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Late Holocene geochemical and environmental changes inferred from a multiproxy investigation in sediments from Kondagai Lake Tamil Nadu, India

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Abstract
Climatic crises have been increasing rapidly since the late Holocene worldwide. Strategic planning needs multi-proxy records to understand the rate of ecosystem and climatic perturbations for generating mitigation maps. We present multiproxy records with isotopic composition ($\delta^{13}C_{TOC}$, $\delta^{15}N_{Bulk}$), total organic carbon (TOC%), total nitrogen (TN%), total organic carbon to total nitrogen (C/N) ratio, palynofacies and grain size analysis of an AMS radiocarbon-dated Holocene sediment profile recovered from Kondagai lake (KLD), Tamil Nadu, India. Data sets are used to interpret the organic matter source and variation in the sediment deposition pattern. Enriched values of $\delta^{13}C_{TOC}$ and finer grain size between ~4.5 and 3.7 k cal yrs BP. represent the sources of organic matter were mostly aquatic plankton and C4-type vegetation (Poaceae), attested with low terrestrial inputs, which supports the fungal production, suggesting the shallower lake levels and drier period (parallel with the 4.2 ka event), indicating the weaker phase of the Indian monsoon. From ~3.7 to 2.5 k cal yrs BP, the lake had a high water level, marked by increased terrestrial flux, with higher sand % and depleted $\delta^{13}C_{TOC}$ values. From ~2.5 to 0.9 k cal yr BP, Lake witnessed the continuity of a warm episode, represented by the depleted values of $\delta^{13}C_{TOC}$ and coarser grain fraction at the episodic scale suggest the lake level fluctuation with marked flooding events. Higher values of $\delta^{15}N_{Bulk}$, and C/N ratio suggest the altered element cycling in the latest phase of KLD Lake, coincides with Roman warm period (RWP). The findings enhance our understanding of organic matter sources, marking flooding events and lake level changes in accordance with monsoon variabilities, land use alteration by the combination of natural and anthropogenic actions. This investigation also highlighted the integrated effects of Indian monsoon and El Niño Southern Oscillation (ENSO) variabilities over the last 4.5 k cal yrs BP.

Keywords
Late Holocene, Carbon and Nitrogen isotope, Indian Monsoon, Lake Ecosystem, 4.2 ka event, Tamil Nadu, India

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Introduction

The Holocene Epoch, covering the past ~11,700 years, is marked by significant climatic variability and sea-level fluctuations, profoundly influencing human settlement patterns (Sengupta et al., 2024). This period witnessed diverse climatic transitions, such as polar cooling, heightened aridity, and shifts in atmospheric circulation. High-resolution archives, including Greenland ice cores, have enabled precise reconstructions of past temperature and precipitation changes (Mayewski et al., 2004; Wanner et al., 2008). Sediment records from the North Atlantic (Dawson et al., 2007; O'Brien et al., 1983), the Mediterranean (Bianchi and McCave, 1999; Insinga et al., 2020), and the Tropical Atlantic (Casford et al., 2001; Rohling et al., 2009) provide evidence of ocean-atmosphere dynamics, while Antarctic data (DeMenocal et al., 2000; Rimbu et al., 2004) indicate hemispheric synchrony in climate shifts. Terrestrial proxies – such as lake sediments (Masson et al., 2000), peat bogs (Jones et al., 2001), speleothems (Magny, 2004), fossil pollen (Odgaard, 1999), and tree rings (Willard et al., 2005) – offer regional insights into vegetation, hydrology, and temperature. Holocene climate change operated on decadal to millennial scales, influenced by orbital forcing (Esper et al., 2002; Moberg et al., 2005) and, more recently, human activity (Bradley, 2003). Integrating diverse datasets helps decipher Holocene climate mechanisms and their relevance to future scenarios.

The late Holocene was marked by pronounced climatic variability driven by natural and anthropogenic forces, leading to significant shifts in regional and global climate patterns (Mann et al., 2008; Rawat et al., 2021). Key climatic intervals include the Roman Warm Period (~350 BCE–350 CE), associated with warmth and agricultural prosperity; the Dark Ages Cold Period or Late Antique Little Ice Age (~400 to 765 CE), characterized

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