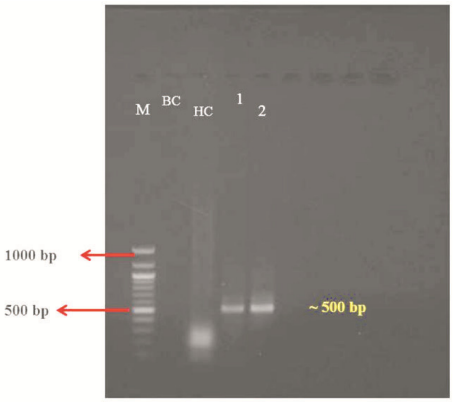

Figure 2. PCR amplification of *CP* gene of ChiLCV infected capsicum samples. Lanes M, 100–1000 bp marker; BC, Buffer control; HC, Healthy control, 1, 2, ChiLCV-Ca-DWD infected capsicum samples.

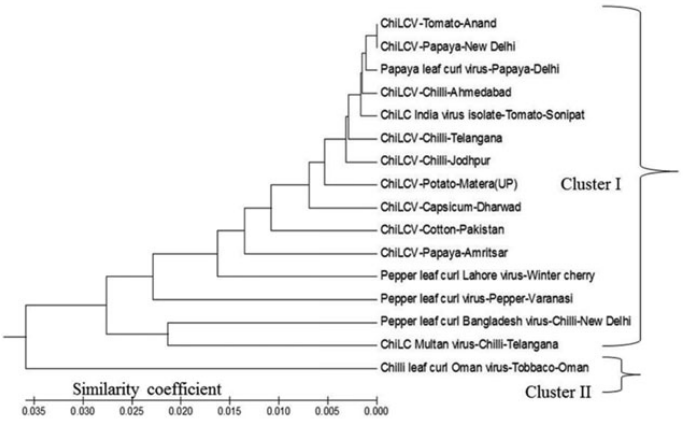

Figure 3. Phylogenetic relationship of *CP* gene of ChiLCV-Ca-Dharwad with other ChiLCV isolates reported on different crops.

be closely related to ChiLCV-Potato-Matera, ChiLCV-Chilli-Jodhpur and ChiLCV-Chilli-Telangana respectively (Figure 3). Based on sequence homology studies and phylogenetic analysis, the present study revealed that ChiLCV-Ca-DWD isolate has a high degree of similarity (~99%) to the *Begomovirus* species. To our knowledge, this is the first report of ChiLCV associated with leaf curl disease on capsicum (Bell Pepper) in Karnataka.

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Drowned valleys of Vaigai and Tamiraparani rivers in the Gulf of Mannar region, India

Due to the low gradient of the eastern slopes of the Eastern and Western Ghats of the Indian Peninsula, the easterly flowing Bay of Bengal-bound rivers display stabilized life histories with well-developed landforms of youthful, mature and old stages[1–3]. The studies carried out in Tamil Nadu (TN) deltas revealed the energy levels and their interfaces between the fluvial and marine dynamics during the evolution of the deltas[4]. The input of tectonics over the development of TN deltas has also been brought out in recent studies enumerating the tectonic–fluvial–marine interface dynamics during the evolution of these deltas[3,5]. However, the two rivers in TN, namely the Vaigai and Tamiraparani, show abrupt truncation in their delta fronts. But the difference between these two is the Vaigai lobate delta, which covers over 2300 km^2 with thousands of arcuately arranged concentric rings of crescent shaped sandy lobes and intervening depressions/water bodies encircling the apex of the delta located in the northwest and spreads up to the present coast in the southeast (Figure 1). This has been attributed to the constant tectonic uplift of the land and consequent progradation of the delta[4]. However, such huge prograding delta seems to have been truncated in the mainland west of Rameswaram Island (Figure 1). Similarly, the Tamiraparani river which has developed wider floodplains in the central plains in its mature stage, has not developed any major delta in the east along the coast in its old stage[4]. In this context, to unfurl the mysterious truncation of the life-histories of Vaigai and Tamiraparani rivers, the offshore region of these rivers has been studied in parts of the Gulf of Mannar (GoM) region of the Indian Ocean.

In the present study, the GEBCO (General Bathymetric Chart of the Oceans) data were downloaded for GoM and the adjacent regions of India and Sri

Lanka from the website: https://www.gebco.net, fed into ArcGIS software and density-sliced colour-coded image was generated assigning different colours to different depth ranges of the ocean floor (Figure 1). The image showed irregular topography of the ocean floor with well-defined, linear and curvilinear depressions and gorges, resembling river valleys in the offshore regions of Vaigai and Tamiraparani rivers. So the IRS-satellite FCC data of the land part were welded with GEBCO density-sliced image of the ocean part to elucidate the linkages between these submarine depressions and the two rivers. Further, to unearth the fluvial parentage of these depressions, topographic profiles were drawn orthogonal to these depressions seen in the offshore regions of Vaigai and Tamiraparani rivers (9–12, Figure 1). Stimulated by the abrupt truncation of these two rivers and the occurrence of linear and curvilinear depressions in the ocean floor resembling river valleys, the past sea-level data were collected[6] for 15, 11, 9, 8 and 7 kyrs and these were wrapped over the digital elevation model (DEM) of the ocean bathymetry of GEBCO data and past shorelines of the above periods were drawn (Figure 2).

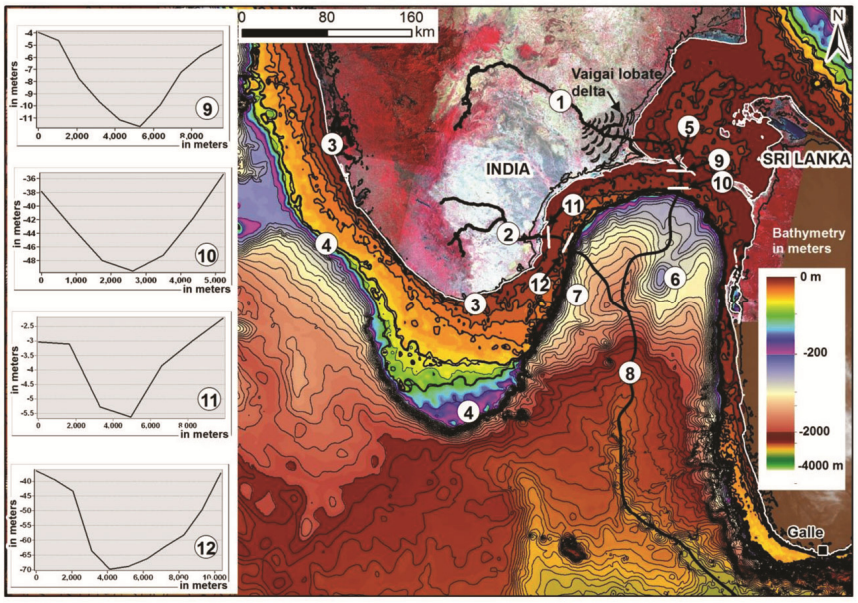

Figure 1. GEBCO density sliced contours, Gulf of Mannar (GoM) region, India: 1, 2, Vaigai and Tamiraparani rivers; 3, 4, Present and the old shorelines of 20 kyrs; 5, Rameswaram island; 6, 7, Drowned valleys of Vaigai and Tamiraparani rivers; 8, Deep linear gorges of Vaigai and Tamiraparani valleys in the ocean floor; 9, 10, *V*-shaped (9) and broader *V*-shaped (10) valleys of Vaigai river in the ocean floor with depth of 11 and 48 m respectively; 11, 12, *V*-shaped (11) and broader *V*-shaped (12) valleys of Tamiraparani river in the ocean floor with the depth of 6 and 70 m respectively.

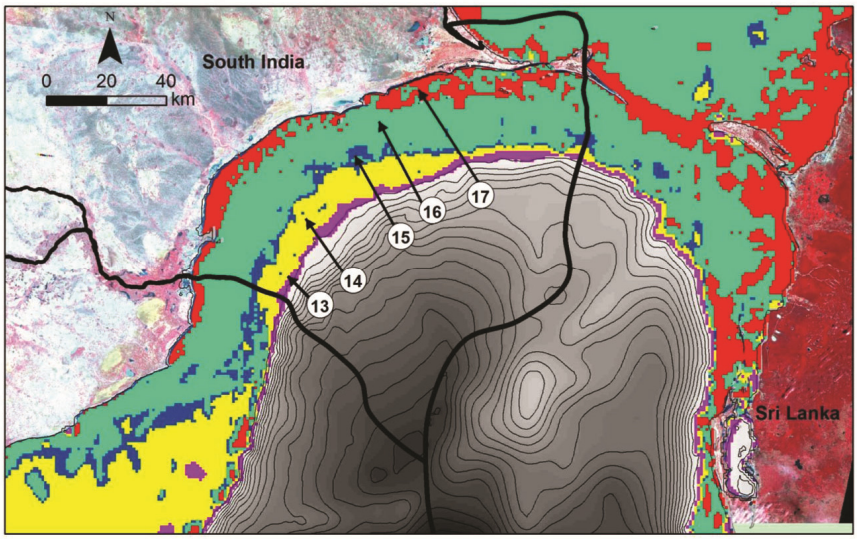

Figure 2. GEBCO density sliced contours of ocean floor welded with IRS FCC data, GoM. Land–ocean boundaries (LOB) since the last 15 kyrs: 13, LOB during 15 kyrs when a level was below 110 m from the present mean sea level; 14, LOB during 11 kyrs/sea level below 50 m; 15, LOB during 9 kyrs/sea level below 25 m; 16, LOB during 8 kyrs/sea level below 20 m; 17, LOB during 7 kyrs/sea level below 5 m.

The conjunctive study revealed that one of the well-defined depressions/gorges coincides with the Vaigai river mouth (Figures 1 and 2). From the river mouth, it extends about 40 km in the easterly direction in the ocean up to north of Rameswaram Island (5, Figure 1). From there, it takes a southerly turn and extends rectilinearly in the southerly direction for over 400 km up to west of Galle, Sri Lanka (Figure 1). From south of Galle, the depression extends for another 300 km in the east-southeasterly and easterly directions, concentrically enveloping the southern part of Sri Lanka. The east–west profiles drawn along such north–south depression (9 and 10, Figure 1), south of Rameswaram showed that it is *V*-shaped with 11 m depth in the upstream, and widens with 50 m depth in the southern downstream (Figure 1). Such morphology of the depression indicates that it is a river-cut valley. So this valley may be the old path of Vaigai river and must have been carved out by the river in GoM region. Similarly, another major depression seen in the ocean floor coincides with the mouth of Tamiraparani river. It extends for over 100 km in the ocean in the east-southeasterly direction and meets the above discussed north–south valley of Vaigai river (Figure 1). As this depression coincides with the mouth of the Tamiraparani river, it might have been the path along which the Tamiraparani flowed in the past and in that process carved out the valley. The N–S set of profiles drawn along this gorge (11 and 12, Figure 1) also showed *V*-shaped morphology in upstream (11, Figure 1) which gradually broadened in the downstream region along with increase in depth (12, Figure 1). So, it can be concluded that the Vaigai river would

have flowed easterly up to Rameswaram and then taken a southerly turn and flowed southerly and easterly enveloping Sri Lanka. The Tamiraparani river might have been a tributary of Vaigai. The extensive fluvial history with major delta in Vaigai river and little development of fluvial landforms in Tamiraparani river also confirms the same.

The well-defined rectilinear flow of Vaigai river with north–south orientation in the GoM region shows that it might have been controlled by a north–south fault, since in parts of South India in general[7] and parts of Cauvery delta in particular[8], the spectrum of such north–south faults related to post-drift kinematics has been inferred. These signatures clearly indicate that Vaigai might have been the major river that flowed in the past in GoM region. The Greek scholar Megasthenes has mentioned that a major river flowed between India and Sri Lanka and called Sri Lanka as 'Taprabane'[9]. Many Tamil scholars believe that Tamiraparani river flowed in the past between India and Sri Lanka[9]. However, the present study clearly demonstrates that it is only Vaigai river flowed in the GoM region separating India and Sri Lanka.

The analysis of past sea-level data collected[6] showed that it was (i) 110 m below the present MSL (mean sea level) during 15,000 YBP (years before present) (13, Figure 2), (ii) 50 m below during 11,000 YBP (14, Figure 2), (iii) 25 m below during 9000 YBP (15, Figure 2), (iv) 20 m below MSL during 8000 YBP (16, Figure 2) and (v) 5 m below present MSL during 7000 YBP (17, Figure 2). This indicates that the sea level has been continuously rising since the last 20,000 years. When the past sea-level data were wrapped over GEBCO-derived DEM and the past shorelines for the above periods were drawn, it indicated that the Vaigai and Tamiraparani rivers have gradually submerged due to rise in sea level that started during 20,000 YBP (Figure 2).

Thus the present study reveals that these two rivers might have been more than 20,000 years old. We also argue that the Tamiraparani was a tributary of the Vaigai in the past; the Vaigai flowed up to the offshore region of Galle, Sri Lanka and submerged due to rise in sea level.

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