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

Aquifers in Sindh have shallow watertables that are generally higher in salinity. Access to fresh groundwater is thus limited to a thin freshwater lens overlying deeper marginal and brackish groundwater. In recent years farmers in Sindh have increasingly been exploiting these freshwater lenses to supplement shortfalls in canal water supplies. Access to these lenses has also allowed farmers to increase cropping intensities thus improving productivity of smallholder farming enterprises. However, extensive exploitation of these lenses is not without risk. Their depletion increases risk of lateral migration of saline groundwater from surrounding areas. At the tail end of canals where groundwater quality is generally poorer, this reliance results in increased use of marginal quality groundwater which in turn impacts soil and crop health from accumulation of salts in the crop root zone. As a common pool resource, groundwater use is dispersed among many thousands of smallholder farmers. This makes regulation a daunting task and implementation of a regulatory framework near impossible. Pakistan is also 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 reduced canal water supplies for agriculture and climate induced rising sea levels and its consequential impact up to 2100. We then simulated a mix of adaptation strategies, including transforming cropping systems towards water efficient crops, and nature-based solutions in the coastal belt. What we found was disturbing. Despite implementing these adaptation strategies, waterlogging and salinity will only be marginally reduced while salinity mobilisation under climate change will accelerate. This will require rethinking new strategies to adapt water and land management practices to the looming threat of climate change.

Waterlogging, salinity mobilisation and rising sea levels under climate change is threatening the sustainability of agriculture in southern Sindh.

Policy makers are increasingly 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 Sujawal and parts of Hyderabad and Tando Muhammad Khan and includes the non-perennial Pinyari canal command area (CCA). The Indus River forms the western model boundary, and the southern model boundary lies along the Arabian Sea.

Simulating current groundwater conditions:

We developed a 3-dimensional groundwater model to help us understand how climate change will affect waterlogging and salinity in the Pinyari CCA and the impact of rising seas on the coastal zone south of the Pinyari CCA. This is of practical concern to policy makers, providing vital information on the extent of adaptive 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 Sindh. We found that waterlogging and high salinities were affecting large areas of Pinyari CCA by 2020. The extensive areas with marginal EC levels up to 4,000 µS/cm are shown in Figure 1. These areas are likely to increase in the future as pumping and climate stresses increase.

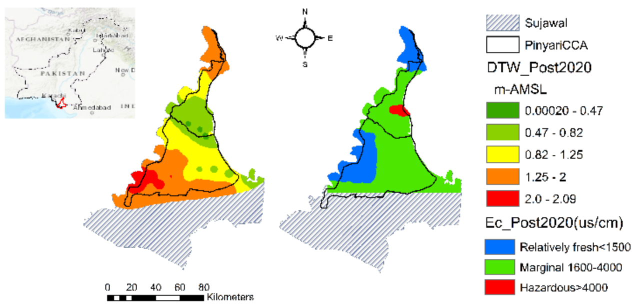

Figure 1. Depth to water and EC post-monsoon 2020 (m).

What has changed between 2010 and 2020?

The water balance showed inflows along the coastal boundary highlighting the risk of seawater intrusion especially in the dry season when rainfall and river flows are low. The net annual gain in aquifer storage during this period was 87.6 MCM/yr, which is contributing to high watertables in Sujawal. The major outflow from the aquifer is evapotranspiration at 2,199.8 MCM/yr due to high summer temperatures and shallow watertables underlying Sujawal. This high rate of evapotranspiration and marginal to brackish watertables increases the risk of salinity transport into the crop root zone and is often manifested by salinity onto the surface (Figure 2).

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

Under climate change large parts of the upper aquifer will be affected by upward salinity transport and sea level rise will further erode coastal areas

The projected rainfall and evapotranspiration for the SSP5-8.5 scenario with reduced flows in Pinyari Canal indicates a reversal of gradients will occur under these climatic conditions with net upward flows of 62.4 MCM into the top layer from Layer 2 and 18.4 MCM transported from Layer 3 to Layer 2 which results in upward mobilisation of salinity from the deeper layers where salinities are generally higher. The mobilisation of salts from the deeper layers to the top layer is likely to exacerbate waterlogging and salinity which will impact agricultural productivity in the region.

Along the sea boundary net inflows of 328.3 MCM for the SSP5-8.5 scenario are significantly greater than 42.6 MCM for the Baseline scenario. The inflows from the sea boundary are expected to continue to increase post-2100 as sea levels continue to rise to 1.86 m by 2150, or, under the potential effect of low-likelihood, high-impact ice sheet processes, the net inflows and coastal inundation are expected to be even greater. The climate scenarios tell us that under climate change, agricultural systems in coastal Sindh may not be sustainable, resulting in significant mobilisation of salinity from the deeper aquifer layers and from the influx of seawater intrusion along the coast. These changes will be of particular concern for smallholder farmers who have restricted access to groundwater for irrigation.

What the salt balance tells us:

The average groundwater salinity in the deeper aquifers in the coastal district of Sujawal was estimated to be 28,000 μS/cm – about half of the salinity of seawater. Under the SSP5-8.5 scenario there will be upward mobilisation of 1.6 million tons of salinity to the upper layers from the deeper layers where salinities are generally higher. The mobilisation of salts from the deeper layers to the top layer is likely to exacerbate waterlogging and salinity mobilisation and will impact agricultural productivity in the region under both climate scenarios.

Can adaptation options help?

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. The SSP5-8.5 scenario with adaptation shows a significant decrease in recharge from 1,801 MCM/yr without adaptation to 1,661 MCM/yr with adaptation, which will reduce the risk of waterlogging and salinity in zones 5, 6 and 7 within Pinyari CCA. Implementing the proposed adaptation options will change the Indus River from a gaining stream to a losing stream which will be beneficial for creating a freshwater lens along the banks of the Indus. However, mitigating seawater intrusion into the Indus delta will require increased flow releases below Kotri Barrage. The adaptation options also result in reduced transport of salinity from the deeper layers indicating salt transport will decrease to 0.9 million tons under the SSP5-8.5 scenario with adaptation as compared to 1.46 million tons under the SSP5-8.5 scenario without adaptation. Our suggested options will play an important role in mitigating waterlogging and salinity intrusion risks in the medium term, but these alone will not mitigate the overarching risk posed by rising sea levels and climate change. The risks posed by sea level rise will need a rethink of additional adaptation strategies, which will need to address politically sensitive issues such as additional allocation of freshwater to the Indus River for release below Kotri Barrage, physical barriers such as dikes, drainage of saline groundwater and extensive land reclamation.

Moderating the impacts of waterlogging and salinity mobilisation under projected climate change conditions will require new adaptation strategies for a sustainable future. Our findings reinforce the urgent need to implement the proposed adaptation strategies for coastal Sindh and to understand that their effectiveness may decrease as climate change intensifies. Thus, rethinking adaptation options and strategies will be required. In the end what we do to improve productivity of agriculture in the coastal areas and preserve the ecosystem of the Indus delta will depend on the value we as a society place on the productive functioning of biodiversity of these unique ecosystems. Sustainable water and land management in the Anthropocene will bring new challenges but also new opportunities.

Adapted from: Jamali S., Punthakey J.F., Ahmed, W., Qureshi, A.L., Raheem, A., and Giskani, M. (2024). Modelling Climate Change Impacts and Adaptation Strategies for Managing Groundwater Resources in Coastal Sindh. Gulbali Institute, Charles Sturt University, Albury, Australia.

For further information contact:

Dr J F Punthakey, Charles Sturt University, Albury, NSW Australia, Ecoseal Developments Pty Ltd, Roseville, NSW Australia E: eco@ecoseal.com

Mr S Jamali, Mehran University of Engineering and Technology, Jamshoro. E: shahryarbaloch456@gmail.com

Mr A Raheem, MNS University of Agriculture Multan, E: Archuhan2015@gmail.com