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Anthropogenic modification of vegetated landscapes in southern China from 6,000 years ago

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**Anthropogenic modification of vegetated landscapes in southern China from
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1. Pollen source of site GeoB16602

The modern distribution pattern of pollen in northern SCS demonstrates that most of the pollen deposited in the northern SCS, particularly to the south of the Pearl River estuary, is supplied by the Pearl River, while the proportions from Taiwan and the Philippines increase to the north¹⁻³. The pollen assemblages of our core-top sample show a predominance of *Pinus* and *Dicranopteris*, corresponding well to contemporary vegetation in the catchment area (Fig. S1). The near disappearance of alpine (such as *Abies*, *Picea* and *Tsuga*) and tropical components (such as Podocarpaceae) indicates very limited vegetation information of mountainous Taiwan and tropical Hainan. Hence the Pearl River catchment is the primary pollen source of our study site.

Recent studies on clay mineral deposition in northern SCS reveal high glacial-interglacial contrasts in sediment transport pattern because of sea-level fluctuations and the reorganizations of ocean circulation, but the clay mineral assemblages are comparable among interglacials⁴, suggesting similar sources and transportation. Also take into account the constant level of Ti/Ca ratios (Fig. S2) which reflect changes in terrestrial input of mainly fluvial origin⁵, we exclude the possibility of fundamental changes in terrigenous dispersal during different interglacials.

As modern pollen distribution pattern and the pollen assemblages of our core top sample support the Pearl River input as the primary pollen source, a different pollen provenance during previous interglacials should have caused apparent decrease of the pollen concentration, because the pollen discharges of other surrounding sources, i.e. Taiwan, Hainan and aeolian input, are much lower². Comparable concentrations of total pollen counts during different interglacials (Fig. S4a) therefore imply relatively homogenous provenance of pollen sediment at GeoB16602. Slightly higher total pollen concentration during the late Holocene is mainly induced by increased *Pinus* pollen (Fig. S4b), which is more productive and easier to be transported to the

deep-sea.

2. Modern vegetation of the study area

Wu (1980) divided the vegetation surrounding the northern SCS into three floristic regions: (i) middle subtropical evergreen broadleaved forest; (ii) southern subtropical evergreen broadleaved forest; (iii) tropical monsoon forest and tropical rainforest⁶. Accordingly, the Pearl River catchment is generally a transition zone between tropical rainforests and subtropical evergreen broadleaved forests. But today such zonation is highly fragmented by secondary forests, wastelands and croplands. *Pinus massoniana*, dominant component of the secondary forest (most of the coniferous forests in the catchment area), and *Dicranopteris*, a widespread fern occupying wastelands, representing severe human disturbance rather than climax vegetation types (Fig. S1).

The extant rainforests on the Hainan Island are dominated by a few taxa from the families of Dipterocarpaceae, Euphorbiaceae, Anacardiaceae, Palmae and Sapotaceae in the lowlands, while coniferous species of Podocarpaceae, such as *Dacrydium*, *Podocarpus* and *Dacrycarpus*, become frequent in the montane rainforests (>600 m elevation). Today, montane rainforests are totally absent on the Chinese mainland, while lowland rainforest patches are still sporadically found in some undisturbed valleys of the Pearl River catchment area. The predominant subtropical evergreen broadleaved forests in the Pearl River catchment area are commonly composed of *Castanopsis*, *Quercus*, *Cinnamomum*, *Magnolia*, etc. Deciduous broadleaved forests and associated conifers, such as *Tsuga* and *Keteleeria*, occur at elevations above 1000m. *Abies/Picea* forests and alpine shrubs are quite typical at higher altitudes (> 2500 m) on the Taiwan Island.

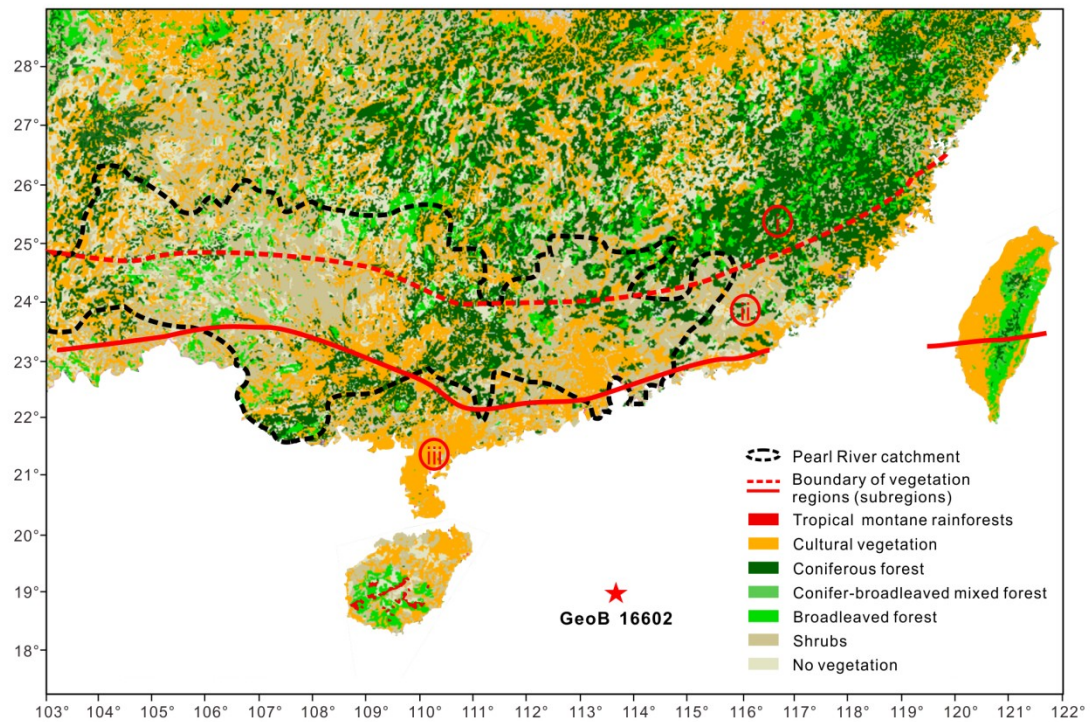


Figure S1. Modern vegetation map of southeastern China (<http://www.nsii.org.cn/mapvege>). (i) middle subtropical evergreen broadleaved forest; (ii) southern subtropical evergreen broadleaved forest; (iii) tropical monsoon forest and tropical rainforest.

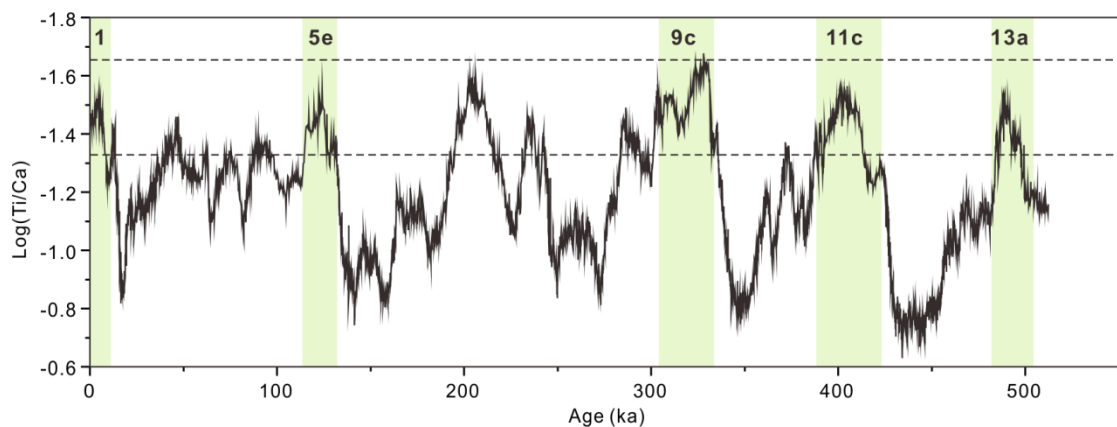


Figure S2. Ti/Ca ratio record of GeoB16602. Interglacial periods are highlighted by light green bars.

3. Variations in the abundances of important pollen and spore taxa.

The variations of pollen assemblages are characterized by predominant glacial-interglacial cycles and less obvious long-term trend. The last two glacial-interglacial cycles have more grasses (Fig. S3i, j) and temperate deciduous trees (Fig. S3g, h) in the regional vegetation than before. But this long-term trend does not influence the steady interglacial feature, the tropical rainforest conifers (Fig. S3a-c, o) flourished during MIS 5e as before. The Holocene (MIS 1) is thus unique in this respect.

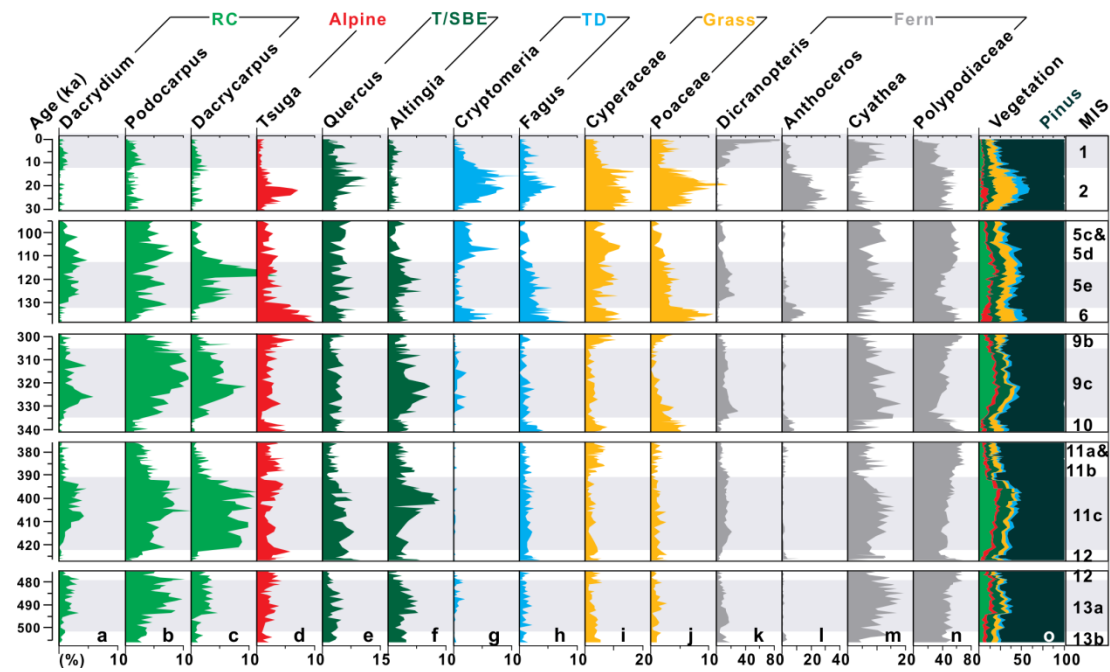


Figure S3. Percentage diagram of selected pollen and spore taxa from site GeoB16602. The pollen and spore percentages are calculated based on pollen sum and spore sum, respectively. Spores are not included in the summary diagram (o). RC: rainforest conifers; T/SBE: tropical/subtropical broadleaved evergreen trees; TD: temperate deciduous trees. MIS: marine isotope stage. The horizontal gray areas indicate the investigated interglacial periods.

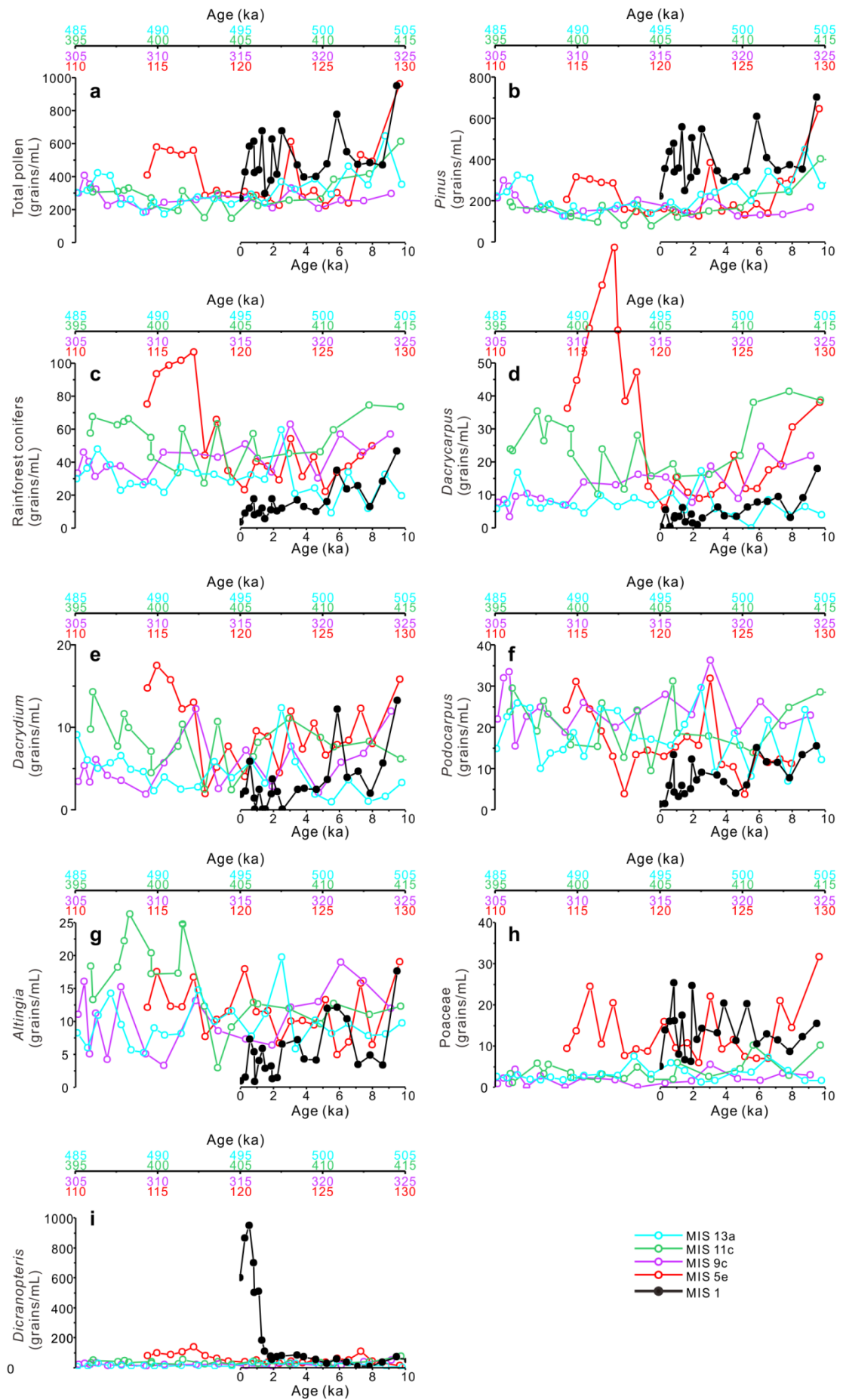


Figure S4. Comparison of pollen and spore concentrations during the five peak interglacials. The Holocene period is distinguished from previous interglacials by an anomalous decrease of the tropical components (c-g) after 5-6 ka, and an anomalous increase of *Dicranopteris* spores (i) after 2 ka.

4. Terrestrial and proximal marine records of tropical vegetation in southern China

The long-term terrestrial records indicate much wider historical distribution of montane rainforests than present (Fig. S5)⁷⁻¹⁰. Although no direct evidences from the core area (the Pearl River catchment), high resolution records from Huguangyan maar (HG)¹¹, marine sites MD05-2906¹² and MD05-2904¹³ (Fig. S5) generally agree with our interpretation of a middle-late Holocene decline of regional tropical montane rainforests. ODP site 1144 (located closely to site MD05-2906) provide a ~1 Myr long pollen sequence¹⁴, but unfortunately, sedimentary hiatuses during the peak interglacials¹⁵, low proportions of Podocarpaceae pollen and possibly different sources of terrigenous content at that site^{2, 5} hamper a detailed comparison with our record.

The rainforest pollen taxa other than those montane species are very rare in marine sediments because of their limited ability of long-distance transportation. As a result, the possible changes in lowland broadleaved rainforests are not so clear in our marine pollen record. The high-resolution terrestrial records from Huguangyan maar¹¹ and Dahu peat (DH)¹⁶ demonstrated clear decreases in *Castanopsis*, *Mallothus*, *Phyllanthus* and Moraceae, etc. that were nearly synchronous with the decreases in montane rainforest species observed in the marine records (Fig. S5), likely implying that the late-Holocene retreat of tropical components involved both the montane and lowland forests. This also seems to be corroborated by the fact that most tropical species are absent from the top section of Tianyang core (~400 kyr long), but quite commonly appear in the lower part¹⁷.

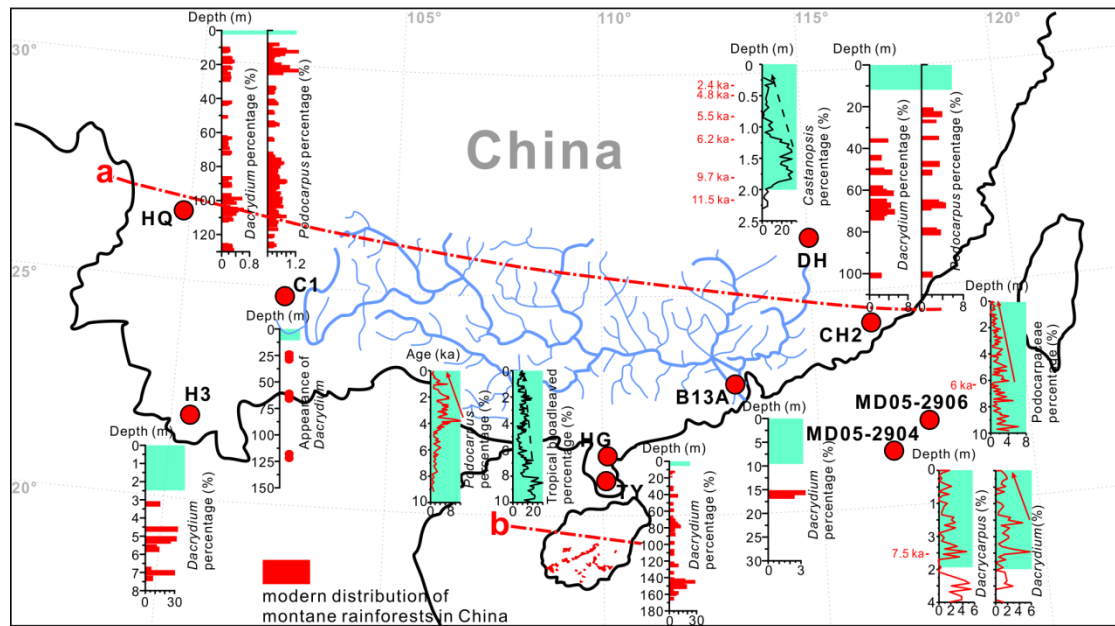


Figure S5. Summary of montane rainforest coniferous pollen records in southern China. Dashed lines depict the modern (b) and historical (a) distribution of montane rainforests than present based on long-term terrestrial records⁷⁻¹⁰. The Holocene period is highlighted in the diagrams.

Table S1.

Radiocarbon ages and cal. ages of Multi-corer GeoB16602-3 and Gravity-core GeoB16602-4⁵.

Lab-ID UCIAMS #	Depth (cm)	Foraminifera Species	¹⁴ C Age ^a (yr BP)	cal. Age ^b (yr BP)	2 σ cal. age range ^c
GeoB16602-3					
133834	0-1	<i>G. ruber</i>	-90 $\pm$ 20 ^d		
133835	16-17	<i>G. ruber</i> .	1580 $\pm$ 20	1145	1063-1218
133836	34-35	<i>G. ruber</i>	3010 $\pm$ 25	2776	2726-2845
GeoB16602-4					
123363	2	<i>G. ruber</i> + <i>G. sacculifer</i>	1005 $\pm$ 25	590	542-651
123364	18	<i>G. ruber</i> + <i>G. sacculifer</i>	3015 $\pm$ 20	2790	2730-2844
123365	34	<i>G. ruber</i> + <i>G. sacculifer</i>	4310 $\pm$ 25	4440	4357-4519
123366	66	<i>G. sacculifer</i>	6455 $\pm$ 25	6950	6852-7043
123367	94	<i>G. sacculifer</i>	9005 $\pm$ 30	9670	9541-9802
123368	126	<i>G. ruber</i> + <i>G. sacculifer</i>	10,790 $\pm$ 30	12,260	12,068-12,465
123369	146	<i>G. sacculifer</i>	11,640 $\pm$ 30	13,140	13,020-13,257
123371	186	<i>G. sacculifer</i>	13,355 $\pm$ 50	15,490	15,269-15,704
123372	234	<i>G. ruber</i> + <i>G. sacculifer</i>	13,795 $\pm$ 50	16,100	15,913-16,285
123373	282	<i>G. sacculifer</i>	16,195 $\pm$ 50	19,040	18,894-19,195
123376	310	<i>G. ruber</i>	18,900 $\pm$ 70	22,360	22,185-22,540
123377	366	<i>G. sacculifer</i>	22,940 $\pm$ 120	26,850	26,486-27,212
123379	406	<i>G. ruber</i> + <i>G. sacculifer</i>	24,850 $\pm$ 140	28,460	28,122-28,793
123381	518	<i>G. ruber</i> + <i>G. sacculifer</i>	32,800 $\pm$ 340	36,450	35,510-37,387
123382	562	<i>G. sacculifer</i>	34,870 $\pm$ 440	39,060	38,328-39,788

^aMeasured at the Keck Carbon Cycle Accelerator Mass Spectrometry Facility (UCIAMS), Earth System Science Department, University of California, Irvine, United States of America.

^bAll raw radiocarbon dates were converted to 2 σ calendar ages with the CALIB 7.1 software using the MARINE13 calibration dataset without a further adjustment for a regional ¹⁴C reservoir age (ΔR , deviation from the average global reservoirage of 400 years).

^c2 σ enclosing 95.4% of probability distribution.

^dThe sample contains excess ¹⁴C from post AD 1950 atmospheric thermonuclear weapons tests.

Table S2.

Early rice remains from Mid-Late Neolithic archaeological sites in southern China.

No.*	Sites	Fossils recovered	Cultural phase	Dates	Dating methods	Refs.
			Xiaojin phase			
2	Xiaojin	rice grains rice grains	2 Xiaojin phase 3	4-6 ka 3-4 ka	AMS ¹⁴ C	18, 19
5	Dingsishan	rice phytoliths	Dingsishan phase 4	~6 ka	Spatially correlating of cultural remains	19, 21
3	Leizhukou	rice phytoliths	Leizhukou phase 2	~6 ka	Spatially correlating of cultural remains	22, 23
6	Xinghuahe	rice grains	Shixia phase	4.3-4.9 ka	AMS ¹⁴ C	20, 25
4	Guye	rice grains		5-6 ka	AMS ¹⁴ C	24, 26
1	Shixia	rice grains rice grains	Pre-Shixia Shixia phase	5.5-6 ka 4.3-4.9 ka	AMS ¹⁴ C	23, 26
7	Shaxia	rice phytoliths& grains	Shixia phase	4.2-5.3 ka	AMS ¹⁴ C	27, 28
8	Tanshishan	rice grains	Tanshishan phase	2.4-4.9 ka	AMS ¹⁴ C	20, 29
9	Shizhaishan	rice grains	Shizhaishan Neolithic	4.5-5.1 ka	AMS ¹⁴ C	20, 30
10	Baiyangcun	rice grains	Late Neolithic	4-4.5 ka	AMS ¹⁴ C	20, 31
11	Pinglingtou	rice grains	Late Neolithic	~4 ka	Spatially correlating of cultural remains	32

*Site numbers are labeled in Figure 1.

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