INTERNATIONAL JOURNAL OF CONSERVATION SCIENCE

ISSN: 2067-533X Volume 9, Issue 3, July-September 2018: 537-548 www.ijcs.uaic.ro

GROUNDWATER DYNAMICS IN MARATHWADA REGION: A SPATIO-TEMPORAL ANALYSIS FOR SUSTAINABLE GROUNDWATER RESOURCE MANAGEMENT

Sagar KHETWANI*, Ram Babu SINGH

Department of Geography, Delhi School of Economics, University of Delhi, Delhi 110007, Delhi, India

Abstract

Groundwater resource, especially in the arid and semi-arid tropics is highly vulnerable to climate change and increased human needs. The rising groundwater overdraft is a big challenge for the ecological and socio-economic wellbeing of the earth. This study investigates the spatio-temporal patterns of groundwater overdraft and ongoing practices for water conservation in the Marathwada region of Maharashtra state in India. The GIS technique has been used for mapping spatio-temporal variability of groundwater overdraft in the region. The region has seen the spatial shift and expansion of groundwater overdraft from northern Marathwada region towards southern Marathwada region, over the sub-districts where the groundwater overdraft was not visible between the years 2001-2005. The water scarcity of the region has attracted the attention of masses and various stakeholders of the society which further gave way to the community-based water resource management in the region.

Keywords: *Marathwada region; Groundwater recharge; Groundwater overdraft; Community; Water conservation; Sustainable development*

Introduction

Groundwater is the most reliable source to meet water requirements in the semi-arid tropical region of India. The increasing gap between groundwater withdrawal and groundwater recharge and mismanagement of groundwater resource pose the serious challenges of groundwater scarcity and deteriorated the quality of groundwater. Worldwide, groundwater holds the share of more than 95 percent among readily available freshwater sources [1-4]. Like the concept of income and expenditure account, groundwater can be wisely spent for the sustainable development of groundwater resources. The concept of groundwater recharge and groundwater withdrawal is similar to the income and expenditure [5]. Groundwater overdraft indicates that groundwater withdrawal exceeds groundwater recharge [6]. Initially, groundwater overdraft contributes more to the dependent community needs than it costs [7]. However, as the level of the groundwater falls groundwater extraction cost increases and quality of groundwater decreases [8-10]. Due to problems like contaminated groundwater and deteriorated quality of groundwater it remains no longer suitable to meet the agricultural or other domestic water requirements [11-13]. Due to its near universal availability, dependability and low capital cost groundwater is the most preferred source of water in major part of India in rural as well as urban areas. Groundwater meets 85 percent of India's rural domestic water requirements, 50

*Corresponding author: sagardse96@gmail.com

percent of urban water requirements and more than 50 percent of irrigation requirements of India [14-15].

Marathwada region lies in the semi-arid tropical region of Maharashtra state in India, where availability of groundwater is confined to the fractures, joints and the weathered portion of the basaltic lava flows [16-17]. However, the haphazard exploitation of groundwater resource is increasing the groundwater stress in the region [18-19]. The Marathwada region has witnessed the three nearby droughts between the years 2012 to 2017, i.e., 2012 drought followed by consecutive droughts in the years 2014 and 2015 [20]. The groundwater is a most important source of irrigation in the Marathwada region, failure of monsoon further intensifies the dependence on groundwater for irrigation which further leads to depletion of groundwater level [21-23]. According to data from the Maharashtra government's Groundwater Surveys and Development Agency (GSDA) which monitors over 875 observation wells in eight districts of Marathwada region, in the year 2015, region has seen a steep fall in average depth of groundwater level in the month of October, from the five-year average of 4.44 meters to 7.13 meters, a dip of 2.69 meters. Generally, the groundwater levels are found up to eight to nine meters during the summer season in the region but in some districts, it can also dip to thirteen meters during drought years. The erratic nature of rainfall distribution within monsoon months from June-September puts heavy stress on the groundwater resources of the region [24-27]. In the last five to seven years, the region has seen the massive exploitation of groundwater to meet day to day needs due to increased frequency of drought [28-31].

The most important task for reducing the groundwater vulnerability is to map groundwater stressed areas for risk identification and develop the priority of actions for groundwater governance in affected areas [32-34]. Some authors [35-36] argue that the identification of factors affecting the groundwater development and Science Policy Interface (SPI) could prove as instrumental steps for the amelioration of the region. The integration of technical and local knowledge with the collaborative efforts of the policy based decision-making community, stakeholders of society and local people would prove fruitful for the sustainable development of groundwater resources [37]. The steep decline in groundwater levels over the years in sub-districts of the Marathwada region raises the pressing need for a detailed study to understand the groundwater level dynamics through both, spatial and temporal dimensions.

The study, therefore, aims at assessing the intensity of groundwater overdraft across talukas and visualize the spatio-temporal patterns of groundwater overdraft. It further investigates the ongoing community-based water conservation practices in the region and provides suggestions for the sustainable development of groundwater resources in the region on the basis of the synthesis of analyzed data.

Study Area

The Marathwada region is situated between 17°37' North and 20°39' North latitudes and 74°33' East and 78°22' East longitudes in the Maharashtra state of India [16]. The Marathwada region comprises of 8 districts, i.e., Aurangabad, Bid, Nanded, Latur, Jalna, Hingoli, Parbhani and Osmanabad, and 76 sub-districts within 8 districts (Fig. 1). The region lies in the rain shadow zone of Sahyadri mountain range in Western Ghats of Maharashtra state. Marathwada region is surrounded by Vidarbha region in the north, Pune region in the south, Nashik region in the west. It is bounded by Karnataka and Telangana state in the south and east. Marathwada is located on the Deccan plateau having the plain terrain with undulations [38]. The topography of the region is marked by the Basaltic Deccan Traps. However, the Nanded district of the region has the exposes of granite and Vindhyans mountain range. The lava flow thickness in the region varies from a few meters to 40 to 45 meters [16]. The total geographical area of Marathwada region is 64813km^2, which constitute around 21 percent area of the Maharashtra state [39].

Marathwada has generally hot and dry climate. The region's average temperature of day ranges from 27.7 to 38.0°C while the average temperature of night ranges from 20.0 to 26.9°C [38]. The normal average rainfall is about 825mm but is highly erratic and often there is a significant time gap between the two successive showers of rain [16]. The Godavari is a most important river of the region, also known as 'Ganges of Deccan' and comprises many large and small projects [38].

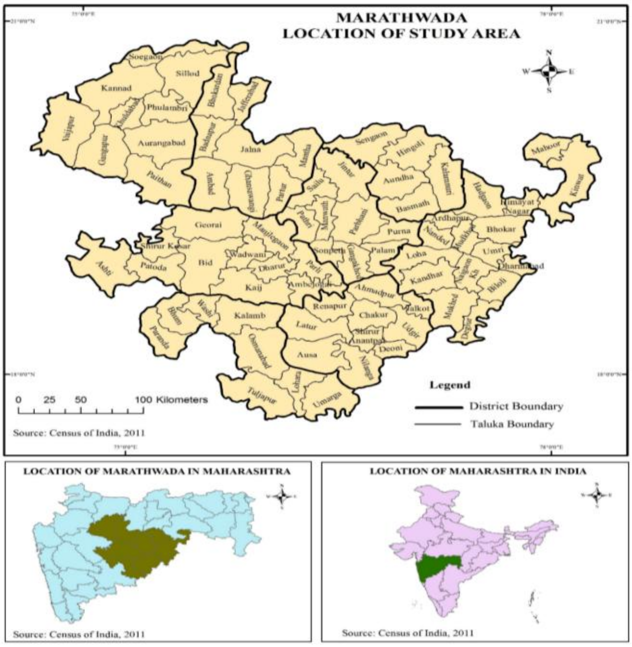

Fig. 1. Location of the study area

According to the census 2011, the total population of Marathwada region is 18,731,872 represents 18.7 percent of Maharashtra state out of which 72.9 percent of the population is living in rural areas and 27.1 percent living in urban areas. Majority of the population of Marathwada region are dependent on agriculture sector [39-41].

Materials and Methods

The secondary data sources include pre-monsoon (May) and post-monsoon (October) groundwater level (GWL) data for 16 years from 2001 to 2016, recorded at 76 sub-districts of the region. The groundwater level data were obtained from the Groundwater Surveys and Development Agency (GSDA) Maharashtra. The Geographic Information System (GIS) technique is an important tool for the effective and sustainable management of groundwater resources as it assists in generating a scientific geodatabase of the resource and also facilitates for mapping the water-stressed areas [35-36]. Earlier also in many groundwater studies, GIS has been used as an effective tool [42-44]. The spatio-temporal patterns of groundwater overdraft were analyzed between the years 2001 to 2015 across 76 sub-districts of the Marathwada region. They were then represented through maps. The groundwater recharge has been calculated with the change between pre-monsoon (May) and post-monsoon (October) groundwater level in a year while it also includes groundwater withdrawal of the same period. Due to negligible rainfall between the months of October to May (non-monsoon months) groundwater is the most important source to meet day to day water requirements. The groundwater withdrawal between post-monsoon (October) and pre-monsoon (May) has been calculated with the help of the change in groundwater level between post-monsoon and pre-monsoon groundwater level of next year. In order to assess the groundwater overdraft, has been calculated with the help of groundwater recharge and groundwater withdrawal, according to the equation (1):

$$GW_o\ (\%) = 100(GW_r - GW_w)/GW_r, \quad (1)$$

where:

GW_o - groundwater overdraft; GW_r - groundwater recharge; GW_w - groundwater withdrawal.

Further groundwater overdraft maps have been generated.

The 5 years average groundwater overdraft percent has been calculated for the periods of 2001-2005, 2006-2010 and 2011-2015 has been calculated. The average groundwater overdraft percent between the years 2001 to 2005 has been computed with the help of data like average groundwater recharge and average groundwater withdrawal during the years 2001 to 2005. The groundwater recharge has been calculated by the change between pre-monsoon (May) and post-monsoon (October) groundwater level for the year 2001, in the similar manner groundwater recharge of years 2002, 2003, 2004 and 2005 were computed and the average of groundwater recharge from 2001 to 2005 was calculated. The groundwater withdrawal has been calculated with the help of change between post-monsoon (October) groundwater level and pre-monsoon (May) groundwater level for the year 2001, in the similar manner groundwater withdrawal of years 2002, 2003, 2004 and 2005 were computed and the average of groundwater withdrawal from the year 2001 to 2005 was calculated. Then average groundwater overdraft percent for the period of 2001-2005 has been calculated, according to the equation (1).

In the similar manner groundwater overdraft percent for the years 2006-2010 and 2011-2015 have been calculated.

The spatio-temporal analysis of groundwater overdraft of 76 sub-districts in the region has been represented with the help of groundwater overdraft maps. The groundwater overdraft maps have been generated at the temporal scales of 2001-05, 2006-10 and 2011-15. Arc GIS 10.2.2 software was used for generating the spatio-temporal variation maps of the groundwater overdraft.

The field survey was undertaken during the month of June in the year 2017 in order to assess the community-based water conservation practices in the two *Gram Panchayats* (rural administrative units), i.e., Awargaon of Dharur sub-district in Bid district and Upla of Osmanabad sub-district in Osmanabad district. The above mentioned two *Gram Panchayats* were selected purposively from the study area with the consultation of key informants. The pictures of community-based water conservation practices were captured using the camera during the field survey. Travel modes used during the field survey included motor vehicles and walking.

Results and Discussions

Groundwater overdraft: 2001-2005

On the basis of average groundwater recharge and average groundwater withdrawal in the period of 2001-05, three sub-districts were marked by groundwater overdraft of more than 32 percent. In the sub-districts like Vaijapur, Khuldabad, and Gangapur, groundwater consumption surpasses the groundwater recharge more than 32 percent. The Vaijapur sub-district was marked by the alarming groundwater overdraft of 52.19 percent, followed by the sub-districts like Khuldabad and Gangapur with the groundwater overdraft of 48.48 and 46.16 percent. In the sub-districts like Sillod and Kannad, groundwater overdraft ranges between 24 to 32 percent, and sub-districts like Phulambri and Badnapur were having the groundwater overdraft of 16 to 24 percent. Ten sub-districts were lying in the category of groundwater overdraft between 8 to 16 percent. Twenty-five sub-districts were marked by groundwater overdraft between 0 to 8 percent. While 34 sub-districts in the Marathwada were not found as groundwater overdraft. In the districts like Aurangabad and Jalna, all the sub-districts were having the groundwater overdraft. While in Osmanabad district none of the sub-districts was having the groundwater overdraft. In the Latur district except for Udgir sub-district, none of the other sub-district was under groundwater overdraft (Fig. 2).

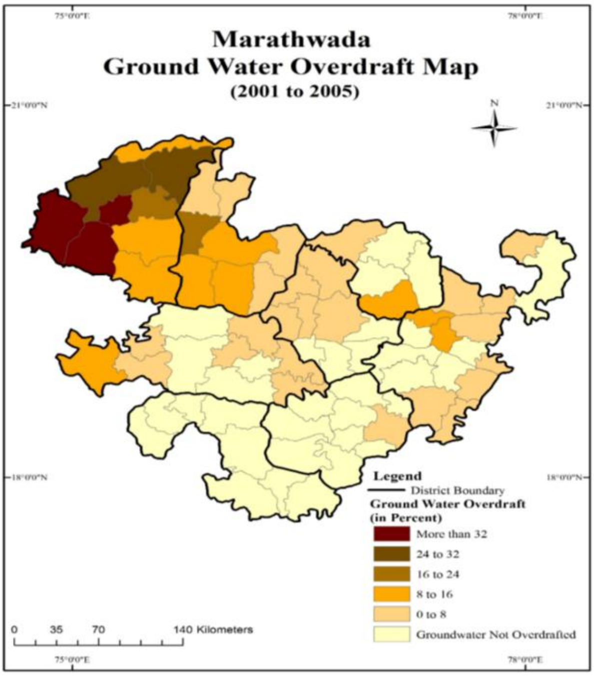

Fig. 2. Groundwater overdraft in the Marathwada Region (2001 to 2005).
Source: Based on data obtained from Groundwater Surveys and Development Agency, Maharashtra

Groundwater overdraft: 2006-2010

The groundwater overdraft was highest during the period of 2006-2010 in the Jalkot sub-district, i.e., 10.58 percent, followed by 10.01 and 8.12 percent in the Kalamnuri and Udgir sub-district. Three Sub-districts, i.e., Jalkot, Kalamnuri, and Udgir were found with the groundwater overdraft of 8 to 16 percent. The period of 2006-2010 has been marked by thirty-two sub-districts with the groundwater overdraft of 0 to 8 percent. While the forty-one sub-districts of the region were not having the groundwater overdraft (Fig. 3).

Groundwater overdraft: 2011-2015

The period of 2011-2015 witnessed the worst groundwater scarcity. The number of sub-districts with the groundwater scarcity of 0 to 16 percent were increased from thirty-five in the period of 2001-2005 to fifty-three in the period of 2011-2015. The sub-districts like Purna, Sailu, and Parbhani are marked by the groundwater overdraft of more than 32 percent. The highest groundwater overdraft was recorded in the Purna sub-district i.e. 63.89 percent followed by the sub-districts like Sailu and Parbhani with the groundwater overdraft of 58.32 and 40.29 percent. The Parbhani was the worst affected district with a significant percent of sub-districts under the groundwater overdraft of more than 32 percent. The groundwater overdraft between 24 to 32 percent was found in the sub-districts like Ashti, Naigaon kh, Sonpeth, Deoni, Dharmabad, and Mukhed. The fourteen sub-districts were having the groundwater overdraft of 16 to 24 percent. The thirty-seven sub-districts were lying under the category of groundwater overdraft of 8 to 16 percent. While the sixteen sub-districts were having the groundwater overdraft of 0 to 8 percent (Fig. 4).

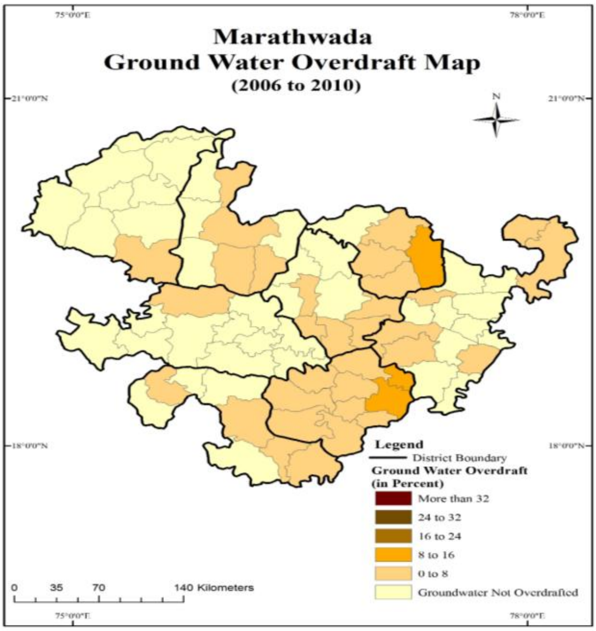

Fig. 3. Groundwater overdraft in the Marathwada Region (2006 to 2010).
Source: Based on data obtained from Groundwater Surveys and Development Agency, Maharashtra

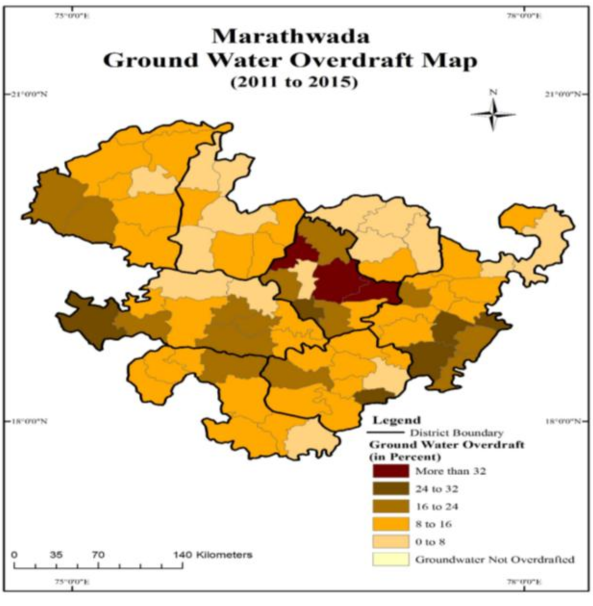

Fig. 4. Groundwater overdraft in the Marathwada Region (2011 to 2015).
Source: Based on data obtained from Groundwater Surveys and Development Agency, Maharashtra

Groundwater overdraft: Spatial Shift and Expansion

The erratic rainfall and rising water requirements in the region have increased the vulnerability of groundwater resources in the region. The availability and variability of groundwater resources have registered spatial shifts over the temporal scale. Between the years

2001-2005, the groundwater overdraft was significant in the sub-districts of Aurangabad and Jalna, followed by sub-districts of districts like Parbhani, Bid, Hingoli, and Nanded of central Marathwada. While in the sub-districts of southern Marathwada except for Udgir sub-district of Latur district none of the sub-district was under groundwater overdraft in the Osmanabad and Latur district.

Though the period of 2006-2010 has been marked by a significant reduction in the number of sub-districts with groundwater overdraft but the spatial shift of groundwater overdraft was seen from northern Marathwada region towards southern Marathwada region, over the previously groundwater surplus sub-districts. All the sub-districts of Latur and half of the sub-districts of Osmanabad have witnessed the deficit of groundwater. Though the years 2005 and 2006 have been marked by the excess rainfall with positive anomalies greater than *+1* but the groundwater overdraft was visible in all the sub-districts of Latur district and half of the sub-districts of Osmanabad district. On the other hand, years 2012, 2014 and 2015 have been marked as critical drought years with negative anomalies lesser than *-1* [20]. The period of 2011-2015 has been marked by the worst groundwater scarcity. The number of sub-districts with the groundwater scarcity between 0 to 16 percent has registered a considerable increase. The Parbhani district was the worst affected with a significant percent of sub-districts under the groundwater overdraft of 16 to 32 percent and more than 32 percent. It can clearly be seen that groundwater scarcity has spread significantly over all the districts of the region in the period of 2011-2015.

Community Based Water Conservation Practices

The concept of community-based watershed development runs on the simple principle, i.e., it aims to teach running water to walk, walking water to stop and standing water to percolate in the land. The community has a central role to play in the community-based watershed development. The integration of decision making community, scientific community and local community integrates the local knowledge with science and technology.

Farm Pond

Farm Pond is a dugout structure, constructed in the low lying portion of farm area; it aims to collect and store surface water runoff. It has its definite shape and size with appropriate inlet and outlet structures, the surface water runoff gets collected in the farm pond. It plays a significant role in developing the water security and self-reliance among the communities, especially in the regions where surface water runoff is high due to poor water percolation capacity of land and in the regions which register the high intensity of rainfall in short duration (Fig. 5).

Fig. 5. Farm pond for rainwater conservation in Upla village of Osmanabad sub-district in Osmanabad district (Source: Picture taken during field visit)

Shosh Khadda

Shosh Khadda (Soak Pit) is a porous-walled covered chamber that allows water to slowly soak into the ground. The wastewater from the settlement outlet pipe is discharged to the underground walled chamber from which it further penetrates into the surrounding soil. The small and big boulders prevent the collapsing of concrete tank walls. The wastewater outlet of settlement is connected to the hole on the cover of the concrete tank with the help of PVC pipe and bend. It also requires special attention to be given in maintaining the appropriate slope for the smooth passage of water from wastewater outlet pipe to soak pit through connected PVC pipe. It is very important to cover the soak pit with the layer of small boulders and sand in order to avoid the direct contact of surface water (Fig. 6).

Fig. 6. Construction of *Sosh Khaddas* (Soak Pits) going on in Awargaon village of Dharur sub-district in Bid district. Source: Pictures taken during field visit

Contour Trenches

Contour trenches reduce the velocity of water runoff and promote surface water infiltration by breaking the slope of the ground. These trenches are dug in such a way that they follow a contour. Along with rainwater harvesting, it also enhances soil conservation (Fig. 7).

Fig. 7. Contour Trenches in Awargaon village of Dharur sub-district in Bid district. Source: Pictures taken during field visit

Nala Widening and Deepening

Nala (Drainage) Widening and Deepening is a crucial measure of watershed development, by deepening and widening the existing water body it revitalizes the water storage capacity of the water body. In the entire process, it not only makes water body deepen and widen but it also removes the silt and clay accumulated in order to enhance groundwater recharge (Fig. 8).

Fig. 8. Widened *Nala* (Drainage) in Awargaon village of Dharur sub-district in Bid district.
Source: Picture taken during field visit

However, deepening of rivers and streams requires special attention that they should not be over-deepened because it may expose the groundwater and result in permanent damage to the aquifers [28].

Conclusion

The haphazard exploitation of groundwater resources in the sub-districts like Purna, Sailu, Parbhani, Ashti, Naigaon kh, Sonpeth, Deoni, Dharmabad and Mukhed needs to be checked, where groundwater overdraft exceeded more than 24 percent as shown in the picture of groundwater overdraft during the period of 2011-2015. The spatio-temporal patterns of groundwater overdraft between the years 2001-2015 clearly indicates that the groundwater resource of the Marathwada region is very dynamic and it requires constant monitoring. The critical status of groundwater resource and frequent droughts in the region has awakened the society and its stakeholders. The community-based practices for water conservation like the construction of *sosh khaddas* (Soak Pits), farm ponds, *Nala* widening, and contour trenches may result in not only rainwater conservation but also improved groundwater recharge. However, the problem of water scarcity may not end just with the creation of structures for water conservation but it requires to develop the vision of the sustainable development of water resources among the masses. The integration of local communities with the scientific community and governments at different levels may result into the smart groundwater management and judicious utilization of the available resources in the region. The region-specific appropriate regulatory mechanism needs to devised, implemented and monitored regularly at ground level for the effective development of groundwater resources. The adoption of area-specific best suited remedial measures will not only reduce the groundwater vulnerability but also contribute to the sustainable development of groundwater resources in the region.

Acknowledgments

The authors gratefully acknowledge the data, informational and logistical support provided by the Government of Maharashtra; the Groundwater Surveys and Development Agency (Aurangabad regional office), Department of Geography, University of Delhi and the Ratan Tata Library, University of Delhi. The study was funded by the University Grant Commission (UGC), Government of India through Junior Research Fellowship to Sagar Khetwani.

References

[1] * * *, **Managing Aquifer Recharge**, International Association of Hydrogeologists Commission on Management of Aquifer Recharge, 2003.

[2] M. Wijnen, B. Augeard, B. Hiller, C. Ward, P. Huntjens, *Managing the Invisible: Understanding and Improving Groundwater Governance*, **Draft Report Water Papers,** Published by the Water Unit, Transport, Water and ICT Department, Sustainable Development Vice Presidency, World Bank, 2012.

[3] * * *, **The United Nations World Water Development Report 2015: Water for a Sustainable World**, United Nations Educational Scientific and Cultural Organization, 2015.

[4] * * *, **Groundwater: Managing the "Invisible" Resource**, United Nations Educational Scientific and Cultural Organization, 1992.

[5] R. Howitt, C.F. Nuckton, *Is overdrafting groundwater always bad?* **California Agriculture**, **35**(1-2), 1981, pp. 10-12.

[6] * * *, **Basic Groundwater Concepts**, Department of Water Resources, 2003, pp. 80-104.

[7] A. S. Richey, B. F. Thomas, M.H. Lo, J. T. Reager, J. S. Famiglietti, K. Voss, S. Swenson, M. Rodell, *Quantifying renewable groundwater stress with GRACE*, **Water Resources Research, 51**, 2015, pp. 5217-5238.

[8] J.A. Roumasset, C.A. Wada, *Optimal and Sustainable Groundwater Extraction*, **Sustainability, 2,** 2010, pp. 2676-2685.

[9] L. Gao, J.D. Connor, P. Dillon, *The Economics of Groundwater Replenishment for Reliable Urban Water Supply*, **Water, 6,** 2014, pp. 1662-1670.

[10] V.P. Gandhi, N.V Namboodiri, *Groundwater Irrigation in India: Gains, Costs and Risks*. **Working Paper No. 2009-03-08**, Indian Institute of Management Ahmedabad, India, 2009.

[11] T. Zhu, C. Ringler, X. Cai, **Energy Price and Groundwater Extraction for Agriculture: Exploring the Energy Water Food Nexus at the Global and Basin Levels**, International Water Management Institute, 2007.

[12] J. Strand, *The Full Economic Cost of Groundwater Extraction, Policy Research*, **Working Paper 5494**, World Bank Development Research Group Environment and Energy Team, 2010.

[13] * * *, **On Target for People and Planet: Setting and Achieving Water–related Sustainable Development Goals**, International Water Management Institute, 2014.

[14] B.M. Jha, S.K. Sinha, *Towards Better Management of Ground Water Resources in India*, **Bhujal News, 24**(4), 2009, pp. 1-20.

[15] * * *, **Dynamic Ground Water Resources of India**, Central Ground Water Board, 2014.

[16] * * *, **Aurangabad Region**, Groundwater Surveys and Development Agency, 2017.

[17] A. Das, *Farmers Perception on Climate Change in Semi-Arid Topic Region of India*, **Report Submitted to School of Rural Management**, KIIT University, Bhubaneswar, India, 2010.

[18] P. Purandare, *Water Governance and Droughts in Marathwada*, **Economic and Political Weekly, 48**(25), 2013, pp. 18-21.

[19] A. Dandekar, S. Naravade, *The Case of Maharashtra's Disappearing Water*, **Economic and Political Weekly, 48**(18), 2013, pp. 19-21.

[20] A. Kulkarni, S. Gadgil, S. Patwardhan, *Monsoon variability, the 2015 Marathwada drought and rainfed agriculture*, **Current Science, 111**(7), 2016, pp. 1182-1193.

[21] P. Dandekar, *Beautiful but Dry: Dug-Wells of Marathwada in the times of drought,* **South Asia Network on Dams, Rivers and People**, Delhi, 18 January, 2016.

[22] * * *, **Ground Water Year Book of Maharashtra and Union Territory of Dadra and Nagar Haveli**, Central Ground Water Board, 2016.

[23] P. Dandekar, *Drought and Marathwada: An Oft repeated Tragedy*, **South Asia Network on Dams, Rivers and People,** Delhi, 18 August, 2015.
[24] S. Kale, J.K. Gond, *Drought in Marathwada: Water Scarcity Worsening Situation in Marathwada*, **International Journal of Innovative Research in Science, Engineering and Technology, 5**(5), 2016, pp. 8376-8384.
[25] N. Pandey, D. Sharma, *Participatory Approach of Water Resource Management: A Case Study of Marathwada*, **IOSR Journal of Business and Management**, **vol. 2016,** 2016, pp. 32-38.
[26] P. Kakodkar, *The man with 48 borewells in drought-hit Marathwada*, **The Times of India**, Mumbai, 23 April, 2015.
[27] *Jalyukta Shivar Abhiyan: Towards Drought-Free Villages*, **Maharashtra Ahead, 4**(8), August. 2015.
[28] N. Jamwal, *Marathwada's dry story*, **Down to Earth**, 15 May, 2017.
[29] S. Fernandes, *Marathwada drought man-made, not caused by climate change: Study*, **Hindustan Times**, Mumbai, 11 October, 2016.
[30] T. Dhara, *Marathwada's drought: Water scarcity has created a region where trust has eroded and left the social fabric frayed*, **First Post**, 12 April, 2016.
[31] K. Iyer, *Waterless in Marathwada: Wells dry, villages shift to cattle camps*, **The Indian Express**, 18 March, 2016.
[32] J. Van Der Bliek, M. McCornick, J. Clarke, **On Target for People and Planet: Setting and Achieving Water–related Sustainable Development Goals, Colombo, Sri Lanka**, International Water Management Institute (IWMI), 2014.
[33] I. Khurana, *Sustainable Management of Water and Sanitation*, **India and Sustainable Development Goals: The Way Forward,** Research and Information System for Developing Countries, New Delhi, India, 2016, pp. 65-76.
[34] Z.W. Kundzewicz, L.J. Mata, N.W. Arnell, P. Doll, P. Kabat, B. Jiménez, K.A. Miller, T. Oki, Z. Sen, I.A. Shiklomanov, *Freshwater resources and their management. Climate Change 2007: Impacts, Adaptation and Vulnerability*, *Contribution of Working Group II to the* **Fourth Assessment Report** of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 2007, pp. 173-210.
[35] R.B. Singh, A. Kumar, *Climate variability and water resource scarcity in drylands of Rajasthan, India*, **Geoenvironmental Disasters, 2**(7), 2015, pp. 1-10.
[36] R.B. Singh, D. Kumar, *Water Scarcity*, **Handbook of Engineering Hydrology: Environment Hydrology**, edited by Saeid Eslamian, Boca Raton, Florida: Taylor & Francis Group, 2014, pp. 519-543.
[37] * * *, IPCC, *Summary for policymakers*, **Climate Change 2014**: Impacts, Adaptation, and Vulnerability, Part A: Global and Sectoral Aspects, **Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change** (Editors: C.B. Field, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2014, pp. 1-32.
[38] * * *, **Environmental Status Report of Aurangabad Region**, Maharashtra Status of Environment and Related Issues, 2007.
[39] * * *, **Report of the High Level Committee on Balanced Regional Development Issues in Maharashtra**, Planning Department, Government of Maharashtra, 2013.
[40] A.H. Nanaware, *A Critical Study of Crop Concentration and Changes Therein In Marathwada Region*, **International Journal of Advance and Applied Research, 1**(5), 2014, pp. 1-8.

[41] M.T. Musande, *The General Land Use Pattern and Changes Therein Marathwada Region: A Geographical Analysis*, **Avishkar – Solapur University Research Journal, 3**, 2014, pp. 120-129.
[42] M. Hasanuzzaman, X. Song, D. Han, Y. Zhang, S. Hussain, *Prediction of Groundwater Dynamics for Sustainable Water Resource Management in Bogra District, Northwest Bangladesh*, **Water, 9**, 2017, pp. 1-17.
[43] T.A. Shalini, A.C. Pandey, M.S. Nathawat, *Groundwater Level and Rainfall Variability Trend Analysis using GIS in parts of Jharkhand state (India) for Sustainable Management of Water Resources*, **International Research Journal of Environment Sciences, 1**(4), 2012, pp. 24-31.
[44] M.G. Abdullahi, M.Gasim, H. Juahir, *Determination of Groundwater Level Based on Rainfall Distribution: Using Integrated Modeling Techniques in Terengganu, Malaysia*, **Geology and Geosciences, 4**(1), 2015, pp. 1-4.

Received: Octomber 25, 2017
Accepted: August 10, 2018