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Assessment of economically optimal water management and geospatial potential for large-scale water storage

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Water is an essential but limited and vulnerable resource for all socio-economic development and for maintaining healthy ecosystems. Water scarcity accelerated due to population expansion, improved living standards, and rapid growth in economic activities, has profound environmental and social implications. These include severe environmental degradation, declining groundwater levels, and increasing problems of water conflicts. Water scarcity is predicted to be one of the key factors limiting development in the 21st century. Climate scientists have projected spatial and temporal changes in precipitation and changes in the probability of intense floods and droughts in the future. As scarcity of accessible and usable water increases, demand for efficient water management and adaptation strategies increases as well. Addressing water scarcity requires an intersectoral and multidisciplinary approach in managing water resources. This would in return safeguard the social welfare and the economical benefit to be at their optimal balance without compromising the sustainability of ecosystems. This paper presents a geographically explicit method to assess the potential for water storage with reservoirs and a dynamic model that identifies the dimensions and material requirements under an economically optimal water management plan. The methodology is applied to the Elbe and Nile river basins. Input data for geospatial analysis at watershed level are taken from global data repositories and include data on elevation, rainfall, soil texture, soil depth, drainage, land use and land cover; which are then downscaled to 1km spatial resolution. Runoff potential for different combinations of land use and hydraulic soil groups and for mean annual precipitation levels are derived by the SCS-CN method. Using the overlay and decision tree algorithms in GIS, potential water storage sites are identified for constructing regional reservoirs. Subsequently, sites are prioritized based on runoff generation potential (m3 per unit area), and geographical suitability for constructing storage structures. The results from the spatial analysis are used as input for the optimization model. Allocation of resources and appropriate dimension for dams and associated structures are identified using the optimization model. The model evaluates the capability of alternative reservoirs for cost-efficient water management. The Geographic Information System is used to store, analyze, and integrate spatially explicit and non-spatial attribute information whereas the algebraic modeling platform is used to develop the dynamic optimization model. The results of this methodology are validated over space against satellite remote sensing data and existing data on reservoir capacities and runoff. The method is suitable for application of on-farm water storage structures, water distribution networks, and moisture conservation structures in a global context.