Groundwater Sustainability in Southern Punjab:
Policy Guidance to Improve Groundwater Management

In Southern Punjab, groundwater levels have depleted over the past two decades due to overextraction. The deteriorating quality of groundwater used for agriculture, industry and household purposes has become a primary issue. Declining groundwater levels and water quality are issues the Punjab Water Policy (2018) recommends be addressed, along with improved monitoring systems for better informed decision making. Across large parts of Southern Punjab, relatively fresh groundwater is no longer accessible leading to increased reliance on marginal quality groundwater. Irrigation with marginal quality groundwater is thus a common practice, especially when surface water supplies are insufficient. This practice is increasing the risk of salinity and sodicity. Dependence on water intensive crops coupled with insufficient awareness of alternative options is exacerbating this groundwater level decline leading to salinity mobilisation from deeper aquifer layers. This groundwater storage decline was confirmed from our simulation of an increased pumping scenario up to 2060 compared with a business-as-usual baseline scenario. However, substantial improvements were observed over the same period from a simulation we ran of adaptation options that combined a revised cropping pattern with storing recharge from occasional floods in River Sutlej and River Chenab. These findings help set an agenda for water security policy which is of significant concern for Pakistan's future. Competition for water from a growing population and industrial base will continue to result in marked surface water reductions. These reductions combined with declining groundwater quality will be a key driver in transforming cropping patterns to less water intensive crops and reduced reliance on groundwater.

Groundwater depletion and salinity mobilisation is threatening the sustainability of agriculture in Southern Punjab.

Increased crop intensities over the past two decades in Punjab has resulted in declining groundwater levels and increased salinity mobilisation. We investigated these trends for the Southern Bari doab study area which traverses the districts of Multan, Khanewal, Vehari, and Lodhran of Southern Punjab. 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. The depth to water and EC in Figure 1 shows considerable depletion in groundwater, particularly in the districts of Khanewal, Jahanian, and Lodhran. It also shows how significant areas have transformed from relatively fresh to marginal quality groundwater with adverse implications for farmers in these areas.

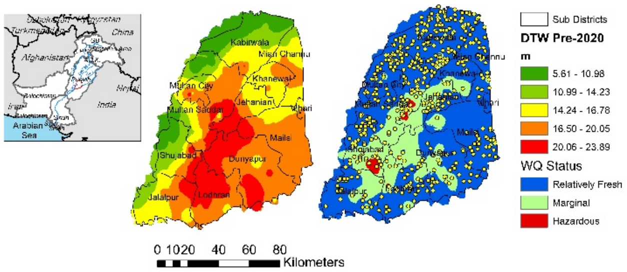

Figure 1. Depth to water and EC pre-monsoon 2020 (m).

Simulating current and future groundwater conditions:

We developed a 3-dimensional groundwater model to help us understand how groundwater extractions and 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 changes that will be required and the limited time frame available to achieve sustainable outcomes.

The water balance for the baseline scenario (where climate, surface water supply and pumping is similar to the 2015-2020 period) tells us the aquifer will adjust to a new average net groundwater storage equilibrium of -302 MCM/year by 2060 as compared with -533

MCM/year during 2010-2020. However, groundwater storage will decline to -939 MCM/year by 2060 if pumping continues at the increasing pace set by historical trends over the past decade and surface water supplies remains unchanged. Comparison of the water levels for the baseline and increased pumping scenario indicates an inflection point where depletion will accelerate at a significantly higher rate beyond 2040.

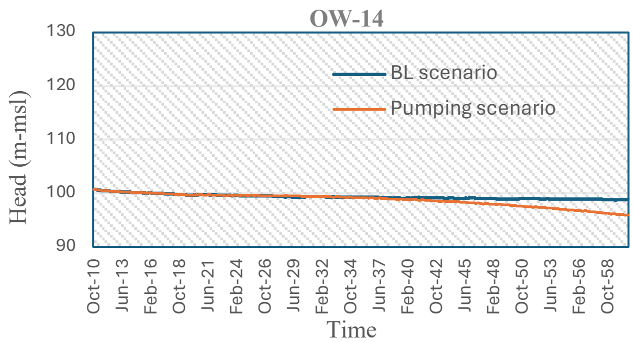

Figure 3. Water levels (m MSL) in the top layer for the baseline and increased pumping scenario.

Uncontrolled depletion and manifestation of salinity on the soil surface for a cotton crop is shown in Figure 2. These areas are likely to increase in the future as pumping and climate stresses increase.

Figure 2. Cotton farm located in Basti Kulab, Jalalpur, Multan, showing intense soil salinity *(Photo courtesy of Mr Faisal Riaz)*

Adaptation strategies that reduce risks and give communities a sustainable future:

We simulated a combination of three adaptation options for the Southern Bari doab: (1) replacing between 20% and 30% of existing high-water use crops, such as cotton, rice, and sugarcane, with water efficient crops, such as mung beans and onions; (2) simulating storage of flood flows in the Chenab and Ravi Rivers; and (3) environmental amelioration of the riverine corridors along the Chenab. The resulting loss in net storage in the underlying aquifer with these adaptations was -586 MCM/year compared with -939 MCM/year without adaptation. We found occasional flood flows in the Sutlej could add 92 MCM/year to groundwater storage, which makes a strong case to implement managed aquifer recharge projects in Southern Punjab. Figure 3 shows the relative change in groundwater levels from the increased pumping and adaptation scenarios compared with the baseline scenario. The increased pumping scenario would lead to groundwater levels declining by 2-3 m but inclusion of adaptation options would moderate these declines over significant parts of the Southern Bari doab. Rising groundwater levels along river Sutlej represented by pink and dark yellow bands is a result of opportunistic recharge from flood events in the Sutlej River.

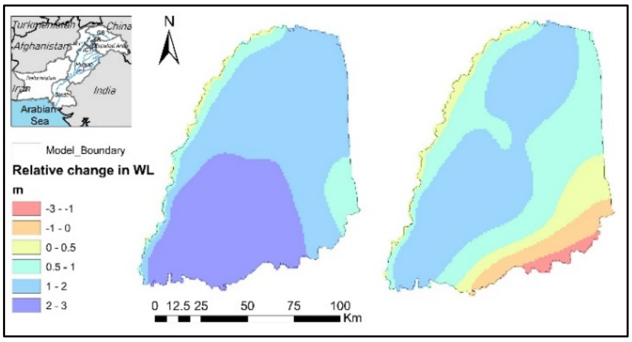

Figure 3. Relative change in water levels for the pumping scenario without adaptation and with adaptation.

Policy guidance to mitigate risks from overextraction and salinity mobilisation in Southern Punjab:

The Punjab Irrigation Department (PID) collects and archives monitoring data on water levels, salinity and other water quality parameters biannually. It would be beneficial for PID to design a robust monitoring program with water level and salinity loggers at different depths and to consolidate these data in a Water Resources Information Management System. This will allow the Water Resources Zone and Irrigation Research Institute to monitor changing water levels and quality across Southern Punjab. The development of sub-regional scale models will assist PID improve planning and management of surface and groundwater resources. These models can assist in estimating sustainable yields, and planning conjunctive management strategies. Developing capacity in groundwater planning and management is important for understanding risks and developing strategies to control overexploitation, salinity intrusion, and impacts from climate change. Strong community engagement and support will be required to manage groundwater sustainably and to co-develop a water sharing plan with strong community buy-in. As knowledge of the Southern Bari doab area increases and trust is built among groundwater users, difficult discussions on regulation of pumping may also be required in hotspots to allow equitable access to groundwater for smallholder farmers. We recommend PID undertake detailed investigations to establish recharge structures such as large diameter vertical recharge wells which could be used to enhance aquifer recharge. These and other adaptation strategies will need to be co-developed with farming communities accompanied by investments in awareness training. An app developed by the ASSIB project can also be used to integrate remote sensing data on crops, soils and crop water requirements with a land capability framework.[1]

Moderating impacts of increased salinity mobilisation will require adoption of water efficient crops and suitable adaptation strategies for a sustainable future. Our findings reinforce the urgent need to implement improved land and water management practices for Southern Punjab and to understand that their effectiveness may decrease as climate change intensifies. Improved monitoring can help irrigators, groundwater users and other stakeholders better understand the impact of intensive aquifer exploitation on declining groundwater quantity and quality. PID will need significant capacity development in groundwater planning and management to assist identify effective responses to salinity intrusion and climate change impacts on groundwater, and to co-develop strategies to improve groundwater management with affected communities. Some regulation of pumping may also be required in hotspots to allow equitable access to groundwater for smallholder farmers. The time to rethink our approach and to take adaptive action is now, given the approaching tipping point for accelerated depletion of groundwater and enhanced salinity transport will occur soon after 2040. Farmers are key stakeholders in improving water resource management. Capacity building to improve on-farm water management, climate smart agriculture and options for managing declining groundwater levels and quality will be essential for farmers as they adapt to water and climate stress.

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.

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[1] Khan, M.R., Barrett-Lennard, E.G., & Punthakey, J.F. (2024). Mobile and Web applications for Land & Water evaluation. Gulbali Institute, Charles Sturt University.