Sustainable Surface Water Storage Development Scenarios for River Basins with Examples from Sri Lanka

Abstract

A key question in sustainable development is how much alteration in natural systems, such as river basins, is acceptable? One of the ways by which humans alter a river basin is by building water storage infrastructure. While storage reservoirs deliver numerous benefits, they can also induce social and environmental costs by displacing people, fragmenting river networks and altering downstream flow regimes. In such a context, merely capping total water withdrawal from rivers for human consumption is not sufficient. River basin plans should also identify optimal (acceptable) limits to surface storage capacities, and optimal numbers, degrees of distribution and locations of storage infrastructure. It remains largely unclear, however, whether it is possible to define a hydrologically, ecologically and socially justified 'surface water storage boundary' for a river basin, or what would be the 'best arrangement' of this bounding storage capacity in the basin's river network to maximize storage benefits and minimize environmental and social costs. The main objective of this research is to develop a suite of tools that may help to answer the above questions of a 'surface water storage boundary' and its 'optimum arrangement' for a river basin. In this context, the research introduces two novel concepts: the 'storage scale' and the 'sustainable storage development framework.' The 'storage scale' has four elements – capacity, number, distribution and location – individual scales that help visualize a 'surface water storage boundary' and its 'optimum arrangement' for a typical river basin. The 'sustainable storage development framework' consists of three dimensions – economic benefits, ecosystems and society – and a set of indicators quantifying each dimension.

This research demonstrates the use of the concepts 'storage scale' and 'sustainable storage development framework' in investigating a 'surface water storage boundary' and its 'optimum arrangement' by taking as examples two contrasting river basins in Sri Lanka - Malwatu Oya in the Dry

The research also presents novel methods that measure flow regulation, river connectivity and social equity implications of surface storage development, and illustrates their use in assessing different reservoir system configurations (different storage capacities, numbers and modes of siting / spatial distribution of reservoirs) in the study basins. The Modified River Regulation Index (MRRI) measures the overall degree of regulation of a river by reservoirs, taking into account not only the volume of flow that is captured by them, but also their placement and type (centralized large or distributed small) – two aspects that are not considered in previous indices. River connectivity indices formulated in the research illustrate that the lowest connectivity in a river basin results from a single new reservoir placed on a main stem of a previously unregulated river, between the two locations that command 50% and 75% of the basin area respectively. The indices illustrate that the current level of connectivity of Malwatu Oya is extremely low due to the presence of a large number of reservoirs in the river network. Approximations to estimate Normalized Externality (NE), a measure of how equitable a storage project is, show that the ratio of the total affected population to the total number of beneficiaries of a storage project increases as reservoir sizes increase.

This research also demonstrates an integrated index, which combines indictors on economic benefits, ecosystems and society to identify "best performing" reservoir system configurations for each river. The results show that while lower cumulative storage capacities score higher on the integrated index than higher cumulative storage capacities irrespective of the reservoir arrangement, the "optimum arrangement" is unique to each river. Other research outputs include (i) Regional storage – yield curves for Malwatu Oya and Kalu Ganga basins; (ii) Linear area-discharge relationships for the Malwatu Oya and Kalu Ganga basins; and (iii) Indices based on storage-yield curves, supporting the identification of dry zone tank cascades with higher potential returns for investment (higher gains in yield) in restoration efforts.