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Change In Magnitude And Rate Of Depletion Of Groundwater- A Research On Water Harvesting Management Harvesting Strategies

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ABSTRACT

Withdrawing water from an aquifer always leads to groundwater depletion. Particularly in impoverished nations and in humid climates, the extent of depletion is seldom quantified, and documentation is scant. Future work will focus on establishing and improving techniques of measuring depletion, which is a prerequisite for addressing the issue. The objectives of this paper is to study about groundwater depletion and water harvesting, to ascertain whether water harvesting management is helpful in reducing water electricity bills or need for importing water, to assess the relationship between water harvesting management and water and energy conservation, and landscape irrigation and to suggest certain management strategies in relation to groundwater depletion and water harvesting. To accomplish this goal Researchers often combine primary and secondary sources. This study employs a mixed method of analysis and description. Information gathered from the literature review that is both relevant and supportive of different elements of groundwater resources, such as groundwater quality, are presented. One hundred persons were selected at random from throughout India to serve as a statistically valid and representative sample of the population. In the end, for these efforts to bear fruit, they must be taken on with the proper attitude and approach. In addition, more people-participatory programmes should be bolstered to raise public awareness about the need of preventing the deterioration of natural resources and effectively managing those that have already been depleted.

Keywords: Groundwater, Depletion, Water Harvesting Management, Natural Resource, Energy Conservation.

1. INTRODUCTION

Around the last 50 years, cities, industries, and farms all over the globe have benefited from the "explosion" in groundwater development made possible by easily accessible pumped wells. An estimated 750–800 km3 of groundwater is extracted annually across the world (Shah et al. 2000). The groundwater economy has seen tremendous growth since its implementation. Yet in many locations, groundwater supplies have been depleted to the point that well yields have dropped, pumping prices have increased, water quality has worsened, aquatic habitats have been destroyed, and land has sunk irrevocably.

Withdrawing water from an aquifer always leads to groundwater depletion. Pumpage, as shown by Theis (1940), is obtained first from water withdrawal from storage and subsequently from reduced discharge and/or higher recharge. No further withdrawals of stored water are made after a new balance has been established. Depletion amounts to permanent groundwater mining in the case of fossil or compacting aquifers, when recharge is either absent or unable to replace the drained pore spaces. Persistent and significant head decreases are indicators of depletion in renewable aquifers.

North Africa, the Middle East, South and Central Asia, North China, North America, and Australia are only few of the locations hit hard by excessive groundwater depletion. However, the senior author's ongoing research suggests that between 700 and 800 km3 of groundwater was extracted from aquifers in the United States over the 20th century, suggesting that the issue is more widespread than previously thought. The central United States' 450,000 km2 High Plains aquifer system is one of the better known examples, with about 240 km3 of water being withdrawn from storage over the 20th century. This represents a decrease of around 6% from the volume of water in storage prior to development (McGuire et al. 2003). Irrigation using groundwater is either not practicable or too expensive in some of the most parched regions (Dennehy et al. 2002).

When the best quality fresh groundwater is pumped out first, sometimes what's left is of lower quality. Part of the reason for this is because salty or polluted water is leaking out from the land's surface, restricting layers, or neighboring aquifers. Seawater intrusion and inflow, induced by head reductions in the aquifer, diminish the amount of fresh groundwater accessible in coastal locations, where many of the world's major cities are situated.

The international effects of depletion are becoming worse, signaling the necessity for a dispassionate examination of the issue and potential remedies. This paper considers potential future approaches to assessing and controlling groundwater depletion in a dynamically changing physical and social environment.

1.1 Quantifying the magnitude of depletion

Particularly in impoverished nations and in humid climates, the extent of depletion is seldom quantified, and documentation is scant. Future work will focus on establishing and improving techniques of assessing depletion as a necessary prelude to resolving the issue.

The decline in underground water supplies may be interpreted in two ways. In one, the quantity of water in the saturated zone is the only metric used to determine depletion; water quality is ignored. One other definition of depletion is the decline in fresh groundwater storage capacity. For instance, saltwater intrusion in a coastal aquifer might result in a significant decrease in water quality while causing only a little decrease in the overall volume of fluid in the subsurface. Due to a lack of information on underlying conditions and interpretive ambiguity, monitoring and assessing the extent of depletion is not a simple and clear process.

Not all the factors leading to and resulting from groundwater depletion are immediately apparent or easily quantified. For instance, it is hard to predict, infrequently monitored, and sometimes disregarded that groundwater drawn from restricted aquifers may be predominantly obtained from leaking from neighbouring confining strata. As a result, phreatophytes may have limited access to groundwater and groundwater discharge to springs, streams, and wetlands if water tables are dropped (Fig. 1). Streamflow may be decreased in areas where aquifers and streams are hydraulically coupled by the reduction of groundwater discharge into the stream and/or the induction of seepage from the stream into the aquifer. It is difficult to separate the portion of streamflow depletion owing to lower base flow from groundwater discharge in rivers already strained by excessive surface-water diversions.

Using integrated maps of head changes across the aquifer region is the most straightforward technique to determine the amount of water extracted from an aquifer. The amount of water stored in an aquifer is determined by multiplying the aquifer's volume by an appropriate storage coefficient. The depletion of the Indian High Plains aquifer was estimated using this method by McGuire et al. (2003). In the future, it will likely be simpler to track water-level fluctuations due to developments in data collecting and telemetry, database management systems, and the networking of information systems. Calculating water budgets for regional aquifer systems is often done with the use of numerical simulation models. Estimates of the rate of depletion may be obtained from a model's output if it is designed with technically sound hydrogeologic judgement and relatively well calibrated for both predevelopment and developed circumstances. Calibrated three-dimensional models of additional aquifer systems will make it simpler to monitor and foresee changes in the amount of groundwater in storage.

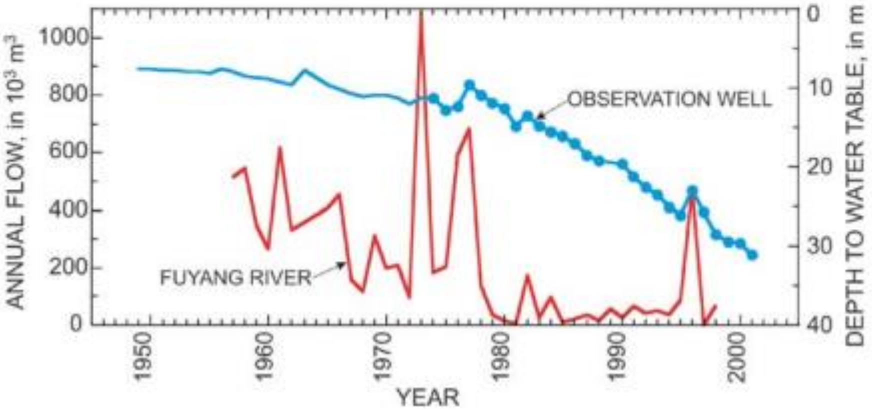


Figure 1 Stream and well hydrographs from North China Plain showing evidence of reduced streamflow caused by groundwater depletion (groundwater levels prior to 1974 from simulation model calibrated by Kendy 2002)

1.2 Management solutions and challenges

As a result of diminishing water sources, societies have shifted their focus in water management from finding and developing new sources to preserving and redistributing what they already have (Molle 2003). Similarly, societal goals are shifting to place a higher value on water for non-traditional use, such as ensuring enough in-stream flows for aquatic ecosystems. These complex problems will need to be solved by the time groundwater management is properly implemented.

One way to increase availability is to increase the amount of water available, while another is to enhance the quality of the water already available. In most cases, depletion caused by quality concerns may be restored by treatment, while substantial volumetric depletion can only be restored by reducing discharge or boosting recharge. For instance, groundwater depletion have been halted thanks to artificial replenishment using stormwater runoff and cleansed sewage. Future generations will rely more heavily on advanced infiltration and recharge systems to collect as much rainwater and treated wastewater as possible.

Administrative, legislative, or managerial restrictions, as well as economic incentives to decrease demand, may all be used to conserve groundwater by lowering pumpage. Focusing on water-saving reductions is crucial. Lining irrigation canals to decrease seepage is one method for achieving this efficiency goal, particularly in agricultural regions. However, in regions like the North China Plain, where leaking canals constitute a significant source of recharge to the aquifer below, this strategy is ineffective (Kendy et al. 2003). There will be no overall decrease in water use if the increases in water efficiency on farms are utilised to irrigate more area.

Groundwater management will become more dependent on the ability to reallocate water supplies. As an alternative to increased depletion, water markets, leasing, trading, and other methods may redistribute scarce water from low- to high-productivity sectors.

Rules are necessary for effective reallocation because they assure fairness and limit damages. Initially, there were no institutional procedures in place to regulate the rate of groundwater withdrawals while they were being made for widespread use. Groundwater supplies were often "controlled" by individual users, in contrast to the centralised management of large-scale surface-water systems. As a result, even in many water-poor regions, groundwater development has been virtually unrestricted.

2. LITERATURE REVIEW

Feng et al., (2018) Weve researched how groundwater is the primary water supply for about half of the world's population and how it contributes to the global water cycle. However, owing mostly to restricted ground observations in location and time, precise measurement of its storage change remains hard. In addition to estimating changes in groundwater storage (GWS) after removing other water storage components using auxiliary datasets and models, the Gravity Recovery and Climate Experiment (GRACE) twin-satellite data has provided global observations of water storage variations at monthly sampling for over a decade and a half. In this study, we use GRACE data to provide a broad picture of GWS variations in three major aquifers throughout China and then analyse the data's correctness in detail with the use of on-the-ground observations from ground wells and hydrological models. In agreement with ground well measurements and model estimates, GRACE finds a considerable GWS depletion rate of 7.2 1.1 km3/yr in the North China Plain (NCP) between 2002 and 2014. In the years 2005-2009, the GWS in the Liaohe River Basin (LRB) decreased at a rate of 5.0 1.2 km3/yr. Since 2010, GRACE-based GWS have shown a gradual improvement in the LRB, correlating extremely well with measurements from ground wells. Neither the LRB nor the Tarim Basin show signs of long-term GWS depletion across the whole research period of 2002-2014. Despite progress, there are still significant unknowns in GRACE-based GWS change estimations, as shown by a case study in the Inner Tibetan Plateau.

Baweja et al., (2017) According to research, Punjab barely takes up 1.57 percent of India's land area and is mostly an agricultural region. Around eighty-five percent of the state is farmed, and the cropping intensity there is around one hundred ninety-eight percent. Consequently, the demand for irrigation water has multiplied by a factor of several due to the paddy-wheat crop cycle. There has been a long-term groundwater loss in the state of 41.6 centimetres per year owing to the state's unreliable surface water supply and excessive groundwater pumpage, caused by free power and agricultural activities. The future of agriculture in the state is highly dependent on the current level of development and management of groundwater resources. The state and federal government's policy measures to address the issue have been reviewed. In the future, people will be able to see the effects of these kinds of efforts. The research highlights the importance of people (participatory approach) in addition to supply and demand side management techniques for bettering the situation.

Bierkens et al., (2014) done research on Only around 17 percent of the world's crops get irrigation, yet that results in 40 percent of the world's food supply. Groundwater depletion is a global problem since more than 40% of irrigation water is drawn from the ground, yet in many locations, groundwater abstraction rates are high and surpass natural recharge rates. In this study, we review the most up-to-date studies on the topic of groundwater depletion across the world. We begin by giving both flux-based and volume-based estimates of worldwide groundwater depletion. We also provide estimates for the percentage of irrigation water that comes from nonrenewable groundwater and how that percentage has changed over the last half-century. After that, we predict how much groundwater will be used up in the next century under different societal, economic, and climatic conditions using a flux based technique. Due to the fact that groundwater depletion is a contributing factor in sea level rise, we also provide estimates of this contribution for both historical and hypothetical time periods. Finally, we provide current findings of a worldwide groundwater flow model, including changes in groundwater levels and changes in river flow as a consequence of global groundwater abstractions.

Crosbie et al., (2013) Sixteen GCMs and three global warming scenarios were used to examine how groundwater recharge rates would differ in the year 2050 compared to the year 1990 in the High Plains of the United States. WAVES is a Soil-Plant-Atmosphere-Transfer model that was used to simulate groundwater recharge for a range of soil and vegetation types typical of the High Plains. The current spatial trend in recharge from the north to the south is amplified by the median projection under a 2050 climate, which includes increased recharge in the Northern High Plains (+8%), a slight decrease in the Central High Plains (3%), and a larger decrease in the Southern High Plains (10%). Predictions of future recharge rates are subject to a great deal of uncertainty, both as to their absolute value and their direction of change. Both higher and lower recharge rates are predicted between the dry and wet future climatic scenarios, with a range larger than 50% of the present-day recharge. The proportional sensitivity of recharging to variations in rainfall shows that regions with high current recharge rates are less vulnerable to variations in rainfall. Analysis of the sensitivity of the relationship between recharge and rainfall changes reveals an amplification in the range of 1 to 6, with an average of 2.5 to 3.5, depending on the global warming scenario.

Wada et al., (2010) A huge aquifer system and recurrent water stress need the use of groundwater as a supplementary water supply, as was explained. Overexploitation or persistent groundwater depletion happens when groundwater withdrawal over a large enough region and for a long enough period surpasses the natural groundwater recharge. By evaluating groundwater recharge using a global hydrological model and removing estimates of groundwater abstraction, we provide a worldwide overview of groundwater depletion (here defined as abstraction in excess of recharge). When we limit our study to dry and semi-arid regions, we find that worldwide groundwater depletion has grown from 126 (32) km3 a1 in 1960 to 283 (40) km3 a1 in 2000. The latter accounts for a sizeable portion of the current sea-level rise, 0.8 (0.1) mm a1, by contributing 39 (10%) of the global annual groundwater abstraction, 2% (0.6) of the global annual groundwater recharge, 0.8% (0.1) of the global annual runoff from continents, and 0.4% (0.06%) of the global annual evaporation.

3. OBJECTIVES

The objectives of this study are as follows:

1) To study about groundwater depletion and water harvesting.
2) To ascertain whether water harvesting management is helpful in reducing water electricity bills or need for importing water.
3) To assess the relationship between water harvesting management and water and energy conservation, and landscape irrigation.
4) To suggest certain management strategies in relation to groundwater depletion and water harvesting.

4. METHODOLOGY

To complete this task, researchers will need access to both primary and secondary sources. Consequently, this study employs an analytical and descriptive research strategy. Information gathered from the literature review that is both relevant and supportive of different elements of groundwater resources, such as groundwater quality, are presented. One hundred persons were selected at random from throughout India to serve as a statistically valid and representative sample of the population. The houses in the study were used as the study population. All adults in the family, not only the head, who are 18 or older and who fit the inclusion requirements were encouraged to take part. Also, everyone involved must provide their informed permission. Households where no adult is present and gives informed permission are not included. Participants are chosen using a random sampling process. In order to evaluate the demographics, groundwater, and water harvesting conditions, a questionnaire survey was done. The gathered surveys and their associations were analysed using the SPSS software suite. The researcher checked the questionnaires for errors, coded them, and put them into SPSS version 26.0 to conduct statistical analysis. All demographic information was shown as a percentage (percentages). The analysis-of-variance (ANOVA) test was used to conduct statistical analysis of the interrelationships between the variables. All ANOVA results were considered significant at the p0.05 level. Each respondent gave their informed agreement before the study was ever conducted, thus the surveyors must have provided them with enough information. All responses to this poll were kept strictly confidential. Respondents' identities were concealed by using serial numbers instead of their names. Participants were assured that dropping out of the research or refusing to take part in it would cost them nothing or result in any negative consequences. After the research is over, there will be no danger to the participants. There was no one else with access to the data, and they were all kept confidential.

5. HYPOTHESIS

Hypothesis 1

- H0: Water harvesting management is not helpful in reducing water electricity bills.
- H1: Water harvesting management is helpful in reducing water electricity bills.

Hypothesis 2

- H0: Water harvesting management is not helpful in reducing the need for imported water.
- H2: Water harvesting management is helpful in reducing the need for imported water.

Hypothesis 3

- H0: Water harvesting management has a negative relationship with water and energy conservation.
- H3: Water harvesting management has a positive relationship with water and energy conservation.

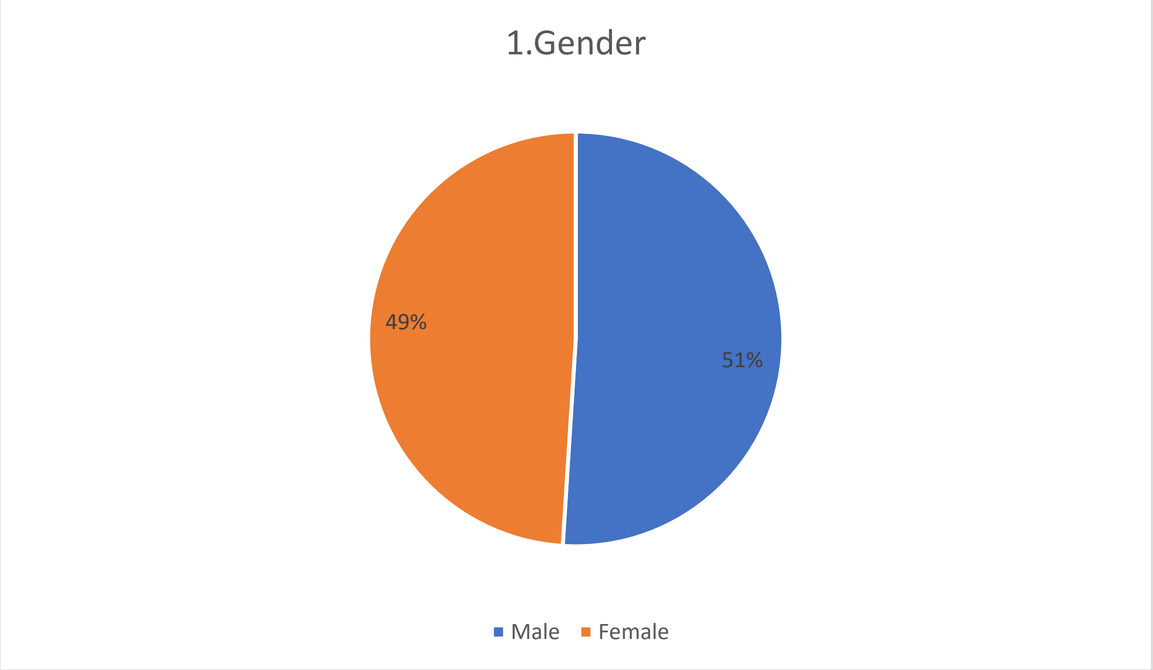
Hypothesis 4

- H0: Water harvesting management has a negative relationship with landscape irrigation.
- H3: Water harvesting management has a positive relationship with landscape irrigation.

6. DATA ANALYSIS

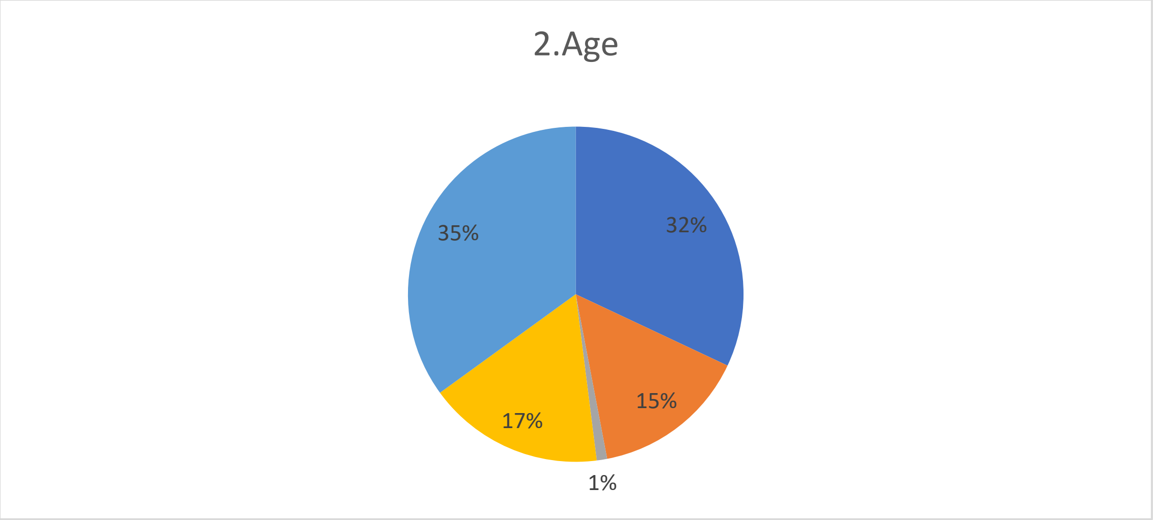
1.Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	51	51.0	51.0	51.0
	Female	49	49.0	49.0	100.0
	Total	100	100.0	100.0	



Looking at the above table and graph, we can say there are 100 respondents in total, wherein 51 (51%) are male and 49 (51%) are female.

2.Age					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	25-30 years	32	32.0	32.0	32.0
	31-35 years	15	15.0	15.0	47.0
	36-40 years	1	1.0	1.0	48.0
	41-45 years	17	17.0	17.0	65.0
	Above 45 years	35	35.0	35.0	100.0
	Total	100	100.0	100.0	



Looking at the above table and graph, we can say there are 50 respondents in total, wherein 32 (32%) are between 25 to 30 years of age, 15 (15%) are between 31 to 35 years, 1 (1%) are between 36 to 40 years, 17 (17%) are between 41 to 45 years, and 35 (35%) are above 45 years of age.

7. HYPOTHESIS TESTING

Hypothesis 1

- H0: Water harvesting management is not helpful in reducing water bills.
- H1: Water harvesting management is helpful in reducing water bills.

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.170[a]	.029	.019	2.65794
a. Predictors: (Constant), 1.Helps in reducing the water bill				

ANOVA[a]						
Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	20.502	1	20.502	2.902	.092[b]
	Residual	692.338	98	7.065		
	Total	712.840	99			
a. Dependent Variable: Water harvesting management						
b. Predictors: (Constant), 1.Helps in reducing the water bill						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	21.362	1.102		19.385	.000
	1.Helps in reducing the water bill	-.472	.277	-.170	-1.704	.092
a. Dependent Variable: Water harvesting management						

The above tables depict the hypothesis tests for the hypothesis 1 wherein the significance level was taken to be 0.05. As we can see, the p-value is 0.092, i.e., more than 0.05, therefore we can reject the alternate hypothesis and accept the null hypothesis. Thus, we can say that water harvesting management is not helpful in reducing water bills.

Hypothesis 2

- H0: Water harvesting management is not helpful in reducing the need for imported water.
- H2: Water harvesting management is helpful in reducing the need for imported water.

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.052[a]	.003	-.007	2.69333
a. Predictors: (Constant), 2.Reduces the need for imported water.				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.945	1	1.945	.268	.606[b]
	Residual	710.895	98	7.254		
	Total	712.840	99			
a. Dependent Variable: Water harvesting management						
b. Predictors: (Constant), 2.Reduces the need for imported water.						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	18.948	1.174		16.136	.000
	2.Reduces the need for imported water.	.149	.287	.052	.518	.606
a. Dependent Variable: Water harvesting management						

The above tables depict the hypothesis tests for the hypothesis 2 wherein the significance level was taken to be 0.05. As we can see, the p-value is 0.606, i.e., more than 0.05, therefore we can reject the alternate hypothesis and accept the null hypothesis. Thus, we can say that water harvesting management is not helpful in reducing the need for imported water.

Hypothesis 3

- H0: Water harvesting management has a negative relationship with water and energy conservation.
- H3: Water harvesting management has a positive relationship with water and energy conservation.

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.308[a]	.095	.086	2.56590
a. Predictors: (Constant), 3.Promotes both water and energy conservation.				

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	67.622	1	67.622	10.271	.002[b]
	Residual	645.218	98	6.584		
	Total	712.840	99			
a. Dependent Variable: Water harvesting management						
b. Predictors: (Constant), 3.Promotes both water and energy conservation.						

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	16.981	.839		20.250	.000
	3.Promotes both water and energy conservation.	.686	.214	.308	3.205	.002
a. Dependent Variable: Water harvesting management						

The above tables depict the hypothesis tests for the hypothesis 3 wherein the significance level was taken to be 0.05. As we can see, the p-value is 0.002, i.e., less than 0.05, therefore we can reject the null hypothesis and accept the alternate hypothesis. Thus, we can say that water harvesting management has a positive relationship with water and energy conservation.

Hypothesis 4

- H0: Water harvesting management has a negative relationship with landscape irrigation.
- H4: Water harvesting management has a positive relationship with landscape irrigation.

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.174[a]	.030	.020	2.65598
a. Predictors: (Constant), 4.It is an excellent source of water for landscape irrigation with no chemicals, dissolved salts and free from all minerals.				

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	21.527	1	21.527	3.052	.084[b]
	Residual	691.313	98	7.054		
	Total	712.840	99			

a. Dependent Variable: Water harvesting management
b. Predictors: (Constant), 4.It is an excellent source of water for landscape irrigation with no chemicals, dissolved salts and free from all minerals.

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	21.193	.983		21.560	.000
	4.It is an excellent source of water for landscape irrigation with no chemicals, dissolved salts and free from all minerals.	-.426	.244	-.174	-1.747	.084
a. Dependent Variable: Water harvesting management						

The above tables depict the hypothesis tests for the hypothesis 2 wherein the significance level was taken to be 0.05. As we can see, the p-value is 0.084, i.e., more than 0.05, therefore we can reject alternate the hypothesis and accept the null hypothesis. Thus, we can say that water harvesting management has a negative relationship with landscape irrigation.

8. CONCLUSION

Understanding groundwater overexploitation/ use is complex and very much influenced by numerous factors. In this study we found that water harvesting management is not significantly helpful in reducing water electricity bills or need for importing water. Also, the relationship between water harvesting management and water and energy conservation, and landscape irrigation turned out to be significantly negative. Though, this study again substantiated the relationship between water harvesting management and water and energy conservation to be a significantly positive one.

However, the future of agriculture in India is threatened by the current status of development and management of groundwater resources. High irrigation demand, which varies with agricultural patterns and rainfall, has been cited as a major factor in the region-wide trends of groundwater depletion. The fast depletion and overexploitation of groundwater resources is also attributable to subsidised or free electricity. The centre zone's sinking water table must be stopped immediately, and either groundwater use must be reduced or groundwater supplies must be increased. Utilizing efficient irrigation practices/technologies, such as micro-irrigation, bed-planting, laser-leveled zero-tillage, crop diversification, and others, may help lessen the strain on groundwater supplies (Aggarwal et al., 2009). Increasing the groundwater potential can be accomplished through the following methods: building various types of checking structures across the vast (3400 km) network of existing but inoperable drains; renovating village ponds to increase their recharging capacity; and maintaining the recommended height of bunds in paddy fields to store maximum rainwater (Khepar et al., 2000). Delaying paddy transplanting, implementing various artificial groundwater recharge schemes, encouraging crop diversification toward low-water-consuming crops like maize, cotton, sugarcane, fodder, and agro-forestry, and offering training and subsidies to promote drip, sprinkler, and playhouse technology are all measures policymakers have taken to slow the rate of water use. The correct attitude and an all-encompassing approach are essential for making progress. In addition, more people-participatory programs should be bolstered to raise public awareness about the need of preventing the deterioration of natural resources and effectively managing those that have already been depleted.

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QUESTIONNAIRES

Demographic Profile

1. Gender
   a. Male
   b. Female

2. Age
   a. 25-30 years
   b. 31-35 years
   c. 36-40 years
   d. 41-45 years
   e. Above 45 years

Management	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1. Catchment- Used to collect and store the captured rainwater.					
2. Conveyance system – It is used to transport the harvested water from the catchment to the recharge zone.					
3. Flush- It is used to flush out the first spell of rain.					
4. Filter – Used for filtering the collected rainwater and removing pollutants.					
5. Tanks and the recharge structures: Used to store the filtered water					

which is ready to use.					

Benefits	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
1. Helps in reducing the water bill					
2. Reduces the need for imported water.					
3. Promotes both water and energy conservation.					
4. It is an excellent source of water for landscape irrigation with no chemicals, dissolved salts and free from all minerals.					