Now it is water all the way in Garhkundar–Dabar watershed of drought-prone semi-arid Bundelkhand, India

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Combating water resource scarcity would be the foremost challenge of the 21st century, particularly in the arid and semi-arid tropics. Semi-arid Bundelkhand, the home of over 15.62 million humans and 8.36 million livestock, suffers from water scarcity, natural resource degradation, low crop productivity (1–1.5 Mg/ha), low rainwater use efficiency (35–45%), high erosion, poor soil fertility, frequent droughts, poor irrigation facilities, heavy biotic pressure on forests, inadequate vegetation cover and frequent crop failure resulting in scarcity of food, fodder and fuel[1]. The average annual rainfall of the area is around 900 mm, the bulk of which (> 90%) is received between June and September. It has been observed that in a cycle of five years, two years have normal rainfall, two years have droughts and one year witnesses excessive rainfall[2]. However, since the last eight years, five years were severe drought years (2002, 2004–2007), and such conditions are likely to be more recurrent due to global warming and the resultant climate change.

The region has serious limitations of ground and surface-water availability and heavily depends upon perched water for drinking as well as irrigation. No major rivers other than the Betwa and Ken traverse the region. Surface-water harvesting and storage in large ponds for meeting irrigation and drinking-water requirement has been in practice since ages. However, the storage capacity of such ponds has reduced due to silting. Accelerated pumping from shallow dug wells (using electric motor/diesel pump) has further reduced the groundwater level. Majority of wells in the region go dry, particularly during summer months. Often, the region experiences drinking-water shortage. Under such a scenario, the Garhkundar–Dabar watershed was taken up for watershed development by the National Research Centre for Agroforestry, Jhansi in 2005.

The Garhkundar–Dabar watershed is situated in the worst-affected Tikamgarh District, Madhya Pradesh, which forms part of the Bundelkhand region. The watershed has an area of 850 ha, and 895 human and 2648 animal populations from three village panchayats inhabit the area.

Soil and water-conservation measures in the watershed included construction of eight check dams in series in approximately 10 km total length of third and fourth-order streams (Figure 1). In addition, 150 gabion structures with volume varying between 3 m^3 (3 m × 1 m × 1 m) and 6.75 m^3 (3 m × 1.5 m × 1.5 m) were laid across the first and second-order streams to check gully formation and silt inflow in main water course. Three 'khadins' (water spreaders) were constructed in depressions to check the concentrated flow of run-off water. Bunding was carried out along the margins of the fields in 40 ha area for *in situ* water harvesting and erosion control. These bunds were provided with proper spillways (15 numbers) for safe disposal of excess water.

To compare and know the impact of integrated watershed treatment on run-off, and soil and nutrient loss, the area adjacent to the treated watershed was also gauged as an untreated watershed. No soil and water-conservation measures were carried out in the untreated watershed, except setting-up a gauging station at the outlet. Datalogger-based automatic stage level recorders were installed at the gauging stations to measure run-off from treated and untreated watershed. Manual and self-recording rain gauges were also installed in the watershed to measure rainfall. Manual run-off water samples were collected at fixed intervals in bottles and analysed in the laboratory for soil and nutrient (N and P) loss. The water table depths in selected representative wells were measured at 15 day intervals using a measuring tape. Similarly, to assess the general water availability scenario in the area, nearby (5–10 km away from the treated watershed) villages, viz. Karguan, Tarichar Khurd and Khiria, having similar geomorphology were surveyed. The geology and geomorphology of the watershed and the neighbouring villages are similar. They are characterized by undulating and rugged topography, highly eroded and dissected land, multidirectional slopes and shallow soil depth (25–150 cm). Disintegrated rock

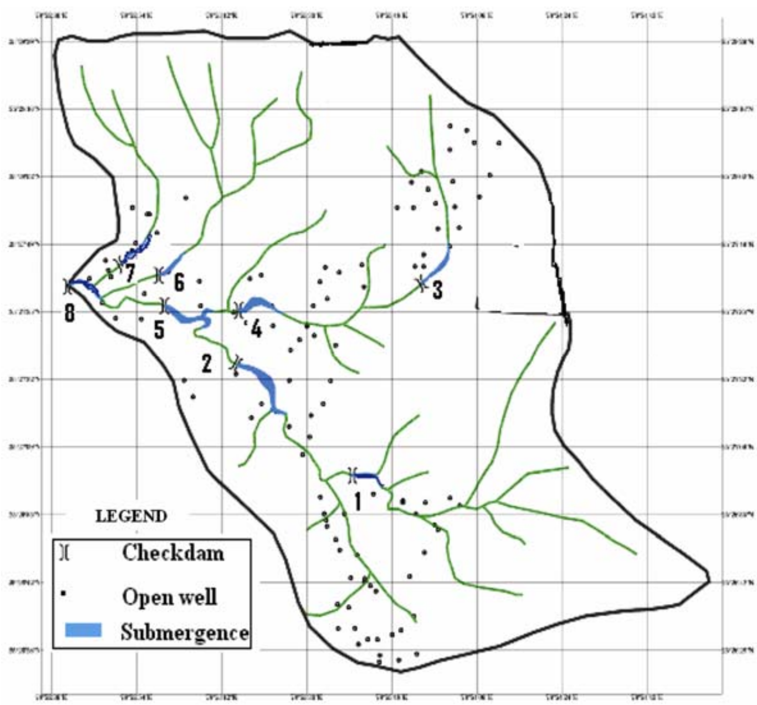

Figure 1. Drainage map of Garhkundar–Dabar watershed.

Figure 2. ***a***, Eight such check dams generated 25,000 m^3 surface water-storage capacity; ***b***, Well full of water in a watershed.

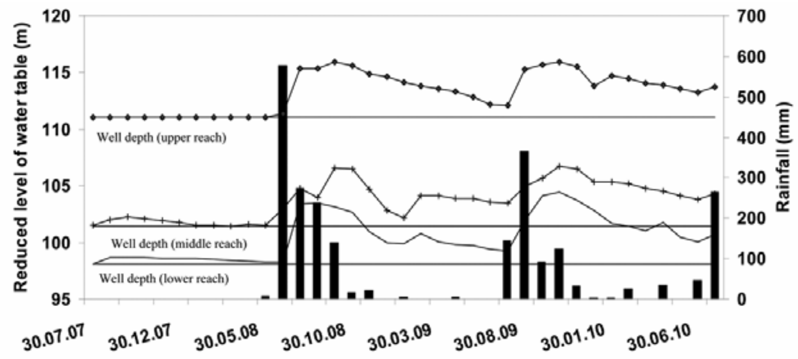

Figure 3. Groundwater availability in different reaches of the watershed and monthly rainfall.

fragments locally called 'murram' were found between 25 cm and 8 m depth. Basement granite rocks were found below 8 m depth.

Adoption of integrated soil and water-conservation measures on a watershed basis not only reduced run-off, but also increased water availability in time and scale. The peak discharge from the treated watershed in 2009 was lower (0.018 m^3/s/ha) compared to the untreated watershed (0.028 m^3/s/ha). Similarly, total run-off recorded from the treated watershed was lower (41.5 mm or 5.4% of annual rainfall) than the untreated watershed (77.3 mm or 10.1% of annual rainfall). Further, run-off per unit area from the treated watershed (415,000 l/ha) was 46% lower than the untreated watershed.

Check dams generated about 25,000 m^3 water-storage capacity in the watershed (Figure 2 *a*). At present, enough water is available in most of the wells round the year (Figure 2 *b*). The number of dry wells in the watershed reduced to 2% in June 2009 from 86% in June 2006. These dry wells were located at the farthest end from the water course in the upper reaches and hillocks. The average water column in the wells within the watershed increased steadily from 0.88 m in 2006, through 1.62 m in 2007 to 5.06 m in 2008 and 4.36 m in 2009. The water column was more than 6 m in 40% of the wells and more than 4 m in 75% of the wells. These wells sustained continuous pumping for 10–12 h with a 5 HP pump. Furthermore, the surface water availability in water courses and groundwater availability in open dug wells in 2009–2010 increased round the year in the middle and lower reaches of the watershed, and for more than 5 months in the upper reaches compared to 4–5 months only in the lower reaches earlier. The amount of water present in the wells depends on both rainfall and watershed management interventions. The average annual rainfall of the watershed area is 951 mm. However, it received 375, 454, 1271 and 769 mm rainfall in 2006, 2007, 2008 and 2009 respectively. The water table in wells in the watershed fluctuated accordingly (Figure 3). However, when the water level in wells in the treated watershed and neighbouring villages (outside the watershed) was compared in October 2009, most of the wells in the treated watershed had enough water. At the same time, over 95% of the wells in the neighbouring (5–10 km away) villages having similar geomorphology were dry. Even wet wells had hardly 1.0 m water column, which could be pumped out within an hour or so using a 5 HP motor. Therefore, integrated watershed management interventions had a pronounced impact on groundwater recharge.

Soil loss from the untreated watershed was 76 and 73% higher compared to the treated watershed in 2008 and 2009 respectively. N and P losses in 2008 from the treated watershed were 7.35 and 4.97 kg/ha respectively, whereas the corresponding losses from the untreated watershed were 12.6 and 8.54 kg/ha respectively. Similarly, the losses in 2009 were 3.29 and 1.17 kg/ha in the treated and 5.70 and 2.03 kg/ha in the untreated watersheds respectively.

Thus, well-planned and properly distributed soil and water-conservation measures comprising construction of field bunds, gabions on first and second-order streams, water spreaders in depressions and a series of check dams on third and fourth-order streams not only reduced soil and nutrient loss, but also generated increased water resources besides imparting drought-proofing. Analysis of the past 66 years' rainfall data from the nearest observatory (Indian Grassland and Fodder Research Institute, Jhansi) revealed that 5% of the years received less than 500 mm rainfall, i.e. 45% deficit than the normal. Therefore, water crisis in the drought-prone Bundelkhand region can be averted by adopting the model described here, even with 50% deficit rainfall, and the region can be transformed into a water-adequate region. Moreover, this technique can be extended to other areas with similar edapho-climatic conditions in the country.

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2. Tiwari, A. K., Sharma, A. K., Bhatt, V. K. and Srivastav, M. M., *Indian J. Soil Conserv.*, 1998, **26**(3), 280–283.

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