Efficient Conjunctive Use of Surface and Groundwater Can Prevent Seasonal Death of Non-Glacial Linked Rivers in Groundwater Stressed Areas

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Abstract The surface and groundwater system is an interdependent system. In the case of alluvial plains, they are best manifested by the relationship between a river and groundwater system. This relationship is vibrant and dynamic in rain-fed rivers or the non-glacial linked rivers. It has been typically observed that many a case such rivers originate from lesser elevation and in downstream stretches; during summers, their flow is maintained by groundwater contribution. In groundwater stressed regions, often these rivers get disconnected from aquifer. Thus there could be different levels of stream-aquifer interaction during monsoon and non monsoon seasons. In this context, the article examines effect of long-term groundwater abstraction on such river flows in a conceptual framework. It also proposes efficient conjunctive use of surface and groundwater to prevent death of such rivers.

Keywords Surface water · Ground water · Conjunctive use · Aquifer Stream–aquifer interaction

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1 Introduction

The growing population and improvement in the standard of living has led to increase in water uses world over. The water resource in many parts of India is under stress (Chatterjee et al. 2009; Rodell et al. 2009; Shekhar 2006a; Tiwari et al. 2009; Mukherjee et al. 2015). The demand–supply imbalance requires a scientifically planned strategy. The two major components of water, the surface and groundwater systems, remain in dynamic equilibrium (Shekhar and Prasad 2009). Hence, one of much talked about such strategy is efficient conjunctive use of surface and groundwater. The strategy involves rational and symbiotic development of both surface and groundwater resources to supply a given urban or irrigation canal command areas (Foster and Steenbergen 2011). This involves detailed estimation of the water demand and allocation of the surface and groundwater sources optimally. The underlying principle is based on restricting uses to environmentally sustainable limits. The conjunctive use strategy is particularly popular in canal command areas. This is so because these areas have assured surface water sources as an alternate to the existing groundwater sources. An optimal and prudent utilization of canal water depends on canal allowances for different regions and efficiency of distributaries networks in different parts of the canal command areas. Further, the conjunctive use strategy links it to the groundwater potential of the region. It is here that efficiency of this strategy is required for sustainable water management.

The overexploitation of groundwater resources can certainly have adverse effect on stream–aquifer interaction. The present article examines changes in stream–aquifer interaction linked to water uses in a conceptual framework. This becomes important as approximately 16% of assessment units in India (total 6607) are overexploited with regard to groundwater resources (CGWB 2014a), see Fig. 1.

2 Decline in Groundwater Levels in India

India experiences strong monsoon season, and monsoon rainfall is the main source of recharge. The deeper water level in a year is observed just before the onset of monsoon (pre-monsoon), while the shallowest water level is observed in the month of August. The groundwater level of November is considered to be very important for water recourses utilization planning, because the month is beginning of main extraction of groundwater for irrigation. Irrigation consumes about 90% of total groundwater extraction. If we observe water level difference between decadal mean of pre-monsoon water level (2003–12) and pre-monsoon 2013, it is obvious that a good part of India has shown decline in water levels (Fig. 2). This is mainly attributed to heavy abstraction of groundwater and demising recharge in many

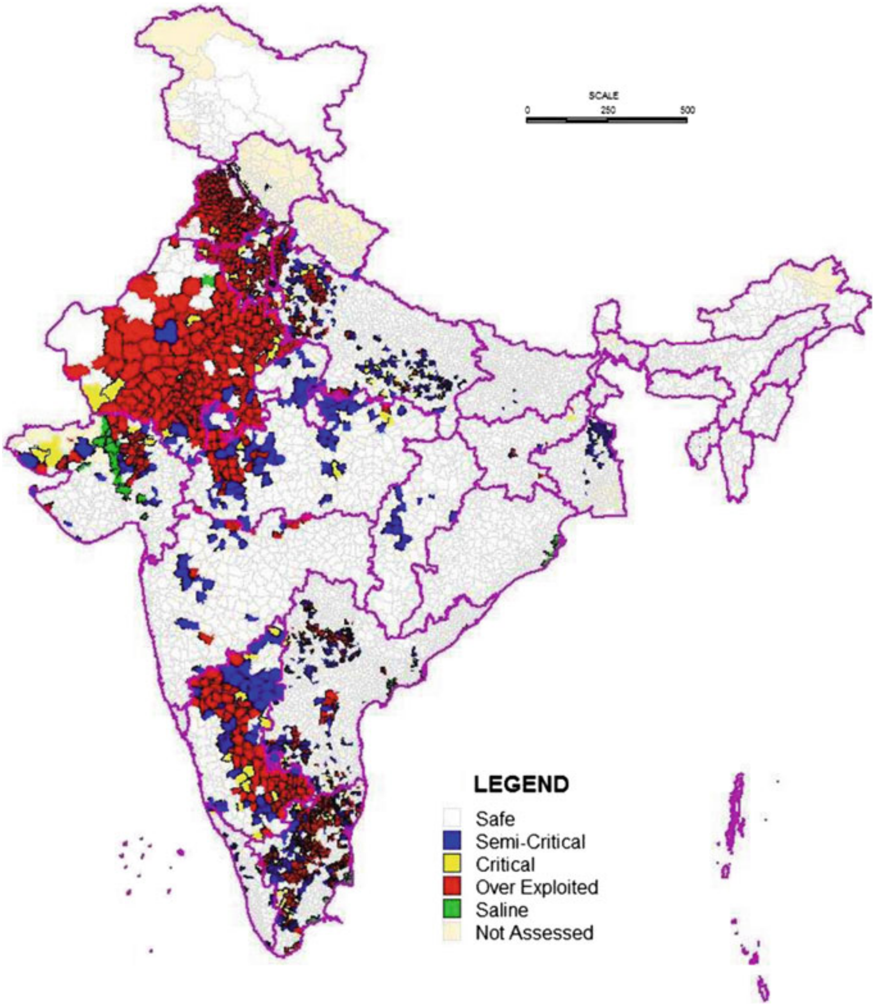

Fig. 1 Categorization of groundwater assessment unit in India (CGWB 2014b)

pockets. A significant part of India has depth to water level in the range of 10–20 m below ground level (mbgl), and some regions have still deeper water levels as observed in pre-monsoon 2013 (Fig. 3). In such regions, the stream–aquifer interaction for non-glacial fed rivers changes gradually. This gradual change is explained further below.

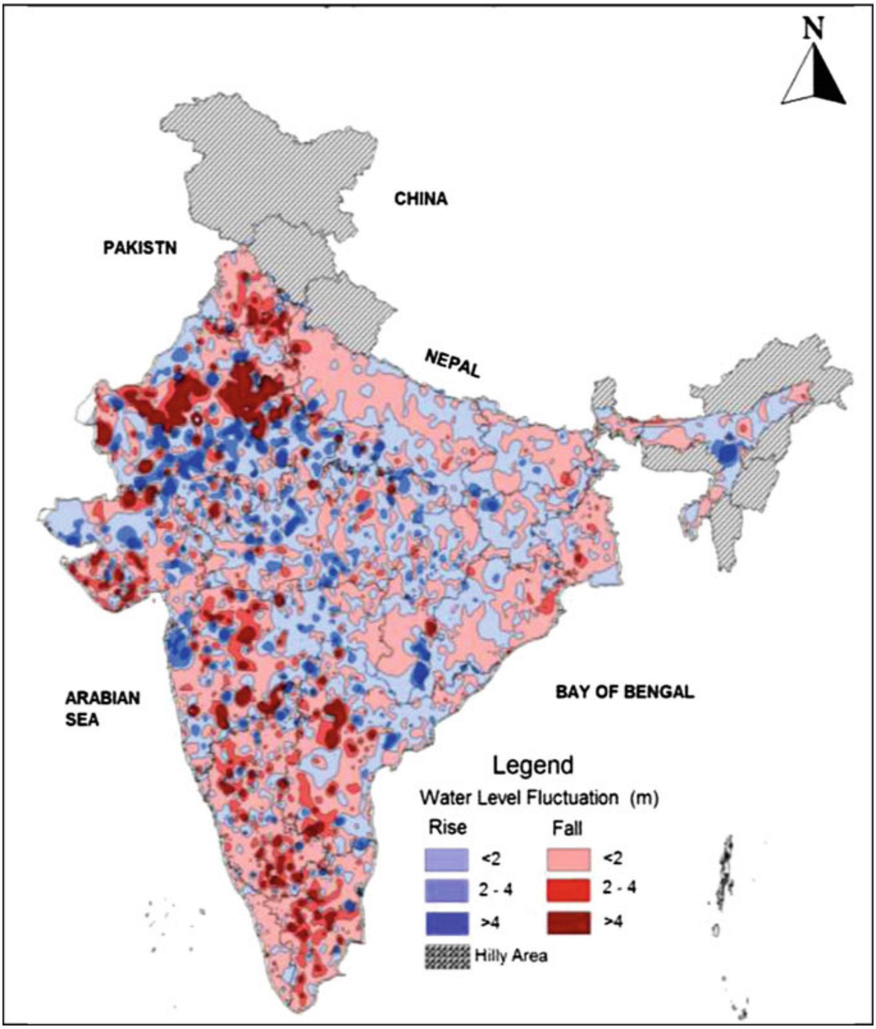

Fig. 2 Decadal water level fluctuation—decadal mean May (2003–2012) versus pre-monsoon 2013 (CGWB 2014b)

3 Stream–Aquifer Interaction in Conceptual Framework from Non-Glacial Rivers

The stream–aquifer interaction for non-glacial rivers in areas with declining water levels is explained with help of a schematic model (Fig. 4). The model demonstrates changes in stream–aquifer dynamics over the years with changes in groundwater level. It shows how the changes in water level over the basin have affected vertical connectivity in the river basin and the stream–aquifer interaction

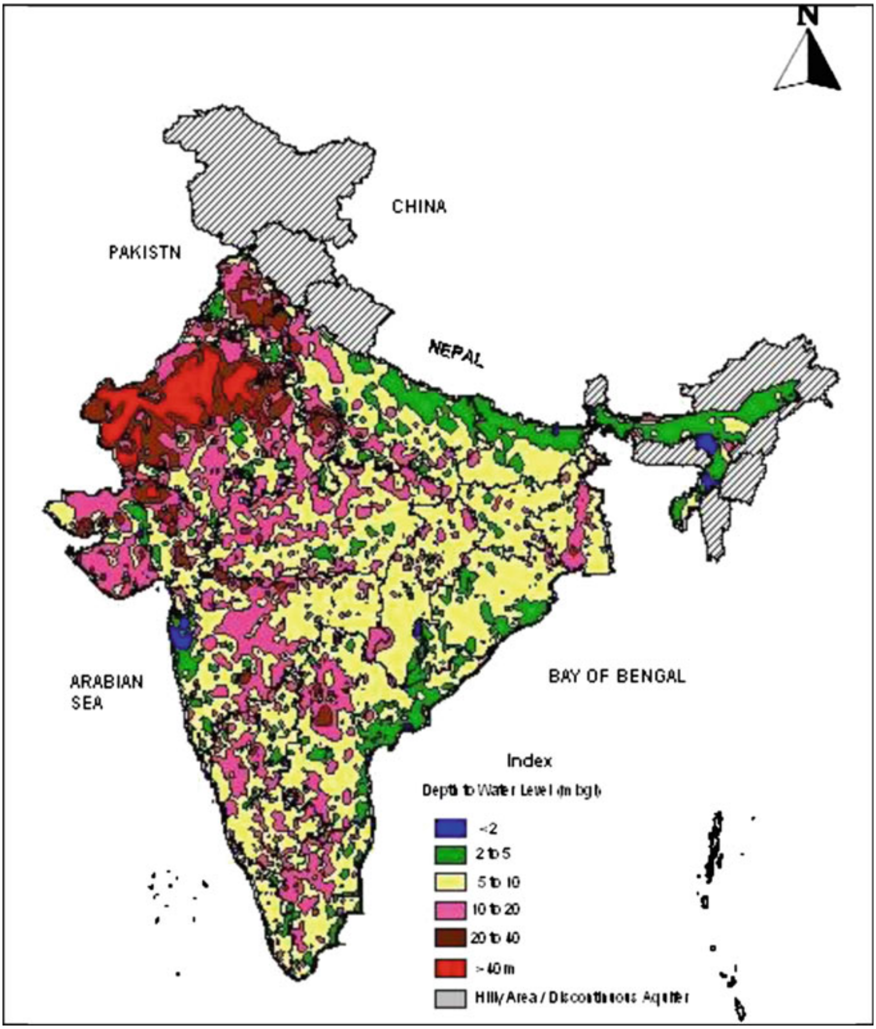

Fig. 3 Depth to water level map pre-monsoon 2013 (CGWB 2014b)

dynamics (Fig. 4). It is clearly observed that the river changes its nature from an effluent stream to influent stream as the water level declines. On account of this, the base flow in the river ceases there by, leading to very limited flow during non-monsoon months. The overall water system dynamics in the basin evolves to a stage that there is continuous decline in groundwater level and river flow. If the water level decline continues, the flow in such rivers during lean seasons becomes dead. An efficient conjunctive use of surface and groundwater resources in such areas would prevent seasonal death of rain-fed or non-glacial linked rivers.

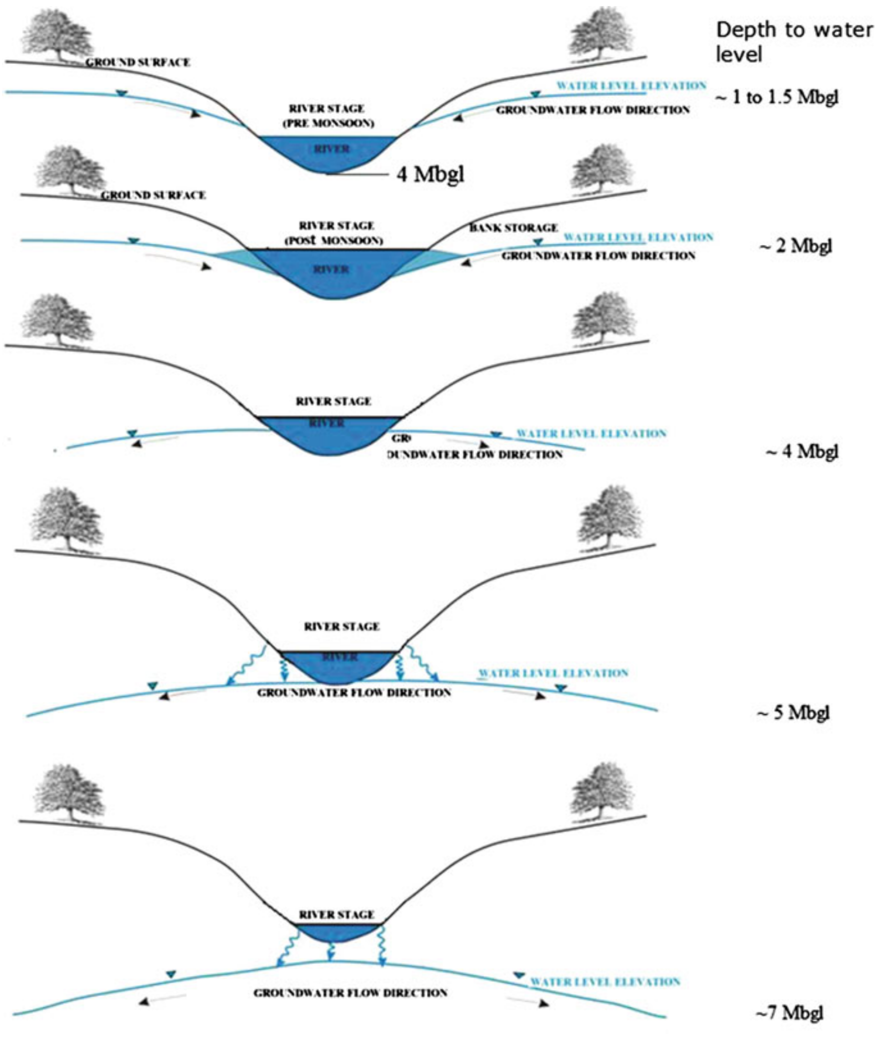

Fig. 4 Schematic model showing changes in vertical connectivity and stream–aquifer interaction in the Ghaggar basin vis-à-vis changes in groundwater levels (Shekhar 2006b)

4 Discussion and Conclusions

Some of the groundwater stressed areas in India such as Punjab and Haryana have excellent network of functional canal irrigation system. The network of canals supplies irrigation water for agricultural activity. When such assured canal water is available, farmers use minimal amount of groundwater. While at the same time when there is non-availability of assured canal water, farmers resort to groundwater pumping for irrigation purposes. This is an area where conjunctive use intervention is required. The conjunctive use strategy optimally allocates water demand to surface and groundwater sources in environmentally sustainable way.

These groundwater stressed areas also have non-glacial linked rivers such as Ghaggar and Chautang. It has been observed that some of these non-glacial linked rivers historically used to have sufficient flow in them during non-monsoon season because of effluent seepage from aquifer. However, in recent past these rivers are dead in some stretches during lean season. This phenomenon can be explained with the help of schematic model above (Fig. 4). Seasonal death of such rivers could have been easily prevented by efficient conjunctive use of surface and groundwater. A visit to one such basin (Ghaggar River) revealed overreliance on groundwater abstraction for agricultural uses. This could be on account of skewed canal supply or canal water distribution-related management issues. However, if prudent and efficient conjunctive use policy would have adopted in the basin, it would have restricted sharp decline in water levels and disconnection of stream–aquifer system. This in turn would have prevented death of the river during non-monsoon periods. Thus, it is essential that sustainable agricultural groundwater abstraction should be estimated in conjunction with the canal allowance. It would have been ideal to work out water balance of the basin considering to sustainable groundwater yield. Such estimate needed to have rider that stream-aquifer connectivity should be retained.

We conclude that the aim should be for maximization of agricultural output with limitation that water resources exploitation remains within environmentally sustainable limits. When we try for this, the best approach is to maintain the inflow and outflow directions of the dynamic equilibrium between surface and groundwater sources. This will certainly not alter base flow or propose over irrigation by canal system so as to induce soil salinity.

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