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Groundwater Exploitation and Its Environmental Consequences in Bangladesh: A Review

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Abstract: The review attempted to present the scenario of groundwater exploitation and its consequences in Bangladesh. The study considered the data and information published in Journals, newspapers, and reports of the government and non-government organizations. The irrigation water use of the country mainly depends on groundwater sources (about 73%). The study observed that groundwater irrigation increased from 41% to 73% between 1983 and 2018, whereas surface water irrigation decreased from 59% to 27% for the same period in Bangladesh. The review observed that the increasing trend in groundwater dependency was higher than the surface water for irrigation purposes across the country. Hence, adequate measures should be taken for sustainable groundwater resources management.

Keywords: *Declination; Exploitation; Groundwater; Irrigation; Water table.*

Introduction: Groundwater, the foremost vital natural resources of the world that includes concerning 95% of the fresh on our planet, makes it a basic would like for human life and socio-economic development. Virtually 2 billion individuals directly take groundwater for drinking purposes.Groundwater dependent agriculture provides 40% of the world food that the role of groundwater is extremely vital in our life [1]. Groundwater containing natural objects of soil, sand, and rocks is named geological formation and it can move slowly in the aquifer [2]. Groundwater is water that is below the ground surface and not exposed to the atmosphere like in ponds or lakes. The surface waters in ponds or lakes are contaminated by human activities and not sufficient for agriculture, domestic or industrial use. The groundwater aquifers area unit most typically used for domestic and agricultural functions within the country because of its accessibility and quality. People drill through the bottom rock below the surface soil and reach the groundwater reservoir from wherever the water is wired out water meeting the strain [3].

The water table may be deep or shallow and may rise or fall depending on several factors. Heavy rains or melting snow may cause the water table to rise, or heavy pumping of groundwater supplies may cause the water table to fall. Groundwater is replenished, or recharged, by rain and snowmelt that seeps down into the cracks and crevices beneath the land's surface. Due to less natural replenishment of groundwater and anthropogenic pollution people face severe water crises in different parts of the world [4].

Aquifers are typically made up of gravel, sand, sandstone, or fractured rock, like limestone. Water can move through these materials because they have large connected spaces that make them permeable. Groundwater flowing speed depends on the porosity of the soil or rock in the aquifer [5]. Water in aquifers is brought to the surface naturally through a spring or can be discharged into lakes and streams. Groundwater may also be extracted through a well drilled into the aquifer. A well is a pipe in the ground that fills with groundwater. This water can be brought to the surface by a pump. Shallow wells may go dry if the water table falls below the bottom of the well. Some wells, called artesian wells, do not want a pump because of natural pressures that force the water up and out of the well. In areas whenever material on top of the aquifer is permeable, pollutants can readily sink into groundwater supplies.

Groundwater quality is deteriorating due to many anthropogenic activities, such as septic tanks, uses of fertilizer and pesticide in agriculture, solid waste disposal from municipalities, and industries that contain heavy metal and other toxic pollutants, etc. [6-8]. Arsenic contamination level in groundwater in many parts of the world has aroused attention due to a lot of higher concentrations than that of the World Health Organization's (WHO) drinking

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water standard. This situation has become more serious in Bangladesh, India (West Bengal in particular), and Nepal in the Indo region as a result of resource pressures from growing populations moreover as surface water contamination [9-12]. As more and more people are drilling borewells to tap the source of water, the groundwater table gets lower and lower. The shallower strata may not yield enough water and also the borewell may become dry and supply less than what we have a tendency to need. The result is that the consequent borewell that is placing within the neighborhood, will go deeper than the previous one. The objective of this review is to assess groundwater exploitation and its consequences on the environment. A holistic approach to groundwater management is to be required to build sustainable water research management.

Irrigation Land and Water Uses: Almost 90 percent of consumptive water uses and about 70 percent of the global freshwater withdrawals are responsible for irrigation purposes [13]. The groundwater availability for irrigation has contributed to manifold increase in crop productivity in Bangladesh [14-16]. About 79 percent of irrigation water in Bangladesh is collected from groundwater [17]. According to the FAO 2011 report, the total water withdrawal was 35.87 km^3 in 2008 in Bangladesh. Approximately 28.48 km^3 of the total water withdrawal comes from groundwater and 7.39 km^3 from surface water [18]. Fig. 1 was drawn using FAO 2011 report, which showed that the agriculture sector is the single largest consumer of the total groundwater resources in Bangladesh. Almost 88% of the total water withdrawal is responsible for irrigation and livestock [18].

Figure 2 was constructed from BUET 2005, BADC 2003, BADC 2013, BADC 2019 and NMIDP 2001 report, presents the historical development of different types of pumps in Bangladesh [19- 23]. It shows that the number of pumps is increasing very rapidly in Bangladesh [22]. The unsustainable withdrawal of groundwater causes water table decline as well as increased water supply cost [24]. Moreover, the continuation of unsustainable groundwater withdrawal caused many shallow and hand pump tube wells exhausted during the dry season of the country.

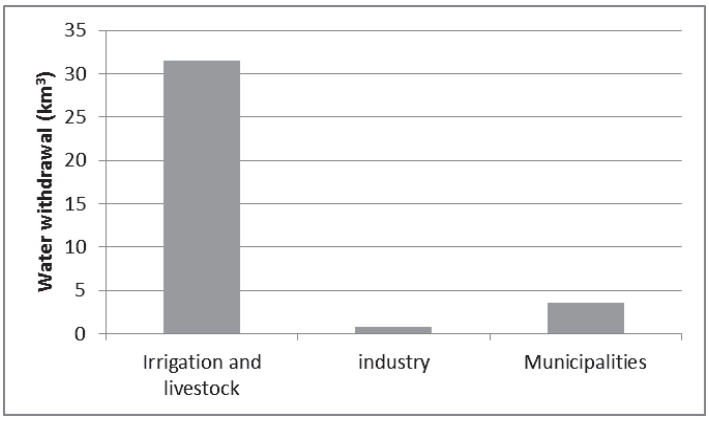

Fig. 1: Sector wise total water uses in Bangladesh.

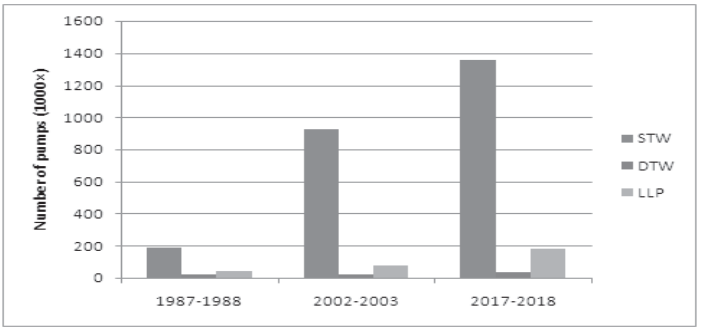

Fig. 2: Different types of water withdrawal pumps used in Bangladesh.
[DTWs: Deep Tube wells, STWs: Shallow Tube wells, LLPs: Low Lift Pumps].

Figure 3 was developed using the data sources BUET 2005, BADC 2003, and BADC 2019 report [19, 20, 22]. It shows that the groundwater extraction for irrigation purposes was higher than that of surface water in Bangladesh. Recently the dependency on surface water irrigation projects is increasing, but the rate is not encouraging yet to meet sustainable water resource management. The irrigation water use of the country mainly depends on groundwater sources (about 73.44%) [22]. Alternative water resources including rainwater harvesting, surface water resources must be considered for use in domestic, agricultural, and industrial purposes for environmental sustainability.

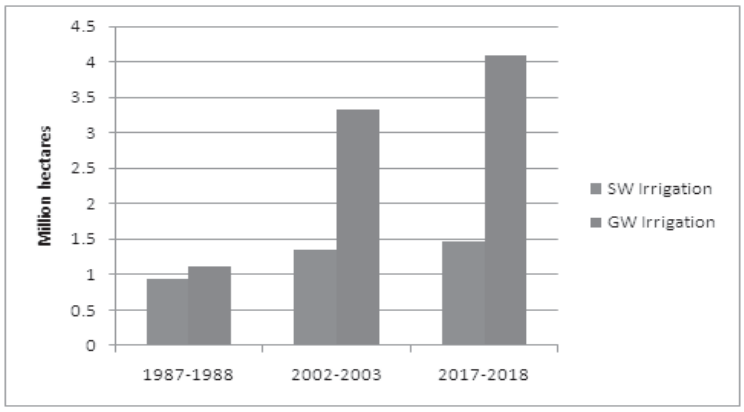

Fig. 3: Area irrigated with groundwater and surface water in Bangladesh between 1987 and 2018 [SW: Surface Water, GW: Groundwater].

According to NMIDP 2001 and BADC 2019, it was found that groundwater irrigation was increased from 41% to 73%, whereas surface water irrigation was decreased 27% from 59% in the year between 1983 and 2018 in Bangladesh (Fig. 4) [22, 23]. As a riverine country, the surface water for irrigation is not enough, and a closer look into the matter should have taken for sustainable water resource management.

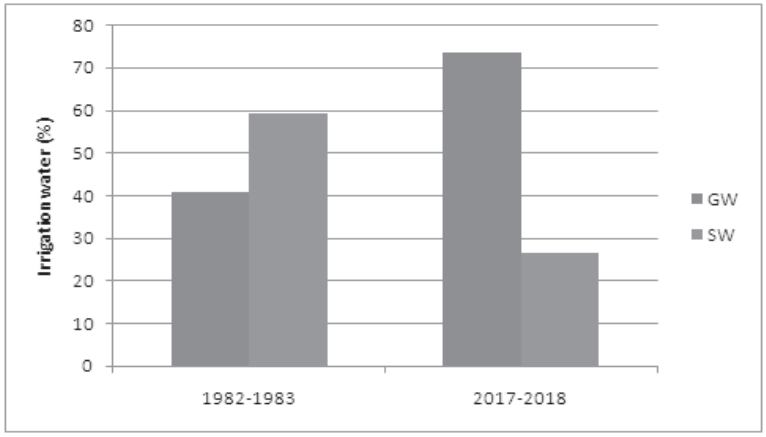

Fig. 4: Groundwater (GW) and surface water (SW) resources (%) for irrigation purposes.

The dependency of Dhaka Water Supply of Dhaka City is mainly dependent (87%) on groundwater through deep tube wells [25]. All deep tube wells withdraw water from the local underlying 140-meter thick Dupitila aquifer, which is a very productive aquifer [26].

Fig. 5 was drawn using data published in the DWASA 2000, and DWASA 2017-2018 reports showed that the drastic increasing trend of water supply quantity parallels with the number of deep tube wells in Dhaka city [25, 27]. The dependency of the water supply of Dhaka city is 87% on groundwater obtained from Dhupitila aquifer [26, 28].

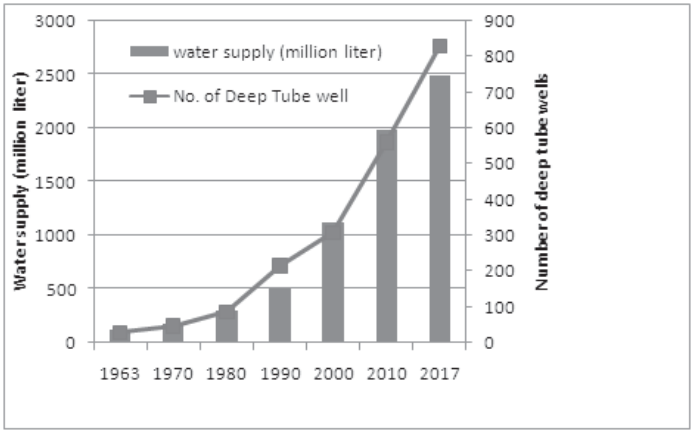

Fig. 5: Water supply and number of deep tube wells of DWASA.

Table 1 shows that water table depletion per year is 0.202 meter in Rajshahi (Tanore) and 1.78 meter in Dhaka (Lalbagh). The groundwater depletion rate in Dhaka City is much higher than that of in Rajshahi. The rapid industrialization and urbanization around Dhaka city are domain causes of groundwater depletion. But, the irrigation water extraction in Rajshahi District is the main cause of water table depletion. The study observed that the water table reached at 23.66 and 83.66-meter depth in Rajshahi District and Dhaka City, respectively, by the year 2050, if the unsustainable withdrawal of groundwater use is continuing.

It is found that groundwater is depleting due to huge withdrawal all over the Rajshahi and some areas are very critical especially the Northern part of Rajshahi. The main source of recharging of groundwater in Rajshahi is rainfall which is also reducing day by day. Average rates of maximum depth in the dry season and minimum depth in wet season groundwater depilation are 0.23 and 0.38 meter/year, respectively. The rate of declination of minimum depth is higher than that of maximum which means groundwater recharge is declining due to the withdrawal of excessive groundwater [31-35].

Table 1. Comparison of water table depth in Rajshahi District and Dhaka City.

Location	Year	Depth (meter)	depletion m/year	Simulated depth in 2050	Reference
Rajshahi (Tanore)	1985	10.30	0.202	23.66	[29]
	2009	15.36			
Dhaka (Lalbagh)	1980	1.50	1.78	83.66	[30]
	2003	42.51			

Consequences of Groundwater Overexploitation: Bangladesh requires a huge quantity of water for irrigation. The groundwater aquifers are the major sources to meet the requirement through groundwater extraction from the shallow and deep aquifers of the country. The study results showed that excess withdrawal of groundwater from these aquifers has resulted in depletion of groundwater level. The management of the water sector has become essential and radical changes towards a balance between resources and demand equation became inevitable for a continuous yield of water resources to ensure the equity of the resources of the future generation. The unsustainable groundwater withdrawal for irrigation, urbanization, and industrial purposes causes serious environmental degradation in Bangladesh. The groundwater and surface water are interrelated, so integrated water resources management should be needed. The following consequences may have occurred due to the overexploitation of groundwater in Bangladesh

- Groundwater overexploitation caused a decline in the groundwater table.
- The water table declination will increase the pump installation cost.

- Groundwater table declining may cause salinity intrusion in coastal areas.
- Land degradation may occur.

Conclusion: The groundwater availability for irrigation has contributed to manifold increase in crop productivity in Bangladesh. About 90 percent of irrigation water in Bangladesh is collected from groundwater. The unsustainable withdrawal of groundwater causes water table decline as well as increased water supply cost. Moreover, the continuation of sustainable groundwater withdrawal caused many shallow and hand pump tube wells to be exhausted during the dry season of the country. The irrigation water of the country mainly depends on groundwater sources (about 73%). The study observed that groundwater irrigation increased from 41% to 73% between 1983 and 2018, whereas surface water irrigation decreased from 59% to 27% in Bangladesh. The study illustrated that the groundwater depletion rate in Dhaka City is much higher than that of Rajshahi. The study found that the main source of recharging of groundwater depends on rainfall. Alternative water resources including rainwater harvesting, surface water must be considered for use in domestic, agricultural and industrial purposes for environmental sustainability.

References:

[1] B. L. Morris, A. R. Lawrence, P. Chilton, B. Adams, R. C. Calow, B. A. Klinck, Groundwater and Its Susceptibility to Degradation: A Global Assessment of the Problem and Options for Management, Report Series, United Nations Environment Programme, 2003.

[2] Groundwater Foundation, National Ground Water Association, Westerville OH, 2020. (Website: https://www.groundwater.org/getinformed/basics/groundwater. html#:~:text=Groundwater%20is%20the%20water%20found, sand%20and%20rocks%20called%20aquifers, last visited: 16.06.2020).

[3] A. S. Qureshi, Z. U. Ahmed, T. J. Krupnik, Groundwater Management in Bangladesh an Analysis of problems and opportunities, Cereal Systems Initiative for South Asia - Mechanization and Irrigation(CSISA-MI), USAID, Bangladesh, 2015.

[4] Groundwater Foundation, National Ground Water Association, Westerville OH, 2020.
(Website: https://www.groundwater.org/get-informed/basics/whatis.html. last visited: 16.06.2020).

[5] U.S. Geological Survey, Water Resources Division, Office of Ground Water, Sunrise Valley Dr. Reston VA, 2001.

[6] S. M. Helal, M. G. Mostafa, A. B. M. H. Haque, Evaluation of groundwater quality and its suitability for drinking purpose in Rajshahi City, Bangladesh, *Water Science & Technology: Water Supply* 11.5(2011).

[7] D. W. Moody, Sources and Extent of Groundwater Contamination. Published by: North Carolina Cooperative Extension Service. Publication Number: AG-441-4, Last Electronic Revision: March 1996 (JWM) (website:last visit: 16-6-2020).

[8] O. Schmoll, G. Howard, J. Chilton, I. Chorus, Protecting Groundwater for Health: managing the quality of drinking-water sources. WHO Drinking-water Quality Series. IWA Publishing (London) and WHO (Geneva), 2006.

[9] M. G. Mostafa, S. M. HelalUddin, A. B. M. H. Haque, Assessment of hydro-geochemistry and groundwater quality of Rajshahi City in Bangladesh, *Appl Water Sci.,* 2017, DOI 10.1007/s13201-017-0629-y.

[10] P. L. Smedley, D. G. Kinniburgh, A review of the source, behaviour and distribution of arsenic in natural waters. Appl. Geochem. 17(2002), 517–568.

[11] S. R. Kanel, HChoi, K.W. Kim, S. M. Moon, Arsenic contamination in groundwater in Nepal: a new perspective and health threat in South Asia. In: Bundschuh, J., Bhattacharya, P. &Chandrasekharam, D. (eds) Natural Arsenic in Groundwater: Occurrence, Remediation and Management. Taylor and Francis (Balkema), London, 2005, pp. 103–108.

[12] M. Mainuddin, M. Kirby, R.A.R. Chowdhury, L. Sanjida, M.H. Sarker, S. M. Shah-Newaz, Bangladesh Integrated Water Resources Assessment Supplementary Report: Land Use, Crop Production, and Irrigation Demand; Water for a Healthy Country Flagship; CSIRO: Canberra, Australia, 2014.

[13] S. Siebert, , J. Burke, J. M. Faures, K. Frenken, J. Hoogeveen, P. Döll and F. T. Portmann, Groundwater Use for Irrigation–A Global Inventory, *Hydrology and Earth System Sciences,* 14 (2010), 1863-1880.

[14] N. C. Dey, S. K. Bala, A.S. Islam, M. A. Rashid, Sustainability of Groundwater Use for Irrigation in Northwest Bangladesh, Policy Report prepared under the National Food Policy Capacity Strengthening Programme (NFPCSP). Dhaka, Bangladesh, 2013.

[15] M. U. Ahmad, M. Kirby, M.S. Islam, M.J. Hossain, M.M. Islam, Groundwater use for irrigation and its productivity: Status and opportunities for crop intensification for food security in Bangladesh. *Water Resour. Manag.* 28 (2014), 1415–1429.

[16] Banglapedia, 2015, available at: http://en.banglapedia.org/index.php?title=Irrigation, last visited on 05.03.2020.

[17] USAID, 2015, Groundwater Management in Bangladesh an Analysis of problems and opportunities, Cereal Systems Initiative for South Asia - Mechanization and Irrigation(CSISA-MI), Dhaka, Bangladesh.

[18] FAO (Food and Agricultural Organization) 2011, Irrigation in Southern and Eastern Asia in figures – AQUASTAT Survey – 2011.

[19] M. A. Hashem, Development of irrigation in Bangladesh, Institute of Water And Food Management, BUET, Dhaka, 2005.

[20] BADC (Bangladesh Agricultural Development Corporation), 2003, Survey report on irrigation equipment and irrigated area in Boro/2002 season, Ministry of Agriculture, Government of Bangladesh.

[21] BADC (Bangladesh Agricultural Development Corporation), 2013, Minor irrigation survey report 2012-2013. Bangladesh Agricultural Development Corporation, Ministry of Agriculture, Government of Bangladesh.
[22] BADC (Bangladesh Agricultural Development Corporation), 2019, Minor irrigation survey report 2017-2018. Bangladesh Agricultural Development Corporation, Ministry of Agriculture, Government of Bangladesh.
[23] NMIDP 2001, National Minor Irrigation Census (NMIC) Report, 2001, National Minor Irrigation Development Project, DAE, Dhaka.
[24] A. Jakeman, O. Barreteau, R.J. Hunt, J.D.Rinaudo, A. Ross, Integrated Groundwater Management; Springer: Berlin, Germany, 2016.
[25] DWASA (Dhaka Water Supply and Sewerage Authority), Annual Report 2017-2018, Dhaka Water Supply and Sewerage Authority, Dhaka.
[26] B. L. Morris, A. A. Seddique, K. M. Ahmed, Response of the DupiTila aquifer to intensive pumping in Dhaka, Bangladesh, *Hydrogeology Journal* 11(2003),496–503.
[27] DWASA (Dhaka Water Supply and Sewerage Authority) 2000, Management information report for the month of November 2000. DWASA, Dhaka, Bangladesh.
[28] K.H. Ahmed, M.K. Hasan, W.G. Burgess, J. Dottridge, P. Ravenscroft, J. J. Van Wonderen, The DupiTila aquifer of Dhaka, Bangladesh: hydraulic and hydrochemical response to intensive exploitation. In: Chilton PJ (ed) Groundwater in the urban environment: selected city profiles. AA Balkema, Rotterdam, 1999, pp 19 – 30.
[29] T. Asraf, M. H. Ali, Water-table dynamics and trend in three Upazilas of Rajshahi district (barind area), Bangladesh, *Asian Academic Research Journal of Multidisciplinary*, 2(6), 2015, 287-310.
[30] A. Zahid, A. Hossain, M. E. Uddin, F. Deeba, Groundwater Level Declining Trend in Dhaka City Aquifer, 2004, Available at: https://www.researchgate.net/publication/320532422_Groundwater_level_declining_trend_in_Dhaka_city_aquifer.
[31] M.A. Aziz, M. A. K. Majumder, M. S. Kabir, M. I. Hossain, N. M. F. Rahman, F. Rahman, S. Hosen, Groundwater Depletion with Expansion of Irrigation in Barind Tract: A Case Study of Rajshahi District of Bangladesh, *International Journal of Geology, Agriculture and Environmental Sciences, 3(1)* 2015,*32-38.*
[32] M. R. Hasan, , M. G. Mostafa and I. Matin, Effect of Rainfall On Groundwater Level Fluctuations In Chapai Nawabganj District, *International Journal of Engineering Research & Technology (IJERT)* Vol. 2 Issue 4, 2013.
[33] M. Hasanuzzaman, X. Song, D. Han, Y. Zhang, S. Hussain, Prediction of groundwater dynamics for sustainable water resource management in Bogura district, Northwest Bangladesh. *Water* 9(2017), 238.
[34] M.R. Hasan, M.G. Mostafa, N. Rahman, M. S. Islam and M. M. Islam, Groundwater Depletion and its Sustainable Management in Barind Tract of Bangladesh, *Research Journal of Environmental Sciences*, 12(2018) 247-255.
[35] G.F. Pinder, Groundwater Hydrology in 2050. In Toward a Sustainable Water Future: Visions for 2050; ASCE: Preston, WV, USA, 2012, pp. 277–287.