commentary

Groundwater sustainability strategies

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Aquifers are the primary source of drinking water for up to two billion people. To avoid overexploitation, lengthy renewal periods of some aquifers must be taken into account.

Groundwater extraction has facilitated significant social development and economic growth, enhanced food security and alleviated drought in many farming regions[1]. But groundwater development has also depressed water tables[2], degraded ecosystems[3] and led to the deterioration of groundwater quality[4], as well as to conflict among water users. The effects are not evenly spread. In some areas of India, for example, groundwater depletion has preferentially affected the poor[1]. Importantly, groundwater in some aquifers is renewed slowly, over decades to millennia, and coupled climate–aquifer models predict that the flux and/or timing of recharge to many aquifers will change under future climate scenarios. Here we argue that communities need to set multigenerational goals if groundwater is to be managed sustainably.

We take as one example the Nubian sandstone aquifer system in northeastern Africa, a massive groundwater reservoir comprising minor shale beds laid between sandstones, tens to hundreds of metres thick[5]. Located in the Saharan desert, the aquifer spans the borders of four countries — Sudan, Chad, Libya and Egypt — and covers more than 2 million km^2. Current recharge rates to this desert aquifer are negligible. Indeed, recent stable isotope and radioisotope data indicate that the aquifer was recharged during periods of the Pleistocene marked by abundant rainfall up to one million years ago[5,6]. Despite this being a practically non-renewable resource, large amounts of water are extracted from the Nubian sandstone aquifer system, primarily for agriculture — either for large development projects in Libya or private farms in Egypt[7]. As a result, naturally flowing springs have dried up and groundwater levels have been declining for decades. In parts of Egypt, water levels have declined by 60 metres as a result of groundwater extraction from this aquifer[7].

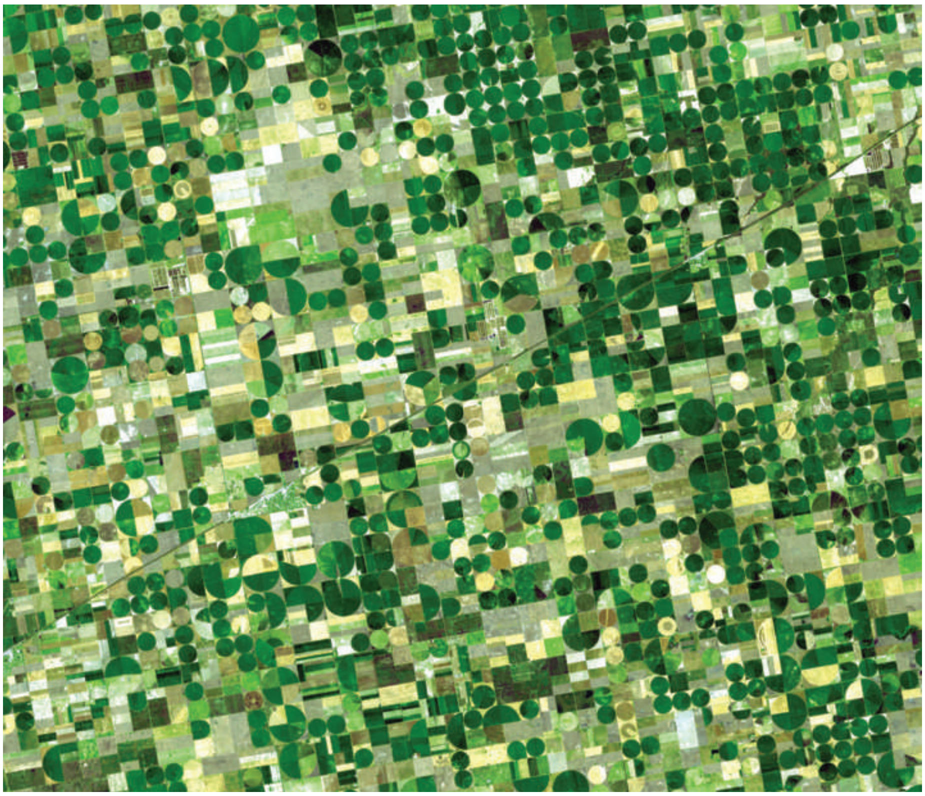

Figure 1 | Satellite image of crops irrigated by groundwater from the High Plains aquifer in Kansas, USA. Aquifers supply drinking water to millions of people, but in some aquifers, water is being depleted faster than it is being renewed. Image courtesy of NASA/GSFC/METI/ERSDAC/JAROS and the US/Japan ASTER Science Team.

The High Plains aquifer (Fig. 1), popularly known as the Ogallala aquifer, and located in the dry continental climate of central North America, is another example of a key aquifer with low recharge rates[8]. Underlying the Great Plains of the United States, this unconsolidated sand, silt, clay and gravel aquifer system spans 450,000 km^2. Groundwater age estimates indicate that most of the water at the base of the High Plains aquifer was recharged before the onset of modern human activity, around 3,400 to 15,600 years ago[9]. An irrigation-based economy and 2.3 million people depend on this aquifer[8]. As a consequence, groundwater levels have dropped in many areas — in some cases by up to 50 metres — since the 1950s, and groundwater-dependent streams and ecosystems have been compromised[8,10]. In western and central Kansas, for example, several streams and cottonwood riparian zones have dried out, and fish populations have disappeared, as a result of groundwater-based irrigation increases in the 1970s[10].

The lengthy residence times observed in the Nubian and High Plains aquifers are not unique. A synthesis of groundwater ages in aquifers in the United States indicates that groundwater residence times that are greater than 11,000 years are common[11]. Overexploitation of such slowly renewed aquifers can have severe social, environmental and economic consequences. To help avoid future problems, we suggest that sustainability goals for water quality and quantity should be set on a multigenerational time horizon of 50 to 100 years, while acknowledging even longer-term impacts.

Community involvement will be essential if long-term management strategies are to succeed. Aquifer- or watershed-based communities should be involved in setting specific goals for groundwater use, and should have an understanding of the fragility of the resource. An example of this form of management can be found in Texas, where a groundwater-availability modelling program has modelled more than 25 aquifers with guidance from aquifer users[8]. These publicly available models are 'living tools' that are continually updated with new data and refined to better meet community needs. Importantly, those in charge of groundwater sustainability must use data from this program when devising groundwater management plans[8].

Also important is whether groundwater is considered interchangeable capital by both local communities and regulatory bodies. The social and economic benefits of large aquifer withdrawals may not compensate for the significant depletion of aquifers that are effectively non-renewable on human timescales. Once the groundwater is gone, there is no getting it back, at least in the foreseeable future. ❐

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