# Exploring Farmers' perception on climate change and farm-level adaptation by small and marginal farmers in North Bihar, India

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# Rationale and Introduction

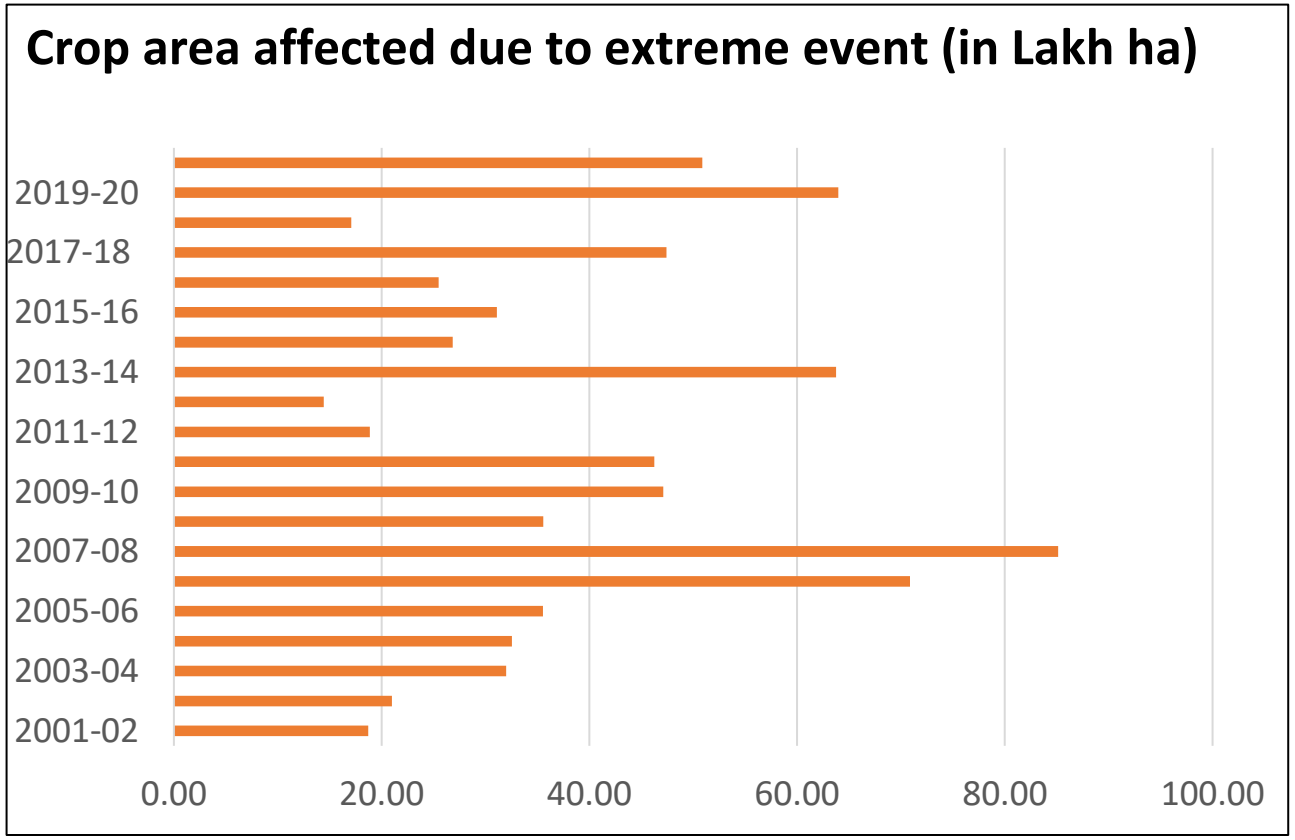



**Fig 1.** Crop area effected by extreme events

*Source: Disaster Management Division, Ministry of Home Affairs*

- Importance of Agriculture
- An average of 30 per cent decrease in crop yields is expected by mid-21st century in the South Asian countries where north Indian states and Bangladesh are highly susceptible due to erratic changes in rainfall and temperature *(World Bank, 2018).*
- Vision 2047: Need to create a resilient and sustainable agricultural sector leveraging cutting-edge technology, data-driven decision-making, and robust adaptation strategies.

# Cont…

- An average of 30 per cent decrease in crop yields is expected by mid-21st century in the South Asian countries where north Indian states and Bangladesh are highly susceptible due to erratic changes in rainfall and temperature *(World Bank, 2018).*

- Comparing to current scenario water use account of agriculture is 70% globally even higher percentage of consumptive water loss due to evaporation loss, the reallocation of water use will be required as much as 25 to 40% for higher productivity particularly in water stressed regions *(World Bank: The impact of irrigation, 2019).*

- 80% of marginal farmers in India affected by adverse climatic events: Report Economic Times : Jun 25, 2024

- Empower farmers with highly accurate and hyperlocal weather forecasts, crop advisories, and risk assessments tailored to their specific needs, ensuring they can thrive amidst the dynamic challenges posed by diverse and unpredictable climate patterns.

**A.** Trend detection analysis of long-term rainfall and temperature data of all districts of the **North Bihar**

**B.** Survey for Identification of Weather extremes associated risk for major crops of **North Bihar**

**C.** Understanding the Farmers perception towards the climate change and the adaptation strategies followed

**D.** Key Outcome and way forward

# Data & Methodology

## ❑ Observed Weather :

Daily gridded maximum temperature at a resolution of 0.5° x 0.5° and rainfall data at 0.25 ° x 0.25° was obtained for the historical period (1970-2020) from IMD.

## ❑ Survey data collection:

Survey was conducted in the study region for **512** farming households. Following variables were included in the study:

a. Socioeconomic and demographic information

b. Weather associated risk for major crops of the area (Rice and Wheat)

c. Farmers perception of climate change

d. Adaptation strategies followed by the farmers in field

- The sample size (n) for the questionnaire survey of was determined using the approach recommended by **Arkin and Colton (1963):**

$$n = \frac{NZ2p(1-p)}{Nd2 + Z2p(1-p)}$$

where, N = total number of households, Z = Z-statistics (i.e., 1.96 at 95% confidence level), P = estimated population proportion (0.05; this maximizes the sample size), and d = error limit of 5%.

- A structured questionnaire was designed with inputs and weights from the scientists of Bihar Agriculture University and KVK East Champaran

- Logistic regression is used to obtain odd ration in the presence of more than on explanatory variable. The odds ratio is the probability of an event happening related to not happening. It is given by Green (2011):

$$\log \frac{Pi}{1-Pi} = \exp(\beta o + \beta i Xi)$$

**Table 1.** Questionnaire Survey used in the study for assessing farmers perception to climate change

| Variables | Description | Data Type |
|---|---|---|
| Age | Age of the farmer | Continuous |
| Education | Education of the farmer divided into 4 category 1. Primary 2. High School 3. Intermediate 4. Graduation or Higher | Continuous |
| Household Size | Total number of family members | Continuous |
| Secondary Occupation | Whether the farmer is having any other source of income | Binary (1,0) |
| Land Ownership | Land owned by the farmer or taken on rent | Binary (1,0) |
| Land Size in Hectare | Total cultivated land of the farmer in Hectare 1.<1 Ha 2. 1- 2 Ha 3. 2-4 Ha 4. >4 Ha | Continuous |
| Irrigation Facility | (Rainfed/Irrigated) | Binary (1,0) |
| **Most effective weather variable of the area for agriculture** | | |
| Dry spell | | Binary (1,0) |
| Flood | | Binary (1,0) |
| Heavy Rain | >64 mm rainfall | Binary (1,0) |
| Heat wave | | Binary (1,0) |
| Cold Wave | | Binary (1,0) |
| Farmers perception on climate change | Whether farmers agree with climate change or not (1 yes 0 No) | Binary (1,0) |

Cont…

| | | |
|---|---|---|
| **Agriculturally important weather variables in which changes observed by the farmers** | | |
| 1. Increase in temperature of Summer ($^0$C) | 1. Yes 2. No 3. Do not Know | Binary (1,0) |
| 2.Increase in temperature of Winters ($^0$C) | 1. Yes 2. No 3. Do not Know | Binary (1,0) |
| 3. Change in monsoon duration | 1. Yes 2. No 3. Do not Know | Binary (1,0) |
| 4. Decrease in monsoon rainfall amount (mm) | 1. Yes 2. No 3. Do not Know | Binary (1,0) |
| 5. Increase in monsoon rainfall amount (mm) | 1. Yes 2. No 3. Do not Know | Binary (1,0) |
| 6. Increase in flood event | 1. Yes 2. No 3. Do not Know | Binary (1,0) |
| 7. Increase in heat wave during March-April | 1. Yes 2. No 3. Do not Know | Binary (1,0) |
| **Adaptation Strategies followed** | | |
| Change in farm level crop practice | Change in crop sowing time | Binary (1,0) |
| | Change in crop variety | Binary (1,0) |
| | Change in cropping pattern | Binary (1,0) |
| Change in farm management practice | Increase/Decrease in irrigation<br>Increase/Decrease in chemicals | Binary (1,0) |

# Results

**Table 2.** Trend analysis of district wise rainfall and temperature

| Districts | | JF | MAM | JJAS | OND | ANNUAL |
|---|---|---|---|---|---|---|
| East Champaran | Rainfall(mm) | -.06* | -0.03 | -1.54* | -.03* | -1.7 |
| | T max ($^0$C) | -0.0005* | 0.0006 | 0.0002* | 0.0003 | 0.001 |
| | T min ($^0$C) | 0.03 | 0.12 | 0.02 | -0.14 | 0.009 |
| West Champaran | Rainfall(mm) | -0.06 | -0.02 | -1.51* | -.03* | -1.4 |
| | T max ($^0$C) | -0.0005 | 0.0006 | 0.0002 | 0.0003 | 0.0002 |
| | T min ($^0$C) | 0.03 | 0.12 | 0.02 | -0.14 | 0.009 |
| Darbhanga | Rainfall(mm) | -.05* | 0.02 | -2.49* | -0.02 | -2.75* |
| | T max ($^0$C) | -0.0005 | 0.0005 | 0.0004 | 0.0004 | 0.0002 |
| | T min ($^0$C) | 0.03 | 0.108 | 0.02 | -0.15 | 0.005 |
| Gopalganj | Rainfall(mm) | -0.06 | -0.05 | -1.3 | -0.003 | -1.38 |
| | T max ($^0$C) | -0.0003 | 0.0008* | 0.0008* | -0.0002* | 0.0003 |
| | T min ($^0$C) | 0.03 | 0.12 | 0.02 | -0.14 | 0.009 |
| Mahbubani | Rainfall(mm) | -0.03 | -0.19 | -2.06* | -0.155 | -2.67* |
| | T max ($^0$C) | -0.006 | -0.0005* | 0.0007 | 0.00001 | .0005* |
| | T min ($^0$C) | 0.03 | 0.14 | 0.02 | -0.15 | 0.004 |
| Samastipur | Rainfall(mm) | -0.03 | -0.19 | -2.23* | -0.07 | -2.67* |
| | T max ($^0$C) | -0.0006 | -0.0006 | 0.0004* | 0.0004 | 0.0002 |
| | T min ($^0$C) | 0.03 | 0.108 | 0.02 | -0.15 | 0.005 |
| Seohar | Rainfall(mm) | -0.09 | -0.17 | 1.2 | 0 | 1.73 |
| | T max ($^0$C) | -0.0005* | -0.0007 | 0.0002* | 0.0004* | -0.00006 |
| | T min ($^0$C) | 0.03 | 0.124 | 0.04 | -0.24 | 0.008 |
| Siwan | Rainfall(mm) | -0.15 | -0.02 | -0.82 | -0.06 | -0.93 |
| | T max ($^0$C) | 0.0004 | 0.0008 | 0.0002 | 0.0005 | -0.000018 |
| | T min ($^0$C) | 0.04 | 0.124 | 0.02 | -0.14 | 0.008 |
| Vaishali | Rainfall(mm) | -.05* | -0.07 | -1.79 | 0.043 | -1.92* |
| | T max ($^0$C) | -0.0005 | 0.0007 | 0.0002* | 0.0003 | 0.0001 |
| | T min ($^0$C) | 0.03 | 0.115 | 0.02 | -0.12 | 0.02 |
| Muzaffarpur | Rainfall(mm) | -0.05 | -0.16 | -1.13 | 0.005 | -1.1 |
| | T max ($^0$C) | -0.0005 | 0.0006 | 0.0003* | 0.0005 | -0.0003 |
| | T min ($^0$C) | 0.03 | 0.117 | 0.02 | -0.15 | 0.006 |

**Table 3.** Descriptive statistics of demographic and socioeconomic characteristics of the surveyed household.

| | **Mean** | **Min** | **Max** | **Std Dev** |
|---|---|---|---|---|
| **Age** | 45 | 26 | 66 | 4 |
| **Household Size** | 9 | 4 | 12 | 1 |
| **Education in (%)** | **High School and Below (%)** | **Intermediate** | **Graduation and above** | |
| | 21.6 | 42.5 | 34.9 | |
| **Secondary Source of Income in (%)** | **Only Farming** | **Farming and Livestock** | **Farming and Job** | |
| | 85 | 15 | 0 | |
| **Land Ownership** | **Yes** | **No** | | |
| | 81 | 19 | | |
| **Land Size in (%)** | **<1 Ha** | **1-2 Ha** | **2-4 Ha** | **>4 Ha** |
| | 57 | 29 | 13 | 5 |
| **Irrigation Facility** | **Irrigated** | **Rainfed** | | |
| | 69 | 31 | | |

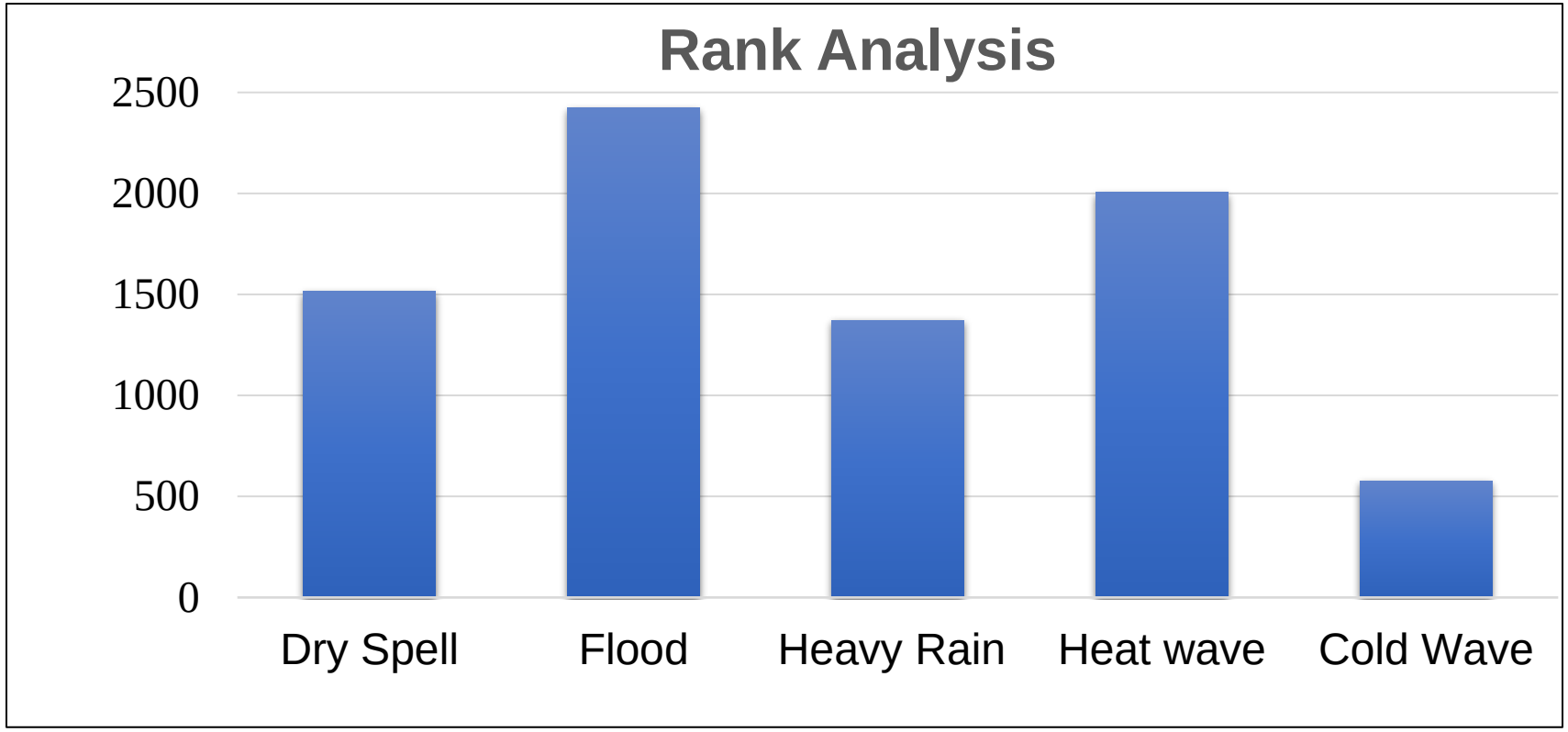



**Fig 2.** Rank analysis of extreme weather evens affecting agriculture

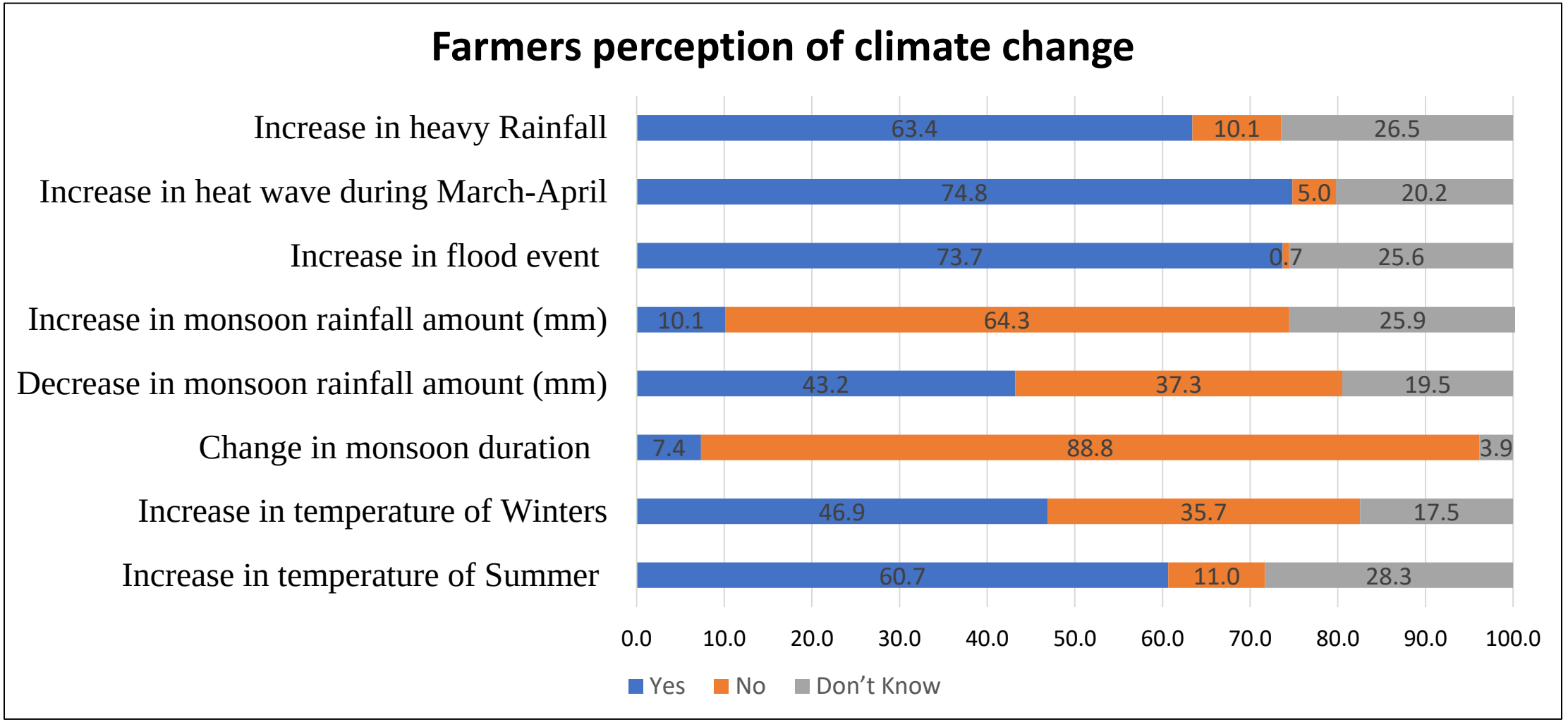



**Fig 3.** Farmers' Perception of Climate Change Impacts on Agriculture

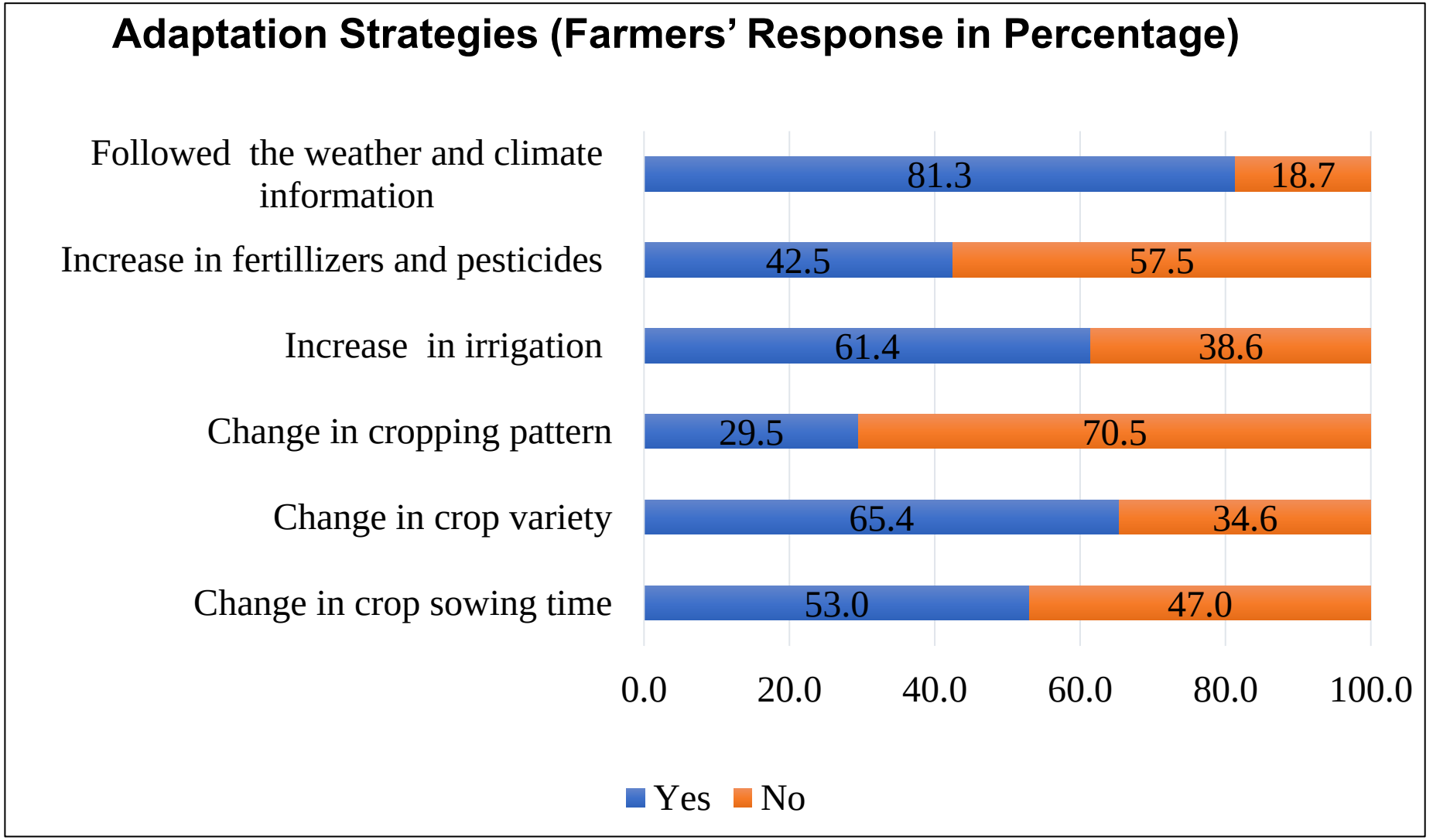



**Fig 4**. Farmers' Adaptation strategy

# Relation between Adaptation strategy and Climate Change perception of farmers

**Change in Sowing Time :**
Changes in summer and winter temperatures , Decrease in monsoon rainfall, Increase in heat waves.

**Changes Crop Variety:** Change in duration and amount of monsoon rainfall. In both cases, an odd ration greater than one indicates that a change in both variables leads to an increase in crop variety.

**Change in cropping pattern:** Least accepted adaptation strategy; it also has a nonsignificant p value with all the independent variables.

**Irrigation application:** Temperature increase, Monsoon deficit and heat wave.

**Use of weather information:** With all the variables

# Key Outcomes

- The observed rainfall trend in all 11 districts of the North West Alluvial Plain Zone for the period 1970–2015 is decreasing with 1.7, 2.23, 2.06, and 2.11 in Sitamarhi, Samastipur, Madhubani, and Darbhanga, and 1.5 in East and West Champaran respectively.

- Non significant increasing trend of Maximum temperature in March, April and May.

- Farmers realizations of climate change in the study area is only 57–59 percent, with maximum percentage of Heavy rain.

- As per the farmers Flood> Heat wave> Dry spell>Heavy Rain is the major yield reducing variable.

- Major adaptation strategy followed by farmers are Weather and climate information utilization>Change in crop variety>Irrigation Inc> Change in sowing time.

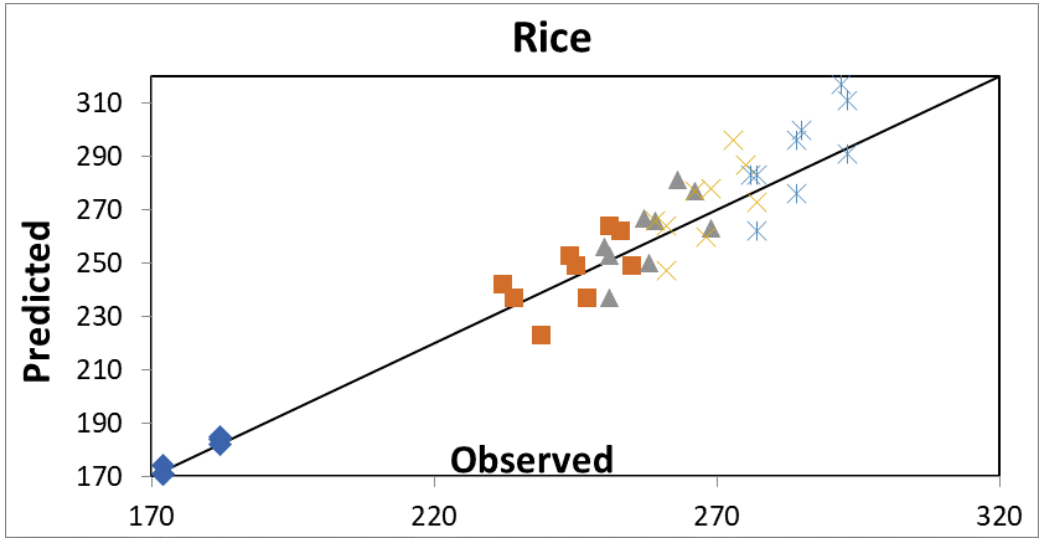
- Weather associated risk for major crops:

**Rice:** Heavy rainfall during the flowering and grain filling stages of the crop followed by dry spells at the vegetative stage.

**Wheat:** terminal stress followed by hail storm as major wheat yield reducing factor.

## Way Forward:
## 1. Predicting the Phenological Stage of the Crop

$$\text{GDD} = \frac{(Tmax - Tmin)}{2} - Base\ Tempertaure \text{ of crop}$$



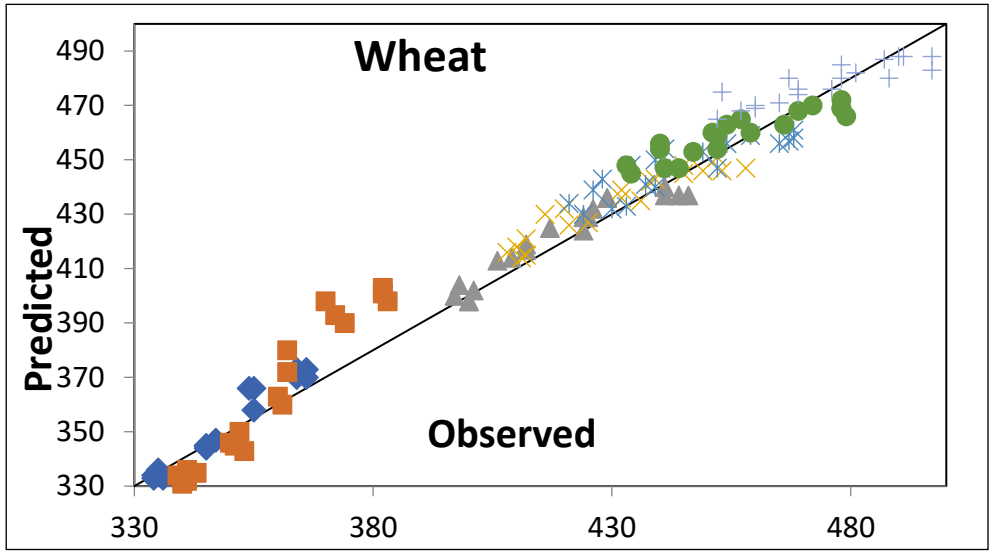




**Fig 5.** Phenology Prediction of major crop of the study area

| Stage | Mean-Observed | Mean-Predicted | RMSE | D-Index | $R^2$ | MAPE |
|---|---|---|---|---|---|---|
| Stage-1 | 171 | 173 | 4.49 | 0.77 | 0.88 | 0.63 |
| Stage-2 | 251 | 253 | 5.71 | 0.72 | 0.89 | 3.64 |
| Stage-3 | 270 | 272 | 5.17 | 0.79 | 0.87 | 3.52 |
| Stage-4 | 280 | 283 | 5.59 | 0.74 | 0.85 | 3.77 |
| Stage-5 | 299 | 301 | 5.73 | 0.73 | 0.86 | 3.20 |

| Stage | Mean-Observed | Mean-Predicted | RMSE | D-Index | R2 | MAPE |
|---|---|---|---|---|---|---|
| Stage-1 | 331 | 334 | 2.93 | 0.96 | 0.97 | 0.93 |
| Stage-2 | 347 | 350 | 2.67 | 0.89 | 0.95 | 3.13 |
| Stage-3 | 402 | 404 | 2.42 | 0.97 | 0.91 | 1.14 |
| Stage-4 | 416 | 419 | 3.64 | 0.94 | 0.90 | 1.28 |
| Stage-5 | 428 | 431 | 4.68 | 0.88 | 0.77 | 1.63 |
| Stage-6 | 439 | 442 | 4.77 | 0.86 | 0.84 | 1.66 |
| Stage-7 | 459 | 462 | 4.52 | 0.82 | 0.81 | 1.64 |

# Crop wise root zone soil moisture estimation for quantification of water stress

**3a.**Estimation of Reference Evapotranspiration

**3b.** Estimation of Actual Evapotranspiration

**3c.** Root zone soil moisture estimation

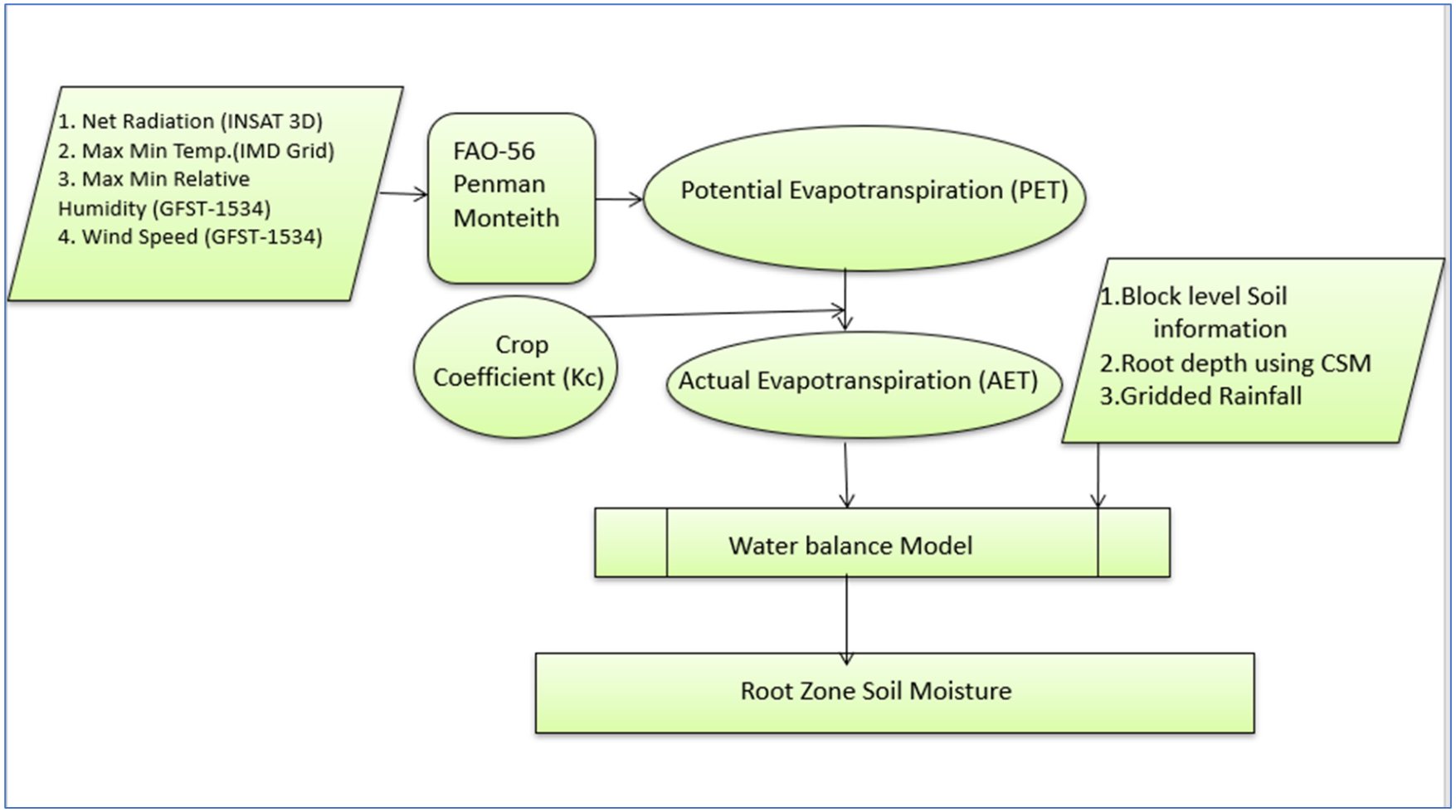



**Fig 6.** Methodology for Soil Moisture estimation

# Monthly distribution of estimated PET 2021

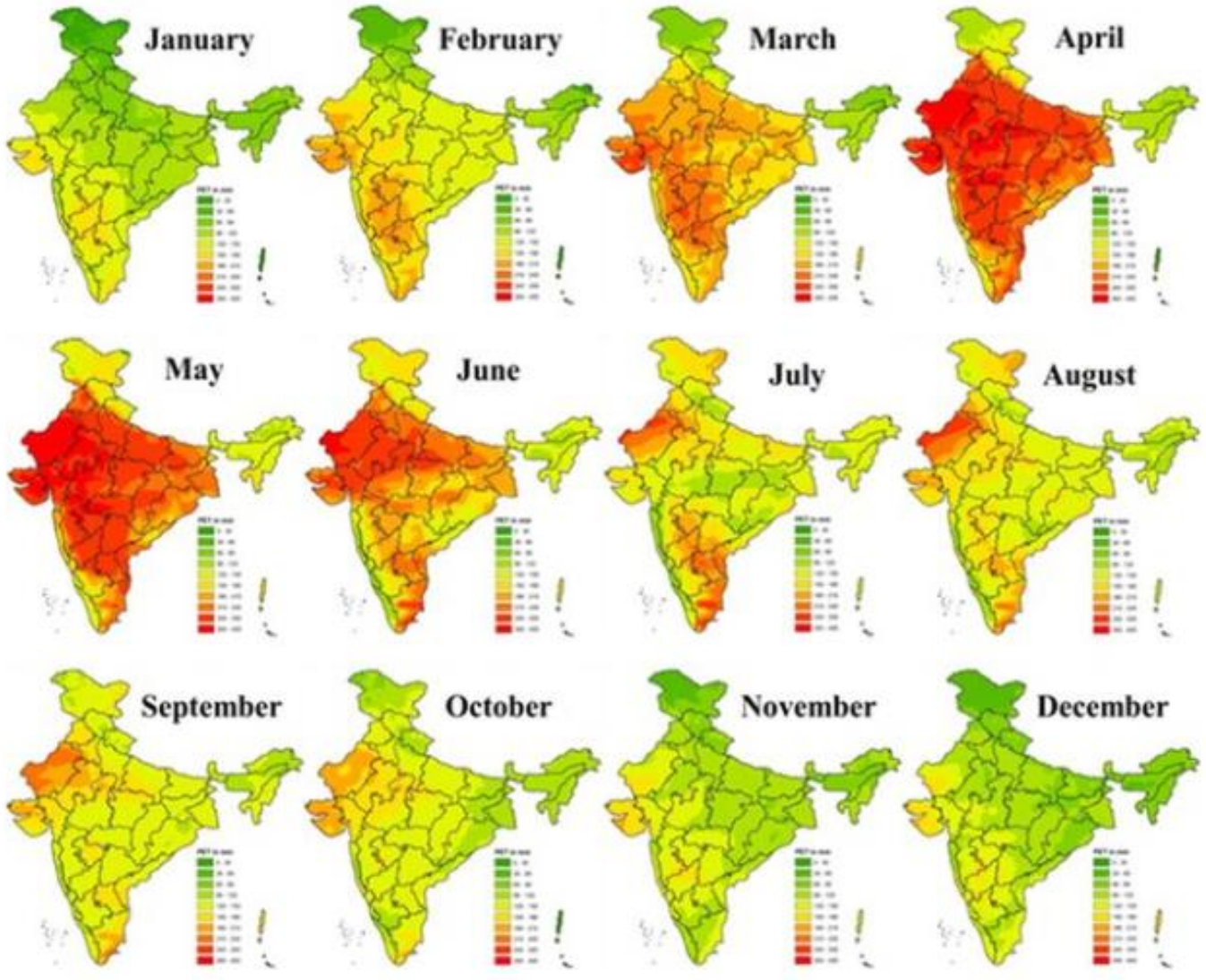



**Fig 10.** Spatiotemporal distribution of monthly PET

# Estimated PET validation

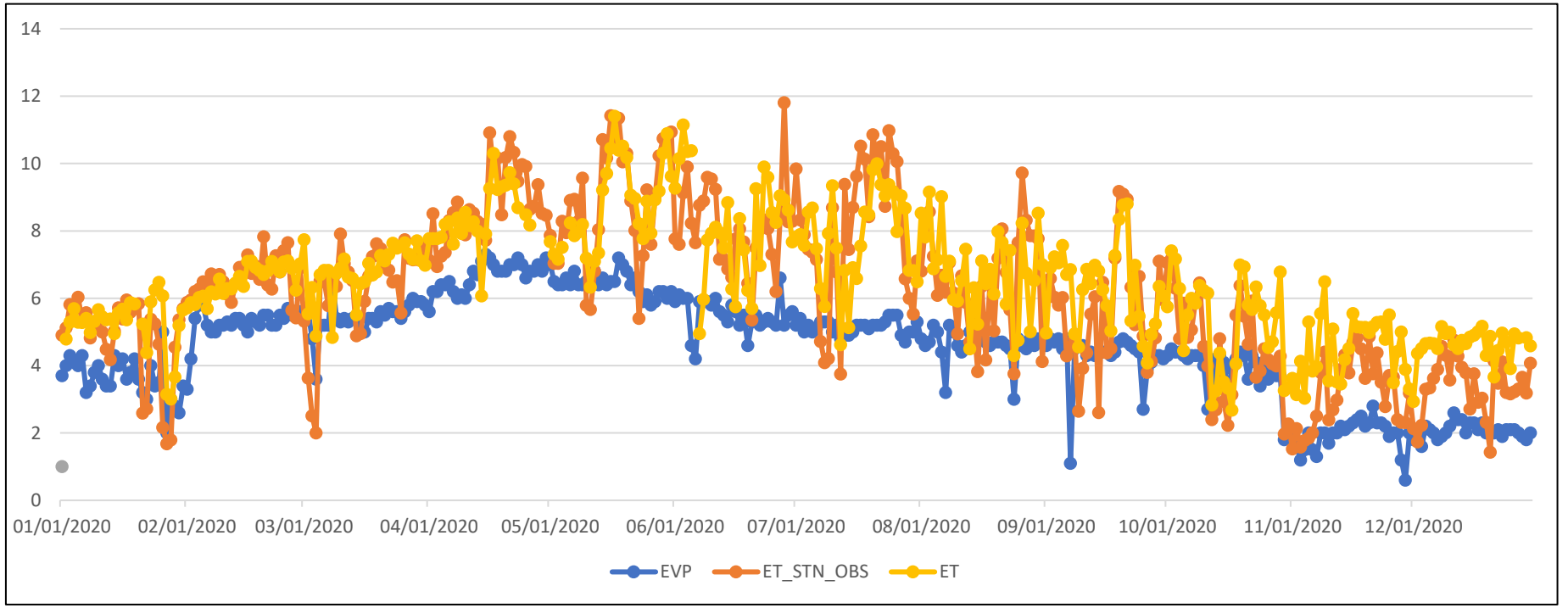



**Fig 11.** Estimated PET Validation

- CC between Station data estimated ET and Grid data estimated ET: **0.814**
- Mean absolute error: **1.075 mm**
- CC between Pan Evaporimeter grid data estimation: **0.77**

## ❑ Crop Data

- The major crops i.e **Rice** and **Wheat** are selected to perform the simulation and provide the information of relevant management practice to be followed by the farmers.
- For running the model following data set were collected with the help of Krishi Vigyan Kendra of East Champaran:

### i. Crop attributes

Planting date, Anthesis date, Physiological maturity date, Grain yield at maturity (kg/ha).

### ii. Management Practices

Planting depth, Row spacing & Plant population at seeding, Plant method & distribution, Fertilizer- amount, type and time, Irrigation- amount, type and time.

### iii. Soil Parameters of all 27 blocks

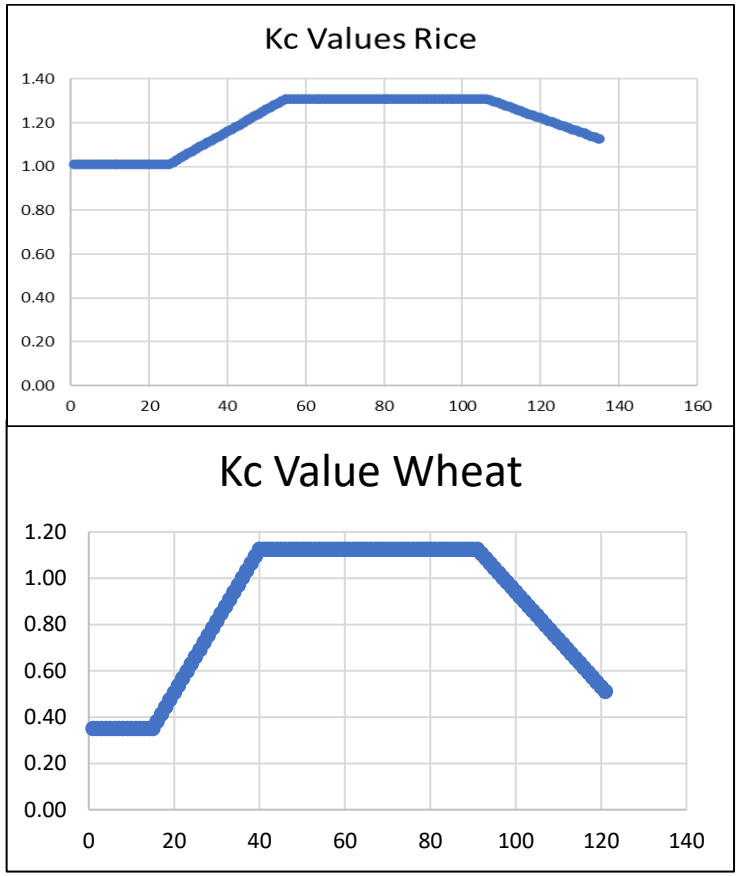
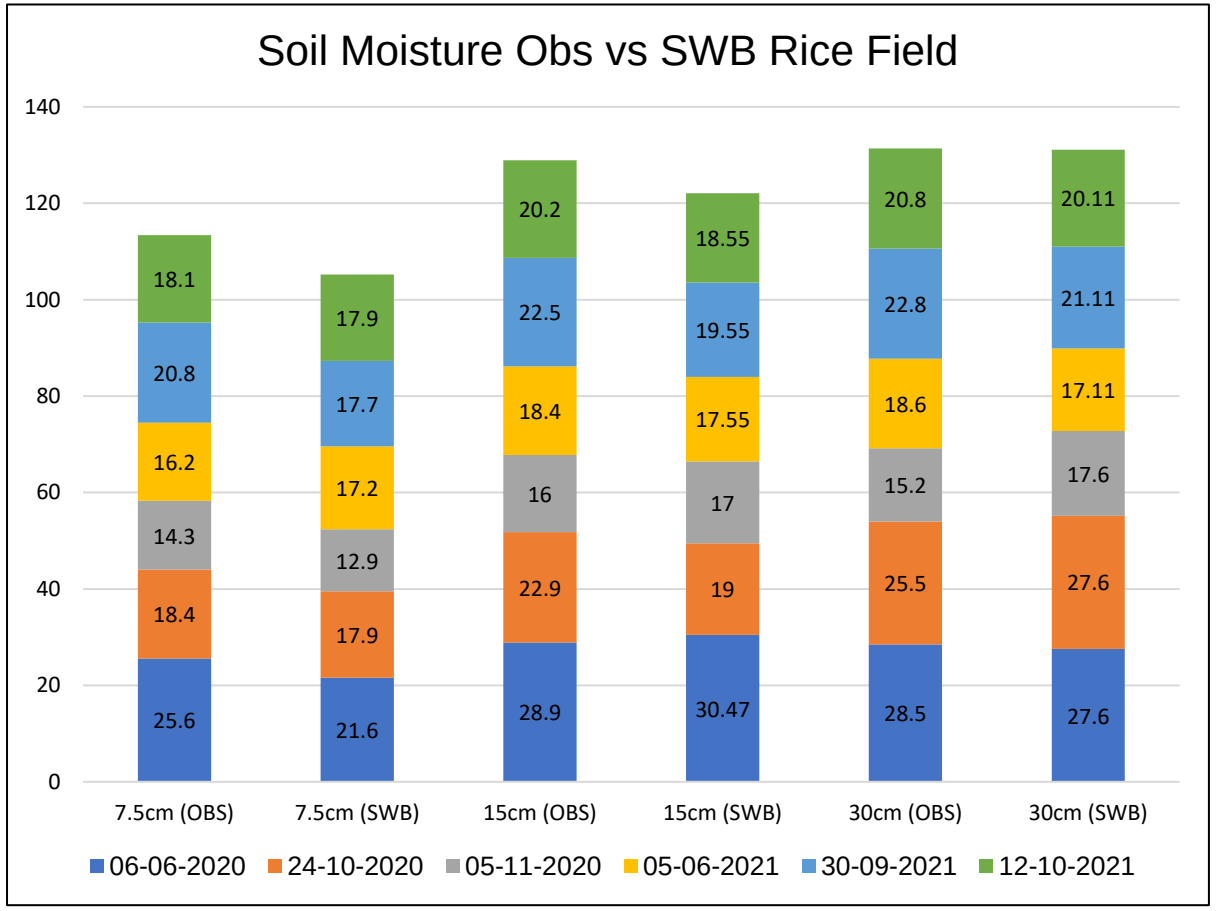



**Fig 12.** Estimated Kc Values of Rice and Wheat

**Rice:** Rajendra Sweta and Sahbhagi of approx. 130-135 days
**Wheat:** HD-2733, PBW-343, HD-2967, HD 2824 of 125-130 and 140-150 days.
Kc Formula Reference: FAO Irrigation and drainage paper 56

# Model performance in Sandy loam soil with Rice and Wheat Crop



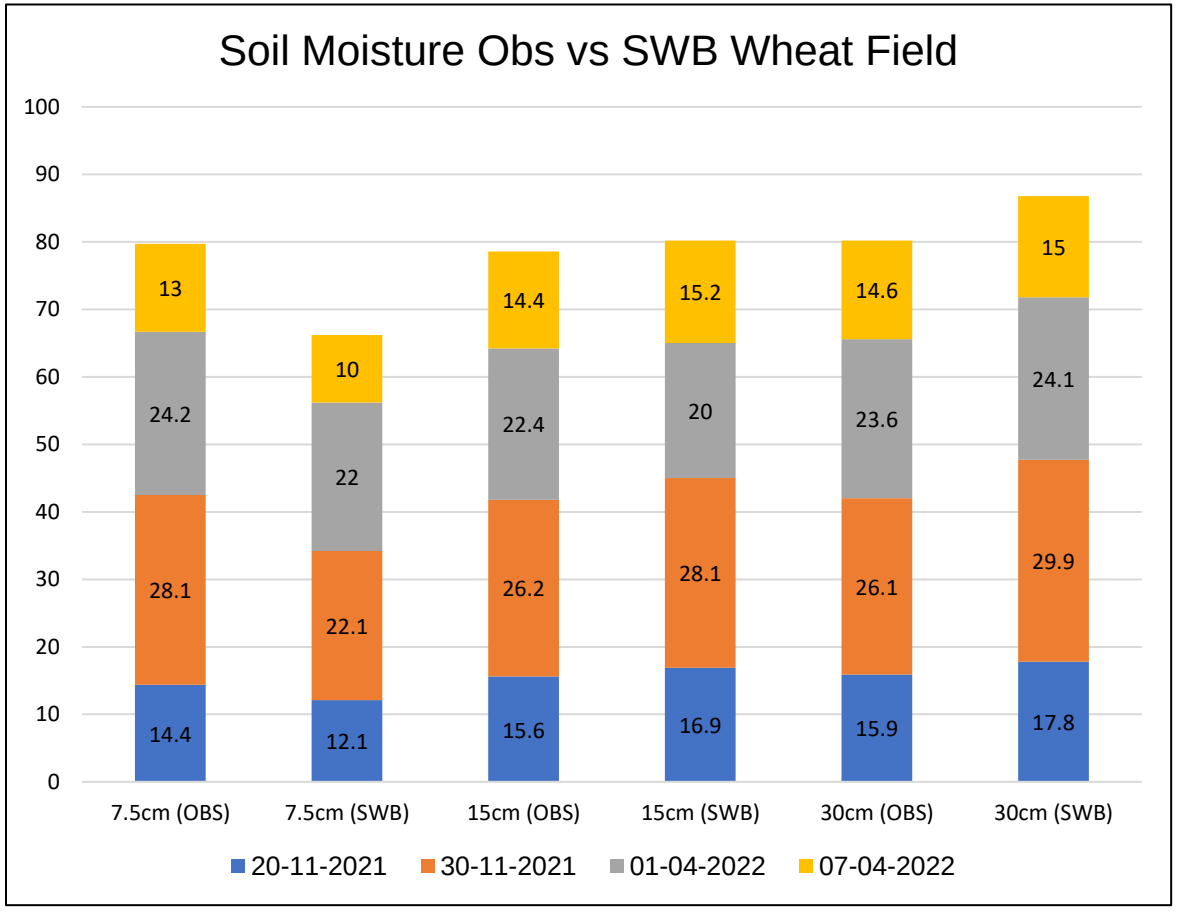




**Fig.** Estimated soil moisture for Loamy soil

*Thank You*