Food, Water and Energy Nexus in India

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With a lot of help from students/staff

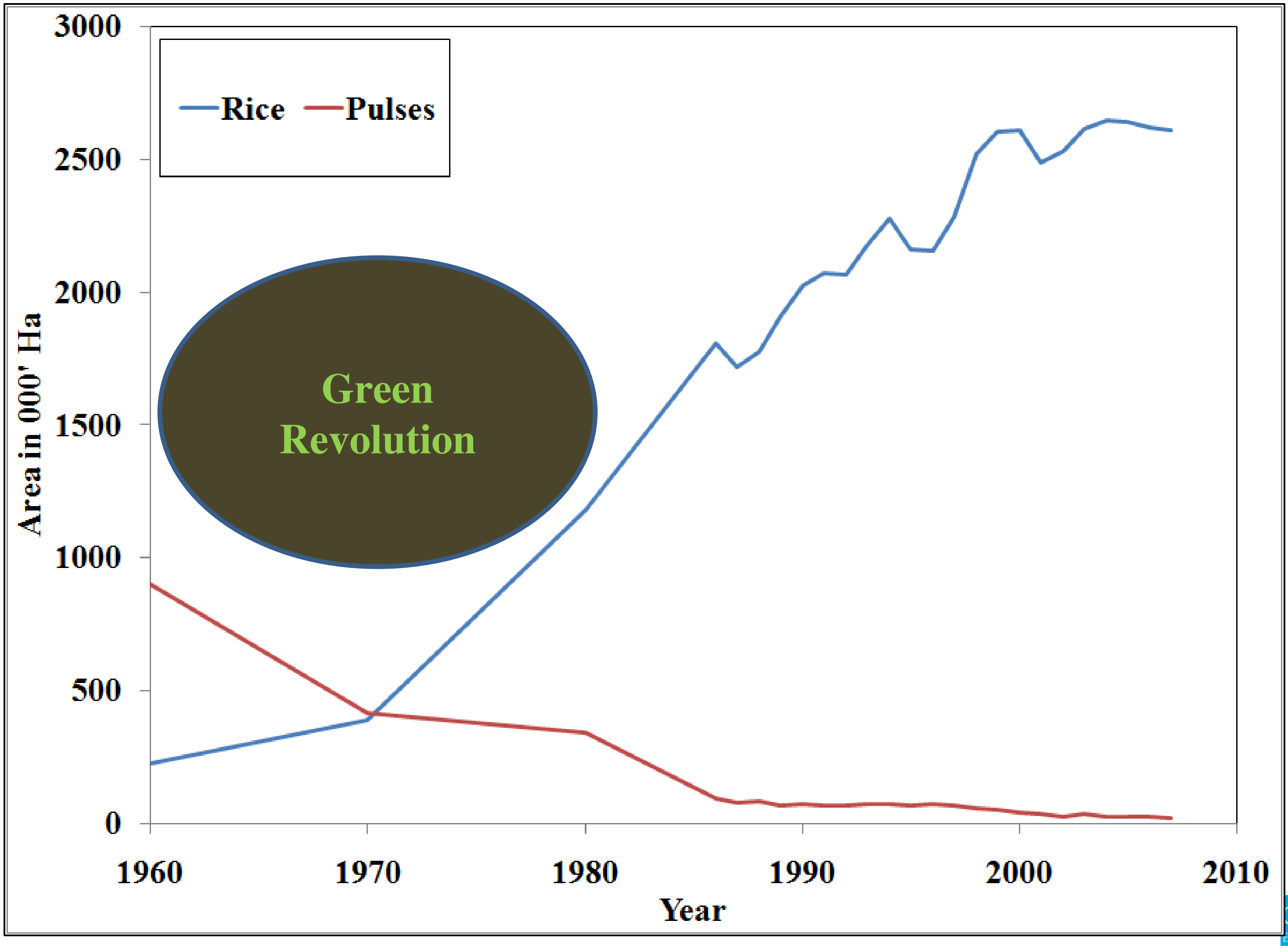
1950-2000 India

- Food production: **4.2x** (population 2.75x)
- [Rice 4x; Wheat 10x; Pulses+coarse: < 2x]
- How was it achieved

➉↑ land area+ same land cropped >1: 1.25x

- Increasing yields per unit land: **3.25x**
- Combination of: fertilizer + seed + **irrigation**

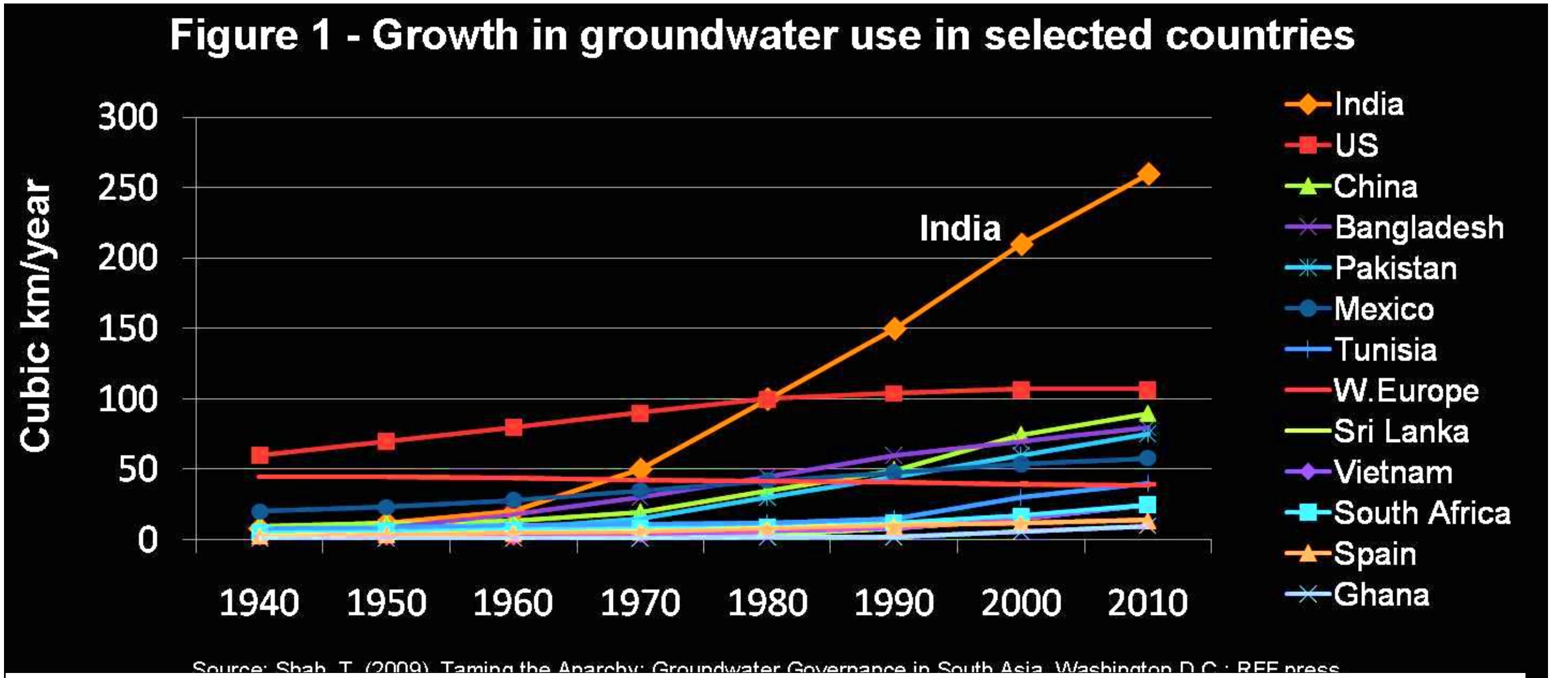
Time series of crop acreage in Punjab under Rice and Pulses (Directorate of Economics and Statistics)

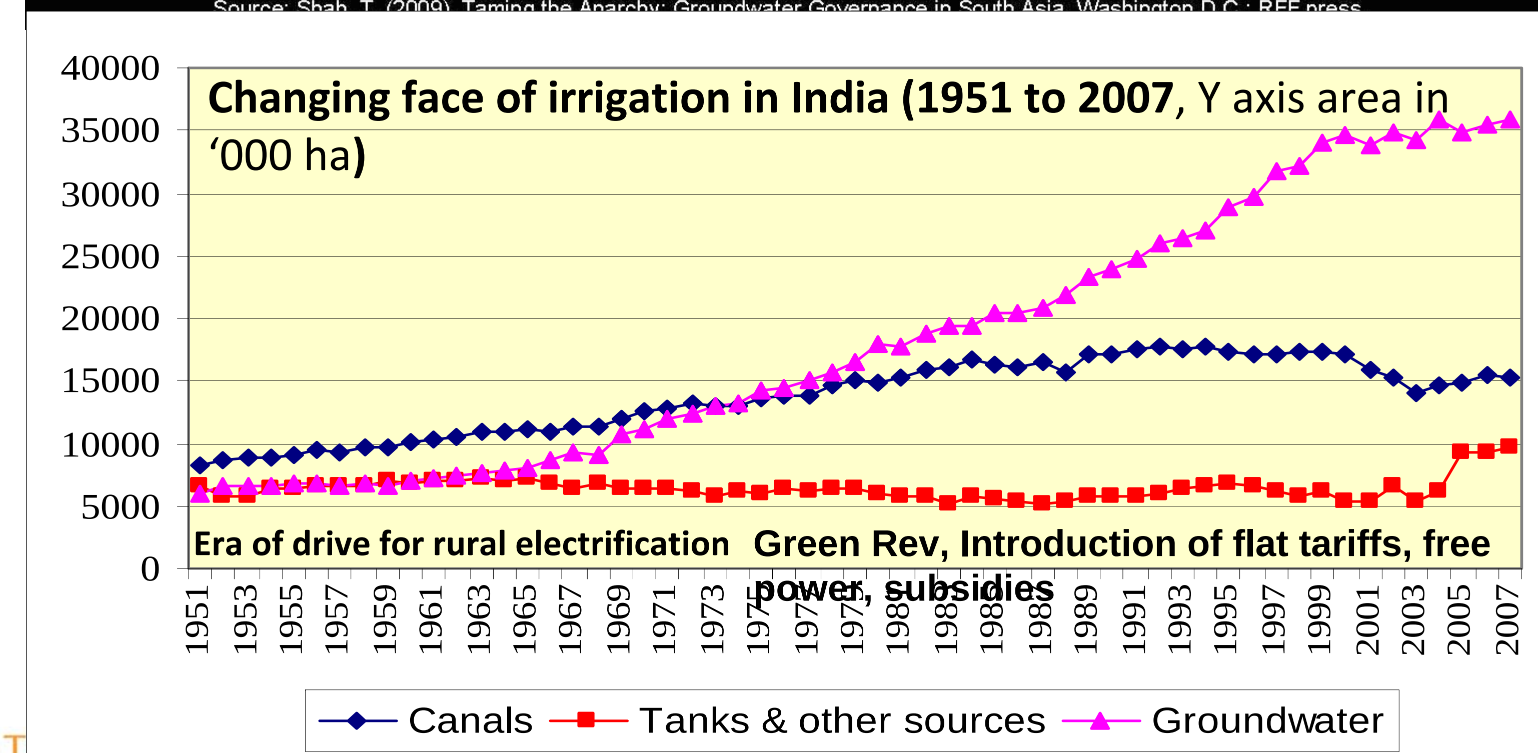


Columbia Water Center
Earth Institute | Columbia University

India- Food

	Food Prod Mil tons	Land Mil ha	Yield (tons/ha)
Total	**210**		
Irrigated	**126**	**56**	**2.25**
Rainfed	**82**	**84**	**0.98**
Add. food from irrigation (est.)		**71 Mil tons**	





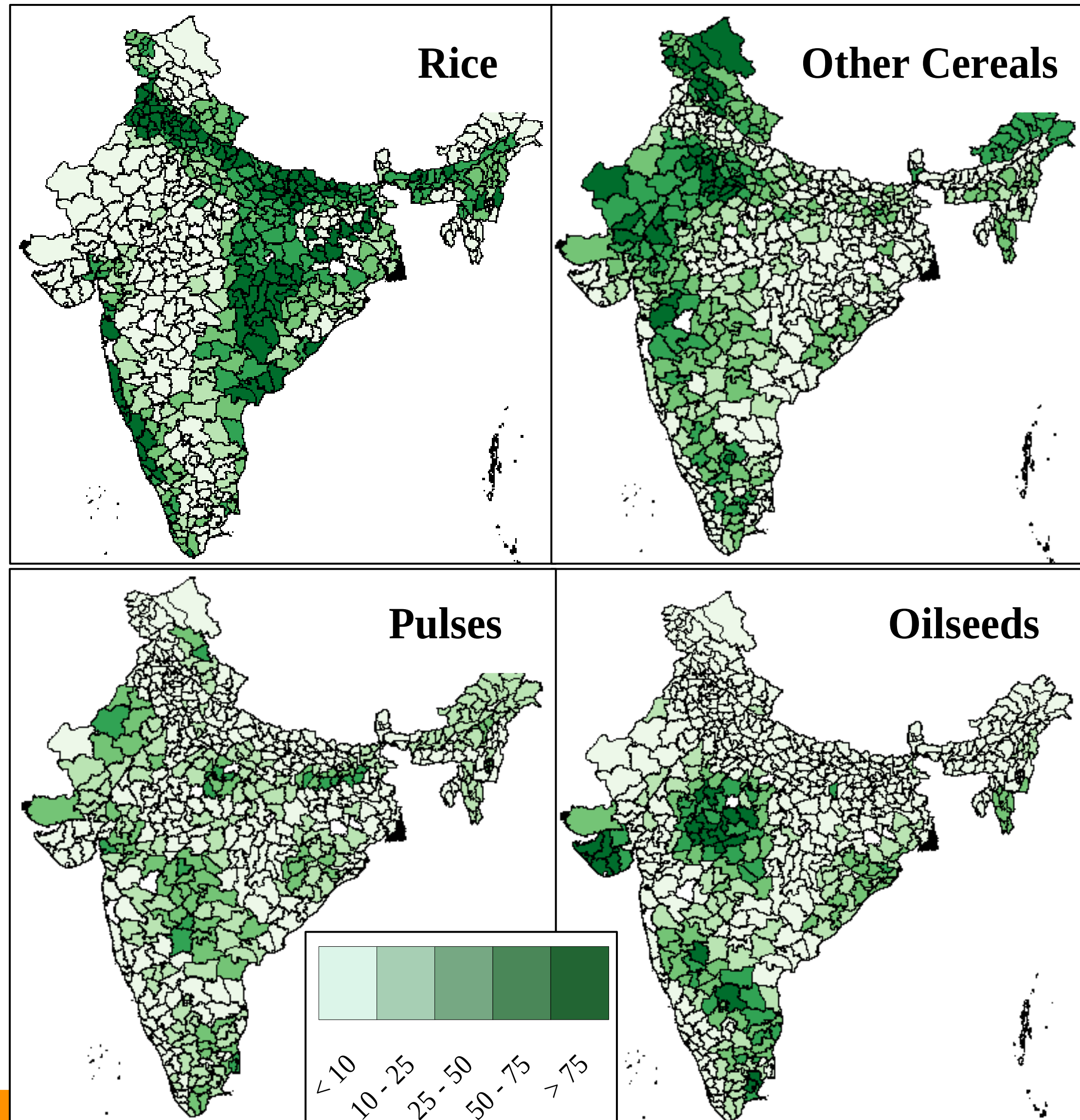
Groundwater use buffers climate variability but mining it kills future options

Source: Agricultural Census, GOI, several years

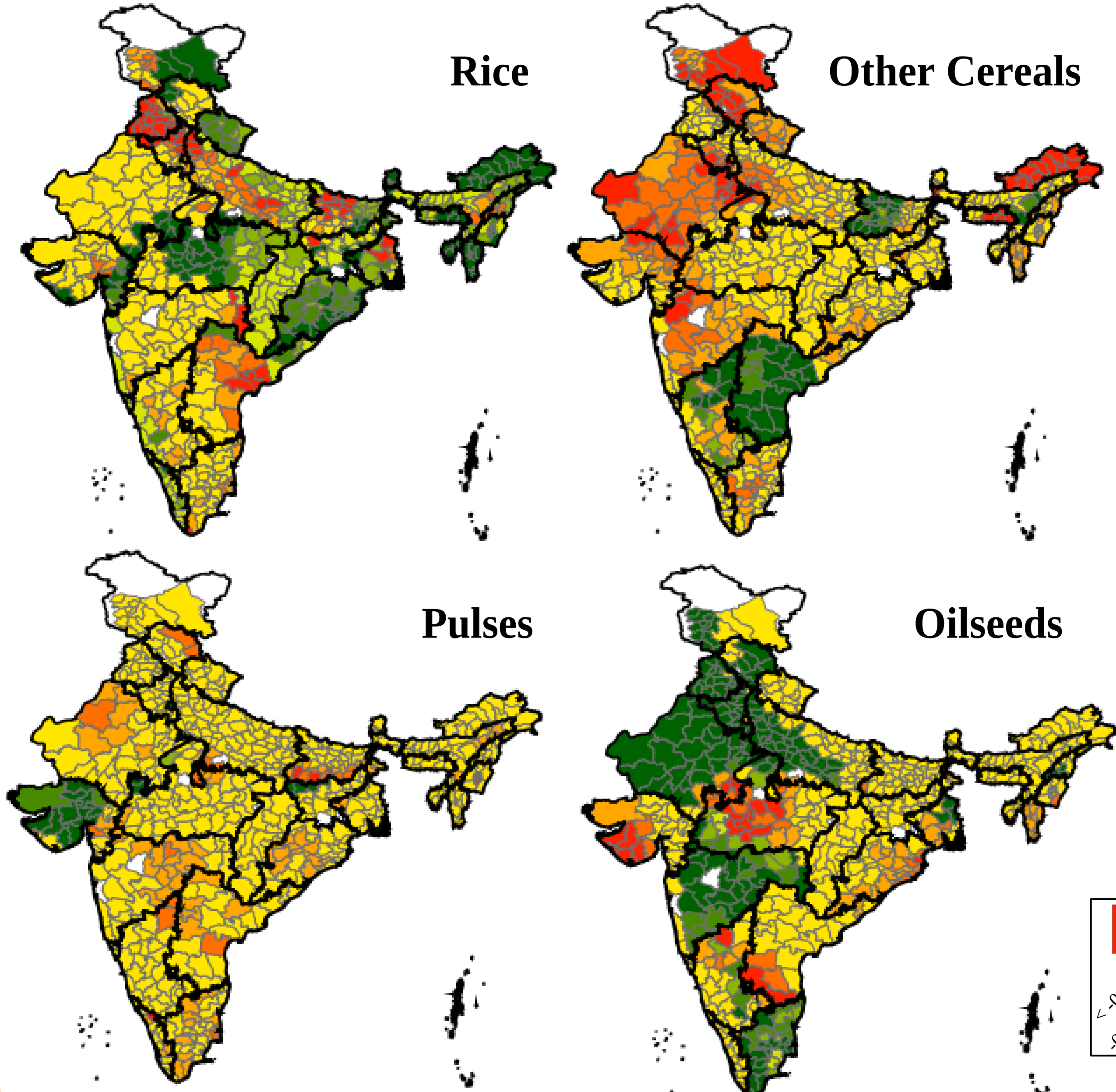
Energy challenge

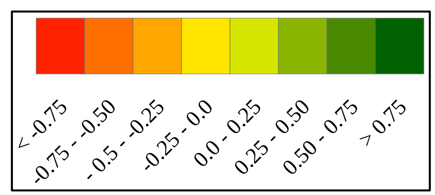
- 71 Billion kg of food crops
- 100 Billion kWh for irrigation pumping
- Parts of India 3 kWh/kg
- At 3 kWh of electricity to grow 1 kg
- Electricity worth Rs 12 to 30
- Food procured at Rs 12/kg
- Leading to all sorts of distortions

Current Cropping Pattern



Rainfed Results – Optimal Cropping Pattern

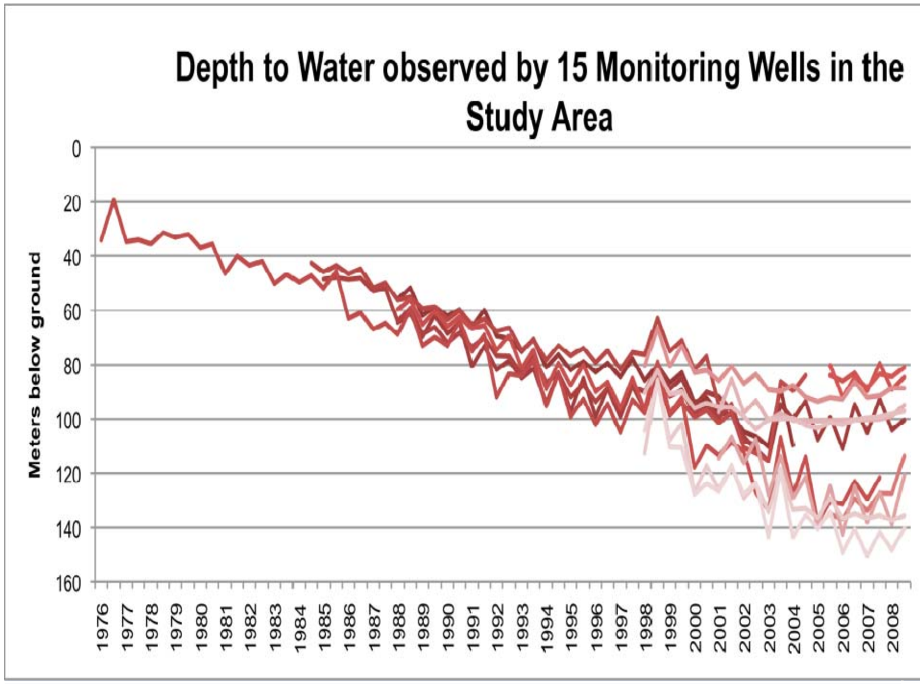


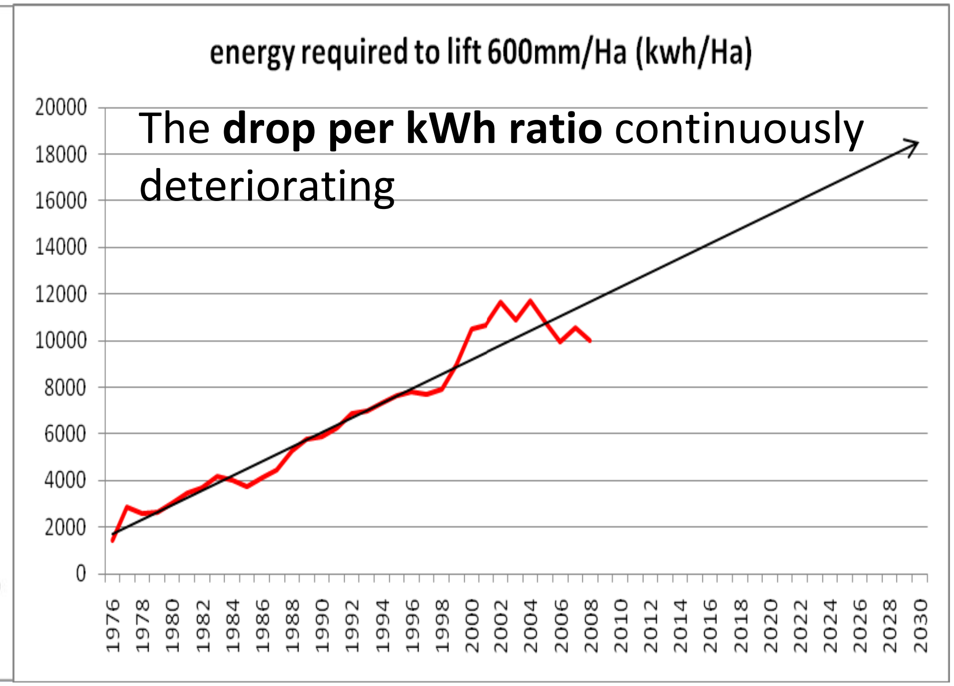


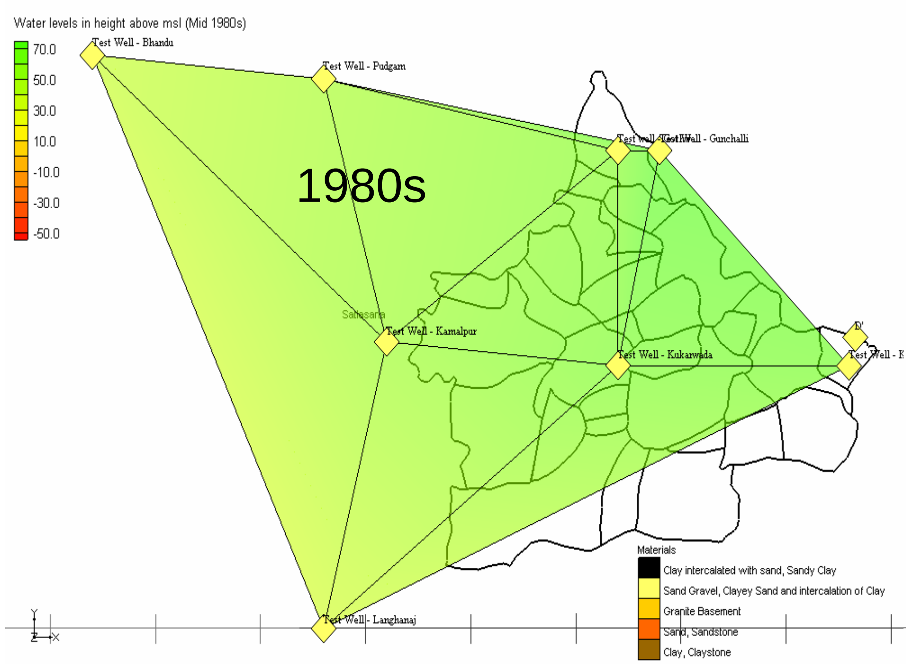
An even bigger story if corporate and government participation was used to address market price risk and technology innovation in the agricultural supply chain

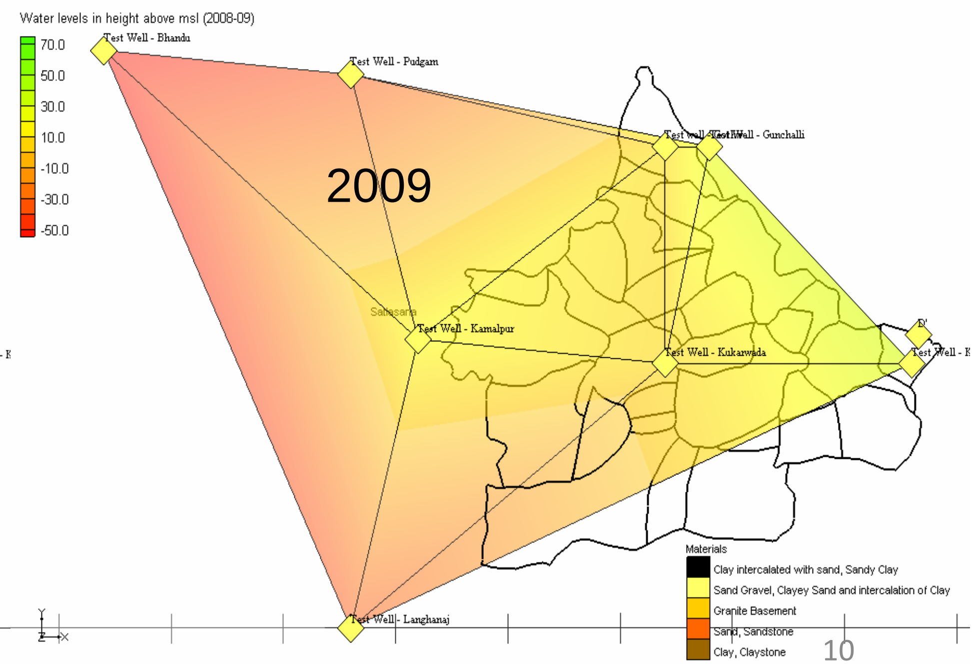
One approach in N. Gujarat

- Can we increase farmer incomes without further depleting (ideally maintaining constant) GW?
- Approach
  - Extension PLUS
  - Incentive to reduce use;
  - Make farmer direct beneficiary of reduced water use
  - Provide information/measurement tools
- **Use historical data→ baseline of electricity**
- **Compensate for "reduction" below baseline**
- **Ensure revenue neutral scheme for govt.**







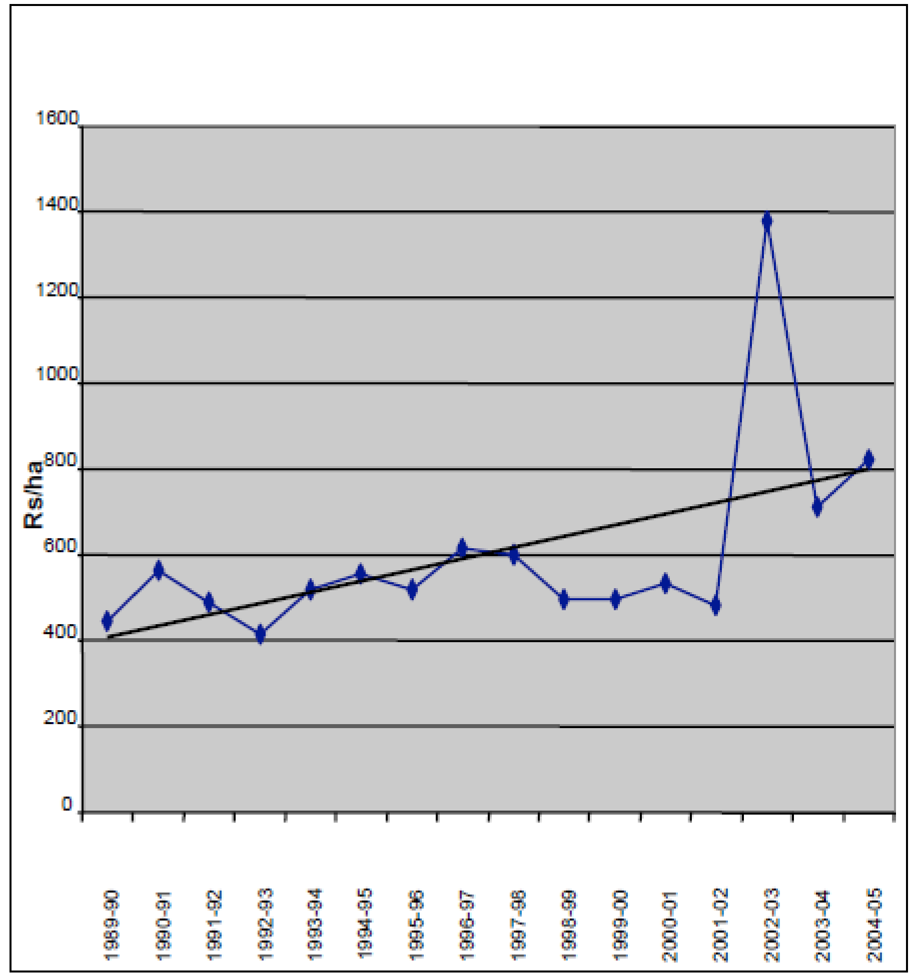


Increasing groundwater salinity

Overexploitation of ground water to sustain Rice production leads to increased expenditure on irrigation (Current + Capital)

From Dr RS Sidhu, PAU

- **Water demand (39.75 MAF) exceeded ground water availability (29.64 MAF)**
- **Water table receded at the rate of above 80 cm per year**
- **Requires frequent deepening of borewells**
- **It requires more investments leading to indebtedness and suicides (especially in case of small holders)**
- **Vulnerability of small holders to income risk has increased**



At 1981-82 prices

Alternative resource conservative cropping systems to Rice-Wheat rotation

From Dr RS Sidhu, PAU

Particulars	Rice equivalent yield (q/ha)	Net returns ('000 Rs/ha)	Saving in irrigation water applied compared to rice-wheat system (cm)
Rice-Wheat	12.1	47.1	-
Maize-Wheat-Summer Moong	13.8	51.1	12.5
Maize-Potato-Moong	19.3	56.4	120
Maize-Potato-Onion	21.8	86.7	97
Groundnut-Potato-Bajra Fodder	21.5	64.4	124

To promote alternative crop system what is necessary is the assured marketing an


Training of farmers and field staff by soil scientists on the installation and working of tensiometers
District level workshops
Farmer group meetings
Meeting village heads

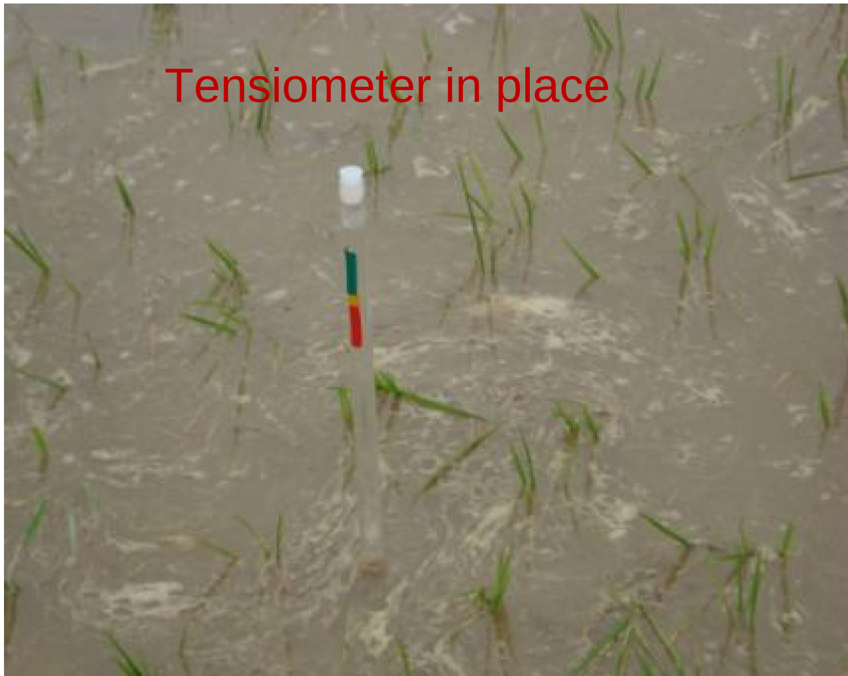

Flowers

What is a tensiometer?

- A simple device designed to measure soil moisture or water potential, i.e. the energy plants need to exert to pull in water from the soil at the current moisture condition
  - A tensiometer consists of a porous ceramic cup, connected through a rigid, body tube to a vacuum chamber, with all components filled with water. The body tube is transparent so that water within the tensiometer can easily be seen.
  - Tensiometers are placed in the field with the ceramic cup in the soil in the plant root zone. The ceramic cup is porous so that water can move through it to equilibrate with the soil water. A partial vacuum is created as water moves from the sealed tensiometer tube. The pressure associated with this vacuum is a measure of the energy that would need to be exerted by the plant to extract water from the soil. It can be recorded by a gauge, or the critical values for a particular plant can be marked on the tube.
- Purpose: If the indicated soil moisture is below what the plant needs to grow, apply irrigation water, else wait. Don't waste water by watering if it is not needed.
- Various types – cost typically $40-200;
  - PAU's simplified model =$7

Punjab Experiment Design

- Phase 1: Field Test with 525 farmers – Reducing Rice Irrigation
  - Each farmer has a control plot and a test plot
  - Strategies tested: Tensiometer, Direct Seeding of Rice, Laser Leveling
  - Record in each case number of irrigations, depth of irrigation, pump horsepower
    - Compute total water and energy use over the season for each treatment
    - Record farmer willingness to adopt and associated reasons
  - Develop recommendation and next level strategy
- Phase 2: Scaling up adoption to 5000 farmers and more
  - Evaluate farmer recruitment and retention strategies
    - Social Networks, NGOs, Self-Help Groups
    - State extension program
    - Corporate extension programs
    - Farmer cooperatives – input, marketing
  - Currently ongoing with >5500 farmers recruited through input cooperatives


Tensiometer in place


PUNJAB WATER DAY MARCH 20, 2010
Farmers' Workshop
INNOVATIONS FOR REVERSING GROUND WATER DEPLETION IN PUNJAB
FROM - PUNJAB AGRICULTURAL UNIVERSITY, LUDHIANA
&
COLUMBIA WATER CENTER, COLUMBIA UNIVERSITY, NEW YORK

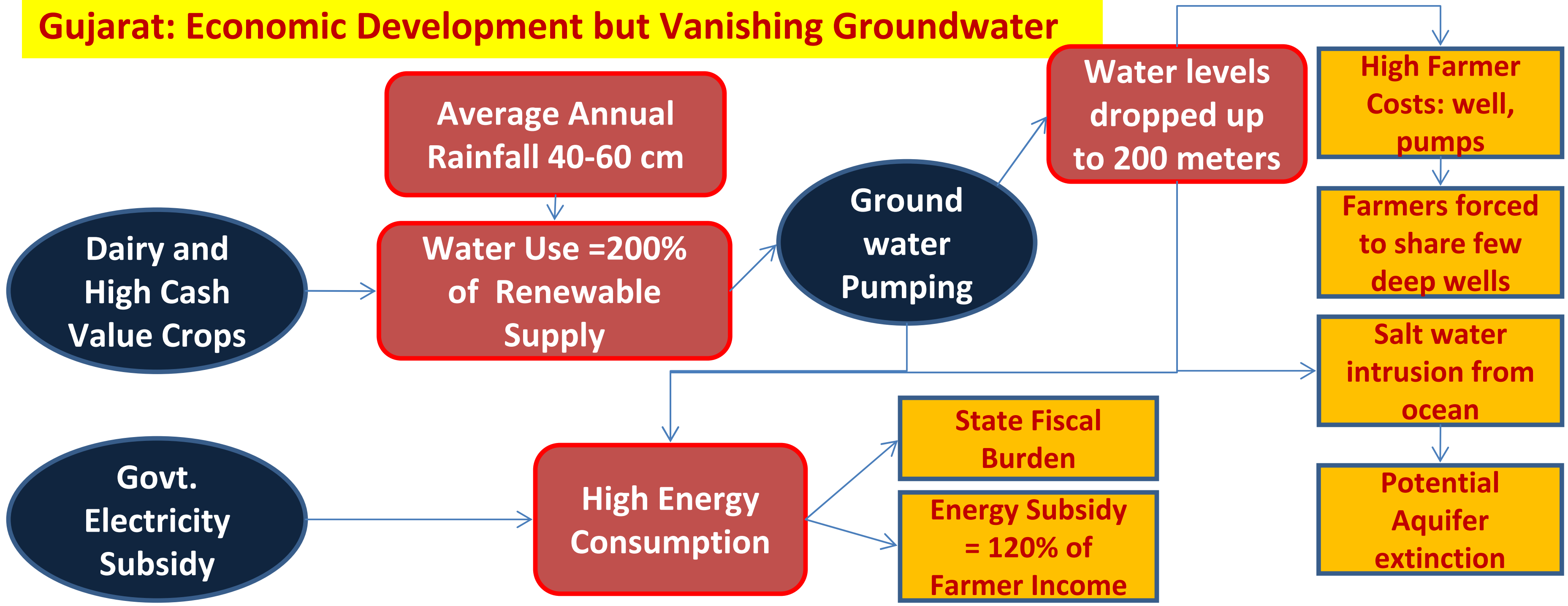
Phase 1 Results

- Application of the tensiometer emerges as an interesting low cost, high potential adoption strategy
- Over 66% of the farmers responded positively to adoption for future
  - Non-adopters key reasons:
    - Season was too wet, did not need the device
    - Device failure or inadequate extension follow up
    - Lack of village leader support
- If 66% of the farmers in the state adopt this practice
  - Average seasonal water savings = 1.8 billion m^3
  - Value of electricity savings/season= $47 to 150 million
  - Cost of tensiometer /season(3 year life and 10% initial failure rate) = $15 million

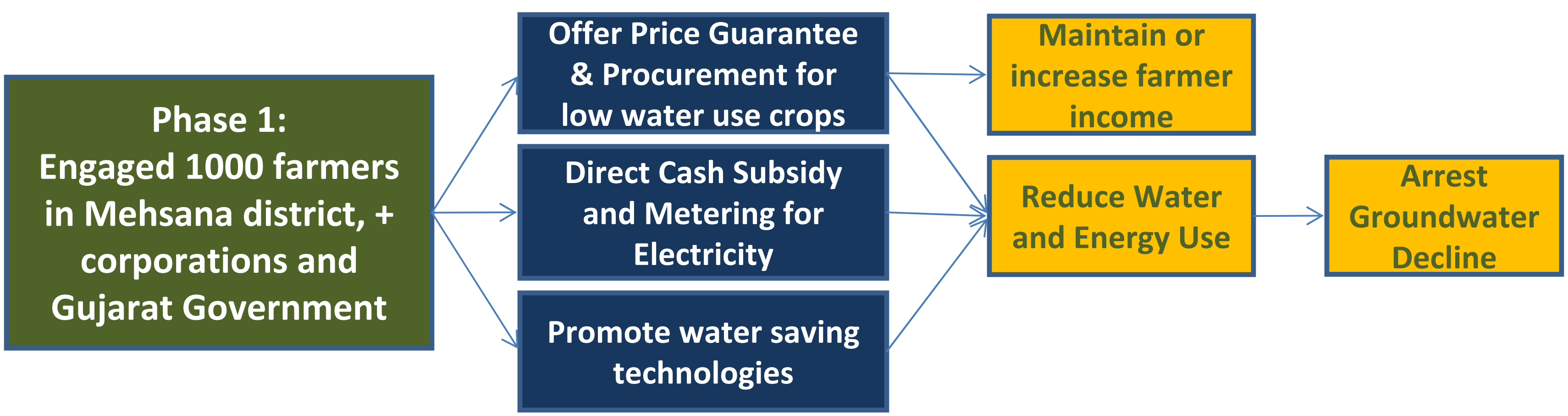
Selected experiment results:

Average savings per hectare	*22%*
Average water savings (liters /hectare/season)	*1,035,083*
Average savings in pumping energy	*24%*
Value of energy savings (monetary value/hectare/season) (@current generation cost=Rs 4.15/kwh)	*Rs 1000 ($22)*

Gujarat: Economic Development but Vanishing Groundwater



Solutions: Pepsico Foundation-Columbia Water Center-Gujarat Government



Location Overview

Principal water-related challenge

Rising **insecurity** in Water-Energy-Agriculture-Livelihood connect

Context

Social: Agriculture mainstay of economy (Mehsana a Food Security Mission district for wheat), land fragmented, small & marginal farmers

Climate: Semi arid, low rainfall & high coefficient of variability

Resource: Groundwater progressively depleting (long term declines as high as 3m /yr), increasing salinization, deepening wells; higher energy usage (> 5 times national average)

Economic: Cost of drilling/maintaining wells increasing for farmers; State's energy subsidy bill rising.

Institutional: Groundwater markets, shareholding system prevalent

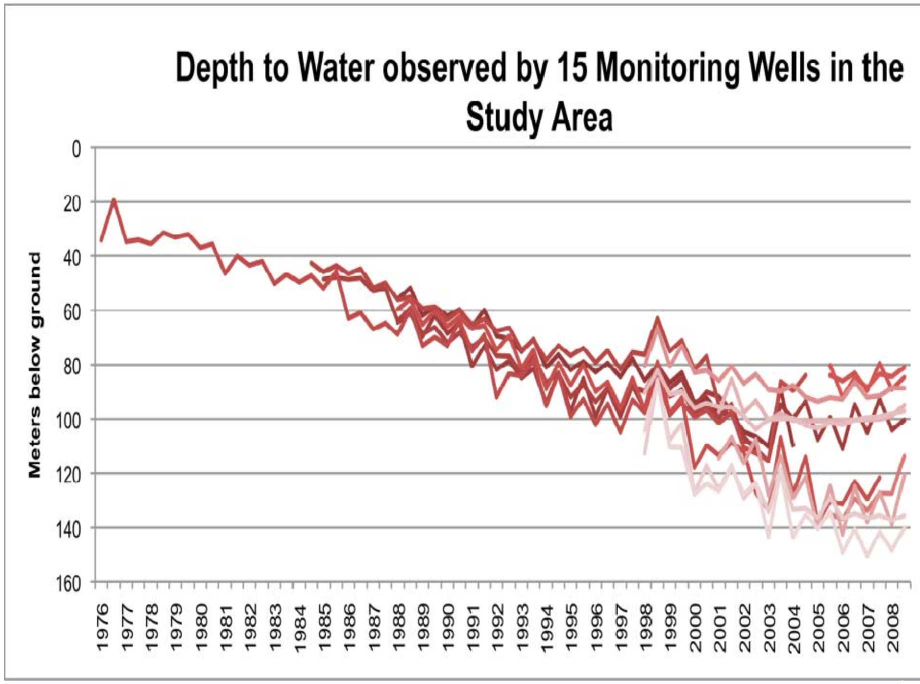
Agriculture soon, likely to be non-viable if above trends continue

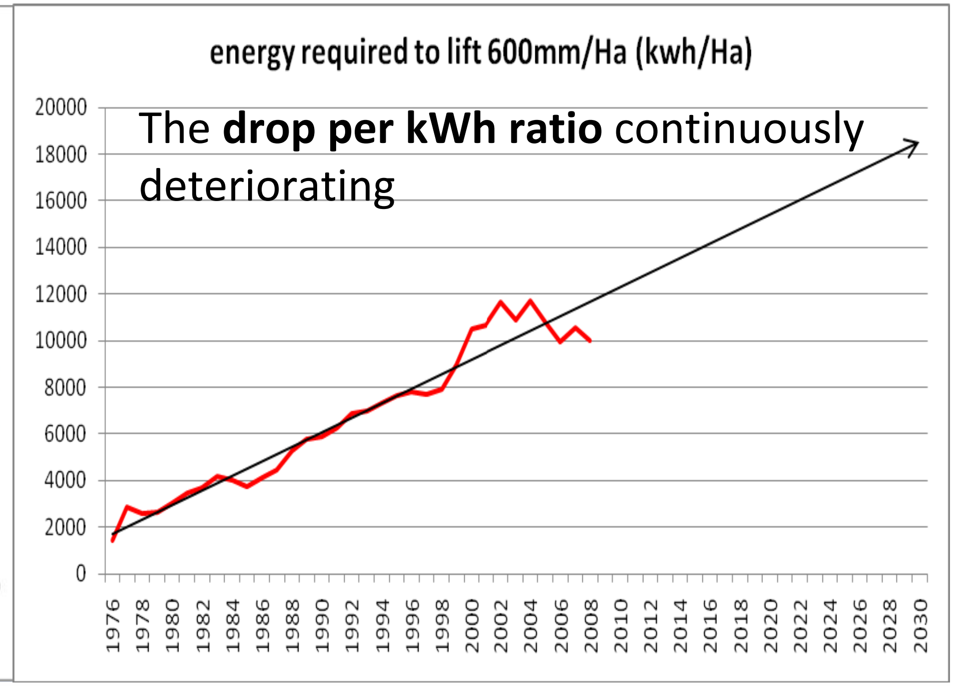
	Rs/Ha/year
Gross income	42,000-50,000
Net income	15,000-20,000
Energy Subsidy	~30,000
Investment in wells	**5,000-15,000**
Water use/ recharge	600mm/ 300 mm
Depth of wells	< 100 m (60 -70s), 100 – 300 m (80s/90s), 300 – 500 m (2000s)
Energy use kWh/ha (N)	10,000 (India avg. 1600)

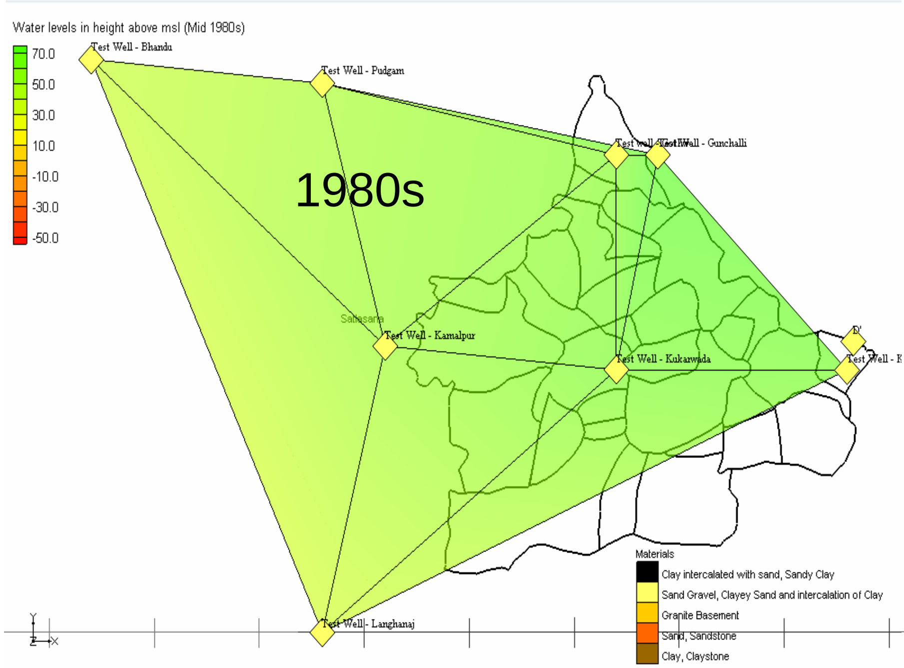
Energy for Irrigation Pumping

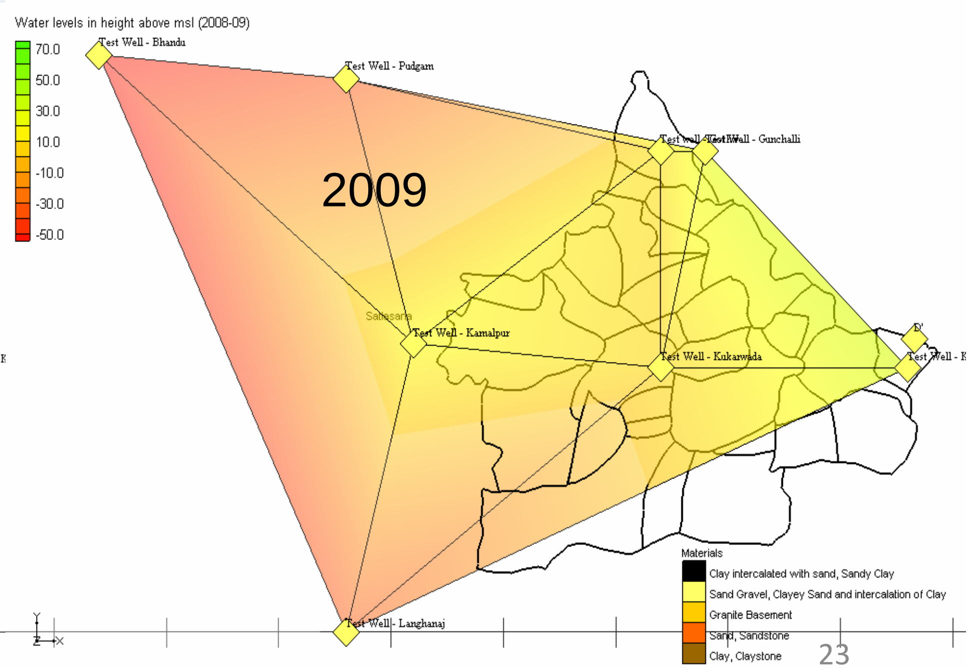
COLUMBIA WATER CENTER
COLUMBIA UNIVERSITY

	INDIA	UGVCL	Kukrvada
Elec (GWh/yr)	99,000	6,000	100
GIA (Kha)	82,000*	730	14
NIA (Kha)	60,000*	570	10
kWh/ha (G)	1,200	8,000	7,000
kWh/ha (N)	1,600	10,000	10,000









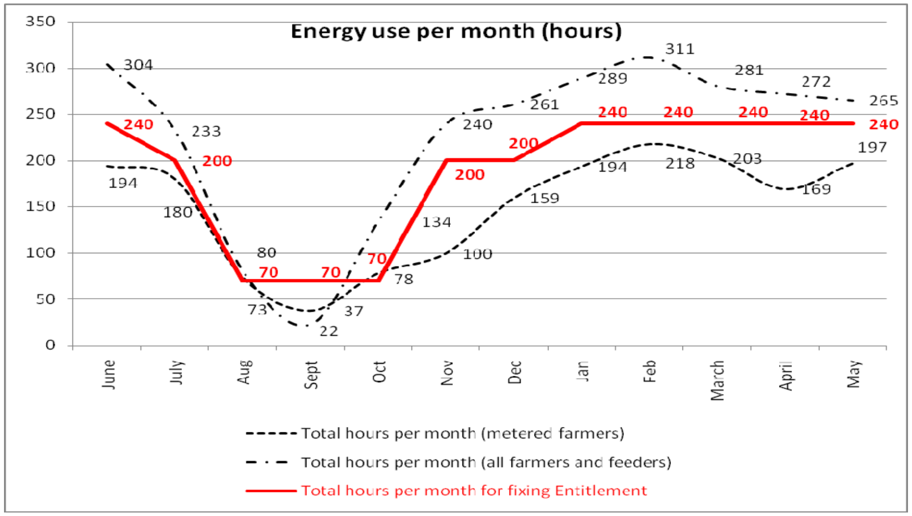
Increasing groundwater salinity

Project approach

- Can we increase farmer incomes without further depleting (ideally maintaining constant) GW?
- Approach
  - Extension PLUS
  - Incentive to reduce use;
  - Make farmer direct beneficiary of reduced water use
  - Provide information/measurement tools
- Use historical use baseline of electricity use
- Against this use, compensate for “reduction”
- Ensure revenue neutral scheme for govt.

How does it work?

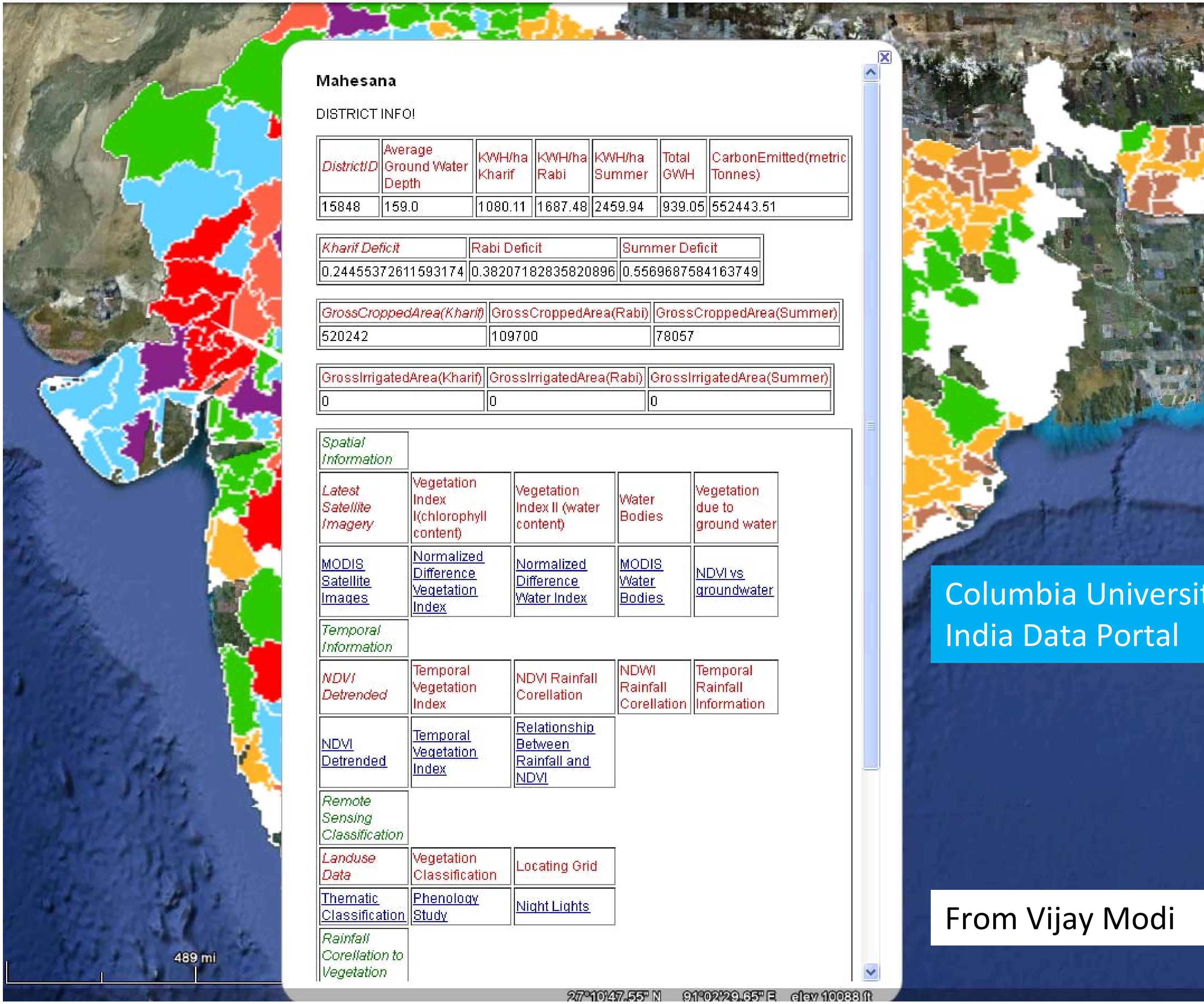
- Establish month-specific baseline using historical use data
- Farmers agree to install a meter on their premises
- Compensation Rate: *recommendation*: 5 Rs/unit (Govt. did Rs. 2.55)
- Means of compensation: tradable voucher (Govt. did credit against existing utility flat tariff bills; capping it at 15% of baseline)
- Frequency: *recommendation*: monthly (Accepted)
- Commitment horizon: *recommendation*: 5 years. (Govt. did to 3 yrs)
- Monthly use varies due to rain.
- 800 Farmers participating
- 27% of farmers saved in 1st cycle
- 90% saved in the 2nd cycle



Lessons, Opportunities and a Challenge

- Groundwater is precious
  - Use for drinking
  - Use as a drought buffer, not as primary agricultural resource(IT)
  - Improve surface water storage, distribution (IT)
- Dramatic reform needed in agricultural sector
  - Energy/water pricing (could be dynamic based on conditions) (IT)
  - Crop selection and Market Access (IT)
    - Seasonal Forecasts of Climate and Markets
    - Optimization of Area allocation and location per crop
    - Government and Private Sector Procurement Supply Chain
  - Water Saving Technologies and Irrigation Practices(IT)
    - Real Time Weather forecasts
    - Yield Enhancement while reducing fertilizer, pesticide and energy use
  - Corporate-Public Extension Program in support of Supply Chain (IT)

To the Indian Academic and Business Community: 5 and 10 year targets – set and achieve
Can India go from a Water Crisis to become the World's Leading Sustainable Agricultural Producer & Marketer with a nX boost in rural income ?



Mahesana

DISTRICT INFO!

DistrictID	Average Ground Water Depth	KWH/ha Kharif	KWH/ha Rabi	KWH/ha Summer	Total GWH	CarbonEmitted(metric Tonnes)
15848	159.0	1080.11	1687.48	2459.94	939.05	552443.51

Kharif Deficit	Rabi Deficit	Summer Deficit
0.24455372611593174	0.38207182835820896	0.5569687584163749

GrossCroppedArea(Kharif)	GrossCroppedArea(Rabi)	GrossCroppedArea(Summer)
520242	109700	78057

GrossIrrigatedArea(Kharif)	GrossIrrigatedArea(Rabi)	GrossIrrigatedArea(Summer)
0	0	0

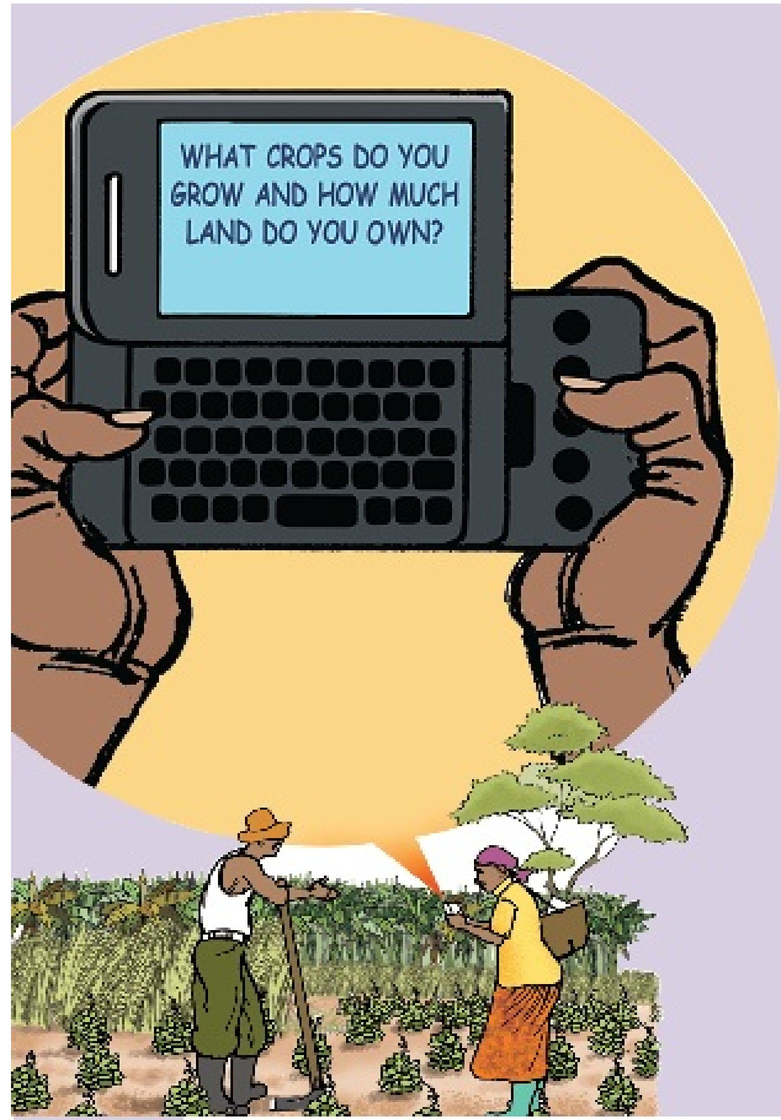
Spatial Information				
Latest Satellite Imagery	Vegetation Index I(chlorophyll content)	Vegetation Index II (water content)	Water Bodies	Vegetation due to ground water
MODIS Satellite Images	Normalized Difference Vegetation Index	Normalized Difference Water Index	MODIS Water Bodies	NDVI vs groundwater
Temporal Information				
NDVI Detrended	Temporal Vegetation Index	NDVI Rainfall Corellation	NDWI Rainfall Corellation	Temporal Rainfall Information
NDVI Detrended	Temporal Vegetation Index	Relationship Between Rainfall and NDVI		
Remote Sensing Classification				
Landuse Data	Vegetation Classification	Locating Grid		
Thematic Classification	Phenology Study	Night Lights		
Rainfall Corellation to Vegetation				

Columbia University India Data Portal

From Vijay Modi

Ict4Ag Services to Farmers

- Fertilizer inputs
- Soil preparation
- Market prices
- Calendarization
- Seed choices
- Weather patterns



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