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ORIGINAL ARTICLE

Evaluation of Hydrogeoethics approach for sustainable management of groundwater resources in the upper Kabul sub-basin, Afghanistan

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Abstract
The upper Kabul Sub-basin is located in the Kabul River Basin. Groundwater is the main drinking water source in the upper Kabul sub-basin. Additionally, groundwater is widely used for domestic and irrigation purposes in the sub-basin. Overexploitation of groundwater in the sub-basin causes negative effects including depletion of the aquifer storage and groundwater level decline. To assure sustainability of the sub-basin determination of groundwater balance is necessary. In this study, a water balance equation was developed based on available information and physio-geographical characteristics of the study area, and it was applied for determining groundwater balance in the sub-basin. The results showed that there is a significant negative balance (− 14.75 MCM) between recharge and discharge in the sub-basin. In addition, to geoethically evaluate water and environmental issues in the upper Kabul sub-basin, an extensive online questionnaire survey was conducted with hydro-geoscientists of the Kabul residents. The survey results showed that all respondents have a good level of awareness toward groundwater and environmental issues. Moreover, the survey results indicated that the respondents are very worried about water shortage and groundwater pollution in the study area, however, they feel medium to high respect and responsibility towards groundwater issues in the region. This was the first geoethical survey conducted in Afghanistan. This study revealed that geoethical approaches can significantly help towards awareness of Afghan hydro-geoscientists on geoethics-related issues and efficient water resources management in the Kabul Basin.

Keywords Water balance · Geoethics approach · Questionnaire survey · Kabul aquifer

Introduction

Groundwater is considered a precious resource, commonly destined for drinking uses, particularly in areas affected by surface water scarcity. However, the growing needs of the agricultural and manufacturing sectors led to an overexploitation of the resource resulting in many negative consequences such as lowering groundwater table and subsidence phenomena. Quantification of the rate of groundwater recharge is a basic prerequisite for efficient groundwater resource management (Sophocleous 1991).

Many approaches are used to assess the rate of groundwater recharge i.g. Darcian approach, soil water balance, groundwater level fluctuation method (Kumar 2012). Assessment of groundwater recharge from rainfall is an integral part of hydrology and hydrogeology. Groundwater balance equation is significant to estimate groundwater recharge. Estimation of groundwater balance of an area requires estimation of all individual inflows to and outflows from a groundwater system and change in groundwater storage over a given period of time (Kumar 2012).

BGR in 2005 and JICA between 2006 and 2008 conducted groundwater balance and potential for the whole Kabul Basin. Their studies indicate that there is a negative balance between recharge and discharge of groundwater in Kabul Bain (Houben et al. 2009; JICA 2009, 2011).

Geoethics is the study and promotion of the evaluation and protection of the geosphere (Peppoloni and Capua 2012). Geoethics is a relatively new branch of the geosciences. However, the development of an ethical thinking towards the Earth system has been developed since a very long time, also as a philosophical reflection in different cultures (Peppoloni et al. 2017), especially in environmental

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ethics and sustainability ethics (Du Pisani 2006; Theodossiou et al. 2011; Bohle et al. 2019).

Geoethics aims to provide a framework of values within which geoscientists can act in a responsible way within the profession while serving society. Geoethics becomes a common way of thinking about the Earth in a sustainable way. Geoethics can provide new comprehension of geosciences as tools for better understanding and management of the Earth. Earth scientists can no longer ignore the impact of their science on the societal and political realm, and society can no longer ignore the role of the Earth sciences in today's world. Increasingly, Earth scientists face considerations of an ethical nature; yet our formal education typically does not address such issues in systematic way (Ryan and Bank 2017). Therefore, to assure a sustainable life, the people need to respect the Earth system as ethical responsibility as much as they can.

Ryan and Bank (2017) conducted an online survey similar to this study to address three questions regarding the awareness of Canadian Earth scientists on geoethics-related issues. They distributed the questionnaire to a variety of geoscience groups and received 123 responses (a small sample size of geoscientists) from government, mining and exploration, petroleum, environmental, teaching and research areas. They found two geoethical-related issues with very strong support to be worth further consideration: health/safety and honest reporting. Also they found that informal activities like reading and discussions with peers are the most frequent avenues into geoethics and the Canadian geoscience community and public must be made aware of geoethical issues and to begin discussions around such issues. The authors claimed that although the survey was restricted to Canada, it can provide a glimpse into the larger geoscience community. Another questionnaire survey in title of "Geoethics in the Geosciences" has been created by International Association for Promoting Geoethics (IAPG). This questionnaire is an initiative of the IAPG, partially funded by the IUGS—International Union of Geological Sciences. They addressed this questionnaire to all members of the geoscience community, and are promoting it through the web channels of the IAPG and partner organisations, to assure wide international participation. The goal of this questionnaire is to understand how much the geoscience community is aware of the importance of the ethical and social aspects of geoscience research and practice (Peppoloni and Capua 2020).

The main objective of this study is to assess groundwater balance and potential of the upper Kabul sub-basin and evaluate the importance of hydrogeoethics approaches on efficient groundwater management in the Kabul Basin through conducting an online questionnaire survey.

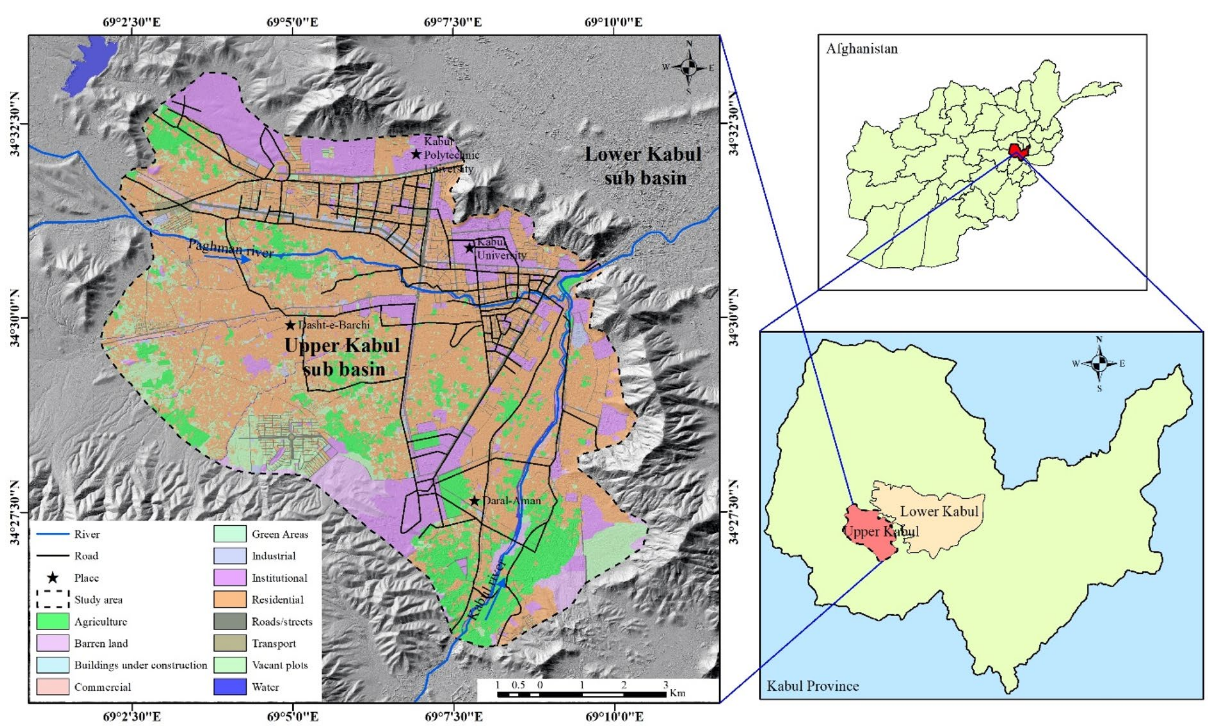

Fig. 1 Location of the study area

Table 1 Summarized data set used in this study

Data	Year	Source
Groundwater level	2008–2018	MEW, JICA (JICA-JI 2009,2011)
Characteristics of aquifer transmissibility and effective porosity, storage coefficient	2005, 2010	BGR, JICA (Houben et al. 2009)
Hydraulic conductivity	Different years	DACAAR, MEW, MRRD, BGR & private companies (Hassan Saffi 2011; Houben et al. 2009)
River flow	2008–2018	MEW
Precipitation and temperature	2018	MEW, AMD
Shallow aquifer thickness	Different years	MEW, MoMP, JICA,USGS, BGR, AUWSSC, LM (Houben et al. 2009; Mack et al 2010, JICA 2011)

JICA Japan International Cooperation Agency, *DACAAR* Danish Committee for Aid to Afghan Refugees, *MEW* Ministry of Energy and Water, *MRRD* Ministry of Rural Rehabilitation and Development, *NSIA* National Statistics and Information Authority, *USGS* United State Geological Survey, *LM* Landell Mills, *BGR* Federal Institute for Geosciences and Natural Resources, *MoMP* Ministry of Mines and Petroleum, *AMD* Afghanistan Meteorological Department, *AUWSSC* Afghanistan Urban Water Supply and Sewerage Corporation

Study area

The study area is located between longitudes (E) 34° 27′ 30″ and 34° 32′ 00′ and latitudes (N) 69° 4′ 30″ and 69° 9′ 30″, covering an estimated area of about 158 km^2 (Fig. 1). Administratively, the study area is located in Kabul Province. Topographically, the study area is classified as a semi-flat area. The study area is surrounded by low, but quite steep mountain ranges. This is called a barrier mountain range. Two rivers including the Paghman River and Maidan River flow in this area (Mack et al. 2010). Paghman River joins to Maidan River in the western part of Kabul City before entering to Central Kabul. The unconfined aquifer area of the upper Kabul sub-basin is around 89 km^2 (Broshears 2005).

Materials and methods

To carry out this study, metrological and hydrological data such as monthly precipitation, runoff, monthly temperature, and also hydrogeological data including hydraulic conductivity, storage coefficient, and transmissivity of the aquifer, were collected from governmental and private organizations. The data used in this study has been obtained from many reports and documents from 2008 to 2018 (Table 1).

All suggested equations in the previous studies have been proposed based on the site conditions and availability of information for study areas (Kumar 2012). We developed a water balance equation based on available information and physio-geographical characteristics of the study area, and it was applied for determining groundwater balance in the sub-basin. The basis of this equation is a model which was developed by Maurya (2017) for Pindra Block Varanasi, India. The general equation for balance is as below:

$$\sum Q_{\text{in}} - \sum Q_{\text{out}} = \text{change in storage.} \tag{1}$$

where:
Q_{in}: recharge parameters.
Q_{out}: discharge parameters.

The below equation has been modified and applied for the calculation groundwater balance of the sub-basin.

$$R_{\text{f}} + R_{\text{r}} + R_{\text{q}} + R_{\text{g}} = Q_{\text{pop}} + Q_{\text{g}} + Q_{\text{out}} + \Delta S \tag{2}$$

where:
R_{f}: recharge from rainfall.
R_{r}: recharge from river seepage.
R_{q}: recharge from Qargha lake.
R_{g}: recharge from green spaces.
Q_{pop}: discharge for urban purposes.
Q_{g}: discharge for green land.
Q_{out}: subsurface outflow.
ΔS: change in storage.

Table 2 Percent of respondents upon education, age and relevant field

Education		Age		Relevant to water	
Class/ degree	%	Class	%	Class	%
< 12	0	18–25	33.9	Yes	79.53
12	11.11	25–35	49.1		
Bachelor	54.97	35–45	15.2	No	20.47
Master	28.65	> 45	1.8		
PhD	5.26				

Table 3 Recharge and discharge parameters in upper Kabul sub-basin for 2018

Parameter	Symbol	Value (MCM*/year)	Parameter	Symbol	Value (MCM/year)
Rainfall	R_f	7.80	Urban purposes	Q_{pop}	22.6
river seepage	R_r	3.264	Green land	Q_g	2.8
Qargha lake	R_q	0.107	Subsurface outflow	Q_{out}	0.34
green land	R_g	N.A	Total discharge		25.74
Total recharge		11.17			

*MCM million cubic meter

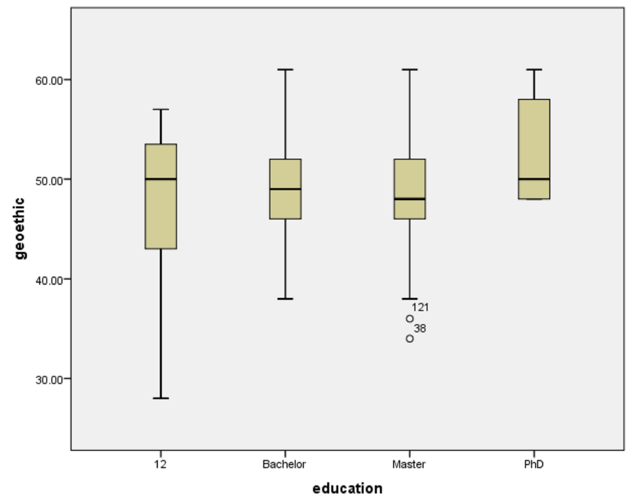

Fig. 2 Geoethic distribution in terms of education

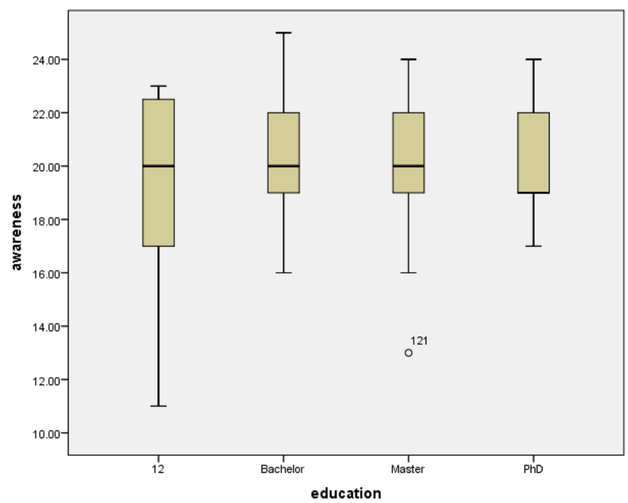

Fig. 3 Awareness distribution in terms of education

All above parameters have been calculated separately based on the collected information and available equations in the literatures and finally, groundwater balance has been calculated for the study area.

To geoethically evaluate water and environmental issues in Kabul Basin, we developed a questionnaire for distribution to the Kabul hydro-geoscience community. We conducted an online questionnaire survey with hydro-geoscientists of the Kabul residents. The questionnaire included 13 multiple choices questions which asked about seven geoethics criteria such as awareness, safekeeping, responsibility, media, importance, respect, contribution. After completion of data collection, statistical analysis was performed using SPSS software. The number of respondents in this survey were 171 persons in which 79.50% of them have either field of study or work field related water issues. The survey was conducted in August 2020, and all the respondents were undergraduate and graduate degree. The information about respondents is presented in Table 2.

Since our target people for the questionnaire survey was hydro-geoscience community, there is no necessity to distribute the questionnaire throughout the public population of the study area. On the other hand, there is no reliable data about the total numbers of hydro-geoscientists in the study area, therefore this survey was sent to a variety of hydro-geoscience groups and water-related professionals in the online form, in an attempt to get a cross-section of different education level and also vary in ages.

We received 171 responses from educated individuals studying or working in a variety of geoscience concentrations (related and non-related to water), and at various education level and ages. We acknowledge that these numbers of responses are a small sample size and not high. However, it should be noted that these responses do represent a cross-section of hydro-geoscience community with respect to education level and age.

Results and discussion

The recharge and discharge parameters of the balance equation were determined and summarized in Table 3. The amount change in storage for the upper Kabul sub-basin was calculated as follow:

$$\Delta S = \sum Q_{\text{in}} - \sum Q_{\text{out}} = 11.17 - 25.74 = -14.57\text{MCM/year}.$$

The result calculation showed that there is a significant negative balance (− 14.75 MCM) between recharge and discharge in the sub-basin. Therefore, an immediate action is required for better groundwater resources management in the sub-basin.

Groundwater is the main source of drinking, irrigation and industrial usage in the basin. Currently, most of the people in the Kabul Basin are digging and drilling more and more wells in Kabul Basin and it becomes typical that every house has deepwater well in the next future. Extraction of groundwater is being carried out without any ethical considerations irrespective of any attention to the effects that the new well might have on the yields of existing wells in the vicinity. This unmoral approach requires to be changed into a geoethical approach, so people should believe that groundwater resources are decreasing and they should have commitment regarding groundwater exploitation. In addition, in the Kabul Basin people do not care about groundwater pollution. They are drilling absorption sewage wells in their ownerships, while the sewage wells are one of the main sources for increasing groundwater pollution. Since geoethical approaches are important for water resources management in any regions, we conducted an online questionnaire survey. The results of the survey are analysed as follows:

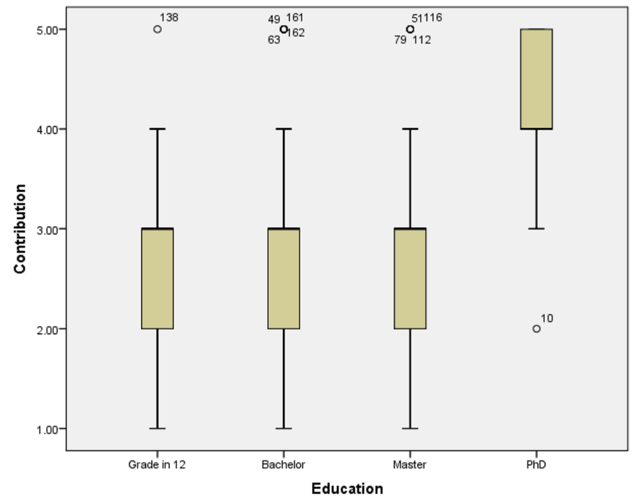

Fig. 4 Contribution distribution in terms of education

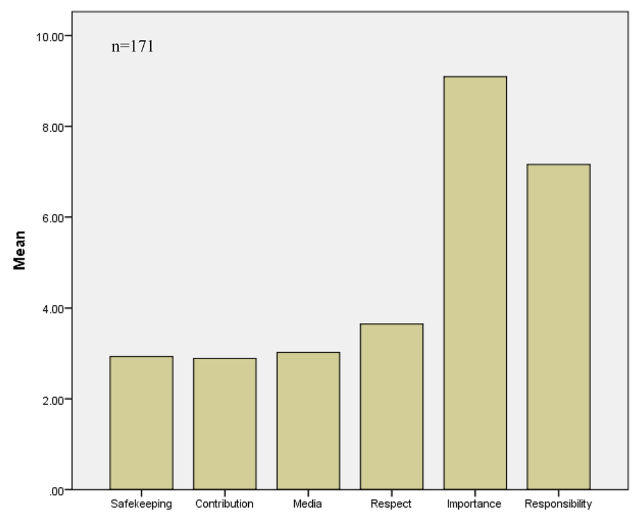

Fig. 5 Geoethics mean distribution in terms of all 6 criteria

Figure 2 shows the distribution of geoethical approach in terms of education. As it can be inferred the mean of geoethical approach in all education categories is about 48.90 which mean that respondents have a fair and respectable level of geoethical approach toward groundwater issues. Although respondents with PhD show a higher and coherent level of geoethical approach and respondents with 12 grade show incoherent and lower from 28.00 up to 57.00 while respondents with master's or bachelor's degree have almost the same distribution.

The mean of geoethical approach for respondents with a relevant field is 49.73 and it is 45.74 for respondents with an irrelevant field which shows no significant difference between these two respondents categorizes.

Figure 3 summarizes the awareness distribution in terms of education. The mean of awareness as one of the geoethical criteria is equal to 20.00 which indicates the before awareness of respondents is at a good level.

According to Fig. 4, the mean of contribution in groundwater management among 12 grade, Bachelor's and Master's respondents is 2.8 which states their contribution is below the average while the mean of this criteria among PhD respondents is 4 which states their contribution is higher.

Figure 5 shows the mean of each geoethics criteria including safekeeping, contribution and media role are around 3 which means geoethical approach regarding these criteria is in a moderate level among all respondents. In addition, this figure shows that the respondents are extremely worried about groundwater shortage and pollution of groundwater, but they feel medium to high respect and responsibility toward groundwater issues in the study area.

The respondents were divided into two categories: the respondents with relevant field of study or work in water sectors and the respondents with irrelevant field. But both categories at all levels of the education shown the same level of geoethical approach toward groundwater which was evaluated well and above average. The results show that there is a good awareness of groundwater quality and quantity and general agreement about the importance of geoethical considerations among the responding Afghan hydro-geoscientists. The results represent that PhD degrees showed a higher level of contribution in saving groundwater. Therefore, it reveals that higher educated people can lead to geoethical approaches with respect to sustainable groundwater management. The results show that all respondents indicate a medium level of geoethics approach in each of the criteria including safekeeping, contribution and respect to other's rights regarding water. They also assessed the average rating for the media role in culture building toward water saving.

However, the results show that respondents were in the highest level of concern about shortage and pollution of groundwater; surprisingly they show an average level of contribution and responsibility. Therefore, working more on the above criteria and also commitment of the society regarding groundwater is required to be considered in schools, media and families.

Conclusion and recommendation

Nowadays, the most important problem is decreasing water quantity and deteriorating groundwater quality due to increasing population and over-exploitation in major cities around the world. In the Kabul Basin, groundwater is the main source for drinking, irrigation and industrial usage. In recent years, many deep wells were drilled in the Kabul basin aquifer and groundwater is extracting without any ethical and sustainable considerations. The sustainable and effective management of natural groundwater resources in semi-arid like Kabul Basin requires a detailed understanding of the regional hydrological and hydrogeological processes. A water balance equation was developed based on available information and physio-geographical conditions of the study area, and it was applied for determining groundwater balance in the sub-basin. The results indicated that there is a significant negative balance (− 14.75 MCM) between recharge and discharge in the upper Kabul sub-basin. It means that the water table declines around 1.2 m per year in the aquifer.

An extensive online questionnaire survey was conducted in August 2020, to geoethically evaluate water and environmental issues in the upper Kabul sub-basin. This survey was the first geoethical survey conducted in Afghanistan with hydro-geoscientists of the Kabul residents. In this survey, the questionnaire contained 13 multiple choice questions asked about seven geoethics criteria. In this survey, the number of respondents were 171 hydro-geoscientists. The survey results indicated that there is a good awareness and general agreement about the importance of geoethical approaches in effective water resources management among the Afghan hydro-geoscientists and they are extremely worried about water shortage and environmental issues in Kabul city. However, they feel medium to high respect and responsibility towards the water and environmental issues in the region. The survey results demonstrated that higher educated people (Ph.D. degree) highly contribute to saving water in the community than others. Since all of the participants in this survey were educated and hydro-geoscientists, so the results of the survey cannot be generalized to the whole of the society. Therefore, it is recommended to extend this survey also through uneducated people like housewives, grandparents, fathers and mothers who have the key role in water consumption.

The findings of this research suggest that the Afghan hydro-geoscience community and the public must be aware of geoethical issues and begin discussions around such issues. Effective water management requires collaboration, meaningful stakeholder participation, and community engagement. Hence, the Kabul residents need to feel more responsible for protecting and sustainable management of their water resources. Interactions between Afghan hydro-geoscientists and the media need to be improved.

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