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Groundwater quality and depletion in the Indo-Gangetic Basin mapped from *in situ* observations

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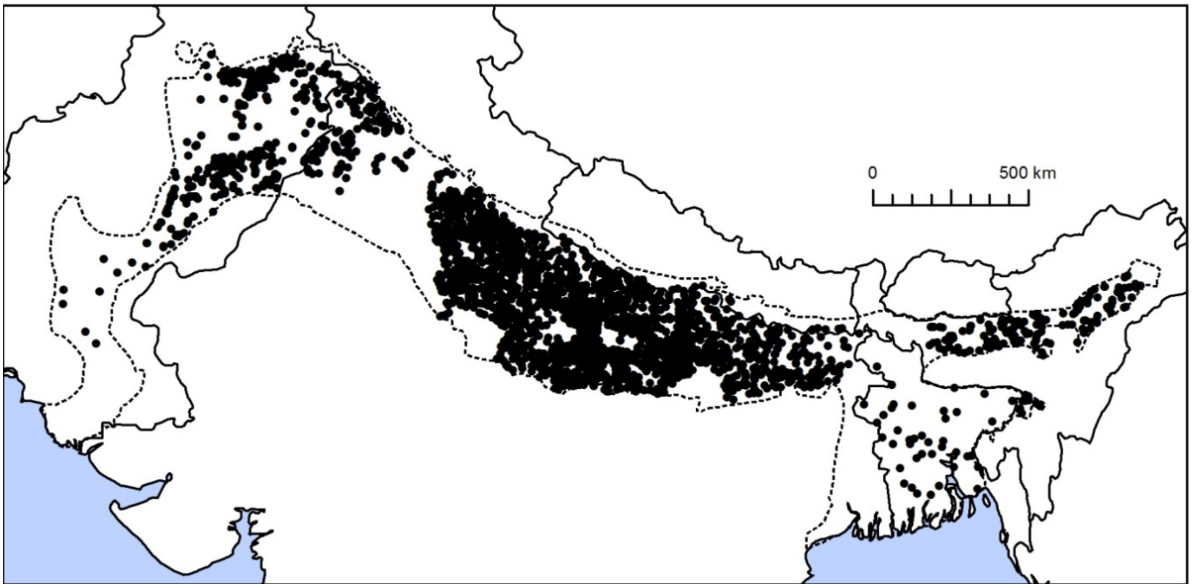
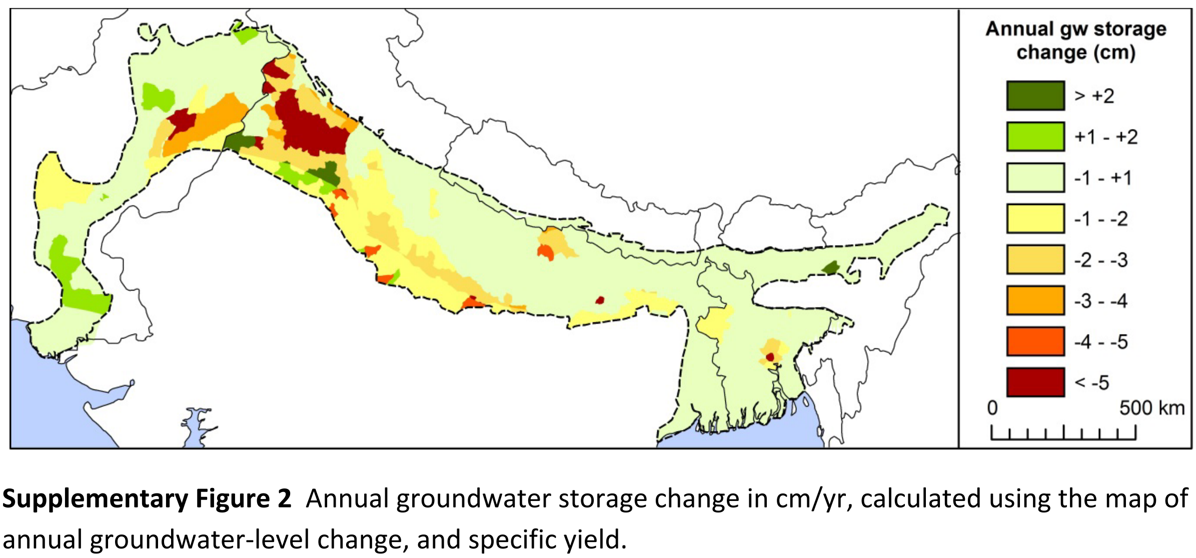
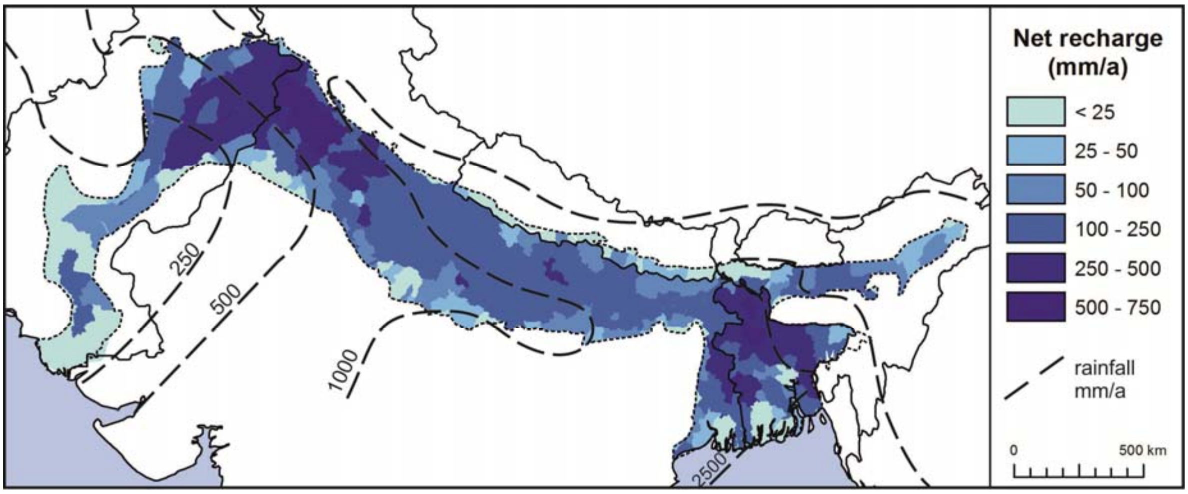


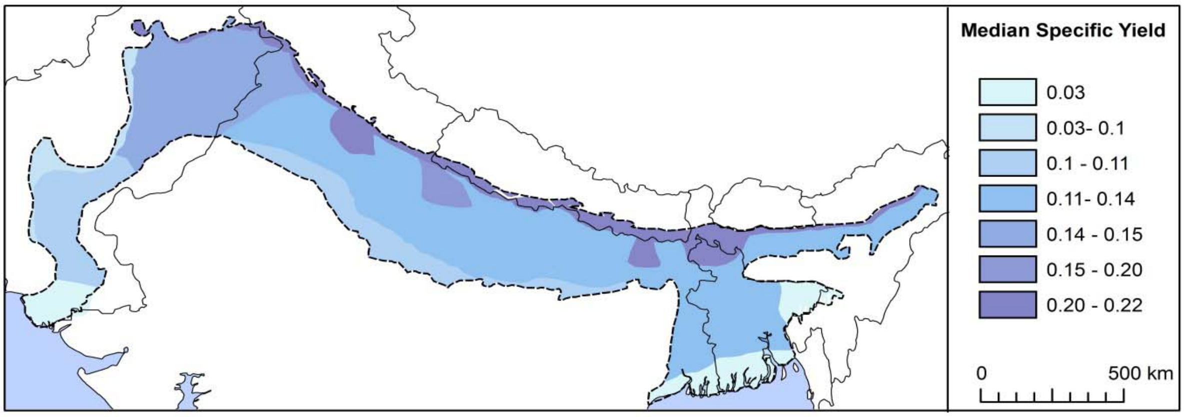
Supplementary Figure 1 Distribution of the finalised water-table time series record dataset for the IGB aquifer. There are 3429 individual time series, each with 7 years or more data and 2 or more records per year.



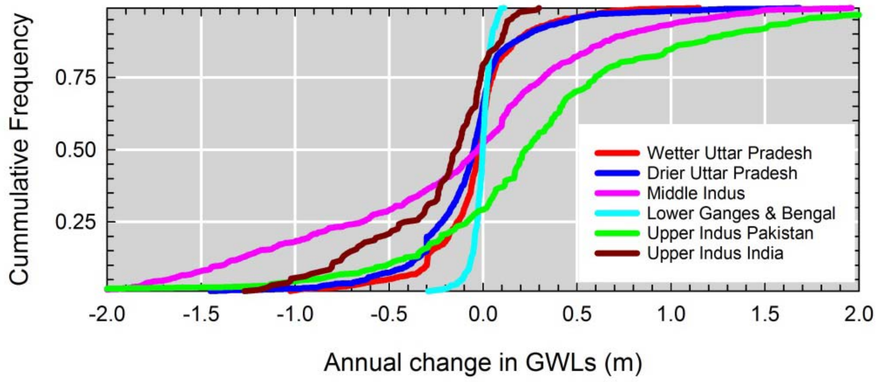
Supplementary Figure 2 Annual groundwater storage change in cm/yr, calculated using the map of annual groundwater-level change, and specific yield.



Supplementary Figure 3 Annual net recharge for the IGB aquifer over the period 2000 - 2012, calculated by subtracting the annual change in groundwater storage from the annual abstraction. The net recharge is therefore the volume of recharge required to balance the abstraction. This may be met from a combination of reduced groundwater discharge and annual direct and indirect recharge. In areas of high rainfall (>1000 mm) the recharge could be dominated by rainfall. In areas of low rainfall, (<500 mm) the recharge will be dominated by irrigation returns and canal leakage. In areas of moderate rainfall (500 – 1000mm) recharge is likely to be met by a combination of canal leakage and rainfall recharge.



Supplementary Figure 4 Median specific yield mapped for the basin. See Methods in the main document for how specific yield was calculated.



Region and mapped annual GWL change range per annum	Annual Groundwater level change from the water-table record (WTR) database						
		Percentile					
	n	10th	25th	50th	75th	90th	Mean
Region 2 Middle Indus							
<-0.75 m	0						
-0.75 - -0.25 m	212	-1.56	-1.29	-0.83	-0.25	0.19	-0.71
-0.25 - -0.05 m	172	-1.76	-1.04	-0.11	0.14	0.46	-0.41
-0.05 - +0.05 m	200	-0.30	-0.01	0.24	0.80	1.31	0.42
0.05 - +0.25 m	166	-0.39	-0.15	0.11	0.38	0.62	0.10
Region 3 Upper Indus Pakistan							
<-0.75 m	0						
-0.75 - -0.25 m	0						
-0.25 - -0.05 m	31	-0.80	-0.38	0.05	0.96	1.52	0.22
-0.05 - +0.05 m	170	-0.68	-0.05	0.38	0.92	1.2	0.34
0.05 - +0.25 m	0						
Region 4 Upper Indus India							
<-0.75 m	17	-1.03	-0.92	-0.80	-0.67	-0.24	-0.73
-0.75 - -0.25 m	16	-1.17	-0.73	-0.45	-0.22	-0.10	-0.53
-0.25 - -0.05 m	59	-0.39	-0.23	-0.12	-0.02	0.10	-0.15
-0.05 - +0.05 m	37	-0.30	-0.14	-0.01	0.10	0.14	-0.10
0.05 - +0.25 m	0						
Region 5 Drier Uttar Pradesh							
<-0.75 m	0						
-0.75 - -0.25 m	25	-0.31	-0.27	-0.07	0.05	0.38	-0.08
-0.25 - -0.05 m	584	-0.45	-0.27	-0.06	0.02	0.41	-0.12
-0.05 - +0.05 m	527	-0.34	-0.17	-0.04	0.03	0.51	-0.01
0.05 - +0.25 m	0						
Region 6 Wetter Uttar Pradesh							
<-0.75 m	0						
-0.75 - -0.25 m	10						
-0.25 - -0.05 m	24	-0.91	-0.39	-0.05	0.12	0.50	-0.14
-0.05 - +0.05 m	284	-0.30	-0.13	-0.03	0.04	0.22	-0.03
0.05 - +0.25 m	0						
Region 7 Lower Ganges & Bengal							
<-0.75 m	1						
-0.75 - -0.25 m	3						
-0.25 - -0.05 m	64	-0.13	-0.05	-0.03	-0.01	0.02	-0.05
-0.05 - +0.05 m	477	-0.07	-0.03	0.00	0.03	0.05	-0.01
0.05 - +0.25 m	8						

Supplementary Figure 5 Cumulative frequency curves for annual changes in groundwater-levels from the WTR dataset divided by the region. The table shows the breakdown of the available WTR data within each mapped range of groundwater-levels in each region. The regions are shown in Figure 2 in the main document.

Supplementary Table 1 Annual groundwater loss for countries and administrative regions in the IGB aquifer estimated from *in situ* water table measurements and specific yield. Results are shown for two different methods: on the left are from directly using estimates of annual groundwater level change from the map shown in Figure 3; results on the right are calculated by re-attributing the mapped ranges in Figure 3 with the median annual water-level change calculated from the available WTR data.

	Annual groundwater loss (km³) using annual water-table trend from map			**Annual groundwater loss (km³) using median annual water-table trend from the WTR data**		
	low Sy	**Median Sy**	**High Sy**	**low Sy**	**Median Sy**	**High Sy**
Bangladesh	**-0.13**	**-0.47**	**-0.67**	**-0.08**	**-0.26**	**-0.3**
India						
Assam	-0.01	-0.02	-0.03	0.01	0.02	0.03
Bihar	-0.10	-0.29	-0.43	-0.06	-0.18	-0.26
Haryana	-0.97	-1.55	-2.18	-0.90	-1.44	-2.02
Punjab	-1.65	-2.59	-3.52	-1.69	-2.62	-3.58
Uttar Pradesh	-1.60	-2.46	-3.57	-0.75	-1.17	-1.74
Others	-0.30	-0.63	-1.01	-0.21	-0.43	-0.69
Total	**-4.62**	**-7.54**	**-10.75**	**-3.60**	**-5.82**	**-8.26**
Nepal	**0.00**	**-0.01**	**-0.01**	**0.00**	**0.00**	**0.00**
Pakistan						
Punjab	-0.74	-1.38	-1.74	-1.12	-2.09	-2.65
Sind	0.18	0.35	0.50	0.15	0.31	0.44
others	-0.10	-0.20	-0.30	-0.06	-0.13	-0.19
Total	**-0.66**	**-1.23**	**-1.54**	**-1.03**	**-1.91**	**-2.39**
Grand Total	**-5.4**	**-9.2**	**-13.0**	**-4.7**	**-8.0**	**-11.0**

Supplementary Table 2 Comparison of annual groundwater mass loss from the *in situ* measurements provided in this study with estimates from GRACE for Northwest India. We have used the mapped annual rates of mass loss in cm/yr for each of the studies, applied spatial scaling factors where published, and integrated over the area of the states of Punjab, Haryana and Rajasthan. Uncertainties in parenthesis are the potential errors quoted in each GRACE study, and the uncertainty in specific yield estimations for our IGB *in situ* measurements.

	Average annual groundwater loss km^3				
	IGB *in situ* measurements	Rodell[a] et al.	Tiwari[b] et al.	Chen[c] et al.	Panda[d] et al.
Period covered	2000-2012	2002 - 2008	2002-2008	2003-2012	2003-2014
Punjab	2.6 (1.7 - 3.6)	1.1 (0.8-1.3)	1.5 (1.3 - 1.8)	2.0 (1.3 - 2.7)	1.1 (0.9 - 1.5)
Haryana	1.4 (0.9 – 2.0)	1.3 (1.0-1.6)	1.4 (1.1 - 1.7)	1.8 (1.2 - 2.5)	0.96 (0.8 - 1.4)
Rajasthan	NA	15.5 (11.5 - 19.4)	10.3 (8.6 - 12.0)	13.7 (8.9 - 18.5)	7.2 (6.0 – 10.3)

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Supplementary Table 3 Main groundwater abstraction data sources

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India
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Bangladesh
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Supplementary Table 4 Main data sources for water-table records

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Nepal

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Supplementary Table 5 Main sources for spatial maps on depth to water-table

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Bangladesh
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Nepal
Geoconsult. Study of tube well inventory of 22 Terai and Inner Terai Districts, Nepal. Groundwater Resources Development Board, Ministry of Irrigation, Government of Nepal, Kathmandu (2012). *Period covered 2011*

Supplementary Table 6 Main sources for water quality maps

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India
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Supplementary Text 1. Criteria for reviewing and selecting studies for inclusion

Over 500 studies were reviewed in total from published studies and grey literature and databases available to the project team within India, Pakistan Bangladesh and Nepal. The approximately 100 studies which provided the highest quality systematic regional data on water quality, abstraction , depth to water-table, sedimentology and aquifer storage form the key benchmark papers and are provided in Table S1-S5. The methods used to systematically review the 500 studies are described below.

The studies were collated from literature reviews, supplemented by specific country knowledge and networks from the international author list. Studies were indexed and stored in an Access database, then georeferenced and output to GIS (Arc 10). The use of the GIS enabled spatial comparison and interrogation of the different types of information relating to each area. Numerical data within the studies relating to storage, recharge processes, water-levels and groundwater chemistry were collated, georeferenced, then output to GIS. Due the large number of data types, sources, and different scales of the data and studies, systematic criteria were applied in reviewing the data to identify a confidence rank to the studies, and data contained. Key inclusion criteria were: (1) that the depth and aquifer unit for the study was well constrained; (2) the date was available for temporal data; (3) there was sufficient methodological description to assess the quality of the data; and (4) appropriate standard methods were used to generate the data. Data which only partially satisfied these criteria were ranked to be of lower confidence. High quality studies were used as the key inputs to develop and parametrise the new basin-wide maps , with lower quality studies being used to provide supplementary information in areas where there were no high quality studies available.