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Development of a Stakeholder-Assisted Socio-Hydrological Systems Dynamic Model to Facilitate Groundwater Management

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Groundwater resources play a vital role in the development of agriculture, especially in arid regions of the world. In Pakistan, groundwater currently provides more than 50% of total crop water requirements. Groundwater sustainability, in terms of depth and quality, is under direct threat in downstream areas of canal networks where the rate of groundwater exploitation is high. The groundwater is easily exploitable as no regulatory policies are effectively enforced in the region. Therefore, there is an urgent need to judiciously manage this resource through policy implementation and stakeholder engagement. In developing countries such as Pakistan, effective management solutions need to consider factors such as small landholdings and the poor economic status and limited technical knowledge of farmers. With that in mind, this presentation introduces a modeling framework that dynamically couples physical, social, and economic components in order to address such challenges. More specifically, this modelling framework, used for evaluating stakeholder preferred policy options, includes bi-directional feedback between a comprehensive distributed hydrological model and a stakeholder-assisted socio-economic model. The two major components of this integrated participatory physical-socio-economic model are: (i) a physically-based model that simulates groundwater changes as well as the salt balance in the root zone with conjunctive use of canal and groundwater irrigation; and (ii) a system dynamics model that describes socio-economic factors such as market values, operation and maintenance costs, production costs, crop yield, and farm income. The coupled model was tested and applied to policy-related scenarios including vertical drainage and canal lining solutions. Economic and environmental trade-off criteria were used to examine the effectiveness of the selected management scenarios. The results of a 20-year simulation of currently implemented government-sponsored vertical drainage projects suggests that these are a short-term solution. The simulation reveals an initial 37% increase in water availability with a 12% increase in farm income. However, this policy is expected to have detrimental effects on groundwater sustainability and soil fertility, as a 5% increase in water table drawdown and a 21% increase in soil salinity were observed. Therefore, the results show that vertical drainage policy is economically feasible, but environmentally unsustainable. On the other hand, based on the simulation results, canal lining would improve groundwater sustainability by reducing soil salinity by 22%, along with reduced drawdown. However, the cost of the lining resulted in an initial reduction of 18% in farm income for the first 5 years. Therefore, to implement the canal lining policy, the most sustainable solution, initial investment from the government is required.