Managing water under climate variability:

Physical Options and Policy Instruments

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Purpose of the session

- This session would discuss :
  - The various physical options for water management both on the supply and demand side, in the face of climate variability
  - Their scope and limitations
  - Market instruments for affecting adoption of demand side solutions.

Content

- Introduction
- Key water management challenges
- Supply side options for water management
  - Scope and limitations
- Demand side options for water management
  - Physical options: scope and limitations
  - Market instruments for promoting water demand management in agriculture
- Summary and Conclusions

Introduction

- Semi arid and arid regions in India, which are naturally water-scarce, are facing three different sets of water problems
  - Over-appropriation of surface water
  - Groundwater depletion, natural quality problems
  - Scarcity of water for competitive and in-stream uses
- Magnitude of climate variability problems are larger there
- During years of low rainfall, with fewer rainy days, higher aridity, the stream flow reduces drastically
- Humid, sub-tropical regions also experience seasonal water shortage

Key water management challenges

- Making sufficient water available for irrigation at the regional level for agricultural growth--naturally water scarce regions
- Improving equity in access to water for irrigation and other uses--both water-scarce and water rich regions
- Improving sustainability of drinking water supply sources
- Making safe water available for drinking & domestic uses--in water rich regions as well as water scarce regions
- Maintaining flows in environmentally water-stressed regions

Standard instruments for dealing with water scarcity

- Supply augmentation
- Water rights in the form of well permits; volumetric use rights
- Indirect charges through energy pricing
- Direct regulation of drilling; pump sets
- Virtual water trade
- Mimicking of river flows

- Need local runoff; otherwise inter-regional water transfer
- Strong political system; institutional mechanisms needed
- Farmers are major vote banks in India
- Difficult to enforce in Indian context
- Many arid & semi arid areas are exporting virtual water
- Competition between agriculture and environment

Deciding on a management intervention

- There are three different types of benefits that the society could accrue from a management intervention.
- They are: economic benefits; ecological/environmental benefits; and social benefits.
- From societal point of view, a management decision would be sound, only if the aggregate of these benefits exceed the costs of proposed interventions.
- The aggregate benefits are a sum of the economic benefits and all the positive externalities on the society associated with the ecological/environmental and social benefits.

Contd..

- This could be quantified in terms of reduction in economic costs associated with any of the negative consequences:
  - Damage to river ecology
  - Long term decline in groundwater levels
  - Intrusion of sea water in coastal aquifers
  - Land subsidence
  - Deterioration of natural quality of groundwater
  - Loss of wetlands
- The approaches to manage water should attempt: i] reducing the withdrawals that are the results of anthropogenic activities; and, ii] increasing the utilizable flows.

Various supply side approaches for water management

- Increasing the Inflows:
  - Local water harvesting and recharging of groundwater through:
    - Spreading basin method
    - Dug well recharging (ASR)
    - Check dams
    - Injection wells
    - Induced recharge
    - Percolation tanks with recharge tube wells

Supply side approaches

- Water transfers from water-rich regions for providing alternative sources of water supply
  - Groundwater banking in California CVP
  - Groundwater banking in MDB in Australia
  - North Gujarat receiving SSP waters
- Recycling and recharge
  - Waste stabilization ponds
  - Soil Aquifer Treatment (Israel)

Potential of local water harvesting and artificial recharge in India

- Naturally water rich regions which experience seasonal shortages can adopt water harvesting
  - North east hilly/mountainous region
  - Mountainous areas and midlands of Nepal, High rainfall areas of Sri Lanka
  - Western ghat and eastern ghat regions
- Water harvesting is unlikely to work in semi arid and arid regions due to:
  - Poor hydrological opportunities for harvesting and poor reliability of water supply
  - Poor economic viability
  - -ive d/s impacts due to high degree of water development

Physical approaches for demand management

- Agricultural water demand management
  - Technological interventions
    - Micro irrigation systems
    - Plastic mulching in arid areas
  - Cropping system change
  - Growing crops in regions with high water productivity due to climatic advantages
  - Improving reliability of irrigation
  - Water control

Potential impacts of micro-irrigation on water use

- Complex factors involved in assessing water saving from micro irrigation
- Water saving depends on three factors:
  - How much water could be saved using the technology at the field level
  - What farmers do with the saved water
  - What opportunities exist at the macro level for adoption of the technology

Opportunities for field level water saving

- Field level water saving through MIS depends on :
  - Agro-climate
  - Type of MI technology
  - Depth to groundwater table
  - Crop type
- Real water saving at field level would be significant in arid and semi arid basins, with deep groundwater table, with drip irrigation used for row crops
- Such areas include alluvial central Punjab, western Rajasthan and north & central Gujarat and deep water table areas of peninsular India

Constraints and opportunities in adoption of micro irrigation systems

- Area under crops that are most amenable to MI systems in terms of water saving benefits and income benefits are low in semi arid & arid regions--7.8 M ha in India
- Area where it can lead to water saving is only 5.9 m. ha
- It can increase if we include surface irrigated area
- Lack of restrictions on groundwater pumping and zero marginal cost of using it reduces the economic incentives for well irrigators having smaller holdings in good aquifer basins
- In hard rock areas, well interference further reduces individual initiatives to save water in the aquifer

Constraints and Opportunities in adoption of micro irrigation systems

- Small operational holding of farmers increases the unit capital and operating cost of MI system
- In the surface irrigated areas, intermediate storage systems are reqd. for use of MI-diggie in Rajasthan
- In areas where power supply limits water abstraction, farmers have least incentive to go for MI systems as it does not help them expand the area
- In hard rock areas, farmers have high incentive to go for MI systems, as they could expand the area under the irrigated crops
- Geographical spread of adoption of MIS is a testimony to this

What is the likely impact of MI systems on aggregate water use at the regional level?

- Often MI adoption is associated with changes in cropping system towards from traditional crops to high valued orchards--north Gujarat, Nalgonda, Jalgaon etc.
- Hence water saving at the field level could be high
- But, this can also lead to expansion in irrigated areas, particularly in situations where percentage irrigated area is less
- In areas where MI system results in "saving in applied water" alone, aggregate impact would be greater depletion of water
- In situations like Punjab, MI system adoption can lead to real water saving, but cropping system is not amenable

What is the likely impact of cropping system changes at regional level?

- Many traditional crops and dairying in semi arid and arid regions have low water productivity
- Replacement of traditional crops by high valued fruit crops can cut down water use even at the aggregate level due to:
  - Significant reductions in depleted water for a unit area
  - Absence of sufficient cultivable area to use up all the saved water at the farm level
- But, many farming systems are composite. Crop residues form inputs for dairying in many areas.
- Dairying yields high water productivity in Punjab, when compliments rice-wheat system

How far can it work in semi arid and arid regions?

- Replacing low water-efficient rice-wheat system will disturb dairying
- Importing fodder would increase the farming risks if done at a large scale
- Large scale adoption of high valued fruit crops can lead to market crash, leading to major drops in water productivity itself
- Also, major regional level crop shifts can take place would be constrained by concerns of food security, stability of farm income and employment generation
- Improving the productivity of existing crops will have to get priority

Agro-climate impact on crop water productivity

- In many basins, major variations in agro-climate exist spatially
  - Krishna basin, Godavari basin, Indus basin, Narmada
- Climate can affect crop yields through solar radiation and sunlight
- It can also affect evapo-transpiration
- Soil conditions will have impact on crop yields
- Hence, agro climate can have big impact on water productivity
- In Narmada basin, wheat water productivity varied widely across 9 agro climatic sub-regions, changes during droughts

PART II

DRINKING WATER

Options for improving drinking water supplies in rural areas

- Creating small local surface storages in naturally water-rich regions (NE, Western Ghat, Eastern Ghat—management by local institutions
- Regional water supply systems based on allocation from large reservoirs in naturally water-scarce regions—institutions both at local and system level
- Decentralized water treatment systems in groundwater-rich regions (of eastern India) for local sources, and local institutions
  - Both household and community systems
- Groundwater based schemes are likely to be unsustainable in naturally water-scarce, hard rock regions

PART III: Use of market instruments for water demand management in agriculture

Using electricity prices as a tool for managing groundwater use in agriculture

- Consumption based pricing creates incentives among farmers to generate higher return from every unit of water
- When confronted with marginal cost, and under higher tariff, they use electricity & water more efficiently; select crops and farming systems that are more water-efficient
- Under higher (pro rata) tariff, they obtain higher returns from every unit of land also
- They use less amount of groundwater per unit of land; improving sustainability of groundwater use
- Returns from farming are elastic not to water/energy tariff; but quality of irrigation

Different modes of pricing & expected outcomes under different energy use regimes

Energy Supply Policy	Monitoring	Pricing Policy Option	Outcomes at farm level	Outcomes for Company
Fixing Energy Quota of Each Farmer	Use is metered	Option 1: Pro rata tariff	Improved efficiency of energy/water use; water productive crops	Theft prevented; revenue loss reduced; Sustainable groundwater use possible
Fixing Energy Quota based on Connected Load & Supply Hours	Use is metered Do	Option 2: Pro rata tariff Option 3: HP based Charges	Improved efficiency of energy/water use by all Improved efficiency of energy/water use by large farmers only	Theft prevented; revenue loss reduced Do
Unrestricted Energy Supply	Use is metered	Option 4: Pro rata tariff a must	Improved technical efficiency of energy/water use + High productivity gains due to improved reliability	No losses to the company But, groundwater use may not be sustainable
Fixing Supply Hours	Use is not metered	Option 5: Fixed tariff based on reported connected load	Poor energy use efficiency; monopoly of large farmers	Theft high; revenue losses to the company Unsustainable Groundwater Use

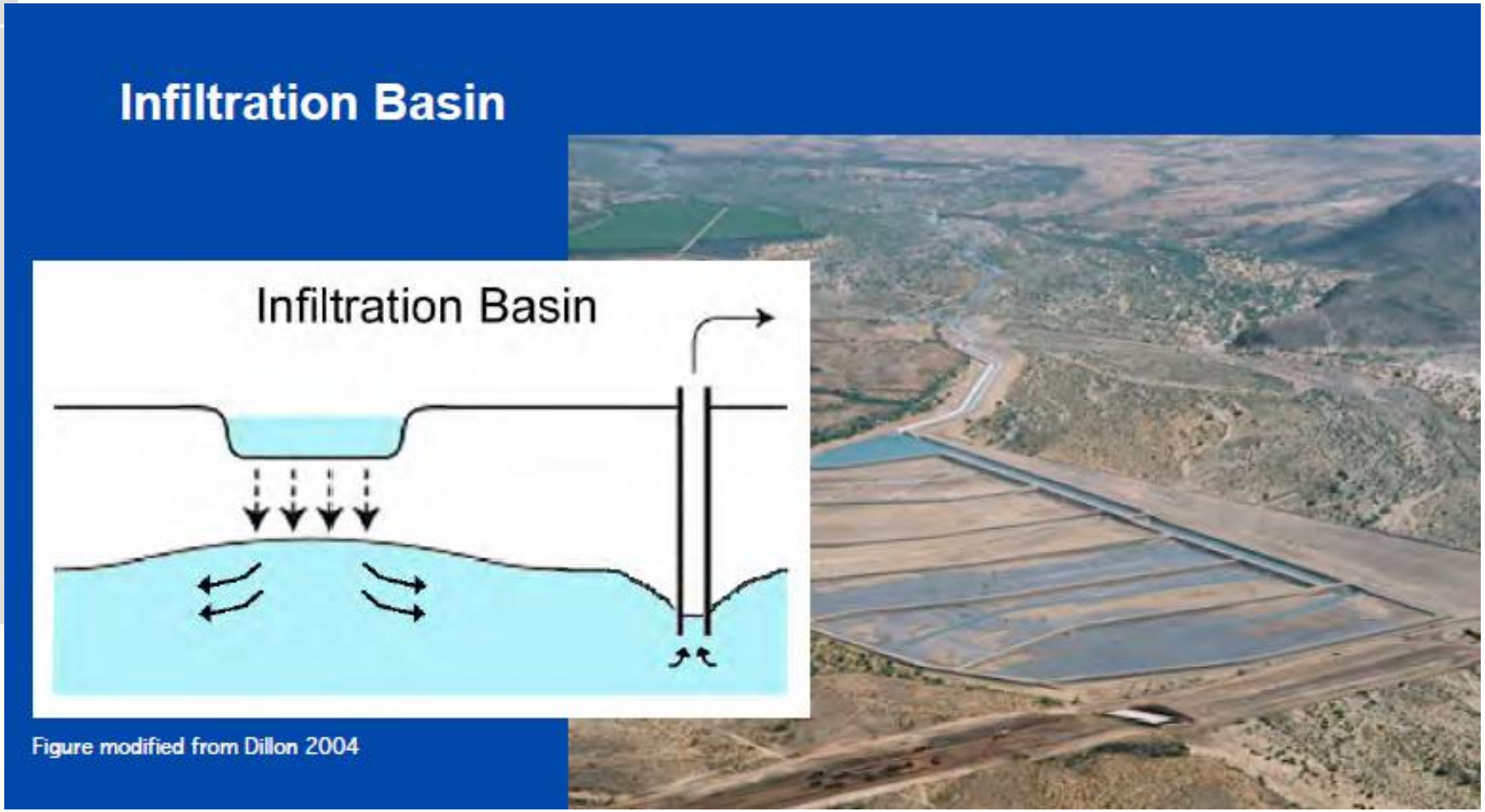
Summary

- The approaches for augmenting water resources in water-scarce areas include: groundwater recharge using local runoff; recharge using imported water; and, recharge using treated wastewater.
- In arid and semi-arid regions, the hydrological opportunities and economic viability of artificial recharge would be generally very low.
- Another major approach is MI system to raise crop water productivity.
- Field level real water saving through MI devices depends on the crop type, climate, soils and geo-hydrological environment
- Water-saving at the aggregate level would depend on availability of extra land for cultivation; the availability of power supply vis-à-vis the amount of groundwater that can be abstracted

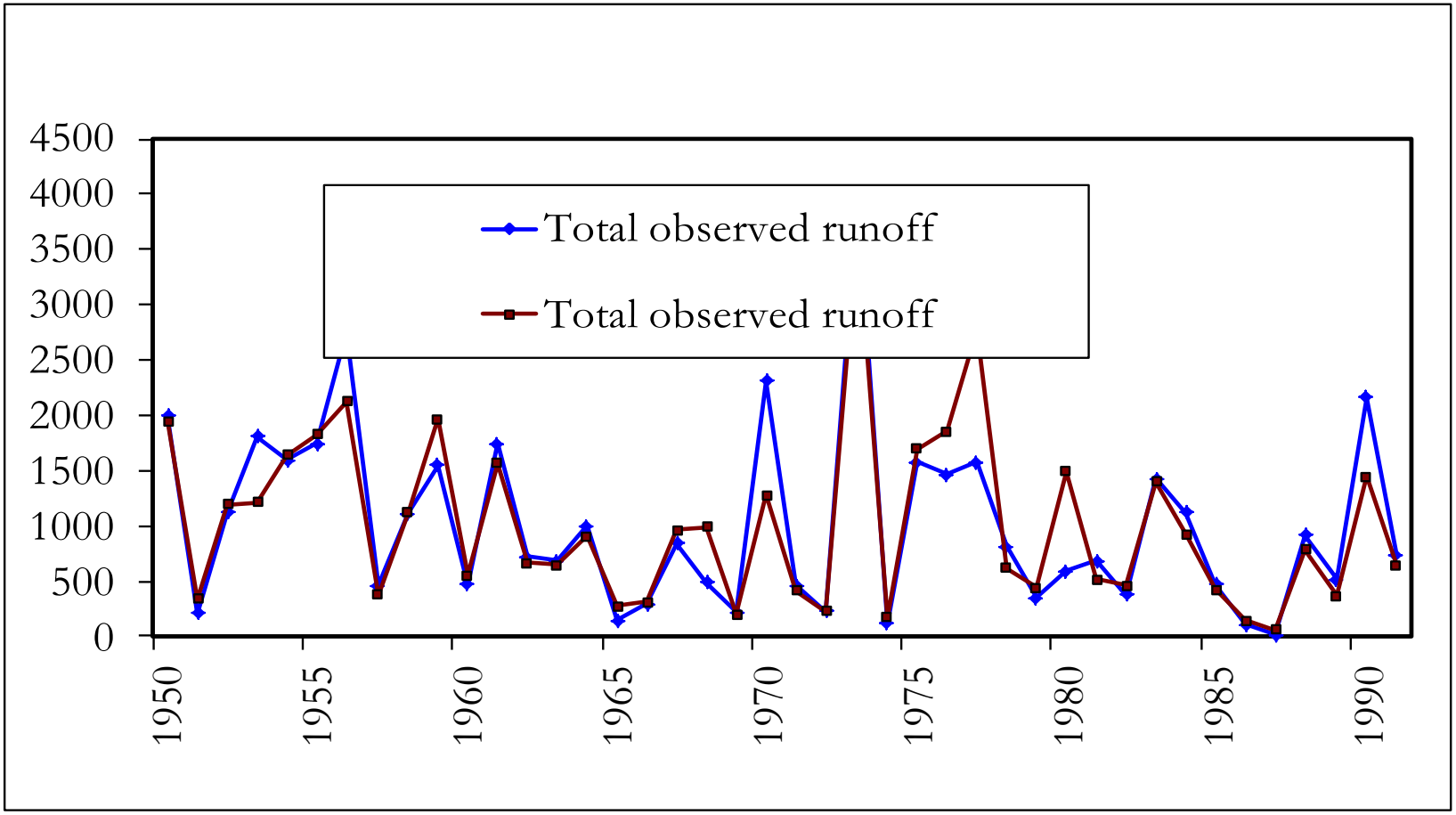
Summary

- Scope for WP improvement at the regional level through crop shift would be determined by
  - Contribution of the existing cropping system to regional food security, the employment generation in rural areas
  - Presence of market infrastructure for high valued crops.
- But, in any case, the outcomes of water productivity improvement through crop shifts in terms of reduction in groundwater draft would also depend on the opportunities for farmers to expand the area
- In some regions, opportunities might exist for enhancing water productivity by taking climatic advantages
- Pro rata pricing of electricity could lead to efficient and sustainable use of groundwater and would also be socio-economically viable

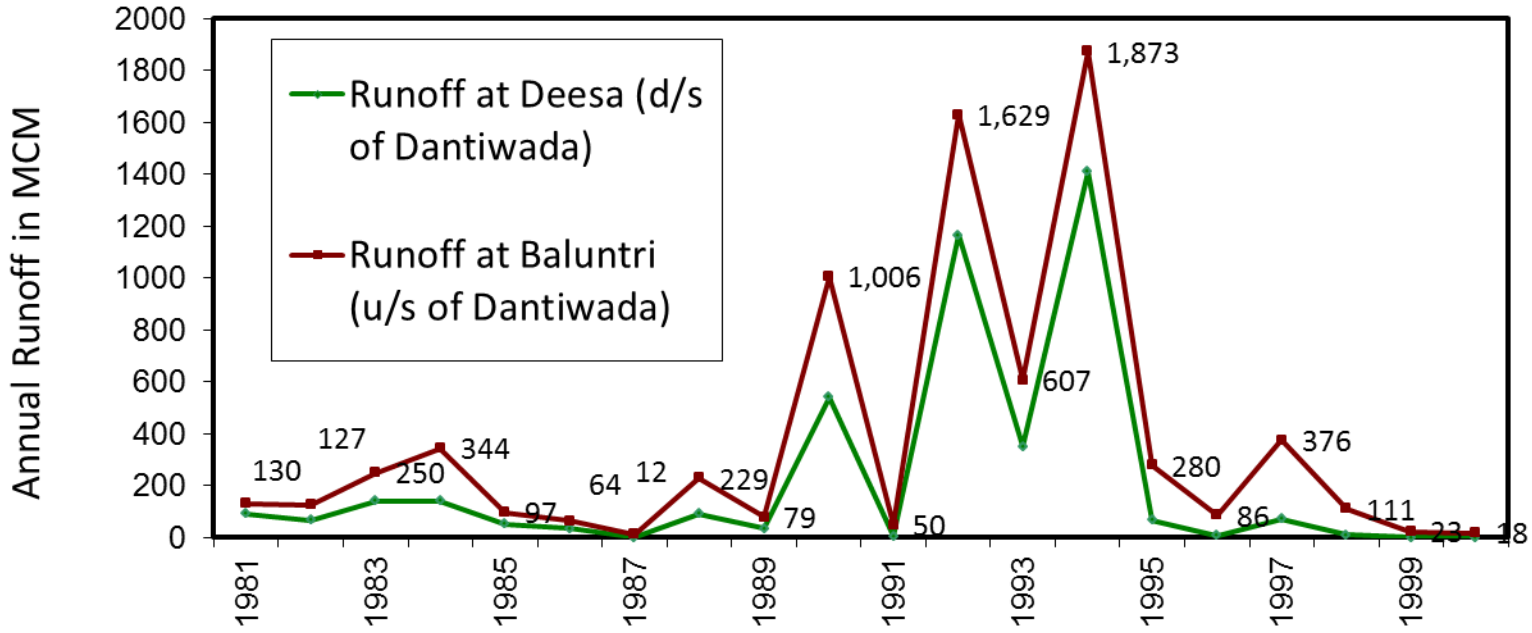
Infiltration basin/spreading basin, Australia



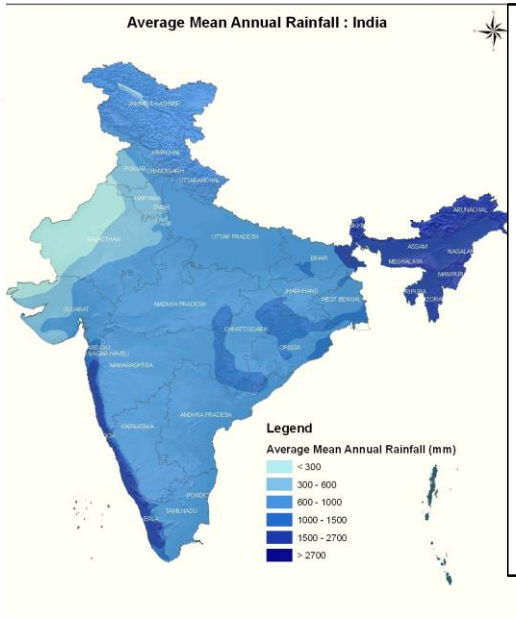
Estimated & observed runoff in Dharoi sub basin (MCM) from 1951-1991

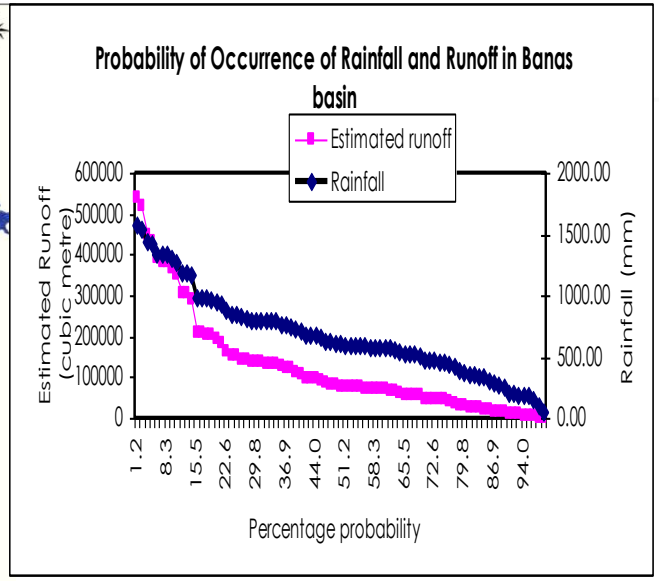


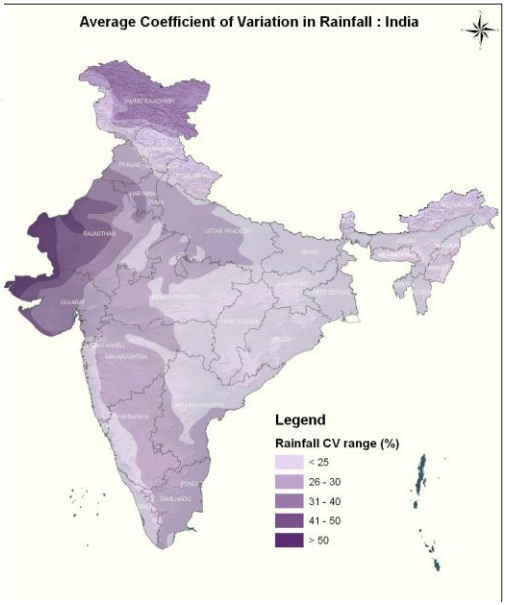
Historical runoff in Banas river

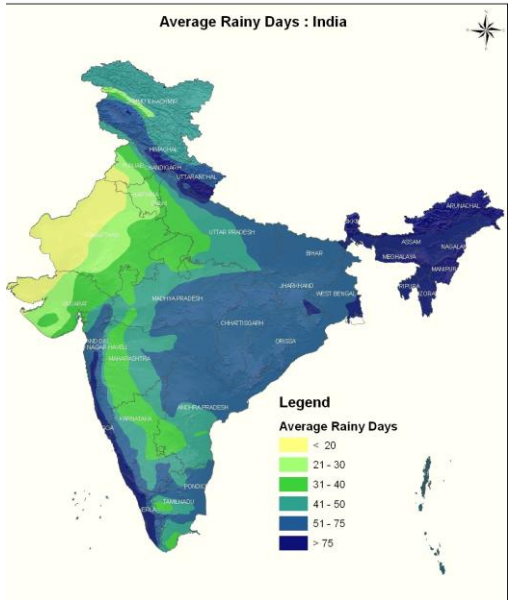


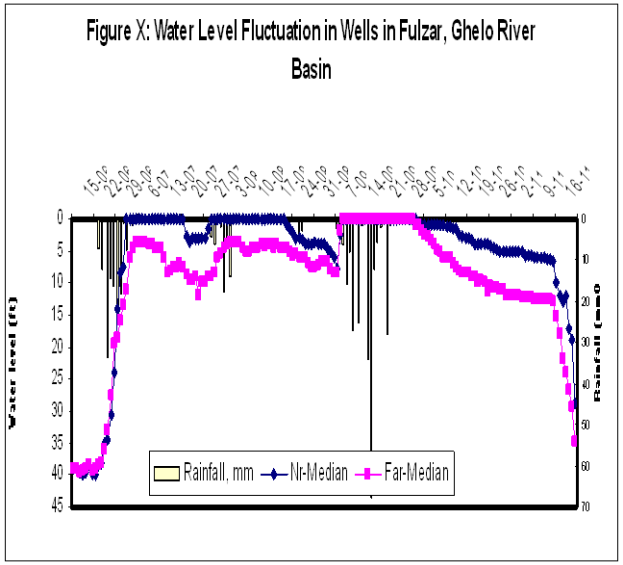
Will water harvesting and local recharging benefit naturally water-scarce regions?

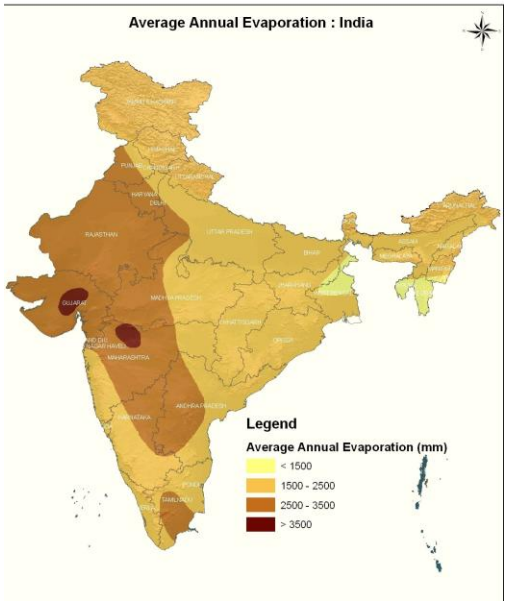








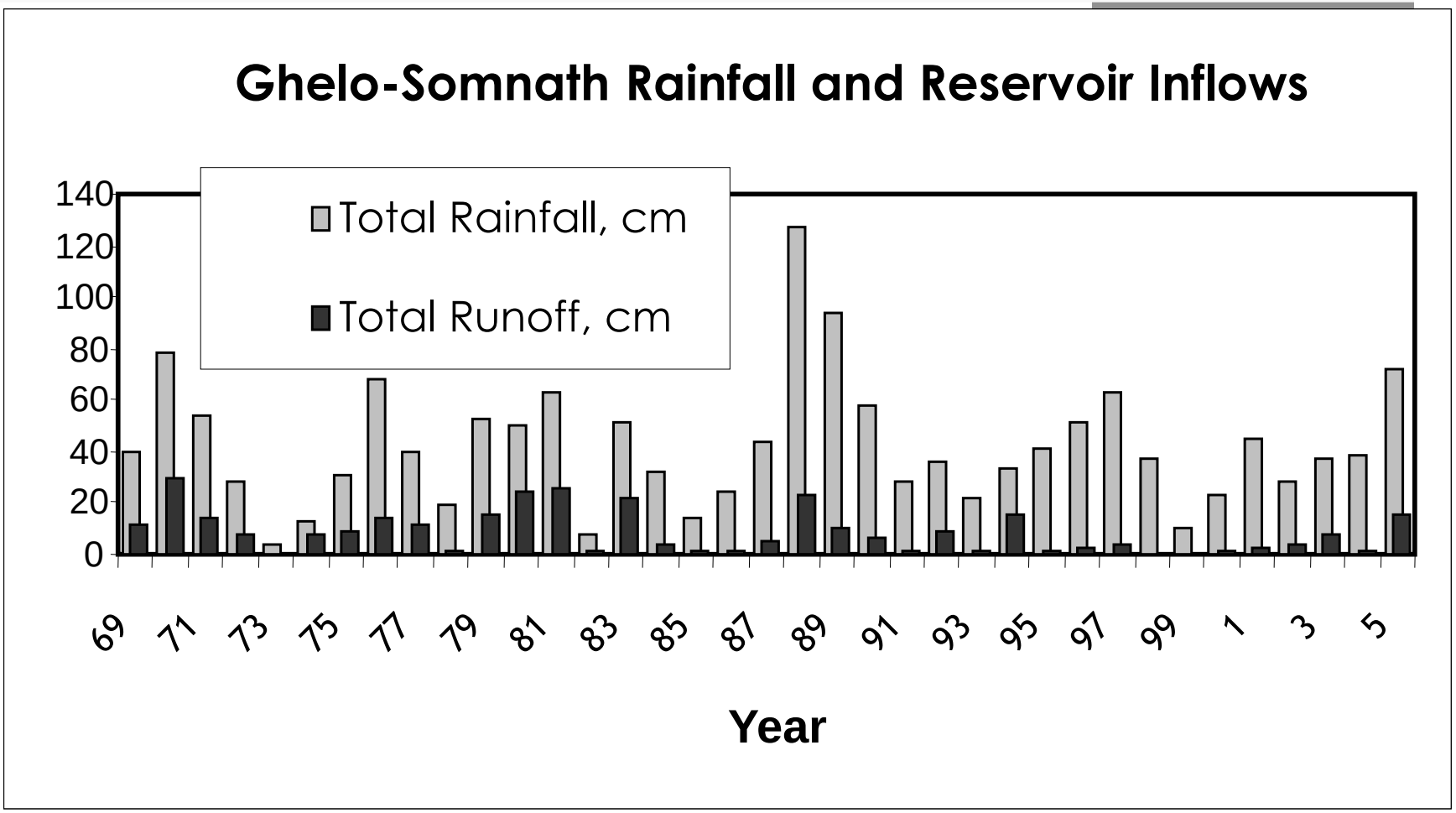




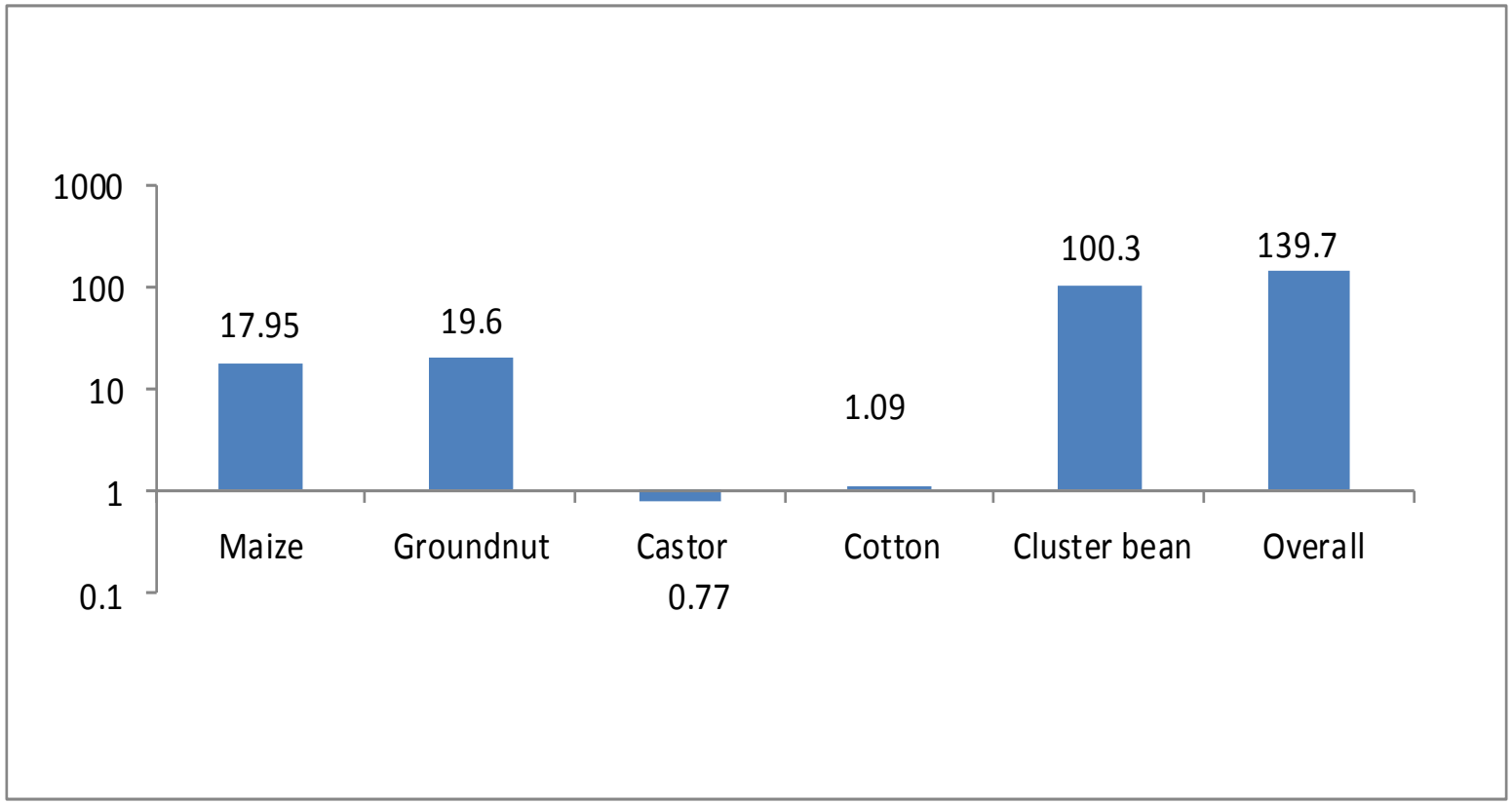
Estimated unit cost of artificial recharge structures built under pilot scheme of CGWB

Sr. No	Type of Recharge Structure (Life in years)	Expected Active Life of the System	Estimated Recharge Benefit (TCM)	Capital Cost of the Structure (in Lac Rs.)	Cost of the Structure per m^3 of water (Rs/m^3)	Annualized Cost* (Rs/m^3)
1	Percolation Tank	10	2.0-225.0	1.55-71.00	20.0-193.0	2.00-19.30
2	Check Dam	5	1.0-2100.0	1.50-1050.0	73.0-290.0	14.60-58.0
3	Recharge Trench/Shaft/	3	1.0-1550.0	1.00-15.00	2.50-80.0	0.83-26.33
4	Sub-surface Dyke	5	2.0-11.5	7.30-17.70	158-455.0	31.60-91.00

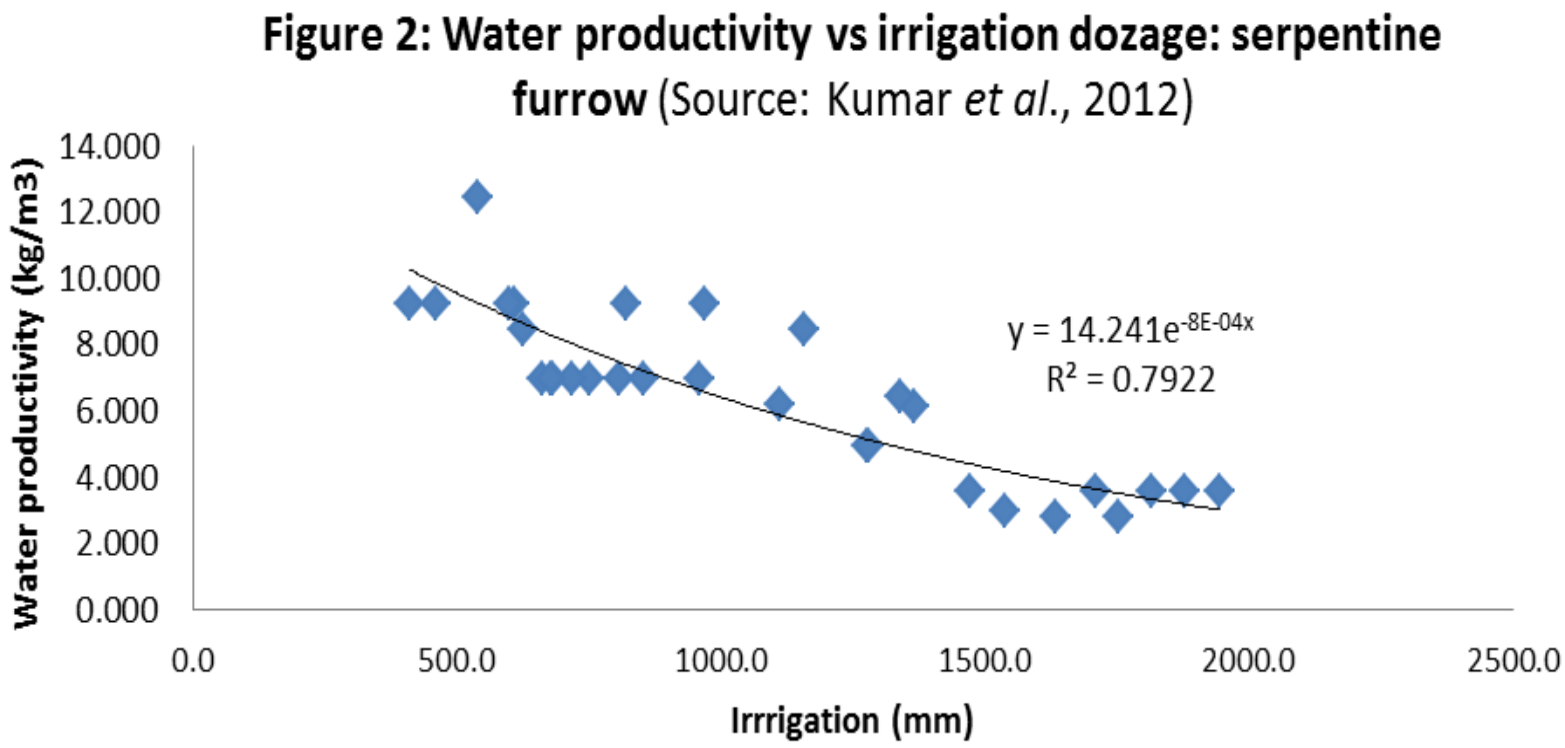
Effect of watershed interventions on reservoir inflows



Impact of plastic mulching in western Rajasthan (Luni river basin)



Changing water allocation: deficit irrigation



Farming system level water productivity in agriculture under different pricing regimes

Name of the Regions	Name of the district	Electric Well Command		Diesel Well Command	
		Flat Rate	Unit Pricing	Well owner	Water buyers
North Gujarat	Banaskantha	6.20	7.90	NA	NA
		Well Owner	Water Buyer	Well Owner	Water Buyer
Eastern UP	Varanasi and Mirzapur	10.95	11.18	8.67	12.89
South Bihar Plains	Patna	9.28	10.13	11.97	12.43

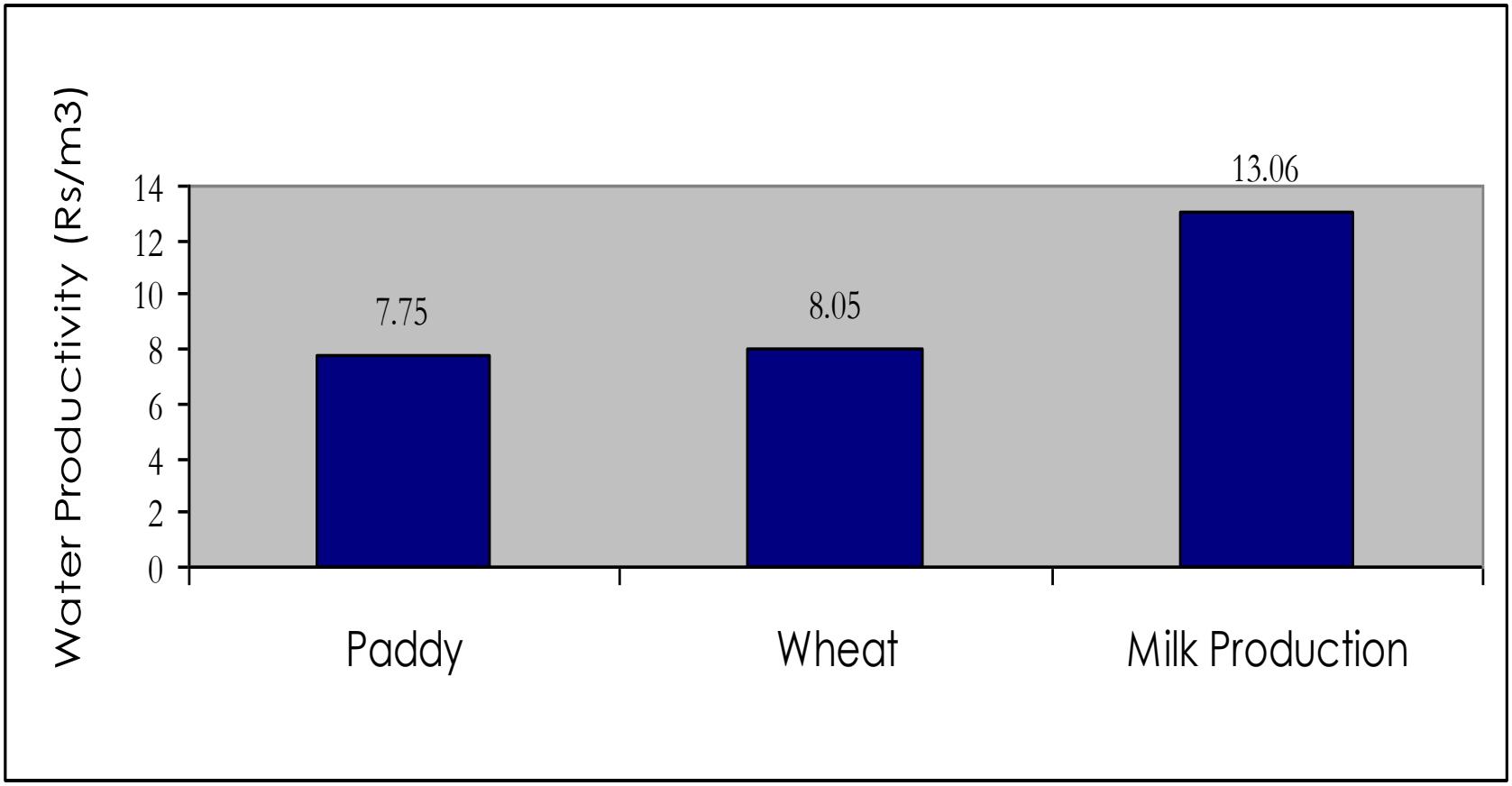
Net income from crop and milk production, three locations

Type of Well Command	Type of farmer	Gross cropped area (Ha)	Net income from crops (Rs)	Net income from dairying (Rs/day)	Total Farm level Income (Rs)	Farm level net income (Rs/Ha)
Electric Well	Well owner	5.29	124587	7152.3	131739.6	24880
	Water buyer	2.21	54637	6165.0	60802.6	27570
Diesel Well	Well owner	5.66	74764	7429.5	82193.9	14528
	Water buyer	3.79	62323	6260.6	68583.7	18075
Electric Well	Flat Rate	13.35	369119	30048.0	768287.4	57531
	Metered	11.77	311807	45636.0	669250.2	56882
Electric Well	Well owner	3.14	120477	10292.6	130769.5	210345
	Water buyer	1.70	61518	8130.9	76023.9	190031
Diesel Well	Well owner	2.49	140105	9958.1	150063.6	191387
	Water buyer	1.60	71810	12232.2	84042.5	197895

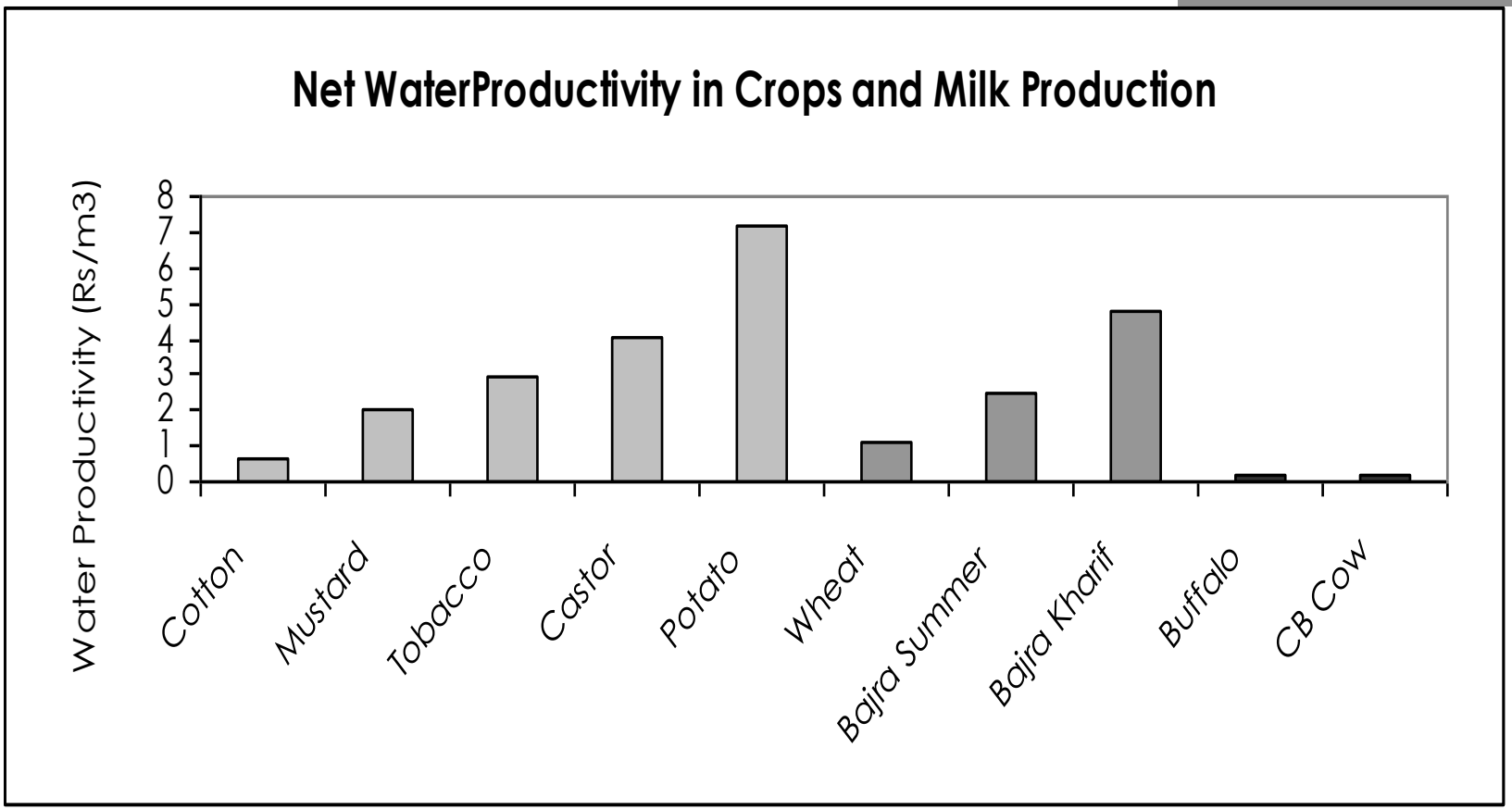
Impact of pro-rata pricing on groundwater use

Name of the Regions	Name of the district	Groundwater Pumpage by Electric Pump Owners		Groundwater Pumpage by Diesel pump	
		Unit Pricing	Flat Rate	Well owner	Water buyers
North Gujarat	**Banaskantha**	**303.88**	**443.88**	NA	NA
		Groundwater Use in Electric Well Command by		**Groundwater Use in Diesel Well Command by**	
		Well Owner	Water Buyer	Well Owners	Water Buyers
Eastern UP	**Varanasi & Mirzapur**	**175.38**	**183.93**	**222.23**	**148.00**
South Bihar	**Patna**	**329.97**	**249. 74**	**231.11**	**197.91**

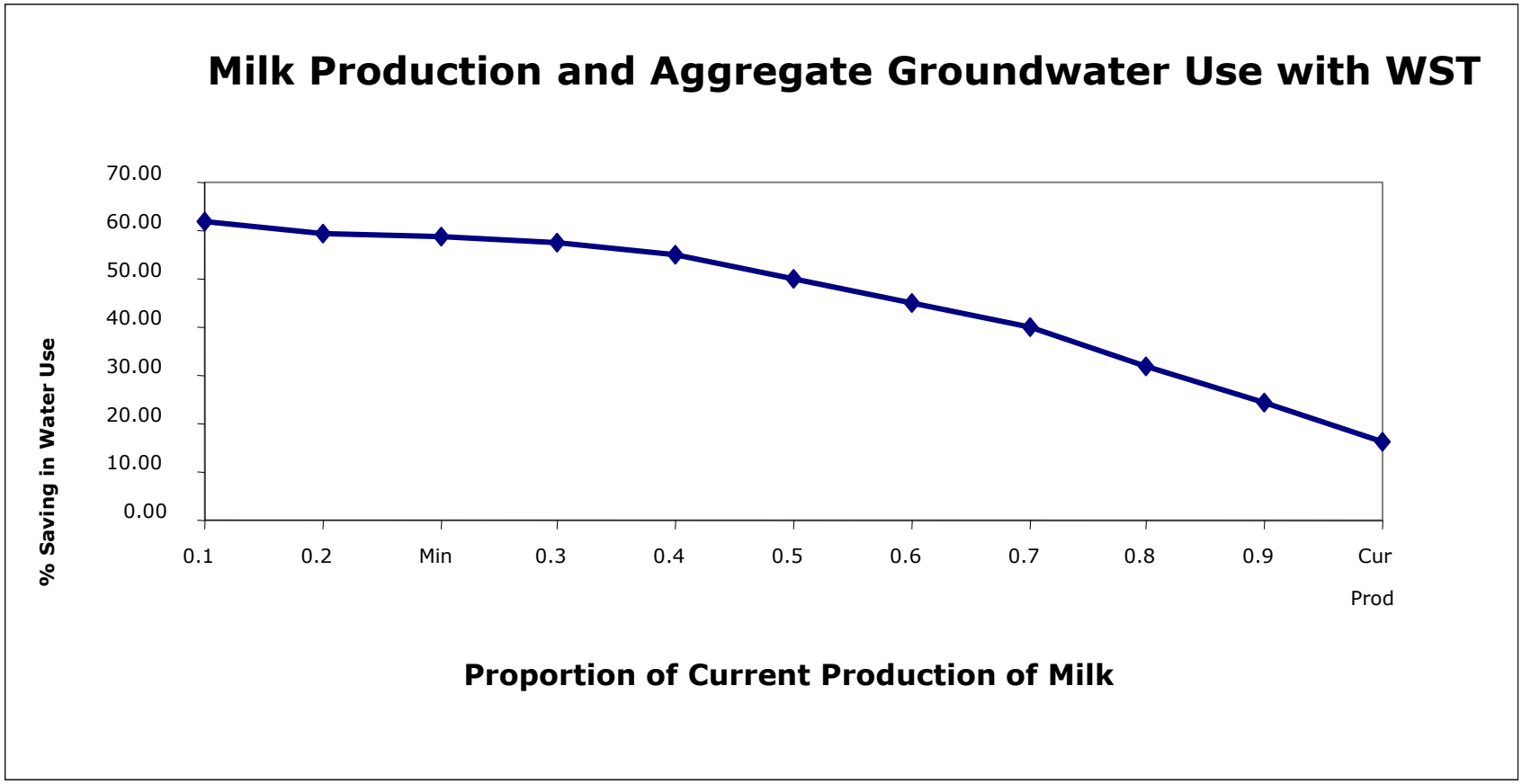
Water productivity in crops and milk production



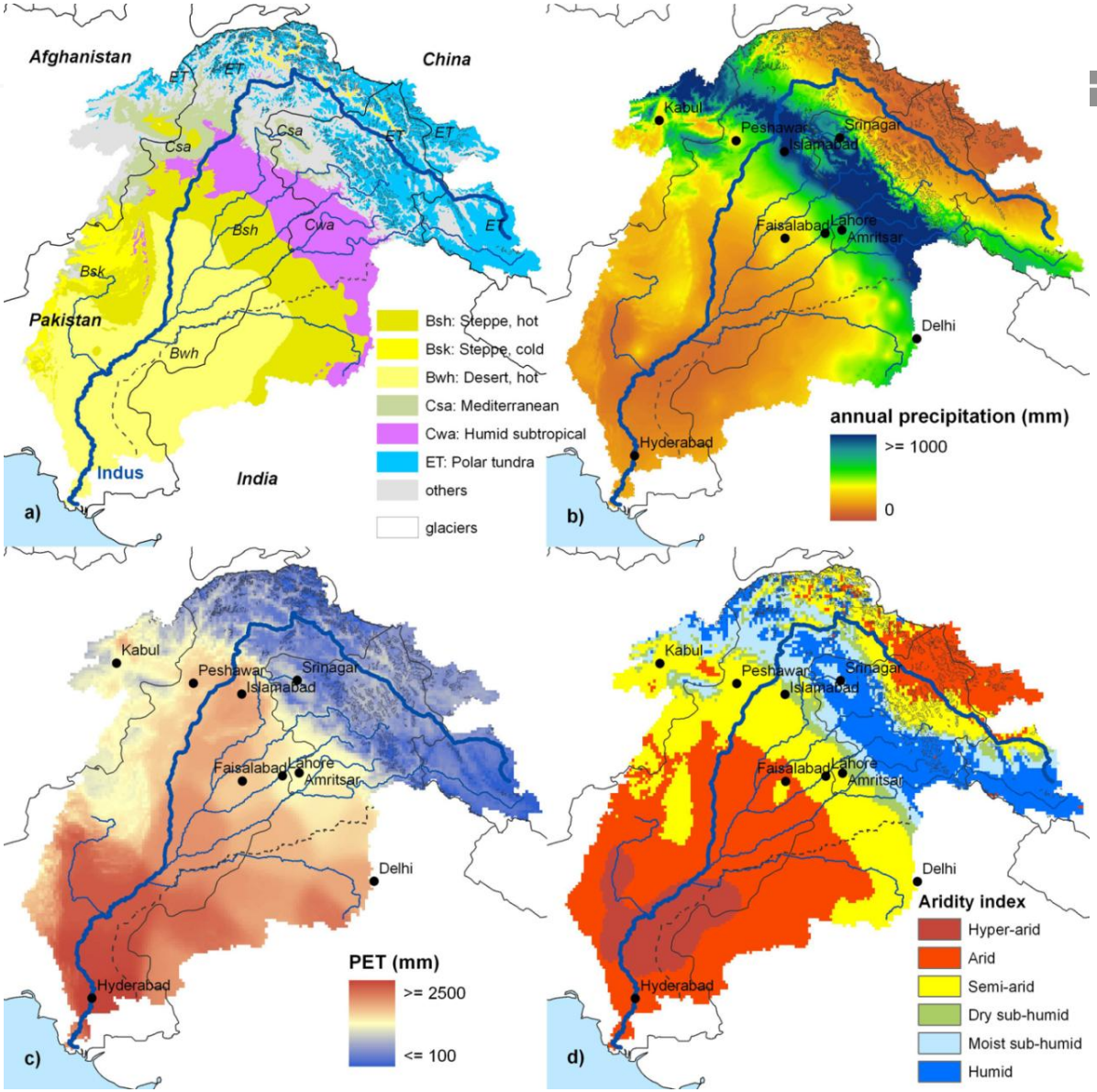
Water productivity in crops and dairying in north Gujarat



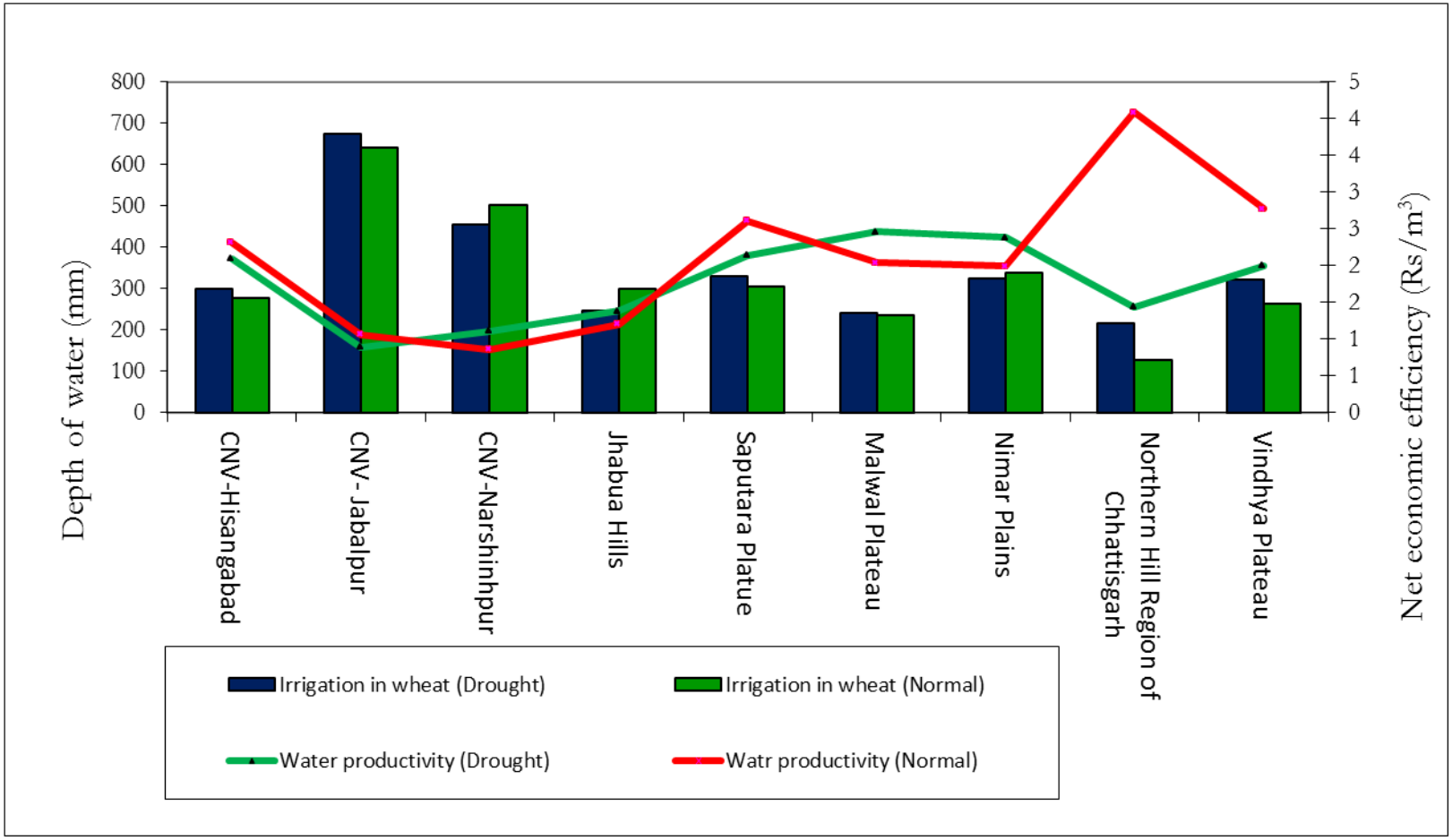
Vibrant dairy economy is a constraint to saving groundwater in north Gujarat



Rainfall and climate varies drastically within the Indus



Irrigation and water productivity in wheat in different regions of Narmada basin



Current scale of adoption of MI systems

Name of States	Area under		Total Area (ha)
	Drip	Sprinkler	
Rajasthan	17002	706813	723815
Maharashtra	482341	214674	697015
Haryana	7136	518367	525502
Andhra Pradesh	363073	200950	564023
Karnataka	177326	228621	405947
Gujarat	169689	136284	305973
Tamil Nadu	131335	27186	158521
West Bengal	146	150031	150177
Madhya Pradesh	20432	117685	138117
Chhattisgarh	3648	59270	62919
Orissa	3629	23466	27095
Uttar Pradesh	10675	10589	21264
Punjab	11730	10511	22241
Kerala	14119	2516	16635
Sikkim	80	10030	10110
Bihar	163	206	369
Others	15000	30000	45000
India Total	1429404	2452680	3882084