alga is a significant contributor for TN removal from the sugar effluent. The oxygenation of wastewater is important to improve its quality. This is done by (i) the removal of chemicals and biological matter that demand oxygen, and (ii) supply of oxygen by diatoms, roots of *Typha*, and free surface flow with intermittent loading (increased air/water interface). Thus the DO content of sugar effluent was enhanced and pollutant concentrations decreased simultaneously.

Tangible outcomes are availability of water which is an adaptive measure for water-scarce situation. Using the source in an integrated manner for aquaculture and then for agriculture, where the fish in addition to growing luxuriantly enrich the water with nutrients, is a rich biofertigation for agriculture minimizing fertilizer usage. Thus dual productivity is gained from fish and crop with the same amount of water.

On 14 January 2016, the Ministry of Environment, Forest and Climate Change, Government of India has notified stricter environment standards in the Gazette of India for sugar industries in the country. Further, it allowed only one outlet/discharge point, to be covered according to the '24 × 7 on-line monitoring' protocol. However water quality from the ETP of KCP industry was unable to meet the regulations. Industry witnessed the performance of CWL that requires no post-treatment and produces reusable effluent suitable for aquaculture and agriculture. To overcome the challenge of '24 × 7 on-line monitoring' protocol, industry adopted the CWL system as the secondary treatment. As shown in Figure 1, an on-line multi-parameter analyser is fixed and connected to the FP for real-time monitoring of water quality by the government. Final discharge values observed using the on-line monitor are presented in Table 1, which meets the environmental pollution regulations and the irrigation standards.

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Quantification of rainfall during the late Miocene–early Pliocene in North East India

The monsoon rainfall contributes about 30% of the total global rainfall[1]. The Asian monsoon system (ASM) is one of the largest systems and is of great significance in the global climate system. It consists of two subsystems, namely Indian summer monsoon (ISM)/southwest (SW) monsoon/South Asia summer monsoon (SASM) and East Asia monsoon (EAM). There are two monsoon seasons in India: (i) SW monsoon of the summer season (June–September/JJAS) producing 70–90% of the total annual rainfall[2], and (ii) northeast monsoon (October–December/OND) accountable for 50% of the east coast annual rainfall[3]. Moreover, the northeastern region (NER) has a special rainfall system as it receives notable rainfall not only in the monsoon season (JJAS), but also in pre-monsoon season (March–May/MAM)[4]. Due to this, the region is affected by floods which wreak havoc[4].

The rainfall pattern in North East (NE) India shows a large variation both spatially and temporally[5]. Due to this, severe flood occurs frequently in the region. Therefore, it is important to study the variability of pre-monsoon and summer monsoon showers of the region in the geological past. The quantitative palaeomonsoonal record from NE India is poor. On the basis of leaf physiognomy, Khan *et al.*[6] suggested that the intensity of the SW monsoon has remained the same since the middle Miocene in Arunachal Pradesh.

In this communication, we deduce pre-monsoon, summer monsoon and dry seasonal (January–February) rainfall using coexistence approach (CA)[7,8] on the fossil assemblage recovered from the late

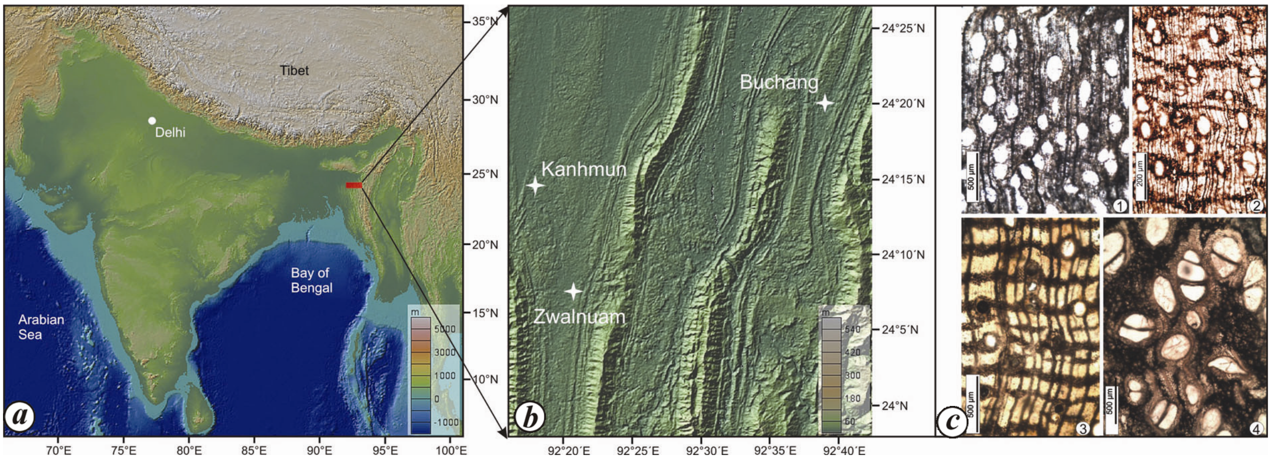

Figure 1. ***a***, Physiographic map showing the study area (red box). ***b***, High-resolution physiographic map showing the fossil localities. ***c***, Fossil woods in transverse section: 1. *Burseroxylon preserratum* Prakash & Tripathi; 2. *Terminalioxylon coriaceum* Prakash & Awasthi; 3. *Cynometroxylon holdenii* Prakash & Bande; 4. *Ormosioxylon bengalensis* Bande & Prakash.

Miocene–early Pliocene (11.6–3.6 Ma) sediments of Mizoram[9–11] (Figure 1).

For the reconstruction of palaeomonsoon, we have used published fossil flora of Mizoram[9–11] (Figure 1), which was recovered from the Tipam Group belonging to late Miocene to early Pliocene period[12,13]. Tipam Group consists of grey to light grey massive buff sandstone and bluish clay bands. The detailed stratigraphic succession of Mizoram is given by Karunakaran[12] and Ganju[13].

CA can be applied to any fossil flora containing leaves, fruits, wood, seeds and pollen[7,8]. It assumes that the fossil plants are closely related with their modern counterparts and presumes that their nearest living relatives (NLRs) are still thriving in similar climatic conditions as in the deep time. Due to this, CA can be reliably applied on the late Cenozoic flora where negligible change in climatic conditions of each taxon has occurred[14–17]. In CA, the fossil taxa are first identified to their modern counterparts, i.e. NLRs. Further, the climatic tolerance of all the NLR taxa is acquired by cataloging the climatic conditions of the plant localities. Coexistence interval (CI) is determined for each climate parameter that permits the majority of NLRs of a fossil assemblage to co-occur. CIs may be used as the plausible range of various climatic parameters for a palaeoflora. In the ideal case, there exists an interval of a given climate variable where all the NLRs can co-occur. In some cases, climatic intervals do not overlap with majority of the ranges. Such taxa are denoted as outliers; this may be due to taphonomic conditions, wrong identification of NLRs and inaccurate information of their climatic requirements. The omission of these outliers will reduce the impact of abnormal climate signatures[7,8]. CA depends only on the existence of the taxa and does not consider their abundance. Earlier the reliability of this technique was checked using other techniques such as Climate Leaf Analysis Multivariate Program (CLAMP) and Leaf Margin Analysis (LMA) on the same fossil flora showing similar results[18–21]. The reconstructions based on CA also complement the marine, continental and palaeovegetational reconstructions[22–24]. The climatic parameters which are discussed here are mean annual precipitation (MAP), mean precipitation of the wettest months (MPWET), mean precipitation of the warmest months (WMP) and mean precipitation of the driest months (MPDRY). Moreover, the annual range of precipitation (ARP) is calculated as the difference between the wettest and driest precipitations (ARP = MPWET – MPDRY). MPWET represents the summer monsoon rainfall and WMP the pre-monsoon showers in the Indian context[25]. The climatic tolerances of all NLRs have been taken from the updated PALAEOFLORA database[26], except for *Gluta travancorica* Bedd. which is endemic to the Western Ghats (Table 1). The modern distribution of *G. travencorica* is taken from Ramesh *et al.*[27] and its modern climate from the Climatological Tables of Observatories in India[28].

CIs of rainfall from the late Miocene–early Pliocene flora of Mizoram are: 2211–2823 mm for MAP (average ~2517 mm), 346–389 mm for MPWET (average ~367.5 mm), 19–56 mm for MPDRY (average ~37.5 mm), 128–177 mm for WMP (average ~152.5 mm), and ~330 mm for ARP (Figure 2). In the present reconstruction maximum fossil taxa (~90%) coexist in the CIs and the outliers are minimum, indicating the robustness of the reconstruction.

The ISM is marked by the seasonal turnaround of surface air mass, created due to the thermal gradient between the continental land and the Indian Ocean, which is mainly governed by solar radiations and topography[29]. The reconstructed rainfall pattern indicates seasonality, i.e. maximum rainfall during the monsoon season, minimum in the dry season and mild during the pre-monsoon season. It has been suggested that the ratio of MPWET and MPDRY higher than 6 : 1 is indicative of a monsoon type of climate[6,30–33]. In this study, the ratio of MPWET and MPDRY is 9.8 : 1, which signifies a monsoon type of climate, though not stronger than the modern day (57.5 : 1), during the depositional period. The resultant pre-monsoon rainfall (average ~152.5 mm) is markedly lesser than that of the modern day (561 mm); however, MPDRY (average ~37.5 mm) is more or less similar to that of the modern day (33 mm). Our monsoonal reconstruction gets support from a previous reconstruction (based on CLAMP analysis of the Siwalik flora of Arunachal Pradesh), inferring a monsoon type of climate whose MPWET/MPDRY ratio ranges between 7 and 13 (ref. 6). The

Table 1. Fossils and their nearest living relatives showing climate data used in the present study

Fossil taxa/Reference	NLRs	Organ	Locality	$\mathrm{MAP}_{\mathrm{min}}$	$\mathrm{MAP}_{\mathrm{max}}$	$\mathrm{MPWET}_{\mathrm{min}}$	$\mathrm{MPWET}_{\mathrm{max}}$	$\mathrm{MPDRY}_{\mathrm{min}}$	$\mathrm{MPDRY}_{\mathrm{max}}$	$\mathrm{MPWARM}_{\mathrm{min}}$	$\mathrm{MPWARM}_{\mathrm{max}}$
Artocarpoxylon deccanensis/10	Moraceae	Wood	Buchang, Mizoram	213	10798	65	2446	2	165	16	1100
Bischofia palaeojavanica/11	*Bischofia javanica*	Wood	ZawInuam, Mizoram	1215	3293	346	988	3	165	38	462
Bombacacioxylon tertiarum/11	Bombacaceae	Wood	ZawInuam, Mizoram	203	3293	60	988	0	165	38	221
Burseroxylon preserratum/10	*Bursera* sp.	Wood	ZawInuam, Mizoram	373	1927	85	296	0	69	0	177
Cynometroxylon holdenii/10	*Cynometra* sp.	Wood	ZawInuam, Mizoram	803	3151	154	389	1	165	128	227
Dalbergioxylon mizoramensis/10	*Dalbergia* sp.	Wood	ZawInuam, Mizoram	631	3151	111	554	1	165	20	462
Dipterocarpoxylon jammuense/11	*Dipterocarpus* sp.	Wood	Buchang, Mizoram	1183	3293	225	988	3	221	38	343
Glutoxylon burmense/10	*Gluta travancorica*	Wood	ZawInuam, Mizoram	1839	3263	833	1948	80	113	414	689
Glutoxylon cuddalorense/9	*Gluta* sp.	Wood	ZawInuam, Mizoram	915	3293	270	988	3	165	38	221
Lagerstroemioxylon eoflosreginum/9	*Lagerstroemia* sp.	Wood	Kanhmun, Mizoram	578	3293	116	985	3	165	38	239
Laurinoxylon dilcheri/9	Lauraceae	Wood	ZawInuam, Mizoram	191	10798	56	2446	0	165	0	1100
Madhuca palaeolongifolia/10	*Madhuca* sp.	Wood	Buchang, Mizoram	1682	3293	320	988	3	165	38	302
Mangiferoxylon assamicum/10	*Mangifera* sp.	Wood	ZawInuam, Mizoram	1096	3293	220	985	0	155	38	319
Millettioxylon palaeopulchra/9	Leguminosae	Wood	Kanhmun, Mizoram	224	3905	46	610	0	196	1	221
Ormosioxylon bengalensis/10	*Ormosia* sp.	Wood	Buchang, Mizoram	979	2823	164	562	7	56	76	304
Shoreoxylon tipamense/10	*Shorea* sp.	Wood	ZawInuam, Mizoram	1183	3293	225	988	3	221	38	343
Swintonioxylon hailakandiense/11	*Swintonia* sp.	Wood	ZawInuam, Mizoram	2211	4178	328	1043	19	165	127	422
Terminalioxylon coriaceum/10	*Terminalia* sp.	Wood	ZawInuam, Mizoram	687	3293	155	985	3	221	38	258

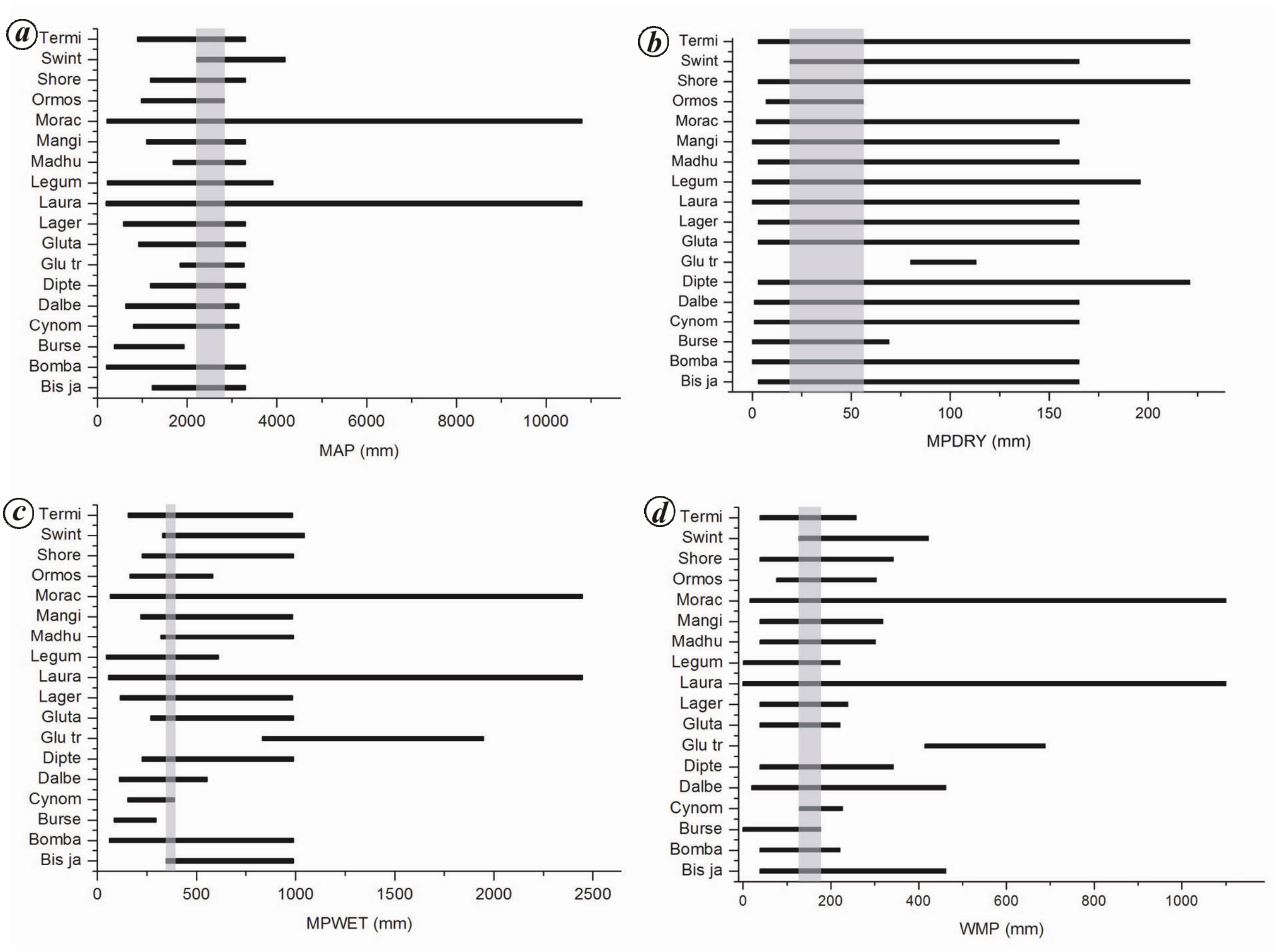

Figure 2. ***a***, Coexistence interval (CI; shaded area) of mean annual precipitation (MAP). ***b***, CI (shaded area) of mean precipitation during the driest months (MPDRY). ***c***, CI (shaded area) of mean precipitation during the wettest months (MPWET). ***d***, CI (shaded area) of mean precipitation during the warmest months (WMP). (Bis ja, *Biscofia javanica*; Bomba, Bombacaceae; Burse, *Bursera* sp.; Cynom, *Cynometra* sp.; Dalbe, *Dalbergia* sp.; Dipte, *Dipterocarpus* sp.; Glu tr, *Gluta travancorica*; Gluta, *Gluta* sp.; Lager, *Lagerstroemia* sp.; Laura, Lauraceae; Legum, Leguminoceae; Madhu, *Madhuca* sp.; Mangi, *Mangifera* sp.; Morac, Moraceae; Ormos, *Ormosia* sp.; Shore, *Shorea* sp.; Swint, *Swintonia* sp.; Termi, *Terminalia* sp.).

present reconstruction is more resolved as it reconstructs the pre-monsoon shower, which plays a significant role in NE India. The reconstruction indicates that in the NER both monsoon and pre-monsoon rainfall were present during the late Miocene–early Pliocene, albeit to a lesser extent than at present. All the aforesaid reconstructed data indicate that drastic enhancement has taken place in the pre-monsoon and monsoon rainfall since the above period.

G. travancorica Bedd. is now restricted to the Western Ghats and the most plausible reason is the increased seasonality in temperature after the Pliocene; this might be due to the rising Himalaya[34]. The genus is still growing in very low latitudes (~7°N) of the Western Ghats, where temperature seasonality is considerably less and the length of the dry season is less than four months[35]. The aforesaid fact gets support from the previous temperature reconstructions[6,10,36,37] and the finding of several other evergreen taxa in the fossil assemblage of the NER, confined to the Western Ghats[38].

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