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Visualisation and drought information (1100 -1940) for the middle reaches of the Yangtze River Valley, P.R. China

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VISUALISATION OF HISTORICAL FLOOD AND DROUGHT INFORMATION (1100-1940) FOR THE MIDDLE REACHES OF THE YANGTZE RIVER VALLEY, P.R. CHINA

by

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J. CHEN and T. JIANG compiled the database during an exchange program at Giessen. The maps were edited by M. GEMMER at the ZEU.

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1 INTRODUCTION

Due to very uneven distribution of precipitation in space and time, China is frequently affected by floods and droughts. These natural disasters have been a major drawback for the economic and social development in China throughout history. Since the beginning of the 1920s, Chinese scientists have compiled a remarkably good inventory of historical climate data. This data is suitable for the evaluation of extreme climate events and for the creation of climatological long-term models which may allow a prediction regarding the future distribution and availability of water. Thereby, the development of climate factors should be projected into the future, starting from the available climate test series in China, as well as those from the historical proxy data (regarding extreme climate events and their effect, such as floods or droughts).

This paper is an introduction to the paleoclimatic research that has been carried out at the Zentrum für internationale Entwicklungs- und Umweltforschung (ZEU) of the Justus Liebig University Giessen in 2000 and 2001. With the research in the Yangtze River Valley it is aimed to assess and analyse historical climatological events in order to interpret flood and drought events in history. Even more important is the sole of this data in the designation of flood prone areas and the magnitude of major climatic events. On the basis of the evaluation of this long-term climatic trend. Predictions about climatic changes can be made.

2 BACKGROUND: PALEOCLIMATIC RESEARCH IN CHINA

Paleoclimatic research has a long tradition in China. First studies of the historical climate were carried out already in the 1920s with detailed analysis of historical archives. These studies were intensified in the sixties, and particularly in the eighties due to the worldwide discussion of global climatic change.

In the past 70 years, Chinese scholars have systematically compiled historical flood and drought records from hundreds of archives all over China. The initiation of this research is connected especially with two names: Prof. Dr. Kezhen ZU from the Chinese Academy of Sciences (CAS) started to analyse the historical records in order to investigate a climate change in the early 1930s. Prof. Dr. Jinzhi XU from the Nanjing Institute of Geography and Limnology, CAS, continued this work and compiled more than 3 million records based on local chronicles from 24 provinces. The Yellow River, the Yangtze River, and the Huaihe River catchments were the focal areas of this historical research.

The results from the 1930s were supplemented by Chinese researchers in the 1970s. At this time, the National Weather Bureau as the umbrella organisation summoned nearly 40 institutions from universities and research institutes and impelled a systematic investigation. Finally, in 1982 the "Atlas of Historical Flood and Drought in the last 500 Years" was published (NMB, 1982). This publication is based on the evaluation of 2,100 local chronics, official historical documents, and old encyclopaedias.

Although many documents were lost especially during the first five years of the Cultural Revolution (1966 - 1976) the available records of paleoclimatic research are still tremendous and worldwide unique. Nowadays paleoclimatic research gets much attention and support in China, and its role for the planning of flood protection measures (designation of historical and therefore present flood/drought prone areas) is well accepted by Chinese authorities (CHEN et al. 1998).

However, despite a paleoclimatic research for many years the data have not been fully analysed to date due to the large amount of available data records. Therefore, there is still the possibility of manifold research activities in this field.

3 DATA DESCRIPTION: SOURCES AND QUALITY

The analysis of flood and drought information is based on semi-numeric data of the regional climatic history of China, supplied by Chinese partners from the Nanjing Institute of Geography and Limnology, CAS.

The general paleoclimatic database collected in China and available to the research group at the ZEU comprises more than 100.000 entries. Supplemented were these data through studies of archaeology, palynology and dendrochronology, as well as from the stratigraphical analysis of dust precipitation. The sources are, however, not homogeneous and very diverse. They consist of many short semi-quantitative observation series of greater importance. Additionally, the temporal and spatial distribution of the historical observation is very uneven. The main results in hand were obtained by the evaluation and interpretation of a large number of comprehensive climatic records in historical archives (cp. Figure 1).

Most of the analysed data are derived from 'local chronicles'. Basically, the original historical data available in China can be assigned to four categories (Figure 1):

1. Reports about extreme climatic events (especially floods, droughts and storms).
2. Semi-quantitative climatic records based on series of systematic measurements.
3. Records on natural phenomenon (especially those influencing the agriculture and diseases).
4. Records on physio-geographic characteristics (e.g. travel reports).

All information based on records of these four categories had to be evaluated, validated, and categorised into data groups. The data were derived from local chronicles, old and very comprehensive encyclopaedia, historic agricultural registers, and official weather reports. Despite the age of these documents (up to 900 years old), they contain valuable information on historical flood and drought events.

Basically, two different kinds of local chronicles have to be differentiated: County chronicles and over-regional chronicles. Counties[1] (in Chinese 'Xian') are in general smaller than the over-regional based 'Fu'-chronicles. Both chronicles consist of

[1] Counties are comparable with the "Landkreise" in Germany.

different sorts of documents. County and Fu chronicles form the major sources of information in this Discussion Paper.

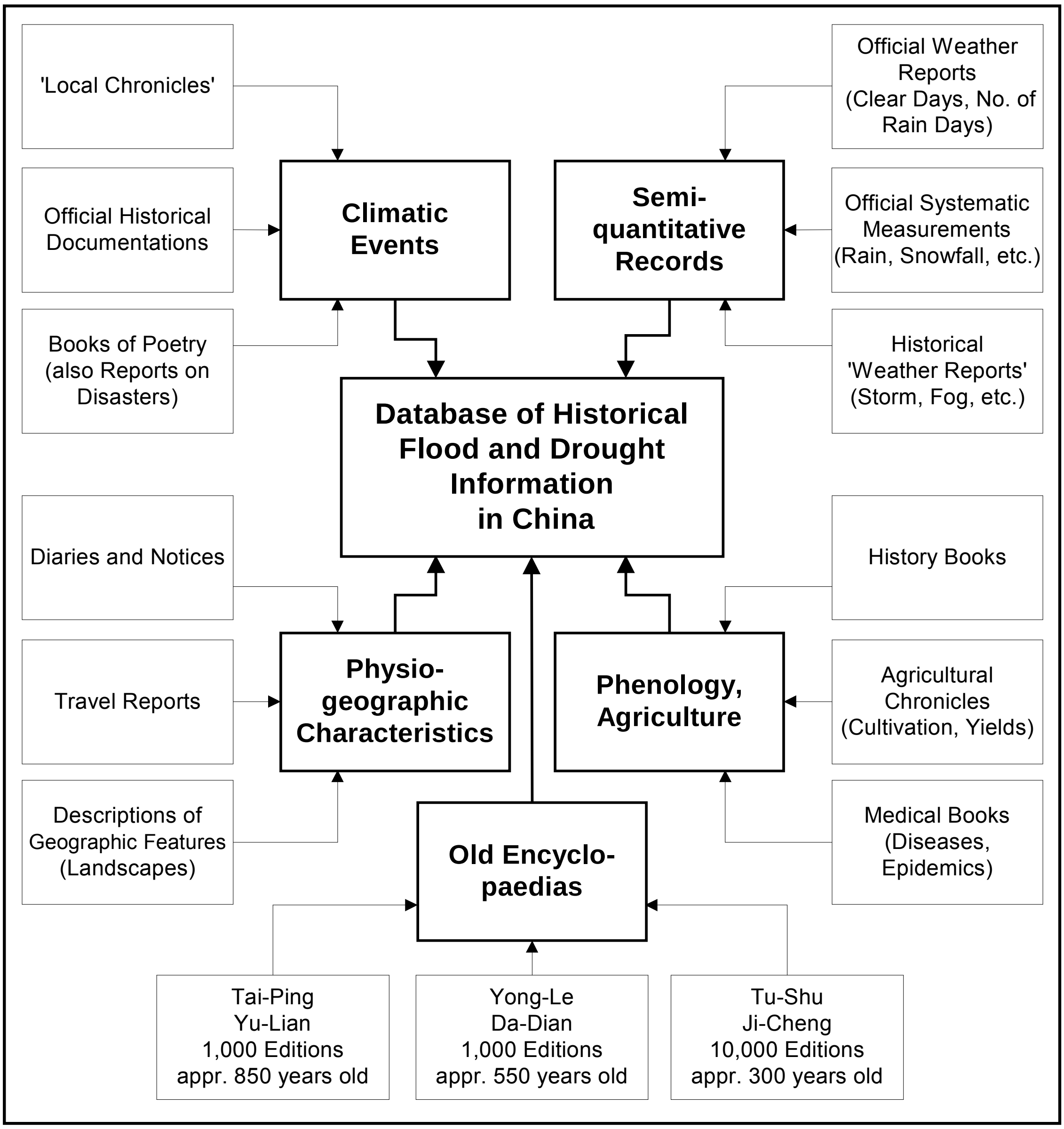
A major problem with the original data is that different authors at different dynasties had their own way to record flood and drought events and also to archive them. The quality of records differs due to different natural conditions, adjustments, standards, and with time. In every dynasty the location of the archival storage varied due to different hierarchical realities. Furthermore, it happened very often that the same natural events were unequally described in different local chronicles. Therefore, a lot of time had to be spent to compare different records, weight, assess, convert them to a value, and to finally put them in the database.

Further difficulties consist in the data availability. As already mentioned before, the data quality differs a lot if different time periods are compared. The same applies for the data availability (although China still has a unique, very good, continuous and complete encyclopaedia of historical flood and drought records). However, many records were lost due to wars, fires, the Cultural Revolution, and other events. Therefore, it is difficult to reconstruct if a year without data means a year without flood and drought events or if for that year is just no data available. Although this means a limiting factor in the data analysis, these uncertainties can be reduced quite well through cross-checking of local chronicles of other locations.

Nonetheless, the method to convert all historical information into a numeric (1 to 5) or - in the case discussed here – into a character value (e.g. F, cp. Table 1) is well tested and reliable.

Since about 100 years the data collection is centrally organised, e.g. (climatological data, discharges and water levels of the Yangtze River at various hydrological stations are taken since 1865) Therefore, there is no political order anymore to collect data in local chronicles. Because of this, the data availability in local chronicles has been decreasing in the 20th century. Of course, the general data availability and quality on flood and drought events is better for the last 100 years than the historical descriptive data but the presently generated data are not archived in local chronicles anymore. Since local chronicles are the most important basis of the research presented in this paper, they were only used up to the year 1940.

Fig. 1: Sources of Historical Flood and Drought Information in China



Source: Revised after CHEN et al. 1998: 164

4 METHODOLOGY

4.1 Selection of the Research Area

The research area covers the province of Hubei as a whole and parts of the Hunan and Jiangxi provinces (Dongting Lake and Poyang Lake Floodplains, see Figure 2). Several reasons led to the selection of this research area:

- The area is an old traditional settlement area and therefore the data situation is very good (see also below).
- In the “Atlas of Historical Flood and Drought in the last 500 Years” (NMB, 1982) are 120 reasonably well distributed locations (or stations) depicted to which the records (the data) are assigned. At the end of the Qing dynasty, eleven 'regions' situated in the research area became the historical 'Fu' or “Zhi-Li-Zhou” (a region directly governed by a province). These 'Fu' (or 'Zhi-Li-Zhou') regions compiled their own chronicles. However, only five Fus were displayed in the atlas (Shanghai, Hangzhou, Nanjing, Yangzhou, and Suzhou). These locations do not suitably represent the availability of historical reports. Immense amounts of historical information are available for the Middle and Lower Reaches of the Yangtze River Valley but they were not displayed in the atlas. Therefore, in 1997 it was begun to gather data based on the Fus situated in the Yangtze Delta. These data are visualised in this publication.
- The working group of the authors has done scientific studies in this area for 16 years and collected tremendous data sets. Because of this, the basic data (e.g. background information, the digital geographic data, climatological and socio-economic data) was already available at the ZEU.
- It is furthermore a valuable supplement to the paleoclimatic research in the Yangtze Delta and the costal areas of eastern China (WOLLESEN et al. 1997). It is therefore possible to connect different research activities to draw a paleoclimatic overall picture covering large parts of the upper and middle reaches of the Yangtze River (a distance of 1,800 km).

4.2 Generation of Historical Data

As already described in previous chapters the basic data originates from local chronicles (e.g. Fu chronicles) which can be characterised as descriptive sources. For example, regarding the flood of the year 1608 the original qualitative information was written down by the historians as:

"In May heavy rain. The land is only accessible by boats.
In July the flood reaches the imperial town of Nanking."

Based on paleoclimatic research, it is nowadays known that the 1608 flood was an event with a return period of 200 years (CHEN et al. 1998). This flood was for instance categorised as a "heavy flood". The historical documents were evaluated by the first author at the Nanjing Institute of Geography and Limnology, looking at weather records going back up to 900 years. Based on these materials, all records were transferred into a digital database at Giessen.

The database used in this publication consists of 900 columns and 90 rows. It includes historical information which were categorised into indexes according to the dimension of the event (e.g. *extreme flood*, *flood*, *drought*, *long-lasting rain*, *no rain*), the point of time, and the timeframe of the incidents. The research area covers counties in the middle reaches of the Yangtze River Valley for which local chronicles as described are available. The time span covers a period of 840 years (from 1100 to 1940). The following table shows the indexes included in the database:

Table 1: Indexes included in the database

F: heavy flood	D: extreme drought
f: flood	d: drought
h: long lasting rain over a long period	n: no rain over a long period
s: spring (March, April, May)	o: Autumn (September, October, November)
u: summer (June, July, August)	w: winter (December, January, February)
1-12: numbering of month	# : records from ‘Fu’ (region)

The indexes named in Table 1 were assigned according to a systematic procedure on the basis of descriptions in local chronicles. This rather sophisticated method is explained in more detail with the following condensed table:

Tab. 2: Original Notes in Local Chronicles and their Categorisation

F ("severe Flood"):	
5	heavy rain („like the Deluge“)
7	heavy flood
8	water rise in lowlands
9	water rises up to 1 Chi (ca. 33 cm)
10	water rises above 1 Chi
11	water piles up to several Chi
12	water rises above 1 meter
13	land is accessible by ships and boats
14	water level of rivers and lakes rises suddenly and very heavily
15	in the whole area of smaller catchments the water levels of all water bodies rises
16	flash floods flow from hills to valleys ("like a dragon")
17	dam failures at water bodies
20	all grain-fields submerged
21	numerous houses are submerged, straw of roofs swims on water surface
22	numerous (to a large extend) agricultural fields and houses are submerged
23	Many people drowned
24	tremendous people drowned
25	flood events occur yearly
26	towns affected by floods
f ("flood"):	
1	rain
2	continuous rain (several days)
3	continuous rain (several month)
4	heavy rain
6	flood
18	low lying fields inundated
19	some grain-fields inundated
D ("severe Drought"):	
5	heavy drought
6	lakes and rivers have low water level
7	people can cross rivers and lakes without boats or ships
8	ground of rivers and lakes dried out
9	springs dry up
10	ground is hard, fields parched ("hard like turtle-shell“)
16	drought destroys most grain
17	trees and grain-fields dried out
18	people die with thirst
19	grain prices explode
20	people eat bark of trees
21	people eat human flesh
22	roads full of refugees
23	roads full of cadavers
24	area of dried out land can not be overlooked
25	droughts for years
d ("Drought"):	
1	no rain
2	no rain for longer period
3	seed does not thrive, seedlings do not germinate
4	locusts come
11	more locusts come
12	locusts destroy grain
13	locusts appear in large numbers
14	countless locusts, clouds of locusts darken the sun
15	grain is destroyed by drought

Table 2 represents the original indexes compiled by the first author. It shows how the historical information had been evaluated and it can be also considered as a manual for map compilation. The first indexes were already used for the research on flood and drought information in the Yangtze Delta and the Huanghe River Catchment. Most of the mentioned indexes can be combined according to the actual appearance of natural climatological events. In order to make this more comprehensible, some of them are presented in the following:

Fu n 4-5:
Heavy flood during summer, no rain between April and May (time of occurrence is exactly known). The occurrence of both, flood and drought is also an indicator for sudden heavy rains.

D n 4-8:
Heavy drought, no rain from April to August.

h D #:
Rain over a long period, heavy drought based on over-regional Fu-records (this means a climatic event with over-regional dimensions).

4.3 Geo-Referencing of Historical Data and Map Compilation

All available data were assigned to counties, which represent the current administrative boundaries on sub-provincial level. The whole research area consists of 84 counties. The fact that most of the current counties are still identical with the historical county boundaries facilitated the assignment of the data.

After conversion of the historical information to values (cp. Chapter 4.2) the data were stored in a digital database in MS Access. This database was then 'linked' (or connected) to the geographical data, i.e. the counties, in a Geographical Information System (GIS). The software ArcView by ESRI was chosen as GIS. All maps were compiled in ArcView. However, no geographic analysis was performed here and all maps are rather a visualisation of historical flood and drought data.

Usually, a Fu-region covers several counties. If data for Fu-regions were available this data were transferred to all counties situated in this specific Fu. Nevertheless, the administrative relationship between some counties and Fus has changed. This means that some counties could not be assigned to the Fu they belonged to in history. These counties were therefore excluded from the analysis. In the maps they are featured blank, i.e. white.

5 PRESENTATION OF RESULTS

After a first review and analysis of the database some patterns of appearance of drought and flood in the Yangtze Valley become obvious.[2] Selected parts of the database are cartographically visualised in figures 4 to 13.

Figures 2 and 3 give an overview over the research area and the individual county names, respectively. The other maps show data for selected years and give therefore an idea about the accessible data in time. Moreover, the respective years demonstrate flood as well as drought events. However, it has to be noted that morphological and other aspects of flood and drought appearances are excluded from this map presentation. Subsequently these maps have to be explained and described in more detail:

Year 1193 (Figure 4)

This maps shows a flood which nowadays still occurs to a similar extend almost each year. It is a typical flood in the lowlands south of the Yangtze River in the area of the Poyang Lake.

Year 1297 (Figure 5)

In this year a similar flood as the one from year 1193 occurred. The dimension of the flood extended additionally to the Dongting Lake basin.

Year 1321 (Figure 6)

In 1321 heavy flood as well as heavy drought events were observed. These events were scattered over large parts of the research area. While the eastern areas of the area were most probably affected by the north-east monsoon, the middle parts were touched by heavy rainfall in late summer and autumn. The drought events might be explained local circumstance which have to be investigated in more closer aspects.

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[2] The significances, implications, and results of these analysis will be published in more detail later in this series.

Year 1493 (Figure 7)

This year was dominated by heavy precipitation during winter (snow or rainfall).

Year 1516 (Figure 8)

This map shows a typical 'Hanjiang-type' flood. Floods can be spotted along the Hanjiang River – the largest tributary of the Yangtze – and beyond its mouth to the Yangtze (for the location of the Hanjiang cp. Figure 2). The flood disaster of the year 1983 can be regarded as the same flood type.

Year 1560 (Figure 9)

For this year a serious summer flood was reported. The area around Dongting Lake, the middle reaches of the Yangtze River, and some counties along the Hanjiang River were most critically affected. The counties along the Hanjiang were affected in April what is related to snow melt in the mountains up north. Nevertheless, in contrast to the year 1516, it can not be said that a typical 'Hanjiang-type' flood happened in this year.

Year 1663 (Figure 10)

The map for the year 1663 shows a heavy flood in the basin of the Yangtze River. Furthermore, it shows some drought affected areas in the river basin adjoining mountains where many main tributaries of the Yangtze River their sources. Our interpretation is that this flood event originated through a large water supply from the upper reaches.

Year 1726 (Figure 11)

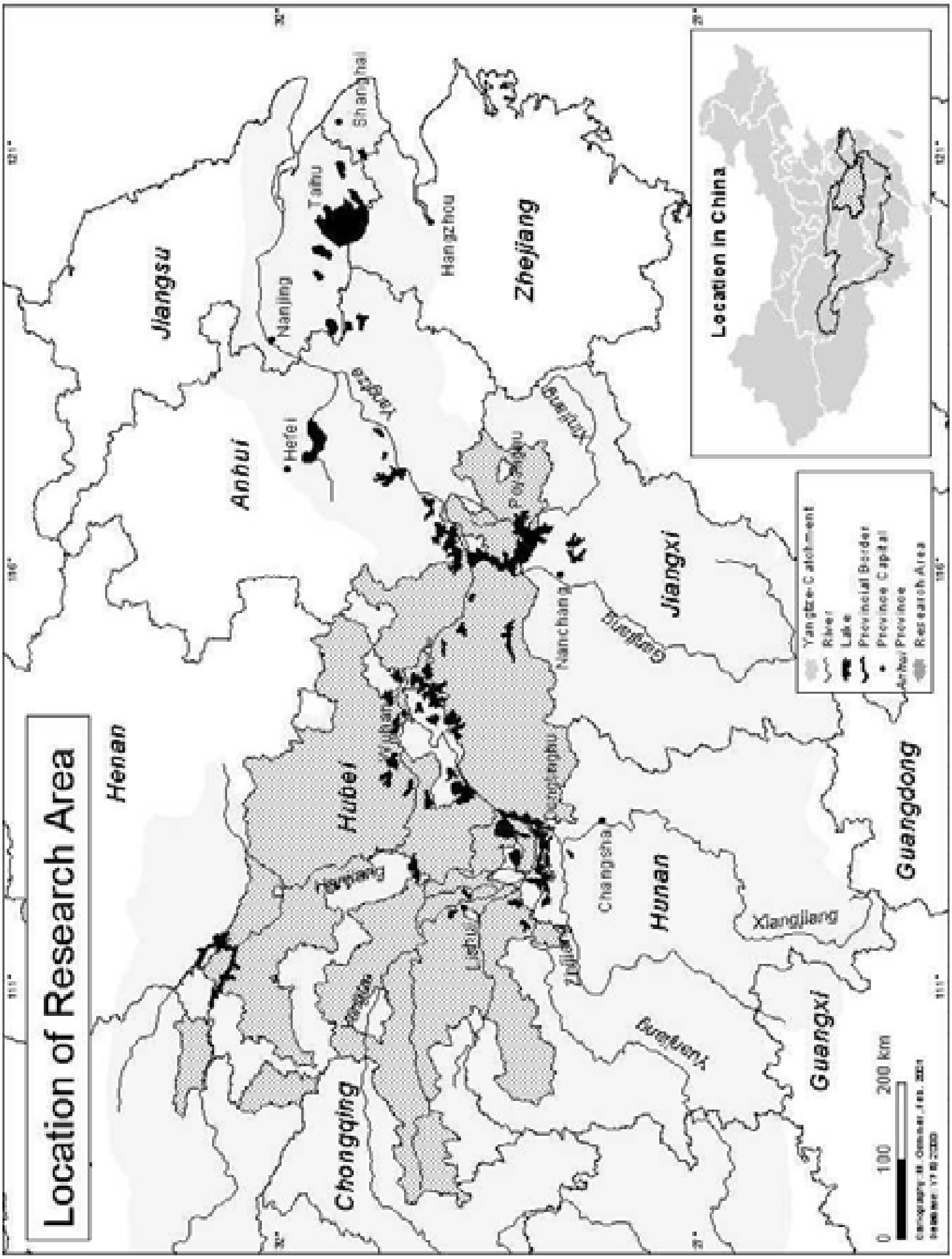
In this year a flood event with a return period of 100 years occurred. I was the most serious flood event during the 18^{th} century. The flood type can be regarded as a typical 'Yangtze flood' with heavy rain in April and June.

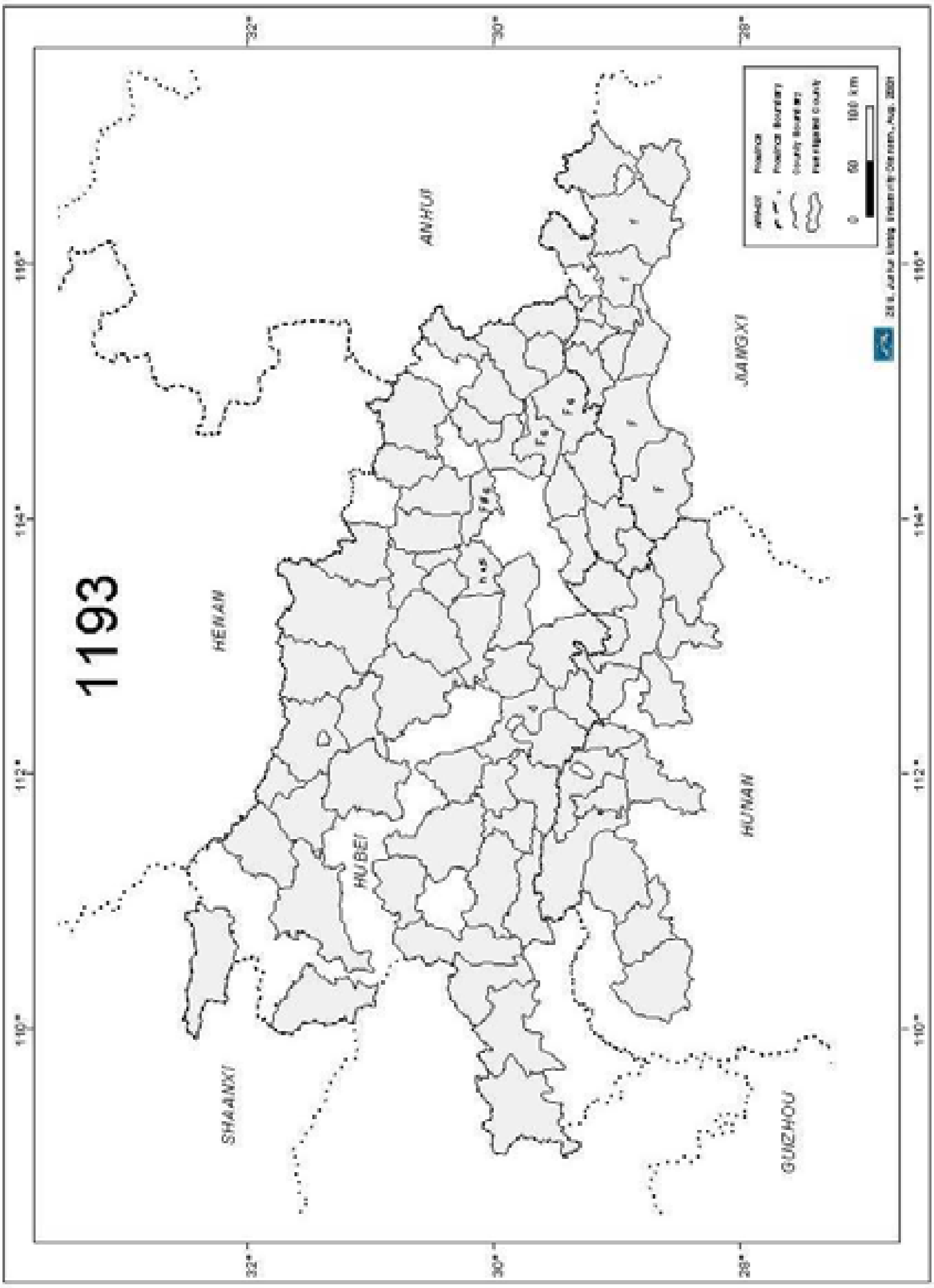
Year 1833 (Figure 12)

During this flood year typical 'Hanjiang' and 'Yangtze' flood events were observed and occurred in summer.

Year 1835 (Figure13)

Only two years after a serious flood, almost the same area as in 1833 was affected by a heavy drought ('D'). Despite some minor exceptions the drought occurred with commencement of the rain season which usually starts in May.


Location of Research Area
Henan
Jiangsu
Anhui
Hubei
Zhejiang
Jiangxi
Hunan
Guangdong
Guangxi
Chongqing
Nanjing
Shanghai
Taihu
Hangzhou
Hefei
Yangtze
Wuhan
Nanchang
Changsha
Ganjiang
Xiangjiang
Location in China
Yangtze Catchment
River
Lake
Provincial Border
Province Capital
Anhui Province
Research Area
0
100
200 km


1193
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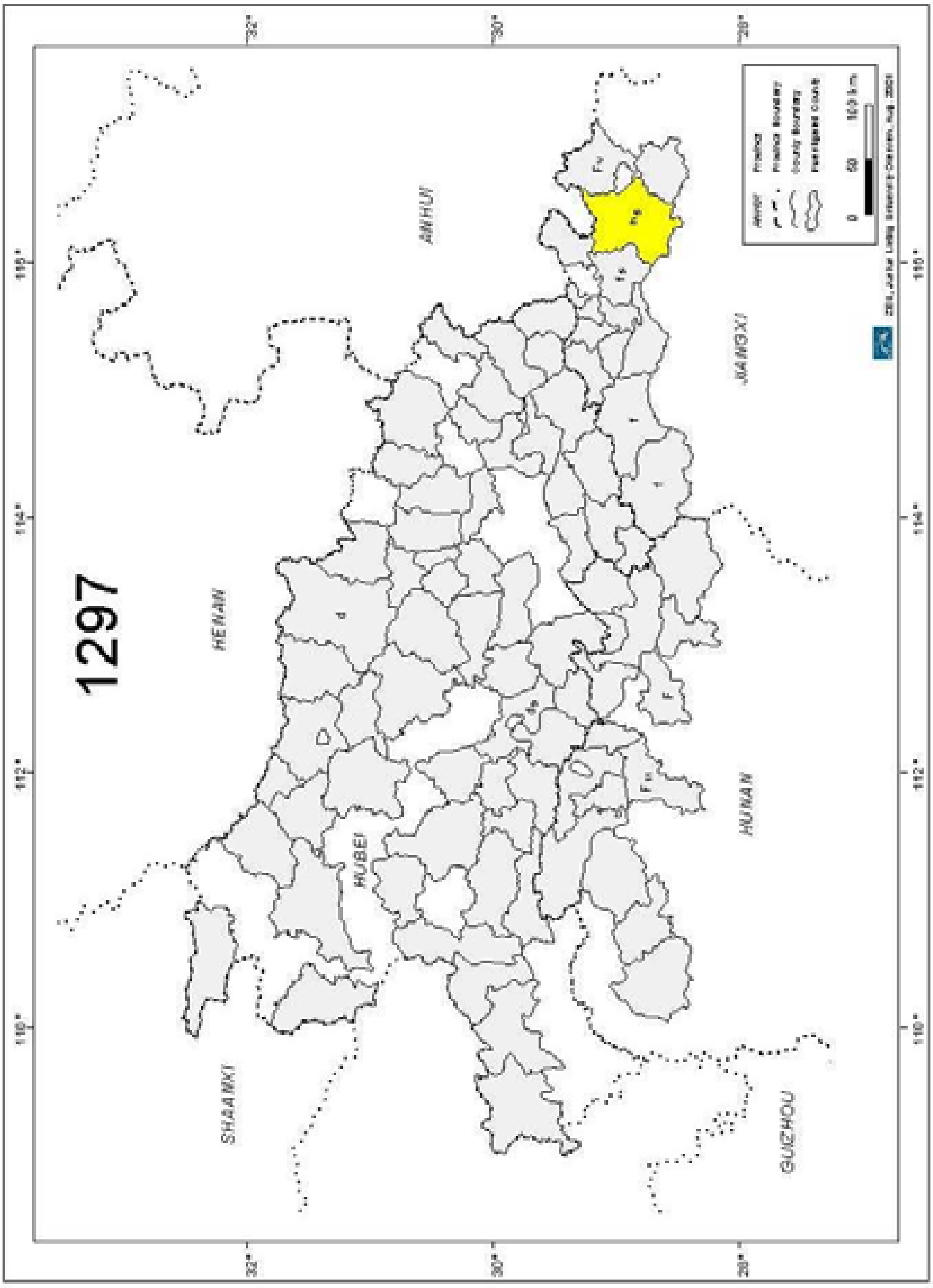
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SHAANXI
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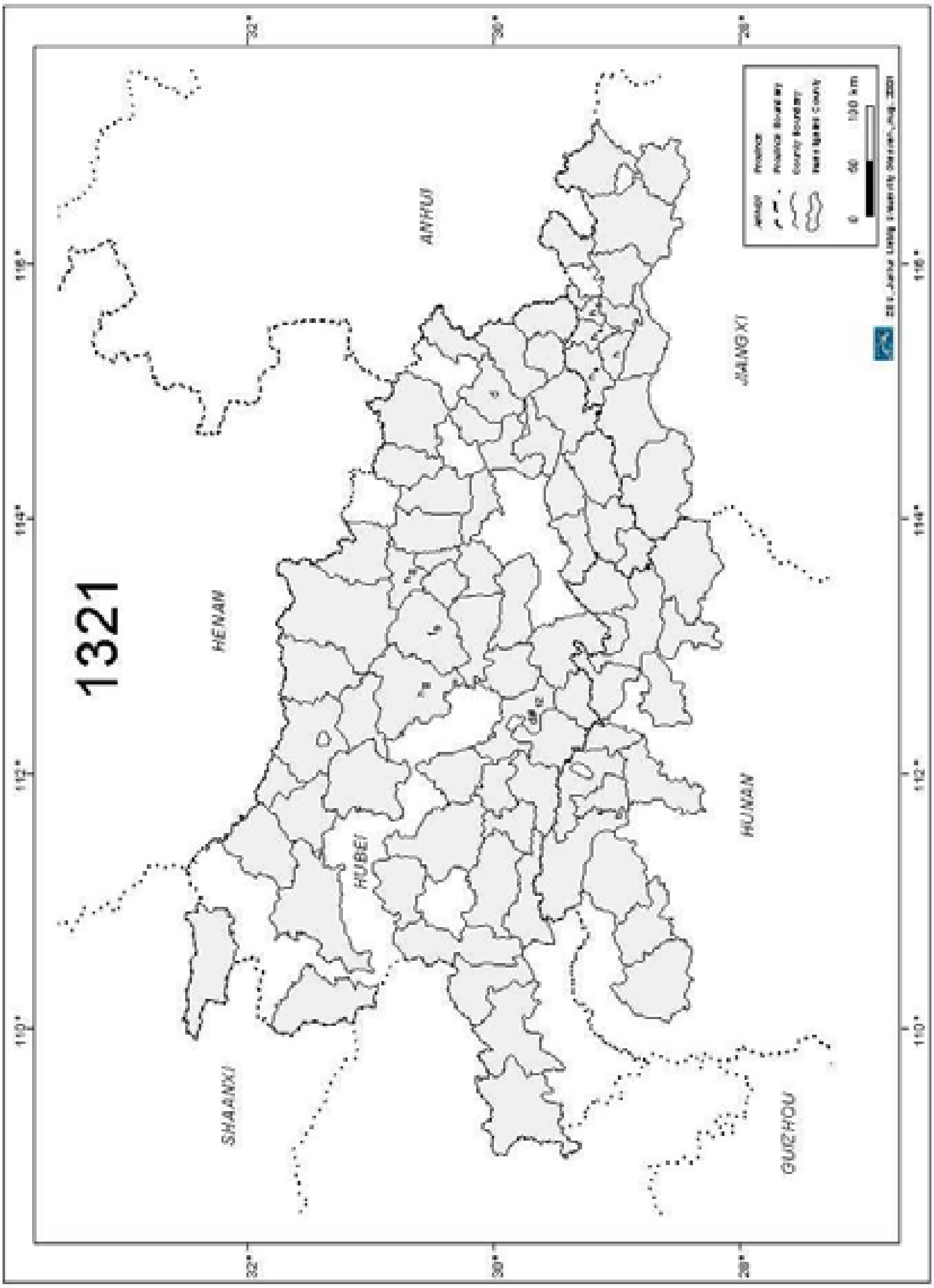
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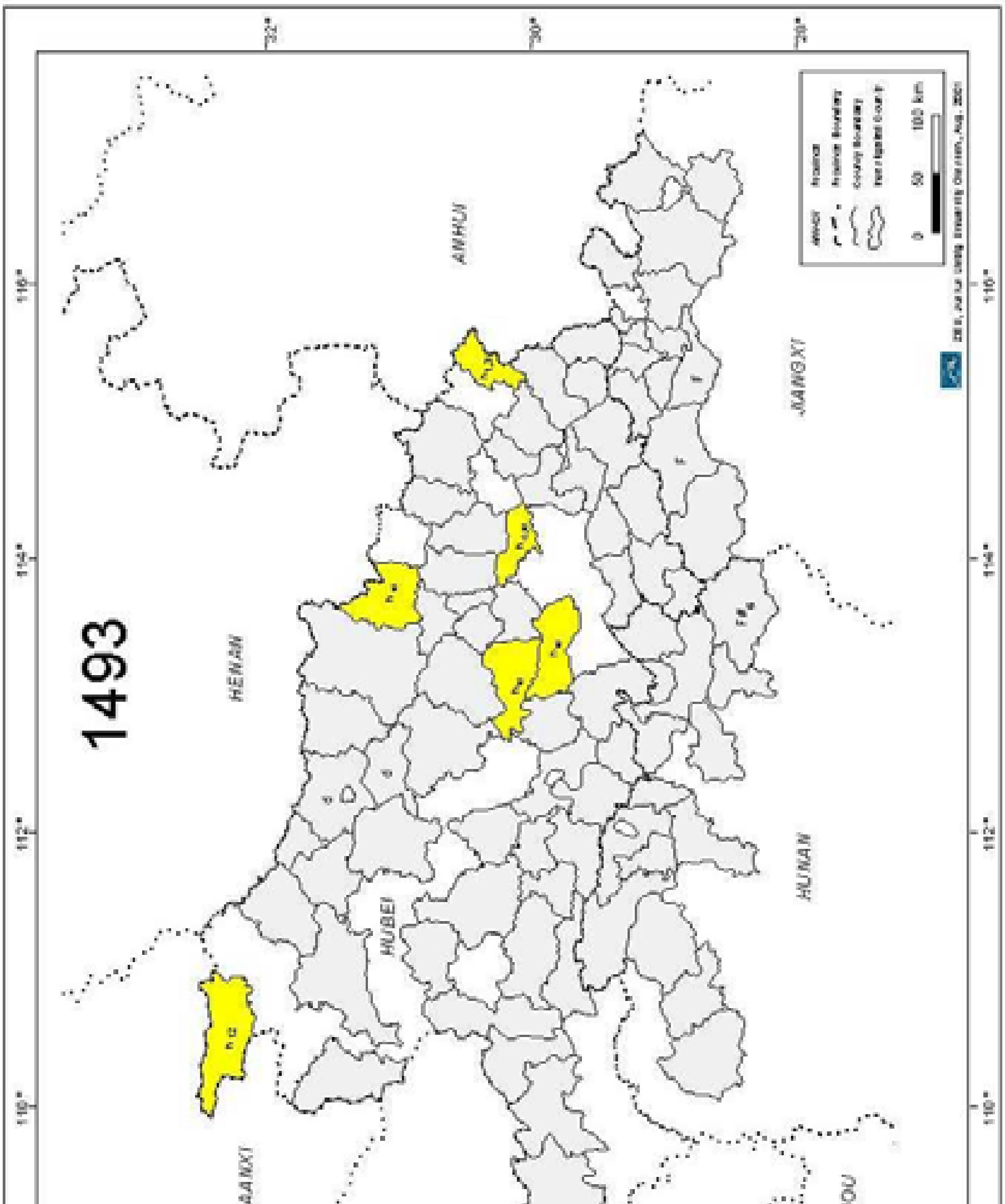

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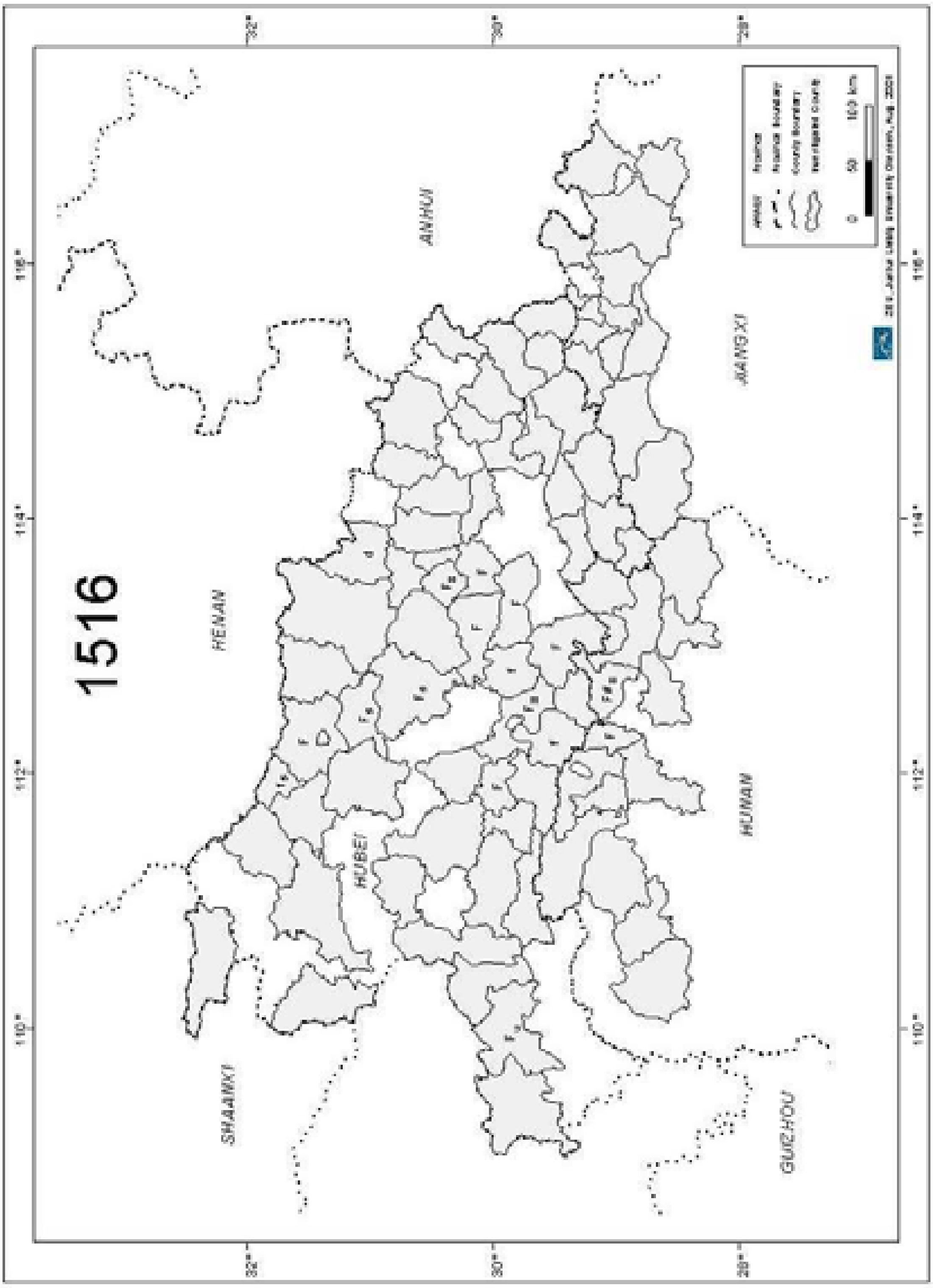
GUIZHOU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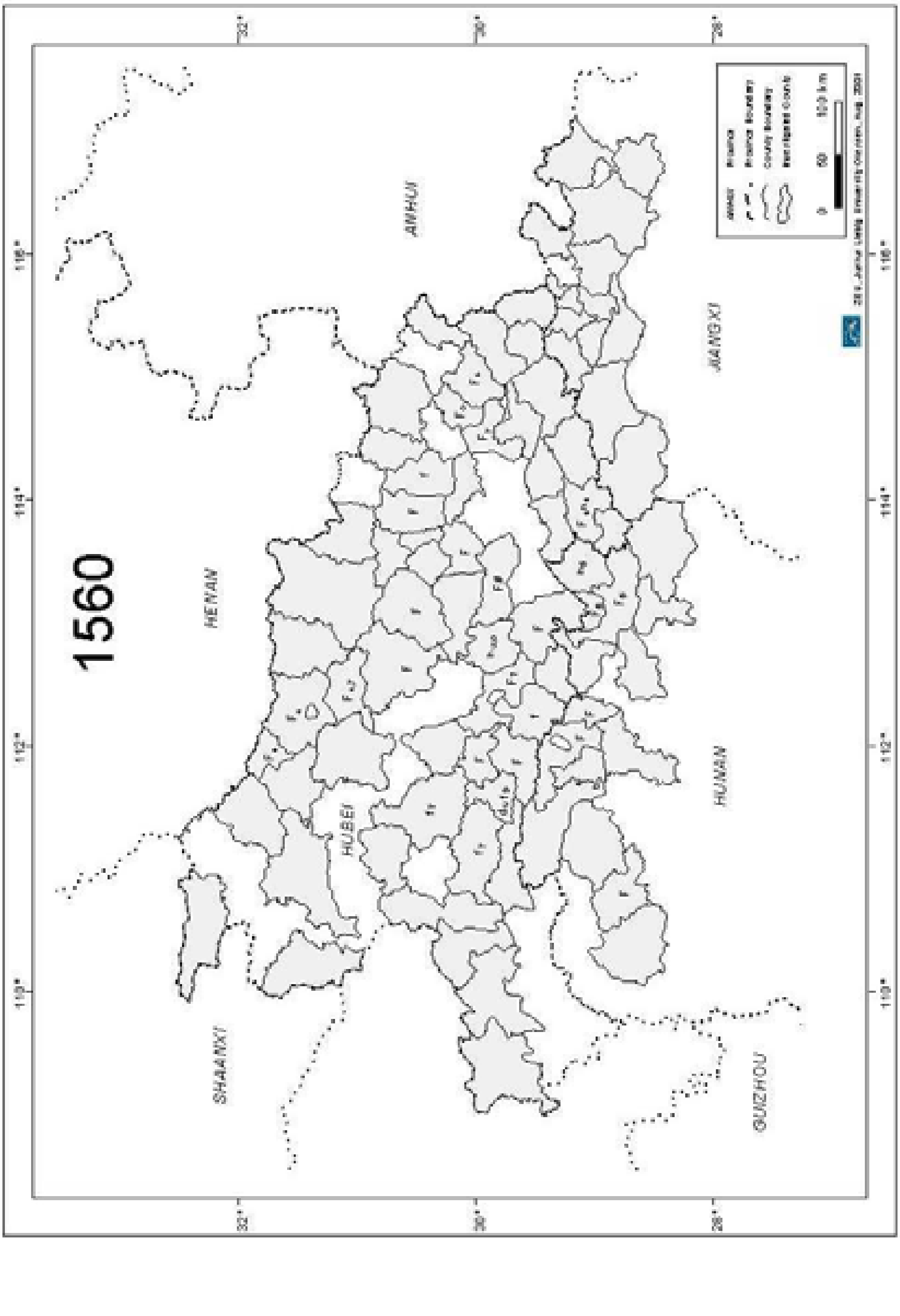
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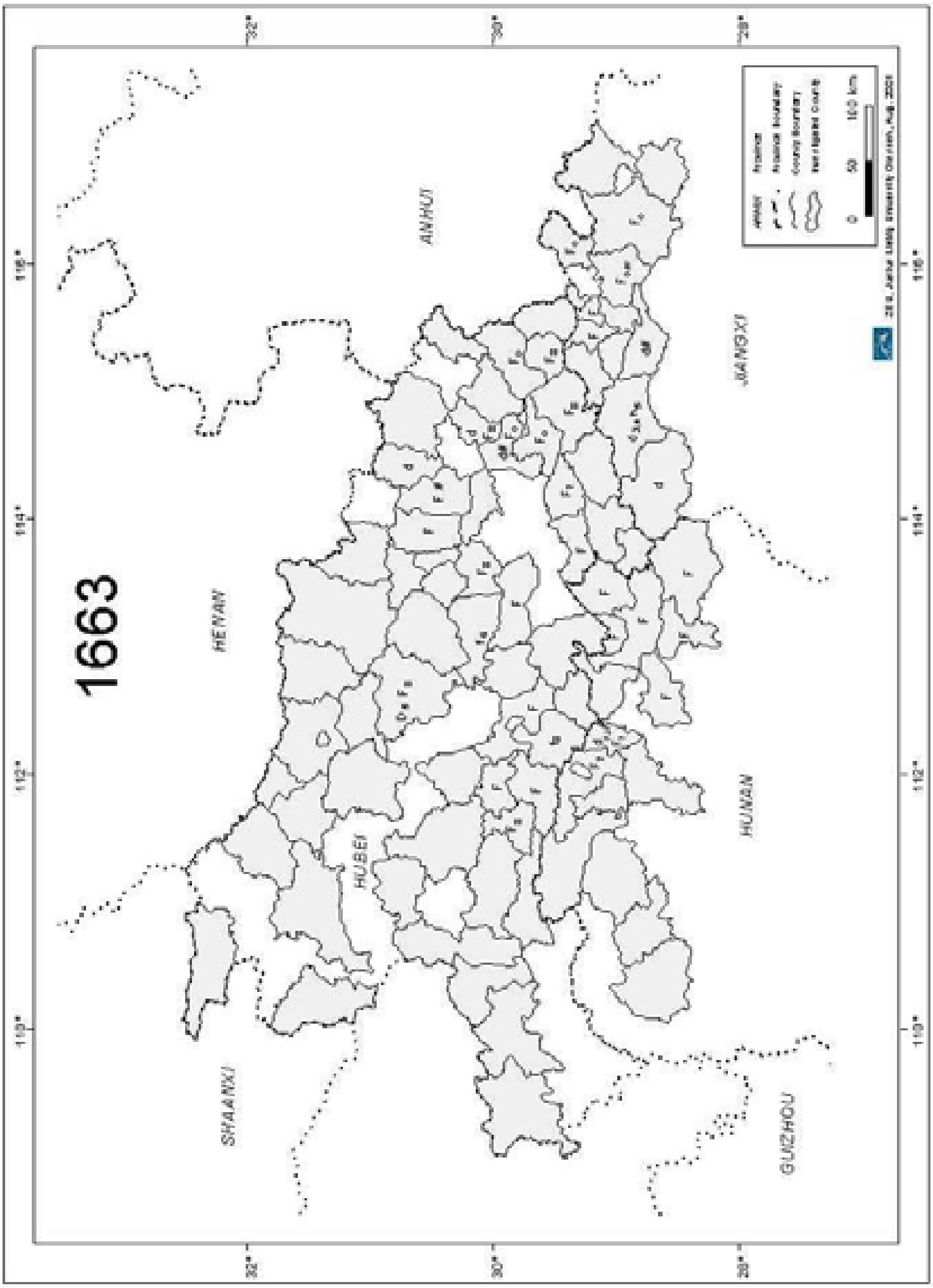
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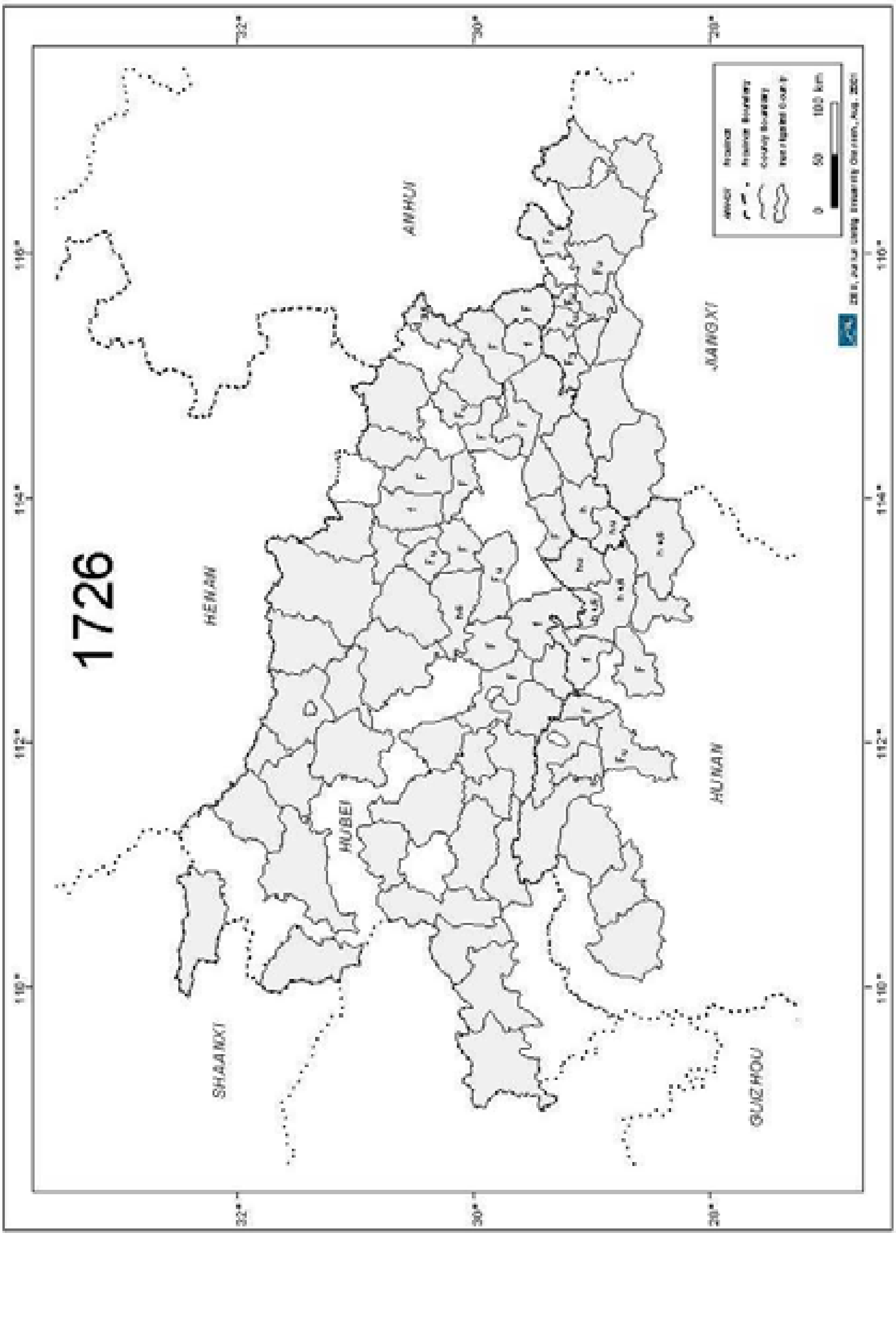
SHAANXI
GUIZHOU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SHAANXI
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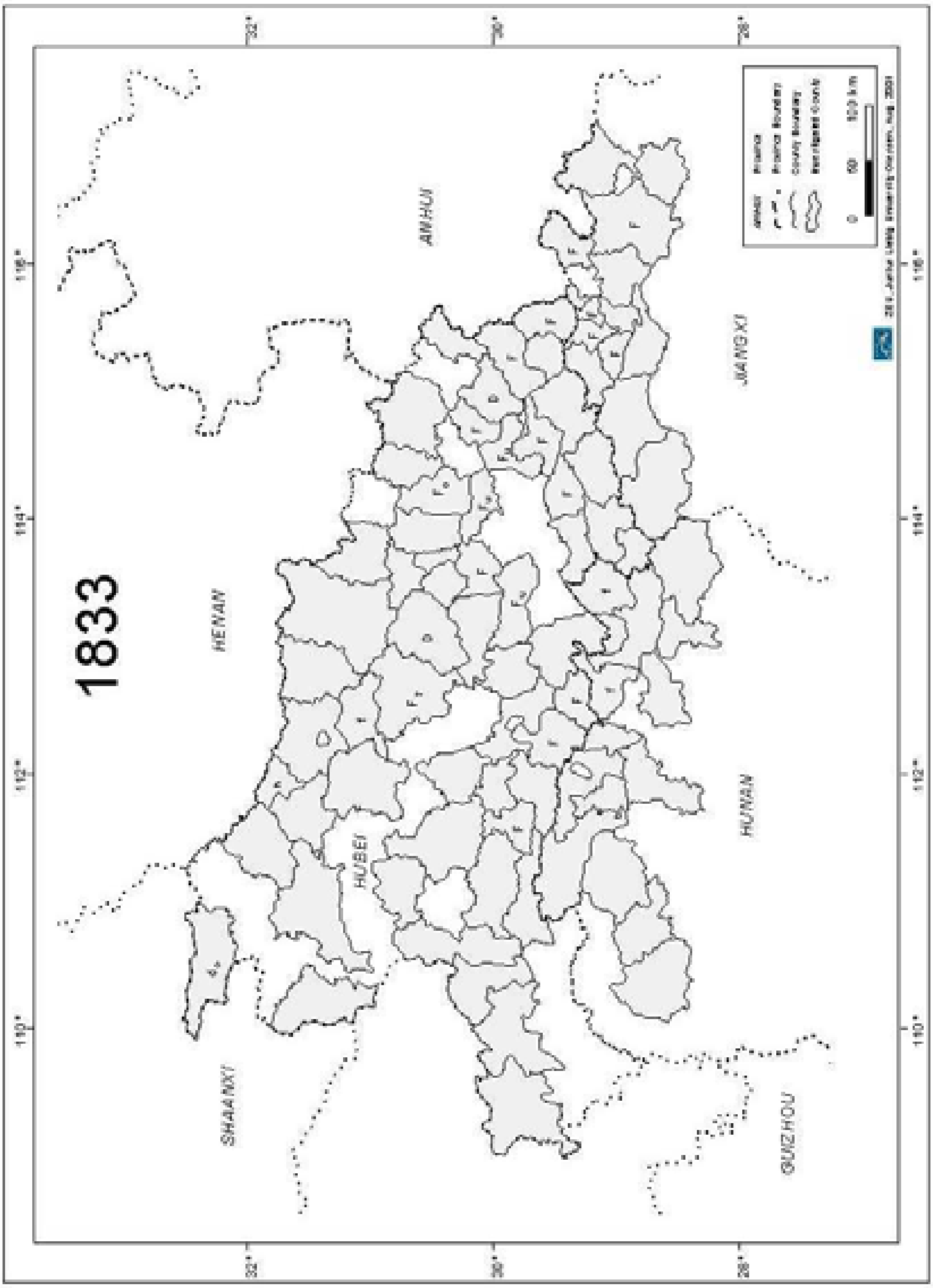
1833
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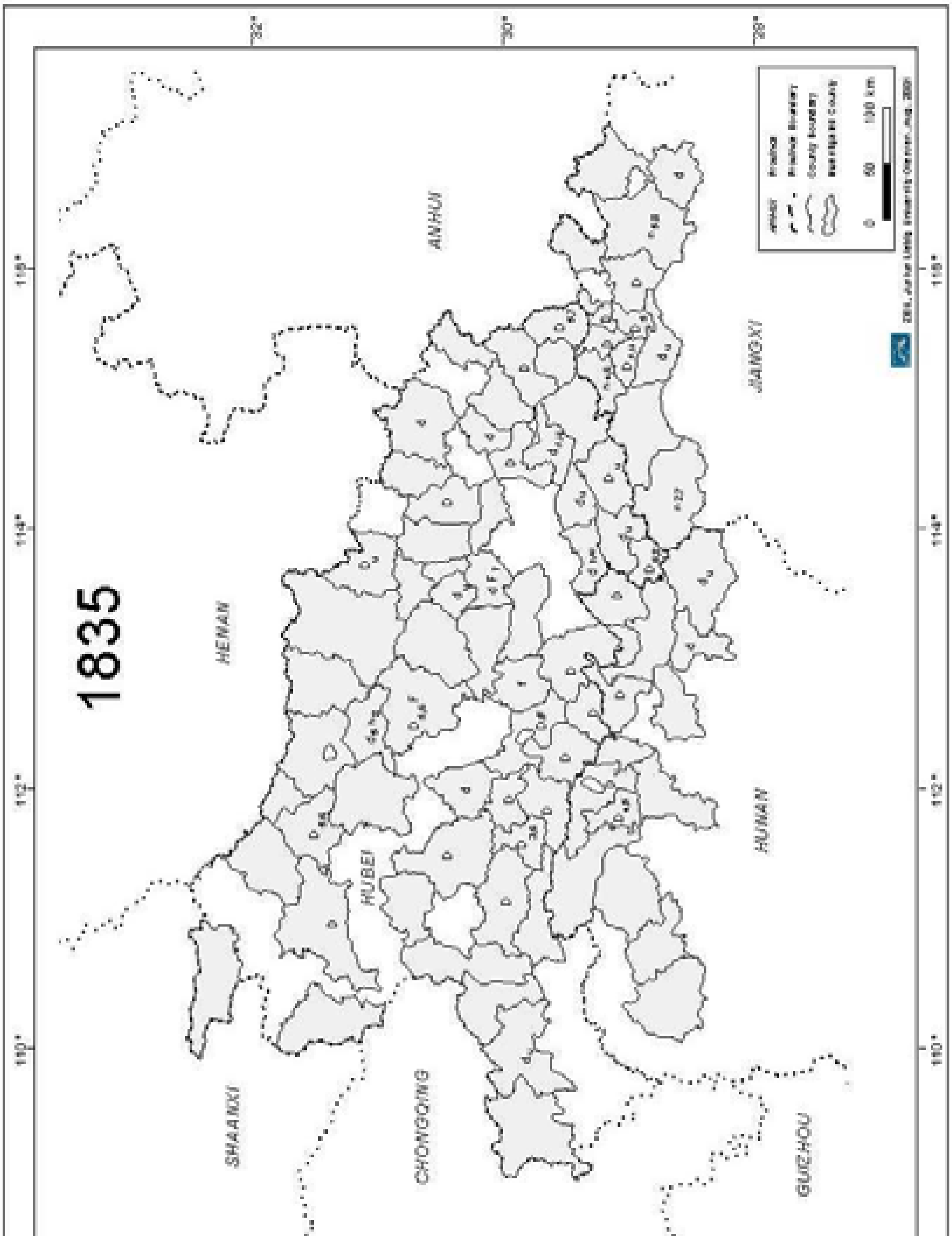
1835
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JIANGXI
HUNAN
SHAANXI
CHONGQING
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116°

6 OUTLOOK

The selected maps (Figures 4 to 13) provide a visualisation of the database on historical flood and drought data. This database includes an enormous amount of historical climatic information that can be the basis for further research activities with a variety of purposes. Some objectives of this research can be the following:

- On basis of this data long-term climatological trends can be detected. This can be helpful in order to estimate the magnitude and extent of future flood and drought events. Therefore, this will be of great importance for disaster forecasting, anti-disaster measures, and planning for the future development of the area.
- With this database county-based risk analysis can be generated for the Middle Reaches of the Yangtze River Valley. The patterns of historical flood/drought events is currently analysed in our research center (ZEU). Such analysis can provide knowledge of both, risk types and patterns of historical extreme flood/drought events. The impacts of potential upcoming events may also be estimated on this source.
- Further research will be also based on indexes for the following climatological factors which are presently compiled by the first author: Coldness (e.g. reports on snowfall and snow-height, frozen-up rivers), warmth (e.g. warm winters, epidemics, heat waves), wind (e.g. waves, broken branches), hail (e.g. size of hailstones, duration, crop failure), and others (e.g. good harvests, frost, fog, long winters). The most important and new aspect of this research will be the calculation and presentation of paleoclimatic temperature cycles and fluctuations and the elaboration of spatial distribution patterns for flood and drought during the last 900 years.
- In addition, with socio-economic and political information concerning settlements, flood types at different dynasties can be assessed. This information will be used to compare historical floods with accurate information about floods in the 20th Century. The estimated result will be a detailed model regarding flood categories such as the 'upper-, middle and lower reaches-type'.
- Due to the large size of the research area (data for the whole of China is available), the database is also expected to help scientists to get new results regarding global weather changes.

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