The Role of Water Storage in Adaptation to Climate Change in the HKH Region

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Increasing water scarcity is a serious threat arising from climate change in Asia in general, and the Hindu Kush-Himalayan (HKH) region in particular. The level of water withdrawal (demand) in Pakistan for example is already about three-quarters the level of annual renewable water resources available (supply); whereby a demand greater than one-third of supply is already considered risky. In 2005, the annual water availability per person in Pakistan was below the critical stress level of 1700 cubic metres (cum) per person per year to meet irrigation, industrial, and household water demand, and judging from the rate at which it declined between 2000 and 2005, it may soon fall below the minimum need of 1000 cum per person. The water availability is quickly approaching the critical stress level in Afghanistan, China, and India as well.

Most rivers in the region are shared between several countries, making water resources and their management a matter of regional concern. Both Bangladesh and Pakistan receive more than three-quarters of their surface water supply from across their borders. And during the dry season in the densely populated and fertile Ganges Basin of India, almost three-quarters of the surface water flows from Nepal.

Climate change is projected to have severe adverse effects on water availability in the region with overall changes in precipitation patterns The total amount may increase in some areas and be less in others, leading to water stress and droughts. More precipitation may fall as rain instead of snow, reducing both long and short-term storage. Precipitation may also increase in intensity with more falling over a shorter time resulting in a higher incidence and intensity of floods in the river basins and a higher proportion of runoff and reduction in groundwater recharge, again reducing storage. A reduced volume of snow and ice, and the changes in precipitation, could lead to a serious shortage of water for drinking and farming. When the consequences of climate change are superimposed on the high degree of intra-annual rainfall variability in the region, marked by too much water in the wet season followed by too little water in the dry season, it is clear that the threat of water scarcity could pose a serious challenge to the approximately 1.3 billion people living in the ten river basins that have their origins in the Hindu Kush-Himalayan mountains. For example, India has a skewed pattern of rainfall distribution, receiving 50% of its annual rainfall in just 15 days. According to Biswas (2004) Cherrapunji, with the highest rainfall in India receives its annual rainfall of 10,820 mm between June and August in about 120 hours, but faces a water shortage problem during the dry months. A critical issue, then, is how to store massive quantities of rain falling in very short periods so that it can be used over the entire year.

Furthermore, there is a relationship between the intra-annual rainfall variability in a country and its level of prosperity. Countries with low rainfall variability typically have high GDPs (gross domestic products), while countries struggling with large seasonal variability in water availability typically have low GDPs (Brown and Lall 2006). Increasing the capacity to store water and reduce seasonal differences in availability may help to redress this balance. The current water storage capacity for countries in the Hindu Kush-Himalayan region is much below the estimated needs for food security. Estimates of seasonal storage requirements are based on the food requirements of the population, the area of cultivated land, and the rainfall distribution pattern over the year. According to estimates, only 33% of the seasonal storage requirement is met in Bangladesh, while 76% is met in India (Table 1). This implies the need to view development of water storage capacity as an integral

Table 1: **The gap between storage capacity and storage needs**

Country	Seasonal Storage Index (cubic km)	Current storage, as a percentage of Seasonal Storage Index
Bangladesh	62.28	33
Bhutan	0.40	0
India	356.60	76
Nepal	29.86	0

Note: The Seasonal Storage Index indicates the volume of storage needed to satisfy annual water demand based on the average seasonal rainfall cycle. The study identified 23 of 163 countries studied as having a positive storage requirement, ie a need to reduce the impact of rainfall variability on food and livelihoods by transferring water availability from wet months to dry months. China and Pakistan were not among the 23; Afghanistan and Myanmar may not have been studied. Source: Brown and Lall (2006)

part of integrated water resources management (IWRM); this is also considered by the IPCC to be an adaptive measure for climate change impacts. To this end, countries in the Hindu Kush-Himalayan (HKH) region with high rainfall variability need to think seriously about developing water storage capacity for adaptation to climate change. Some of the potential water storage options for adaptation to climate change and rainfall variability are discussed in the following sections.

Potential water storage options for climate change adaptation

To understand the potential of water storage for climate change adaptation in the Himalayan region, it is necessary to look at the natural storage systems in the cryosphere and the biosphere, as well as examining constructed systems. The natural systems in the cryosphere include snow, ice, and the glacial lakes. The natural systems in the biosphere include soil moisture, groundwater aquifers, and natural water bodies and wetlands. The constructed systems include artificial ponds and tanks, as well as small and large reservoirs (see Figure 1). In addition, there are constructed systems designed to augment existing natural storage, like groundwater recharge systems, bunds, and temporary runoff collection areas. A comprehensive ecosystem framework is needed to explore the potential and opportunities at the river basin level holistically. Different types of natural and artificial storage systems are discussed in the following.

Ice and snow

The greater Himalayan region has the largest bodies of ice outside the polar caps with a total area of more than 100,000 sq.km. From a storage point of view, these glaciers, ice-fields, and snow packs provide important intra- and inter-annual water storage facilities.Snow can store water for anything from hours to years, but perhaps most important is its storage on a multi-monthly basis, thereby retaining water from the wet to the dry part of the year. Glaciers are also crucial. A glacier is a complex physical feature in which water as a liquid can be stored on, in, under, and adjacent to the ice. Water can be stored in a glacier as snow, firn (perennial snow), and ice, thereby delaying the release of water from the glacier by anything from hours, to days, weeks, months, years, decades, or even centuries (see Figure 2).

Thus, both snow packs and glaciers provide important water storage facilities in the greater Himalayan region. However, the contribution of meltwater from snow and ice to the rivers of the greater Himalayas still needs to be understood much better. In general, the relative contribution is larger in the west, for example in the Indus and Amu Darya basins, while in the east where large parts of the meltwater coincide with abundant runoff derived from monsoon precipitation, meltwater contributes a relatively smaller proportion (Eriksson et al. 2009).

Figure 1: **Water storage options** (Source: adapted from IWMI 2009)

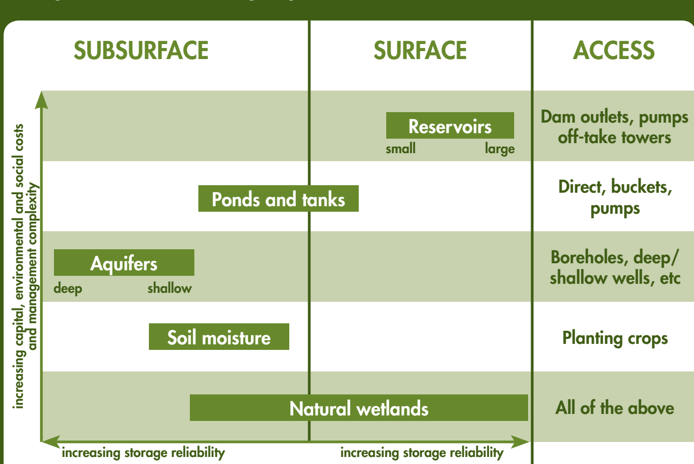
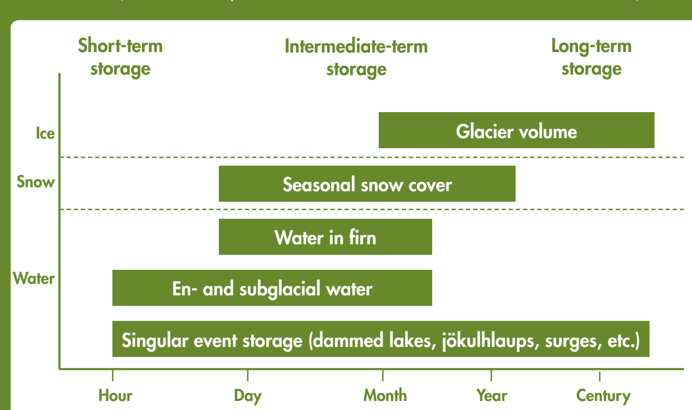


Figure 2: **Schematic graph showing different forms of glacier storage and their corresponding time-scales**
(Source: adapted from Jansson, Hock, and Schneider 2003)

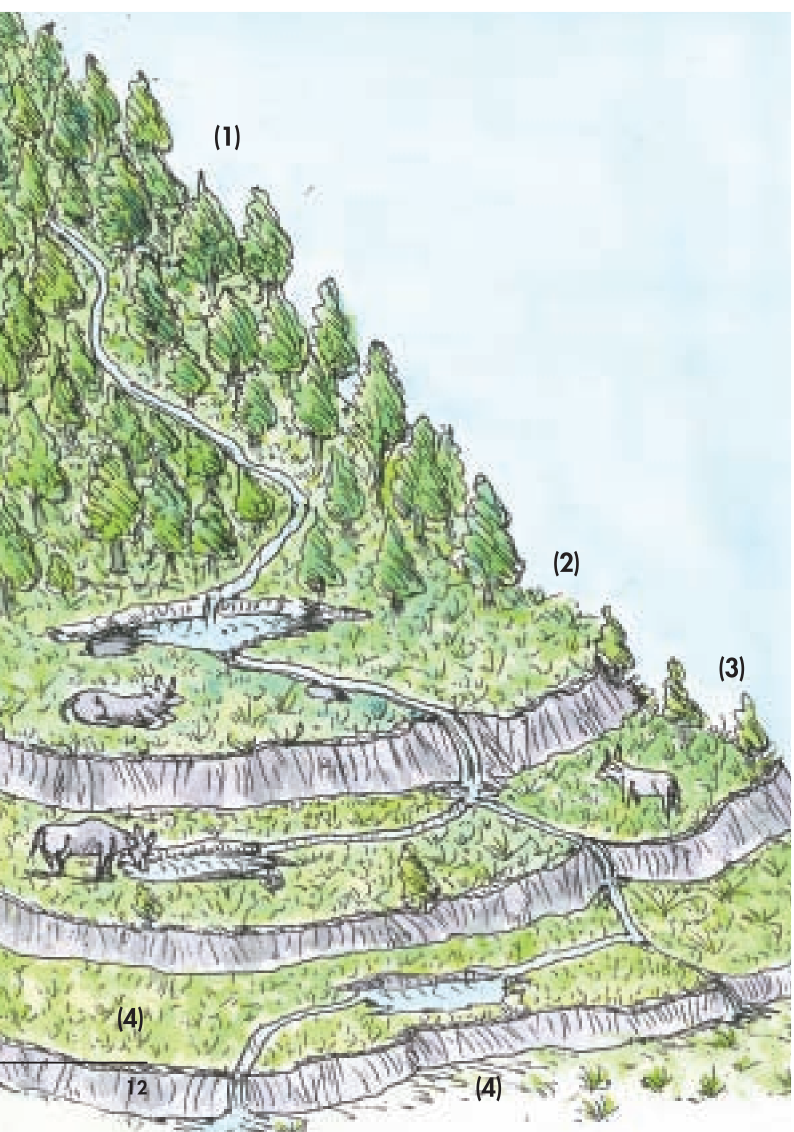


Natural wetlands

There are around 665 sq.km of wetlands within the HKH region. The Ruoergai Marshes on the Qinghai-Tibetan Plateau in southwest China, located at 3400-3900 masl, are a good example of the role Himalayan wetlands play in a natural system of water storage. The marshes soak up the snow and ice meltwaters of the Himalayas, and release them steadily to the streams that feed the Yangtze and Yellow rivers. This helps to regulate flow and prevent the flash floods that could endanger the livelihoods of people living downstream.

In recent times, many glacial lakes have formed in the Himalayan region due to the retreat of valley glaciers. According to ICIMOD's inventory, there are 8790 glacial lakes with a total area of around 800 sq.km, in Bhutan, Nepal, and selected areas of China, India, and Pakistan. These lakes may also have the potential to be used to increase water storage capacity, provided appropriate technology is available to mitigate GLOF (glacial lake outburst flood) risks. We need to explore the range of mitigation measures that could be taken against potential GLOFs along the lines of the initiatives in the Andes in South America, to make such water harvesting safe.

Figure 3: The zabo system of water storage and management



Soil moisture and constructed ponds

Soil moisture plays a vital role as a natural system of water storage. For soil moisture, the frequency and intensity of rainfall are at least as important as the total amount of precipitation. Watershed management, through improved land cover and water conservation practices, can help to maintain soil moisture and support rainwater harvesting. It could play a crucial role in improving infiltration so that groundwater percolation can be increased to help aquifer recharge. This is often achieved by practising low tillage farming and mulching in farmlands and by increasing humus on topsoil in forests. Surface water runoff can, of course, be stored in built structures such as ponds and tanks.

As an example, it is interesting to note the indigenous 'zabo' system of cultivation practised in Kikruma village of Nagaland, which uses a holistic approach to watershed management. A catchment area at the top of a slope is kept under natural vegetation to serve as a water source during the monsoon (1); ponds with earthen embankments are dug below the catchment area to harvest water for irrigation and livestock (2); cattle yards fenced with ordinary branches or bamboo are maintained below the ponds and the pond run-off water used for cleaning the yards (3); finally, the cleaning water, now enriched with manure, flows into rice terraces at the lowest level of the slope (4) (Figure 3, redrawn from Agarwal and Narain 1997).

Aquifers

Five ways have been identified in which a portion of the monsoon flows could be stored underground by groundwater aquifer recharge in the Ganges Basin through increasing infiltration into the water table. These are (i) water spreading in the piedmont deposit (Bhabar zone) north of the Terai belt of springs and marshes; (ii) constructing bunds at right angles to the flow lines in uncultivated fields to slow down run-off and increase infiltration; (iii) pumping out the underground aquifers during the dry season in the neighbourhood of nallahs (natural drains) which carry water during the monsoon; (iv) pumping out groundwater during the dry season along certain tributaries of the Ganges to provide space for groundwater storage; and (v) increasing seepage from irrigation canals during the monsoon season by extending the network of canals, distributaries, and water courses for kharif (rainy season) irrigation and pumping out this seepage water during the dry season (Revelle and Laksminarayana 1975).

The unconsolidated Bhabar zone and the Terai plains constitute a very large groundwater reservoir in the Himalayan region. Every year in Nepal, 2800 million cu.m of groundwater recharge takes place in the Bhabar zone, the piedmont deposit north of Nepal's Terai belt, and another 8800 million cu.m in the Terai belt itself. Generally, the rate of recharge from vertical percolation is much higher in the Bhabar zone than in the Terai. The Bhabar zone is also the main recharge site for the Terai, but there is no clear information available on the exact demarcation and area of the zone.

Reservoirs

Since constructed reservoirs can have a wide range of capacity for water storage, it would be helpful to think in terms of small and large reservoirs. The standard definition of small dams is for structures less than 15 metres high with an embankment volume generally less than 0.75 million cu.m. Small reservoirs can be built at a low cost in a short period. Their proximity to the point of use makes them easily manageable by the local community. The evaporation loss in these small reservoirs is, however, high due to the high surface area to volume ratio.

Both upstream and downstream communities can take advantage of 'positive externalities' by choosing to build storage projects of a multipurpose type. A number of large dams have been built in in the HKH areas of China and India during the last six decades to service storage type hydropower plants . Water storage capacity in the hydropower plants of China and India has been found to be large enough to provide irrigation water benefits as well. The storage capacity in the hydropower plants of Bhutan and Nepal, however, is relatively small with the projects providing hydroenergy benefits only.

Sedimentation may be the greatest challenge facing existing reservoirs, both large and small. In addition, seismic risks and GLOF risks are also important. Furthermore, an important general issue facing large dams is their social and environmental impact, mainly land submergence and population resettlement.

Conclusion

It is possible to utilise the potential of water storage capacity in the HKH region for adaptation to climate change. It may be feasible to harness the natural systems in the biosphere through initiatives such as wetlands conservation and watershed management in the hills and mountains, as well as groundwater aquifer recharge in the foothills. Small ponds and tanks for rainwater harvesting could also be built on hill farms. Constructing large dammed reservoirs in the downstream plains is a further option. Depending upon the geophysical characteristics of a specific location in the region, a combination of natural and artificial systems could be selected to meet the water needs of the community.

It is necessary, however, to turn the natural storage options, including ponds, lakes and aquifers, from a passive source to a planned and active source of water storage. To this end, the knowledge gap concerning the cryosphere and biosphere will have to be addressed. The changes in glacial volume and snow cover must also be examined further, and information sought on the contribution of snow meltwater to stream flow in river basins. Scientific investigations to assess and monitor groundwater resources in the region, including the three transboundary aquifers of the Indus, Ganges, and Brahmputra basins, must also be launched.

Traditional institutional mechanisms for community water governance play a very important role for the success of water storage capacity development initiatives. Institutional mechanisms may also be necessary to encourage the downstream beneficiaries of aquatic ecosystem services to reward and compensate the upstream communities in managing watersheds or wetland conservation projects. Furthermore, institutional mechanisms for transboundary cooperation are vital for taking advantage of 'positive externalities' and making compromises on the 'negative externalities' of large reservoirs.

To conclude, it is necessary to close the knowledge gaps concerning the cryosphere and biosphere and to craft appropriate institutional mechanisms to successfully harness the water storage potential of the HKH region for adapting to climate change.

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