Groundwater Use, Productivity and Market Participation in India: Implications for Reforms

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Introduction

- 27 million extraction units- 60%-75% of GIA- 70 to 80 billion irrigation economy- water decline by 3mt/year. Lender of the last resort' has become the main (only) resort.
- GW development unsustainable- Punjab (145%), Rajasthan (125%), Haryana (109%), TN (85%), Gujarat (76%), UP (75%)- 31% districts, 34% of land area unsafe for GW in 2004
- Reform process in agricultural markets has bypassed water, especially groundwater segment accounting for more than 60% in India (Rosegrant et al, 1995)
- Tradable rights/incentives for water markets- expected to move towards opportunity cost pricing. Water rights allowed in Mexico, Chile and other places
- Discourse on GW use- moved away from 'development' to 'management'. From public development to 'atomistic irrigation boom' to need to curtail (based on hydrogeology)

Introduction

- Groundwater governance throughout the world is a ‘work in progress’ (Shah, 2008; Kuzdas et al, 2015)
- Problems in estimation- not accounting for hydrogeological factors in estimating blocks in regard to GW (Shankar et al, 2011), and assumption of aquifer transmitivity,
- Draft bill

- Called ‘Model Bill for the Conservation, Protection, Regulation and Management of GW, 2016’ - GW Protection Zones- distance to new wells, pumping regulation, regulatory protocols, depending on hydrogeological & socio-economic conditions.
- GW Protection Zone 2, in case of droughts- restrictions on crops to be grown with binding undertaking.
- Institutions until the village level. State GW Advisory Council at state level
- Gujarat Irrigation and Drainage Act, 2013- covers both surface and GW regulation

Conceptual framework

- CPR dilemma- individual rationality leads to an outcome not rational to group (Ostrom et al, 1994)
- Welfare losses by competitive extraction varies from basin to basin depending on economic, hydrologic and agronomic factors (Koundori, 2004)
- Investments to boost water productivity and improve energy use efficiency in crop production are two pathways to reduce environmental footprint (Khan and Hanjra, 2009)
- Several studies highlight the importance of studying water productivity (Woolley et al, 2009; Wang and Segarra, 2011; Kumar&van Dam, 2013; Molden, 1997; Sakthivadivel et al, 1999). Also as a determinant of poverty (Hussain et al, 2006)
- WP need to be studied at farm level rather than crop level, because farmers try to optimize water allocation over entire farm, rather than individual crops (Kumar and van Dam, 2013)
- Contrary to physical productivity, very few studies on economic return of crops with respect to each unit of water depleted (Barker et al, 2003; Kumar & van Dam, 2009, 2013)

Conceptual framework

- Vaidyanathan and Sivasubramaniyan (2004) estimated efficiency of water use and highlighted need for empirical studies
- Wang and Segarra (2011) show that a sub-optimal outcome arises under competitive extraction in the presence of heterogeneity in water productivity, because a coordinating mechanism to allocate resources on the basis of productivity is lacking (property rights). But not because of stock externalities as in several models. Welfare loss rising for aquifers with higher storage capacity. Calls for more attention to heterogeneity in productivity
- Water markets for both efficiency and equity (Manjunatha et al, 2011; Shah, 1993; Brennan, 2006; Palanisami..; Tiwari and Ankinapalli..). Active in Gujarat, Punjab, UP, AP, TGN, TN, WB KTK
- Water markets- alternative to group ownership
- Counter arguments- oligopoly does't necessarily increase competition and efficiency, much less equity (Dubash, 2000)
- Water markets shrinking in IGB

Conceptual framework

- Dubash (2000)- Water markets shaped by spatial characteristics, land patterns, water depth, socioeconomic factors such as distribution of land ownership, access to credit, caste, village specific characteristics.

Conceptual framework

- Raising marginal price of electricity to somewhere near MC substantially mitigates overexploitation (Somanathan and Ranindranath, 2006)
- Costa III (2015) applies endogenous growth model and postulates that increasing demands on water resources lead to higher transaction costs, which then induce institutional adjustment ultimately to transferable water rights (as water economies ‘mature’).
- The shift to more efficient irrigation technology has often increased GW extraction, in part due to shifting cropping pattern (Pfeiffer and Lin, 2014; Dagnino and Ward, 2012)
- WTP for water services in Uganda determined mainly by joint influence of attitudes, perceived control and perceived social pressure, apart from a small measure by gender, income, occupation of HH and tenure status (Mugabi and Kayaga, 2010).
- WTP for water pricing depended in Vietnam positively on trust in authority, market awareness and demand response, seasons to crop/yr, off-farm income. And negatively with low-input and involvement farming, and education level (Toan, O’Keefe and crase, 2015).

Objectives, data and methodology

Objectives

Water productivity heterogeneity and determinants

Water market participation including WTP for water (energy) and participate in water conservation measures

Data

- Primary data collected from 506 users and 219 non-users in Godavari River basin in MH, Telangana and AP
- For water markets, 8% of 825 households are participants (6%+2%)

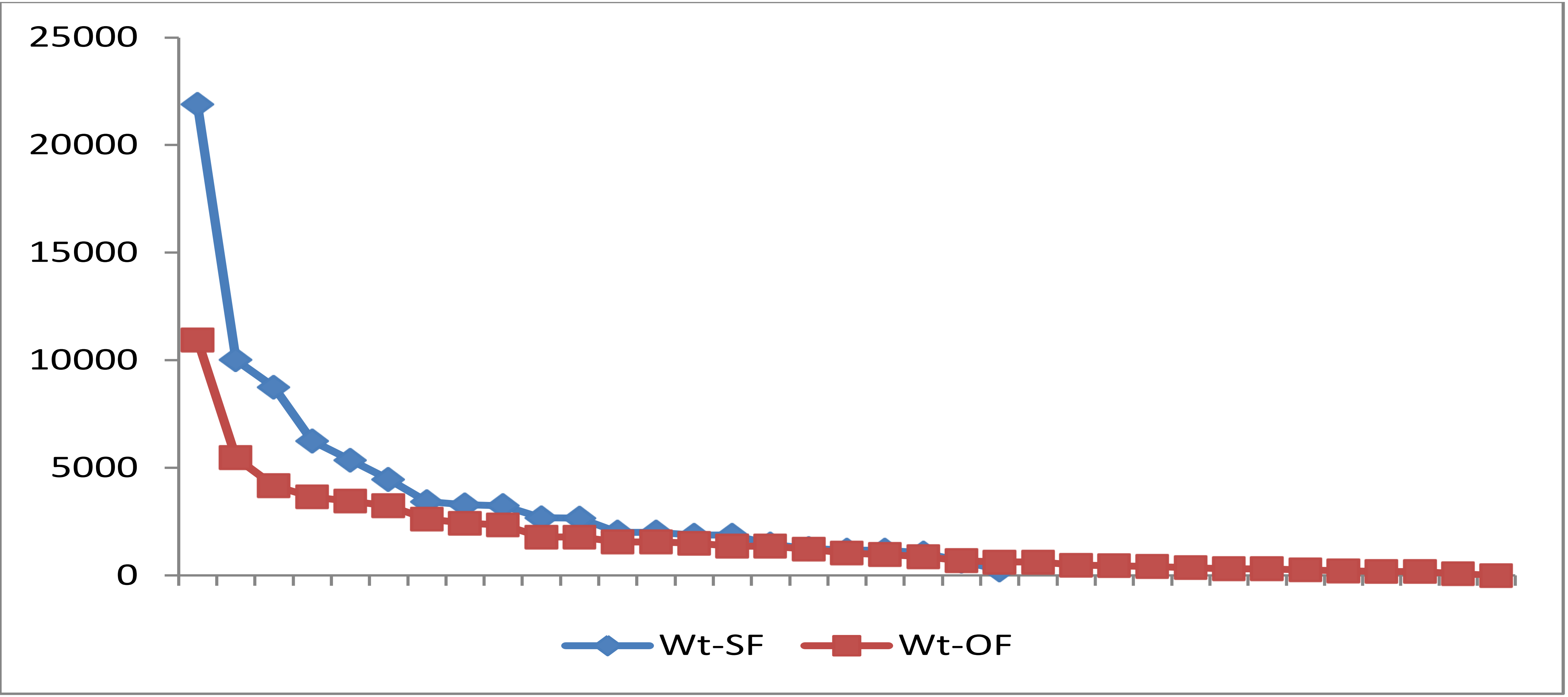
Methodology

- Tobit regressions for water use and water productivity
- Logit equations with marginal effects for WTP for water, WT participate in water conservation, water markets

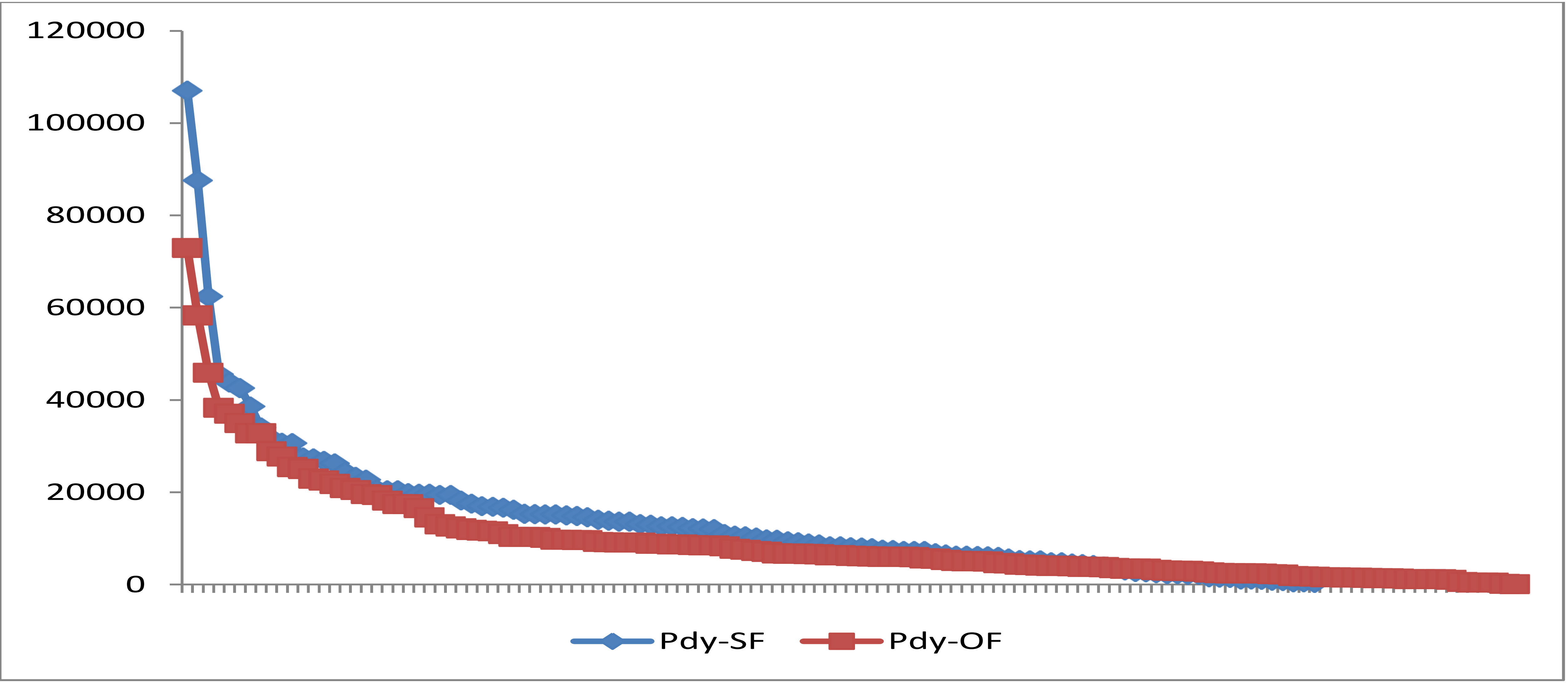
Water use- small farmers vs.others

Small farmer dummy	Small farmers		Other farmers	
	Mean	SD	Mean	SD
Wheat	3946.43*** (22)	4738.95	1674.78 (35)	2079.32
Paddy	14425.11*** (108)	15933.52	9606.70 (130)	11388.51
Maize	5549.73*** (105)	9056.82	2542.3 (100)	2498.58
Bajra	1733.06 (19)	1628.89	1047.01 (20)	1548.21
Bengal gram	8402.62 (6)	16785.09	603.18 (10)	938.06
Cotton	2882.35 (23)	4435.73	1915.17 (25)	3103.00
Grapes	13513.33 (12)	23097.10	3501.01 (12)	5392.32
Ground nut	2258.41 (2)	1228.41	2322.05 (7)	2544.13
Onions	3689.05 (12)	3668.34	2659.68 (20)	3277.07
Soybean	2137.97 (27)	3668.54	1317.24 (42)	3241.86
Tobacco	2743.97 (9)	1617.88	2275.88 (19)	1696.63
Tomato	10564.53 (25)	27704.82	2411.92 (18)	2394.66

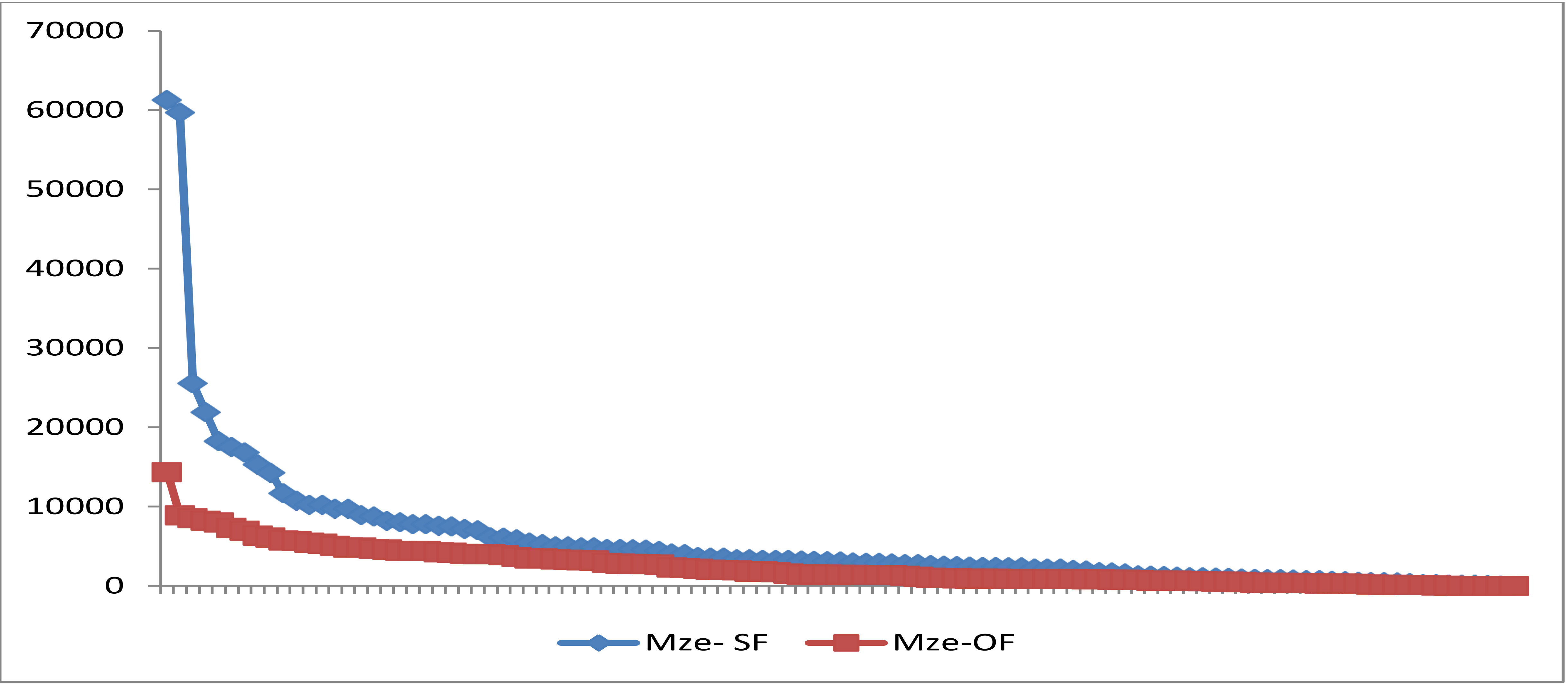
Water use in wheat for small farmers



Water use in paddy for small farmers



Water use in maize for small farmers



Water productivity in Godavari River Basin (Rs./Ac/M^3)

Reaches	Farmer category	Mean	SD	N
Upper	Large	504.72	2774.75	84
	Small	166.57	659.60	95
	Total	325.25	1961.76	179
Middle	Large	41.17	72.51	94
	Small	19.73	46.86	94
	Total	30.45	61.82	188
Lower	Large	41.14	56.76	68
	Small	22.86	34.84	71
	Total	31.80	47.58	139
Total	Large	199.44	1630.86	246
	Small	74.24	404.90	260
	Total	135.11	1174.04	506

Tobit regression on determinants of water use

Variable	Coefficient	SE
Constant	-19470.6700***	5584.528
HH size	352.8875	287.8522
Owned land in acres	71.7346	116.0155
No of crops cultivated	2801.9960***	700.3521
Age of head of HH	-4.4515	47.9891
Gender of HHH	4361.9930***	2306.59
SC	-2757.4120**	1358.7060
Upper reach	-7597.447***	1596.733
Lower reach	2975.682	2424.522
Occupation	1855.1870	1669.357
No.of functioning well	12909.38***	2699.312
Water sufficiency dummy	-138.6481	1812.933
Illiterate dummy	1421.328	1330.947
High value crops dummy	-2875.479**	1318.525
Distance to output market	-208.4645***	71.3455
Rainfall	16.4444***	5.8925
Dummy for water availability	-49.2635	1345.28
Depth of well	-91.9486***	15.0021
Energy cost	0.3083***	0.0931
Drip/sprinkler dummy	7076.154***	1927.777
Water market participation dmy	2331.093	1819.673
Poverty dummy	718.4975	1367.944

Tobit regression for water productivity

Variable	Coefficient	SE
Constant	-1268.132***	541.1933
HH size	13.9895	27.2541
Owned land in acres	60.2257***	11.0741
No of crops cultivated	-228.851***	67.3384
Age of head of HH	-4.1238	4.6119
Gender of HHH	216.3916	224.3576
SC	-58.9589	131.106
Upper reach	188.9546	153.7495
Lower reach	-75.4080	232.6714
Occupation	-261.8026*	158.2119
No.of functioning well	588.4239**	276.4089
Water sufficiency dummy	123.1581	175.668
Illiterate dummy	25.0816	128.4596
High value crops dummy	103.969	126.6274
Distance to output market	-18.1552***	6.7084
Rainfall	1.6519***	0.5679
Dummy for water availability	238.5029**	129.6862
Depth of well	4.0685***	1.4418
Energy cost	0.0069	0.0090
Drip/sprinkler dummy	346.9218**	185.6861
Water market participation dmy	-230.1117	178.2893

Determinants of water use vs. water productivity

Variable	Water use	Water productivity
Constant	-19470.6700***	-1268.132***
HH size	352.8875	13.9895
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Depth of well	-91.9486***	4.0685***
Energy cost	0.3083***	0.0069
Drip/sprinkler dummy	7076.154***	346.9218**
Water market participation dmy	2331.093	-230.1117
Poverty dummy	718.4975	-
No.of observations: 506 Log likelihood: -5016.3489 Sigma: 11467.46*** LR Chi^2 (16): 169.63 Prob> chi^2 : 0.0000 Pseudo R^2 : 0.0166		No.of observations: 506 Log likelihood: -3972.3494 Sigma: 1103.97*** LR Chi^2 (16): 106.99 Prob> chi^2 : 0.0000 Pseudo R^2 : 0.0133

Logit regression on willingness to pay electricity tariff

Variable	Coefficient	Marginal effect
Constant	-3.6209***	-
Own land	-0.0508*	-0.115*
HH size	0.1089	0.0246
Age of head of HH	-0.0185*	-0.0041*
Gender of HHH	-0.1384	-0.0306
SC	-0.0586	-0.0133
Upper reach	5.9102***	0.7977***
Lower reach	1.4648***	0.2856***
Occupation	0.3341	0.0778
Livestock ownership	0.8605***	0.2025***
Acquifer	0.9930	0.2241***
Awareness on man	0.9745**	0.2244**
Rainfall c decision	0.4944*	0.1136*
Ground water rights	-0.4675	-0.1013
GW externality	0.3771	0.0860
Ground water conflict	1.1706***	0.2352***
Water use	-0.000000786	-1.77e-07
Log likelihood: -187.21228; No.of observations: 506		
LR Chi^2 (16) : 323.55		
Prob> chi^2 : 0.0000		
Pseudo R^2 : 0.4636		

Logit regression on willingness to participate in ground water conservation

Variable	Coefficient	ME
Constant	-1.9553***	-
User dummy	0.3802	0.0573
Owned land	-0.0283	-0.0041
HH size	0.0076	0.0011
No of crops cultivated	0.2013	0.0295
Age of head of HH	-0.0083	-0.0012
Gender of HHH	0.7306**	0.1288*
SC	0.0433	0.0063
Upper reach	3.9832***	0.4633**
Lower reach	1.1217***	0.1399***
Occupation	-0.9215***	-0.1112***
Livestock ownership	0.4819**	0.0740**
Acquifer	0.8034***	0.1195***
Awareness on man.	0.9749***	0.1514***
Rainfall c decision	1.4009***	0.2250***
Ground water rights	-1.0843***	-0.1392***
GW externality	0.3959**	0.0579*
Ground water conflict	0.5936**	0.0792**
Log likelihood: -335.77646; No. of observations: 825		
	LR Chi^2 (16)	: 306.82
	Prob> chi^2	: 0.0000
	Pseudo R^2	: 0.3136

MEs in Logit model for WTP for water and conservation

Variable	WTP for electricity	WT participate in water conservation
Own land	-0.115*	0.0041
HH size	0.0246	0.0011
No.of crops cultivated	-	0.0295
Age of head of HH	-0.0041*	-0.0012
Gender of HHH	-0.0306	0.1288*
SC	-0.0133	0.0063
Upper reach	0.7977***	0.4633**
Lower reach	0.2856***	0.1399***
Occupation	0.0778	-0.1112***
Livestock ownership	0.2025***	0.0740**
Acquifer	0.2241***	0.1195
Awareness on management	0.2244**	0.1514***
Rainfall c decision	0.1136*	0.2250***
Ground water rights	-0.1013	-0.1392***
Ground water externality	0.0860	0.0579*
Ground water conflict	0.2352***	0.0792**
Water use	-1.77e-07	-
User dummy	-	0.0573

Logit regression for determinants of water market participation

Variable	Coefficient	Marginal effect
Constant	-5.6379***	-
HH size	-0.0513	-0.0021
Owned land in acres	-0.0028	-0.0001
No of crops cultivated	0.1407	0.0059
Age of head of HH	0.0021	0.0001
Gender of HHH	-0.4106	-0.0202
SC	0.2255	0.0097
Middle reach	2.3353***	0.1485**
Lower reach	3.5508***	0.3600***
Occupation	0.1833	0.0072
No.of functioning well	-0.0782	-0.0033
Water sufficiency dummy	-1.3307***	-0.0387***
Illiterate dummy	-0.0742	-0.0031
High value crops dummy	-1.2823***	-0.0577***
Total irrigated area	0.0008	0.00004
HV food crop dummy	2.7516***	0.3126*
Rainfall	0.0009	0.00004
User dummy	0.6474	0.0256
Depth of well	0.0039	0.0002
Drip/sprinkler dummy	0.9241***	0.0562
Poverty dummy	0.5037	0.0187
Log likelihood: -192.39 Prob> chi^2 0.0000	No .of obs:825; LR Chi^2 (16) :89.69 Pseudo R^2	 : 0.0189

Conclusions

- Water productivity increases as size of land owned increases, though water use does not vary.
- Awareness about GW scarcity increases water productivity for the same level of water use. So also depth of well, which reduces water use too. Similar findings in Mugabi&Kayaga, 2010; Toan et al, 2015
- High value crops cultivation associated with lower use and no significant difference in productivity
- Advanced irrigation technologies increase water use (Pfeiffer and Lin, 2014; Dagnino and Ward, 2012) and productivity.

Conclusions

- Farm diversification with livestock associated with higher WTP for water and also participation in water conservation. Similar findings in Toan et al, 2015
- Awareness of aquifer and management increased both, while users in relatively higher level of GW development not willing for both
- Users in conflict villages have higher levels of WTPay and Wtparticipate
- As size of land owned increases, WTP for water goes down
- While users with food crops participated in markets, while high value crops do not
- Expectedly, higher level of GW development associated with market participation
- Sprinkler/drip adopters not participating in markets

Implications

- Heterogeneity in productivity among GW users in the basin is a cause for concern. It negatively impacts welfare, as shown by Wang and Sigerra (2015). Measures aimed at productivity might be planned. Similar findings from IGB by Sharma et al (2010)
- Awareness of GW externalities, aquifer management, and need for water conservation found to increase water productivity and WTP for water and participation in water conservation. It has implications for planning water reforms
- Advanced irrigation technologies increase water productivity and used for application in owned fields. Their encouragement can be useful in reducing heterogeneity among GW users

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Implications

- Diversification of incomes enhances WTP, which is a good indication that the ongoing diversification can help in bringing in more reforms, as endogenous water model for evolution of water rights by Costa III (2015) suggests.
- Small farmers found to be WTP for water , though reaping lower productivity of water. This might be because they might value protecting water resources more than others for livelihood sustainability. D'Exelle, Lecoutere and Campenhout (2012) show small farmers in Tanzania showed strong preference for equity sharing and participation in willingness to alternate
- Above two points imply situation might be right for water reform in India
- Output market infrastructure improves water use and prody. So, public and private sector initiatives needed for investments