J. Geogr. Sci. 2021, 31(8): 1222-1242
DOI: https://doi.org/10.1007/s11442-021-1894-0

China's agricultural land use change and its underlying drivers: A literature review

WANG Xue[1], LI Xiubin[1,2]

1. Key Laboratory of Land Surface Pattern and Simulation, Institute of Geographic Sciences and Natural Resources Research, CAS, Beijing 100101, China;
2. College of Resources and Environment, University of Chinese Academy of Sciences, Beijing 100049, China

Abstract: Understanding the manifestations and underlying drivers of agricultural land use change in China is of great importance for both domestic and global food security. However, little is known about the holistic pattern of agricultural land use change across China, especially from the perspective of intensity since the evidence has been gathered mainly through case studies at local levels. This study conducts a systemic review of agricultural land use change and its underlying drivers in China by aggregating 169 relevant case studies from 123 publications. The cases related to intensification and disintensification, which are the two types of agricultural land use change, are generally equal, accounting for 50% of the total number of cases. Intensification and disintensification can be further divided into the same three categories: expansion/contraction of agricultural land, changes in agricultural land use activities and changes in land management intensity. Demographic, economic, technological, and institutional drivers, together with location factors, are frequently noted as significant underlying drivers, while sociocultural drivers and farm(er) characteristics are less frequently recognized. Finally, three major land use change trajectories are summarized mainly concerning rising labor costs and the concomitant increase in off-farm employment, the ecological improvement policy, and advances in agricultural technology.

Keywords: agricultural land; land use intensity; driving forces; aggregate analysis; China

1 Introduction

Agricultural land is one of the major land use types worldwide, with its main functions including food production, recreation services provision, and agricultural civilization preservation (Carpentier *et al*., 2015; Kennedy *et al*., 2016; Folberth *et al*., 2020). Agricultural land use change can have significant impacts on food security, ecosystem stability and landscape security (Fezzi *et al*., 2015; Taylor *et al*., 2016; Zeng *et al*., 2018), and its manifestations and underlying drivers have attracted widespread attention from scientists around the

Received: 2020-09-22 **Accepted:** 2021-03-09
Foundation: National Key Research and Development Program of China, No.2017YFE0104600; National Natural Science Foundation of China, No.41930757
***Corresponding author:** Wang Xue (1989–), PhD and Associate Professor, specialized in land use change. E-mail: wangxue@igsnrr.ac.cn

world (Karelakis and Tsantopoulos, 2017; Meyfroidt *et al*., 2018; Lai *et al*., 2020).

China has always faced a great challenge in feeding a continuously growing population (Piao *et al*., 2010; Cui *et al*., 2018). Agricultural land use change in China can not only affect its own food production but also even have an impact on global food security (Jiang *et al*., 2013). Since the implementation of the reform and opening up policy and the household contract responsibility system in 1978, China has experienced rapid economic growth and dramatic changes in agricultural land use (Lu *et al*., 2019; Xu *et al*., 2020). Small households have become the basic unit of agricultural land use (Cui *et al*., 2018). Although in recent years, the Chinese government has begun to promote the system of 'Trifurcation of Land Rights' and to encourage the transfer of management rights of agricultural land, and as a result, a large number of new types of agricultural business entities have emerged, the dominant position of the small household in agricultural land use in China remains unchanged (Lai *et al*., 2020). Their agricultural land use behavior is affected by many external factors, including economic growth, population density, urbanization, relevant policies and local conditions (Qin and Zhang, 2016; Li and Li, 2017). In addition, the characteristics of the households, such as farmland size and the age and education level of the head of household, may also impact land use decisions of the household and ultimately affect agricultural land use (Su *et al*., 2016; Yan *et al*., 2016b; Xu *et al*., 2017; Xia *et al*., 2020).

Most studies on agricultural land use change and its driving factors in China have been conducted at the regional or local scale (Yan *et al*., 2016b; Wang *et al*., 2017b; Xia *et al*., 2020), as it is difficult to characterize changes in global agricultural land use in this country with its large area and rich diversity. Several studies have attempted to portray the national changes in agricultural land use, but they do not address the underlying drivers (Liu *et al*., 2014; Song and Liu, 2016). Studies have also been conducted to develop a single indicator or an integrated indicator to analyze changes in agricultural land use and its drivers at large scales (Wang *et al*., 2014; Xie and Liu, 2015), but it is difficult to make targeted and practical policy recommendations based on results from the use of comprehensive indicators. In comparison, systematic analysis can synthesize a number of case studies to portray the national picture and at the same time depict spatial details that can help recommend overarching and regionally differentiated land use policies (van Vliet *et al*., 2015). However, no study has reviewed the change in agricultural land use and its driving forces in China, especially in terms of intensity. In addition, the relevant case studies are published partly in Chinese and partly in English, which makes aggregate research more difficult.

Against this background, the present study uses systematic analysis to aggregate relevant case studies at the subnational level, taking into account publications in English and in Chinese, and gives a systemic presentation of case studies on agricultural land use change and its underlying drivers in China. Two types of agricultural land use change are distinguished, intensification and disintensification, both containing three aspects: expansion/contraction of agricultural land, changes in agricultural land use activity and changes in land management intensity. We also identify three major trajectories of agricultural land use change according to the combinations of manifestations and the underlying drivers associated with them. This study is important for not only providing a sketch of agricultural land use change in China but also contributing to future research on agricultural land use in China. In addition, it is beneficial in that it provides a reference for similar studies in the world.

2 Materials and methods

2.1 Research framework

Based on van Vliet *et al*.'s research (2015), changes in agricultural land use can be divided into two types: intensification and disintensification, representing opposite change directions. Intensification includes increase in agricultural land area and changes towards more intensive land use and land management practices, while disintensification includes decrease in agricultural land area and changes toward more extensive land use and land management practices. The above two manifestations are further divided into three categories (Figure 1): expansion/contraction of agricultural land, changes in agricultural land use activities (for example changes in crop choices), and changes in land management intensity (for example fertilizer or machinery application). Underlying drivers are grouped into seven categories: demographic, economic, sociocultural, technological, and institutional drivers, together with location factors and farm(er) characteristics, based on previous studies (van Vliet *et al*., 2015; Su *et al*., 2016). Each category contains several subcategories (Figure 1). Here, farm(er) characteristics are treated as a separate category, as households are the primary unit of agricultural land use in China, and the characteristics of farmers and their farms play significant roles in agricultural land use change. As distinct from this category, demographic and economic drivers mainly represent external factors rather than the corresponding characteristics

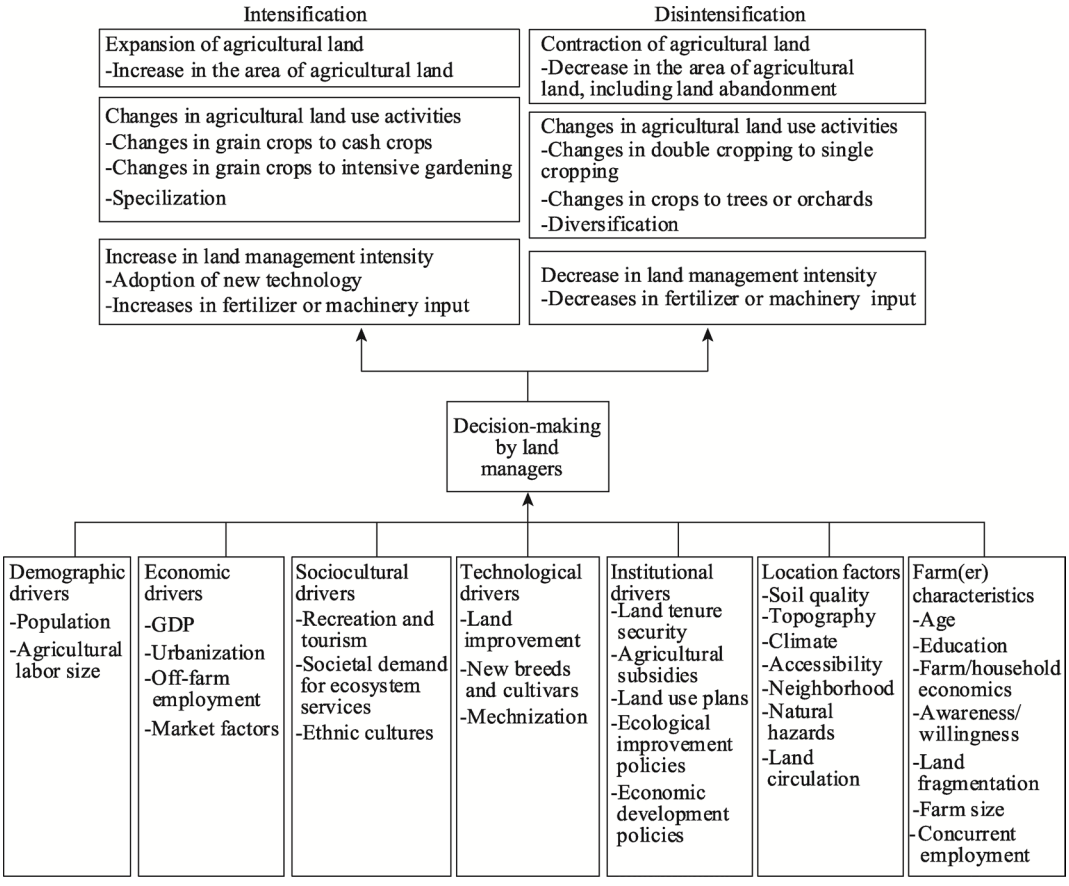

Figure 1 Framework of agricultural land use change and the underlying drivers

of farmers.

2.2 Case study collection

Peer-reviewed publications in Web of Science were major sources of case studies on agricultural land use change and its driving factors, and a systematic analysis was applied to comprehensively synthesize findings from a diverse set of publications. Publications in English or in Chinese with English abstracts and keywords were both considered. The search for publications (Topic=(land + use + change + agricultur*) OR (land + intensification) OR (land + abandonment) AND Topic=Chin*; Timespan=1978–2017; Search=English OR Chinese) yielded 2829 potentially relevant publications. The sources of the publications were limited to the databases of the Science Citation Index –Expanded (SCI-Expanded), Social Science Citation Index (SSCI), and Chinese Science Citation Database (CSCD) to ensure quality. This study focuses on the changes in agricultural land use after the implementation of the reform and opening up policy and the household contract responsibility system; therefore, the starting point of the timespan was set to 1978, which was the year when the above policies began to be implemented.

A total of 56 publications were selected after reading the abstract of the potential publications, which covered case studies since 1978 on agricultural land use change and its driving factors at regional scales in China. Specifically, we excluded publications describing agricultural land use at a certain time point and those only considering direct drivers, such as the transfer between different land use types. Then, the selected publications were read carefully and thoroughly, and a snowball search procedure was conducted to hunt for eligible studies from their references and citations; this yielded another 67 publications. Therefore, a total of 123 publications were included in this study.

Next, 169 cases were identified and coded from the 123 publications. Here, a case refers to a combination of the agricultural land use change type (intensification or disintensification) and the separate study area within one publication. Cases were treated individually when in one publication with different study areas and unique descriptions. Cases were also considered different if they were located in the same study area but used different datasets or methodologies from different publications. A record of a case included a general description of the case study area, the study period, the data source, the performance of land use change, and the underlying drivers. When searching for drivers, the full text of the publications was read, and we recorded the indicators that had a significant impact based on the quantitative analysis and those that played a significant role based on the qualitative analysis of the authors where no statistical analysis was applied. We assumed the authors interpreted the actual land use changes and their causes. Finally, based on the descriptions in the article, case studies were grouped into several major trajectories of land use change, and the trajectories were mainly referred to as the changing trends of agricultural land use summarized by Lai *et al*. (2020), Li and Wang (2003) and Wang *et al*. (2020).

3 Results

3.1 Case study overview and representativeness

The number of publications has been on a generally upward trend over the past 40 years

(Figure 2a). More than two-thirds of the publications were published during 2010–2017, and just under one-third were published before 2010. At the same time, after 2010, scholars focused on the international exchange of research in China. The total number of publications in English during 2010–2017 was 4.3 times the total before 2010, while the ratio of the two totals of Chinese publications during 2010–2017 and before 2010 was only 1.5. The size of the study area ranges between 0.67 km^2 and 4,270,000 km^2, with a median value of 8074.30 km^2. Approximately 80% of the case studies had study areas larger than 5000 km^2, while approximately 10% of them had study areas smaller than 100 km^2 (Figure 2b).

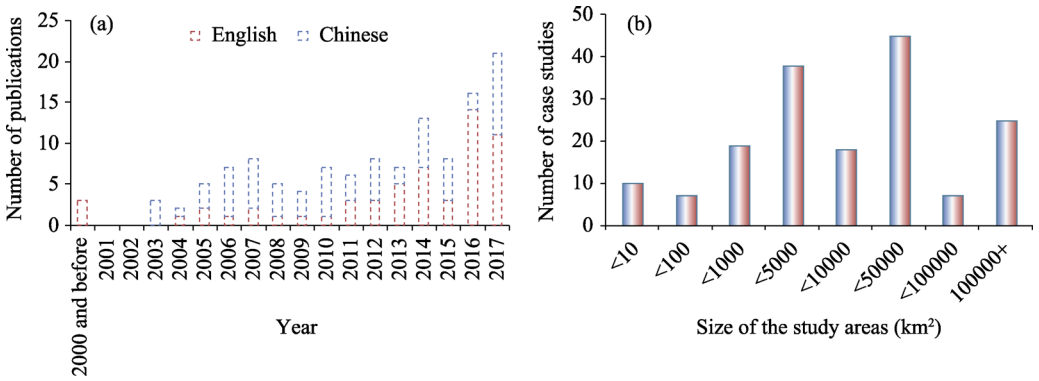

Figure 2 Changes in the number of publications over time (a) and the number of case studies grouped by study area size (b)

Spatial and statistical data were the most common data sources utilized, followed by survey/interview data, while other data were less commonly applied in case studies. Data sources are often used in different combinations, with the most common combination being that of spatial and statistical data, followed by a combination of survey/interview and statistical data (Figure 3).

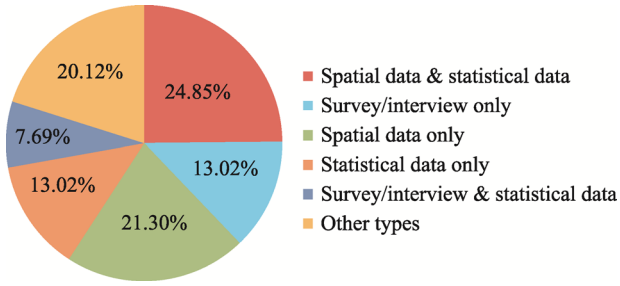

Figure 3 Proportions of different case study groups, categorized by data sources

Case studies were unevenly distributed across China, and their spatial pattern followed that of agricultural land (Figure 4 and Table 1). Approximately 1/2 (47.93%) of the case studies were concentrated in three agricultural regions, i.e., the YRR, the HHH and the LPR, whose proportions of agricultural land equaled 44.27%, slightly lower than the former figure. In comparison, 52.07% of the case studies were located in the other six agricultural regions, with a slightly higher proportion of 55.73% in terms of agricultural land. Specifically, the

proportions of case studies and agricultural land in the YRR, the HHH, the IMR, the SER and the TPR were similar. However, in the LPR and the GXR, the proportions of case studies were higher than those of agricultural land, indicating that these two regions are hot spots for case studies. In contrast, the proportions of case studies in the NER and the SWR were much lower than those of agricultural land. However, there was still a strong interest in the disintensification of agricultural land in a particular region, as evidenced by the concentration of relevant cases in Chongqing city of the SWR. In general, the cases were relatively widely distributed and broadly reflected in changes in agricultural land use in China.

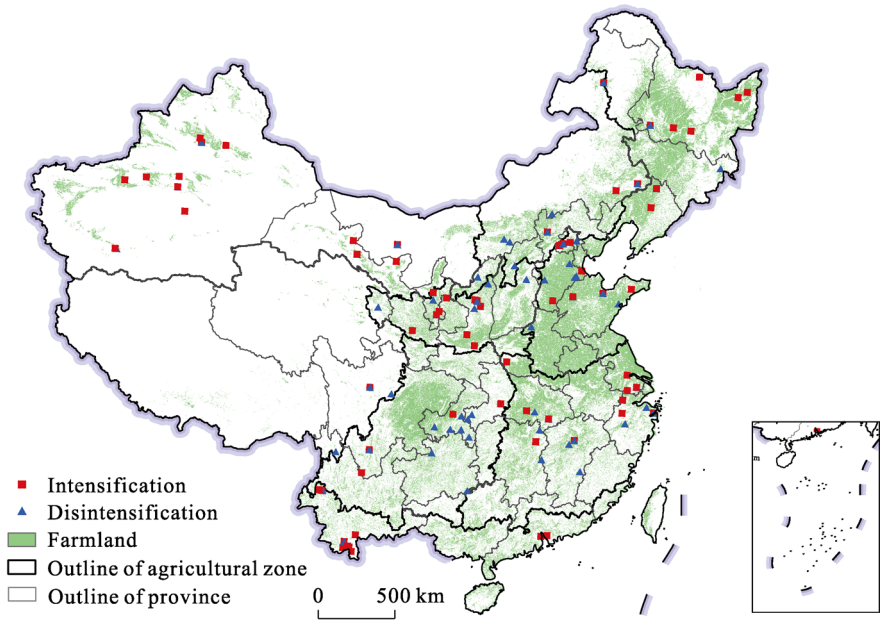

Figure 4 Locations of the case studies and their types of agricultural land use change
(Note: Geometric centers of the study areas are presented for case studies. YRR, the Middle-Lower Reaches of the Yangtze River Region; HHH, the Huang-Huai-Hai Region; GXR, the Gansu-Xinjiang Region; LPR, the Loess Plateau Region; SWR, the Southwest China Region; SER, the Southeast China Region; NER, the Northeast China Region; IMR, the Inner Mongolia-Great Wall Region; TPR, the Qinghai-Tibet Plateau Region.)

Table 1 Proportions of case studies and agricultural land in nine agricultural regions

Region	Proportion of case studies (%)			Proportion of agricultural land (%)
	Int	Dis	Total	
YRR	7.69	10.06	17.75	18.65
HHH	7.69	8.88	16.57	16.89
GXR	11.24	4.14	15.38	6.09
LPR	6.51	7.10	13.61	8.73
SWR	2.37	8.88	11.24	16.57
SER	6.51	2.37	8.88	6.31
NER	5.92	1.78	7.69	17.62
IMR	1.78	4.14	5.92	8.39
TPR	0.59	2.37	2.96	0.76

3.2 Agricultural land use change and its underlying drivers

The numbers of case studies on two types of agricultural land use change were similar, as 85 of the 169 case studies related to intensification and 84 of them related to disintensification (Figure 5). Notably, there were 38 publications that contained case studies on both types of agricultural land use change. With respect to underlying drivers, the most frequently mentioned ones include economic and institutional drivers, and also location factors. In addition, the relative importance values of the above three drivers for both intensification and disintensification were generally equal and approximately higher than 50%. In comparison, demographic and technological drivers, together with farm(er) characteristics and sociocultural drivers appeared less frequently. Among them, demographic drivers were spotted in 38% of the intensification cases and 29% of the disintensification cases. Technological drivers were more frequently mentioned in cases related to intensification, as they occurred in 38% of the intensification cases and only 7% of the disintensification cases. In contrast, farm(er) characteristics were more frequently recognized in cases related to disintensification, yet they occurred in 19% of the disintensification cases and only 11% of the intensification cases. Sociocultural drivers were the least noted drivers, appearing in only 8% and 7% of the intensification and disintensification cases, respectively.

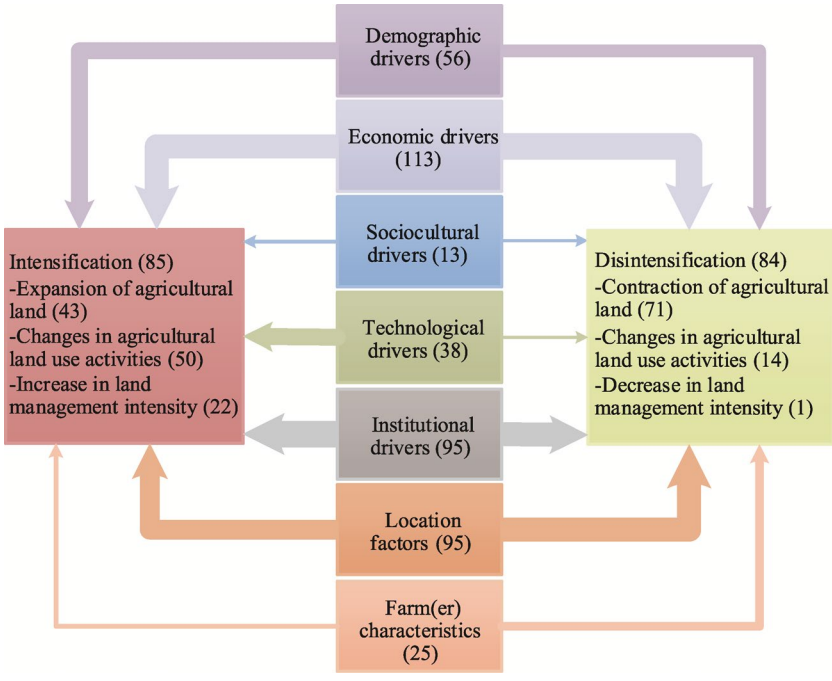

Figure 5 Underlying drivers and their impacts on agricultural land use change
(Note: With respect to manifestations of agricultural land change, the number in the parentheses refers to the number of the case studies reported. In terms of underlying drivers, the number in the parentheses refers to the frequency with which a driver is related to a manifestation of change, and the width of the line is drawn proportional to this number.)

The main manifestations of agricultural land intensification were changes in agricultural land use activities and expansion of agricultural land, and their occurrence frequencies were

50 and 43, respectively. In comparison, the number of cases related to increases in land management intensity was relatively small, at 22. In addition, the cases related to increases in land management intensity were usually also related to changes in agricultural land use activities, and there were 14 of these cases, which was higher than the number of cases reporting both changes in agricultural land use activities and the expansion of agricultural land at 12. From the perspective of spatial distribution (Figure 6a), cases that reported expansions of agricultural land were mainly concentrated in the GXR and the NER. In contrast, cases that reported changes in agricultural land use activities, with the main manifestations being conversion of food crops to cash crops or intensive gardening (Sjögersten *et al*., 2013; Yin *et al*., 2014; Su *et al*., 2016; Zhou *et al*., 2017), were predominantly located in the HHH, the YRR, the LPR and the SER. Cases that reported an increase in land management intensity, mainly manifested by the adoption of more fertilizer or advanced machinery, were also mainly located in the above four regions. Moreover, the NER was another area with a concentration of cases reporting changes in agricultural land use activities, with the main manifestation being the expansion of paddy fields (Yan *et al*., 2016a; Lu *et al*., 2017).

Intensification of agricultural land is typically a result of multiple underlying drivers (Figure 7a). Among the seven underlying drivers, economic and institutional drivers were mentioned more often, followed by location factors, demographic drivers and technological drivers, whereas farm(er) characteristics and sociocultural drivers were reported in few cases. The situation was different when considering the three manifestations. Specifically, demographic, institutional, economic, and technological drivers, together with location factors were all frequently reported in cases concerning agricultural land expansion, accounting for more than 40% of the related cases. Economic and institutional drivers, together with location factors were also the drivers most frequently mentioned in cases related to changes in agricultural land use activities, with a frequency of occurrence above 50% of the total number of related cases. In terms of the increase in land management intensity, economic drivers and institutional drivers, together with technological drivers, were the most frequently reported in cases, and their occurrence frequency was over 60% of the total number of cases. Detailed information describing the relations between agricultural land use change and the underlying drivers can be found in Table 2.

The disintensification of agricultural land was mostly displayed by agricultural land shrinkage, mainly including land abandonment and the return of agricultural land to forest/grassland, whose frequency of occurrence equaled 71. Changes in agricultural land use activities, mainly those involving the switch from double cropping to single cropping in one year, had a frequency of occurrence of 14. Only one case related to an increase in land management intensity. Notably, the majority of the cases reported only one manifestation rather than two or more manifestations (Figure 7b). Spatially, more than 70% of the cases were related to disintensification, and approximately 2/3 (68%) of the cases were related to the shrinkage of agricultural land concentrated in the YRR, the HHH, the SWR and the LPR (Figure 6b). For cases concerning changes in agricultural land use activities, the HHH, the YRR and the TPR were the three main regions where the changes were concentrated. The only case that reported a decrease in land management intensity was located in the YRR, where land inputs were reduced on the marginal lands in Xianning city of Hubei Province (Liu and Huang, 2014).

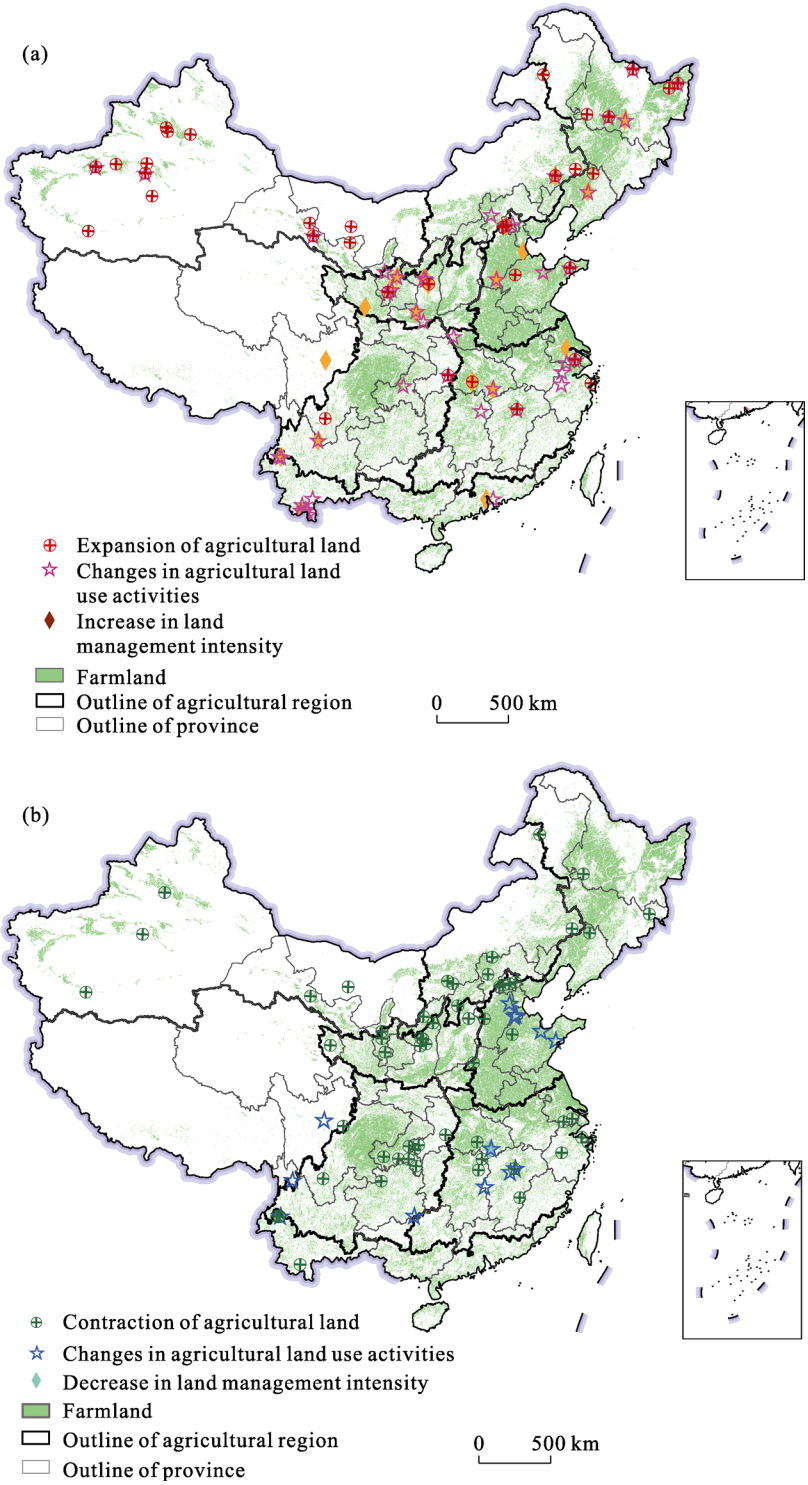

Figure 6 Locations of the case studies for three categories of intensification (a) and disintensification (b) of agricultural land

(Note: The geometric centers are presented for case studies with multiple areas or large areas.)

Approximately 80% of the cases related to disintensification reported two or more underlying drivers, and 50% of these cases were caused by no less than three underlying drivers. Specifically, economic drivers, location factors and institutional drivers were more frequently mentioned than the other drivers, and they often simultaneously affected disintensification, especially in terms of agricultural land contraction (Figure 7b and Table 2). However, for changes in agricultural land use activities, the situation was different, with the most important ones being economic drivers and location factors. In addition, farm(er) characteristics were also important drivers influencing agricultural land use activities, which were reported in six (or 43%) of the related cases. Here, the analysis of the underlying drivers of the decrease in land management intensity was not included because the number of cases was too small.

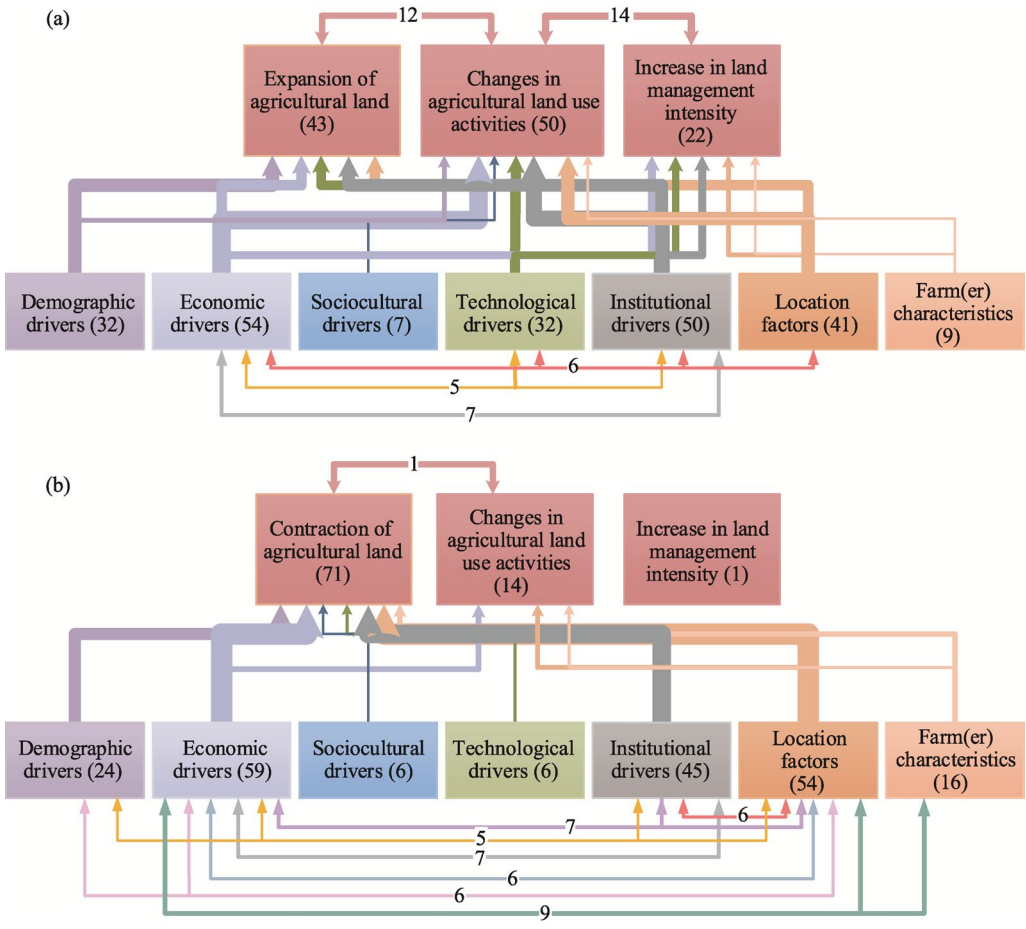

Figure 7 Manifestations and underlying drivers of intensification (a) and disintensification (b) of agricultural land

(Note: With respect to manifestations of intensification/disintensification, the number in the parentheses refers to the number of the case studies reported. In terms of underlying drivers, the number in the parentheses refers to the frequency of a driver that is related to a manifestation of change, and the width of the line is drawn proportional to this number. The number on the arrow refers to the cooccurrence frequency of manifestations or underlying drivers within one case. Here, only drivers or cooccurrences that were reported in no less than 5% of the cases are shown.)

Table 2 Frequencies of the manifestations of intensification/disintensification of agricultural land and the related underlying drivers

Underlying drivers	Intensification (*n*=85)								Distensification (*n*=84)							
	n	%	Expansion of agricultural land (*n*=43)		Changes in agricultural land use activities (*n*=50)		Increase in land management intensity (*n*=22)		*n*	%	Contraction of agricultural land (*n*=71)		Changes in agricultural land use activities (*n*=14)		Decrease in land management intensity (*n*=1)	
			n	%	*n*	%	*n*	%			*n*	%	*n*	%	*n*	%
Demographic drivers	32	38	25	58	9	18	4	18	24	38	23	32	1	7	0	0
Population	30	35	24	56	9	18	3	14	20	23	20	28	0	0	0	0
Agricultural labor force	9	11	3	7	4	8	2	9	14	15	9	13	5	36	0	0
Economic drivers	54	64	20	47	38	76	15	68	59	70	49	69	11	79	1	100
GDP	13	15	10	23	5	10	1	5	16	24	16	23	0	0	0	0
Urbanization	8	9	3	7	6	12	0	0	26	34	26	37	0	0	0	0
Off-farm employment	15	18	1	2	12	24	8	36	23	29	17	24	6	43	0	0
Market factors	35	41	9	21	29	58	11	50	29	24	21	30	9	64	1	100
Sociocultural drivers	7	8	2	5	5	10	1	5	6	5	5	7	1	7	0	0
Recreation and tourism	2	2	0	0	2	4	0	0	2	2	2	3	0	0	0	0
Societal demand for ecosystem services	1	1	1	2	1	2	0	0	1	1	1	1	0	0	0	0
Ethnic cultures	4	5	1	2	2	4	1	5	3	3	2	3	1	7	0	0
Technological drivers	32	38	18	42	19	38	14	64	6	12	6	8	0	0	0	0
Land improvement	22	26	15	35	10	20	8	36	5	8	5	7	0	0	0	0
New breeds and cultivars	11	13	3	7	10	20	8	36	1	1	1	1	0	0	0	0
Mechanization	11	13	6	14	7	14	4	18	5	10	5	7	0	0	0	0
Institutional drivers	50	59	24	56	35	70	15	68	45	54	43	61	3	21	0	0
Land tenure security	13	15	2	5	11	22	7	32	0	1	0	0	0	0	0	0
Agricultural subsidies	6	7	5	12	5	10	0	0	0	23	0	0	0	0	0	0

(*To be continued on the next page*)

(*Continued*)

Underlying drivers	Intensification (n=85)								Distensification (n=84)							
	n	%	Expansion of agricultural land (n=43)		Changes in agricultural land use activities (n=50)		Increase in land management intensity (n=22)		n	%	Contraction of agricultural land (n=71)		Changes in agricultural land use activities (n=14)		Decrease in land management intensity (n=1)	
			n	%	n	%	n	%			n	%	n	%	n	%
Land use plans	25	29	16	37	15	30	6	27	13	34	13	18	0	0	0	0
Ecological improvement policy	12	14	4	9	10	20	8	36	41	18	39	55	3	21	0	0
Economic development policy	12	14	4	9	10	20	4	18	9	56	9	13	0	0	0	0
Location factors	41	48	20	47	25	50	9	41	54	15	46	65	9	64	1	100
Soil quality	7	8	4	9	3	6	2	9	17	24	13	18	4	29	1	100
Topography	12	14	4	9	7	14	3	14	24	11	21	30	3	21	1	100
Climate	16	19	9	21	9	18	3	14	12	12	11	15	1	7	0	0
Accessibility	23	27	10	23	14	28	4	18	33	31	26	37	8	57	1	100
Neighborhood	6	7	1	2	5	10	0	0	7	11	5	7	2	14	0	0
Natural hazards	9	11	4	9	6	12	5	23	13	14	13	18	0	0	0	0
Land circulation	0	0	0	0	0	0	0	0	4	13	4	6	0	0	0	0
Farm(er) characteristics	9	11	1	2	5	10	5	23	16	21	10	14	6	43	0	0
Age	2	2	1	2	1	2	0	0	7	8	4	6	3	21	0	0
Education	3	4	1	2	0	0	2	9	2	4	1	1	1	7	0	0
Farm/household economics	5	6	0	0	3	6	4	18	9	1	4	6	5	36	0	0
Awareness/willingness	2	2	0	0	1	2	1	5	4	4	4	6	0	0	0	0
Land fragmentation	3	4	0	0	1	2	2	9	9	14	6	8	3	21	0	0
Farm size	2	2	1	2	0	0	1	5	4	3	3	4	1	7	0	0
Concurrent employment	0	0	0	0	0	0	0	0	1	2	1	1	0	0	0	0

3.3 Major trajectories of agricultural land use change

According to the previous analysis, agricultural land use change is often influenced by multiple underlying drivers, and the contributions of different underlying drivers differ. At the same time, the same underlying driver often plays a role in different manifestations, and the direction of this driver action may also differ. By integrating the manifestations of intensification/disintensification of agricultural land and the related underlying drivers, we identified three dominant trajectories of agricultural land use change that spread across China. These trajectories were the simultaneous appearance of the intensive use of high-productivity agricultural land and the extensive use of low-productivity agricultural land due to rising labor costs and the concomitant increase in off-farm employment across China, the return of sloping agricultural land to forest or grassland together with diverse changes in agricultural land use activities related to ecological improvement policy in mountainous areas of China, and the spatial shift in agricultural land characterized by the expansion of agricultural land due to regional population growth and agricultural techniques improvement in Northwest and Northeast China.

The combination of intensive and extensive use of agricultural land is relatively widespread in China and can be attributed mainly to the rise in labor prices and the concomitant increase in off-farm employment. With rapid economic development and urbanization, China is also undergoing a transformation of rural to urban dual structure, represented by these rising labor prices and large amounts of off-farm employment opportunities offered by secondary and tertiary industries. Rising labor prices lead to higher costs of agricultural production, and to obtain higher profits, some farmers may choose to shift their land use behavior to more profitable cash or horticultural crops and to increase their labor or capital inputs. This occurred more often on the plains or on mountainous agricultural land with high productivity than on other lands (Xu *et al*., 2007; Zhai and Liu, 2009; Liu *et al*., 2012; Yu *et al*., 2017). Changes in the dietary patterns of urban dwellers have facilitated this shift and have led to a greater concentration of cases that note the conversion of agricultural land to intensive horticulture in suburban areas (Liu *et al*., 2012; Song *et al*., 2017). In contrast, some other farmers have opted for off-farm employment, which tends to result in the extensive use of abandoned agricultural land due to labor shortages. This mainly occurred in mountainous areas or on less-favored land plots with poor soils and small areas and under poor irrigation conditions in plain areas (Xin and Li, 2009; Hua *et al*., 2013; Wang *et al*., 2016; Zhao and Li, 2016). Thus, the coexistence of intensive and extensive use of agricultural land can be identified at both large and small scales in China.

Ecological improvement policies, including the Sloping Land Conversion Program (SLCP), the Natural Forest Protection (NFP) policy and the Return Land to Lake (RLL) policy, were other essential driving factors of agricultural land use change, which led to the conversion of sloping cultivated land to forest, grassland or wetland (Liu *et al*., 2007; Li *et al*., 2012; Yin *et al*., 2014). Notably, the SLCP is regarded as the largest payment program for ecosystem services not only in China but also in the developing world (Yin *et al*., 2014). A total of 25 provincial-level administrative regions and 1897 county-level administrative units are involved in the SLCP in China, and more than 1.48 million ha of sloping arable land has been returned to forest or grassland, with a total investment of approximately 534 billion yuan (Office of SLCP, 2018; SFC, 2018). The SLCP not only directly reduces farm-

land area but also accelerates the out-migration of rural labors to off-farm sectors. Thus, the use of the remaining limited arable land tended to become diversified. Some farmers opted for disintensification, such as land abandonment or leasing out their land (Hageback *et al*., 2005; Hao *et al*., 2015; Wang *et al*., 2017a). At the same time, another group of farmers opted for intensification, shifting to cash crops and simultaneously increasing production expenditures to offset the negative impact of the SLCP program on the income of household (Yin *et al*., 2014; Wang *et al*., 2017a). Overall, given the transformation of the urban-rural dual structure, the SLCP has promoted diversification of agricultural land use in mountainous areas, resulting in a more diverse pattern of farmland use than that prior to the program (Bai *et al*., 2015; Wang *et al*., 2017a).

The expansion of agricultural land occurred mainly in the GXR and the NER. Of the types of expansion, oasis expansion, originating from grassland, desert and alkaline land, was the primary manifestation in the GXR, whereas the main manifestation in the NER is paddy field expansion, originating from grassland, wetland, and dry land (Tang *et al*., 2011; Yan *et al*., 2016a; Maieryemu *et al*., 2017; Zhou *et al*., 2017). The increase in regional population has led to an increased demand for arable land, especially from the large number of in-migrants as new agricultural operators and their demand for continuous large-scale cultivation, which has been the main driver of expansion (Cheng *et al*., 2005; Zhu and Li, 2011; Zhang *et al*., 2015). In addition, agricultural technological improvements, especially the advancement of irrigation technology, the improvement in seed technology, and the promotion of agricultural machinery, have effectively increased the feasibility of land expansion (Chen *et al*., 2010; Zhang *et al*., 2015; Yan *et al*., 2016a). In comparison with the GXR and the NER, in other regions of China where reserve arable land resources are abundant, there is little room for agricultural land expansion. The agricultural land around cities has even been largely occupied by construction land, a phenomenon that is particularly evident in the eastern coastal regions and has spread significantly to the central and western regions in recent years (Wang, 2020). Thus, taking into account the decreasing amount of arable land in mountainous areas due to rising labor prices and the SLCP program, the center of gravity of China's agricultural land is shifting northwards.

4 Discussion

4.1 Comparison with agricultural land use change and its underlying drivers in Europe

The economic development of Europe occurred much earlier than that of China, and the processes of agricultural land use change that have occurred in Europe may be occurring or about to occur in China (Li and Li, 2017). Therefore, it is important to compare the agricultural land use change and its underlying drivers in China and Europe, which may help find the research gaps and make recommendations for future research in China.

As mentioned above, van Vliet *et al*. (2015) has synthesized agricultural land use change and its underlying drivers across Europe. A comparison of van Vliet *et al*.'s (2015) study and our study reveals that case studies in Europe focus more on the disintensification of agricultural land, while Chinese case studies focus on both intensification and disintensification, as the number of cases in both areas are similar. In terms of the specific manifestations of ag-

ricultural land use, only three, not five, categories of manifestation were used in the present study to summarize agricultural land use change across China more concisely and explicitly. Specifically, in the present study, the category named change in agricultural land use activities covered three categories, including change in landscape elements, change in agricultural land use activity and specialization/diversification, as noted in van Vliet *et al*. (2015). Most Chinese cases focused on the expansion/contraction of agricultural land and changes in agricultural land use activities. Fewer cases related to increases in land management intensity, and only one case related to decreases in land management. This scenario may have been because the increase or decrease in inputs can related to the phenomenon of changes in agricultural land use activities, such as the conversion of food crops to cash crops or intensive gardening, land abandonment, and the switch from double cropping to single cropping in one year. In addition, a decrease in land management intensity may have been overlooked in the context of China's continuous increase in total grain production (Zuo *et al*., 2018; Huang *et al*., 2020).

The major underlying drivers grouped in this study were similar to those in Europe, although there were differences in the specific contents of some drivers or their frequencies of occurrence. Specifically, the role and importance of technological, institutional, and sociocultural drivers to intensification and disintensification of agricultural land were similar in both studies. However, in comparison with the case in Europe, where demographic and economic drivers were usually used to explain disintensification of agricultural land, the cases in present study showed the importance of these two drivers to both intensification and disintensification of agricultural land in China. As mentioned above, regional population growth mainly contributed to the expansion of agricultural land in western and eastern China, while off-farm employment and market prices were frequently cited to explain changes from food crops to cash crops or intensive gardening and increases in land management intensity (Xu *et al*., 2007; Zhai and Liu, 2009; Dong *et al*., 2011; Zhang *et al*., 2015). In addition, although location factors play important roles in both intensification and disintensification of agricultural land in both China and Europe, there were more studies on location factors in Chinese case studies. Typically, natural hazards were more frequently mentioned in China (Table 2), as one of the world's most natural disaster-prone countries (He *et al*., 2016; Yan *et al*., 2016b; Wang *et al*., 2017a). Additionally, in comparison to European case studies, Chinese case studies focused less attention on farm(er) characteristics, and the specific contents were also different, as age and household economics were mostly noted, leading to diverging land trajectories in Chinese case studies (Tian *et al*., 2015; Yan *et al*., 2016b; Wang *et al*., 2017b). The reason for this divergence may have been that although many studies have used household data for agricultural land use analysis, a greater proportion of them have used one year's data to explain the causes of agricultural land use variation among farmers rather than having used change, and studies more often used quantifiable information on farm(er) characteristics and tended to avoid information that was difficult to quantify (Xu *et al*., 2014; Chen *et al*., 2015; Hao *et al*., 2015; Hua *et al*., 2016). In addition, few cases related to motivations for farming, attitudes, and succession, i.e., the frequently mentioned farm(er) characteristics in the case studies in Europe (Sang *et al*., 2007; Hao and Ma, 2014).

4.2 Recommendations for future research on agricultural land use change and its underlying drivers in China

Based on the results of the present study and their comparison with the results of van Vliet *et al*. (2015), we propose recommendations for future research on agricultural land use change and its underlying drivers in China. We recommend that while continuing research on regional differences in changes in agricultural land intensification and on trends in arable land expansion and its drivers in areas with abundant reserve arable land resources, emphasis should also be placed on the following topics: *changes in land management intensity, especially the input side; in-depth exploration of the impact of farm(er) characteristics on agricultural land use change; changes in land use intensity due to the changes in agricultural operators*, and *construction of a research paradigm combining theoretical and empirical research on changes in land use intensity*.

Future research is recommended to complement the research on changes in land management intensity, which has not been given as much attention as the other two manifestations, i.e., expansion/contraction of agricultural land and changes in land use activities, in existing case studies. Notably, almost no research has focused on the decreases in land management intensity. There are many cases of land abandonment and seasonal abandonment (the switch from double cropping to single cropping in one year), and their impacts on food supply have been quantified (Wang *et al*., 2015; Li, 2017; Jiang *et al*., 2019). However, land abandonment is an extreme sign of extensive land use. Decreases in land management intensity during the process of extensive land use (often manifested as a decrease in capital and labor input) also significantly affect the output of arable land, which may cause more serious threats to food security than land abandonment (Li and Wang, 2003). However, due to low data availability, existing studies have conducted such research mostly at a national scale and have found decreasing trends in labor, seed, chemical and pesticide input in food production (Liu and Li, 2006; Chen *et al*., 2009). Where are these changes mainly concentrated? What are the driving mechanisms? The answers to these questions require more case studies. In addition, increases in land management intensity, for example chemical fertilizers, are often accompanied by changes in agricultural land use activities, but minimal research has been focused on increases in land management intensity. Although the addition of chemical inputs has increased output to a certain extent, the environmental damage and land quality degradation caused by these chemicals are also severe and have attracted widespread attention (MAC, 2014; Zuo *et al*., 2018). Thus, future research should also focus on increases in land management intensity, especially the causes of changes in chemical inputs, to help optimize farmland management measures. We also must note that in case studies on changes in land management intensity, detailed household survey data, including input-output data, may be the most appropriate data source (He *et al*., 2014).

An in-depth exploration of the impact of farm(er) characteristics on agricultural land use change is another recommendation for future case studies in China. Farm(er) characteristics are advantageous for explaining agricultural land use changes, especially in explaining different manifestations of agricultural land use changes from the same causes (Hageback *et al*., 2005; Wang *et al*., 2017a). However, as revealed in the present study, farm(er) characteristics are the second least frequently mentioned drivers in existing cases, only more than sociocultural drivers. As noted earlier, many studies have only used one year of household data

to analyze the impact of farm(er) characteristics on the differences in agricultural land use (Xu *et al*., 2014; Chen *et al*., 2015). This approach is not consistent with the changes in agricultural land use that the present study focuses on, and therefore, those studies were not included as case studies, limiting the frequency with which farm(er) characteristics appear in the cases. In the future, it is necessary to examine farm(er) characteristics more deeply, especially those that are difficult to quantify, such as motivation for farming, attitude, and succession, which will affect changes in agricultural land use. We recommend carrying out follow-up household surveys and using multiyear data to analyze the influence of farm(er) characteristics on agricultural land use change more scientifically and extensively. When restricted by conditions, one-year household data should also be combined with remote sensing data or theoretical models to more accurately determine the contribution of farm(er) characteristics to agricultural land use change (Su *et al*., 2016; Yan *et al*., 2016b).

In addition, future research should also pay attention to the changes in agricultural operators and the corresponding changes in land use intensity. After the implementation of the 'Trifurcation of Land Rights' system and the transfer of management rights of agricultural land in China, small households that have been dominant since 1978 are being replaced by new types of agricultural business entities, such as large-scale households, large farms, cooperatives, and agricultural enterprises. Although the small-scale operation of small households has not completely changed, the large-scale operation of agricultural land by new types of agricultural business entities will become a trend in the future (Lai *et al*., 2020). Compared with small households, large-scale arable land management by the new types of agricultural business entities is likely to result in changes in land use intensity (Wu *et al*., 2018). Only a few case studies have analyzed the impact of farm size and its approximate indicator, land fragmentation, on changes in agricultural land use (Tian *et al*., 2010; Xin and Wang, 2014). Are there differences in land use intensity before and after operation scaling in the same land plot? What are the influencing factors? Relevant research has only been conducted in recent years (Sheng *et al*., 2019). In the future, more attention should be paid to clarifying the changes in regional land use intensity resulting from arable land transfer and large-scale operations and their influencing factors. These studies are meaningful in that they provide suggestions for high and stable production and sustainable use of large-scale arable land.

Considering the deficiencies of the method in case studies, there is an urgent need to construct a research paradigm combining theoretical and empirical research. The present study reveals that the change of agricultural land use in China is the outcome of multiple underlying drivers. However, most of the cases only used statistical or qualitative analysis to detect the underlying drivers, there was some arbitrariness in the relevant indicators chosen, and the indicators of similar cases were partly different. Although these cases revealed the influencing factors of land use change, the results may not be reliable due to a lack of theoretical support (Zhang *et al*., 2014; Yan *et al*., 2016b). In the future, we should focus on the construction of a research paradigm for agricultural land use change, combining theoretical and empirical analyses, as well as on the construction of a driving force factor database (Su *et al*., 2016). These efforts could help analyze the causes of agricultural land use change more comprehensively and systematically by accurately revealing the key drivers and their mechanisms (Xin and Wang, 2014; Fezzi *et al*., 2015; Yan *et al*., 2016b). Thus, in compari-

son to other approaches, this approach will allow more rational and optimal agricultural land use policy recommendations be given.

5 Conclusion

This study uses systematic analysis to obtain a general overview of agricultural land use change and its underlying drivers after the initiation of the reform and opening up policy in 1978 in China. The analysis is based on the aggregation of evidence from 169 case studies from 123 publications during 1978–2017. Intensification and disintensification are two types of agricultural land use change, both containing three categories: expansion/contraction of agricultural land, changes in agricultural land use activities and changes in land management intensity. Five categories of underlying drivers, including demographic, economic, technological, and institutional drivers, together with location factors, play significant roles in both intensification and disintensification of agricultural land, while sociocultural drivers and farm(er) characteristics are less frequently mentioned in case studies. Three major trajectories of agricultural land use change were summarized according to the manifestations and their major underlying drivers, which were the simultaneous appearance of two types of agricultural land use change due to rising labor costs and the concomitant increase in off-farm employment across China, contraction of sloping land accompanied by diverse changes in agricultural land use activities related to ecological improvement policy in mountainous areas of China, and the northward shift in agricultural land dominated by regional population growth and agricultural technique improvement.

In addition, based on the above findings and a comparison of the findings with van Vliet *et al.*'s (2015) study in Europe, we provide recommendations for future research on agricultural land use change and its underlying drivers in China. It should be noted that the findings of this study are limited by cases in the published literature, which although widely distributed across the country, have inevitable omissions and may be updated in the future and as research hotspots change. Overall, this study provides a good reference for a comprehensive and systematic understanding of the agricultural land use change and its underlying drivers in China, as well as a good reference for similar studies in the future.

References

Bai X, Yan H, Pan L *et al*., 2015. Multi-agent modeling and simulation of farmland use change in a farming-pastoral zone: A case study of Qianjingou Town in Inner Mongolia, China. *Sustainability*, 7(11): 14802–14833.

Carpentier A, Gohin A, Sckokai P *et al*., 2015. Economic modelling of agricultural production: past advances and new challenges. *Review of Agricultural and Environmental Studies*, 96: 131–165.

Chen H, López-Carr D, Tan Y *et al*., 2015. China's Grain for Green policy and farm dynamics: Simulating household land-use responses. *Regional Environmental Change*, 16(4): 1147–1159.

Chen H, Wu S, Feng X, 2010. Study on the changes of cultivated land and the driving factors in Xinjiang based on RS and GIS. *Journal of Natural Resources*, 25(4): 614–624. (in Chinese)

Chen Y, Li X, Tian Y *et al*., 2009. Structural change of agricultural land use intensity and its regional disparity in China. *Journal of Geographical Sciences*, 19(5): 545–556.

Cheng W, Zhou C, Liu H *et al*., 2005. The expansion of oasis areas and its eco-environemntal changes during the past 50 years in the Manas River Basin. *Science in China Ser. D Earth Sciences*, 27(2): 71–76. (in Chinese)

Cui Z, Zhang H, Chen X *et al*., 2018. Pursuing sustainable productivity with millions of smallholder farmers. *Nature*, 555: 363–366.

Dong J, Liu J, Yan H *et al*., 2011. Spatio-temporal pattern and rationality of land reclamation and cropland abandonment in mid-eastern Inner Mongolia of China in 1990–2005. *Environmental Monitoring and Assessment*, 179(1–4): 137–153.

Fezzi C, Harwood A R, Lovett A A *et al*., 2015. The environmental impact of climate change adaptation on land use and water quality. *Nature Climate Change*, 5(3): 255–260.

Folberth C, Khabarov N, Balkovič J *et al*., 2020. The global cropland-sparing potential of high-yield farming. *Nature Sustainability*, 3(4): 281–289.

Hageback J, Sundberg J, Ostwald M *et al*., 2005. Climate variability and land-use change in Danangou Watershed, China: Examples of small-scale farmers' adaptation. *Climatic Change*, 72(1/2): 189–212.

Hao H, Li X, Zhang H *et al*., 2015. Impact of the opportunity cost of farming labor on the agricultural land marginalization. *Journal of Arid Land Resources and Environment* 29(3): 50–56. (in Chinese)

Hao R, Ma L, 2014. Discussion on the farmland abandonment in the semiarid area in Inner Mongolia: A case study of Hollinger County. *China Land Science*, 28(10): 48–56. (in Chinese)

He J, Lang R, Xu J, 2014. Local dynamics driving forest transition: Insights from upland villages in Southwest China. *Forests*, 5(2): 214–233.

He W, Yan J, Zhou H *et al*., 2016. The micro-mechanism of forest transition: A case study in the mountainous areas of Chongqing. *Journal of Natural Resources*, 31(1): 102–113. (in Chinese)

Hua X, Yan J, Li H *et al*., 2016. Wildlife damage and cultivated land abandonment: Findings from the mountainous areas of Chongqing, China. *Crop Protection*, 84: 141–149.

Hua X, Yan J, Zhou C *et al*., 2013. Marginalization of agricultural land use in hilly areas and its explanation from the livelihood strategy of farmers: A case study on Youyang County. *Acta Scientiarum Naturalium Universitatis Pekinensis*, 49(6): 1047–1055. (in Chinese)

Huang J, Ridoutt B G, Sun Z *et al*., 2020. Balancing food production within the planetary water boundary. *Journal of Cleaner Production*, 253.

Jiang L, Deng X, Seto K C, 2013. The impact of urban expansion on agricultural land use intensity in China. *Land Use Policy*, 35: 33–39.

Jiang M, Li X, Xin L *et al*., 2019. Paddy rice multiple cropping index changes in Southern China. *Journal of Geographical Sciences*, 29(11): 1773–1787.

Karelakis C, Tsantopoulos G, 2017. Changing land use to alternative crops: A rural landholder's perspective. *Land Use Policy*, 63: 30–37.

Kennedy C M, Hawthorne P L, Miteva D A *et al*., 2016. Optimizing land use decision-making to sustain Brazilian agricultural profits, biodiversity and ecosystem services. *Biological Conservation*, 204: 221–230.

Lai Z, Chen M, Liu T, 2020. Changes in and prospects for cultivated land use since the reform and opening up in China. *Land Use Policy*, 97: 104781.

Li P, Feng Z, Jiang L *et al*., 2012. Changes in rice cropping systems in the Poyang Lake Region, China during 2004–2010. *Journal of Geographical Sciences*, 22(4): 653–668.

Li S, 2017. An etimation of the extent and risk assessment of cropland abandonment in mountainous regions of China [D]. Beijing: University of Chinese Academy of Sciences. (in Chinese)

Li S, Li X, 2017. Global understanding of farmland abandonment: A review and prospects. *Journal of Geographical Sciences*, 27(9): 1123–1150.

Li X, Wang X, 2003. Changes in agricultural land use in China: 1981–2000. *Asian Geographer*, 22(1/2): 27–42.

Liu C, Huang L, 2014. Analysis on changes of land use inputs and their willingness of land use for farmers. *Transactions of the Chinese Society of Agricultural Engineering*, 30(20): 297–305.

Liu C, Li X, 2006. Regional disparity in the changes of agricultural land use intensity in China during 1980–2002. *Journal of Geographical Sciences*, 16(3): 286–292.

Liu H, Yu G, Wang Q *et al*., 2012. Characteristics of farmers' land use behaviors in metropolises suburb: A case study in Sujiatun District of Shenyang City, Liaoning Province. *Resources Science*, 34(5): 879–888. (in Chinese)

Liu J, Kuang W, Zhang Z *et al*., 2014. Spatiotemporal characteristics, patterns and causes of land use changes in

China since the late 1980s. *Acta Geographia Sinica*, 69(1): 3–14. (in Chinese)

Liu M, Hu Y, Chang Y *et al*., 2007. Landscape change and its spatial driving force of farmlands in Wenchuan County of Minjiang River upper reach. *Chinese Journal of Applied Ecology*, 18(3): 569–574. (in Chinese)

Lu Y, Zhang Y, Cao X *et al*., 2019. Forty years of reform and opening up: China's progress toward a sustainable path. *Science Advances*, 5: eeau9413.

Lu Z J, Song Q, Liu K B *et al*., 2017. Rice cultivation changes and its relationships with geographical factors in Heilongjiang Province, China. *Journal of Integrative Agriculture*, 16(10): 2274–2282.

Maieryemu Y, Maimaiti S, Aishan T *et al*., 2017. Spatial-temporal characteristics of cropland in the Ugan-Kuqa river delta oasis. *Scientia Agricultura Sinica*, 50(18): 3506–3518. (in Chinese)

Meyfroidt P, Roy Chowdhury R, de Bremond A *et al*., 2018. Middle-range theories of land system change. *Global Environmental Change*, 53: 52–67.

Ministry of Agriculture of China (MAC), 2014. Bulletin of the cultivated land quality grade. available at: http://www. moa.gov.cn/govpublic/ZZYGLS/201412/t20141217_4297895.htm. (in Chinese)

Piao S, Ciais P, Huang Y *et al*., 2010. The impacts of climate change on water resources and agriculture in China. *Nature*, 467(7311): 43–51.

Qin Y, Zhang X, 2016. The road to specialization in agricultural production: Evidence from rural China. *World Development*, 77: 1–16.

Sang G, Ou Y, Chen Y, 2007. Analysis of cultivated land abandoning in developed areas of non-agricultural economy in Zhejiang Province *Journal of Anhui Agricultural Sciences*, 35(5): 1459–1461. (in Chinese)

SFC, 2018. China Forestry Development Report 2017. Beijing: China Forestry Publishing House. (in Chinese)

Sheng Y, Ding J, Huang J, 2019. The relationship between farm size and productivity in agriculture: Evidence from maize production in northern China. *American Journal of Agricultural Economics*, 101(3): 790–806.

Sjögersten S, Atkin C, Clarke M L *et al*., 2013. Responses to climate change and farming policies by rural communities in northern China: A report on field observation and farmers' perception in dryland of north Shaanxi and Ningxia. *Land Use Policy*, 32: 125–133.

Song B, Robinson G M, Zhou Z, 2017. Agricultural transformation and ecosystem services: A case study from Shaanxi Province, China. *Habitat International*, 69: 114–125.

Song W, Liu M, 2016. Farmland conversion decreases regional and national land quality in China. *Land Degradation & Development*, 28(2): 459–471.

Su S, Zhou X, Wan C *et al*., 2016. Land use changes to cash crop plantations: Crop types, multilevel determinants and policy implications. *Land Use Policy*, 50: 379–389.

Tang H, Zhang X, Yang D *et al*., 2011. Dynamic change and driving forces of cultivated land use in Sangong River Basin in recent 60 yeas. *Arid Land Geography*, 34(5): 843–850. (in Chinese)

Taylor M J, Aguilar-Støen M, Castellanos E *et al*., 2016. International migration, land use change and the environment in Ixcán, Guatemala. *Land Use Policy*, 54: 290–301.

Tian Q, Brown D G, Zheng L *et al*., 2015. The role of cross-scale social and environmental contexts in household-level land-use decisions, Poyang Lake region, China. *Annals of the Association of American Geographers*, 105(6): 1240–1259.

Tian Y, Li X, Ma G *et al*., 2010. Influences of labor emigration from agriculture on the production abandonment of cultivated land in ecological sensitive areas. *China Land Science*, 24(7): 4–9.

van Vliet J, de Groot H L F, Rietveld P *et al*., 2015. Manifestations and underlying drivers of agricultural land use change in Europe. *Landscape and Urban Planning*, 133: 24–36.

Wang C, Zhen L, Du B, 2017a. Assessment of the impact of China's sloping land conservation program on regional development in a typical hilly region of the Loess Plateau: A case study in Guyuan. *Environmental Development*, 21: 66–76.

Wang G, Liu Y, Li Y *et al*., 2014. Dynamic trends and driving forces of land use intensification of cultivated land in China. *Journal of Geographical Sciences*, 25(1): 45–57.

Wang X, 2020. Consumption of cropland with high yield and low irrigation water intensity by urban expansion in China during 2000–2015. *Ecological Indicators*, 117.

Wang X, Li X, Fischer G *et al*., 2015. Impact of the changing area sown to winter wheat on crop water footprint in the North China Plain. *Ecological Indicators*, 57: 100–109.

Wang X, Li X, Tan M *et al*., 2017b. Hierarchical determinants of winter wheat abandonment in the North China Plain: A case study of Xingzhuangzi village in Hebei Province. *NJAS - Wageningen Journal of Life Sciences*, 80: 49–56.

Wang X, Li X, Xin L *et al*., 2016. Ecological compensation for winter wheat abandonment in groundwater over-exploited areas in the North China Plain. *Journal of Geographical Sciences*, 26(10): 1463–1476.

Wang X, Xin L, Tan M *et al*., 2020. Impact of spatiotemporal change of cultivated land on food-water relations in China during 1990–2015. *Science of the Total Environment*, 716: 137119.

Wu Y, Xi X, Tang X *et al*., 2018. Policy distortions, farm size, and the overuse of agricultural chemicals in China. *Proceedings of the National Academy of Sciences of the United States of America (PNAS)*, 115(27): 7010–7015.

Xia M, Zhang Y, Zhang Z *et al*., 2020. Modeling agricultural land use change in a rapid urbanizing town: Linking the decisions of government, peasant households and enterprises. *Land Use Policy*, 90.

Xie H, Liu G, 2015. Spatiotemporal differences and influencing factors of multiple cropping index in China during 1998–2012. *Journal of Geographical Sciences*, 25(11): 1283–1297.

Xin L, Li X, 2009. Changes of multiple cropping in double cropping rice area of southern China and its policy implications. *Journal of Natural Resources*, 24(1): 56–63. (in Chinese)

Xin L, Wang J, 2014. Driving factors of fast-growing forest planting and its policy implications: Based on the household survey in two cities of Shandong Province. *Journal of Natural Resources*, 29(12): 1991–2000. (in Chinese)

Xu D, Guo S, Xie F *et al*., 2017. The impact of rural laborer migration and household structure on household land use arrangements in mountainous areas of Sichuan Province, China. *Habitat International*, 70: 72–80.

Xu H, Huang X, Zhong T *et al*., 2014. Chinese land policies and farmers' adoption of organic fertilizer for saline soils. *Land Use Policy*, 38: 541–549.

Xu J, Yang Y, Fox J *et al*., 2007. Forest transition, its causes and environmental consequences: Empirical evidence from Yunnan of Southwest China. *Tropical Ecology*, 48(2): 137–150.

Xu Z, Chau S N, Chen X *et al*., 2020. Assessing progress towards sustainable development over space and time. *Nature*, 577(7788): 74–78.

Yan F, Zhang S, Kuang W *et al*., 2016a. Comparison of cultivated landscape changes under different management modes: A case study in Sanjiang Plain. *Sustainability*, 8(10): 1071.

Yan J, Yang Z, Li Z *et al*., 2016b. Drivers of cropland abandonment in mountainous areas: A household decision model on farming scale in Southwest China. *Land Use Policy*, 57: 459–469.

Yin R, Liu C, Zhao M *et al*., 2014. The implementation and impacts of China's largest payment for ecosystem services program as revealed by longitudinal household data. *Land Use Policy*, 40: 45–55.

Yu B, Song W, Lang Y, 2017. Spatial patterns and driving forces of greenhouse land change in Shouguang City, China. *Sustainability*, 9: 359.

Zeng Z, Estes L, Ziegler A D *et al*., 2018. Highland cropland expansion and forest loss in Southeast Asia in the twenty-first century. *Nature Geoscience*, 11(8): 556–562.

Zhai R, Liu Y, 2009. Dynamic evolvement of agricultural system and typical patterns of modern agriculture in coastal China: A case of Suzhou. *Chinese Geographical Science*, 19(3): 249–257.

Zhang Y, Li C, Wang T *et al*., 2015. County-level patterns of cropland and their relationships with socio-economic factors in northwestern China. *Agriculture, Ecosystems & Environment*, 203: 11–18.

Zhang Y, Li X, Song W, 2014. Determinants of cropland abandonment at the parcel, household and village levels in mountain areas of China: A multi-level analysis. *Land Use Policy*, 41: 186–192.

Zhao Y, Li X, 2016. Spatial correlation between type of mountain area and land use degree in Guizhou Province, China. *Sustainability*, 8(9): 849.

Zhou D, Wang X, Shi M, 2017. Human driving forces of oasis expansion in Northwestern China during the last decade: A case study of the Heihe River Basin. *Land Degradation & Development*, 28(2): 412–420.

Zhu H, Li Y, 2011. An empirical analysis of the causes of farmland expansion in Northwest China. *Progress in Geography*, 30(5): 615–620. (in Chinese)

Zuo L, Zhang Z, Carlson K M *et al*., 2018. Progress towards sustainable intensification in China challenged by land-use change. *Nature Sustainability*, 1(6): 304–313.