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Futuristic Policies Reviewing Groundwater Depletion at North-East India: A Conceptual Study

Sarmah Gowal Ranu [a++*] and Sarma Arnab [a#]

[a] *Department of Civil Engg., the Assam Royal, Global University, Guwahati, Assam-781035, India.*

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Groundwater a very vital natural resource for human use and for irrigating crops. India is world's largest user of groundwater, but because of diversities in geomorphological and meteorological aspects, both abstraction and depletion of ground water varies state wise. The food habit and crop yield varies in terrains and valleys with strength of population and no uniform formula can exist throughout the country for assessing the depletion. Depletion however is a continuous process as groundwater recharge is also not uniform. Scenario decrees that within few decades we will land up in a crisis if we fail to create and develop a sustainable policy to reduce depletion or rather fail to recharge our aquifers. In this paper the authors intend to impress more use of satellite-based data and remote sensing technologies to near- accurate assessment of the gap between depletion and recharge of groundwater and reduce the non- renewable groundwater. Referring to various random literature and recent UN data base the authors attempt to impress about the necessary relation between the interface of science and that of policies which can control misuse for a sustainable future.

[++] *Research Scholar;*
[#] *Prof. & Head;*
**Corresponding author: Email: sarmahranu@gmail.com;*

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1. INTRODUCTION

Major parts of the basin of the international river Brahmaputra engulfs the states at the north eastern part of India viz. Assam, Arunachal Pradesh, Meghalaya, Nagaland etc. along with some parts in the basin of Barak. The area inundated by the river Brahmaputra during flood seasons have wetlands and swamps in abundance. The natural basins in this area retain floodwater and contain variety of flora and fauna. The areas of basins are reducing over time due to accumulation of deposits, reduction in depth of wetlands, blockage of feeder channels, construction of roads, embankments and habitation structures. At the same time, it is a fact that Assam amongst other north eastern states has the highest groundwater potential. Even then the north eastern states often suffer from water shortages in dry seasons due to lesser retention of water due to rapid runoff during monsoon (rainy season) because of the topographic formations as well as drying up of springs and streams during non-rainy seasons. The subsurface groundwater when used in surface irrigation causes depletion in water resources due to partial over irrigation, evapotranspiration etc. and demands planned cropping to ensure minimization of depletion. A thorough study on environmental flow requirements, cost benefit analysis and incentives are very significant to establish the positive socio-economic impact. Studies reveal that out of total withdrawal of approximately 9.9 cubic Kilometers from Brahmaputra, 81% accounts for irrigation, 10% for domestic and 9% for industrial use. An estimated 3% of total utilizable water resources in Brahmaputra basin are lost in evapo-transportation causing depletion (Mahanta, 2006).

According to medium projection of population of India considered as 1.64 billion by 2050, the projected food grain requirement for northeast population at a rate of 500 grams per capita per day is likely to be in the order 16 million ton for 80 million people by 2050 and the corresponding water demand needs to be assessed in a manner for which proper fortitude of sustainable policies are a must (Namrata Chindarkar, 2019; Meha et al., 2021; United Nations, 2022). There are several factors like ongoing depletion of groundwater due to rapid urbanization, huge hydropower potential in North east, future demands of yielding water intensive crops, unforeseen effects of climate change (due to warming all over the globe). This paper attempts to highlight some directions which can pave the roadmap for sustainable future policies. The imbalances between unplanned extractions of groundwater, unhappening of equivalent recharge potential etc. raises a query whether the remnant water resources will be able to meet with the possible demands of its usage or scarcity will be unavoidable to make all ends meet. Probably the later only will be true.

2. REVIEW OF LITERATURE

Available information about the resources at North East India along with relations between its natural resources, environment and water in the Study Report by IIT Guwahati is one of the first such kind of documentation on all aspects related to water resources in North East. These report states in details about future water demands, possible short falls with tables and data and indicates the need for sustainable policies along with mentioning the technical and engineering challenges in the said aspect. Historically, carrying a colossal hydraulic and sediment volume in the Brahmaputra-Barak system (one of the highest in the world), as per Hadley Centre model, the annual average runoff in Brahmaputra is speculated to decline by 14% by the year 2050 even after considering melting of ice from the Himalayan glaciers. The essentiality for improvement in assessment and monitoring of flow has been stressed upon in the report by identification of critical gaps in the knowledge base. The importance of online data system with help of satellite and remote sensing technology using Geographical Information system & considering climate change impacts has been highlighted for hydrological and meteorological information apart from flood forecasting. The future geophysical, biological and socio-economic changes will be mapped and a holistic approach aiming to integrate objectives like improved forecasting, minimization of hazards, conservation of natural resources, watershed protection and carbon sequestration will need to be adopted (Mahanta, 2006).

R. K. Mall et al. examined the possible opportunities (2006) for maintainable expansion of water at surface along with groundwater reserves considering the restraints imposed by changes in climate and assessed the necessity of research at India in future. Various researches done in many places in the world indicate that variation in macroclimate is certainly going to impact the obtainability of resources of freshwater, significantly. Aquatic Requirement India, has already amplified manifold through the years due to over-urbanization, expansion in agricultural needs, growing population, fast industrialization and financial progress etc. The cycle of hydrology in many river basin regions in India with varied climate zones in recent time has undergone gradual changes along with modification in the land-use plans and patterns in cropping. Also, the irrigation and drainage got modified and caused over-abuse of stored water storage. The unavoidable anticipated effects of climate variation and its capriciousness are also critical and is required to be assessed correctly for arriving the at long-term regional strategies for sustainable development.

There are two ways of looking at the resource of groundwater which can be categorized as static resources (aquifer) and dynamic resources (replenished annually). The static and dynamic resource in India is assessed as 10812 Billion Cu.M and 432 Billion Cu, M respectively (Mall, et al., 2006). During the period from 1951 to 2050, decline in per capita annual average availability of freshwater in comparison with population growth indicates (Fig. 1) the effect on water resources. As a result, availability of water is bound to reach critical levels sooner or later. Fall in levels of groundwater contribute in danger of extinction of groundwater. Unfortunately, level of water has gone much deeper beyond a level of economic lifting and pumping. Upsurge in evaporation and wetness in soil happens during summer and monsoon on yearly basis. More accuracy on relationship between 'damage from flood' and 'damage out of drought' is to be ascertained with periodical updates for improved quantifiable calculation due to effect of changes in climate. This critically holds good for areas where fast socio-economic growths are ongoing (Mall, et al., 2006).

Rodell et al. observed (2009) that groundwater being the primary source of fresh water, although much attention was not given for regional assessment of the rate of depletion of groundwater in North East India, consumption of groundwater has been much more than what is naturally recharged and such fast consumption including considerable wastage causes irreversible decline in water table. The authors mentioned about observations by NASA's GRACE (Gravity Recovery and Climate Experiment) satellite during August 2002 to October 2008 (their period of study) indicating that groundwater depletion in India is in the order of loss of 109 km3 of water, in highest range (Fig.2) highest although rainfall was almost normal annually during that period. In the observed decline in total water levels contribution from other terrestrial components like surface waters, glaciers, soil moisture, snow, biomass did not have much of significant contribution. Radars and radiometers earlier had the limitation of measuring atmospheric and near-surface phenomena, whereas observations from GRACE could sense water stored at all levels, including ground- water. As per traditional concept the groundwater dynamics responds faster in near surface components of earthly water cycle, whereas the retaliation is slower to meteorological conditions (1988, Changnon et al.). Recovery of groundwater to its state of dynamic equilibrium (dynamic) from perturbations is slower. North East India is no exception from the world for this particular matter of concern due to its varied geophysical and meteorological conditions (Rodell et al., 2009).

Wada et al. assessed (2010) widespread long-time groundwater depletion for when abstraction of groundwater du7e to over exploitation surpasses the naturally occurring recharge of groundwater. The increase in global groundwater depletion in totality in arid to sub-humid areas was estimated as 283 (±40) km3 per year in 2000 (including 0.8 (±0.1) mm sea-level rise per year) against 126 (±32) km3 per year in 1960. GGIS (Global Groundwater Information System), a global wholistic base of data for ground-water resources was compiled internationally and recorded for estimation of abstraction of groundwater by IGRAC (The International Groundwater Resources Assessment Centre), based on prevailing statistics with index year 2000. In this report region-wise notional depletion per country were accredited using map of geological and physical features of the globe for respective regions. The estimated total global groundwater abstraction for the year 2000 was 734 (±82) km3 per annum. While down-scaling groundwater depletion to a 0.5°×0.5° resolution from global map total water in a year, large abstraction rates in India is seen. The total water demand is calculated from domestic, irrigation, and industrial water demand, keeping aside large aquifer systems (Wada et al., 2010).

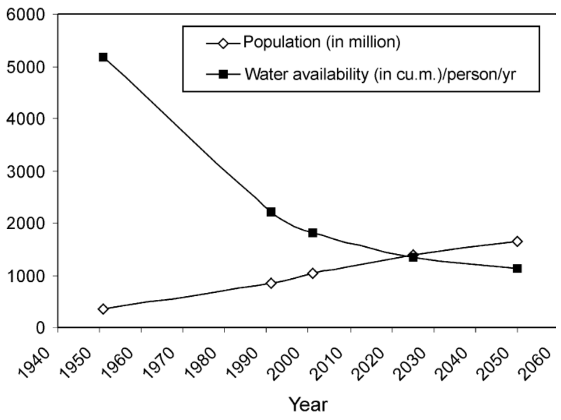

Fig. 1. Decline in per capita average annual freshwater availability vs. population rise (1951-2050)
(*Source: Ministry of Water Resources, Govt of India,2003*)

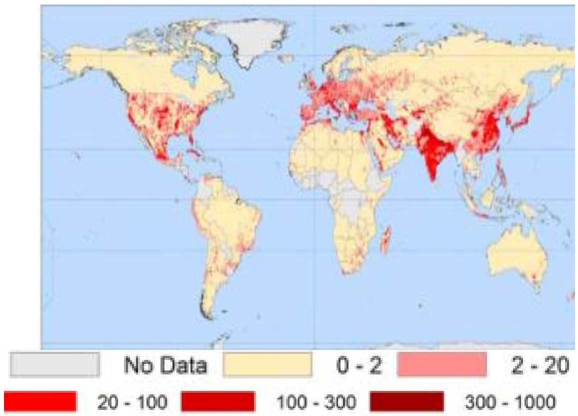

Fig. 2. Total worldwide Groundwater abstraction for 2000 in mm /annum
(*Source: Alcamo et al., 2000*)

Gleeson et al. (2012) disclosed water equilibrium of global aquifers from their groundwater footprint. There still remains lots of dearth of clarity as to how the momentum of depletion of global groundwater is comparable with the supply required to back global eco-scenario and pace of natural renewal thereof. Groundwater footprint is demarcated as the area required for maintainable use of groundwater and dependent ecosystem services. The footprints especially in Asia and North America shows that anthropogenic overexploitation of groundwater happened in many large aquifers, which are essentially critical to agriculture. Groundwater-dependent ecosystems and/or Groundwater resources are under threat in area where 1.7 billion people live and global groundwater footprint's estimated size is about 3.5 times the actual area of aquifers. That said, the net global value of groundwater footprint is governed by a few heavily overexploited aquifers because 80% of aquifers have footprint, which is less than their area. Groundwater footprint eventually is the first such suitable tool for gauging consistent use, renewal and requirement of groundwater at an aquifer scale for its ecosystem. Combining this with water footprint and virtual water calculations can be used to evaluate the capacity for cumulative yields in agriculture with renewable groundwater (Bierkens, et al., 2019; Mays, 2013; Aeschbach-Hertig, 2012). The technique could be altered to assess other resources (such as fisheries, forestry or soil) with slower renewal rates and spatially heterogeneous in nature (Tom et al., 2012).

Chinnasamy et. al. first (2015) investigated behaviour of recharge and discharge of groundwater in various agro-climatic zones in western India relating to the characteristics of climate (arid vis-à-vis humid) and hydro-geological characteristics (well drained soils vis-à-vis flooding). It was observed that effective framework and ways to measure sustainability of groundwater is absent. It was observed to be a multifaceted problem termed "misfortune of the commons". Future researchers were advised to explore remote sensing datasets, precisely (Pennan, et al., 2015).

Bierkens et al. reviewed (2019) groundwater depletion along with urban use of groundwater by populated megacities, economic development amplified the mandate for cooking and drinking need. The state-of-the-art of research related to use non- renewable groundwater differentiates it from fossil groundwater from the point of view of hydrological analysis. The groundwater which cannot be renewed termed as Non-renewable groundwater is that proportion abstracted from the aquifers and not likely to be replenished during human time scales. Fossil groundwater relates to the component of a certain time (the time that has passed since a drop of groundwater has recharged) that outstrip human history. In a human time, scale of 100 years the extraction of groundwater is not likely to be replenished for the current set of generations, which essentially means Groundwater is non-renewable. These authors overviewed methods to estimate groundwater deletion, the adverse impacts of depletion of groundwater in the perspective of hydro economics. Some direction on future research was suggested for the challenges. The uncertainties in depletion rates and non-renewability were focused (Marc et al., 2019).

Chindarkar et al. analysed (2018) transforming the science and technology related to controlling India's ongoing reduction of groundwater into policies to be followed by people mainly by grouping feeder separation. They mentioned about Jyotigram Yojana (JGY) scheme, introduced in Gujarat which provides rationed water supply to farmers unrationed power supply to non-agricultural users. Effect on this scheme on assessment of groundwater storage drawing a relationship between the distance from the soil surface to the groundwater aquifer was reported to be studied for the first time (Namrata, 2019).

Jain Meha et al. re-emphasized (2021) groundwater depletion to appear as a threat to global food security and pointed out lack of proper accurate quantification and scientific adoption strategies. They used high-resolution satellite and census data for India's groundwater status, which in fact is the largest consumer in the world. Studies suggest that, cropping intensity may decline by 20% nationwide in the scenario of current depletion trends. It is already established that canal irrigation is not a substitute to Groundwater. So, in the face of groundwater depletion, secondary ancillary strategic policies are needed to be adopted to perpetuate status quo in the levels in yield of crop generation (Meha et al., 2021).

The most recent United Nations World Water Development Report (2022), which was released by UNESCO on behalf of UN-Water, highlights the necessity of managing groundwater responsibly and declares once more the immense potential of this resource. Groundwater, which makes up 99 percent of Earth's liquid freshwater, has enormous potential to assist societies in social, economic, and environmental ways. About 25% of all water extracted is used for irrigation, and groundwater already supplies half of the amount of water extracted for domestic use by the world's population. This includes drinking water for the great majority of villagers who do not yet have access to public or private supply systems. But this natural resource is frequently misunderstood, which results in its undervaluation (United Nations, 2022).

3. CONCLUSIONS

In view of the foregoing, it is opined by the authors that sustainable livelihood is dependent on agriculture, which successively is dependent on irrigation for which adequacy in groundwater is a must. More specifically the depletion of groundwater should be minimum as very often recharge is not in equilibrium with abstraction. For this reason, a considerable quantity termed as 'non- renewable' groundwater is extant, which in other words means that groundwater is depleting in a faster rate than recharges is taking place. A prominent portion of 'the remainder of the hydrological cycle' is diminishing which is being lost forever. It is high time that administrative policies should be created based on scientific facts on statistical depletion of groundwater and the policies are to be sustainably implemented with caution to preserve groundwater. This is equivalent to sort of lifeline for the human/animal and plant population. The largest extraction of groundwater in the world takes place in India. People generally believe in a wrong concept that if someone owns a land, whatever natural resource like water, fossil fuel beneath the land exists also belongs to land owner.

The concept should be otherwise. Land may be yours but groundwater belongs to mother earth and the nation. There are policies in different states with different characteristics, Government authorities charge for the electricity for pumping irrigation water. The moment one has to pay people will at least be cautious and will hesitate to waste water unnecessarily. But the rate of depletion is different from state to state due to geomorphological and meteorological changes and also variation in the electricity tariff for pumping.

It is felt water needs rationing. Every family has to get water depending on per capita consumptions prescribed by India Standard Codes depending on number of members of family. The policies so far although might have controlled some depletion and brought some awareness, it is not known whether the policies are full proof or how far has been effective. Today one cannot assure whether in 2050 we will get adequate water to live.

It can be inferred that to avoid the 'barrier effect' task force science and policies should have an acceptable interface. In fact, taking help of remote sensing technology and satellite-based data the relevant wings of Central Ground Water Board and corresponding state wings should to the extent possibly work hand in hand to ensure availability of groundwater 2050 or 2100, even after taking care of the climate change effect. It's a common experience that for unplanned urbanization, people's tendency to leave the villages and rushing to cities to find jobs compels the system to build high rise buildings and because of excessive abstraction of groundwater, many cities like Jakarta, Singapore, Mumbai and Kolkata are sinking. Land subsidence is happening which leads to uncertainty. When there is seldom any chance of recharging why should this trend continue? In this paper the authors raise this question whether we can find out a way when there is no enmity between science and policy. So public and Government both should lead a win-win situation as per as Groundwater preservation principles are concerned.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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