Ashoka Trust for Research in Ecology and the Environment

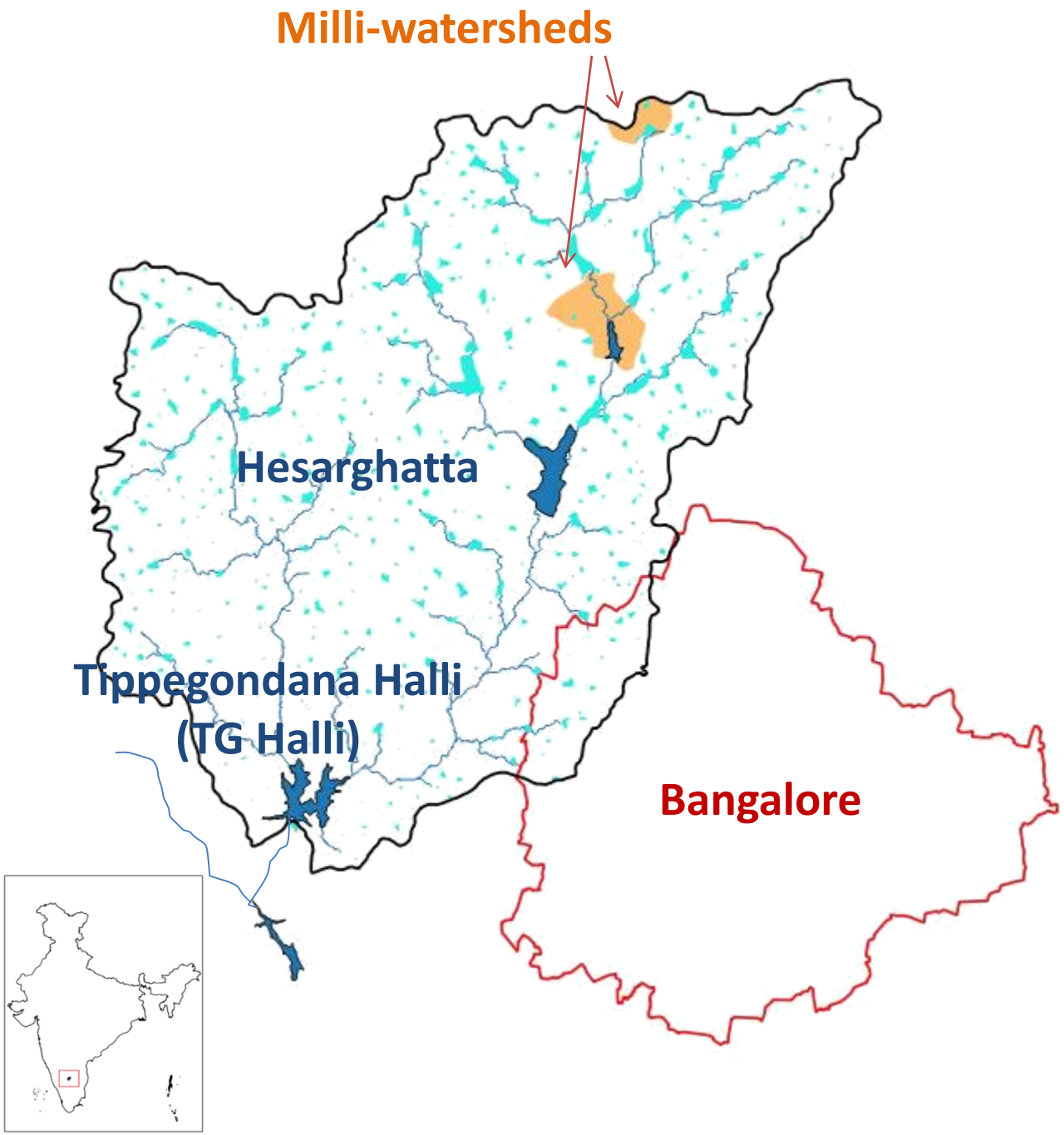
2303: Disaggregating the effects of climatic and anthropogenic drivers on groundwater availability in the Arkavathy watershed, India.

Veena Srinivasan

(w/ Sharad Lele, Bejoy Thomas, Sally Thompson)

IAH Conference, Montpellier, Sep 26, 2016

25-29th September 2016 Montpellier, France CORUM CONFERENCE CENTER 43rd IAH congress

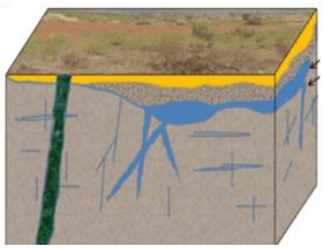


TG Halli Catchment in peri-urban Bangalore in South India

- 1447 sq km

Traditional Approach: Downscale climate projections, apply them to hydrologic models

Climate Stressors:
Rainfall
Temperature



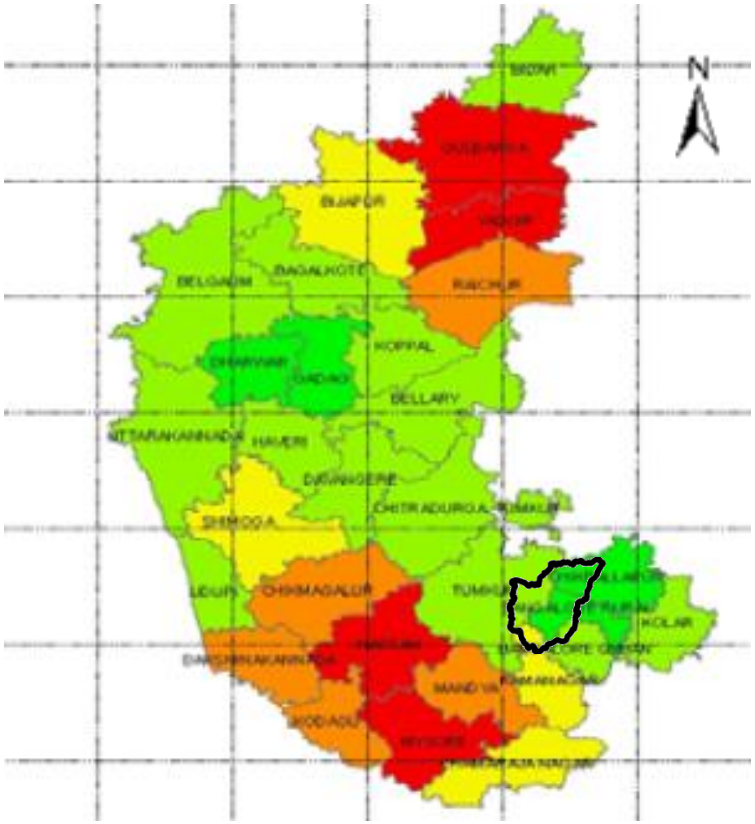
Water Supply (Quantity, Quality, Timing)

Water Demand (Quantity, Quality, Timing)

Livelihood / Domestic Water Security. Sustainability

Assumes stable rainfall-runoff relationships

Climate models suggest an increasing trend in annual rainfall.

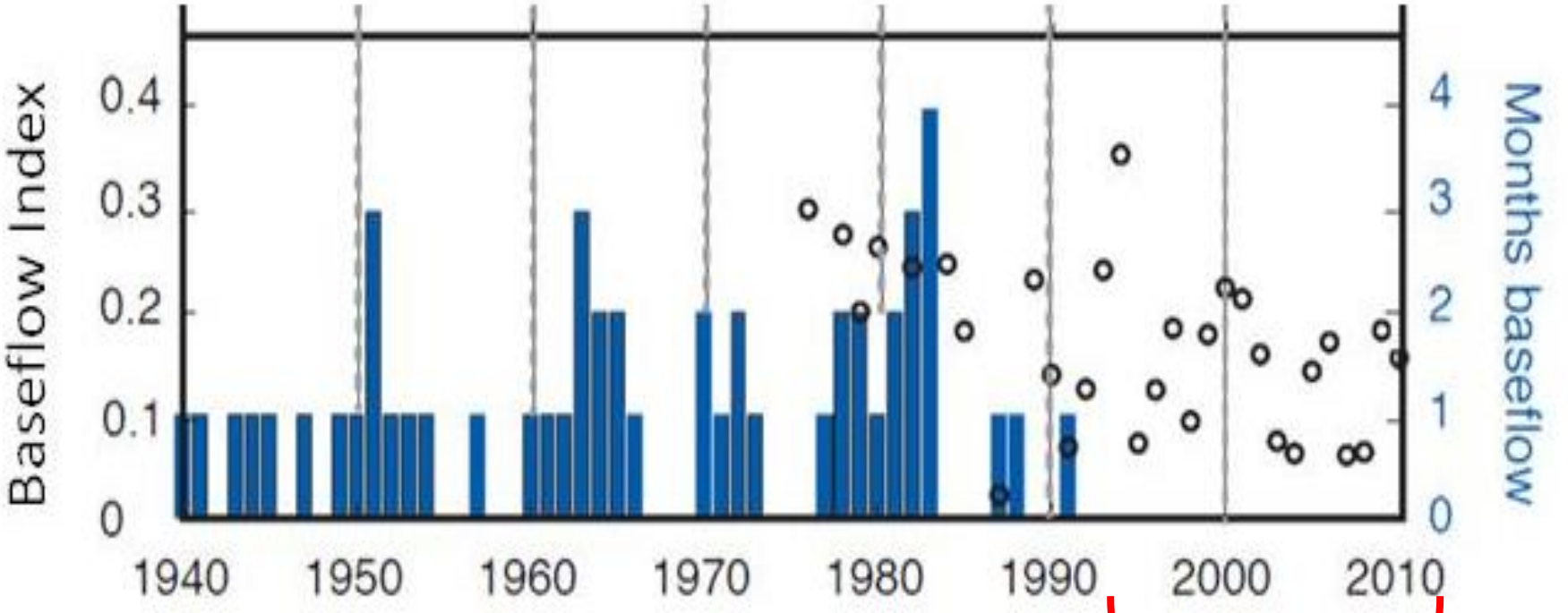


Projected Increase in Rainfall
2035 A1B Scenario

	< -5%
	-5% - 0%
	0% - 5%
	5% - 10%
	10% - 15%

Source: BCCI-Karnataka, 2011

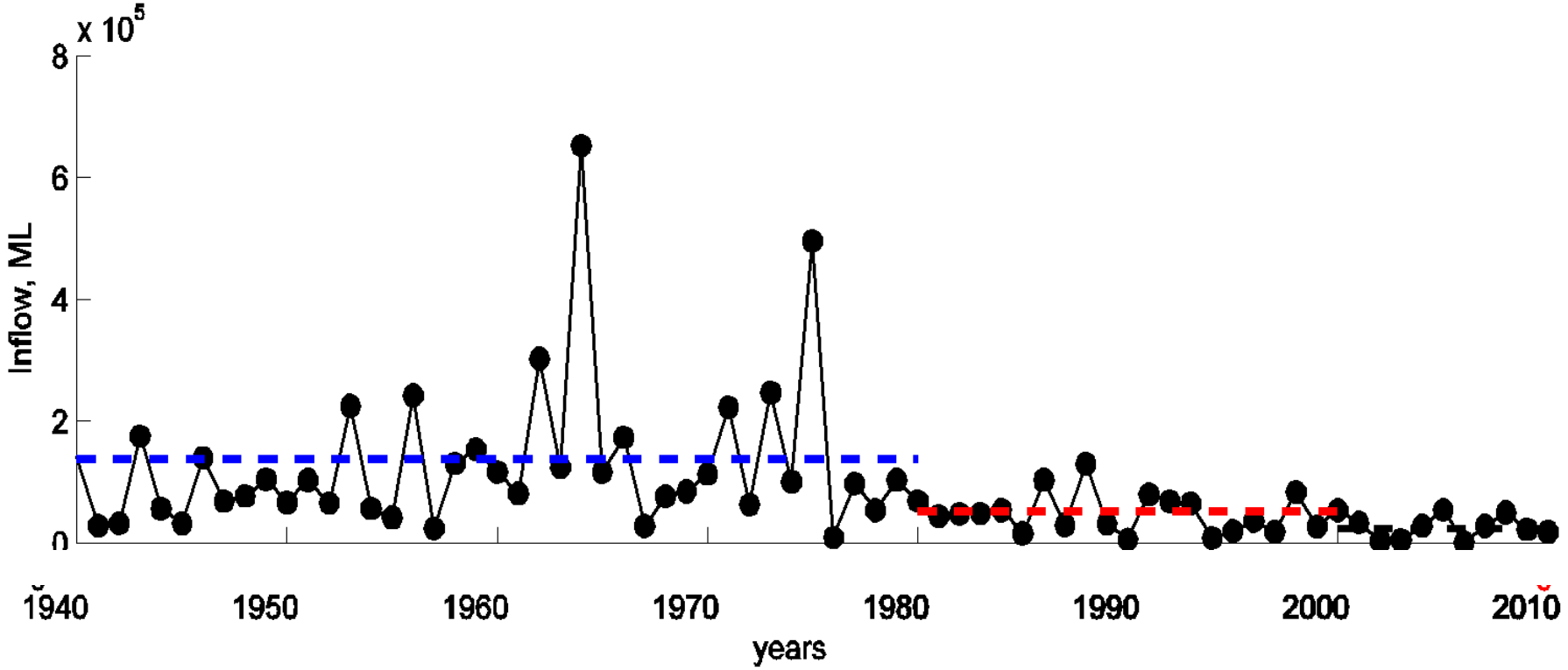
Baseflows into TG Halli also declined – virtually disappeared after 1992



Not one month after 1992, where there was inflow into TG Halli in a no-rain month

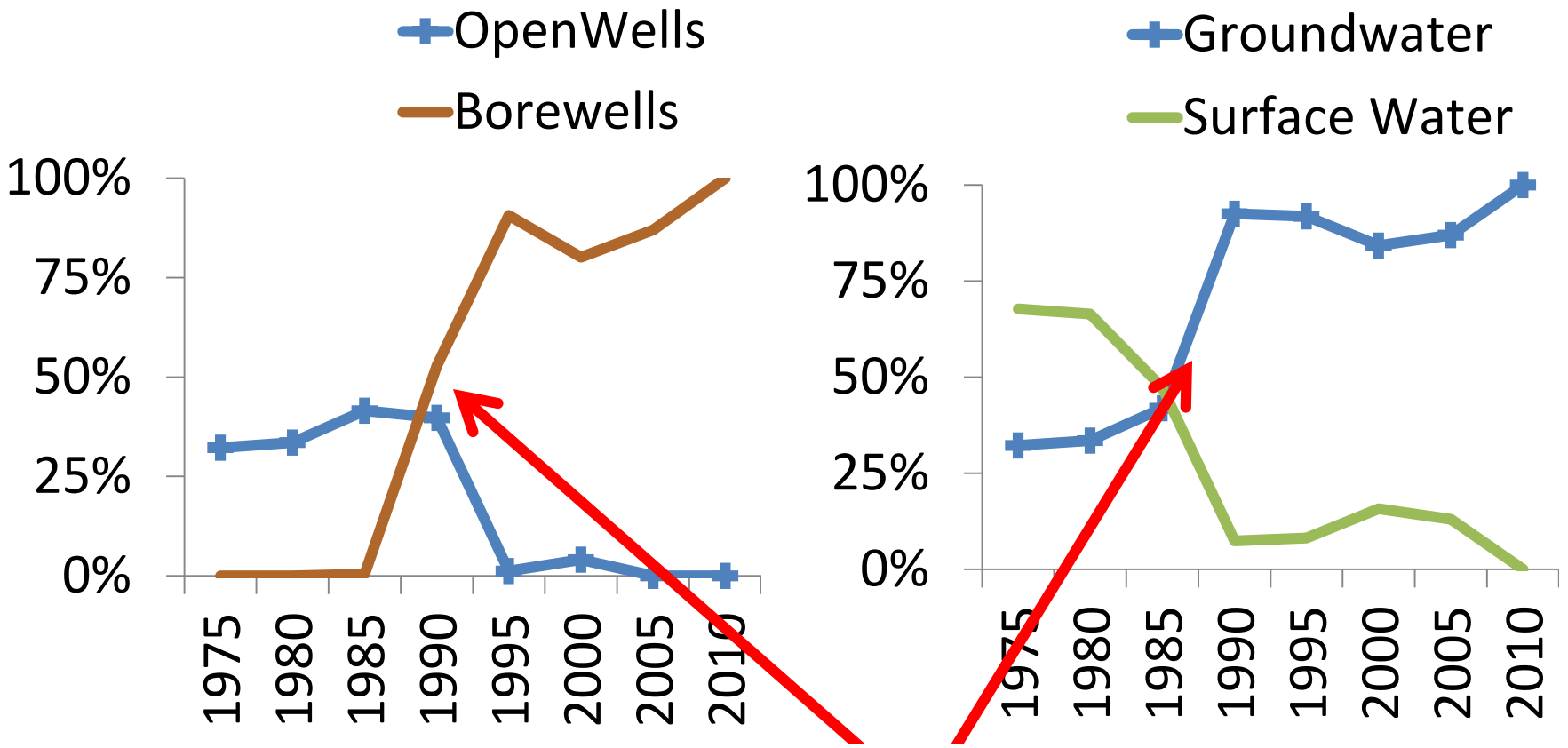
Source: Srinivasan et al. (2015)

BUT inflows into TG Halli catchment have declined sharply.



Source: Srinivsan et al., 2015

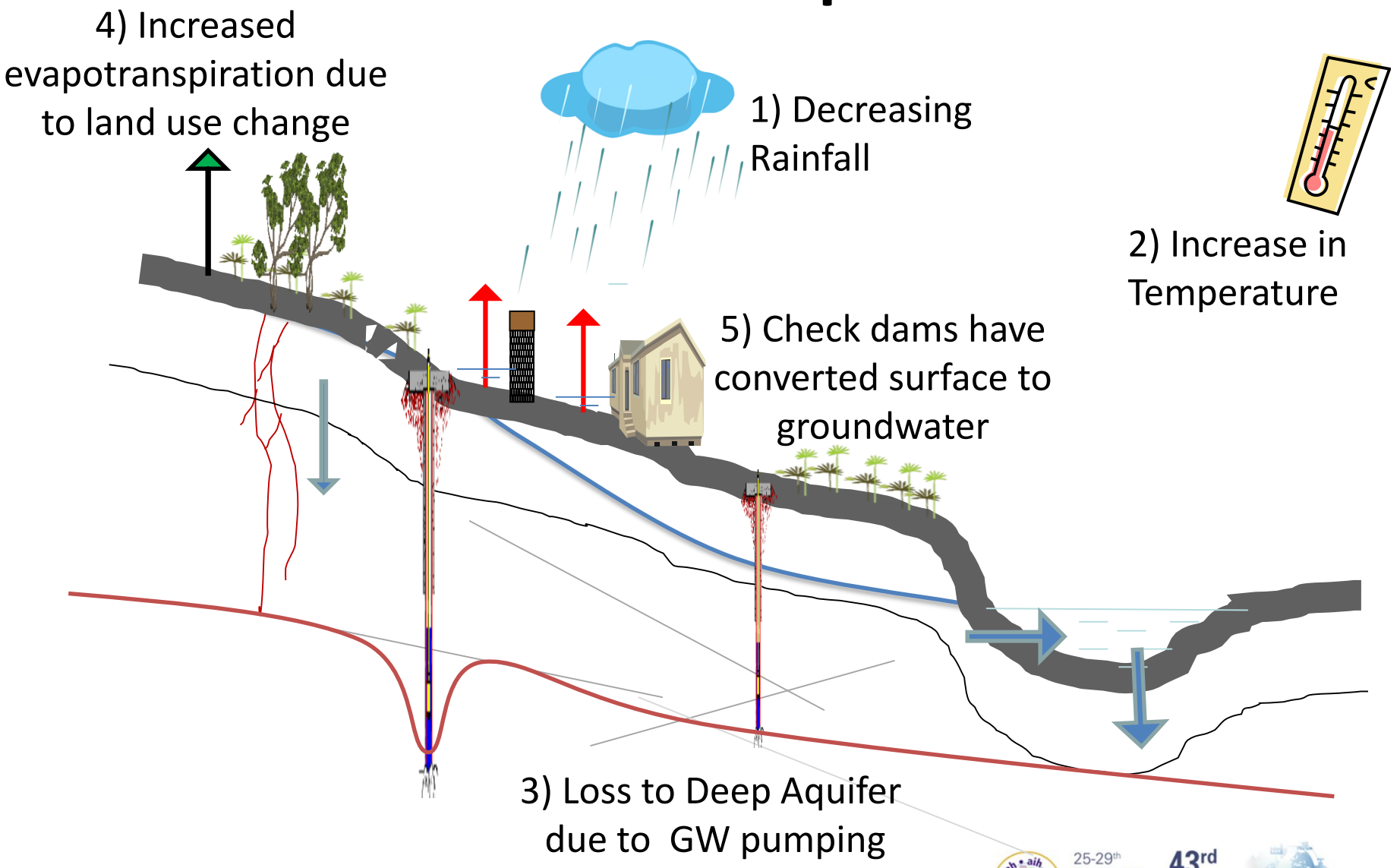
Secondary data show that the surface water irrigation and open wells disappeared by the mid-1990s.



Evidence the shallow aquifer dried up in the early 1990s

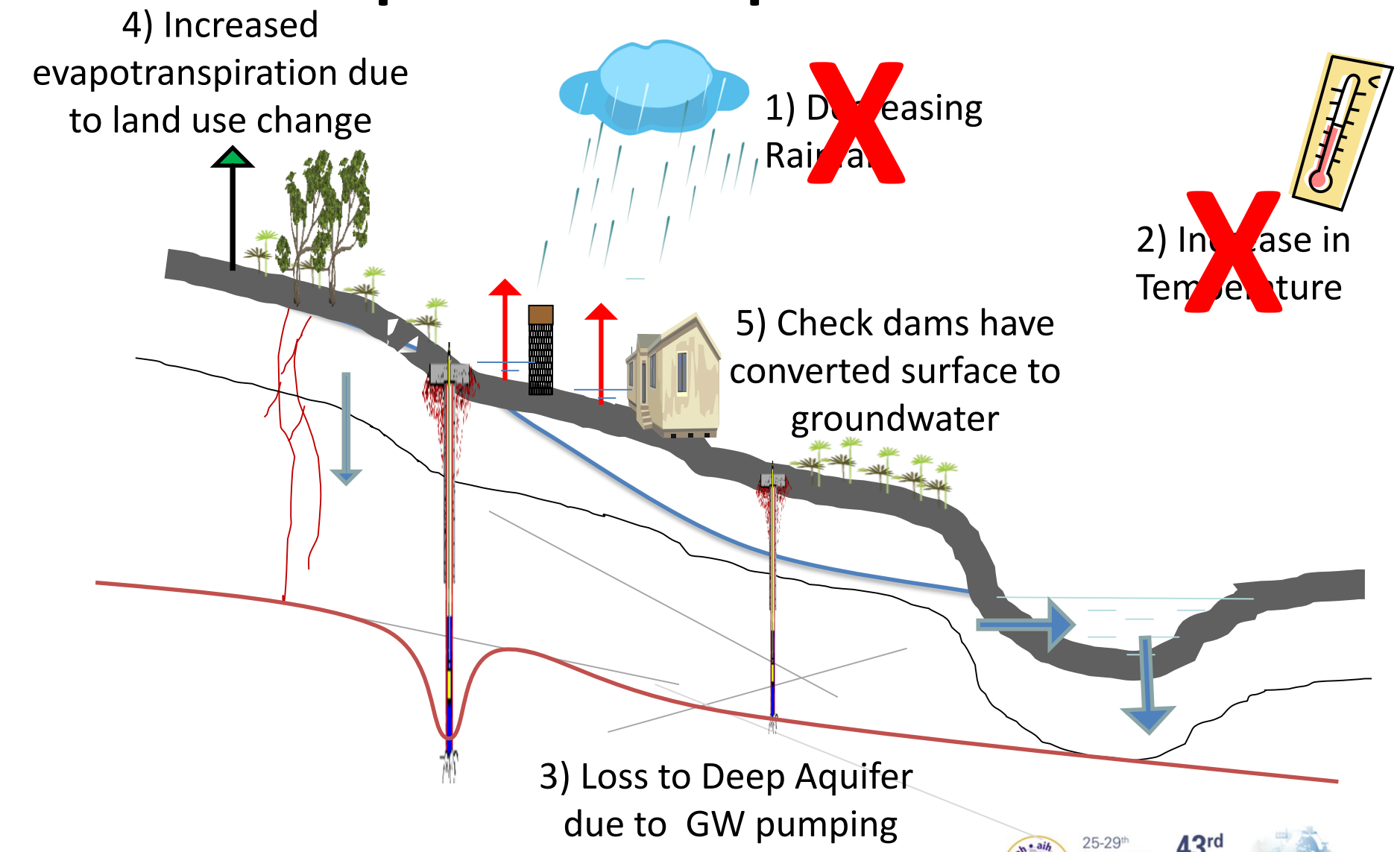
Source: KA Annual Season Crop Report. Doddaballapur Taluk

Secondary data suggest that climatic factors alone cannot explain the decline



Source: Srinivasan et al., 2015

Anthropogenic factors must have been responsible for past declines…



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Anthropogenic changes in TG Halli catchment over the last 3 decades

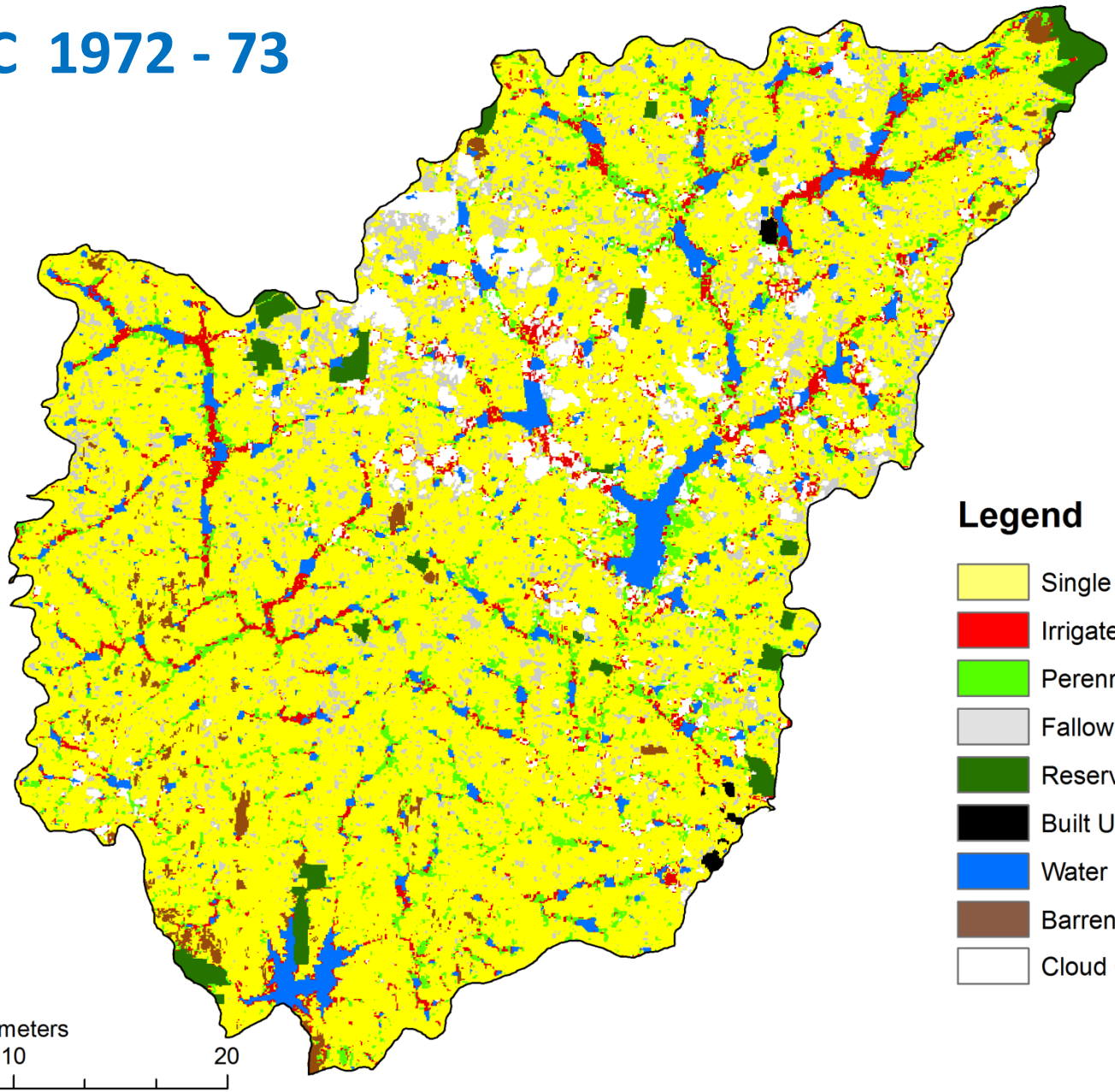
1. **Go big or quit:** Urbanisation induces farmers to intensify (deep borewell irrigated commercial agriculture) or abandon agriculture (and place land under eucalyptus and work in the city.

2. **Conversion of surface to groundwater:** As groundwater has depleted, villages have introduced check-dams on streams to increase recharge.

3. **Shallow to deep aquifer connectivity:** As deeper fracture aquifers have depleted, this has induced recharge from shallower to deeper fractures.

=> Increase in ET, GW depletion AND surface water declines.

LULC 1972 - 73



N

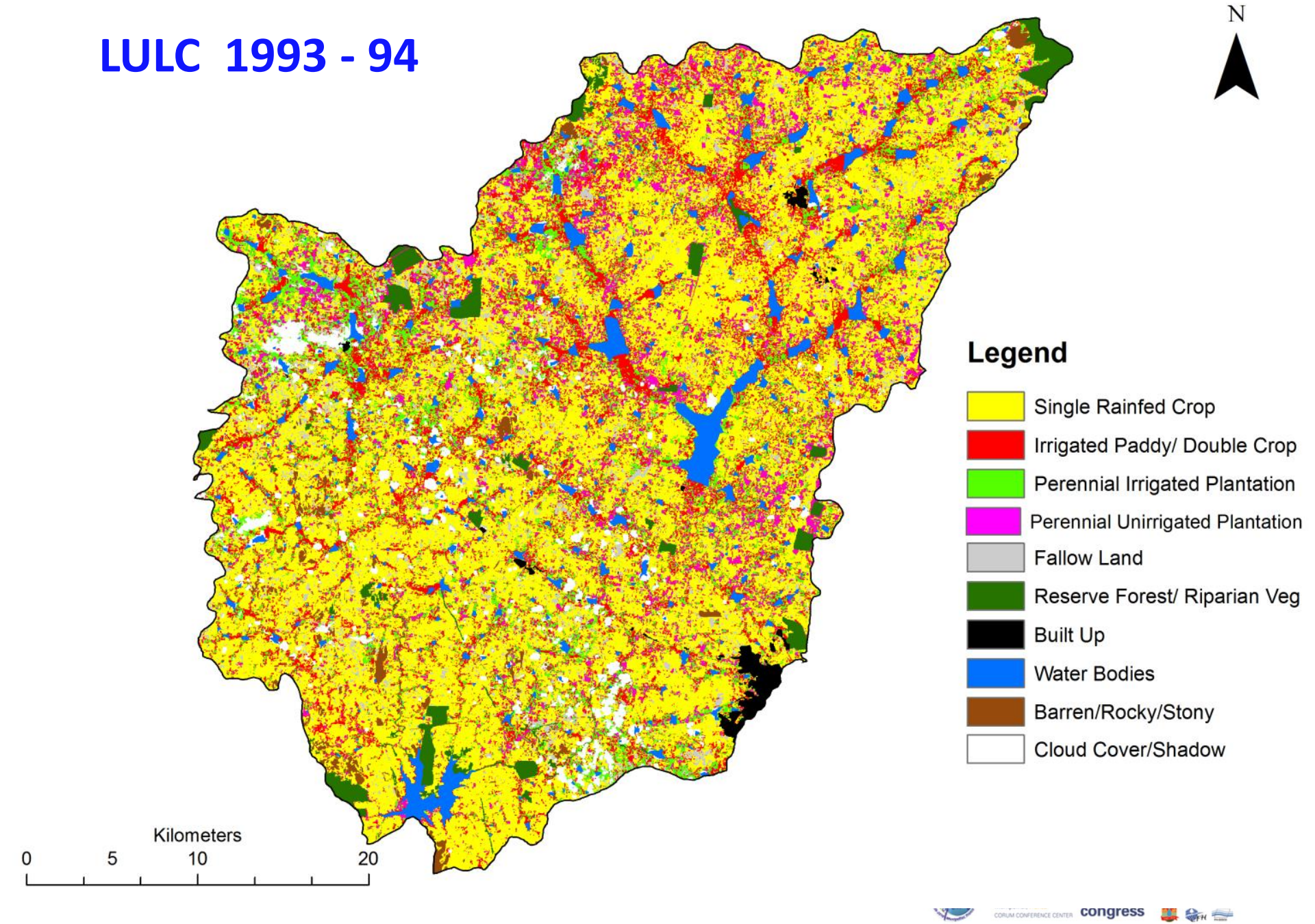
Legend

- Single Rainfed Crop
- Irrigated Paddy/ Double Crop
- Perennial Irrigated-Sugarcane
- Fallow Land
- Reserve Forest/ Riparian Veg
- Built Up
- Water Bodies
- Barren/Rocky/Stony
- Cloud Cover/Shadow

Kilometers

0 5 10 20

LULC 1993 - 94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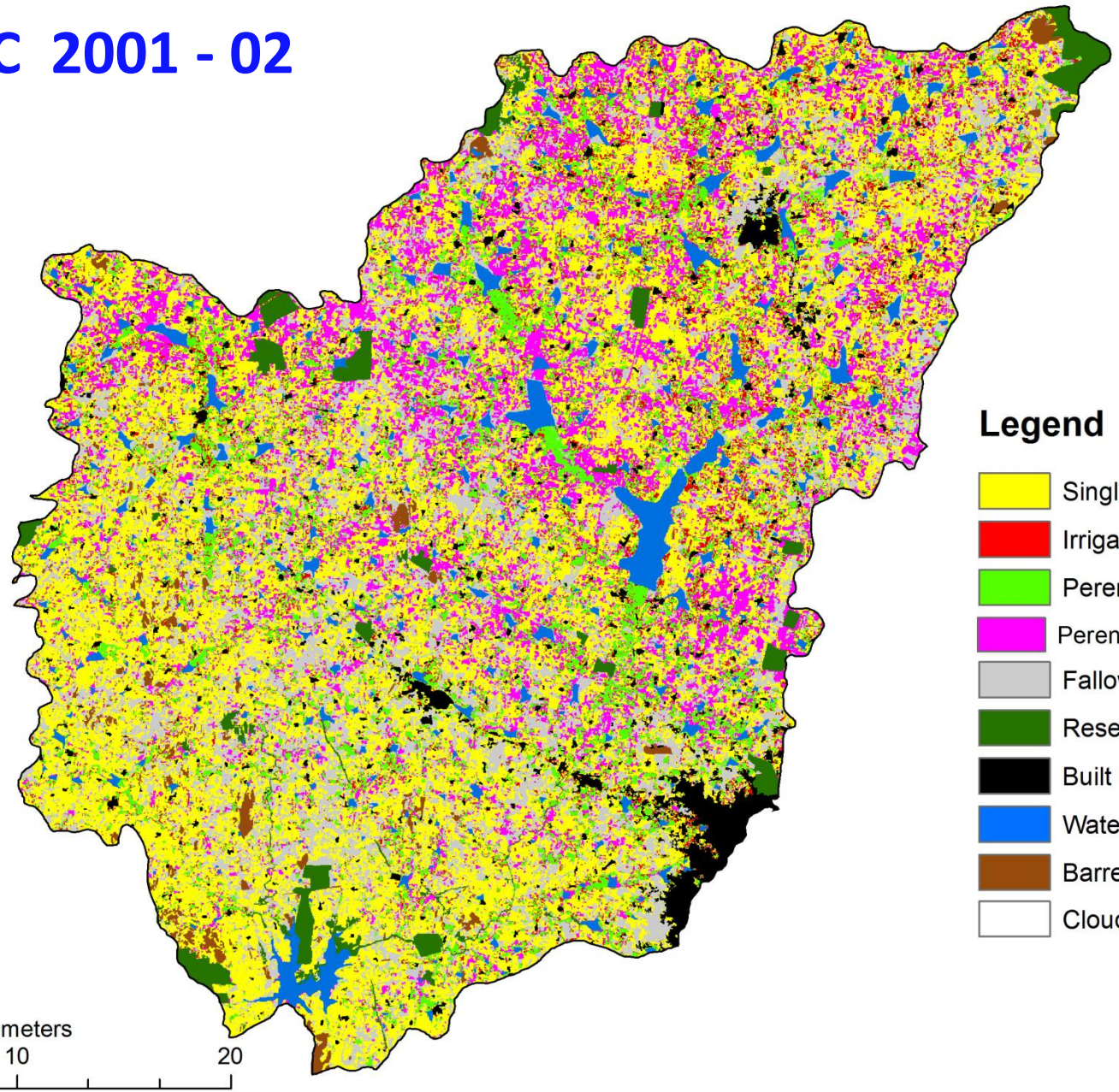
Built Up
Water Bodies
Barren/Rocky/Stony
Cloud Cover/Shadow
Kilometers
0
5
10
20

LULC 2001 - 02



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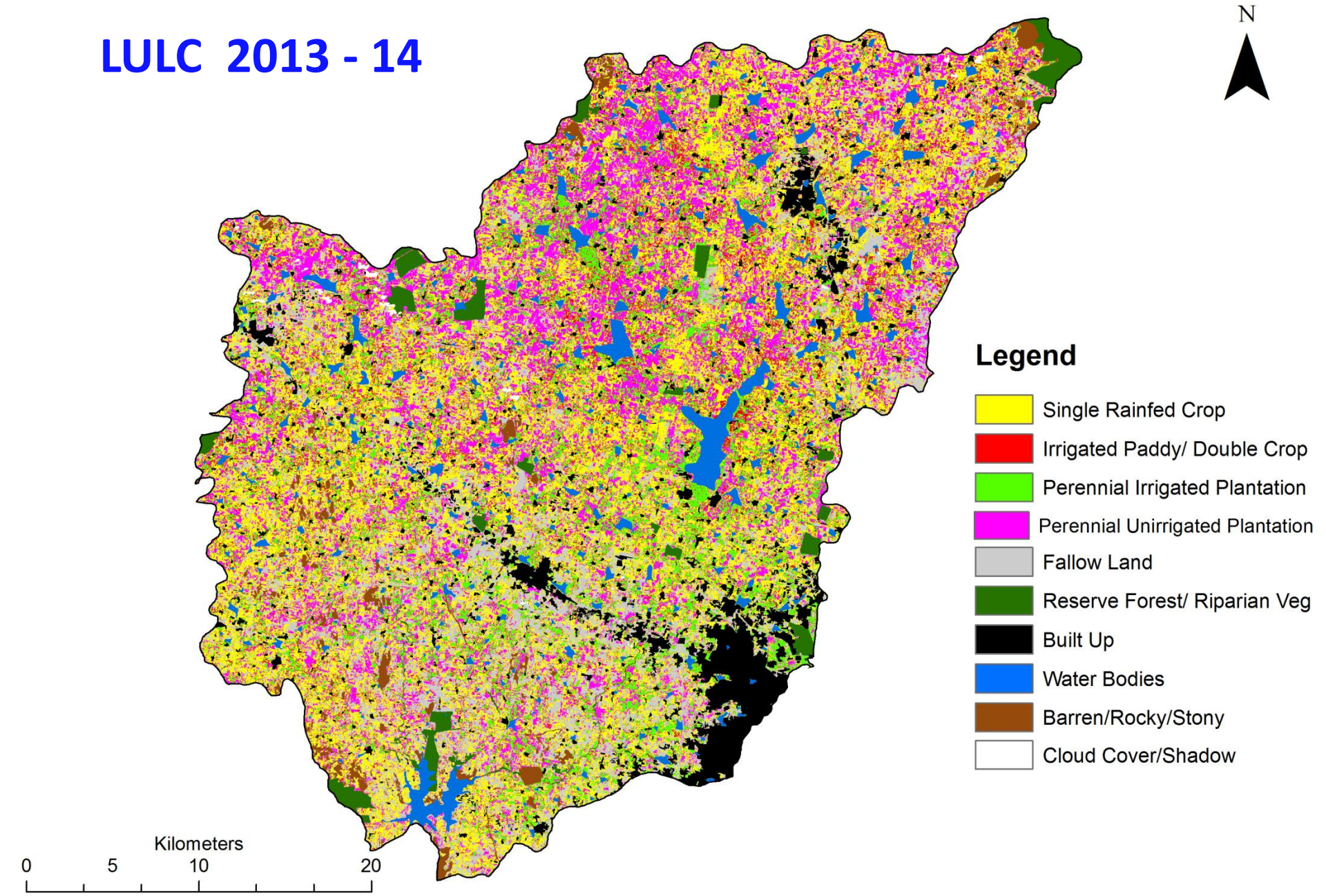
Kilometers

0 5 10 20

LULC 2013 - 14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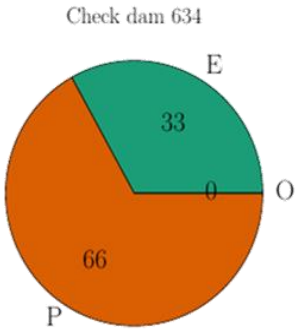
1. **Go big or quit:** Urbanisation induces farmers to intensify (deep borewell irrigated commercial agriculture) or abandon agriculture (and place land under eucalyptus and work in the city.

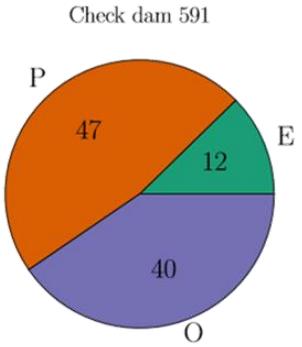
2. **Conversion of surface to groundwater:** As groundwater has depleted, villages have introduced check-dams on streams to increase recharge.

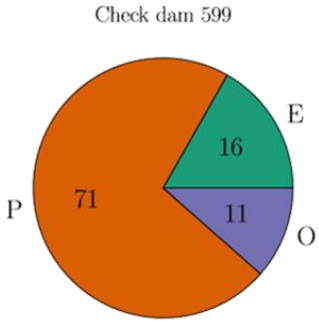
3. **Shallow to deep aquifer connectivity:** As deeper fracture aquifers have depleted, this has induced recharge from shallower to deeper fractures.

=> Increase in ET, GW depletion AND surface water declines.

Check dams reduce runoff and increase recharge







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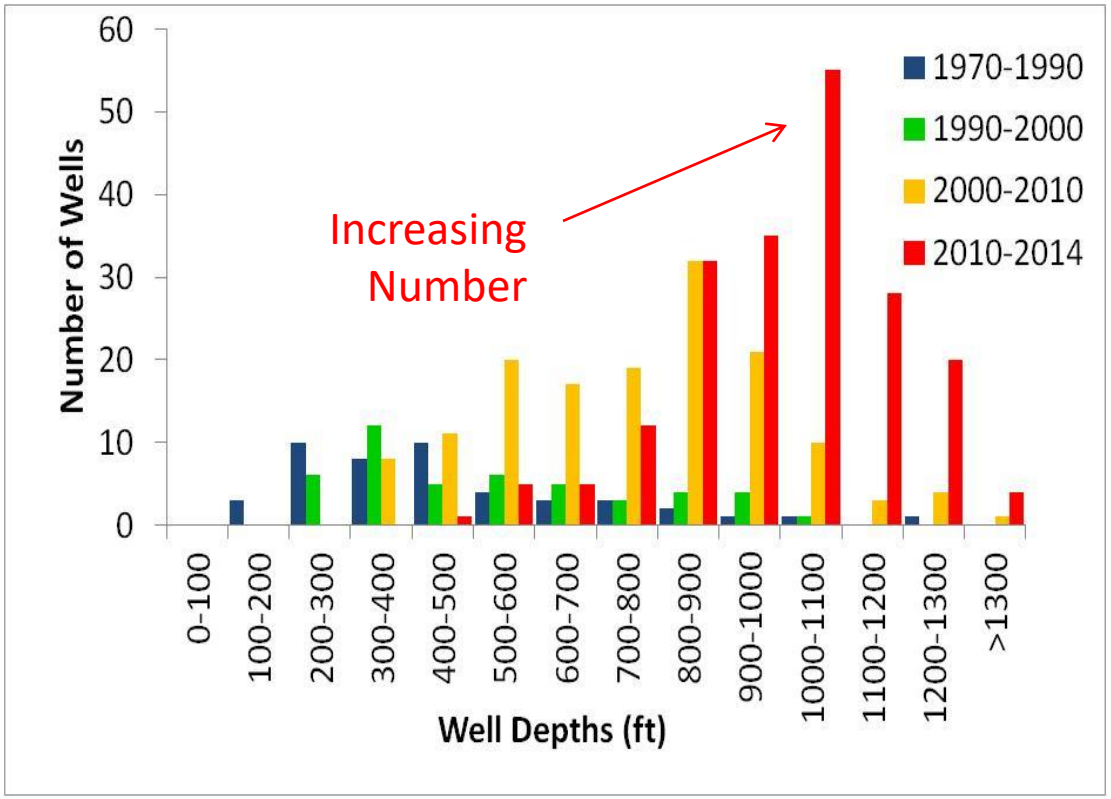
Evidence of depletion of deep fracture aquifers



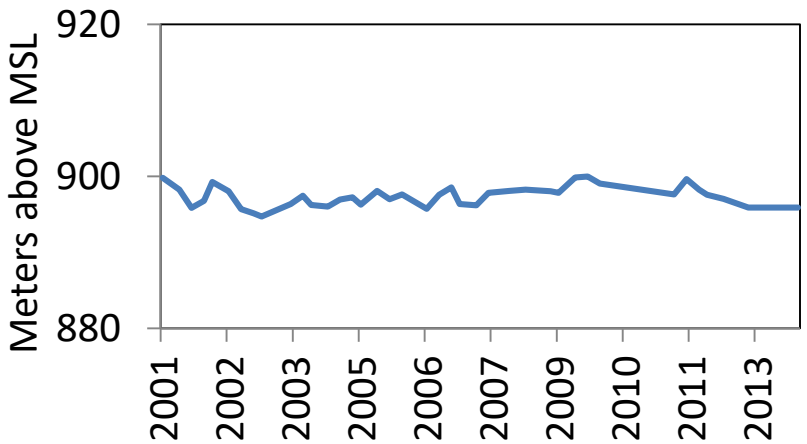
- Farmers have been drilling deeper and deeper borewells
- Yet, the number of functioning borewells has increased.

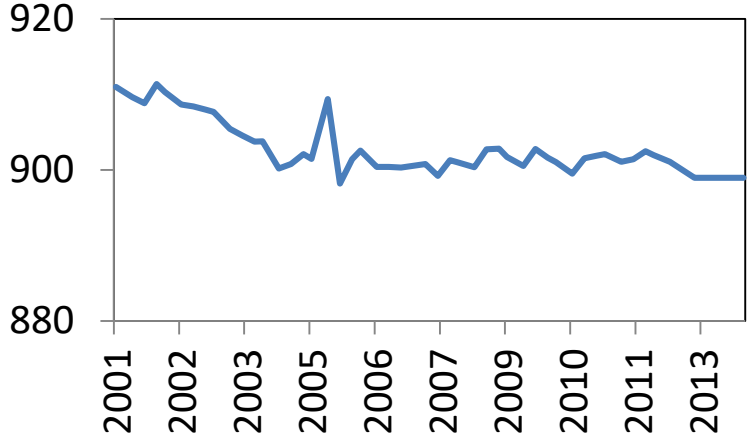
=> More, deeper borewells irrigating a smaller area.

Source: Primary Surveys - Well Census in two milli-watersheds

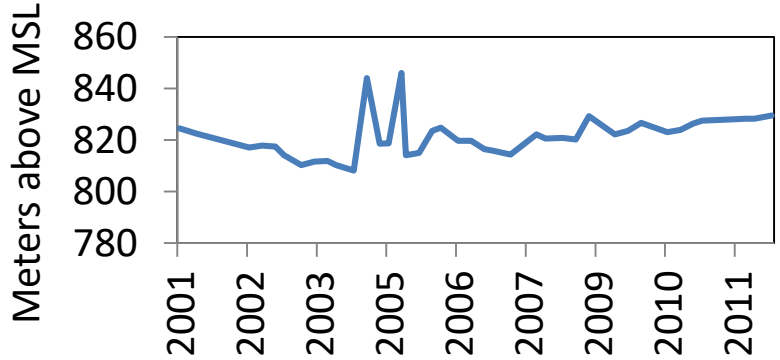
Note: Government monitoring wells do not show depletion

Dug Wells



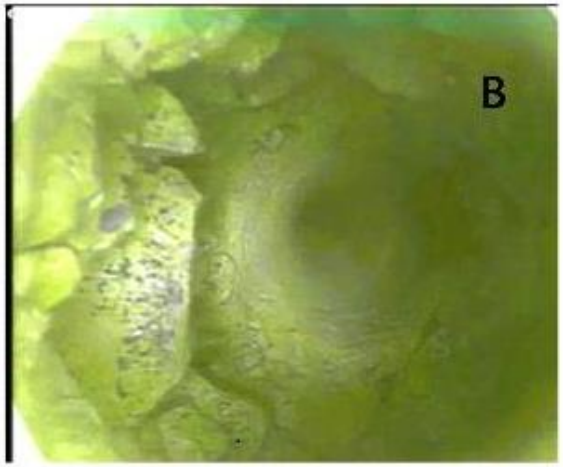


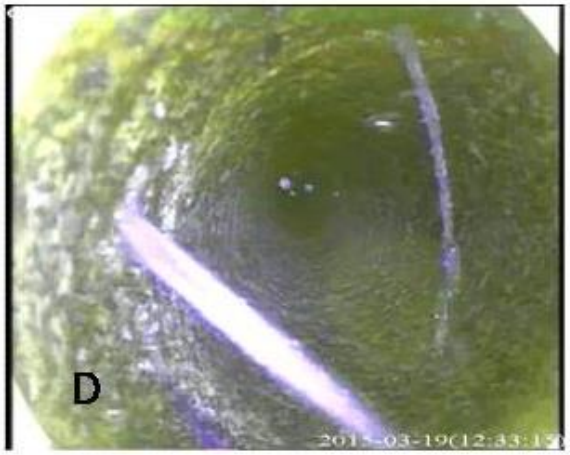
Borewells



Evidence of depletion of deep fracture aquifers

Novel, low-cost approach: Crowdsourced borewell scans

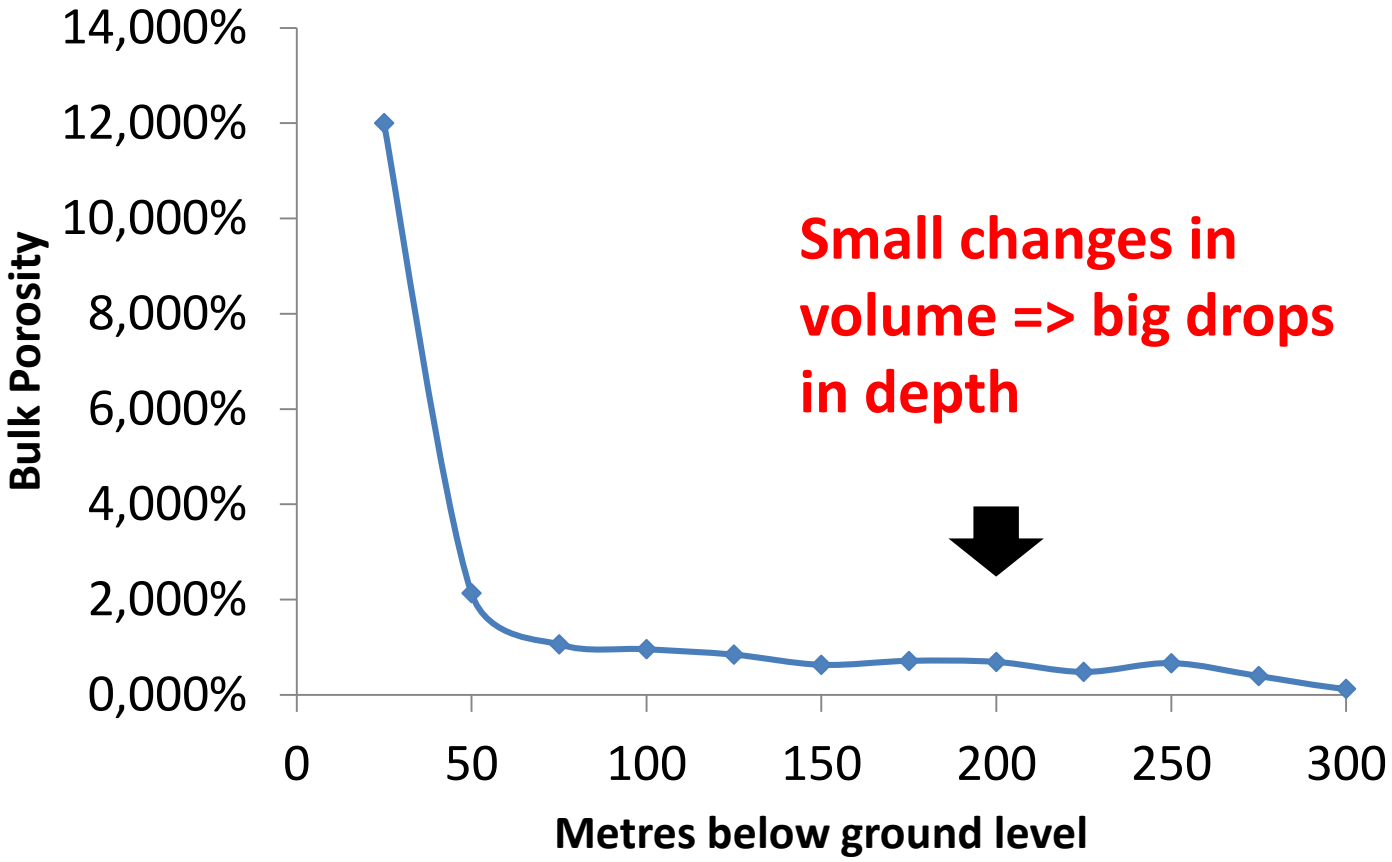




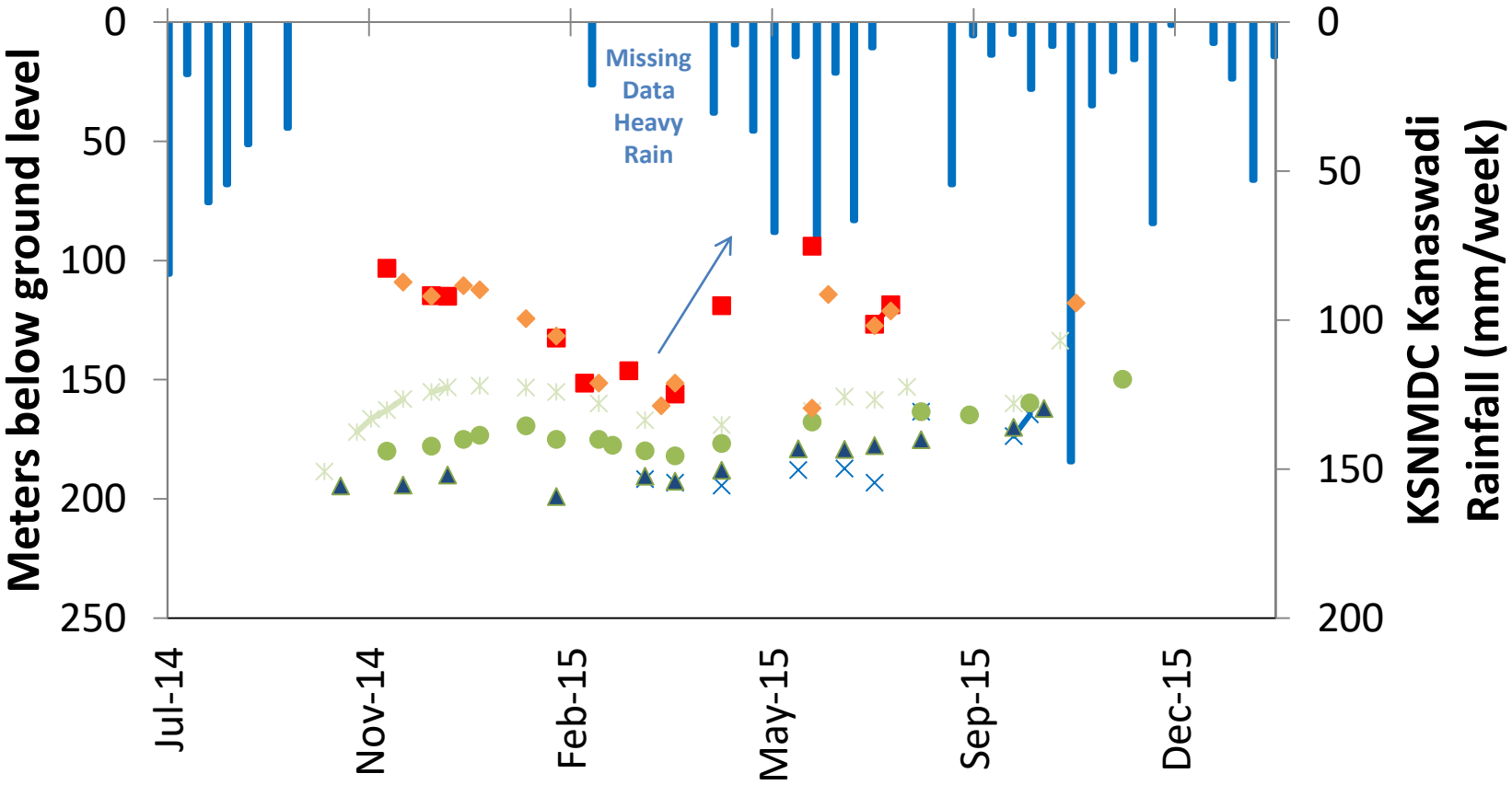
Over 150 Well scans in two milli-watersheds!

43rd IAH congress

Evidence of depletion in deep aquifers
Very little deep storage



Evidence of connectivity: Recharge from shallow zones reaches deep zones



Participatory groundwater monitoring wells respond to rain => Rainfall recharge is definitely reaching deeper fractures.

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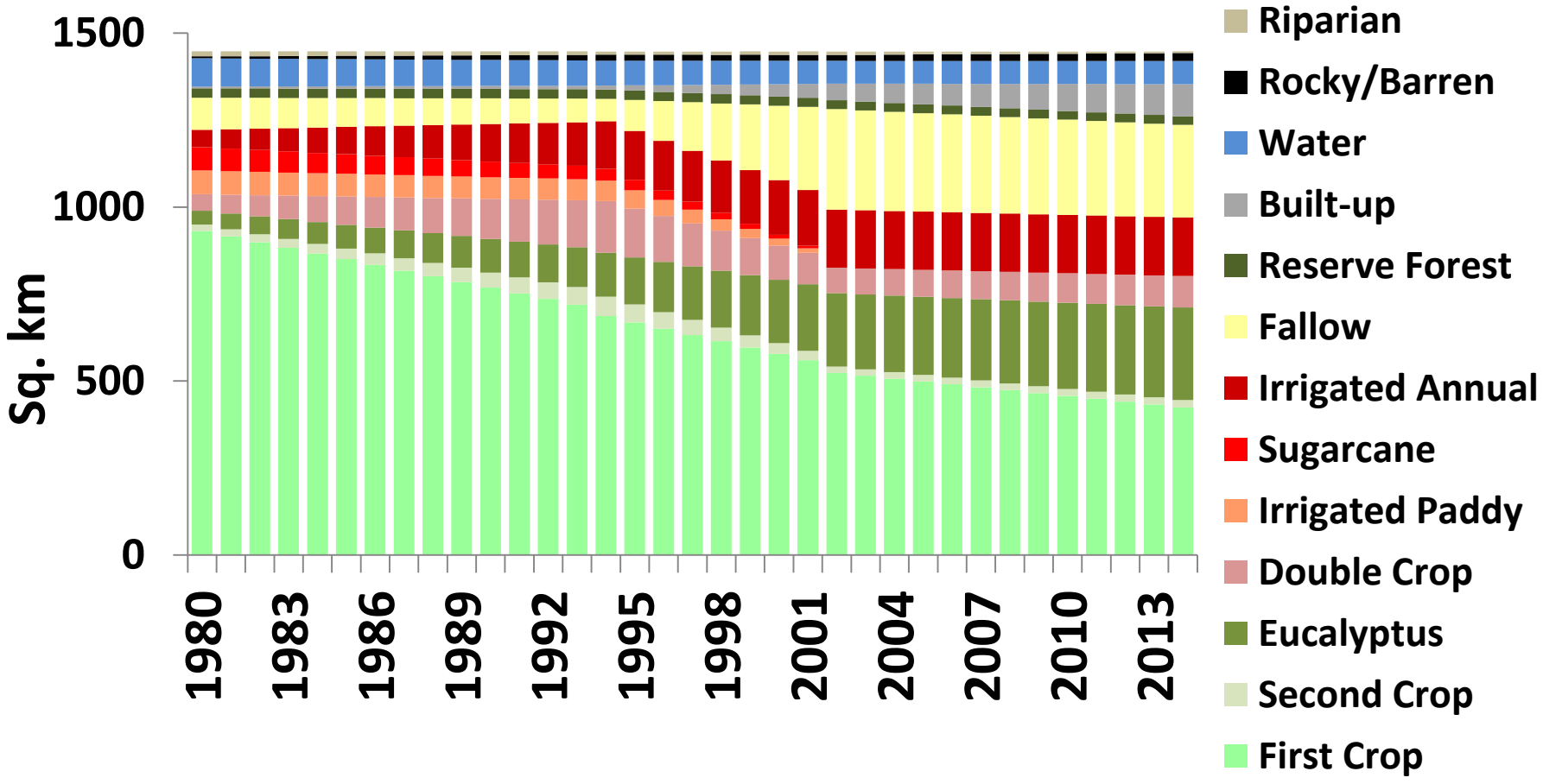
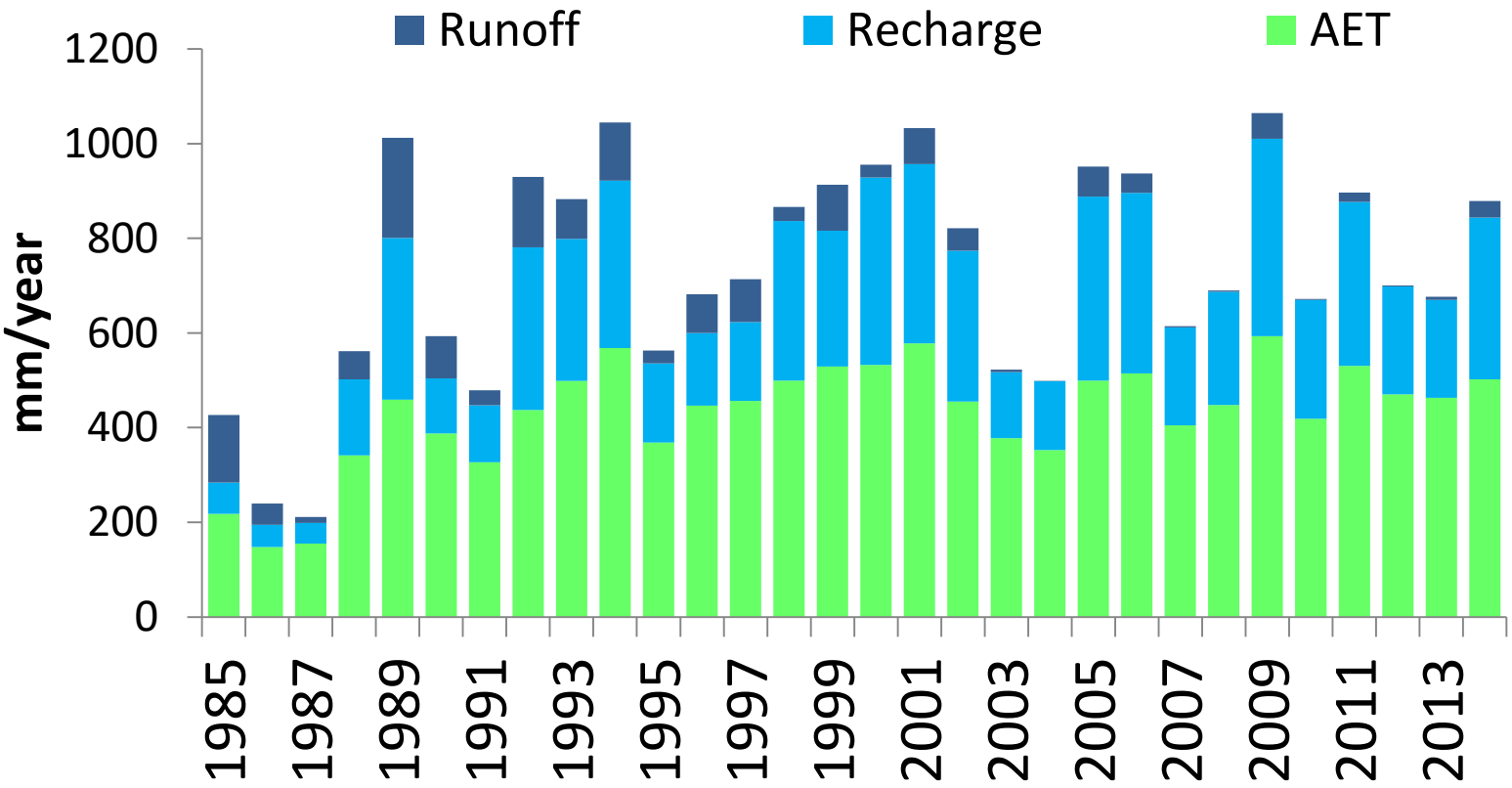
Recap: Land Use, Land Cover Change

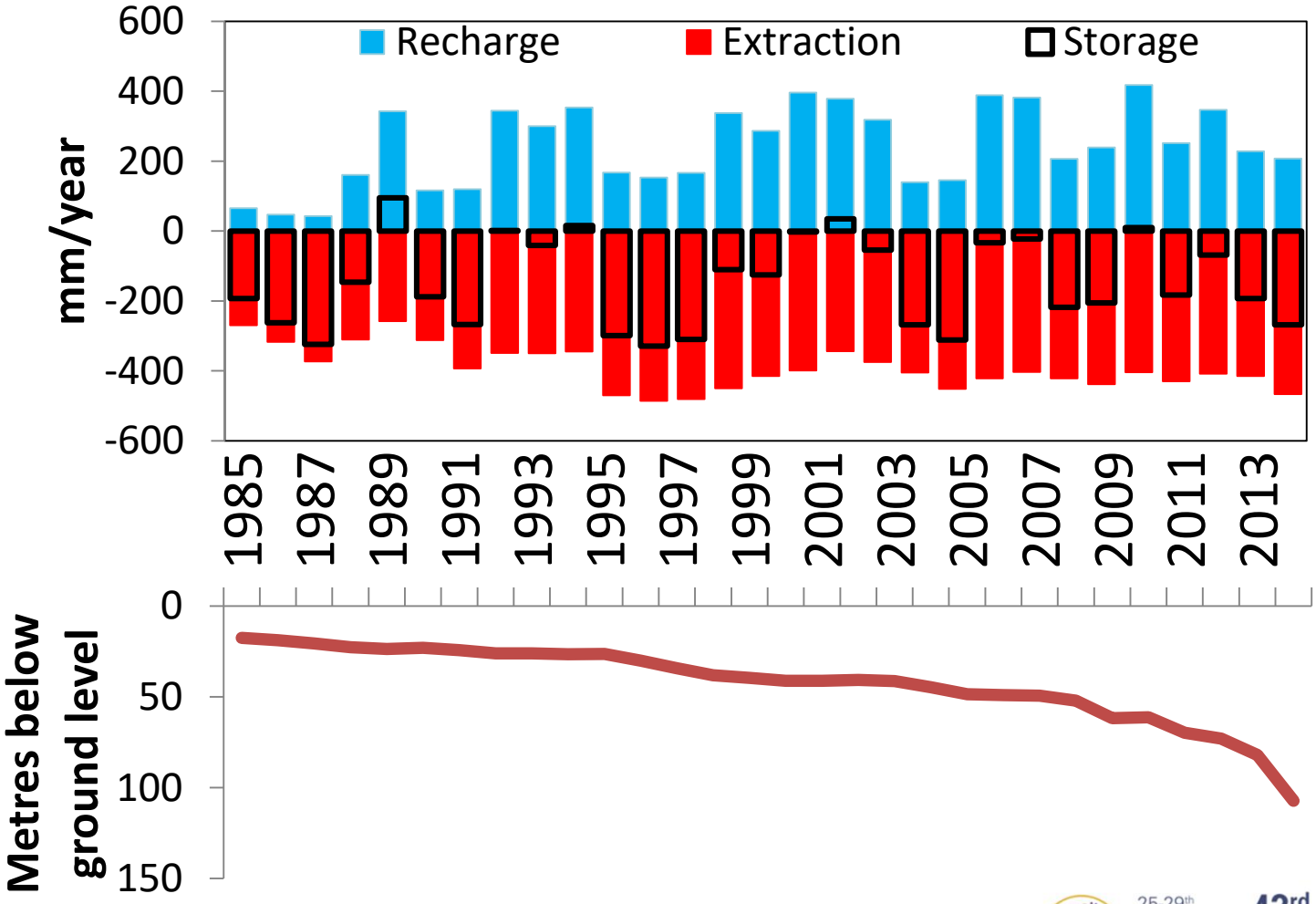


Greens are rainfed, reds are irrigated, yellows are fallow

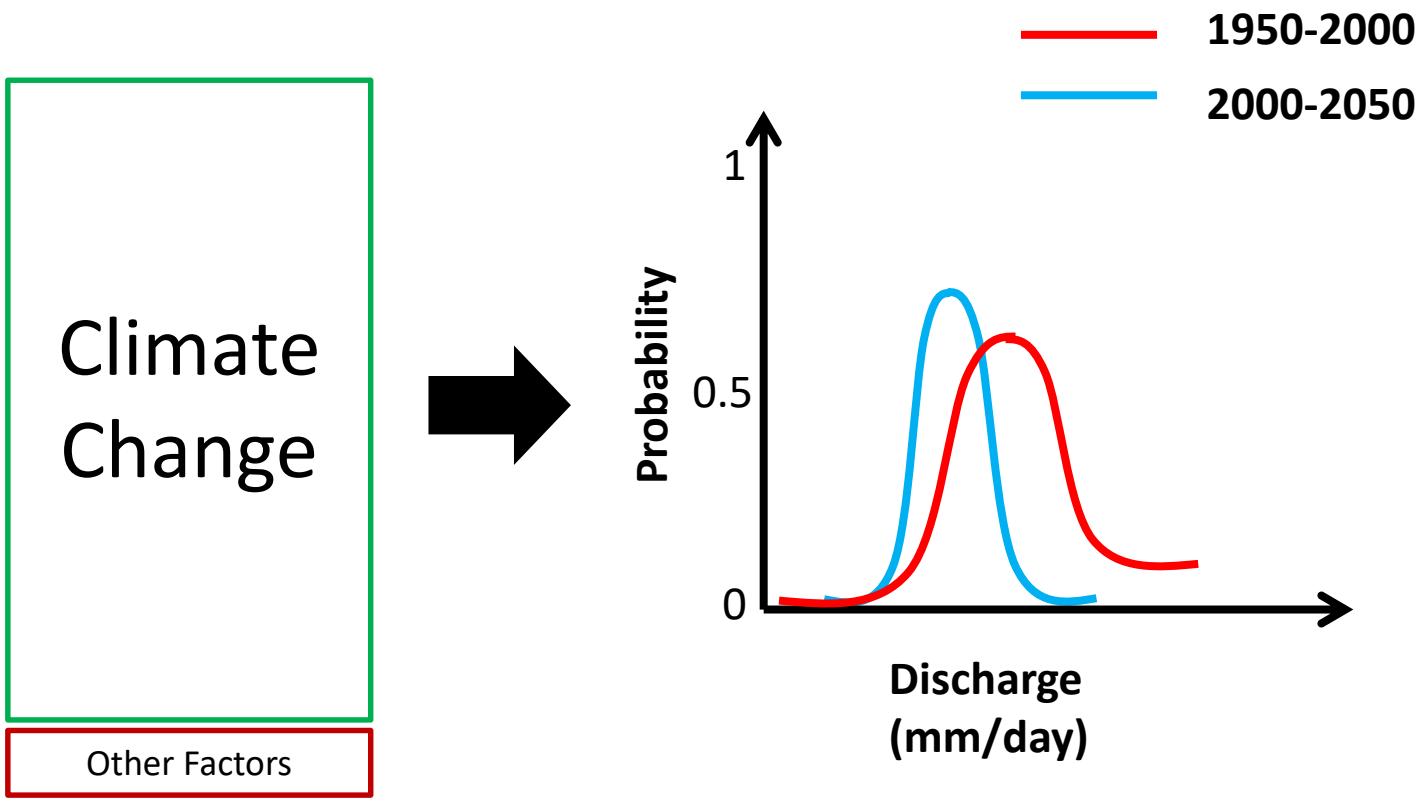
Where does the rain end up?



Agricultural pumping and eucalyptus => GW depletion



Conclusion: Including climatic drivers isn't enough



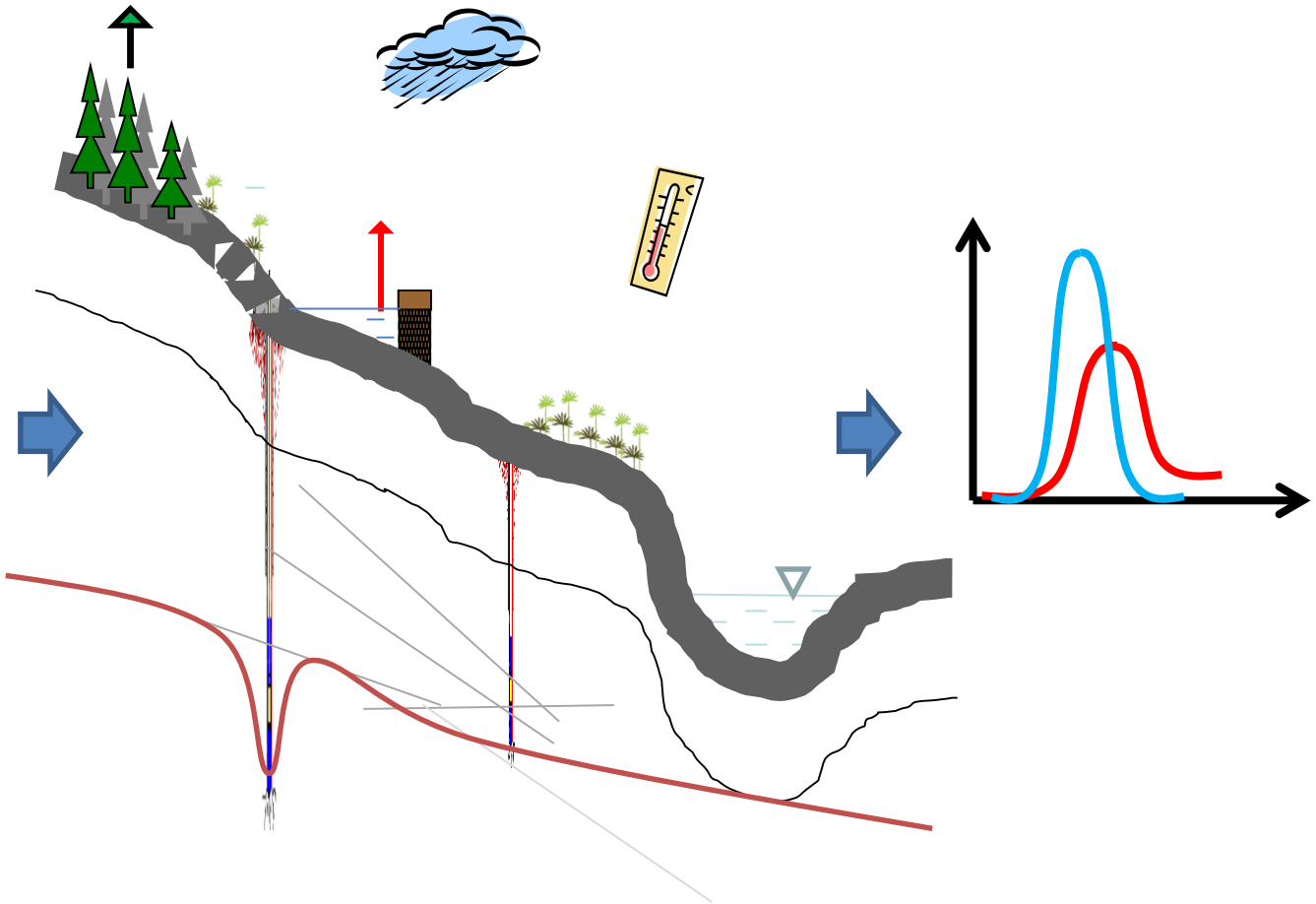
Conclusion: Need to examine ALL factors especially regions undergoing rapid change.

Climate Change

Land cover change

Infrastructure, Drainage Works

Human Adaptation to change



THANK YOU!

ARKAVATHY RESEARCH TEAM

Research Staff
Meghana Eswar, Sanjeev Kenchaigol, T. Zuhail, M. Idris, Praveen Urs, Kirubaharan Jeremiah, Apoorva R., Karthik Madhyastha, A. Kavitha, Dipak Samal,

Field Enumerators
Chidanand, G. C. Guruswamy, D. S. Kumar, B. K. Manjunatha, P. Nagendra, A. H. Sathish.

Outreach/ Water Literacy Campaign
G.,Manjunatha, K. Janardhan

USAID-RI Fellow: Gopal Penny

Interns (2013, 2014)
Tagore, Nagaraju, Shilu, Veena, Pradnya Shilpa, Sayan, Sana, Arjun, Kritika, Aravind

Consultants
Dr. Ballukraya (Hydrogeology)

RS/GIS support
Jayalakshmi, Ameya, Sowmyashree, Muneeswaran

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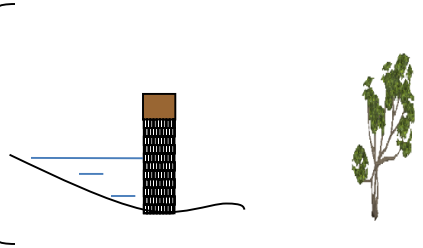
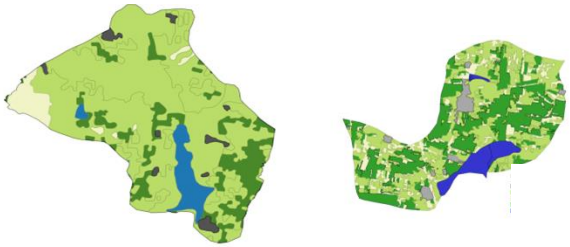
NSF SESYNC Grant for socio-hydrologic synthesis work

Research Approach: Upscaling of Data and Models

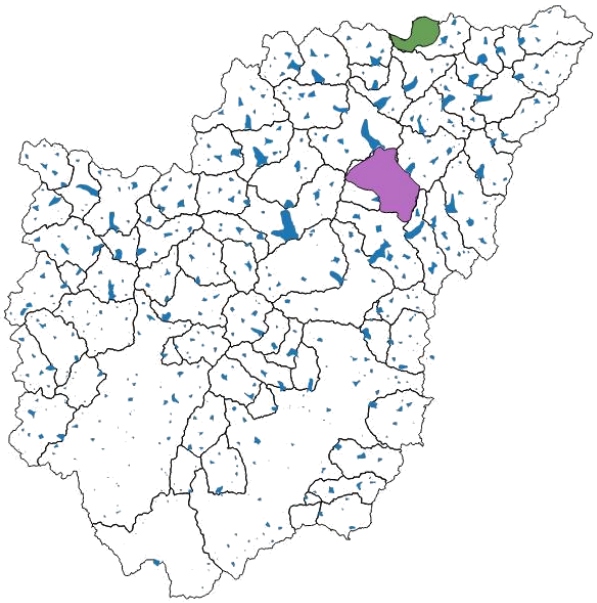
Micro Scale



Milli-watershed



TG Halli scale



Infiltration Expts, Isotopic Studies, Borewell Camera Scans, Soil Moisture Sensors

Individual Check Dam Model (Python)

Vadose zone model (MATLAB,C++)

Well census, Land use mapping, stream surveys

Milli-watershed model (Visual Basic)

Satellite Imagery Analysis, Census Data Analysis

TG Halli "cascading tank" model (Visual Basic)

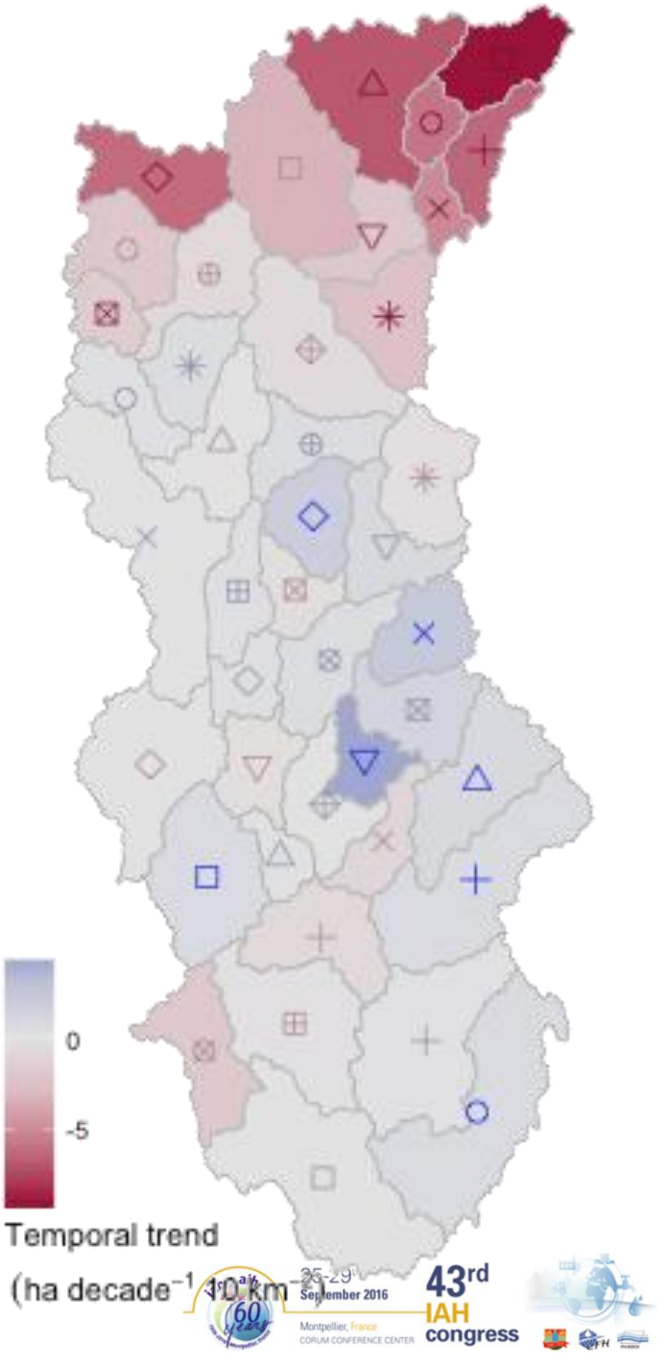
Satellite imagery analysis show that streamflow generation declined almost everywhere in TG Halli catchment

Methods:

- Classify water in Landsat images (1970s-present)
- Trends in time-series of surface water

Results:

- Increased streamflow downstream of urban areas
- **Decreased stream flow everywhere in TG Halli catchment**



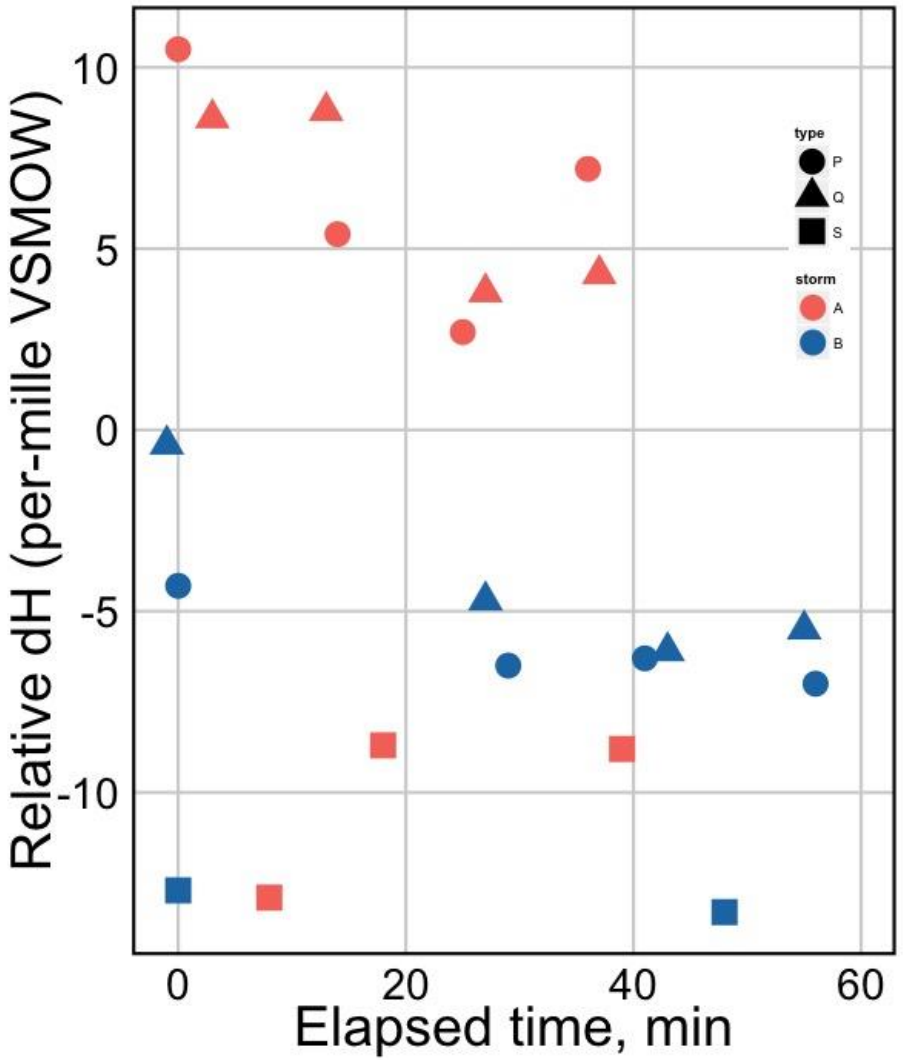
Source: Penny et al (forthcoming)

1A. No base flow: Overland flow is the primary mechanism of runoff generation

Relative deuterium concentrations (dH) in two storms (**A** and **B**)

1. Soil water (S) samples were relatively unaffected by the storm.

2. Stream water and rainfall have similar signatures.



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