Supporting Information to

"Reconstruction of a 1,910–y–long locust series reveals consistent associations with climate fluctuations in China" by Huidong Tian, Leif C. Stige, Bernard Cazelles, Kyrre Linne Kausrud, Rune Svarverud, Nils C. Stenseth and Zhibin Zhang

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Part A. Reconstruction of locust abundance series

1. Locust records in historical documents.

There are 8343 locust records in *A Compendium of Chinese Meteorological Records of the Last 3000 Years* (1), most of which derive from two types of historical documents: standard histories and local gazetteers. Standard histories, such as *Twenty –four Histories*, *Comprehensive Mirror to Aid in Government* and *Draft History of Qing Dynasty*, were stringently organized and compiled by the succeeding dynasty and are generally considered authoritative and credible sources of Chinese history (2). Local gazetteers (including provincial, prefectural and district gazetteers) were compiled and produced by local officials, which embrace various types of information concerning historical, geographical, economic, administrative, natural and other aspects of a locality in China. The earliest locust records appeared in *The Spring and Autumn Annals* in BC 707. However, systematic and continuous recording of locust outbreaks only starts from the year AD 2 in the *History of the Former Han Dynasty*. From then on, locust records frequently appeared in standard histories. In AD 1418, the Yongle Emperor (AD 1360–1424) ordered all counties of China to compile gazetteers, and decreed *The Guideline of Gazetteers Compilation* (3). By the end of the Ming dynasty (AD 1368–1644), almost every county or prefecture had its own gazetteer (4) and numerous locust records were preserved.

We separated the locust records into two periods characterized by different recording frequencies as well as different types of source documents: period A (AD 2–1367) and period B (AD 1368–1911). In period A, 598 out of 639 locust records derive from standard histories, while in period B, 7519 out of 7677 locust records derive from local gazetteers. Eastern China, mainly covering the Yellow River basin and the Yangtze River basin, is the most important agricultural region in China. Almost all of the locust records are from this region, although some records appeared from areas further south in period B (Fig. S1A, B). In order to ensure consistent spatial coverage throughout the period studied we restricted our study area to the area around the middle and lower parts of the Yellow River and Yangtze River basins (yellow polygon in Fig. S1A, B). This area also coincides with the core distribution area for Oriental migratory locusts (*Locusta migratoria manilensis*) in China (5).

The descriptions of locust outbreaks in period A are quite diverse in the level of detail, and some of them are ambiguous especially in its earlier period. For example: *"summer, locust"; "12 provinces had locust"; "6 states had locust"; "Province Si, Ji, Qing and Yong had locust"*. Period B contains more detailed descriptions of locust outbreaks. For example: *"Locusts ate up all crops"; "Flying locusts darkened the sky and seriously injured crops"; "Locust outbreak from spring to autumn"*. Further, the spatial extent of the outbreaks in period B can generally be inferred from the information in the various local gazetteers.

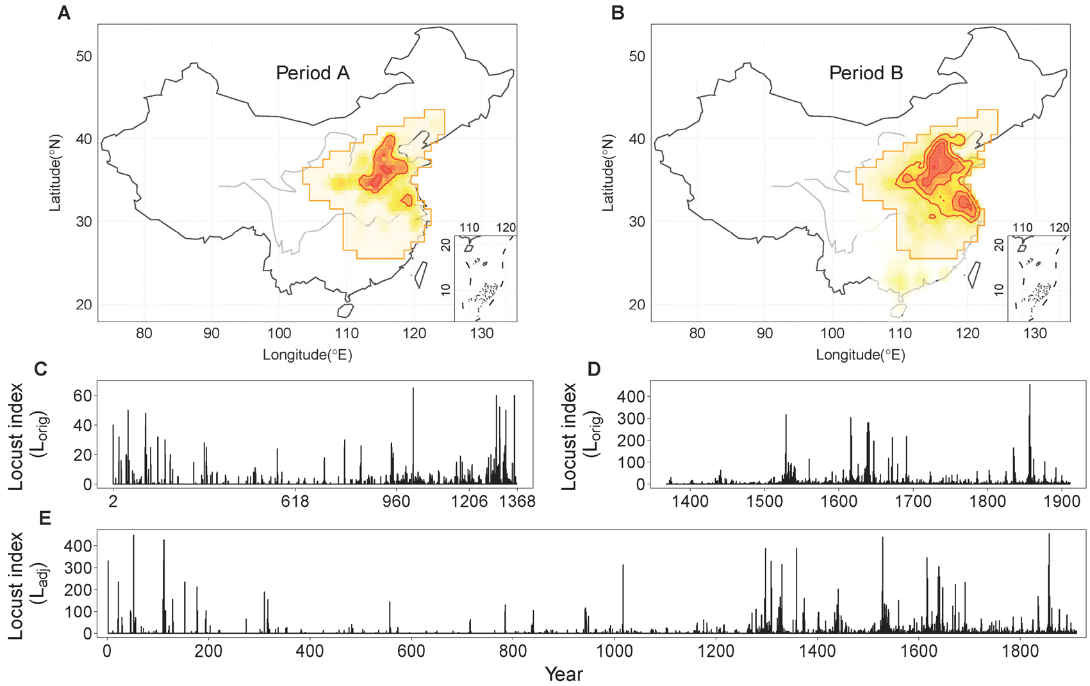

Fig. S1. Spatial extent of locust records in China in period A (AD 2–1367; panel A) and period B (AD 1368–1911; panel B). The yellow polygon shows the area considered in this study. The mean frequency of locust records is indicated by background colors ranging from light–yellow (low frequency) to dark–red (high frequency). (C) Initial reconstructed locust abundance index for period A (L_{orig}; scale: number of prefectures with locust reports). The index is comparable within but not among four sub–periods due to variation in administrative boundaries: Han–Sui, AD 2–618; Tang, AD 618–960; Song, AD 960–1206 and Yuan, AD 1206–1368. (D) Initial reconstructed locust abundance index for period B (L_{orig}; scale: number of counties with locusts multiplied with outbreak intensity, ranked 1–3). (E) Final reconstructed locust abundance index for AD 2–1911 (L_{adj}) before log–transformation.

2. Reconstruction method

The number of prefectures with reports of locusts per year was chosen as the initial locust index (L_{orig}) for period A because most of locust records referred to the number or list of prefectures having locust outbreaks. For ambiguous records, the numbers of prefectures were assigned by author's comprehension of the historical context.

Since the administrative divisions of China were not fixed but changed from dynasty to dynasty, prefecture numbers in different periods can not be compared directly. For example, the numbers of prefectures in Later Han (AD 25–220), Three

Kingdoms (AD 220–280), Jin (AD 265–420), South and North Dynasties (AD 240–589) and Sui (AD 581–618) are 105, 158, 172, 628 and 190, respectively (6). To partly address this problem, period A was divided into four sub–periods with relatively stable administrative divisions (Fig. S1C), and prefecture numbers were standardized within each sub–period. For example, the first sub–period (AD 2–618) includes a unified and stable period Han (AD 2–220) and several divided and chaotic periods (Three Kingdoms – Sui dynasty, AD 220–618). Locust index values for this sub–period were standardized to Later Han prefecture number units by comparing outbreak locations on maps from around the time of the outbreak with a map of the administrative division of the Later Han dynasty. Note that the initial locust index values are thus comparable within but not among sub–periods.

The majority of locust records in period B come from district gazetteers (about 5700) and the rest are mainly from prefecture gazetteers (about 1400). There were 179 and 276 prefectures in Ming and Qing dynasties, respectively, and this difference could potentially bias a locust index based on numbers of prefectures with locust outbreaks (period A). However, the total number of counties changed proportionately less (being 1427 and 1579, in Ming and Qing dynasties, respectively) (6). Moreover, prefectural gazetteers were generally compiled by summarizing the information in district gazetteers under their jurisdiction, and areas of counties were relatively stable in imperial era of China (6). Thus, county was used as spatial unit for period B. Locust records in period B contain detailed descriptions about the intensity of locust outbreaks. An intensity grade ranked 1–3 was assigned to each record according to its context. Grade 1 was used for commonly occurring records, such as: "*Locusts*"; "*Nymphs*"; "*Locusts ate crops*". Grade 2 was used for records of serious outbreaks, such as: "*Serious locust outbreak*"; "*Flying locusts darkened the sky and seriously injured crops*"; "*Locusts ate up all crops*". Grade 3 was used for records of extreme upsurge, such as: "*Locust outbreak all the year*"; "*Locusts covered the land nearly one foot deep*"; "*Serious locust outbreak from summer to autumn, locusts ate up crops, grass and small branches, darkened the sun and filled up all lower places wherever they arrived, thus causing men and horses trouble to walk"*. The original locust index (L_{orig}) for period B (Fig. S1D) was calculated by summing the intensity grade values across all counties with recorded locusts in a year (the highest grade was used if there were several locust records for a county in one year). The locust index for period B thus integrates information about spatial extent and intensity of locust outbreaks.

The reconstructed locust series for period B displayed a significant increasing trend ($P < 0.05$), and its first one third seems to be abnormally lower than the rest (Fig. S1D). One likely reason for this trend is bias from increased recording effort (number of available gazetteers). The total number of meteorology–related records (including records of locusts, flood, drought, rainfall etc.) of each year in the source compendium for the locust data (1), which can be taken as a proxy of recording effort, also showed increasing trend ($P < 0.001$) and was abnormally low during the first one third of period B (Fig. S2A). The locust abundance series was first attempted corrected for recording effort by using the formula:

$$L_{rect} = (G_{max}/\ G) \cdot L_{orig} \quad (1),$$

where L_{rect} is the rectified locust index, L_{orig} is the original (uncorrected) locust index for period B, G is smoothed meteorological record number (Fig. S2A) and G_{max} is the maximum of G (smoothing: natural cubic spline function of year in a generalized additive model, as implemented using the *gam* function in the *mgcv* package (7) of the program R (8). However, L_{rect} decreased significantly ($P < 0.05$), indicating that this method over–compensated for lower sampling effort in the earliest period. Thus we used the formula:

$$L_{adj} = (L_{rect} + L_{orig})/2 \quad (2),$$

to balance the rectified and the original locust abundance. In contrast to L_{orig} and L_{rect}, L_{adj} (Fig. S2B) showed no significant linear trend ($P > 0.1$).

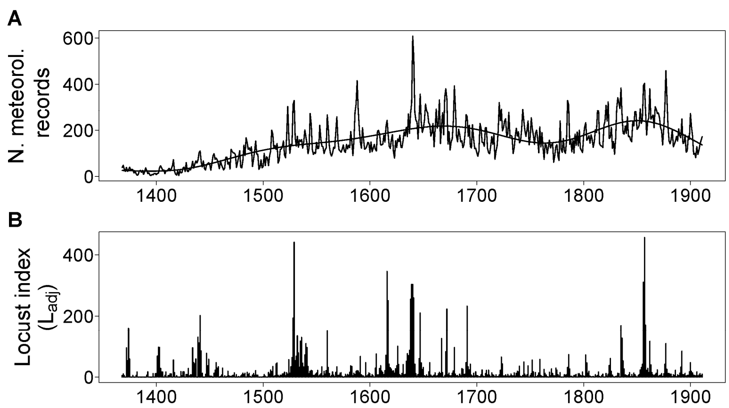

Fig. S2. (A) Number of all meteorology–related records in period B and smoothed line (*G*, eq. 1) used as indicator of recording effort. (B) Locust abundance index for period B adjusted for recording effort (L_{adj}).

As mentioned above, the initial locust index values for different sub–periods in period A are not comparable with each other or with locust index values for period B. These values were therefore transformed to the same unit used for period B. To do so, a regression equation was developed for each of the four sub–periods, to convert from numbers of locust–infested prefectures (the initial locust unit for period A) to the L_{adj} index scale of period B. The regression equations were developed by transposing maps of period A prefecture boundaries on the county–resolved maps of locust reports in AD 1512–1911 (relative stable recording effort, see Fig. S2A), counting how many period A prefectures were infested by locusts for each of these years (i.e., given the older administrative divisions), and finally regressing these calculated prefecture numbers on the L_{adj} index values for the same years. For example, given that the locations of locust outbreaks in a year in period B with L_{adj} = 150 fell inside of 30 prefectures in Later Han's map (the first sub–period of period A), then the locust index value 30 in this sub–period of period A corresponds to a locust index value of 150 in period B. The maps for the four sub–periods of period A were selected from the Later Han, Tang, Song and Yuan dynasties, respectively (9). The regression equations were developed using generalized additive models of L_{adj} as natural cubic spline functions of calculated prefecture number, shown in Fig. S3A–D. By combining the transformed locust index values for period A with those from period B, a 1910–years long (AD 2–1911) annual locust series was constructed (Fig. S1E, Dataset S1, Dataset S2). The reconstructed annual locust series was highly skewed, and for the convenience of statistical analysis, the final annual locust index was log–transformed: $L_{ann} = \ln(L_{adj} + 1)$.

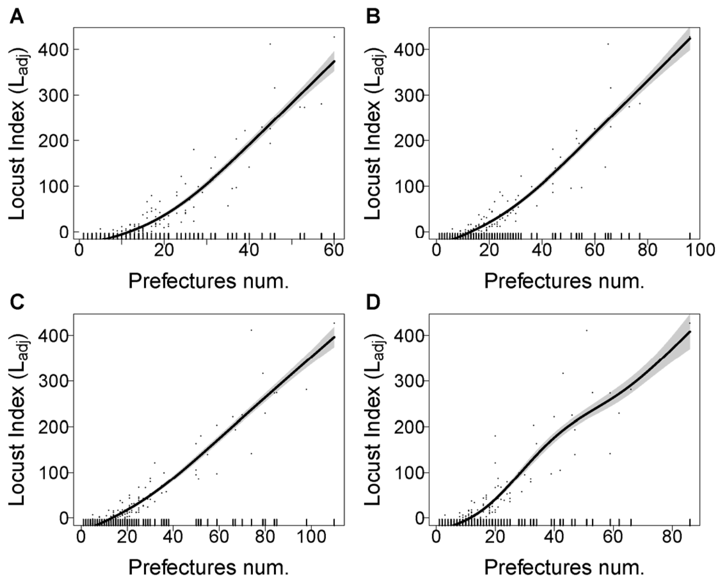

Fig. S3 Regression lines used to transform locust index values (L_{orig}) for the four sub–periods in period A to the scale used in period B (L_{adj}). (A) Han–Sui, AD 2–618; (B) Tang, AD 618–960; (C) Song, AD 960–1206 and (D) Yuan, AD 1206–1368 (see Fig. S1C). Response: locust index values for years 1512–1911. Predictors: calculated numbers of locust–infested prefectures using maps for each of the four sub–periods. Deviances explained by the four regression models are: 0.936, 0.957, 0.963, and 0.911, respectively.

3. Comparison of our locust series with Ma's 1000–years–long locust series

The number of locust records used to construct the new locust index is twice of that used by Ma (5), thus the new locust index should be more reliable. We here extracted Ma's locust series for AD 960–1959 from Fig. 9A in (5) by consulting the literature sources (10, 11) used by Ma to obtain accurate temporal resolution. We can see that the two locust indices matched very well and that they have similar trends (Fig. S4A, B). The frequency distributions of the two locust series have similar patterns, although our series contain a higher proportion of intermediate values. The correlation between the two locust series is 0.79, which shows that reconstructed locust abundance is not very sensitive to reconstruction method. Periodicity analysis shows that the two locust series have similar wavelet decomposition and global spectrum pattern: two predominant frequencies appeared around periods of 110 years and 30 years, but our new locust series shows somewhat smoother frequency spectrum (Fig. S4C, D).

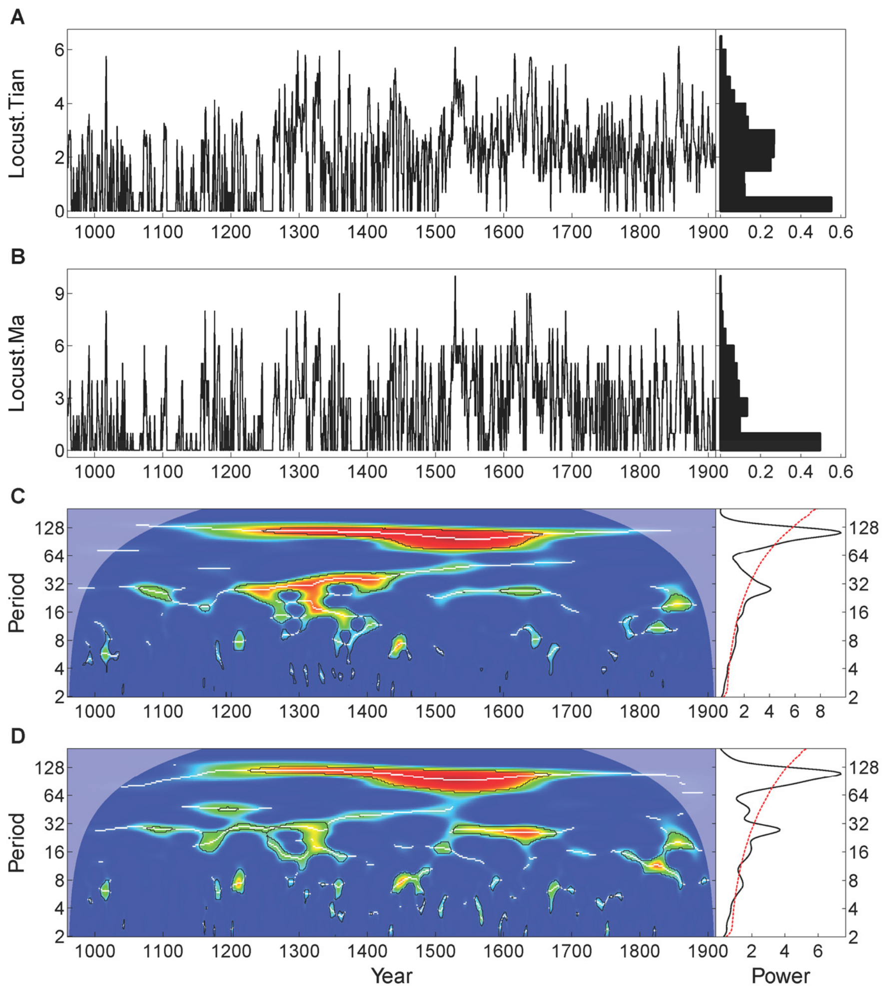

Fig.S4 Comparison between our newly constructed locust series and Ma's locust series (5). The two locust series and their frequency distributions (A: newly constructed, L_{ann}; B: Ma's locust series). Wavelet decomposition and global power spectra of the two series (C: newly constructed; D: Ma's locust series). See legend of Fig. 2 for wavelet decomposition.

4. Decadal locust series

A decadal locust series was constructed as described in the main text. The assumption behind the construction of this index is that years without locust reports are a random subset of the years. Alternatively, one could hypothesize that years with locusts reports were years with heavy locust outbreaks. Period A has a higher proportion of years having no locust report than period B (73% compared to 12%). If data were missing at random, one would expect similar frequency distributions of non-missing locust index values for periods A and B, whereas if missing values generally represented low locust abundance one would expect a distribution skewed towards high values in period A. The frequency distributions for the two periods appear similar (except for a higher proportion of very low values in period A; Fig. S5), providing support for the assumption of randomness. Mean and standard deviation of the normalized decadal locust index (L_{dec}) did not differ significantly between periods A and B (P>0.10; A: Mean = –0.13, SD = 1.37; B: Mean = –0.09, SD =1.55), providing additional support for the assumption of randomness being approximately correct.

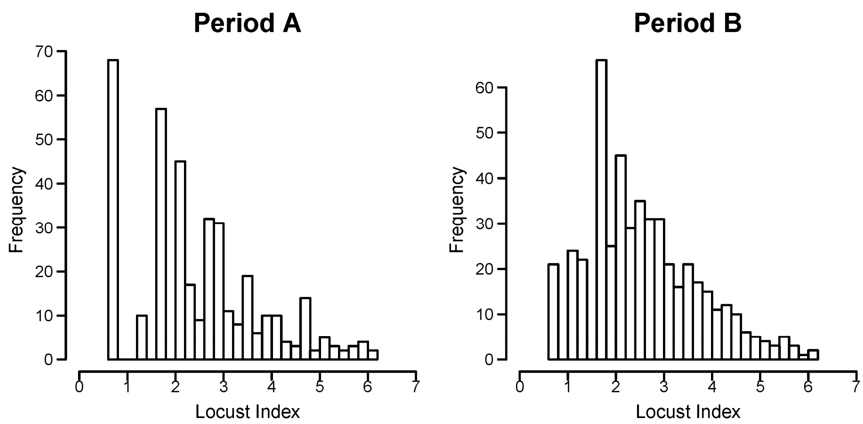

Fig. S5 Distribution histograms of annual locust index in periods A and B.

Part B. Additional modeling material

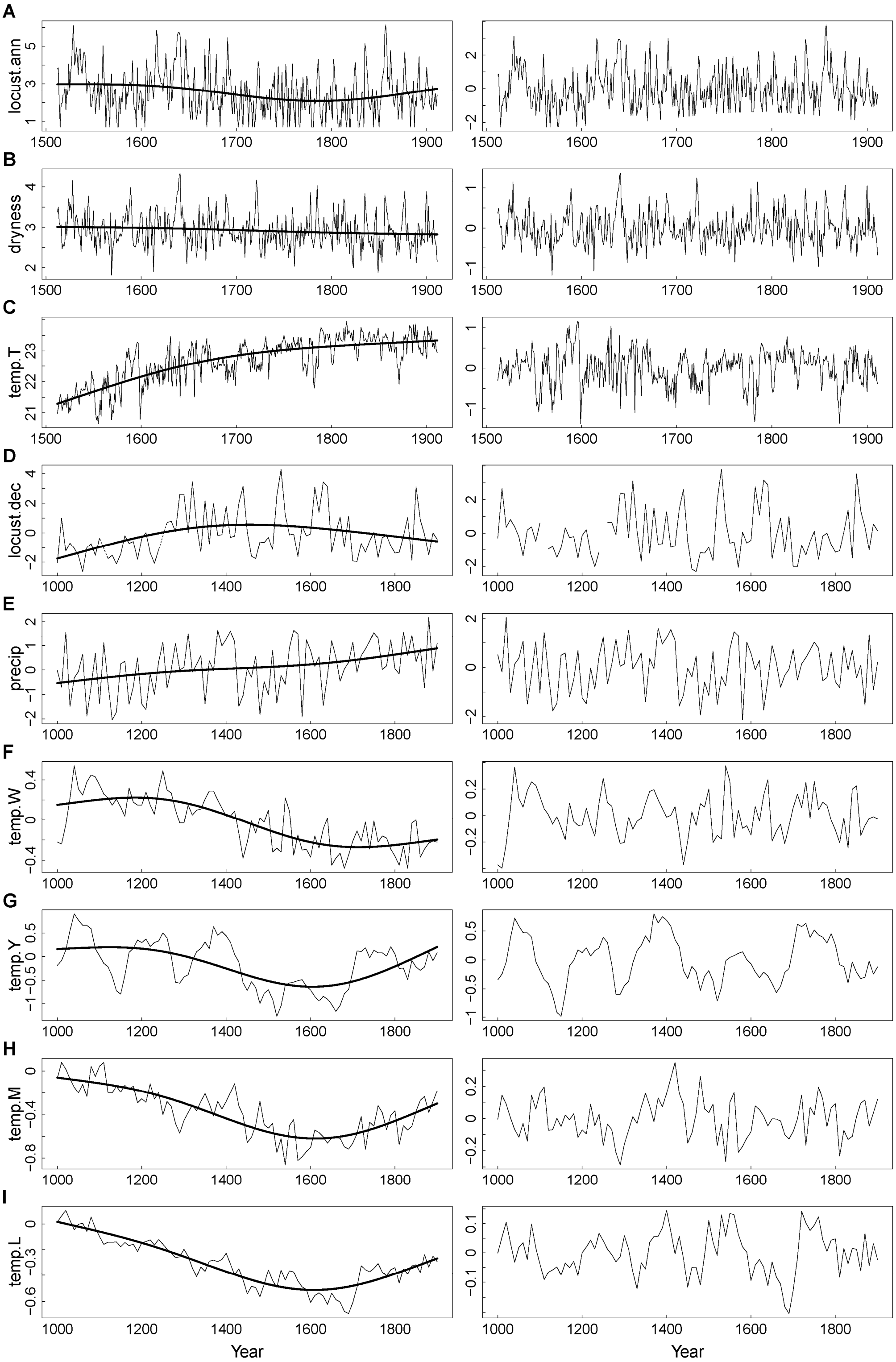

Fig. S6 Original data series with low–frequency trend imposed (left column) and their detrended version (right column). Trends were estimated using generalized additive models of the climate variable as a smooth function of year (natural cubic spline with the number of knots fixed at 4).

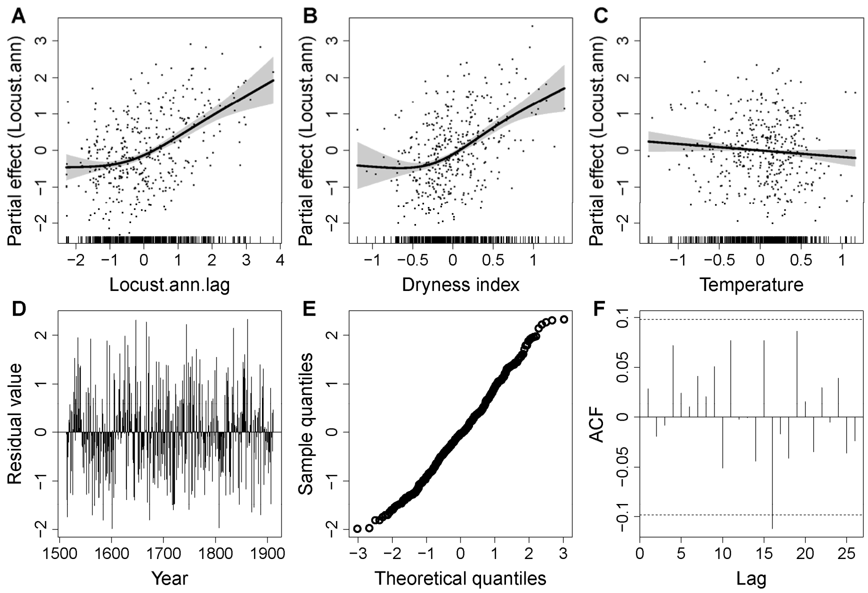

Fig. S7. Regression analysis of effects of climate on annual–scale locust dynamics using detrended data (shown in the right column of Fig. S6). Panels A, B and C show the effects of previous–year's locust abundance, dryness and temperature, respectively, on locust abundance. Residual diagnostics reveal no residual trend (D), approximate normal distribution of residuals (E, the quantile plot of residuals forms a nearly straight line), and a significant negative autocorrelation function (ACF) of residuals at lag 16 (F), which is, however, unlikely to invalidate statistical inferences. The model explained 43.2 % of the variance in the detrended locust series. Estimated effects of predictor variables are qualitatively similar to results obtained using the original (not detrended) data (Fig. 3).

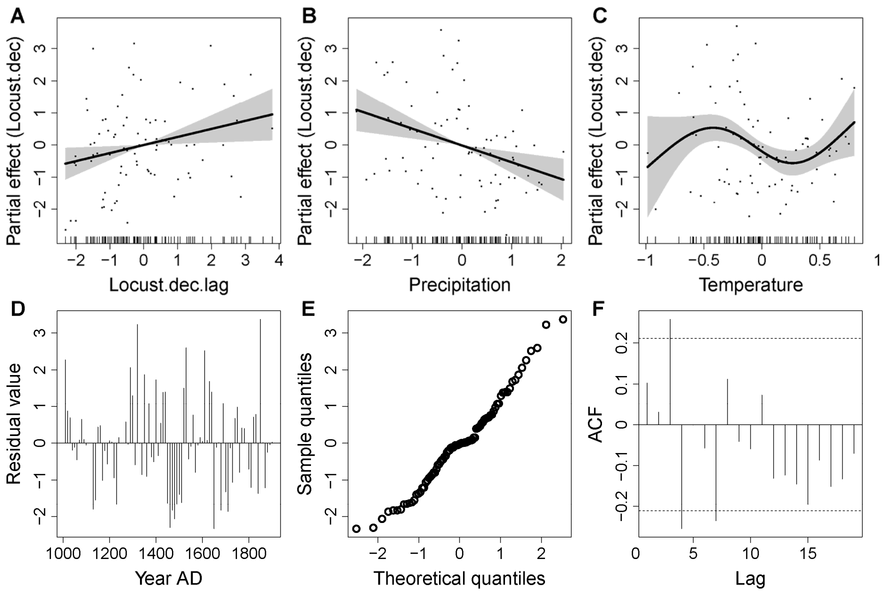

Fig. S8 Regression analysis of effects of climate on decadal–scale locust dynamics using detrended data (shown in Fig. S6). Panels A, B and C show the effects of previous–decade's locust abundance, precipitation and temperature, respectively, on current decade's locust abundance. Time–series of residuals reveals no residual trend (D). Residuals were approximately normal distributed (E). Autocorrelation function of residuals (ACF) reveals significant positive auto–correlation at lag 3 decades and negative autocorrelation at lag 4 and 7 decades (F), which are not thought to have large influence on statistical inferences. The model explained 26.3 % of the variance in the detrended locust series. Estimated effects of previous–decade locust abundance and precipitation are qualitatively similar to results obtained using the original (not detrended) data (Fig. 4), whereas the estimated temperature effect is nonlinear instead of linearly negative.

Table S1. Summary of alternative regression models of locust dynamics. Model: generalized additive model, as described in main text or with one or both climate terms removed. L_{ann}: annual locust index. L_{dec}: decadal locust index. P: precipitation index (annual analysis: "dryness"; decadal analysis: "precip"). T: temperature index (annual analysis: "temp.T"; decadal analysis: "temp.Y"). Effect: general sign of effect and approximate statistical significance (+: positive, –: negative, ~: wave–shaped; *: P<0.05, **: P<0.01, ***: P<0.001; the assumptions of independence of residuals not checked in all models). Dev.expl: proportion of deviance explained by the models.

Data series	**Model**	**Effect**			**Dev.expl**
		L_{T-1}	P	T	
Original annual	$L_{ann,T} \sim f(L_{ann,T-1})$	+***	+***		0.308
	$L_{ann,T} \sim f(L_{ann,T-1}) + g(P_T)$	+***			0.459
	$L_{ann,T} \sim f(L_{ann,T-1}) + h(T_T)$	+***		–***	0.327
	$L_{ann,T} \sim f(L_{ann,T-1}) + g(P_T) + h(T_T)$	+***	+***	–**	0.470
Original decadal	$L_{dec,T} \sim f(L_{dec,T-1})$	+**			0.108
	$L_{dec,T} \sim f(L_{dec,T-1}) + g(P_T)$	+***	–**		0.213
	$L_{dec,T} \sim f(L_{dec,T-1}) + h(T_T)$	+*		–*	0.171
	$L_{dec,T} \sim f(L_{dec,T-1}) + g(P_T) + h(T_T)$	+**	–*	–*	0.256
Detrended annual	$L_{ann,T} \sim f(L_{ann,T-1})$	+***	+***		0.264
	$L_{ann,T} \sim f(L_{ann,T-1}) + g(P_T)$	+***			0.427
	$L_{ann,T} \sim f(L_{ann,T-1}) + h(T_T)$	+***		–*	0.270
	$L_{ann,T} \sim f(L_{ann,T-1}) + g(P_T) + h(T_T)$	+***	+***	–*	0.432
Detrended decadal	$L_{dec,T} \sim f(L_{dec,T-1})$	+*			0.046
	$L_{dec,T} \sim f(L_{dec,T-1}) + g(P_T)$	+**	–***		0.177
	$L_{dec,T} \sim f(L_{dec,T-1}) + h(T_T)$	+		~*	0.161
	$L_{dec,T} \sim f(L_{dec,T-1}) + g(P_T) + h(T_T)$	+*	–**	~*	0.263

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Dataset S1. Reconstructed annual locust time series for period A (AD 2–1367). Sub–period: Han–Sui, AD 2–618; Tang, AD 618–960; Song, AD 960–1206 and Yuan, AD 1206–1368. L_{orig}: initial locust index (unit: number of prefectures with locusts). L_{orig} is comparable within, but not between the four sub–periods. L_{adj}: final locust index, scaled to the same unit used for period B. The annual locust index used in the analysis and for the construction of a decadal index was log-transformed, $L_{ann} = \ln(L_{adj} + 1)$.

Sub–period	*Year (AD)*	L_{orig}	L_{adj}
Han–Sui	2	40	331
Han–Sui	11	4	11
Han–Sui	21	15	64
Han–Sui	22	32	235
Han–Sui	29	16	71
Han–Sui	30	10	34
Han–Sui	46	20	104
Han–Sui	47	19	95
Han–Sui	48	2	4
Han–Sui	49	2	4
Han–Sui	52	50	450
Han–Sui	53	6	18
Han–Sui	54	12	45
Han–Sui	55	14	57
Han–Sui	56	16	71
Han–Sui	67	9	30
Han–Sui	72	7	22
Han–Sui	75	2	4
Han–Sui	82	3	8
Han–Sui	87	1	1
Han–Sui	91	1	1
Han–Sui	92	3	8
Han–Sui	96	3	8
Han–Sui	97	5	14
Han–Sui	110	25	155
Han–Sui	111	40	331
Han–Sui	112	48	426
Han–Sui	113	20	104
Han–Sui	114	6	18
Han–Sui	115	20	104
Han–Sui	121	5	14
Han–Sui	122	10	34
Han–Sui	129	25	155
Han–Sui	130	13	51
Han–Sui	136	1	1
Han–Sui	137	1	1
Han–Sui	142	1	1
Han–Sui	153	32	235
Han–Sui	154	1	1

Han–Sui	157	1	1
Han–Sui	158	1	1
Han–Sui	166	3	8
Han–Sui	175	3	8
Han–Sui	177	30	212
Han–Sui	178	20	104
Han–Sui	194	15	64
Han–Sui	195	20	104
Han–Sui	197	2	4
Han–Sui	203	10	34
Han–Sui	220	5	14
Han–Sui	222	5	14
Han–Sui	274	15	64
Han–Sui	281	1	1
Han–Sui	301	6	18
Han–Sui	304	2	4
Han–Sui	305	3	8
Han–Sui	310	28	189
Han–Sui	316	15	64
Han–Sui	317	25	155
Han–Sui	318	12	45
Han–Sui	319	5	14
Han–Sui	320	6	18
Han–Sui	332	6	18
Han–Sui	337	8	26
Han–Sui	352	7	22
Han–Sui	354	8	26
Han–Sui	374	1	1
Han–Sui	381	2	4
Han–Sui	382	6	18
Han–Sui	383	4	11
Han–Sui	390	2	4
Han–Sui	391	2	4
Han–Sui	426	5	14
Han–Sui	452	2	4
Han–Sui	457	5	14
Han–Sui	467	5	14
Han–Sui	477	8	26
Han–Sui	478	1	1
Han–Sui	481	2	4
Han–Sui	482	11	39
Han–Sui	483	2	4
Han–Sui	484	7	22
Han–Sui	492	1	1
Han–Sui	503	2	4
Han–Sui	504	6	18
Han–Sui	507	3	8
Han–Sui	508	1	1
Han–Sui	512	1	1

Han–Sui	530	2	4
Han–Sui	535	5	14
Han–Sui	550	4	11
Han–Sui	554	1	1
Han–Sui	556	2	4
Han–Sui	557	24	144
Han–Sui	558	8	26
Han–Sui	559	6	18
Han–Sui	571	3	8
Han–Sui	573	8	26
Han–Sui	594	1	1
Han–Sui	596	2	4
Tang	623	1	1
Tang	628	2	4
Tang	629	4	10
Tang	630	3	7
Tang	646	1	1
Tang	647	2	4
Tang	650	4	10
Tang	653	1	1
Tang	682	4	10
Tang	692	1	1
Tang	693	2	4
Tang	710	1	1
Tang	713	2	4
Tang	714	1	1
Tang	715	16	53
Tang	716	18	62
Tang	717	3	7
Tang	721	1	1
Tang	737	1	1
Tang	764	5	14
Tang	784	25	99
Tang	785	30	130
Tang	786	4	10
Tang	805	3	7
Tang	806	3	7
Tang	807	1	1
Tang	810	3	7
Tang	822	1	1
Tang	823	3	7
Tang	824	2	4
Tang	825	2	4
Tang	827	1	1
Tang	830	2	4
Tang	832	2	4
Tang	836	3	7
Tang	837	12	37
Tang	838	6	17

Tang	839	14	45
Tang	840	26	105
Tang	841	4	10
Tang	851	2	4
Tang	854	2	4
Tang	862	3	7
Tang	865	5	14
Tang	866	6	17
Tang	868	4	10
Tang	869	2	4
Tang	875	5	14
Tang	878	5	14
Tang	885	2	4
Tang	886	3	7
Tang	907	5	14
Tang	920	1	1
Tang	925	6	17
Tang	928	2	4
Tang	932	1	1
Tang	939	6	17
Tang	940	1	1
Tang	941	1	1
Tang	942	27	111
Tang	943	28	117
Tang	944	25	99
Tang	945	18	62
Tang	947	1	1
Tang	948	12	37
Tang	949	21	77
Song	972	1	1
Song	985	1	1
Song	953	2	4
Song	960	2	4
Song	961	2	4
Song	962	6	16
Song	963	5	13
Song	964	7	19
Song	965	5	13
Song	969	2	4
Song	974	2	4
Song	977	3	7
Song	981	2	4
Song	982	6	16
Song	983	3	7
Song	986	3	7
Song	989	1	1
Song	990	8	22
Song	991	6	16
Song	992	12	35

Song	996	7	19
Song	997	1	1
Song	1001	1	1
Song	1004	3	7
Song	1005	3	7
Song	1006	2	4
Song	1006	4	4
Song	1007	3	7
Song	1009	1	1
Song	1010	1	1
Song	1011	7	19
Song	1016	13	39
Song	1017	65	313
Song	1018	4	10
Song	1020	1	1
Song	1022	2	4
Song	1024	5	13
Song	1027	4	10
Song	1028	3	7
Song	1033	8	22
Song	1034	3	7
Song	1037	1	1
Song	1039	5	13
Song	1041	4	10
Song	1044	3	7
Song	1047	2	4
Song	1048	2	4
Song	1052	3	7
Song	1053	2	4
Song	1056	1	1
Song	1066	1	1
Song	1067	1	1
Song	1068	1	1
Song	1070	1	1
Song	1072	5	13
Song	1073	7	19
Song	1074	4	10
Song	1075	4	10
Song	1076	6	16
Song	1077	4	10
Song	1079	1	1
Song	1081	6	16
Song	1082	4	10
Song	1083	2	4
Song	1088	2	4
Song	1098	1	1
Song	1100	1	1
Song	1101	2	4
Song	1102	9	25

Song	1103	5	13
Song	1104	8	22
Song	1105	7	19
Song	1120	1	1
Song	1121	5	13
Song	1123	2	4
Song	1124	1	1
Song	1128	4	10
Song	1129	3	7
Song	1135	1	1
Song	1141	1	1
Song	1142	2	4
Song	1145	3	7
Song	1149	1	1
Song	1156	1	1
Song	1157	5	13
Song	1158	1	1
Song	1159	5	13
Song	1160	4	10
Song	1162	12	35
Song	1163	15	46
Song	1164	3	7
Song	1165	3	7
Song	1166	1	1
Song	1167	5	13
Song	1173	1	1
Song	1174	3	7
Song	1176	19	61
Song	1177	2	4
Song	1180	1	1
Song	1181	2	4
Song	1182	15	46
Song	1183	7	19
Song	1187	3	7
Song	1191	6	16
Song	1194	2	4
Song	1196	1	1
Song	1198	1	1
Song	1200	1	1
Song	1202	10	29
Song	1205	1	1
Song	1206	6	16
Song	1207	6	16
Song	1208	9	25
Song	1209	7	19
Song	1210	2	4
Song	1214	3	7
Song	1215	12	35
Song	1216	13	39

Song	1217	3	7
Song	1218	4	10
Song	1222	3	7
Song	1226	1	1
Song	1230	1	1
Song	1234	1	1
Song	1235	1	1
Song	1238	5	13
Song	1239	4	10
Song	1240	6	16
Song	1241	5	13
Song	1242	3	7
Song	1243	1	1
Song	1245	2	4
Song	1246	3	7
Song	1262	5	13
Yuan	1263	7	22
Yuan	1264	2	5
Yuan	1265	10	35
Yuan	1266	11	41
Yuan	1267	5	15
Yuan	1268	4	12
Yuan	1269	5	15
Yuan	1270	6	18
Yuan	1271	18	93
Yuan	1273	1	3
Yuan	1278	1	3
Yuan	1279	20	111
Yuan	1280	7	22
Yuan	1281	4	12
Yuan	1282	6	18
Yuan	1283	2	5
Yuan	1284	1	3
Yuan	1285	9	30
Yuan	1286	2	5
Yuan	1288	6	18
Yuan	1289	9	30
Yuan	1290	17	84
Yuan	1292	5	15
Yuan	1293	7	22
Yuan	1294	2	5
Yuan	1295	5	15
Yuan	1296	25	158
Yuan	1297	7	22
Yuan	1298	60	388
Yuan	1299	10	35
Yuan	1300	9	30
Yuan	1301	12	47
Yuan	1302	9	30

Yuan	1303	4	12
Yuan	1304	3	8
Yuan	1305	13	53
Yuan	1306	10	35
Yuan	1307	8	26
Yuan	1308	10	35
Yuan	1309	52	328
Yuan	1310	31	208
Yuan	1312	1	3
Yuan	1313	3	8
Yuan	1315	1	3
Yuan	1320	4	12
Yuan	1321	15	68
Yuan	1322	10	35
Yuan	1323	2	5
Yuan	1324	21	120
Yuan	1325	13	53
Yuan	1326	21	120
Yuan	1327	26	167
Yuan	1328	9	30
Yuan	1329	20	111
Yuan	1330	50	315
Yuan	1331	10	35
Yuan	1333	2	5
Yuan	1334	7	22
Yuan	1336	1	3
Yuan	1337	4	12
Yuan	1339	1	3
Yuan	1340	3	8
Yuan	1341	3	8
Yuan	1342	3	8
Yuan	1343	1	3
Yuan	1344	3	8
Yuan	1345	2	5
Yuan	1348	2	5
Yuan	1352	14	60
Yuan	1357	1	3
Yuan	1358	14	60
Yuan	1359	60	388
Yuan	1360	3	8
Yuan	1361	4	12
Yuan	1362	5	15
Yuan	1365	1	3

Dataset S2. Reconstructed annual locust time series for period B (AD 1368–1911). L_{orig}: initial locust index (not corrected for recording effort). Unit: number of counties with locusts multiplied with outbreak intensity, graded 1–3. N_{met}: number of meteorological–related records in the source archive for that year. Smoothed N_{met} was used as proxy of recording effort. L_{adj}: locust index adjusted for recording effort. The annual locust index used in the analysis and for the construction of a decadal index was log-transformed, $L_{ann} = \ln(L_{adj} + 1)$.

Year (AD)	L_{orig}	N_{met}	L_{adj}
1368	1	38	5
1369	2	48	10
1370	1	31	5
1371	0	22	0
1372	18	39	95
1373	10	22	53
1374	30	29	160
1375	11	40	59
1376	0	26	0
1377	0	31	0
1378	1	29	5
1379	0	15	0
1380	0	22	0
1381	1	12	6
1382	3	5	17
1383	0	8	0
1384	0	23	0
1385	0	26	0
1386	0	18	0
1387	0	26	0
1388	0	9	0
1389	0	19	0
1390	0	37	0
1391	1	25	6
1392	3	13	17
1393	0	15	0
1394	0	6	0
1395	0	4	0
1396	0	9	0
1397	2	7	12
1398	0	13	0
1399	2	13	12
1400	2	8	11
1401	12	13	69
1402	17	14	97
1403	17	38	97
1404	5	46	28

1405	3	36	17
1406	3	26	17
1407	0	28	0
1408	1	12	5
1409	3	25	16
1410	0	23	0
1411	1	29	5
1412	1	35	5
1413	2	26	10
1414	2	33	10
1415	0	45	0
1416	11	72	55
1417	3	23	15
1418	0	10	0
1419	1	6	5
1420	0	25	0
1421	0	4	0
1422	0	24	0
1423	4	15	18
1424	1	17	4
1425	4	37	17
1426	4	40	17
1427	0	21	0
1428	2	60	8
1429	2	22	8
1430	7	21	28
1431	1	36	4
1432	2	28	8
1433	2	43	7
1434	26	65	96
1435	13	36	47
1436	12	53	42
1437	17	67	59
1438	0	58	0
1439	39	71	130
1440	34	103	111
1441	63	110	202
1442	27	62	85
1443	4	41	12
1444	0	67	0
1445	0	35	0
1446	3	28	9
1447	27	51	78
1448	13	55	37
1449	21	59	58
1450	1	52	3
1451	1	27	3
1452	1	55	3

1453	0	88	0
1454	5	98	13
1455	9	74	23
1456	19	79	47
1457	12	72	29
1458	14	55	33
1459	0	33	0
1460	1	68	2
1461	3	50	7
1462	13	39	29
1463	0	28	0
1464	2	37	4
1465	0	83	0
1466	1	83	2
1467	9	53	19
1468	2	61	4
1469	1	32	2
1470	1	117	2
1471	2	107	4
1472	3	102	6
1473	7	101	14
1474	0	94	0
1475	4	39	8
1476	0	61	0
1477	1	81	2
1478	0	111	0
1479	2	40	4
1480	4	37	7
1481	7	69	13
1482	5	135	9
1483	7	90	12
1484	0	167	0
1485	9	146	16
1486	5	117	9
1487	7	123	12
1488	1	111	2
1489	0	128	0
1490	4	43	7
1491	7	74	12
1492	3	109	5
1493	13	153	21
1494	4	96	6
1495	4	96	6
1496	0	31	0
1497	0	39	0
1498	0	72	0
1499	0	37	0
1500	1	43	2

1501	5	99	8
1502	2	47	3
1503	0	85	0
1504	0	80	0
1505	10	47	15
1506	6	89	9
1507	15	110	23
1508	12	200	18
1509	23	183	34
1510	1	120	1
1511	3	134	4
1512	29	117	43
1513	31	142	46
1514	4	58	6
1515	1	70	1
1516	4	116	6
1517	4	119	6
1518	7	128	10
1519	7	153	10
1520	11	92	16
1521	3	81	4
1522	10	175	14
1523	7	304	10
1524	40	172	57
1525	9	100	13
1526	24	139	34
1527	45	138	63
1528	138	312	193
1529	316	330	441
1530	38	166	53
1531	49	131	68
1532	97	173	135
1533	57	126	79
1534	23	158	32
1535	85	151	117
1536	94	159	129
1537	33	122	45
1538	24	149	33
1539	53	201	72
1540	80	171	109
1541	71	141	97
1542	25	98	34
1543	8	123	11
1544	14	272	19
1545	16	224	22
1546	15	116	20
1547	4	95	5
1548	4	104	5

1549	7	99	9
1550	10	147	13
1551	16	120	21
1552	2	122	3
1553	5	221	7
1554	8	162	11
1555	25	131	33
1556	3	128	4
1557	14	99	18
1558	7	114	9
1559	16	123	21
1560	115	266	151
1561	24	206	31
1562	9	131	12
1563	1	99	1
1564	4	88	5
1565	13	101	17
1566	5	126	6
1567	1	121	1
1568	12	192	15
1569	26	258	33
1570	4	156	5
1571	5	116	6
1572	10	110	13
1573	11	105	14
1574	2	118	3
1575	0	136	0
1576	1	110	1
1577	7	104	9
1578	2	138	3
1579	7	119	9
1580	5	135	6
1581	12	124	15
1582	29	194	36
1583	28	151	35
1584	3	90	4
1585	10	156	12
1586	7	279	9
1587	15	316	18
1588	17	416	21
1589	16	288	20
1590	11	206	13
1591	55	148	67
1592	6	122	7
1593	3	210	4
1594	3	159	4
1595	0	117	0
1596	39	121	47

1597	3	130	4
1598	6	147	7
1599	11	143	13
1600	9	104	11
1601	2	149	2
1602	7	107	8
1603	4	121	5
1604	0	138	0
1605	25	118	29
1606	64	110	75
1607	6	195	7
1608	6	199	7
1609	24	181	28
1610	32	136	37
1611	17	136	20
1612	13	140	15
1613	7	178	8
1614	18	148	21
1615	62	215	71
1616	303	242	346
1617	220	182	251
1618	37	130	42
1619	27	121	31
1620	23	158	26
1621	17	180	19
1622	18	105	20
1623	11	79	12
1624	24	154	27
1625	33	125	37
1626	90	162	100
1627	37	151	41
1628	7	178	8
1629	4	126	4
1630	11	125	12
1631	37	155	41
1632	6	193	7
1633	8	175	9
1634	47	212	51
1635	70	172	77
1636	64	270	70
1637	80	186	87
1638	235	272	255
1639	280	319	304
1640	280	608	303
1641	240	516	259
1642	39	276	42
1643	10	242	11
1644	3	236	3

1645	8	162	9
1646	56	253	60
1647	196	358	210
1648	43	233	46
1649	23	190	25
1650	29	208	31
1651	4	243	4
1652	2	315	2
1653	7	284	7
1654	2	274	2
1655	16	231	17
1656	44	224	47
1657	6	174	6
1658	2	189	2
1659	3	229	3
1660	6	128	6
1661	13	202	14
1662	3	293	3
1663	4	209	4
1664	10	227	11
1665	15	333	16
1666	11	142	12
1667	119	220	125
1668	14	275	15
1669	0	180	0
1670	5	345	5
1671	78	381	82
1672	212	337	223
1673	7	140	7
1674	12	194	13
1675	4	114	4
1676	4	151	4
1677	12	161	13
1678	19	237	20
1679	91	393	96
1680	9	296	10
1681	4	174	4
1682	5	150	5
1683	1	204	1
1684	9	181	10
1685	4	149	4
1686	26	154	28
1687	24	124	26
1688	8	138	9
1689	9	184	10
1690	44	267	47
1691	217	257	233
1692	31	173	33

1693	22	221	24
1694	39	129	42
1695	6	123	6
1696	3	223	3
1697	11	163	12
1698	3	121	3
1699	16	122	17
1700	5	103	5
1701	4	87	4
1702	1	109	1
1703	2	229	2
1704	7	208	8
1705	21	147	23
1706	3	147	3
1707	1	130	1
1708	10	211	11
1709	19	210	21
1710	6	121	7
1711	20	103	23
1712	5	98	6
1713	1	130	1
1714	12	172	14
1715	6	139	7
1716	5	180	6
1717	1	74	1
1718	6	109	7
1719	1	131	1
1720	2	194	2
1721	6	321	7
1722	19	241	22
1723	55	292	65
1724	36	197	43
1725	3	210	4
1726	3	239	4
1727	6	249	7
1728	2	170	2
1729	7	185	8
1730	2	277	2
1731	3	173	4
1732	8	177	10
1733	3	172	4
1734	3	99	4
1735	11	123	14
1736	2	173	2
1737	10	208	12
1738	15	174	19
1739	13	193	16
1740	28	145	35

1741	2	154	3
1742	1	205	1
1743	4	291	5
1744	38	242	49
1745	7	198	9
1746	3	173	4
1747	6	202	8
1748	28	240	36
1749	0	136	0
1750	4	172	5
1751	9	253	12
1752	42	205	55
1753	13	177	17
1754	0	138	0
1755	11	186	15
1756	1	200	1
1757	4	160	5
1758	10	102	13
1759	43	214	57
1760	4	127	5
1761	2	189	3
1762	1	126	1
1763	19	74	25
1764	9	139	12
1765	5	135	7
1766	1	98	1
1767	0	127	0
1768	12	157	16
1769	3	123	4
1770	20	137	27
1771	9	141	12
1772	3	61	4
1773	3	90	4
1774	22	129	29
1775	17	137	22
1776	6	87	8
1777	2	69	3
1778	11	240	14
1779	0	118	0
1780	0	104	0
1781	0	164	0
1782	6	109	8
1783	5	100	6
1784	6	156	8
1785	25	330	32
1786	58	311	73
1787	21	138	26
1788	2	156	3

1789	2	106	2
1790	0	158	0
1791	4	101	5
1792	5	183	6
1793	7	134	9
1794	0	192	0
1795	9	132	11
1796	9	200	11
1797	5	121	6
1798	3	112	4
1799	14	103	17
1800	3	175	4
1801	2	214	2
1802	62	232	72
1803	40	156	46
1804	11	164	13
1805	16	176	18
1806	3	144	3
1807	1	180	1
1808	1	160	1
1809	2	126	2
1810	0	150	0
1811	7	202	8
1812	3	190	3
1813	5	286	6
1814	15	285	16
1815	2	140	2
1816	0	133	0
1817	5	131	5
1818	9	125	10
1819	0	219	0
1820	0	239	0
1821	11	309	12
1822	3	239	3
1823	9	324	9
1824	36	164	38
1825	58	170	61
1826	18	212	19
1827	6	121	6
1828	1	151	1
1829	0	96	0
1830	2	164	2
1831	3	296	3
1832	12	342	12
1833	11	321	11
1834	0	295	0
1835	166	384	169
1836	125	265	127

1837	52	186	53
1838	26	183	26
1839	7	218	7
1840	5	186	5
1841	4	258	4
1842	7	172	7
1843	14	173	14
1844	1	157	1
1845	8	150	8
1846	2	238	2
1847	13	218	13
1848	8	280	8
1849	3	279	3
1850	0	203	0
1851	5	210	5
1852	8	220	8
1853	23	294	23
1854	31	229	31
1855	42	242	42
1856	310	394	311
1857	455	404	457
1858	170	280	171
1859	22	179	22
1860	28	239	28
1861	14	252	14
1862	115	381	116
1863	39	247	39
1864	14	257	14
1865	7	265	7
1866	5	210	5
1867	8	303	8
1868	12	292	12
1869	23	272	24
1870	2	274	2
1871	5	255	5
1872	6	212	6
1873	11	197	11
1874	2	136	2
1875	10	207	11
1876	40	297	42
1877	103	459	109
1878	24	343	26
1879	11	214	12
1880	11	153	12
1881	9	141	10
1882	8	162	9
1883	1	204	1
1884	7	128	8

1885	5	140	6
1886	20	153	22
1887	1	173	1
1888	6	153	7
1889	4	205	5
1890	11	177	13
1891	28	167	32
1892	73	248	84
1893	7	142	8
1894	6	145	7
1895	10	179	12
1896	3	105	4
1897	4	110	5
1898	5	174	6
1899	14	160	17
1900	38	272	47
1901	15	214	19
1902	11	174	14
1903	5	96	6
1904	4	100	5
1905	3	81	4
1906	13	129	17
1907	3	95	4
1908	5	113	7
1909	8	141	11
1910	4	156	5
1911	7	172	10