

Abstract

This chapter dedicates to the evolution of research hotspots and datasets on historical farmland reconstruction in China and abroad. Based on the statistical analysis and literature review, related studies are analyzed by research paradigms, assumptions, working methods and model validation. From the perspective of methodology, there are two main types, i.e. a top-down method based on historical records and a bottom-up reconstruction method based on geographic spatial model. For model validation, direct verification of reconstruction pattern is obviously a more precise method, but it is often restricted to the spatial-temporal scales of research and data source; indirect validation method provides a new idea for accuracy evaluation of the reconstruction results.

Keywords

Land cover • Reconstruction • Spatial pattern
Literature review

2.1 Statistical Analysis of Historical Land Use Based on Literature Review

Land use/land cover change (LUCC) is the most prominent landscape marker for land surface systems (Houghton et al. 1983; Shi et al. 2000; Jain and Yang 2005). Human land use activities have a significant impact on land use/land cover change at the regional and global scales, which significantly affect regional and global climate and ecological environments by influencing the surface energy balance and material recycling (Pongratz et al. 2008; Verburg et al. 1999; Verburg and Chen 2000). LUCC in the historical period is an important part of global change research, thus the establishment of high-precision historical land use/cover datasets is the key to the study of historical LUCC. It is also an important database for relevant climate change, environmental evolution, and terrestrial system carbon cycling

studies (Lambin et al. 2003; Lamprey et al. 2005). In the context of global change research, the International Geosphere and Biosphere Program (IGBP) and International Human Dimensions Programme on Global Environmental Change (IHDP) have co-sponsored research projects such as LUCC, PAGES and BIOME, GLP and Future earth (Fig. 2.1). These projects all take historical land use reconstruction as a key issue and stress the need to use various means to reconstruct the land use changes over the historical timeline in the detailed process (Turner et al. 1995; Loveland and Belward 1997; Jäger 1999; Ge et al. 2004a; Liu et al. 2009).

2.1.1 Statistical Analysis of Literature Quantity

Many Chinese and international experts and scholars of geography, ecology, and environment have already put great efforts into historical land use/land cover reconstruction work from the global or regional scope. Some progresses have been made in reconstructing the historical land use environment, especially in the past 300 years. A series of representative and supporting land use/land cover change reconstruction results have been obtained at global and regional scales.

In this study, based on the literature extraction method, the “Web of Science”¹ database and keywords “historical land use reconstruction” or “land cover reconstruction”², a total of 14,077 articles from 1990 to 2016 have been collected (retrieval time is May 30th, 2017). According to the

¹<http://apps.webofknowknow.com>.

²According to the search Protocol of WOS (Web of Science), search condition was set as follows: (land use SAME reconstruct*) OR (land use SAME rebuild*) OR (land use SAME reestablish*) OR (land cover SAME reconstruct*) OR (land cover SAME rebuild*) OR (land cover SAME reestablish*) AND (history*).

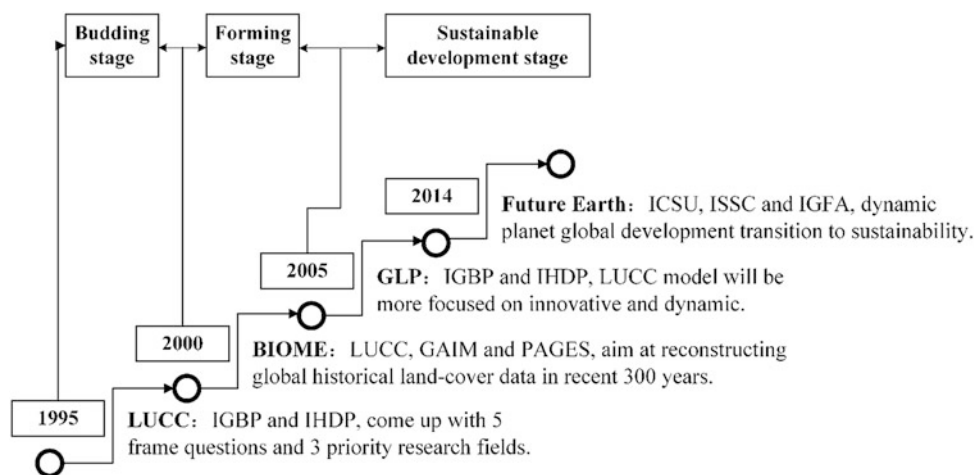


Fig. 2.1 The development of historical LUCC reconstruction research

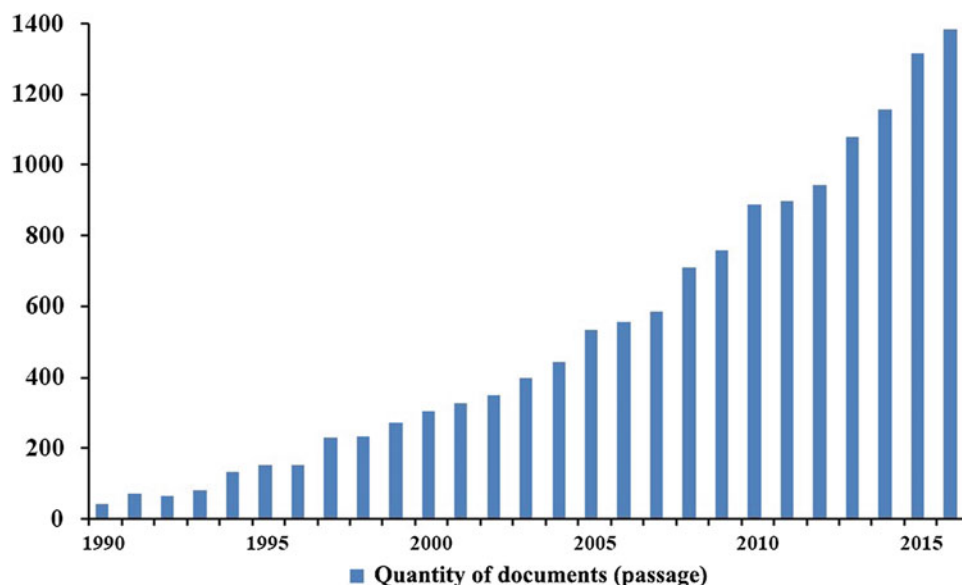


Fig. 2.2 Historical LUCC literature in Web of Science database from 1990 to 2016

results of document retrieval, the number of documents on historical LUCC has been increasing during the past 30 years, and the growth rate has increased slightly year by year (Fig. 2.2). Secondly, there are significant differences in the number of literature related to various historical LUCC research areas. Three major research areas were environmental sciences ecology (52.71%), zoology (39.79%) and geology (29.16%), followed by paleontology (25.16%), biodiversity conservation (23.09%), atmospheric sciences (22.03%), life sciences (21.16%), physical geography (14.60%) and so on. The proportion of literature refers to the study of different historical LUCC research areas' literature accounted for the proportion of the total number of literature, as shown in Fig. 2.3. Statistical distribution shows that

historical LUCC research involves a wide range of study fields and there is a significant interdisciplinary phenomenon (the total proportion of different study areas' proportion of literature >1).

2.1.2 Statistics of Research Hotspots and Frontier Direction

In order to fully understand the research of "LUCC" reconstruction and grasp the hotspots and frontiers in this study field, the method of "Citespace" has been introduced to track the development of this study field so that it can provide a reference for subsequent and further studies.

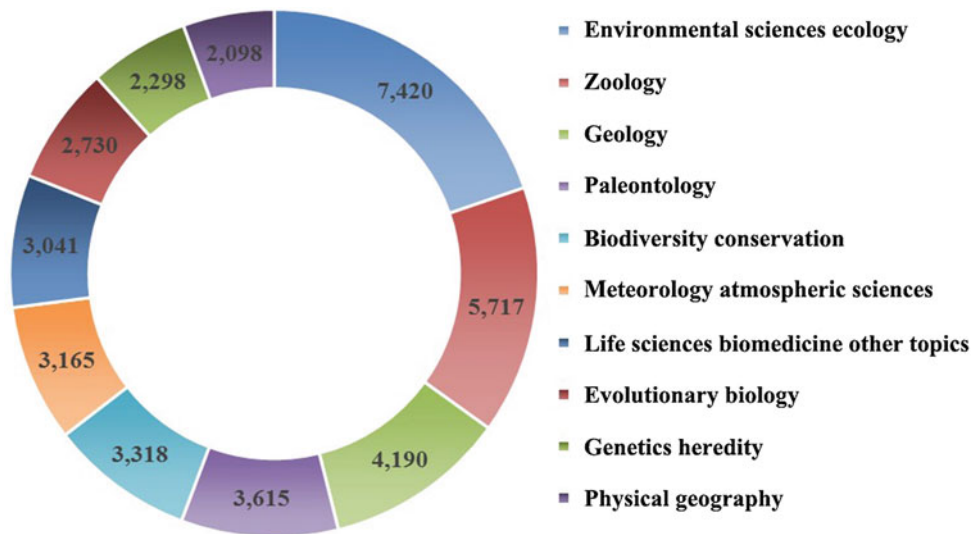


Fig. 2.3 The number of literature in different research directions of historical LUCC

Citespace is based on a hypothesis that “scientific knowledge keeps changing”. It is a Java-based application for visualizing knowledge domains which use “co-citation analysis theory” and “Pathfinder network scaling”. By measuring the papers in the specific area, Citespace can be used to track the critical path and the turning point, analyze the dynamic mechanism and explore the development of discipline front of the subject’s evolution through a series of visualizing maps. Citespace used in this study is Version 5.0.R1 (64-bit).³ By searching the database of “Web of Science” and excluding research citations that are not directly related to historical LUCC (e.g., zoology, biodiversity conservation, genetics heredity), 2666 related papers are obtained and then analyzed from the aspects of the cluster of “co-author”, “keyword concurrency” and the evolution of the related research fields.

2.1.2.1 Co-author Analysis

Researchers and their research teams are the basic elements, without which an academic research cannot proceed with prosperous development. This study uses the map of co-authors to dig out the close associations among scholars. The closer the clustering nodes of a group of scholars, the closer the group, and the greater their influences. The density of the cluster represents the scholar’s position in the whole research area.

As shown in Fig. 2.4, there are a large number of clustering nodes in the mapping co-occurrence of authors in LUCC research. Some of them constitute the networks among authors/scholars. The size of the groups which involves Verburg P. H., Mazier F., Herold M., Pongratz J. and Zhang X. Z. as the core of research team is

relatively greater than that of other groups. Their networks are of a great influence on studies in LUCC and these core scholars also play an important role in the research field of historical land use reconstruction.

2.1.2.2 Keyword Co-occurrence Analysis

Figure 2.5 shows the keywords in historical land use research with higher citation index. The larger the size of a node, the higher the citation index rate. The distance between two nodes can represent citation relations of the relevant researches. Overall, the research hotspots of LUCC have focused on the process, pattern, mechanism and environmental effect of land use change recently in terms of research contents, with the study methods usually based on “3S” (RS, GIS and GPS) technology, dynamics models and etc., and the study areas of China, the United States, and Europe. Some frequently cited keywords in relevant researches include land-use change, landscape, forest, plant, pattern, GIS, dynamics, climate change, the United States and etc.

2.1.2.3 Evolution of Research Hotspots

Through converting the cluster density view which generates from titles, abstracts, and keywords into timeline view, the nodes of the same cluster can be arranged in chronological order. So that the papers of each cluster can be organized and displayed on one timeline so as to analyze the whole evolution process of a scientific domain. As shown in Fig. 2.6, the research scope of LUCC has become broader in the past 30 years. In the early 1990s, the research focused on the land use change process and models. The researches of land use change mechanism, land use forecast, the environmental effects and other research hotspots increase gradually and the application of new methods, new data such as remote

³<http://cluster.cis.drexel.edu/~cchen/citespace/>.

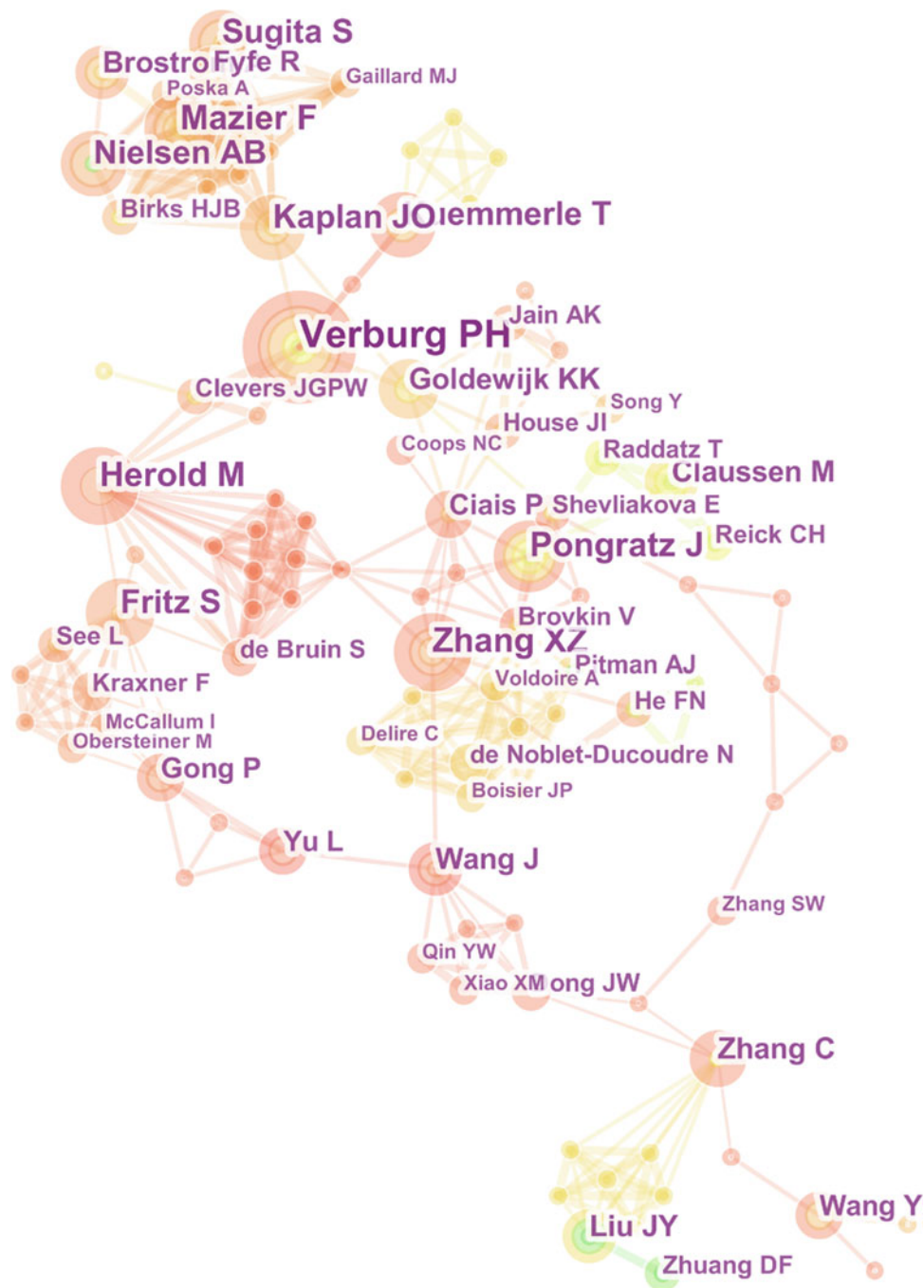
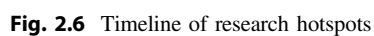
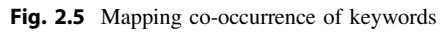


Fig. 2.4 Mapping co-occurrence of authors



sensing data and dynamic models is becoming more common and mature.

2.2 Outline of Reconstructing Spatial Historical Land Cover

2.2.1 Reconstruction Ideology

Most contemporary domestic and international researches uphold the idea of “reconstructing the spatial pattern based on quantitative reconstruction” (Yang et al. 2015). Quantitative reconstruction mainly refers to efforts such as collecting, compiling, identifying, calibrating historical land resource statistics from all sorts of historical literature, books, taxation records, statistics and available research outcomes. Spatial pattern reconstruction furthers a research into reconstructing a spatial-temporal specified datasets based on a quantitatively

reconstructed datasets, a designated historical period, a designated regional setting, a few theoretical assumptions, and a carefully-designed spatial analysis methodology with its own featured transitional rules, allocation methods, and limits as shown in Fig. 2.7 (Zhu et al. 2012; Long et al. 2014; Yang et al. 2015). Quantitative reconstruction is the start point and an essential data source for spatial pattern reconstruction. Spatial pattern reconstruction is the further development and application of quantitative reconstruction.

2.2.2 Assumptions for Spatial Pattern Reconstruction

A few assumptions should be made before initiating the process of spatial pattern reconstruction with considerations over contemporary spatial pattern, natural conditions, socio-economic conditions, and etc. (Bai et al. 2007;

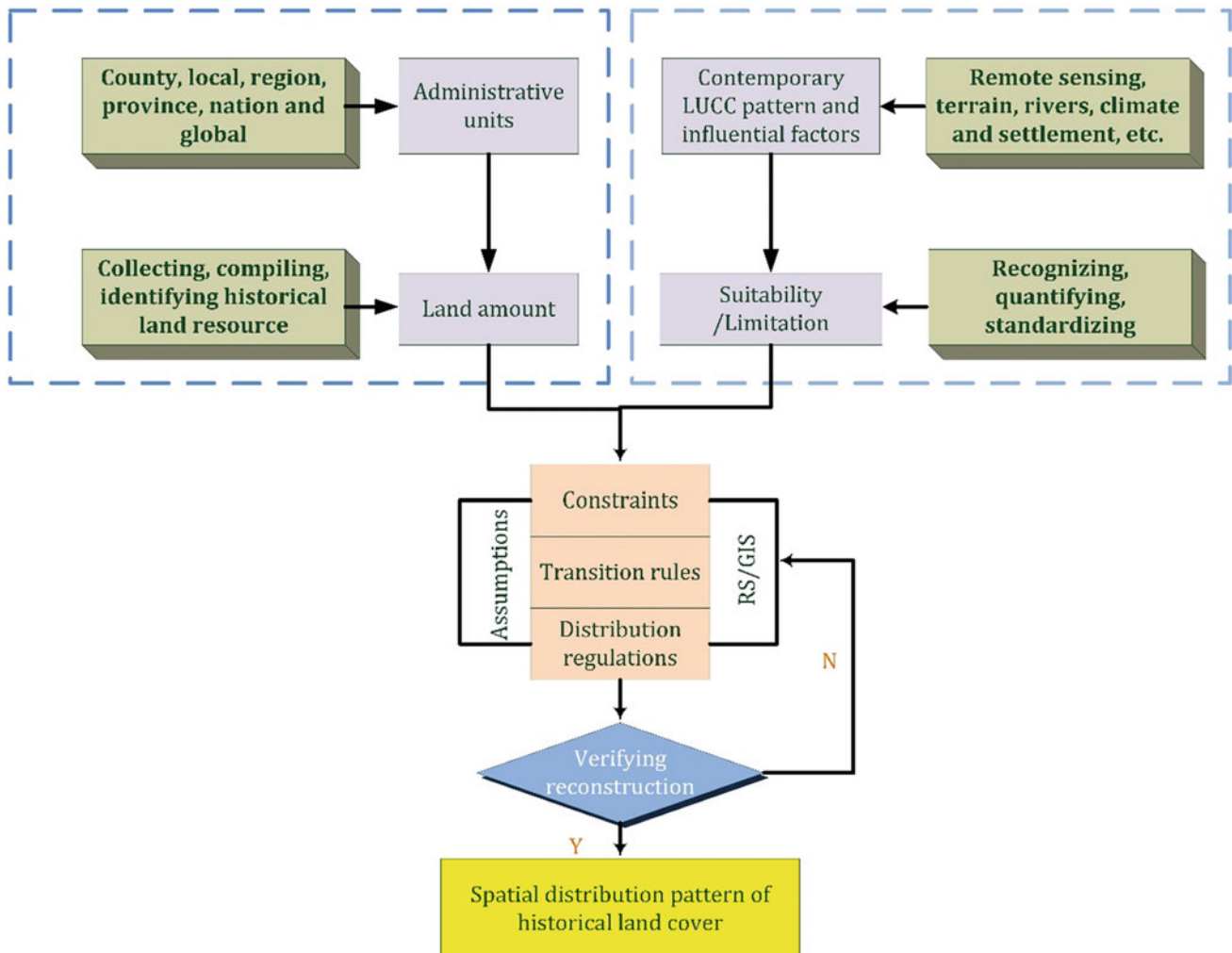


Fig. 2.7 Research outline of reconstructing historical land cover spatial pattern

He et al. 2014; Li et al. 2012; Lin et al. 2008; Long et al. 2014; Ramankutty and Foley 1999; Zhang and Chen 2007). Among these assumptions, those about data, historical geographic distribution, influence factors, and hypotheses of possible outcomes are fundamental for subsequent historical spatial pattern reconstruction.

- Assumptions about data
 - A simple retroactive method may be more effective when data availability cannot be guaranteed
 - The more complete the collected data, the better the model. Model simulation cannot solve all problems
 - Contiguous provinces share a similar tendency of farmland changes while within a province, all prefectures and counties share the same change rate in terms of historical regional farmland changes (Li et al. 2015)
- Assumptions on historical geographic distribution
 - Distribution can be traced in historical records as much as possible
 - The percentage of farmland being actually farmed in any historical period cannot exceed its contemporary counterpart
 - The contemporary distribution serves as the maximum coverage for historical farmland distribution (Li et al. 2011)
 - All grids within an administrative unit are a uniform percentage of farmland resource
 - Historical farmland shall not be allocated to grids where urban area congregated or population density is less than $0.10/\text{km}^2$
 - Land close to coastal areas and flood plains is more suitable for human habitat
 - No agricultural activities would be conducted in areas where the annual average temperature is below zero centigrade
 - Rivers, lakes, and so-like water bodies are not suitable for human habitat
 - Farmland can be allocated to the current location of counties/prefectures for better spatial resolution
- Assumptions about influence factors
 - Contemporary natural conditions can be upheld for historical studies due to their stability over times (Long et al. 2014)
 - Since agricultural development correlates greatly to population and labor force status, it is feasible to estimate the historical farmland location or distribution based on data on historical population
 - Topography, heat, climate conditions are critical in allocating farmland
 - Land that is flat and of little elevation is more likely to be farmed

- Distance to linear landmarks such as rivers and roads does effect on farmland distribution
- The most likely land use and the actual land use can be referred in simulating spatial changes
- Assumptions on possible research outcomes
 - The reconstructed historical spatial pattern is the potential one but may not be the actual one (Yang et al. 2015)
 - All researches assume the similarity of historical spatial pattern to the contemporary spatial pattern and conduct the reconstruction based on this assumption even though the reliance on such similarity differs across researches (Zhu et al. 2012).

2.3 Historical Spatial Pattern Reconstruction Methodology

Regarding the differences in data sources and research ideology, historical spatial pattern reconstruction methodology can be of two types: one based on historical records and the other based on a spatial model.

2.3.1 Reconstruction Based on Historical Records

Historical records, including local records, archives, landownership records, pollen, sediments, relics and etc., contain important information about historical LUCC, which provide data to studies on historical LUCC directly or indirectly. In terms of the medium of historical records, historical LUCC reconstruction could be of forms described as below.

2.3.1.1 Reconstructing Land Use Pattern Based on Historical Records

Most human manipulations on land surface have been recorded and distributed based on the paper medium in forms such as land taxation, local records, historical records, toponym records, travel notes, personal notes, topography, land ownership maps, landscapes, and etc. It will, directly and indirectly, facilitate the qualitative and semi-quantitative analysis of historical LUCC based on data extracted from these historical records after being correctly recovered, identified, calibrated, and distributed in both spatial and temporal dimensions.

This reconstruction relies on the diversity and distinguishability of available historical records. It is expected to have a tedious and time-consuming process of data reorganization. It is most likely of a limited spatial-temporal space and generally confined within a relatively complete

geographic unit such as a province or a lower-rank administrative unit.

There are a few studies conducted with this reconstruction methodology. Ge et al. (2004b) reconstructed the farmland for 18 provinces within the traditional agricultural area dated back to 1661 based on official local records in Qing Dynasty, statistics, and related survey data. He et al. (2002) reconstructed the urban land coverage for 18 provinces in year 1820 based on the length of city/town walls in each province, which used data sources such as reorganized national records during the period of Emperor Jiaqing, History of Qing Dynasty, Geographic records in Qing Dynasty and grouped these data into 6 administrative ranks/categories: prefecture, Zhili state, national department, ordinary state, ordinary department, and county to facilitate the spatial pattern reconstruction. He and his colleagues also recalibrated forest land data of six-time intersects since 1700 based on official records, local records, classification books, travel notes, scholars' notes, and forest land survey statistics conducted by the China Republic. He et al. (2003) rebuilt the temporal-spatial pattern of farmland resource for Shannxi in the middle of Qing Dynasty based on historical records in Shannxi, land reclamation regulations, land taxation records. Ye et al. (2009a, b) reconstructed the changes of forest land and farmland in Northeast China in the past 300 years based on historical records such as local records, personal diaries, Yearbook, forestry history, historical documents, thematic maps, records of Shenyang as Shengjing, the early edition of Eight Banners records, history of the Northeast in Qing Dynasty, unofficial records of Jilin Province and etc. Zeng et al. (2011) reconstructed the spatial pattern for residential area changes and agricultural land reclamation process for Jilin Province through studies on toponyms. Li et al. (2005) reconstructed the process of land reclamation and farmland pattern for northeast China in Qing Dynasty based on historical records, i.e., official and historical records of Shenyang. Kuang et al. (2005) reconstructed urbanization process for Changchun city ever since 1900 based on the integration of TM and SPOT remote sensing images, topography, and thematic maps. Xie and Wang (2014) reconstructed the spatial pattern of water resources and agricultural areas along the stream of Heihe River based on field investigation, relics, local records, historical and contemporary maps, and remote sensing images.

2.3.1.2 Reconstruction Based on Historical Natural Records

Besides documentary records, the history of human activities can also be established by tracing their footprints, i.e., natural records such as pollen, relics, animal and plant fossils, plantation coal, plant annual rings, and etc. By applying analytic methods such as geological dating, carbon tracking, archeology, it is feasible to derive characteristics of human

activities and their corresponding temporal dimension, climate, and natural vegetation.

Such reconstructed history can be of the time span about 103/104 years. For an instance, Ding et al. (2011) investigated the representative meanings of pollens in the mild hilly areas in East China on local land use structure based on their analysis of representative pollens and their indications for human activities under different climate conditions. Shi et al. (2008) collected cultural deposits in the Zhongba Site and supplemented with temporal estimates based on tree annual rings and material identifications to establish a sequence of comprehensive time intersects for the site and corresponding local land use characteristics.

Outcomes of LUCC reconstruction based on historical records are more likely to be on a macro scale and based on land use statistics but short of manifest spatial characteristics. It is necessary to establish a land cover data set with high spatial and temporal resolution to better the simulation of the climate and ecological effects upon historical land use (Zhu et al. 2012).

2.3.2 Reconstruction Based on a Spatial Model

It is an effective way to analyze the historical LUCC space scenarios with a mathematic model based on the simulation of the whole process of historical LUCC changes (Hu and Li 2012). Focusing on whether the reconstruction of historical LUCC depends on the contemporary land use pattern, Zhu et al. (2012) classified the models or methods of reconstructing historical LUCC into three categories: fully-dependent, partially-dependent and dynamically dependent. This classification does tell the differences in algorithm across models somehow. However, it is unable to reveal the evolution mechanism of any single different models. It is still of nature "best suitability fits". According to the mechanism and characteristics of a reconstruction model, this study deems a spatial reconstruction model is either "top-down" or "bottom-up".

2.3.2.1 Top-Down Reconstruction

A top-down reconstruction model allocates the quantitatively reconstructed historical LUCC data into the corresponding spatial grid(s) based on land suitability, population density, or contemporary land use pattern. Such models can further be grouped into two subsets as discussed below according to the natural resource allocation.

(1) Spatial Allocation Based on Land Suitability

With available historical LUCC data (i.e., types and amounts) collected from historical records, it is foremost to select and quantify influencing factors on historical LUCC such as historical population, elevation, slope, distance to rivers and streams, distance to residential lots. Then combine

them with the land suitability function derived from contemporary land use pattern, allocating historical LUCC based on sorted land suitability, and grids for historical LUCC can be set up.

A few studies have been conducted by applying this research methodology and spatial reconstruction method. Lin et al. (2008) constituted the spatial grid pattern for farmland in Chinese traditional agricultural area with 6 times intersects based on a population-topography gravity model which has been influenced by population and slope. This method was also applied by He et al. (2011) and Li et al. (2012) to reconstruct the farmland spatial pattern in Southwest China for Mid-Song Dynasty and Qing Dynasty respectively with calibrated population and farmland coverage data. Li et al. (2011) established the grids for farmland resource in Yunnan Province in 1671 and 1827 based on elevation and slope data derived from MODIS land coverage remote sensing data. Xie et al. (2013) set up $5 \text{ km} \times 5 \text{ km}$ grids for farmland resources along the middle stream of Heihe River in four time intersects, i.e., A.D. 2, 140, 753, and 1290, based on slope, elevation, and population density. Li et al. (2014) and He et al. (2014) erected the spatial grids for forest land in Northeast China and Southwest China respectively based on weighted land suitability analysis. Feng et al. (2014), Zhang et al. (2014), Luo et al. (2014) and Li et al. (2015) all used population, slope, contemporary agricultural farming intensity to evaluate land suitability and further structure farmland spatial grids for the nation, Heilongjiang Province, He-Huang valley area in Tibet plateau and the whole Tibet respectively.

(2) Spatial Reconstruction Based on Historical Population Density and/or Contemporary Land Use Pattern

This category of spatial pattern reconstruction treats LUCC as a cumulative outcome of human activities on earth surface without much concern over effects of land suitability. Thus, population density or contemporary land use pattern will function as the indicator in allocating land resources to reconstruct historical LUCC. In both HYDE 1.1 (Goldewijk and Battjes 1997) and HYDE 2.0 (Goldewijk 2001), contemporary population density works as the base map to lay out land use pattern by referring to historical population. In SAGE (Ramankutty and Foley 1999), Liu and Tian (2010), and Tian (Tian et al. 2014), the contemporary land use patterns derived from the interpretation of remote sensing images serve as the base maps. Such base maps are then adjusted by the corresponding ratio as collected historical data to the contemporary data derived from image interpretation. This is actually a process of allocating land resource quantitatively for specific time intersects. Finally, historical LUCC has been formed.

2.3.2.2 Bottom-up Reconstruction

Top-down reconstruction is of the static nature and depends greatly on econometric techniques. Bottom-up reconstruction can integrate all kinds of representative activities human conducted on land into framing spatial land use grids by applying the artificial intelligence algorithm onto grids one by one with loop iterations. Considering non-farming plots close to existent farmland being actually farmed are more likely to be exploited, Bai and Zhang (2004), Bai et al. (2007), Long et al. (2014), and Yang et al. (2015) respectively reconstructed the spatial pattern for historical LUCC pattern in DuErBoTe County, that for farmland resource in Jiangsu Province and Shandong Province by applying a Cellular Automata (CA) spatial transition model with an exploitation intensity function for contiguous land.

With the belief that multiple temporal remote sensing images of the same geographic area imply the transitional “rules” for local land use changes, Ray and Pijanowski (2010) applied artificial neural network algorithm and integrate GIS technologies to simulate land use changes to reconstruct the spatial pattern of construction land, farmland, and forest land in Muskegon River watershed of Michigan in Wisconsin, USA. Acknowledging the heterogeneity of farmland evolution in terms of space and speed, Yang et al. (2015) structured a multi-partition synchronic confined CA model to reconstruct the spatial pattern for farmland in traditional agricultural areas in China.

The top-down spatial evolution methodology advances greatly in predicting land use pattern changes such as urban expansion (Zhang 2008; Wang et al. 2013). However, it is still at the start point for tracing back, i.e., reversing the timeline, historical land use pattern. The methodology is difficult to apply in spatial allocation since it not only requires the selection, quantification, and normalization of factors effecting on land use but also demands the understanding of characteristics of human activities onto land use changes and the capability to depict these understandings with mathematical language, i.e., abstract functions or a series of models.

We can illustrate the differences between the top-down methodology and the bottom-up one in Fig. 2.8.

The pattern of historical farmland in the first two lines is derived from top-down methodology while the pattern reconstructed with proportional data type is exactly the same as that of contemporary farmland except that the numbers shown in every grid differ. The pattern of historical farmland derived with Boolean data is just similar but not exactly the same as that of the contemporary farmland.

The pattern of historical farmland derived with the bottom-up methodology is very different from previous two. It is probably due to the integration of a variable representing the density of neighboring farmland into the model and/or

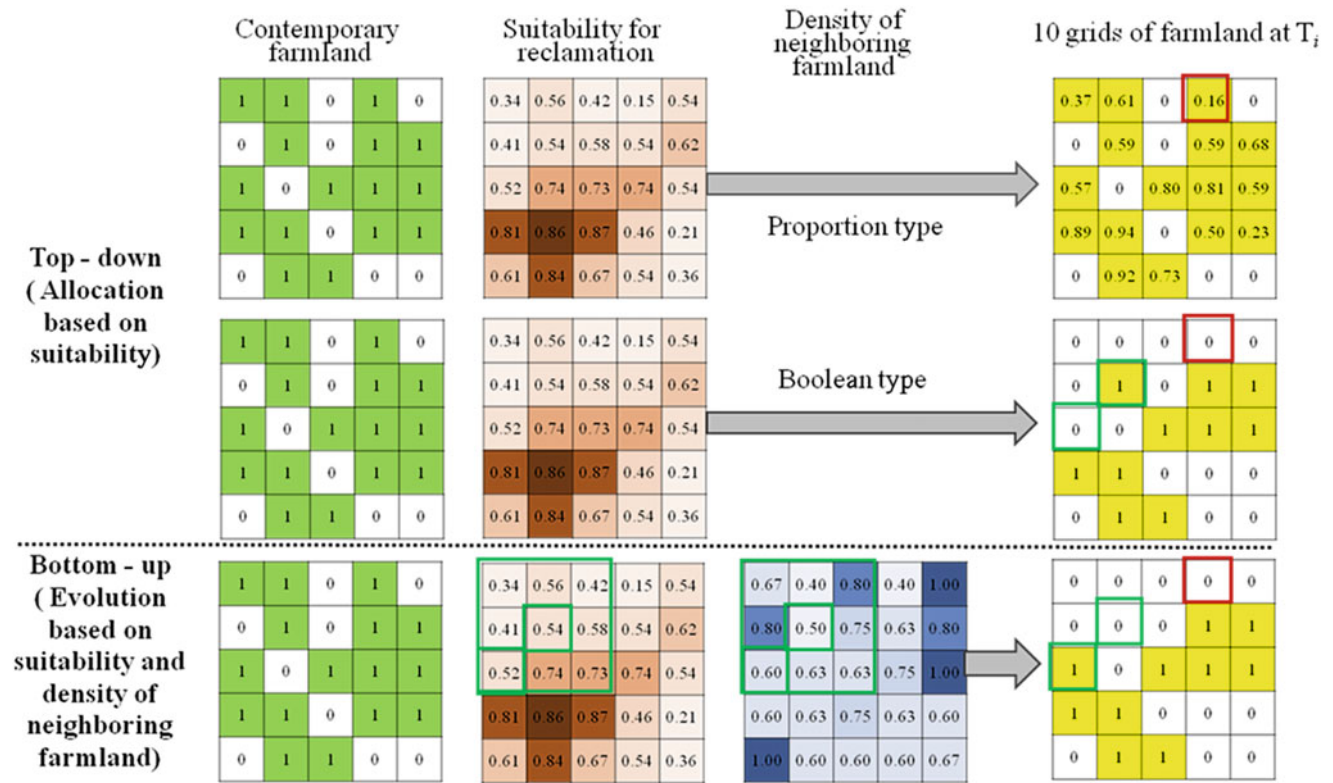


Fig. 2.8 Differences between top-down and bottom-up methodologies

the removal of isolated or impossible farmland from farmland dataset.

Moreover, we can further explore the mechanism behind these differences among reconstructed historical farmland patterns. Grids highlighted by red rectangles are ones where differences can be traced back to data types while those with green rectangles are ones where differences are resulted from applied methodology, i.e., bottom-up or top-down.

In all, data sources tend to be more diverse and methodologies tend to be more comprehensive in reconstructing the spatial pattern for historical LUCC. With different spatial-temporal dimensions, data sources, and methodology, reconstructed spatial patterns for historical LUCC vary greatly in terms of fitness and precision. Generally, the more limited the spatial-temporal dimension, the more recent the historical period, the greater the data availability, the greater precision and reliability the reconstruction outcomes (Fig. 2.9).

2.4 Reconstruction Verification

Reconstruction verification can be conducted either directly or indirectly.

2.4.1 Direct Verification

A direct verification method is to point-to-point compare the reconstructed historical LUCC outcome with available data sources, such as remote sensing images, survey results, relics, and etc. It is highly reliable.

Fuchs et al. (2012) conducted point-to-point comparison onto 73 pairs of land use patterns in Europe between the reconstructed land use pattern in 1950 and remote sensing images in 1990 focusing on residential lots, farmland, grassland, forestland, which led to the conclusion that the more ancient the reconstructed historical LUCC, the greater errors involved.

Due to the lack of remote sensing images before the 1980s, very few studies have applied such direct verification method. Bai et al. (2007) interviewed old farmers and village governors to qualitatively verify their reconstructed historical LUCC pattern. Xie et al. (2013) incorporated information about relics and concentration sites of human activities into their reconstruction model, which naturally guaranteed the success of passing such direct verification tests.

In general, the greater the spatial-temporal reconstruction dimension, the more likely the unavailability of verifiable data/evidences. Therefore, the direct verification method is

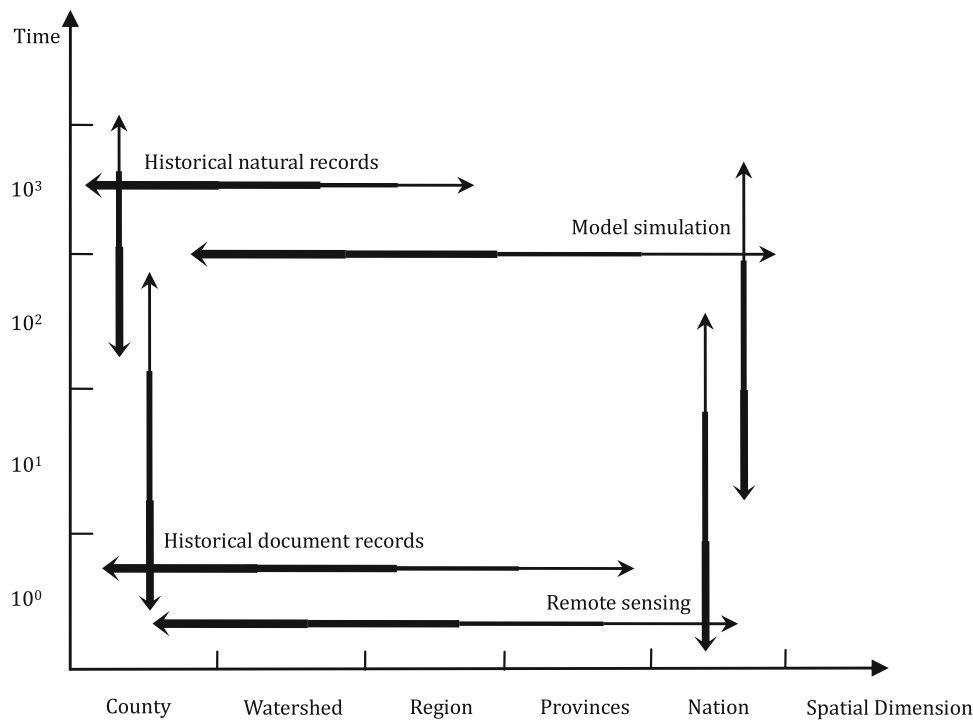


Fig. 2.9 Dimension and accuracy of reconstruction methodologies. *Note* (1) The wider the line, the greater the precision and the reliability; (2) Despite the difficulty in data collection, the limited spatial-temporal coverage, the tediousness of information integration, historical documents are main sources for historical classified land use data and are still of the priority as the data source for regional historical land use

changes; (3) Although natural records are importance supplements for historical documents, they are more valuable for studies set in ancient historical periods rather than those in recent years; (4) The contemporary land use pattern derived from remote sensing images is of distinct spatial-temporal dimension. It has been available only since the 1970s. Thus, it is generally used as the base map

more likely to be applied in micro-scale regional studies with plentiful historical records, especially spatial information from not-too-ancient historical periods.

2.4.2 Indirect Verification

An indirect verification method is a compromise in the absence of direct evidence. It is of several types as below:

(1) Cross-Compare Reconstructed LUCC Qualitatively or Quantitatively with Corresponding Historical Records or Available Research Outcomes

Such verification is generally conducted upon the comprehensive qualitative description for a region even a grid by referring to reconstructed land use scales, pattern features with corresponding historical regional records, statistics, and available credible research outcomes. Li et al. (2011) took the grand perspective in comparing reconstructed historical LUCC pattern with historical records qualitatively and deemed the reconstruction outcome was generally consistent with historical facts. Zhang et al. (2014) verified their reconstructed historical LUCC pattern quantitatively at the county level with “the development history in Heilongjiang”, “Heilongjiang immigrants”, and research outcome of Ye

et al. (2009a, b) by focusing on per capita farmland and the direction of immigrants reclaiming land. Lin et al. (2008) validated their reconstructed spatial grids based on a t-test over their reconstructed prefecture farmland percentages and historical records in National Record by Emperor Jiaqing. Li et al. (2011) and He et al. (2012) compared their reconstructed Northeast China and China traditional agricultural area with their counterparts in HYDE and SAGE datasets from perspectives of overall, province level, and grid level with detailed absolute errors and relative errors, which led to their conclusion that foreign datasets are not objectively capable of reflecting historical farmland changes in China.

(2) Structure the Contemporary Land Use Pattern Based on Model-Reconstructed Historical LUCC Pattern and Compare it Quantitatively with Remote Sensing Images

Feng et al. (2014) and Luo et al. (2014) conducted such comparison from the perspective of county and grid onto reconstructed farmland spatial pattern in the 1980s. Li et al. (2014) and He et al. (2014) analyzed the difference, namely absolute error and relative error, between reconstructed forest land spatial pattern and corresponding remote sensing images in 2000 in Northeast China and Southwest China.

2.5 Representative Historical LUCC Datasets

2.5.1 Representative Global Historical LUCC Datasets

Two of the earliest and most representative global LUCC datasets are the “Global Land Use Database” (hereinafter referred to as SAGE datasets) established by Ramankutty and Foley of the Center for Sustainability and the Global Environment, University of Wisconsin, USA (Ramankutty and Foley 1999), and the “Historical Database of the Global Environment” (hereinafter referred to as HYDE datasets) established by Klein Goldewijk of the Netherlands Environmental Assessment Agency (Goldewijk and Battjes 1997; Goldewijk 2001; Goldewijk and Van 2006; Goldewijk et al. 2011). Based on the Global Land Use Classification in 1992 (DISCover), combining with historical statistics on farmland in various countries and regions, the SAGE datasets reconstructed the global farmland distribution datasets with explicit geographic spatial information for nearly 300 years (1700–1992) with the spatial resolution of 0.5° latitude and longitude grid, and the temporal resolution of 10 years. The latest version of the HYDE datasets (HYDE 3.2) improves the data accuracy and distribution algorithms used in previous versions while extending the reconstruction time scale from 10,000 years ago to 2000. The HYDE datasets rebuilt the global pattern of farmland, grassland and urban land with the spatial resolution of 5' latitude and longitude grid, and the temporal resolution of 10 years after 1700AD.

On the basis of the above two global typical datasets, some scholars have applied or revised the existing reconstruction results to enrich the historical land use rebuilt types. Hurtt et al. (2006, 2011) improved the above datasets to generate the Land Use Transformation Database. Pongratz

et al. (2008) generated the “Global Agriculture and Animal Husbandry Spatial Data Collection” (800–17,700) based on the land use pattern in 1700AD reconstructed by the SAGE datasets (hereinafter referred to as PJ datasets, as shown in Table 2.1). SAGE, HYDE and PJ datasets have relatively high temporal and spatial resolution. It is regarded as the basic data for quantitative evaluation of environmental impact resulted from historical land cover change and is widely used in environmental studies such as environmental evolution and climate simulation (IPCC 2001).

2.5.2 Typical Historical Land Cover Datasets in China

2.5.2.1 National Scale

Constrained by the availability of basic data and the complexity of the reconstruction method, the research results of historical LUCC changes in the whole area of China with clear geographical space attributes are rare. The main achievements are based on farmland or forest reconstruction showing the historical land use characteristics and changing trend, e.g., Ge et al. (2004a) established the data of farmland in 18 provinces in the past 300 years by revising historical data. Liu and Tian (2010) reconstructed the Chinese land use datasets at 10 km resolution from 1700 to 2005 based on modern remote sensing images and historical statistics, including farmland, woodland and urban land. Feng et al. (2014), Li et al. (2016), Wei et al. (2016) focused on different influencing factors to rebuild the spatial pattern of farmland under typical historical time sections in China during the recent 300 years, respectively. He et al. (2015) reconstructed the spatial distribution of forest in China according to the terrain slope, elevation and other

Table 2.1 Representative global historical land-cover data sets with explicit geographic spatial information

Datasets/authors	Data sources	Land use types of reconstruction	Data type	Period of reconstruction	Spatial resolution
SAGE (1999)	The continental conversion rate of arable land in 1980 and the area of cultivated land in 1700–1980 (Houghton et al. 1995; Richards 1990) Global land data from 1961 to 1992 (FAO and FAOSTAT-PC 1995)	Farmland	Proportions	1700–1992	0.5°
HYDE 1.1 (1997)	Farmland/pasture area in continental and national scales, 1700–1980 (Richards 1990; Goldewijk and Battjes 1997)	Farmland and grassland	Boolean	1890–1990	Regional
HYDE 2.0 (2001)	Data of global farmland/pasture from 1961 to 2000 (FAO and FAOSTAT-PC 2008)	Farmland and grassland	Boolean	1700–2000	0.5°
HYDE 3.2 (2017)		Farmland, grassland and urban	Proportions	10,000BC–2000AD	5'
Hurtt et al. (2006)	Results of SAGE and HYDE datasets	Farmland and grassland	Proportions	1500–2100	0.5°
Pongratz et al. (2008)	SAGE datasets in the year of 1700AD	Farmland and grassland	Proportions	800–1700	0.5°

natural factors for consecutive time periods nearly three hundred years.

2.5.2.2 Regional Scale

Generally, the results of historical LUCC reconstruction are relatively more abundant in traditional agricultural China, provincial administrative units or regions with complete or typical geography as a result of sufficient historical records, long history of land reclamation and the obvious changes of land use status. In contrast to the large-scale reconstruction studies in the whole country scale, the historical LUCC reconstruction in regional scale has been aimed at improving the accuracy of the results and the applicability of the model methods and expanding the reconstructed land types to grassland and urban land (Fig. 2.10).

In the large regional scale of inter-provincial administrative units, the reconstruction results are mainly distributed in the northeastern, southeast and southwest regions where

the cultivation conditions are better, the cultivation history is longer and the historical records are abundant, such as the reconstruction of farmland in traditional agriculture of China (Lin et al. 2008; He et al. 2011, 2016; Yang et al. 2015); the farmland (Ye et al. 2009a), forest and grassland (Ye et al. 2009b; Li et al. 2014) rebuilding in Northeast provinces; reconstruction of farmland (Li et al. 2012) and forest (He et al. 2014) in Southwest China, the farmland rebuilding in Northwest China (Li et al. 2015); the farmland reconstruction in eastern provinces of China (Zhang and Chen 2007), the farmland reconstruction in the Songnen Plain (Jiang et al. 2015) and etc.

In the scale of provincial administrative units, the research area mainly concentrated in those provinces where human activities drastically changed the land surface state, such as reconstruction of farmland in Heilongjiang Province (Zhang et al. 2014), rebuilding of farmland (Long et al. 2014), construction land (Lin et al. 2015, 2017) and various

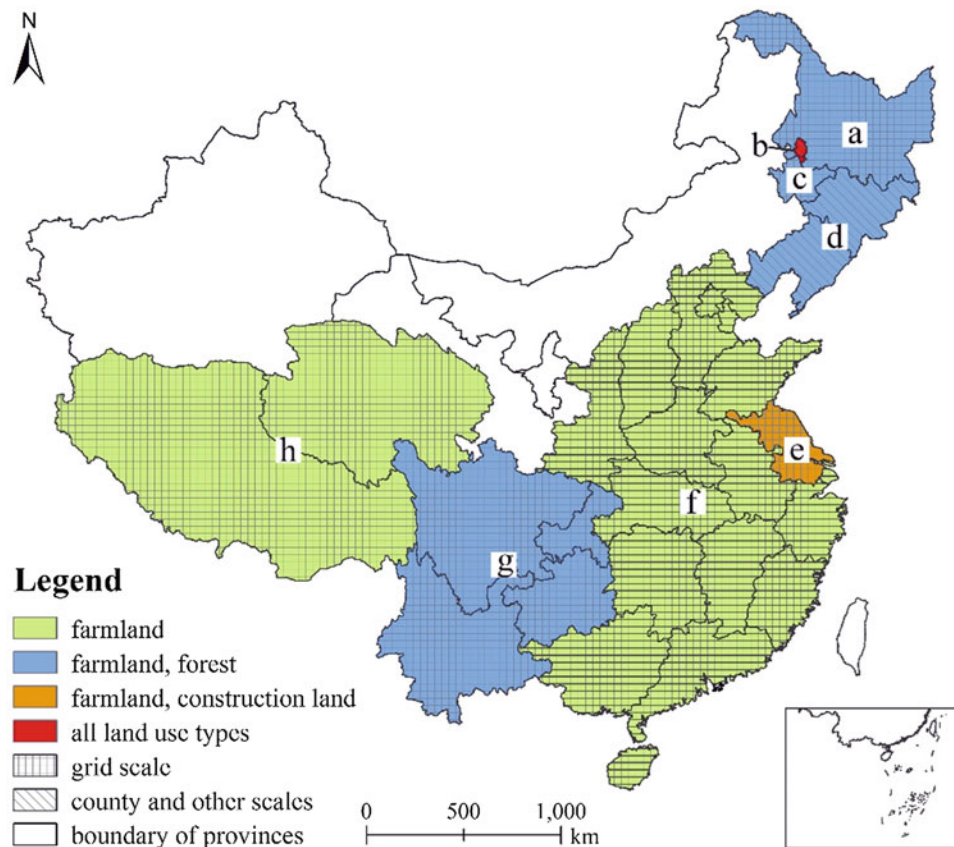


Fig. 2.10 Historical spatial land-cover data sets at regional scale in China. *Note* (1) Heilongjiang Province's farmland raster data over the past 100 years, according to Zhang et al. (2014), forest raster data over the past 300 years, according to Li et al. (2014); (2) DuErBoTe County's all land use type data in the 1930s, 1950s, according to Bai et al. (2007); (3) The west of Jilin Province's farmland raster data in the 1930s, according to Lv et al. (2015), forest data at county level over the past 300 years, according to Ye et al. (2009b); (4) Jilin Province's and Liaoning Province's farmland and forest data at county level over the past 300 years, according to Ye

et al. (2009a, b) and Li et al. (2014); (5) Jiangsu Province's farmland raster data in 1820, according to Yang et al. (2015), construction raster data in 1820, according to Lin et al. (2015) and Pan et al. (2015); (6) Traditional agriculture of China's farmland raster data over the past 300 years, according to Yang et al. (2015); (7) The southwestern of China's farmland raster data over the past 300 years, according to Li et al. (2012), forest raster data over the past 300 years, according to He et al. (2014); (8) Qinghai Province's and Xizang Province's farmland raster data over the past 100 years, according to Li et al. (2015)

types of land (Pan et al. 2015) in Jiangsu Province, farmland rebuilding in Yunnan Province (Li et al. 2011) and etc. In addition, in typical geography range, the historical LUCC reconstruction mainly chose those areas where the data was available, such as the farmland reconstruction in the middle reaches of Heihe River Basin (Wang et al. 2013) and Hehuang Bottom of Qinghai-Tibet Plateau (Luo et al. 2014). Corresponding to the scope of the study, the spatial resolution of the reconstructed objects is mostly based on

provincial or municipal (county) administrative units or spatial grid, varying from $0.5^\circ \times 0.5^\circ$ (Zhang and Chen 2007), $60 \text{ km} \times 60 \text{ km}$ (Lin et al. 2008; He et al. 2011), $10 \text{ km} \times 10 \text{ km}$ (Li et al. 2012, 2014; He et al. 2014), $5 \text{ km} \times 5 \text{ km}$ (Xie et al. 2013), $2 \text{ km} \times 2 \text{ km}$ (Luo et al. 2014), $100 \text{ m} \times 100 \text{ m}$ (Lin et al. 2015; Pan et al. 2015) to $90 \text{ m} \times 90 \text{ m}$ (Li et al. 2011), reflecting the characteristics of regional land use/land cover status from different aspects (Table 2.2).

Table 2.2 Historical land-cover data sets with explicit geographic spatial information in China

Authors	Land use types of reconstruction	Time section of reconstruction	Data type	Spatial resolution	Coverage of results
Liu and Tian (2010)	Farmland, forest and urban	1700–2005	Proportions/boolean	10 km	China
Feng et al. (2014)	Farmland	1913, 1933, 1950, 1970, 1990, 2000	Proportions	10 km	China
Li et al. (2015) (CHCD)	Farmland	1661, 1724, 1784, 1820, 1873, 1933, 1980, 1996	Proportions	10 km	China
He et al. (2015)	Forest	1700–2000	Proportions	10 km	China
Wei et al. (2016)	Farmland	1820, 1936	Proportions	10 km	China
Lin et al. (2008)	Farmland	1820	Proportions	60 km	Traditional agriculture of China (TAC)
He et al. (2011)	Farmland	1077	Proportions	60 km	TAC
Yang et al. (2015) (HCTC)	Farmland	1661, 1724, 1820, 1887, 1933, 1952	Boolean	1 km	TAC
He et al. (2016)	Farmland	976, 997, 1066, 1078	Proportions	Lu (like province)	TAC
Zhang and Chen (2007)	Farmland, forest and waterbody	1724, 1784, 1820, 1887, 1933, 1955	Proportions	0.5°	East China
Ye et al. (2009a) (CNEC)	Farmland	1683, 1735, 1780, 1908, 1914	Quantity and cultivation rate	County	Northeast China
Ye et al. (2009b)	Forest and grassland	1700, 1800, 1940, 1980, 1990, 2000	Proportions	County	Northeast China
Li et al. (2014)	Forest	1780, 1940	Proportions	10 km	Northeast China
Li et al. (2012)	Farmland	1661, 1724, 1784, 1820, 1873, 1911	Proportions	10 km	Southwest China
He et al. (2014)	Forest	1724, 1784, 1820, 1873, 1911	Proportions	10 km	Southwest China
Li et al. (2015)	Farmland	1910, 1960, 1980, 2000	Proportions	1 km	Qinghai and Tibet
Jiang et al. (2015)	Farmland	1908	Proportions	1 km	Songnen Plain
Li et al. (2011)	Farmland	1671, 1827	Boolean	90 m	Yunnan Province
Zhang et al. (2014)	Farmland	1900s	Proportions	1 km	Heilongjiang Province
Long et al. (2014)	Farmland	1661, 1820, 1887, 1933, 1980	Boolean	1 km	Jiangsu Province
Lin et al. (2015)	Urban and rural construction land	1820	Boolean	100 m	Jiangsu Province
Pan et al. (2015)	Farmland, rural settlement and others	1820	Boolean	100 m	Jiangsu Province
Bai et al. (2007)	Farmland, forest, construction land and others	1930s, 1950s	Boolean	County	DuErBoTe county
Xie et al. (2013)	Farmland	2, 140, 753, 1290	Proportions	5 km	Heihe River basin
Luo et al. (2014)	Farmland	1726	Proportions	2 km	Hehuang Valley
Lv et al. (2015)	Farmland and others	1930s	Boolean	90 m	West of Jilin

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