Article

Review of Urbanization-Associated Farmland Research in China: A Sustainability Perspective

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Abstract: Farmland loss in drastically urbanizing landscapes has long been a research concern for resource management, landscape planning, and spatial governance, especially in the context of China. In recent years, the issue of urbanization-associated farmland loss (UAFL) seems to be increasingly recognized as relevant to sustainability. To date, however, existing studies have not yet comprehensively addressed the research gap between UAFL and sustainability. Here, we aim to help fill this knowledge gap by considering UAFL research as an example of the broader land/landscape-related literature, in a hope of informing future studies to better advance sustainability through land-related approaches. Specifically, we combined bibliometric analyses with code-based content analysis to reveal the knowledge base, thematic evolution, and historiographic paths of the literature on UAFL across China and the empirical case studies' relevance to sustainability. Our main findings include: (1) the examined literature barely draws insights from sustainability science and sustainability only started to arise as a notable topic at around 2016; (2) over half of the empirical studies show awareness in advancing sustainability and interest in understanding the social-environmental drivers and processes underlying landscape dynamics, yet few demonstrate methodological transdisciplinarity; (3) those sustainability-relevant studies either frame UAFL as depletion of the farmland resource that may threat China's food security and consequently hinder sustainable urbanization or frame UAFL as part of widespread landscape dynamics that affect the environmental outcome(s) or social–environmental tradeoffs of landscape multi-functions; and (4) existing empirical studies are disproportionately focused on 1991–2006, national, regional, and city scales, and some of China's most developed areas. Our findings provide an overview of this specific research avenue on UAFL and, more importantly, point to the imperative for land/landscape scholars to break out of their disciplinary silos, especially in the natural sciences, to generate more actionable sustainability insights.

Keywords: bibliographic review; cropland loss; urban sustainability; land system science; landscape sustainability science; social–environmental system

1. Introduction

Urbanization is a long-term global trend with multi-faceted social–environmental impacts and profound sustainability implications [1–5]. Particularly, the phenomenon of drastic farmland loss along with China's dramatic urbanization since its opening up to the world system in 1978 has long been raising socio-political and scholarly concerns from home and abroad [6–8]. In fact, the issue of urbanization-associated farmland loss (UAFL) has been widely researched across the world, especially in places that have undergone rapid urbanization [9–11]. The case of China is perhaps the most prominent, given the

pressure to feed China's world-leading population and potential impacts on the global food market [12]. Aside from the significance for China *per se*, studies of the Chinese case may provide insights for other places facing or to face the UAFL challenge [13]. In addition to the recognized practical significance of researching UAFL in China, Zhou and Lv [14] made an argument for the scientific significance of deciphering UAFL as a prototype of general sustainability issues—i.e., what/where to sustain versus what/where to develop—in advancing landscape sustainability [15–17] and sustainability science [18–20]. In this regard, one may wonder what sustainability insights the growing literature on UAFL has offered, if any. With such a big picture of the existing research landscape, there may be more fruitful discussions on how future UAFL studies can better contribute to land-related sustainability discourses.

To be fair, some two decades ago, founders of modern land-system science had synthesized the global patterns and causes of the few dominating land use/cover changes including farmland change [21–24]. More recently, Li and Li [25] reviewed existing studies about the patterns, causes, and consequences of global farmland abandonment as well as related policies. For farmland research particularly in the context of China, Wang and Li [26] conducted a systematic review of 169 case studies in 123 publications in the English and Chinese languages to synthesize the patterns, drivers, and change trajectories of farmland use intensification/deintensification. Also, there are studies synthesizing a plurality of datasets to reveal historical nationwide patterns of China's farmland change (e.g., [27,28]). These noted synthetic or review studies have made valuable contributions to depicting the general transition dynamics of the whole land system, including farmland change, or summarizing some specific aspects of farmland change such as abandonment and de/intensification. Yet, these studies tend to conceptualize farmland change as purely an issue of natural resource management instead of a lens for revealing the underlying human–environment architecture and dynamics [14,17]. In other words, the traditional natural resource perspective limits the potential of farmland research in providing broader sustainability implications [29,30].

In the above context, it is imperative to bridge the gap between UAFL and sustainability. Timely attempts should be made to synthesize the sustainability insights embedded in the substantial UAFL literature. This research aims to bridge the gap by conducting such a synthetic review of the existing literature about the UAFL issue that explicitly takes a sustainability perspective [31,32]—namely, examining farmland change in relation to urbanization, with farmland as part of what is desired to be sustained versus urban land as part of what is intended to be developed. Prior to the synthesis, an overarching question must be addressed first, i.e., to what extent has the UAFL issue been studied as a prototype of the more general sustainability issues? Following from this, it might be possible to synthesize what has been known about UAFL's empirical patterns, key social–environmental processes, and common sustainability consequences. Here, we present a quantitative–qualitative review [16,30] of the existing literature on UAFL in the context of China as well as a preliminary meta-analysis [25,26] of the empirical studies therein. On top of existing review methodologies, our study integrates the comprehensiveness of bibliometric reviews [16], the idiosyncratic depth of traditional expert-based reviews [33], and the empirical insights of meta-analysis reviews [34]. Furthermore, our focus is on China, given that UAFL has been most extensively researched in China and that land-related sustainability studies are gaining increasing momentum. The analyses contained in our paper will help clarify how future UAFL research can better advance land-related approaches toward local, regional, and global social–environmental sustainability. The remainder of this paper is organized as follows: Section 2 documents data and methodological details; Section 3 reports the respective findings of the review and case synthesis; Section 4 discusses implications for advancing land-related approaches to sustainability, with the literature on China's UALF considered as a case of broader land-related research; and Section 5 presents the concluding remarks.

2. Materials and Methods

2.1. Literature Search and Data Collection

The data collection for this study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol [35] (Figure 1). Specifically, a literature search was conducted on 23 March 2021 using the Scopus Core Collection database (www.scopus.com). Scopus is more comprehensive than some other popular bibliographic databases, e.g., Web of Science Core Collection [36], and, thus, has been widely used. The first author searched for research articles published before 2021 that contained the terms of "urban*" AND "China" AND ("farmland" OR "cropland" OR "arable land" OR "cultivated land") in their titles, abstracts, or keywords, which resulted in 1496 items. The first author then did a follow-up screening of the titles and abstracts of the papers to exclude any study that did not focus on farmland in the context of urbanizing China, which resulted in 615 "relevant" papers. The bibliographic information of these papers was then exported and saved as our first database in this study for subsequent bibliographic analyses. Furthermore, the authors made their best efforts to download the full texts of the 615 papers (see Table S1 for bibliographic overview), which unfortunately included 9 papers with only abstracts available and even 3 papers missing their abstracts (see Table S2 for details). Next, the first author read the full texts of the 603 papers to select studies for qualitative coding of empirical cases that met the following four criteria: (1) categorized as empirical research; (2) focused on at least one of the three aspects of farmland, including spatiotemporal characteristics of farmland change, drivers of farmland change, and social–environmental consequences of farmland change; (3) employed quantitative analysis of any kind; and (4) researched an area at the city scale or above (n.b. a city in China corresponds to a county in the USA in terms of its administrative level). The selection resulted in 103 eligible papers as our second database for subsequent thematic coding of a range of variables for case synthesis.
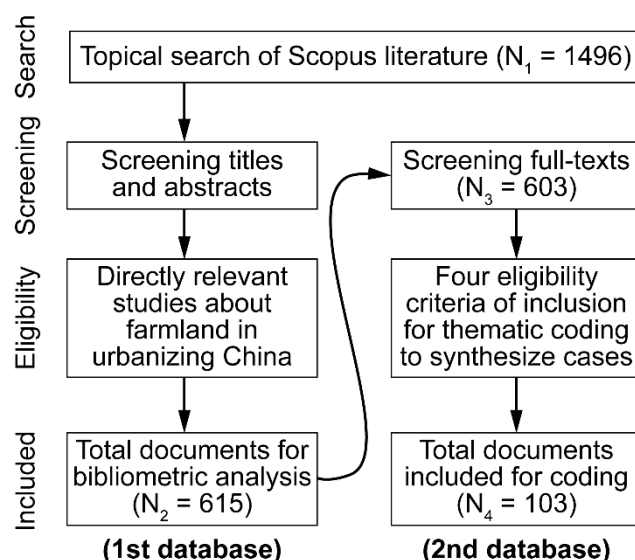

Figure 1. Flow diagram of data collection based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol. See text for the four criteria to filter eligible studies for thematic coding and case synthesis.

2.2. Bibliometric Analyses: Topic Mining, Historiography Mapping, and Beyond

To depict the big picture of the progress in researching farmland in the context of urbanizing China, we collected the bibliographic information of the 615 relevant papers for bibliometric analyses. First, we used the Bibliometrix R Package 3.2.1 (R version 4.2.0) [37] to gain an overview of the research landscape, with the 615 papers spanning from 1973 to 2020 (Table S1). Then, we deployed VOSviewer 1.6.13 [38] to mine the prominent research

topics from the keywords, titles, and abstracts, respectively, as implemented in Zhou, Wu, and Anderies [16], with topics mined from the keywords interpreted as expressed topics and those from titles and abstracts as latent topics. Furthermore, we harnessed HistCite^TM 12.3.17 (by Clarivate, London, UK) [39] to map the historiography of the research field (i.e., the literature's development paths over time) based on the top 25 papers with the most citations from within the 615 sampled papers (i.e., local citations). The full texts of the 25 seminal papers were read carefully and in relation to each other, as so recommended in Zhou, Wu, and Anderies [16]. Lastly, we also utilized HistCite^TM to identify the 20 most-cited references of the 615 papers for careful and relational reading of their full texts to understand the knowledge base of the research field. Note that our applications of VOSviewer and HistCite^TM adopted default settings.

2.3. Thematic Coding and Meta-Analysis of Case Studies

To understand the scope and depth of empirical studies examining farmland change in the context of urbanizing China, with regard to sustainability, we applied thematic coding [32,40] to the 103 empirical studies. First was the proposal of the initial codebook, based on informal coding, discussion, and revisions. Specifically, based on the first and second authors' full-text reading of the 25 top-cited sampled papers and the 20 most-cited references, as noted above, they discussed and proposed an initial set of themes. Based on the pilot coding by the first author and feedback from all the other authors, the formally coded themes were limited to: (1) whether the study was oriented toward improving sustainability; (2) whether the study adopted a social–environmental systems (SES) perspective; (3) the methodology of the study, i.e., qualitative, quantitative, or mixed, as so advocated by the sustainability science literature; (4) study period; (5) geographical scale of the study; and (6) study area. Particularly, the theme of sustainability orientation was included to synthesize whether a study goes beyond UAFL *per se* to further address UAFL's social-environmental impacts, and the theme of SES perspective to synthesize whether a study delves deeper into the social–environmental processes or mechanisms that underlie various types of UAFL. Zhou, Wu, and Anderies [16] distinguish three types of sustainability interpretations, namely, the sustainability of natural capital (i.e., landscape *per se*), sustainability of ecosystem services (i.e., landscape-based functions or services), and sustainability of human wellbeing (i.e., landscape-based social–environmental systems). Here, those focusing on sustaining farmland *per se* were not coded as sustainability-oriented. Moreover, according to the synthesis by Zhou, Wu, and Anderies [32], sustainability science is characterized by the social–environmental systems perspective and the transdisciplinary perspective. Here, we code the transdisciplinary perspective as a qualitative–quantitative mixed methodological orientation, which is less controversial. While coding, the first author also noted down some of the 103 studies' data sources, research methods, and empirical findings on the spatiotemporal characteristics, drivers, and social–environmental consequences of farmland change, although these additional codings are not presented as part of the results.

3. Results

3.1. Knowledge Base, Thematic Evolution, and the Literature Development Paths

The knowledge base of the 615 sampled studies on urbanization-associated farmland in China can be inferred from their references, of which we analyzed the top-cited 20 (Table 1). These key references were published mainly in *Land Use Policy* (45%), followed by general journals (i.e., *Science*, *Nature*, and *Proceedings of the National Academy of Sciences of the United States of America*; 20%), with the rest published in journals related to the environment or geography (e.g., *Remote Sensing of Environment*, *Catena*, and *Journal of Geographical Science*; 35%). Full-text reading of these references showed that the majority were relevant empirical studies, with Tan et al. [41] and Deng et al. [42] directly addressing UAFL in China and some others focusing on either farmland [43–47], urbanization [48,49], or land use/cover change in general [50–56]. Among the remaining four that are not so closely related to

UAFL in China, Lambin et al. [21] and Foley et al. [24] provide theoretical insights about land use change trends and transitions, Grimm et al. [57] introduce the ecological basis of urban sustainability in particular in an era of global change, and the ecosystem services evaluation method proposed in Costanza et al. [58] has been widely used in assessing the impacts of land use/cover change. Overall, these references seem to confirm our tentative observation in the Introduction that the existing studies of UAFL in China mostly take a natural resource management perspective, lacking a sustainability perspective to treat farmland loss and urban expansion as two intertwined "landscape signals" of their underlying social–environmental architecture.

Table 1. The 20 top-cited references of the 615 sampled papers on UAFL in China.

Publication	Title	Source
Tan, M.H. et al. (2005) [41]	Urban land expansion and arable land loss in China—a case study of the Beijing–Tianjin–Hebei region	*Land Use Policy*
Lichtenberg & Ding (2008) [46]	Assessing farmland protection policy in China	*Land Use Policy*
Foley et al. (2005) [24]	Global consequences of land use	*Science*
Liu, J.Y. et al. (2005) [44]	Spatial and temporal patterns of China's cropland during 1990–2000: An analysis based on Landsat TM data	*Remote Sensing of Environment*
Liu, J.Y. et al. (2003) [50]	Study on spatial pattern of land-use change in China during 1995–2000	*Science in China Series D-Earth Sciences*
Costanza et al. (1997) [58]	The value of the world's ecosystem services and natural capital	*Nature*
Liu, Y.S. et al. (2014) [56]	Key issues of land use in China and implications for policy making	*Land Use Policy*
Chen (2007) [48]	Rapid urbanization in China: a real challenge to soil protection and food security	*Catena*
Long et al. (2009) [47]	Spatio-temporal dynamic patterns of farmland and rural settlements in the Su–Xi–Chang region: Implications for building a new countryside in coastal China	*Land Use Policy*
Liu, J.Y. et al. (2014) [55]	Spatiotemporal characteristics, patterns, and causes of land-use changes in China since the late 1980s	*Journal of Geographical Sciences*
Long et al. (2012) [54]	Accelerated restructuring in rural China fueled by 'increasing vs. decreasing balance' land-use policy for dealing with hollowed villages	*Land Use Policy*
Liu, J.Y. et al. (2010) [53]	Spatial patterns and driving forces of land use change in China during the early 21st century	*Journal of Geographical Sciences*
Deng, X.Z. et al. (2015) [42]	Impact of urbanization on cultivated land changes in China	*Land Use Policy*
Yang & Li (2000) [43]	Cultivated land and food supply in China	*Land Use Policy*
Seto et al. (2012) [49]	Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools	*Proceedings of the National Academy of Sciences of the United States of America*
Long et al. (2007) [52]	Socio-economic driving forces of land-use change in Kunshan, the Yangtze River Delta Economic Area of China	*Journal of Environmental Management*
Deng, X.Z. et al. (2006) [45]	Cultivated land conversion and potential agricultural productivity in China	*Land Use Policy*
Grimm et al. (2008) [57]	Global change and the ecology of cities	*Science*
Lambin et al. (2001) [21]	The causes of land-use and land-cover change: Moving beyond the myths	*Global Environmental Change*
Lin & Ho (2003) [51]	China's land resources and land-use change: Insights from the 1996 land survey	*Land Use Policy*

To provide more direct evidence for the lack of a sustainability perspective in studies about China's UAFL, text mining was conducted to reveal the prominent topics of the 615 sampled papers. The expressed topics that the papers claimed to cover (i.e., *keywords*)

fall mainly into four clusters (Figure 2A): (1) the red cluster on urban planning, development, and growth considering farmland for sustainability; (2) the blue cluster on techniques and tools for monitoring land use/cover change; (3) the green cluster on environmental protection and natural resource conservation in the face of economic development and climate change; and (4) the yellow cluster on the ecological, economic, and social impacts of landscape dynamics and related ecosystem services tradeoffs for sustainable development. The latent topics that the papers actually address (in their *titles* and *abstracts*) also cluster into four groups (Figure 2B): (1) the red cluster on farmland and construction land research in the context of rural transition and sustainability; (2) the yellow cluster on conversions between multiple land uses including farmland; (3) the blue cluster on the impacts of urbanization; and (4) the green cluster on place-based and scenario-based studies of urban agglomerations and their impacts such as on ecosystem services value, ecological space, and carbon storage. The two topical landscapes seem to reaffirm the above-noted observation—more specifically, the existing studies relevant to UAFL in China mostly address land use/cover change in general, sustainable landscape urbanization considering multi-dimensional impacts, or farmland use for food security and rural sustainability. Furthermore, the thematic evolution of the topics suggests that sustainability is still a nascent topic within UAFL research in China, which emerged as only mildly noticeable around 2016 (Figure 2C,D).
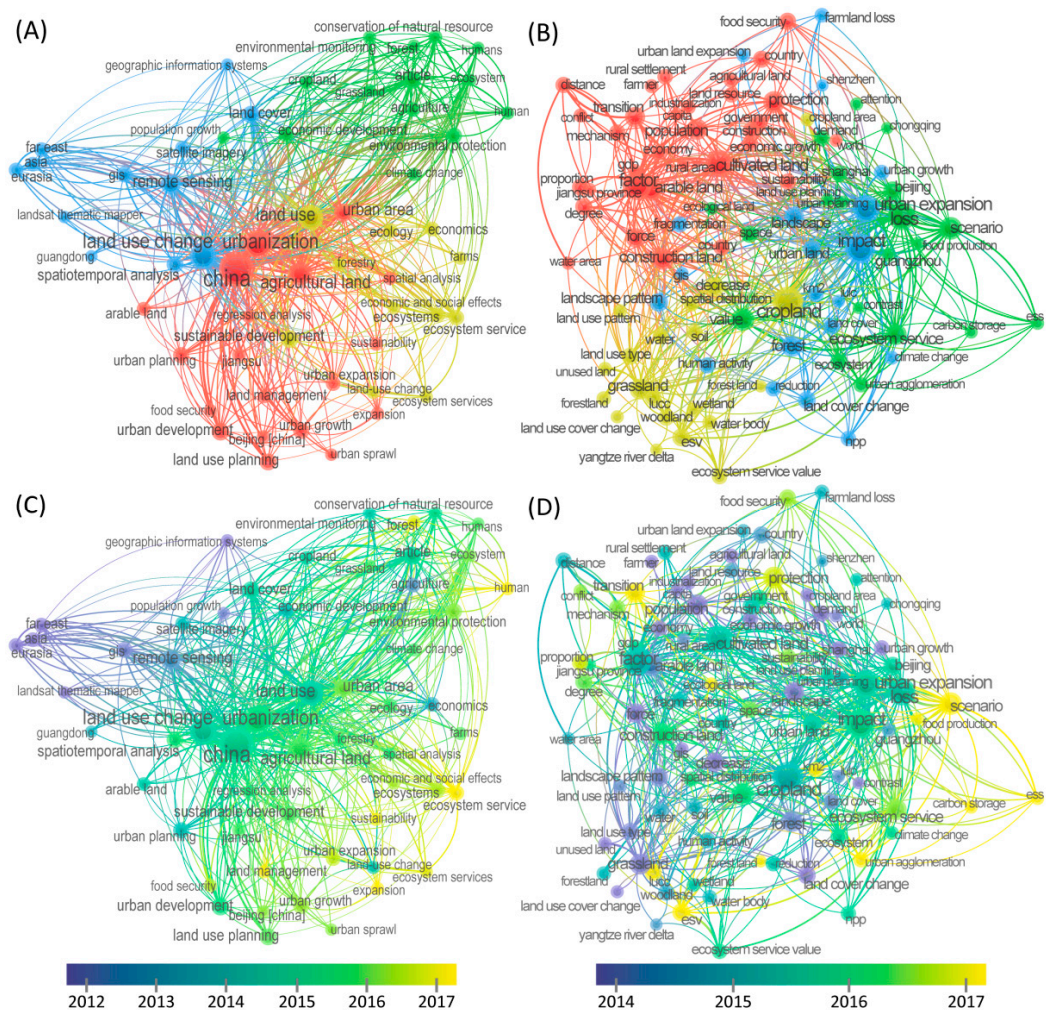

Figure 2. Thematic clustering of the topics identified from the *keywords* (**A**), *titles*, and *abstracts* (**B**), as well as their temporal evolution (**C,D**). The node size of a phrase is proportionate to its relative frequency. The analyses adopted VOSviewer's default settings; the association strength method was used for normalizing the strength of the links between nodes.

To provide further and more in-depth insights into how UAFL research in China has evolved, a historiograph of the literature development paths was mapped out based on key citation linkages among the 615 sampled papers. The closely intertwined topology of the historiograph suggests the existence of a cohesive research community studying UAFL in China, which has come into formation especially since around 2005 (Figure 3). The future-oriented simulation study of China's land use/cover change by Verburg et al. [59] was perhaps among the earliest to raise scholarly concerns over China's farmland loss and reduction in production capacity along with urbanization (and desertification and afforestation) as well as the quality of lost farmland. These concerns have been intensively researched by subsequent studies of UAFL in China, e.g., the area and quality of lost farmland, urban uptake of farmland, urbanization impacts on farmland change, and food production capacity reduction due to farmland loss.

The majority of the seminal papers after Verburg, Veldkamp, and Fresco [59] are those empirically examining land use/cover change in China or its different regions often based on either remote sensing or official survey data, and have reported widespread farmland loss and urban expansion [44,47,51,60–68]. Yet, based on official survey data of national land use, Lin and Ho [51] found that China's farmland loss since the 1990s was due mainly to agricultural restructuring and, following that, non-agricultural developments (Tables 7–9 therein). The view that urban expansion is mainly to blame for farmland loss was revisited by Liu et al. [69] based on the same survey data. They further revealed that, of the farmland lost to non-agricultural developments, the primary consumer was China's zeal for developing economic development zones, followed by transportation and rural settlements, while urban expansion (i.e., cities and towns) contributed the least. Relatedly, Tan et al. (2005b) [41] studied the urbanization side in more depth, and investigated the relationship between urban uptake of farmland and the administrative level of an urban region, based on remote sensing data. They found that about 74% of the newly urbanized land across the Beijing–Tianjin–Hebei region was converted from farmland, with the ratio tending to be higher for small cities. In this regard, Deng, Huang, Rozelle, Zhang, and Li [42] employed econometrics to model the potentially different impacts of urbanization modes (city, town, versus village modes) on farmland change, and concluded that the impact of urbanization was marginal and varied with the urbanization mode. Also using econometrics, Jiang et al. [70] directly modeled how the area of farmland converted for urban development was influenced by multi-level socioeconomic and policy factors, and demonstrated the dominant role of local factors and the unexpected role of agricultural investment in driving urban uptake of farmland. Further, Jiang et al. [71] modeled urbanization's impact on farmland use intensity (with the multi-cropping index as a proxy) and showed that farmland scarcity, agricultural investment, and land suitability have positive impacts on farmland intensification while urban uptake of farmland has a small and negative impact (Table 2 therein). Insightful as they are, the above-noted studies focus primarily on the "tree" *per se* instead of the "forest"—UAFL has been studied mainly for better farmland protection or smarter urban growth, lacking interest in UAFL's broader implications for social–environmental sustainability—in line with the preceding bibliographic analyses (Table 1, Figure 2).

There are a few UAFL papers out of the 25 mapped that contribute to sustainability, and these fall into two strands. The more traditional strand of papers frames UAFL as an issue with significance for food security and as a sustainability challenge. With proxies such as net primary productivity for farmland food production potential, Xu et al. [72], Yan et al. [73], and He et al. [74] assessed the impact of reduction in food production potential due to farmland loss caused by urban expansion or land use/cover change in general. A related earlier study by Chen [48] discussed how farmland loss affects soil erosion and food security. The other growing strand of papers frames UAFL as an issue significant for social–environmental sustainability, often in a rural context. Long, Liu, Wu, and Dong [47] linked the land use/cover change in the Su–Xi–Chang area with China's national strategy of "Building a New Countryside" and discussed the implications of

farmland and rural settlement changes for rural sustainability, arguing for rural–urban integrated development. Liu, Wang, and Long [65] made a similar case for the farmland and rural settlement changes in southern Jiangsu Province in terms of their effects on rural sustainability. More recently, by using ecosystem services value as a conceptual instrument for assessing social–environmental tradeoffs, Long, Liu, Hou, Li, and Li [67] examined the implications of urbanization-associated land use/cover change for sustainability. Li et al. [75] explicitly studied farmland change as a consequence of rural–urban system dynamics, extending the focus onto sustainability of the coupled rural–urban systems. Subsequently, Liu et al. [76] used the loss of rural land use/cover types (i.e., farmland and rural settlement) as a proxy for studying non-agriculturalization in relation to urbanization and discussed the implications for coupled rural–urban sustainability.
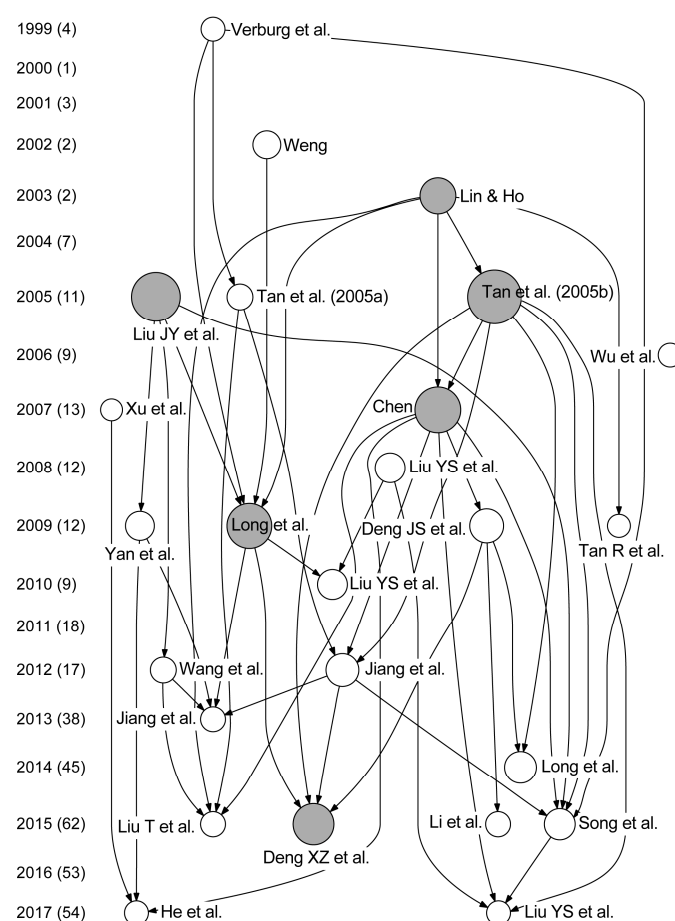
Figure 3. Main paths of the development of UAFL research literature in China, based on citation linkages among the top 25 papers with the most local citations (from within the sampled 615 papers) (see Table S3 for bibliographic details). The six seminal papers shaded gray are among the top 20 cited references within the 615 papers (detailed in Table 1), suggesting their relatively larger influences on subsequent research about UAFL in China. Note that the two seminal papers published in 2005 by Tan and his colleagues is distinguished in the main text by Tan et al. (2005a) [61] and Tan et al. (2005) [41].

Full-text reading of the mapped seminal papers reaffirmed that sustainability studies of UAFL in China are still marginal relative the UAFL literature, yet such research seems to be on its way into the mainstream. In this vein, despite policymaking having often been a central topic in UAFL studies, further efforts are needed for more rigorous policy studies that could delve into the social–environmental architectures beneath the landscape change of UAFL—such as the one by Tan et al. [77] on the governance structures of managing farmland conversion in China, Germany, and the Netherlands, which appear to be less connected with and recognized by the mainstream UAFL literature (Figure 3).

3.2. Meta-Analysis of Empirical Case Studies

Out of the 103 empirical studies about China's UAFL, 50.49% are sustainability-oriented (Figure 4A), with the other half focusing on landscape change *per se*, including farmland, urban land, or land use/cover in general. Note that the 50.49% excludes studies oriented toward farmland protection, which is an administrative task in China. In fact, as revealed above in Figure 3, those sustainability-oriented empirical studies address mainly one or more aspects of UAFL's social–environmental impacts, with only a few exceptions assessing UAFL's overall sustainability impact by integrating multidimensional synergies and tradeoffs (e.g., [67]). There is no single study that assesses empirically UAFL's impact on the sustainability of farmers' or households' human wellbeing. Furthermore, regarding the SES perspective as advanced by sustainability science, 59.22% of the coded studies explicitly adopt this stance. Most of these studies are like the conventional research that investigates the drivers underlying one or more specific land use/cover changes, with only a few exceptions focusing on social–environmental processes and their sustainability implications instead of merely landscape changes (e.g., [76]). In addition, as sustainability science advocates for transdisciplinarity, which translates into mixed methodological approaches to researching sustainability issues (e.g., [78]) including UAFL, the methodological aspect was also coded in the present study, highlighting that only 8.74% of the quantitative case studies were also mixed with qualitative methods. These few exceptions use mostly deductive reasoning to assist their quantitative methods (e.g., [63,75,79,80]), insufficient for taking advantage of the broad ranges of qualitative methods (e.g., participatory observation, focus group, interview) for researching social processes and developing theories.
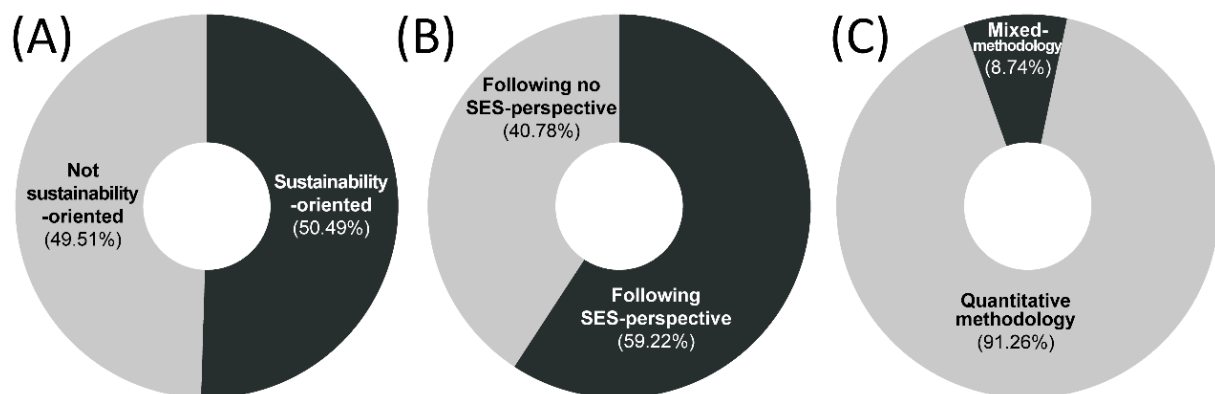

Figure 4. Sustainability features of UAFL case studies in China (N = 103): (**A**) oriented toward addressing social–environmental sustainability impacts or not; (**B**) delving into underlying social–environmental processes or not; and (**C**) adopting qualitative, quantitative, or mixed research methodology.

Additionally, the empirical contexts of the 103 cases were also coded. These empirical studies covered mostly the period from 1991 to 2006, of which the years 1992, 1995, 1997, 2001, 2002 were less covered; China's UAFL prior to 1991 and after 2006 have also been insufficiently studied (Figure 5A). Furthermore, 39.81% of the studies were conducted at the above-city regional scale, 33.01% at the national scale, and 22.33% focus on a city (c.f., a county in the United States), while 4.85% examine the area of a district (c.f., a city in the United States) or even smaller. The dominance of large-scale studies hinders the employment of qualitative methods usually more applicable at the local scale. Lastly, in terms of study area, these studies cover mostly China, including the Three Gorges Reservoir area as well as the relative more developed areas such as Beijing, the Beijing–Tianjin–Hebei region, Jiangsu, Huang–Huai–Hai Plain, Pearl River Delta, Guangzhou, and Nanjing. The spatial concentration of the study areas is insufficient to reveal the full spectrum of the social–environmental complexities related to UAFL.

Figure 5. Empirical focuses of UAFL case studies in China (N = 103): (**A**) study period; (**B**) geographic scale; and (**C**) study area. Word size in panels A and C are proportionate to its relative frequency.

4. Discussion

Sustainability is the theme of our era, and our common journey toward sustainability calls for the promotion of sustainability thinking among scholars, policymakers, and other stakeholders alike. Sustainability science characterizes sustainability thinking through the ontological lens of complex social–environmental systems and the transdisciplinary epistemic perspective [16,18,32]. In our research context, sustainability thinking calls for understanding and addressing urbanization-associated farmland loss (UAFL) as an emergent "landscape syndrome" of coupled social–environmental systems based on transdisciplinary approaches. Regretfully, our findings reveal that such sustainability thinking is still marginal in the existing literature about China's UAFL (Table 1, Figures 2 and 3)—though it is on its way into the mainstream (Figures 2 and 3). On the other hand, our findings show that over half of the related empirical studies are indeed sustainability-oriented and explicitly follow the SES perspective that characterizes sustainability science (Figure 4A,B). Here, a contradiction seems to arise. One possibility is that, although there do exist considerable scholarly interests in researching UAFL in China for advancing sustainability, the sustainability insights of such studies remain underappreciated. Alternatively, one may speculate that existing studies have not yet provided sufficient significant sustainability insights. We believe that both aspects have an impact and that they may even be the two sides of the same coin.

The issue of UAFL was originally examined in the field of natural resource management [9,81] and blossomed as part of the land use/cover change research program in the 1990s thanks to the fast development of remote sensing techniques [82]. This research program later developed into a so-called land change science that aims to link pixels to people by going beyond land use/cover change *per se* to understand the underlying drivers and (social–environmental) processes [83,84]. With sustainability science exerting increasing inter-and trans-disciplinary influence since the early 2000s, science-oriented land change research has gradually developed into a use-inspired basic science that is nowadays often called land system science, emphasizing its unique contribution to sustainability [85,86]. Turner II et al. [87] elaborated on this development history of land system science and its link to sustainability. On the other hand, it was not until early 2010s that sustainability science was systematically introduced to China [88,89]. Thus, it is unsurprising that recent studies by Chinese scholars have been more inclined to frame UAFL in relation to farmland sustainability [48,61], rural sustainability [47,65], sustainability of coupled rural–urban systems [75,76], and the sustainability of core–periphery systems [12,14]. In this vein, it is reasonable to expect that future studies of UAFL and other significant land use/cover changes would gain more and more research momentum that explicitly takes a sustainability perspective, thus providing more sustainability insights.

Relatedly, it is also unsurprising that sustainability might have been abused as a buzzword in the existing literature on China's UAFL—thus failing to fulfill the potential

of generating actionable sustainability insights. In short, the mainstream and latest developments of sustainability science were selectively introduced to Chinese geographers, ecologists, and other land/landscape-related research communities mainly through another research strand coined as landscape sustainability science [15,90]. Roy Chowdhury and Turner II [91] elaborated on the paralleled and increasingly confluent developments of land system science and landscape sustainability science. In general, however, it is fair to say that the so-called landscape sustainability science is mostly based on landscape ecology (the intersection of geography and ecology [92,93]) and highly science-oriented (or ecology-biased), less useful for integrating with social sciences (especially governance and policy sciences) for generating actionable knowledge (see Figure 5 in [16]). This background can also explain why land/spatial governance has not been well integrated into China's UAFL research (Figure 3) and why mixed methodology is so scarcely seen in the empirical studies (Figure 4C). In contrast to landscape sustainability science, land system science is explicit in its use-inspired, basic research nature; for example, Turner II et al. [94], Verburg et al. [95] and Munroe and Müller [96] explicitly advocate for the idea of land system architecture (and governance). In fact, land system architecture is very similar to the idea and practice of (comprehensive) land consolidation in China [30,34], although the land-related Chinese scholars have not yet widely realized this similarity. In this regard, it is reasonable to propose that for future studies of UAFL to provide more actionable sustainability insights, it is imperative to break down the epistemic biases and interest barriers of any single discipline and advance real inter-and trans-disciplinary studies on UAFL and other landscape changes alike. Only by so doing might we see the hope of deciphering the black box of social and social–environmental architectures beneath (un)sustainable "landscape signals".

This paper was originally designed also to synthesize UAFL's landscape patterns, key social–environmental processes, and common sustainability consequences that were commonly reported in the 103 empirical cases. However, the reported findings are highly context-dependent, thus it is challenging to conduct comparable coding. Our preliminary coding shows that over half of the studies reported net farmland loss and that less than a quarter reported fluctuation, with two cases reporting farmland increase and others reporting no such information. The drivers of farmland change examined or discussed encompass a wide range of factors, such as agricultural restructuring, natural hazards, construction, urbanization, economic growth, population increase, afforestation, and reforestation. In general, these findings are in line with the proposals made by Zhou, Aggarwal, Wu, and Lv [12] that frame UAFL as an emergent and complex "landscape syndrome" [14,16] of coupled core–periphery systems [97], of which the coupled rural–urban system is an archetype. Regarding the common sustainability consequences of UAFL in China, existing studies refer to certain farmland functions such as food production, carbon storage, and land pollution, as well as using ecosystem services value to evaluate multifunctional tradeoffs toward social–environmental sustainability. However, such tradeoff-based sustainability studies of UAFL are still limited. Fortunately, recent publications have increasingly taken this more comprehensive sustainability perspective, as has been widely recognized in sustainability science, see Fan et al. [98], Han et al. [99], Zhang et al. [100], Li et al. [101], and Zou et al. [102] for examples.

Together, our findings show that the existing literature in English on China's UAFL demonstrates strong sustainability awareness yet is still insufficient in providing authentic actionable sustainability insights, due to its long research tradition of a natural resource management perspective on UAFL and the associated methodological dominance of related natural sciences like remote sensing, land change science, and landscape ecology. Looking into the future, it is urgently necessary to conduct more conceptual and theoretical studies that explicitly frame UAFL and other complex landscape syndromes as emergent properties of dynamic social–environmental landscapes/systems. Particularly, governance, the largely missing piece in the existing literature, needs to be explicitly incorporated into the framing of social–environmental systems [103–106]. Future studies can go one step further than Tan, Beckmann, van den Berg, and Qu [77] (Figure 3) to examine the common governance

structures of social–environmental systems and those peculiar governance architectures causing specific challenges to sustainability, like UAFL. Furthermore, methodological plurality needs to be embraced by sustainability scholars, especially those social science methods that could engage non-academic stakeholders such as ethnographic observation, field interviews, focus groups, and case studies [40,78]. In this regard, promoting the idea and practice of transdisciplinarity [107–109] among Chinese land-related sustainability scholars remain daunting challenges in the foreseeable future. Lastly, our meta-analysis points to understudied issues that future empirical studies on China's UAFL can further explore, such as periods prior to 1991 and after 2006, below the city scale and at local scales, and in less developed and urbanized areas. Nonetheless, it should be noted that the identified gaps are limited to the literature in English before 2021. More recent studies may well align with the directions we propose above. Also, relevant studies published in other languages such as Chinese may present a more encouraging research landscape than what we have found. Our findings should be interpreted with caveats.

5. Concluding Remarks

Advancing sustainability through land-related approaches has been and will continue to be a fruitful research mission that has its unique theoretical and practical niches. Yet, for such research to generate more actionable sustainability insights, it is time to move beyond the narrow focus on land *per se* as a natural resource toward, on the one hand, seeing land as a landscape "X-ray" for diagnosing SESs, and on the other hand, a land-based governance instrument for intervening in SESs. In this paper, we applied such a sustainability perspective to conducting a bibliometric analysis of 615 sample papers concerning the widespread sustainability-related UAFL issue and a preliminary meta-analysis of the 103 empirical case studies therein. Our study bridges the gap between UAFL and sustainability, which has not been comprehensively addressed in the existing literature. We provide an overview of the existing literature in English involving China's UAFL, clarify the status quo of embedded sustainability thinking, and identify future research directions for better contributing to land-related approaches toward social–environmental sustainability in the context of China.

Our bibliometric analysis shows that the examined studies barely refer to the core sustainability science literature and that it was not until around 2016 that sustainability started to arise as a notable topic. The results also suggest that those sustainability-relevant studies are framed in one of two ways: with farmland loss as a threat to China's food security and consequently a challenge to sustainable urbanization; or with UAFL as part of featured modern landscape dynamics affecting environmental outcome(s) or social–environmental tradeoffs of a multi-functional landscape. The meta-analysis indicates that, though lacking sustainability insights and methodological transdisciplinarity, over half of the empirical studies demonstrate awareness in advancing sustainability and interest in understanding the social–environmental drivers and processes underlying landscape dynamics. The analysis also highlights understudied time periods, areas, and scales that remain potentially fruitful for conducting theory-driven empirical studies, especially those capturing the complexity of urbanization and farmland change. With the examined literature on China's UAFL as representative of the existing land/landscape-related literature, our more general conclusion is that sustainability thinking is still marginal in these traditional fields, yet it has been attracting growing interests and is on its way into the mainstream. We argue that a major barrier to advancing sustainability through land-related approaches is the epistemic and methodological superiority held (implicitly or explicitly, intentionally or unintentionally) by some natural sciences like landscape ecology and perhaps also remote sensing, that have long contributed to researching land/landscape. It is necessary to further utilize the lens and transdisciplinary perspective of social–environmental systems in future studies, for which better understanding the socio-political subsystem and integrating social science methods are imperative. In this vein, the two increasingly integrated fields of land system science and landscape sustainability science still have a long way to go.

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