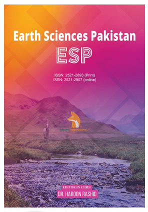
ZIBELINE INTERNATIONAL™ PUBLISHING
ISSN: 2521-2893 (Print)
ISSN: 2521-2907 (Online)
CODEN: ESPADC

Earth Sciences Pakistan (ESP)

DOI: http://doi.org/10.26480/esp.01.2021.33.37



CrossMark

RESEARCH ARTICLE

SURFACE AND GROUNDWATER NEXUS: MANAGEMENT OPTION IN IRRIGATED AREAS OF LOWER BARI DOAB CANAL USING MODELING APPROACH

Hafsa Muzammal[a*], Lubna Anjum[a], Muhammad Usman Farid[b]

[a]*Department of Irrigation and Drainage, University of Agriculture, Faisalabad Pakistan*
[b]*Department of Structures and Environmental Engineering, University of Agriculture, Faisalabad*
**Corresponding Email: hafzamuzammal990@gmail.com*

ARTICLE DETAILS

Article History:

Received 17 March 2021
Accepted 19 April 2021
Available online 20 April 2021

ABSTRACT

Lower Bari Doab Canal is the oldest irrigation system, however LBDC inequitably distribute the water from head to tail end. Spatial climate variability across the command area of LBDC has impact on reallocation of canal water supply and usage of irrigated water from head end to the tail end. The irrigation demand is increased with the increasing of cropping intensity due to increase of population, hence the surface water supply and rainfall do not fulfilled the crop water requirement then farmer abstracted more groundwater for fulfilled these requirement. At the tail end of LBDC, farmer extracted more water is causing groundwater mining due to lack of technical knowledge related to the management of groundwater. Now to management of this problem using simulation water balance approached from the data 2017- 2018 year. The water balance result show that total inflow in to system is 8197.13MCM from considering the parameter of recharge is 4006.278 MCM, supply from the canal is 4190.85 MCM but the total annual outflow is 18487.872 MCM from considering the parameter of evapotranspiration and groundwater abstraction. The change in water storage is (-10290.74MCM). The future scenarios result show that Scenario1: Due to climate change and uneven rainfall my cause to the now condition of groundwater and canal is not fulfill the crop water requirement. Scenario 2: Due to increase of groundwater the water table abstraction more decline at the end of the tail as compared to the head, the water abstraction falling at the 2.06m as compared to the head end 1.2m from the year 2017-2018 then it also effect on the water balance (-1131.31 MCM) to (- 12812.44). The result suggested that to manage the canal water supply, to build the storage system from saving the water at head end then to easily provide this to tail end and to avoid those crops which required more irrigation water and to use the artificial technique for the recharge of groundwater.

KEYWORDS

Water Balance, Future Prediction, GIS, LBDC

1. INTRODUCTION

Groundwater is essential human need and a critical nation source and also a significant component of the water balance. The geographical area is covered the land area 79.69 Mha out of this agricultural land area 34 Mha of Pakistan. The groundwater resource is one of the largest volume retain in the Indus plain, covering about 20 million hectares. Groundwater has played a major role in growing over 22.75 million hectares of total crop production in 2000-2001 periods then it should increase 24.01million hectare next 2009 to 2010 periods (Qureshi et al., 2003).

Consequently the world population is 5,930 million at present, it should be increased 8100 million in the year 2020, In next 50 year population is increased, also need to be increased the food production, the groundwater draw down is increased for the production of crop and maintain the yield of crop for the feed of population, the food requirement in 2020, the production need to be increased at least 35 to 45 percent, the major crops are used in Pakistan such as cotton wheat, maize, sugarcane and rice (Anonymus.,2011). (PWP., 2012) has described 59BCM of ground water drawdown for the agriculture, domestic and industrial sectors. The water requirement of domestic and industrial is fulfilled by 400 million cubic meter groundwater in Pakistan (Qureshi et al., 2010). The groundwater extracted is more than 283 Gm3year-1 in the world, because urban, agricultural and industrial water demand increase with further increased the population growth rate and irregularity of climate (Wada et al., 2010a). In last two to three decades, the surface water or precipitation is not fulfill our requirement, that's why there has been increased the exploitation of groundwater for fulfill the requirement, it has been extensive distribution, good quality used for drinking and low development costs (Wada et al., 2010a).

Groundwater management approaches should be directed to towards water balancing demand; conceptually the water balance approach is straight forward, many component of water are difficult to estimate and were not available because groundwater was hidden source that's why groundwater inflow and outflow are difficult to estimate from an area of interest. The major component of inflow precipitation ad outflow from evapotranspiration it should be determined for calculating the storage

Quick Response Code	Access this article online	
	Website: www.earthsciencespakistan.com	**DOI:** 10.26480/esp.01.2021.33.37

change of water at the earth's surface, water balance methodology used for analysis of water resource and how much water need for irrigation. With the growing demand of irrigation and competition across sectors of water use, the nation now faces the challenge of meeting more food with less requirement of water (Mollinga, 2006).

2. METHODOLOGY

2.1 Description of Study Area

Lower Bari Doab located between (the river Ravi and river Sutlaj) 73°50'42" to 72°10'50"E longitude, 32°18'56" to 30°50'42"N latitude and 640 feet altitude lies in the central Punjab. Lower Bari Doab canal was covered the cultural command area 0.7 Mha and gross command area 0.8 Mha. The lower Bari Doab Canal discharge 278m3/s off takes from left bank of Head.

Balloki barrage at River Ravi, flows from supplies water 201km of length to its distributaries. The climatic condition is semiarid, most beneficial zones of Agro climatic in Pakistan. In LBDC irrigation second largest in Punjab, command area has 65 distributaries.

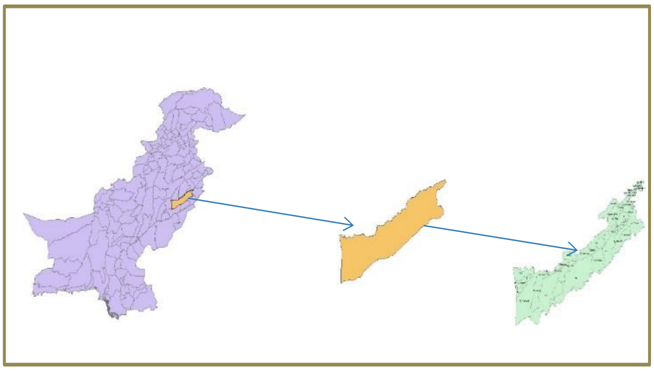


Figure 1(a): Command Area of LBDC

2.2 Population and Crop covered in Command Area

During Rabi season Wheat is occupied 59% of cultivated farmland but the Rabi fodder covered8 percent but intensity of Rice crop 61% is higher at the head end of Kasur but towards the tail end 26% and also cotton is more occupied 50 percent at the tail end but lowest covered at the head end that is show in table 4.7. These patterns of crop suggest that to used appropriate crop where the groundwater abstraction is more at the side of Khanewal. Rice take more water, however to suggest the farmer do not grow water tolerance crop, to grow the fodder, Oilseed and vegetation.

Table 1: Describes Population and Household in LBDC area

	Population	House hold
Kasur	22.16%	12.3%
Okara	72%	42.9%
Sahiwal	59.7%	34.1%
Khanewal	18.06%	10.57%

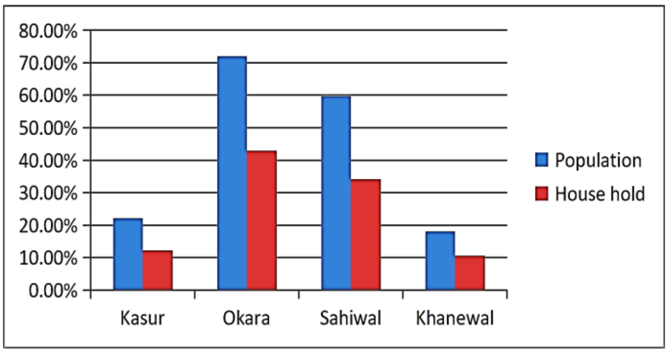


Figure 1(b): Population at the command area of LBDC

Table 2: Agricultural Area covered the command area of LBDC

Divisions	Balloki	Okara	Sahiwal	Khanewal	LBDC
CCA(ha)	86950	108423	742731	108604	1046708
	Intensities of CCA in %				
Kharif Land Use					
Rainfed	6.39	19.1	18.51	0.35	11.0875
Fodder	1.44	4.7	1.2	0.21	1.8875
Orchards	8.98	20.7	16.92	17.05	15.9125
Sugarcane		10.4	7	2.73	6.71
Rice		61.9		26.15	44.025
Cotton	30.8	42.6	56.2	50.7	45.075
Rabi Land use					
Wheat	9.8	75.7	77.17	75.7	59.5925
Orchards	0.26	11.5	8.2	8.2	7.04
Fodder	1.19	7.9	10.86	12.2	8.0375
Rainfed	0.134	4.7	3.6	3.7	3.0335

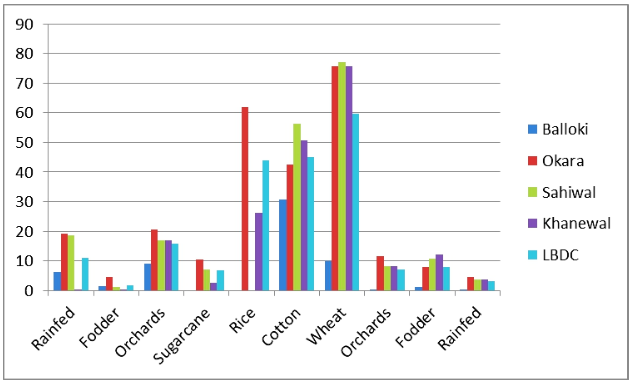


Figure 2: crop covered the CCA of LBD

3. RESULT AND DISCUSSION

3.1 Water Balance Summary

The measurement of water balance is very important for the management of groundwater, the estimation of annual average water balance during the year 2017 to 2018 from the study area of LBDC. Describe the water balance from volume of water enter in to the system and volume ofout flow from the system, then to calculate the net storage in the aquifer system of LBDC. Considering the inflow water parameters are recharge from the rainfall and canal water supplied to ground water, while the outflow parameters area abstraction of ground and actual evapotranspiration. The general equation of water balance:

Inflow - Outflow = Change in Storage

When change in storage showed in positive then this show that recharge is more than pumping, the recharge fulfilled the requirement of crop but the negative storage show that abstraction is more from the groundwater table then the recharge, the recharge do not fulfill the crop requirement then to abstract more water, if inflow is equal to outflow show that change in storage should be zero. Shakoor et al. (2018) to calculate the water balance and to predict the scenario up to 2030year. Groundwater level decline to 14m and maximum decline thegroundwater level up to 18m from the year 2030.

Table 3: Annual Estimation of water Balance in MCM

	Inflow	Out flow	Change in Storage
Recharge	4006.278015		4006.278015
Abstraction		8405.683067	-8405.683067
ET		10082.18969	-10082.18969
River	4190.85246		4190.85246
Total	8197.130476	18487.87276	-10290.74229

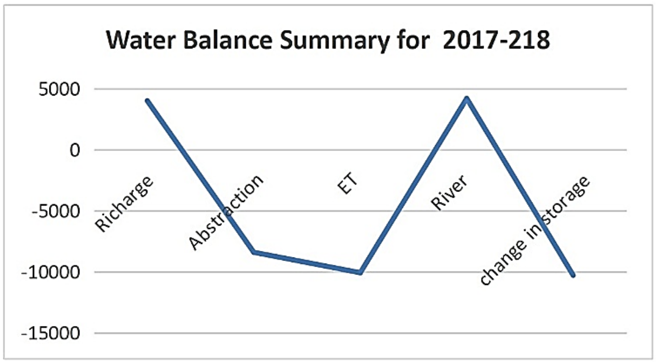


Figure 3: Water Balance summary of Command Area (MCM)

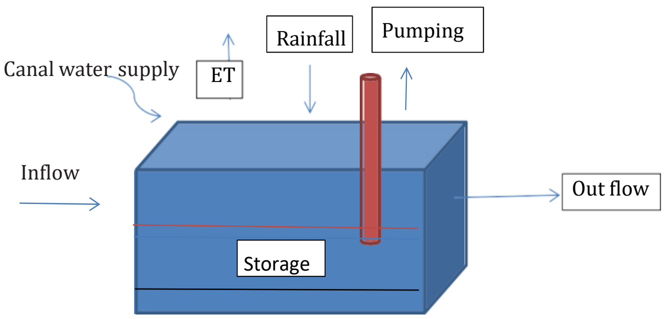


Figure 4: Conceptual Water Balance

The annual water balance was estimation from the year 2017 to 2018 at the command area of LBDC is shown in figure 4.8. According to result the outflow is more than the inflow, however water loses is more than due to groundwater recharge. The inflow value is 8197.13 MCM is less than the volume of out flow value is -18487.872MCM but the change in storage is -10290.74 MCM, the negative storage represented that volume of water more abstracted from the tube well with increased to fulfill the demand of Crop water. Khaliq (2014) described the summary of mass balance for the pumping of groundwater indicates that recharge is decrease from year 1998 to 2002.

3.2 Future Scenarios Analysis

3.2.1 To see what will happen if the same condition (BAU)

The results indicate that, the groundwater pumping and canal water supply will used at the same rate if management of groundwater are not take the action of future groundwater pumping then groundwater pumping will affect at the same rate. If the groundwater abstraction and canal supply do not change throughout the year, in year 2017 to 2018 the average seasonal groundwater abstraction 63% in Kharif and 30.7 % in Rabi. The more groundwater head at the tail end of LBDC as compared to the head end because the more groundwater abstraction at the tail ends. Canal water supply is not properly reached to the end of tail due to some loses then farmer abstract more water from the ground, then groundwater table should be decline throughout the year.

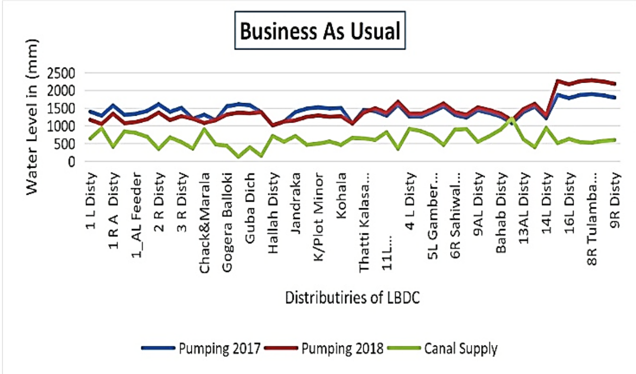


Figure 5: GW abstraction and Canal water supply are Business As Usual

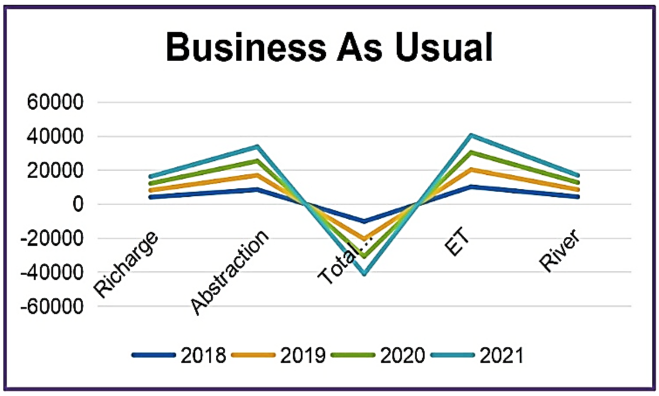


Figure 6: GW abstraction is same as Canal water Supply

3.2.2 Increased the Groundwater Abstraction with the same condition ofCanal water supply

When increased the groundwater abstraction from 10 %, 20% and 30% for the prediction of tillat year of 2021 on basis of year 2017 and 2018 but the surface water supply is same, the Average annual groundwater abstraction result show that the groundwater level is 1.4 m in year 2018, 1.6m in 2019, 1.771m in year 2020 and 1.98m in year 2021 the groundwater level is falling on 0.15m per year on average basis. The groundwater table is falling due to increasing the intensity of cropping 170 % to 190% and also increasing the intensity of population. The water tablefalling at the tail end 2.06m as compared to the head end 1.2m, however the Khanewal distributaries moved from water stress to water scarcity. At the tail end, farmer required more cost per acre for the pumping due to the deeper depth of water table.

Table 4: Annual GW abstraction increased 10% with same Canal water supply (MCM)

	Inflow	Out flow	Change in Storage
Recharge	4006.278015		4006.278015
Abstraction		9246.251374	-9246.251374
ET		10082.18969	-10082.18969
River	4190.85246		4190.85246
Total	8197.130476	19328.44107	-11131.31059

Table 5: Annual GW abstraction increased 20% with same Canal water supply (MCM)			
	Inflow	Out flow	Change in Storage
Recharge	4006.278015		4006.278015
Abstraction		10086.81968	-10086.81968
ET		10082.18969	-10082.18969
River	4190.85246		4190.85246
Total	8197.130476	20169.00938	-11971.8789

Table 6: Annual GW abstraction increased 30% with same Canal Supply (MCM)			
	Inflow	Out flow	Change in Storage
Recharge	4006.278015		4006.278015
Abstraction		10927.38799	-10927.38799
ET		10082.18969	-10082.18969
River	4190.85246		4190.85246
Total	8197.130476	21009.57768	-12812.44721

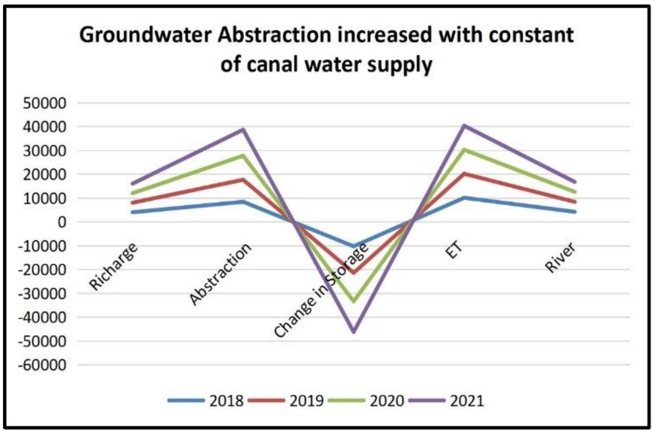


Figure 7: GW Abstraction increased with the Canal water supply (MCM)

3.2.3 Decreased Groundwater pumping with the increased of the canal watersupply

When the groundwater abstraction increased 10%, 20% and 30% combined with the increased of canal water supply is slightly reduce the abstraction from groundwater but do not stop the pumping from the groundwater and also do not sufficient to stop the out flow from the aquifer. The reducing of pumping and increasing the canal water supply seems to be only affective to reduce the draw done trend will help to favorable GW than the ones prevailing today.

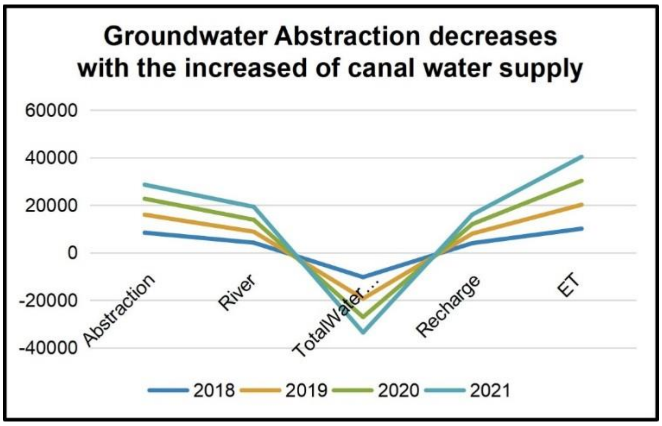


Figure 8: increased the canal water supply with Decreased the GW abstraction

Table 7: Annual GW abstractions decreased 10% with increased the Canal Supply (MCM)			
	Inflow	Out flow	Change in Storage
Recharge	4006.278015		4006.278015
Abstraction		7565.114761	-7565.114761
ET		10082.18969	-10082.18969
River	4609.937706		4609.937706
Total	8616.215722	17647.30446	-9031.088734

Table 8: Annual GW abstractions decreased 20% with increased the Canal Supply (MCM)			
	Inflow	Out flow	Change in Storage
Recharge	4006.278015		4006.278015
Abstraction		6724.546454	-6724.546454
ET		10082.18969	-10082.18969
River	5029.022952		5029.022952
Total	9035.300968	16806.73615	-7771.435181

Table 9: Annual GW abstractions decreased 30% with increased the Canal Supply (MCM)			
	Inflow	Out flow	Change in Storage
Recharge	4006.278015		4006.278015
Abstraction		5883.978147	-5883.978147
ET		10082.18969	-10082.18969
River	5448.108198		5448.108198
Total	9035.300968	16806.73615	-10290.74229

4. Conclusion

The major conclusions of this study were as below:

Annual normal rainfall decreased from head to tail end from the year 2017 to 2018, at the head end of rainfall is 619mm to the tail end is 165mm and also increased evapotranspirationin head 1602mm but in tail increased ET 2040 annually. Due to this situation framerextracted more water than decline the water table level from head 1.2m to tail 2.06m.

When calculated the water balance approached the results described that less inflow as compared to the more outflow because farmer pumping more water as compared to the recharge. The total recharge is 10038.2215Mm3 but the total outflow from the system is 18600.54 then to calculate the change in storage -8562.320 Mm3 represented that not storage in to the system.

Scenario 1: The total water storage is -11131.31059 MCM in year 2019, -11971.8789 MCM in year 2020 and -12812.44721MCM in year 2021 effected due to the increased of GW abstraction at the constant of canal water supply.

Scenario 2: when the groundwater abstraction is increased 10%, 20% and 30%, the pumping from the groundwater is also increase the water level from 1.245m to 1.61m at head end of LBDC but at the tail end groundwater pumping is from 2.08 to 2.68m from the year 2017 to 2021. The groundwater level is falling 0.15m/year due to increase of the pumping.

Scenario 3: When GW pumping is decreased with the increased of canal water supply is affected the total GW storage -9031.088734 MCM in year 2019, -7771.435181MCM in year 2020 and -6511.781628 MCM in year 2021. When to decreased the canal water supply further due to the poor management and lack of proper maintained then farmer more moveto move more ground water, thus groundwater water father decline from that situation.

Recommendation

- An integrated approach to water management (the implementation of an effective irrigation network, increased surface water supply and decreased groundwater pumping) should be developed and implemented in the canal command area.
- Waste water should be treated, then this treated water used in field.
- The underlying unconfined aquifer of the study area has massive potential to store water during the high flow of the river in the flood season and monsoon season. The shallow aquifer must be pilot project to artificially recharge the aquifer so that farmer can use this shallow groundwater to satisfy their irrigation needs.
- Climate variation around the LBDC regulation has a pernicious impact on the unequaluse of irrigation water from head to tail in the form of rising water depth at the tail end.
- Farmers should be made aware of innovative water saving technologies in order to minimize groundwater reliance and encourage a reduction in crop consumption of water. This can be achieved by adopting crops that are low in delta. They need to be made awareof the importance of groundwater, and its significance for future generations needs to be understood in order to be able to use groundwater judiciously.

References

Basharat, M. 2014. Surface Water and Groundwater Nexus : Groundwater Management Optionsfor Indus Basin Irrigation System, Institute of International Waterlogging And Salinity Research Institute (IWASRI), Lahore. Pakistan Water

Khan, S., T. Rana, M. Ullah, E. Christen and H. Ahmed. 2003. Investigating conjunctive water management options using a dynamic surface-groundwater modelling approach: a case study of Rechna Doab. Transport.

Mollinga, P. et al. 2006. Integrated Water Resources Management: Global theory, Emerging Practice and Local Needs. Water in South Asia, Volume I, SAGE Publication. Nettasana.

Power Dev. Auth. Publicatio. Khaliq, A. 2014. Modeling the Effects of Groundwater Pumping on Watertable of a Faisalabad Water Supply Scheme, PhD thesis in Agricultural engineering from uni of AgriFSD, PAK, 2014.

PWP. 2012. Supplement to the Framework for Action (FFA) for Achieving the Pakistan Water Vision 2025, Available on website: http://www.pwp.org.pk/, Visited on: 18-1-2013.

Qureshi, A.S., P.G. Mc Cornick, A. Sarwar and B.R. Sharma. 2010. Challenges and Prospects ofSustainable Groundwater Management in the Indus Basin, Pakistan. Water Resour. Manag.24, 1551–1569.

Shakoor, A., M. Arshad, R. Ahmad, Z.M. Khan, U. Qamar, H.U. Farid, M. Sultan and F. Ahmad. 2018. Development of groundwater flow model (Modflow) to simulate the escalatinggroundwater pumping in the Punjab, Pakistan. Pakistan J. Agric. Sci. 55, 635–644.

Wada, Y., L.P.H. Van Beek, C.M. Van Kempen, J.W.T.M. Reckman, S. Vasak and M.F.P. Bierkens. 2010a. Global depletion of groundwater resources. Geophys. Res. Lett. 37, 1–5.