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Addressing the Water Crisis in Gujarat, India

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Columbia Water Center's mission is to creatively tackle the issue of global water scarcity through innovations in technology, public policy and private action. Combining the rigor of scientific research with the impact of effective policy, we aim to design reliable, sustainable models of water management and development that can be implemented on local, regional and global levels.

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TABLE OF CONTENTS

ABSTRACT	1
INTRODUCTION	2
STUDY REGION	3
FARMER AND WELL OPERATOR FIELD SURVEY	4
SUMMARY OF FINDINGS	4
CONCLUSIONS	9

ABSTRACT

This paper presents the results of the Columbia Water Center's study of the severe groundwater crisis in the Mehsana region of Northern Gujarat, India. The study concludes that the current pattern of groundwater exploitation is both costly for the state and unsustainable for farmers, and could lead to the complete failure of agriculture in the area within a few years if left unchecked.

The study was conducted as the first phase of a CWC project to design more sustainable policy options to help conserve water and energy while improving farmer incomes in North Gujarat; future papers will outline the initial outcomes of the area pilot project along with resulting recommendations for policymakers in the area.

INTRODUCTION

Over the last several years, scientists have grown increasingly alarmed about the depletion of groundwater in many parts of India. However, even in a country with severe, widespread looming water shortages, the case of North Gujarat stands out.

For more than three decades now, the farmers of North Gujarat have been productively utilizing the rich groundwater resources of the region in order to cultivate a variety of crops and a thriving dairy industry. The state of Gujarat (along with the Government of India) has also played its role in supporting this enterprise by providing these farmers with a variety of subsidized inputs, including reliable electricity for pumping groundwater as well as marketing and price supports.

Unfortunately, because of the low levels of natural recharge of local aquifers, groundwater tables have fallen steadily throughout the same period. The groundwater situation is now so dire that the future of agriculture in North Gujarat is in jeopardy. Farmers are the first to suffer, as they must continually invest in deeper wells and more powerful pumps to irrigate, but nonetheless face a decline in both the quantity and quality of the water they are able to pump.

The effect of acute water shortages goes beyond immediate impacts on farmers, however. Under the current subsidy system, each year the government is forced to finance increasing amounts of expensive electricity for irrigation pumping, even as the benefit of pumping for farmers stagnates or declines as the amount of water available decreases. In addition, high consumption of electricity for irrigation puts pressure on the electrical grid and reduces available electricity for other sectors.

This situation is not unique to North Gujarat. Many parts of India where agriculture is dependent on groundwater are or will soon be facing similar problems. However, the situation in this part of Gujarat is extreme. While the severity of the situation in North Gujarat places great pressure on Gujarat's farmers and the energy sector, it also provides the state with an opportunity to not only reverse the trend, but to also show the way forward for the rest of the country.

For the initial phase of its Gujarat project, the Columbia Water Center conducted an analysis of the water crisis in the Kukarwada sub-district in the Mehsana region. The study included a detailed survey of farmers and well operators in the region, along with an analysis of local hydrology, current energy policy and the potential for combining new incentive structures with water-saving technology to stabilize or reverse groundwater depletion in the region.

We have identified enormous potential for improvements in water and energy use that can generate very large reductions in energy costs while maintaining food production and farmers income. For example, a water savings of 30% through well established technologies and practices can allow the power utility in North Gujarat (UGVCL) to free up as much as 2.7 billion units of electricity for use in non-agricultural sectors, and would reduce groundwater extractions by a corresponding amount.

Our survey results indicate that farmers in the area possess considerable openness and interest in adopting new, more water and energy efficient irrigation practices. Despite the potential, however few farmers have adopted these technologies and practices to date. We believe that the missing ingredient is a proper incentive structure that could dramatically accelerate the rate of adoption and the modernization of agriculture in Gujarat.

STUDY REGION

The study region covers a total geographical area of 180 sq. km. It forms a part of two districts: Mehsana and Gandhinagar, and three talukas (counties), Vijapur, Visnagar (in Mehsana district) and Mansa (in Gandhinagar district).

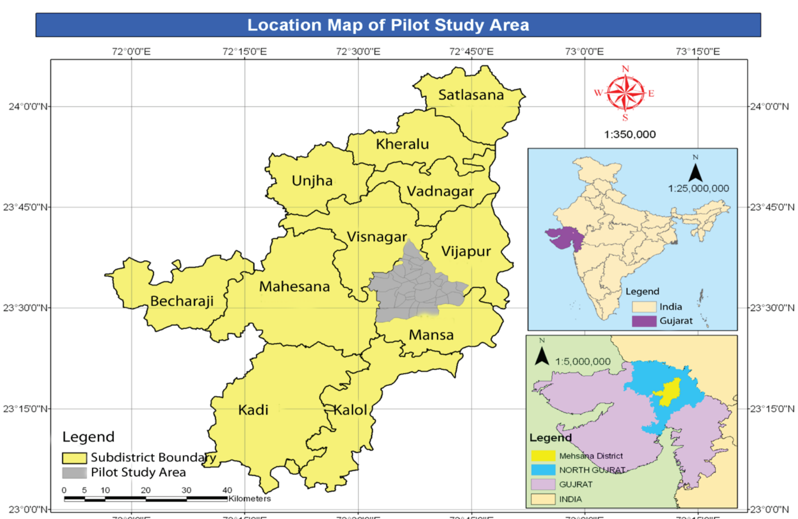


Figure 1. Extent of study region (shown in shaded grey)

Mehsana district is characterized by hilly upland in the northeast, followed by shallow alluvium and residual hills, rolling to a gently sloping vast, sand and silt tract, alluvial plains in the southwest. Alluvial plains are the single most prominent geomorphic unit and cover the major part of the district.

The region has a semi-arid climate characterized by extreme temperatures, erratic rainfall and high evaporation (potential evaporation is more than twice the normal annual rainfall). Over 90% of the annual rainfall occurs during the southwest monsoon period between June and September. July and August are the wettest months, receiving more than 70% of the annual rainfall. The mean annual rainfall is around 738 mm. The year-to-year variability also ranges from 45 - 50%. The district experiences agricultural droughts (defined as 25 – 50% negative departure of annual rainfall from mean annual rainfall) almost every third year. Severe and rare droughts (defined as 50 to 75% and more departure from annual mean) have an average recurrence interval of five to six years.

This part of India, like many others, experiences decadal shifts in rainfall, so one can be deceived by a decade of higher rainfall, followed by significantly lower rains for multiple years as seen in the figure below. The area is currently in a period of high rainfall.

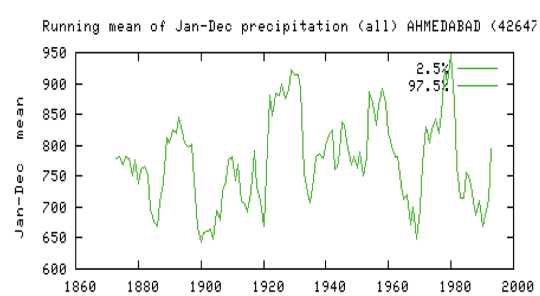


Figure 2. Rainfall in the study region

Agriculture accounts for around 90% of the total water use followed by domestic and industrial water use. More than 80% of the land area is under cultivation. Of the total area under cultivation, around 65 -70% is irrigated. Net area irrigated in the study region is estimated to be around 10,000 hectares. Almost 55 – 60% of the working population is engaged in agriculture and agro related activities.

FARMER AND WELL OPERATOR

FIELD SURVEY

To more accurately assess the groundwater situation in the region, Columbia Water Center designed and commissioned a detailed survey of irrigation water use in the area. The survey was conducted by the Taleem Research Foundation.

The survey centered around 170 tube-wells used for irrigation in the area; a single well can service a number of farmers. Well-operators (most of whom are also farmers) were the principal respondents, although the responses of other farmers at the well at time of the interview were also recorded.

Respondents were asked about their perceptions of the groundwater situation, energy use, frequency and amount of irrigation, agricultural practices (cropping schedules, crop preferences, major constraints to crop production) among other questions.

In addition, the team coupled results from energy data that UGVCL (the local power utility) agreed to share for the purpose of the study. The study area consisted of 22 feeders, totaling about 700 customers. These measurements allowed the team to determine accurate baseline usage. Finally, results of the survey and energy data were integrated with regional data about water use taken from observation wells.

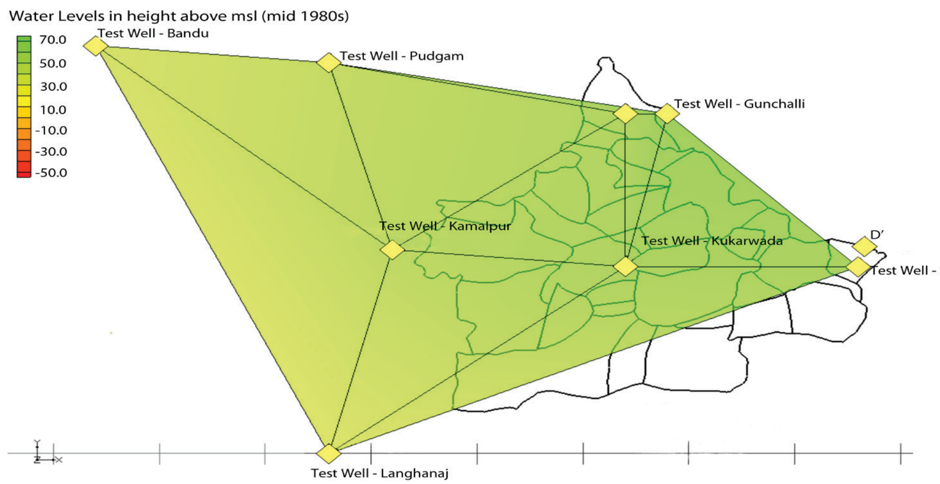
SUMMARY OF FINDINGS

Water tables in the study area have been falling steadily over the last 15-20 years, and have reached about 600ft below ground level, risking irreversible salinization of aquifers. The declining trend is seen in observation wells and confirmed by farmers' own recollection of water depth. The rate of decline is anywhere between 9 feet per year (based on observation wells) to 20 feet per year (based on farmer recollections).

82% of wells reported the appearance of salt in their water over the last 5-15 years.

Furthermore, this steep decline has occurred during a relatively wet period. In the next decadal period of low rainfall this rate could more than double, especially if farmers increase cropping intensity.

In much of the study area, water levels are either approaching or already below mean sea level, which increases the risk of intrusion of saline or brackish water, an irreversible transition that could end agriculture in the area. In our sample, 82% of wells reported the appearance of salt in their water over the last 5-15 years. Other changes in water quality include increasing temperature (reported by 52%) fluoride (30%) and dust (30%).



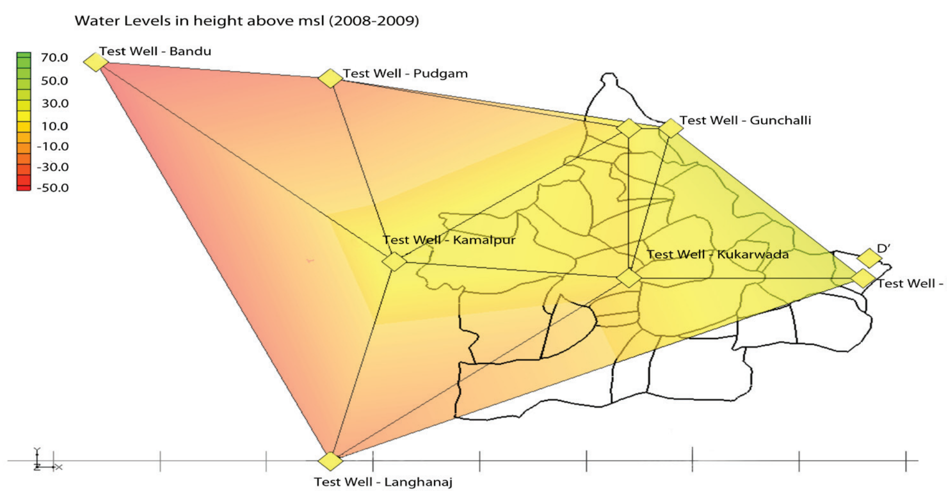


Figure 3. The two maps show groundwater levels obtained from test wells in the study area (outlined). Colors show the estimated average groundwater level between the different test well points. The first map shows data from the mid-1980s; groundwater at that time was mostly above sea level. The second map from the same area in 2008 and 2009 shows a groundwater level that has already dropped below the average sea level for much of the area. Where groundwater drops below sea level, there is a greatly increased chance for saltwater to enter underground aquifers and contaminate wells.

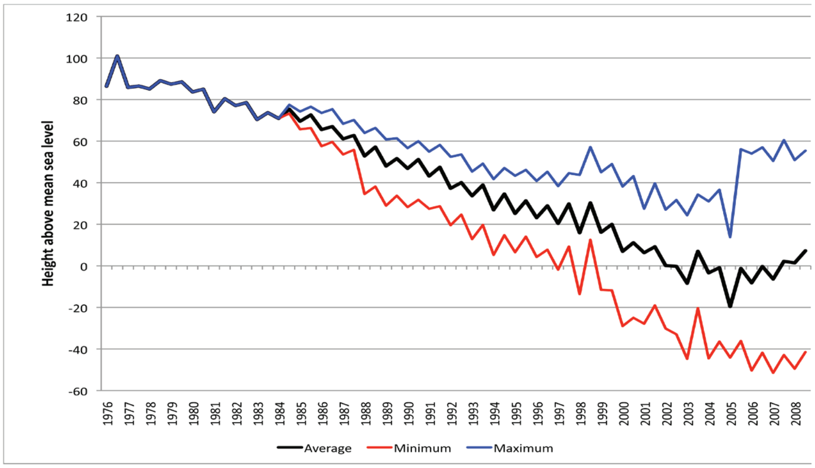


Figure 4a. Declining water tables. Water table dropping by an average of 9 feet per year, based on data from observation wells. The water table rises during Monsoon, drops between monsoons, with drop generally larger than recharge.

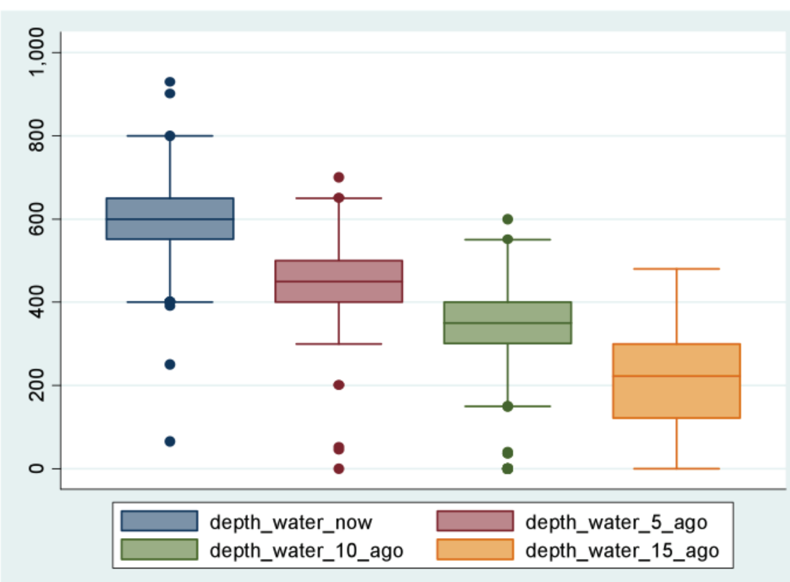


Figure 4b. Farmers themselves report an even steeper ongoing decline of 20 feet per year.

Farmers are adversely influenced by the falling water tables. They need to continuously drill deeper wells and buy more powerful pumps. Based on our surveys, a conservative annualized estimate of these costs amount to Rs 5,000 per hectare. Although the horsepower usage and the depth of wells have increased dramatically over time (Figure 2), an average well can now irrigate only about 60% of its command area during the Rabi, or winter-crop season. Farmers recall a significant increase in the number of hours needed to irrigate a single unit of land since they installed their current pump. Furthermore, nearly all respondents expected the water table to continue its decline, and on an average expect water to last for about six years. Once that happens, farmers plan to deepen their wells (30%), migrate (30%) or restrict crop cultivation to the rainy season (20%). More than half of farmers in the area plan to abandon irrigated agriculture.

Energy use appears to have increased over the last two decades without a matching increase in irrigated area. In other words, the "drop per unit of energy consumed" continues to deteriorate.

A simple calculation based on the water requirement during the Rabi (winter) season for wheat suggests that the energy required to lift water from the current average depth is about 8,000 kilowatt hours per hectare. Our survey results suggest that the motors used for pumping are such that nearly 10 horsepower capacity is installed per hectare of irrigated land.

If this capacity were operated for eight hours of electric supply hours per day, the energy needed would be about 6,000 kWh of electricity during the winter-crop season. (Energy consumption data from feeders in the study area suggest a value about 20% higher. A 20% higher reading on the utility side is indeed quite plausible if one takes into account the distribution losses and possible under-reporting of horsepower from the survey.)

While data on energy use is not available to us over a significant time scale, the increase in horsepower over time suggests a significant increase in energy use over time. This is consistent with the fact that the water table has fallen precipitously, which increases the amount of energy needed to lift a given amount of water.

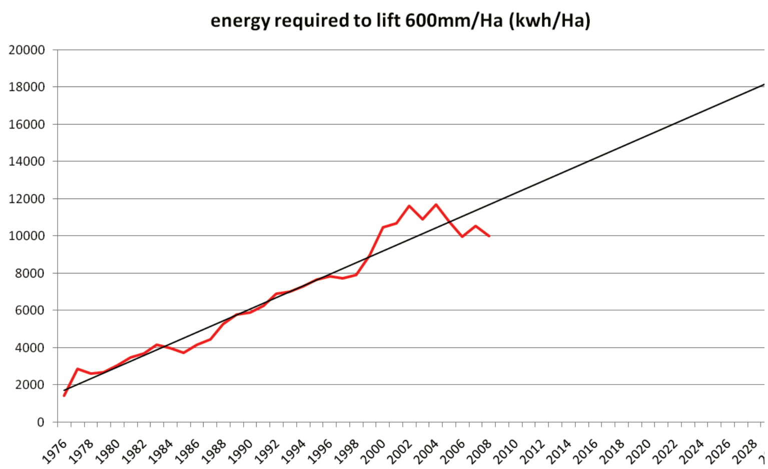


Figure 5. The increase in the amount of energy needed to pump the same amount of water.

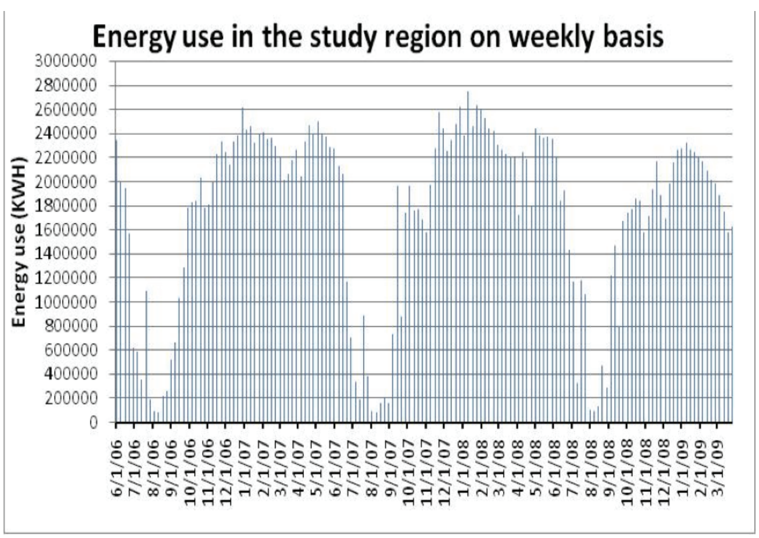


Figure 6. Energy use peaks during dry periods

At depths from which groundwater is currently extracted, tubewell irrigated agriculture as practiced today is probably not financially viable. If farmers had to pay for the energy used, they would find it unprofitable to engage in agriculture. It is estimated for the study region that the utility provides about 10,000 kWh of electricity per hectare over the year, worth about Rs 40,000 per hectare. (By contrast, the average kWh per hectare for India as a whole is 1,600 kWh per hectare).

The utility currently recovers on average roughly Rs 10,000 per hectare through flat horsepower-based tariffs, representing a subsidy of about Rs 30,000 per hectare.

We estimate the net income from crops to be about Rs 20,000 per hectare per year, which suggests a net economic loss of Rs 10,000 per hectare. Livestock-based gains could increase the income figures from this value, but are unlikely to change the overall equation.

After applying the energy subsidy, our study suggests a net economic loss of Rs 10,000 per hectare.

Even with heavy subsidies for electricity and purchase support, farmer income has stagnated. Farmer livelihoods and their evolution were studied in detail by looking at what was cropped and the reported yields of major crops, including both food and non-food or cash crops. Along with market prices collected from APMC (agriculture produce marketing commission) it was possible to estimate crop derived agricultural income per hectare for the study region.

Income was estimated by assuming a hypothetical hectare on which the representative mix of crops grown in the county is farmed. Using the annual evolution in this mix, the crop yields and market prices, we computed the gross revenue from agriculture on this hypothetical hectare. The time series of this evolution is shown in Fig. 7 both in real terms and in inflation adjusted terms, for years 1990-91 to 2008-09. Based on the crop mix and the crop water requirements, the evolution of the water needs per hectare is also shown in Fig. 7.

Crop	Area (hectares)	Crop	Area (hectares)
Cotton	1820	Castor	424
Wheat	1200	Potato	991
Bajri	615	Jowar	528
Winter fodder	287	S.fodder	85
Tobacco	413	Fruits	180
Vegeta-bles	60	Others	7

Table 1. Major crops grown.

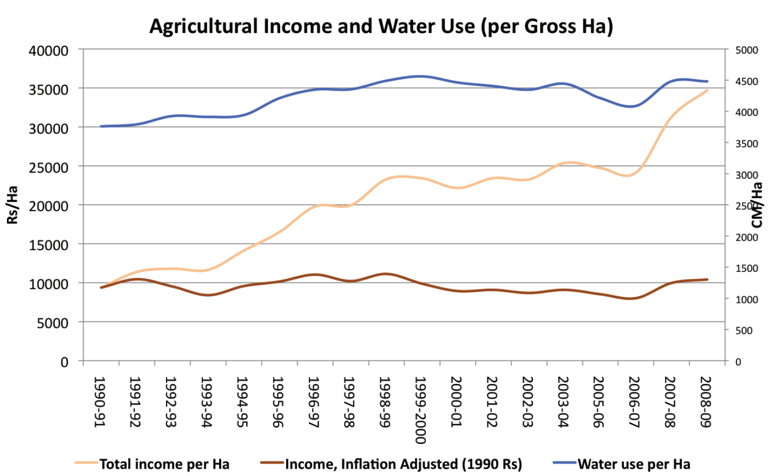


Figure 7. Farmer income trends.

The results reveal that modest yield increases combined with growing more cash crops does generate more income, but when adjusted for inflation that increase in income is not dramatic. Real physical income seems to be more or less stagnant, at least on a per-unit irrigated land basis. (Agricultural income could potentially still be increasing through the expansion of irrigated area, income from livestock through the domestic use of fodders or other factors not captured in our estimates. The important point is that real, direct revenue from irrigated crops has not risen significantly).

Potential practices and technologies do exist to increase water and energy use efficiency, but they are, with few exceptions, not adopted in the study area. Promising technologies and techniques exist for saving energy and water, but survey results show that these technologies are overwhelmingly not adopted in the study area. For example, only 9 out of 136 wells surveyed make any use of drip irrigation or sprinklers. The main reasons farmers give for lack of adoption are high cost (mentioned by 60% of farmers), land fragmentation (23%) and lack of familiarity (16%).

Broader effects. As deeper wells accelerate the use of electricity, the state will have to make attempts (some of which it is already undertaking) to cap the subsidy amounts to the utility. It is not clear whether a greater investment in improved dissemination of technology, additional localized research and creating improved market conditions for high value crops alone could stabilize or reverse groundwater depletion. However large expenditures by the state to subsidize water and electricity consumption could be crowding such investments.

In partnership with local partners and with financial support from the PepsiCo Foundation, the Columbia Water Center is designing and implementing a pilot program in Gujarat to provide farmers with a financial incentive to conserve water and energy while supporting them to implement conservation technologies.

CONCLUSIONS

Farmer and well operator surveys confirm what many observers knew already—that the groundwater crisis in North Gujarat is severe and likely to get worse.

Farmers are already suffering, with as many as half of those surveyed saying that they plan to give up irrigated agriculture at some point in the near future. On a per unit land basis, farmer incomes have stagnated as well.

Furthermore, the cost of electricity now required to pump water from increasing depths is so high that it would render agriculture unprofitable if not for government subsides. The depletion of groundwater has turned agriculture into a net economic loss for the state of Gujarat, a situation that can only get worse if current trends continue.

Perhaps most alarming, continued depletion of groundwater resources for irrigation at the current rate creates the risk of permanent saltwater intrusion into aquifers, a development that would put an end to agriculture in the area.

However, numerous technologies and practices that could save significant amounts of water and energy already exist, and farmers surveyed showed considerable interest in applying them, as long as they have the needed support. Such support could come in the form of greater extension outreach and research on water-saving technologies, but will most likely require a new incentive scheme that will reward farmers for water conservation without costing the state money.

Such a scheme offers the potential for a long-term win-win change for farmers and the utility, through a reduction in water use that does not compromise farmers' income. This would slow (stabilize or even reverse) the decline of the water table and preserve the vibrant agriculture of the region.