the ability of a formation to take in or release water from storage is dictated by the ability of the material to deform elastically and change porosity. Such strain-based storage coefficient is usually small in magnitude compared with the storage coefficient of desaturation drainage. Second, as seen from figure 4 in Gupta and Deshpande[1], areas of groundwater surplus lie largely in Maharashtra, Madhya Pradesh, Andhra Pradesh, Orissa and Assam, and their environs. Large parts of these areas are wilderness tracts, occupied by many indigenous tribal people. Their welfare and the need for wilderness protection may preclude large-scale groundwater recharge in these areas. If so, the projected 125 km^3 may require downward revision.

Regardless quantities, one clear message is that surface water and groundwater are intimately interlinked. This recognition persuades us to devote attention to the hydrological cycle within which surface water and groundwater are linked. An important development in the earth sciences during the early 1960s was the concept of regional groundwater motion[3]. At its core, this concept recognizes that water moves vertically down in recharge areas of higher elevations in a watershed, moves vertically up in discharge areas at valley bottoms, and moves laterally in between. This regional flow pattern has profound influence on water chemistry, distribution of soil, and zoning of ecosystems. An implication is that groundwater recharge cannot be arbitrarily carried out everywhere, because induced recharge will have physical, chemical and biological impacts on the total system.

Gupta and Deshpande[1] are enthusiastic in their support of rain-harvest when they state, '. . . rainwater harvesting and artificial groundwater recharge, where people and communities can directly participate due to the low level of technologies involved'. This statement seems to suggest that the general public can simply be empowered to intercept, store and recharge water, regardless of where they may be located within the hydrological system. The wisdom of this perception merits reflection from the perspective of regional groundwater motion. Sites for artificial recharge, disposal of wastes, land reclamation, and so on, are to be chosen based on the nature of groundwater flow systems on appropriate spatial and temporal scales. This statement does not negate active public participation in water management. Rather, a water-literate public is essential in other ways for judicious management of available water resources.

Gupta and Deshpande[1] state, 'Therefore, acquiring quantified knowledge about the spatial and temporal distribution of the different components of the local, regional and national hydrological cycle is vital to plan and develop water resources of the country at different scales at the least cost to ecology and environment . . . '. This statement goes to the heart of India's water resources woes. Climate, landscape, geology and ecosystems subject to physical laws of nature dictate the quantity of water available within the country. The challenge is to adapt our living needs to what is available, tempered by our human and social values. This adaptation entails a coming together of science and society in unprecedented ways. It is becoming abundantly clear that water resources systems cannot be subdued at will by engineering and technology.

Managing water is not just about water anymore. It requires management of interlinked hydrological, nutritional and erosional cycles. Earth scientists and ecologists now recognize that learning to sustain human living from these cycles, without unduly disturbing the balance among them, is a formidable challenge. If India is to be optimistic about its water resources in 2050, the time is now to embark on a major initiative to delineate and characterize hydrogeological basins on various scales, establish permanent monitoring stations, generate water budgets and initiate procedures of rational water management that combine short-term as well as long-term objectives.

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Response:

We thank Narasimhan for his interest in our work. Though presently not in a position to comment on the reasons for the differences in estimates of evaporation and groundwater recharge components between California and India, we recognize the difference. The error in our evapotranspiration estimate cannot be ruled out, as this is the least certain component estimated from the water-balance studies, although this alone may not explain the observed difference.

Figure 4 in our article does take into account the gross hydrogeology of various river basins while estimating achievable artificial groundwater recharge potential of ~ 125 km^3/yr. Achieving this would certainly require detailed investigations of hydrogeology and several innovations in technology together with social, political and legal aspects, as suggested by Narasimhan.

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