
- **Soil mulching (residue, polythene)**
- **Over tree sprinkler,**
- **Shade netting,**
- **Fruit bagging,**
- **Transpiration Suppressants (kaolin or calcium carbonate) and**
- **Chemical protectants**

Crop Diversification

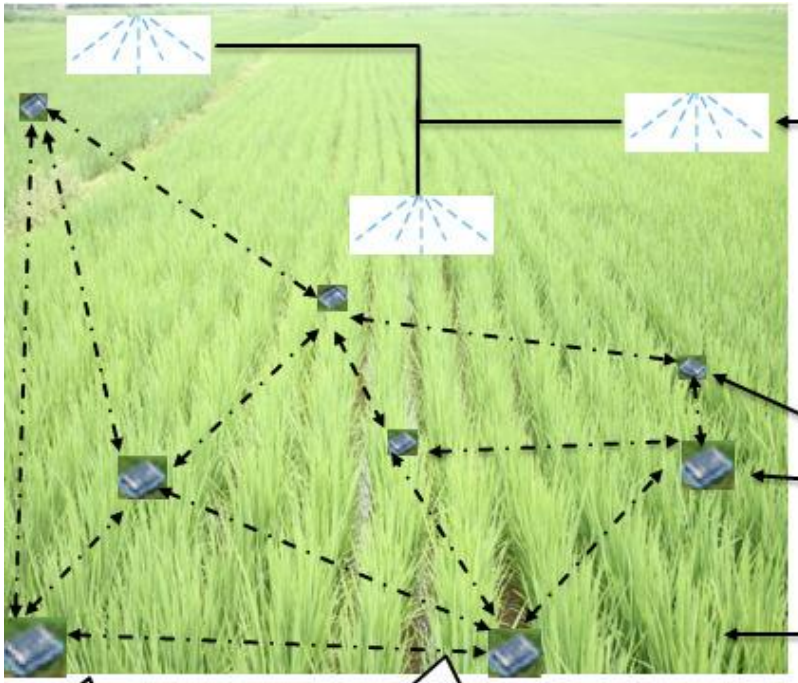
Water-saving Technologies

Laser land leveling -
A Precursor technology

Raised bed planting

Drip irrigation

Precision Water Management



Sensor nodes

Rice field

Actuate Irrigation scheduling, Fertilization

Sink Node

Internet Network

Local User

Database

Farmer's Mobile

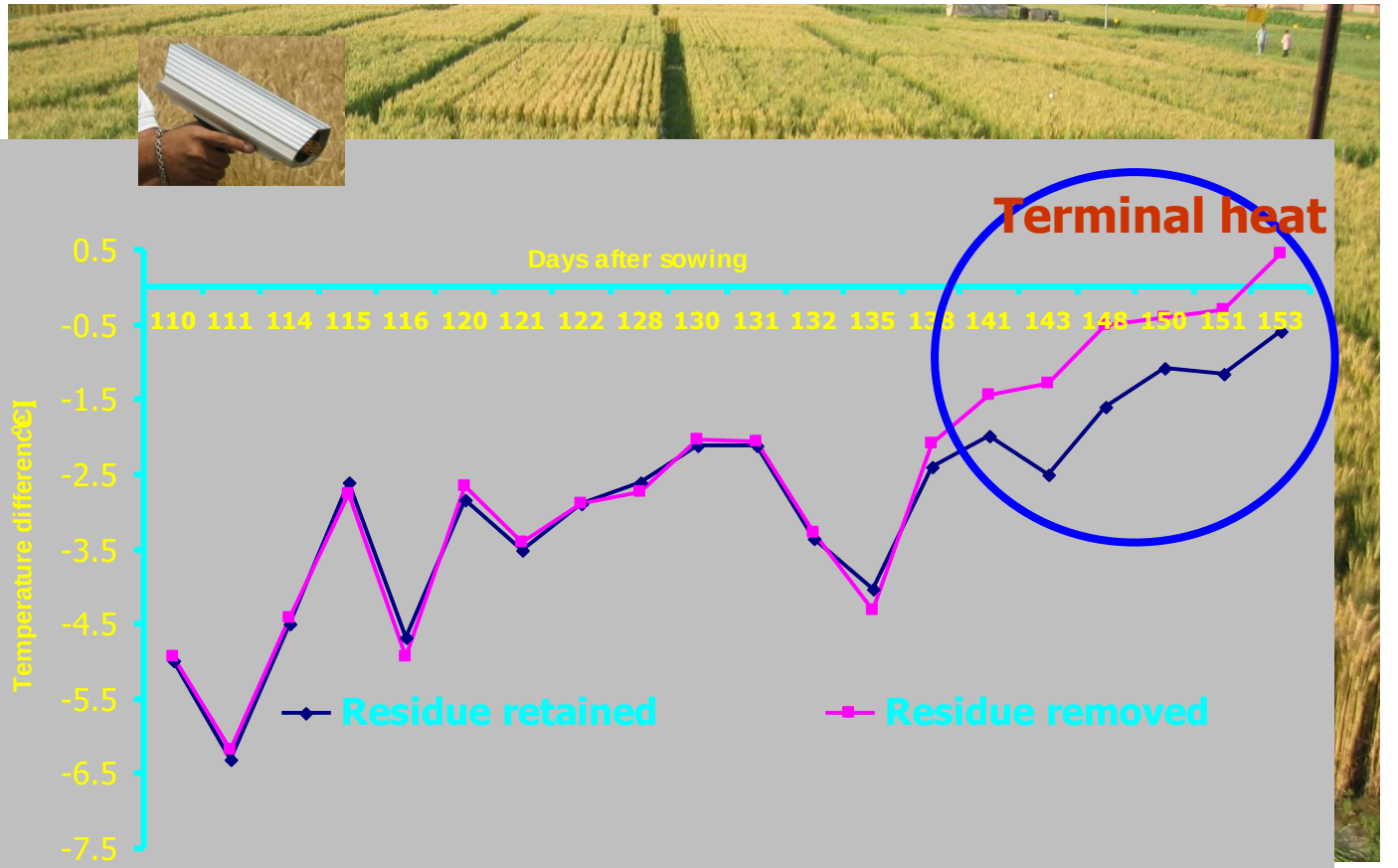
Cover Cropping / Mulching

Conservation Tillage in Wheat

Zero Tillage Minimizes Yield Loss due to Climatic Extremes

Conventional tillage

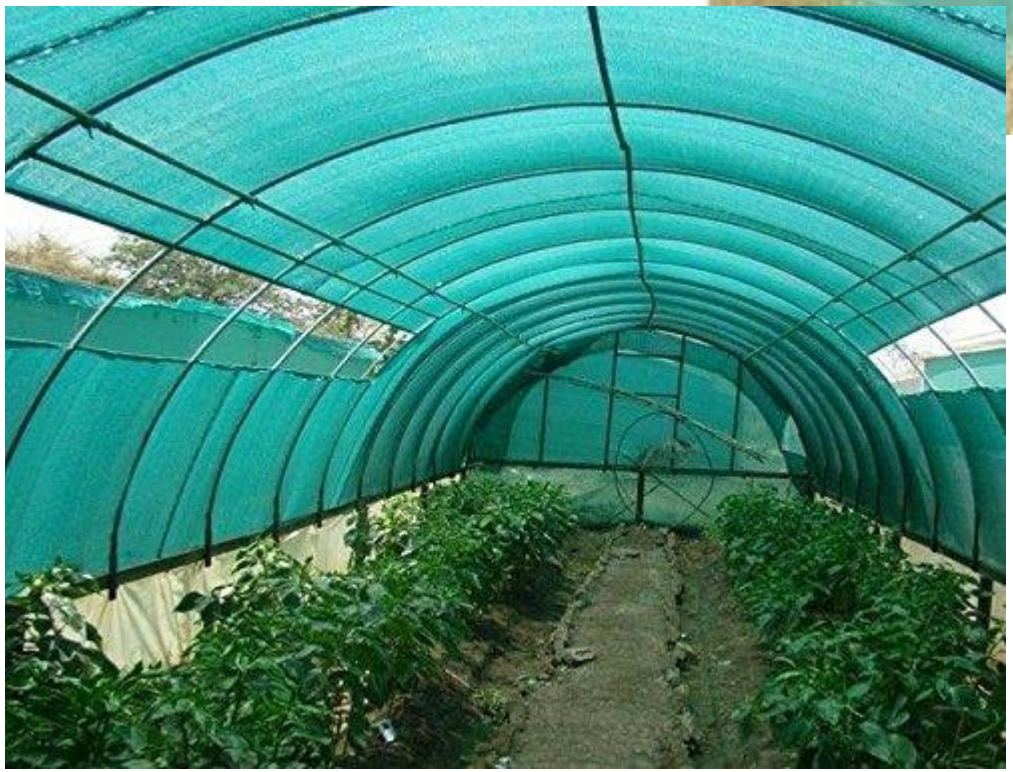
Zero tillage



NICRA (2016)

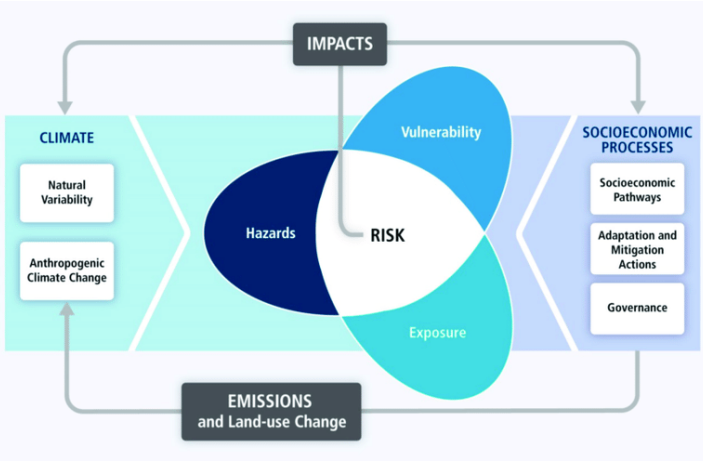
Jat et al. (2012)

Shade Nets for Commercial Crops



Atlas of Climate Adaptation in South Asian Agriculture (ACASA)

Risk Assessment Framework

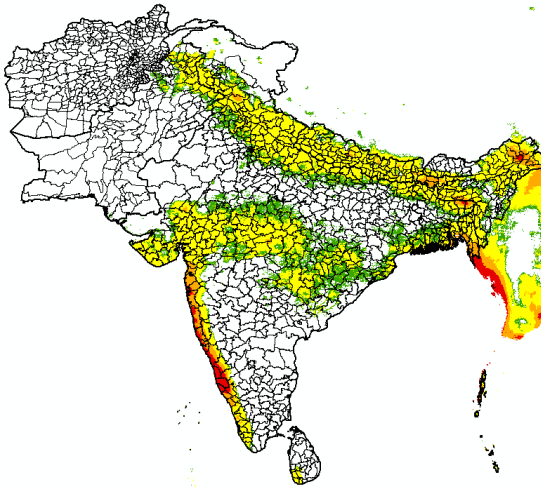


India: Crop Commodities

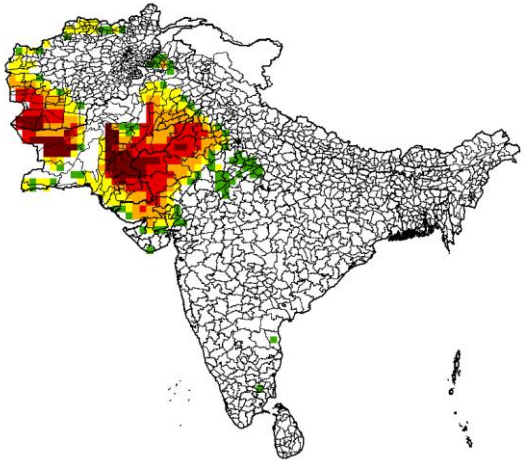
- Rice (43662300)
- Wheat (29318780)
- Maize (9027130)
- Sorghum (4092870)
- Pearl millet (7542680)
- Finger millet (1004460)
- Soybean (11131260)
- Groundnut (4730760)
- Mustard (6123930)
- Chickpea (9547030)
- Pigeon pea (4549540)
- Potato (2173000)

- Climate Risk Assessment
- Assessment of Climatic Impacts on Commodities
- Portfolio of Adaptation Options
- UI/UX Development
- Capacity of stakeholders

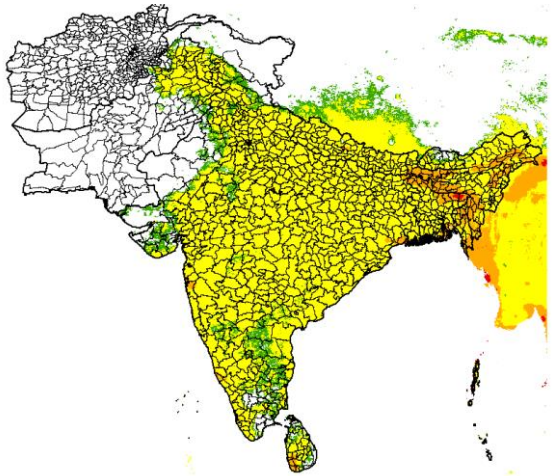
Extreme Rainfall



High Temperature



Unseasonal rainfall



Summary

1. Extreme temperature have become a reality over India and its affecting the growth of crops in the county. Higher impact in areas with higher yields.
2. The combination of elevated atm CO_2 concentrations and drought and heat stress can further limit soil mobility and root uptake of mineral nutrients, leading to decreased nutrients in edible parts adversely impacting health.
3. Need to develop region and crop specific extreme temperature and heat wave criteria for India. Focused research on crop responses and sustainable mitigation/adaptation strategies.
4. Food security of the country is equally important and so need to include "Agriculture" in national guidelines for the management of heat waves. Successful risk management depends on the availability of technological or biological solutions, as well as policy and economics.
5. The institutions in the country have adequate research capacity and systems in place to adapt/manage heat stress in agriculture but have scattered actions – need to put policy framework to focus the efforts through legal / economical instruments .

Thank You

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