The collapse of the Bronze Age Harappan or Indus Civilization remains an enigma (1). The Harappans inhabited the Indus plain at the arid edge of the monsoonal belt and developed one of the earliest urban civilizations over a territory larger than the contemporary extent of Egypt and Mesopotamia combined (Fig. P1A). Between the Indus and Ganges watersheds, a now largely defunct drainage system, the Ghaggar-Hakra, was also heavily populated during Harappan times. Controlled by the monsoon and the melting of Himalayan snow, the variable hydrologic regime must have been a concern for Harappans, as it is today for a billion people living on the Indo-Gangetic Plain. We investigate how climate change affected this civilization by focusing on fluvial morphodynamics, which constitutes a critical gap in our current understanding of the Harappan environment. Shuttle Radar Topography Mission (SRTM) data combined with field surveys and radiocarbon and optically stimulated luminescence dating offer us a way to analyze fluvial landforms and date deposits of the Indo-Gangetic Plain. We reexamine archaeological site distribution in relation to climate changes and argue for a gradual decrease in flood intensity leading to a cumulative process of settlement shift eastwards, rather than a sudden collapse linked to a single arid event.

Brief Harappan History. The Harappan cultural tradition (1, 2) evolved during an Early Phase (5,200–4,500 y ago) from antecedent agricultural communities of the hills bordering the Indus alluvial plain to the west and reached its urban peak (Mature Phase) between approximately 4,500 and 3,900 y ago. The Harappans were agrarian, but developed large, architecturally complex urban centers and a sophisticated material culture coupled with a robust trade system. In contrast to Egypt and the neighboring hydraulic civilization of Mesopotamia, Harappans did not develop large-scale canal irrigation. Deurbanization after approximately 3,900 y ago was characterized by...
increasingly regional artifact styles and trading networks and the disappearance of the Harappan script (1, 2). While these changes are often referred to as “collapse,” archaeological evidence indicates a protracted and regionally varied process (1, 2).

**Morphodynamics of the Indo-Gangetic Plain.** Our analysis reveals a palimpsest of fluvial forms and deposits in the western region of the Indo-Gangetic Plain (Fig. P1A); however, one constant trait that is evident across the entire Harappan landscape is the change from an energetic fluvial regime earlier in the Holocene to increased stability of alluvial forms by Early Harappan times, as the climate became more arid (3). In contrast to the alluvial megafans of the eastern Indo-Gangetic Plain, we document that rivers in Punjab incised after approximately 10,000 y ago, but before approximately 3,900 y ago, probably driven by sediment load declining during centuries-long weak monsoon periods (4). Speculations have advanced the idea that the Ghaggar-Hakra, at times identified with the lost mythical Sarasvati River, was a large glacier-fed Himalayan river. Potential sources for this river include the Yamuna River, the Sutlej River, or both rivers, but the absence of wide, deeply entrenched valleys between the Sutlej and the Yamuna (Fig. P1A) demonstrates that large, glacier-fed rivers did not flow across the Ghaggar-Hakra region during the Holocene. However, our evidence shows widespread fluvial redistribution of sediment, suggesting that monsoon rains were able to sustain perennial rivers and explaining why Harappan settlements flourished along the entire Ghaggar-Hakra system. Further south, we document fluvial deposition during Harappan times both at the confluence region between the Indus and Ghaggar-Hakra systems and along channels running through the desert toward the Nara valley. The Nara itself, which runs parallel to the Indus, had active fluvial sedimentation approximately 2,900 y ago (Fig. P1A). Downstream, in Sindh, the Indus River built a unique distributive-type fluvial system that we term the Indus fluvial mega-ridge (Fig. P1A). The alluvial plain here is convex-up, showing maximum aggradation near the modern channel belt and tapering out toward the plain edges. Radiocarbon-dated deposits of old channel belts indicate that aggradation was minimal during the last approximately 3,000 y compared to earlier in the Holocene, which indicates that the development of the Indus fluvial mega-ridge was the direct consequence of late Holocene aridity (3). The reduction in sediment load compared to water discharge linked to monsoon weakening can explain the channel incision and stabilization.

**Settlement Dynamics in the Harappan Domain.** Occurrence of Harappan sites within the incised valleys of Punjab (Fig. P1 B and C) indicates that rivers were already entrenched by approximately 5,200 y ago. Numerous sites are located at the confluence zone of the Indus with the Punjabi rivers, where backwater flooding would have been common. Settlements on the Punjabi interfluves, including Harappa itself, tend to occur near their edges, close to fertile, annually flooded areas. Farther to the east, Harappan sites occur in the upper region of the Ghaggar-Hakra domain (Haryana and upper Punjab), but also along and within the incised valley of the Yamuna and on the Yamuna-Ganga interfluve. Settling of the Ghaggar-Hakra took advantage of the smaller floods typical for non-}

Himalayan monsoonal rivers. However, the largest agglomeration of mature Harappan sites, including the urban Ganweriwala, occurs on the lowermost Ghaggar-Hakra palaeeochannel system in modern Cholistan. Proximity to both Ghaggar-Hakra and the well-watered confluence of the Indus with its Punjabi tributaries provides the best explanation for the continuity and high-density occupation there. Harappan discoveries in the Thar Desert adjacent to and along the Nara valley support our reconstructions of a better-watered past for this dry region. In upper Sindh (Fig. P1 B and C), good preservation of Harappan sites on the alluvial plain suggests that the Indus mega-ridge has been relatively stable. In contrast, in the southwestern Sindh, any settlement on the alluvial plain that may have existed is now buried under fluvial deposits.

**Climate Change and the Harappans.** Inundation agriculture during the winter was dominant along the Indus from the Harappan era until modern times. Hydroclimate reconstructions for South and Central Asia (Fig. 4) show that precipitation from both monsoon and westerly sources was at its lowest after approximately 4,000 y BP (3). Aridification would have diminished flood intensity and allowed agriculture to expand along rivers. However, our analysis of fluvial landscapes suggests that further drying was detrimental for the Harappans, who relied on annual floods to sustain their economy. Preservation of archaeological sites at locations seemingly vulnerable to flooding, erosion, or burial suggest that, as aridity intensified, monsoon-augmented floods became less frequent and/or less intense. The most spectacular case of climate-controlled landscape transformation is the Ghaggar-Hakra system, which became ephemeral and was largely abandoned after approximately 4,000 y ago. Posturban settlements are preferentially located near the regularly flooded region at the Indus confluence with the Punjabi rivers, or in eastern regions with more reliable rains. Diversification of agriculture towards summer rain-based crops and the increase in drought-tolerant crops at the end of the urban phase (see SI Text) reveal efforts to adapt to hydroclimatic stress. Although snowmelt continued to provide water to the Indus and its Himalayan tributaries, the Harappans did not develop canal irrigation. In contrast to inhabitants of Mesopotamia and Egypt, which were surrounded by arid lands, the Harappans had the option to migrate toward more humid regions of the Indo-Gangetic Plain. Migration toward the periphery could have contributed to the decline of urban centers in the core region of the Harappan domain. Without striving for deterministic explanations for the Indus Civilization collapse, it is likely that the unprecedented scale of hydroclimatic stress must have increased the vulnerability of floodwater farmers in Harappan society.