Eco. Env. & Cons. 28 (1) : 2022; pp. (179-192)
Copyright@ EM International
ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2022.v28i01.023

What do Farmers *Don't* Know? A Generic Index to Summarize Cognitive Awareness of Groundwater-sourced Irrigation and Conservation at Grassroots

Ankita[1], Vivek U. Padvetnaya[2] and *Sriroop Chaudhuri[3]

[1]Research Analyst, The Economist Intelligence Unit, TEG India Pvt. Ltd., Skootr Spaces, Tower B, Building 9, DLF Cyber City Phase-3, Gurgaon, Haryana- 122002, India
[2](Associate Professor and Associate Dean, Jindal School of Governmental Policy, O.P. Jindal Global University, Sonipat, Haryana 131 001, India
Professor, Environmental Studies and Geospatial Modeling
Co-Director, Center for Environment, Sustainability and Human Development
Advisory Board, International Academy of Environmental Sanitation and Public Health (IAESPH))
Associate Dean of Research, Jindal School of Liberal Arts and Humanities
O.P. Jindal Global University, Sonipat, 131 001, Haryana, India
(Received 10 May, 2021; accepted 5 July, 2021)

ABSTRACT

Rise of groundwater-sourced irrigation in India towed along grave concerns over water resources conservation. In this narrative, we offer the authorities (groundwater and irrigation systems' managers) a Groundwater Depletion Awareness Index (GDAI) – a collective expression of farmers' cognitive awareness, integrating four key aspects of irrigated agriculture: (i) groundwater depletion; (ii) water-efficient crops; (iii) irrigation innovations for water conservation; and (iv) uptake of recent irrigation policies at grassroots. We employed a mixed method approach, a cross-sectional survey (10 villages, 100 farmers in Sonepat, Haryana) combined with multivariate statistics (principal component analysis and multivariate regression). Results indicated that although there is certain level of awareness about groundwater depletion, only about 8% of the interviewees adopted water-efficient practices, such as micro-irrigation (MI) and poly house farming (PH). About 42% of interviewees heard of government's MI policy (Per Drop More Crop; launched in 2015), while only 7% were aware of its benefits. None was aware of the advantages of PH. At the grassroots, farmers appeared more aware of potential challenges of MI and PH than their opportunities. None was aware of the Haryana state government's recent *Jal Hi Jeevan Hai* policy (Water is Life; 2019) that urges farmers to diversify and switch to water-efficient crops. Overall, the GDAI revealed multidimensional cognitive barriers to increase uptake of water-efficient farming. It owes to profound disconnect between policy-making and awareness generation at grassroots. We outline means to bridge the gap about how to (i) promote PH-based farming; (ii) restructure financial packages for MI; and (iii) motivate farmers by hands-on demonstration of economic returns of PH and MI.

Key words : *Groundwater depletion, Water conservation, Farmer's awareness, Water-efficient cropping, Micro-irrigation, Poly house farming, Per Drop More Crop, Jal Hi Jeevan Hai, Benefit-Cost Ratio (BCR)*

Introduction

India is currently the global leader of groundwater-sourced irrigation (Siebert *et al.*, 2010). Growth of groundwater-sourced irrigation has become a key tool of rural poverty alleviation and overall develop-

1. Research Analyst, 2. Professor and *Associate Dean* - Research, 3. Professor and *Assistant Dean* - Research

ment. However, unregulated drafting, and consequent depletion, are presently limiting rural economic opportunities on multiple levels (NITI Aayog, 2019), with several negative socio-economic outcomes (Sayre and Taraz, 2019). A vast tract of the Indian sub-continent is presently under intense groundwater stress (Chaudhuri and Kaur, 2017; Chaudhuri and Roy, 2016a, b). A great wealth of recent research identifies north-western states as epicentre of groundwater depletion, which also happen to be hot-seats of rice-wheat production and agronomic excellence in the country (Parakh and Chaudhuri, 2021; Duhan *et al.,* 2017; Girotto *et al.,* 2017; Srivastava *et al.,* 2017; Long *et al.,* 2016; Humphrey *et al.,* 2010; Rodell *et al.,* 2009).

Unregulated use of groundwater systems entails a host of eco-environmental crises including, soil-water salinization (Krishan *et al.,* 2020; Nehra, 2016; Ravish *et al.,* 2018; Chaudhuri and Ale, 2014a-d) and enhanced greenhouse gas emission (Rajan *et al.,* 2020). Depleting groundwater reserves have already compelled farmers to overuse harmful agrochemicals, use deep tillage, that, undermines land systems' sustainability (Chaudhuri *et al.,* 2022; Nehra, 2016). In a cyclic feedback loop, it necessitates more aggressive farming and more groundwater draft.

The government is cognizant of the situation, and developed several forward-thinking policies to promote water-efficient irrigation and cropping practices. For example, the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY, 2015) was launched with the motto of promoting micro-irrigation (MI). In May of 2019, Haryana state government launched *Jal Hi Jeevan Hai* scheme (Water is Life) (Singh, 2019) to encourage farmers transition from traditional crops (rice and wheat) to less water-intensive varieties to conserve groundwater.

But how aware are the farmers about such innovations? Do ideas developed at top-level eventually trickle down to grassroots?

We take up this pilot-scale study in Sonepat District, Haryana, to capture the cognitive dimensions of farmers at grassroots to present to the authorities (groundwater and irrigation systems' managers) a Groundwater Depletion Awareness Index (GDAI), that integrate four key aspects of groundwater-sourced irrigation:

A. Awareness of governmental policies about water conservation
B. Awareness of water-efficient irrigation practices - MI and poly house farming (PH)
C. Key challenges of MI and/or PH adoption at grassroots
D. Willingness to switch to water-efficient crops

To best of our knowledge, our study is first of its kind in India to shed light on cognitive behaviours, that should be duly accounted for in future policy making. Moreover, the normative and conceptual reasons for shifting the discourse remain applicable to groundwater-dependent rural economies anywhere in the world. Generic techniques to develop GDAI could be replicated for similar purposes with nominal modifications.

Methodology

Nearly 94% all groundwater drafted in Sonepat tehshil is currently used for irrigation alone, which makes it the second largest groundwater user in the district (Fig. 1). The Central Groundwater Board (CWGB), nodal agency in India to watch over groundwater-related affairs, labels Sonepat tehshil as 'over-exploited', where rate of groundwater drafting substantially exceeds natural rate of recharge. Moreover, future projections of availability of groundwater for irrigation appears in negative quantities. Given the fact that over 90% of the rural population in Sonepat tehshil is engaged by farming and allied sectors, such projections indicated that there could be major shortages of groundwater in future, which will undermine rural livelihood and income, water security, and food/nutritional security. These will, collectively impede rural development initiatives currently underway in the region.

Study Design

The study was structured in three stages:

I. Data Collection – Cross-sectional field survey (personal interviews) involving 100 farmers from 10 villages in the Sonepat tehshil (January 12 and 23, 2020). The names of the villages are Bayanpur, Bayanpur Khurd Bandepur, Bindroli, Chhatera, Gaddi Sisana, Gaddiwala, Jagdishpur, Jatheri, Malla Majra, and Saboli (Table 1).
II. Parameterization – the perception of the overall state of groundwater resources
III. GDAI Development, involving multivariate statistical methods to integrate information from Stage II into a comprehensive Groundwater Depletion Awareness Index (GDAI) (Figure 1)

Table 1. Socio-demographic characteristics of farmers included in the study

Characteristics	Frequency	Percent
Age (in years)		
Young (<=40)	30	29.13
Middle aged (41-60)	45	43.69
Old (More than 60)	28	27.18
Education		
Not literate	2	1.94
Literate without formal schooling	4	3.88
Primary schooling	8	7.77
Secondary schooling	36	34.95
Higher Secondary schooling	21	20.39
Middle	23	22.33
Graduate	9	8.74
Household size		
1 – 4 members	27	26.21
5 - 10 members	61	59.22
> 10 members	15	14.56
Landholding size (in Acres)		
Marginal (<=2.5)	45	43.69
Small (2.5-5)	37	35.92
Others (>5)	21	20.39
Experience in Farming (in years)		
1 – 10 years	8	7.77
11 - 20 years	13	12.62
> 20 years	82	79.61
Agricultural Income (in Lakhs)		
Less than 2L	93	90.29
2L-5L	10	9.71
Method of Irrigation		
Traditional	95	92.23
Drips/Sprinklers	8	7.77

Interviews were conducted based on a semi-structured questionnaire (Table 2)

GDAI Model Development

The second stage involved the conceptualization of GDAI using a deductive approach, around four aspects of groundwater-sourced irrigation (Figure 2):

1. Awareness of Groundwater Depletion (AGWD)
2. Awareness of Water Intensive Crops (AWIC)
3. Awareness of Innovative Farming (AWIF)
4. Awareness of Government Policies (AWGP)

The latter focused on two government policies (a) *Har Khet Ko Paani* (Per Drop More Crop), and *Jal Hi Jeevan Hai* (Water is Life). The GDAI was computed by two methods: (i) Linear Aggregation ($GDAI_{sum}$) and (ii) Principal Component Analysis ($GDAI_{PCA}$).

Linear Aggregation: In this method, each variable within the four dimensions were first standardized, and linearly combined by arithmetic summation as follows:

$$GDAI_{sum} = w\sum_{n=1}^{4} f(AGWD, AWIC, AWIF, AWGP)$$

where, n:GDAI Dimensions

AWGD: WHY-208 + EVID-209

AWIC: RWS-214 + RWS-219 + OVAR-215 + OVARF-219

AWIF: KMI-221 + KPH-223

AWPG : KIH-225 + KPD-227

W: Weightage factor for each of the above

Principal Component Analysis (PCA): This was performed by Varimax orthogonal rotation. Results

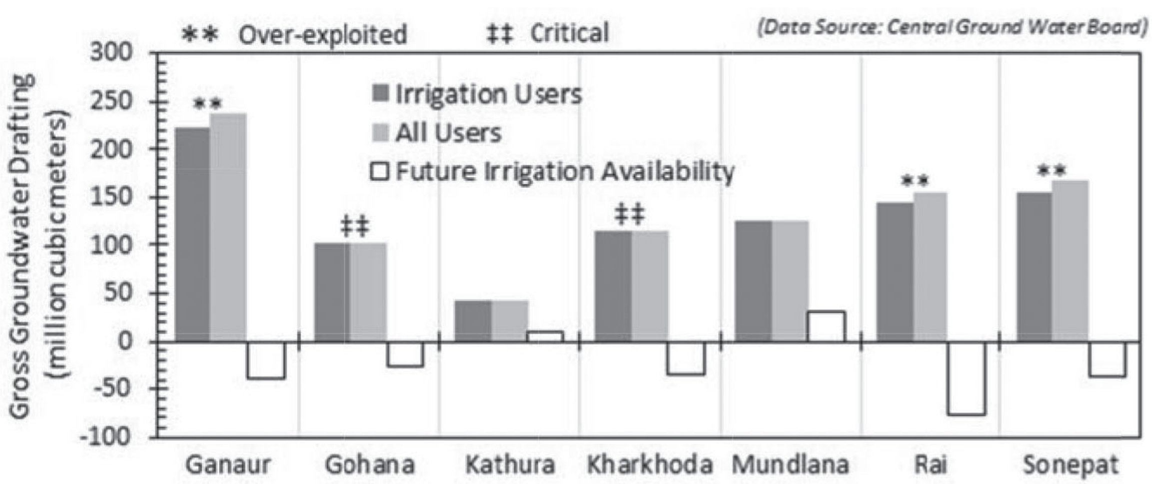

Fig. 1. Pattern of groundwater drafting and availability of groundwater for future irrigation users in Sonepat district, Haryana (NOTE: negative quantities for 'Future Irrigation Availability' indicate potential irrigation shortages in future; Over-exploited = drafting >> natural recharge; Critical = drafting is > 90% of natural recharge, as defined by the Central Ground Water Board)

were validated by a number of diagnostic checks such as Bartlett's Sphericity ($p<0.05$); Kaiser-Meyer-Olkin measure of sampling adequacy (KMO); and average Squared Multiple Correlation (SMC).

Multivariate Regression: Multivariate regression was performed to check for possible associations of GDAI with a series of explanatory variables using the following equation:

$$GDAI = \beta_0 + \beta_1\, age + \beta_2\, exper + \beta_3\, edn + \beta_4\, aginc + \beta_5\, irr + \beta_6\, src\_207 + \beta_7\, drh\_212 + \beta_8\, otb\_201 + \beta_9\, btb\_202 + \beta_{10}\, wq\_204 + \beta_{11}\, atb\_205 + \beta_{12}\, trf\_210 + \beta_{13}\, drc\_211 + u \quad \text{….. (Eq. 2)}$$

Where,

- b_0 : Regression constant
- u : Regression residual
- age : Age of the farmer in years
- exper : Experience in farming (number of years as a full-time active farmer)
- edn : Education (number of years of formal education)
- irr : If using any innovative way of farming (Binary, Y/N)
- aginc : Agricultural income (income range)
- src_207 : Sources from where they heard about groundwater depletion (based on the summation of the number of sources from where information was shared)
- drh_212: Anticipation of droughts (Binary, Y/N)
- otb_201 : Awareness about water levels in their own tube well (Binary, Y/N)
- btb_202 : Awareness about the water level in the tube wells in their block (Binary, Y/N)
- wq_204 : Awareness of water quality concerns (Binary, Y/N)
- atb_205 : Had to dig another bore well because of depletion in existing well (Binary, Y/N)
- trf_210 : Aware of rainfall variability (Binary, Y/N)
- drc_211 : Awareness of droughts in other parts of India (Binary, Y/N)

Diagnostic checks for 'robustness' of regression were performed using tests for (i) normality of residuals; (ii) residual vs. fitted plots; (iii) multi-collinearity; (iv) heteroskedasticity; and (v) for multivariate outliers: (a) Cook's Test and (b) Leverage-versus-squared-residual plot.

Results

Table 3 presents the overall awareness levels among farmers. For $GDAI_{sum}$, nearly 35% of our interviewees seemed 'moderately aware', while about 17% were 'highly aware about the current groundwater scenario (depleting trend over time) in the region. For $GDAI_{PCA}$, nearly 78% of the interviewees showed high to moderate level of awareness.

GDAI Development: Linear Aggregation ($GDAI_{sum}$)

Table 4 presents the descriptive statistics of the original and the standardized variables (0-1, with 1 being the highest awareness level) aggregated linearly. Awareness about innovative cultivation of

Table 2. Questions asked under each dimension (AGWD, AWIC, AWIF, AWPG), and corresponding variables used to construct the GDAI

Module	Theme	GDAI Model Variable
1	Awareness about Groundwater Depletion (AGWD)	
1.a	Causes of groundwater depletion	WHY-208
1.b	Evidence of groundwater depletion	EVID-209
2	Awareness about Water Intensive Crops (AWIC)	
2.a	GWD due to Rice, Wheat, Sugarcane (RWS)	RWS-214
2.b	Innovative ways of farming/RWS strains needing less water	RWS-219
2.c	Awareness about other crop varieties requiring less water	OVAR-215
2.d	Awareness about other crop varieties suitable for their soil	OVARF-219
3	Awareness about Innovative ways of Farming (AWIF)	
3.a	Awareness about micro-irrigation	KMI-221
3.b	Awareness about poly house/ greenhouse farming	KPH-223
4	Awareness about Policies of the Government (AWPG)	
4.a	Awareness of Jal Hi Jeevan Hai	KJH-225
4.b	Awareness of Per Drop More Crop scheme	KPD-227

Note: Details of responses and scoring patters are documented in APPENDIX B.

RWSC displays higher variability (standard deviation: 0.36). Awareness about water-efficient crops is generally high (mean: 0.99) with lower variation (standard deviation: 0.10). It indicates that, although the farmers are aware of eco-environmental footprints of groundwater-sourced irrigation practices, yet they indulge in water-intensive RWCS, owing largely to current agriculture policies that offer lucrative benefits (Minimum Selling Prices offered by the government for rice and wheat).

Awareness about innovative irrigation practices (MI and Poly-House farming, PH) is high (averaging at 0.82 and 0.76, respectively). A paradoxical outcome was observed for water-saving interventions implemented by the government. For example, a moderate level of awareness was found for *Jal Hi Jeevan Hai* ("Water is Life") and Per Drop More Crop scheme (mean 0.12 and 0.30 respectively). However, there appeared high variability (standard deviation of 0.32 and 0.31 respectively). In other words, a

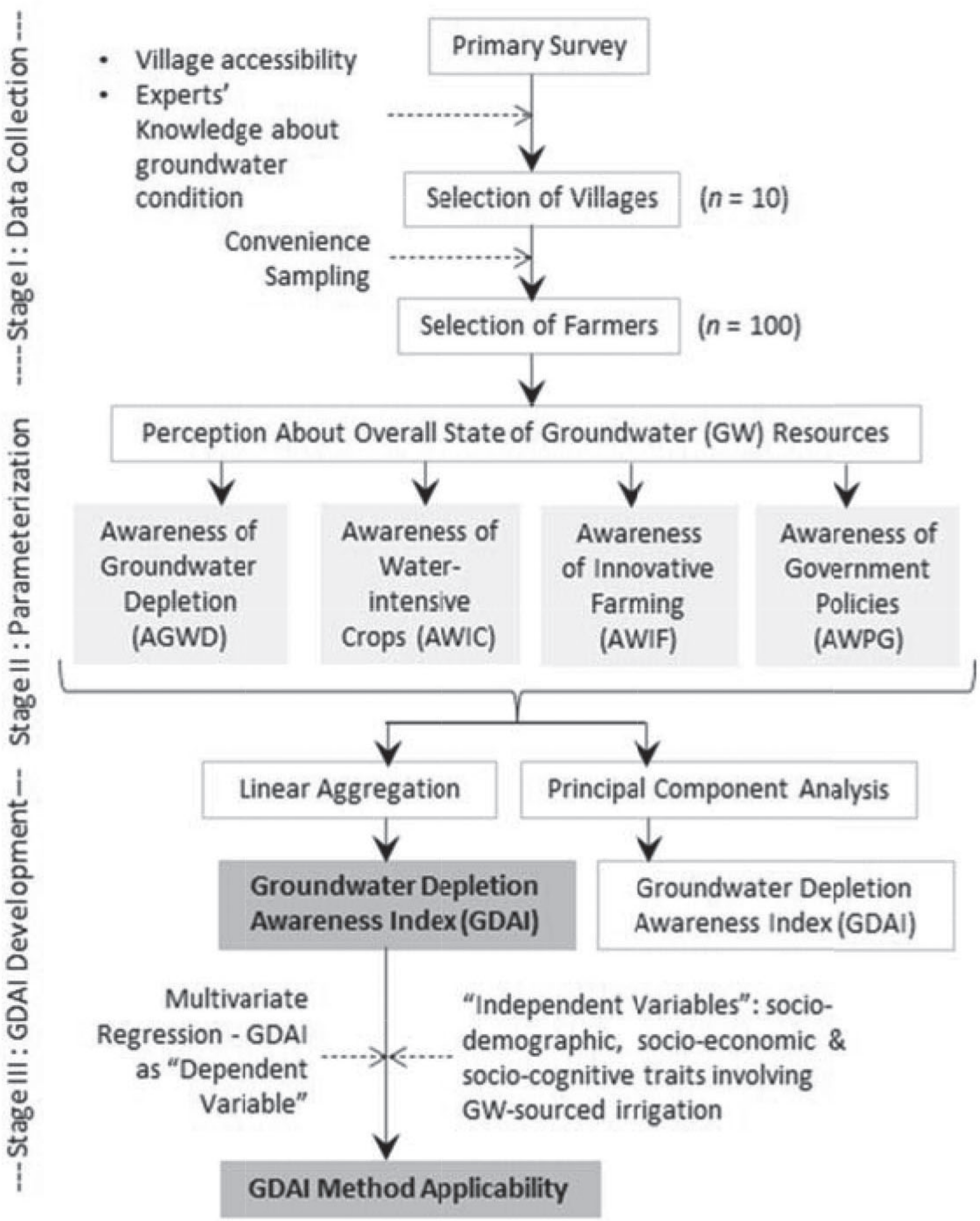

Fig. 2. Conceptual layout of field survey design and GDAI computation

handful of farmers were aware of the schemes, raising the average value, while most still unaware of such interventions.

Gdai Development: Principal Component Analysis ($GDAI_{PCA}$)

The PCA is a nonparametric variable reduction technique that seeks to collapse a set of correlated variables into fewer uncorrelated variables as linear combinations of the original values (Muzamhindo., 2017). By the same token, PCA offers the authorities (groundwater and irrigation systems' managers) a unique opportunity to identify 'principal' issues, by collapsing several mutually correlated variables into fewer variables, so as to develop targeted interventions. The items loading into the $GDAI_{PCA}$ exhibited internal consistency with a Cronbach's Alpha of 0.50. Bartlett's test of Sphericity was significant (p<0.00), suggesting inter-correlation among the variables was significant, the Kaiser-Meyer-Olkin (KMO) was 0.55 which indicated 'adequacy' in sampling. The average Squared Multiple Correlation (SMC) was 0.36, while average communality was 0.40, both indicating usefulness of PCA-based assessment. Comparing the two methods, variability in awareness indicators is made more apparent with PCA as compared to the linear aggregation of values (higher standard deviation values as seen in (Table 4). The PCA yielded four prime components with Eigen value >1. The first component represented the Awareness of Innovative Farming (AWIF) (Eq. 1). The second, third, and fourth components explained 16%, 15%, and 12% of the variance, respectively, and represented the levels of farmers' Awareness about Groundwater Depletion (AWGD), Awareness about Water Intensive Crops (AWIC), and Awareness about policies (AWPG), respectively (Table 5). Item 6 (drivers of groundwater depletion) was complex with a loading of >0.3 in two components.

Multivariate Regression

Model 1 in Table 6 presents results of regression analysis, using the $GDAI_{PCA}$ as the outcome variable. MODEL 2 was computed by excluding the outliers prior to regression analysis. Similarly, Table 7 presents the results of the regression with $GDAI_{SUM}$ as the outcome variable. The model with the highest coefficient of determination (MODEL 4, Table 7) has been interpreted and discussed.

In MODEL 4, the coefficient of multiple correlations (R^2 of 0.50), coupled with goodness of fit measures [F (13, 66) = 5.10; p< 0.000], indicates that the

Table 3. Groundwater awareness categories among farmers

Category	$GDAI_{sum}$		$GDAI_{PCA}$	
	Range	Percentage	Range	Percentage
Unaware	2.5 – 4	8.42	-10 – -6	2.11
Slightly Aware	4 – 5.5	40.00	-6 – -2	18.95
Moderately Aware	5.5 – 7	34.74	-2 – 2	55.79
Highly Aware	7 – 8.5	16.84	2 – 6	23.16

Note: The 'Range' term indicates the range in final value of GDAI obtained.

Table 4. Descriptive statistics of variables used to create GDAI

Awareness About	Variable code	Original Mean		Standardized	
			Std. Dev.	Mean	Std. Dev.
Causes of groundwater depletion	WHY_208	1.86	0.88	0.22	0.22
Evidence of depletion	EVID_209	2.22	0.77	0.74	0.26
Depletion due to RWSC	RWS_214	1.67	0.79	0.56	0.26
Innovative RWSC	RWS_219	0.72	0.72	0.36	0.36
Water-efficient crops	OVAR_215	1.98	0.21	0.99	0.10
Water-efficient crops suitable for own farm	OVARF_216	1.72	0.48	0.86	0.24
Micro-irrigation	KMI_221	1.64	0.58	0.82	0.29
Poly House (PH)	KPH_223	1.53	0.58	0.76	0.29
Jal Hi Jeevan Hai	KJH_225	0.12	0.32	0.12	0.32
Per Drop More Crop	KPD_227	0.60	0.63	0.30	0.31
Cronbach's alpha	0.49		0.50		

model explains half of the observed variability in GDAI. Among the various indicators of experiential learning, awareness about water quality becoming hard (WQ_204: *b* =0.48, p<0.01), awareness about the water level in tube wells in their block (BTB_202: *b* =0.27, p<0.05) show a significant positive association (influences) with the GDAI. The anticipation of droughts (DRH_212: *b* =0.27, p<0.05) also revealed significant positive association with the GDAI.

Irrigation for Conservation: Cognitive Barriers

Experienctial Learning Alone?

Contrary to earlier studies, we found negative association between age and awareness. Apparently, it is expected that an aged farmer would be more 'aware' of groundwater depletion-related issues. However, in our case, younger farmers appeared more aware (and concerned), probably due to growing apprehensions over future uncertainties in economic returns and pursuing farming as vocation (Tang *et al.,* 2013). Moreover, younger farmers can access farm-related information from multiple sources. In a recent study in the Limpopo Region, South Africa, Fallon *et al.* (2019) emphasized on the need of information dissemination strategies to make the farmers feel compelled to participate in sustainable groundwater management projects. In the present scenario, less than 4% of interviews ever received farm-related information from local horticulture centres and/or regional *Krishi Vigyan Kendra* (KVK).

Farmers' prime sources of information were informal chats with fellow farmers and/or village agriculture stores, indicating lack of organized platform (farmers' networks). The latter, could be a gamechanger for dissemination of information about drought, weather, innovative tools and techniques, soil fertility enhancement, seeds, financing schemes (subsidies and loans), market dynamics, labour (Chaudhuri *et al.,* 2020). None of the interviewees mentioned about any governmental efforts to establish such information networks. The farmers left to rely on their own understanding of ecosystem functioning and inter-generational wisdom to decide on best practices, which was in line with similar studies from other parts of the world (State *et al.,* 2017; Tang *et al.,* 2013).

The GDAI was also positively associated by farm income, largely as, farmers with higher income had higher access to technology/information. However, contrary to our expectations, the level of education had no significant impact on GDAI. One plausible cause is that, in this region farmers are engaged in the field early in their lives and most do not get the opportunity to attend formal schools. However, more in-depth investigation is necessary using contextual evidence.

Innovative Farming: Apprehension Before Appreciation?

About 68.7% of the interviewees had heard of water-efficient farm 'innovations'. However, only about 8% are currently practicing MI and/or PH-based

Table 5. Loadings of the items into the principal components

Awareness	Communality*	Component			
		1	2	3	4
Awareness about Innovative Farming (AIF)					
Poly house/Greenhouse farming	0.370	**0.5918**	0.0350	0.0407	-0.1312
Micro Irrigation	0.378	**0.5797**	0.1115	-0.1706	0.0037
Innovative cultivation of Rice Wheat Sugarcane (RWS)	0.387	**0.4625**	-0.2769	0.0982	0.2948
Awareness about Ground Water Depletion (AGWD)					
Evidence of ground water depletion	0.372	0.1618	**0.5583**	0.0245	-0.1824
Water depletion due to Rice Wheat Sugarcane (RWS)	0.333	-0.1474	**0.5544**	0.0587	0.0056
Causes of Ground water depletion	0.396	0.0536	**0.5373**	-0.0427	0.3199
Awareness about Water Intensive Crops (AWIC)					
Water efficient crops	0.479	-0.0512	0.0214	**0.6895**	0.0162
Other water efficient crops	0.383	0.0104	-0.006	**0.6190**	0.0003
Awareness of Policies of Government (APG)					
Jal Hi Jeevan Hai Scheme	0.459	0.1022	0.0339	0.1953	**0.6395**
Per Drop More Crop Scheme	0.444	0.1894	0.0159	0.2387	**-0.5925**

*Proportion of common variance found in a particular item farming. Nearly 88% of interviewees were unaware of benefits, which are widely reported from other parts of India. For example, a wealth of research from various southern Indian states reports on increased cropping and irrigation intensity by adopting drip irrigation, and greater opportunities of crop diversification (Kumar and Palanisami, 2010). Narayanmoorthy (2018), Singh *et al.* (2015), Chandran and Surendran (2016) reported substantial increase in farmers' income and savings on electricity, water, fertilizers, labour costs for a variety of crops (e.g. sugarcane, cotton, banana, grapes) by transitioning to MI from traditional flood irrigation.

In our study region, however, none were aware of such success stories. Little has been done by the authorities (groundwater and irrigation systems' managers) to ward off apprehensions about MI. Similarly, none was aware of the benefits of PH-based farming either (Bhandralia *et al.,* 2016). The PHs create a suitable microclimate, by simulating artificial environment, favourable to high-value horticultural crops. However, a confluence of economic, technical, labor and market factors limits mass adoption of PH-based farming **(Fig. 3)** (Prabhakar *et al.,* 2017; Ghanghas *et al.,* 2015; Sajid *et al.,* 2015).

"What if it goes wrong?"

"Who do we talk to if in trouble?"

"Who will pay for our 'losses'?"

"These things only work with the government."

The above were common remarks all around. The last remark implied that farmers have little confidence of what government asserts. Farmers believe, it is difficult for them to 'control' all the parameters at their farm, like the government does. Farmers mostly rely on experiences of fellow farmers, who have actually tried these 'innovative' methods and gained on monetary returns.

Such apprehensions are rooted in the lack of mentoring at grassroots. For example, none of the interviewees reported of any official awareness campaigns in the regions (workshops and/or focused group discussion). None could recall either of any promotions on electronic/social media, or financial packages announced by the government to help farmers adopt the innovative techniques. Overall, we experienced a hard disconnect between the policies developed at top level and what farmers actually expect at grassroots.

Fig. 3. Major constraints to promote poly house-based farming at grassroots.

Water-conserving Irrigation: The Gap?

Har Khet Ko Paani (Per Drop More Crop)

The 'Per Drop More Crop' scheme was launched by the central government in 2015, under the aegis of the *Pradhan Mantri Krishi Sinchai Yojana* (PMKSY) with the objective of:

- Improving water use efficiency (on-farm water conservation)
- Expansion of cultivable area under irrigation
- Convergence of investments in irrigation at farm-level
- Adoption of other water-saving technologies

On field, however, we experienced rather contrasting opinions. Nearly 79% of the interviewees believe that there is no urgency since *"land can easily be levelled using modern machines to use traditional methods of irrigation"*, as "*these techniques are more apt for uneven topography*". Overall, about 42% of our interviewees have actually heard of the government's MI schemes under the Per Drop More Crop program, and about 7% were aware of its benefits.

Most interviewees (even those who adopted MI), echoed a common concern: high upfront installation cost, which corroborates with earlier findings (Chaudhuri, 2018; Grant Thornton, 2016). However, there are other issues as well that the authorities need be aware of to develop context-relevant solution to increase MI adoption at grassroots (Fig. 4).

Jal Hi Jeevan Hai (Water is Life)

Launched by the State Government of Haryana in 2019, the idea was to encourage farmers switch to less water-consuming crops (maize, pigeon pea) (Indian Express, 2019). The scheme promised direct transfer of subsidies to the farmer's account, partially at the time of registration and the balance after verification of sowing data within two months. In the first round, the scheme was implemented in seven districts in Haryana, including Sonepat. Interviewees were all aware of the proverbial notion, "Water is Life", while none was aware of *it* as

Fig. 4. Prime challenges of micro-irrigation adoption at grassroots

a government scheme. Upon explanation, they maintained, "*What does the government expect us to eat if we stop growing rice and wheat*?" This again underscores a classic disconnect between decisions made at higher levels (top-down policy-making) and farmers' expectations/aspirations.

To Bridge the Gap…?

To increase PH uptake at grassroots, there is need to rethink production from both research and development (R & D) and policy making angels **(FIGURE 5)**. Even then, it will require strategic mentoring of farmers at grassroots, robust institutional mechanisms, and right political will to welcome innovative ideas.

Mi Adoption: Reimagining Financial Packages

Increasing MI adoption requires restructuring of the financial packages to farmers at grassroots (loans and subsidies). The current scheme of *direct transfer of subsidy to the producer firms of MI systems*, instils competition among producer firms, and thus fails to incentivize technology upgradation and cost reduction by (Suresh and Samuel, 2020). Following approaches could be considered (Grant Thornton, 2016):

- **Interest Subvention of Loans:** This would allow easier financing for farmers to cover their share of the cost of MI installation. Relaxing the financing norms, in turn, will increase the MI adoption rate. Benefitting the government, this measure can help cut the subsidy rate as the government can promote this form of financing for purchase and installation of micro irrigation systems.
- **Credit Gurantee Funds**: As seen in the case of Micro, Small and Medium Enterprises (MSMEs), which can get collateral free loans up to INR 1 crore through banks due to support provided by CGTMSE (Credit Guarantee fund trust for MSEs). Borrowers pay a small amount, for example 1% guarantee fee, with banks will-

Table 6. Regression results for Groundwater Awareness Index (GDAI) estimated using Principal Component Analysis ($GDAI_{PCA}$)

Variable Name and Type	*r*	MODEL 1		MODEL 2	
		β	SE	β	SE
AGE	0.02	**-0.48***	0.05	**-0.58****	0.13
WQ_204 (Binary)	0.36	**0.38*****	0.71	**0.45*****	0.65
EXPER	0.08	0.35	0.05	0.42	0.13
BTB_202 (Binary)	0.08	-0.21	1.63	-0.15	1.5
DRH_212 (Binary)	0.29	0.18	0.73	**0.23****	0.65
TRF_210 (Binary)	0.08	0.16	1.31	-0.04	1.38
ATB_205 (Binary)	0.28	0.14	0.78	0.01	0.91
DRC_211 (Binary)	0.15	0.11	0.67	**0.29*****	0.6
IRR (Binary)	0.01	0.12	1.1	0.035	1.03
EDN	-0.03	-0.1	0.08	-0.02	0.07
OTB_201 (Binary)	0.09	0.07	1.47	0.12	1.3
SRC_207	-0.08	0.06	0.41	0.04	0.38
AGINC	-0.05	0.04	0.9	-0.02	0.9
Constant[1]	-	-1.88	2.43	-0.09	0
Model R^2	0.26	0.38			
Adjusted R^2	0.14	0.25			
F	2.12; p<0.0217	3.05; p<0.0014			
Sample size (N)	91	80			

r: Pearson's correlation coefficient
â: Standardized regression coefficient
R^2: Coefficient of determination
SE: Standard Error
***p<0.01; **p<0.05; *p<0.10

Minimum = -9.22
Maximum = 5.29
Mean = 0.07
Standard Deviation = 2.68

Model 1: Non-standardized constant
Model 2: Outliers and influential observations excluded by Leverage plot and Cook's Test

ing to take on more risk due to the guarantee of the trust. Similar funding schemes are currently operational under the Small Farmer Agribusiness Consortium (SFAC) for collateral free loans to Farmer Producer Organisation (FPOs).

Guarantee on Economic Returns

But besides the above, real motivation will take hands-on enumeration of the benefit. This will require full-scale Benefit-Cost-Ratio analysis (BCR):

$$BCR = \frac{\sum_{t=1}^{n} \frac{B_t}{(1=i)^t}}{\sum_{t=1}^{n} \frac{C_t}{(1+i)^t}}$$

where, B_t = benefit in year t

C_t = cost in year t

t = year 1, 2, 3......n (project life)

i = rate of interest (opportunity cost of investment)

If the BCR > 1, then the project (MI/PH) taken up by the farmer yields healthy returns and can be pursued in future.

Another potential strategy could be to estimate the Net Present Value (NPV) – Benefit (B) less the Cost (C) of an initiative (e.g. PH adoption) over a given period of time (t). It is performed by discounting future values, by introducing a discount rate 'r' in the computation. A method with NPV > 0 is a good candidate for implementation. The formula used to calculate the NPV is:

$$NPV = \sum_{t=0}^{T} \frac{(B_t - C_t)}{(1+r)^t}$$

On the same note, the estimation of 'payback period' could help too. This is the time period required for the total discounted costs of a project to be surpassed by the total discounted benefits. However, the BCR should ensure that the assumptions and methodological approach are consistent for the various projects being compared. To that end, some

Table 7. Regression results for Groundwater Awareness Index (GDAI) estimated using linear aggregation ($GDAI_{SUM}$)

Variable Name and Type	*r*	MODEL 3		MODEL 4	
		β	SE	β	SE
AGE	0.06	**-0.46***	0.02	**-0.77****	0.05
WQ_204 (Binary)	0.35	**0.42*****	0.29	**0.48*****	0.28
EXPER	0.12	0.35	0.02	0.61	0.05
BTB_202 (Binary)	0.12	**-0.32***	0.67	-0.30*	0.61
IRR (Binary)	0.17	**0.28*****	0.45	0.15	0.5
OTB_201 (Binary)	0.19	0.22	0.61	0.23	0.53
TRF_210 (Binary)	0.07	**0.21***	0.54	0.01	0.58
DRH_212 (Binary)	0.35	**0.20***	0.3	**0.27****	0.29
DRC_211 (Binary)	0.22	**0.19***	0.28	**0.35*****	0.25
EDN	-0.02	-0.1	0.03	-0.01	0.03
AGINC	-0.03	0.06	0.37	0.04	0.37
ATB_205 (Binary)	0.28	0.06	0.32	-0.03	0.37
SRC_207	-0.15	-0.02	0.17	-0.03	0.15
Constant[1]	-	**4.44*****	1	**5.47*****	1.4
Model R^2		0.35		0.5	
Adjusted R^2		0.24		0.4	
F		3.23; p<0.0006		5.10; p< 0.0000	
Sample size (N)		91		80	

r: Pearson's correlation coefficient	Minimum = 2.5
â: Standardized regression coefficient	Maximum = 8.17
R^2: Coefficient of determination	Mean = 5.76
SE: Standard Error	Standard Deviation = 1.18

***p<0.01; **p<0.05; *p<0.10

Model 1: Non-standardized constant

Model 4: Outliers and influential observations excluded by Leverage plot and Cook's Test

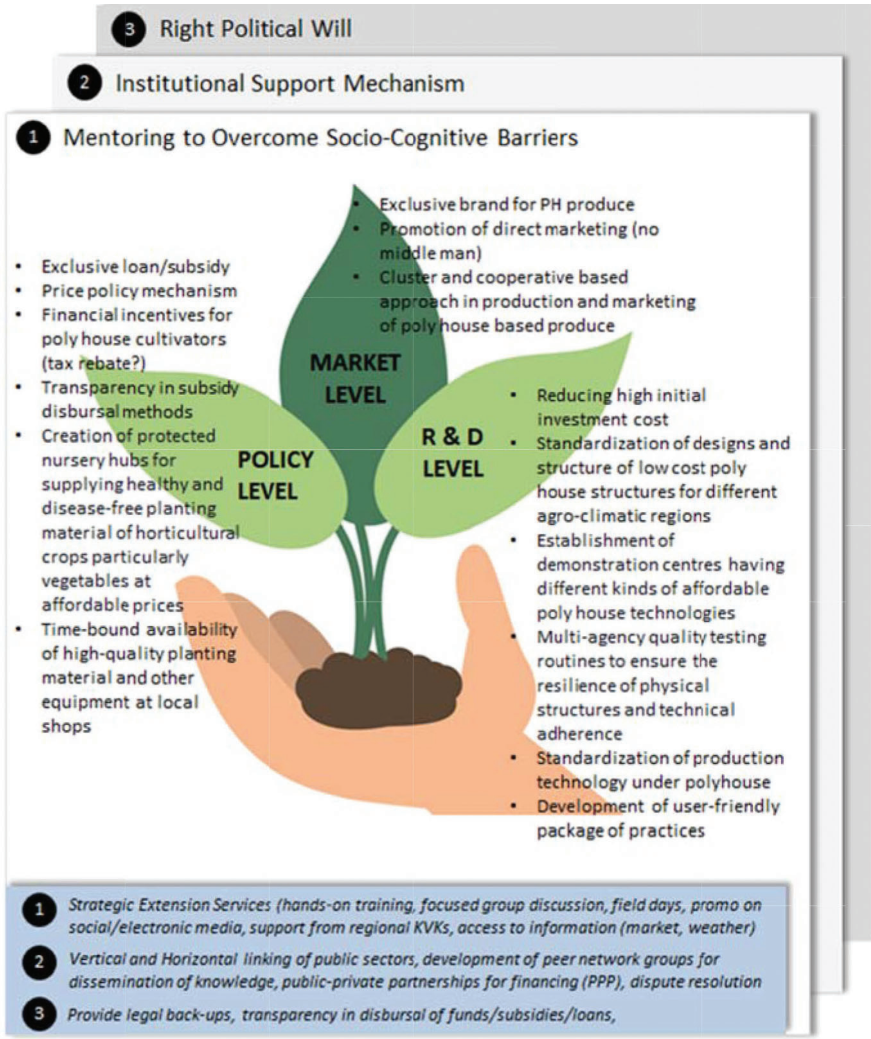

Fig. 5. Potential measures to increase uptake of PH-based farming at grassroots, by integrating three key spheres of development –mentoring, institutional arrangement, and political processes

questions need to be answered:

- o With what baseline will the benefits of the project(s) be estimated?
- o What is the chronological and spatial extent of project impact(s)?
- o Which specific elements of the project/activities are most relevant to the CBR?

References

Bhandralia, A., Arya, R., Panda, S.N. and Ahuja, S. 2016. Poly house agricultural marketing system using big data hadoop. *International Journal of Advances in Applied Sciences.* 5(2) : 78-84.

Chaudhuri, S., Parakh, D., Roy, M. and Kaur, H. 2021. Groundwater-sourced irrigated agriculture and agro-power subsidies in India: Boon or bane for small/marginal farmers? *Groundwater for Sustainable Development*. 15(100690). DOI: 10.1016/j.gsd.2021.100690.

Chaudhuri, S., Roy, M., Kesavan, A. and Kaur, H. 2022. A Nation Desertified: *Lets Blame it On Farmers?* Reflections on Land Degradation-Desertification (LDD) in India. *International Journal of Agrictlural Sustainability.* 21(1) (Forthcoming).

Chaudhuri, S., Roy, M., McDonald, L.M. and Emendack, Y. 2020. Reflections on Farmers' Social Networks: A Means for Sustainable Agricultural Development? *Environment, Sustainability and Development.* 23: 2973-3008.

Chaudhuri, S. and Roy, M. 2019. Irrigation water pricing in India as a means to conserve water resources: Challenges and Potential future directions. Environ*mental Conservation*. 46(1) : 99-102.

Chaudhuri, S. 2018. The micro-irrigation challenge. The Statesman. September 28, 2020. Accessed: September 19, 2020. https://www.thestatesman.com/opinion/micro-irrigation-challenge-1502599259.html

Chaudhuri, S. and Kaur, H. 2017. Delhi is on verge of groundwater crisis – and it's time we stopped ignoring it. The Wire. Accessed: July 23, 2020. https://science.thewire.in/environment/groundwater-crisis-delhi/

Chaudhuri, S. and Roy, M. 2016a. Groundwater on brink of destruction. Millennium Post. December 11. Accessed: July 29, 2020. http://www.millenniumpost.in/groundwater-on-brink-of-destruction-173604

Chaudhuri, S. and Roy, M. 2016b. Reflection of groundwater quality and urban-rural disparity in drinking water sources in the state of Haryana, India. *International Journal for Scientific Research and Development*. 4(4) : 837-843.

Chaudhuri, S. and S. Ale. 2014a. Long-term (1930-2010) Trends in groundwater levels in Texas: Influence of soils, land cover and water use. *Science of the Total Environment*. 490 : 379-390.

Chaudhuri, S. and S. Ale. 2014b. Long-term (1960-2010) trends in groundwater contamination and salinization in the Ogallala aquifer, Texas. *Journal of Hydrology*. 513 (26): 376-390.

Duhan, A.K. 2017. Groundwter pumping irrigation in Haryana: issues and Challenges. *International Journal of Research in Geography*. 3(2) : 18-21.

Fallon, A.L., Villholth, K.G., Conway, D., Lankford, B.A. and Ebrahim, G.Y. 2019. Agricultural groundwater management strategies and seasonal climate forecasting: perceptions from Mogwadi (Dendron), Limpopo, South Africa. *Journal of Water and Climate Change*. 10(1) : 142-157.

Ghanghas, B.S., Mukteshawar, R. and Shehrawat, P.S. 2015. Protected cultivation (Poly House) in Haryana: problems and Prospects. *Indian Journal of Applied Research*. 5(8). https://www.worldwidejournals.com/indian-journal-of-applied-research-(IJAR)/fileview/August_2015_1438586570__200.pdf

Girotto, M., De Lannoy, G.J.M., Reichle, R.H., Rodell, M., Draper, C., Bhanja, S. and Mukherjee, A. 2017. Benefits and Pitfalls of GRACE Data Assimilation: A Case Study of Terrestrial Water Storage Depletion in India: India GRACE data assimilation. *Geophysical Research Letters*. 44(9). DOI: 10.1002/2017GL072994

GoI. 2011. Agricultural contingency plan District: Sonepat. Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India. http://agricoop.nic.in/sites/default/files/Sonipat-26-06-11.pdf. Accessed: July 31, 2020.

Grant Thornton. 2016. Accelerating growth of Indian agriculture: Micro-irrigation and efficient solution. Strategy Paper. https://www.grantthornton.in/globalassets/1.-member-firms/india/assets/pdfs/micro-irrigation-report.pdf

Humphreys, E., Kukal, S.S., Christen, E.W., Hira, G. S., Singh, B., Yadav, S. and Sharma, R.K. 2010. Halting the groundwater decline in North-West India-Which crop technologies will be winners? *Advances in Agronomy*. 109 : 155-217.

Indian Express. 2019. Haryaa: Lukewarm response to diversification scheme for water conservation. June 14, 2019. Accessed: September 18, 2020. https://indianexpress.com/article/cities/chandigarh/haryana-lukewarm-response-to-diversification-scheme-for-water-conservation-5780059/

Krishan G., Bisht M., Ghosh N.C. and Prasad G. 2020. Groundwater Salinity in Northwestern Region of India: A Critical Appraisal. In: Singh R., Shukla P., Singh P. (eds) *Environmental Processes and Management. Water Science and Technology Library*, vol 91. Springer, Cham

Kumar, S. D. and Palanisami, K. 2010. Impact of drip irrigation on farming system: evidence from southern India. *Agric. Econ. Res. Rev.* 23 : 265–272.

Long, D., Scanlon, B.R., Wada, Y., Hong, Y., Singh, B.P., Chen, Y., Wang, C., Han, Z. and Yang, W. 2016. Have GRAVE satellites overestimated groundwater deletion in the northwest India aquifer? *Scientific Reports*. 6:24398. doi: 10.1038/srep24398

Muzamhindo., S. (2017) 'Principal Component Analysis As a Ranking Tool - a Case of World Universities.', *International Journal of Advanced Research*. 5(6) : 2114–2135. doi: 10.21474/ijar01/4650.

Narayanmoorthy, A. 2018. Water management in India: Financial performance of India's irrigation sector: a historical analysis. *International Journal of Water Resources Development*. 34 : 116-131.

Nehra, K. 2016. Evaluation study on optimization of agriculture power subsidy and irrigation water Intensity in Haryana. Report, Department of Economic and Statistical Analysis, Center for Research in Rural and Industrial Development (CRRID), Government of India.

NITI Aayog. 2019. Composite Water management Index. National Institution for Transforming India, Ministry of Jal Shakti and Ministry of Rural Development, Government of India, New Delhi.

Parakh, D. and Chaudhuri, S. 2021. Groundwater Market (GWM) Development in South Asia – A Sustainability Paradigm for Small/Marginal Farmers in Face of Groundwater Depletion and Irrigation Scarcity? Groundwater for Sustainable Development. *(In Review)*

PTI. 2020. Khattar govt's new scheme will discourage farmers from cultivating paddy: Cong. Press Trust of India. May 10, 2020. Accessed: September 24, 2020. https://www.business-standard.com/article/pti-stories/khattar-govt-s-new-scheme-will-discourage-farmers-from-cultivating-paddy-cong-120051000680_1.html

Rajan, A., Ghosh, K. and Shah, A. 2020. Carbon footprint of India's groundwater irrigation. *Carbon Management.* 11(3) : 265-280.

Ravish, S., Setia, B. Deswal, S. 2018. Groundwater quality in urban and rural areas of north-eastern Haryana (India): a review. *ISH Journal of Hydraulic Engineering,* DOI: 10.1080/09715010.2018.1531070

Rodell, M., Velicogna, I., and Famiglietti, J.S. 2009. Satellite-based estimates of groundwater depletion in India. *Nature* 460: 999–1002.

Sayre, S.S. and Taraz, V. 2019. Groundwater depletion in India: Social losses from costly well deepening. *Journal of Environmental Economics and Management.* 93(C) : 85-100.

Sekhri, S. 2014. Wells, water, and welfare: the impact of access to groundwater on rural poverty and conflict. *Am. Econ. J. Appl. Econ.* 6 : 76–102.

Siebert, S., Burke, J., Faures, J. M., Frenken, K., Hoogeveen, J., Döll, P. and Portmann, F. T. 2010. Groundwater use for irrigation - A global inventory. *Hydrology and Earth System Sciences.* 14(10) : 1863–1880.

Singh, P. K. *et al.* 2015. Assessing the relative impacts of the factors affecting MI adoption process. International Journal of Sustainable Development and World Ecology. *Taylor and Francis.* 22(3) : 213–218.

Srivastava, S.K. Chand, R., Singh, J., Kaur, A.P., Jain, R., Kingsley, I. and Raju, S.S. 2017. Revisiting groundwater depletion and its implications on farm economics in Punjab, India. *Current Science.* 133(3) : 422-429.

State, A., Ifeanyi, U. and Obinna, C. 2017. Analysis of Farmers Awareness of Climate Change and Adaptation Methods in North Lga, Abia State, Nigeria. *International Journal of Research in Agricultural Sciences.* 4(1) : 23–27.

Suresh, A. and Samuel, P. 2020. Micri-irrigation development in India: Challenges and strategies. *Current Science.* 118(8) : 1163-1168.

Tang, J., Folmer, H. and Xue, J. 2013. Estimation of awareness and perception of water scarcity among farmers in the Guanzhong Plain, China, by means of a structural equation model. *Journal of Environmental Management.* 126 : 55–62. doi: 10.1016/j.jenvman.2013.03.051.