Climate Change Impacts on Availability of Groundwater Resources in Southern Punjab: Adaptation Strategies for Groundwater Sustainability

Increasing reliance on groundwater to supplement crop water requirements is leading to steady declines in watertables in many parts of the world, but more so in China, India, and Pakistan. To achieve sustainable groundwater use, resource managers and water policy experts have long advocated the need to improve irrigation efficiency. However, the perceived water savings is often used to expand irrigation or increase cropping intensities. As a common pool resource, groundwater and its use is dispersed widely among many thousands of smallholder farmers. This makes regulation a daunting task and implementation of a regulatory framework near impossible. Pakistan is especially susceptible to climate change and is ranked the seventh most affected country in the Global Climate Risk Index. We simulated a range of climate change scenarios to understand possible future outcomes from increasing groundwater use for agriculture and its consequential impact up to 2100. We then simulated a mix of adaptation strategies, to understand how agriculture and water management practices will need to change for a sustainable future. What we found was disturbing, in that despite implementing adapatation strategies, groundwater declines and salinity mobilisation will continue to impact agricultural livelihoods. This will require rethinking new strategies to adapt water and land management practices to the looming threat of climate change.

Groundwater and salinity mobilisation under climate change is threatening the sustainabaility of agriculture in Southern Punjab.

Policy makers are increasingly becoming aware that past trends in surface water and groundwater cannot be extrapolated into the future as climate change is adding several layers of complexity in how natural systems are changing. In the Anthropocene we can expect climate change to have significant impacts on the entire agricultural system through extreme climate events such as extreme summer temperatures, prolonged droughts, and the 2022 pluvial floods experienced in the Southern Indus Basin. Our study area traverses the districts of Multan, Khanewal, Vehari, and Lodhran. The area forms a large triangle with the Chenab River on the western boundary, the Sutlej River to the south, and the southernmost point forming the confluence of the Sutlej and Chenab Rivers in Southern Punjab.

Simulating current groundwater conditions:

We developed a 3-dimensional groundwater model to help us understand how climate change will affect access and availability to groundwater resources into the future. This is of practical concern to policy makers as it provides vital information on the extent of adapative changes that will be required and the limited time frame available to achieve sustainable outcomes.

Our first step was to simulate the groundwater system from 2010 to 2020 to establish the current condition of groundwater resources in Southern Punjab. We found that high salinities and enhanced depletion were affecting larges areas by 2020 where the depth to watertable shows hotspots designated by the dark red areas have develop along the southern parts of the study area between Jehanian and Lodhran (see Figure 1). These areas are likely to increase in the future as pumping and climate stresses increase.

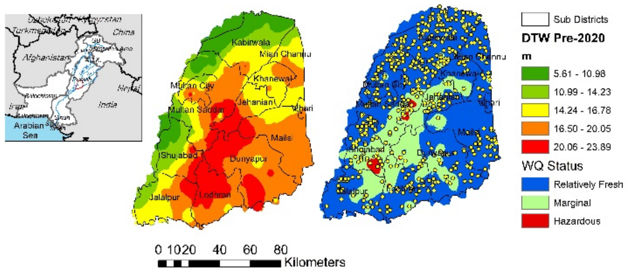

Figure 1. Depth to water and EC pre-monsoon 2020 (m).

Under climate change large parts of the upper aquifer will be depleted.

The simulated heads in 2100 for the SSP5-8.5 climate scenario in Figure 2 indicate the extent of depletion in the top layer. The maroon colour indicates the drying out of a large part of the upper aquifer by 2100, which will harm smallholder farmers relying on shallow tubewells for irrigation. It will also mean households relying on handpumps for potable water supply will be denied access to groundwater, with far-reaching impacts on health and livelihoods.

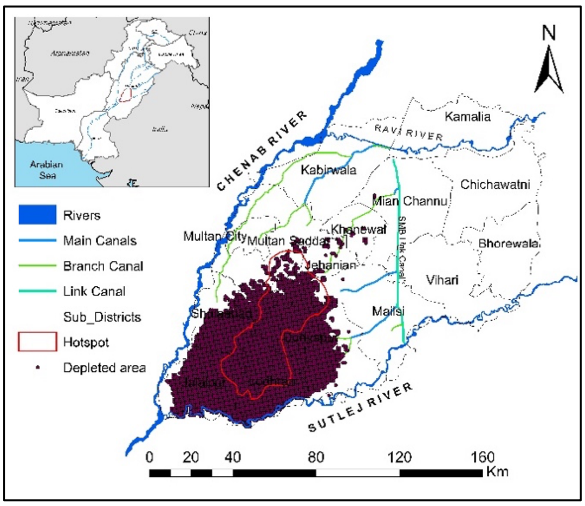

Figure 2. Water levels (m MSL) in the top layer for SPP5-8.5 scenario.

What the salt balance tells us:

In the Southern Bari doab, groundwater pumping from 2010–2020 averaged 3,355 MCM/year. The average groundwater salinity was estimated to be 1,000 μS/cm from 2010 to 2020, with 20% return flows resulting in 1.7 million tons of salt deposited in the root zone. The estimated salt load for the Indus Basin is about 1 ton/ha; however, our estimate for Southern Punjab is conservatively 1.48 tons/ha, which increases the risk of salinisation for agricultural lands in Southern Punjab.

Under the SSP5-8.5 climate scenario groundwater pumping will average 5,574 MCM/year. The average groundwater salinity was estimated to be 1,400 μS/cm from 2010 to 2100, with 20% return flows resulting in 4 million tons of salt deposited in the root zone which increases salt deposits to 3.43 tons/ha in the root zone under climate change.

An analysis of the pumping from 2010–2100 and 2090–2100 indicates that pumping will increase under the SSP5-8.5 climate regime from 5,574 to 8,723 MCM/year, respectively. This has huge implications for salt transport – salt deposition in the root zone will increase to 5.37 tons/ha between 2090 and 2100. This level of salt transport will result in an existential threat to farming livelihoods in Southern Punjab.

Increasing pumping trends under climate change scenarios will not be sustainable, resulting in significant declines in groundwater storage, water levels, and water quality.

Water levels for both climate scenarios will rapidly decline, particularly beyond 2040, after which the declines accelerate. The drying out of a large part of the upper aquifer will significantly impact farmers, who will be forced to deepen wells to access groundwater and increasingly use groundwater with higher salinity levels. In the worst-case scenario, farmers will be forced to abandon groundwater irrigation, which will impact food security in Southern Punjab. The dewatering of the upper layer of the aquifer in response to pumping in the middle layer is of particular concern for smallholder farmers who may have restricted access to groundwater. Equally concerning is the increased inflow from the deepest layer (Layer 3) into the middle layer which amplifies the risk of salt mobilisation by groundwater pumping, adding to the buildup of salts in the crop rooting zone.

Photo courtesy of Mr Faisal Riaz

Adaptation options can help communities achieve a sustainable future:

We simulated a combination of adaptation options to help communities move towards a sustainable future. The simulated adaptation options for the Southern Bari doab included: (i) replacing between 20% and 30% of the existing high-water use crops, such as cotton, rice, and sugarcane, with low delta crops, mainly mung beans and onions; (ii) simulating flood flows in the River Chenab and Ravi; and (iii) environmental amelioration of the riverine corridors. The inclusion of the recharge options by simulating flood flows adds 92 MCM/year to groundwater storage. Despite including these adaptation options, there would be a significant loss in net storage in the underlying aquifer of 681 MCM/year by 2100, resulting in significant declines in groundwater levels and salinity mobilisation into the cropping zone.

Moderating the impacts of overexploitation of groundwater and increased salinity mobilisation under projected climate change conditions will require new adapatation strategies for a sustainable groundwater future. Our findings reinforces the urgent need to implement the proposed adaptation strategies for Southern Punjab and to understand that their effectiveness may decrease as climate change intensifies. Thus rethinking adapatation options and strategies will also require consideration of appropriate planning horizons as the tipping point for accelerated depletion of groundwater and enhanced salinity transport will occur soon after 2040 which underscores the limited time for changed management for Southern Punjab. Sustainable water and land management in the Anthropocene will bring new challenges but also new opportunities.

Adapted from: Raheem, A., Saifullah, M., Punthakey, J.F., Zakir-Hassan, G., & Baig, I.A. (2024). Modelling Climate Change Impacts and Adaptation Strategies for Managing Groundwater Resources in Southern Punjab. Gulbali Institute, Charles Sturt University, Albury Australia.

For Further information contact:
Dr J F Punthakey, Charles Sturt University, Albury Australia,
E: eco@ecoseal.com