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Mountain Waters Crucial for Irrigated Agriculture in the Indus, Less so in the Ganges and Brahmaputra Basins

About HI-AWARE

HI-AWARE aims to enhance the adaptive capacities and climate resilience of the poor and vulnerable women, men, and children living in the mountains and flood plains of the Indus, Ganges, and Brahmaputra river basins. It seeks to do this through the development of robust evidence to inform people-centred and gender-inclusive climate change adaptation policies and practices for improving livelihoods.

The HI-AWARE consortium is led by the International Centre for Integrated Mountain Development (ICIMOD). The other consortium members are the Bangladesh Centre for Advanced Studies (BCAS), The Energy and Resources Institute (TERI), the Climate Change, Alternative Energy, and Water Resources Institute of the Pakistan Agricultural Research Council (CAEWRI-PARC) and Wageningen Environmental Research (Alterra). For more details see www.hi-aware.org.

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Key Message

130 million farmers in the downstream plains of the Indus and the north-western part of the Ganges basin depend on water originating from glacier and snow melt from the mountains.

In terms of crop production, 9% of the ~46 million metric tonnes of wheat that is harvested each year in the Indus Basin can be attributed to water from glacier and snow melt. Similarly, 15% of the annual 19 million metric tonnes rice production, 28% of the 4 million metric tonnes cotton and 17% of the 53 million metric tonnes of sugarcane can be attributed to this meltwater. In the Ganges Basin, 3% of cotton production and 7% of sugarcane production can be attributed to meltwater.

Discharge from glacier and snow melt and groundwater provide a reliable supply of irrigation water during parts of the growing season when other water sources are scarce. Any changes in the future availability of meltwater or further groundwater depletion will therefore impact agriculture.

Understanding the links between sources of water demand and sources of water supply is important for developing appropriate adaptation measures. In HI-AWARE we developed a water resources model to help understand risks and to evaluate solutions to manage the water budget.

Introduction

Food production in the Indus, Ganges and Brahmaputra basins (IGB) is intricately linked to timely water supply. A constant supply of water for irrigation in the plains results from the unique interplay between seasonal snowmelt in spring, glacier melt rising during the Asian summer months and into the monsoon season when rainfall starts to contribute, with slowly recharging groundwater resources supplementing shortfalls in supply throughout the year. The vast amounts of water stored as snow and ice make the mountains Asia's 'Water Towers' on which almost a billion people depend in the IGB basins.

Socio-economic development, a growing population and higher demand for domestic use and industry, is expected to strongly increase water demand and will likely lead to a further increase in the water gap – the difference between demand and supply - in the 21st century (Wijngaard et al., 2018). These changes are considered a serious threat to crop productivity, and hence to food production and food security.

With climate change, the modulating effect that snow and glacier melt provide might strengthen at first, due to increased melt, before eventually weakening. Moreover, a shift in the timing of meltwater might cause problems to water users who need the water at a specific time. In recent years, our insight into these shifts and their impact on water availability has increased (Lutz et al., 2016, Lutz et al., 2014), whereas a similar, detailed understanding of the seasonal patterns in the demand for water has been surprisingly absent. Moreover, a quantitative assessment on the extent to which the lives and livelihoods of people living in the downstream plains depend on the water from the mountains is missing from current studies.

To anticipate change, and adapt management accordingly, a thorough understanding of the dependence of agricultural production on different sources of water supply is essential. In HI-AWARE, we developed a coupled state-of-the-art high-resolution cryosphere-hydrology-crop model to assess the spatial and intra-annual variations in glacier- and snow-melt water contribution to streamflow for the entire Indus, Ganges and Brahmaputra basins. First, we investigated the temporal pattern of irrigation water demand. Subsequently, we quantified for the first time the dependence of agricultural production in the Indo-Gangetic plains on upstream snow and glacier melt water. Finally, we estimated the number of people that depend on meltwater, both for their livelihoods and for their food. These insights are important to properly anticipate and timely adapt agriculture to the expected changes in water availability and other climate change impacts.

Major Findings

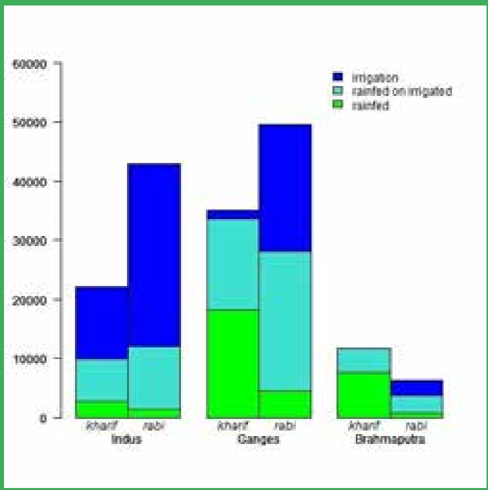


Figure 1. Mean annual seasonal irrigated (blue) and rainfed (green) production of food crops (sum of wheat, rice, maize, tropical cereals and pulses) in South Asia (Nepal, Pakistan, India and Bangladesh) and individual river basins. Light blue corresponds to potential rainfed production on irrigated land, i.e. dark blue corresponds to the increase in production due to irrigation.

We have investigated the seasonal pattern of irrigation water demand resulting from the typical practice of multiple cropping in South Asia. We show that the demand for irrigation water differs sharply between seasons and regions; for instance, in Pakistan, the irrigation water demand during winter (*rabi*) and summer monsoon (*kharif*) are almost equal (133 km3/yr and 110 km3/yr), whereas in Bangladesh, irrigation water demand during the *rabi* season is about a hundred times higher than during *kharif* (24 km3/year and 0.2 km3/year). In India the average annual *rabi* demand is around 307 km3/yr, whereas it is around 136 km3/year during *kharif*. Moreover, the relative importance of irrigated agriculture versus rainfed agriculture decreases sharply from west to east (Figure 1) (Biemans et al., 2016).

In a second study, we have related those seasonal patterns of irrigation water demand to different sources of water supply (Figure 2). We show that a large fraction of Indus' discharge and irrigation water supply originates from mountain water. This makes food production in Pakistan heavily dependent on water originating from snow and glacial melt at high altitudes (Figure 3) (Biemans et al., submitted). Because mountain water – and meltwater more specifically – is especially important during the pre-monsoon period, the production of early *kharif* crops such as cotton and rice, and annual crops like sugarcane, largely depend on this source of supply. Similarly, we looked into the contribution of groundwater, which is mostly used for growing *rabi* crops like wheat (Figure 4).

Our analysis shows that for 130 million farmers in the Indus and north western part of the Ganges, at least 10% of their irrigation water is originating from snow and glacier melt. Moreover, we estimate that snow and glacier melt provides the water to grow food crops sustaining the daily caloric intake of 30 million people.

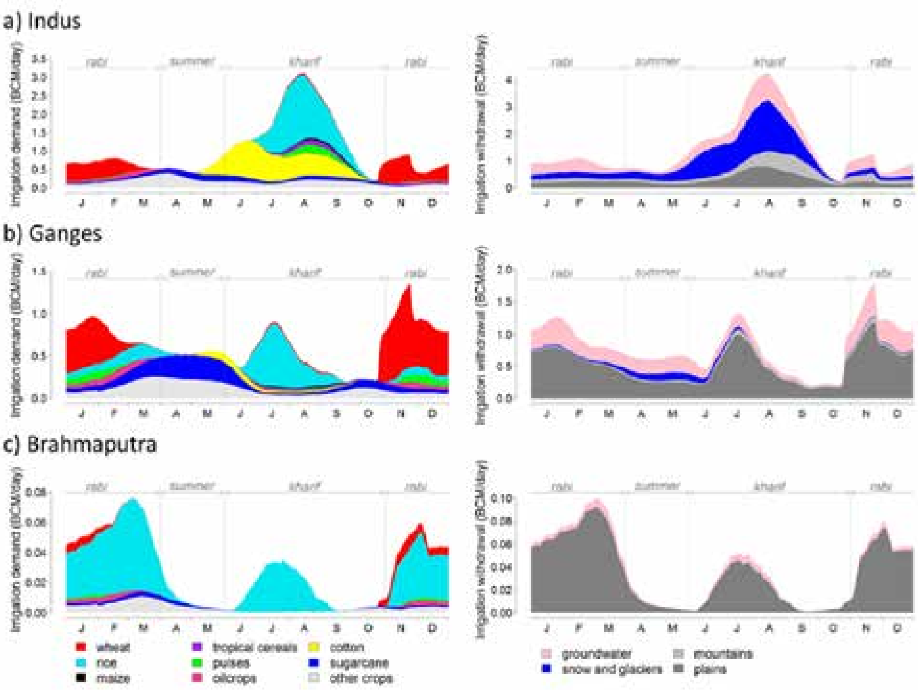


Figure 2. Mean annual cycle of irrigation water applied per crop (left) versus annual cycle of irrigation withdrawal per source (right) in Indus (a), Ganges (b) and Brahmaputra (c). Numbers in the right figures (withdrawals) are slightly higher than the left figures (applied water) due to losses during conveyance of the water from source to field.

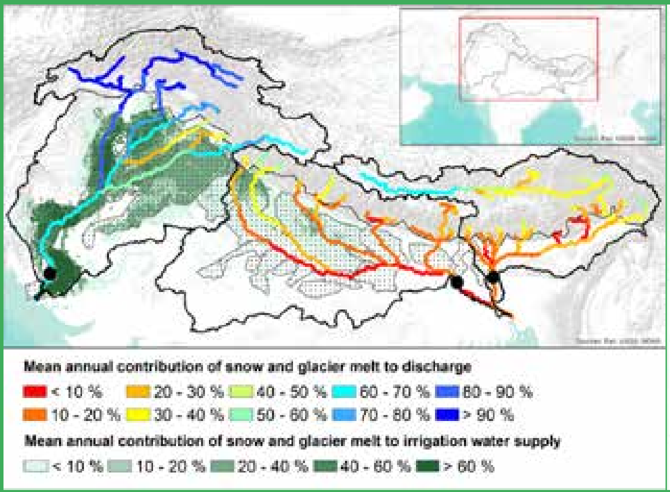


Figure 3. Contribution of snow- and glacier-melt to downstream discharge and irrigation supply (1981-2010). Dotted polygons represent the command areas of the large scale irrigation canal systems through which water from the main river is diverted and distributed.

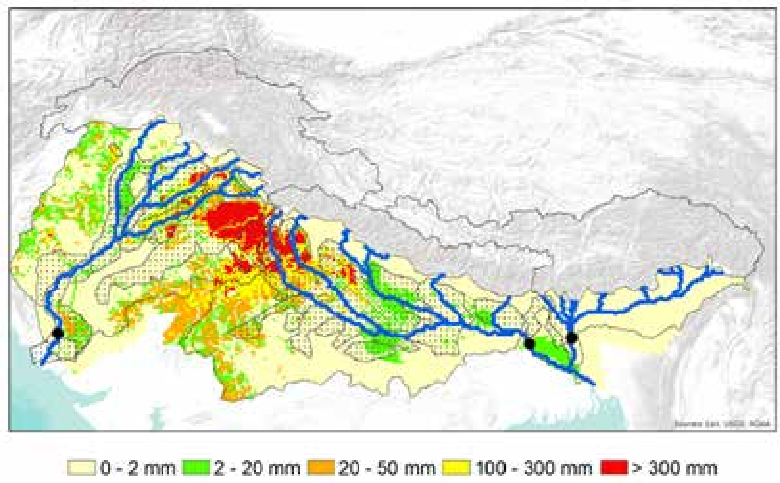


Figure 4. Mean annual groundwater depletion (mm) in the plains due to groundwater extractions for irrigation.

Policy Action

Better insight into the timing and sources of water demand and supply can support decisions on policy measures to decrease water scarcity or increase water productivity. It helps to evaluate different measures – rainwater management, expansion of cropland into other areas, change of crop type, change of sowing date, and/or improved storage capacity. Improved understanding and estimates of the timing and quantity of groundwater used, and the crops that it sustains, can support policies to reduce overexploitation.

We have shown that cotton and rice production in the Indus basin, and sugarcane production in the north-west Ganges basin are largely dependent on snow and glacier meltwater, whereas groundwater is mostly tapped for wheat production. This implies that any shift in the timing or amount of meltwater will affect production of cotton and rice, and that a change in sowing date or crop type might be the best adaptation solution. On the other hand, it also implies that any changes in upstream water use or measures affecting the hydrological regime, such as the expansion of irrigation or storage of water for hydropower supply, might affect downstream water use. These upstream–downstream linkages should be quantified and taken into account in future management decisions.

Looking Ahead

Water resources from the mountains are crucial for downstream agriculture in the Indus basin, and to a lesser extent in the Ganges basin. In the Brahmaputra, the use of melt water in agriculture is less than 10% of annual water supply.

Any reduction in the future availability of meltwater will impact crop production, and necessitate adaptive measures such as changes in sowing dates or crop types.

The water resources model further developed under HI-AWARE provides greater insights into the links between the sources of water supply and demand, helps to understand the risks and can therefore be a useful tool in the formulation of policies to manage the water budget.

This brief is based on the following HI-AWARE publications:

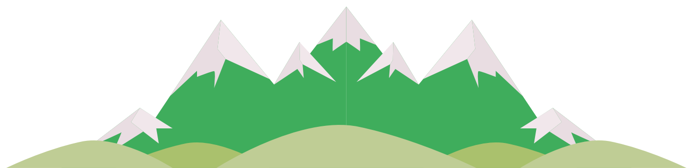
Biemans, H., Siderius, C., Lutz, A. F., Nepal, S., Ahmad, B., Hassan, T., Bloh, W. V., Wijngaard, R. R., Wester, P., Shrestha, A. B. & Immerzeel, W. W. submitted. Mountain water resources from high mountain Asia crucial for downstream agriculture

Biemans, H., Siderius, C., Mishra, A. & Ahmad, B. 2016. Crop-specific seasonal estimates of irrigation-water demand in South Asia. Hydrology and Earth System Sciences, 20, 1971-1982.

Lutz, A. F., Immerzeel, W., Kraaijenbrink, P., Shrestha, A. B. & Bierkens, M. F. 2016. Climate change impacts on the upper Indus hydrology: Sources, shifts and extremes. PloS one, 11, e0165630.

Lutz, A. F., Immerzeel, W. W., Shrestha, A. B. & Bierkens, M. F. P. 2014. Consistent increase in High Asia's runoff due to increasing glacier melt and precipitation. Nature Climate Change, 4, 587-592.

Wijngaard, R. R., Biemans, H., Lutz, A. F., Shrestha, A. B., Wester, P. & Immerzeel, W. W. 2018. Climate change vs. socio-economic development: Understanding the future South-Asian water gap. Hydrology and Earth System Sciences Discussions.



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