Pollen-based reconstruction of vegetation in China during the mid-Holocene and last glacial maximum

Jian Ni [1,2]; Ge Yu [3]; Sandy P. Harrison [1,4] & I. Colin Prentice [1,5]

[1] Max Planck Institute for Biogeochemistry, PO Box 100164, D-07701 Jena, Germany; [2] Institute of Botany, Chinese Academy of Sciences, 100093 Beijing, China; [3] Nanjing Institute of Geography and Limnology, Chinese Academy of Sciences, 210093 Nanjing, China; [4] Present address: School of Geographical Sciences, University of Bristol, UK; [5] Present address: Department of Earth Sciences, University of Bristol, UK

Pollen-based biome reconstruction, using a standard objective biomisation technique based on plant functional types (PFTs), could be used for evaluation of model experiments in order to better understand the dynamic of past climate change and subsequently future global change. In this study, we apply the global scheme of PFTs to a comprehensive set of surface, mid-Holocene (MH, 6000 ^{14}C yr BP) and last glacial maximum (LGM, 18,000 ^{14}C yr BP) pollen records available from China, in order to demonstrate a good empirical relationship between modern vegetation and surface pollen and to obtain a well-founded reconstruction of changing palaeovegetation patterns.

A total of 806 pollen surface samples, 188 MH and 50 LGM pollen records were used to reconstruct vegetation patterns in China, based on a new global classification system of PFTs and a standard numerical technique for biome assignment (biomisation). The data represents a considerable expansion (141 surface samples, 35 MH records and 15 LGM records) of earlier data sets used for vegetation mapping (Yu et al., 1998, 2000). The new global PFT classification is based principally on the four elements: bioclimatic control, phenology, leaf form and life form (Harrison et al., submitted). Seventy-six PFTs occur in China, including 21 arboreal PFTs, 23 shrub PFTs, 9 remaining woody PFTs (lianas or vines, mangrove, woody parasite, epiphyte, stem succulent, leaf succulent) and 23 non-woody PFTs (climbers, forbs, fern or fern ally, halophyte, hydrophyte, aquatic, grass, sedge, rush, geophyte, moss, root parasite). The biomisation method has five steps (Prentice et al. 1996; Prentice & Webb 1998; Prentice et al., 2000) : (1) each pollen taxon is assigned to one or more PFTs (PFT vs. taxon matrix), on the basis of the biology and biogeography of the plant species it includes; (2) biomes are defined in terms of their characteristic PFTs (biome vs. PFT matrix); (3) the two matrices are multiplied to produce a taxon vs. biome matrix, indicating which pollen taxa may occur in which biome; (4) affinity scores for each biome are then calculated for all pollen samples; (5) each pollen sample is assigned to the biome having the highest affinity score, subject to a tie-breaking rule that favours the less PFT-rich biome in the case where the affinity score for two or more biomes is equal.

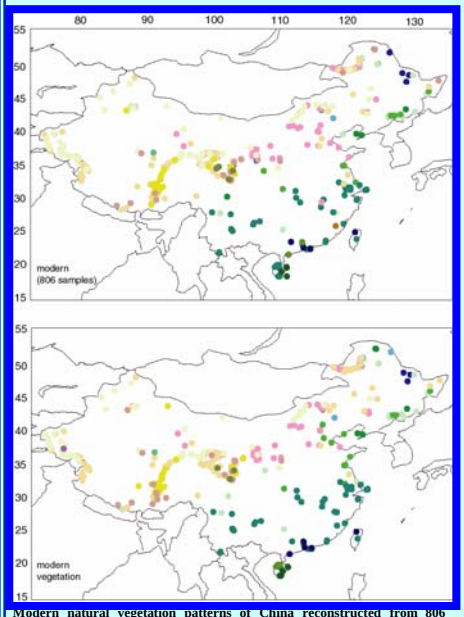
The biome reconstruction based on pollen surface samples showed convincing agreement with present potential natural vegetation. Coherent patterns of change in biome distribution between MH, LGM and present are observed. In the MH, cold and cool-temperate evergreen needle-leaved forests and mixed forests, temperate deciduous broad-leaved forest, and warm-temperate evergreen broad-leaved and mixed forest in eastern China were shifted northward by 200-500 km. Cold deciduous forest in northeastern China was replaced by cold evergreen needle-leaved forest while in central northern China, cold deciduous forest was present at some sites now occupied by steppe and desert. The forest-steppe boundary was 200-300 km west of its present position. Temperate xerophytic shrubland, steppe and desert covered a large area on the Tibetan Plateau, but the area of tundra was reduced. Treeline was 300-500 m higher than present in Tibet. These changes imply generally warmer winters, longer growing seasons and more precipitation during the MH. Westward shifts of the forest-shrubland-steppe and steppe-desert boundaries imply greater moisture availability in the MH, consistent with a stronger summer monsoon. During the LGM, in contrast, cold deciduous forest, cool-temperate evergreen needle-leaved forest, cool mixed forests, warm-temperate evergreen broad-leaved and mixed forest in eastern China were displaced to the south by 300-1000 km, while temperate deciduous broad-leaved forest, pure warm-temperate evergreen forest, tropical semi-evergreen and evergreen forests were apparently absent from the mainland of southern China, implying much colder winters than present. Strong shifts of temperate xerophytic shrubland, steppe and desert to south and east in northern and western China and on the Tibetan Plateau also imply much drier conditions than present.

Plant functional types (PFTs) used in the biomisation procedure

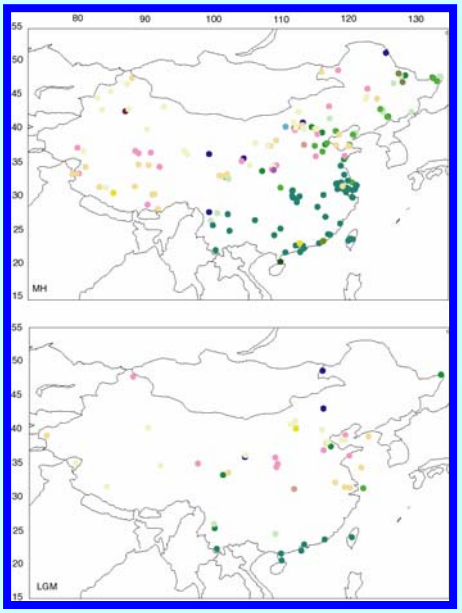
PFT code	PFT name
bo.e.n.t	boreal evergreen needle-leaved tree
c-te.e.n.t	cool-temperate evergreen needle-leaved tree
te.e.n.t	temperate evergreen needle-leaved tree
wt.e.n.t	warm-temperate evergreen needle-leaved tree
eu.e.n.t	eurythermic evergreen needle-leaved tree
bo.cd.n.t	boreal cold-deciduous needle-leaved tree
wt.d.n.t	warm-temperate deciduous needle-leaved tree
wt.e.sb.t	warm-temperate evergreen sclerophyll broad-leaved tree
wt.e.mb.t	warm-temperate evergreen malacophyll broad-leaved tree
tr.e.sb.t	tropical evergreen sclerophyll broad-leaved tree
tr.e.mb.t	tropical evergreen malacophyll broad-leaved tree
bo.cd.mb.t	boreal cold-deciduous malacophyll broad-leaved tree
te-ft.cd.mb.t	temperate (spring-frost tolerant) cold-deciduous malacophyll broad-leaved tree
te-fa.cd.mb.t	temperate (spring-frost avoiding) cold-deciduous malacophyll broad-leaved tree
te-fi.cd.mb.t	temperate (spring-frost intolerant) cold-deciduous malacophyll broad-leaved tree
wt.cd.mb.t	warm-temperate cold-deciduous malacophyll broad-leaved tree
tr-m.dd.mb.t	tropical mesic drought-deciduous malacophyll broad-leaved tree
tr-x.dd.mb.t	tropical xeric drought-deciduous malacophyll broad-leaved tree
lp.t	leptophyll tree
sl.t	small-leaved tree
tut	tuft tree
ar.e.n.lhs	arctic evergreen needle-leaved low or high shrub
ft.lp.lhs	frost-tolerant leptophyll low or high shrub
dt.sl.lhs	drought-tolerant small-leaved low or high shrub
di.sl.lhs	drought-intolerant small-leaved low or high shrub
wt.e.sb.lhs	warm-temperate evergreen sclerophyll broad-leaved low or high shrub
ar.e.mb.lhs	arctic evergreen malacophyll broad-leaved low or high shrub
bo.e.mb.lhs	boreal evergreen malacophyll broad-leaved low or high shrub
wt.e.mb.lhs	warm-temperate evergreen malacophyll broad-leaved low or high shrub
tr.e.mb.lhs	tropical evergreen malacophyll broad-leaved low or high shrub
ar.cd.mb.lhs	arctic cold-dediduous malacophyll broad-leaved low or high shrub
bo.cd.mb.lhs	boreal cold-deciduous malacophyll broad-leaved low or high shrub
te.cd.mb.lhs	temperate cold-deciduous malacophyll broad-leaved low or high shrub
wt.cd.mb.lhs	warm-temperate cold-deciduous malacophyll broad-leaved low or high shrub
eu-x.dd.mb.lhs	eurythemic xeric drought-deciduous malacophyll low or high shrub
ar.e.mb.eds	arctic evergreen malacophyll broad-leaved erect dwarf shrub
ar.cd.mb.eds	arctic cold-dediduous malacophyll broad-leaved erect dwarf shrub
ar.e.n.pds	arctic evergreen need-leaved prostrate dwarf shrub
ar.e.mb.pds	arctic evergreen malacophyll broad-leaved prostrate dwarf shrub
ar.cd.mb.pds	arctic cold-dediduous malacophyll broad-leaved prostrate dwarf shrub
cs	cushion shrub
tr-dt.lv	tropical drought-tolerant liana or vine
tr-di.lv	tropical drought-intolerant liana or vine
ar.fb	arctic forb
te-dt.fb	temperate drought-tolerant forb
eu-dt.fb	eurythermic drought-tolerant forb
rcfb	rosette or cushion forb
hal	halophyte
g	grass graminoid
s	sedge graminoid
ssuc	stem succulent
lsuc	leaf succulent
tf	tree fern

Assignment of plant functional types (PFTs) to biomes used in the biomisation procedure

Biome name	Code	PFTs
cold deciduous forest	CLDE	bo.cd.n.t, eu.e.n.t, bo.cd.mb.t, bo.e.mb.lhs, bo.cd.mb.lhs,
cold evergreen needle-leaved forest	CLEG	bo.cd.n.t, bo.e.n.t, eu.e.n.t, bo.cd.mb.t, bo.e.mb.lhs, bo.cd.mb.lhs
cool-temperate evergreen needle-leaved and mixed forest	CLMX	bo.cd.n.t, c-te.e.n.t, eu.e.n.t, bo.cd.mb.t, bo.e.mb.lhs, bo.cd.mb.lhs
cool evergreen needle-leaved forest	COEG	bo.cd.n.t, c-te.e.n.t, eu.e.n.t, bo.cd.mb.t, te-ft.cd.mb.t, bo.e.mb.lhs, bo.cd.mb.lhs
cool mixed forest	COMX	bo.cd.n.t, c-te.e.n.t, eu.e.n.t, te-ft.cd.mb.t, te-fa.cd.mb.t, bo.e.mb.lhs, te.cd.mb.lhs
temperate deciduous broad-leaved forest	TEDE	te.e.n.t, eu.e.n.t, te-fa.cd.mb.t, te-fi.cd.mb.t, bo.cd.mb.t, te.cd.mb.lhs
warm-temperate evergreen broad-leaved and mixed forest	WTEM	wt.e.n.t, wt.d.n.t, eu.e.n.t, wt.e.sb.t, wt.e.mb.t, wt.cd.mb.t, te-fi.cd.mb.t, wt.e.sb.lhs, wt.e.mb.lhs, wt.cd.mb.lhs
warm-temperate evergreen broad-leaved forest	WTEG	wt.e.n.t, eu.e.n.t, wt.e.sb.t, wt.e.mb.t, wt.e.sb.lhs, wt.e.mb.lhs, tf
tropical semi-evergreen broad-leaved forest	TRSE	tr.e.mb.t, tr-m.dd.mb.t, wt.e.n.t, wt.d.n.t, wt.e.sb.t, wt.e.mb.t, tr.e.mb.lhs, tf, tr-dt.lv
tropical evergreen broad-leaved forest	TREG	tr.e.mb.t, tr.e.sb.t, tut, wt.e.n.t, wt.d.n.t, wt.e.sb.t, wt.e.mb.t, tr.e.mb.lhs, tf, tr-di.lv
tropical deciduous broad-leaved forest and woodland	TRDE	tr-x.dd.mb.t, tr-m.dd.mb.t, g
temperate xerophytic shrubland	TEXE	lp.t, sl.t, dt.sl.lhs, te-dt.fb, g
steppe	STEP	di.sl.lhs, te-dt.fb, eu-dt.fb, g, s
desert	DESE	ft.lp.lhs, dt.sl.lhs, eu-x.dd.mb.lhs, cs, hal, lsuc, ssuc, g,
cushion-forb tundra	CUSH	rcfb, ar.fb, g
graminoid and forb tundra	DRYT	ar.fb, g, s
prostrate dwarf shrub tundra	PROS	ar.e.mb.pds, ar.cd.mb.pds, ar.fb, g
erect dwarf shrub tundra	DWAR	ar.e.mb.pds, ar.cd.mb.pds, ar.e.mb.eds, ar.cd.mb.eds, g, s
low and high shrub tundra	SHRU	ar.e.n.lhs, ar.e.mb.lhs, ar.cd.mb.lhs, ar.e.mb.eds, ar.cd.mb.eds, ar.e.n.pds, ar.e.mb.pds, ar.cd.mb.pds, g, s



Modern natural vegetation patterns of China reconstructed from 806 surface pollen samples and obtained from the digitised vegetation map and the observation



Pollen-derived biomes in China in the MH and at LGM

Citations

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Contact: Dr. Jian Ni (jni@bgc-jena.mpg.de)