Groundwater Sustainability in Pinyari Canal Command and Coastal Sindh: Policy Guidelines to Improve Groundwater Management

In the Sindh district of Sujawal, shallow watertables with high salinities together with high summer temperatures and evapotranspiration rates enhance salt transport into the crop root zone. This affects agriculture across the Pinyari canal command area (CCA). Farmers here are reluctant to use the marginal to brackish groundwater available to them for irrigation, and instead prioritise using limited surface water for their crops. Competition for water from a growing population and industrial base will continue to result in marked reductions in surface water flows. Many coastal communities are forced to use marginal quality groundwater to meet their potable and domestic water needs as no other freshwater sources are available. These contexts cement water security as a significant policy concern for Pakistan's future. The reduction in surface flows will be a key driver in transforming cropping patterns to less water intensive crops, helping to mitigate the risk posed by shallow watertables and salinity. The Sindh Water Policy (2023) has already recognised the need to establish a dedicated groundwater management section within the Sindh Water Resources Management department to coordinate efforts that address these waterlogging and salinity issues across the region.

Waterlogging and salinity is threatening the sustainability of agriculture in southern Sindh.

Rainfall and irrigation recharge, seepage from canals and the Indus River, and high evapotranspiration rates are key drivers for the prevalence of waterlogging and salinity in the Pinyari CCA. Water levels are generally shallow across the Pinyari CCA, and salinities are generally marginal to brackish except along the Indus riverine corridor (Figure 1).

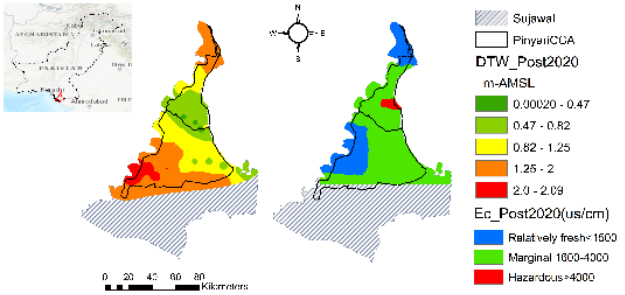

Figure 1: Spatial variation in depth to watertable and salinity.

The water balance findings from the model we developed for the Pinyari CCA and coastal areas of Sujawal indicated the average annual river and canal seepage from 2010 to 2020 was 720.4 MCM/year while recharge from rainfall and field application losses of canal supplies was 2,246.3 MCM/year. Inflows along the coastal boundary of 316.7 MCM/year indicate a risk of seawater intrusion along the coastal zone, particularly during the dry season when rainfall and river flows are very low. Outflows to the Indus River along the western model boundary are 610.7 MCM/year and net flows are 109.7 MCM/year indicating this section of the river is highly connected to the aquifer. Net annual gain in aquifer storage during this period is 87.6 MCM/year, no doubt contributing to Sujawal's high watertables. Evapotranspiration due to high summer temperatures and shallow watertables is a significant outflow at 2,199.8 MCM/year. The high evapotranspiration rate coupled with shallow marginal to brackish watertables across Sujawal increases the risk of salinity transport into the crop root zone and often appears as salt on the surface (Figure 2). To explore possible future outcomes, we undertook a series of scenarios to quantify the state of the aquifer in response to baseline and reduced surface flow conditions.

Figure 2: Surface salinity from shallow groundwater in Jongo Jalbani village, Shah Bandar taluka, Sujawal, Sindh. *(Photo courtesy Dr Abdul Latif Qureshi)*

Salinity and waterlogging risk under different managerial scenarios (2010-2060)

Our Baseline (business-as-usual) scenario simulates similar levels of rainfall and canal flows that had occurred from 2010 to 2020 through to 2060, which we compared with a Reduced Flow scenario that simulated the response through to 2060 if the flows matched the lowest levels that occurred over the five years between 2008 and 2012. By comparing these two scenarios, we found that the decline in surface water flows available for irrigation would result in a 17.9% decrease in irrigation recharge, thus leading to a small decline in water levels in the aquifer underlying the Pinyari CCA. This decline would decrease evapo-transpiration by 15.8% and decrease drain outflow by 15% in comparison to the BL scenario. These results also suggest that improving irrigation use efficiency and adoption of water efficient crops could further reduce the extent of areas affected by shallow watertables and salinity across the Pinyari CCA.

What is the water budget of the Reduced Flow scenario telling us?

Competition for water from a growing population and industrial base will likely result in marked reductions in surface water flows. The reduction in surface flows will be a key driver in transforming cropping patterns to less water intensive crops. The resulting decrease in water levels will also reduce evapotranspiration rates, and reduce mobilisation of salinity to the soil surface, which can

potentially improve agricultural production in areas prone to salinity and waterlogging. Additional benefits from reducing waterlogging include reduced flooding as a small increase in the depth to water will allow greater infiltration of monsoon rains. Such rains would normally result in inundation and loss of cropping land. The benefits of lowered water levels from the Reduced Flow scenario could be further enhanced by simulating adaptation options. We designed a mix of adaptation options which include changes to cropping systems and nature based solutions to guide farming communities and institutional actors on possible strategies to reduce the risk of land salinisation and seawater intrusion in the coastal district of Sujawal. Figure 3 shows relative lowering of the water levels with and without adaptation to mitigate some of the risks posed by salinity mobilisation into the root zone.

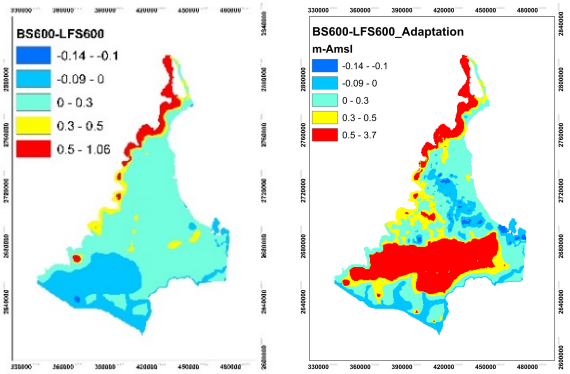

Figure 3: Relative change in water levels for the reduced flow scenario with and without additional adaptation options.

There are significant inflows of 2,735 MCM from the sea boundary into the top layer in the coastal areas of Sujawal indicating that areas adjacent to the sea and tidal rivers are at risk of waterlogging and salinity. To preserve Pakistan's coastline in the future, new strategies will be required to manage salinity and inundation as well as the loss of biodiversity in the coastal zone south of the Pinyari CCA. This will require a rethink of how coastal ecosystems can be protected and made productive.

Proposing policy guidelines to mitigate salinity and waterlogging:

Although much of Pinyari CCA is underlain by marginal to brackish groundwater (Figure 1) there are areas along the Indus River with relatively fresh groundwater lenses which are suitable for livestock, domestic use and small-scale agricultural activities at the household level. Mapping these lenses and assisting farmers to adopt skimming wells may provide benefits of lowering the watertable and providing supplementary water when surface water supplies are reduced or not available. However, adopting skimming wells will require financial assistance and knowledge transfer for participating farmers. With a good network of drains, one possible option could be use of solar-powered tubewells to pump saline groundwater from deeper levels for disposal into the drainage network via a tidal link to the sea. A word of caution though: this option may work only for a few decades until rising sea levels will impact the drainage system.

An urgent requirement for Sindh is investment in collecting, storing and making available monitoring data on water levels, salinity and other water quality parameters. The Sindh Irrigation Department (SID) can capitalise on existing investments in data portals by the World Bank, ADB, FAO and ACIAR. Also urgent is the design of a robust monitoring program using water level and salinity loggers at strategic sites in agricultural areas and the coastal region, with data consolidated in a Water Resources Information Management System. Each of the SMO functional monitoring bores needs to be digitised with bore coordinates, size, depth and condition recorded and an asset number assigned, and a plan for rehabilitation if required. The development of sub-regional scale models will allow SID to improve planning and management of surface and groundwater resources. These models can assist in assessing the resource, estimating sustainable yields, and planning conjunctive use strategies.

Crucially, SID as the resource manager would need significant capacity enhancement in groundwater planning and management to improve understanding of risks to groundwater from salinity intrusion and climate change impacts, and to co-develop strategies to improve groundwater management with affected communities for a sustainable future. This will allow SID to develop effective groundwater management plans and have community support to implement management changes. Adaptation options suited to different zones in Sindh need to be co-developed with farming communities accompanied by investments in awareness training. An app *Apna Farm* developed by the ASSIB project can be used to integrate remote sensing data on crops, soils and crop water requirements with a land capability framework[1].

Moderating the impacts of waterlogging and increased salinity mobilisation will require adoption of water efficient crops and suitable adaptation strategies for a sustainable future. Our findings reinforces the urgent need to implement improved land and water management practices along with adaptation options for coastal Sindh and to understand that their effectiveness may decrease as climate change intensifies. Adaptation strategies for Pinyari CCA will require improved management of the supply system and suitable water efficient crops, and nature based solutions for a productive and healthy coastal ecosystem.

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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.