GROWING MORE WITH LESS: **SMART TECHNOLOGY SOLUTIONS TO FEED THE WORLD**

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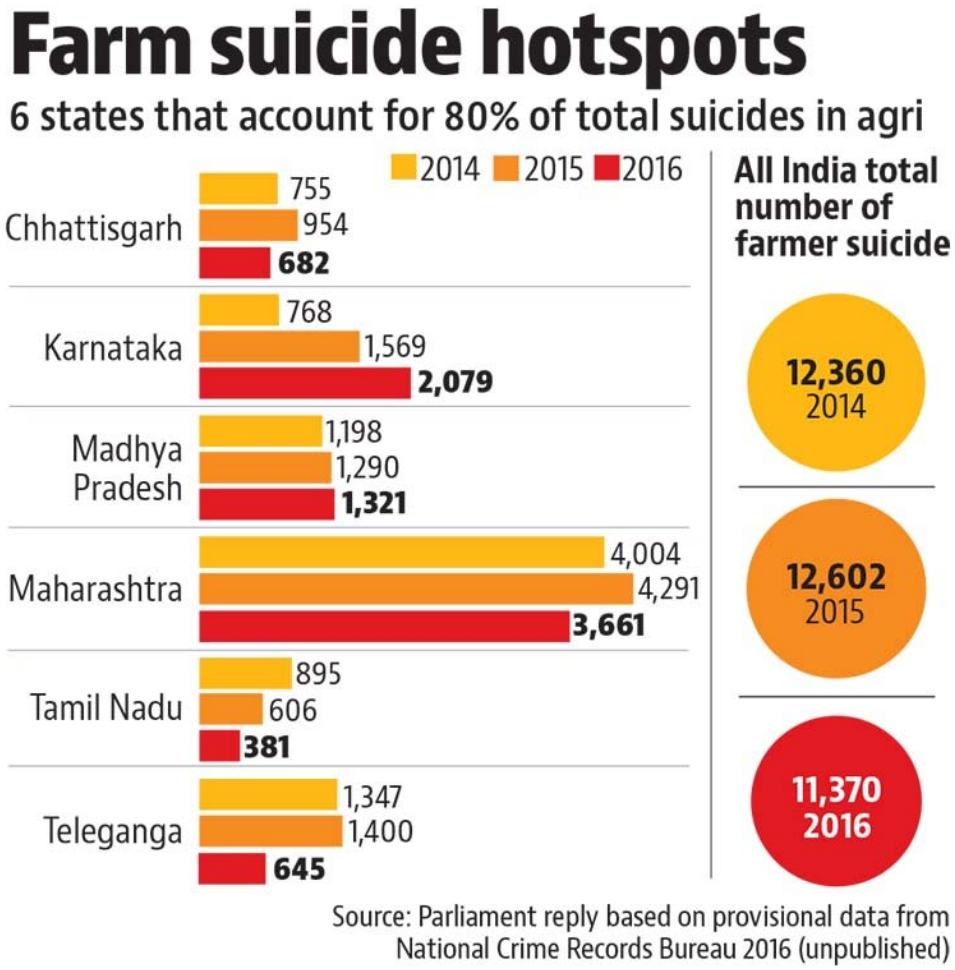
University of Washington

October 10 2019

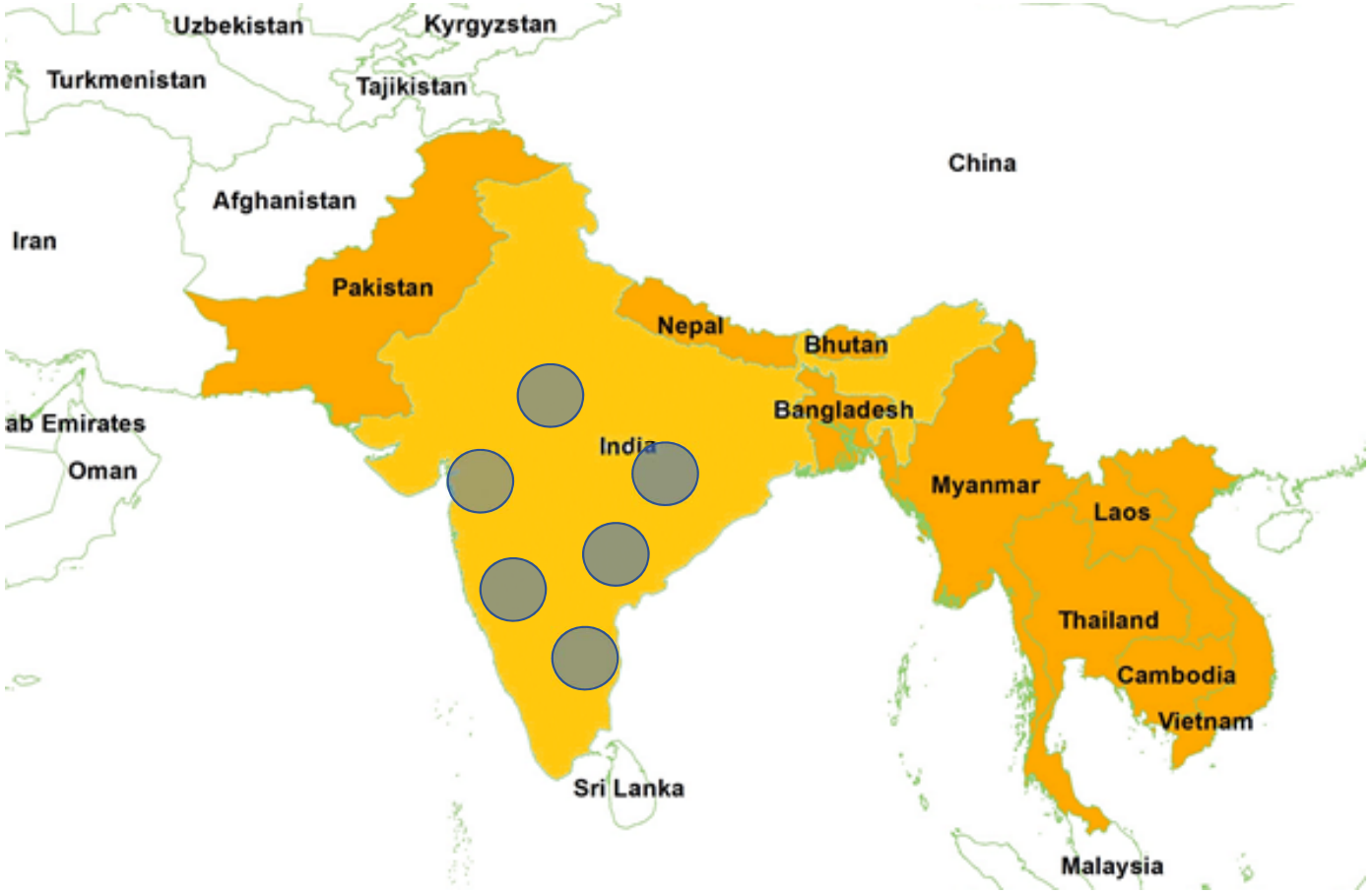
BACKGROUND: FARMER SUICIDES



Total reported suicides since 1995 nearly 300,000

(Source: National Crime Records Bureau, India)

BACKGROUND: FARMER SUICIDES



20TH CENTURY FAMINES IN ASIA

(*THAT COULD HAVE BEEN AVOIDED WITH BETTER ACCESS TO INFORMATION)*

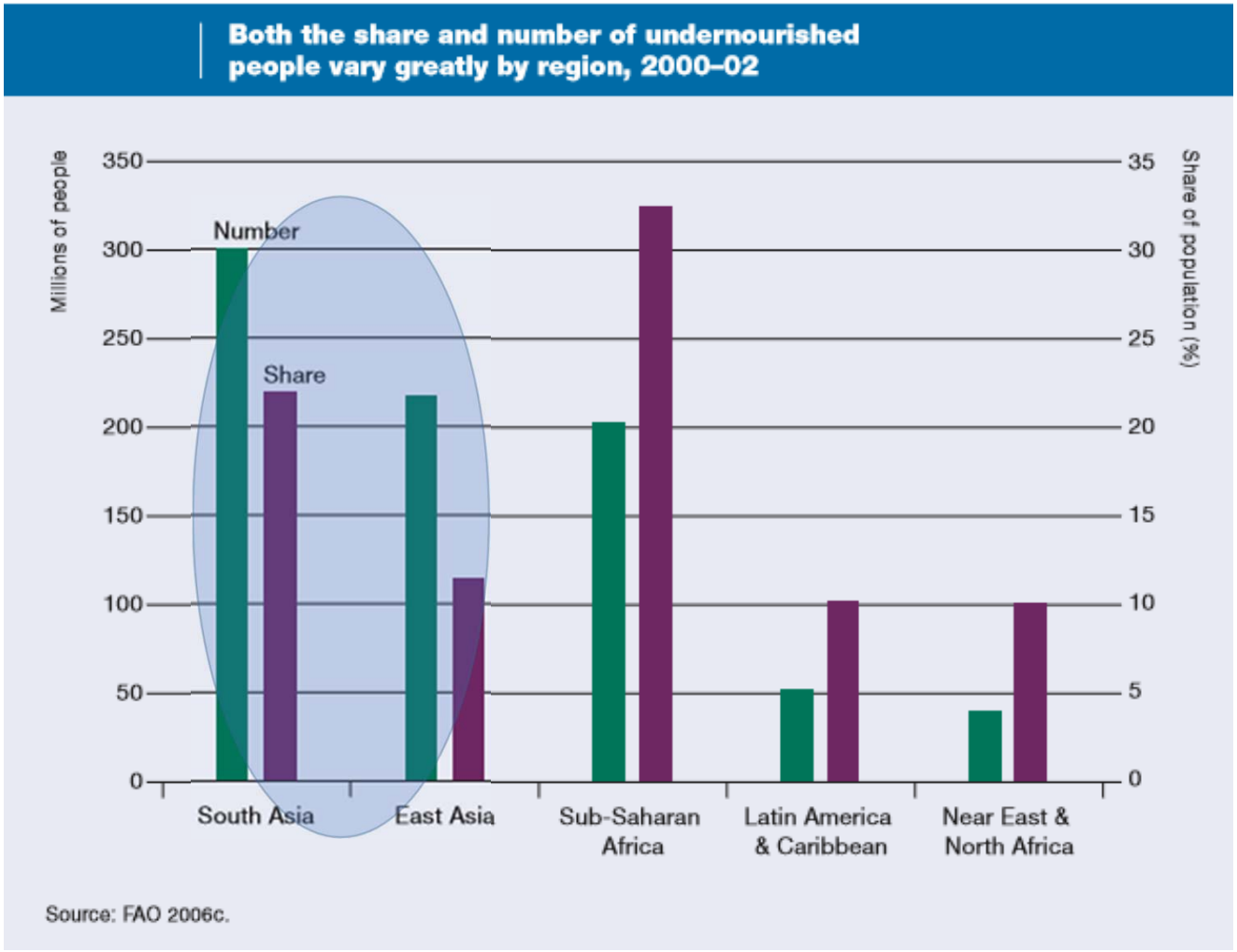
1943 Bengal Famine; 1-2 million death

Source: Historical Archives, Kolkata

1974 Bangladesh Famine; 24,000 death
(Source: ELCA Archives; BDnews24.com)

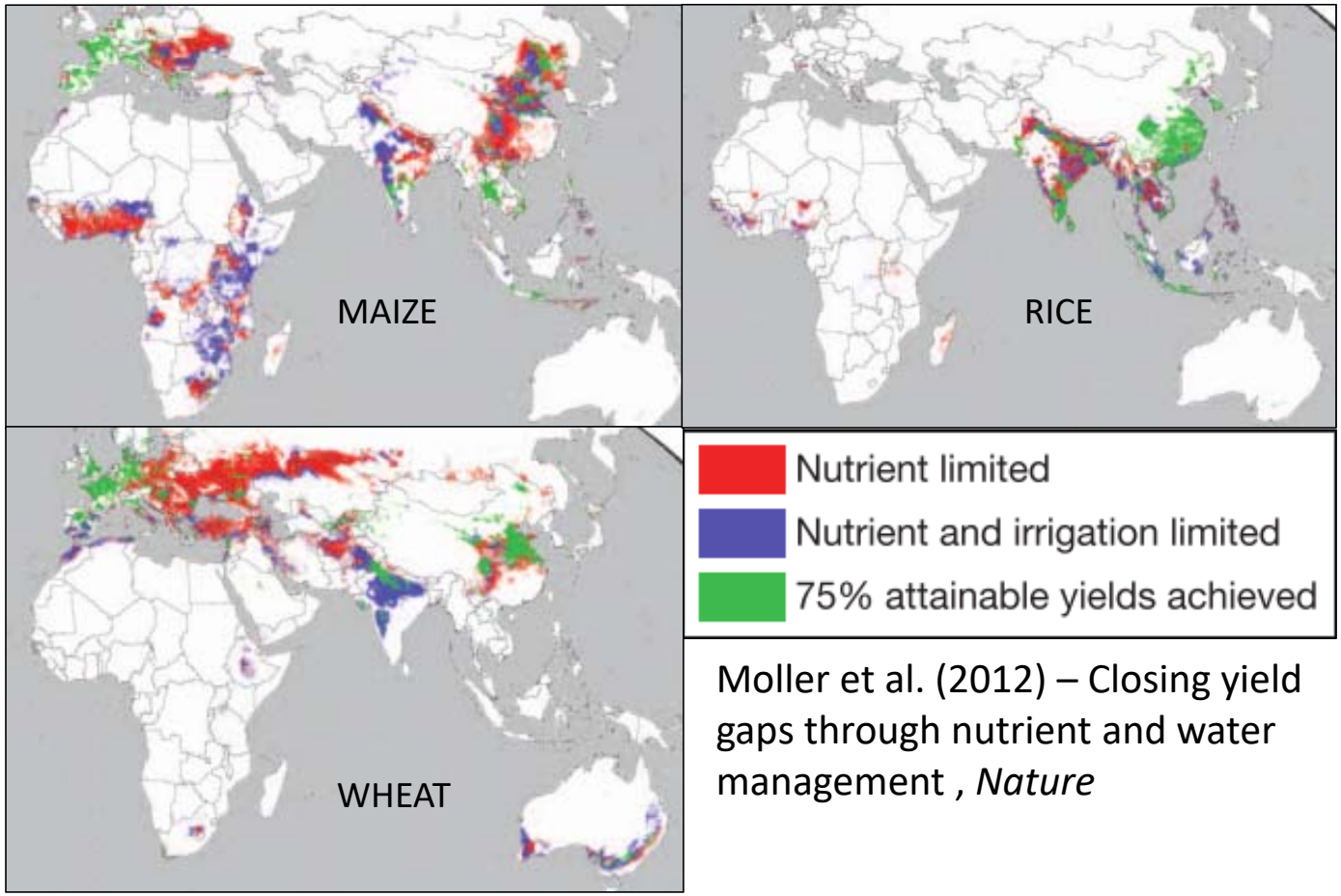
THE UNDERNOURISHED OF ASIA

Number of Undernourished People (millions)



% of total Undernourished People

WHERE ARE WE IN FOOD PRODUCTION NOW?



Moller et al. (2012) – Closing yield gaps through nutrient and water management , *Nature*

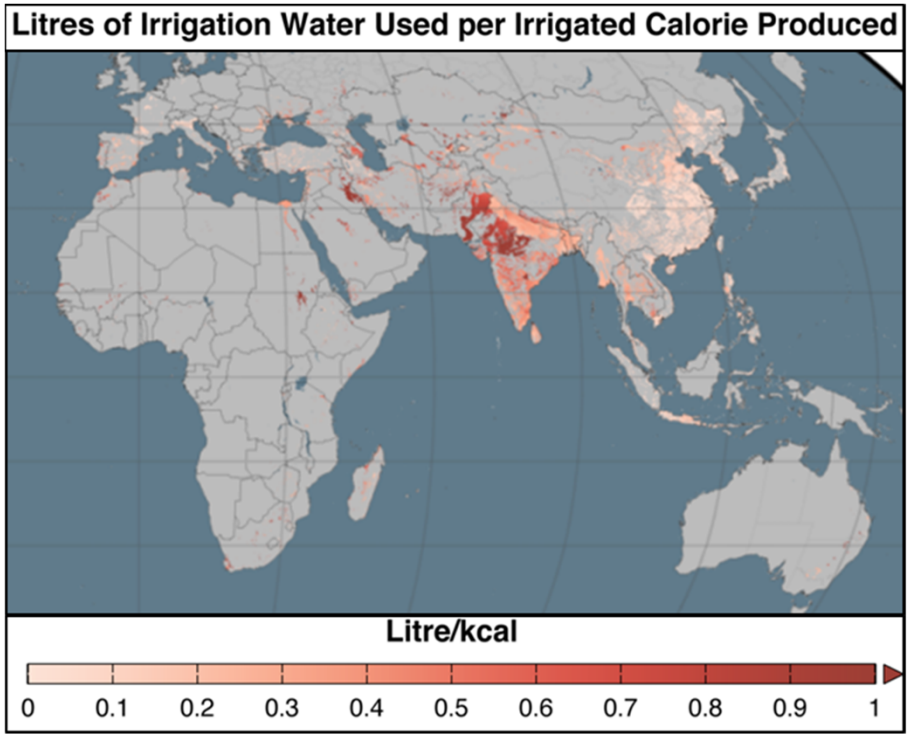
AVERAGE WATER USE FOR CEREAL CROPS TODAY

China: 0.82 kg (food)/ m^3 of water

India: 0.39 kg (food)/ m^3 of water

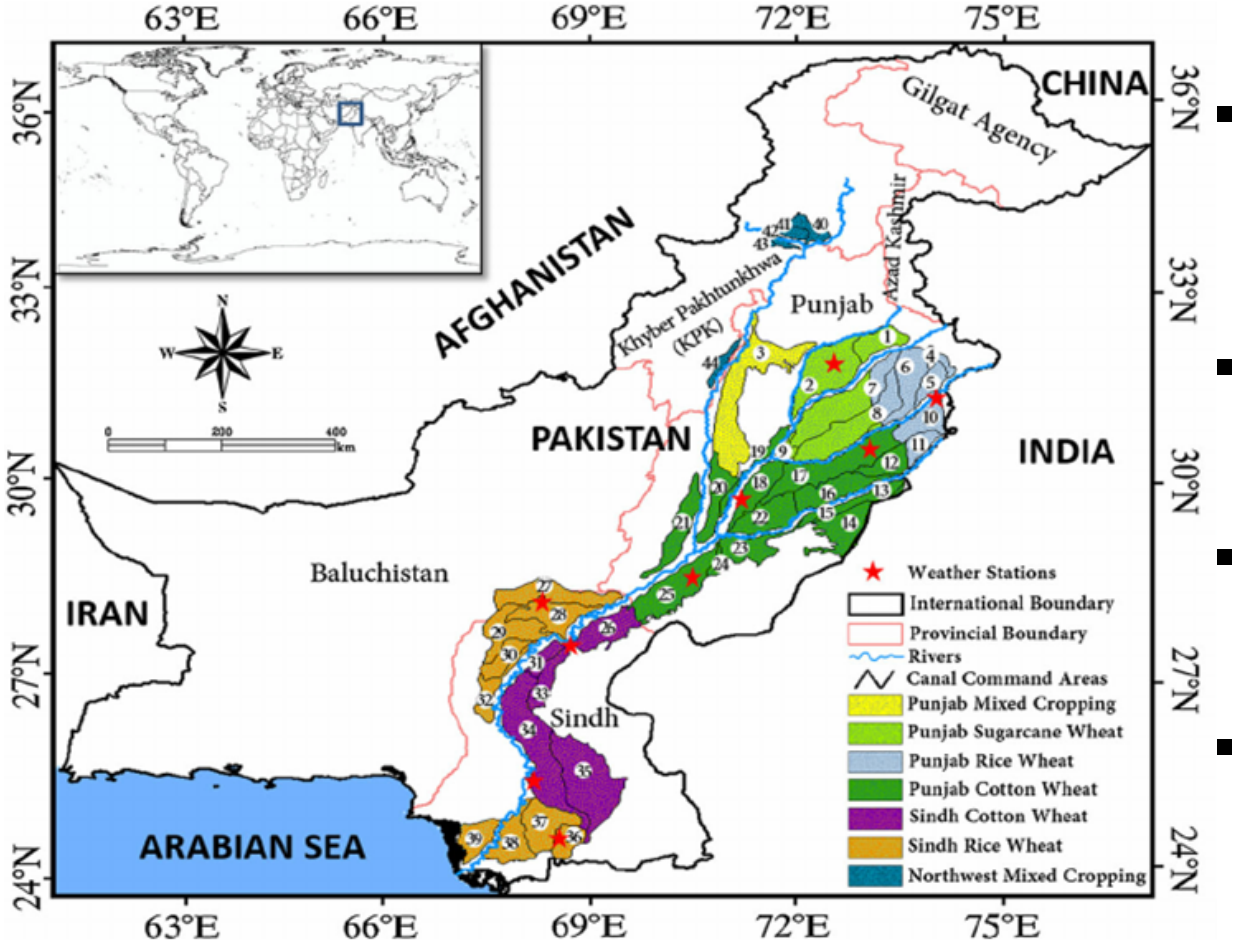
Pakistan: 0.13 kg (food)/ m^3 of water

Source: *International Water Management Institute (IWMI), working paper#60*, Author: MD Kumar (2003)



Foley et al., 2011 Solutions for a Cultivated Planet, *Nature.*

CAN WE GROW MORE WITH LESS?



- Lowest water use efficiency in Asia = 0.13 kg of food/m3 of water
- The world's largest surface water irrigation system.
- Operating since the early 1900s
- Centrally planned with large crop zones (~1000 sq km)

Indus Basin Irrigation System –IBIS (Surface Water)

CAN WE GROW MORE WITH LESS?

Original design: One crop/year **< surface water (=ok for 33.7 million people)**

Reality Today: 2.5 crops/year **> surface water (=not ok for 198 million people)**

LET'S TALK ABOUT RICE FOR EXAMPLE

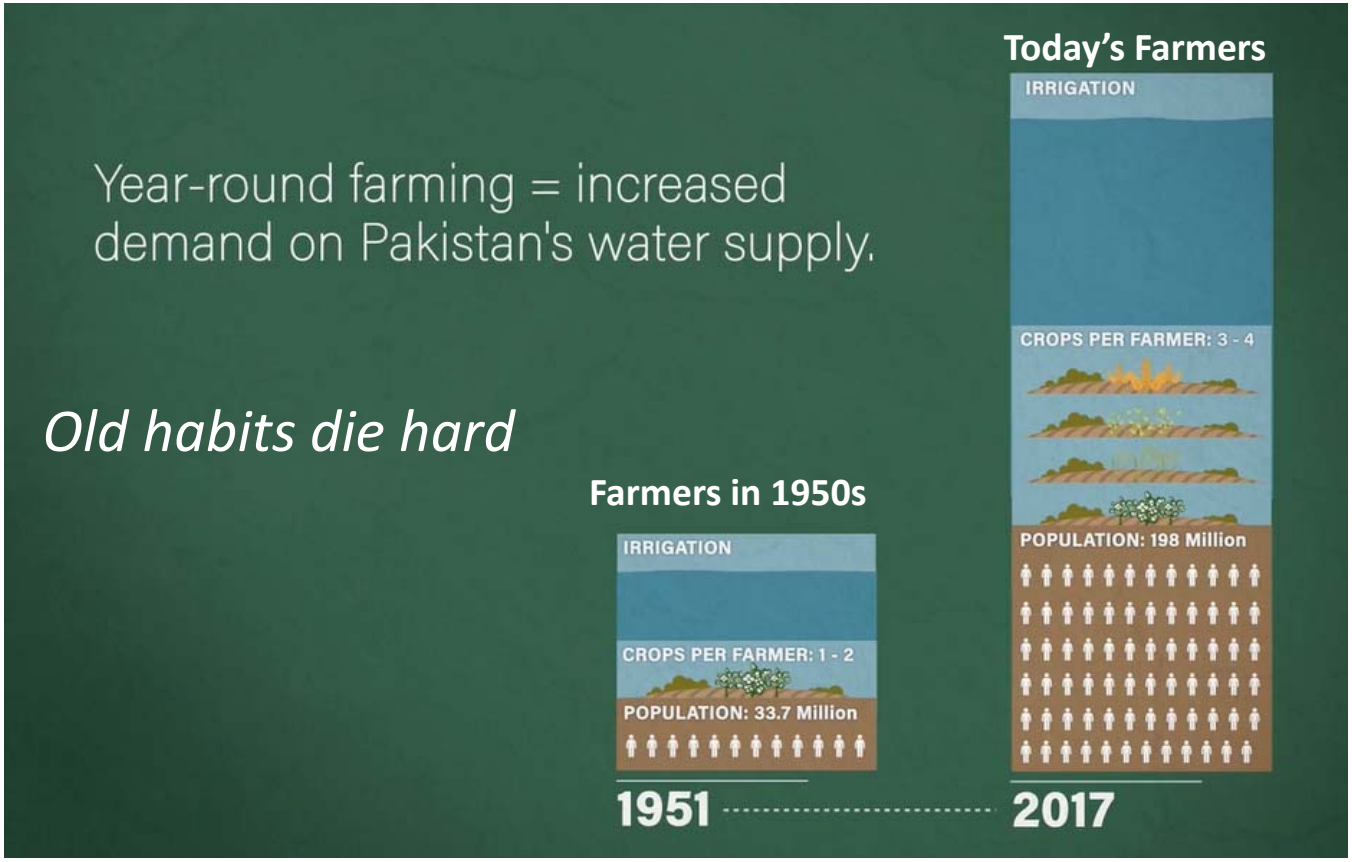
- Crop water requirements for rice **> 60 percent** of irrigation water
- **600 mm** in Punjab (humid) province **1,400 mm** in Sindh (dry) province
- Farmers apply **2,200 mm =** tremendous water loss = groundwater decline = costlier pumping each year
- Excessive irrigation = nutrients flow to sub-soil below the root zone= ***decrease in soil/crop productivity***

How do we change farmers mindset (that they do not need to 'irrigate' that much)?

How do we make the solution Affordable and Sustainable?

- Water use efficiency of rice = **0.45 kg of rice/m3;** lowest on record - **0.08kg/m3** (world average = **0.71 kg/m3**)

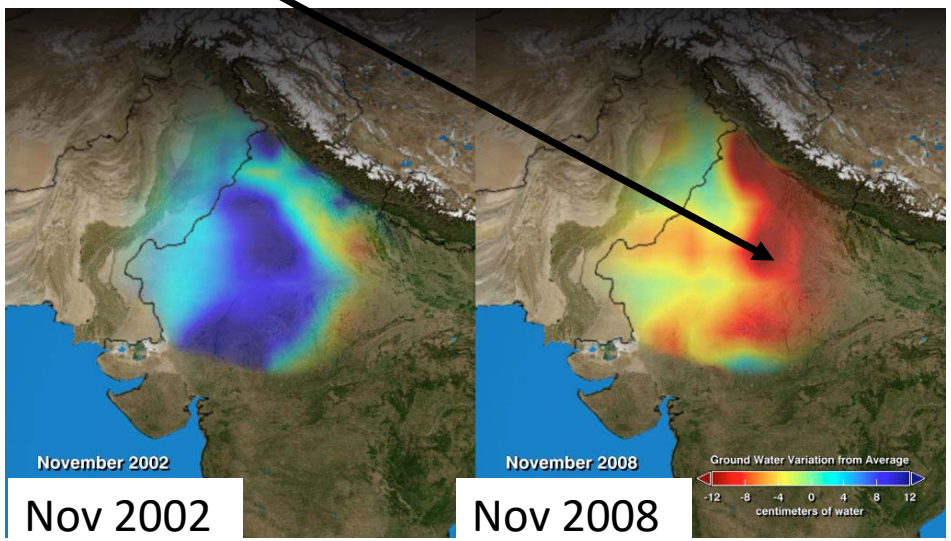
BUT WHY ARE FARMERS OVER IRRIGATING?



IT IS A GENERATIONAL PRACTICE HANDED DOWN FROM FOREFATHERS

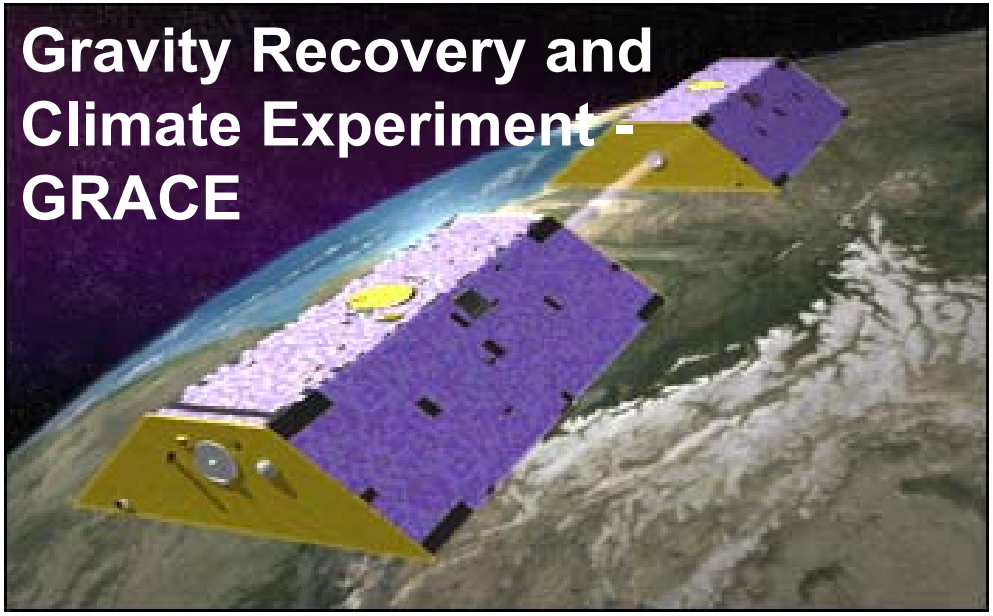
HOW DID UW GET INVOLVED IN ALL THIS?

GRACE-detected extreme groundwater depletion in Western India



Nov 2002 Nov 2008

Rodell et al. (2009), Nature; NASA SV Studio

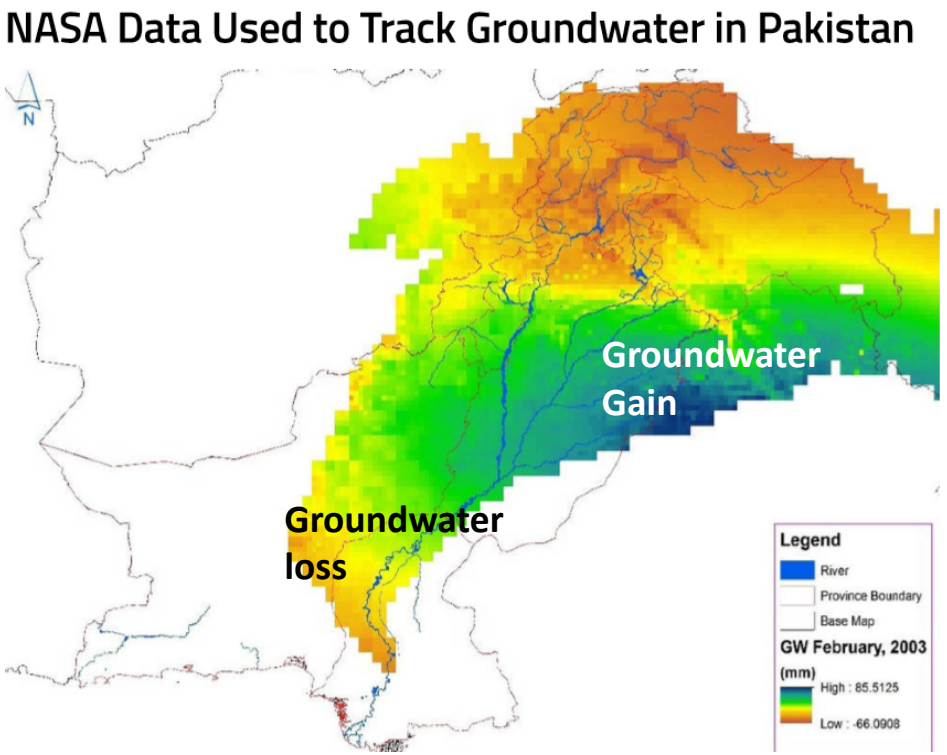


STAKEHOLDER AGENCY - ***PAKISTAN COUNCIL FOR RESEARCH IN WATER RESOURCES (www.pcrwr.gov.pk)***

HOW DID UW GET INVOLVED IN ALL THIS?

Feb. 29, 2016

- Satellite-piezometer estimated groundwater loss: **0.50-1.50 km³/year**
- Decline entirely due to ***over-irrigation during dry season from groundwater pumping***
- Grand Coulee Dam: **11km³**



ESTIMATING A CROP'S NEED FOR WATER: EVAPOTRANSPIRATION (ET)

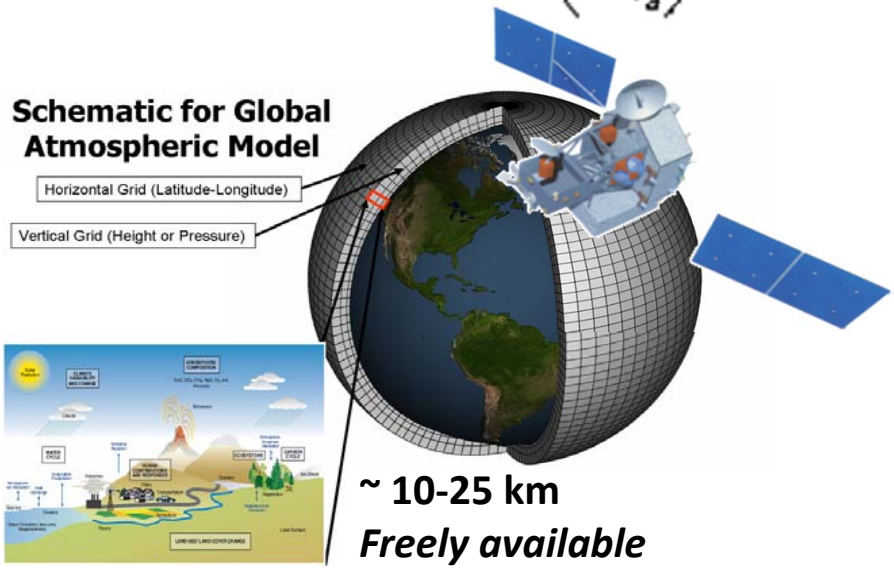
Most common for **crop water demand (ET)** is:

FAO-56 (Penman-Monteith)

$$\lambda ET = \frac{\Delta(R_n - G) + \rho_a c_p \frac{(e_s - e_a)}{r_a}}{\Delta + \gamma\left(1 + \frac{r_s}{r_a}\right)}$$

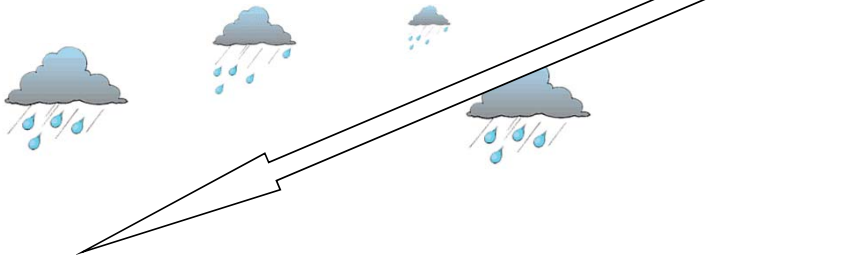
"Practical" inputs to apply FAO56 method:

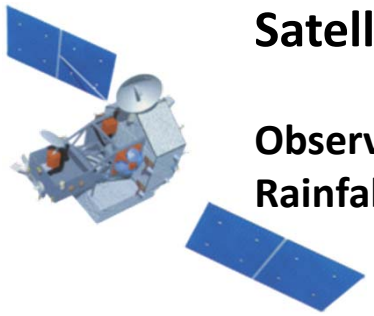
1. Daily maximum temperature
2. Daily minimum temperature
3. Daily maximum relative humidity
4. Daily minimum relative humidity
5. Daily mean wind speed
6. Latitude of the location
7. Elevation of the location
8. Julian day of the year



~ 10-25 km

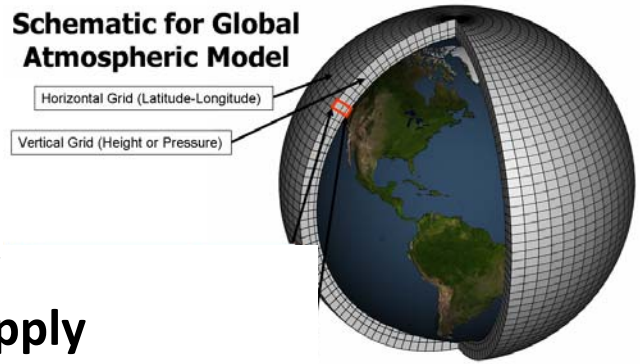
Freely available





Earth Observing Satellites

Observe *Current/past* Rainfall and Crop ET



Global Numerical Weather Prediction Model

Predict *Current/Future* Rainfall and *Current/Future* crop ET

Irrigation if Demand> Supply
No irrigation if Demand < Supply

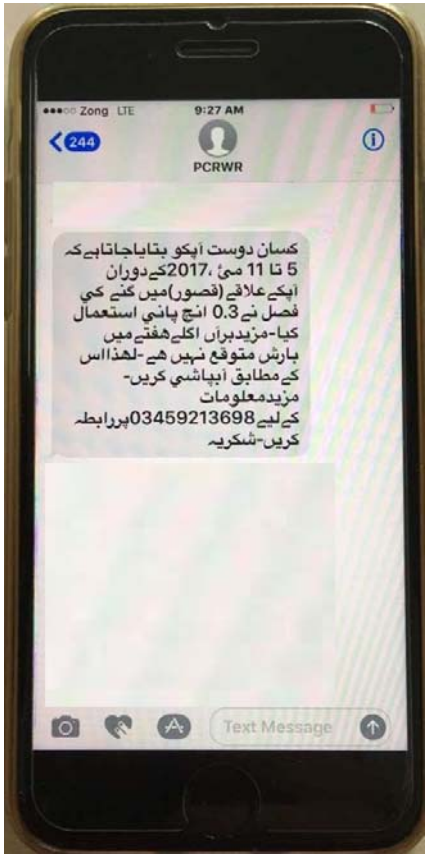
Demand: Crop ET
Supply: Rainfall or recent irrigation

BRINGING THE SOLUTION TO FARMERS

Forecast-based Advisory was added later and it was in highest demand

Dear farmer friend, we would like to inform you that your wheat crop does not need irrigation due to sufficient rainfall during the past week.

Dear farmer friend, we would like to inform you that the irrigation need for your banana crop was 2 inches during the past week.



700 farmers — **10,000** farmers — **100,000** farmers

2016 — **2017** — **2018**

FARMER FEEDBACK

Mr. Muhammad Ashraf, a **12 acre** farmer from Sargodha-Pakistan called on 5/11/2017 to provide feedback on the Irrigation Advisory system.

" ***Keeping in view the advised water consumption and rainfall forecast, I only applied 3 irrigations, whereas my neighboring farmers applied 6-7 irrigations. I have recently harvested my crop and got 48 maunds/acre (4,742 kg/ha) yield, whereas my neighbors could get 42 maunds/acre (4,149 kg/ha). The irrigation advisory system let me get better yields and the water pumping cost was substantially reduced"'***

QUANTITATIVE IMPACT EVALUATION

2.5 billion cubic meter a year saved per 100,000 farmers

[2.5 km3; Grand Coulee: 11 km3]

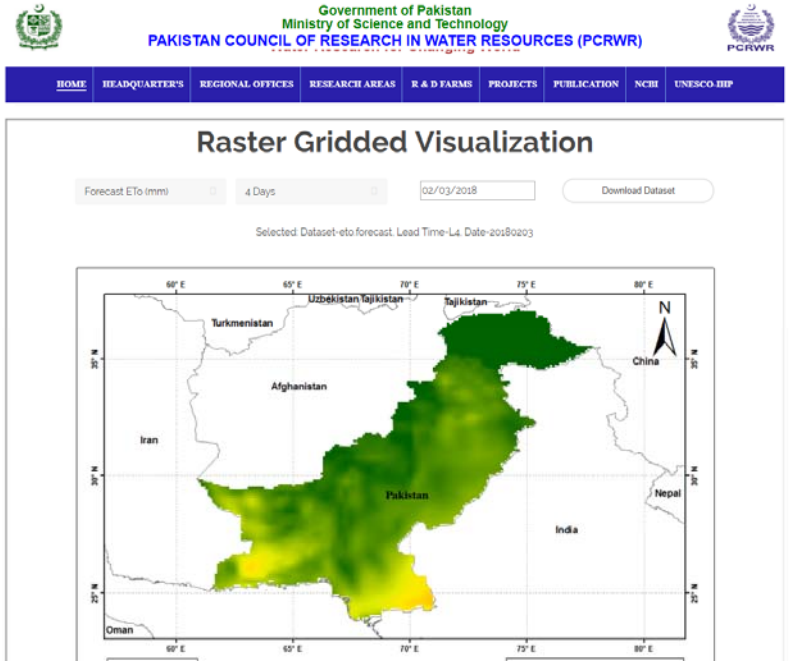
40% saving in irrigation water

80% usage rate among farmers

50-100% increase in farmer income

CAPACITY BUILDING AND TECHNOLOGY TRANSFER

At Pakistan Council for Research in Water Resources (PCRWR)



Portal co-developed by UW and PCRWR

- Stakeholder Agency needs to ‘own’ the co-developed solution
- UW engineers can then focus on the next problem to solve

MEANWHILE IN NEIGHBORING INDIA……

Image courtesy of Dr. Ryu, University of Melbourne

- **140 million farmers** in India
- Most (65%) are marginal (**plot size < 1 acre**)
- No single or centralized & large scale irrigation system like IBIS
- Coarse resolution data (~10-25km)from satellites and weather models ***will not work***
- Need ***finer*** resolution plot-scale crop/irrigation advisory (~1km-500m)

“Internet of Things” and Low Power Wide Area Network (LPWAN)

IoT compatible water level sensor – *Runs on 2 AA batteries for 2 years*

Router for LPWAN – *Needs one solar panel* Collects data and pushes to cloud

IoT sensors- *Runs on 2 AA batteries- for 2 years*

LPWAN AND IoT SENSORS ARE *AFFORDABLE*

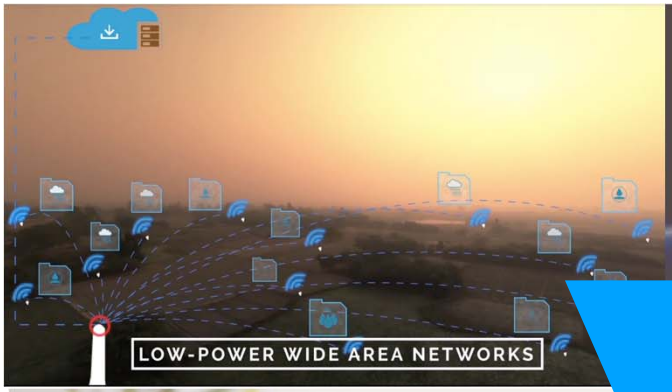
(low maintenance like your smart home security system)

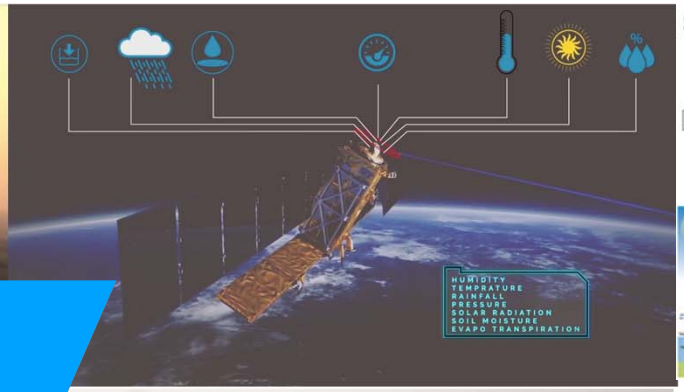
IoT Soil Moisture Sensor

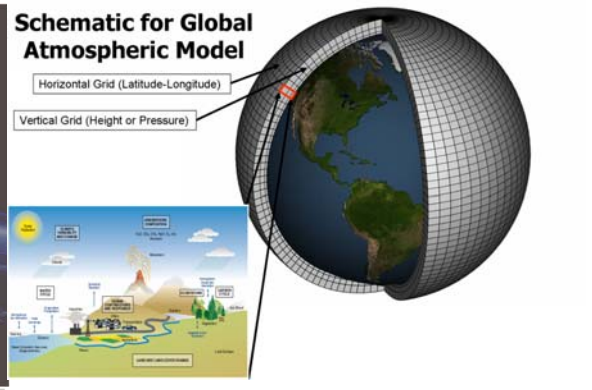
IoT Integrated Weather and Soil Sensor

Low-cost IoT ready Weather Station

INTEGRATION OF HIGH RESOLUTION IoT SENSOR DATA IN THE CLOUD



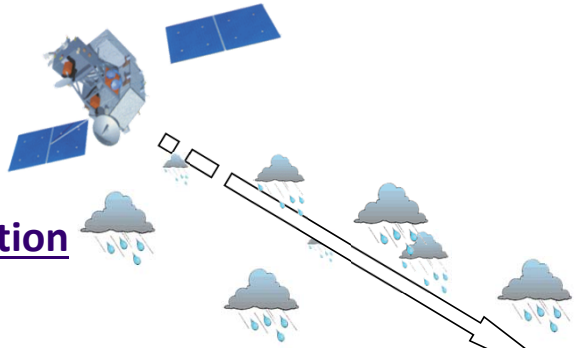


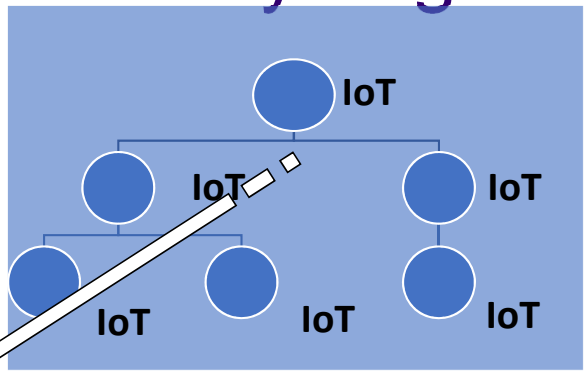


THE BIRTH OF *PANI*

Provision for **A**dvisory on **N**ecessary **I**rrigation

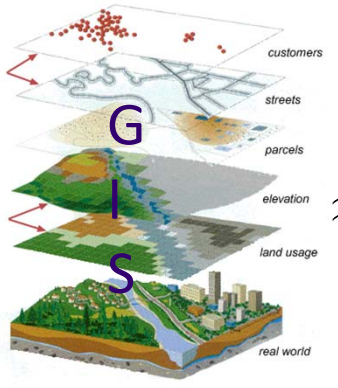
Coarser Resolution





Finer Resolution

PANI



Finer resolution databases

Collaborating Partners:

IIT Kanpur - India

Kritsnam Technologies - India

GeoKno – India

UW - USA

Plot scale Farmer Advisory

HOW AFFORDABLE IS *PANI*?

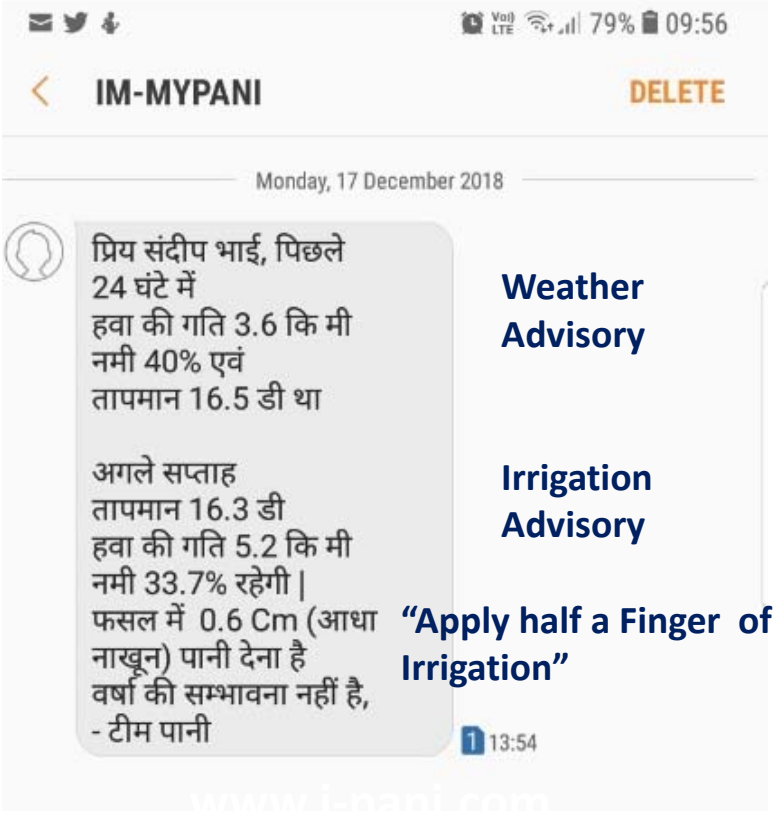
- LPWAN gateway = **800.00 USD** (with solar panels and cloud connectivity)
- LPWAN communication node= **80.00 USD**
- Multi-sensor module (temperature, humidity, rainfall, pressure and windspeed) = **120.00 USD**
- Good quality soil moisture sensor = **80.00 USD**
- ONE LPWAN tower covers at least 100 km^2 with 100 environmental sensors

HOW AFFORDABLE IS *PANI*?

If 100 farmers live in 1 km^2 (average farmer density in rural India), setup cost per farmer= **5.00 USD/year**

Note: Average Farmer income = **1200 USD/year** (*according to National Sample Survey Office – India*)

PILOTING *PANI* DURING WINTER 2019
(Nov 2018-May 2019)

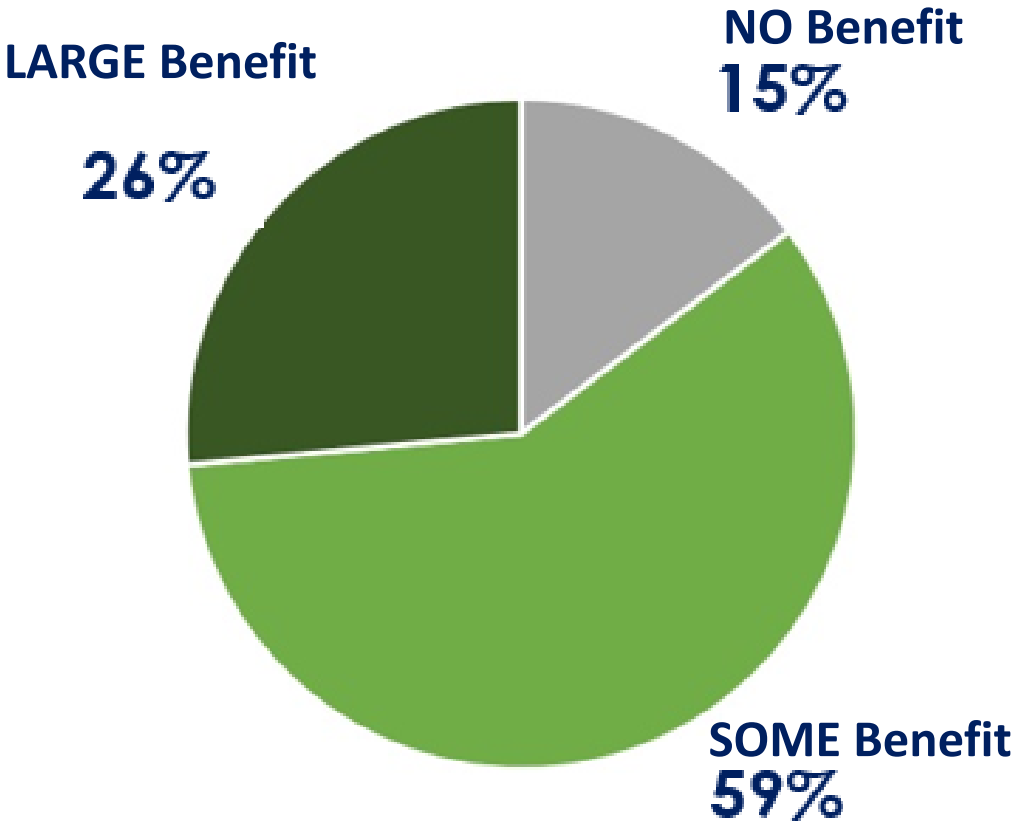


Weather Advisory

Irrigation Advisory

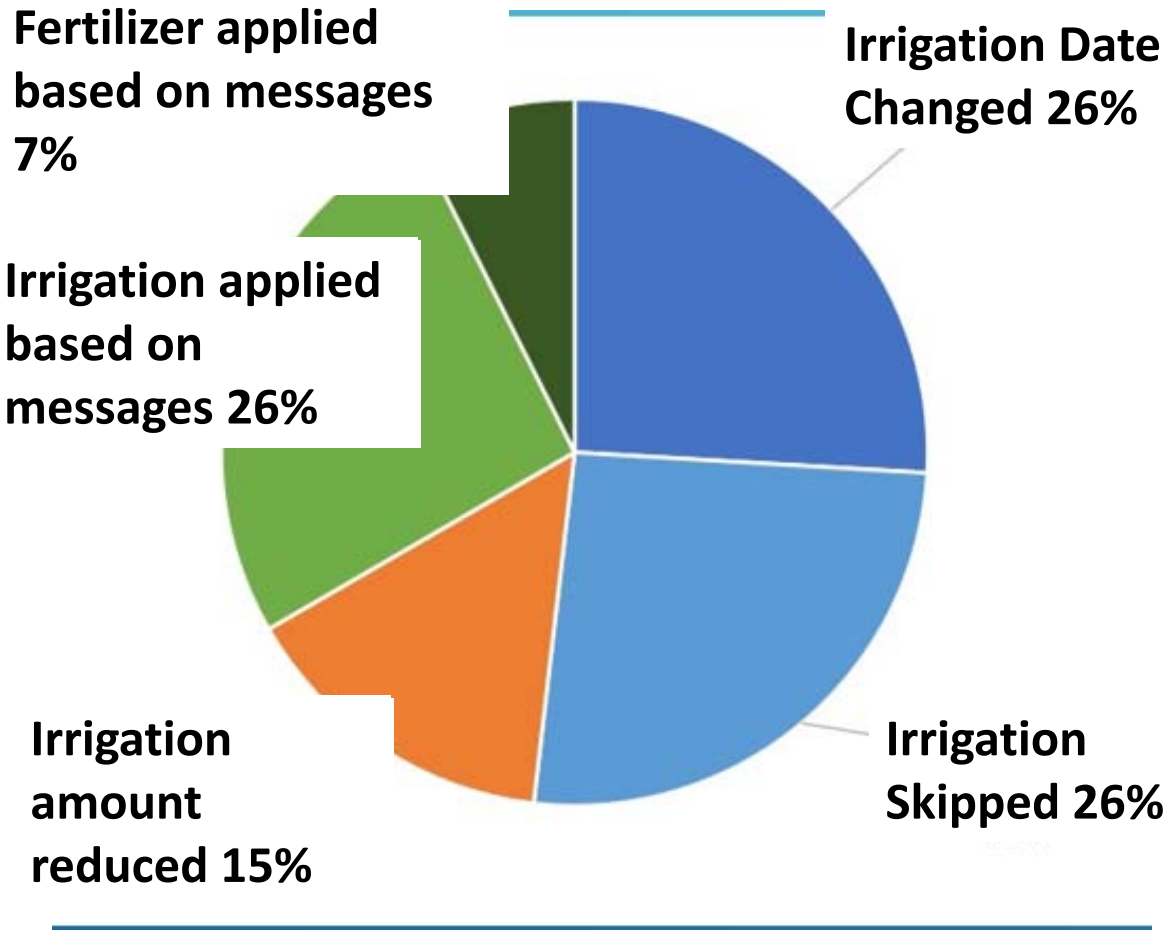
"Apply half a Finger of Irrigation"

FARMER FEEDBACK ON *PANI*



A sample of the farmers during the pilot

FARMER FEEDBACK ON *PANI*

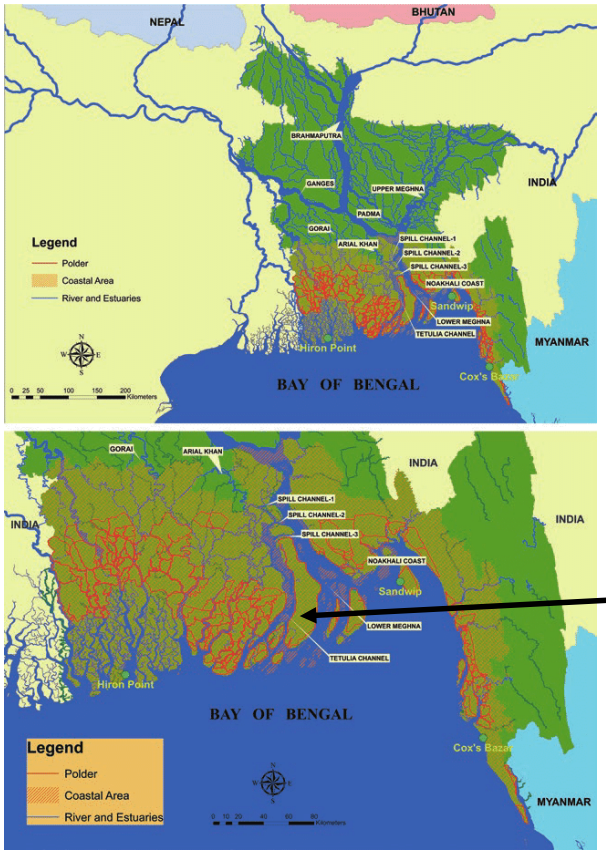


- Average Wheat Yield 4000 kg/ha-5100 kg/ha with PANI
- Govt reported historical yield at the site: 2867 kg/ha
- National average:
  2600 kg/ha in 2004
  3140 kg/ha in 2011

A FEW OTHER LESSONS LEARNED FROM *PANI*

- Potato growers were unusually attentive to irrigation/weather advisory on their phones **– *potato blight (fungal attack)***
- Temperature & humidity forecasts have extra value during sowing/harvesting – ***farmers care about comfort level to work outside long hours during planting/harvesting***
- Voice-based advisory preferred to text messages
- Century-old local irrigation canal system need to be modernized by Irrigation Department using *PANI*

WHAT'S NEXT FOR *PANI*?

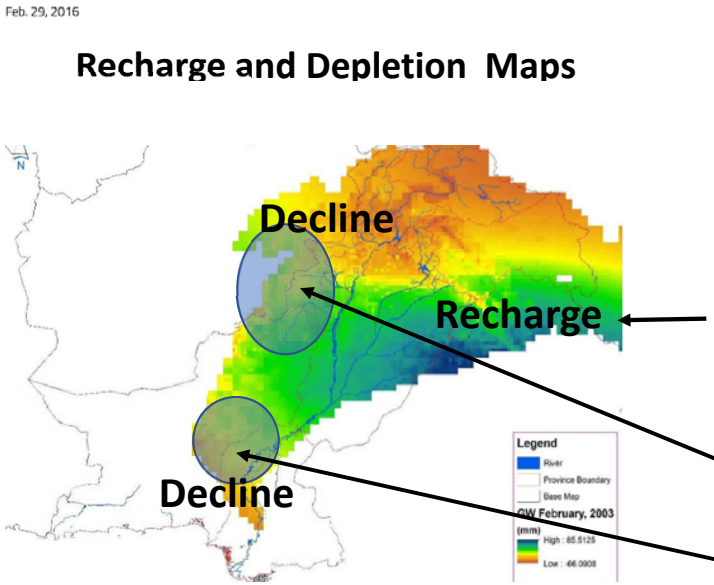


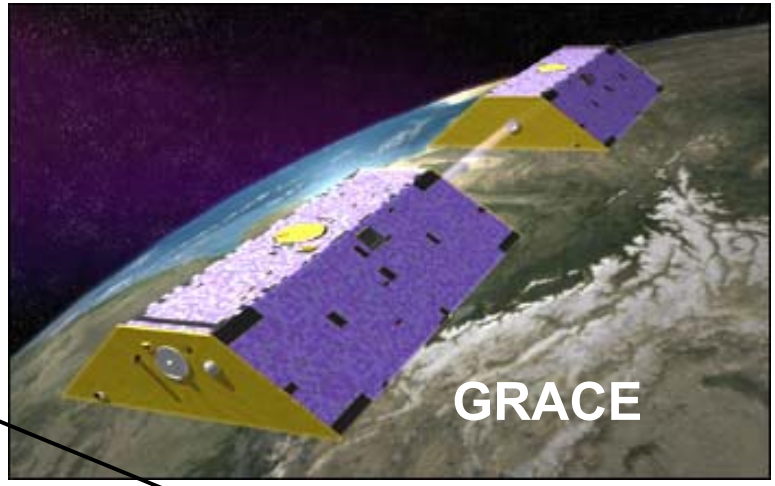
- Scaling up in India for 50,000 farmers in **2019-2020 (goal: 50 million by 2024)**
- *PANI* piloting for **250 farmers in Bangladesh** from October 15, 2019. *[Note: Fourth Largest Rice Producer*]
- **Farmers in low-lying coastal regions** with brackish surface/ground water – freshwater (harvested rainwater) conservation very important)

CAN SMART IRRIGATION BE *SMARTER?*

- SMS texting has an operational cost
- For 100,000 farmers – **10,000 USD/yr for Government Stakeholder Agency like PCRWR (Pakistan)**
- Sending SMS texts to all 3 million farmers – *EXPENSIVE*
- Which of those 100,000 farmers (from 3 million) should receive this service for maximum impact? *Random/Uniform selection?*
- **GRACE satellite** can make the smart irrigation *smarter*

CAN SMART IRRIGATION BE *SMARTER*?





THE SMARTER IDEA?

- **Step 1:** Use GRACE data to identify regions experiencing faster groundwater decline

- **Step 2:** Target SMS texting on Weather/Irrigation Advisory to 100,000 farmers in those regions where groundwater is declining at an unsustainable rate

THREE TAKE HOME MESSAGES

- **FREELY AVAILABLE SATELLITE EARTH OBSERVATIONS AND NUMERICAL WEATHER MODELS ARE LOW HANGING SOLUTIONS FOR *GROWING MORE WITH LESS WATER IN ASIA***

- **FEEDING ASIA = *EMPOWERING MARGINAL FARMERS***

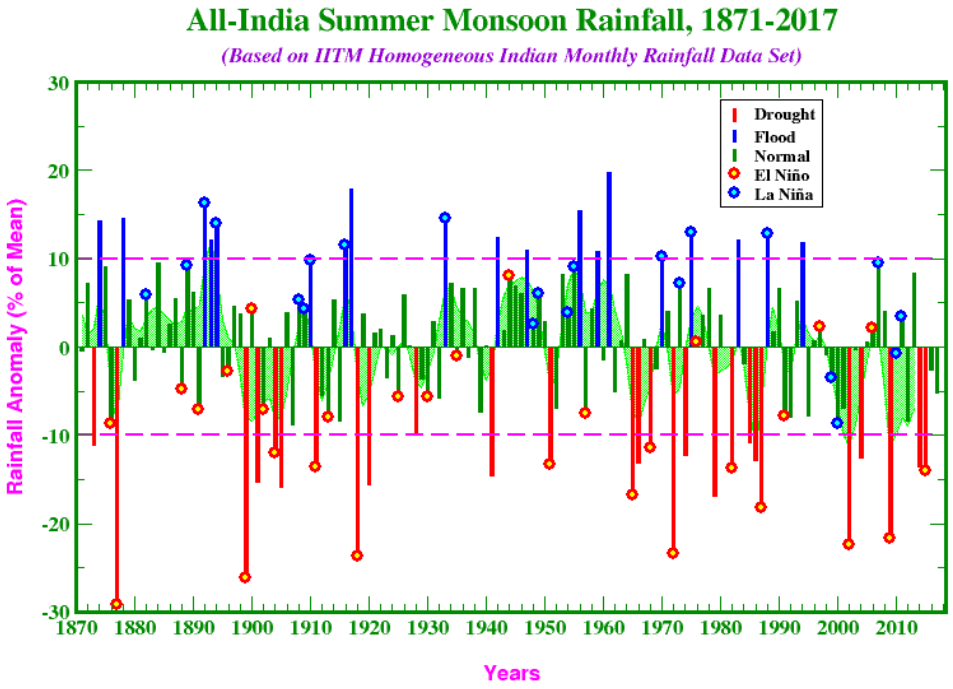
- **TECHNOLOGY THAT HAS PRECISION AND IS SMART *DOES NOT HAVE TO EXPENSIVE (IoT sensors & LPWAN)***

ACKNOWLEDGEMENTS

- Sponsors – Ivanhoe Foundation, World Bank, Asian Development Bank, USAID, NASA Applied Sciences Program.
- Stakeholder agencies - PCRWR, IITK, Geokno, Kritsnam, Bangladesh Water & Agriculture Ministries, HMRC.
- UW students- Shahryar Ahmad, Nishan Biswas, Hisham Eldardiry, Claire Beveridge, Kensey Daly, Matt Bonnema, Safat Sikder, Indira Bose, Asif Mahmood.
- Collaborators/Volunteers - Ahmed Zeeshan, Naveed Iqbal, Faizan Ul Haque, Muhammad Ashraf, Bharat Lohani, Shivam Tripathi, Harsha Karumanchi, Soham Adla, Sandeep Goyal and many more……..

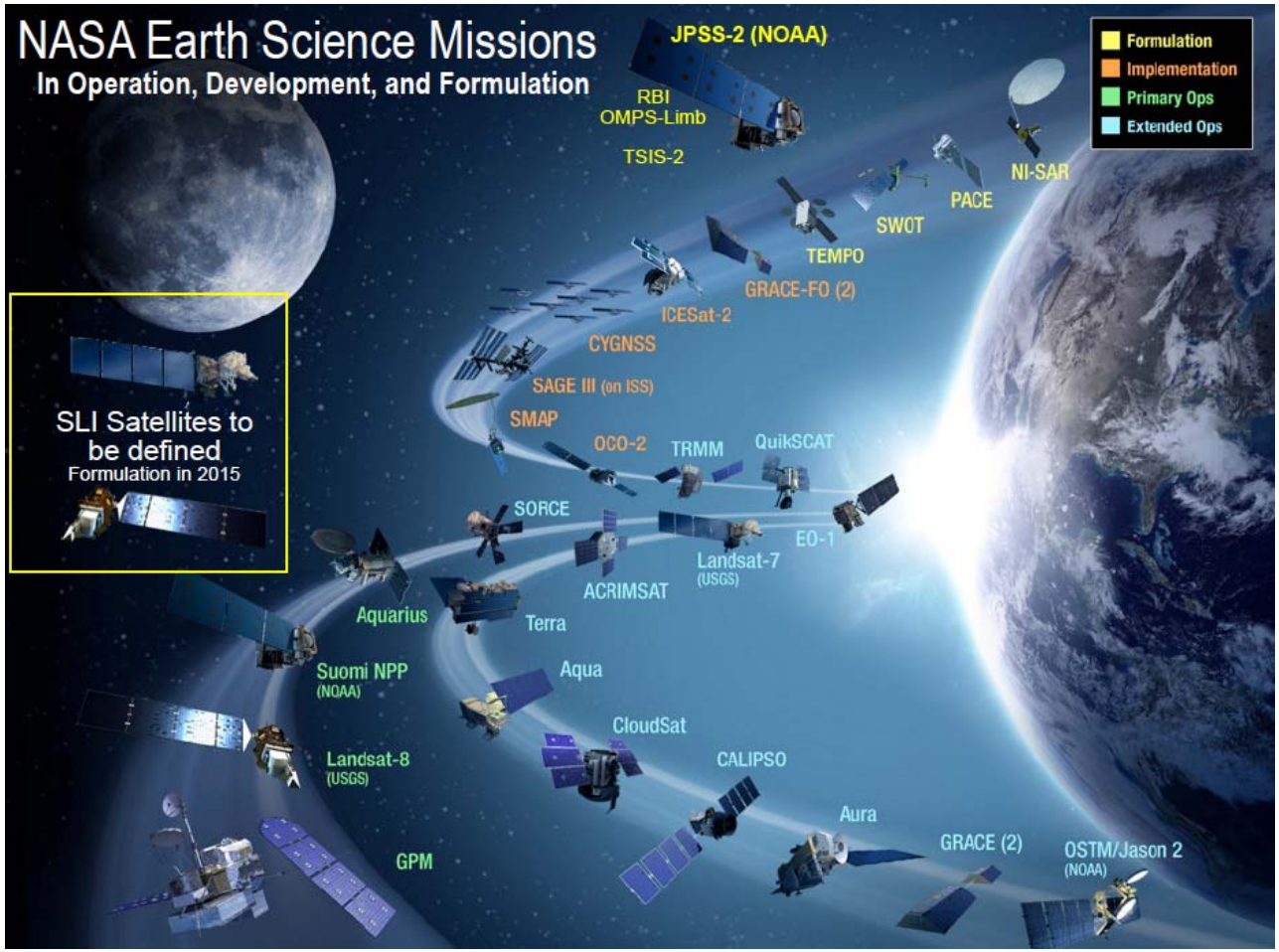
THANK YOU!

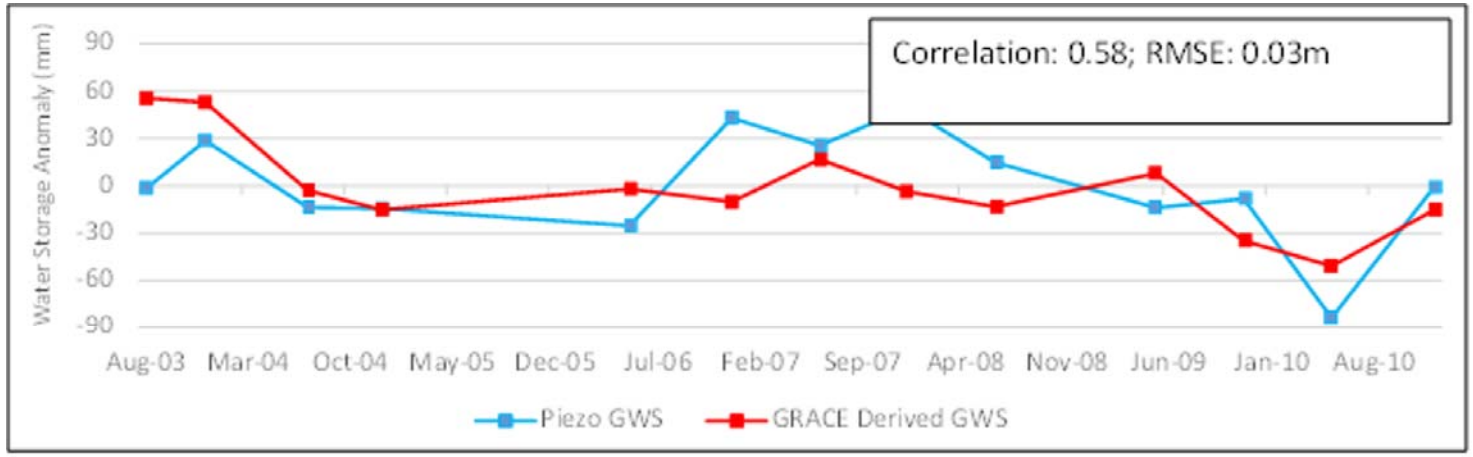
QUESTIONS?

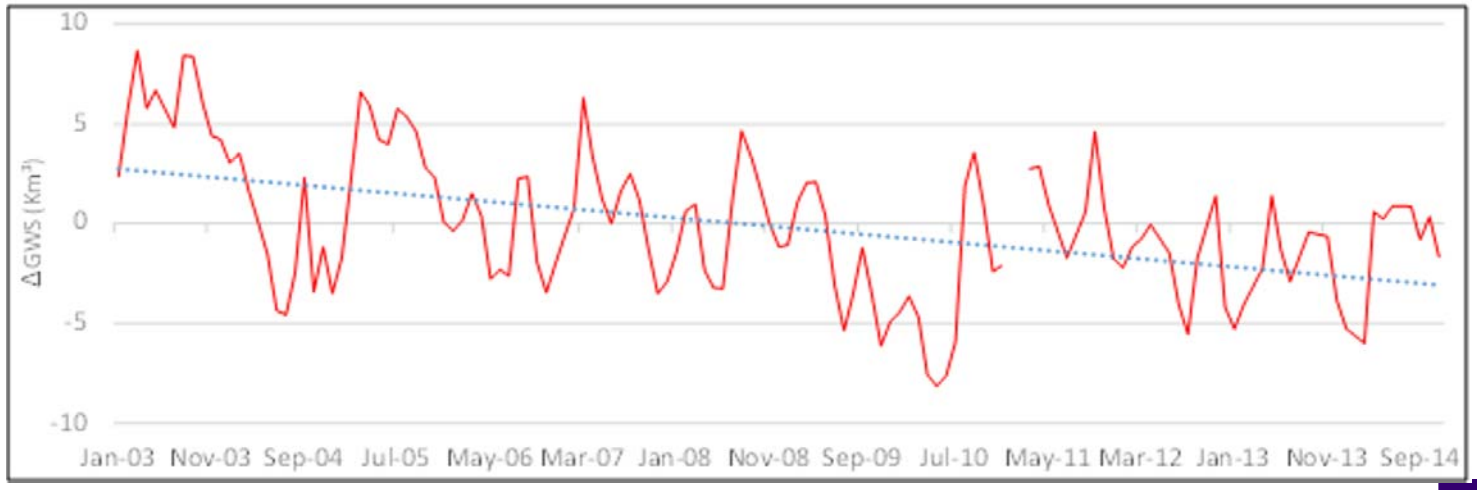


BACKGROUND: Natural cycle of variability

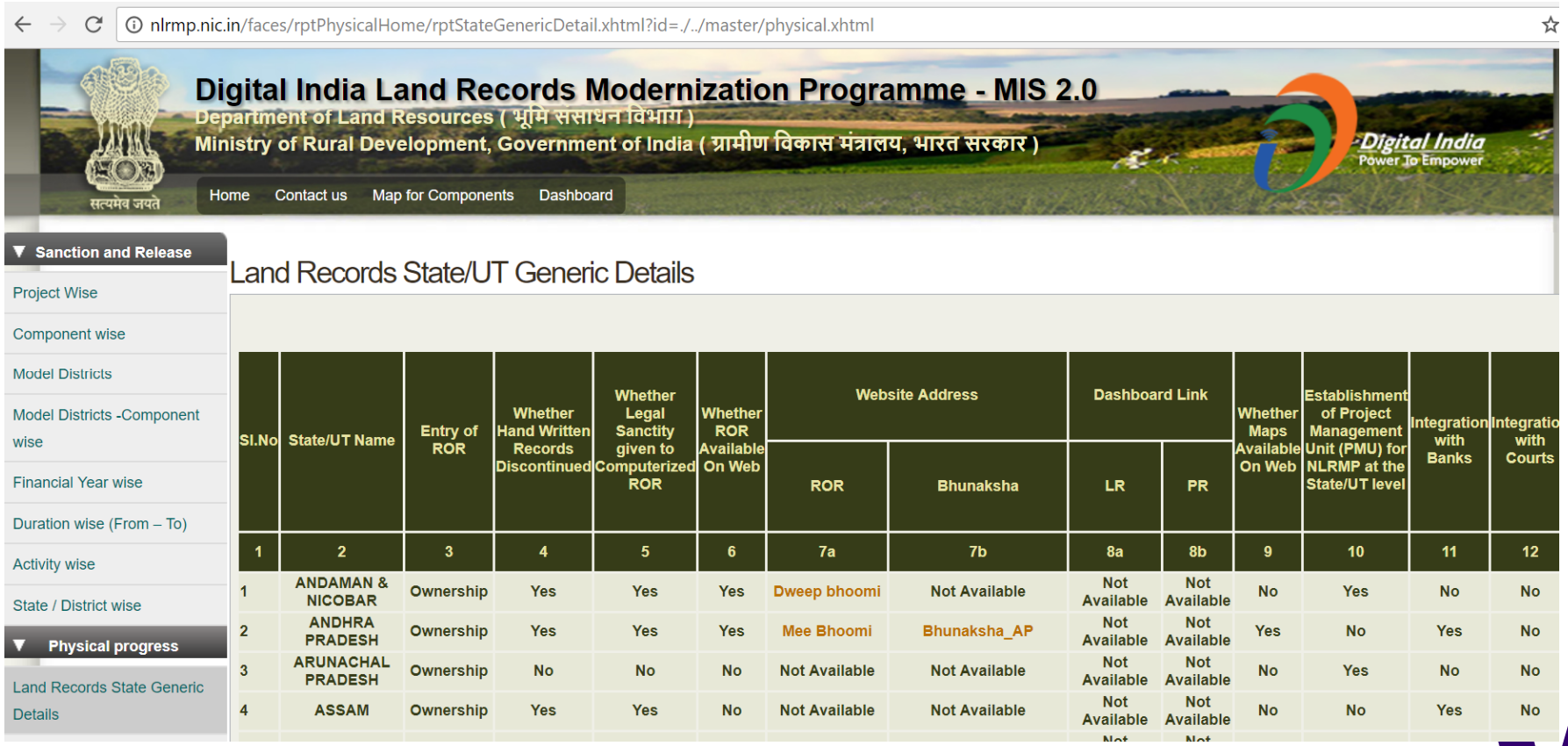
(FREE) SATELLITES FOR A LOW COST SOLUTION




Correlation: 0.58; RMSE: 0.03m
Water Storage Anomaly (mm)
90
60
30
0
-30
-60
-90
Aug-03
Mar-04
Oct-04
May-05
Dec-05
Jul-06
Feb-07
Sep-07
Apr-08
Nov-08
Jun-09
Jan-10
Aug-10
Piezo GWS
GRACE Derived GWS


ΔGWS (Km³)
10
5
0
-5
-10
Jan-03
Nov-03
Sep-04
Jul-05
May-06
Mar-07
Jan-08
Nov-08
Sep-09
Jul-10
May-11
Mar-12
Jan-13
Nov-13
Sep-14

(FREE) GOVERNMENT BIG GEO-DATA



nlrmp.nic.in/faces/rptPhysicalHome/rptStateGenericDetail.xhtml?id=./../master/physical.xhtml

Digital India Land Records Modernization Programme - MIS 2.0
Department of Land Resources (भूमि संसाधन विभाग)
Ministry of Rural Development, Government of India (ग्रामीण विकास मंत्रालय, भारत सरकार)

Digital India
Power To Empower

सत्यमेव जयते

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- ▼ Sanction and Release
  - Project Wise
  - Component wise
  - Model Districts
  - Model Districts -Component wise
  - Financial Year wise
  - Duration wise (From – To)
  - Activity wise
  - State / District wise
- ▼ Physical progress
  - Land Records State Generic Details

Land Records State/UT Generic Details

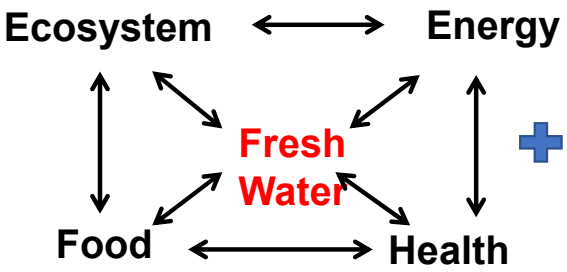
Sl.No	State/UT Name	Entry of ROR	Whether Hand Written Records Discontinued	Whether Legal Sanctity given to Computerized ROR	Whether ROR Available On Web	Website Address		Dashboard Link		Whether Maps Available On Web	Establishment of Project Management Unit (PMU) for NLRMP at the State/UT level	Integration with Banks	Integratio with Courts
						ROR	Bhunaksha	LR	PR				
1	2	3	4	5	6	7a	7b	8a	8b	9	10	11	12
1	ANDAMAN & NICOBAR	Ownership	Yes	Yes	Yes	Dweep bhoomi	Not Available	Not Available	Not Available	No	Yes	No	No
2	ANDHRA PRADESH	Ownership	Yes	Yes	Yes	Mee Bhoomi	Bhunaksha_AP	Not Available	Not Available	Yes	No	Yes	No
3	ARUNACHAL PRADESH	Ownership	No	No	No	Not Available	Not Available	Not Available	Not Available	No	Yes	No	No
4	ASSAM	Ownership	Yes	Yes	No	Not Available	Not Available	Not Available	Not Available	No	No	Yes	No

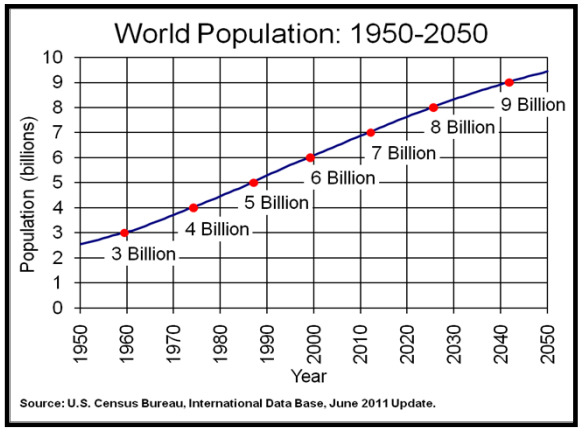
Govt Buy-In

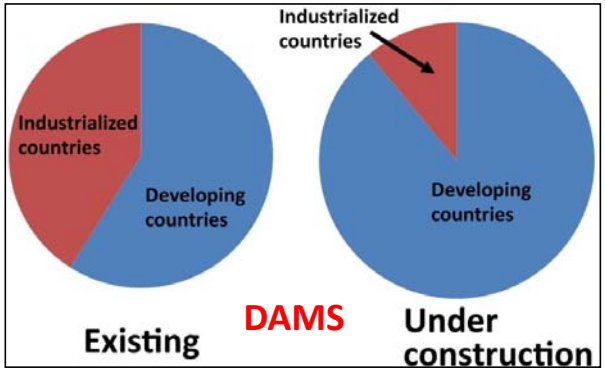
Sept 19, 2019 – Meeting with High ranking Government Officials of Bangladesh for Government buy-in of smart tech ideas

- Govt buy in - critical
- Other issues:
- Cash Crops – Mangoes, pulses, aromatic rice for business model
- Cash crops have higher margin of profit
- Rice fields getting replaced with Mangoes – impact unknown
- Weather important for pest management, pollination, blast prevention

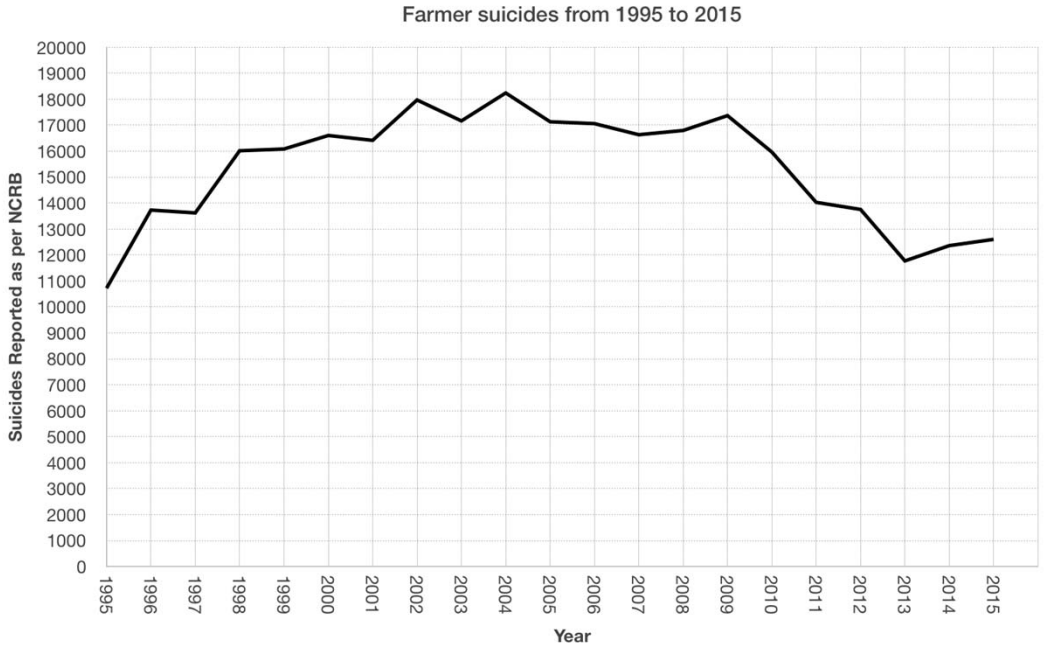
THE BIG PICTURE



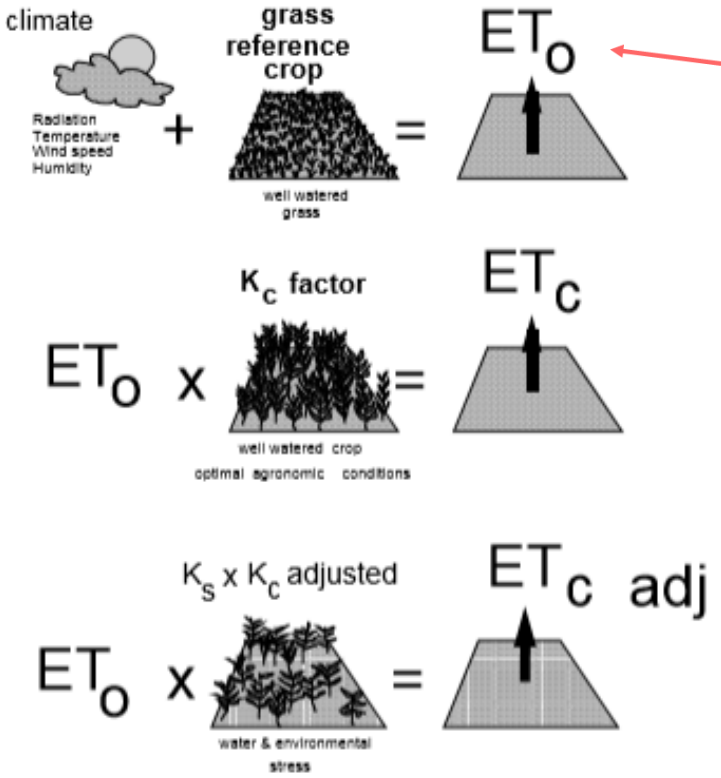




Long-term Trends in Farmer Suicides In India



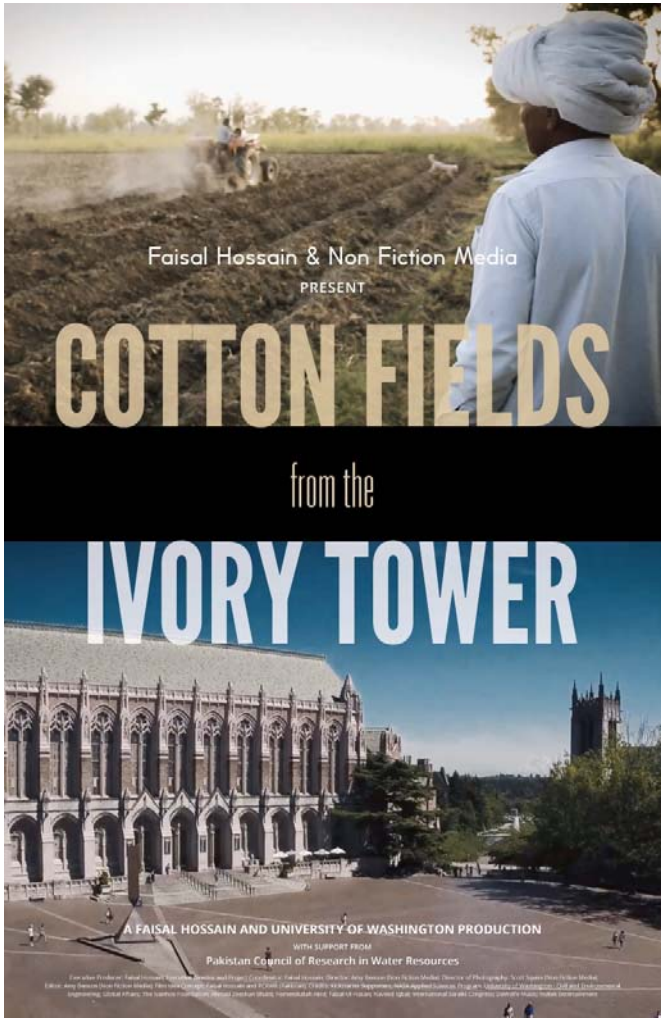
CROP WATER DEMAND: FROM WEATHER AND SOIL CONDITIONS



$$\lambda ET = \frac{\Delta(R_n - G) + \rho_a c_p \frac{(e_s - e_a)}{r_a}}{\Delta + \gamma\left(1 + \frac{r_s}{r_a}\right)}$$

Necessary inputs to forecast crop water demand

1. Daily maximum temperature (˚C)
2. Daily minimum temperature (˚C)
3. Daily maximum relative humidity
4. Daily minimum relative humidity
5. Daily mean windspeed in m/s
6. Latitude of the location
7. Elevation above msl of the location in m
8. Julian day of the year



www.saswe.net/cinematography

LAST WORDS: MONEY! MONEY MONEY!

- World sitting on 50 Trillion US dollars of Liquidity
- Can we get just 1% of it to accelerate commercialization of R&D for Weather-based products?

AN ECONOMIC ARGUMENT

- Hailstorms damage 5% of annual production
- Total Annual production: 10 million USD
- 5% of Total Annual Production: 500,000 USD/year
- Cost of Weather (Hailstorm) Forecasting < 10,000 USD/year
- Weather forecasting = 400,000 USD potential loss avoided/year

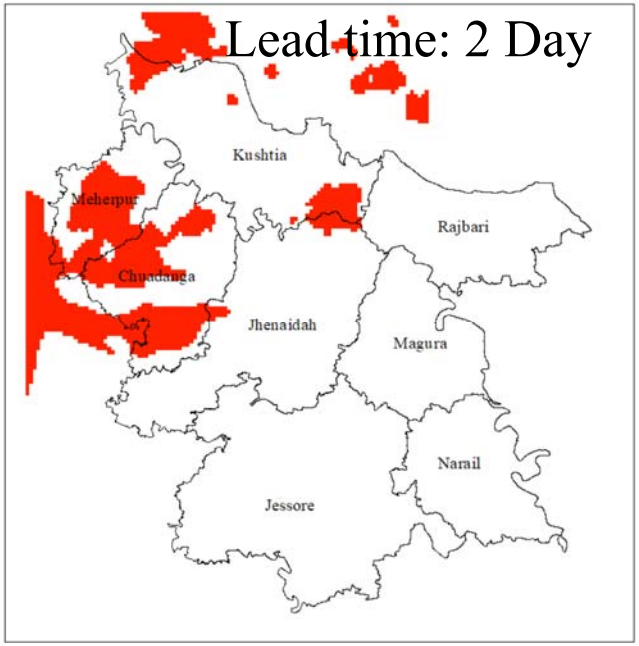
HAIL FORECASTING

April 1 2019

HAIL FORECASTING

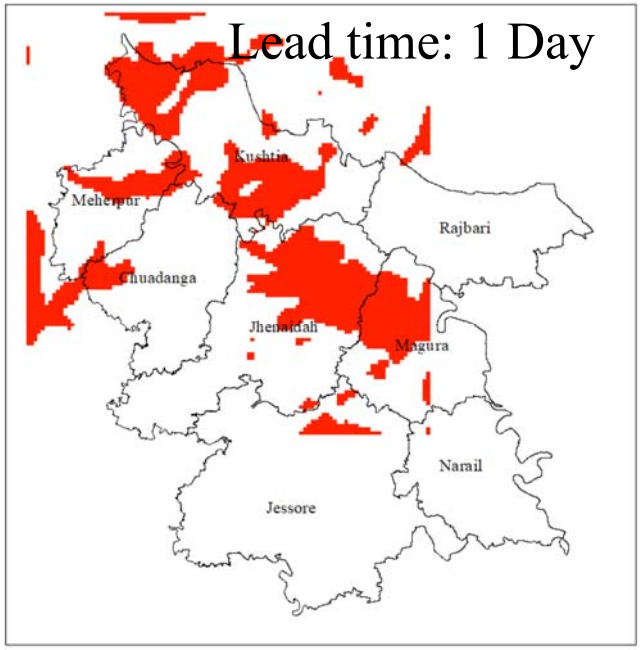
April 1 2019

HAIL FORECASTING



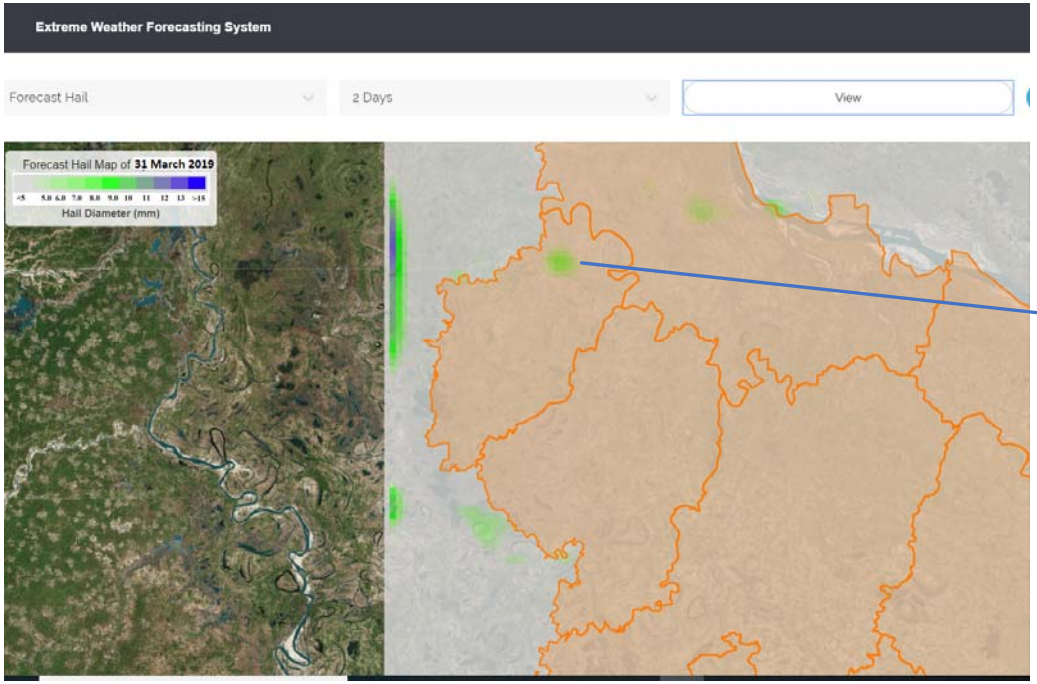
April 1 2019

HAIL FORECASTING



April 1 2019

HAIL FORECASTING



Hail and Extreme Weather Forecasting System using WRF HAILCAST http://depts.washington.edu/saswe/batb

- Hail observed April 1, Southeastern Bangladesh
- Enduser (30 Billion/year Company)
- Historical Hail Forecast skill:
- 80% (1 day) 60% (3 day lead)