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Helping communities manage risks from the ground up.

"Climate Cost of Cultivation": A Method to Quantify the Cost to Farmers of Climate Change

Presentation based on a research paper by

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(Micro Insurance Academy, New Delhi, India)

at the **2nd Workshop on Crop Insurance**

Institute of Actuaries of India

Mumbai, 19 September 2014

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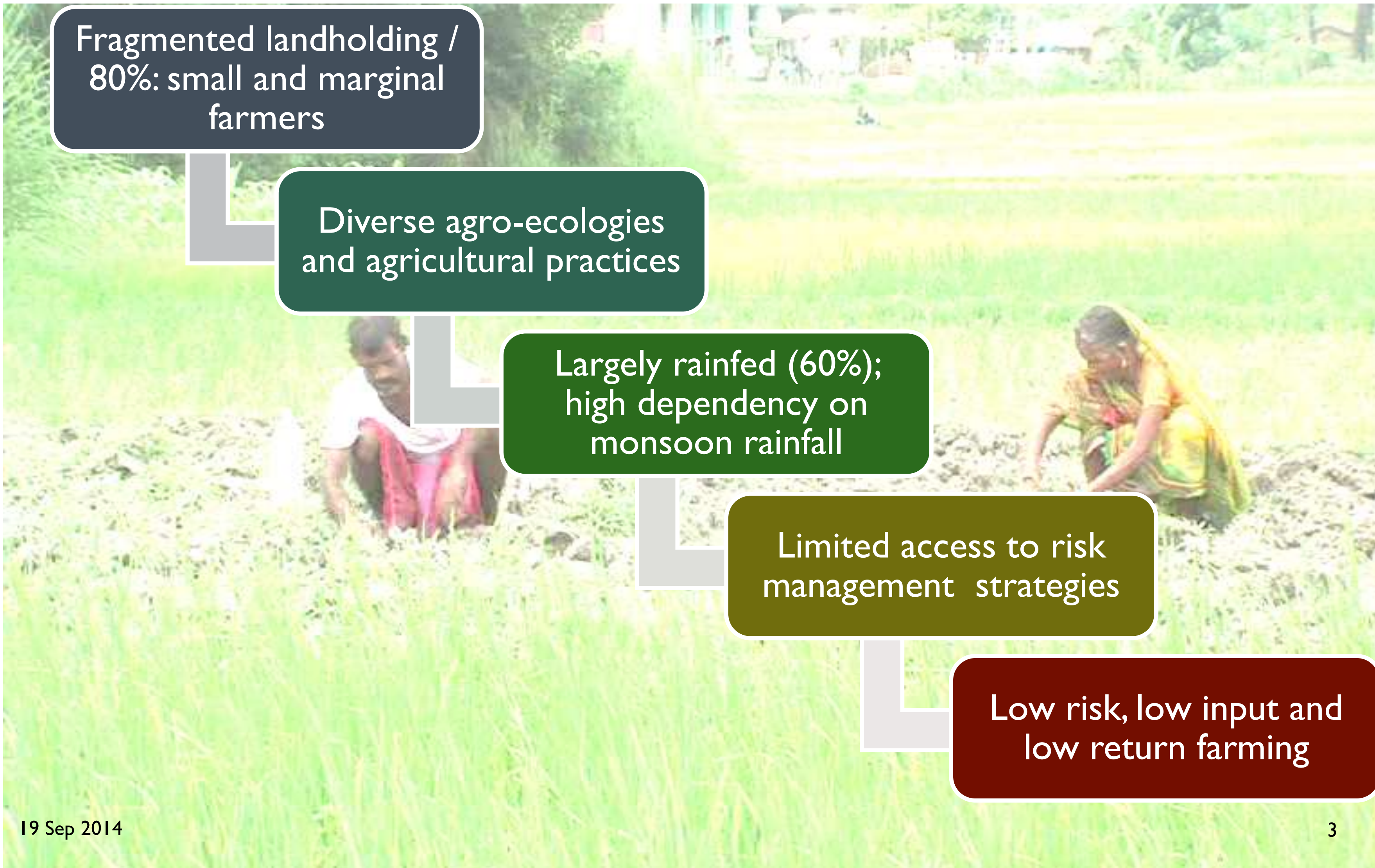
Outline

- Background on risks farmers face
- Problem statement: basis risk
- “Climate Cost of Cultivation” method
- Way forward / discussion

Background: Agriculture in India



Fragmented landholding / 80%: small and marginal farmers

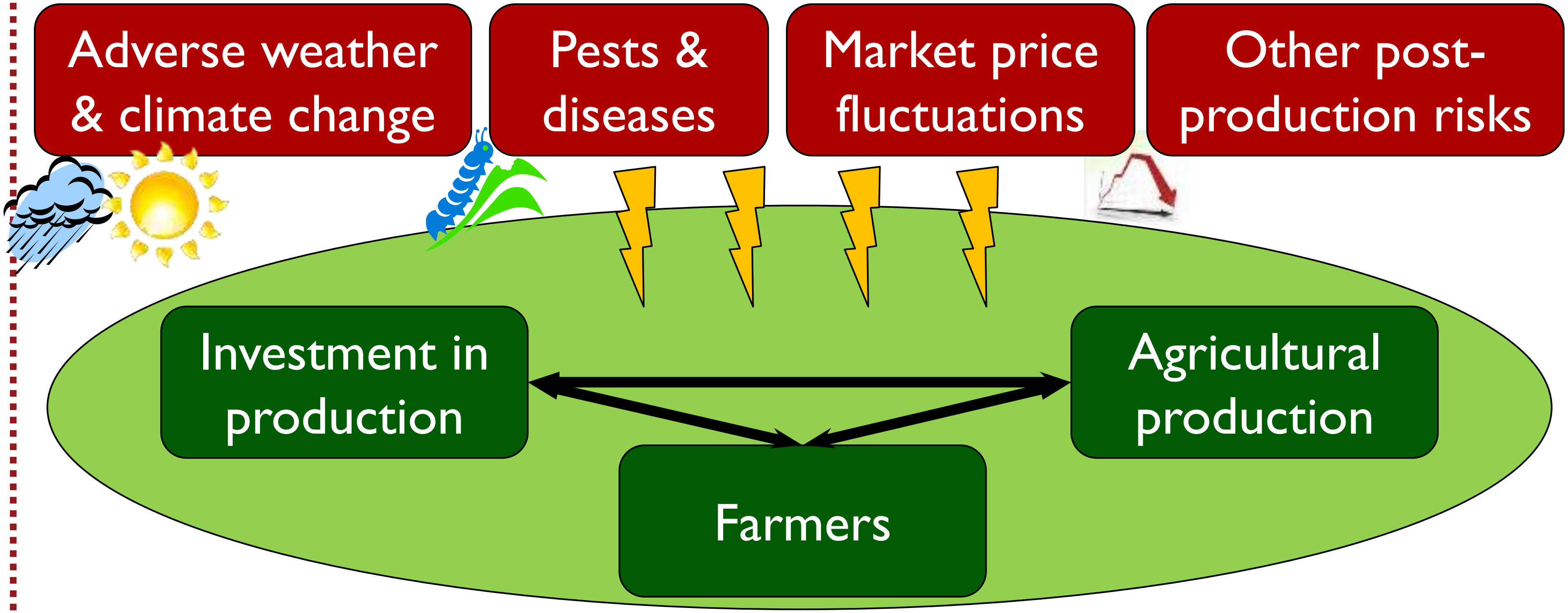
Diverse agro-ecologies and agricultural practices

Largely rainfed (60%); high dependency on monsoon rainfall

Limited access to risk management strategies

Low risk, low input and low return farming

Background: Agricultural Production Risks



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Background: Types of Agricultural Insurance

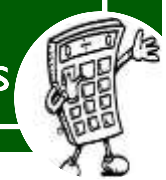
High — Admin Costs — Low

Indemnity-based

Payments based on actual losses

Area yield-based

Payments based on area-yield estimate, e.g. through crop cutting experiments



Weather index-based

Payments linked to weather index, e.g. based on rainfall, temperature

Low — Basis Risk — High

Problem Statement: Challenges with Index-Based Insurance I

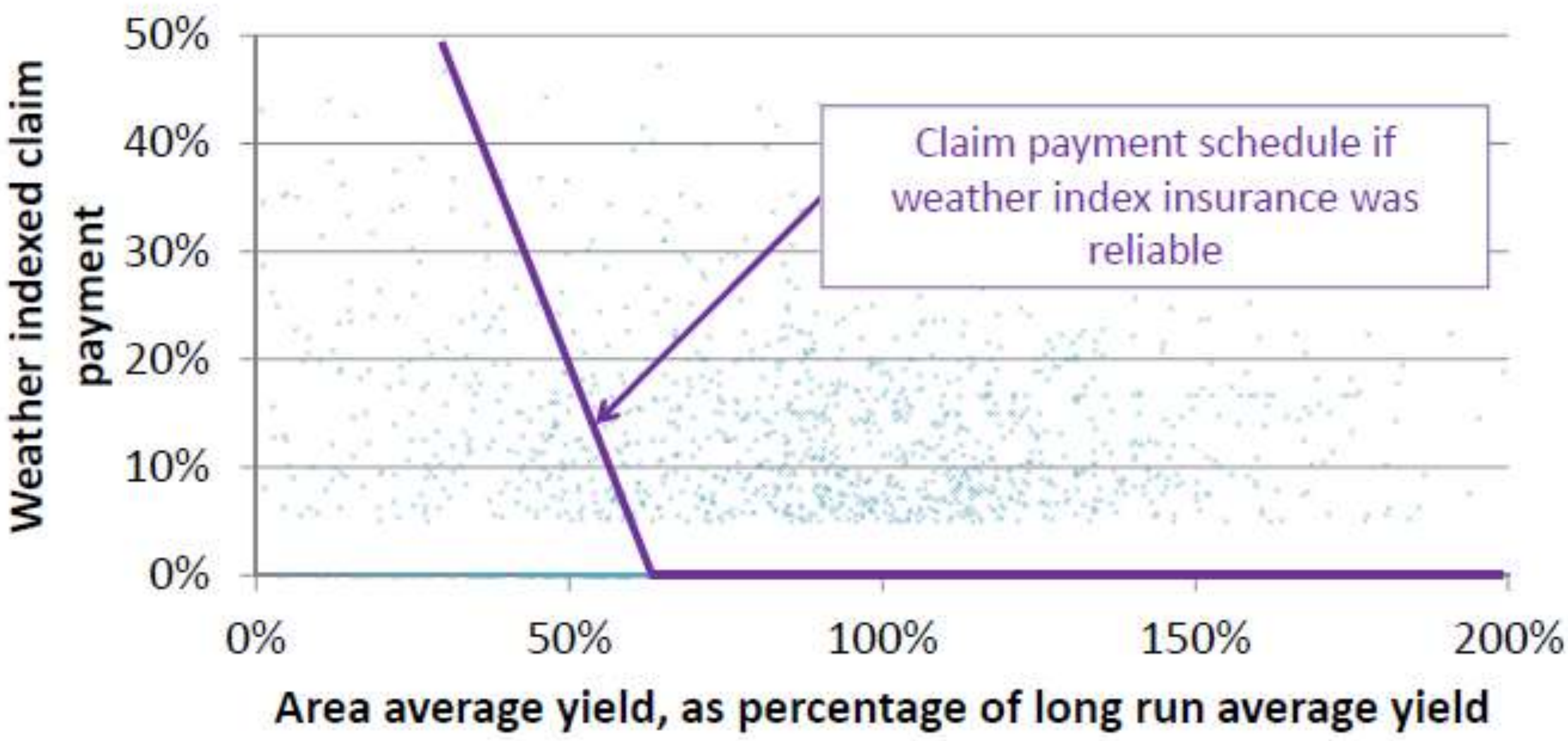
Two unwanted scenarios in index insurance:

- Farmer suffers loss, but does not receive payout
  - → Frustration
- Farmer does not incur loss, but receives payout

"There is currently no convincing statistical evidence from any reliable protection for farmers' program suggesting that weather index insurance can be relied on to pay in years that are bad for smallholder farmers." (Clarke et al, 2012)

Problem Statement: Challenges with Index-Based Insurance 2

Example: Weather Based Crop Insurance Scheme (WBCIS) in India

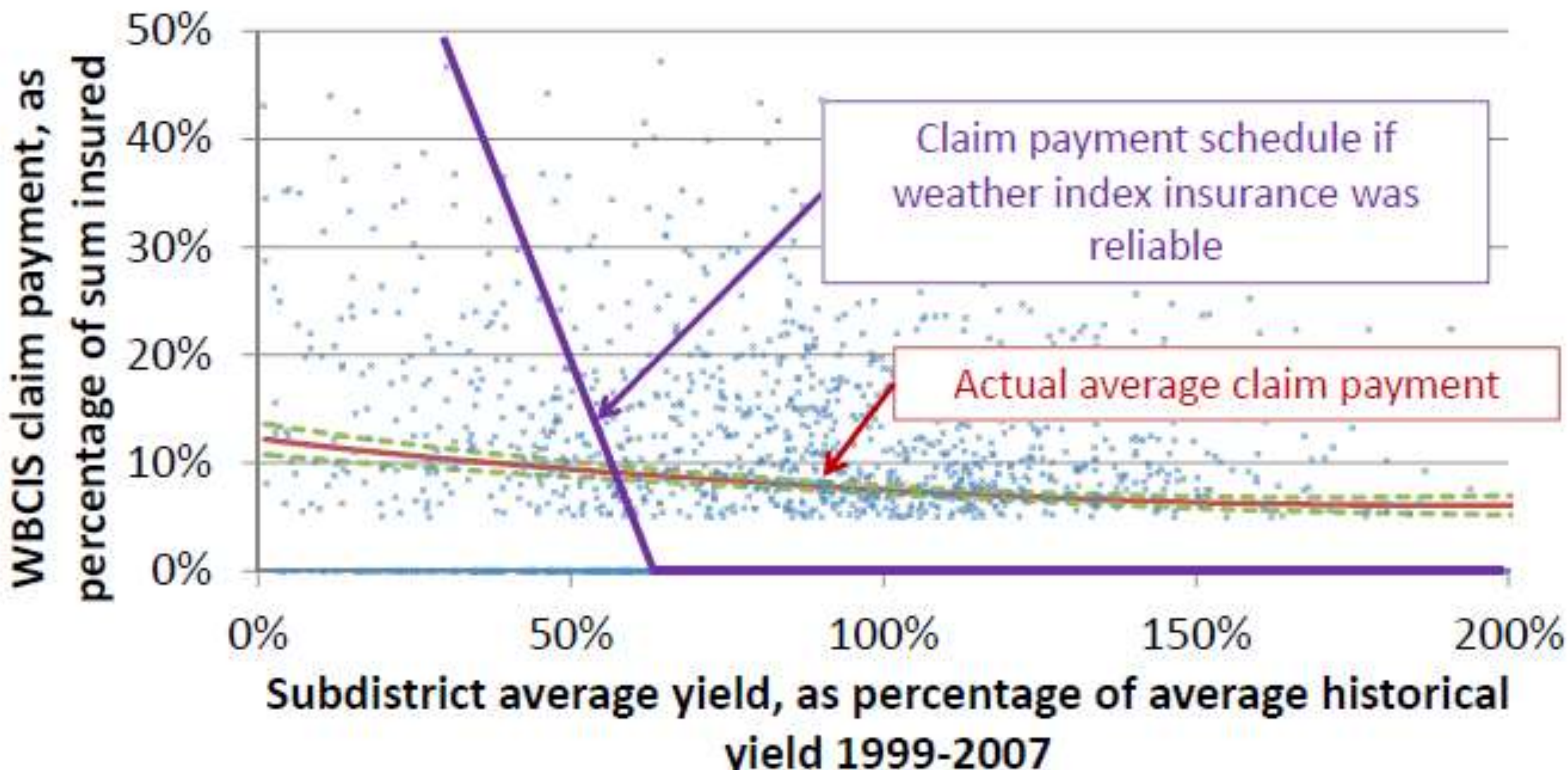


(Clarke et al, 2012)

Problem Statement: Challenges with Index-Based Insurance 3

Example: Weather Based Crop Insurance Scheme (WBCIS) in India

9 years of data (1999 – 2007), 318 products in1state: correlation only -13%



(Clarke et al, 2012)

Problem Statement: Challenges with Index-Based Insurance 4

→ On individual farm level the correlation between index payout and crop yield is most likely even weaker

→ **Basis Risk = mismatch between actual losses incurred by a farmer and insurance payout**

→ But: Farmers want **reliable** protection

Reasons for high basis risk:

- Certain extreme weather events and catastrophes cannot be captured by local weather parameters only
- Certain other perils also not captured, e.g. losses due to pest attacks and diseases, wild animal grazing
- Some relevant parameters and other risk factors are ignored
- Farming practices differ considerably
- Weather and yield data inadequate (quality, resolution) for calibration of index and determination of payout

Climate Cost of Cultivation (CCC): Towards a comprehensive index

"Climate Cost of Cultivation": a method to quantify the added cost to farmers of climate change

Objectives:

- To develop a method for quantifying climate (change) risks to farmers (insufficient rainfall, excessive rainfall, high temperature).
- To design index with lower basis risk.
- To develop agriculture risk profiling on the basis of high resolution climatic and bio-physical parameters.

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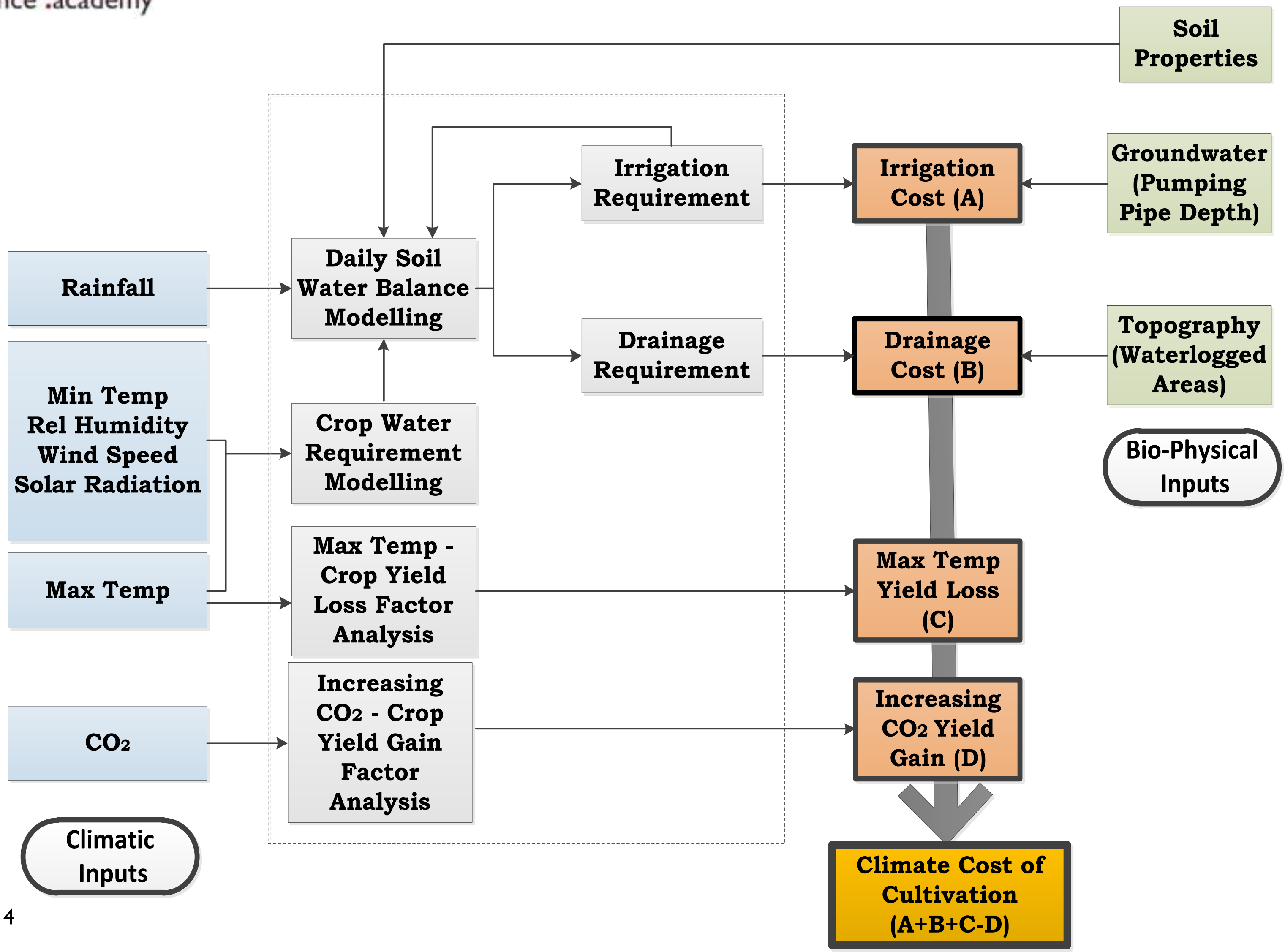
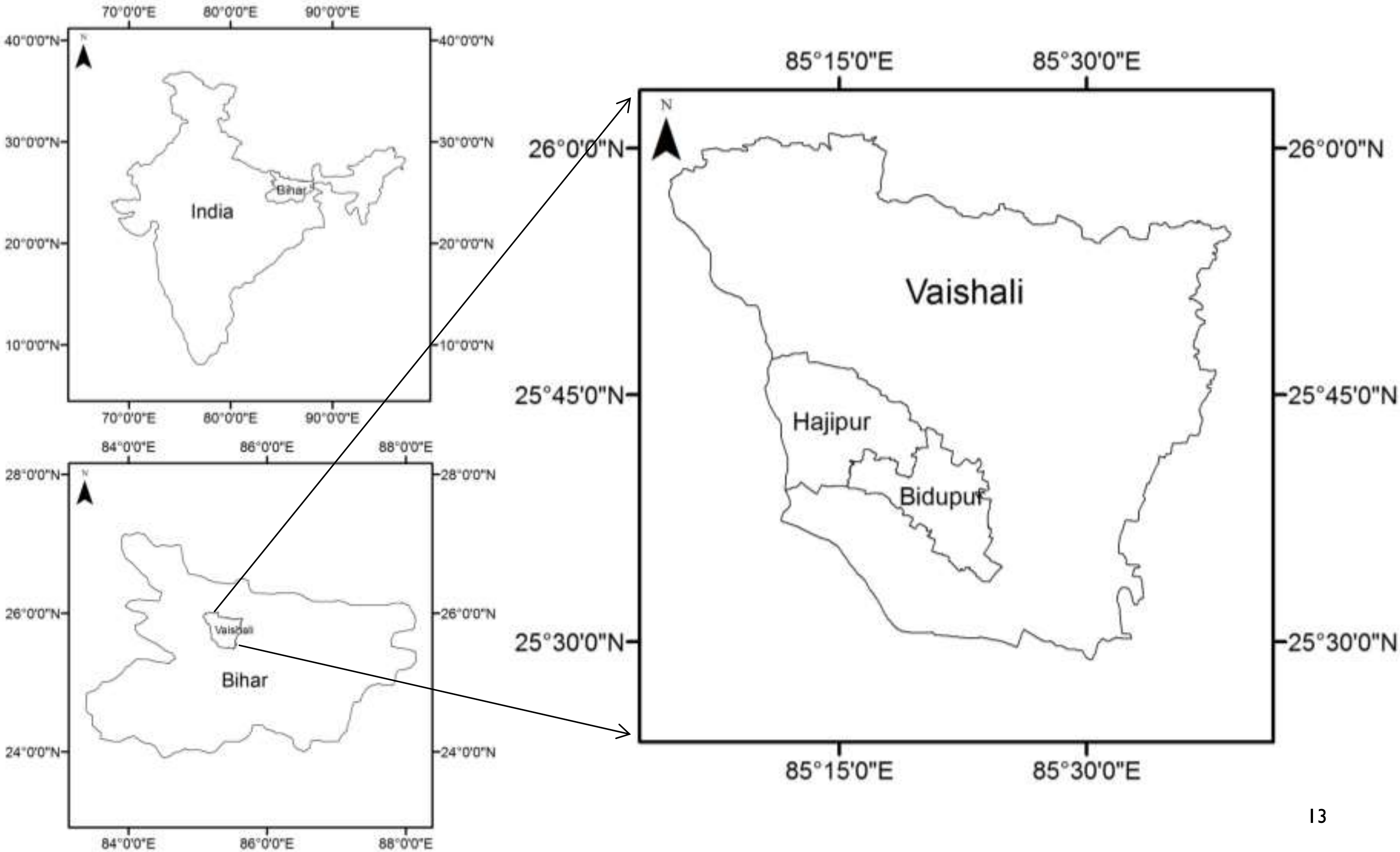
CCC Data Requirements

Data Type	Data	Data Parameter	Available Scale (1°=110 km at equator) — Free	Available Scale (1°=110 km at equator) — Payable	Desirable Scale
Climate Data	Precipitation	Rain gauge / weather station data, daily		0.25° by 0.25° (daily)	Higher spatial and temporal resolution
	Max/min temperature	Satellite grid data, daily	2.5° by 2.5° (daily)	0.25° by 0.25° (daily with many data gaps)	
	Relative humidity				
	Wind speed				
	Solar radiation				
	CO_2	Observed data, annual	Single location data		
Bio-physical Data	Soil type	Primary or secondary data		1° by 1° or own soil sampling and testing	
	Groundwater pumping pipe depth (needed when too little rain)	Primary data			
	Topography	Digital elevation map	30 m by 30 m		
	Waterlogged area	Secondary data	30 m by 30 m		

CCC: Schematic Model



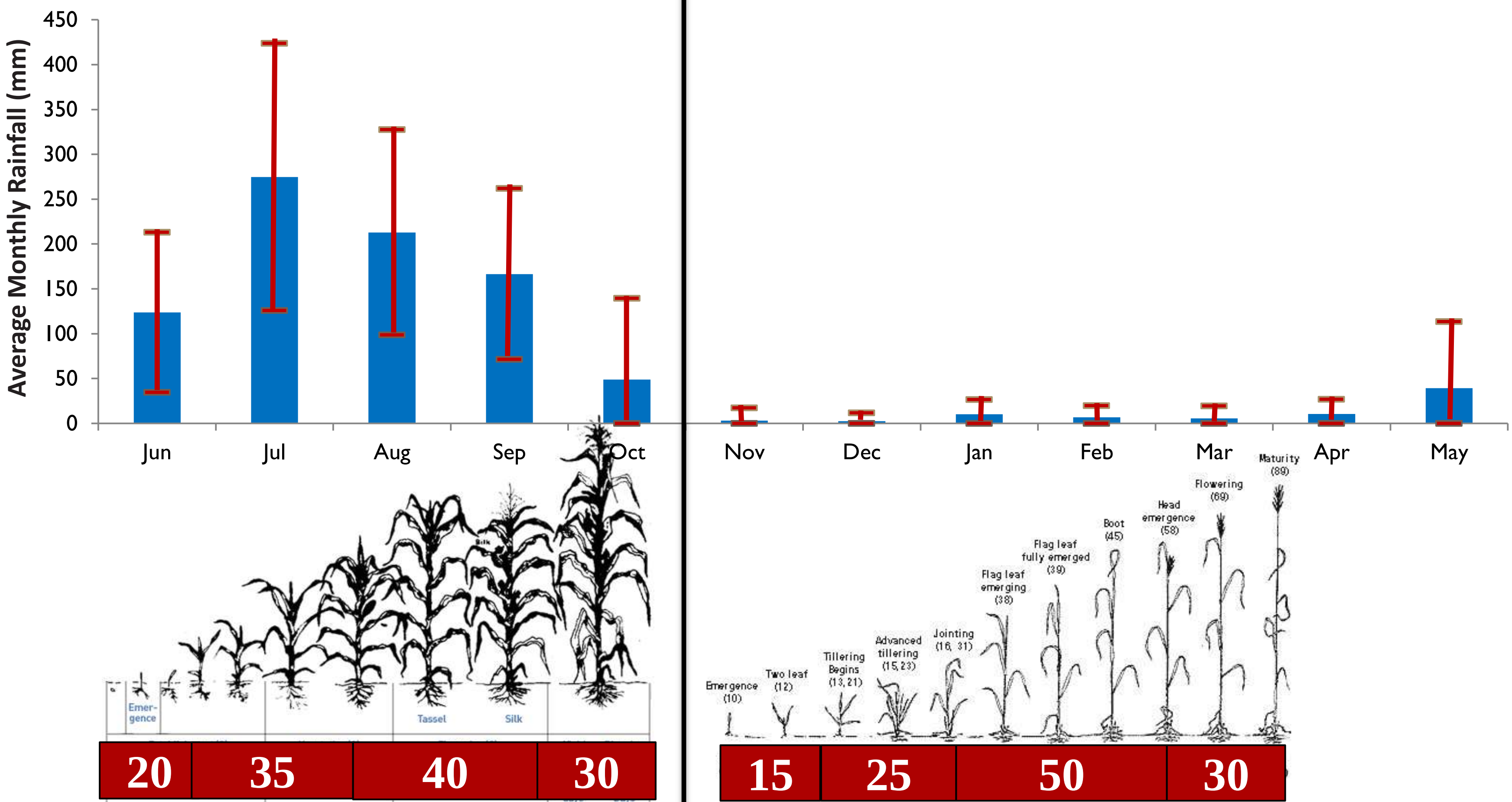
Study Area: Bihar, India
(Hajipur & Bidupur Blocks, Vaishali District)



Crops Studied: Maize and Wheat

Maize: Rainy Season Crop

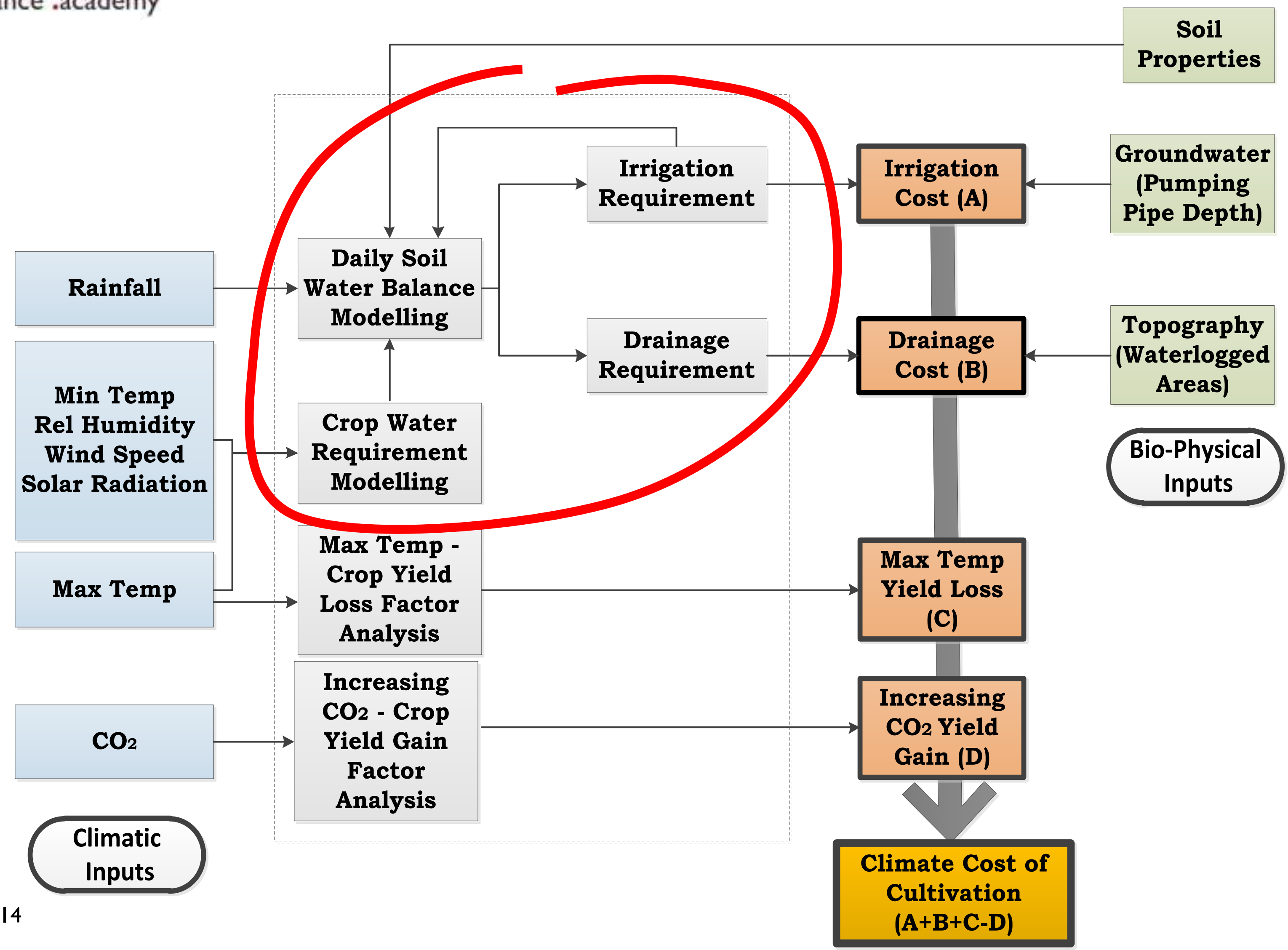
Wheat: Post Rainy Season Crop



125 Days

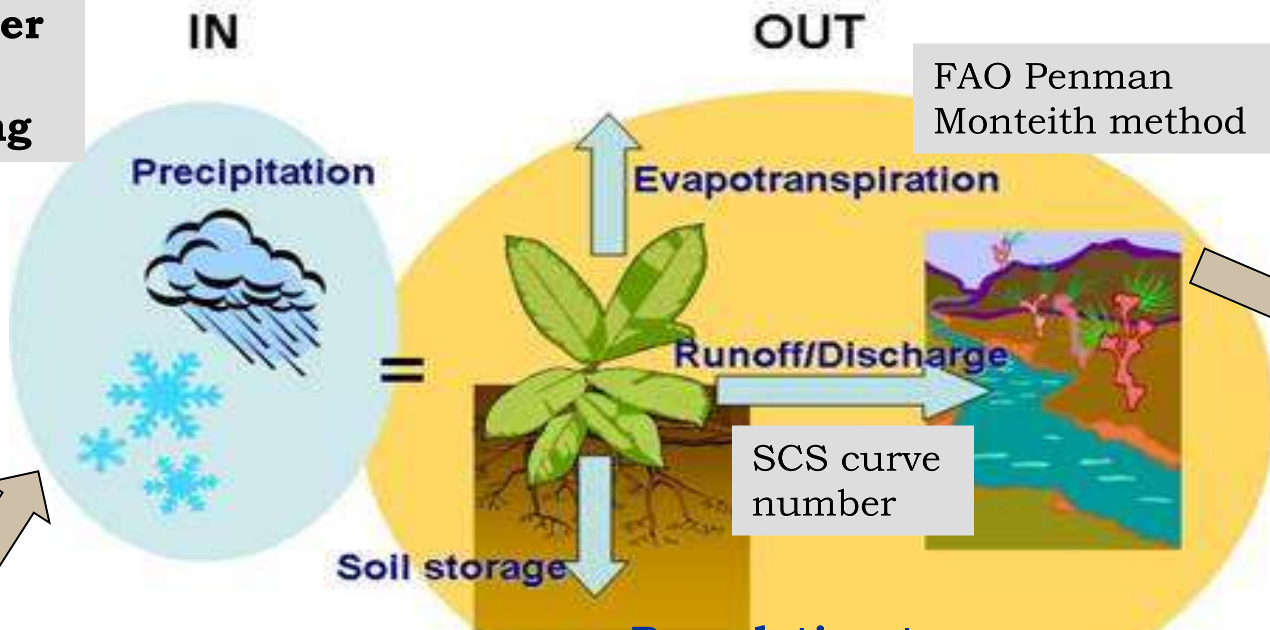
120 Days

CCC: Schematic Model



CCC: Methodology (Insufficient and Excessive Rainfall)

Soil Water Balance Modelling



FAO Penman Monteith method

SCS curve number

Percolation to Groundwater

Excess Water

Diesel cost, waterlogged area

Crop water requirement – Soil water availability

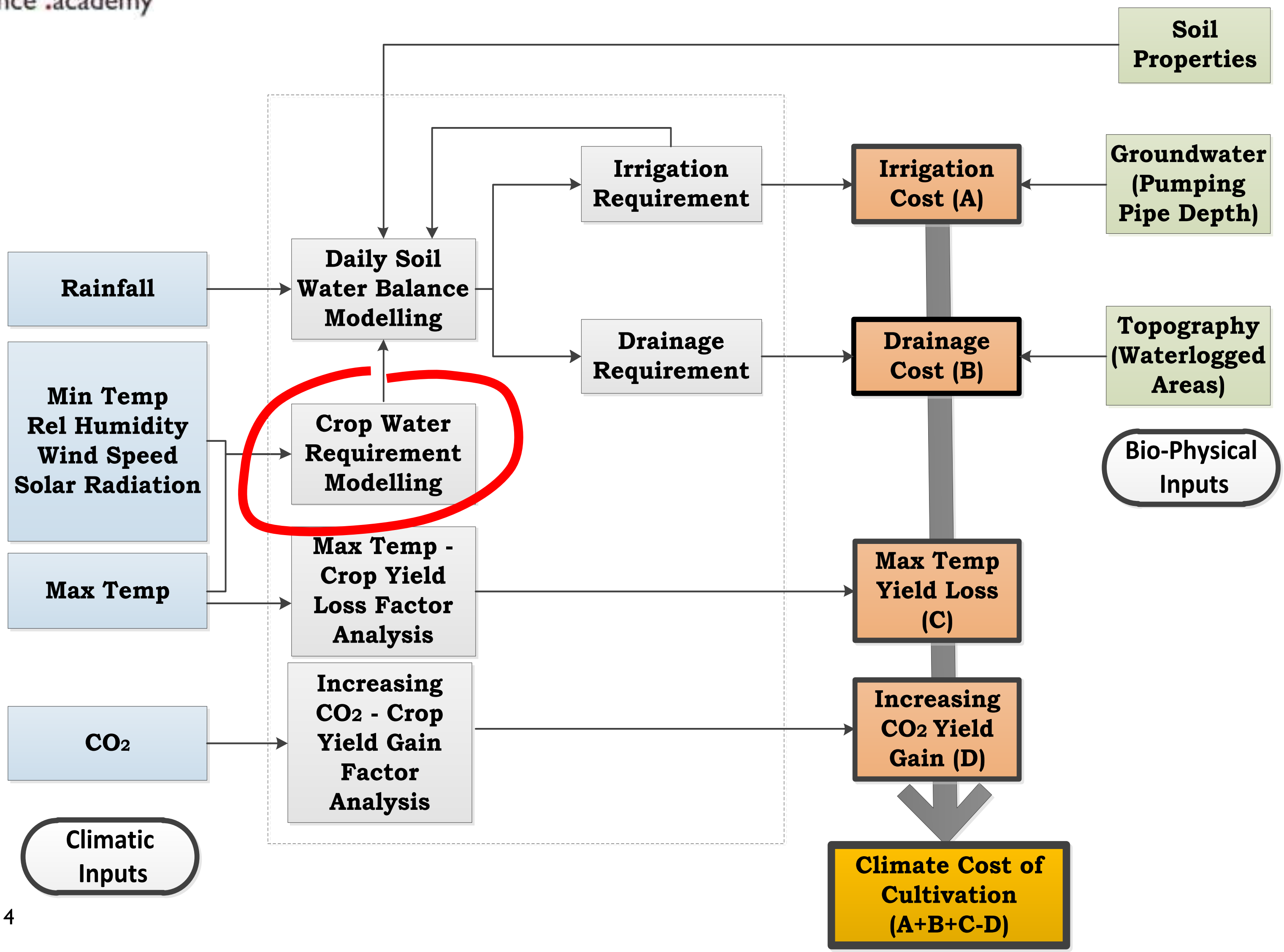
Irrigation

Diesel cost, pumping pipe depth

Irrigation Cost

Drainage Cost

CCC: Schematic Model



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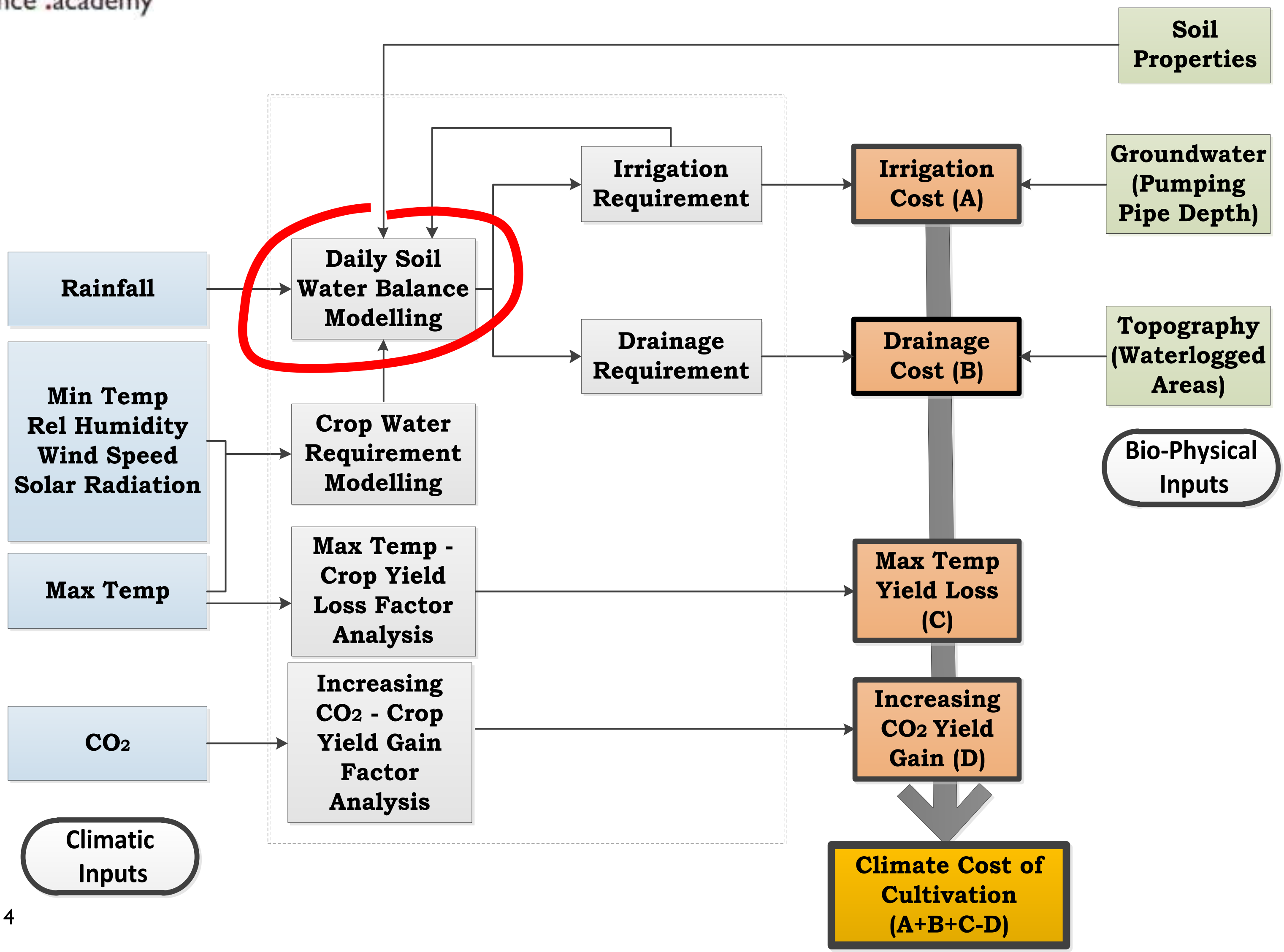
CCC: Methodology: Crop Water Requirement

- Evapotranspiration *ET* : Evaporation + Plant Transpiration
- Potential Evapotranspiration ET_C : *ET* if sufficient water available
  - Crop, season and crop growth stages specific
- Reference evapotranspiration ET_0 : *ET of* reference surface (surface of green, well-watered grass of uniform height, completely shading the ground)

- Crop Water Requirement = ET_C
  - Assumption: no water stress → either sufficient rainfall or irrigation
- $ET_C = ET_0 * K_C$
  - K_C: Crop coefficient factor (Crop, season and crop growth stages specific)
- ET_0 is calculated using F AO Penman-Monteith method
  - Requires e.g. radiation, air temperature, air humidity and wind speed data.

(Allen et al. 1998)

CCC: Schematic Model

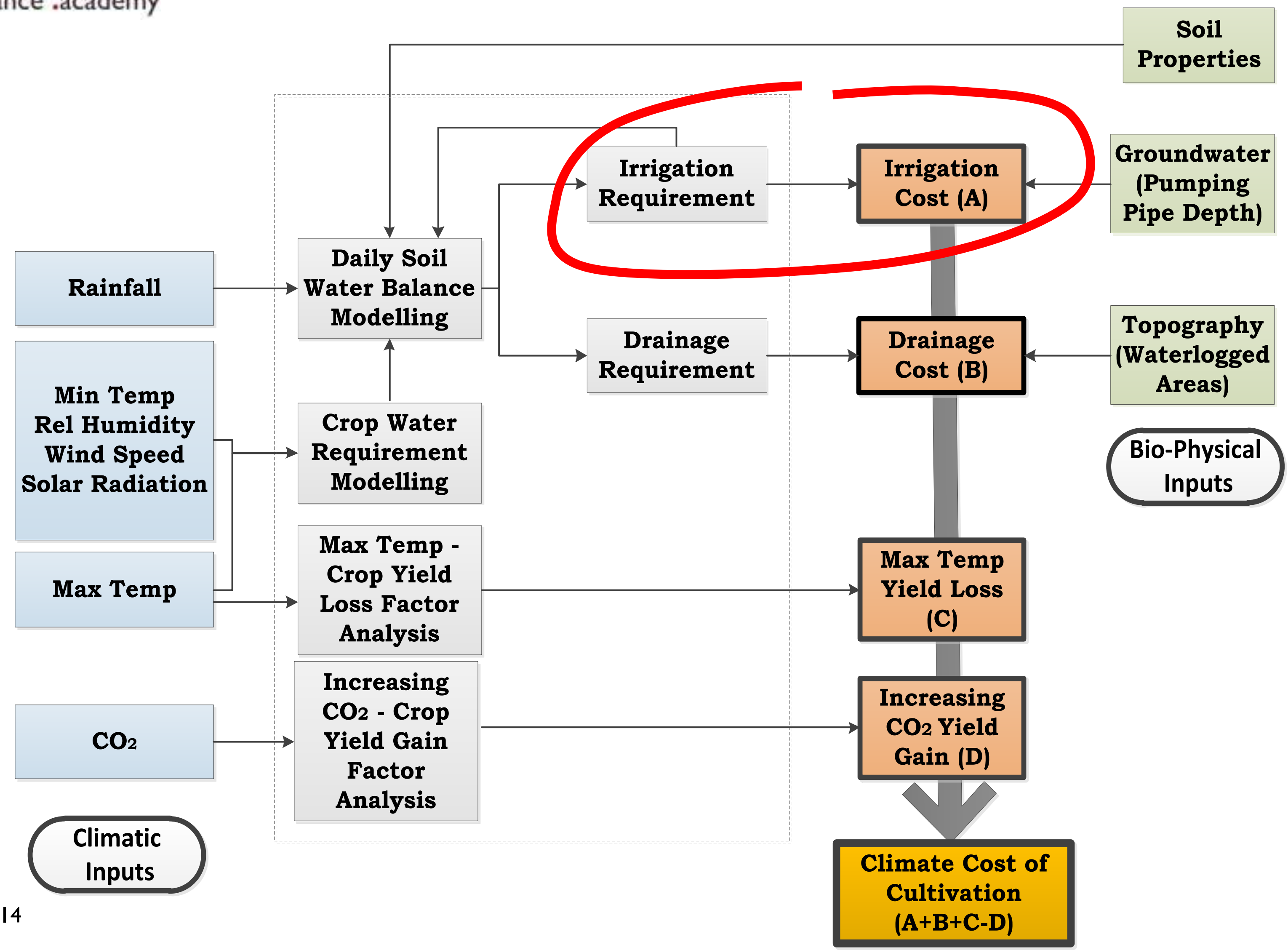


CCC: Methodology: Soil Moisture Modelling (Daily)

- Input (daily data)
  - Crop water requirement (CWR) = ET_C
  - Soil type (determines available water capacity and influences run-off)
  - Growth of plant root (crop specific)
  - critical soil depletion (crop and crop growth stages specific)
  - Irrigation (triggered when critical soil depletion is reached)
  - Initial soil moisture is determined by rainfall prior to studied crop season

- Modelling daily root zone soil moisture depletion (RD), from day to day:
  - RD is increased by: CWR, deep percolation
  - RD is decreased by: (rainfall – runoff)

CCC: Schematic Model



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CCC: Methodology: Irrigation Requirement and Cost

- Irrigation requirement (season)
  - Irrigation whenever critical threshold of soil moisture depletion is reached
  - Irrigation amount depends on level of depletion
  - Aggregate all seasonal (net) irrigation
- Pumping cost
  - Depended on pumping pipe depth and diesel costs
- Irrigation cost (season) = irrigation requirement * pumping costs

→ In this model insufficient rainfall leads to increase in cultivation costs and not yield loss.

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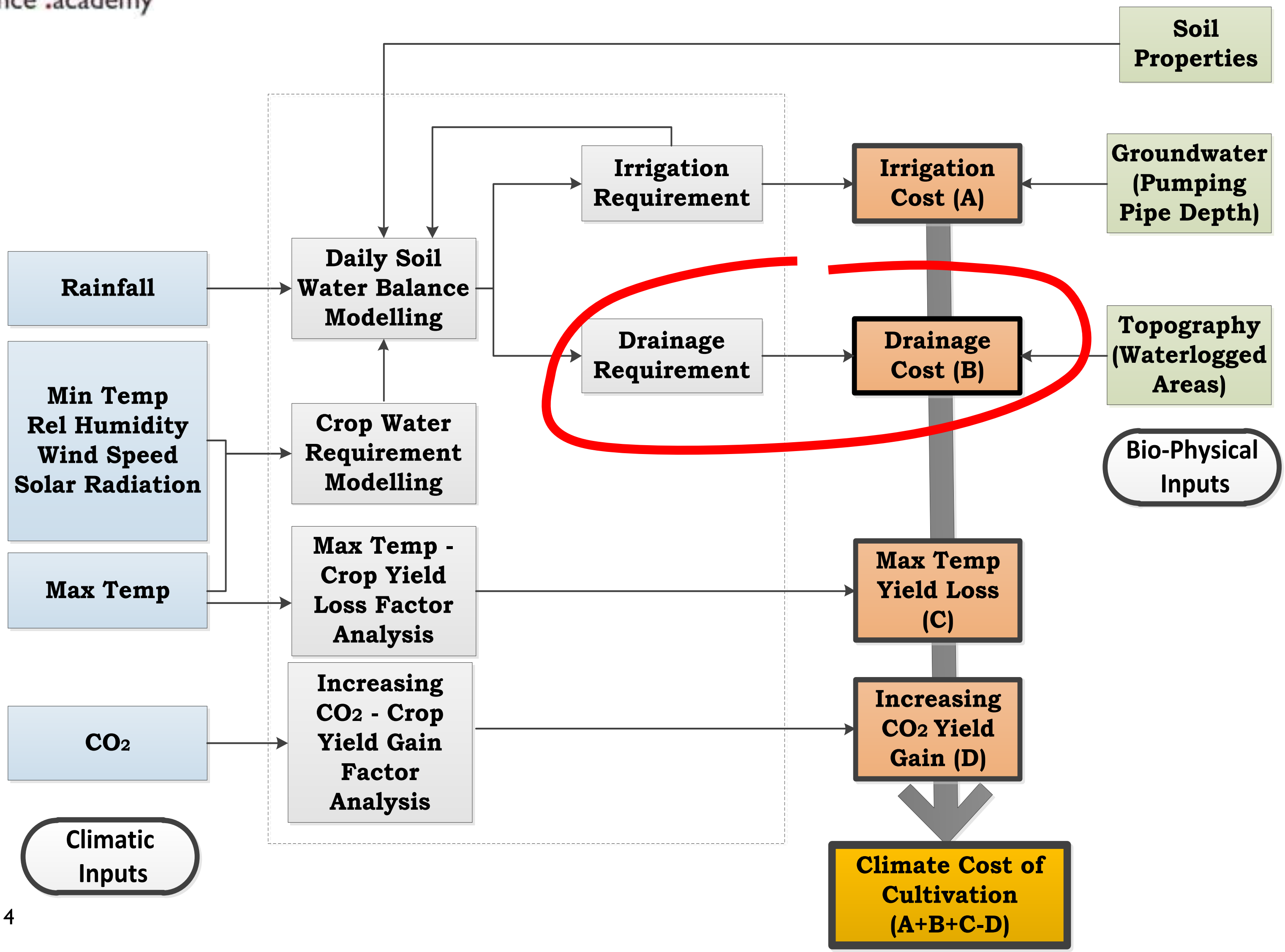
CCC: Schematic Model



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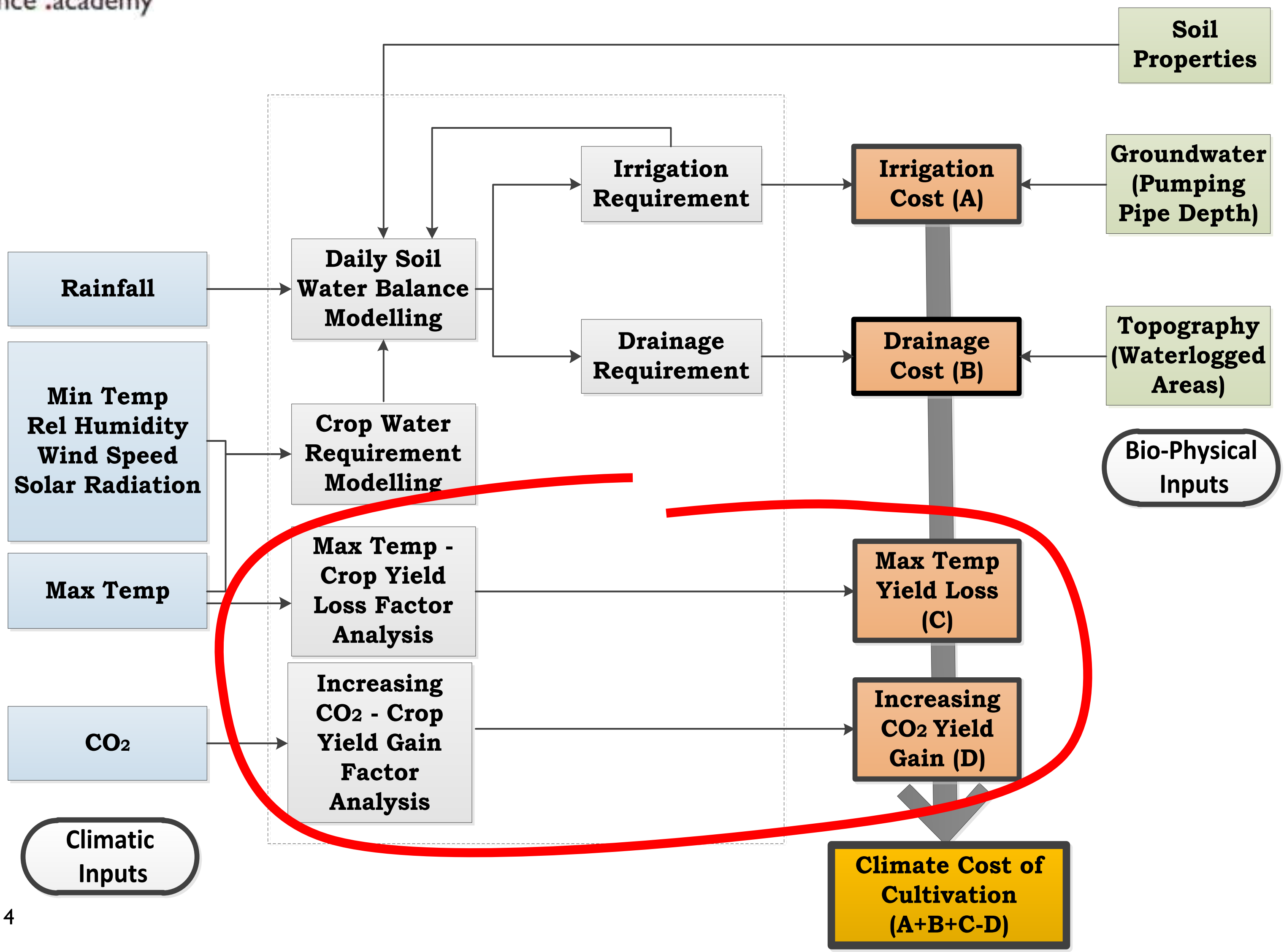
CCC Methodology: Drainage Requirement and Cost

- Yield loss due to excessive rainfall is difficult to model
  - As a proxy we estimate drainage costs
- Risk to waterlogging map
  - Based on wetland maps and elevation map
- Drainage requirement (season)
  - Aggregate all seasonal runoff
  - Weight by risk given by waterlogging map
- Drainage cost
  - Pumping costs
- Drainage cost (season) = drainage requirement * pumping costs

→ In this model excessive rainfall leads to increase in cultivation costs and not yield loss.

CCC: Schematic Model



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CCC: Methodology: High Temperature and CO_2

High max temperature induced yield loss

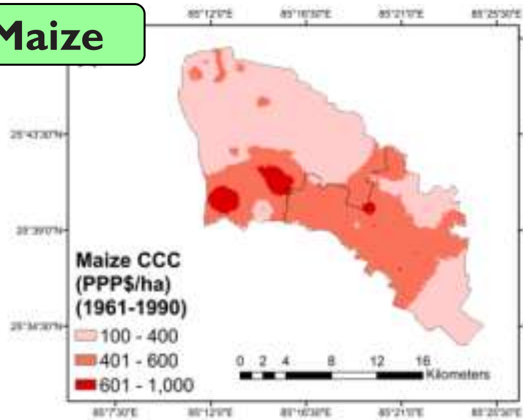
- Agronomic relationship for yield loss due to high temperature
- Sum of daily max temperature above long term average (ignore values below)
  - Wheat: 8% yield loss / 1°C
  - Maize: 6% yield loss / 1°C

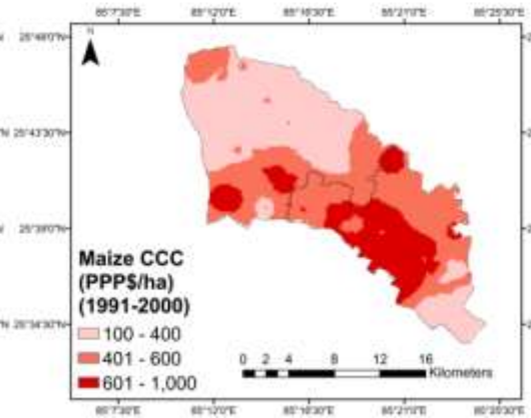
Yield gain due to increase in atmospheric CO_2

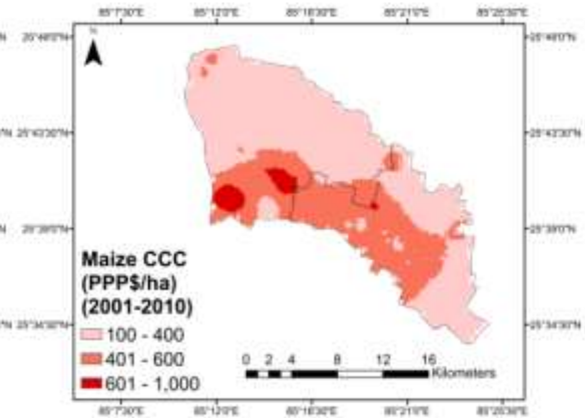
- Agronomic relationship for yield gain due to increase in CO2
  - Wheat: 0.028% yield gain / 1 ppm increase of CO_2
  - Maize: 0.008% yield gain / 1 ppm increase of CO_2

Results: CCC Maps in Study Area

Maize

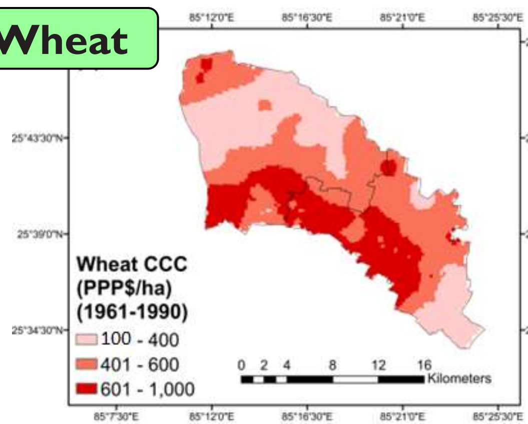


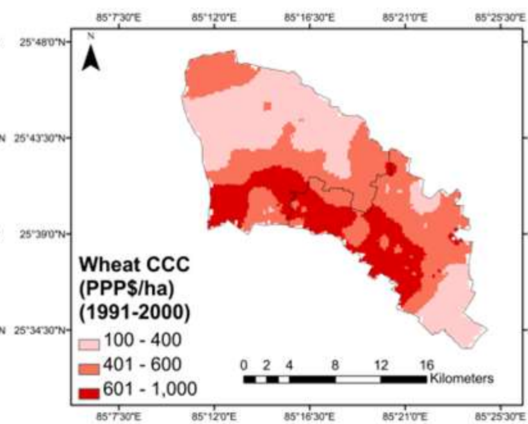


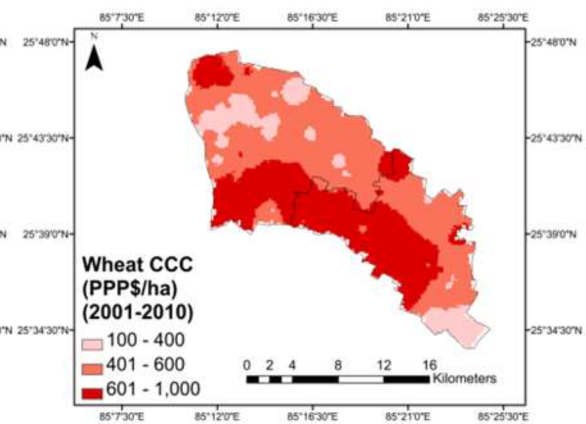


1961 - 1990 | **1991 - 2000** | **2001 - 2010**

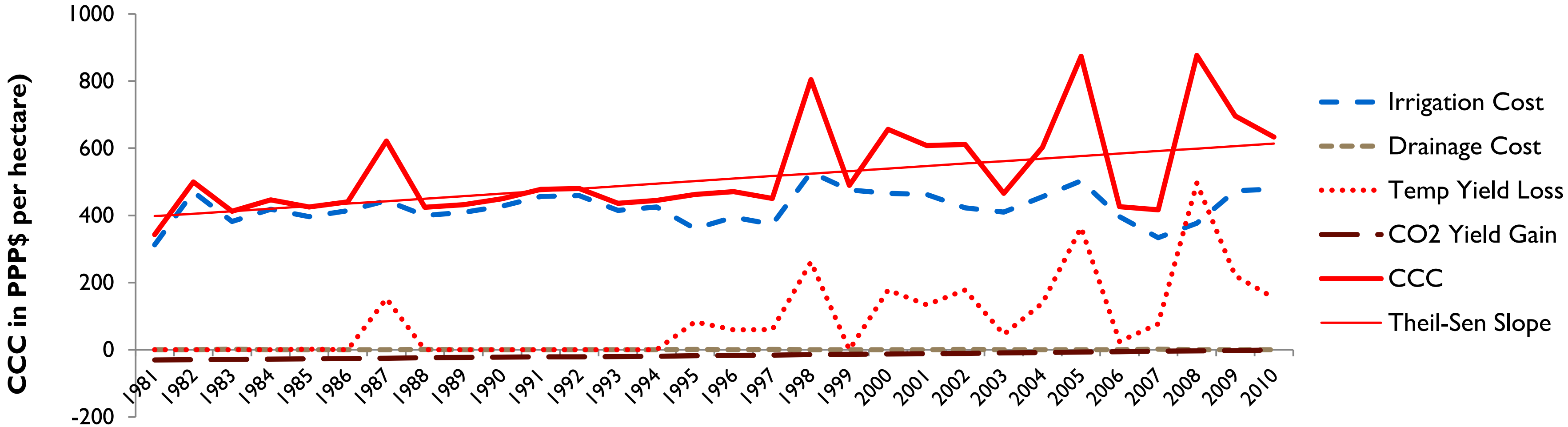
Wheat







Results:
Significant Increase in CCC for Wheat



Significantly increasing trend in CCC - Wheat (99.5% confidence level,) over recent 30 years (two-tailed Mann-Kendall test, $Z_S = 3.25$)

Increase in CCC per year for wheat: 7.45 PPP$/ha or 1.43% relative to1961-1990 average

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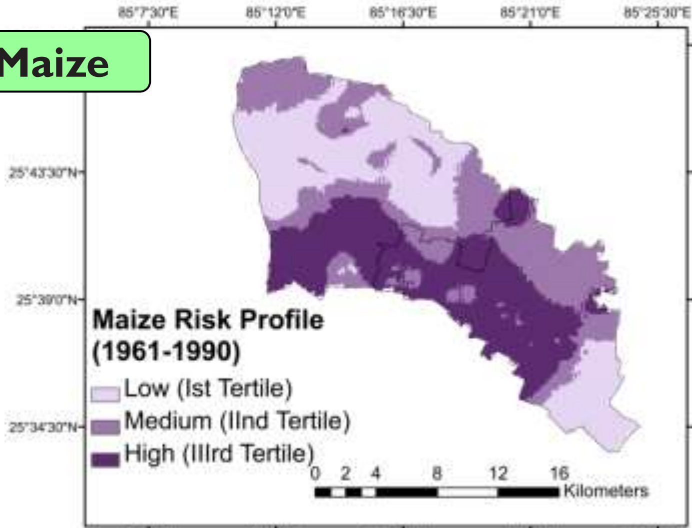
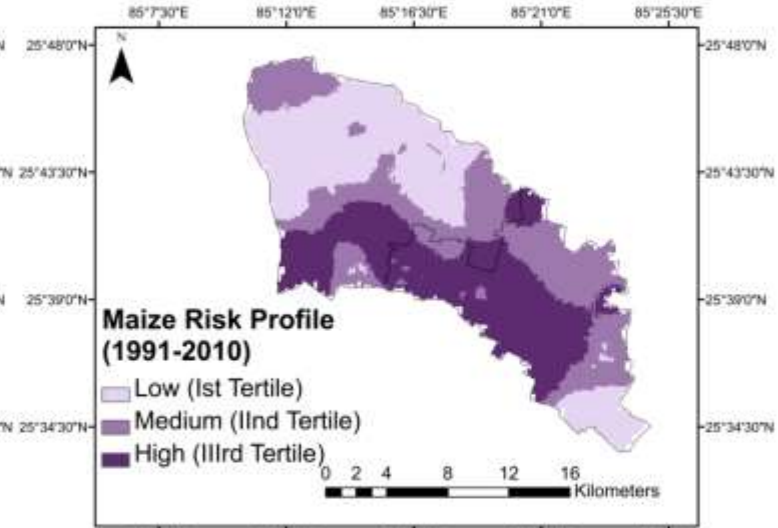
Results: CCC Risk Profiling

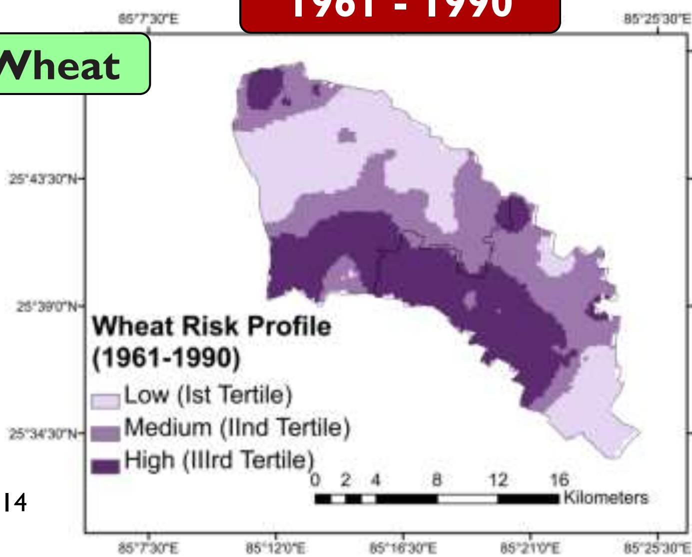
Maize

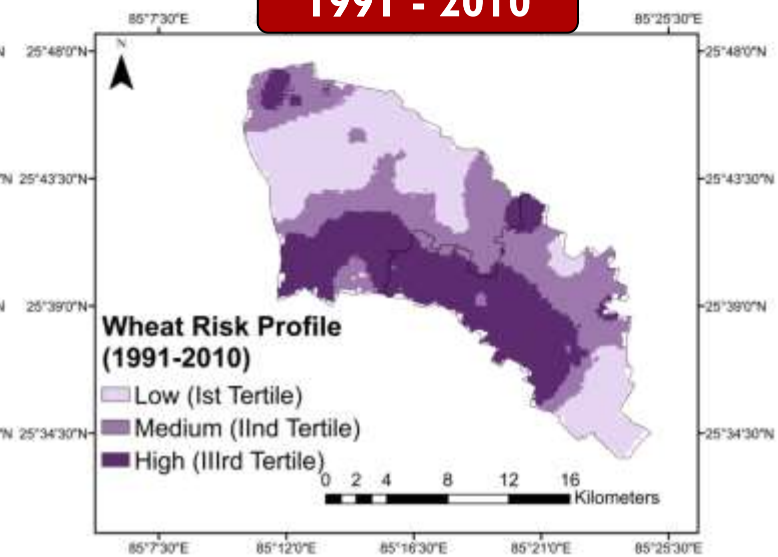




1961 - 1990 | **1991 - 2010**

Wheat





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Way Forward: Mutual-aid to Further Reduce Basis Risk

Farming Risks

Covariate Risks

idiosyncratic Risks

- Community better placed to make individual loss assessment
- Can operate at lower costs

CCC:
Payout on community level

Risk Layering:
- Mutual-aid at local level
- Commercial underwriting at community level

Mutual-aid scheme:
Allocates funds to community members

Reduction of Basis Risk

Way Forward: CCC Index with Community as Aggregator and Stakeholder

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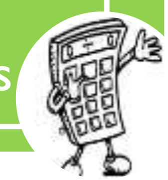
High — Admin Costs — Low

Indemnity-based

Payments based on actual losses

Area yield-based

Payments based on area-yield estimate, e.g. through crop cutting experiments



Weather index-based

CCC + Community as aggregator

Payments to community pool based on CCC index

Low — Basis Risk — High

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Conclusions

- "Climate Cost of Cultivation (CCC)" uniquely captures four aspects of climatic risk: too much water, too little water, too much heat, increase in atmospheric CO_2
- Location-specific bio-physical + climatic parameters

- CCC Applications:
  - Improved weather index-based insurance → CCC index
  - CCC index + mutual-aid

    → **reduced basis risk**

    → **increased demand** for agri insurance among farmers


THANK
YOU!