Are small reservoirs important?
The regional sociohydrology and climatic sensitivity of irrigation systems in southern India

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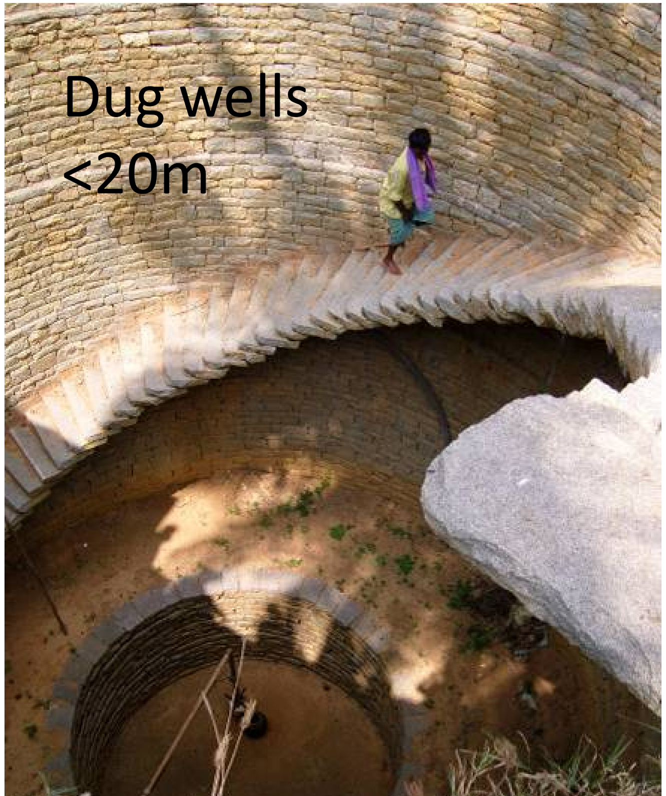
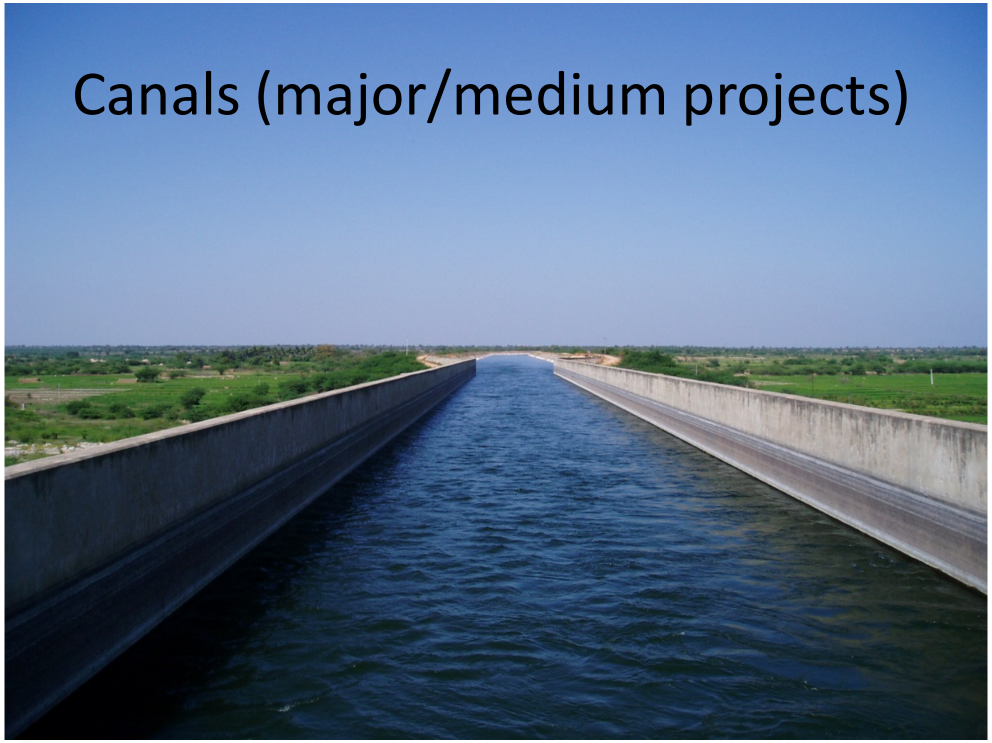
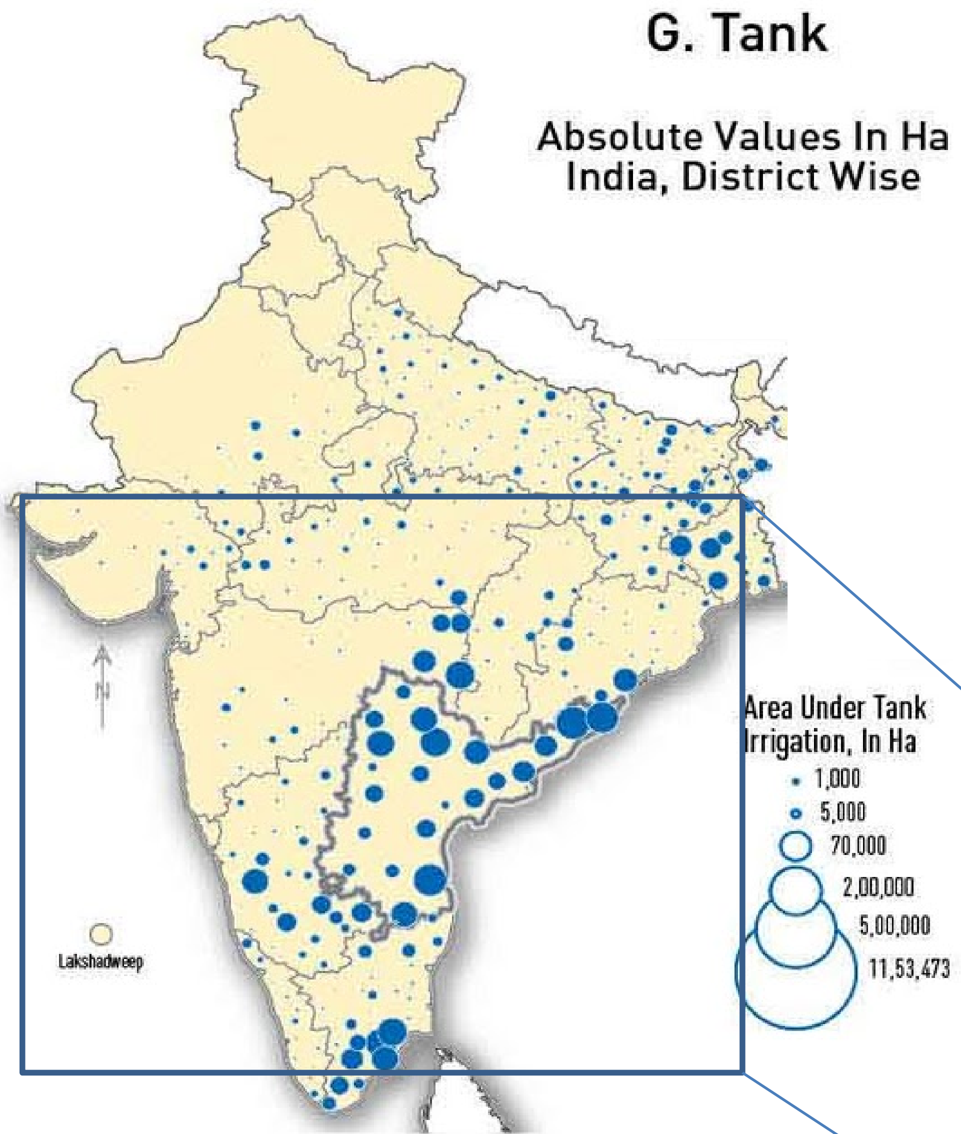

Dug wells
<20m


http://www.solutionsforwater.org


Canals (major/medium projects)


Tube wells 20m-150m



Source: Govt of India

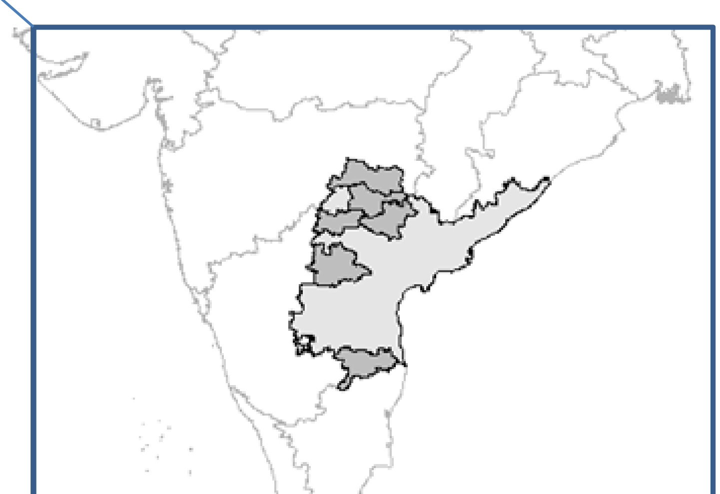
Year	Tank
1950–1951	17.6 %
1960–1961	18.5
1970–1971	13.2
1980–1981	8.2
1990–1991	6.1
2002–2003	4.1

Study area:

Tank-dominated districts in AP

>50% tanks in 1955

<25% canal in 2010



c.f. Fishman et al, WRR, 2011

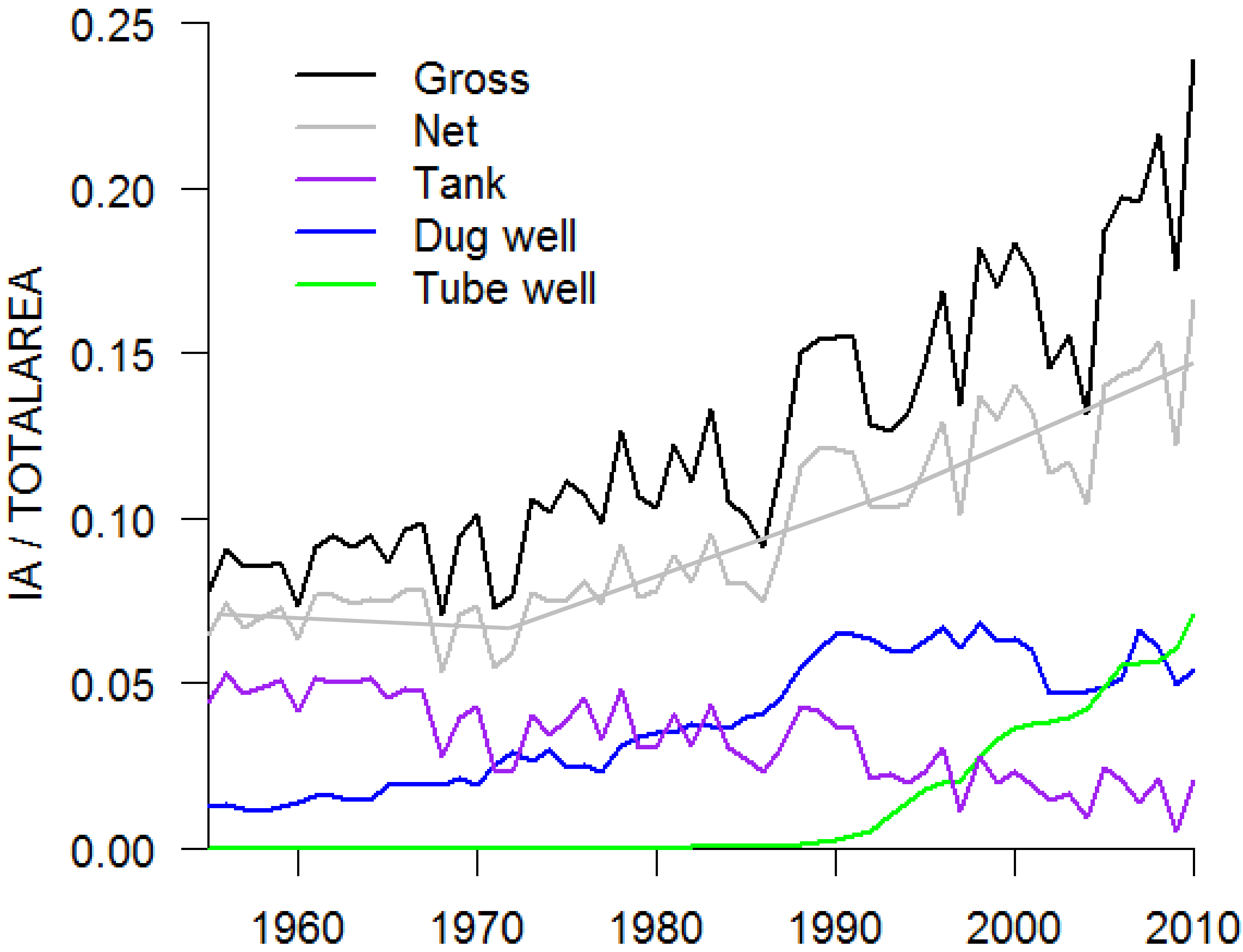
Research questions:

Q1: How and where has the area irrigated (IA) by each source changed over 1955-2010?

Q2: What are the sociohydrologic reasons for decadal trends in IA by source?

Q3: Have trends in source coincided with in/decrease in IA variability? Does hard-rock aquifer development buffer IA?

Data: Agricultural census, minor irrigation census, Q, P



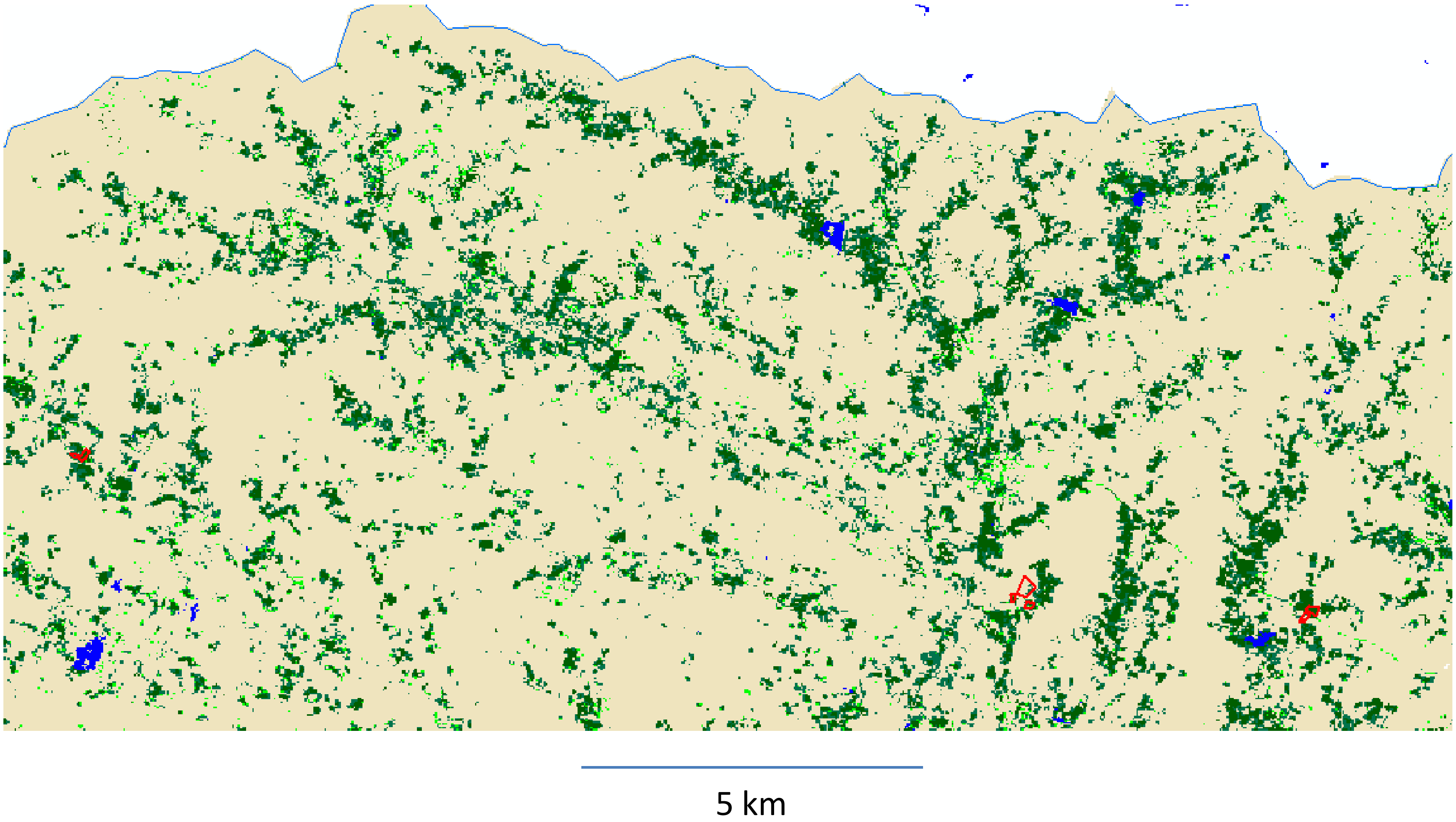
Net irrigated area = Area irrigated in at least one cropping season (~ $A_{monsoon}$)
Gross irrigated area = Area irrigated, both cropping seasons ($A_{monsoon}$ + $A_{postmonsoon}$)

Groundwater ▪ expansion of NIA and GIA

Cf. Fishman et al, 2011

Where is irrigated area expanding?

- Tank-dominated district (ASTER image classification, February 2005)
- Most irrigation not immediately downstream from tanks



Q2: Why did tank IA decrease dramatically?

Maintenance hypothesis:

"…mass sinking of borewells tended to undercut the social compacts integral to tank maintenance and operation, leading to the latter falling into disrepair." Taylor (2013):

"...vicious cycle of "rehabilitation-poor maintenance-deterioration-rehabilitation". Sakthivadivel at al, (2004):

Others: Lack of maintenance, siltation

Solution: Better institutions and investment will revive tanks and "provide a safety net to protect livelihood of millions…" Sakthivadivel at al, (2004):

Does lack of maintenance drive tank decline?

Constraint	Fraction of tanks (MAP = 922mm)		
	1993-1994 (84% MAP)	2000-2001 (100% MAP)	2006-2007 (93% MAP)
Storage not filled or low discharge	**0.39**	**0.43**	**0.58**
Maintenance-related	**0.13**	**0.10**	**0.07**
Inadequate power	NA	NA	0.03
Mechanical	0.10	0.09	0.02
Siltation	0.03	0.01	0.02
Other	**0.14**	**0.04**	**0.17**
Total	**0.66**	**0.57**	**0.82**

Implication: Better maintenance may not improve tank performance

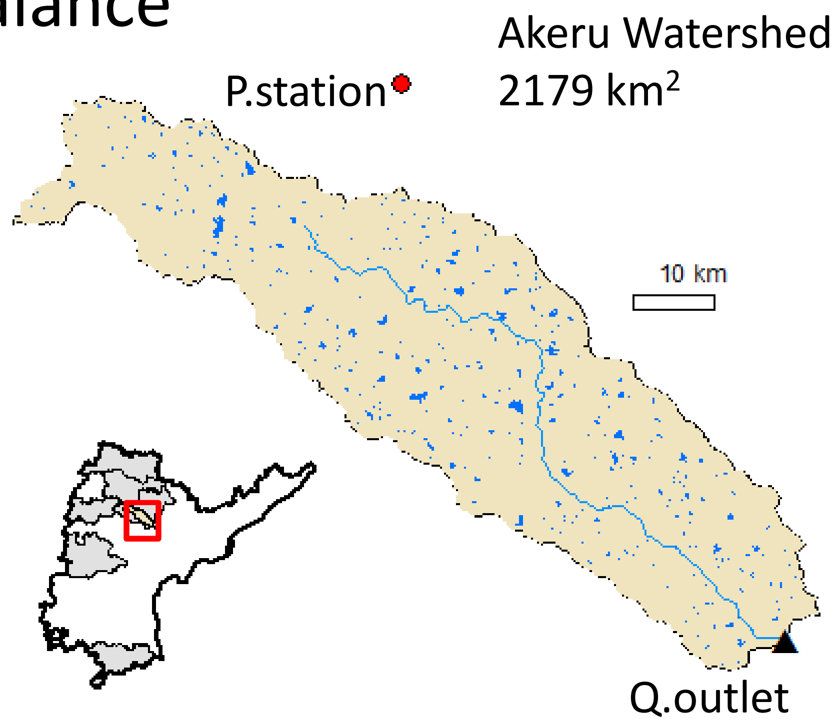
Does GW irrigation impact tank storage?

Irrigation and the basin water balance

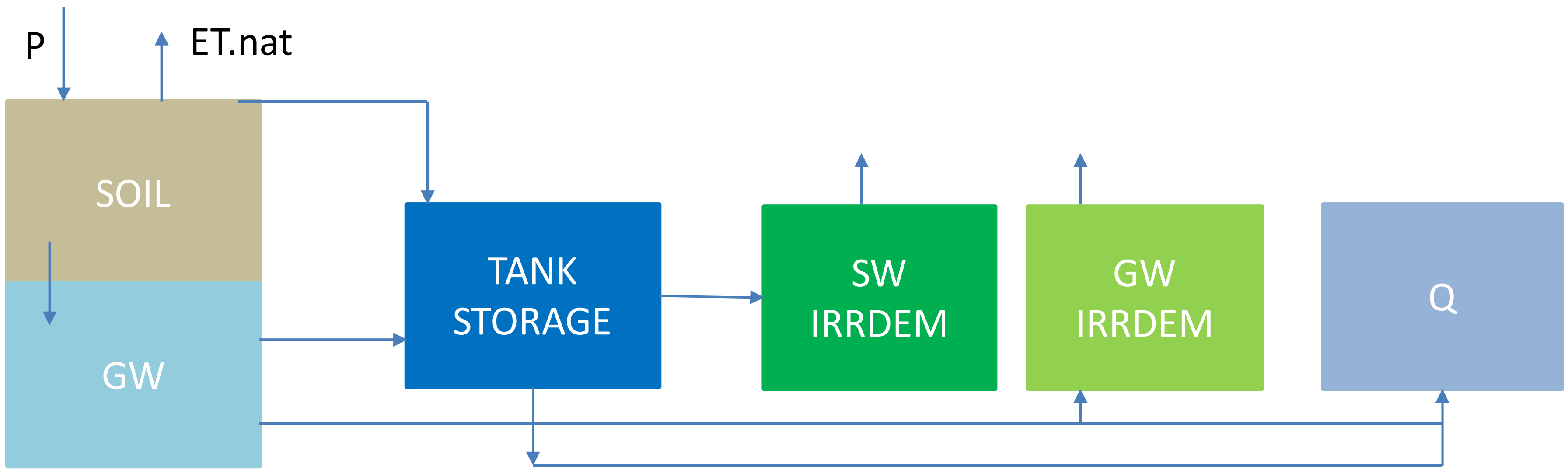
	1992-1999
P	795 mm
Qobs	38 mm
Q:P	0.05

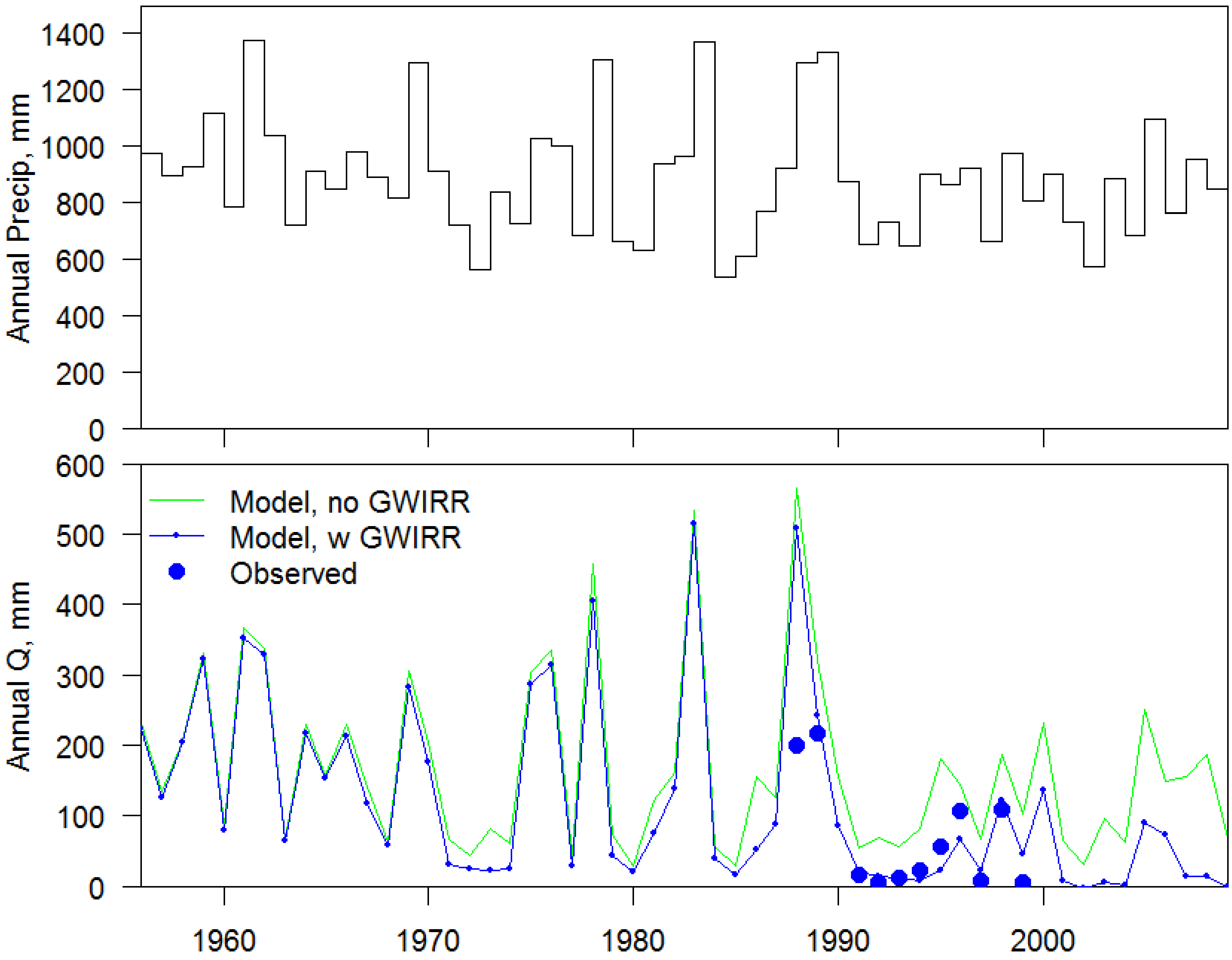
Tank storage: $V = 0.00183A^{1.5169}$

A = Water surface area (Landsat TM)



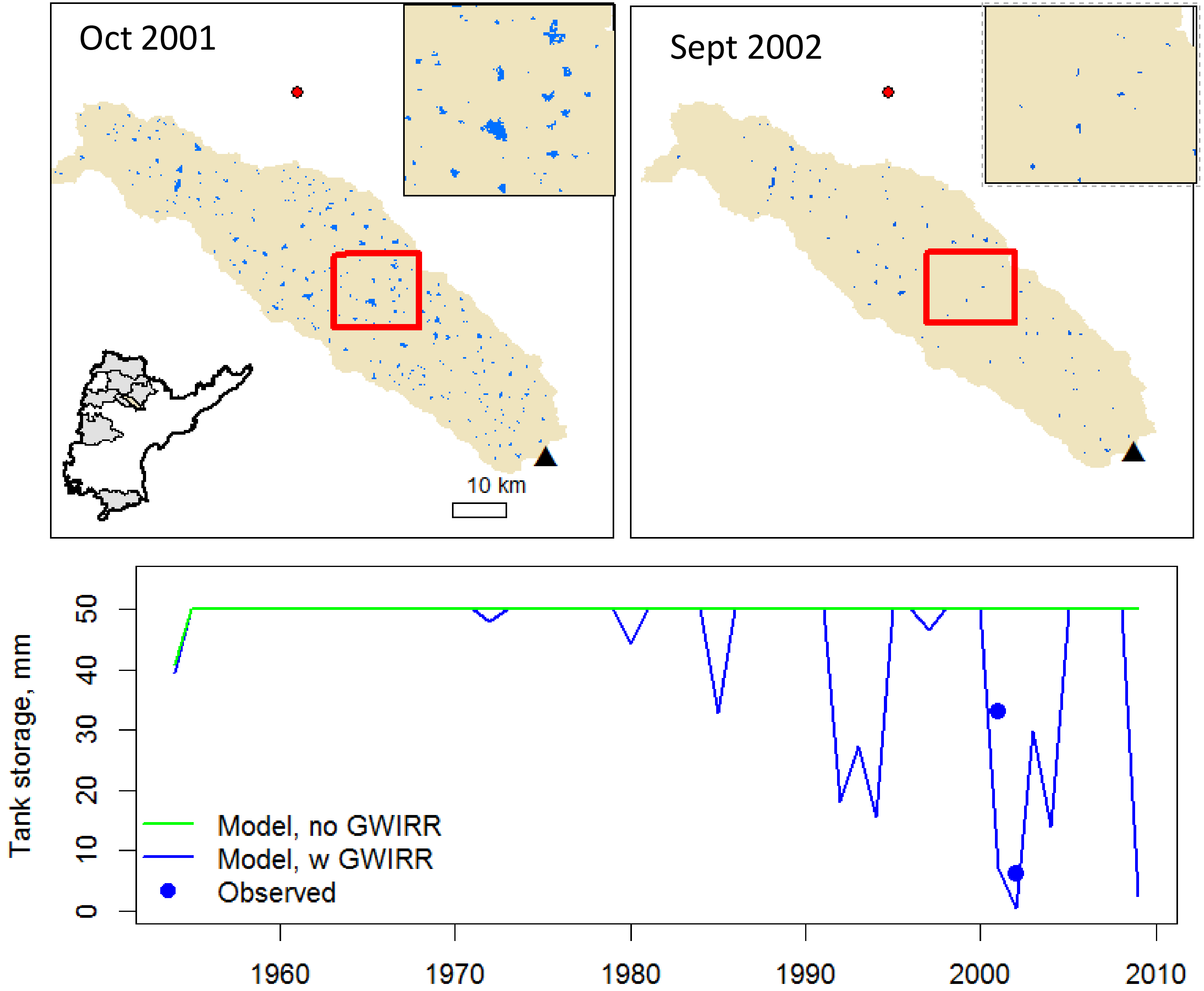
abcd(e) model with irrigation module





1400
1200
1000
800
600
400
200
0
Annual Precip, mm
600
500
400
300
200
100
0
Annual Q, mm
Model, no GWIRR
Model, w GWIRR
Observed
1960
1970
1980
1990
2000

Changes in post-monsoon tank storage, 2001 and 2002



How does groundwater irrigation impact surface discharge?

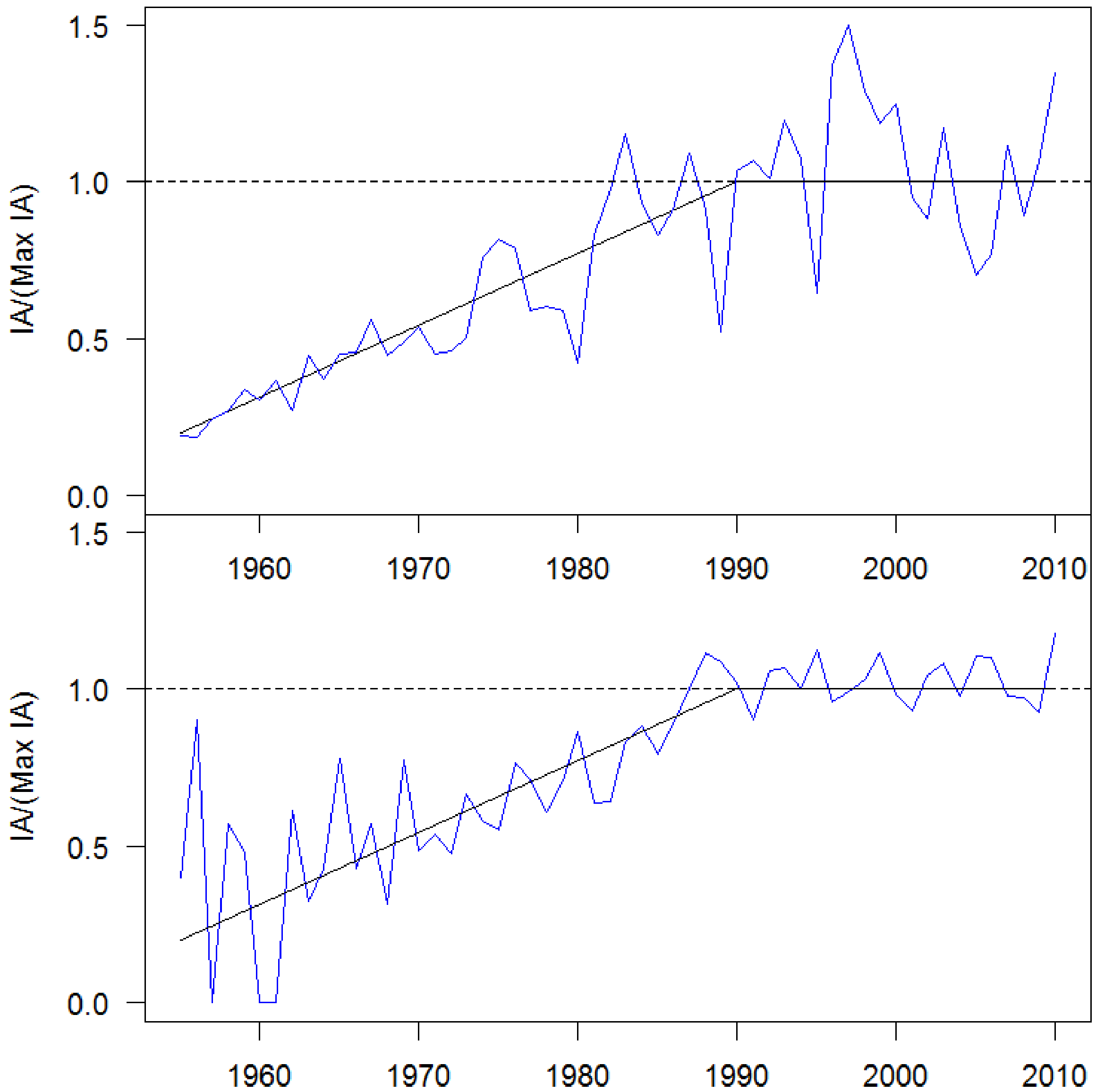
Watershed development for groundwater recharge

Small watershed: Reduced annual runoff 50% (Garg et al. 2012)

Q3: Have recent trends made IA more or less variable?

Trajectory 1:
Variance increases as use ▪ available resource
"Hitting bottom"
Var(IA) α IA^2

Trajectory 2:
Variance decreases due to shift to GW
"Buffering"
Var(IA) α 1/IA

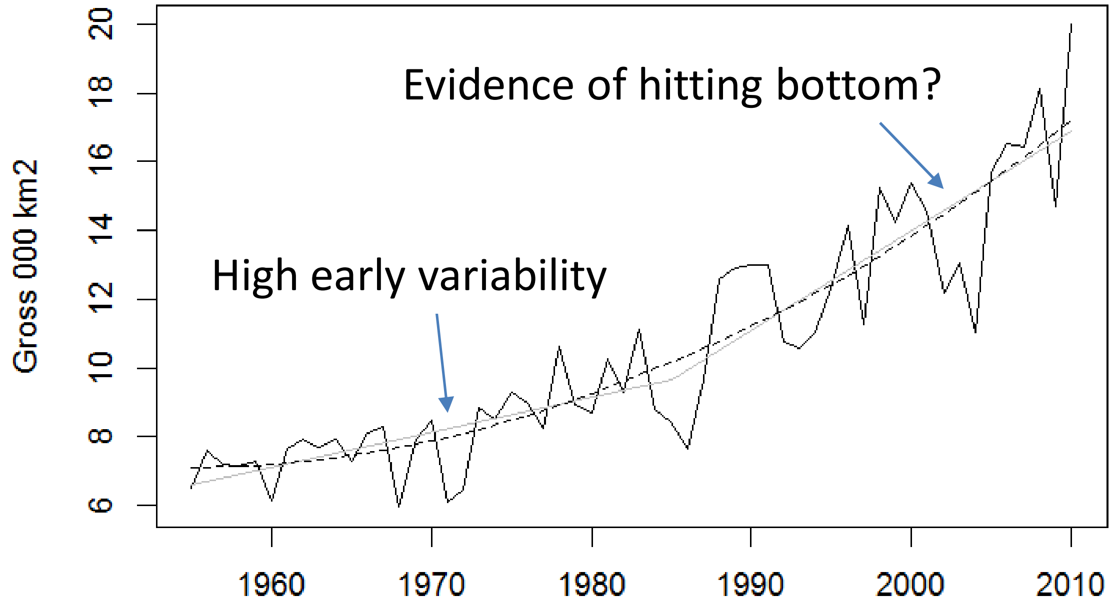


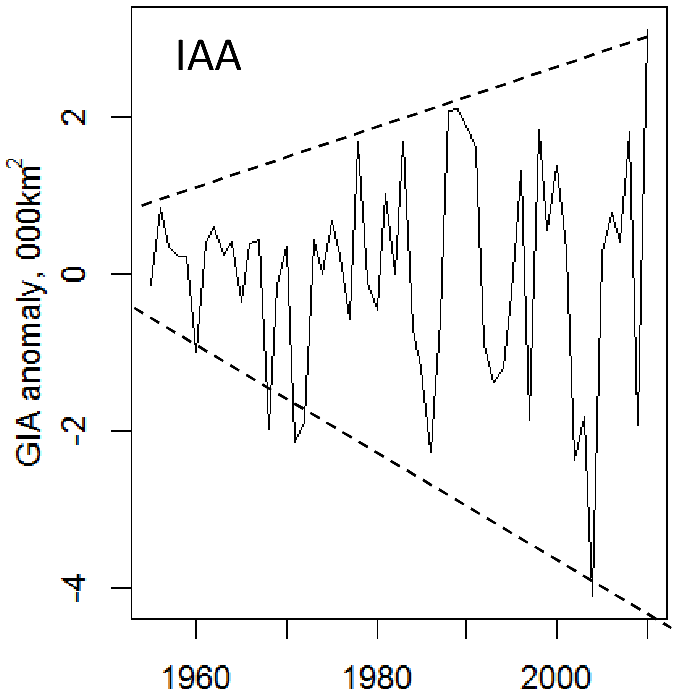
Gross irrigated area

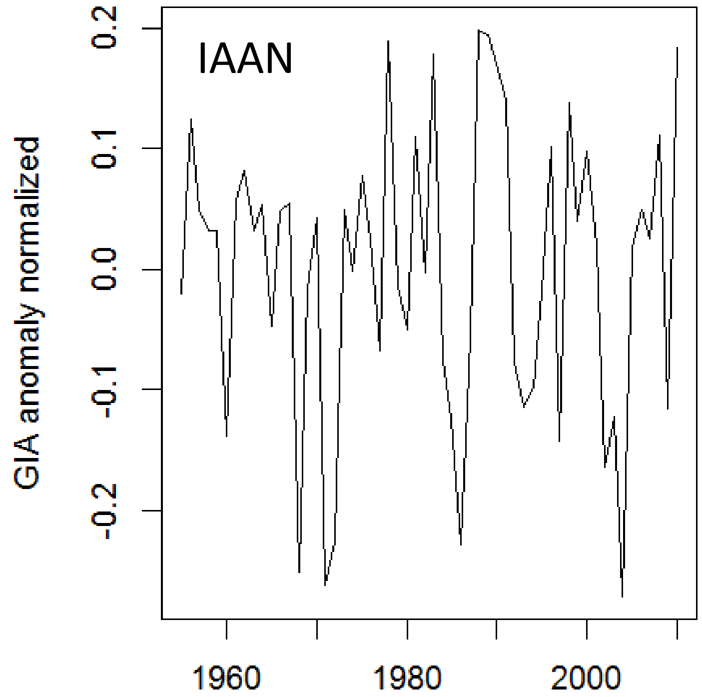
Trend in var(IAA)

No trend var(IAAN)

“Moving bottom”…always at bottom, or at maximum use of available resource.







Conclusions

- Main source: surface water ▪ groundwater
- Water stress is main reason for decline of tanks
  (not lack of maintenance)
- Water balance shows impact of GW irrig on tank storage
- Variability increased (absolutely) or stayed the same (relatively) during the sw-gw transformation

Future research

- Will interannual variability increase with further GW depletion? Does variance depend on climate?