commentary

Asia's water balance

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Multiple factors determine how much water is and will be available in the river basins of Asia. To expose hotspots and help adaptation, these factors must be assessed together at the basin level.

The availability of water for human consumption and agriculture can no longer be taken for granted. Various facets of water stress at different spatial scales, such as groundwater depletion[1,2], climate change and population increase[3], and glacier and snow melt[4,5], have been recognized as contributors to potential water scarcity. However, what matters for potential interventions is an integrated view of all contributions to water availability at the river-basin scale.

Potential water scarcity, by definition, implies that demand on water resources exceeds supply in a sub-humid to arid climate. Taking the basins of ten rivers that originate in High Mountain Asia (Fig. 1) as an example, we argue here that five main factors will determine whether water will become scarce in the foreseeable future: glacier melt, groundwater extraction, reservoir construction, future precipitation and population growth.

The role of glacier melt for water supply varies strongly between the different river basins considered[4], even though all the rivers originate in partly glacierized areas. For the Indus Basin, for example, it is estimated that glacier melt may contribute up to 26% of the total runoff generated in the basin because of the presence of large glacier systems in the source areas in combination with an arid downstream climate. For the Ganges Basin, the glacier-melt contribution is estimated to be only 3% as a result of a much-wetter, monsoon-dominated climate and a smaller glacier extent[4]. Together with deep groundwater, glacier melt is one of two non-renewable or slowly renewable natural water sources, as opposed to reservoirs. Because of large measurement uncertainties and the inaccessibility of the Asian high-mountain region, the magnitude of the ice stock is uncertain — as is the rate at which it will be depleted as a result of climate change.

Large-scale groundwater abstraction augments surface water supply in the Indus, Ganges, Yangtze and Yellow river basins at rates that generally exceed both natural and return-flow recharge. This extraction supplies the region's large-scale irrigation systems, and thus supports agriculture. Depletion of groundwater is likely to continue in these basins until groundwater levels have dropped so far that pumping becomes too expensive for small-scale farmers[6].

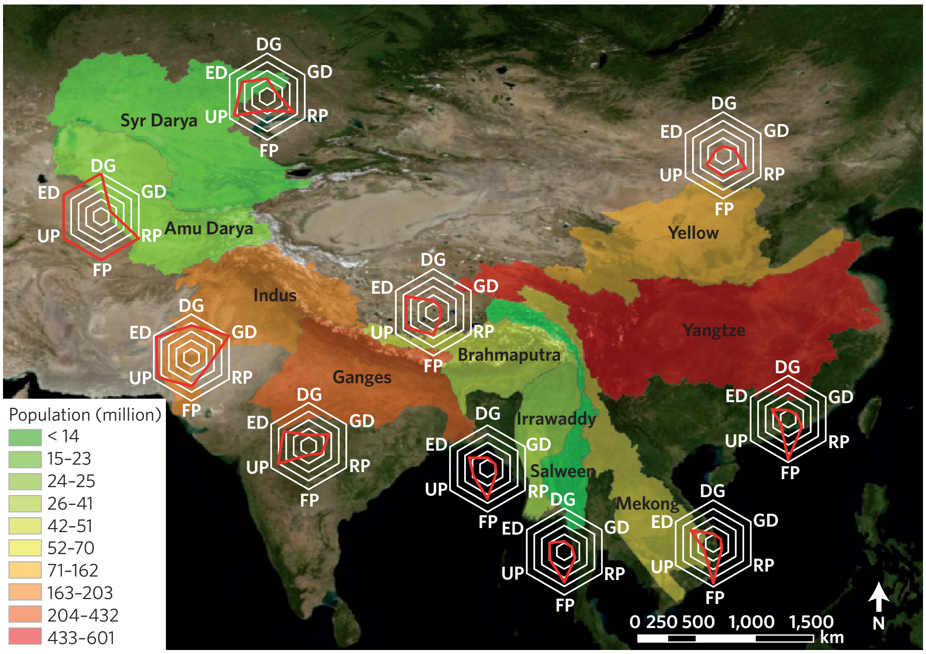

Figure 1 | Multiple facets of future water shortage. The basins of ten large rivers that originate in Asia's high mountains vary in their total population (numbers for the year 2000 by colours), in their susceptibility to water scarcity and in the relative importance between potential causes for future scarcity: dependence on glacier melt (DG)[4], groundwater depletion (GD)[10], reservoir potential (RP)[7], future precipitation (FP) and the uncertainty in future precipitation (UP; W. W. I., M. Suklitsch, A. Gobiet, F. Pellicciotti and M. F. P. B., unpublished data) and economic development in terms of gross domestic product[11] and population growth (ED)[12]. Radar charts: qualitative ranking between low susceptibility and/or large coping capacity (1) and high susceptibility and/or small coping capacity (5) for each of the five factors discussed in the text.

The construction of reservoirs is an effective way to manage discrepancies between the seasonal cycles of water supply and demand. The melt season does not necessarily coincide with the growing season of agricultural crops. Reservoirs store both rain and melt runoff, and water is released when downstream demand is highest. As ice stocks decline, a stable and reliable source of runoff is disappearing, increasing the need for additional reservoirs. In some basins, such as the Amu Darya, the full potential for reservoirs has already been exploited. That is, the reservoir capacity[7] is already large compared with rainfall. For those basins, the options for adaptation to future changes in water availability are limited.

On the supply side, projected changes in future precipitation are of prime importance. On average, the latest generation of global climate models project a modest increase in total precipitation over the ten river basins considered here. However, because of the extreme topographic relief and the complexity of the monsoon[8], the

Box 1 | Water availability in ten Asian river basins.

The Syr Darya Basin is at an intermediate level of risk of water scarcity, mostly because there is only limited potential to increase reservoir capacity and there is large uncertainty in future precipitation. The basin scores low on other criteria and the number of people potentially affected is relatively small.

The Amu Darya Basin scores highest on all risk factors, except for groundwater depletion. The basin strongly depends on glacier melt, only a small and highly uncertain increase in precipitation is projected, there is limited scope for increasing reservoir potential and the demand is likely to increase. Yet, the number of people potentially affected is relatively small.

The Indus Basin is most vulnerable to changes in water availability. A strong dependence on non-renewable or slowly renewable natural water resources such as glacier melt and groundwater in combination with rapid economic and population growth in an already densely populated area makes the Indus Basin Asia's hotspot.

The Ganges Basin is at an intermediate risk. Climate models project an increase in precipitation, there is ample scope for increasing reservoir capacity and there is a small dependence on glacier melt. However, demand is likely to increase strongly, future precipitation is uncertain and the basin is densely populated.

The Brahmaputra Basin is at low risk in terms of water shortage and scores similar on most facets as the Ganges, yet the number of people being potentially affected is smaller. In this most monsoon-dominated basin of Asia, the risks lie with an occurrence of extreme rainfall that, in combination with sea-level rise, could result in severe flooding.

The Irrawaddy, Salween and Mekong basins are very similar. They do not depend strongly on either groundwater or glacier melt, future precipitation is likely to show a modest increase, there is sufficient scope to increase the reservoir capacity and the demand side only shows a gradual increase. In combination with a relatively small population, the vulnerability to water stress is likely to be very limited. Yet the trans-boundary nature of these rivers poses an additional risk on water security.

The Yangtze and Yellow river basins score low on all facets considered, except that only a very modest increase in future precipitation is projected. However, in 2000, over 601 million people in the Yangtze Basin and 162 million people in the Yellow River Basin depended on its water resources, so although the risk is small the impact may be large.

uncertainties are considerable. The models predict variations between the different basins ranging from an increase in annual precipitation in of 0.8% in the Amu Darya Basin to 6.5% in the Ganges Basin (2021–2050 relative to 1961–1990; W. W. I., M. Suklitsch, A. Gobiet, F. Pellicciotti and M. F. P. B., unpublished data). However, the spread between climate models — and hence the uncertainty — is considerable. Any attempts to adapt to potential future water scarcity in Asia must fully account for the full range of possible precipitation scenarios.

Finally, water demand is expected to increase steeply with population growth, as well as with rising per capita food intake as a region becomes more developed. There are considerable differences between river basins in terms of growth projections for population and economy[9]. In the Indus Basin, for example, a strong projected population increase in combination with rapid per capita economic growth is expected to cause a steep increase in water demand. Furthermore, many parts of Asia are politically unstable, limiting the potential for sharing, trading or exchanging resources.

An overview of the various factors for each of the river basins (Fig. 1 and Box 1) reveals a large divergence in susceptibility to future water scarcity between basins, as well as the differences in the causes of water scarcity. For example, with 601 million inhabitants, the Yangtze Basin has the largest population in the region, but the rankings are low for almost all variables. Overall, vulnerability is low.

The Ganges Basin represents an intermediate case: dependence on glacier melt is limited, the depletion of groundwater resources is average and the potential for increasing reservoir capacity is sufficient. A projected increase in precipitation, although with large uncertainty, and a medium increase in water demand yield an overall susceptibility to water scarcity in the middle range. However, the number of people that would be affected if water became scarce in the Ganges Basin is large: in 2000, 432 million people lived in the region.

In the Indus Basin, by contrast, a large population that is growing quickly in numbers and prosperity is faced with a strong dependence on unpredictable glacier melt, severe groundwater depletion and an uncertain future precipitation regime. Here, the vulnerability to water scarcity is the highest in Asia.

The projected large growth in population and prosperity in the Indus Basin, despite limited water to support development, seems contradictory. Over time feedbacks are likely to develop — economic development will slow down in response to resource scarcity and demand will be reduced. At the same time, technical or societal mechanisms for adaptation are likely to emerge, allowing people to cope better with water scarcity. At present, neither of these effects is accounted for in models for the assessment of water resources.

Multidisciplinary research and development should focus on basins like that of the Indus River, where several factors conspire to make water scarce both now and in the future. In a quickly changing physical and economic climate, robust and comprehensive adaptation strategies must be developed for these basins to make the best use of the water available. ❐

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