RECKONING THE GROUND WATER RECHARGE IN SEMI-ARID REGION: AN ASSESSMENT OF COMMUNITY LED POLICY PERFORMANCE IN SAURASHTRA

Praharsh Patel[1] and Dipankar Saha[2]

ABSTRACT

Easy access, round the year availability even in the draught years and lack of regulations coupled with advanced and cheap technology to create extraction structure have been major factors responsible for indiscriminate extraction of groundwater. With a rise in population leading to increasing water requirement, the untapped groundwater resource has been the biggest bone of contention amongst multiple stakeholders with a threat of serious depletion in many parts of the world especially regions without perennial surface water availability and arid or semi-arid climate. India is the largest extractor of groundwater and the alarming situation has already tapped in. Semi-arid region of Saurashtra has the most extreme case with just 500 mm of rainfall and almost 40 percent of coefficient of variation leading to frequent drought-like condition. Saurashtra's almost 83 per cent of the total irrigated area is through groundwater. High extraction of groundwater of Saurashtra caused major groundwater depletion in the region. The condition even intensified during consecutive drought years of 1985-87 when Saurashtra received just 93 mm of total rainfall during 1987 on top of 60 per cent rainfall in 2 consecutive drought years of 1985 (299 mm) and 1986 (298 mm). Severity of the condition led to a mass movement for rainwater harvesting as well as a decentralized groundwater recharge at an unprecedented scale. The community-led movement with the support of local leaders, merchants and religious gurus in the early 90s got support from the state government. The movement was formalized as Sardar Patel Sahkari Jal Sanchay Yojana (SPSJSY) soon after Narendra Modi assumed office as Chief Minister of Gujarat. Under this pan-Gujarat scheme, 5 lakh structures created (113738 check dams, 55917 bori bandhs, 240199 farm ponds, besides 62532 large and small check dams) making way for 808 MCM (Million Cubic Meter) of storage capacity. The scheme performed best in Saurashtra as almost 60 per cent of this storage capacity (482 MCM) confined in 7 districts of Saurashtra. The success of the program was much lauded by state and central governments making it exemplary for other semi-arid regions like Marathawada and Vidarbha those that have comparable terrain, soil and aquifer characteristics. The comparative analysis of the movement's success with pre-post analysis by considering monsoonal groundwater recharge during good rainfall spell of 1975-84 (pre) and 2004-09 (post) show almost a two-fold increase in the groundwater recharge during the similar monsoon years in Saurashtra. This temporal analysis enables to establish the impact of the collective efforts by people as well as the government for groundwater rejuvenation in Saurashtra. With availability of dependable irrigation, Saurashtra has also emerged as a major contributor to Gujarat state's agriculture growth which has normally been shadowed by other regions of the state making the state agriculture growth reaching the double-digit figure.

This paper is part of working paper named "Sustainability of Groundwater Through Community Driven Distributed Recharge: An Analysis of Arguments for Water-Scarce Semi-Arid India"

[1] Research Consultant, IWMI-Tata Water Policy Program (ITP), Anand, p.patel@cgiar.org

[2] Ex-Member (Head Quarter), Central Ground Water Board, MoWR, RD & GR, Govt. of India, dsaha002@yahoo.com

Keywords: Groundwater; Semi-Arid India; Saurashtra, Water Policy; Impact of Managed Aquifer Recharge; Impact Analysis.

1. INTRODUCTION

India's Water requirement has been increasing with increasing population burden as well as the development of the economy. Having diverse climatic and hydrological regimes within its boundary, India consists of water-rich Ganga-Yamuna flood plains in North, Narmada, Godavari, Krishna and Kaveri Basins in Central and South of India (Figure 1). Apart from this, India also has arid and semi-arid regions in western and central India. The major source of water for their domestic, agriculture as well as industrial needs, India was very much dependent on the rivers in large river basins whereas natural and artificial tanks and ponds used to take charge for semi-arid regions. These surface water resources were highly dependent on rainfall for water availability. The monsoonal rainfall used to play an important role in the economy and livelihood of people until 1970. Post-1970s, the use of groundwater as a source of irrigation and for domestic purposes has been increasing tremendously. This has led to an increase in groundwater structures in India from less than 1 million in 1960 to almost 24 million in 2014 putting India on top of groundwater abstraction in the world (CGWB 2014). Currently, about 85 per cent of rural water supplies and 60 per cent of irrigated agriculture is possible due to groundwater (Shankar 2011). Easy access and lack of regulations have been major factors responsible for indiscriminate extraction of groundwater. With a rise in population leading to increasing water requirement, the untapped groundwater resource has been the biggest bone of contention amongst multiple stakeholders with a threat of serious depletion in many parts of the country. Today, the condition is such that almost 60 per cent of groundwater resources are facing issues of water availability or quality (Kulkarni 2014).

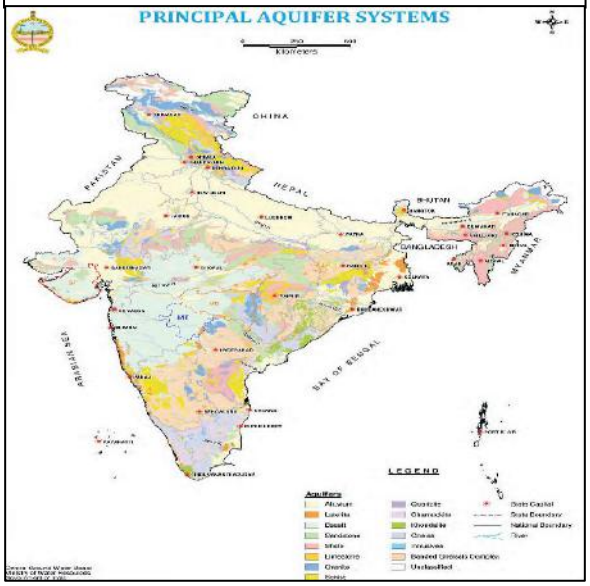

Figure 1: Principle Aquifer Map of India (ST : Saurashtra, MT : Marathawada, VD : Vidarbha) (Saha et al, 2017)

As per Stamp's Classification; Majority of Saurashtra, Maharashtra, Madhya Pradesh, Telangana and North Karnataka lies under Moderate rainfall receiving annual average rainfall between 500mm to 1000 mm and having high variability in rainfall (Coefficient of variation more than 20 per cent). (Stamp, 1967) Out of all these regions, Saurashtra has the most extreme case with just 500 mm of rainfall and almost 40 per cent of coefficient of variation leading to frequent drought-like conditions. With a lack of major perennial source of water for year around irrigation and domestic water requirements, Saurashtra predominantly relies on its groundwater

resources. Almost 83 per cent of the total irrigated area is through groundwater (Agricensus,2010). High extraction of groundwater of Saurashtra caused major groundwater depletion in the region. The condition even intensified during consecutive drought years of 1985-87 when Saurashtra received just 93 mm of total rainfall during 1987 on top of 60 per cent rainfall in 2 consecutive drought years of 1985 (299 mm) and 1986 (298 mm). Severity of condition led to a mass movement for rainwater harvesting as well as decentralized groundwater recharge at an unprecedented scale. The community-led movement with the support of local leaders, merchants and religious gurus in the early 90s got support from the state government. The movement was formalized as Sardar Patel Sahkari Jal Sanchay Yojana (SPSJSY) soon after Narendra Modi assumed office as Chief Minister of Gujarat. Under this pan-Gujarat scheme, 5 lakh structures created (113738 check dams, 55917 bori bandhs, 240199 farm ponds, besides 62532 large and small check dams) making way for 808 MCM (Million Cubic Meter) of storage capacity. The scheme performed best in Saurashtra as almost 60 per cent of this storage capacity (482 MCM) confined in 7 districts of Saurashtra. (Shah, 2014) The success of the program was much lauded by state and central governments making it exemplary for other semi-arid regions like Marathawada and Vidarbha.

Marathawada and Vidarbha also lie under moderate rainfall area and also lack a perennial source of water north Indian planes having perennial rivers like Ganga, Yamuna. Although their condition is marginally better than Saurashtra due to better average rainfall (790mm for Marathawada and 1095mm for Vidarbha) and less variability (Coefficient of Variation: 24 percent for Marathawada and 18 per cent for Vidarbha). Even the soil, geology, climate and aquifer characteristics of these 3 regions are comparable as they have mainly black soil and basalt aquifers.

All three regions (indicated in Fig 1) have received much attention for long due to frequent droughts and their depleting groundwater resources. To tackle this condition different measures have been adopted by respective state governments. Maharashtra Groundwater Act (1993) focused more on saving the depleting sources through regulatory measures, whereas Gujarat emphasized on a combination of rationing power for groundwater extraction and groundwater recharge investment by providing support to communities and NGOs. Researchers have indicated the groundwater table's rejuvenation in Gujarat and Saurashtra [(Dinesh Kumar 2018); (Bhanja 2017); (Jain 2012); (Shah 2009)]. However there is a difference in opinion in the reason for groundwater storage has improved in the case of Saurashtra, witnessed as a post-2002 phenomenon. Most of these authors accepts that the conducive rainfall as a positive factor for improves groundwater but varies the opinion on water harvesting. Dinesh Kumar (2018) considers Sardar Sarovar Project a major game changer whereas Jain (2012) and Shah (2009) are putting their opinion on water harvesting which enabled the more recharge through monsoon rainfall.

2. ABOUT THE ANALYSIS

This analysis focuses to do a tangible impact assessment of the Saurashtra's much-hyped groundwater recharge movement that started in the early 90s and shows major expansion in the early 2000s have improved groundwater recharge between 2004 and 09 based on the groundwater level and rainfall data. Here, the hypothesis is such that, if the Saurashtra's groundwater movement is as effective as it is proposed then there should have been sufficient increase in groundwater level during the monsoon rainfall period which major contributor in recharging the aquifers. This can be observed by fluctuation in groundwater level between pre-monsoon and post-

monsoon observations of groundwater level. There is a proposed argument that most of the recharge activities have bear fruits post 2004 due to the spell of above normal rainfall in districts of Saurashtra during 2004-2009 (Period 2). Hence the comparison of Period 2 (average annual rainfall = 651mm) with an immediate spell of low rainfall during 1991-2003 (Average Annual Rainfall 469 mm, 28 per cent lower than Period 2) does not provide equitable treatment and control comparison. To eliminate biased comparison, we have taken 1975-84 (Period 1) (average annual rainfall 626mm) which is before any major managed aquifer recharge interventions as a control condition and 2004-09 as treatment. This comparison shall enable us to ensure unbiased comparison of monsoonal groundwater recharge during these two periods.

When Saurashtra was observing major investment of efforts for Managed Aquifer Recharge (MAR) in a mission mode, although having comparable characteristics, Maharashtra and Vidarbha lacked such initiative. Planning commission report on drought impact of Vidarbha quoted, “The Team recommends large scale efforts for water harvesting and popularizing participatory water harvesting and management measures so that at least one supplementary irrigation is available to the cotton crop. The team also found that, surprisingly, only a few attempts at bori-bund program were visible by the roadside. A comprehensive program for the development of harvesting structures or watershed programs were not available”(PC 2006). It has been proposed earlier that the lack of watershed development and MAR are the major cause behind Vidarbha’s shuffling agrarian condition. (Shah,2012) The condition of Marathawada has also been limping due to increasing groundwater dependence over years and lack of efforts to recharge it.

Marathawada and Vidarbha also have witnessed good rainfall during Period 1 and Period 2 in absence of major drought years in between. Saurashtra like comparison of these two regions can enable to check if there has been an improvement in these regions in the absence of major movement and whether just a good rainfall is sufficient in improving recharge. Investigation of these three regions with similar terrain, landform and aquifer characteristic in detail has been taken up for two periods of 1975-84 and 2004-09 when all three have witnessed non-drought years with normal or above normal rainfall. Period 2 also provides an advantage to check the long term impact of water harvesting and aquifer recharge through managed aquifer recharge which immersed during the early 90s to early 2000s. The comparison ensures major groundwater replenishment work as a differentiating factor among these three regions in two separate time spell.

3. DATA: SOURCES, DESCRIPTION

For analyzing the groundwater recharge, pre and post-monsoon groundwater level data was sourced Central Ground Water Board (CGWB). it has a network of observation sites throughout the country to monitor and observe groundwater levels. The observation wells represent the shallow unconfined aquifers that get immediate recharge from rainfall from any artificial recharge intervention adopted. To determine the district average groundwater level, an average of groundwater level of all the observation wells within the district boundaries are considered. The regional average groundwater level is computed using the area weighted average the district average groundwater level. Due to insufficient observation for the year 1981 in Marathawada, this particular year has to be dropped from the further comparison.

To have an equitable comparison of groundwater recharge vis-à-vis monsoonal rainfall, monthly district average rainfall was sourced from Indian Meteorological

Department (IMD). It has a maintained district-wise the rainfall observation data for a long time series (1901-2017). For the current purpose, district average monthly rainfall data was used. The weighted average of the observation centers was calculated to prepare month-wise district average rainfall. For continuity, Porbandar district which was created by bifurcating Rajkot district in 1998 has been included in the Rajkot district only for the present study. Due to missing data from IMD of Rainfall in Jamnagar and Junagarh district during 1975-84. They are imputed using state weather center data.

4. RESULTS AND DISCUSSION

4.1 Rainfall Observations

Rainfall in Saurashtra is mainly limited to monsoon period that normally starts in June and ends in September receiving almost 90 per cent total annual rainfall. Considering the period of 1975-2009, total precipitation in Saurashtra has seen many variations with continuous drought years of 1985-87 as well as a deficit rainfall spell in 1999-2002. 1975-84 and 2004-09 are the two spells when the rainfall has been on the above normal for most of the years. Similar are the cases with Marathawada and Vidarbha. These two-time spells provide a comparable period of relatively stable rainfall. Table 1 gives an overall comparison of monsoon rainfall distribution during these two spells. Rainfall is a natural phenomenon there is very less probability to have exactly similar patterns, thus rainfall with a little variation shall be sufficient for to determine comparable time spells for comparison.

Table 1: Statistics of Sub-divisional Monsoon Rainfall (IMD).

Region	1975-84 (P1)			2004-09 (P2)		
	Mean	Min	Max	Mean	Min	Max
Saurashtra	585.7	273.6	861.4	646.7	468.5	887.4
Marathawada	731.7	530.3	1173.2	707.2	588.8	911.3
Vidarbha	1007.9	757.2	1283.3	936.8	692.7	1157.3

4.2 Groundwater Condition

CGWB measures the groundwater level for 4 times a year. Out of this pre-monsoon and post-monsoon level are of our interest as a part of the monsoonal rainfall is percolated which recharges the upper unconsolidated aquifer levels leading to a rise in the groundwater level. The pre-monsoon water levels are measured during the last week of May or the first week of June whereas the post-monsoon levels are measured after the withdrawal of monsoon during the last week of October or early November.

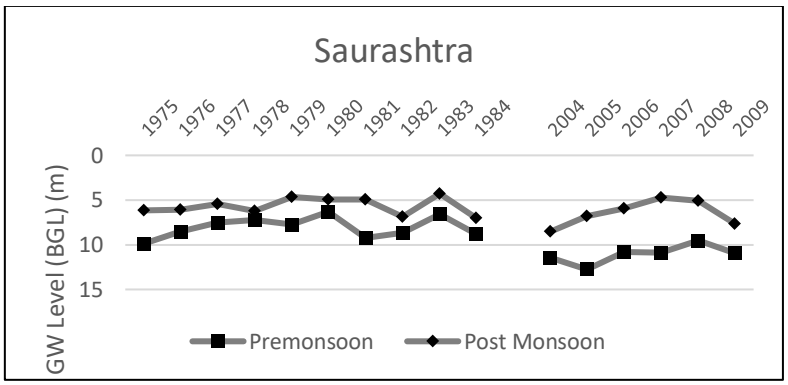

Figure 2: Groundwater Level in Saurashtra (CGWB)

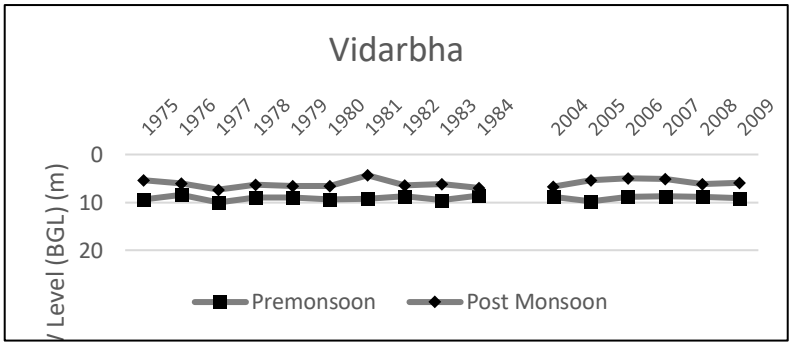

Figure 3: Groundwater Level in Vidarbha (CGWB)

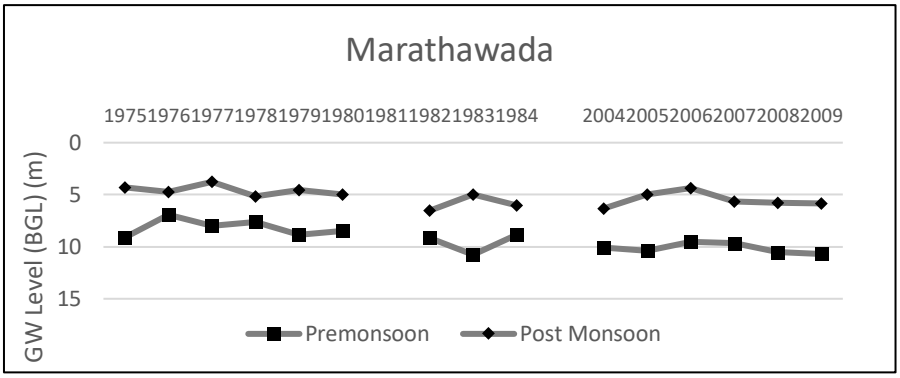

Figure 4: Groundwater Level in Marathawada (CGWB)

As per available data for the pre-monsoon level, groundwater is much depleted in the case of Saurashtra as compared to Vidarbha and Marathawada between two periods of observation. (Fig 2,3 & 4) The average depth of the groundwater has increased from 7.99 m to 11.19 m (140 per cent). (Fig 5) This suggests a high extraction of groundwater post-monsoon in recent years. This is anticipated as Saurashtra has increased its stage of groundwater development to a great extent between these two time-spells (Shah et al (2009)). Post Monsoon water levels are still comparable (5.6 m

in 1975-84 and 6.5 m in 2004-09). The depletion is not as much visible as in the case of pre-monsoon.

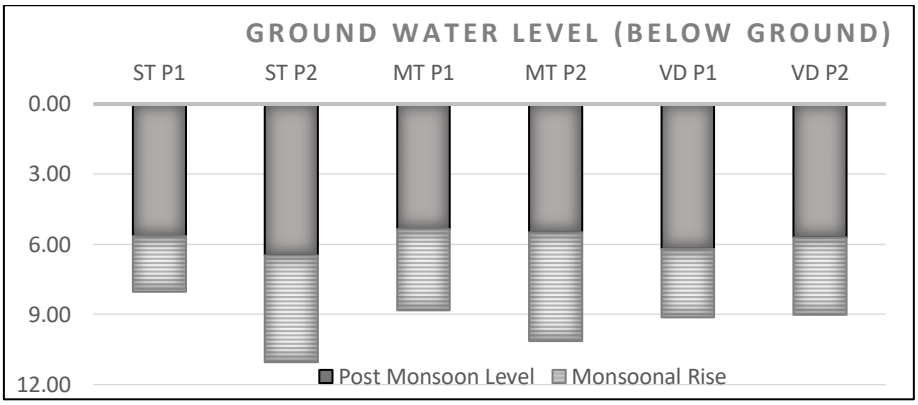

Figure 5: Rise in GW Level During monsoon in meter (m) (ST: Saurashtra, MT: Marathawada, VD: Vidarbha, P1: 1975-84, P2: 2004-09)

Vidarbha and Marathawada groundwater conditions are marginally better than Saurashtra. Saurashtra districts have consistently shown groundwater draft against groundwater availability as more than 60per cent for all the CGWB groundwater dynamics reports during and after period 2 (CGWB 2004,2009,2011,2013). Saurashtra has outperformed the other two regions in terms of rise in water levels in post monsoon water levels between Period 1 and 2. To check the groundwater recharge through monsoonal rainfall, it would be more important to check the quantum of rainfall against the quantum of groundwater recharge.

4.3 Comparison of Rainfall with Ground Water Recharged.

Considering hydrology of water from rainfall, out of the total quantum of rainfall received, a part of it is evaporated, another part is lost to run-off or captured in the upper layer of soil as soil moisture and the remaining part that percolates underneath the ground recharges the aquifer .Major efforts for groundwater recharge are in order to increase the deep percolation so that more water is stored in underground aquifers which prevents losses due to evaporation .In this analysis, the ratio of the total quantum of water received in rainfall and estimated recharge is used as an indicator of an effective increase in the groundwater recharge from rainfall.

Recharge factor = $\sum RV/\sum TR$

RV = Recharge Volume
TR = Total Quantum of Rainfall

Table 2: Recharge factors for 3 regions over 2 period

Region	Mean Recharge Factor		% Increase
	1975-84	2004-09	
Saurashtra	0.063	0.114	80%
Marathawada	0.073	0.090	24%
Vidarbha	0.065	0.072	13%

The results from analyzing the ratio of the groundwater recharge vs. the total amount of rainfall received show that Saurashtra has improved more than two folds in Period 2 as compared to Period 1 in terms of recharge. The rise in the case of Marathawada (24 percent) and Vidarbha (13 per cent) are not at par with Saurashtra (80 per cent). Considering there would not have been a reduction in evaporation and water usage, the runoff must have been controlled and diverted into groundwater recharge.

5. CONCLUSION

The analysis present above indicates that the Saurashtra's groundwater monsoonal recharge through rainfall has been significantly higher compared to Marathawada and Vidarbha. This can be attributed to rainfall as well as other sources such as interbasin transfer of water reduced groundwater draft. Given the condition of Saurashtra. Interbasin transfer of water is not the case as Saurashtra has not imported a considerable amount of water from any other region during 2004-2009 that can explain the two-fold rise in the water level. Further considering that the pipeline distribution of domestic water for Saurashtra may have caused percolation after release in drainage, this amount would not be sufficient enough to increase the level beyond a few centimeters. Doing the simple calculation of 1.058 BCM allocated for drinking purpose in SSP storage (For the whole state of Gujarat, Saurashtra is less than 1/3rd of total land mass of Gujarat), if we consider as high as 33 per cent is reaching Saurashtra during Period 2 and as high as 80 per cent of it is percolating to recharge the upper aquifers in 64454 km2 area of Saurashtra, the average rise would not have been more than 20 cm. what we have observed is the improvement in recharge to the tune of 2.2 m. This is indicative that Saurashtra has improved its groundwater recharge from the rainfall it is receiving or reducing the draft.

This monsoonal rise is in Saurashtra is when the Saurashtra has increased much of the groundwater by increasing the area under groundwater irrigation. Although estimates are not available for Period 1, groundwater irrigated area has to be very low for Period 1 of 1975-84 due to lack of extraction resources then. The ever-increasing groundwater draft is also discussed earlier citing the Central Ground Water Board Data. All these convergence to indicate that there has been a significant positive impact of Saurashtra's groundwater recharge movement.

Saurashtra's groundwater recharge movement has been described as a major success in the field of managed aquifer recharge. The empirical evidence from Marathawada and Vidarbha haven't been able to improve the condition to the tune of Saurashtra. The increase in Saurashtra is surpassing similar developments in Marathawada and Vidarbha with a great margin. This is suggestive of the fact that to improve groundwater conditions, nature's knack is necessary but not sufficient. It has to be coupled with better policies that can help manage groundwater resources more effectively. This study also emphasizes the effectiveness of managed aquifer recharge strategies in drought-prone and hard rock regions facing groundwater depletion.

In recent years after 2010, Marathawada and Vidarbha have also focused on managed aquifer recharge with the introduction of Sujalam Sufalam Yojana as well as many NGOs investing heavily on the community based sustainable water management practices. In the next couple of years, it will be interesting to check if they also have improved significantly the way Saurashtra did and whether the effectiveness of managed aquifer recharge continues to be supported by data.

6. REFERENCES

Asoka, A. G. (2017). Relative contribution of monsoon precipitation and pumping to changes in groundwater storage in India. Nature Geoscience, (10):109–117, https://doi.org/10.1038/ngeo2869.

Athawale, R. N. (2003). Water Harvesting and Sustainable Supply in India. Delhi: Centre for Environment Education.

Banerjee, D., Mukherjee, A., Acharya, S., Chatterjee, D., Mahanta, C., Saha, D. and Raju, D. S. (2012). Contemporary Groundwater Pollution Studies in India: A Review. Proc Indian National Science Academy.

Bhanja, S., Mukherjee, A., Rodell, M., Wada, Y., Chattopadhyay, S., Velicogna, I. and Famiglietti, J. (2017). Groundwater rejuvenation in parts of India influenced by water-policy change implementation. Scientific Reports 7.

CGWB (2006). Dynamic Ground Water Resources of India. New Delhi, Central Ground Water Board (CGWB).

CGWB. (2007). Manual on Artificial Recharge of Ground Water. New Delhi, Central Ground Water Board (CGWB).

CGWB. (2011). Dynamic Ground Water Resources of India. New Delhi, Central Ground Water Board (CGWB).

CGWB. (2014). Dynamic Ground Water Resources of India. New Delhi, Central Ground Water Board (CGWB).

CGWB. (2017). Dynamic Ground Water Resources of India. New Delhi, Central Ground Water Board (CGWB)

Chindarkar, N. and Grafton, R. Q. (2019). India's depleting groundwater: When science. Asia & The Pacific Policy Studies, 1-17.

DES (2019), Web Based Land Used Statistics Information System, Directorate Of Economics & Statistics, Ministry Of Agriculture and Farmers Welfare, Govt. Of India, New Delhi, Accessed on Jan 15, 2019, <https://aps.dac.gov.in/LUS/Public/Reports.aspx>

Goswami, B. N., Venugopal, V., Sengupta, D., Madhusoodanan, M. S. andXavier, P. K. (2006). Increasing Trend ofExtreme Rain Events Over India in a Warming Environment. Science, 314 (5804): 1442-1445. <DOI:10.1126/science.1132027.>

Jain, R. C. (2012). Role of Decentralised Rainwater Harvesting And Artificial Recharge In Reversal Of Groundwater Depletion In The Arid And Semi-Arid Regions of Gujarat. IWMI Tata Water Policy Research Highlights, 49. Anand, India: IWMI-Tata Water Policy Program.

Kulkarni, H. A. (2014). Groundwater Resources in India: An Arena for Diverse Competition. Local Environment, pp. 990–1011.

Kumar, C. P. (2012). Climate Change and Its Impact on Groundwater Resources. International Journal of Engineering and Science, 1(5): 43-60.

Kumar, D. and Perry, C. J. (2018). What can explain groundwater rejuvenation in Gujarat in recent years? International Journal of Water Resources Development, 1–16. https://doi.org/10.1080/07900627.2018.1501350.

MoA. (2015). Ninth Agricultural Census of India 2010-11. New Delhi: Ministry of Agriculture and Farmers Welfare (MoA), Retrieved from http://agcensus.dacnet.nic.in/

Narmada Control Authority (Nd). Frequently Asked Questions. Retrieved from Narmada Control Authority (Accessed on Jan. 21st, 2019): <http://nca.gov.in/faq3.htm>

Nathan, K. K. (2001). Poor Water Resources and Drought in the Gujarat/Saurashtra Regions of India. Drought Network News (1994-2001), 58. Retrieved from <http://digitalcommons.unl.edu/droughtnetnews/58>

Planning Commission (India). (2006). Report of Fact Finding Team on Vidarbha: Regional disparities and rural distress in Maharashtra with particular reference to Vidarbha. New Delhi, Government of India

Saha, D. and Agrawal, A. K. (2006). Determination of specific yield using water balance approach- a case study of Torla-Odha watershed in Deccan Trap Province, Maharastra State, India. Hydrogeology Journal, 14(4): 625-635.

Saha, D. and Roy, R. (2018). Groundwater Resources of India: Potential, Challenges and Management- In Groundwater Development and Management, Issues and Challenges in South Asia. New Delhi: Groundwater Development and Management. <https://doi.org/10.1007/978-3-319-75115-3_2>

Saha, D., Marwaha, S. and Mukherjee, A. (2017). Groundwater Resources and Sustainable Management Issues in

India. In: Saha, D., Marawaha, S. and Mukherjee (Eds) Clean and Sustainable Groundwater in India. Singapore: Springer, pp. 4551-4556. <https://doi.org/10.1007/978-981-10-4552-3_1>.

Shah, T. (2014). Towards Managed Aquifer Recharge strategy for Gujarat, India: An economist's dialogue with hydro-geologists. Journal of Hydrology, 518(2014): 94-107.

Shah, T., Bhatt, S., Shah, R., and Talati, J. (2008). Groundwater governance through electricity supply management: Assessing an innovative intervention in Gujarat, western India. Agriculture Water Management, 95(11):1233-1242. <https://doi.org/10.1016/j.agwat.2.>

Shah, T., Gulati, A., Hemant, P., Shreedhar, G. and Jain, R. (2009). Secret of Gujarat's Agrarian Miracle after 2000. Economic and Political Weekly 44(52): 45-55.

Shankar, P. V., Kulkarni, H., and Krishnan, S. (2011). India's Groundwater Challenge and the Way Forward.

Stamp, L. D. (1967). Asia: Regional and Economic Geography. London: Methuen.