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Research for a better Afghanistan

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Policy Note

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PhD candidate Najibullah Sadid

Surface-groundwater interaction in the Kabul region basin

Introduction

In the Kabul region, air pollution, groundwater pollution and rapid groundwater drawdowns are the major environmental concerns. Groundwater—the main water supply source for Kabul residents—has been extensively exploited in the past two decades, with groundwater levels decreasing an average of about 1m per year, and maximum drawdowns near central Kabul sub-basin boundaries of about 30m in just 14 years.

The large imbalance between groundwater extraction and recharge is the main reason for these unprecedented drawdowns. While the increasing population puts more stress on the groundwater, urbanisation has turned natural permeable surfaces to paved surfaces, reducing further the already minor contribution of regeneration from direct precipitation.

Therefore, surface waters such as rivers, streams and irrigation canals are the remaining sources for groundwater regeneration. Surface waters partly compensate for groundwater extraction in the central Kabul sub-basin, but what are the exact groundwater recharge rates? And if the densely populated central Kabul sub-basin's high groundwater demand is supplied by long-distance water supply from the neighbouring Logar, Shamali, upper Kabul/Paghman or Deh Sabz sub-basins, what are the regeneration rates from surface waters there and how can this potential be enhanced?

This policy note explores the existing groundwater recharge potentials in the five sub-basins in the Kabul region and provides policy recommendations for reviving and enhancing the available groundwater recharge potentials.

Methodology

Few studies have focused on the surface-groundwater interactions, preferring instead to concentrate on groundwater recharge in a larger scale of basin water balance. As a result, the groundwater recharge rate from rivers and streams remain mostly unknown. Therefore, in this research, groundwater recharge from rivers and streams is comprehensively studied in detail in five sub-basins of the Kabul region. In general, the study covers three important aspects:

1. Basin-scale water balance studies using recent hydro-meteorological data (2008- 2018)
2. River reach length water balance using data acquired from field measurements to determine transmission losses in rivers, streams and irrigation canals
3. Groundwater mounding (GWM) using groundwater level growth data (2004 to 2013) in wells close to rivers and streams for study of recharge rate through riverbed and banks

Key Findings

Basin-scale water balance

The basin-scale water balance revealed that water surplus and deficit vary strongly from one water year to another depending mainly on the rates of precipitation and evapotranspiration. The variation of precipitation rates is the dominant factor in the water balance, while the actual evapotranspiration rates do not vary considerably. Surplus of water is observed in years 2009, 2011 to 2014 for central Kabul, upper Kabul/Paghman, and Logar sub-basins.

The situation in the Panjshir sub-basin (Parwan and Kapisa provinces) is more promising, with water surplus throughout the 2008-2018 period. Despite expected uncertainties in rates of precipitation and evapotranspiration, the water balance analysis provided significant information about surplus and deficit of water that affects groundwater regeneration.

River reach length water balance

The river reach length water balance is conducted by measuring flow discharge at two or more locations of the rivers, streams and irrigation canals. This measurement was conducted in Maidan and Paghman rivers in upper Kabul/Paghman, Logar rivers in Logar, Shakar-Dara and Istalef rivers in Shamali and Khawja irrigation canal in Panjshir sub-basins. The resulting transmission losses reveal that riverbed and bank sediment properties are one of the main controlling parameters, namely, that rivers and streams with coarse sediments and natural banks show larger transmission losses.

Groundwater mounding

The GWM analysis is performed using the Hantush 1967 groundwater growth equation. The monthly measured groundwater level change from 2004 to 2013 for wells close to rivers and streams in all five sub-basins determines the corresponding recharge rates that can induce the observed groundwater growth. These rates show up to two orders of magnitude variations between observations made at different wells, as well as due to various river flows for the different water years (2004-2013). GWM analysis reveals good agreement between observed groundwater growth in rivers' vicinity to wells and calculated groundwater growth for a range of aquifer-specific yield values (0.01 to 0.15) and permeability rates (10 m/day to 60 m/day) naturally found for the sediments in the Kabul region aquifers. The GWM analysis shows that Logar, Maidan, Shakar-Dara and Paghamn rivers have respectively higher recharge rates per unit riverbed area compared to Deh Sabz, Kabul and Istalif rivers.

The relationship between recharge, river flow, precipitation and actual evapotranspiration (ETa) indicates that rivers are the primary driver of flow discharge in most sub-basins. At the same time, higher ETa is the main driving parameter for recharge stoppage. In Shamali and upper Kabul/Paghman sub-basins, the flow down the valleys such as Paghman, Shakar-Dara and Istalef induces a mountain-front recharge, even during summer months, despite the rivers being dry at their downstream reaches. The coarse alluvial fan sediments, with higher permeability and large groundwater level gradients downslope, allow the upstream surface water the most reaches to flow in the subsurface and contribute to groundwater recharge during summer months.

The bulk of the groundwater recharge occurs from October to May; however, Paghman, Shakar-Dara and Istalef rivers have shown extended recharge periods from September to July as a result of additional MFR.

Recommendations

To utilise the limited recharge period, policy changes in urban/town planning, river training works (RTWs), and establishing additional recharge basins for surface and subsurface recharge are suggested:

- **Urban planning/ town planning**

Kabul is a fast-growing city with an urban area expansion rate of 13.7 % between 1999 and 2008 (Ahmadi and Kajita, 2017). The expansion in urban areas is directly affecting groundwater recharge from precipitation because the areas exposed to infiltration are converted permanently to housing areas. The urban area expansion is associated with increases in paved areas of roads, streets and walkways. More importantly, urbanisation is associated with the protection of riverbanks, streambanks and drainages from erosion, which otherwise serves as natural infiltration basins. The heavily protected urban drainages convey the collected surface runoff water much faster into the Kabul River, where, after a short residence, it will leave the basin. Similarly, in the areas where the drainages have poor connectivity, the accumulated water on the surface is quickly evaporated without contributing to groundwater regeneration. The direct precipitation on the land surface may have a marginal contribution to groundwater regeneration, but the drainages collecting the water from the urban area's catchment can significantly contribute to the groundwater recharge.

The paved areas either entirely obstruct water infiltration or sharply reduce its rates. The outcome of a complete sealing of surfaces by paving is already affecting Kabul inhabitants in the form of flooding, even during very moderate precipitation for a few hours. Moreover, the accumulation of water on the surface endangers the lives and properties of people and restricts regeneration.

One strategy to cope with this kind of human-made flooding is to adapt a permeable pavement and drainage design practice that allows rainwater infiltration either through porous pavers or through gaps between impermeable blocks. The permeable pavements can be used for all roads of low traffic load and walkways. With regard to households, families should be made aware of the benefits of permeable pavements in terms of groundwater recharge and their effects on avoiding rainwater accumulation flooding. The permeable pavement and drainage practice should be applied to all future projects of Kabul city's expansion, as well as to those existing places requiring replacement or repair.

- **Adaptation of permeable river training works**

River training works (RTWs), including riverbank protections, have mainly been focused unidirectionally on the protection aspects of the RTWs, while the ecological and the surface-groundwater interaction aspects are ignored. In the Kabul region, riverbanks are increasingly protected by stone masonry walls to avoid bank erosion and ensure flood protection. Gaps in stone masonry retaining walls are filled with cement mortar and hinder the relationship between the riverbank with flora and fauna and the surface water-groundwater. Kabul River, Maidan River, parts of Paghman and Istalef rivers are good examples of such bank protections. While groundwater recharge as a result of direct precipitation on the land surface has minor contributions to the total groundwater regeneration, rivers and streams are making the bulk of groundwater recharge. Worldwide, a new trend of rivers and streams' re-naturalisation is taking place. This re-naturalisation occurs wherein the relationship between water bodies and their surroundings are re-established by removing the obstacles such as weirs and retaining walls. These measures not only improve groundwater recharge but also help enhance the quality of water and are ecologically friendly.

In Afghanistan, RTWs are conducted by several administrations, such as the Ministry of Urban Development and Land, Ministry of Rural Rehabilitation and Development, Ministry of Energy and Water, Ministry of Agriculture, Irrigation and Livestock and city municipalities. Therefore, on the government level, a new policy concerning the RTWs is required to replace traditional practices with ecologically friendly ones. In particular, concerning achieving more recharge area for surface water infiltration, riverbanks should be protected by permeable measures such as by rip-raps and vegetation, instead of stone masonry walls to allow river bank filtrations and habitats for biodiversity. If, for instance, the stone masonry bank protection of Kabul River is replaced by permeable protection, groundwater recharge will increase by 10% to 15%.

- **Establishing additional/artificial recharge basins**

While urbanisation in the Kabul region has reduced the infiltrative surface for groundwater regenerations that cannot be fully reversible, some measures can partially compensate for this challenge. There are common methods used for artificial groundwater recharge.

The first method is known as direct surface recharge, which allows water infiltration into groundwater by passing through the porous medium (soil). Since the infiltration occurs from the surface, this method requires land surfaces that can be used as infiltration basins. A prerequisite for establishing infiltration basins is to make sure the area is infiltrative (soil is permeable); otherwise, ponding water may contribute to more water loss due to evaporation. The basins are often established within the river system, namely, the floodplains of the river system, which function as natural retention basins. On the one hand, they reduce flood peaks by spreading the floodwater over a large basin area, while, on the other hand, they allow groundwater recharge. In the central Kabul sub-basin, the river floodplains have been heavily urbanised; therefore, re-establishing river floodplain retention basins is increasingly becoming challenging. Reclaiming the natural floodplains of rivers is, therefore, a prerequisite. However, upper Kabul/Paghman, Shamali, Logar and Deh Sabz sub-basins provide large land surfaces for direct recharge.

A second method is the injection of surface water to aquifers known as direct subsurface recharge. This method can be applied in particular to the central Kabul basin, where the land availability for surface recharge is limited. Since, in this method, a direct connection between surface water and the aquifer is established, the risk of polluting the groundwater by the surface water is high. Additionally, direct subsurface recharge implementation is associated with higher costs, because, for this method, wells must be constructed.

Direct subsurface recharge can be implemented on different scales. At the smaller scales, such as public and private buildings, rainwater harvesting and snow storage in shallow wells can function as artificial groundwater regeneration, as well as helping reduce water accumulations on the surface. One advantage of subsurface direct groundwater recharge is the minimisation of water lost due to evaporation because the water is stored in wells with large depth-to-surface area ratios. The hand-dug shallow wells traditionally exist in yards of private and some public buildings in Kabul that were used for groundwater withdrawal for drinking and irrigation. These wells now are mostly dry, but the structure can be easily adapted for rainwater/snow storage. In this regard, public awareness and supportive policies such as a reduction in water supply costs for those families who have established a recharge well in their yard can be examined.

In a short period, re-naturalisation of riverbanks (re-establishment of river water linkage with surrounding soil) will directly increase the groundwater recharge in Kabul region basins. In the long run, more research is needed on determining specific locations for functioning infiltration basins that can be utilised to recharge groundwater.

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